FUSION

MAGAZINE OF THE FUSION ENERGY FOUNDATION
December 1978
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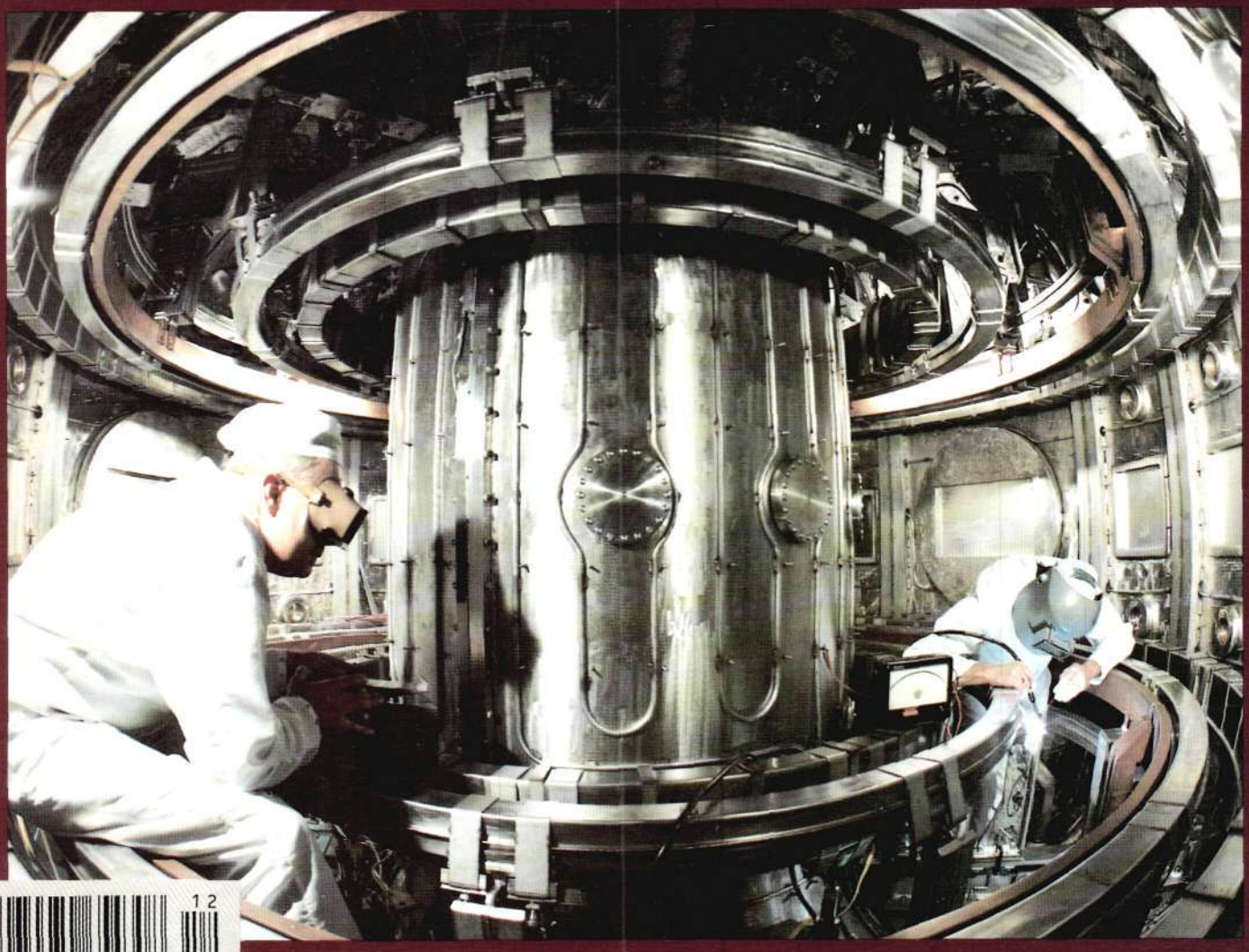
Energy and Machines

From Carnot to Fusion



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FUSION

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The FEF publishes a wide variety of material for the benefit of decision makers and the interested public. The views of the FEF are stated in the editorials. Opinions expressed in signed articles are not necessarily those of the FEF directors or the scientific advisory board.

Features

News

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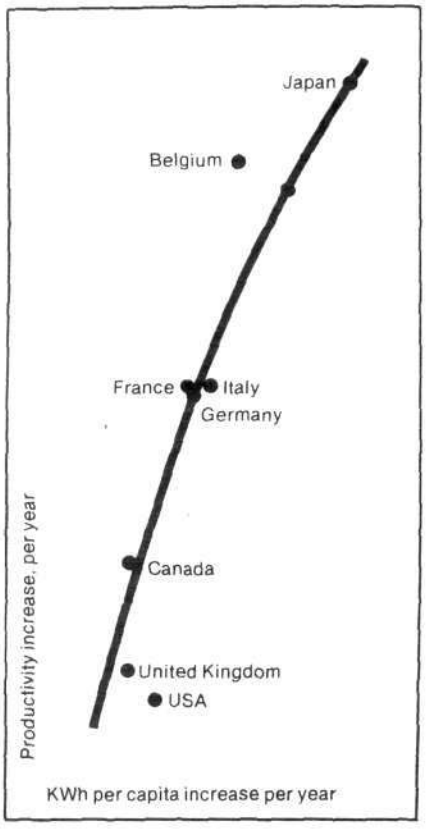
Editorials

Fusion Development Or 4th Place For the U.S.

The United States is still capable of turning out masterful engineering and construction projects, as this issue's article on fusion technology and the Princeton tokamaks makes clear. But even in those few areas, like advanced fusion research, where the United States is maintaining a marginal technological edge, it is becoming more and more difficult to find engineering and technical specialists to fill the relatively small number of existing positions. For this reason, the common response to the Fusion Energy Foundation's proposal for an Apollo-style fusion effort is, "Where is the skilled manpower going to come from?"

Although this is a legitimate question, it is an upside-down approach to fusion policy. Precisely because the nation has suffered such deterioration in the quantity and quality of its skilled workforce, we need a pacing program —fusion—to reverse the trend. In fact, the trend is probably more severe than most people recognize. Some of the nation's most honored scientists estimate that the United States is now or soon will be in fourth place internationally in terms of overall scientific research—behind the Soviet Union, Western Europe, and Japan.

The general situation can be measured by the falloff in enrolled and graduating students in science and engineering, a decline that parallels the sharp drop in R&D funding since its leveling off in the 1966-1968 period. For example, the number of graduate students in physics has been approximately cut by a third in the last decade, falling from 11,043 in 1968 to 7,743 in 1975. During the same period, undergraduate engineering enrollment fell from about 80,000 in 1968 to 70,000 in 1975. Overall, U.S. investment in research and development as a percentage of the GNP has dropped 33 percent since 1965.



The correlated economic effects of the scientific decline have been equally striking. During the past 10 years, the United States has increased its rate of productivity by only 2 percent per year. This is a lower rate than that of any other industrial nation, and five times lower than Japan. Even more telling, when the rate of increase of productivity is plotted against the rate of increase of per capita energy consumption, the United States (along with the United Kingdom and Canada) shows the worst performance in the advanced sector (see graph).

It is not simply our nation's scientific and technological capacities that are being destroyed, but the quality of U.S. labor power—a quality that has historically been based on the higher material and cultural living standards that the nation pursued. A few dimensions of the crisis were reported in the *Wall Street Journal* Oct. 16. Even in the aerospace and machine tool sectors, the *Journal* documented, there is an acute shortage of engineers, machinists, computer programmers, and other skilled technicians, to the point where certain companies have been unable to fill top skilled positions after several months of advertising. And at the other end of the spectrum, the U.S. Office of Education estimates that one out of every five adult Americans is functionally illiterate.

A national commitment to fusion development can reverse this degeneration. We must begin from the top down promoting the most advanced and broad-based scientific and technological research and development. New, high-technology industries radiating in concentric circles around fusion R&D, a vast nuclear export program, and general industrial renovation will provide the material basis for rebuilding a scientific culture and a sense of national purpose.

In fact, the scientific renaissance that a crash fusion program will necessitate is even more important for our nation's future than the unbounded material resources the achievement of fusion energy will make possible.

The Japanese Way

The Carter administration has a lesson to learn from Japan. The Japanese have a $220 billion ten-year energy program featuring nuclear power and fusion; they have given top priority to restoring high growth in the world economy; they have fought to bolster the U.S. dollar, and they have proposed and begun to institute long-term Third World economic cooperation and development projects. They have also offered the United States a $1 billion package for joint fusion research.

But the real lesson behind these impressive programs is that Japanese policy epitomizes the principles of technologically advancing economic growth upon which this nation was built, principles often referred to as the American Way.

This similarity is not coincidental. The founding fathers of modern Japan were the Meiji, who from the time of the 1868 Meiji Restoration undertook to transform their backward, feudal nation into a modern industrial state within one generation. As their model, the Meiji founding fathers chose America; explicitly the economic thinking of Alexander Hamilton and Henry Carey. From

Continued on page 4

Calendar

December

4-6
Energy and Southeast Asia:
Energy Economics, LNG Manufacturing,
Energy Policy and Outlook
Council for Energy Studies
Singapore

5-6
MHD Conference
Control Data Educational Company
Washington, D.C.

10-14
1st Brazilian Energy Congress
Universidade Federal de Rio de Janeiro
Rio de Janeiro

10-15
ASME Annual Winter Meeting
ASME
San Francisco

12-13
MHD Conference
Control Data Educational Company
Los Angeles

January

3-5
16th Annual Solid State
Physics Conference
Institute of Physics
London

4-5
Laser Plasma Interactions Conference
Institute of Physics
London

29-31
1st Topical Meeting
on Fusion Reactor Materials
DOE, ANS, Electric Power Research Inst.,
American Insti. of Mining, Metallurgical,
and Petroleum Engineers
Miami Beach

Readers wishing to have their events published in the Calendar *are invited to write:* Calendar, *Fusion Magazine, P.O. Box 1943, GPO, New York, N.Y. 10001.*

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America came the idea of industrial protection, the creation of a national bank to promote industrial capital formation, and development through science and the mass education of the population.

The Meiji tradition is very much alive today, as it was in the years of the so-called postwar economic miracle of Japan. The core of this guiding philosophy is expressed in the contemporary Japanese phrase "knowledge intensification." In short, this means that the economic growth and technology transformation must come by shifting the emphasis of the economy to areas of more highly skill-intensive—that is, knowledge-intensive—production. Specifically, this concerns areas like nuclear energy, computer technology, and highly sophisticated heavy industry that has an increasing use of computerized production processes.

Like the American founding fathers, today's Meiji thinkers do not envision their development program as a short-term plan nor one confined to domestic matters. It is a Grand Design based on the knowledge that if mankind is to have a future, we have a responsibility to take the potential for progress today as far as we can go.

The Japanese think big. It's a lesson the Carter administration cannot afford not to learn. Especially since—as the Japanese themselves are well aware—the full success of their ambitious global program *depends* on reexporting the American Way to the United States, and harnessing American industrial might to the knowledge-intensive revolution.

THE NUCLEAR DEBATE IN MEXICO

The fight to develop a major nuclear energy program in Mexico and the Fusion Energy Foundation's central role in this effort have been front-page news in the Mexican press, as this letter from noted Mexican cardiologist Dr. Demetrio Sodi Pallares attests. The Sodi Pallares letter was originally published in the Mexico City daily newspaper Uno Mas Uno *Oct. 19 as a reply to a series of front-page articles by Mauricio Shoijet, an Argentinian devotee of solar power who had attended the founding conference of the Mexican FEF affiliate in August.*

The nuclear issue has continued in the news as the Mexican Congress debates a new nuclear regulatory law designed to reorganize Mexico's uranium and nuclear industries and to prepare for a large-scale nuclear expansion program. Mexico's first nuclear plant, the twin reactors of Laguna Verde, is due to come on line in 1982, and the government plan calls for 20 nuclear reactors to be in operation by the year 2000.

Since the appearance of the Shoijet articles, which criticized the FEF and its pronuclear program as "imperialist," the Mexican FEF affiliate organized a highly successful pronuclear conference in Torreon, an industrial city in the northern state of Coahuila. More than 100 persons attended the meeting to discuss Mexico's task in developing a nuclear program, in particular the development of the necessary skilled labor force.

To the Editor:

Under the title "The Science and Technology of Provocation," a series of articles by Mr. Mauricio Shoijet appeared Oct. 5, 6, and 8 that involved the Fusion Energy Foundation and that were lacking in fact. For this reason I am writing this letter, to clarify and emphasize certain points.

The FEF is an international association of scientists with different political and religious beliefs. For example, the FEF includes socialist scientists, like physicist Cecilia Soto de Estevez, and Catholic scientists, like the author of this letter, Dr. Demetrio Sodi Pallares, a member of the international advisory board of the FEF. What unifies the members of this organization is their love of universal science, their humanist conviction, and their opposition to all Malthusian policies, which—outside of all natural law—want to limit population growth.

The FEF believes that the development of the creative capacities of the human intellect requires scientific progress—progress including heavy industry and the nuclear industry—oriented always toward humanist ends, such as peace and love among all men on earth.

I was truly amazed that Mr. Schoijet identified all supporters of high technology as agents of imperialism. I was perplexed by his expressions of sympathy for the Egyptian peasants who "are today so poor because of the unfavorable ecological consequences of massive systems of energy generation." I can only ask Mr. Schoijet if he is opposed to technology and progress.

The 'Soft' Solution

To fight imperialism, Mr. Schoijet pleads for limiting "technological dependence," which seems correct to me. But the very strange solution he offers is inadmissable. He suggests the adoption of "soft, unsophisticated technologies," "unconventional sources of soft energy," and "the greatest possible use of labor power." If the developing countries should take this kind of medicine, and for an indefinite period, their people would be condemned to the severity of unskilled labor—enfeebling work at low wages. This would consign man to sickness and ignorance. It would create a permanent and long-term shortage of skilled jobs to assimilate the industrial technologies of the future, and it would force acceptance of the same foreign monopolies that the columnist asserts he is fighting.

I want to point out that I belong to the FEF for three fundamental reasons:

(1) The FEF conceives of the world in which we live and of the universe in

The Aug. 24 founding conference of the FEF Mexican affiliate drew 80 representatives of business, industry, government agencies, trade unions, and press.

its totality as a negentropic system in which there are unlimited possibilities for development and available energy.

(2) Human intelligence and its creative power are the only means to achieve the increasing development at a constantly accelerating pace, of the world in which we live. This implies a constantly increasing negative growth in the world's entropy.

(3) As a consequence of the above, human life must be defended in all respects: fetal life, birth, growth, development, maturity, and old age. Creative intelligence in each period of human life is the earthly "prime mover" of the world-universe system.

Reductionist systems, such as abortion and antinatural birth control, are entropic; for although it may be covered up, the damage done to the woman is done to her entire person.

On the basis of these principles is it possible that Mr. Schoijet still believes that the FEF is an imperialist organization? To support what I'm saying, it is worth repeating one of the fundamental principles of the FEF, which Eric Lerner [FEF director of physics research] summarized as follows:

"Any increase in the population signifies a greater capacity to produce and consume. The death of any individual is a loss to all. Hunger, illness, and the damage to the creative ability of any person, thus is my hunger, my illness, and damage to my creativity."

Antiscientific, Antihumanist

I can only hope that the columnist will reflect upon his attitude, which, in these times, seems to me to be antiscientific and, what is worse, antihumanist. I also hope that Mr. Schoijet will come to appreciate the negentropy of the universe that God has put in our hands, as well as the humanist position of the FEF, because intelligence like his is needed for the establishment of a peaceful world for all of humanity, without distinction of race or creed.

Dr. Demetrio Sodi Pallares
Member of the International
Advisory Board of the
Fusion Energy Foundation
Ex-President of the Mexican
National Academy of Medicine

The Lightning Rod

My dear friends,

Knowing as you do the humble pride I took in placing the Colonies' postal service on a surefooted, speedy basis, you will understand why recent news coming my way about postal irregularities has raised my blood pressure. It seems that numerous letters—including some requesting substantial orders of *Fusion* magazines—have found their way into the circular file rather than onto the circuit. Keeping in mind the principle that a man need not ask a robber to steal from him again in order to ascertain his enduring character as a thief, *Fusion*'s publishers understandably suspect corruption in the postal service itself.

They have come to me, the postal service founder, for aid. My first ruminations on the problem could not get me beyond the irony of this turn of events. The national postal service was established by me as a specific aid to scientific and political correspondence, one might even say the "fusion" of a nation and its intellectual leadership. Has this gain in efficiency now been turned to the purposes of pure and simple fraud?

This struck me as unlikely, for, sadly, I am told by many reliable friends that the postal service has no reputation for efficiency at all, these days. Even thieving has to be proportional to the means at hand! And in this case, I have been informed by the same good authorities that the mechanical capabilities of the postal service were decreased dramatically.

After further pondering, and, I must

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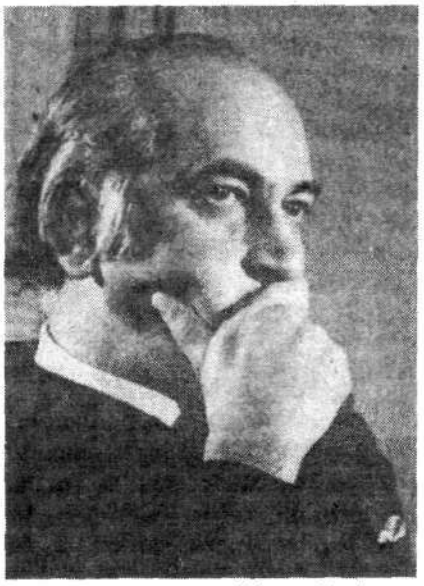
News Briefs

1980 ENERGY BUDGET SLATED FOR OMB CUTS

Informed Washington sources report that the Office of Management and Budget will severely cut the proposed 1980 fiscal year budget for the Department of Energy, submitted to the OMB in September by Energy Secretary Schlesinger. The 1980 magnetic confinement fusion budget, the sources said, will probably remain at the fiscal year 1979 level of $350 million. Schlesinger's proposed budget had included an increase in magnetic confinement fusion to $365 million, barely enough to keep pace with inflation.

In addition, the fusion design studies for the Engineering Test Facility, the next tokamak planned after Princeton's TFTR, are under the administration's antiinflation axe. The present three design groups — Princeton, Oak Ridge, and General Atomic — will be consolidated into one project located at Oak Ridge at an overall cut in funding.

The OMB cuts are expected to cause bitter DOE infighting in the competition for funds.



Zulfikar Ali Bhutto

THE BHUTTO PAPERS: NUCLEAR LEADER FACES DEATH SENTENCE

In a telegram smuggled out of a Pakistani prison Sept. 20, former Pakistan President Zulfikar Ali Bhutto wrote UN general secretary Kurt Waldheim that he was being "subjected to brutal hardships ever since the coup d'etat of July 5, 1977," and he named his strong nuclear program as one of the reasons he was sentenced to death by the Pakistani junta. Bhutto is being held incommunicado while the Pakistan Supreme Court reviews the junta's death sentences.

"The conscience of the world community gets aroused when the representative of a firm is arrested for alleged blackmarketing of currency," Bhutto wrote, "but what happens to the same world community when the undisputed leader of his people is subjected to physical cruelty and mental torture for inter-alia waging a dauntless struggle against oppression, for valiantly upholding the banner of justice for the Third World and for equipping an Islamic state with nuclear capability."

To answer the junta's charges against him, Bhutto has produced a 319-page document, "Statement of the Appellant," which was also smuggled out of the country. The statement reviews in detail Bhutto's fight to bring his country into the nuclear age and the sabotage against this nuclear project, for which he named Henry Kissinger.

We quote from part of the Bhutto statement:

"I have been actively associated with the nuclear programme of Pakistan from October 1958 to July 1977, a span of 19 years. I was concerned directly with the subject as foreign minister, as minister for fuel, power, and natural resources, and as minister in charge of atomic energy. . . . Assiduously and with granite determination, I put my entire vitality behind the task of acquiring nuclear capability for my country. I sent hundreds of young men to Europe and North America for training in nuclear science. . . . We were on the threshold of full nuclear capability, when I left the government to come to this death cell."

SOUTH KOREA TO BUILD 40 NUCLEAR PLANTS BY 2000

President Park Chung-hee of the Republic of Korea told the French newspaper *Le Figaro* Nov. 4 that his nation is determined to build 40 nuclear power plants by the year 2000. France is now discussing the sale of two nuclear plants to South Korea. The country has one plant in operation, four under construction, and two more being bid on by international suppliers; all seven are planned to be in operation before 1986.

In an interview with the *Executive Intelligence Review* the same week, Dr. Bong Suh Lee, assistant minister for planning and administration in the South Korean Ministry of Energy and Resources, elaborated on the nuclear program:

"...Our projection is that the economy will probably grow at a rate of 10 percent for the next 10 years or so....And if that is the case, certainly we will need a lot of power. And if we need a lot of power, we will have no choice but to rely on nuclear rather heavily...."

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

AUSTRIAN NUCLEAR PROGRAM LOSES REFERENDUM

In the first nationwide referendum on nuclear energy in Western Europe, Austrian voters Nov. 5 refused to allow the $530 million Zwentendorf nuclear power plant to begin operation next year. The vote was 50.47 percent to 49.53 percent, a margin of 30,000 votes. Informed sources also reported that at least 70,000 ballots were invalidated.

Although Austrian Chancellor Bruno Kreisky and his Social Democratic party support nuclear energy, he has promised to abide by the referendum and scrap the plant or begin a costly conversion to coal. The West German-designed reactor, a massive capital investment for a country with Austria's 7 million people, was designed to provide power for the entire country.

Both opposition parties, the conservative Austrian People's Party and the liberal Austrian Freedom Party, opposed the reactor and were joined by the nation's environmentalist and proterrorist left wing. This unlikely coalition of conservatives, liberals, environmentalists, and some neo-Nazi opponents of Kreisky, was aided by environmentalist groups in neighboring West Germany, who viewed the referendum as a back-handed way of attacking West German Chancellor Helmut Schmidt's strong nuclear energy program. The environmentalist campaign centered around their claim that a nuclear accident would contaminate Austria's tourist image.

As columnist Christian Guery commented in the French *Le Figaro* Nov. 7, "We do not see what democracy has gained with the referendum."

West German environmentalists campaigned against Austria's nuclear plant...and Schmidt.

NEW ALL-STAR JOINS ENVIRONMENTALIST TEAM

"The orange-bellied mouse threatens to hold up construction of a $2 billion power plant in California, thus joining such other endangered species all-stars as the orange-footed pimpleback, the snail darter, and the furbish lousewort, all of which we are said to need more than electricity," the *Voice of Business*, the U.S. Chamber of Commerce's press organ, recently wrote. "But there's hope," said the *Voice*. "The Mexican duck has just been banished from the list by the Fish and Wildlife Service, due to a timely discovery that it does not exist."

LOUSEWORT LAURELS TO ALL-WET STERNGLASS STUDY

Dr. Ernest Sternglass, professor of environmental science at the University of Pittsburgh, is notorious among the community of nuclear engineers and physicists here and in Europe for his wild statistical analyses that purport to prove the dangers of nuclear fission. His latest unsubstantiated statistical analysis, for which we are awarding him this month's lousewort laurels, was relayed to us from a reader in Pittsburgh. In a press release reported on CBS affiliate KDKA radio, Sternglass claimed that a new study showed that those college-age children today who were born during the 1950s—before air and ground testing of nuclear weapons was prohibited—scored lower on their SATs (scholastic aptitude tests) if their mothers lived in rainy areas. The radio report did not mention what other variable Sternglass included in his correlation. As soon as we receive the study, we promise readers a full review.

Washington

Schlesinger Uses 'Antiinflation' As New Excuse to Cut Fusion

The administration's cost-cutting campaign has provided Energy Secretary Schlesinger with a new excuse to weaken the fusion program and other high-technology projects. Two days after President Carter's Oct. 24 press conference announcing an antiinflation policy, the Department of Energy fusion office received a memorandum outlining the effect of the 50 percent hiring freeze on the division: In order for anyone to be hired into the DOE fusion office, the memo stated, two people will have to leave.

According to the fusion office, the 10 or so vacant positions in the division will now be "frozen" and cannot be filled unless there are more division resignations. The cut in manpower will have a serious effect on the central coordinating role of the fusion office in overseeing the experiments in the various laboratories and it will hamper the quality of leadership that the fusion office can provide.

In addition to the personnel cutbacks, the DOE informed the fusion office that travel expenditures would be slashed 27 percent. Since the fusion research and development program oversees facilities scattered around the country, and since personal direction and evaluation are often required, the travel reduction will have serious consequences. Also, this month the key division scientists were not able to attend the plasma physics meeting of the American Physical Society in Colorado, and it is expected that the travel restriction will affect the division's ability to participate in future scientific conferences.

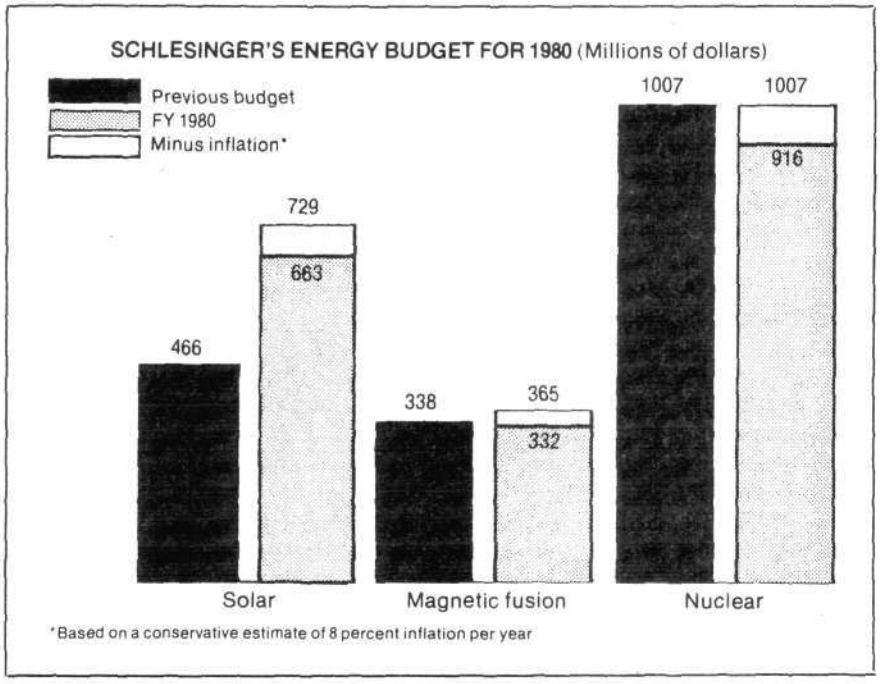
Most serious, according to one DOE spokesman, is that the unavailability of funds may hamper U.S. participation in the international tokamak experiment under the sponsorship of the UN International Atomic Energy Agency. The DOE had sent representatives to the initial meetings of European, Soviet, and Japanese fusion scientists, but there may not be enough money to send U.S. scientists to the continuing discussions on the Unitor tokamak proposal at the IAEA's Vienna headquarters. In other words, the current leadership of the United States in the international fusion effort may depend on whether the fusion office can afford to buy plane tickets.

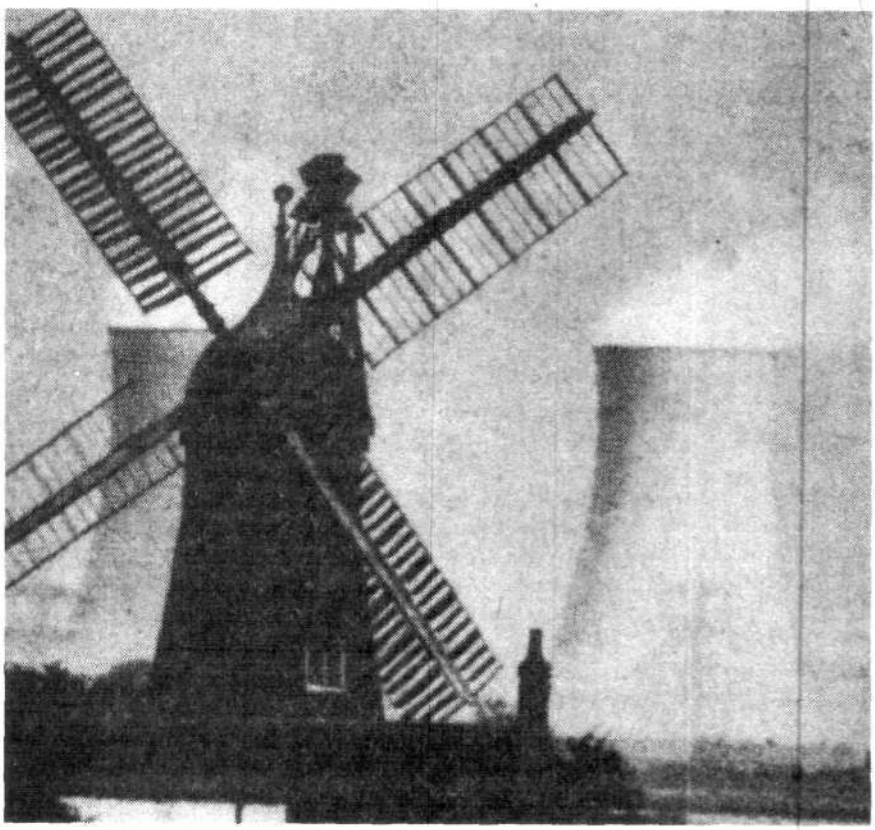
These latest cuts in fusion office operations are separate from the go-slow fusion research budget that DOE submitted to the Office of Management and Budget in September for fiscal year 1980. DOE proposed an increase of $35 million for the magnetic confinement fusion budget for a total of $365 million—an increase that barely keeps pace with inflation.

Other Divisions Attacked

Several DOE scientists, in particular those who have been the backbone of the high-technology research program within the department, have been hit with the antiinflation axe, under the ruse that suddenly their work has become unnecessary and is being eliminated. For example, Dr. William Jackson, who headed the DOE's magnetohydrodynamics program until he was removed from that important position last winter, was informed Oct. 27 that his division of technical analysis and special projects in John Deutch's Office of Energy Research was being abolished. If he wished, Dr. Jackson was told, he could report the following Monday to a different division within the office, at a cut in civil service classification and status.

Dr. Jackson is one of a group of competent scientists who have been forced out of leadership positions in the DOE over the past month. These have included Dr. G.W. Cunningham, who led the nuclear division in Robert Thorne's Office of Energy Technology, and Dr. Nelson Sievering, deputy assistant secretary for international affairs, in charge of international nuclear cooperation.





As Schlesinger knows, it takes 33,333.33 windmills to equal the power output of one nuclear plant.

The Energy Act— Less Energy at Greater Cost

Now that the nation's first no-energy bill has been signed into law, Energy Secretary James Schlesinger plans to introduce number two in the next congressional session. The no-energy sequel will include a combination of low-technology solar power and coal liquefaction measures. In addition, President Carter has pledged to let the price of domestically produced crude oil rise to world market levels, by revising the crude oil tax proposal, which was cut out of the first energy bill, or by permitting the legislated authority that sets oil prices to expire in 1979, which would give the oil companies the additional revenues.

There is every reason to believe that energy policy in this next session will continue on as a sort of guerrilla war between Congress, which is concerned with long-range energy production, and Schlesinger's office, which is more concerned with energy shortages and conservation. The question is whether President Carter, having claimed a victory on getting energy bill number one through a reluctant Congress, can now respond to the wishes of Congress by getting a new energy secretary who has some credibility for the job. It is no secret on Capitol Hill that Schlesinger's department is in shambles and that the secretary's capabilities are often called into question.

The Energy Act in Brief

In brief, here's what the National Energy Act will do:

Through a combination of five separate legislative acts, the NEA will raise the price of primary fuels, raise the price to consumers of electric power, institutionalize the idea of conservation as an energy alternative, and pour government tax monies into expensive, retrogressive energy technologies.

The NEA never addresses the question of producing more energy. In fact, Energy Secretary Schlesinger did not even pretend that the legislation would improve the nation's energy supply; instead he pledged the opposite: "The NEA represents an historic turning point. The era of cheap and abundant energy is recognized to be over. . . . The purpose of the National Energy Act is to put into place a policy framework for decreasing oil imports."

Having less energy will cost the nation more. Ironically, two weeks after the energy bill's passage, President Carter announced a campaign to cut inflation, partly by cutting government spending and balancing the federal budget. Yet, Carter's prized energy act will fuel inflation by increasing the government's contribution to nonproductive investment and by pushing the Consumer Price Index steadily upward with rising energy costs.

Conservation Institutionalized

The National Energy Conservation and Policy Act of 1978, one of the five NEA bills, is the primary vehicle through which billions of dollars will be wasted on patchwork measures to improve energy conservation. Instead of spending tax dollars on new construction to replace 100-year-old schools and turn of the century housing, this act mandates insulation and paste for cracks to improve energy efficiency. The provisions include $5 billion in federal loans to improve home conservation, $200 million in grants for home weatherization, $100 million in loans for residential solar use, and $900 million in grants for schools and hospitals for conservation.

Additional millions will be spent to enforce federal energy efficiency standards for buildings and to set electric appliance energy standards for industry. The act reasons that as primary and electrical energy costs

skyrocket, consumers will be more and more willing to add gadgets to their homes to keep in the little heat they can afford.

Nonproductive Investment

Congress greatly modified the original Schlesinger coal conversion bill, which it recognized as the most straightforward antiindustry part of the proposed NEA. The major provision of this part of the bill is to prohibit the use of natural gas or oil in *future* utility power plants. Since industry plans virtually no oil- or gas-burning power stations, the bill has little meaning.

However, it does include an $800 million loan program to enable utilities to meet pollution control standards. This nonproductive investment is a sure bet for forcing up electric power rates. Industry sources have estimated that the cost to industry of meeting all pollution control standards will drain multibillions of dollars out of real investment into new capacity to meet future power needs.

By far the most ridiculous and potentially expensive bill in the NEA package is the Energy Tax Act. In addition to providing tax credits for residential insulation and conservation, this bill gives a gigantic boondoggle for what are otherwise completely noncompetitive (costly and inefficient) alternate technologies. Tax dollars will now subsidize devices like windmills, which could never compete on the open market with large-scale, centralized power generation and use.

The bill mandates for a nonrefundable income tax credit for the residential installation of solar or wind equipment—up to a maximum credit of $2,200 for an expenditure of $10,000. Business tax credits also are provided for industrial investment in alternate energy property development. In addition, incentives will be extended for development of geothermal resources through an investment tax credit. Another part of the NEA, the Public Utility Regulatory Policies Act of 1978, established a loan program to aid in the development of small hydroelectric projects.

—*Marsha Freeman*

International

Japan Announces Crash Fusion Effort

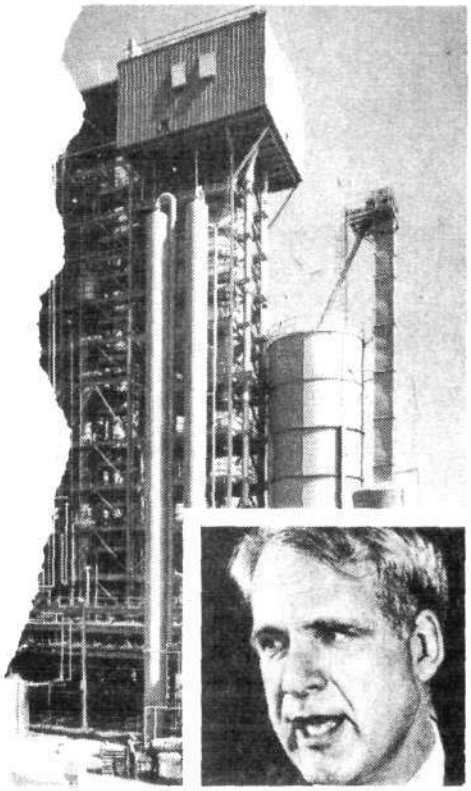
The American way: Japan's Fukuda (l.) is backing U.S. high technology like the

Japanese Prime Minister Takeo Fukuda has been meeting with his nation's fusion scientists to map out a strategy for harnessing Japan's scientific and industrial manpower in a program for full-scale fusion development. According to Japanese sources, the discussions have included a proposal to increase the current Japanese fusion effort, now about $200 million per year, to double that amount next year—well above the U.S. Department of Energy's projected 1980 funding level of $365 million.

Scientific experts have advised Fukuda to set up a special budget exclusively to step up the government efforts to develop fusion systems, reported the *Mainichi News* Oct. 28. Japanese scientific experts also advised Fukuda to select members of the joint Japan-U.S. committee on scientific and technical cooperation by the end of 1978, so that the two nations can begin cooperating in the development of new energy resources. According to embassy representatives, U.S. Energy Secretary James Schlesinger will meet with Prime Minister Fukuda Nov. 6 on his way back from China, and agreement is expected on the outlines of the Japan-U.S. cooperation.

Reports from various sources, including *Science* magazine, the *Energy Daily* newsletter, and U.S. DOE scientists who went to Tokyo in September, indicate that the Japanese consider fusion cooperation so important that they will be willing to compromise with Schlesinger on other parts of the joint research proposal. The Fukuda initiative, made public in the United States last May, posed joint fusion research and development as the priority for Japan-U.S. cooperation. Secretary Schlesinger countered that fusion alone was not enough and that the Japanese must contribute money to the DOE's coal liquefaction program, SRC II.

The coal liquefaction program, which U.S. industry has been very hesitant to invest in, will be paid for partly by West Germany and Japan. Each nation has agreed to pay between $175 and $200 million over five years, or 25 percent each of the total project cost. The Japanese have agreed to go along with this arrangement mainly because they understand that their long-term fusion commitment represents a focus for a positive diplomatic relationship into the next century, and that they will not be able to conclude the fusion agreements



Doublet III tokamak, while Schlesinger pushes coal liquefaction and sunshine.

without some kind of compromise with Schlesinger.

The details available on the Japan-U.S. fusion cooperation indicate that the prime candidates here for an infusion of Japanese funding are General Atomic's Doublet III tokamak in San Diego and Princeton University's TFTR. The Doublet may receive as much as $30 million from the Japanese, enough to upgrade the device for the purpose of reaching the Lawson criterion of energy breakeven.

The proposed plan is to share instrumental techniques and data from the Princeton TFTR and the Japanese JT 60 tokamak and to initiate joint fusion materials testing, which will involve work at Oak Ridge National Laboratory and Hanford Laboratory in Washington State. The materials testing could mean up to $175 million in Japanese funds.

In addition, the Japanese have proposed a joint theoretical institute for the study of plasma physics and joint experimental work in high-energy physics, funded at approximately $75 million over five years.

IAEA Head Eklund:

Third World Must Go Nuclear

UNITED NATIONS, N.Y.—In his annual report to the United Nations General Assembly Nov. 5, Dr. Sigvard Eklund, head of the International Atomic Energy Agency, strongly criticized those who "persist, irrationally, to maintain that nuclear power leads to proliferation." Eklund demanded that nuclear power, particularly nuclear breeder technology, be shared as rapidly as possible with the developing sector.

In an unusually strong show of support, the General Assembly voted to accept Eklund's report and passed two resolutions backing up the thrust of his remarks.

"Hiding behind terms like 'appropriate', 'soft' or 'intermediate' technology there are many wishful thinkers today who would have a world where the developing countries can make do with windmills, while the industrial world contents itself with zero growth and consumes the fruit of past achievement," Eklund said.

"Let me repeat that there should be no mistake: Small nonconventional energy sources may provide the best way of meeting the energy needs of small, rural communities but they cannot turn the wheels of industry of any country, nor can they help it to eventually attain a self-sustaining economic base, nor can the industrialized world maintain its standard of living without expanding energy consumption."

Reminding the major industrial powers of their commitment to nuclear power development at the July 1978 economic summit meeting in Bonn, Eklund said: "Despite this commitment at the highest level, the introduction of nuclear power has slowed down considerably or even halted in some countries." He then ascribed this to the "incredible complexity of the regulatory and juridical procedures that nuclear projects must now contend with."

The main function of the IAEA, Eklund told the General Assembly, is to provide "reliable and impartial" energy planning studies, technical assistance, and training to developing nations.

Strong Support

The General Assembly not only accepted Eklund's report but passed two resolutions introduced by Saudi Arabia calling for a conference on the peaceful uses of atomic energy for development in 1981 or 1982, and the strengthening of the IAEA's technical assistance programs. On suggestion from Pakistan, the conference resolution was amended to eliminate reference to a 1977 General Assembly resolution that had linked the issue of nuclear energy to nuclear proliferation.

Pakistan also strongly emphasized the applicability of nuclear power to the poorest of the developing countries, rebutting the thesis of former West German Chancellor Willy Brandt that nuclear power might work in the "advanced developing countries" but that only solar power, windmills, or wood burning could be appropriate for the poorest nations. The Brandt view has been publicized by some UN institutions, like UNCTAD, the UN Commission on Trade and Development, the International Monetary Fund, and the World Bank, which are committed to "appropriate technologies," solar power, and other forms of inefficient, nonconventional energy production.

The IAEA, which plans to expand its membership to include new Third World members, is strongly influenced by protechnology forces in Europe. The collaboration in the ongoing UN session between European and Third World forces to strengthen the IEAE is expected to have a positive influence on the current UN debate on the New International Economic Order.

—Leif Johnson

Kapitsa's Prize Should Have Been for Fusion

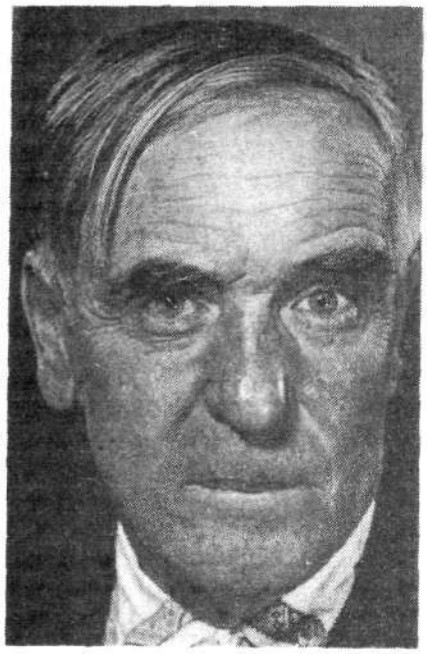
The dean of Soviet physics, Petr Leonidovich Kapitsa, was awarded the Nobel Prize for physics last month, for his work in low-temperature physics. Kapitsa, who is 84, received the prize jointly with two U.S. Bell Laboratories scientists who discovered the experimental evidence for the existence of a general background of radiation in the universe.

Ironically, Kapitsa is being awarded the Nobel Prize for his work on developing refrigeration systems, which was only a secondary goal of his research efforts in superfluidity and other experimental fields. The award should have been for his contributions to fusion development. Kapitsa was a pioneer in efforts to develop fusion energy, which he defined as the key technology to provide the necessary rate of "energy density" for solving the world energy crisis. Kapitsa described the concept of increasing power density as the essential attribute of any energy technology in a 1975 speech to the Soviet Academy of Sciences (see box).

The main thread in Kapitsa's scientific research has always been energy production and transformation from the standpoint of both large-scale industrial applications and the theoretical frontiers of physics research. He played a leading role in the Soviet fusion research effort in the late 1940s, and he developed the technology of microwave generation, which he was also the first to apply to generating hot plasmas. This work is actively pursued today in fusion research, and it is also the direct forerunner of laser fusion research.

Misinformation

The Western press has made the Kapitsa award the subject of a misinformation and slander campaign against Soviet science. The manufactured information is as follows: (1) Kapitsa is a leading Soviet "dissident," kidnapped by Stalin in 1934 when he returned to the Soviet Union for a brief visit; (2) Kapitsa completed his work in low-temperature physics while at the Cavendish Laboratory in Great Britain in the late 1920s and early 1930s; by implication Kapitsa's great achievements in low-temperature physics are not at all representative of Soviet science; (3) besides being a Soviet prisoner for the past 44 years, Kapitsa was actually incarcerated by Stalin in 1946 when he refused to work on the development of nuclear weapons.



Petr L. Kapitsa: Acknowledged leader of Soviet science

The truth is that Kapitsa has been awarded two Stalin Prizes, five Orders of Lenin, the Red Banner of Labor, and the Hero of the Soviet Union award; he was made director of the Institute of Physics Problems, chairman of the Coordination Council of the Moscow Physicotechnical Institute; and since 1955 he has been editor-in-chief of the leading Soviet science journal, the *Journal of Experimental and Theoretical Physics*.

Furthermore, Kapitsa was elected to the Praesidium of the Soviet Academy of Sciences in 1957; he has written scores of articles for the leading Soviet press; and he was the first to call for the Soviets to develop nuclear weapons, in a speech delivered in the fall of 1941, as well as the first to advocate use of the A-bomb on the Nazis.

In reality, Petr Kapitsa personifies the humanist roots upon which the modern institutions of Soviet science are based. Moreover, as an acknowledged leader of Soviet science, he has directly contributed to the Soviets' adoption of the "Grand Design" and "new world economic order" policies of the French and West German governments.

When Kapitsa completed his education as an engineer, A.F. Ioffe, the father of Soviet nuclear science and a collaborator of V. Vernadsky in running the Soviet Academy of Sciences, directed him to go to Rutherford's Cavendish Laboratory in Britain in 1921 to study the nuclear physics of the West. Soviet science was then almost completely embargoed by Western science.

At first, Kapitsa's application to work at Cavendish was rejected by Rutherford, but his persistence finally won him a minor appointment. His consummate engineering and scientific skills led to his rapid promotion to deputy director of Cavendish in 1924, to membership in the Royal Academy, and finally to his own laboratory, the Mond Laboratory, for low-temperature physics research, in 1933. (The entire Mond Lab was purchased and transported to the Soviet Union by the government in 1934.)

Science and Industry

When Kapitsa came to Britain in 1921, Rutherford's Cavendish Lab was at the forefront of nuclear physics research. However, Rutherford policy-makers adamantly denied that the great energy potential of the atomic nucleus would ever have major practical applications. Influenced by Vernadsky's work, Kapitsa believed not only that nuclear energy would find useful application, but also that scientists would make significant progress in nuclear research only if they had useful industrial applications in mind.

Kapitsa pioneered the development of technology for concentrating large amounts of energy for various uses in nuclear experiments. He developed the apparatus for pulsing large elec-

trical currents to generate intense magnetic fields; and he was the first to apply these intense magnetic fields to the Wilson Cloud Chamber, an apparatus that permitted scientists to track atomic and subatomic particles. In this, Kapitsa developed the most essential tool of experimental nuclear physics.

To perfect his sytem for producing intense magnetic fields, Kapitsa explored various ways to refrigerate the magnetic coils. Electrical resistance is the chief limit to the amount of current that can be passed through a coil, a limit that decreases with decreasing temperature. Kapitsa therefore sought to develop refrigeration systems with the lowest temperatures, resulting in a refrigeration system that used hydrogen as the working fluid. He then explored helium as a refrigeration fluid.

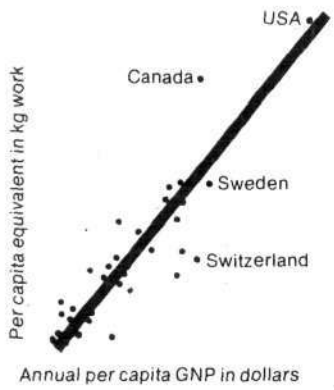
Later he refined an existing technology for liquifying hydrogen and helium, applying this in the Soviet Union to liquify air, producing liquid oxygen. In 1970, Western countries alone used Kapitsa's technology to produce about 53 billion cubic meters of oxygen, about half of which is used in the metal industry and the rest in the chemical industry and in rocket technology. In 1941 Kapitsa received the Stalin Prize for this work.

Kapitsa most emphatically deserves the Nobel Prize for his work on refrigerators but, characteristically, this was only a by-product of work that revolutionized that field and created an entire new field of physics research—superfluidity. In 1962, Kapitsa's student Lev Landau received the Nobel Prize for developing a theory of superfluidity to explain Kapitsa's prior, pioneering experimental work.

Even today, superfluidity is being directly applied to the technology of fusion reactor design, as seen in the most recent Nuwmak tokamak reactor design of the University of Wisconsin in which superfluid helium is used to cool the magnets efficiently. Superfluidity represents an essential complement to the study of self-organizing structures found in plasma physics.

—Charles B. Stevens

Kapitsa On Energy And Progress



In a speech to the Soviet Academy of Sciences in honor of the Academy's 25th birthday Oct. 8, 1975, Kapitsa emphasized that the development of fusion was necessary for the increased "material well-being" of populations. He outlined the energy-density criterion for judging the appropriateness of any energy-producing technology to power a mode of production more efficient than the present industrial system, and emphasized that fusion was the only suitable technology for providing for world growth today. In addition, Kapitsa thoroughly discredited solar energy and geothermal and wind schemes as "unrealistic" and inefficient. Excerpts of the speech follow.

It is generally realized that the basic factor determining the development of people's material culture is the creation and utilization of energy resources.... The role of energy in the national economy is well illustrated by the curve in the figure. On the horizontal axis is the per capita value of the Gross National Product for various countries, and on the vertical axis is a per capita representation of energy resources. Within the limits of normal fluctuation, it is apparent that there exists a simple proportionality. Therefore, if people are deprived of energy resources, their material well-being will undoubtedly fall...

I will confine my self to a survey of the laws which define the development of large-capacity energetics and which are related to the natural limitations on the density of energy flux. As will be apparent, these limitations are often not taken into account, and that leads to expenditures on projects which are known to be without prospects. This will be the basic theme of my report.

All energetic processes of interest to us boil down to the transformation of one type of energy into another, and this takes place according to the law of conservation of energy. The most commonly used forms of energy are electrical, thermal, chemical, mechanical, and now so-called nuclear. The transformation of energy can usually be viewed as taking place in a certain volume, through whose surface one form of energy enters and transformed energy comes out.

The density of the yielded energy is limited by the physical properties of the medium through which it flows. In a material medium, the power of energy flow is limited by the following expression:

$$U < vF,$$

where v is the velocity of diffusion, usually equal to the speed of sound, F can be either mechanical or thermal energy, and U is a vector. In stationary processes, div U [the variation of energy flux from place to place in the medium] determines the magnitude of energy transformation into another form. . . .

National

Court Gives EPA a Free Hand With Carcinogenic Substances

In a decision that will have serious consequences for U.S. industry, the United States Court of Appeals ruled this month that "the Environmental Protection Agency does not need to establish a direct link between cancer in man and a toxic chemical before prohibiting its discharge. . . ."

The court stated: "In effect, they [the defendents from the electronics industries] assert EPA must demonstrate the toxicity of each chemical it seeks to regulate through studies demonstrating a clear line of causation between a particular chemical and harm to the public health or the environment. We do not agree." Federal law, the court said, gives EPA "an ample margin-of-safety provision that directs EPA to guard against incompletely known dangers."

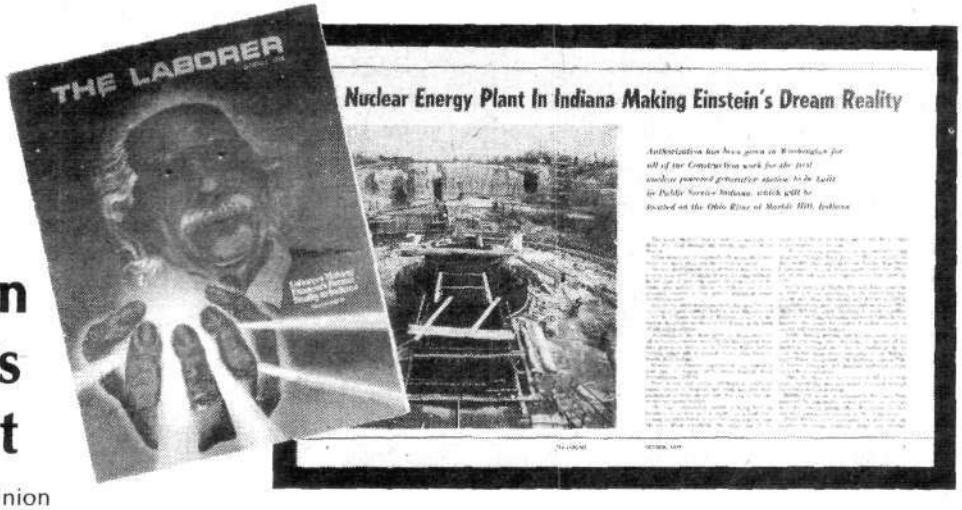
The ruling opens the door to the antiindustrial environmentalists who have attempted to ban everything from saccharin to hair dye as carcinogens.

Along similar lines, the Occupational Safety and Health Administration has extended its public hearings on a proposal to give OSHA arbitrary power to ban substances from the workplace. OSHA's proposed ruling would enable the agency to prohibit any substance once it decides that the substance was proven or *suspected* to be dangerous.

Nearly all the testimony to date has emphasized the destructive consequences of the OSHA proposal. To quote from the testimony of John Hanley, *the chairman and president* of Monsanto Company:

Enormous Burden

"What we are seeing . . . is an epidemic rise in the discovery of *experimental* carcinogens—materials which are suspect simply because of animal or laboratory tests, or, in some cases, simply because they are related to something on a suspect list. . . . If exposure controls for a large number of substances were required beyond the limits which prudence dictates, substantial engineering changes would be required in plants. The arbitrary listing of several hundred category one chemicals would create an enormous engineering and technical burden on industry. We would have to generate much new science, with no reasonable expectation that our efforts would make any real contribution to occupational health. . . . The proposal would curtail the very sciences we need to help solve the riddles of cancer causation."



Laborer Union Hails Indiana's 1st Nuke Plant

The Laborer's International Union featured as a lead story in this month's union magazine the news that the Nuclear Regulatory Commission has approved full construction of the long-delayed nuclear power station on the Ohio River near Marble Hill, Indiana.

Titled "Nuclear Energy Plant in Indiana Making Einstein's Dream Reality," the article proudly hails the critical role its skilled and semiskilled membership has played in bringing the benefits of nuclear energy to the American people. "Nuclear developments," the monthly states, "have proved a boon to mankind in such fields as medicine and the other sciences. . . . In the area of providing power for man's use in his homes and industry, nuclear is perhaps the principal answer to the world's impending power production crisis."

Debunking the scare stories of the environmentalist groups, the monthly quotes from the Massachusetts Institute of Technology Rasmussen report, which demonstrates the excellent safety record of today's nuclear plants. "Opponents of nuclear energy ignore the great benefits and magnify the risk. . . . Nuclear power production means that electric bills will not be as high as they would be if more costly fuels were used, such as gas or coal," the article states.

The $1.85 billion project, the first nuclear plant in Indiana, is expected to begin partial operation in 1982 and full operation in 1984.

1978 APS Plasma Physics Meeting

Scientists Urge Fusion Development

Scores of major scientific and technical advances toward harnessing fusion power were announced at the annual meeting of the American Physical Society's Plasma Physics Division in Colorado Springs, Colorado Oct. 30 - Nov. 3 (page 17), but the main focus was the "politics of fusion." As stressed in the major presentations, the Carter administration's go-slow fusion program has to—and will be—turned around as fusion research breakthroughs proliferate in the coming months.

The APS meeting, the largest annual U.S. fusion conference, included 1,500 fusion scientists from 20 countries and 1,100 research papers.

The first day of the week-long meeting was capped by invited papers in a session titled "Social, Political and Economic Aspects of Controlled Fusion." During two presentations on the "International Aspects of Fusion Research" and "Current Status of the Magnetic Fusion Program," Dr. Edwin Kintner, director of the U.S. Fusion Office in the Department of Energy, detailed what the chief features of the fusion community's political strategy must be.

Kintner began by outlining the Carter administration's present policy assumption that fusion cannot be developed before 2025. Then, noting the recent success of the Princeton PLT tokamak reactor in obtaining breakeven fusion temperatures, Kintner predicted that the advances that will certainly be achieved over the next six to eighteen months will force the United States to reassess this policy and to reorient its program at least to realize commercial fusion by the 1990s.

In his presentation on "International Aspects of Fusion Research," Kintner noted that some factions of the Carter administration have opposed international collaboration in fusion research because of their general policy against technology transfer. Kintner added, however, that the success of the fusion program depends on international collaboration. In this context, he reviewed the unprecedented offer last spring of Japanese Prime Minister Fukuda for major joint U.S.-Japan development of fusion power, pointing out that Fukuda had recently restated Japan's commitment to develop fusion as quickly as possible before the Japanese Diet.

Up to this point Kintner had outlined the scientific, technical and political status of fusion power development. He then quoted from the final sections of his Artsimovich Memorial Lecture delivered at the Aug. 23, 1978 Seventh International Conference on Plasma Physics and Controlled Nuclear Energy Research in Innsbruck, Austria:*

". . . I would like to speak on a thought first proposed by Artsimovich which seems especially pertinent to our circumstances and for the individuals and programs whose leadership is represented so well in this auditorium. Artsimovich wrote in 1970 that there were three main reasons for mastering controlled nuclear fusion: first, it would provide access to practically inexhaustible energy sources; second, it did not require formation of great quantities of radioactive by-products; and finally—a philosophical reason—success in developing fusion for the practical benefit of all mankind would reestablish the self-confidence of scientists in themselves and in science. . . .

"In the United States, and I sense to some degree in the rest of the world, science has lost its own internal confidence and the confidence of the lay public in it. The assumed certainty that it is 'good' to penetrate the dark corners of nature with the illumination of the human mind is being questioned. Science is held responsible for the doubts that it has raised about the existence and nature of

Kintner: "We should proceed with confidence."

God, as explained by medieval man, with all the moral questions those doubts raise. Science is blamed for the development of weapons which can end civilization in seconds. Science is charged with providing the modern industrial processes which contaminate the environment and allow the population to increase to the point that life is not as full as many wish. Science is feared when it begins to experiment with the more fundamental aspects of genetics.

"And so, in many places, there is a turning of the back on science and scientists, at least in those areas which might be oriented toward further development of modern applied technology. Some scientists have accepted this value judgment. Many of the most brilliant have turned from working on or supporting any subject, including fusion, which might have direct, practical results.

"Perhaps it is precisely in this context that we should examine and try to learn from the life and contribution of Lev Andreevich Art-

* For the full text of Kintner's Artsimovich Memorial Lecture, see *Fusion*, October 1978.

simovich. If we in the fusion community can build on the great beginning which has been made and carry forward with the development of fusion—hopefully, optimistically, enthusiastically working together toward providing unlimited energy, the fundamental energy of the universe, in a controlled, environmentally benign manner—we can once more believe in ourselves and in science as the noblest, most constructive activity to which the mind of man can be turned. We may help reestablish that no one need fear shining the bright searchlight of the human mind on the many remaining dark corners of our understanding of the universe around us.

"We have made great progress in that direction. We are on the threshold of accelerating our pace. We are not yet at 'the beginning of the end,' but we may be 'at the end of the beginning' of the most difficult technological development man has ever attempted. We can and should proceed from this point with confidence—the confidence Artsimovich expressed in the quotation with which I began, 'Nevertheless, there can be no doubt that our descendants will learn to exploit the energy of fusion for peaceful purposes.' "

Thus Kintner made absolutely clear to the audience of 1,500 fusion scientists that the chief goal of the fusion program is igniting a renaissance of human reason mediated through the specific and scientific and technical advances of fusion researchers over the coming months. This, Kintner insisted, must be the immediate tactical strategy of the fusion community.

Foster: Next Five Years the Most Exciting

On the third day of the meeting, Dr. John Foster, vice president of TRW, made a major presentation on "Fusion: What Emphasis?" Foster's speech followed the presentation of the Maxwell Prize to Dr. Richard Post, one of the pioneers in fusion research and chief developers of the mirror machine approach to fusion at Lawrence Livermore Laboratory.

Foster, who heads up TRW's Energy Systems Division, is currently the chief advisor to the Carter administration on fusion research representing industry's viewpoint, and he is chairman of the DOE Ad Hoc Panel on Fusion. In the early 1960s, he was director of Lawrence Livermore Lab, and in 1965 he was appointed director of the Department of Defense division of research and engineering.

Foster outlined the Carter administration's energy plan for the United States over the next 22 years, based on a 3 percent rate of economic growth and primary dependence on coal and oil until the end of the century. Although this looks good on paper,

Foster said, its fundamental premise makes it very unlikely to succeed. Referring to industry studies, most likely a recent Westinghouse study, Foster reported that by 1985 new nuclear fission plants will not be assured of fuel supplies for their full 30-year lifetimes.

Therefore, Foster predicted, the administration will shortly have to change its policy on reprocessing and storage of nuclear waste to accelerate nuclear power plant construction and to increase fuel supplies. Foster cited in particular the fusion-fission hybrid reactor as a "national need," essential for the national and economic security of the United States in the following way.

First, he referred the audience to the policy of not developing fusion until 2025 put forward by John Deutch, DOE assistant secretary for energy research. Foster noted in passing that "Congress has not yet reached a decision on this policy." Next he outlined the "remarkable, incredible progress achieved in fusion research, both magnetic and inertial, over the past few years and months. The next five years will be the most exciting years in the history of fusion research. We will certainly achieve a fusion burn, but we must look beyond just good physics." Foster continued, however, that we are not and will not be prepared to apply these achievements of magnetic and inertial fusion burns to our national needs until we begin to establish the next phase of fusion development, the industrial phase.

Referencing the forthcoming invited talk by Dr. Hans Bethe, Foster then explained that the fusion-fission hybrid reactor must become a major focus of U.S. industry. The hybrid greatly eases the physics and technical requirements for harnessing economically feasible fusion energy and greatly accelerates the rate at which fusion can become the major source of energy for the world, he said. One hybrid fusion reactor can supply the fuel of five to ten or more fission power plants. But, Foster noted, it is chiefly the responsibility of industry to see that the hybrid is developed.

Foster complimented Kintner's direction of the U.S. Fusion Office, saying "the U.S. has an outstanding fusion program." Foster also underscored that the tremendous breakthroughs in fusion research were a result of international collaboration, probably referring to the contributions of the Soviet Union. In conclusion, Foster repeated Kintner's earlier call for rekindling the scientific spirit in the United States, insisting that this must be the immediate political strategy of the fusion community.

During the discussion period, this author questioned Foster on how the situation in fusion research could be turned around, given the Carter administration's recent rejection of a Westinghouse proposal to develop commercial laser fusion on a 50-50 basis and its obstruction of the Fukuda proposal. Foster pointed to the audience and stated: "You must turn the situation around, through your achievements over the coming period."

Bethe: Fusion-Fission Hybrid Essential

On the last day of the conference, Nobel Laureate Dr. Hans Bethe made

Continued on page 62

Fusion Advances Announced

Here are some of the most important advances in fusion and plasma physics research announced at the APS meeting. More detailed evaluations will appear in the next issue.

(1) The Princeton Large Torus tokamak at the Princeton Plasma Physics Laboratory continues to proceed to higher temperatures, about 70 million degrees, with a stable plasma and what appears to be better confinement of electrons as the plasma gets hotter in the center of the discharge.(The electrons previously have not been contained as long as the positive ions.)

(2) Experiments on the PLT conducted during the weekend before the conference indicated that radio wave heating was just as efficient as neutral beam heating. (The PLT has up to 3 megawatts of neutral beam heating potential and over 5 megawatts of wave heating. The breakthrough experiments at Princeton in July used only about 2 megawatts of beam heating.)

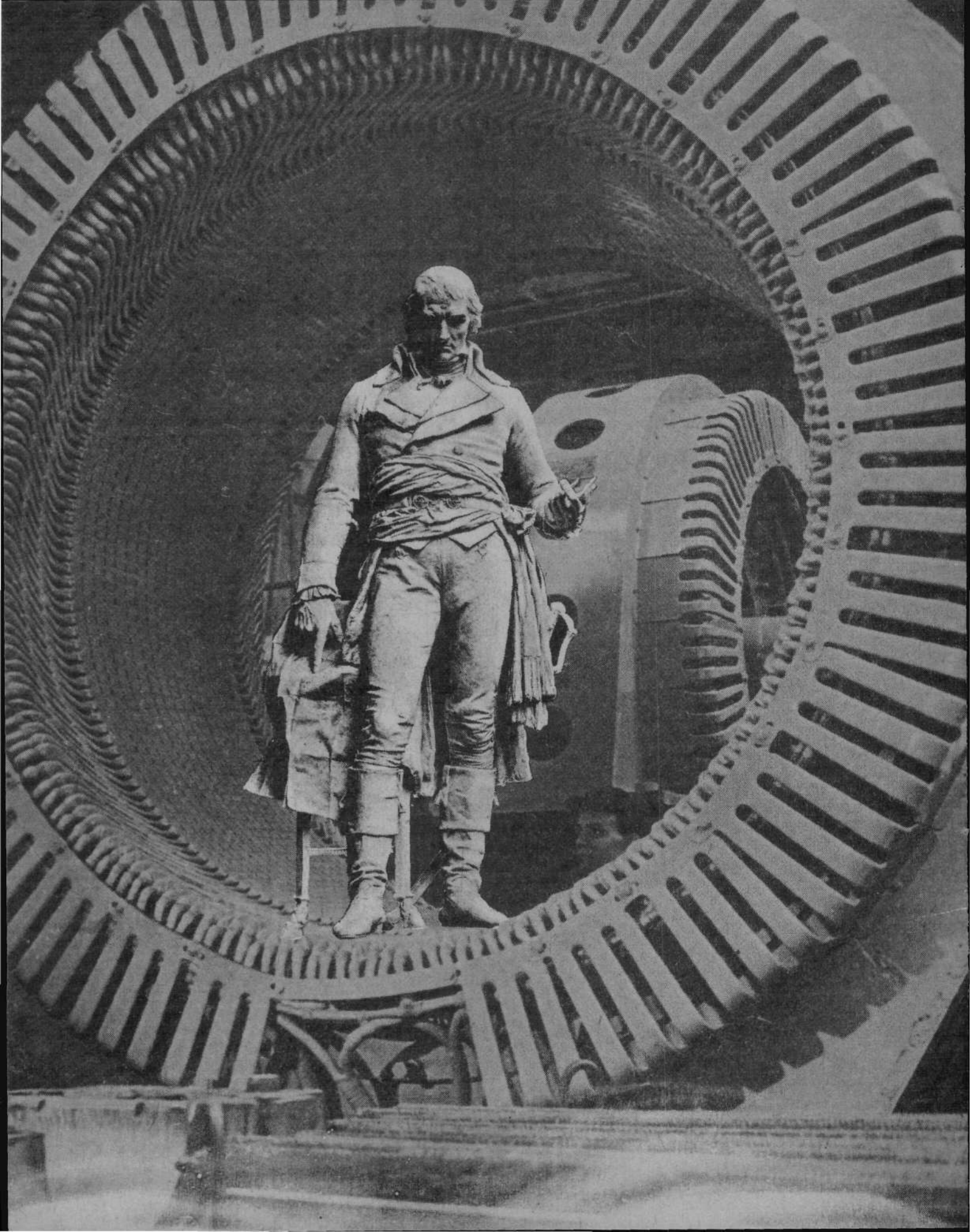
(3) The eight-beam carbon dioxide laser, Helios, at the Los Alamos Scientific Laboratory reports achieving 100 million fusion neutrons, comparable to the same output achieved at Lawrence Livermore Laboratory using equivalent power level glass lasers. The Livermore Shiva laser team reports over 10 billion fusion neutrons in their latest shots.

More important, the Los Alamos Helios reported two shots in which they got a significant delay between the time of maximum compression and neutron release. This indicates that the fusion fuel is being compressed to more than five times liquid density before being ignited. This process is key to achieving the so-called adiabatic or isentropic compression needed for high-gain energy-producing laser fusion pellets.

(4)The Oak Ridge National Laboratory's ISX-B tokamak reports initial results indicating the achievement of a beta (the ratio of plasma to magnetic pressure, a critical index of economic feasibility) of more than 2 percent.

(5) Experimental confirmation was reported at Sandia Laboratory in New Mexico that intense electron beams can be deposited efficiently in thin foils, a phenomenon first reported by Soviet Academician and top fusion scientist L.I. Rudakov in his electron beam fusion experiments.

(6) Major new experiments by A.Y. Wong of the University of California at Los Angeles on basic research on self-organizing structures in plasma physics.



Lazare Carnot And the Leibnizian Machine

by Dr. Morris Levitt

Lazare Carnot, known as the architect of industrial republicanism in France, mobilized the nation's scientific resources to give the French Republic an in-depth military capability, as well as making notable contributions to science. His work on the science of machines and his conception of geometrical motions, derived from the Neoplatonic physics of G.W. Leibniz and his disciples Euler and Bernoulli, provide still-relevant insights into the relationship between energy and machines as we enter the fusion age.

LAZARE CARNOT, WHOSE WORK laid the basis for modern mechanical engineering practice, is one of the select number of historical figures most responsible for the development of the technology-based republic. In fact, to understand Carnot's work in its broadest epistemological implications for economics and physics permits us to fully grasp the scientific and economic implications of the fusion technology era immediately before us.

Carnot was the first scientifically trained engineer to fully appreciate the concept of energy efficiency: the ratio of the amount of energy of a given form—relative to the maximum possible amount (the energy input)—actually utilized by a machine for productive purposes. Carnot's great contribution was to recast the most advanced formulation of the general science of mechanics of the 18th century, the Leibniz-Euler Principle of Least Action, to make clear the relationship between efficiency and the conditions governing motion and interaction in a physical machine. He showed that the maximum efficiency is realized when a machine with constrained motions undergoes smooth enough motions to satisfy the Principle of Least Action, the condition usually obeyed only by freely interacting bodies.

Carnot's achievement is of immediate relevance today in two important ways. First is his conception of greater efficiency as an increase in the throughput of productive forms of energy. The onset of fusion means a revolution in the efficiency of energy productivity both as a quantum leap in the conversion and amplification of electromagnetic and thermal energy via plasma-fusion-plasma processes and as a quantum leap in world economic productivity via the enormously increased efficiency of integrated agroindustrial complexes (nuplexes) powered by fusion energy. We need a new scientific conception of

A statue of Lazare Carnot, *erected in 1882 at his birthplace in Nolay, is shown here framed by components of an electrical generator.*

efficiency appropriate to these two great transformations, just as Lazare Carnot and his son Sadi provided such new concepts for machines and engines.

The second point that makes Carnot's work important to us today is his conception of the connection between energy throughput and the nature of the mediating physical processes. The Principle of Least Action, as he developed it, provides a critical juncture between two physical domains. Relative to the domain of entropic processes it is the upper bound of efficiency; but relative to more general processes, like the self-concentration and transformation of energy in plasmas, least action defines a lower domain of efficiency. The problem is that physics today conceptually ends at just that boundary.

In both nuclear physics and plasma physics, our present inadequate understanding of basic processes, as well as recent anomalous results in high-energy particle physics,* demand more fruitful theoretical approaches to the field-particle problem. This field-particle question is fundamental to understanding how the world works: why the existence of single particles cannot be accounted for by the fields of interaction between particles, and why the laws of interaction can qualitatively change as the number of particles or field intensity (energy density) is varied.

As an older and wiser Werner Heisenberg put it in 1976, the year of his death, we must see beyond the surface symmetries of physics to hypothesize "the underlying (dynamical) law."**

Ignoring Heisenberg's advice, physics today approaches fundamental problems like someone who has been struck on the head while at work. Upon regaining consciousness, the victim can still skillfully perform his job, but he is stuck when presented with a new problem because he can't remember how he got there or how he learned his trade.

The purpose of this article and the series on humanist science and the unified field problem is to contribute to curing such amnesia.

As the series will show, we can summarize all that is essential about the positive content and deficiencies of contemporary physics by examining the contributions of a handful of critical figures over the past three centuries—Lazare Carnot, Christian Huyghens, Joseph-Louis Lagrange, Joseph Fourier, Max Planck, and Erwin Schroedinger. Along with other works referred to here, this series of articles will demonstrate both the continuity and the indispensable role of the Neoplatonic-humanist outlook and institutions for scientific progress.

Although the scientific contributions presented here are not uniquely due to these few individuals, in all cases their work represents the necessary condensation or qualitative advance of physical theory, through the noetic activity of the *preconscious*, into forms crucial for further conceptual progress.

More specifically, their work was critical in generating the three essential principles of contemporary physics: (1) Huyghens Principle, (2) the Principle of Least Action, and (3) the Principle of Quantization of Energy. These principles concern, respectively: (1) how energy propagates in space; (2) what principles govern the mechanical transmission of energy; and (3) the compacting of energy into discrete units. Each principle can be generalized from its original context and the three can then be synthesized into one unified conception. Present physics, in fact, can be summarized in just one sentence!

These principles are not independent; they are different aspects of the unitary lawfulness of physical process. That lawfulness, as we will show, is not reducible to so-called conservation laws that are determined by the same principles. Rather, lawfulness is the higher-order process of the self-development of the physical universe.

This was the issue for Leibniz versus the enemy of humanism, Newton,† as it was for Plato against Aristotle: the lawfulness of the universe as a whole, the cosmos. The particular (or the particle) participates in that higher lawfulness through the process of self-differentiation and self-development of the universe. For the Neoplatonist, energy is a live force; the universe is alive with energy and its transformations. The Newtonian sees only the dead particles and the occult forces between them; for him, the universe is a machine doomed to run down.

Lazare Carnot was the epitome of the humanist technologist, basing his practice on Leibnizian science and political economy. Through his application of the universal energy principle to the general class of machines, he forged a critical link between theoretical and applied science. That link was crucial for subsequent industrial progress. What is more, Carnot's treatment of the mechanics of machines directly embodies the worldview that is still indispensable to solution of fundamental scientific problems today.

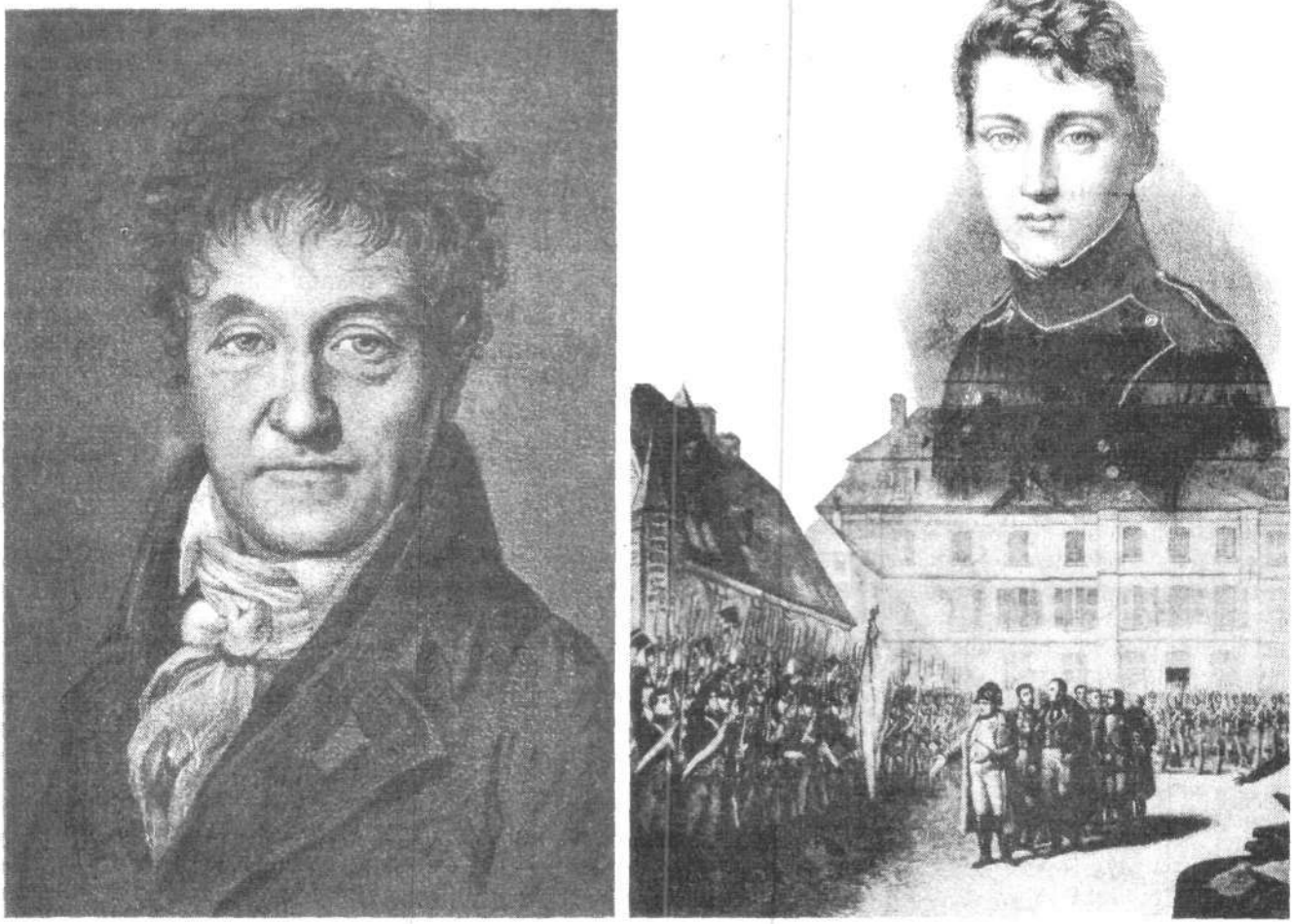
As in Carnot's time, the fight for progress today is not just a question of growth versus no growth; more fundamentally, the battle lines will be drawn by the scientific epistemology that prevails in shaping the future.

Carnot's Humanist Roots

One of the richest periods of humanist scientific and technological development was the 50 years spanning the last quarter of the 18th century and the first quarter of the 19th.‡ This was the age that witnessed the establishment of France's great École Polytechnique and that produced the brilliant work of Gaspard Monge, Lagrange and Fourier, Lazare and Sadi Carnot, and their many students and collaborators. This work not only laid the basis for the entirety of modern dynamics, but, through Cauchy, Dirichlet, Gauss, and Weierstrauss helped to initiate the seminal mathematical contributions of Riemann and Cantor. In France today we know this tradition directly in the continuum physics of Henri Poincaré and Prince Louis De Broglie.

The quality of this period is not lost on those who know something about how West Point was created and how American engineering science got its start. Nor is it lost on European republicans in the tradition of de Gaulle, who are today working for the realization of the Giscard-Schmidt design for global economic and scientific progress.

Less readily understood, however, is the way in which these accomplishments draw upon the earlier organizing of the networks of Gottfried Leibniz and Cardinal Mazarin



Lazare Carnot (left) in an 1813 portrait by L. Boilly. His son Sadi is shown (top right) in his École cadet uniform from a portrait painted the same year by L. Boilly. In the accompanying illustration, Napoleon is reviewing cadets in the courtyard of the École Polytechnique in 1814. Napoleon failed to carry out Carnot's plans.

and the plan for a "Christian commonwealth of Europe." Lazare Carnot, the political and scientific genius behind the École, was the product of these networks. Since this means that he was *not* a Jacobin, nor a deist, nor a Newtonian, it is worthwhile, prior to considering Carnot's scientific theories, to see just how his faction arose.

The Carnot family was from the staunchly Catholic and promonarchy province of Burgundy, and Lazare was sent in his youth to the Oratorian College d'Autun.

The Oratorian monastic order was established in 1611 by Cardinals Richelieu and Berulle, with help from Descartes, as an explicit counterpole to the Jesuits and their useless, reactionary Aristotelian dogma. Seeing themselves as builders of the French nation, the order organized their teaching instead around Saint Augustine, Plato, and the Christian-Platonic tradition in literature and the arts. They brought this directly to the sons of the important noble and bourgeois families who supported the crown. They also taught what was called the new science of Kepler, Galileo, Huyghens, and Descartes as an undertaking consistent with the Augustinian mission of the church. With the great families of De Broglie and Savoy among the patrons of this order, Mazarin and his protégé, Colbert, were able to recruit from among its teachers and students some of their most trusted military, scientific, and economic advisors.

In the late 17th and early 18th centuries the Abbots Malebranche and Houtteville brought something new and decisive into the Oratorian schools—Leibniz and Bernoulli. The Leibnizian method mediated against some of the more reductionist elements of Cartesian epistemology and brought the quality of education to a point where scientific genius of the order of a Monge, Carnot, or Fourier could be produced. (Fourier's Benedictine Abbey at Auxerre was modeled on the Oratorian program.)

It is not surprising, therefore, to find Carnot, from his

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* Eric Lerner, "The End of Quarkery," *Fusion*, October-November 1977; and "Quarks on Way Out?" *Fusion*, July 1978, p. 48.

**Werner Heisenberg, "The Nature of Elementary Particles," *Physics Today*, March 1976.

† Carol White, "The Royal Society," *Fusion*, December 1977-January 1978; and "Science Is Politics," *Fusion*, May 1978.

‡ This section was written in collaboration with Dr. Henry Moss, who is completing a larger study on 17th and 18th century French scientific humanism, including a complete political biography of Carnot. A valuable source of biographical and scientific material on the Carnot family is provided by the writings of Professor Charles C. Gillespie of Princeton, which are listed in the reference section.

position on the Directory in 1796, appointing two Oratorian masters, Lakanal and Danou, to the job of designing for the fledgling French republic the world's first public educational system. Characteristically, each school was equipped with a full scientific laboratory.

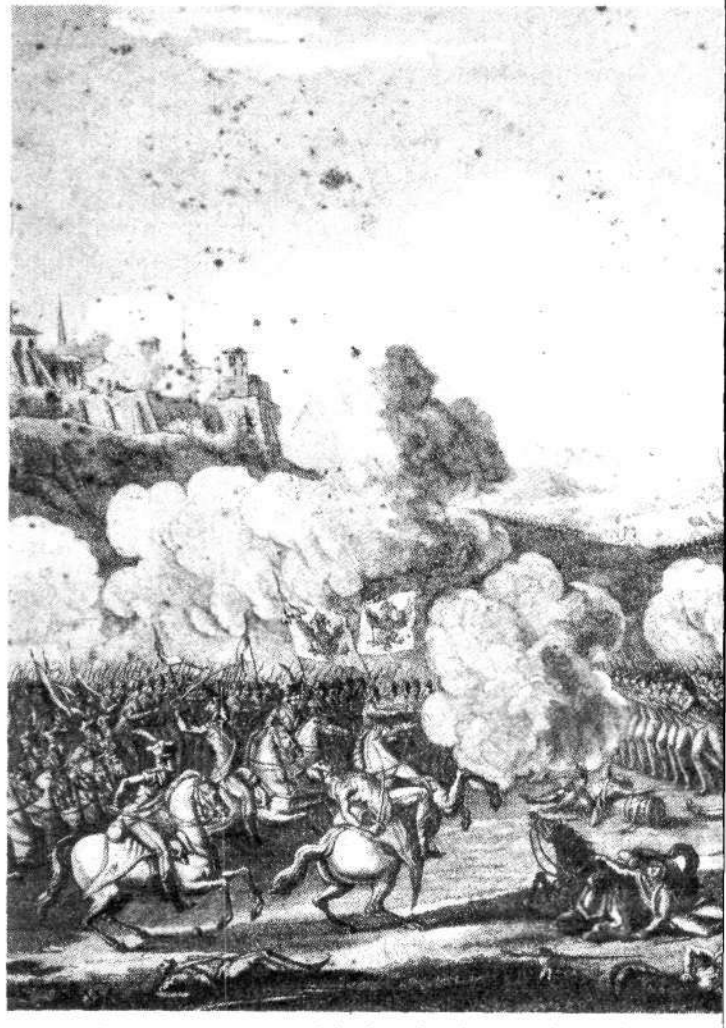
After graduating from the college, Carnot entered the École du Genie at Mézières, the outstanding military engineering school in Europe. Here again Carnot was at the center of intense discussion of the Mazarinist industrial policies and the Leibnizian scientific epistemology.

The Mazarin policies were most closely associated with the tradition of Marshal Sebastien Vauban, who, along with Marshals De Broglie and Turenne, made up the guts of the French armed forces under Louis XIII and Louis XIV. In 1675, Vauban established the Corps des Ingenieurs du Genie Militaire as the brains of a vast scientific humanist organizing force that built the army into the most advanced militia in the world, laid plans (along with Colbert) for the industrial development of France and Europe, and called upon the king to initiate vast, urban-based colonization of the new world.

In 1672 to 1675 the feudal particularist interests around the Houses of Conde, Orleans and the Dutch Oranges pulled a coup against the Mazarinists and undermined their policies. With the revocation of the Edict of Nantes and the French-Dutch wars, Colbert, Turenne, De Broglie, and Savoy were isolated from the court, and after Huyghens and Papin were driven out of France, the Colbert-founded Academy of Sciences became dominated by the aristocratic pseudoscience of La Mettrie, Condillac, Diderot, and the British Royal Society. It was Vauban's Corps du Genie that kept alive the tradition of Leibniz, Bernoulli, and, later, Euler and that fought in Paris against the encroachments of the so-called Enlightenment. The Mézières was the most outstanding immediate center for this tradition, along with its sister institutions the École des Mines, the École des Ponts et Chausees (bridges and roads), and the École d'Artillerie—all products of the work of Vauban.

At the Mézières there was consistent agitation for policies of expanded urban and technological growth for the French nation, and for the mobilization of the armed forces to lead the way. Coulomb wrote *memoires* calling for the integration of all the technical corps and their centralization at Paris. He called for the priority of peacetime deployment of the engineering corps. Carnot wrote *memoires* calling for a national commitment to apply the latest results in dynamics to the massive technologization of industry.

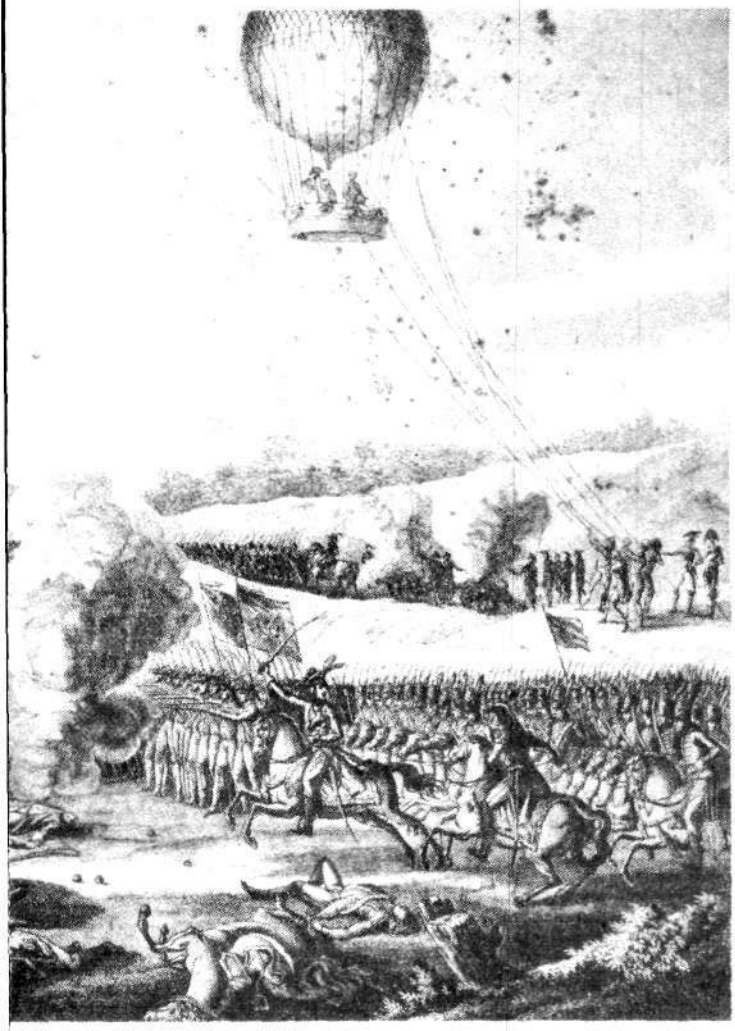
Neither Coulomb nor Carnot stopped at the level of political agitation. Under the guidance of the Abbe Charles Bossut, who introduced Leibnizian topology and Bernoulli's *Hydrodynamica* into the Mézières, and through the teaching of the gifted Gaspard Monge, who introduced the geometry of Leonhard Euler, Coulomb and Carnot were both able to make important contributions to the modern theory of machines. Far from the hollow speeches of the academy, Coulomb and Carnot developed their theories while on garrison duty! It is not surprising, then, that Carnot used the Mézières as the explicit model—down to



Lazare Carnot was responsible for developing the industry and militia that permitted the in-depth military defense of the Republic. His colleagues at the École Polytechnique ex-

the transfer of equipment—upon which to construct the École Polytechnique. Nor is it surprising that he appointed as the initiating staff Monge, Bossut, Prony, Lamblardie, and others from the engineering tradition.

When the French nation was threatened by British-instigated foreign war and the Jacobin levelers in Paris, Carnot took his case directly to the Lesiglative Assembly, playing a leading role on the education and military subcommittees. When the Girondist and then the Montagnard regimes refused to prosecute the war and sabotaged the nation's ability to mobilize its vast natural and human resources, Carnot went directly, on mission, to the armies, where he consolidated immense political power among the artillery, engineering, and logistical corps and among both aristocratic and nonaristocratic patriotic officers. Through his role in organizing the defense of the northern front, Carnot gained sufficient political clout to *force* his way onto the otherwise hostile Committee of Public Safety. From this position of power, he organized the great defense of 1794, and after his famous *Levée en Masse*, the



perimented with an early air force, using heated-air balloons. Above, French troops fighting the victorious battle of Fleurus, June 1794, aided by their air force.

great offense in 1795. Through the Levée Carnot directed the mobilization of the entirety of the nation for the military effort and for the immediate establishment of a true industrial republic.

The offense of 1795 secured Prussian and Spanish neutrality and laid the basis for Carnot's dream of a great continental system that would break William Pitt's power and destroy the British looting system once and for all. The Coup of Fructidor ended these plans and Napoleon fell far short of the humanist industrial policies of Carnot. Despite these setbacks, Carnot succeeded at making industrial republicanism a permanent part of the French national identity. Equally important, he left behind him in the form of his scientific followers and of institutions like the École Polytechnique, the basis upon which the modern republicanism of de Gaulle could be built and upon which it could be linked, through the Grand Design, with the tradition of Franklin and Hamilton in the United States.

This paper will focus specifically on bringing to light a crucial feature of Carnot's scientific outlook. Carnot was not just an exceptional practitioner of mechanics or a mechanical engineer, although his work proved indispensable to both fields. He proceeded from the standpoint of humanist political economy; namely, that a more successful economy is the result of a population that better masters the lawful ordering of the physical universe.

More specifically, Carnot knew that the classical principles governing the operation of machines, such as conservation of energy, must be subsumed by the principles of development of human society. He knew that the design and application of machines are determined by the need to increase the productivity of the economy as a whole. These are epistemological conceptions without which science cannot function.

It is not surprising, therefore, that in his abstract science as well, Carnot at least implicitly recognized that mechanical principles are not the last word in physics.

The Essay on Machines and the Principle of Least Action

Lazare Carnot's major scientific works are the following: the 1783 *Essay on Machines* (*Essai sur les machines en général*), later generalized in 1803 as the *Principes fondamentaux de l'équilibre et du mouvement* (*Fundamental Principles of Statics and Dynamics*); his 1786 essay submitted to the Berlin Academy prize competition on the infinite, and published in 1797 in fully developed form as the famous *Réflexions sur la métaphysique du calcul infinitésimal* (*Reflections on the Metaphysics of the Infinitesimal Calculus*); and his own favorite work, the *Géométrie de position* of 1803. He also published in 1801 *De la corrélation des figures en géométrie*.

The original *Essay on Machines* is most important for purposes here. Because the essay is so thoroughly Leibnizian in its method, it provides the essential conceptual link between Huyghens's geometrical optics and subsequent crucial developments in geometrical mechanics and analytic heat-radiation theory. Most important, Carnot's work reveals the actual motive-force of the Leibnizian method. We shall approach this method in two steps.

First, the basic principles of Leibnizian physics: One of the most vulnerable flanks of the Cartesians to the Newtonian onslaught was the gap between Descartes's transfinite principle of *perfection* and his principle of *conservation of momentum*, the inappropriate cornerstone of Cartesian physical dynamics. Perfection as Descartes and Leibniz understood it meant the continual increase in humanity's ability to comprehend and control the physical universe through the ever-higher ordering of the predicates of scientific knowledge. This process of evolution cannot coexist with the principle of conservation of momentum. It must be due instead to the transformation of the forms and efficiency of energy.

As Leibniz and his followers recognized, the problem with building an invariance principle around the "quantity of motion" (or momentum, the product of the amount of matter, the mass, times the velocity of displacement of the mass) is that you are flung back into the pernicious dichotomies of the Newtonian universe. The velocity term

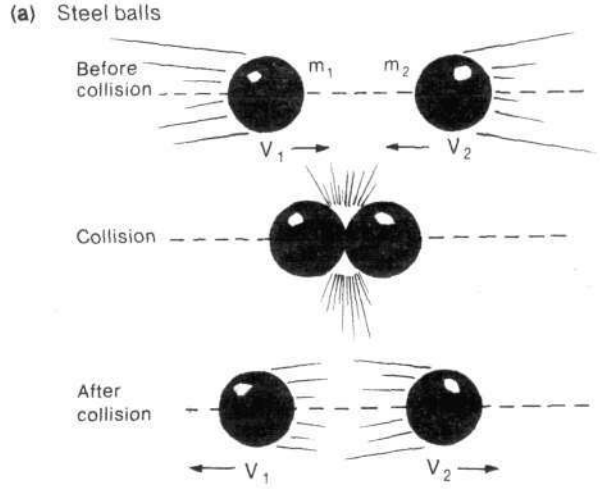


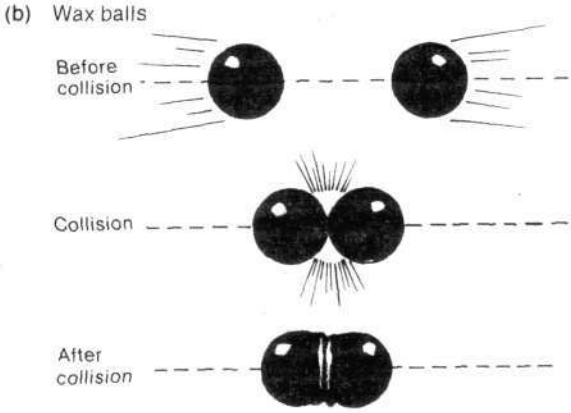
Figure 1
LINEAR MOMENTUM

Linear momentum is the product of mass times velocity for an individual particle. For a group of particles, it is the vector sum of the individual momenta. For two particles approaching along a common line and colliding, as shown, the momentum along any axis must be the same before and after the collision. That is the principle of conservation of momentum, which in the simple case shown takes the form:

$$m_1V_1 - m_2V_2 = m_2V_2 - m_1V_1.$$

If the masses are equal and the initial velocities are equal and opposite, the total momentum of the system is zero. Conservation of momentum means that "empty" space is homogeneous; wherever the particles go, the total momentum remains zero.

If there is no interaction, then the total energy is of the form $(\frac{1}{2}m_1V_1^2 + \frac{1}{2}m_2V_2^2)$. *If* $m_1 = m_2$ *and* $V_1 = V_2$ *and the particles collide and stick together, then the energy appears to discontinuously go to zero. In reality, the process of interaction transforms the energy into other forms. This process of energy transformation is the invariant of the physical universe, and not some static total quantity of momentum.*



in the quantity of motion is measured against absolute space and time frames, but the conservation of linear momentum (see Figure 1) means that you could not detect any arbitrary linear displacement of either a moving body or the "absolute" space as a whole!

A simple example suffices to show why the actual physical universe cannot be built up from as simple a principle as conservation of linear momentum. Consider two particles of equal mass moving toward each other with equal velocities. Suppose that the particles are either perfectly hard or perfectly sticky. What happens at the point and moment of contact? The two bodies cannot penetrate or separate from each other, and the preservation of the linear sum of the momenta produces an aggregate body that just sits there, motionless.

The real world doesn't work that way! (Nor, as Bardwell has shown, is the real world representable by the billiard table.)*

The Leibnizians asked: What dynamical quantity—independent of the unknown quality of microscopic impact and interaction—is related to the active transformation of the physical universe and to humanity's operations, efficient to transform the ordering of the physical universe? That question serves as a natural introduction to the concepts of force, work, and energy.

The net *vector* result of all the physical interactions to which a static or moving body is subjected is called the *force* acting on it. In a given physical manifold, the integral of the vector product of force times displacement through which it acts,

$$\int F \cdot dl = W,$$

yields the scalar measure of reproducible transformations within an invariant manifold, the *moment of activity*, known more familiarly as *work*. (See Figure 2 for a discussion of force and work.)

A simple example, well known to Carnot from Bernoulli's work, was the expression for the work necessary to raise a weight and potentially recoverable in the weight's fall. The work done in lifting a brick is represented by a simple expression. The gravitational force is very nearly constant, and if at each instant the lifting force is just overcoming it, the lifting force is $F = mg$. Suppose the distance lifted is H. Then the work done is just $W = mgH$. If you look at the units in which this form of work is expressed,

$$\text{mass} \times (\text{distance}/\text{time}^2) \times \text{distance},$$

you quickly find that it consists of mass times the square of velocity, as shown in Figure 2. Therefore, the dynamic scalar equivalent of force realized as work is not momentum, but *quantity of motion in realized motion*.

This is what Leibniz and his followers called *vis viva* or *live force*. It is known today by that less exciting term, *kinetic energy*.

Now we come to the second step, the real problem of Neoplatonic investigation of work and energy: How is conservation of *vis viva* incorporated into a coherent con-

ception of self-reflexive change in the physical universe? That is the problem of reintegrating the independent time element into a higher-order synthesis. Carnot's treatise achieves this by developing the relationships between work and two other key concepts: *action*, the integrated product of work and time ($A = \int W\,dt$), and *power* ($P = dW/dt$), the rate at which work is done or energy is transformed. More importantly, Carnot's *Essay on Machines* provides the answer to how physical science is efficient for human control of the rate of increase of negentropy of the physical universe.

Carnot's Mechanics

Carnot's contribution was to formulate the *vis viva* principle for machines in a way that made clear the efficiency conception. Before summarizing Carnot's line of approach to this problem, consider a different example: Why does a physical system, like the solar system, do what it does from moment to moment? (See Figure 3.) The usual explanation is that the smooth continuity and regularity in the observed pattern of motions are proof of the innate nature of the forces and axiomatic mathematical equations at play. Aristotle, through his godchild Newton, observes the order of the solar system and induces laws for each part which, when combined, predict that the whole business has no predictable order. But as Bardwell has summarized, the research on the problem shows that the many body problem ($n > 2$) is in principle indeterminate!**

Once one rids one's mind of the superfluous baggage of Aristotelian logic, it becomes clear that the planets do not move according to the linear sum of all the two-body forces. *The energy content of the system as a whole* determines the unique transformations of the form of energy and geometrical configuration. The Newtonian forces are fictions invented after the fact, fictions that can describe only a very limited part of the totality of real physical situations.

Carnot approaches the problem from the other end, the side of physical reality. "Engineer" Carnot approaches not the specific machine, but the *species machine*, from exactly the standpoint that physics must approach the physical universe. The machine for Carnot is a device for transmission of energy throughput. What defines a particular subspecies of machine is the specific form of the constraints placed on the motion of its members. In other words, a machine is a material mediation of energy throughput, in which the ratio of energy input and output is determined by invariants of the machine's geometrical dynamics.

To make this more specific in the form employed by Carnot, consider the following two conceptions essential to his work:

(1) All motions consistent with the geometrical constraints on the motions of a machine (produced by physical interaction with constraining members) are called *geometrical motions* (Figure 4).

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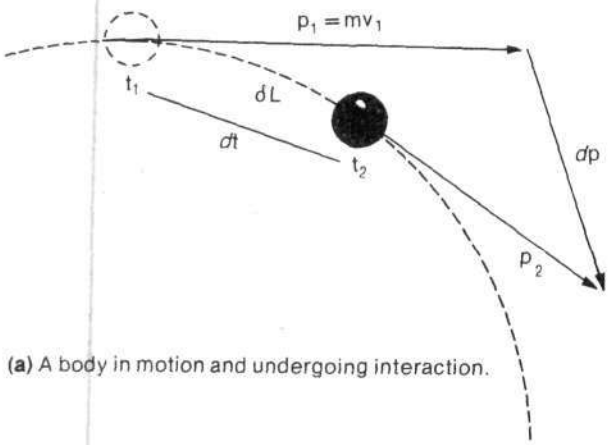
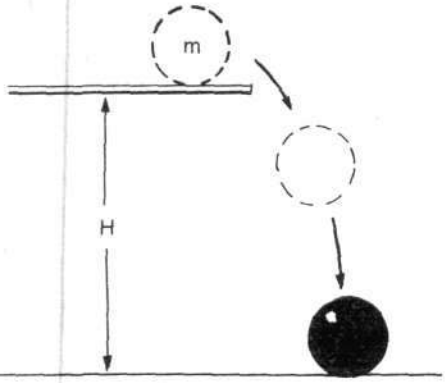
* Dr. Steven Bardwell, "Solving the Three-Body Problem," *Fusion*, June 1978.

**Dr. Steven Bardwell, "Solving the Three-Body Problem."



(a) A body in motion and undergoing interaction.



(b) A body falling through height H.

Figure 2
FORCE, ENERGY, AND WORK

As bodies undergo interaction, their directed motion or momentum may change. Force is a deduced vector quantity that is equal to the rate of change of momentum:

$$F = dp/dt.$$

To effect a change of energy, the body must move in the direction of its time rate of change of momentum; that is, along F. *If the body moves through an incremental displacement* δL *along the direction of* F, *then the "work" done, or the energy change effected is given by*

$$\delta W = F \cdot \delta L = dp/dt \cdot \delta L = \delta E.$$

Since p *is expressed in units of mass times velocity, inspection immediately shows that work is equivalent to the change in quantity of energy expressed in units of mass times velocity squared.*

If a steel ball falls through a height H, therefore, it will have kinetic energy E given by

$$E = \tfrac{1}{2}mV^2 = mgH.$$

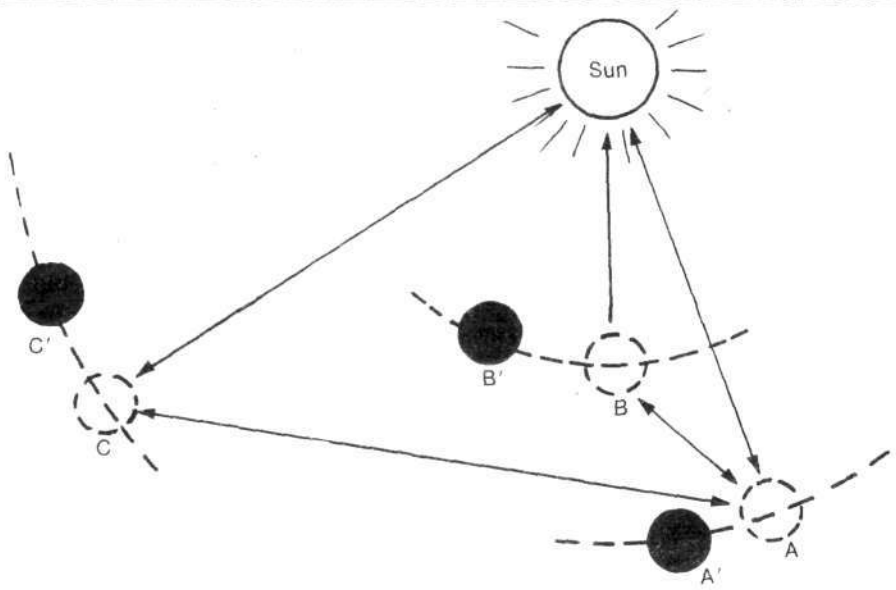


Figure 3
HOW DOES THE SOLAR SYSTEM WORK?

Suppose the figure represents a planetary system like our own. Is it a big machine or clock that moves because of the two-body forces (as defined in Figure 2) indicated, or is there a principle operative for the system as a whole?

Under some circumstances, the two descriptions give equivalent results when computations are performed. But as Nobel Prize winner I. Prigogine has recently demonstrated (Celestial Mechanics, *December 1977), once there are more than two interacting bodies, the mechanical result must become statistical.*

Nature, however, is much better behaved. The self-interaction of the system as a whole—its total energy—determines a continuous set of motions. Whether the system is stable or flies apart, the process is lawful, although not determinist.

(2) There are an *infinite* number of possible geometrical motions. In other words, from moment to moment there is a nondenumerable nested set of displacements of the masses of the system (or *continuous mappings of* the manifold of the system if it is thought of as a physical topology rather than as connected mass points) consistent with the stable constraints on the system.

What sort of principle—consistent with the physical reality of the integrality of the system and the existence of geometrical constraints—can then account for the determination from these infinite possibilities of a unique solution in both theory and practice?

Carnot solves the problem by showing that for each hypothetical geometrical motion there is a specific amount of *vis viva* transferred from the machine to elements of its constraining members. The mathematical expression for the conservation of the total amount of *vis viva* is given by

$$\int muU \cos z = 0.$$

Carnot then hypothesizes that of all these possible geometrical cases the one actually realized is the dynamical solution for which the transfer of *vis viva* to the constraining members is *minimized*. This can be expressed in the form of the variational principle

$$\delta \int mU^2 = 0.$$

This is equivalent to minimizing the action (as defined earlier) of the system—that is, the Principle of Least Action—and it thereby determines differential equations of motion for the system such that *vis viva* is conserved for the system as a whole.

Let us now review in greater detail Carnot's derivation of his mechanical principles. For each geometrical motion, there is a transfer of momentum and *vis viva* from the mass centers of the system. Thus, the constraints determine a family of trajectories in the phase space (the mapped relationship between each position and each momentum value of each mass) of the system.*

* For a description of simple phase spaces and how constraints and conservation principles contract the phase space appropriate to a physical system into a specific topology, see Dr. Steven Bardwell, "Solving the Three-Body Problem," *Fusion*, June 1978. A brief explanation is given in the box on page 28.

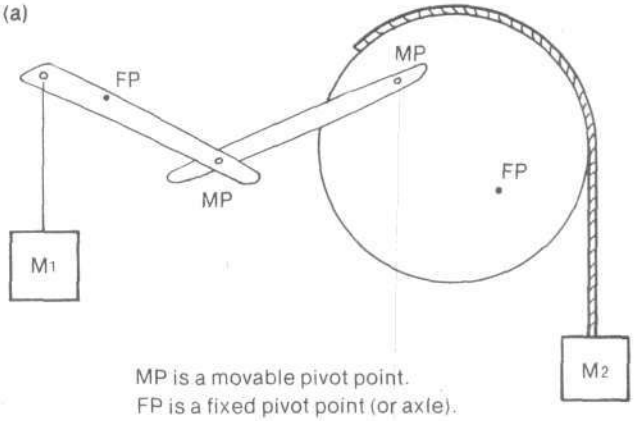
Figure 4
GEOMETRICAL MOTION

The conception of geometrical motions, now more commonly known as virtual displacements, *is the essential link in the generation of the integro-differential equations of motion for the dynamics of any well-defined physical system.*

As examples, consider the two systems shown in a *and* b. *Imagine that the diagrams represent either static positions of the systems or instantaneous pictures of the systems while they are in motion. In either case, a geometrical motion is any displacement of the components of the system from the positions shown at time t, to some other configuration at some later time* $(t + \delta t)$, *so long as no defining physical feature of the system is violated.*

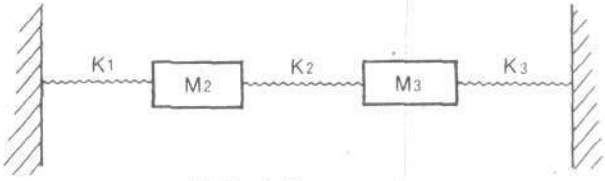
Some geometrical motions are shown for b; *the reader can imagine what they are like for* a.

(a)



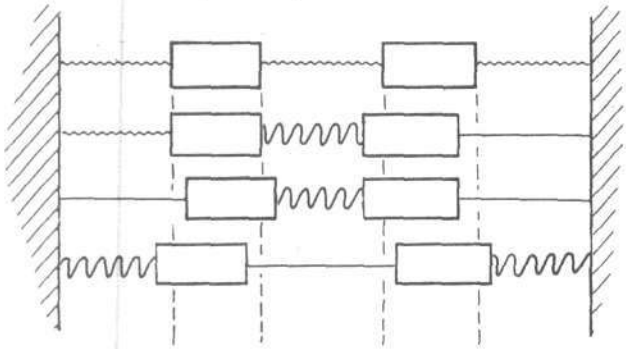
MP is a movable pivot point.
FP is a fixed pivot point (or axle).

(b)



M stands for a mass.
K is the spring constant.

Some possible geometrical motions



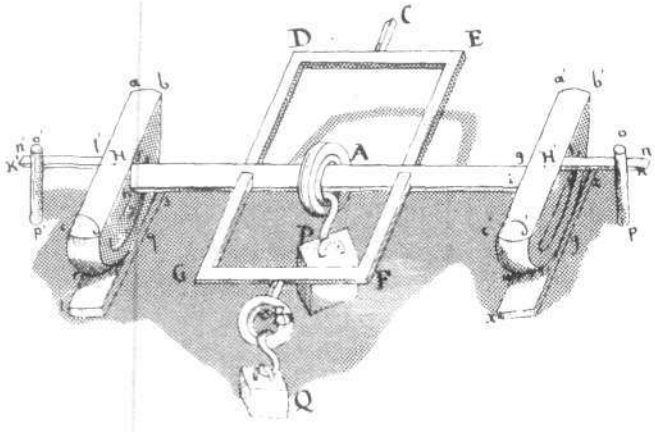
Carnot provides three other examples of geometrical motions in his Essay, *as summarized by his biographer Gillespie:*

(1) Two globes in contact. An impulse displacing both in the same direction along the line of centers would produce a geometric motion; an impulse separating them along the line of centers would not.

(2) Several bodies attached by flexible but inextensible wires to a common center. Any motion in which all remain equidistant from the center is geometric even if they shift among themselves; any motion altering the length of a radius is not.

(3) A body moving on a curved surface. A movement tangential to the surface would be geometric; any departure from the tangent would not.

At right is an illustration from Carnot's mechanics treatise showing a machine designed to study the effects of friction on machine performance.



Carnot's method is based on outflanking the unknown microscopic details of impact by transforming *determinate* mechanics, via geometrical motions, into an *indeterminate* form from which all the basic results can be obtained.

At the heart of Carnot's mechanics is the conception that whatever difficulties the mode of particle interaction presents (for example, hard or sticky rather than elastic impact, or discontinuity of interaction), or the physical state of the system (gas or liquid, rather than solid), there are conditions under which the system can undergo reversible motion at the macroscopic level. Conversely, reversible motion implies that the quality of microscopic interaction is not altered. *Therefore, geometrical motion bears a relation to the macrodynamics similar to that between the geometry of phase space and the microscopic dynamical parameters.*

Carnot makes such a connection explicit in his 1803 *Principes*:

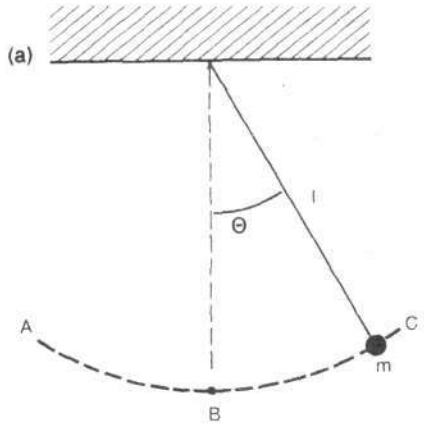
> Any motion will be called geometric, if, when it is impressed upon a system of bodies, it has no effect on the intensity of the actions that they do or can exert on each other when any other motion is impressed upon them.

The indeterminate topology of the totality of geometrical motions (the macroscopic expression of the phase space topology) provides the determinate principles on the basis of which the physical dynamics of a system, when acted on by specific external forces, can be determined.

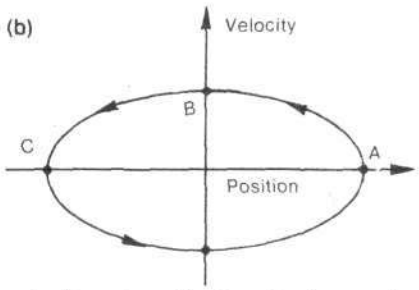
Indeterminate-Determinate Dynamics

The analytic kernel of this approach is contained in Carnot's expressions for determinate and indeterminate dynamics. In this work, he employed the following quantities:

- m the mass of each "corpuscle" (in the machine);
- V the actual velocity of a mass corpuscle;
- u the velocity of the mass corpuscle during an infinitesimal geometrical motion;
- U the velocity lost to the internal constraints as a result of undergoing (real or vitual) displacement;
- z the angle between u and U;
- Z the angle between V and U.



The pendulum mass m moves along orbit ABC, changing the angle with the vertical, Θ.



Each point (A, B, C) shows the direction, speed, and position of the pendulum in phase space at a certain time.

Carnot's Method: The Case Of the Pendulum

Carnot's analysis can be applied to the problem of the motion of a pendulum—a case study in simple harmonic motion, which forms the basis of most physics. Figure (a) shows a pendulum of length l and mass m. The only constraint on this system is the fixed length of the pendulum. The only necessary coordinate, therefore, is the angle Θ, which measures the displacement of the pendulum from the vertical.

The first step in Carnot's approach to mechanics is the identification and analysis of the geometric motions of the pendulum. As Carnot defined it, the geometric motions of a system are those motions consistent with the physical constraints on the system. In the case of the pendulum, the geometric motions are the class of orbits of the pendulum that leave the length of the pendulum fixed; that is, the pendulum can move only along an arc of (fixed) radius, l. Any displacement of the pendulum along this arc (shown with a dotted line in Figure a) is a possible geometric motion.

As Carnot stressed, the actual motion of the pendulum is *not* determined by the so-called engineering constraints on the system. In the case of the pendulum, this indeterminacy is obvious; but compare the case of a steam engine. Is it so obvious that the size of the piston, the radius of the wheels, and the pitch of the stroke do not suffice to determine the motion of the engine?

Bernoulli-D'Alembert

Carnot recognized the fundamental point that a higher-order specification was required to determine which geometric motion, out of all possible such motions, would be the actual trajectory of the pendulum. He knew that some global principle inherently irreducible to a sum of the constraints on the system had to be found.

For this reason, Carnot attributed significance to the Bernoulli-D'Alembert principle of virtual work. This principle takes a particularly simple form in the case of the pendulum, and can be stated efficiently (following Hamilton) as, "The actual

The first result obtained is based on two simple axioms concerning the interactions between mass corpuscles during a displacement: equal action and reaction, and zero relative motion of corpuscles after an impact event. Carnot expresses this verbally as:

> . . . the sum of the products of the quantities of motion impressed on each other by the corpuscles . . . multiplied by the velocity of the corpuscle on which it is impressed, evaluated in the direction of that force, is equal to zero;

and mathematically as

$$\int (mV)(U \cos Z) = 0.$$

Since

$$U \cos Z = V,$$

this reduces to the conservation principle (on which it is actually based) for *vis viva* of the system:

$$\boxed{\int mV^2 = 0.}$$

If, instead of undergoing a real displacement, the system undergoes a geometrical motion, similar considerations lead to Carnot's indeterminate equation

$$\int (mu)(U \cos Z) = 0.$$

Since

$$u = U \cos Z,$$

the expression reduces to the pseudoconservation principle applicable to the whole class of geometrical motions:

$$\boxed{\int mu^2 = 0.}$$

Therefore, regardless of the type of internal or external interaction, as long as the actual motion of the system is a member of the class of geometrical motions, the system will obey some form of the "conservation of *vis viva*" principle. The unique result for this general case, which is consistent with conservation of *vis viva* obtained for the more restricted case of elastic collisions, is the minimization of transfer of live force to the constraints:

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motion is the geometric motion that minimizes the sum of the virtual work done by that motion and the kinetic energy of that motion."

This is the higher-order principle that governs the motion of the system.

To translate this principle into an equation of motion, we need to know the dependence of the kinetic energy and forces in terms of Θ. Simple calculations show that the force in the direction of Θ depends on gravity, g, and the mass of the pendulum, m; that is, for small Θ,

$$\text{Force} = mg \sin \Theta \approx mg\Theta.$$

The amount of work done is a product of the force and the displacement:

$$\text{Work} = \int mg\Theta \cdot l\, \delta\Theta = \tfrac{1}{2} mg\Theta^2 l.$$

And the kinetic energy depends on the mass, the length, and the change in the angle theta:

$$\text{Kinetic energy} = \tfrac{1}{2} ml^2\Theta'^2,$$

where $\Theta' = d\Theta/dt$.

The problem then is to minimize the sum of the work and the kinetic energy over the trajectory, as a function of the geometric motion $\delta\Theta$, the change in the angle Θ. Thus, symbolically, if the trajectory starts at time t_1 and ends at time t_2, we want to set the variation of the sum over the whole trajectory equal to zero (this is equivalent to setting the derivative equal to zero to find the minimum of a function):

$$\delta \int_{t_1}^{t_2} (\text{Kinetic energy} + \text{Work}) dt = 0,$$

where δ is the symbol for the variation. Substituting in the above expressions for the kinetic energy and the work, we find

$$\delta \int_{t_1}^{t_2} [(\tfrac{1}{2} ml^2\Theta'^2) + (mgl\Theta^2/2)]\, dt = 0.$$

For this variation to be zero to minimize the kinetic energy plus work sum, the integral itself must be zero. This gives us the simple equation

$$\tfrac{1}{2} ml^2\Theta'^2 + mgl\Theta^2/2 = 0$$

or

$$\Theta' = \sqrt{-g/l}\,\Theta.$$

Using A as an arbitrary constant, and $i = \sqrt{(-1)}$,

$$\Theta = A \exp(i\sqrt{g/l})t,$$

which is the classic differential equation for simple harmonic motion with frequency $\sqrt{(g/l)}$!

Phase Space

A continuation of Carnot's method in attacking the problem of the pendulum leads directly to a hydrodynamic analogy for the above equation. We can then understand the dynamics as a succession of nested manifolds, leading from the simplest manifold (determined by the geometric motions) to increasingly complex and internally differentiated manifolds (specified by the equation of motion), to the family of solutions to this equation as a function first of the amplitude of the motion (the energy), and then as determined by the interaction of harmonic oscillators. (See "Solving the Three-Body Problem" in *Fusion*, June 1978, for discussion of this point.)

The simplest geometrical aspect of this is demonstrated if, instead of plotting the motion of the pendulum in physical space (a), we plot the motion in a coordinate space, the phase space (b). The phase space shows the relationship between position and velocity at every point in time.

—Dr. Steven Bardwell

$$\delta \int mU^2 = 0.$$

Carnot then showed that if that condition was satisfied, the machine would transmit the maximum possible amount of energy throughput. The ratio of the energy input to the energy output in that case is unity. He summarized this situation of maximum *mechanical* efficiency as follows:

> Now, in order to fulfill that condition [input equals output], I say, first, that any impact or sudden change is to be avoided, for it is easy to apply to all imaginable cases the reasoning developed in that of weight-driven machines; whence it follows that whenever there is impact, there is simultaneously a loss of moment-of-activity on the part of the impelling forces, a loss so real that their effect is necessarily diminished.... It is then with good reason that we have proposed that in order to make machines produce the greatest possible effect, they must never change their [state of] motion except by insensible degrees. We must except only those that by their very nature are subject in their operation to various percussions, as are most mills. But even in this case it is clear that all sudden changes should be avoided that are not essential to the constitution of the machine.

This formulation for the first time provided a scientific criterion for determining the range of optimal designs for any type of machine and for evaluating its performance. As Sadi Carnot was later to remark about his comparable achievement in founding thermodynamics, the ability to replace British-style trial-and-error tinkering with rigorous conceptions of how to optimize efficiency and power was a more powerful force than even the British Navy.

Carnot's Humanist Epistemology

There are three important conceptual aspects of Carnot's results:

First and most important, the Principle of Least Action is not an inductive generalization of empirics, but a *hypothesis* that is creatively synthesized by preconscious mentation and whose relative truthfulness and limits are to be tested by unique experiment. Carnot does not add up pieces from or abstract from the existent body of knowledge of his day. He leaps over this knowledge to a higher conception of the ordering of the physical universe, which is articulated as the conception of geometrical motion.

The process of concept-formation stands as a higher-order transfinite with respect to the specific concepts of (indeterminate) geometrical motions and (determinate) least action, while those concepts are themselves transfinite with respect to each other and to vector and scalar conservation laws.

The concept of indeterminacy is a determined predicate of the higher-order, indeterminate process of concept formation. Carnot's theory is not just mathematically descriptive—it is beautiful as well.

Second, Carnot realized that the Principle of Least Action and derived conservation laws hold if and only if a system is constrained to undergo geometrical motion; that is, if the dynamics are *reversible*. As the word implies, a reversible process is one that can, in principle, proceed just as well from state A to state B as vice versa, like a pendulum. As a practical matter, that may be difficult if one state is more "probable" (has more ways to exist) than another. More basically, however, reversability for mechanical systems implies that there is no singularity or discontinuity in the dynamics.

Thus, the principle holds only under a restricted range of interactions and motions or energy inputs consistent with that class of interactions. (This is the mechanical extension of Euler-Bernoulli considerations of the laws of fluid flow with respect to the limiting case of turbulence; it also illuminates from another perspective the author's earlier analysis of the geometrical-dynamical relationship between the First and Second Laws of Thermodynamics.)* The principle breaks down under other forms of motion and interaction such as jarring or vibratory impact, or, as we shall see, through transformation of the physical manifold to a higher-order phase space.

Third, Carnot explicitly demonstrates that these investigations of the principles of the species machine provide *no* absolute rules for machine design abstracted from specific contexts of human social reproductive practice. Here is the heart of the Leibnizian epistemology: Man, society, and the physical universe are not, as the willfully ignorant Barry Commoner thinks, machines through which entropy spreads. Machines—even of the mechanical-thermodynamic type—are linkages between the higher-order physical processes that mediate the negentropy of humanity's expanded reproduction.

We can now go beyond Carnot's results per se, to examine the even more important connection between his results and the fundamental invariants of the physical universe that are necessarily present in Carnot's own preconscious processes of hypothesis formation. The most striking aspect of Carnot's applied science is the fact that the very content of his conceptions directly expresses the relationship between specific scientific abstractions and higher-order physical and mental processes.

The Hypothesis of Indeterminacy

The crucial conception in Carnot's work is that of *indeterminacy*. The most general definition of the content of that conception is the following: There are no axiomatic, fixed laws of nature or equations blazoned in the heavens forever. Physical configurations do not proceed logically one from another according to some a priori and determinist rule.

The most general mathematical representation of a physical system available to us, probably due originally to Euler, is the concept of *phase space*, or configuration space (see box, page 28). Phase space is a Riemannian manifold—that is, a multidimensional, nonlinear coordi-

nate system. The phase space P_i for a physical system in state i may have a finite or an infinite number of dimensions. These dimensions, or phase space coordinates, are the appropriate set of variables for defining the energy of the system as a scalar function (for example, the positions and momenta of all particles).

At this level of conceptualization, physical process is assumed to be reducible to the "motion" of a system through a simply connected (or continuous) manifold, the phase space, which expresses the general geometrical aspects of the scalar energy. As we will see, more general physical processes require the more advanced conception of a higher-order geometry, analogous to the difference between a simply connected manifold and a *multiply connected manifold*.

The principle of indeterminacy has two, related implications: First, the evolution from one stage (or moment) of physical process, designated by m, to the next, $m+1$, is not *predetermined* by the configuration associated with m. The conditions at stage m indicate only that there is an operative set of restrictive conditions on the physical interactions and geometrical configurations. From the standpoint of m, therefore, there is a restricted but infinite set of specific configurations that could be realized as $m+1$.

Second, two possibilities follow. Either the self-interaction of the system passing through stage m is or is not changed in quality. If the latter occurs, then the energy content of the system determines a *unique* state for $m+1$ that also satisfies the condition of conservation of energy as measured in the phase space of the system. This is the case, for example, in the motion of a pendulum or a freely falling body, or the operation of a machine. The process $m \rightarrow m+1$ may be reversible or irreversible. As we will show in a subsequent discussion of Huyghens and Planck, this is only a peculiarity of the phase space and not a fundamental distinction. Carnot's principle is a limiting case for this class of mechanical processes.

If the former of the two possibilities occurs—that is, change of quality of interaction as, for example, during a fusion reaction—then the passage from m to $m+1$ is a physical singularity marked by transformation of the effective phase space. The indeterminacy in this case is of a higher order—that of the phase space of $m+1$ relative to m. There is now a range of phase spaces, $P_{(m+1)}$, consistent with the initial condition that stage m is characterized by phase space P_m. In this case, a higher-order transition must be made—in the "phase space of the phase spaces"—even less determinist, but nonetheless still lawfully unique. Only the worst epistemology could label this situation as obeying an "uncertainty" principle.

So-called conservation of energy here is nothing but a convention in which so many units of "energy" with respect to P_i are set equivalent to so many units of "energy" with respect to P_j since they can be converted back and forth into each other (as, for example, when fusion releases kinetic energy that can be converted into heat, and so forth). This interpretation is as misleading, however, as the Newtonian assumption that particles interact through so-called innate forces just because such a mathematical representation sometimes gives accurate computational results.

The most general principle of indeterminacy, therefore, can be stated as follows: There is no axiomatic connection between the successive phase spaces, P_m and $P_{(m+1)}$ characterizing the stages of the physical universe or its subsumed physical systems. Nor is the physical universe adequately represented at any moment by any single simply connected manifold, no matter how general. P_m must itself be a multiply connected manifold, in some sense the *union* ($\cup$) of simpler manifolds, $P_i^{(m)}$,

$$P_m = \bigcup_{i \in I} P_i^{(m)}$$

where the $P_i^{(m)}$ are simply connected manifolds and where I is an arbitrary index set which can be finite or infinite.**

The appropriate heurism for the evolution of the physical universe or physical process in general is thus the process of transition between members of the nested set of multiply connected manifolds progressing as Cantor's transfinite numbers do, one on top of the preceding number:

$$P_m \rightarrow P_{(m+1)}.$$

The lawfulness in this succession is not just a mathematical abstraction. The Riemann-Cantor heurism above represents the actual governing principle of the physical universe: the ordered progression to states of higher negentropy. Only when you combine Leibniz, Euler, Riemann, and Cantor do you get an adequate epistemological framework for physics and for the definition of the efficiency of nonlinear processes.

Carnot's physics and engineering is important precisely because it contains the germ of this conception.

Evolution of the Principle of Least Action

For humanity to progress, the Principle of Least Action must be superseded by more advanced conceptions. To that end, we briefly review its history.

The general physical hypothesis known as the Principle of Least Action has been formulated in a number of ways. Prior to Carnot's work summarized here, somewhat dif-

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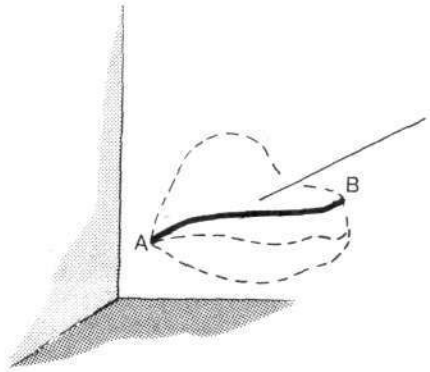
* Dr. Morris Levitt, "Linearity and Entropy: Ludwig Boltzmann and the Second Law of Thermodynamics," *FEF Newsletter*, Vol. II, No. 2 September 1976.

** As future articles in this historical series will emphasize, the principle of least action described here is not a primary physical principle. The universe does not economize on energy for metaphysical reasons. Rather, the least action principle has a definite geometrical (that is, relativistic) basis in the phase space manifolds defined by certain classes of singularity-free physical processes. For these cases, the principle is the unique, determined result consistent with the boundary conditions. The fundamental principle, however, is the negentropic evolution of the physical universe as a whole to even higher order (transfinite) processes and physical manifolds. See also Uwe Parpart, "The Concept of the Transfinite," *The Campaigner*, Vol. IX, Nos. 1-2, January-February 1976.



Of all the possible trajectories in phase space, only one satisfies the Principle of Least Action.

Carl Jacobi

Figure 5
ENERGY AND GEOMETRY

Imagine a multidimensional (finite or infinite) phase space, heuristically depicted here through the simple, three-dimensional Euclidean space.

Jacobi's geometric formulation of the Principle of Least Action means that in a given phase space, the path that a system takes between any two endpoints is the unique path that satisfies the Principle of Least Action—that is, the unique path associated with energy conservation. Energy is concentrated on a characteristic curve in the space that energy itself defines. For the mathematically more complex case of a nonlinear plasma, another relationship between a characteristic geometrical coordinate system and the flow of energy has been derived. Here one deals with concentrations of energy in physical space.

In the publications referenced in the text Dr. Steven Bardwell has reviewed the research that showed that the natural coordinate system for soliton (particlelike) states in plasma is the vortex filament. Other high-density plasma states include a sheath of vortex filaments or the formation of vortex rings in various types of plasma foci.

Physics has yet to solve the problem of going beyond these geometrical conceptions of phase space or physical singularities (exemplified by the formulations of Jacobi, Lamb, Wells, and Bostick) to an adequate comprehension of high-energy plasma or particle processes.

ferent versions were put forward by D'Alembert and Maupertuis. D'Alembert's principle relies on defining an *inertial force*, the product of mass times acceleration, in addition to the forces of interaction. In any virtual displacement, δL, of this generalized force, F_D, the work done, $F_D \cdot \delta L$, is zero.

Maupertuis's principle is more directly based on the concept that there is a universal law of action, but it lacks the crucial virtual displacement notion. In these respects, both principles are blatantly tainted with Newtonianism. Furthermore, there is evidence that Euler had, in fact, earlier formulated the full variational principle in the appropriate form later modified by Carnot.

The basic conception underlying Carnot's formulation of the principle is the Leibnizian hypothesis that "the change of the kinetic energy is equal to the work done by the force." Carnot's principle thus follows the line of 18th century versions of the principle in which the integral of the kinetic energy T with respect to time is minimized:

$$2 \int T \, dT = 0.$$

Since work and (kinetic) energy are interchangeable, this also can be thought of physically as minimizing the integrated work done by the conservative forces in a given time interval in bringing about a reversible transformation.

In the 19th century, Jacobi and Hamilton generalized this result in forms that, like Carnot's interpretation, lend themselves more readily to connection with the most general physical processes. Jacobi showed that the time integral in the "action" could be transformed into a path integral in configuration (phase) space such that the following integral is minimized:

$$\int \sqrt{2(E - V)} \, \overline{ds},$$

where $\overline{ds}$ is a "distance" in phase space, E is total energy, and V is potential energy (the interaction energy associated with the geometrical configuration).

Jacobi's version of the least action principle is the direct analogue in phase space of Fermat's principle for light traveling in media with various indices of refraction, n [rather than $\sqrt{2(E - V)}$] and physical displacement, ds. In both cases, the path followed is the *shortest distance*; that is, the path that takes the least time to traverse between two definite end points. Jacobi's formulation, however, reveals the actual geometrical basis for this concept in the relationship between energy and the dynamics in phase space.

Hamilton completes this phase of the development of mechanics by showing that the Leibniz-Euler-Carnot time variational principle, which holds most generally (both for

variations with respect to real and virtual displacements, and for nonconservative systems), is the result

$$\delta \int_{t_1}^{t_2} L\, dt = 0,$$

where $L = T - V$ is the Lagrangian function.

Hilbert later pointed out, however, that the Hamiltonian formulation obscures the critical geometrical correlates of the energy principle so beautifully demonstrated by Jacobi.

As this brief review shows, Carnot's principle of least action is at the center of the geometrical dynamical viewpoint of classical mechanics: Every form of energy and interaction is associated with an appropriate Riemannian geometry (phase space) within which the energy is concentrated along characteristic minimal paths. (For illustration of this point and the immediately following ideas see Figure 5.)

As the more recent theoretical work of Wells and Lamb, and the experiments of Bostick, Wells, and others have shown,* this variational-geometrical result can be generalized to higher-energy-density plasma regimes where vortical geometries provide the force-free framework for plasmoid or soliton solutions. This raises two basic questions: First, at what point in plasma processes does nonlinear interaction supersede these analytical-geometrical principles; and, second, what principle of movement from one phase space topology to another is then operative? Is this the same order of problem as the existence and transformation of so-called elementary particles?

Put another way, these Riemannian geometrical-mechanical considerations are all contained within the domain of inorganic physics, of transfinite order "n." What are the transfinite orders, $m < n$, contained within n, and what principles govern the transformations between each? We have explored here the conceptual generation of Carnot's level, m_{L-C}, the Leibniz-Carnot level of work and *vis viva*, to illuminate the more general features of physical systems of order m and n, which must now be comprehended.

Carnot, Humanist Engineer

Carnot understood, as few after him have, the physics and economics of the machine. He extended his investigation of geometrical motions to show that although conditions of reversibility represent the maximization of efficiency of energy throughput, in the more general case there is another characteristic invariant, the moment of the quantity of motion. This means that the machine obeys conservation of *angular momentum*. In this more general case, the transmitted quantity of relevance is *power*.

The physics of machines does not determine, however, how to actually design a specific machine. Its most important general function is to totally discredit utopian fantasies about turning the world into one big perpetual motion machine.

In Carnot's time the republican humanists seeking to implement a Europe-wide Grand Design to hook up with the American Republic had to contend with two British-inspired ideologies: the Enlightenment's fetishism about mechanical contrivances on one hand, and antiscience "naturalism" on the other. These flip sides of the anti-humanist coin present themselves in the contemporary period as, respectively, the utopian, fixed-technology world of a Buckminster Fuller or the zero-growth antitechnology ravings of the environmentalists. For Carnot, the ultimate function of machines was to eliminate physical misery and toil, not science and thought.

As Carnot emphasized, strictly continuous motion is an ideal limit for maximizing efficiency of energy throughput in a particular device. But that is not where productivity is located; productivity involves the relationship of the local productive process to the output of the economy as a whole. Thus, Carnot argued, the general principles of the machine tell you exactly how optimizing one aspect of machine function will compromise another, but you must then evaluate that information for a series of hypothetical machine designs with respect to the fundamental unit, the economy as a whole.

For example, running a machine at lower efficiency but higher torque to produce a part may augment social productivity more than by maximizing local thermodynamic efficiency. Or achieving greater power transmission may shorten machine life intolerably. In the well-known case of the water wheel, drawing off the most power from the moving water also introduces the most percussion into the blades of the wheel. It's no good to have maximum efficiency for one second and a bunch of splinters the next.

Carnot was no reductionist efficiency expert. His work reminds us that the ultimate measure of science and technology is their ability to enhance the productive powers of humanity. The increased negentropy of the human economy, in turn, reveals that the real content of scientific conceptions like those of Carnot, is the common creative principle governing the development of the physical universe and human reason.

Morris Levitt is the executive director of the Fusion Energy Foundation.

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* For a review of these results see Dr. Steven Bardwell, "Fusion Plasma: An Overview of the Research," *FEF Newsletter*, Vol. II, No. 1, July-August 1976; "The History of the Theory and Observation of Ordered Phenomena in Magnetized Plasmas," *FEF Newsletter*, Vol. II, No. 2, September 1976; "The Implications of Nonlinearity," *FEF Newsletter*, Vol. II, No. 3, March 1977.

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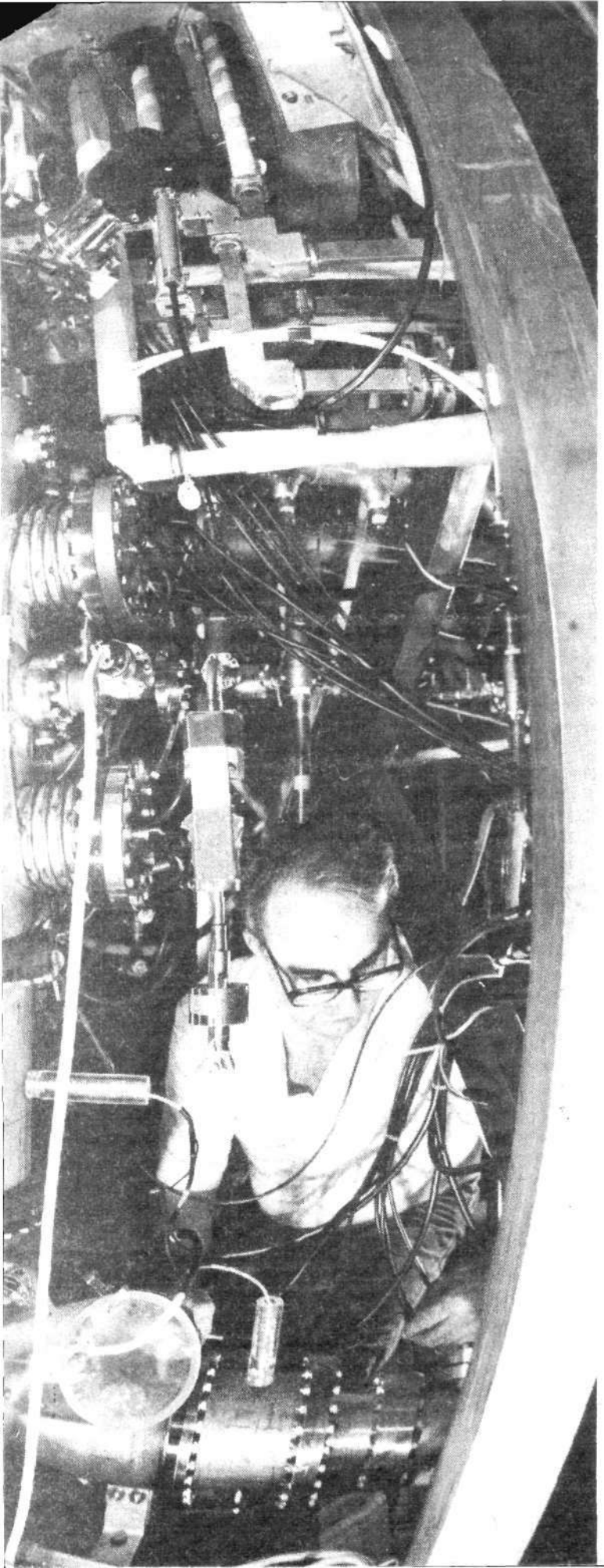


The Technology For Fusion:

by Marsha Freeman

THE COMMERCIAL APPLICATION of fusion energy for advanced industrial processing and electricity by the 21st century will require the creative collaborative work of scientists, skilled technicians, and high-technology industry within the next few years. The scope of the industrial and engineering effort required is enormous—from the precision technology required for the reactor components to their mass production, fabrication, and transportation to sites here and around the world.

The model for this necessary scientific renaissance can come right out of the recent history of the Princeton Plasma Physics Laboratory. There the collaboration between scientists, technicians, and industry developed the technology first to build the Princeton Large Torus, which reached record tokamak temperatures last summer, then the more complex Poloidal Divertor Experiment, just coming on line, and, finally, the Tokamak Fusion Test Reactor, which is now under construction.

The greatest technological challenge of fusion is the control, understanding, and most efficient use of an ionized state of matter that has never before been harnessed for power production—a multimillion-degree plasma. Fusion plants will not present any significant engineering challenge simple resulting from size—a conventional steel plant has dozens of pieces of machinery many times the size of a fusion vacuum vessel. Nor will there be a problem with the utility systems design aspect of energy conversion and use.

The major scientific challenge for fusion is twofold. First, continuing research into materials that can withstand fusion temperatures and neutron bombardment is required, as long as fusion reactors are designed to rely on deuterium-tritium fuels. Second, the most important

Fusion machines require a complex, delicate balance of magnetic and electrical fields. Here a technician works on a section of the PLT.
PPPL

From PLT to TFTR

scientific, engineering, and design consideration, which defines the work for the physicist, the engineer, and the industrial technician, is how to produce fusion within an incredibly precise and delicate balance of magnetic and electrical fields.

The Princeton Large Torus

Up through the building and testing of the Princeton Large Torus (PLT) now in operation, the scientists were the "design engineers" for building the magnetic systems, the diagnostic apparatuses, and the configuration considerations for the machine. Only they could define theoretically how to measure temperatures in the millions of degrees, how to construct magnetic systems that could confine such a plasma, precisely what the physical relationship of the magnetic systems had to be for the magnetic and electrical fields to produce no energy-loss instabilities, and how the neutral beam injectors would affect the machine's operation.

For this reason, every part of the PLT, the magnetic systems, the vacuum vessel, the structural support, and most of the diagnostics were designed and built at the Princeton Plasma Physics Laboratory (PPPL). Of the approximately 970 people at PPPL, almost 500 are lab and shop technicians, who work intimately with the 270 scientists and engineers.

Three Magnetic Systems

The PLT controls and heats the plasma with three magnetic coil systems. The 18 *toroidal field* coils, responsible for the strongest component of the magnetic confining field, were insulated and wound into 450-foot continuous coils at Princeton from 20-foot copper bars provided by Phelps Dodge Copper Products. The copper bars were brazed or soldered with a high-temperature alloying metal, insulated with epoxy in 250-degree ovens specially built for that purpose, and wound on a vertical rotating boring mill.

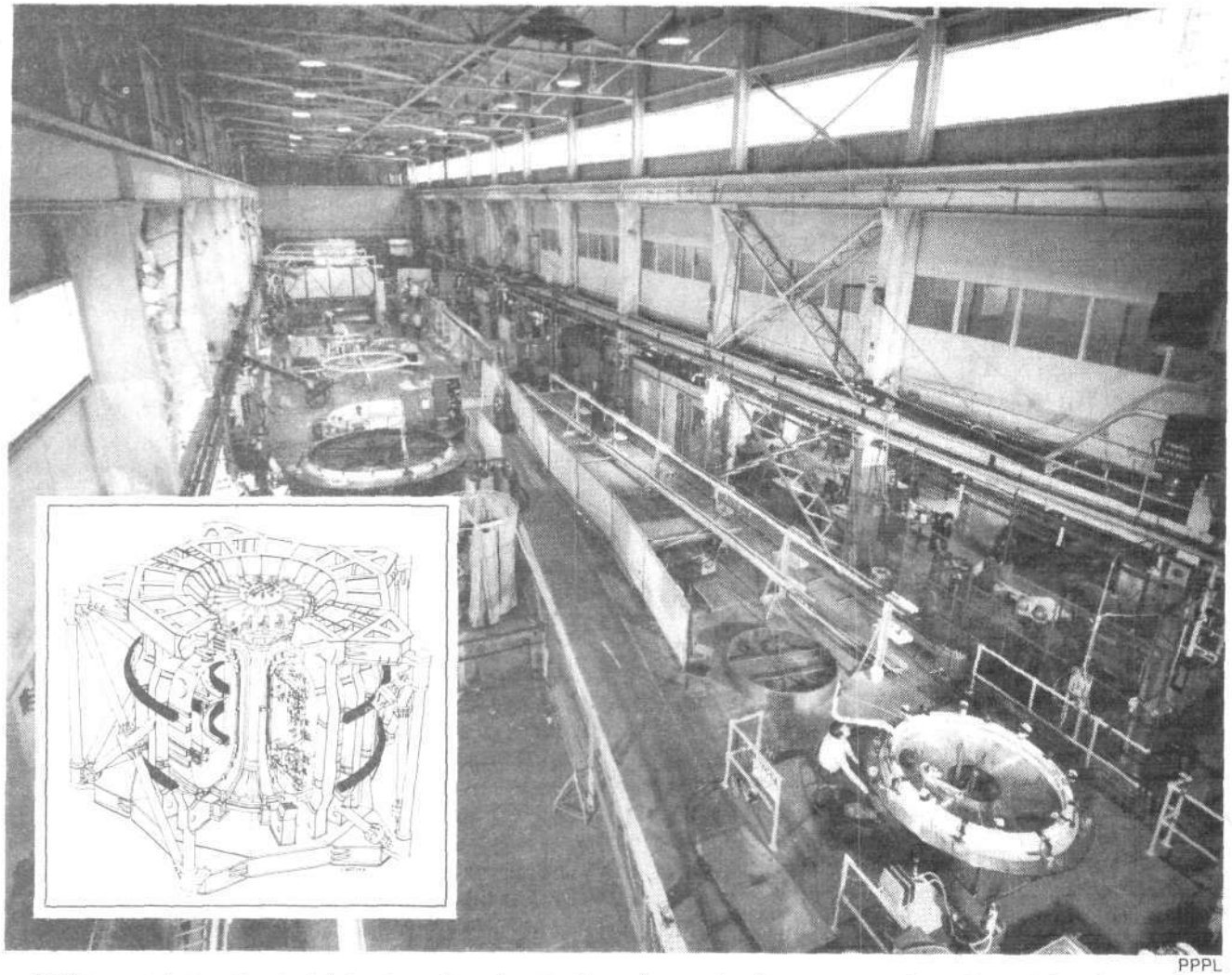
The *ohmic heating* coils, which induce a current in the plasma and add confinement parallel to the plasma flow, were also fabricated at the PPPL coil shop. To induce a current in the plasma, these ohmic heating (OH) coils rapidly change their current from +20,000 amperes to −20,000 amperes, which presented a unique switching problem to the experimenters. The speed with which the current had to be switched surpassed the limits of current mechanical switching technology. Put to work on the problem, General Electric developed a solid-state switching gear. This was combined with the OH rectifiers used to change alternating current to direct current, leading to a less costly system with greater reliability.

The third magnetic system on the PLT is the *equilibrium field* (EF) system. These magnets, which are adjacent to the ohmic heating coils, generate a uniform vertical field, providing vertical stability and preventing an outward pull on the plasma ring that could otherwise expand to the walls of the vacuum vessel. This coil system was also fabricated at PPPL. Since both the OH and EF coils are arranged *within* the toroidal field (TF) coils, their installation was a more time-consuming and complex task than originally anticipated, requiring precision placement and relationship between the three magnet systems.

The 12-foot diameter vacuum vessel was fabricated at PPPL from welded stainless steel sections with two ceramic rings as part of the wall to keep the electrical resistance high compared to the plasma. The external structural support system is designed to withstand over 3 million pounds of centering force from each toroidal field coil and millions of pounds of magnetic force from the three-magnet system.

PDX—Adding a Fourth Magnetic System

The $26 million Poloidal Divertor Experiment (PDX), which will begin operation as soon as the assembled parts are tested, presented a new problem in fusion technology. Designed to test various magnetic geometries for plasma purity experiments by diverting the plasma and impurities out of the magnetic trap, the PDX has a fourth magnetic system, which involves actually placing poloidal field coils *inside* the vacuum vessel. This required new designs for the other coil systems and the development of new technology



PPPL

PPPL's special shop for the fabrication of insulated coils and power bus bars uses a variety of special tools—winders, epoxy impregnation equipment, and drying ovens. Inset: A schematic of the three-story PDX tokamak showing the poloidal coils made in the shop.

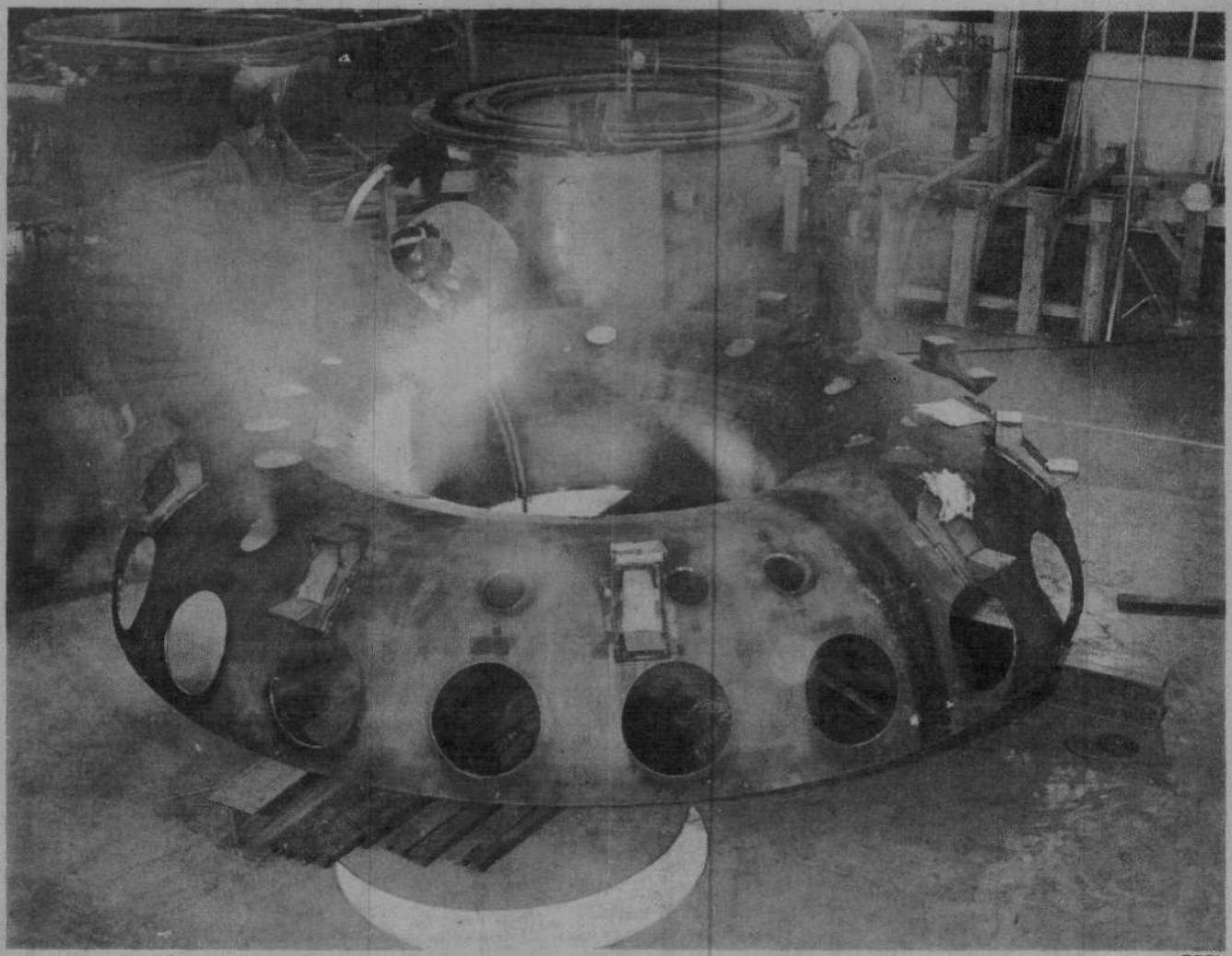
for magnets that must operate in a very hot, corrosive environment.

In addition, the PDX represents the transition step from the PLT, which was an in-house fabrication, to the Tokamak Fusion Test Reactor, which is being built wholly by outside industrial subcontractors. The outer poloidal field (PF) coils were fabricated at the PPPL coil shop, by the same methods described for the PLT coils. The toroidal field (TF) coils, however, had to be built in segments so that the PF divertor coils could be placed inside them.

Built by Phelps Dodge Copper Products, the toroidal field coils were fabricated in C-shaped sections, which were joined together on-site. The extrusion and drawing of the copper sections of the coils are standard precision technology. The TF-coil extrusion, which forms a groove inside the copper for the cooling tube, was a particularly complex operation because of the elliptical shape of these coils. Since this was the largest tokamak fusion device fabricated so far, considerations of economy were important, and magnet designs were affected by the need to operate within defined electrical supply parameters. Maximizing the amount of copper used for the TF coils allowed the PDX engineers to stay within the limited power supply available for the experiment.

Though the poloidal field coils for the PDX are standard fusion coils and were built at Princeton, the internal divertor PF coils required special stainless steel jackets, manufactured by Custom Manufacturing, to protect them. These 10 internal coils, of five different sizes, are approximately 114 inches in toroidal diameter with a diameter tolerance of ± 1/16 inch.

High-precision technology for positioning and aligning the divertor PF coils was essential for two reasons. First, the outer stainless steel jacket makes it impossible to ascertain precisely where the magnetic field center is after the jacket is on. Second, because of the proximity of the divertor coils to the plasma inside the vacuum vessel, the slightest distortion in placement could disrupt the entire fusion experiment. To be able to place the divertor coils within a tolerance of 1 mm tilt in any direction, precise



PPPL

PPPL technicians working on the dome to the PDX vacuum vessel, one of the most complex pieces of spin-formed steel in existence. The vacuum vessel is 7 feet in diameter, 10 feet high, and weighs 22 tons. It was fabricated by Princeton and private industry.

measuring techniques had to be employed.

The first technique was using an eddy-current probe to locate the exact position of the copper of the magnet beneath the lumpy and uneven epoxy insulation. By laying a high-frequency coil on the magnet and measuring the resonance of the eddy current as the coil was lifted away from the insulated magnet, the exact position of the copper underneath the surface was located.

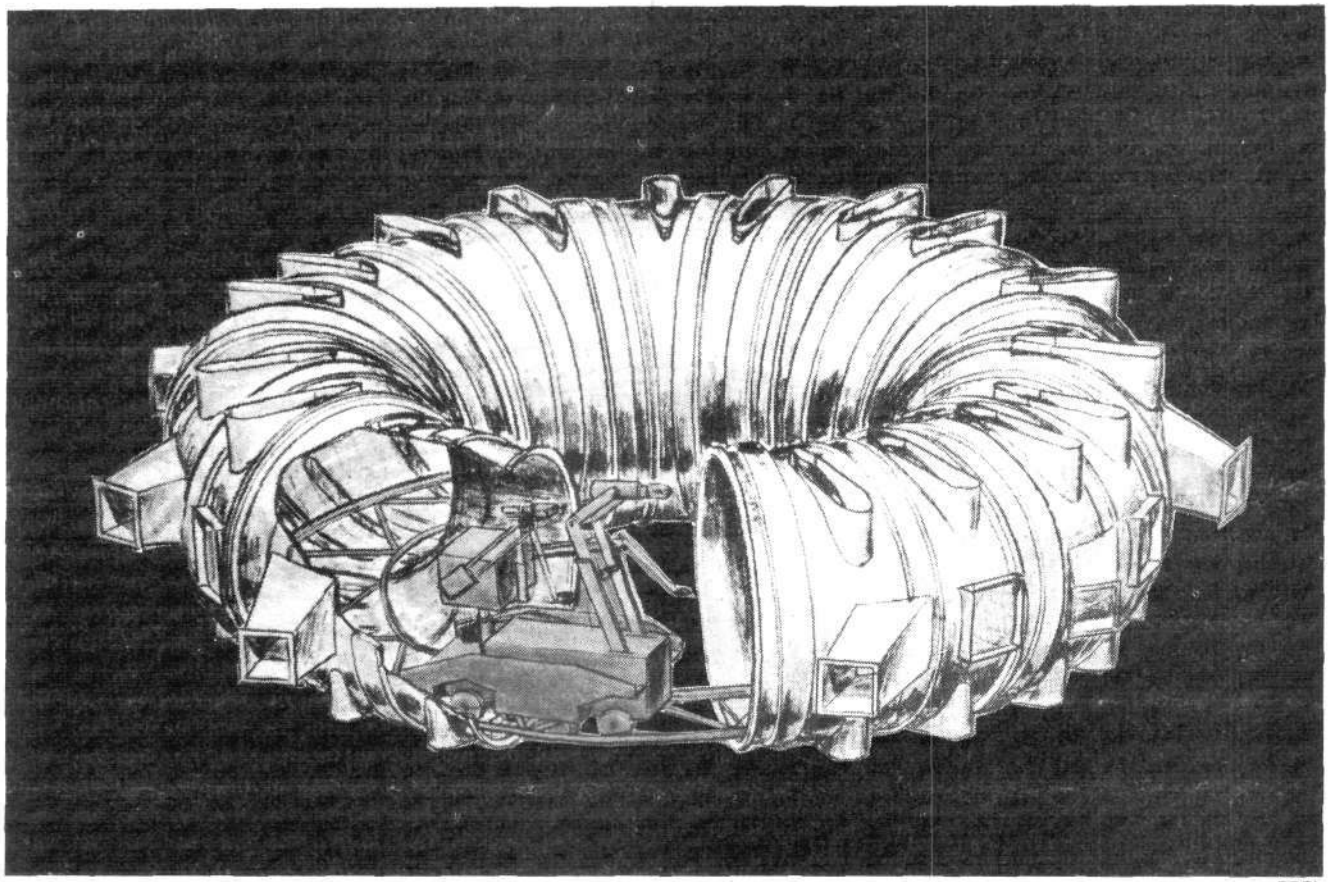
Once the divertor coil is placed inside its stainless steel jacket, ultrasonic waves are used for position mapping. The ultrasonic waves are bounced off the steel jacket and then off the coil's insulation. After the precise location of the copper within the insulation has been mapped, the measurement of variations in the returned echo from the stainless steel locates the magnetic center when the magnet is "canned" in the vacuum vessel.

Using a very sophisticated and precise optical measuring device, called the K&E optical bar system (similar to a surveyor's instrument), each array of poloidal magnets is optically aligned in precise geometric configuration.

The PDX vacuum vessel is one of the transitional components fabricated by Princeton and private industry. The walls of the vessel were made at the lab in much the same way as the PLT vessel walls. But the size of the upper and lower domes of the vessel, one of the largest and most complex pieces of spin-formed steel in existence, required the work of Torngren Spincraft in Massachusetts.

The vacuum vessel domes had to be spin-formed because they have surfaces that curve in more than one dimension. This technology has been in use on a smaller, less complex scale for the manufacture of radar reflector dishes and microwave transmitters. The process involves placing the metal on a form that rotates. The metal is then stretched into the form's shape by the application of either manual or hydraulic force, and the dome is completed as one component.

The completed PDX vacuum vessel is 7 feet in diameter and about 10 feet high. The total weight is 22 tons, with a standard design. The PDX will have both neutral beam heating (an upgraded version of the PLT neutral beams)



PPPL

The TFTR will be the first tokamak to have a remote-control system to aid in repair and maintenance of the machine. Above: An artist's cutaway drawing of the remote-control device and its circular track.

and radiofrequency heating. The PDX is the last tokamak that will have a major part of its fabrication work done at the PPPL.

TFTR—Toward a Commercial Reactor

The Tokamak Fusion Test Reactor (TFTR), to be completed at Princeton in 1981, will be built almost entirely by private industry, with a total budget of $230 million. The $100 million device, twice the size of the PLT, is being contracted to Ebasco, Inc., with Grumman Aerospace Company having a major, $20 million subcontract for design and fabrication of some of the unique technology that the TFTR will require.

Remote-Control Maintenance System

As the first tokamak to burn a plasma of deuterium and radioactive tritium, the TFTR will require the application of the radioactive-material handling technology now employed in the conventional fission industry. It is also the next step toward a utility-system commercial fusion power plant, with the ease of maintenance that a commercial plant requires.

Therefore, one of the most important innovations that will be incorporated in the design and construction of the TFTR is an entirely remote system to remove parts of the vacuum vessel for repair and maintenance. The vacuum vessel, which will be built by Chicago Bridge and Iron, will be built in 10 segments, each with two of the toroidal field coils around it. The vessel will contain 240 separate and different-sized penetration points for the insertion of the neutral beams, various diagnostic instruments, and the zirconium-aluminum getters (absorbers) that collect the tritium gas after it passes through the vacuum system.

All of the coils for the TFTR will be built by industry except the four largest poloidal field coils. These 32-foot, 8-ton coils, which are too large to transport by conventional means, will be fabricated at the PPPL coil shop. It will take more than a year to build them.

Removable Parts

The most challenging technology for the TFTR is allowing the actual *removal* of any one of the 10 vacuum vessel segments to examine neutron damage and repair any leaks or pitting that might occur if the plasma strikes the vessel walls. In a conventional commercial reactor the difficult and time-consuming task of removing and repairing a vessel segment, which could take a couple of months, would only be necessary in extraordinary circumstances.

In order to avoid the need to disassemble vessel segments, Grumman and Ebasco are developing the tech-

nology for remote maintenance. With this facility, repair work in the vessel's radioactive environment can be done entirely by remote-controlled manipulators. The remote-controlled system will involve an overhead bridge crane with a capacity to lift 400 pounds. A smaller "brute force and ignorance" manipulator with a capacity of 150 pounds will be used with the overhead crane to pass machinery and materials into the vessel from outside.

Inside the vessel will be a set of dextrous manipulators, with a lift capacity of 20 pounds each, able to perform cutting, welding, and other repair functions, as well as separating a segment if it has to be removed. Grumman has developed a unique "force feedback" mechanism in the dextrous manipulators, which allows the operator to determine the amount of pressure that the manipulator is applying to its work. This forced feedback system, which has been developed for commercial nuclear plants, will be uniquely developed for highly precise in-vessel remote-controlled work.

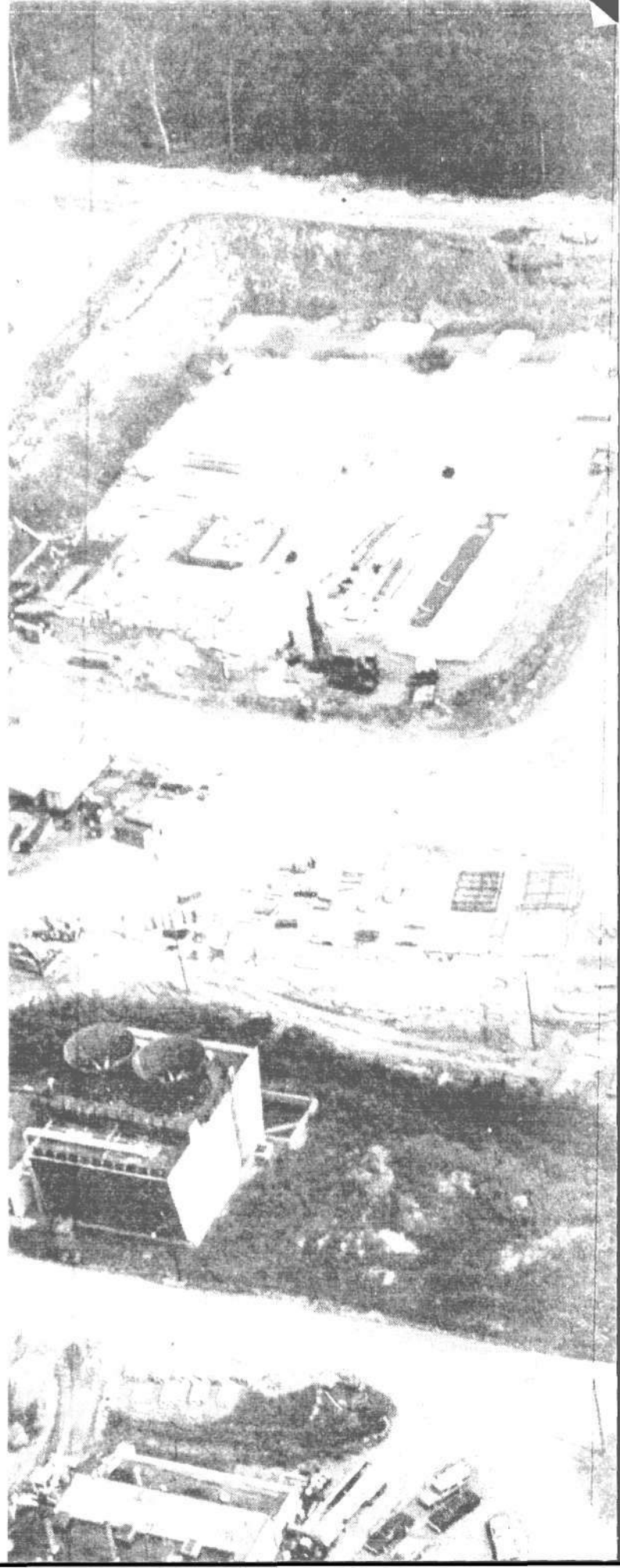
The Manpower for Fusion Technology

The evolution of the role of industry in the developing Princeton tokamak devices has been dependent upon an active collaboration with high-technology companies. In 1954, when the Princeton C Stellerator was under development, Dr. Lyman Spitzer, at the time head of the Princeton lab, asked GE and Westinghouse each to send two scientists who would begin design studies for future commercial reactors. Don Grove, one of the two Westinghouse scientists who then worked on the six-month design study, is still at PPPL and is now overseeing the building of the TFTR, after performing similar work on the PLT.

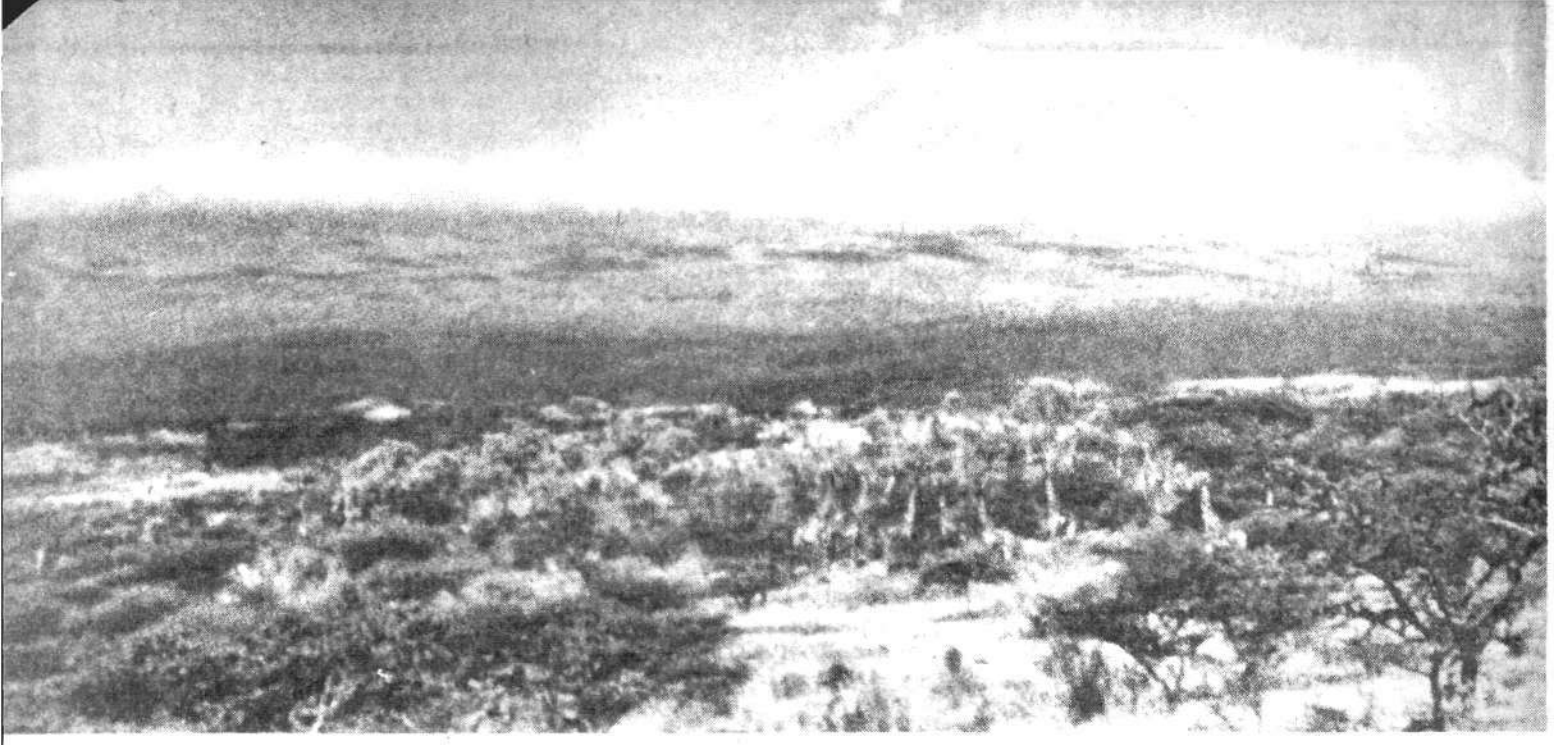
Princeton has brought industry scientists and engineers into the daily operation of the laboratory to train them in preparation for what will be a mass-production technology at the end of the century. Industry has provided the personnel at its own expense to be trained for this challenge in the power supply field and to contribute industry's scientific and technical knowledge and experience to the fusion effort.

The next step is to bring the very small number of companies—including Westinghouse, General Electric, and United Technologies—that have entire power systems design and engineering experience into the full-scale power plant design work. The scientists and engineers at PPPL see this as the major task of the TFTR years at Princeton, and as one of the major commitments that both industry and the government must now make to ensure that the technology for commercial fusion is ready when the scientific experiments have made fusion a reality.

Marsha Freeman is the director of industrial research for the Fusion Energy Foundation.



An aerial view of the TFTR construction site (top). Will the United States meet the challenge of developing the technology for commercial fusion?
PPPL



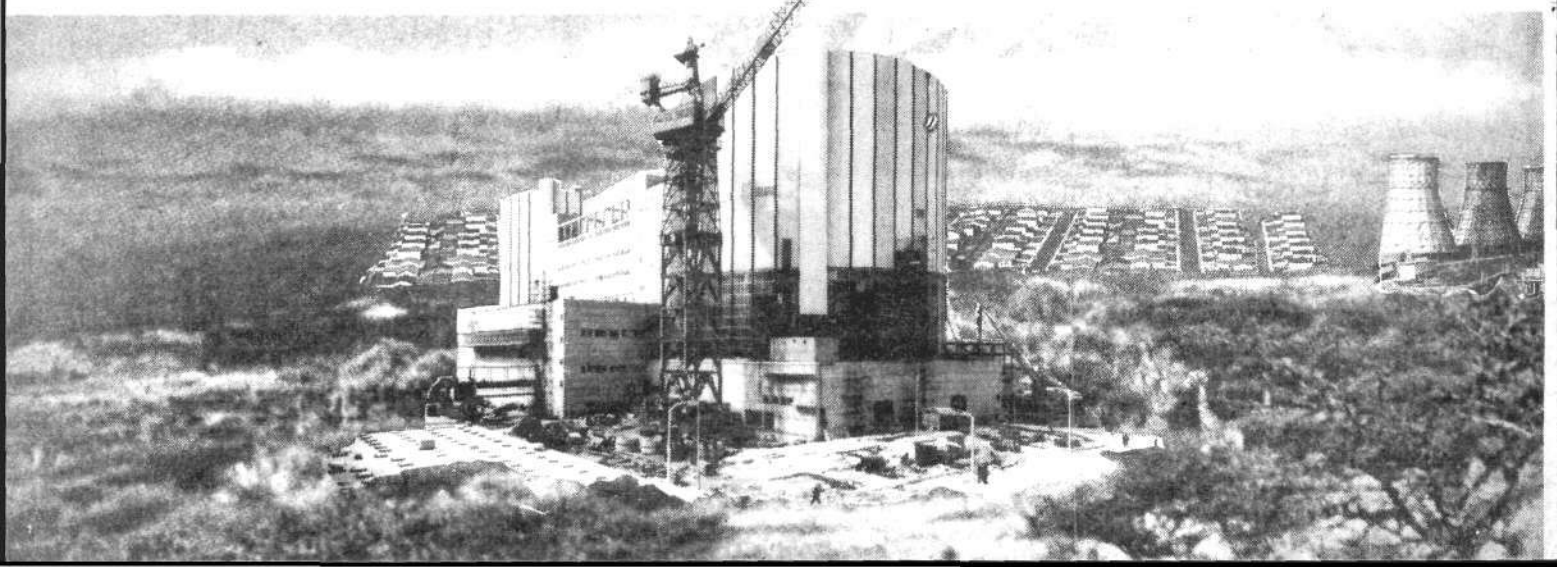
Nuclear Steelmaking

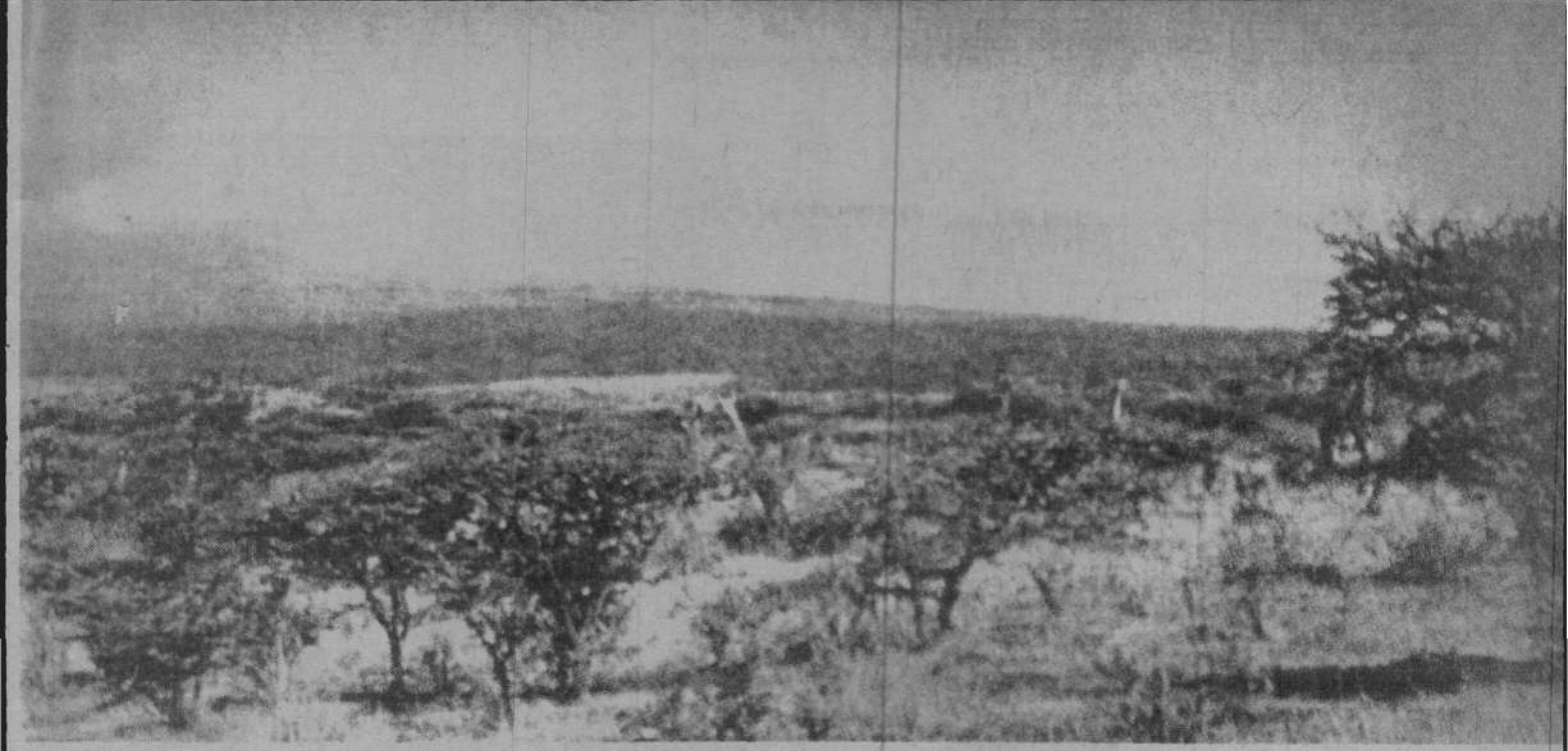
The Building Block For Nuplex Cities

by Jon Gilbertson

NUPLEXES, agroindustrial urban complexes centered around one or more nuclear power plants, will be the new cities that bring the majority of the world's population—the Third World—up to and beyond the standard of living in the United States. At the same time, the task of nuplex city building in the next few years will provide the basis for reviving and expanding U.S. production and getting the economy permanently out of its depression.

As discussed in the first article in this series (*Fusion*, November 1978), the concept of nuplex city building is not new; in fact, it has been around almost since the initial development of nuclear power in the mid-1950s. The basic idea, as developed by the Oak Ridge National Laboratory, is to integrate several industrial and agricultural manufacturing plants and processes around the highly concentrated and inexpensive source of thermal and electrical energy of a nuclear power reactor. Each nuplex would include a large city to house the manpower to build and run the nuplex, as well as all the educational, cultural, and recreational institutions needed to create and continually upgrade the skill levels of the immediate and regional population.





If human society is to have a real future, we must develop and use the increasingly energy-dense sources of technology that can efficiently provide for man's continuing growth. In past periods of human development the steam engine and electricity have provided the necessary technological innovations. Today, fission reactors are the only energy source dense enough to meet the criterion of feeding and providing for a growing world population; and by the end of the 20th century, fusion energy, an even more dense energy source, will replace fission.

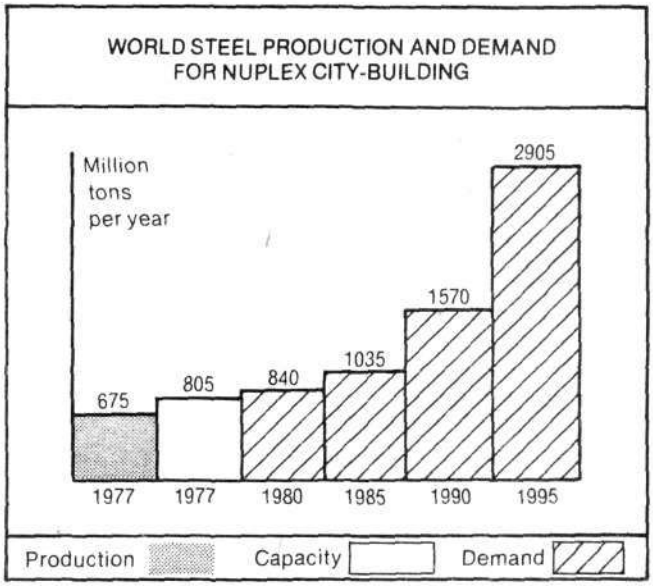
The world economic collapse cut off the construction of the nuplex designs created in the early 1960s for the United States, Puerto Rico, and India. Today for the first time since then, the political leadership exists worldwide to put together the capital and the technology to reactivate these shelved nuplex projects and to plan for building at least 20 nuplex cities a year. Under the direction of West Germany and France, the European Monetary Fund is scheduled for operation January 1, 1979, and its explicit purpose is to promote the flow of advanced sector technology into the Third World around such development projects. Furthermore, the intention and specifics of the EMS have the backing of the Soviet Union, Japan, and developing nations like Mexico.

In this country, the Fusion Energy Foundation has begun a campaign to push the United States—the nation uniquely capable industrially, scientifically, and technologically to mass produce nuplexes—into this plan for world development. The publication of this series of articles and the assembling of a nuplex design team are part of the foundation's effort to finish the process begun in the 1960s by Oak Ridge.

The Role of Steel

The growth of nuplexes worldwide will be directly limited by the *rate* of increase of steel production capacity. Although nuclear steelmaking is only one part of an industrial nuplex, vast amounts of steel and other construction materials are necessary to construct the new cities and to provide for the transportation systems, agricultural equipment, and heavy industry. To meet this growth requirement, the new and advanced methods of steel production, discussed below, are essential.

The only way to look at steel production in the nuplex



(or for that matter the production of any basic capital goods) is first to determine where we have to be 25 to 50 years from now. Given that our task in the next two generations is to build at least 1,000 new nuplex cities around the world, the obvious question is: "How?" A lot of thought internationally has gone into defining future steelmaking processes—surprising as that might be considering the sorry state of the industry today, especially in the United States.

As the trade and development policies put forward by the European Monetary Fund become a reality, steel production in the next 50 years should be guaranteed. This will require the development of nuclear fusion energy before the end of this century, and the production of steel and other basic metals by direct application of fusion plasma energy (that is, the fusion torch) within the early decades of the 21st century. This is the future for steel production, and the target of today's international fusion energy development effort.

In the interim, and well beyond the transition to nuclear fusion-based industrial processing, we must continue to produce steel by more conventional methods, while greatly expanding total world steel production capacity. This means that for at least the next 25 to 50 years, we must be able to increase steel production by already proven or yet-to-be-proven chemical processes. Of course, the major factor is energy and where it will come from.

By far the largest portion of worldwide steel output today is produced by the blast furnace-basic oxygen process combination, whose energy comes in the form of heat, primarily from the combustion of high-grade coking coal in the blast furnace. A considerably smaller, but ever growing, quantity of steel is produced by the direct reduction-electric arc furnace combination. Its energy input is a combination of heat and electricity. The heat is usually produced by burning natural gas, while the electricity comes from the public utilities.

Both processes are large users of fossil fuels, energy resources that are becoming limited in supply and, therefore, more expensive compared to nuclear energy. For example, the U.S. steel industry uses more than 5 percent of the total energy consumed in the United States and more than 75 percent of that is from coal. In Japan, 20 percent of the total energy is used in the steel industry.

The Demand for Steel

The time has come to start using current state-of-the-art nuclear fission energy as the primary energy source for steelmaking. Steel plants that will be constructed toward the end of the next decade should be designed to use nuclear energy both in the form of heat and electricity to achieve maximum economic and product efficiency benefit, while conserving the important fossil energy base for more productive uses. The steelmaking technologies discussed in detail below are now state-of-the-art processes or will be by the late 1980s. These new nuclear fission-based steelmaking processes will be the key to the transitional 25 to 50 year period immediately ahead of us. After that, nuclear fusion plasma-based processing will take up the bulk of the steel production.

Lloyd McBride, president of the United Steel Workers union, underscored this concept most clearly in a recent interview with the industry daily, *American Metal Market*. McBridge stressed: "The American steel industry needs new technology and profitability....The steelworkers' leadership believes that whatever dislocation arises will be temporary inconveniences auguring well for long-term job security and solid wage benefits for the membership...."

The launching of a world city-building program will place heavy demands on global steel production, with only moderate annual increases in the beginning, but approaching annual rates of increase of 15 to 20 percent by the end of this century. Overall world crude steel production requirements through 1995 are given in the graph.

A total world requirement of 1,035 million tons (MT) per year by 1985 is based on the current demand of 675 MT per year plus another 360 MT per year to supply steel for the construction of 50 nuplex cities annually by 1985, as well as steel for the expansion of industrial and agricultural production in the advanced sector and Comecon nations. The bulk of this increased production by 1985, 225 MT per year, will be used for machinery and equipment in the following six categories: steelmaking, machine tools, energy production, heavy industry, construction, and agriculture.

Of the 360 MT per year increase in production, approximately 130 MT per year will come simply from increasing the production of the Western industrial nations (including Japan) to full capacity over a one to two-year period. Current production in these nations is conservatively assumed to be at only 75 percent capacity; the Comecon and Third World nations are assumed to have no idle capacity.

The remaining 230 MT per year will be achieved by a moderate rate of expansion (4 to 5 percent annually) of plant capacity of existing plants and an upgrading of old plants (particularly in the United States) to more advanced and efficient technologies. This expansion will consist pri-

marily of what is called brown field development; that is, the addition of blast furnace and hydrogen reduction furnaces to existing steel plants; the conversion of some blast furnaces to the more productive Jordan concept; and the change from batch processing to more productive and efficient continuous-processing techniques. After 1985, most of the increased production will come from construction and start-up of new advanced steel plants in the Western industrial and Comecon nations—many based on nuclear energy—plus the output of the nuplexes that will then exist, particularly in the Third World.

Most of the current crude steel output is used in the production of regular carbon steels. Less than 5 to 10 percent is turned into special steel alloys such as stainless steel, high-nickel steels, etc. Most of this specialty steel is produced in the Western industrial nations, with the United States producing about 15 MT per year (1976) or about 12 percent of its total steel production.

Specialty steel production rates will continue to increase moderately over the next six to seven years and after that, much faster as more advanced technologies will take over. For example, current water-cooled reactors primarily use regular carbon steels in most of their components and equipment. However, the next generation fission reactor, the liquid metal fast breeder reactor, almost exclusively will be made out of a special stainless steel alloy. Future fusion reactors will use even larger quantities of specialty steels.

Steel Technology in the Nuplex

To construct the nuclear-based cities to last for centuries, the transitions and advances in industrial and agricultural production technologies must be considered *now* so that they can be integrated readily as they become necessary and available. A nuplex designed today for construction within the next five to ten years must take into consideration at least three transitions in its steelmaking technology.

It would first start out as a fossil-fuel-based industry, using either or both the blast furnace and direct reduction processes. The blast furnaces should use the very latest in design development, which means incorporating the more efficient oxygen-based Jordan blast furnace concept. Metallurgical grade coal is the primary energy source for the blast furnaces, while natural gas will provide the heat as well as the hydrogen gas for the direct reduction furnaces.

The electrical and steam requirements of the steel plants will be supplied by nuclear energy from one or two currently available light water or heavy water cooled reactors. These reactors will be the central energy source of the nuplex and will provide steam, electricity, and low temperature process heat to the city as well as to other integrated industrial and agricultural processes, such as chemical production, fuel production, fertilizer production, desalination, and so forth.

However, the steel industry and the synthetic fuel and chemical industries should be designed with the idea in mind that a new, more versatile and efficient fission reactor will soon be available; the high-temperature gas-cooled reactor. Because this reactor can produce high-temperature process heat, 1,400 to 2,000 degrees F. in the primary helium coolant system, it can be used economically to re-form natural gas and other fossil-based fuels to hydrogen (H_2) gas and other by-product gases.

Hydrogen gas is the basic ingredient to many products in the chemical industry as well as in the direct reduction of iron ore in the steel industry. The HTGR, therefore, will lay the basis for new, more economical nuclear steelmaking processes, and the steel plant must be prepared for this conversion. Future nuplexes may be designed entirely around the HTGR without the water-cooled reactors of today.

The next major technological transition in the steel industry will occur at the end of this century or the beginning of the next, when fusion energy becomes available in large economic quantities. Because the fuel source, deuterium from seawater, is readily available and cheap, fusion energy will be extremely cheap. Electricity from fusion, first via the thermal cycle, will be more economical than fission-based electricity. Later, using direct conversion, costs will decrease an additional 60 to 80 percent. This cheap electricity will fuel the mass production of steel by heating with high-temperature nonfusion plasmas—a technology that now is possible for specialty steels, but very expensive because of the high electricity costs.

The final and the greatest, technological transition in the foreseeable future will be the direct use of nuclear fusion plasmas from the reactor in producing steel. This will be far more efficient than using electricity to produce plasmas; furthermore, these plasmas will be at far higher temperatures and energy content, thus reducing steel production costs even further.

The Fusion Torch

The fusion torch technique will extract iron directly from iron ore in ionized elemental form, rather than simply acting as a heat source for chemical reduction with carbon monoxide and hydrogen, or for melting of iron as with electric arc plasmas. Fusion plasma processing represents an entirely new concept in steel production, completely eliminating the blast furnace or direct reduction shaft furnace and their chemical processes. Iron produced by the fusion torch can be introduced directly into the steelmaking part of the plant, the electric or plasma arc furnace, for conversion into various steel alloys, as described below.

These evolving technologies should be considered in designs for the nuplex steel plant and other industrial processes. In addition, there must be space for adding more fission reactors to the complex as well as fusion reactors when they become available. Space and flexibility must also be provided to pipe the process heat or steam and to conduct the electricity and transport fusion plasmas to the industrial plants that will need them. The decommissioning and removal of an old nuclear power plant and industrial plant, of course, will provide space for a future generation facility.

Nuclear steelmaking with fission-based energy does not

depend on the development of any "far-out" technologies requiring years to perfect. Instead it will employ a combination of current and just-around-the-corner technologies that should be commercially viable by the mid-1980s. Three regions currently have major research efforts underway, a European consortium, Japan, and the United States. The first two are the most serious and advanced programs, both having plans to finish pilot plant operations by 1983-84. These will be followed closely by large commercial demonstration plants, to be operational by the late 1980s. The United States has no such firm research and development program, although planning and design work has been carried out.

The primary goal of these countries is to replace as much as possible of fossil fuel energy input in the steel production process with nuclear energy. The European Nuclear Steelmaking Club (consortium) has identified which of the potential processes are most appropriate.* Of those six, only three stand out as obtaining more than 50 percent of their total energy from nuclear sources.

The most viable of these are the two direct reduction processes, which get all of their energy from the nuclear plant. This energy is first in the form of high-temperature process heat and steam for re-forming natural gas, coal, or oil residuals into hydrogen, carbon monoxide, and other by-product gases. The remaining nuclear energy in the form of electricity goes to the electric arc furnace, which is used to refine the sponge iron produced in the direct hydrogen-reduction shaft furnace into steel.

The other process that uses up to 57 percent of its energy as nuclear energy is a blast furnace modified for hydrogen injection into the reducing region of the furnace. The hydrogen would be produced by steam re-forming. Although this type of blast furnace has not yet been developed for standard commercial practice, there appear to be no technical limitations or barriers to bringing these furnaces on line in a few years. A large savings in high-grade coking coal, over 45 percent, will be realized with this system. It is clear that nuclear energy is practical and advantageous in several of these modified standard steelmaking processes, particularly the direct reduction-electric arc furnace method.

The absence of coal in Japan and the relatively high cost of coal in West Germany have spurred the high level of steel-related development there. The Japanese program is concentrated on the direct reduction steelmaking process in which reducing gas (hydrogen plus carbon monoxide) is produced by steam methane re-forming.** The methane comes from the steam cracking of oil residual. The German work concentrates on synthesizing high-energy intense gas from both brown (lignite) and bituminous coal, also for the direct reduction process.

The steelmaking processes described so far rely on hydrogen (and some carbon monoxide) produced from steam re-forming of fossil-based hydrocarbons. This will be the most economic source of hydrogen for the immediate future, but will eventually become quite costly as fossil fuel supplies shrink. Future supplies of hydrogen, therefore, will be produced from the direct dissociation of water by electrolysis. This method uses electricity as the energy source; it will become cheaper as more nuclear reactors are brought on line, bringing overall electricity costs down. Of course, fusion-produced electricity will be even cheaper, bringing electrolysis costs down proportionately.

The HTGR Workhorse

The workhorse of the nuclear steel plant will be its HTGR, a versatile high-temperature gas (helium) cooled reactor, which will provide most or all of the required energy to the steel plant. The versatility of this reactor stems from its ability to provide a high-temperature process heat, high-temperature steam, electricity, or a combination of all three to any appropriate industrial process in the nuplex (Figure 1).†

Since the nuclear steelmaking processes will require the input of large quantities of hydrogen, the majority of the nuclear energy will be used to re-form hydrocarbons by producing process heat and steam. Some of the steam can also be used to produce electricity, using a turbine generator for energizing the electric arc furnaces and supplying the other electrical needs of the steel plant and nuplex.

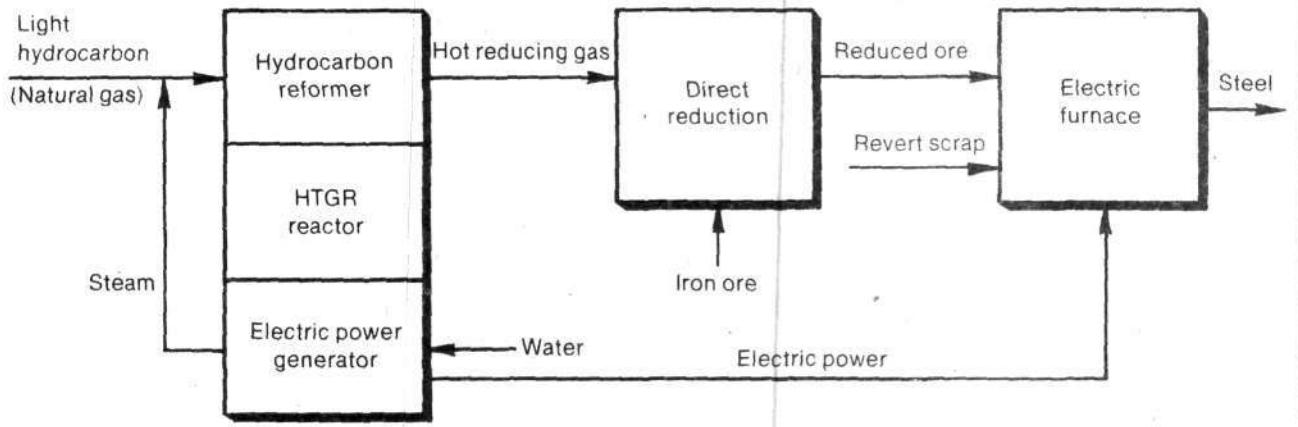
The temperature of the primary coolant helium is much higher than the water in water-cooled reactors, and, therefore, the thermal conversion efficiency for producing electricity is also much higher, about 40 percent compared to 30 percent for light water reactors—a significant economic advantage to the nuplex as a whole. It also has an additional future economic advantage in that it can incorporate a direct cycle gas turbine, thus eliminating the steam turbine-generator system and reducing power costs even further.

Development of HTGRs is already in an advanced stage in the United States and West Germany. In the United States, General Atomic Company has an operating 300-megawatt demonstration plant in Fort Saint Vrain, Colorado, which is producing electricity from high-temperature steam-driven turbines. At least eight commercial-size HTGRs were sold to utilities in the United States prior to 1975-76, when the market collapsed. All orders have since been canceled, but design and development have continued on higher temperature process heat versions as well as on the gas-cooled fast breeder reactor.

West Germany is almost as far along with a 300-megawatt-electric temperature steam-electricity plant slated for start-up in 1980. A smaller 15-megawatt-thermal (MWt) version, the AVR, has been operating for several years. The AVR has reached its goal to produce high-temperature process heat having attained temperatures of 950 degrees C. (1,710 degrees F.), well over the 1,600 degrees F. needed to re-form fossil-based hydrocarbons. A larger commercial size plant is planned for the mid to late 1980s.

Japan is also moving rapidly ahead with a 50-MWt process-heat HTGR, planned for operation in 1983, as the energy source for a direct reduction, nuclear steelmaking pilot plant (see box).

Figure 1
HYDROCARBON REFORMING FOR DIRECT REDUCTION



Steelmaking Economics—Nuclear Versus Conventional

Economic comparisons of the various steelmaking systems based on fossil and nuclear energy, which were conducted by several participants in these development programs, all come to the same conclusion. Nuclear-based steelmaking will be more economical than fossil-based processes as soon as the HTGRs can deliver commercial process heat at 1,600 degrees F. or higher. A 1974 comparison done in the United States by the American Iron and Steel Institute, shown in Figure 2, best illustrates this point. The results even surprised old-timers in the steel industry, who were quite sure prior to the study that nuclear energy couldn't compete with conventional methods.‡

The results indicate that the direct reduction process based on nuclear energy would be more than competitive right now with the standard blast furnace production technique, using metallurgical-grade coal at $20 per ton, the approximate price in 1973-74. However the study was done purposefully on a relative basis so that the results would remain valid in later years as prices rose. Therefore, with current coking coal prices more than double what they were in 1973-74 we see an even bigger advantage for nuclear energy. Even more surprising was the indication that producing hydrogen by electrolysis of water would be economical even at the current price of coking coal; that is, at costs greater than $38 per ton.

The costs are plotted as a function of the cost of delivered hydrocarbons. Re-formed fossil fuel for the HTGR-based direct reduction process was assumed to be natural gas, while the conventional process is the standard coke-fueled blast furnace. For reference purposes, current costs of delivered natural gas on an overall average basis are about $1.50 per MBtu. Nuclear-produced electricity was taken as the basis for the electrolysis cost calculations.

A more recent cost analysis, using an HTGR for the reforming of gasified low-grade coal in the United States, also indicates a cost advantage over other conventional steelmaking processes.†† These results show that nuclear steelmaking costs are lower in capital and operating cost categories—this difference would increase as coking coal costs continue to rise. It should be remembered, however, that at some point in the near future, approximately 10 to 15 years, production of hydrogen by electrolysis will be cheaper than any fossil-based process and, at that time, the major source of industrial process hydrogen.

Future Technologies and Processes

Besides upgrading the energy source to nuclear power and conserving fossil fuels for other more productive uses, an additional important innovation in future steel plants is continuous processing. That is, wherever possible, all newly designed steelmaking plants, especially those associated with nuplexes, should incorporate the latest technologies so as to eliminate inefficient batch processing. For example, the typical blast furnace today is a batch operation, which has input and output materials charged and discharged at regular intervals. Batch processing is used throughout the plant.

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* Dr. Robert Barnes. "Nuclear Steelmaking in Europe." *Iron and steel Engineer*. May 1976.

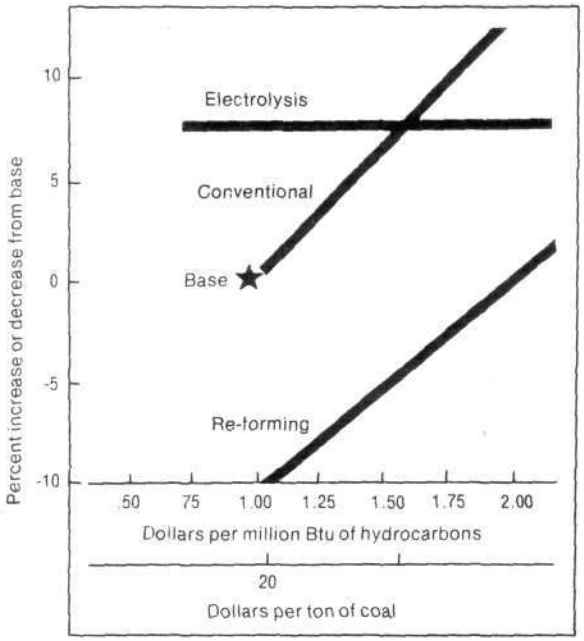
** Takesi Sugeno. "Nuclear Steelmaking in Japan." *Iron and Steel Engineer*. November 1976.

† Donald J. Blickwede. "The Use of Nuclear Energy in Steelmaking—Prospects and Problems." *Report by the Task Force on Nuclear Energy in Steelmaking*. American Iron and Steel Institute. 1974.

‡ R. N. Quade. "The Multipurpose HTGR—An Integrated Nuclear System for Power Generation and Direct High Temperature Process Heat Applications." paper presented at American Power Conference. General Atomic Co., Chicago, Illinois. April 1976.

†† Dr. Donald J. Blickwede. "Nuclear Steelmaking in the U.S.—Prospects and Plans." *Iron and Steel Engineer*. April 1976.

Figure 2
ECONOMIC COMPARISON:
NUCLEAR Vs. CONVENTIONAL STEELMAKING



Two methods of hydrogen production with the HTGR, re-forming of natural gas and electrolysis, are both far cheaper than the conventional method of blast furnace steelmaking when coal costs are more than $38 per ton. The base case, shown by the star, represents conventional blast furnace casts at metallurgical-grade coal costs of $20 per ton.

Continuous processing, on the other hand, if established throughout the steel plant, will result in a continuous input stream at one end, consisting of iron ore, reducing agent and energy. At the other end, a continuous output of finished steel product will be produced. In between, there will be continuous flows of liquid iron, liquid steel, and various by-products. This very efficient and economic system is almost completely automated—the direction in which all advanced industrial processes must move.

One example of a fully continuous, potentially near-term, steelmaking process (Figure 3) has been proposed by Eketorp.* It is not yet an industrial process, but a high-temperature smelting-reduction method that replaces the blast furnace. This type of furnace proposes the injection of a mixture of coal powder (that is, it eliminates coke), iron oxide, and oxygen directly into a molten iron bath. This carbon-based reduction to iron takes place at a high temperature (2,600 degrees F.) in the molten bath. The burning of carbon monoxide by oxygen above the bath provides part of the heat, while electric induction heaters supply the remainder. Plasma arc heaters may replace the induction heaters at a later date, while nuclear power will supply most of the electrical energy for induction, plasma heaters, and electromagnetic (MHD) pumps.

The molten iron is continuously transferred by MHD pumps from the smelting-reduction furnace to the electric arc or plasma arc furnace for additions of scrap metal and other refinements. Further continuous processing and refinement of the liquid-iron stream is accomplished until it is finally transferred to the casting operation. Continuous casting is already, of course, a developed technique.

Another of the new upcoming technologies that will greatly advance steelmaking is the advent of the plasma arc heater. This device, already in use in Eastern Europe

Japan's Steelmaking Goes Nuclear

A new method for reducing iron ore to extract pig iron that uses the heat from a nuclear reactor's helium coolant was recently announced by the Japanese, who are world leaders in the development of nuclear steelmaking. In a Sept. 28 article in the *Mainichi News*, the Japanese Agency of Industrial Science and Technology reported that an experimental heat exchanger, developed for the Ministry of International Trade and Industry by Ishikawajima-Harima Heavy Industries Company of Tokyo, has been completed and put on trial run in Yokohama.

The heat exchanger removes the heat from the helium coolant used in a High Temperature Gas Cooled Reactor (HTGR) and transfers it to a reducing gas of hydrogen and carbon monoxide, which chemically reduces the iron ore to extract pig iron. This not only eliminates the need for costly, messy, and polluting coking coal and blast furnaces, but also could be integrated directly into an electric steelmaking facility.

This technological breakthrough, whose development has mainly waited for new materials that could withstand the 1,000°C temperatures in the helium heat exchanger, is part of a long-term Japanese national project for nuclear steelmaking that began in 1973.

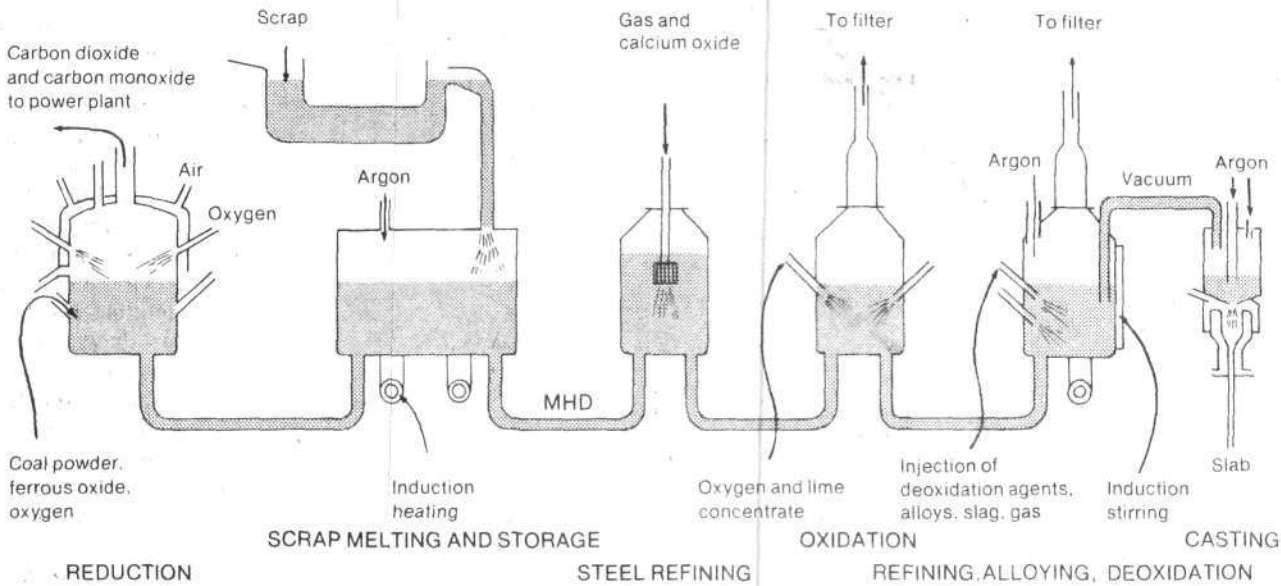
First Commercial HTGR

Last May the agency announced the completion of a plant to generate the necessary reducing gas reagent for this direct reduction process, and the first trial runs. The heat exchanger will require the commercial application of HTGRs specially designed for the steelmaking process. A test model of such a proposed nuclear reactor is now being developed by the Japan Atomic Energy Research Institute at its Tokaimura experimental station, northeast of Tokyo. The Japanese 10-year energy plan has budgeted money for HTGR development to make it commercial by the mid-1980s.

According to a U.S. representative of Nippon Steel, USA, the entire nuclear steelmaking system will be developed and designed by 1985, with a working steel mill by 1995. The carbon monoxide for the reduction of the iron ore need not come from imported coal, but may be produced from residual by-products of Japan's existing oil refineries. These tar and other residuals have very little use in current chemical processing.

—*Marsha Freeman*

Figure 3
CONTINUOUS PROCESS LINE USING SMELTING-REDUCTION



and the Soviet Union, has the capability of achieving much higher temperatures than electric arc furnace heaters (15,000 degrees C. or higher, compared to 3,600 degrees C.). In addition, the plasma arc operates at only 40 decibels compared to the incredibly intense 140 decibels of the conventional electric arc furnace, and thus does not require expensive noise-control equipment. The plasma arc is now only economical for use in producing very high-quality specialty steels from scrap iron.

The eventual application of this heating system to the basic steelmaking process has been proposed for a future high-temperature hydrogen-reduction furnace. In this process, hot hydrogen and iron ore concentrate are injected into a molten iron bath in the furnace, which is at a temperature of over 2,900 degrees F. The hydrogen is heated to these high temperatures by plasma arc heating before entering the reduction furnace. The hydrogen no doubt will be produced by electrolysis of water, since cheap nuclear-produced electricity will be the energy input to the entire steelmaking process.

Reduction of iron ore at such high hydrogen temperatures has never been done before, but development of the plasma arc will make this possible. Since no carbon will be present in this process, all the steps up to the molten steel stage in modern plants will become a one-step function in this high-temperature furnace. Capital costs for such high-energy intensity equipment are expected to be much lower than the costs for what is in use today. Combined with the lower operating costs and energy costs, this process will very likely be the ultimate in steel produced by means of chemical reactions.

A revolutionary change in steelmaking, as well as in other metal production, will occur with the advent of the direct applications of fusion reactor plasmas. Fusion reactors will make cheap plasma energy available in very large quantities and at temperatures in the tens of millions of degrees centigrade range—far beyond the temperature and energies possible from electrically produced plasmas. Such plasma conditions will permit the direct production of iron rather than by the chemical processes now used.

Using the fusion torch, a pulverized raw material such as iron ore can be injected into and mixed with a jet of plasma discharged from a fusion reactor.** The kinetic energy of the particles in the very hot (50 to 100 million degrees C.) plasma is exchanged with the iron ore, causing immediate shock vaporization to occur. The iron ore is ionized and reduced to its basic elemental ingredients within the torch. The final task is to separate out the desired element—in this case iron—and transfer it on for further processing into steel.

As the plasma mixes with the iron ore, and the velocity of the plasma reduces through volume expansions within the torch, the average temperatures are decreased to the 2,000 to 6,000 degrees C. range. During the element separation process, which could be done electromagnetically, or by plasma centrifuge, temperatures will be reduced further.

Jon Gilbertson, a nuclear engineer with the Fusion Energy Foundation, is a frequent contributor to Fusion.

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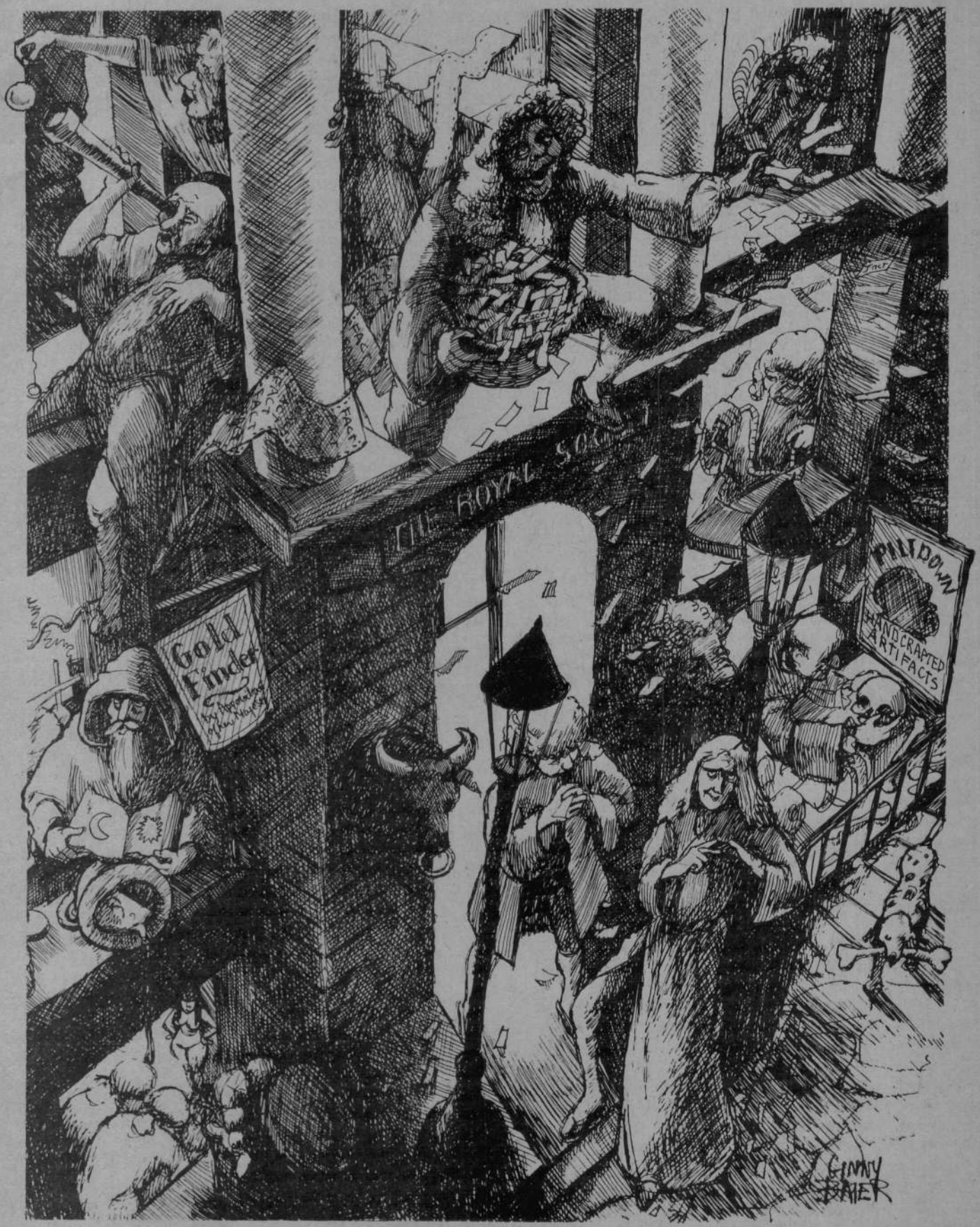
* Dr. S. Eketorp, "Steel Plant of the Future," *Iron and Steel International*, October 1976.

** B. J. Eastlund and W. C. Gough, *The Fusion Torch: Closing the Cycle from Use to Re-Use*. U.S. Atomic Energy Commission Report, WASH-1132, May 1969.


Gold Finder
PILTDOWN
HANDCRAFTED
ARTIFACTS
GINNY
BAER

I Don't Make Hypotheses — I Manufacture Data

The Royal Society Revisited

by Carol White

TWO ASTOUNDING FRAUDS have come to light in the past year. In 1977 Robert Newton published his findings that the Ptolemaic system was based largely upon fraudulent sightings. And last month in *Science* magazine, psychologist D. D. Dorfman documented that the whole environment versus heredity debate in the field of psychology likewise was based upon fraud.

Although some may consider the case of Ptolemy a historical curiosity today, the facts are that Ptolemy's manufactured data were just one of the practices he employed in his conscious effort to stamp out the Platonic tradition of reason and replace it with the Aristotelian method of empiricism. The motivation behind Ptolemy's falsifications, as I shall show, is essentially the same as that which prompted leading British eugenicist Cyril Burt, years later, to falsify data in order to beef up his racist side of the nature versus nurture debate.

First, the Burt case. Cyril Burt's work on the importance of heredity, which Dorfman exposes as a hoax, formed the basis of a school of psychology known in this country primarily through the works of his students, A.R. Jensen and R.J. Herrnstein, both formerly of the Harvard University faculty. Herrnstein and Jensen have been the center of heated controversy since they alleged in the 1960s that Negroes were probably intellectually inferior to whites, on average, because of heredity. Since Herrnstein and Jensen found the theoretical basis for their work in Burt's 20-year study of the correlation between social class, intelligence, and heredity, it is reasonable to suppose that their data now will be subject to the same scrutiny as Burt's.

Dorfman's Findings

Dorfman summarized his findings as follows:

> Cyril Burt presented data in his classic paper "Intelligence and Social Mobility" that were in perfect agreement with a genetic theory of IQ and social class. A detailed analysis of these data reveals, beyond reasonable doubt, that they were fabricated from a theoretical normal curve, from a genetic regression equation, and from figures published more than 30 years before Burt completed his surveys.

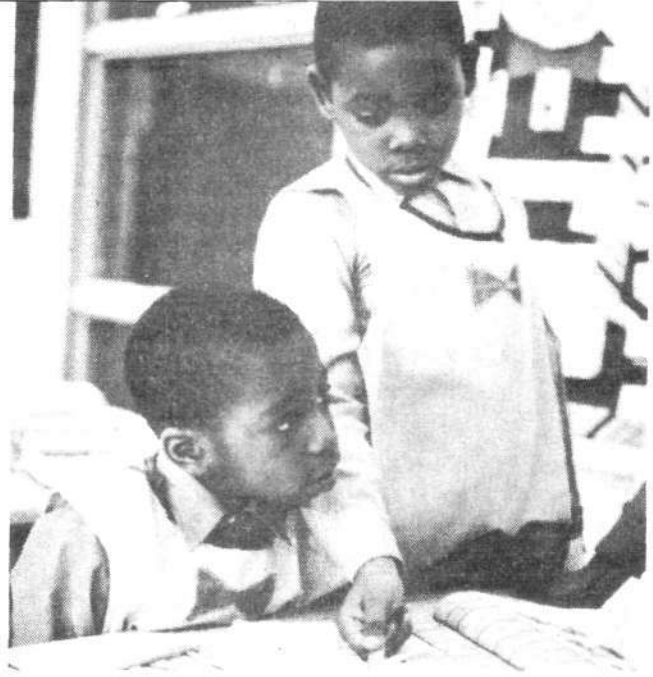
Dorfman's article in *Science* seethes with his justified indignation. A professor of psychology at the University of Iowa, Dorfman attempted for years to controvert the racist findings of Burt, only to be lectured to by Burt and his epigones on the quality of Burt's data.

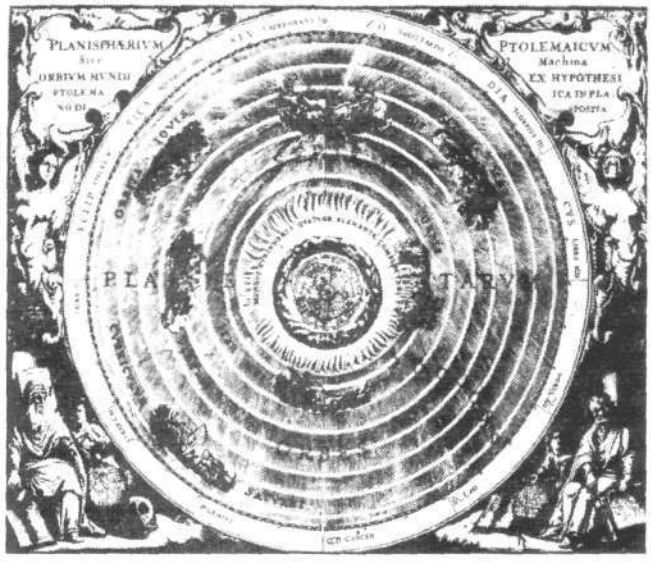
Dorfman's suspicions were aroused because Burt's data were too perfect. When he subjected the agreement between Burt's findings and theoretically predicted results to statistical test, Dorfman found the agreement beyond the range of expectation. In one case, by no means atypical, Dorfman found that the probability was 1 in 100,000 that such agreement could have taken place without some tampering of the data. Further checking revealed, in fact, that one of the assistants who purportedly collected and tabulated these data, Jane Conway, was not even a real person.

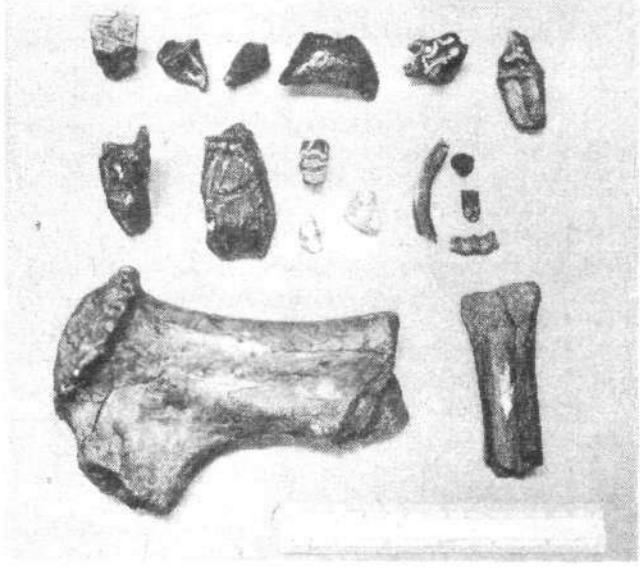
Burt's Legacy

Cyril Burt, who has been called the father of British psychology, was a leader of the British eugenicist school connected with the Tavistock Institute in London, an institution otherwise famous for its studies of brainwashing. He was the first British psychologist to be knighted. Incredibly, Burt received his knighthood in 1967 for his contribution to education—a contribution essentially directed to justifying the existence of unequal educational opportunity. He claimed that the attempt to educate the lower classes beyond their station would necessarily be of little value because of the inherent genetic limitations of these classes.

The effect of Burt's contribution to education can be seen in this country in the debate provoked by Jensen and







Herrnstein's work around the question of who is to blame for the failure of black children to learn in the schools. Although the Jensen-Herrnstein side of the debate is clearly fascist in implication (blacks, they say, on average are genetically prevented from academic success), the other side of the debate in academic circles also has had a negative effect on the problem. Typically, the anti-Jensen-Herrnstein faction has targeted teachers as being the responsible agents for the fact that black students, on average, have a poorer performance record than whites. Unfortunately for American education, both sides in the debate ignore the basic underlying issues such as the high jobless rate, poor living conditions, the spread of drugs, and the crowded classrooms and general underfunding of schools.*

After he died in 1972, Burt was eulogized by his student Jensen in a passage so ridiculous—in view of Dorfman's *findings—as to be worth quoting*:

> The overall picture that Sir Cyril leaves in one's memory, after corresponding with him, seeing him, and conversing with him, is very clear indeed. Everything about the man—his fine, sturdy appearance; his aura of vitality; his urbane manner; his unflagging enthusiasm for research, analysis, and criticism; even such a small detail as his firm, meticulous handwriting; and, of course, especially his notably sharp intellect and vast erudition—all together leave a total impression of immense quality, of a born nobleman.

Similar praise of this natural nobleman by his British collaborator, H.J. Eysenck, only makes the case more absurd. In the same year Eysenck wrote that Burt "was a deadly serious critic of other people's work when this departed in any way from the highest standards of accuracy and logical consistency."

Inevitably, one is reminded of descriptions of Sir Isaac Newton, whose seamier side included concocting documents that purported to show that he, not Leibniz, had established the calculus as a mathematical discipline. Of course, Newton was unsparing in his attacks on Leibniz, whom he charged with plagiarizing his work. (In fact, not only did Newton take the idea of the calculus from Leibniz, but this was only one in a long line of such borrowings.**)

The case of Ptolemy is another example of manufactured data.† In summary, as astronomer Robert Newton has demonstrated in *The Crime of Claudius Ptolemy*, Ptolemy manufactured astronomical sightings to support

Manufactured data:
Burt's fraudulent data on the role of heredity and intelligence promoted the myth that black children like these could not learn because of genetic limitations; Ptolemy's geocentric map of the planets, which dominated astronomy for more than a millenium; the Piltdown zoo of artificially aged bones, which included hippo and rhino teeth and a deer antler.

his and Aristotle's geocentric cosmology against competing heliocentric theories. In Newton's words: "The answer is simple and tragic.... The measurements Ptolemy claims to have made were not made."

The impetus for Robert Newton's discovery was his concern for the validity of ancient observations important for his own work. Newton is a practicing astronomer at the Johns Hopkins Applied Physics Laboratory, and he is engaged in research supported by the Department of the Navy into the secular acceleration of the earth and moon and the precise measurement of time.

A third famous scientific fraud, which was a product of Isaac Newton's Royal Society, is the so-called Piltdown hoax in which dog and ape bones were mixed and artificially aged to create the apparent remains of a bestialized baboonlike ancestor to man (see box). The purpose of this fraud was to reinforce the erroneous impression that man is a close relative of existing ape species, with obvious philosophic implications about man's inherent bestiality.

The Royal Society Connection

Although the Ptolemy fraud long preceded the similar practices of the British Royal Society, Burt's work and the Piltdown hoax are directly attributable to members of that institution. The Royal Society connection to Ptolemy exists through the work of Sir Francis Bacon, spiritual father of the society and avowed founder of the so-called school of British empiricism. Bacon, in turn, indirectly acknowledged his debt to the Ptolemaic tradition in his unfinished essay, *New Atlantis*, as I shall demonstrate.

This Ptolemaic tradition is not simply one of falsifying data to prove an incorrect theory. Ptolemy, part of an intelligence operation run out of the Aristotelian-Babylonian Museum in Alexandria, was also well known in his day as an astrologer. He belonged to the post-Peripatetic school that adopted Babylonian astrological practices‡ and carried them a step further to construct personal horo-

* Typical of the anti-Jensen-Herrnstein side of the argument is sociologist Kenneth Clark, whose Ford Foundation-funded research organization, the Metropolitan Applied Research Center, organized community groups against teachers during the 1968 teachers strike in New York City. As an antidote to the problem, Clark proposed that school systems rate and pay teachers according to the reading scores achieved by the classes they taught.

** The case against Isaac Newton was developed by the author in two previous *Fusion* articles, "The Royal Society" (Dec.-Jan. 1977-1978) and "Science Is Politics" (May 1978).

† The material in this section is based on a to-be-published paper by Molly Kronberg on Ptolemy and on the Robert Newton book, *The Crime of Claudius Ptolemy*.

‡ Astrology in its modern form—the fantasy that the stars bind an individual's fate beyond any hope of his control—was launched in approximately 300 BC in Greece and Graeco-Egypt by the post-Aristotle Peripatetics and their allies, the Stoics. Drawing on the "ancient Chaldean (Babylonian) star lore"—with which the Lyceum at Athens and the Aristotelian Museum and Library at Alexandria had strong affinities—they evolved a new pseudoscientific cult for Greece, Rome, and the rest of the West.

The new ingredient introduced by Theophrastus (Aristotle's successor at the Lyceum) and the Stoics was the notion of a *personal horoscope*. The Chaldeans had read the skies merely for portents of national significance, but effective social control of the Hellenized West required a nod to Hellenic notions of individuation. It is generally suggested in the classical sources (for example, Proclus) that Theophrastus's *in-the-public-record* propaganda for horoscopic astrology is the first known endorsement of the cult in the Hellenic world.

The Piltdown Hoax

The British weekly science magazine, *Nature*, will report the full story of the participants in the Piltdown Man hoax in November, according to an Oct. 30 wire release from Associated Press and the British news agency, Press Association. The story will include a 20-minute tape recording made earlier this year by Professor James Douglas, professor of geology at Oxford University, that identifies William Sollas (former professor of geology at Oxford) as the perpetrator of the hoax. Douglas, who succeeded Sollas, was for many years his aide at Oxford. He made the tape recording shortly before his death this year at age 93.

The Piltdown hoax involved the discovery in 1912 of a faked prehistoric human skull in Piltdown, England that was fabricated to prove the Darwinian so-called missing link between man and the apes. It was discovered by Britain's famous amateur paleontologist, Charles Dawson (implicated in Professor Douglas's tape recording as part of the conspiracy with Sollas), and was immediately proclaimed genuine by scores of British scientists.

However, there were persistent suspicions about the discovery because the skull consisted of the cranium of a *homo sapiens sapiens* individual and an entirely apelike jaw — indicating an impossible "evolution by degrees" from ape to man.

In 1953, modern dating methods confirmed the jaw was that of a young orangutan attached to a modern human cranium. Then it became necessary for British empiricism to abandon, reluctantly, *Eoanthropus dawsoni*, who had so well confirmed Darwin's Malthusian misrepresentation of evolution.

Eoanthropus dawsoni *and its creator, Charles Dawson.*

Worship of the Egyptian mother goddess Isis was perpetuated by a Royal Society elite through the practice of alchemy and mysticism. Note the similarity of headdress on Isis (left) and the high priestess on a 19th century British Tarot card.

scopes. Just this type of astrology was part of the fabric of the Royal Society. For example, Isaac Newton, a lover of the occult, prophesied that the coming of the final day of judgment and the end of the world would coincide with the appearance of Halley's comet.

In fact, these astrological practices are carried on by the Royal Society up to the present day. Cyril Burt's so-called genetic map of intelligence is, after all, merely a more sophisticated form of a horoscope, meant to condemn a child to a fixed fate preordained for him by his betters.

And as British intelligence services have long recognized, the use of astrology is a favored device to control the credulous through suitable predictions. For example, Hitler was known to consult astrologers, most of whom were well connected to British intelligence agents.*

To anyone familiar with the Royal Society's history, the recurrence of magic (Newton was also notorious as an alchemist), mysticism, and fraud in British Royal Society circles should come as no surprise. Francis Bacon was an intelligence agent through all of his adult life. In the pay of his relatives in the Cecil family and their associates in Genoese banking circles such as the Palavicino family, Bacon directed himself to destroying Neoplatonic currents in Tudor England, which at that time were centered around the Dudley family.

Furthermore, the Royal Society and its predecessor institutions, such as Ptolemy's Alexandrian Museum and Library, were deliberately created as a cover for sophisticated intelligence operations. As such, they conducted psychological warfare, including the manufacture of synthetic religious sects, as well as industrial espionage. And the Royal Society is famous for appropriating the discoveries of other nations, as Joseph Henry, first director of the Smithsonian Institute, complained.**

With this in mind, let us turn to Bacon's *New Atlantis* and substantiate the historical link between Cyril Burt and Ptolemy.

The New Atlantis

Prematurely retired from public life after being convicted of swindling the public treasury, Bacon wrote a number of proposals all leading to the formation of the Royal Society. The *New Atlantis* is a mythical treatment of the same subject. In the fable, Bacon describes the society as Salomon's house. The hero of the tale is introduced to the house's precincts by a follower of the Gnostic religion, a synthetic cult of the early Christian period that included Christ as one of a number in a pantheon of lesser gods. The members of Salomon's house also practiced a cult of the family, which Bacon details.

As Bacon describes it, one of the main purposes of the society is to conduct industrial espionage. In his words in *The New Atlantis:*

> Every 12 years there should be set forth out of this kingdom two ships, appointed to several voyages; that in either of these ships there should be a mission of three of the Fellows or Brethren of Salomon's House, whose errand was only to give us knowledge of the affairs and state of those countries to which they were designed, and especially of the sciences, arts, manufactures, and inventions of all the world. . . . Now for me to tell you how the vulgar sort of mariners are contained from being discovered at land; and how they that must be put on shore for any time colour themselves under the name of other nations. . . .

The New Atlantis is no mere fable. Not only the Royal Society, but the Scottish Rite branch of the Free Masons, which was organized by Elias Ashmole, a secretary of the Royal Society and protégé of Isaac Newton, acknowledged Bacon as their inspiration. This branch of Free Masonry based its rituals on the cult of Isis, the Egyptian mother goddess, which is also the basis for the Gnostic religion mentioned in *New Atlantis*. (Not coincidentally, a branch into the Thames River at Oxford University is named the Isis.)

Throughout history, practitioners of the cult of Isis, like Bacon, have denied the primacy and even the existence of reason. Instead, empiricism is the doctrinal belief the initiate impose on cult followers. This false belief holds that the world is knowable simply by gathering and correlating sufficient facts.

As Burt's practice shows, the elite of the empiricists do not, of course, subscribe to such a ludicrous view themselves. Since the theories they promote are not in accord with natural law and, therefore, cannot be demonstrated factually, Burt and others like him are quite prepared to take the necessary steps to manufacture the data they need.

The explanation for the black magic practices of supposed scientists like Newton? Since reason is denied them, the followers of such cults are immediately vulnerable to magical thinking—like astrology—in an attempt to establish some sort of quasi-coherent worldview.

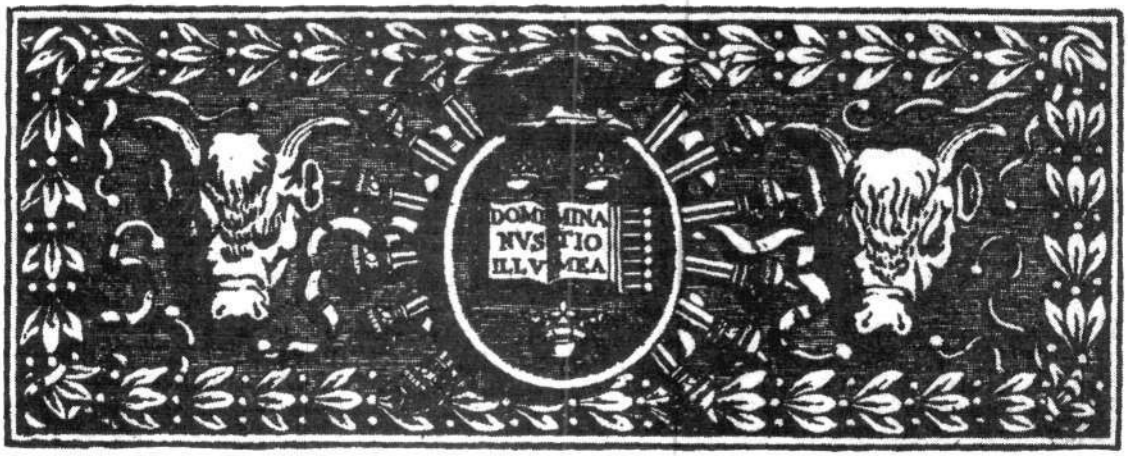
The Open Attack on Science

Modern scientific history is deliberately distorted to overlook the work of a core group of Neoplatonic scientists, broadly contemporary to Bacon, who were both independent of Bacon and in opposition to the Aristotelian tendency. This group, which includes Bruno, Kepler, Descartes, and Leibniz, broke decisively with medieval practice and instituted experimental-theoretical modern physics, laying the basis for the study of mechanics and astronomy.

In turn, these scientists trace back to the 15th century Cardinal Nicholas of Cusa, who rightly can be called the founder of modern science because of his fight to reestablish the Platonic tradition over the Aristotelian tendency of his time.

Although the group around Cusa is better known for its

* Lyndon H. LaRouche, Jr., "The Truth About German Collective Guilt," *New Solidarity*, Part I, Oct. 10, 1978; Part II, Oct. 13, 1978.
** *Scientific American*, July 1954.



The Cult of the Bull

As Bacon (and Plato) were aware, Poseidon was connected in Greek mythology with Apollo, the god of the Persian and Babylonian-run oracle of Delphi, which was the main support for the oligarchy in classical Greece. Among other things, Poseidon was supposed to have helped Apollo in the construction of Troy—whose destruction by the Greeks is celebrated in the Greek national epic, the *Iliad*. And Poseidon had contested unsuccessfully with Athena, the goddess of wisdom, for the position of patron god of Athens, Plato's home city.

In Plato's time, the bull was sacred to Dionysus, whose degenerate cult was invented by the cult of Apollo. Dionysus's maenad worshippers—believing the bull to be the god incarnate—are said to have performed sodomy with the beasts. The bull was also sacred to the Egyptian death-cult of Osiris, the consort of Isis. In Roman times—doubtless known to Bacon—the bull was propagated throughout the Greek and Roman world together with the cult of Isis as the sacred animal of Serapis, a god invented by the Aristotelians in Alexandria. In Bacon's own time, of course, the cult of Isis was continued at Oxford, and the head of the bull adorns the emblem of "Ox-ford," with an inscription reading in Latin: "the lord is my light."

revival of Plato, it also retranslated Archimedes from the Greek; and through this work on Archimedes, the foundations were laid for the modern treatment of integration upon which Leibniz based his discovery of differential calculus.

Up until the time of Bacon, Plato's dialogue *Timaeus* was considered one of the important scientific dialogues of its day. In the *Timaeus,* Plato gives the first systematic treatment of scientific method, based on a concept of relativistic space-time. Although the predicates of Plato's treatment have been superseded with the growth of scientific knowledge, it is a sad fact that under the hegemony of the Royal Society the understanding of scientific method has deteriorated—aside from a core group of Neoplatonic scientists.

This is the real crime of Bacon and the Royal Society—the replacement of the Platonic tradition by the school of British empiricism, also known as modern scientific tradition—that is, the Newtonian prescription "I don't make hypotheses." In truth, British empiricism is a continuation of the Aristotelian tradition that has been attacking Platonism—reason—since Aristotle was sent into Plato's academy to subvert it in the year 367 BC.*

Bacon's *New Atlantis* makes explicit, ironical reference to Plato's description of the lost city of Atlantis in the *Timaeus* and in another dialogue, *Critias*. The naive reader is led to assume that Bacon means his title to suggest the replacement of Plato's Atlantis (that is, classicism) by the school of British empiricism.

The initiate (like Ashmole and the Scottish Rite Free Masons) knows better. Plato describes Atlantis as a degenerate culture founded by the god Poseidon and dedicated to a cult of the bull (see box). Atlantis seeks to enslave Greece, but is foiled by a higher culture modeled in accordance with the precepts of Plato's *Republic*. Bacon's *New Atlantis* is modeled after the cult practices of Atlantis, the enemy of Platonism.

I will simply assert here that only the Platonic tradition provides a basis for scientific theory, a thesis discussed thoroughly elsewhere.** The real swinishness of Aristotle, Ptolemy, Bacon, Newton, and Burt is not in their pathetic frauds, nor in their appropriation of other people's work. Their bestiality lies in their frontal attack on science and on their deliberate propagation of a cult of irrationality. The practical effects of this philosophy can be seen by looking at those places where British empiricism reigns supreme—for example, the rotting industrial base of England, which is on its way to Third World economic status.

The method of Baconian inductive generalization, the school of British empiricism, can never produce more than the ludicrious series of lists like those Bacon presents in the *New Atlantis* and the *Novum Organum*. And the mentality that underlies Burt's work—and the analogous dedication by Bacon and Ptolemy to destroying the humanist currents of their own times—can never receive factual substantiation except through fraud.

It is fitting to give Edgar Allan Poe, a humanist who fought to establish reason and the American System of technology and growth, the last word on the subject. The following is his description of British empiricism in the essay "Eureka":

> *Well, Aries Tottle flourished supreme, until the* advent of one Hog . . . who preached an entirely different system, which he called the *a posteriori* or inductive. He proceeded by observing, analyzing, and classifying facts—*instantiae naturae* as they were somewhat affectedly called—and arranging them into general laws. . . . Baconian, you must know . . . was an adjective invented as equivalent to Hog-ian, and at the same time more dignified and euphonious. . . . The error of our progenitors was quite analagous with that of the wiseacre who fancies he must necessarily see an *object the more distinctly, the more closely he holds it* to his eyes. They blinded themselves, too, with the impalpable, titillating Scotch snuff of *detail*; and thus the boasted facts of the Hog-ites were by no means always facts—a point of little importance but for the assumption that they always *were*. The vital taint, however, in Baconianism—its most lamentable fount of error—lay in its tendency to throw power and consideration into the hands of merely perceptive men—of those inter-Tritonic minnows, the microscopical savans—the diggers and peddlers of minute *facts*, for the most part *in physical science—facts all of which they retailed at* the same price upon the highway; their value depending, it was supposed, simply upon the *fact of their fact*, without reference to their applicability or inapplicability in the development of those ultimate and only legitimate facts, called Law. Than the persons thus suddenly elevated by the Hoggian philosophy into a state for which they were unfitted—thus transferred from the sculleries into the parlors of Science—from its pantries into its pulpits—than these individuals a more intolerant—a more intolerable set of *bigots and tyrants never existed on the face of the* earth.

Carol White, a former teacher of mathematics and philosophy, is a national executive committee member of the U.S. Labor Party.

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Research

Soviet Space Mission Studies Weightlessness

The effect of prolonged weightlessness on humans and other organisms was a major topic of study in the record Soviet space mission that returned to earth Nov. 2. The 140-day mission, during which Soviet Cosmonauts Vladimir Kovalenok and Aleksandr Ivanchenkov lived and worked in the orbital complex Salyut-6-Soyuz, established that man can adjust to the environment of weightlessness.

The cosmonauts are now at a special readaptation center where they will live with their families while extensive medical tests are carried out. Their 14 weeks of living beyond earth's gravity began June 15, 1978 and broke the limit for manned flight.

According to Soviet press reports, the studies show that when the force of gravity is removed, the human body gradually begins to adapt. The gravity sensors cease to function and a redistribution of blood begins, with surplus blood reaching the brain and the heart. The heart responds by decreasing the amount of blood and a weight loss is experienced. The muscles and bones become weaker, and less oxygen is required.

In time, the human starts to feel fine, operating at a new level—just as people take time to adjust to living in mountainous areas.

According to the Soviet doctors caring for Kovalenok and Ivanchenkov, their adjustment was as good as that of cosmonauts spending much shorter times in space. The crucial challenge was preparing them for reentry to earth's gravity field. High-technology equipment has made this possible, with the two cosmonauts carrying out exercises on special machines and wearing "penguin" and "lapwing" suits that place a load on the muscular-skeletal framework and reduce pressure to draw blood down into the legs.

Tass from Sovfoto

The crew of the Soviet space mission, Colonel Vladimir Kovalenok (l.) and flight engineer Alexander Ivan Chenkov, shown here at a preflight training session at the Gagarin Cosmonauts Training Center.

By the time the Soviet space colonization program takes off, they expect this technology to be advanced to the point where earthlike conditions can be re-created wherever man goes.

In addition to the breakthrough in vacuum living, the cosmonauts carried out numerous scientific experiments and observations. They discovered the regular movement of glaciers in Latin American mountains, hitherto unknown; observed forest fires all over the world, which were reported to the appropriate authorities; studied chemical and technological processes in a weightless vacuum; and created new semiconductor and optical materials, metallic alloys, and compounds that cannot be produced in earthlike conditions.

Their successful production of the semiconductor *lead telluride*, for example, breaks ground for future space factories in which machinery can operate free from the friction and gravity-load conditions of earth.

Biological experiments were also carried out, and extensive photographs made of the earth's surface to study the dynamics of changing vegetation cover, water balance, and other seasonal natural phenomena.

Researchers Produce Human Insulin

Using recombinant DNA techniques, a group of California researchers centered around Dr. Herbert Boyer of Genentech and the University of San Francisco have induced bacteria to produce human insulin.

The project included the laboratory synthesis of the entire human insulin gene from small molecular building blocks, the insertion of the gene into a plasmid (a strand of bacterial DNA), and the transfer of the plasmid into the bacterial cell as an active functioning gene. Human insulin was then extracted from the bacterial culture.

Their achievement makes it possible to provide large amounts of human insulin, which can immediately benefit the thousands of diabetics who are allergic to the currently used beef and pork insulin.

Of more far-reaching significance is the implication that scientists may be able to produce other human proteins cheaply and in large quantity. High on the list would be substances like interferon, a chemical that humans produce in small quantities for immunological defense.

Interferon, which is being tried as a possible cancer drug in research centers in Texas, is now extremely expensive and available only in small quantities. The recombinant technique would reduce the price and increase availability by a factor of thousands.

Other possibilities include a number of human hormones, such as growth hormone. The cheapness and availability would make possible studies on the action of hormones, as well as their increased use in therapy.

Books

Knowing Leonardo da Vinci

by Nora Hamerman

Carlo Pedretti, *The Literary Works of Leonardo Da Vinci*, A commentary on Jean Paul Richter's edition. University of California Press, 1977, Two Volumes, $59.50.

When Leonardo da Vinci died in France in 1519, he left behind fewer than two-dozen easel paintings. His great commissions in mural painting and sculpture already either had been prevented from completion or had undergone partial destruction, and only fragments of the canals, fortresses, cities, and architectural projects of his design had come to fruition. However, he bequeathed to his heir, the Milanese nobleman Francesco Melzi, a vast collection of writings and drawings that he intended to be transformed into treatises on painting, botany, anatomy, geography, mechanics, hydraulics, and other topics. He had even invented a new system of reproduction for his delicate scientific illustrations to facilitate production of the books, as the recently discovered "Madrid codices" reveal.

It is upon these notebooks, chiefly available through the transcripts and English translations first published in a two-volume topical arrangement by Jean Paul Richter nearly a century ago, that Leonardo's reputation as the greatest modern scientist-artist rests. Carlo Pedretti, the noted Vincian expert, has now prepared a *Commentary* to the Richter books, described by the publishers as a "Summa Vinciana," or what amounts to extensive footnotes incorporating most of what has been unearthed during the past 90 years on Leonardo's manuscripts and their history.

Pedretti acknowledges that he deliberately chose this Aristotelian footnoting approach, *instead* of going with a completely revised new edition of Leonardo's writings. The choice results in a devastating flaw.

The central problem with most discussions of Leonardo's celebrated merging of art and science is that they proceed from reductionist conceptions of both. What is left out is that Leonardo expresses a very clear idea of the universal law that subsumed his entire creative process. However, this universal law cannot be understood outside of his relationship to the political Grand Design of the Renaissance which nearly succeeded in bringing off the industrial revolution centuries in advance of the late 1700s, and which transmitted the Neoplatonic tradition that made the later revolutions possible. Leonardo was both the product, and then a leading protagonist, of the 15th century Grand Design, along with Nicholas of Cusa, Ficino, Cosimo and Lorenzo de' Medici, Gemisthos Plethon, Erasmus, Machiavelli, and Rabelais.

To know this is to be able, at last, to *know* Leonardo da Vinci, rather than simply to know *about* that genius in the form of the ultimate collection of footnotes. To *know* Leonardo has been a key to political potency for both artists and scientists ever since the 16th century. And to keep us from knowing Leonardo, a host of so-called scholars and restorers have gutted the Vincian heritage of its political-philosophical core, including the outrage of chopping apart Leonardo's notebooks into segregated scraps representing "art," "science," "polemics," and "humor." Behind this butchery have been the political enemies of the Grand Design.

Leonardo's Thinking Process

The very ordering of the Treatise on Painting, the central document of Leonardo's notebooks and the treatise that is most complete in its extant form, is like a map of the thinking process that governed Leonardo's diverse activities and made his "artistic" side so integral to the success of his "scientific" conceptions.

The core problem for realizing Leonardo's famous inventions and city-building projects—which involved his detailed planning down to manhours of labor, development of special machines to carry out difficult tasks, and even the mechanisms of financing—was the question of *labor power*. The chief obstacle was to mobilize, raise the cultural and material standard of living of, and deploy as an effective skilled labor force a population of which more than one-third of active age were wasted in monasteries and mercenary armies. The great art of the Renaissance, including the *Colloquies* of Erasmus and Leonardo's paintings (political cartoons), was intended to intersect the subjective, institutional problem and make a higher process of Reason—Platonic Reason—accessible to a wider population otherwise oppressed by ignorance.

Thus, the matchless marshaling of the technical means of the painter that Leonardo lays out in his treatise (Richter's volume I, much elaborated by Pedretti), is never very distant from his city-building projects per se, particularly the waterworks, which were the primary program of the Grand Designers of his age. All his life, Leonardo was working in the orbit of a political alliance set up between, principally, the Florentine Medici and Louis XI of France. Their Grand Design was intended to ruthlessly suppress the feudal, localist, landholding interests and their banking (and church) backers in order to build (colonize) new cities around canal networks.

The canals had a threefold purpose: One, to harness water power to a range of new, high-technology, labor-saving manufactures; two, to provide cheap transport of the finished commodities for commerce; and three, either to bypass strongholds of the feudal oligarchies or to coopt such areas into the Grand Design on the basis of their self-interest in the new prosperity.

It is most significant, therefore, that Leonardo's Treatise on Painting opens with seemingly unrelated observations on "the science of the motions of water," and includes asides reminding the author to put his material "on digging a canal" in his planned "Book of Useful Inventions." Next, when he poses an overview of the problem of painting, he defines perspective—the painter's equivalent of counterpoint—as "physics"!

> Among all the studies of natural causes and reasons, Light chiefly delights the beholder; and among the great features of Mathematics the certainty of its demonstrations is what preeminently (tends to) elevate the mind of the investigator. Perspective, therefore, must be preferred to all the discourses and systems of human learning. In this branch the beam of light is explained on those methods of demonstrations which form the glory not so much of mathematics as of Physics and are graced with the flowers of both.

Despite his apparent awe for "mathematical certainty," Leonardo's real claim to scientific genius is his ability to make *visible* (and audible, in many of his written fragments) the very process of hypothesis formation that is the essence of scientific thought. It is not accidental that the two areas of his most profound study, aside from hydraulics and mechanics, were optics and anatomy. Painting is posed as the meeting-point between the operation of light in the physical universe and the physiology of seeing, which makes perceived physical phenomena accessible as abstract ideas.

Leonardo, an alleged autodidact, voraciously read the writings of earlier Neoplatonists like Avicenna, Nicholas of Cusa, and Roger Bacon. The fact that many of his insights, previously believed original to him, actually came from these sources, does not diminish his own contribution, but merely defines it more precisely. He took up the Neoplatonists' vision of mind *reproducing* mind, and through his practice and theory of painting (including drawing) he made the law of universal self-development visible. It was because Leonardo continually posed the problem of how the unique individual, or singularity, intervenes to order the process of growth in nature that he was able to make significant contributions to the study of anatomy—he was the real founder of modern anatomical science—and

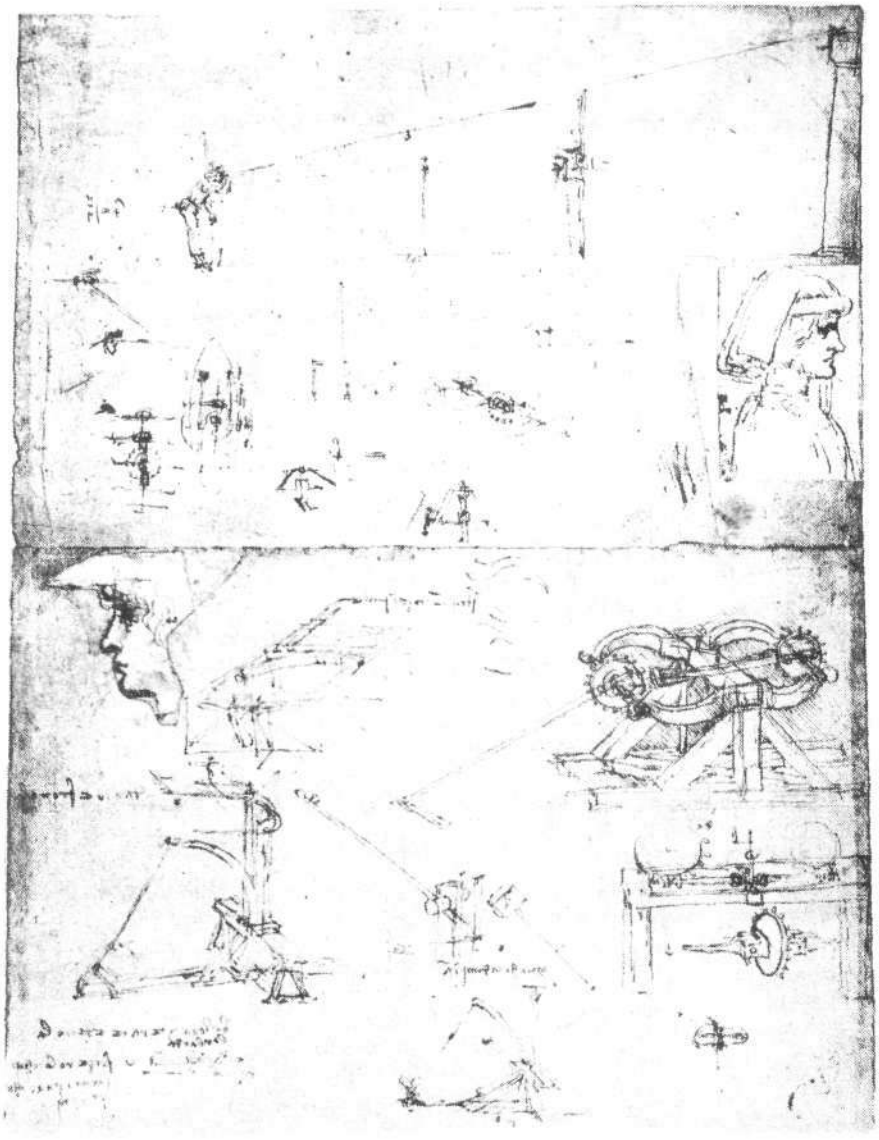


Figure 1
NOTEBOOK PAGE RECONSTRUCTED BY PEDRETTI

Carlo Pedretti's 1957 photomontage reconstruction of a page from Leonardo da Vinci's notebook showing two drawings of heads that were detached by Hapsburg agent Pompeo Leoni and are now in Windsor Castle. The notebook page is currently in the Codex Atlanticus of the Ambrosian Library of Milan.

The original page combined drawings of a military invention (a catapult) with the distinctly recognizable portrait of Lorenzo de' Medici (top right), Leonardo's Florentine patron.

fluid dynamics, to name but two fields.

Leonardo was fully self-aware of the implications of this hubristic intervention. "I wish to work miracles," he bluntly begins his notes on anatomy. If you think you would be better off simply watching a dissection than reading my book, you're wrong, he continues. My work is the synthesis of years of braving the loathesome circumstances of the dissecting-room, and an understanding of the principles of physics. Furthermore, my method is uniquely correct: I approach the human body from the standpoint of how it is reproduced, grows, develops and eventually perishes. The *process* is central.

Thus Leonardo proceeds, beginning with the fetus and extending into the psychological life of the adult—culminating in music!

The emphasis throughout the manuscripts on developing *concentration span* belies the petty but persistent lie that Leonardo was somehow psychologically incapable of completing his great works. The two camps of Leonardo's critics on this score, critics who became particularly vociferous in the Hapsburg degeneration of southern Europe in the late 16th century, totally ignore the central trend of Leonardo's work: to reproduce geniuses like himself who would complete and go beyond the tasks he had mapped out. One camp of critics bemoaned his preoccupation with "mechanics," a word that had acquired pejorative connotations in the rapidly refeudalizing Italy of the late 16th century, and his consequent failure to complete more paintings. A slightly more subtle form of this prejudice, which underlies the Pedretti book, is to subsume all of Leonardo's theoretical and technological work under the phrase, "He saw the world as a painter."

The other camp, apparently represented today by the IBM Corporation, wondered why Leonardo had ever bothered with such frivolities as painting and did not stick to his engineering projects. Both groups viciously and willfully ignore the *enemies* of Leonardo—the political enemies of the Grand Design, who in the five centuries since his birth have conspired to suppress, dismember, and destroy his work. And by lying about Leonardo's aims, his critics have failed to recognize his success.

Leonardo's Success

Leonardo, the most talented youth of Florence, was sent to Milan in 1482, by his patron Lorenzo de' Medici. Milan was the resource-rich, strategically vital, and politically volatile heartland of historical Grand Designs going back at least to the Hohenstaufen emperors, to unify Italy, Germany, and France through great canal arteries. Both the Medici and their ally, Louis XI, considered this area the most dangerous source of potential destabilization and the bridge-land for their mutual Grand Design.

In Milan for roughly the first half of his creative life, Leonardo was engaged on that combination of art and science paradigmatic of his entire career. For example, his two key projects of the early 1490s have never been considered together—and therefore have never been understood.

One was his plan for expanding the city of Milan by a series of concentric-circle modules that would be financed through the most advanced industrial areas of the already existing city. Under the French rule of the early 16th century, much of this expansion plan actually was carried out. In addition, as Pedretti notes in his commentary to the "Plans for Towns" section of the Richter edition, Leonardo worked out fairly complete specifications for new towns for his Sforza patrons in Milan. According to Pedretti, the new town was to have been built along the Ticino river, which flows into Milan. Leonardo designed an unprecedented system of high-level and low-level double roadways as well as canals to accommodate the distinct functions of the urban fabric including previously neglected sanitation measures.

The second project of this period was the Last Supper, painted for the refectory of the Dominican monastery of St. Maria delle Grazie in Milan. This mural, still powerful today by reason of Leonardo's grasp of relationships despite being seven-eighths destroyed, cannot be understood except as a call to a mission to spread Platonic Reason throughout the world in emulation of Christ's atonement. Goethe observed how Leonardo deliberately imitated the paraphernalia of the monkish meal in the hall below, to make the Last Supper drama immediate to the viewers. But, because of his own lack of political morality, Goethe failed to understand that the betrayal of Judas is a mere subsumed theme—a sin of omission, as it were—in Leonardo's revolutionary treatment. It is the apostles' *mission*, in an architectural universe that is recognizably similar to, but discontinuous with the refectory, that sweeps across the wall and confronts the monks with the intolerable banality of their silent existence.

Leonardo's manuscripts, or copies of key portions of them, came to the attention of Kepler, Cardanus, and Galileo; formed the basis of the reputation of the University of Padua in anatomical science in the 16th century; were available to such humanist artists as Brueghel, Velasquez, and probably Rembrandt; and became (at least the treatise on painting) a factional document during subsequent humanist resurgences. Nonetheless, by and large they have fallen victim to the enemies of the Grand Design.

This continues to be true down to the present day, and Professor Pedretti is the best living example of the kind of stoical, *grundlich* scholarship that gives us more and more of the pieces of evidence *about* Leonardo while withholding the real Leonardo, ultimately presenting the great Florentine as an impotent stoic like his compilers and editors.

As Pedretti admits, the Richter compilation takes no account of the order of development of Leonardo's thoughts, nor of their arrangement in the original notebooks. One of the main things that is lost is the way in which Leonardo used a Rabelaisian wit to comment on his projects, interjecting caricatures, visual puns, and jokes on the pages with more "serious" studies. These Richter dutifully compiled under the rubric of "humorous writings."

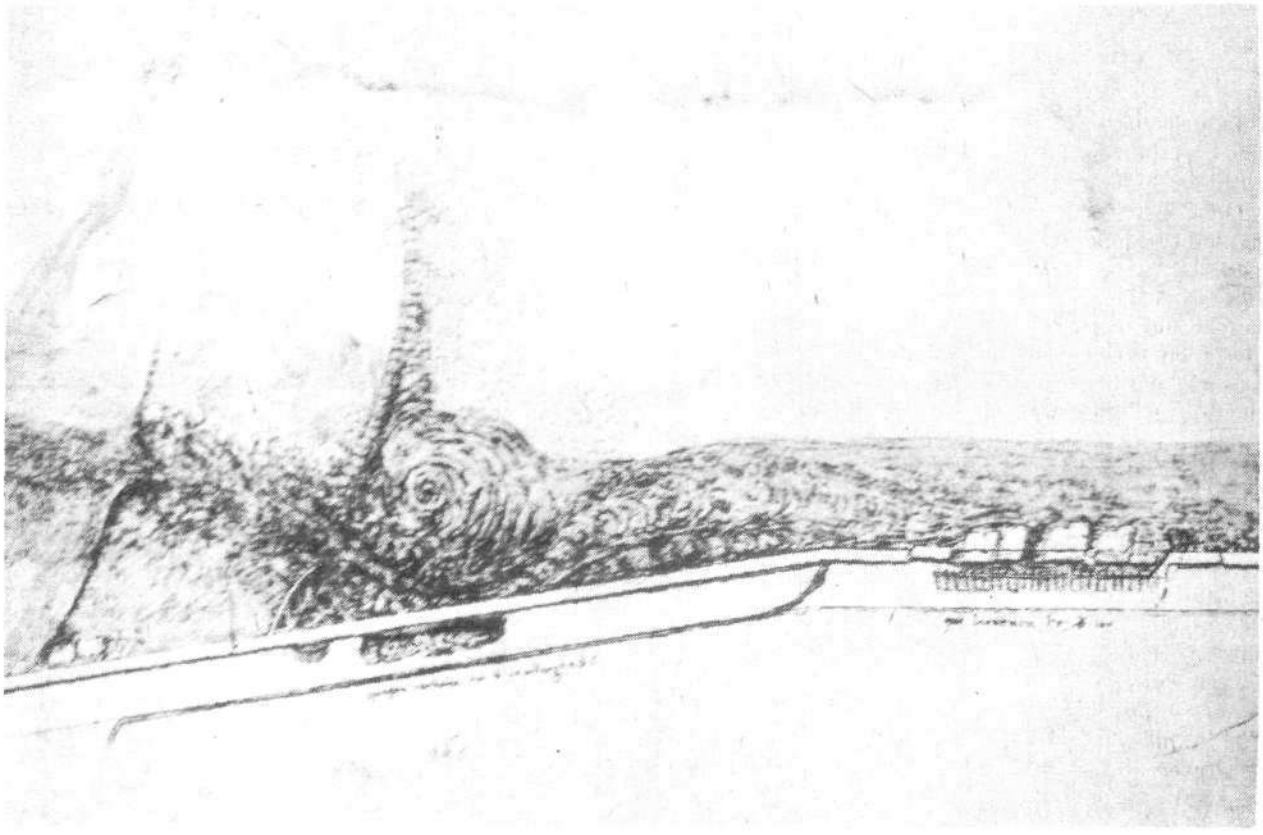


Figure 2
LEONARDO DA VINCI AND THE GRAND DESIGN

Leonardo's canal projects began after he went to Milan in 1482, a city that had long been a center of advanced irrigation and canalization technology. There he devised a new system of locks for the Ticino river's flow into Milan. Subsequently, during his brief (1502-1503) employment as a military engineer by Cesare Borgia, Leonardo developed plans for the dredging machinery, pile drivers, and other equipment necessary for draining the swamps and reclaiming agricultural land in the Romagna territory under Borgia's control, and he drew the first known modern aerial-view perspective map of a city, Imola.

These earlier ventures reached fruition around 1504 in projects for rectifying the Arno river, which flowed through Florence. In these plans, which would have required a Europeanwide political and financial mobilization to implement, Leonardo's documented collaborator was Machiavelli, then Florentine secretary of state.

Sir Kenneth Clark and other British slanderers of Leonardo have often used the Arno plan as their proof that the great Florentine was dreamily oblivious to the practical problems of implementing his projects, since the one aspect of the plan which the Florentines tried to carry out—the diversion of the Arno at its mouth from Pisa, for military reasons—had failed. However, the project as a totality was not military in nature. It involved a massive system of reservoirs, locks, and even the rerouting of the Arno (to be financed by taxing the Wool Guild of Florence) to guarantee year-round navigability, and the upgrading of property values along its banks as manufacture became powered by the steady flow of waterpower. In a note in the Codex Atlanticus, Leonardo listed some 14 industries that would be run by the energy of the rerouted Arno, including a reference to textile machinery (an area of many Vincian inventions) that would do the work of 100 workers.

Most fascinating for readers of Fusion*—and worthy of future elaboration—is the way in which Leonardo wanted to use the self-ordering process of water flow in rivers and oceans to man's benefit in these projects. This figure, Leonardo's drawing of currents in the river Loire, is remarkably evocative of plasma behavior. The drawing was preparatory to designing a system of dams to power mills, one of his last projects while in the entourage of King Francis I of France (1515-1519).*

Ironically Pedretti himself in 1957 published the most stunning evidence of deliberate tampering with Leonardo's manuscripts by enemies of the Grand Design. The culprit was Pompeo Leoni, a sculptor in the employ of the Hapsburgs, who came into possession of most of the Leonardo papers around 1600 and compiled two large books. In dozens of cases Leoni scissored out heads and figures from pages containing mathematical and technical material and pasted them down in a second book. The heads and figures are now in the collection at Windsor Castle, while the pages from which they were cut are in the Codex Atlanticus in Milan (Figure 1).

Conspiracy

It cannot be accidental that at the time Hapsburg agent Leoni was separating a Leonardo "wizard" from a Leonardo "artist," France had once again become the center for a Grand Design conspiracy, this time determined to militarily destroy the Hapsburg power and set into motion a Europeanwide economic development program. The conspirators spanned France, England, parts of Italy, parts of Central Europe, and the Low Countries. One of them, the French King Henry IV's minister Sully, was studying the implementation of Leonardo da Vinci's plan for a canal cutting across southern France from the Atlantic to the Mediterranean—an engineering feat eventually carried out under Colbert. For these individuals, the *whole* Leonardo—city-builder, speculative thinker, political cartoonist—was a vital ally.

This was especially the case because, at that very time, the Fugger and Genoese backers of the Hapsburg atrocity were busily deploying the poisonous ideology of Roman Stoicism, the doctrine that man cannot intervene in the inexorable unfolding of destiny, into what had been the centers of Neoplatonic humanism all over Europe. The spread of the cult of Stoicism in Platonic guise aborted such great talents as the musician Monteverdi, the artist Rubens—and, to an important extent, the physicist Galileo.

Pedretti recounts that the first serious project to publish the Vincian notebooks came in 1640, in the Roman circle of Cardinal Barberini and the antiquarian Cassiano dal Pozzo, with whom Galileo was associated. This project came to naught in that closing decade of the Thirty Years War, however; and one wonders whether that Stoicism-infected Roman circle would have published Leonardo's works as he intended, or in the politically expurgated manner of a Leoni or a Richter.

Leonardo's Indictment

Leonardo da Vinci's remarks on the subject sufficiently indict the fraud of the tamperers, provided his words are removed from Richter and Pedretti's false category of polemics and restored to their original context in one of Leonardo's anatomical notebooks.

> Abbreviators do harm to knowledge and to love, seeing that the love of any thing is the offspring of this knowledge, the love being the more fervent in preparation as the knowledge is more certain. And this certainty is born of a complete knowledge of all the parts, which, when combined, compose the totality of the thing which ought to be loved. Of what use then is he who abridges the details of those matters of which he professes to given thorough information, while he leaves behind the chief part of the things of which the whole is composed? It is true that impatience, the mother of stupidity, praises brevity, as if such persons had not life long enough to serve them to acquire a complete knowledge of one single subject, such as the human body; and then they want to comprehend the mind of God in which the universe is included, weighing it minutely and mincing it into infinite parts, as if they had to dissect it!
>
> Oh! human stupidity, do you not perceive that, though you have been with yourself all your life, you are not aware of the thing you possess most of, that is of your folly? And then, with the crowd of sophists, you deceived yourselves and others, despising the mathematical sciences, in which truth dwells and the knowledge of the things included in them. And then you occupy yourselves with miracles, and write that you possess information of those things of which the human mind is incapable and which cannot be proved by any instance from nature. And you fancy you have wrought miracles when you spoil a work of some speculative mind, and do not perceive that you are falling into the same error as that of a man who strips a tree of the ornament of its branches covered with leaves mingled with the scented blossoms or fruit. . . .

This famous passage by Leonardo was directed against an antiscience cabal operating inside the Roman Curia—the same faction that assured the election of the Hapsburg Charles V as Holy Roman Emperor in 1519, the year of Leonardo's death, and that employed papal "abbreviators" to sieve out of the great writings of the Neoplatonic past all implications that the laws of the universe are not fixed but may develop through human intervention.

It is here that Pedretti's effort to be a serious Vincian scholar is clinically flawed by his determination to be a stoic. He cannot help but acknowledge the connection between this impassioned statement and the celebrated Vincian anatomical studies, and even provides new corroborative evidence of that. But he interprets Leonardo as an "environmentalist" by a literal reading of the final words quoted above (and a highly dubious rendering of the semi-legible ones that follow in the original) to mean that Leonardo *opposed* human intervention into nature. Were we to believe Pedretti, Leonardo da Vinci would thus have repudiated not only his documented life's work in engineering, but the specific activity of anatomical dissection which that passage was penned to defend.

Nora Hamerman is the associate editor of New Solidarity *and frequently writes on the Renaissance.*

Lightning Rod

Continued from page 5

admit, a good deal of unproductive complaining to myself about the sad state of my postal service, I decided that to get to the bottom of this theft I had better consult with an expert at purloined letters, my dear friend Edgar Allan Poe. As usual, Edgar got right to the heart of the matter. "It's no use dallying about the decay of the postal service," he said rather impatiently. "Cui buono? Who would benefit from such theft? Let's look at the enemies of *Fusion*. That's where the case must rest."

Back in my library, we then pulled off the shelf the last several issues of *Fusion*. It didn't take long to mark Schlesinger as the ranking enemy of fusion. He stood out in the cartoons like a sore thumb. But as Edgar quickly noticed from scanning several articles, Schlesinger was involved in it but obviously not the brains of the crime. We had to go higher.

"Holy Buzzard," I said. "This is a real conspiracy."

To make a long story short, we pinned the blame on that old snake Zbigniew Brzezinski, because his National Security Council (and I cringe every time I reflect on the fact that our Nation's security is in such reptilean hands) would have exactly the authority necessary to purloin letters. And, as Edgar pointed out, there is a certain treasonous tradition at the very top of our government that, when not curbed, has always devoted itself to filling the coffers of the very British royalty we both fought to overthrow.

At this point, and I must pat myself on the back for this, I suddenly saw the whole thing clearly. I was thinking of that lovely British nest egg of stolen *Fusion* letters, when my mind jumped to my old friend Poor Richard and the two fat hens he was taking down to Washington as consultants to the Department of Energy last month. (As I recall, I wrote about it here.)

Of course! The theft operation had to meet the standards of the Brzezinski, Schlesinger, Gloomenthal crowd. It had to be no more than 14th century technology, cheap, and satisfying to the counterculture environmentalist types like our poor Poor Richard. Those were no hens I saw Poor Richard with; they were carrier pigeons. He was supplying carrier pigeons for the mail fraud against *Fusion*'s publishers.

Edgar and I chortled with glee at pinning down the nasty feathers involved in this flap and seal crime so quickly. Now the real work begins. No doubt when the *Fusion* group gets moving those environmentalists will put up quite a fuss about their endangered carrier pigeons.

Yr. Obt. Svt.

Editor's Note

We thank our columnist Ben Franklin for his help in tracking down the villains in the theft of FEF mail. Readers who have sent in contributions and subscriptions that have not been acknowledged should contact the FEF.

APS Plasma Meeting

Continued from page 17

an unusual appearance to give an invited talk on the fusion-fission hybrid reactor. Bethe was awarded the Nobel Prize in the late 1930s for discovering the fusion reactions that drive the sun, and he headed up theoretical work on the U.S. hydrogen bomb program. In the last decade, Bethe has rarely attended major meetings of U.S. fusion scientists.

Bethe's chief goal in his presentation was to galvanize the fusion community behind the perspective developed by Foster on the "national need" for the fusion-fission hybrid reactor, reiterating that it is essential to the future of the world. Bethe cogently detailed the scientific, economic, political and environmental reasons that the hybrid must be developed. Most emphatically, Bethe noted that the Soviet Union is already committed to such a hybrid policy.

FEF News

PITTSBURGH CONFERENCE REVIEWS HIGH-TECHNOLOGY POLICY

The FEF Pittsburgh conference on "A High-Technology Energy Policy for the United States" Nov. 9 was highlighted by announcements from participating scientists of advances in their field of research. James Blink, a laser fusion specialist from Lawrence Livermore Laboratory, announced that the recent laser fusion Shiva experiments have just achieved record neutron count levels with a yield of 2.7×10^{10} neutrons, nearly two times better than previous results. And in the magnetic confinement area, Dr. John Schmidt, who heads the theoretical physics work on the Tokamak Fusion Test Reactor project at the Princeton Plasma Physics Laboratory, said that further results with the PLT tokamak reached temperatures of 70 million degrees.

Responding to both announcement, FEF executive director Morris Levitt said that, "Here we have in this room representatives of the two most advanced fusion concepts in the world, presenting results that put us in the lead in both areas. Consider the irony of this; for at the same time, funding for this vital research has been stagnating and decreasing. . . . Both of these men will agree that their projects could absorb twice the present allocation." Levitt then compared these advances with costly, inefficient solar energy pushed by the environmentalists.

The day-long conference included presentations on magnetic and laser fusion, the fast breeder reactor, the accelerator breeder, the fusion-fission hybrid breeder, and the nuplex complex. The morning session on "fusion—the scientific frontier," featured Schmidt and Blink from Princeton and Lawrence Livermore, respectively, and the afternoon panel on "advanced energy technologies: closing the nuclear fuel cycle," included Dr. Richard Noyes, manager of breeder engineering development at the Combustion Engineering Corp., Dr. Ronald Kostoff, senior scientist at the Department of Energy's Office of Energy Research, and Jon Gilbertson and Marsha Freeman from the FEF staff.

In the concluding presentation, FEF director of research Uwe Parpart told the audience that the "war" on U.S. scientific and technological capacity spearheaded by Energy Secretary James Schlesinger "must be turned around quickly to meet the energy needs of 8 billion people in the year 2000." Parpart then reviewed the international development deals underway that the United States must become part of.

A Quantum Jump

The conference drew 60 participants, including representatives from Westinghouse, Pittsburgh Des Moines Steel, Babcock and Wilcox, Pennsylvania Power and Light, and several Pittsburgh industries, six engineering firms and the operating engineers union among them.

FEF director Levitt noted that the conference marked a quantum jump in FEF's stature as the political leadership of the scientific and engineering communities. The FEF's first annual conference in Pittsburgh in April 1977, Levitt said, required a temporary federal court injunction to stop the threats and harassment against conference participants from Energy Secretary James Schlesinger and his antiscience crew. At the time, Schlesinger forced 12 out of 14 speakers to cancel during the five days preceding the event. Conference attendees this year included representatives from corporations and institutions who were last year told in no uncertain terms to stay away, and did.

Jon Gilbertson addressing the Pittsburgh conference.

LEVITT, PARPART TOUR WEST COAST FACILITIES

Executive director Dr. Morris Levitt and research director Uwe Parpart toured major research facilities in New Mexico, California, and the Pacific Northwest in late October, as part of an ongoing foundation review of U.S. research and development programs.

Levitt, whose written remarks will appear in a future issue of *Fusion*, reported

Dr. Morris Levitt

Energy not free, says Fusion editor

Fusion on the newsstand.

that tremendous potentiality remains in the major research laboratories, given the proper program and resources. Levitt said the tour convinced him that U.S. science desperately needs a sound scientific methodology, a nation-building perspective, and the type of leadership that FEF provides.

FUSION ON THE RISE; NORTHWEST LEADS

Sales trends of *Fusion* magazine are rising around the country, the business department reports. Newsstand sales have doubled over a three-month period, with an expansion drive underway to add new cities here and in Canada. *Fusion* now distributes 40,000 copies per issue, with newsstand distribution in 26 major cities. Subscriptions are at 4,200 and a recent direct mail subscription drive is just beginning to bring in new subscribers. The goals for the next year of publication include a drive to raise circulation to 100,000 copies of *Fusion* per month.

The biggest boom in *Fusion* sales is in the Northwest. In the Tri-Cities area of eastern Washington, *Fusion* sales on the newsstands run four to one above *Scientific American*, selling about 1,000. The *Tri-City Herald*, an eastern Washington daily newspaper, featured *Fusion* in an Oct. 24 article interviewing Dr. Morris Levitt. "The magazine Morris Levitt edits is sold on Tri-Cities newsstands next to publications like *True Confessions* and *Hot Rodder*," the *Herald* wrote about *Fusion*'s high visibility.

SCHOONOVER BRIEFS ST. LOUIS ON NUCLEAR FUSION

In a forum sponsored by the Washington University chapter of the American Society of Mechanical Engineers in St. Louis Oct. 19, Dr. John Schoonover briefed an audience of scientists and engineers on the importance of this summer's Princeton PLT breakthrough in nuclear fusion research and the implications for future fusion development. Schoonover is the FEF campus coordinator.

In other talks to campus groups and businessmen in the area, Schoonover stressed the role that fusion energy will play in our continuous redefinition of the resource base for human society: "The *differentia specifica* of humanity . . is our ability to deliberately transform the basis for human existence through creative technological innovations." The response to the FEF presentations was excellent, with most scientists and students expressing a "let's get the job done" attitude.

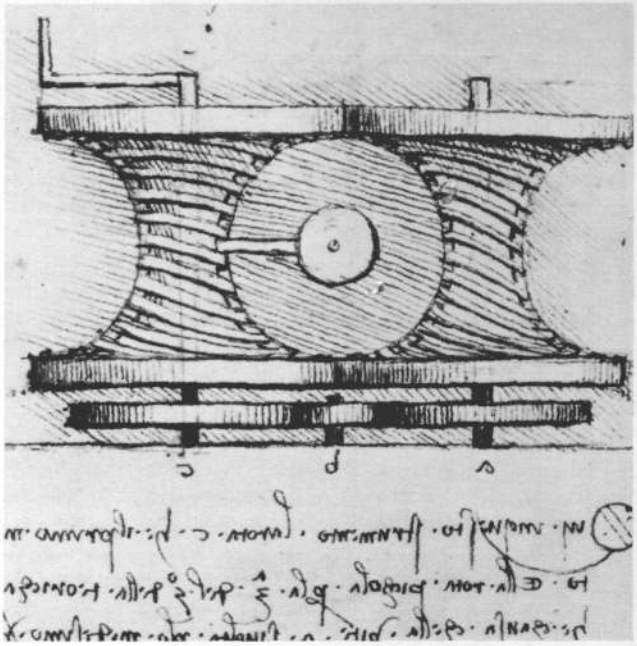
POWER EXEC ADDRESSES GEORGIA TECH FUSION CLUB

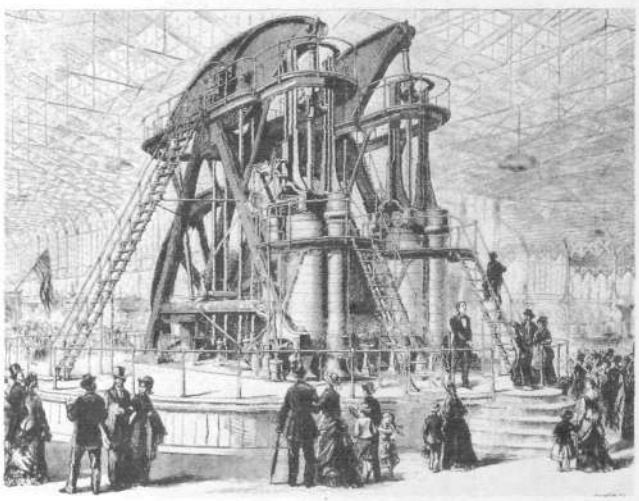
"Until 1973, being in the energy business was fun, but now it's become very tough," Grady Baker told the Georgia Tech Fusion club members at an Atlanta meeting Nov. 2. Baker, the senior vice president for corporate planning of the Georgia Power Company, underlined the vital need for nuclear power growth, but noted that no new nuclear plants were now planned in the state of Georgia and that the capital markets have been hard to approach for funds. The utility has invested heavily in solar power, he said, even though it knows that the energy output of such systems will be marginal at best. Grady commented that the progrowth attitude of the fusion club students in the audience was encouraging.

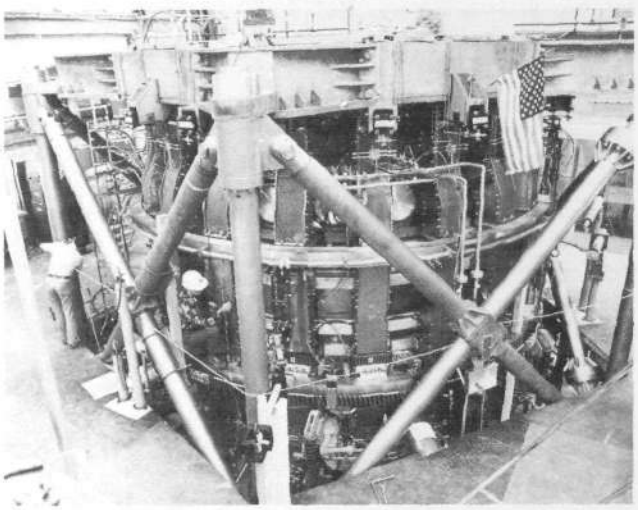
The FEF Chicago booth.

SUPPORTERS AID FEF DISPLAYS AT TRADE SHOWS

Thanks to generous contributions from supporters, the FEF has been able to set up displays at major trade shows. At the International Machine Tool show in Chicago in September, a successful FEF booth sold memberships, subscriptions, and literature to high-technology companies around the world. And at the October Triple Engineering show in Philadelphia, the FEF booth attracted crowds with its model of the Princeton Large Torus tokamak, on loan from the Princeton laboratories.







Energy, Machines, And Progress

Man's progress on earth is measured most concisely by looking at the rate of the rate of increased consumption of energy and the advances in technology and machines that made this increase possible. In fact, the criterion by which to judge any energy-producing technology is whether it will provide an increased throughput, or flux, of energy density at least sufficient to power a mode of production more productive than the present system.

This concept was fully developed in a 1975 speech to the Soviet Academy of Sciences by Academician P.L. Kapitsa, whose award of the 1978 Nobel Prize in physics is reviewed in this issue. And as this issue discusses, the great humanist thinkers of previous generations, including Lazare Carnot and Leonardo da Vinci, contributed to the development of this idea, linking energy throughput to the necessity for scientific and technological progress. In its most scientifically enriched form, this outlook supersedes the concept of conservation of energy and exposes the lethal incompetence of policies based on zero growth and so-called appropriate technology.

Today, the only technology that meets the criterion laid out by Kapitsa—and that satisfies the conditions of accelerating the rate of total energy use and of the ratio of free energy to the total energy—is fusion. The special form of electromagnetic energy in the fusion plasma (the fusion torch) and the wide variety of the fusion reactor's energy forms make obvious what past energy sources and machines have demonstrated only implicitly: The fundamental feature of science and technology, like the universe, is its process of self-development.

The front cover shows technicians working inside the now-completed PDX tokamak at the Princeton Plasma Physics Laboratory. On the back cover are (from the top) a drawing from Leonardo da Vinci's Codex Madrid, which analyzes machine elements and traces the transmission of power and motion through screws and wheels; an illustration of the 1876 centennial exhibition in Philadelphia featuring the Corliss steam engine (a technology for which Carnot's work paved the way); and a view from the top story of the PDX tokamak.

Cover design by Christopher Sloan. The PDX photographs are courtesy of Princeton Plasma Physics Laboratory.