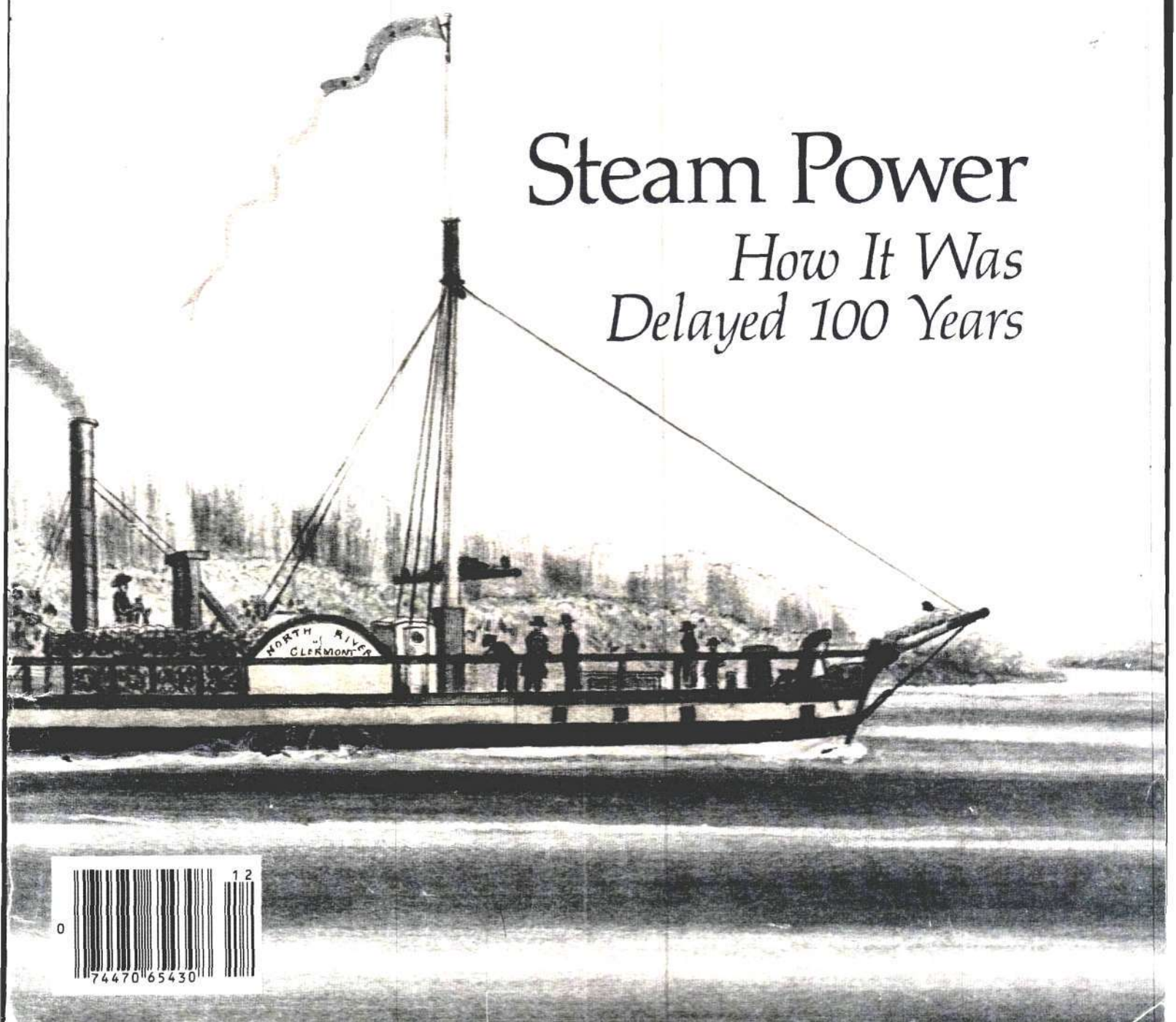
FUSION

MAGAZINE OF THE FUSION ENERGY FOUNDATION
December 1979
$2.00/ $2.25 in Canada



Steam Power

How It Was Delayed 100 Years

0 74470 65430 12

FUSION

MAGAZINE OF THE FUSION ENERGY FOUNDATION

Vol. 3, No. 3
December 1979
ISSN 0148-0537

FUSION *is published monthly, 10 times a year except September and April, by the Fusion Energy Foundation (FEF), 888 7th Ave., 24th Floor, Suite 2404, New York, New York 10019, telephone (212) 265-3749.*

Subscriptions by mail are $18 for 10 issues or $34 for 20 issues in the USA and Canada. Airmail subscriptions to other countries are $36 for 10 issues.

Address all correspondence to *Fusion,* Fusion Energy Foundation, 888 7th Ave., 24th Floor, Suite 2404, New *York, New York 10019.*

Second class postage paid at New York, New York.

The FEF publishes a 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

Departments

Courtesy of the Milwaukee Sentinel

If God had meant us to use nuclear energy, He'd have given us brains !

Nuclear Power Versus The New Dark Ages

At a recent speaking appearance in Hartford, Connecticut, antinuclear media star Tom Hayden was stopped dead in his tracks when a pronuclear spokesman associated with the Fusion Energy Foundation confronted him. "Being against nuclear power means being against the development and survival of several billion people in the Third World, and it means the Cambodian model of genocidal depopulation," the pronuclear spokesman told the audience. Hayden had no reply.

There is more than hypocrisy involved in claiming to be simultaneously humanitarian and antinuclear, or in claiming ignorance of the connection between attacks on nuclear power and the genocide in Cambodia (Kampuchea) documented in this issue of *Fusion*. The larger strategic question involved is whether the United States will continue to support the most backward policies or, instead, will join with its sister republics of France, Mexico, and West Germany to implement a new monetary system and investment fund that can break the back of the present economic downslide and political chaos.

This poses a challenge to the supporters of nuclear power as well. You can't be pronuclear and tolerate the International Monetary Fund "conditionalities" of perpetual austerity or its U.S. corollary, the credit strangulation policy of Federal Reserve chairman Paul Volcker. (Volcker, it should be noted, not only participated in the Council on Foreign Relations *1980s Project* that calls for

"controlled disintegration in the world economy," but has enthusiastically endorsed such "disintegration" by name.)

Development Versus Disintegration

Nuclear power cannot exist as the energy supply of a depression-ridden little island surrounded by a collapsing world.

Nuclear power is a universal energy source, appropriate to development everywhere. It means the universal progress of humanity in transition to the new world epoch of fusion and plasma-based technologies. But universal technology can exist only in a world of global-scale development in which the scientific and industrial genius of America and its people is realized to its fullest potentiality. That can happen only with full U.S. participation and leadership in the European Monetary System and the European Monetary Fund, to gear up hundreds of billions of dollars worth of U.S. nuclear and other capital exports.

This is precisely what leading officials like Secretary of State Cyrus Vance are determined to prevent. Is Vance, the New York Council on Foreign Relations' man, merely a hypocrite because he stonewalled on aid to the barely alive survivors of the holocaust in Cambodia and is now demanding that the Phnom Penh government bend to his "conditions" to get the food aid it needs? After all, Vance is a supporter of the council's policy of "controlled disintegration in the world economy," and he officially stated that he will not permit transfer of U.S. nuclear and other advanced technology to the Third World.

Is that how to create independent and viable allies for the United States? Is Vance's culpability less than that of the barbarians who committed the actual decapitation of Cambodia's doctors, scientists, and intellectuals? Should Vance be considered less responsible than closet-Maoist Ralph Nader, who long before his antinuclear days called for "the industrial oppressor to experience directly what it is like to be himself oppressed?"

We cannot call ourselves human if we do not do all we can to ease the pain of Cambodia and restore it to life. We cannot call ourselves pronuclear if we do not make the commitment to eliminate and replace the institutions and policies that are the source of the Malthusian evil behind the destruction of civilization in Cambodia.

Money Is Better

The near-term potential of fusion energy has been receiving significantly more attention lately in the media. Words are nice, but money is better.

The budget baseline to keep the magnetic confinement part of the fusion program moving ahead is contained in the model legislation appearing in this issue's Washington news section. There are two points to make. First, the fusion research effort has demonstrated an excellent record of meeting or exceeding program goals according to DOE schedule. Second, there has been a direct correlation between money put into the program and results produced.

These facts and future energy needs are indisputable. Now is the time to throw in the massive support for accelerated fusion development that the Fusion Energy Foundation and *Fusion* Magazine have been building. As we pass the fifth anniversary of the FEF and are well into the third volume of *Fusion*, our circulation of 75,000, subscribership of 27,000, and membership of 3,000 continue to grow rapidly.

Let's put our numbers to effective use. Use the attached postcard to send to Congressman Mike McCormack and others to promote an upgrading of the U.S. fusion effort; use the other attached subscription and gift postcard to build our strength even further.

P.S. Happy Holidays to all readers and contributors to *Fusion*!!

Calendar

December

3-7
Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation
Mining and Mineral Research Institute
Lexington, Kentucky

6-7
Power Industry Development and Application of MHD Technology in the Soviet Union
Institute for Advanced Technology
Washington, D.C.

10-13
In-Service Inspection of Nuclear Power Plants
Technical Seminars, Inc. New York
Fort Lauderdale, Fla.

11-12
Power Industry Development and Application of MHD Technology in the Soviet Union
Institute for Advanced Technology
San Francisco

17-21
Lasers '79, Int'l Conference on Lasers and Applications
Society for Optical and Quantum Electronics
Orlando, Fla.

Join us in celebrating the Fusion Energy Foundation's
5th anniversary
Friday, November 30
8 p.m.
Grand Ballroom, Biltmore Hotel
43rd Street and Madison Avenue
New York City

$25 per person
RSVP: Mike Tobin at the FEF New York office

The Lightning Rod

My dear friends,

It saddens me to observe that, for some who count themselves human, the multiplication of our species enjoined on us by our Creator is an ongoing tragedy from which nothing but the most awful Apocalypse may deliver us.

A new oracular pronouncement to that effect was issued recently by the president of the World Bank, Mr. Robert Strange McNamara, upon the occasion of an International Monetary Fund conference in Belgrade.

"There are only two possible ways in which a world of 10 billion people can be averted," Mr. McNamara solemnly intoned. "Either the birth rate must go down, and quickly, or the current death rate must go up. There are of course many ways in which the death rate can go up. In a thermonuclear age, war can accomplish it very quickly and efficiently. Famine and disease are nature's ancient checks on population growth . . . ."

Having invoked the Biblical four horsemen, Mr. McNamara went on to suggest the situation might be ameliorated if a team of certified public accountants were empowered to apportion War, Famine, Pestilence, and Death according to the most modern calculations, so that the rich might suffer equally with the poor. (He did not, however, offer to cut salaries at the World Bank.)

Experience may have endowed his audience with a certain coolness to Mr. McNamara's schemes. They might recall that, after a notable start at the Ford Motor Company, during which his slide rule bestowed the Edsel on a somewhat ungrateful world, Mr. McNamara distinguished himself as U.S. Secretary of Defense by applying computerized accounting principles of "cost-effectiveness" to the science of war. This activity produced that immensely useful statistic known as the "body count." The United States won many battles with that weapon—on paper.

I am afraid that, along with his large computers, Mr. McNamara possesses a small spirit, too small to allow him much success in any endeavor respecting human progress. I have always been of the opinion that our problem is not that of "too many people," but of not enough who are equipped to do what must be done. And that it is up to those of us who have proceeded further on the path of human development to organize a supply of material and moral resources so that others coming down the road might move along a great deal faster than we have.

True, our geography is finite. And is there not something glorious for man in the thought that this planet is too small to hold him?

I refer my dear readers to a little essay I penned in 1729 in defense of cheap credit, another idea which seems to have fallen into disfavor with our modern sages.

"We can never have too many people (nor too much money)" said I. "For when one branch of trade or business is overstocked with hands, there are more to spare to be employed in another. So, if raising wheat proves dull, more may (if there is money to support and carry on new manufactures) proceed to the raising and manufacturing of hemp, silk, iron, and many other things the country is very capable of, for which we only want people to work and money to pay them."

There have been a few refinements in political economy during the quarter of a millennium since I stated my case, but perhaps it will not be thought too immodest if I insist that, even then, I had come further down the road of common humanity than Mr. McNamara.

Your obt. svt.

Benj. Franklin

Letters

To the Editor:

While racing to catch a plane at the San Jose, California airport I encountered two of your disciples. The 30 seconds they asked for turned into 3.5 minutes which caused me to miss my flight. The inconvenience and anger I suffered vanished as I plunged into your magazine. Your are to be highly complimented for your descriptive analysis of (1) nuclear systems, (2) timely related subject matter, and (3) exposing the antinuclear demagogs who will be the first to scream when the lights go out. NO NUKES ARE NUD NIKS.

Richard A. Palmer
Irvine, California

PARENTS AND POTHEADS

To the Editor:

The feature article, "The Drug Plague: Who's Fighting It?" by Ned Rosinsky, M.D. and its companion, "The Biological Effects of Marijuana" by Gabriel Nahas, M.D., should be read by every parent of teenagers. I would like to begin in a small way to get this information into our neighborhood at least. Should you have copies available, I would be interested in buying as many as 25 to start with . . . .

Catherine S. Godsey
Walnut Creek, Calif.

The Editor Replies

Reprints of this article are now available at $1.00 each plus postage, and readers should contact *Fusion* for rates on bulk orders. By all means, let's get the article widely circulated.

To the Editor:

After all the news of scientific progress and cultural hope, solid facts, wild humor, and courageous journalism *Fusion* has had to offer in the past months, I must express my disappointment and dismay at your granting a forum to the unscientific horror stories of Dr. Gabriel Nahas . . . .

It is no surprise that dosing rats and monkeys with humanly unconsumable amounts of pure synthetic delta 9THC results in cell deformation, embryo, death, etc. If we exposed laboratory animals to a 10-year accumulation of low-level radiation in a matter of hours and then went ranting on about our incontestable "proof" of the horrors of nuclear power, would the bias implicit in such a claim be somewhat more transparent to your editors? . . .

There is no justification for the punishment, humiliation, and destruction of the people at every level of world society who wish to grow, share, and enjoy marijuana. Decriminalization will not increase consumption, and mounting an incredible, futile, and economically destructive assault against human weakness in the form of a so-called "antidrug" police state will quicken the collapse of the individual freedoms the FEF supposedly exists to preserve . . . .

(letter received anonymously)

The Editor Replies

The doses of marijuana or THC, the psychoactive chemical component of marijuana, used in the various experiments outlined by Dr. Nahas were generally in the range of one average marijuana cigarette (3 to 5 percent THC content) per day for humans, or the equivalent of this for the weight of the animal in the monkey and rat experiments.

This level of marijuana consumption is now considered "moderate." According to statistics of the Department of Health, Education, and Welfare, 11 percent of high school seniors in the United States smoked marijuana every day of their senior year last year.

Concerning the effect of the decriminalization of marijuana, New York State marijuana use has tripled in the junior high and high schools since the state passed a decriminalization bill two years ago, and this is the experience across the country.

The anonymous writer should not receive the entire blame for his or her mistaken assertion that unduly large amounts of marijuana have been used in these experiments because this is precisely the slander that has been put out by such sources as *High Times* magazine and other prodrug media.

Dr. Nahas's article on the biological effects of marijuana did, indeed, indicate the level of marijuana exposure used in the various experiments. Perhaps the letterwriter was suffering from one of the effects of smoking marijuana and did not have the necessary attention span to find this out by reading the Nahas article to the end!

Ned Rosinsky, M.D.

MORE REPRINTS

To the Editor:

You are commended for your excellent publication, *Fusion*.

Could your please tell me how I could buy about 20 reprints of "The 1980s Project: Blueprint for 'Controlled Disintegration' " by Kathleen Murphy in the October 1979 issue.

David Ohlwiler, M.D.
Goldenrod, Fla.

The Editor Replies

Reprints of the *1980s Project* article are available at $1 each plus postage, and readers should contact *Fusion* for bulk order rates.

CONSERVATION IS SINFUL

To the Editor:

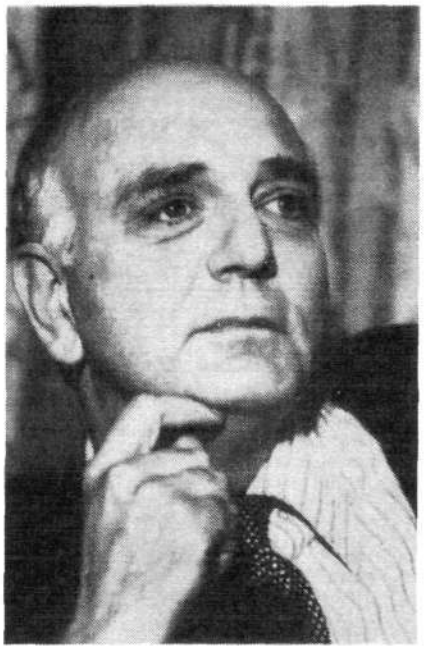
(This was received as an open letter to the National Council of Churches.)

. . . Contrary to the National Council of Churches outlook behind its antinuclear power stand, conservation is sinful, because conservation is like a greedy man hoarding his wealth: he entrusts his energy to stagnant entities. Perfection is dynamic, not stagnant. It is not the exploitation of energy which is sinful—its consumption —but how energy is invested. Do we spend it on what is analogous to riotous living, or do we wisely invest so as to reap manyfold the ability to sustain and advance others of our brethren, believer and unbeliever alike?

It is not advancing civilization which is sinful; but to what purpose a civilization exists which is crucial. Do technology and culture work hand in hand to develop human abilities, or are policies and practices conformed for the purpose of sustaining a factional oligarchy?

. . . Do you advocate that we return

(Continued on page 64)



Paul Volcker

News Briefs

FIGHTING THE ANTINUCLEAR ONSLAUGHT

As this issue of *Fusion* goes to press, the report of the President's Commission on Three Mile Island combined with a variety of antinuclear scare headlines in the national media have heightened the onslaught against the U.S. nuclear power industry. We will report fully on who is behind this attack and how it is part of Federal Reserve head Volcker's credit strangulation policy to shut down U.S. industry in the January issue.

Meanwhile, the Fusion Energy Foundation is urging individuals in the nuclear industry and concerned organizations to send the following telegram to elected officials from President Carter on down the line. The message was drafted and signed by Dr. Joseph Dietrich, chief scientist at Combustion Engineering in Connecticut. To add your name to the telegrams or for more information about sending out similar messages, contact the FEF New York office.

Text of Telegram

Dear (Elected Official):

You must do two things to save this nation: (1) Stop Federal Reserve head Volcker's insane interest policy before it destroys the nation. Call for his impeachment if he doesn't turn it around. (2) Publicly endorse a strong nuclear energy policy for this nation immediately. The nation will be destroyed by propitiating the antinuclear "enviromentalists."

The telegram notes that affiliations of signees are listed for identification purposes only.

VOLCKER CREDIT POLICY WILL LEAD TO ECONOMIC COLLAPSE

The restrictive credit policies of Federal Reserve Chairman Paul Volcker will provoke a 15 percent collapse in the U.S. economy over the short term, according to a Fusion Energy Foundation study that used the new Riemannian economic model. Volcker's credit-constriction measures, announced in early October have sent the prime lending rate of major New York City banks soaring beyond 15 percent.

The Riemannian computer model was developed during summer 1979 by a team of FEF scientists working on a proposal by Democratic presidential candidate Lyndon H. LaRouche, Jr. The model measured the impact of the ongoing credit squeeze and a rise in the price of oil to $30 a barrel by January 1980 on basic categories of the economy's productive activity.

Volcker's policy intent is knowingly in line with the "controlled disintegration" policy for the world economy specified in the New York Council on Foreign Relations *1980s Project* (see *Fusion*, Oct. 1979 for details). Volcker began a 1978 speech at Warwick University in England commemorating Fred Hirsch, the man who coined the "controlled disintegration" concept for the *1980s Project*, with these words: "I was tempted to take as my text today one of Fred Hirsch's last dictas: 'A controlled disintegration in the world economy is a legitimate object for the 1980s.' . . . The phrase captures what seems to be the prevailing attitudes and practices of most governments in this decade."

The European governments, particularly France and West Germany, have lambasted the Volcker depression prescription.

CARTER OPTS FOR DOMESTIC 'DISINTEGRATION'

Former Time-Life editor-in-chief Hedley Donovan, executive director of the New York Council on Foreign Relations and special aide to President Carter, announced the formation of a presidential Commission for a National Agenda for the 1980s at a White House press conference Oct. 24.

Donovan will serve as presidential liaison to the group, which is expected to have a budget of $3 to $5 million.

At the press conference, Donovan drew snickers when he explained the reason for the commission was the president's feeling that "the country suffers from a lack of vision, goals and purpose." In answer to a reporter's question on whether there was any difference between the work of this commission and the *1980s Project* of the Council on Foreign Relations, Donovan noted that the council, unlike the presidential commission, does not make policy recommendations but issues such studies under the names of the individual authors.

Uwe Parpart

FEF RECEIVES MATHEMATICAL SOCIETY GRANT

The Mathematical Society of America has awarded the Fusion Energy Foundation a grant of $8,400 dollars for a special project to translate the Bernhard Riemann archives into English. Uwe Parpart, FEF director of research who has translated several of Riemann's papers, will oversee the project. The translations will be done in collaboration with the institute at Göttingen University in West Germany that houses the Riemann archives.

FEF'S PARPART TOURS NORTHWEST

Uwe Parpart, director of research for the Fusion Energy Foundation, completed a highly successful speaking tour in the Northwest in early October. Among Parpart's appearances were a dinner in Bellevue, Wash. attended by 50 FEF members; an address before 250 members of the Northrup Management Club in Los Angeles, a well-attended forum at the University of Southern California, and the keynote speech at a Nuclear Energy Education Day luncheon in Richland, Wash., attended by 40 *Fusion* subscribers.

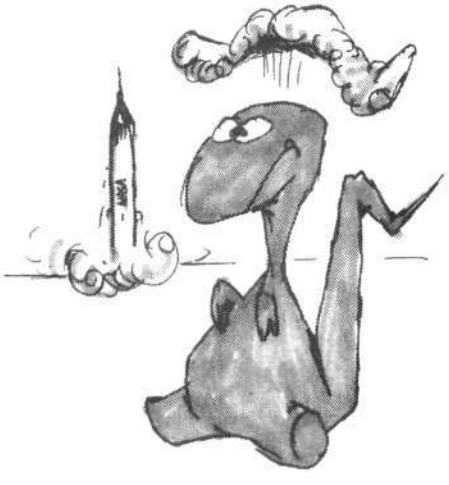
The FEF plans similar tours and speaking engagements in 30 to 40 areas around the country, starting in January 1980. Interested readers should contact the FEF New York office.

SOVIETS EXPECT ANGARA-5 TO REACH BREAKEVEN

The Soviet Union has announced the schedule for completion of the Angara-5 fusion device at the Kurchatov Laboratory in Moscow. Angara-5 is a pilot electron-beam facility, one of the major Soviet approaches to fusion energy development.

Professor Leonid I. Rudakov, head of the Soviet electron beam pellet research, noted at the Oct. 5 dedication of the first of 48 electron beam units for the Angara-5 facility: "When it is completed we hope to obtain a controlled thermonuclear reaction as a result of which the facility will be producing more energy than it consumes. Angara-5 will demonstrate that an industrial plant can be built."

The *New York Times*, generally unfriendly to the prospects for fusion power development, gave unusual front-page coverage to the Soviet announcement.

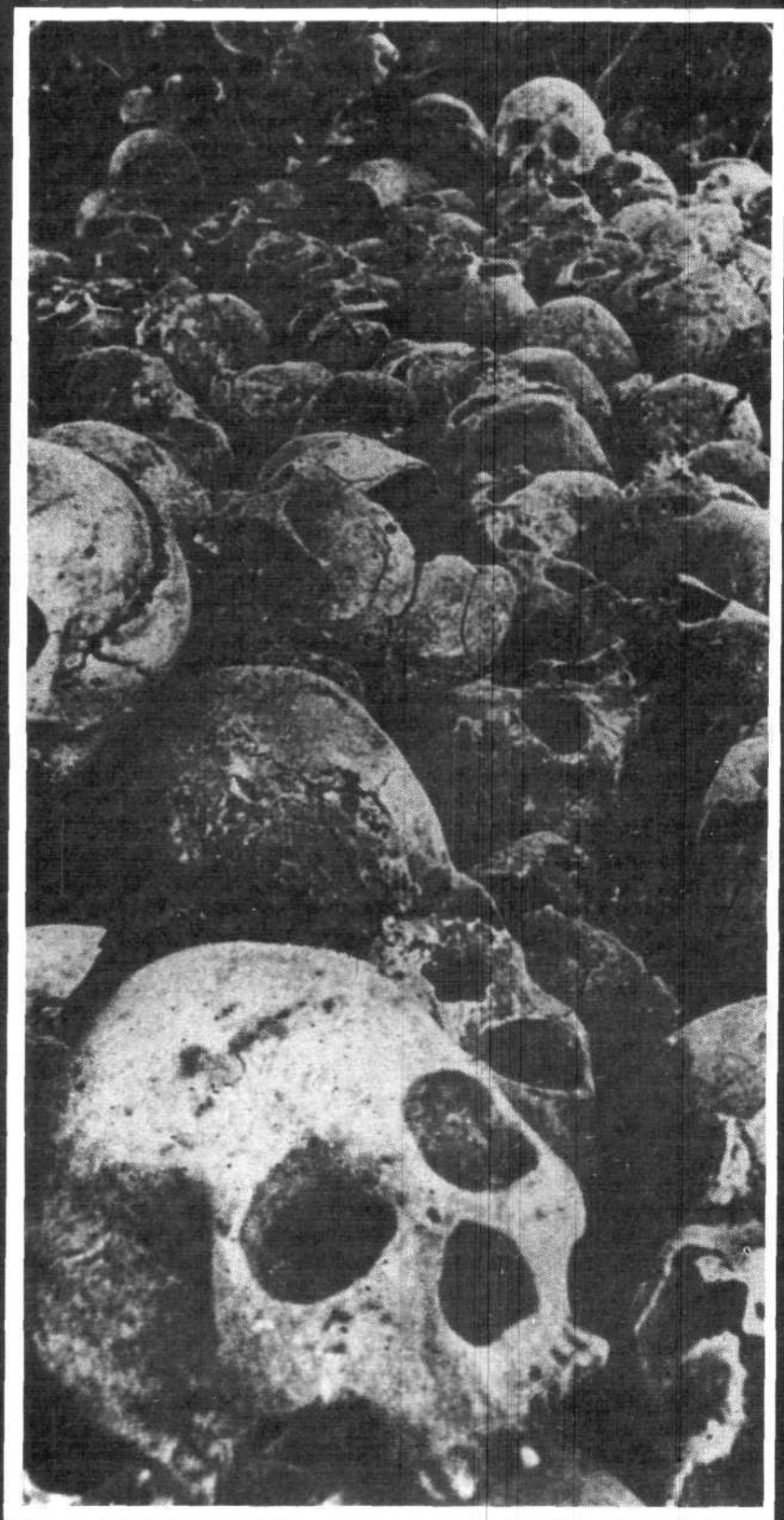


LOUSEWORT LAURELS TO SENATOR PROXMIRE

The lousewort laurels award this month goes to Wisconsin Democrat Senator William Proxmire for his Dark Ages approach to science and technology. In an Oct. 27 news release, the senator announced that he would be holding hearings on the progress of the nation's space shuttle program, which he characterized as "just one more example of the American taxpayer being conned into buying a pig in a poke."

Proxmire bitterly complained that the National Aeronautics and Space Administration would probably be requesting yet more funds to prevent further slippage in the shuttle schedule.

More than one Washington observer questioned Proxmire's judgment in conducting such a cost/benefit analysis of America's scientific frontier, noting that the senator himself had spent a five-figure amount in a hair transplant.



Cambodia: Destruction Of a Civilization

"Kampuchea . . . has been turned into a vast graveyard. . . . I think Vietnam committed only one mistake. . . . They should have gone into Kampuchea at least one year earlier and much of the butchery would have been avoided."

During the past four years, a horror equal to that of Hitler's Nazis has taken place in the tiny Southeast Asian nation of Kampuchea (Cambodia). Three million people, more than 40 percent of that nation, were exterminated by the Chinese-allied government of Pol Pot, which reigned from April 1975 until January 1979, when it was overthrown by the combined armed forces of the Kampuchean Front for National Salvation and the Socialist Republic of Vietnam.

What happened in Kampuchea was not simply the murder of 3 million people. As told by journalists whose on-the-scene reports are now reaching the American news media, Kampuchea under Pol Pot entered a New Dark Ages. The principal enemy of the government was civilization itself. Any manifestation of urban culture came under its attack. The factories were closed, the libraries plundered, machines smashed, hospitals destroyed, books burned, the national bank blown up, and the use of money abolished.

The Fusion Energy Foundation has been active in forcing the story of the Kampuchean holocaust into the news nationally. But while many details of the tragedy are now being reported, much of the true story has been covered over with lies. Kampuchea's plight has been treated as a gory sensation for the masses. The fate of that nation has been presented as the outcome of a struggle between two imperialist ("communist") powers in Southeast Asia, Vietnam and China.

These are scurrilous misrepresentations. The fundamental issue in Kampuchea, and throughout the Third World, is economic development. The proponents of Third World economic growth number among their ranks the government of Mexican President José López Portillo, the leadership of OPEC, and the founders of the new European Monetary System, particularly France's President Giscard and West German Chancellor Helmut Schmidt. As *Fusion* outlined in its October issue, the opposing line-up is centered in the United States at the New York Council on Foreign Relations. Our coverage of the council's wide-ranging *1980s Project* detailed their program to eliminate science and development in the Third World, curb technological advance and economic expansion in the advanced sector, and to use the "controlled disintegration" in the world economy to eliminate 3 billion of the earth's 4 billion inhabitants.

This report on the situation in Kampuchea, compiled from articles and public statements of prominent Indian journalist Ganesh Shukla, makes clear that the Kampuchean holocaust is the most successful implementation of that program undertaken to date.

The Useless Eaters

In Pol Pot's Kampuchea, the population was divided into two portions: the workers, who were separated from their families and sent to produce rice on communes in the countryside, and the "useless eaters"—the doctors, scientists, educated communist cadre, and other professionals. This portion was hunted down and murdered, according to a policy developed by Pol Pot's Chinese advisors. Workers and peasants in the rural areas, including all children over 10, worked until hundreds of thousands died of exhaustion and starvation.

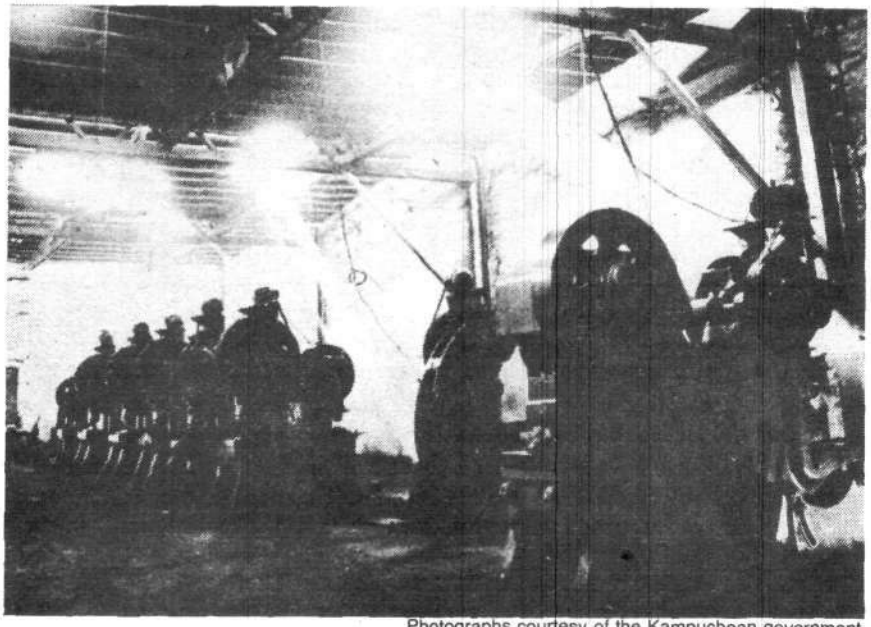
By mid-1977, a million Kampucheans had been murdered or had died from lack of medical care and food. It was then that the systematic butchery of the population at large began. By the time of Pol Pot's ouster in January 1979, 2 million more Kampucheans died. The regime's method of extermination, moreover, did not include the use of guns or bullets. Most victims were bludgeoned to death with axes, steel pipes, and bamboo rods. Many died at the hands of preadolescent children, trained by Pol Pot's military in special techniques of extermination.

"Kampuchea is a complete zero. It has been turned into a vast graveyard."

These are the words of Ganesh Shukla, editor of the national Indian weekly newspaper *New Wave*. Shukla, who is highly regarded as a political commentator among traditional Congress Party circles, was in Kampuchea from August 15 to August 20 of this year. He attended the trial-in-absentia of the deposed Pol Pot and his protégé Ieng Sary for the murder of 3 million of their countrymen. Shukla brought his eyewitness report to tens of thousands of Americans during a September-October tour of the United States sponsored by the U.S. Labor Party.

"Phnom Penh was [once] the most

Within hours of its "liberation" by Pol Pot, the Kampuchean capital city of Phnom Penh was emptied; within three years, most of its population was murdered by the Peking-supported government. The photograph is from the files of the Tuol Sleng prison camp, one of many prisons where Pol Pot pursued a policy of extermination against the nation's educated and intellectual elite.



Photographs courtesy of the Kampuchean government

Above: The national library was ransacked and thousands of years of treasures of the Khmer civilization were destroyed. Below: Machines were smashed and factories were closed or blown up.

beautiful city in Southeast Asia. Now it is a ghost city," one of Shukla's recent press reports on the Kampuchean holocaust begins. "Phnom Penh's 800,000 inhabitants are nearly dead and gone. Their bones lie buried or scattered over the plains of Cambodia . . . . Believe me when I say that of the 7 million and odd Cambodians, at least 1 million have perished either through starvation, disease, or physical exhaustion in slave labor camps called "communes" but built like animal farms. Two million more people were hacked to death or bludgeoned to death and thrown into mass graves."

What remains, Shukla reported, is desolation and starvation: "In the countryside people are roaming, not able to locate their villages and homes, eating whatever they can lay their hands on—like leaves, wild fruits, cockroaches, and insects." And Pol Pot's policies have rendered the nation nearly helpless to rebuild itself: "Kampuchea is denuded of educated people. There are no teachers, no office workers, no cadre to man the civil and military services. Education had been abolished by the Pol Pot barbarians and the educated have been put to death . . . . Today, Cambodian hospitals have no doctors, no nurses, no medicine, no equipment . . . . [Pol Pot] abolished medicine and replaced it with the traditional system . . . ."

Peking's Role

Pol Pot stopped at nothing to accomplish the systematic annihilation of Kampuchea's elite, Shukla said. He emphasized the regime's policy of genocide against intellectuals and the educated with the following story: "They invited all Kampucheans who were abroad to return to the country and serve their motherland. And what happened to them? They arrived at the airport, they were received properly, they would feel they were welcome at home. And then they were taken straightaway to Tuol Sleng, a secondary school converted into torture cells, where they had to disrobe themselves, put on prisoners' clothes, and then were taken to the torture chambers."

During the sessions of the United Nations General Assembly, where 71 nations voted to seat the deposed Pol Pot government as the representative of Kampuchea, Shukla held a press

conference at the UN to report his findings to the international news media. The Indian journalist was adamant in asserting that the fallen regime's Chinese advisors masterminded the genocide.

"I can say with conviction that the guilt for those crimes lies not only with Pol Pot-Ieng Sary but with the government of the People's Republic of China, whose advisors, numbering in the thousands, were everywhere in the country during this time," Shukla told reporters. "The Chinese not only knew what was happening but it is clear from the evidence presented to me that they directed the genocide hand in hand with their surrogates in Phnom Penh."

Shukla also referred to Peking's use of Kampuchean territory and troops of the Pol Pot regime under Chinese direction for repeated murderous raids into neighboring Vietnam. His statement strongly countered the view, evident in the General Assembly vote to seat Pol Pot, that the Vietnamese had illegally interfered in Kampuchean internal affairs when the Socialist Republic joined forces with the Kampuchean Front for National Salvation to overthrow Pol Pot last January. While there is "no justification for mindless invasions" by one country into another, Shukla said, "Vietnam had every justification to invade Kampuchea," given Pol Pot's aim of destroying the Kampuchean population.

"I think Vietnam committed only one mistake," Shukla said. "I think they should have gone into Kampuchea at least one year earlier, and much of the butchery would have been avoided."

When asked to describe the current situation in Kampuchea, Shukla reported: "There is an acute food shortage. There is a shortage of medicine, there is a shortage of clothing, there is a shortage of even a small ballpoint pen, a typewriter, a dictionary, and a book —because the whole offensive was against education, against culture, and against civilization. So nothing remains there."

"They need everything," Shukla said. "But despite all aid, many will die, because it is too late for them. There are 1 million disabled persons in Kampuchea, a quarter of what remains of the population."

Currently, only a small fraction of the 16,000 tons of rice Kampuchea needs monthly is reaching that nation. International relief agencies such as UNICEF and the Red Cross are sending small amounts of grain, but recent press reports indicate that most of these supplies are being distributed to refugees along the Thai-Kampuchea border, where they swiftly make their way into the hands of the Thailand-based remnants of Pol Pot's army. The U.S. State Department continues to refuse full-scale relief to the Phnom Penh government, on the pretext that food aid will legitimize the Vietnamese role in Cambodia; the relatively poor nation of India, however, voted major relief, 100,000 tons of rice Oct. 18.

—Christina Nelson Huth

How Pol Pot Murdered 3 Million

April 17, 1975:
The black-clad troops of Pol Pot's revolutionary armed forces capture Phnom Penh and declare victory over the government of Cambodian dictator Lon Nol. The new regime's first order is for the immediate evacuation of the capital city, and within three days, the majority of Phnom Penh's 2 million residents have packed their belongings and are traveling by foot to prearranged destinations to the north and south of the city. Those who refuse to leave their homes are killed.

April 18, 1975:
Military vans equipped with loudspeakers circulate throughout Phnom Penh urgently appealing for doctors, technicians, and other professionals to turn out for the reconstruction of the country. Military men are called out to aid in the national defense. All professionals who report to the new Pol Pot government during its first days in Phnom Penh are murdered.

Summer-Autumn 1975:
Survivors of the evacuation of Phnom Penh and Cambodia's other population centers are settled in rural "communes." Families are separated; marriage is abolished; men, women, and all children over 10 are put to work in the fields.

December 1975:
The former Lycee Tuol Svay Prey in Phnom Penh is transformed into the Tuol Sleng extermination camp. Between 10,000 and 12,000 are murdered here by June 1977.

September 1977:
The Pol Pot government issues directives for the extermination of all intellectuals, clergy, and other professionals remaining in Kampuchea. Implementation begins, and soon after, the systematic murder of prisoners and even whole villages. In all, 3 million Kampucheans are killed.

January 7, 1979:
The Pol Pot government is overthrown by the forces of the Kampuchean Front for National Salvation, with backing from the Socialist Republic of Vietnam. Pol Pot's retreating troops bulldoze villages, poison wells, murder village populations en masse, and burn rice stockpiles—some of which are so large they burn for days.

July 15, 1979:
The People's Revolutionary Tribunal of Phnom Penh charges the Pol Pot-Ieng Sary government with crimes of genocide, as stipulated in the Nuremberg Statutes of international law. In August, Pol Pot and Ieng Sary are found guilty of systematic mass murder, torture, destruction of the national economy of Kampuchea, and other crimes, and sentenced to death in absentia.

September 1979:
The Pol Pot government is seated at the United Nations, by majority vote of 71 nations of the General Assembly, as the representative of the Kampuchean people.

Mexican Pres. Urges 'Power of Reason' to Resolve World Energy Crisis

In a speech to the United Nations General Assembly Sept. 27, Mexican President José López Portillo called on the international community to draw on the power of reason to resolve the "disorder of the world economy" and, in particular, the energy crisis.

The problem of energy resources has brought mankind to a "watershed between two different eras," he stated. Either there will be war—"perhaps the most violent in all history"—or man will make the transition to a new era dedicated to the continuity of progress."

"Let us develop a consciousness that is based on rational thought, the gift that is ours alone among all Earth's species," the Mexican president said.

López Portillo called for "the adoption of a world energy plan that covers all nations . . . and has as its fundamental objective the assurance of an orderly, progressive, integrated and just transition from one age of man's history to the next."

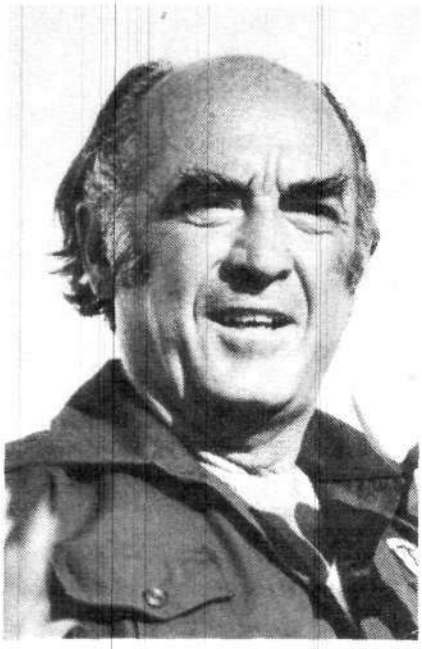
Said the Mexican president: "The plan must contain programs designed to:

"Guarantee the full and permanent sovereignty of each nation over its own natural resources.

"Rationalize the exploration, production, distribution, consumption and conservation of present-day sources of energy, particularly as regards hydrocarbons, by providing financial and technical assistance.

"Ensure and increase the systematic exploitation of potential reserves of all types, both traditional and nonconventional, which have not yet been exploited owing to lack of financing or applied research. . . .

"Make it possible for all nations to draft energy plans that are compatible with world policy. . . .



Lopez Portillo: "Let us not offer remedies for tomorrow."

"Devise measures for the promotion in developing countries of the formation and integration of auxiliary industries in the energy field, and especially of capital goods.

"Establish a short-term system, to be put into effect immediately, for resolving the problems of developing countries that import petroleum, which would guarantee supply and the honoring of contracts, stop speculation, provide for compensation for price increases, and even ensure considerate treatment on the part of the exporting countries.

"Set up financing and development funds, which could be made up of proportional and equitable contributions from the developed consumer countries and from producer and exporter countries, in order to meet both the long-term objectives and the urgent needs of the underdeveloped oil-importing countries.

"Institute a system for disseminating and transferring technologies, together with their respective training programs, that would include a worldwide registry of advances and follow-up in energy research and experimentation.

"Support the establishment of an international energy institute. . . .

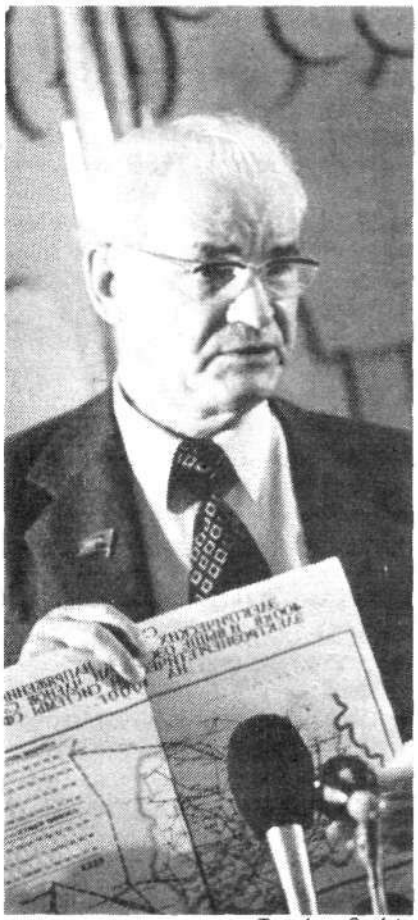
"To carry forward this world energy plan, I propose:

"The establishment of a working group, composed of representatives of the petroleum-producing countries, of industrialized countries, and of developing petroleum-importing countries, which would prepare the documents and pertinent specific proposals."

López Portillo's call for a producers-consumers dialogue on world energy requirements dates back to winter 1979 and has been endorsed by the OPEC nations, the European Community, and several nations of the East bloc. Third World development and the importance of transfers of technology from the advanced sector to the developing nations were the underlying themes of his entire address, because, as the Mexican president told the United Nations delegates:

"Men are dying today. Let us not offer remedies for tomorrow. In the face of harsh reality, let us not propose idealized stoicism; in the face of true but difficult roads, artificial, dead-end labyrinths; in the face of concrete obstacles, would-be shortcuts; in the face of hard-to-overcome lethargy, ephemeral and selfish solutions; in the face of sound arguments, threats and lies; in the face of the power of intelligence, the brute force of arms; nor in the face of problems shared by all, partial, bilateral, or bloc solutions. . . ."

UN observers noted that although unsaid explicitly, López was specifically refusing to put the Nonaligned Movement nations at the mercy of the International Monetary Fund and Carter administration's policies for no-growth and energy war between the industrialized and developing nations.



Tass from Sovfoto

Soviet Minister of Power Industry and Electrification P.S. Neporozhniy at a June press conference in Moscow on cooperation of the Soviet bloc countries in the development of power industries.

Neporozhniy Dedicates First MHD Facility

Soviet Minister of Power and Electrification Petr Neporozhniy was interviewed on the front page of Pravda *on October 1 on the occasion of the ground-breaking for the construction of the world's first commercial demonstration magnetohydrodynamic generator. The facility will be in a commercial power-generating plant located 140 miles from Moscow in Ryazan.*

Here are excerpts of his remarks.

Question: What are the special features of this new station?

The MHD method is one of the most promising ways of transforming thermal energy into electricity. It makes possible a significant improvement in the economic efficiency of thermal power stations. We anticipate that first-generation MHD power stations will have a conversion efficiency of approximately 50 percent, and the second-generation ones up to 60 percent, which compares with 40 percent at the best thermal stations. Furthermore, in the first phase the input of fuel will be reduced by between 20 to 30 percent. . . .

Question: What scientific ideas are used in the building of the new installation?

. . . The creation of an industrial MHD power installation was preceded by intense research, particularly on the famous Soviet U-02 and U-25 at the Academy of Science's High Temperatures Institute. These enable specialists to solve many scientific and technical problems. Experiments on the experimental installation U-25, which has been in operation over 20,000 hours, are continuing.

Question: What can you say about MHD power stations from the standpoint of environmental protection?

Let us recall that out of 100 grams of coal, mazut [peat], or gas burned in conventional thermal power stations, only 40 percent goes into obtaining electricity. This leads to environmental pollution. The increased thermal efficiency of the MHD station is accompanied by a reduction in waste and thus in polluting the atmosphere . . . . Of course, the MHD power stations cannot be viewed as some sort of panacea for all the difficulties connected with the energy problem. But the MHD method will take a deserved place in the ranks of progressive means of producing energy.

See Washington news, this issue, for an update on the U.S. MHD program.

Saudi Minister Endorses Fusion

In a telegram message to an international conference on energy held in October in Rimini, Italy, Saudi Oil Minister Sheik Ahmad Zaki Yamani endorsed nuclear fusion energy as the best long-term alternative to petroleum.

Earlier this year Saudi Arabia announced its intentions to install a fission nuclear capacity for medical purposes and desalination. In 1977, Saudi Arabia signed a research agreement with France for nuclear research along with a joint effort for uranium exploration on the Saudi peninsula.

The oil minister from the United Arab Emirates, Mana Saeed Oteiba, a close ally of Yamani, spoke at the Rimini conference urging closer cooperation with the European Community in an aggressive oil-for-technology relationship.

Oteiba stated that if such a development program were implemented then the "deserts of the Middle East will bloom."

New Soviet Plan Puts Science First

"Science has the first say." This slogan from the popular Soviet magazine *Ogonyok* captures the main goal of the 11th Five-Year Plan (1981-1985) for the Soviet Union, outlined in an August resolution of the Soviet govern-

ment and elaborated in the Soviet press.

According to press reports, starting with a 20-year plan of progress in science and technology and ending at the factory level with incentives to introduce new technologies, the system will be oriented to favor qualitative advances as the measure of economic success.

The Nuclear Role

In a Sept. 15 article in the trade union daily *Trud*, V.A. Kirillin, chairman of the State Committee on Science and Technology, spelled out what distinguishes the new plan. "The modern revolution in science and technology is the basis of progress and gives a powerful boost to the accelerated development of all branches of the national economy. In the recently adopted resolution . . . a scheme of planning the national economy is defined. Special attention is drawn to raising the role of science in planning. . . ."

Kirillin went on to list the main areas of the program, starting with nuclear energy, fission, the breeder, and controlled thermonuclear fusion power.

The announcement of the plan raises a number of questions about the planning problems Soviets have had in the past, about the relationship of the Soviet economy to the rest of the world, and where the Soviets fit in on the basic discussions going on concerning the European Monetary Fund and the theory behind it.

Brazil's Energy—Nuclear or Biogas?

Although Brazil's nuclear fission program remains under political attack, Energy Minister Cesar Cals announced Oct. 1 that the government will implement the full arrangement with Kraftwerke Union of West Germany for eight nuclear power stations, plus fuel enrichment and reprocessing. Cals said that the completion of the program would be stretched out to 1995 instead of the original 1990 target.

Also in the high-technology area, Brazilian scientists achieved the first magnetic confinement of a plasma in Latin America Oct. 4 in a tiny tokamak at the University of Sao Paulo. Researchers in Brazil have been working on fusion for the past eight years in collaboration with the fusion research center at Julich, West Germany.

Energy Minister Cals also announced that he will sign an agreement with the Princeton Plasma Physics Laboratory at the end of October that is aimed at helping Brazilian scientists join with the mainstream of international fusion development.

'Appropriate Technology'

Brazil is looking to a diverse range of energy sources—from thermonuclear fusion to chicken droppings to contain its growing petroleum consumption. At the low end of the energy spectrum, Brazilian President Figueiredo's thrust to substitute alternatives for imported petroleum—what Figueiredo has termed a "war economy"—has intensified Brazil's alternative fuels program. The nation's growing gasohol program was recently praised by President Carter's scientific advisor Frank Press as "the world vanguard in the research and use of alcohol as fuel." And next year, Brazil plans to introduce a tractor model that will be fueled by wood and charcoal—a throwback to the turn of the century.

At the same time, Brazil's inflationary food prices have made clear the price that must be paid for turning food-producing lands into croplands for fuel substitutes like gasohol.

Carrying the "appropriate technology" concept still another step backward, one Brazilian energy researcher has proposed the production of methane from chicken droppings. "With the daily excrement of 330 chickens," this researcher wrote, "it is possible to obtain the energy equivalent of a liter of gasoline. This might appear to be a modest figure, but if we consider that, by processing the excrement of Brazil's cattle herd (4 million head) we could obtain the equivalent of 30,000 liters of gasoline a day, we have an idea of what this biogas potential represents."

FEF Designs Nuclear Plan For India

India could be a net exporter of nuclear power plants by the turn of the century and at the same time provide more than one-third of its own nuclear energy needs, according to a study just completed by a task force of Fusion Energy Foundation engineers.

In addition, India's vast resources of thorium, the largest in the world with more than 500,000 tons, will eventually be used to fuel the country's entire nuclear power system as well as to provide another income-generating item for export.

Attaining the goals set forth in the FEF program will require that India imports approximately 100 nuclear power plants over the next two decades, thus providing a large export market for U.S. nuclear reactor technology. As the report states, this is precisely what is needed to get the economies of United States, India, and the rest of the world back in shape.

By the year 2000, the study outlines, India should develop its full 40 gigawatts nuclear potential to capacity, add another 40 gigawatts of fossil-based capacity, and make up the balance of a 230-gigawatt goal with 150 gigawatts of new nuclear energy. Of this 150 gigawatts, India would build nearly 50 gigawatts itself, mostly in Indian-designed CANDU-type reactors.

The FEF nuclear study was done at the request of a group in India that is involved in promoting the election campaign of Indira Gandhi for prime minister. The pronuclear group reports that the plan is likely to be incorporated into Gandhi's campaign platform during the coming three-month election period.

Copies of the Indian nuclear report are available from the Fusion Energy Foundation at $10 each ($5 for FEF members).

Shutdown of Hanford Facility Threatens Cancer Research

The closing of the nuclear waste disposal site in Hanford, Washington in mid-October has threatened the cutback of cancer diagnostic studies at a number of U.S. hospitals.

Washington Governor Dixy Lee Ray bowed to environmentalist pressure and took the action that closed one of the only three disposal sites for low-level wastes in the nation.

Officials at the only two other such disposal sites—located in Barnwell, South Carolina and Nevada—have made it known that they will not accept overflow waste created by the closing of the facility at Hanford. Barnwell had already cut back its handling of wastes from the nuclear plant at Three Mile Island in Pennsylvania. Officials at Barnwell had announced in August that their site could not accommodate low-level nuclear waste overflow resulting from the closed disposal site in West Valley, New York—a facility kept closed for several years by New York Governor Hugh Carey.

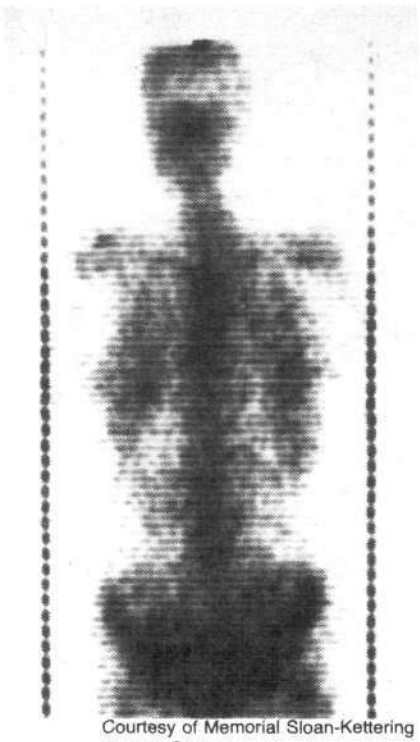
Governor Ray said she will keep the site closed until she receives assurances from the Nuclear Regulatory Commission that proper inspections of packaging are made at the site of origin of the low-level waste.

According to Murray Bolton, protection officer at the Massachusetts Institute of Technology, the areas most affected by Ray's action are cancer research and treatment, biology and nutrition studies, and clinical research, all of which use slightly radioactive materials that now cannot be easily disposed of.

Bolton said MIT has officially asked for "cooperation in trying to reduce the volume in use of liquid scintillation fluids." Scintillation fluids, which contain radioactive tracer elements tritium and C-14, are used in diagnostic studies to measure metabolic activity

Above: Gov. Dixy Lee Ray. Bowing to environmentalist pressure? Below: Part of the Hanford facility in Richland, Washington.

Battelle-Northrop Photography



Courtesy of Memorial Sloan-Kettering Cancer Center

This anterior photoscan shows the distribution of the radioactive tracer element fluorine-18 in a young woman with Hodgkin's disease. The shutdown of the Hanford nuclear waste reprocessing facility threatens scientists with a shortage of low-radiation tracer elements and scintillation fluid used in cancer research.

that is associated with cancer.

"The radioactive waste left over from the use of the scintillating fluids is equivalent to concentrations in soil where there's a lot of granite," an angry Bolton said this week. "The radioactivity is so slow that if you spilled the tritium on your hand it wouldn't penetrate the epidermis." In fact, according to official Environment Protection Agency standards, used scintillation fluid could be poured down any drain, without causing ill-effects.

Despite the lack of danger in radiation levels associated with this low-level waste, Harvard University now has no facilities for storing the material which has to be picked up once a week. Since the Hanford facility was closed, Harvard can't ship its waste.

According to a spokesman who asked not to be identified, "Harvard officials have asked their personnel to cut their medical research, especially in cancer. That cut covers cancer diagnostic tests and cancer treatment at Massachusetts General Hospital. I know for a fact that doctors there have been told to perform scintillation diagnostics on only the most severe of cancer cases. It's real triage. I'm sure that's going on in hospitals all over the country but the public would never know about it."

—Mary Gilbertson

TVA Head Says 'No' to Nuclear

Tennessee Valley Authority chairman S. David Freeman told the 20th annual conference of United Press International in Houston in October that the "utilities have no business in the nuclear field."

Today's nuclear reactors were really built for submarines and are probably not safe for commercial utilities, Freeman told the UPI group. Then the head of the nation's largest utility proclaimed, "Solar energy is not just a distant dream."

Freeman used the argument that commercial nuclear power was developed out of the U.S. Navy program—a route necessitated because former TVA head David Lilienthal, among others, prevented the independent development of commercial nuclear power—to call for a "second generation" of utility nuclear power plants.

Instead of the breeders and high-temperature reactors that his own TVA engineers have worked on, Freeman said, "The second generation reactors should be developed from scratch to meet specific utility requirements such as . . . low radiation to the environment and the workforce, and designs that will be resistant to terrorist threats and concerns about proliferation of nuclear weapons . . . ."

Lousewort Laureate

Freeman was awarded *Fusion* magazine's lousewort laurels award last February for his program to put wood-burning stoves into residences to save fuel costs.

AMERICAN ASSOCIATION OF MEAT PROCESSORS

Meat Processors Urge U.S. to Go Nuclear

The 1,500-member American Association of Meat Processors has called on the federal government to step up development of the nation's nuclear power resources. The call came in the form of a resolution passed at the association's 1979 national convention Aug. 15.

The meat processors' resolution read in part:

"In recognition of the critical shortage of energy in our nation and the constantly growing need for increasing supplies of a variety of power sources, and,

"In recognition that no form of effective energy production, including coal, oil, hydroelectric, or natural gas is completely safe in terms of freedom from physical or environmental harm, and,

"In recognition of the proven efficiency of nuclear power generation and the comparative safety of its use, including the lack of any demonstrable injury or illness to individuals or to people in general, and . . .

"In acknowledgement of the need for increasing availability of electric power to insure the continued economic growth of our economy,

"Be it resolved by the members of the American Association of Meat Processors assembled in convention at Caesars Palace in Las Vegas, Nevada . . . that the United States government be strongly urged to diligently foster and pursue the continued development of nuclear energy."

The association noted in a letter to *Fusion* that it has the distinction of having its headquarters located closer to the Three Mile Island nuclear power station (about six miles) than any other national association.

Washington

Fusion Postcard Campaign:

Put Fusion On Line by 1995!

A team of specialists including Fusion Energy Foundation staff members have drafted legislation that will gear up the U.S. fusion program for a crash effort in the 1980s. The bill, based on recent research advances in fusion and expert studies, is briefly summarized here.

The fusion postcard insert in this issue supporting an upgrade of the fusion program is addressed to Rep. Mike McCormack (D-Wash), a leading fusion supporter in Congress and chairman of the House Subcommittee on Energy Use and Production, which has oversight over the fusion program. Other supporters of the fusion effort on the Science and Technology Committee who should hear from fusion's constituency are Don Fuqua (D-Fla), Manuel Lujan (R-NM), Robert Roe (R-NJ), John Wydler (R-NY),and Tom Bevill (D-Ala), who chairs a subcommittee of the House Appropriations Committee.

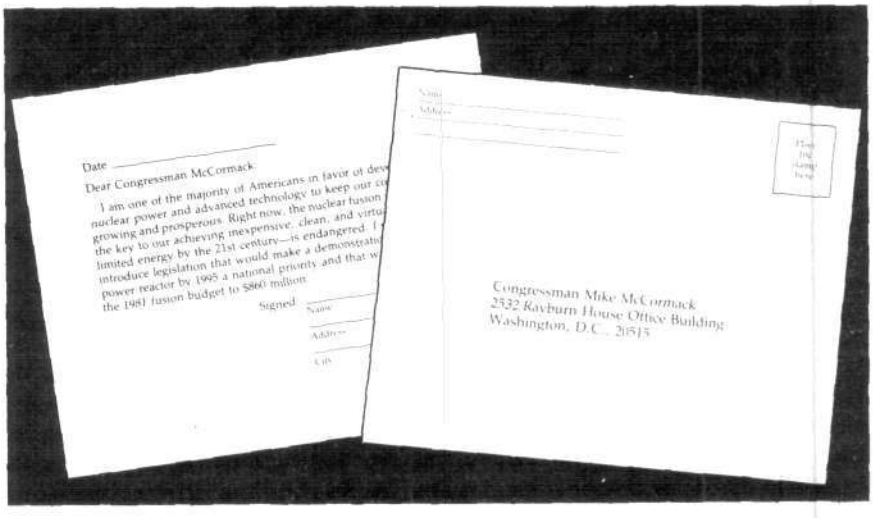
For copies of the bill and bulk orders of postcards, contact the FEF in New York City.

Demonstration Reaction by 1995

The proposed Fusion Energy Act notes that "recent progress in fusion experiments has demonstrated that fusion energy can be realized as a safe, clean, and economical source of electric power production" by the 1990s, given sufficient funds and manpower. On this basis, the act calls for the development and construction of an electric power demonstration fusion reaction by 1995, along with its alternative applications, to become a national priority of the United States.

The proposed act then provides the specific direction and authorization for the Department of Energy to fund an accelerated magnetic fusion program for fiscal year 1981 on the scale defined in the "Logic IV" plan for fusion by the Energy Research and Development Administration in 1976. The total amount of the fiscal year 1981 budget suggested is $860 million.

The act specifies that international cooperation in fusion energy research and development be maintained and enhanced and that incentives be provided to encourage participation of industry in the development of fusion energy and its applications, including hydrogen generation, nuclear waste destruction, and fossil fuel production.



The Fusion Postcard Campaign: Let Congress know there is a pronuclear, pro-technology majority in this country!

Congressman Mike McCormack

McCormack Submits Add-On To Fusion Budget

Congressman Mike McCormack (D-Wash) submitted two amendments to the House of Representatives for upgrading the funding for the Department of Energy's fusion effort Oct. 11. McCormack is chairman of the House Subcommittee on Energy Research and Production.

The first amendment involves a $5 million authorization for beginning the conceptual design and engineering for the next step in the tokamak program —an engineering test facility, ETF. The current DOE program plan would not begin such design work until initial results are in from the Tokamak Fusion Test Reactor (TFTR) now under construction at Princeton. This would delay the ETF design work until at least 1983.

The second amendment McCormack submitted would authorize $5.5 million for the civilian portion of the inertial confinement fusion program, which the House Armed Services Committee had declined to authorize.

McCormack motivated the $5 million ETF increase as follows: ". . . I want to report . . . that we have been extraordinarily successful in our research in magnetic fusion during the last 18 months. The successes that we have encountered have literally run away from the program, run away from our funding levels. It has left us almost breathless with excitement and satisfaction, but also recognizing that the program is moving on its own momentum and we must keep up with it. . . .

"When we succeed, and when we demonstrate that fusion works satisfactorily and when we can put it on line, the human race will have taken the second most important step in history, second only to the controlled use of fire. We will be able to provide, from that time forward, as these plants come on line, an absolutely unlimited source of energy for all humanity for all time. . . ."

DOE Replies on Budget Upgrade

McCormack reported on the DOE's answer to his July letter to Dr. John Deutch, DOE undersecretary, requesting that the department prepare a timetable and budget for having a demonstration fusion plant on line by 1995. (See *Fusion* Oct. and Nov. 1979 for details.) The DOE's reply showed that $2 billion would be saved if the fusion program were pursued more aggressively, McCormack said.

The McCormack request was forwarded from Deutch's office to the Office of Fusion Energy, which answered McCormack's questions, giving adequate notice to the fact that such a timetable was not now DOE policy. This answer was then sent "upstairs" and the scientists and the administrators in the fusion office were told by the acting assistant secretary for energy technology, Charlie Williams, that their answer had not stated the DOE's position strongly enough.

When the reply to the congressman's letter finally reached the staff of the House subcommittee, staff members called the fusion office to make sure that Deutch's office had not changed their numbers before sending the DOE reply to the Hill.

—Marsha Freeman

Wydler Bill Defuses Safety Hysteria

New York Republican John Wydler, an aggressive nuclear energy advocate and ranking minority member of the House Science and Technology Committee, has introduced an amendment to the 1980 fiscal year authorization bill for the Department of Energy to provide funding for additional research and development to improve the safety of operating nuclear power plants.

Congressman Wydler's amendment, which passed the House of Representatives, authorizes an additional $5 million for technical programs to analyze human error factors, achieve improved nuclear plant control room designs, and study accident phenomena. "We know now what is important for nuclear plant safety and it is not necessary to wait for the report of a special commission appointed by the president or new regulations from the Nuclear Regulatory Commission," Wydler said.

Putting the experience from Three Mile Island in the appropriate perspective, Wydler stated, "it should serve to spur the nuclear industry on to greater efforts at developing reactor safety technology just as the tragic Apollo spacecraft fire of 1967 pushed NASA to greater safety considerations for the space program."

Wydler's comments and action were meant to put a brake on the attacks on nuclear power coming from both the President's Commission on Three Mile Island and from Mitchell Rogovin, the antinuclear attorney who heads the NRC's Independent Investigation of Three Mile Island. Rogovin has used his position to attack the pronuclear staff members of the NRC.

Presidential Comm. May Recommend Nuclear Moratorium

Six of the twelve members of the President's Commission investigating Three Mile Island voted on at least two occasions for a moratorium on the construction of any new nuclear power plants, according to information leaked to the *New York Times* the week of Oct. 20.

Although it probably will not end up as an official recommendation because it did not get the required seven votes (an absolute majority), the effect will be the same with a vote of six for, four against, and two abstentions. The source said that the moratorium was recommended for an indefinite period until Congress votes up the safety recommendations put forward by the commission.

The Nuclear Regulatory Commission has applications now for building 14 new reactors, and there are 55 reactors in various stages of construction. It is not clear whether the commission, which is headed by Dartmouth College President John G. Kemeny, includes the latter group in the moratorium.

Blaming the development of science and engineering technology for the Three Mile Island incident, the commission source told the *New York Times* that "nuclear power represents a generic problem of society, in that the technology has moved so rapidly that we have a great deal of trouble knowing what we don't know."

The commission recommendations reportedly state that "the amount of radiation that leaked into the environment during the accident was minimal and so small that there will be no detectable additional cases of cancer, developmental abnormalities, or genetic ill health." Yet, the report ignores any damage to the U.S. economy from the commission's proposed moratorium on nuclear construction.

The report also ignores the question of sabotage—an issue the Fusion Energy Foundation has kept in the news.

GAO Pans Fusion As 'Unknown'

The General Accounting Office, the research arm of Congress, published a pessimistic report on fusion in September that concluded that fusion's "potential for becoming a viable commercial energy source is unknown...."

The report, titled "Fusion—A Possible Option for Solving Long-Term Energy Problems," is based on information assembled nearly two years ago. As a result, it does not include any of the groundbreaking fusion experimental results, beginning with the Princeton PLT tokamak temperatures reached in August 1978.

One of the report's principal investigators readily admitted to *Fusion* that the report was researched nearly two years ago and that its conclusions do not reflect present concerns. He said that he has not been involved in energy for the past six months and that he did not know why the GAO released the report in September.

The GAO, which is not subject to oversight by Congress, is headed by Elmer Staats, a former National Security Council staffer under Henry Kissinger. Its recent reports have stressed zero-based budgeting and attacked the highly skilled jobs and wage levels that are vital for a growing economy.

DOE Too 'Optimistic'

Incredibly, the GAO report considers the Department of Energy to be "soft" on fusion. The report reads: "The Department of Energy's annual budget reflects optimistic views of fusion as an energy source, without effective balancing statements that (1) characterize fusion as a long-term energy option with unknown potential for becoming a viable commercial energy source and (2) describe the program in terms of its present status and near-term goals. . . .

"GAO cautions, however, that disappointments are possible in the fusion effort because a number of elements or questions affecting the fusion program require basic or fundamental research. . . ."

In its recommendations, the report says: "The secretary of energy should take steps to make sure that the department's budget justification for the fusion program and its public announcements relating to program accomplishments do not overstate the prospects for commercial fusion power. . . . In the past . . . predictions have proven to be too optimistic. . . ."

The GAO also recommends that the DOE classify fusion research not as an "energy technology" but as a "basic research" program. However, because both the DOE and the Office of Science and Technology of the President objected to this reclassification, it was not included in the final draft.

It is not likely that any proscience members of Congress will take the report seriously.

—*Marsha Freeman*

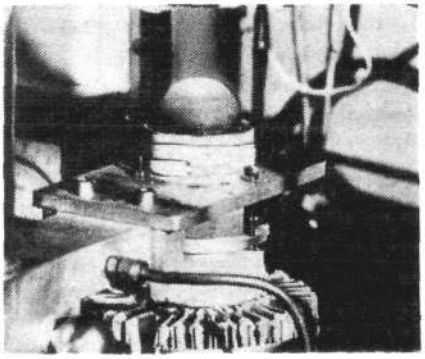
Reorganization Has No Place for Advanced Technology

Since the departure of energy secretary James Schlesinger, the DOE has been conducting a reorganization of the basic energy technology programs. The fossils, nuclear, fusion, nuclear waste, and some solar and geothermal research programs that were formerly the responsibility of one DOE assistant secretary will be recategorized separately on the basis of fuel source, along the lines of the structure of the former Energy Research and Development Administration.

The question that everyone is asking about the new scheme is under whose direction will the advanced technologies fall?

The fusion program will be placed in the Office of Energy Research, indicating the DOE's policy perspective that fusion is not going to be a commercializable technology for at least 50 years. The advanced fossil technologies, such as MHD and thermionics, which will be important energy-conversion techniques when combined with nuclear and fusion energy sources, are in limbo.

Similarly, advanced transmission, such as superconducting systems and advanced high-temperature component work, vital for any advanced system, has no place to go. Power systems development, advanced heat engines, and other potential new ideas also do not fit into the new structure.



Materials testing for a thermionics experiment at Thermo Electron, Waltham, Mass.

Industry sources report a movement to consider the creation of an additional post for an assistant secretary that would encompass all of the advanced technologies from MHD to fusion. And several sources in the scientific community feel that the best way to solve the problem is to eliminate most of the research DOE is funding in solar, conservation, coal synthetics and other uneconomical areas and return to the original idea of the Atomic Energy Commission—to have the federal government finance the development of the next generation of technologies for the nation's future.

Playing Budget Games With Technology

As the fiscal year 1981 budget winds its way through congressional committees, the fight is continuing between top-level DOE bureaucrats and pro-technology forces in Congress, and some program managers are still trying to restore funding cuts instituted by the DOE for the fiscal year that began Oct. 1.

According to industrial contractors in the thermionics program, although Congress authorized and appropriated adequate funding for their research projects in the 1979 fiscal year budget, the DOE decided to spend this money over a *two-year* period, effectively cutting the program by 50 percent. The scientists are now trying to get a supplemental budget allocation for the second half of fiscal year 1980 to restore the program to former levels.

So far, the House Science and Technology Committee, which has authorization over the program, has added $4.5 million to the paltry $2.5 million that the DOE requested. The Senate appropriations added $3.75 million, and both proposals will go to a House-Senate conference committee to work out the difference.

In similar shenanigans, the DOE has attempted to cut the hydrogen energy storage and related development programs in half. The DOE budget request for fiscal year 1980 was $2.4 million, less than half of the $6.3 million budgeted the year before.

Recognizing that this technology is the only high-technology synthetic fuel alternative for the future, congressional committee members are trying to restore funding to $6.5 million, but there is no assurance that the DOE will then spend the money in the way the Congress and the program managers see as most effective.

Decentralization

In addition to the budget sabotage, John Deutch, the new DOE undersecretary, has arbitrarily decided to implement a decentralization program that will weaken the high-technology programs. Decentralization was first suggested by former assistant secretary for energy technology Robert Thorne, with the idea that it would give more responsibility to DOE field administrators who are geographically closer to the actual research programs. Deutch, however, is using the plan to destroy centralized program leadership.

After a vigorous public campaign in August 1979 to convince the world that the results on the Princeton PLT tokamak fusion experiment were "not a breakthrough," Deutch decided that the Elmo Bumpy Torus experiment at Oak Ridge National Laboratory is now a "mature" experiment and should be removed from the national laboratory and farmed out to industry to develop. Still in the proof-of-principle stage of research, the EBT is being bid on by four consortia of industrial firms, none of which has the scientific expertise to carry the program forward at this stage.

The DOE scientists and program managers are worried both that the 100 scientists and engineers who have worked on the EBT for years will now be thrown out of fusion work and that the experiment will not be effectively handled through industry. They have spent months trying to figure out a way to keep the program near the laboratory so that the current staff could keep on top of the scientific experiments. In addition, the town of Oak Ridge, the Oak Ridge staff, and the congressional delegation of Tennessee are working to prevent the program from being "decentralized" out of existence.

—Marsha Freeman

Soviets Report Promising Results With Field-Reversed Theta-Pinch

Recently reported experimental results achieved by Soviet fusion scientists at the Red Square laboratory near Moscow indicate that the theta-pinch field-reversed approach shows great promise as a competitor to the successful tokamak magnetic confinement approach. Unfortunately, recent cuts in the U.S. fusion research budget have obstructed the efforts of U.S fusion scientists to duplicate and elaborate on the Soviet successes in this area.

The theta-pinch field-reversed approach is a high beta system in which the plasma itself generates the magnetic fields that confine it. (Beta is the technical term for measuring the efficiency with which magnetic fields confine hot plasma; it is the ratio of the plasma gas pressure to the pressure generated by the magnetic fields.)

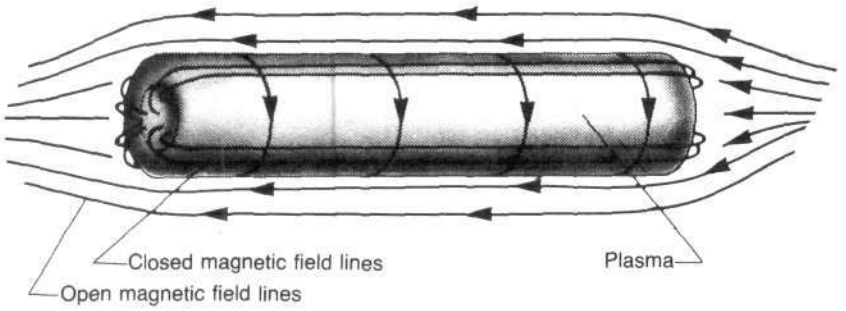
In simple terms, here's how it works: First, let's take a regular theta-pinch device. Here, a circular electrical current is induced in a cylindrical plasma, the short way round the diameter of the cylinder. This induced current generates an axial (that is, the long direction of the cylinder) magnetic field that compresses and heats the plasma. In other words, the plasma "pinches" itself.

In the regular theta pinch, the plasma is confined only in a radial direction; the hot plasma can simply stream along parallel to the axial magnetic field and escape out the two ends of the cylinder.

In a field-reversed theta-pinch, other plasma currents are induced at the lengthwise ends of the cylinder to get a closed magnetic field configuration that will effectively stop the plasma from leaking out the ends. The chief task in doing this is to keep the closed plasma configuration stable so that confinement is maintained.

A key advantage to the pinch system is that it does not require the large and costly magnets used in the tokamak device.

The main problem here is that magnetohydrodynamic instabilities will develop in which the plasma robs energy from the confining magnetic fields to generate macroscopic motions and distortions that permit the plasma column to escape from confinement.



This configuration depicts the final state of a reversed field pinch. The configuration is achieved by first setting up a theta-pinch plasma in which the magnetic field is all going in the same direction, parallel to the plasma column. By inducing additional currents at each end of the plasma column, the interior magnetic field is made to reverse direction and turn inward on itself. This results in the formation of a thin elongated donut-shaped plasma.

In the U.S. reversed-field theta-pinch experiments, two related MHD instabilities have been observed: first, a rotation of the entire plasma column; and second, a doubling up of the plasma column (this is very similar in form to what happens when a rope or a rubber band is twisted in opposite directions under tension—it doubles up).

The Soviet experiments, as reported by R. Kh. Kurtmullaev, apparently have demonstrated how to overcome these MHD instabilities. U.S scientists at Los Alamos Scientific Laboratory are now setting up experiments to duplicate the Soviet work and to answer some of the key remaining questions concerning the Soviet approach.

The Soviet Results

By theta-pinch standards the temperatures and densities achieved in the Soviet experiments are modest: 1 to 10 million degrees and 100 to 10,000 trillion nuclei per cubic centimeter densities. But the confinement reported on the larger of the two Soviet experimental devices is quite substantial —1 ten-thousandth of a second. This is more than 10 times better than that achieved on regular open-ended theta-pinch experiments.

According to one Soviet report[1] the key to preventing the disastrous onset of MHD instabilities is to properly program the shock waves that are generated during the compression of the theta-pinch plasma. In particular, the speed with which the compression is generated is kept slower than is usual with theta pinches. This permits the electrons to be kept hotter than the ions in the plasma, which helps dissipate the growth of the MHD instabilities and may also prevent the onset of the rotation instability.

U.S. Cutbacks

Cutbacks in the funding of the Applied Plasma Physics Division of the U.S. fusion program have caused a major decline in U.S. research into field-reversal approaches. The very promising investigations at Cornell University and the Naval Research Laboratory in Washington, D.C. on ion and electron-beam-induced field re-

versal have been almost wiped out by these budget cuts—just as the programs were achieving successful results.

In addition, the fast liner system, for which the field-reversed theta-pinch system is the ideal input plasma (combining many aspects of the magnetic and inertial fusion approaches), is on the rocks because of a political decision to curtail a joint U.S.-Soviet fast liner program at Los Alamos. (See "The Case of the Fast Liner" in the March-April issue of *Fusion*.)

—Charles B. Stevens

Notes

1. See A. G. Es'kov et al. 1978. "Features of Plasma Heating and Confinement in a Compact Toroidal Configuration." *Proceedings of the 7th IAEA Conference.*

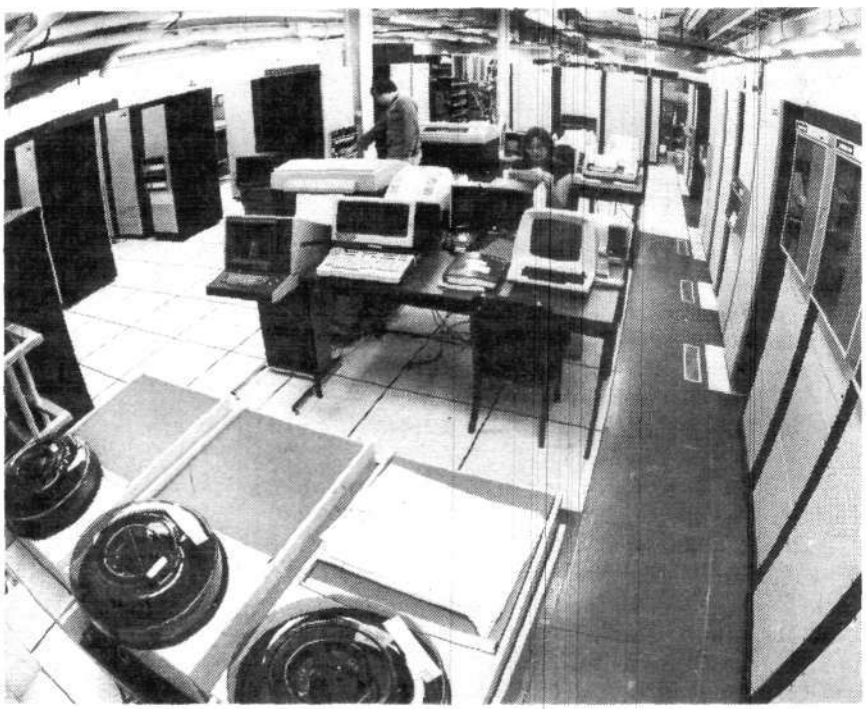
Sandia Laboratory Shows Progress with Light Ion Beams

Scientists at the Sandia Laboratory in New Mexico report continuing progress both in the generation and deposition of light ion beams in their inertial confinement fusion research. The Sandia researchers use their electron beam machines to collectively accelerate light ions, such as hydrogen.

In the past year, ion beam power densities have been increased by almost a factor of 10, to approximately 10^{12} watts per square centimeter. Depending on the target design, the power density needed for reactor power production is in the range of 10^{12} to 10^{17} watts per square centimeter for reactor pellet compression. (Laser beams now readily achieve between 10^{13} to 10^{17} watts per square centimeter, and electron beams are in the range of 10^{13} watts per square centimeter.)

According to the Sandia group, recent deposition experiments indicate that the ions are absorbed in matter as efficiently as classical theory predicts.

Light ion beams have many advantages over electron beams for pellet fusion. They do not generate the hard X-rays associated with electron beams and therefore they permit isentropic implosion to be achieved more readily.



The PLT control room

Princeton Plasma Physics Laboratory

LLL Proposes New Fusion Approach

Fusion scientists from Lawrence Livermore Laboratory in California have proposed a new approach to inertial confinement fusion that uses intense beams of microwaves on deuterium-tritium fusion fuel droplets. The researchers calculated that fuel droplets can be imploded by microwaves to reach at least fusion energy breakeven.

In magnetic confinement fusion, microwaves have been used to heat plasmas, and Soviet scientist Petr Kapitza is exploring the use of microwave fields to confine fusion plasmas. In inertial confinement, however, microwaves have been used only to simulate laser-plasma interactions.

According to a paper presented by the Livermore scientists at the IEEE plasma physics conference in Montreal in June, "both thermonuclear and non-thermonuclear reactions in the imploding droplet are important in the overall process."

PLT Scientists Report Observation of Thermonuclear Neutrons

Researchers from the Princeton Plasma Physics Laboratory have reported on measurements of neutron production that demonstrate that thermonuclear fusion is taking place within the PLT tokamak, the world's hottest fusion experiment.

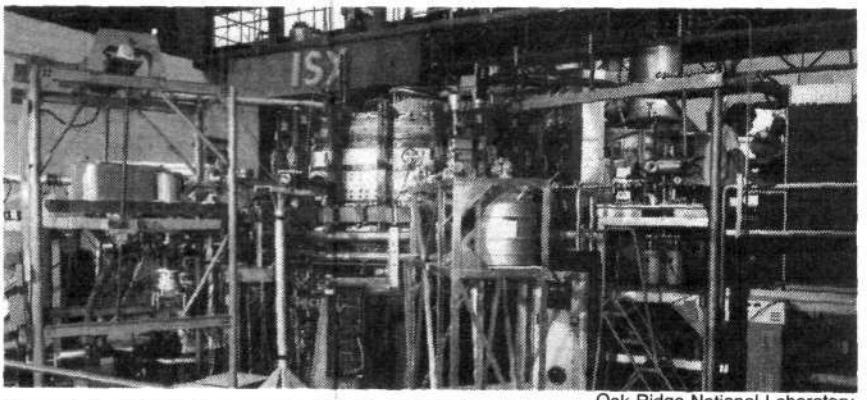
Although the PLT tokamak is not designed for maximum fusion energy output (because it does not use tritium fuel, only deuterium), its extremely high temperatures of 60 million (and more) degrees have led to the generation of large numbers of fusion neutrons.

The number of neutrons generated by deuterium-deuterium and deuterium-tritium (this tritium is generated in the first deuterium reaction) are a measure of how much thermonuclear fusion is taking place in the reactor.

ISX-B Beta Results Are Confirmed

The initial results reported here last month on the high betas achieved in the Oak Ridge National Laboratory's ISX-B tokamak experiment have now been reviewed and confirmed. The ISX-B experiments indicate that no instability develops, and no experimental limits on beta are observed even though the experiments are in plasma regimes that are theoretically unstable. (Beta is a measure of the efficiency with which magnetic fields confine fusion plasmas and a high beta is extremely important for economical fusion electric power plants based on the tokamak.)

Soviet experiments similar to the ISX-B have achieved the same results.



The ISX-B: No experimental limits on beta. Oak Ridge National Laboratory

The ISX-B and the Soviet experiments have attained average betas of almost 2 percent, with peak betas at better than 8 percent. Tokamaks have previously operated with betas much lower than 1 percent.

Oak Ridge researchers reported that a new phenomenon associated with gas puffing was observed in the ISX-B. During an experimental run, gas puffing usually leads to higher plasma densities. But at high-power neutral beam injection, this density rise is damped or "clamped" to a fixed value. Although experimentalists have found ways to circumvent such "density clamping," the phenomenon has not yet been theoretically explained.

"Coherent Structures in Turbulent Flow," LaJolla, Calif.,

The Beginning of a Determinist Theory of Turbulence

by Dr. Steven Bardwell

A three-day workshop on coherent structures in turbulent flow, held at the Scripps Institute of Oceanography Sept. 26-28, in LaJolla, California, marked an important point in the evolution of a new direction in continuum mechanics—the formalization of the idea of coherent structure as a definable body of physical phenomena. The conference, sponsored by the LaJolla Institute, brought together 50 physicists from many disciplines.

This new direction is part of the profound change that has occurred in the past 10 years in the fields of physics that deal with continuum mechanics. In fluid mechanics, meteorology, planetary atmospheres, plasma physics, and solid state physics, there has been a new attack on the problems of dynamic evolution that not only reformulates the problems in these disciplines, but provides new avenues of attack on the frontier areas of physics generally.

Prior to 1970, the history of continuum mechanics—until recently called fluid mechanics—divides itself neatly into two periods, with World War II marking the division.[1] From the beginning, the so-called classical period of fluid dynamics drew its empirical inspiration from the intuitively most striking feature of turbulence—the formation of vortices, eddies, and other large-scale, coherent motions.[2]

Although tremendously fruitful research came out of this approach in continuum mechanics, culminating in the work of the great German hydrodynamics school of von Karman, Prandtl, Meyer, Busemann, Guderley, and their coworkers, the direction of the mainstream of research gradually shifted under the influence of G.B. Taylor and a growing school of "statistical" fluid mechanics, beginning in the 1920s and 1930s.

Faced with the serious mathematical and physical challenges of complex, "turbulent" fluid behavior, this approach attacked the problem from the standpoint of its statistical definition. The apparent randomness, the instability of small perturbations, and the similarity of different time and spatial scales in many turbulent flows led this school to formulate the problem of turbulent flow in terms of the average values of the dynamical variables, giving up attempts to describe the actual appearance of any *given* flow.

Reevaluating the Statistical Approach

In 1971, two of the speakers at the LaJolla conference, G. Brown and A. Roshko, published a paper that marked the first significant break with the statistical approach to fluid mechanics in the period since World War II. Their work on the structure of turbulent wakes began a process of reevaluating the basic assumption of statistical continuum mechanics—the assumption that turbulent flow is *random*.

The importance of the past 10 years of the Brown and Roshko research was described recently by a leading fluid mechanician as follows: "Ironically these [observations] were not made with sophisticated electronics instrumentation but visually with rather simple optical techniques. The essence of these observations was the discovery that turbulent flows of simple geometry are not so chaotic as had been previously assumed: There is some order in the motion with an observable chain of events recurring randomly with a statistically definable mean period. The surprising result encouraged researchers to reexamine the line of inquiry for designing their experiments, and they began seriously questioning the relevance of some of the statistical quantities they had been measuring."

Brown and Roshko's work reported at the LaJolla conference summarized two critical insights into turbulence that represent a major step forward in our understanding of the physical mechanisms underlying the seeming disorder of turbulent flow:

First, Brown and other researchers have discovered the basic "law" of vortex dynamics in vortex streets and wakes—a property called *pairing*. In the superficially jumbled intermingling of vortices in a wake, these structures are actually coalescing in a paired interaction. An initial vortex street will undergo a region of transition, which seems random, in which neighboring like-signed vortices will coalesce into larger vortices, resulting in a new vortex street with larger length scales.

This regularity, previously unsuspected but now thoroughly documented, is the equivalent of Kepler's three laws of planetary dynamics. It is the first insight into the dynamics of collective vortex motion and promises the beginnings of a new, "determinist" theory of turbulence.[2]

Second, in his conference presentation, Roshko also developed a philosophy of approach to turbulence. The primary generalization that has guided previous research on turbulence is a hypothesis concerning its inherent asymptotic disorder. If one either waits long enough or looks at a fluid with high enough velocities (That is, high Reynolds numbers), the flow will converge on randomness.

This is perhaps the quintessence of the statistical approach to turbulence—the belief that it is merely a matter of waiting long enough for the actual statistical nature of turbulence to show itself. However, this generalization has never been proved either mathematically or empirically. Roshko challenged this hypothesis and counterposed to it his dictum: "Large-scale structure *is* turbulence."

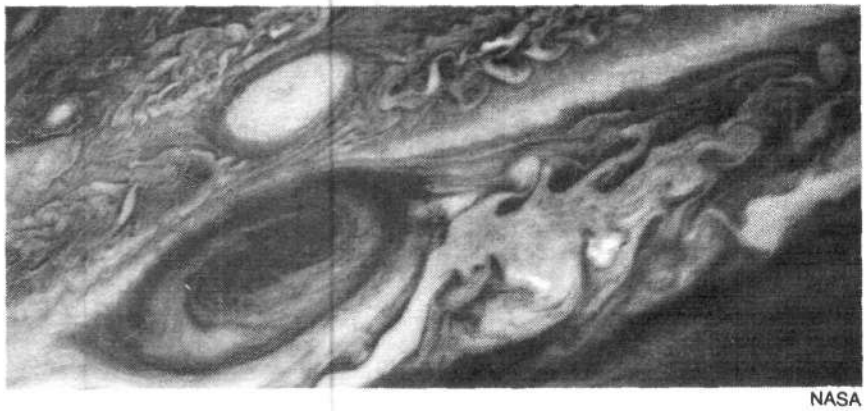
One of the most interesting and con-

troversial papers presented at the workshop was by Akira Hasegawa from the the Bell Laboratories in Whippany, N.J. Hasegawa described his recent research on the nonlinear partial differential equation that describes drift waves in magnetized plasmas and their importance in the phenomena of electron transport.[3] His discussion, however, began from the standpoint that the phenomena responsible for the remarkable properties of electrons in magnetized plasmas are actually of much broader significance. This was at least formally demonstrated by the fact that the same equation describing these drift waves also governs the two-dimensional flow of a fluid (like the atmosphere) on the surface of a rotating sphere. There is a very deep analogy between the three-dimensional motion of a plasma in a magnetic field and the two-dimensional fluid in the presence of the Coriolis force; both are characterized by force-free (geostrophic in the atmospheric case) motion, both show a tendency toward the formation of large-scale vortex motion out of small-scale "turbulence," and both develop well-defined scale lenths from initial isotropy.

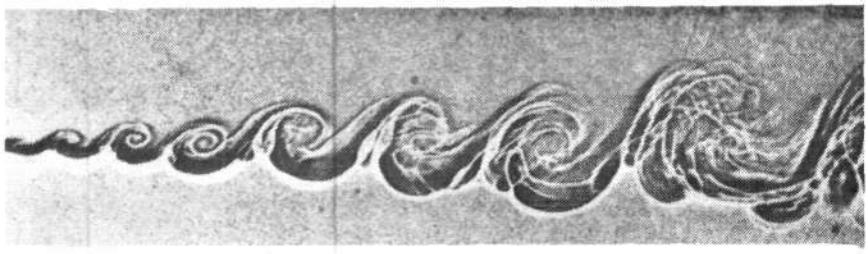
Hasegawa's paper reported on new results that account for the "inverse cascade" property of both systems—the astounding fact that both can take energy originally in small-motion and turn it into large-scale coherent flow.

Perhaps more important, Hasegawa speculated on a deeper property of systems that exhibit this property of self-ordering. He pointed out that there is a feature of the energy-containing modes of a continuum system that determines the significance of the direction of energy-cascade and the dispersion relations of these modes are the more basic aspect of these (and other) continuum systems.

Hasegawa's observation has important implications for research into other intuitively striking "self-ordering" phenomena in continuum systems: shock waves are created by the presence of dispersion,[4] and solitons, in fact, are the result of a "balancing" of dispersion (which would normally be expected to spread out energy in a random way) and nonlinearity of a system whose net result is the stable propagation of structure in the system.[5]



NASA



Two examples of vortex streets. Above: cloud vortices in the region of Jupiter near the Great Red Spot in an image taken by Voyager 2, July 3, 1979; Below: shadowgraphs of mixing layer between helium and nitrogen from the work of Brown and Roshko.

One of the last presentations at the conference, reporting on the work of the NASA team studying Jupiter and its atmosphere, captured the sense of discovery and really new physics that pervaded the meeting.

Astrophysics

A. Ingersoll showed a series of spectacular movies and slides of the Jovian atmosphere. The simple empirics of the planet are astounding: There are large-scale (many earth-diameters wide), very stable (existing for at least 200 years) vortex motions in the atmosphere of the planet. Its overall flow is highly structured, into zonal flow with superimposed vortex motion. Imagine the impact of compilation of these facts, presented to an audience that knows that flow in any high-Reynolds-number fluid is turbulent. (The Reynolds number of Jupiter is astronomical, since the upper layers of its atmosphere are diffuse and the planet rotates every nine hours!)

As Ingersoll summarized his talk and movies in response to a question from the audience that offered a rather lame explanation for some particular phenomenon on the planet, "Everything about Jupiter is astounding."

Steven Bardwell, associate editor of Fusion *magazine, is director of plasma physics for the Fusion Energy Foundation.*

Notes

1. See S. Bardwell, "The History of the Theory and Observation of Ordered Phenomena in Magnetized Plasmas," *FEF Newsletter*, 2:19 (1976).
2. For a more detailed history and references on continuum mechanics, see S. Bardwell, "Some New Directions in Fluid Mechanics," *International Journal of Fusion Energy*, 1:69 (1978).
3. Steven Bardwell, "Electron Transport in Tokamaks," *Fusion*, 2:30 (Sept. 1979).
4. See Uwe Parpart, "Riemann Declassified," *Fusion*, 2:24 (March-April 1979), for a detailed discussion of shock waves and their properties.
5. See Uwe Parpart, "The Theoretical Impasse in Inertial Confinement Fusion," *Fusion* 3:30 (Nov. 1979), for a discussion of a continuum developing singularities in a high-temperature plasma. The Fusion Energy Foundation is now pursuing research on the general problem of spontaneously formed structure in continuum systems as the mediation of qualitative, "geometric" transformations. The phenomenological evidence for these "phase changes" in inertially confined plasmas is reviewed in the Parpart article.

NOUVELLE MANIERE
POUR LEVER
L'EAU
AR LA FORCE DU
FEV.
SE EN LUMIERE
Par Mr. D. PAPIN,
Dr. en Med. Prof. en Ma-
them. à Marbourg, conſeiller
de S.A.S. de Heſſe & membre de la
ſocieté Royale de Londres.

A Caſſell
Pour Jacob Eſtienne Libraire
de la cour.

d Voguel imprimeur,
CC. VII.

A Case Study of British Sabotage

Leibniz, Papin, and The Steam Engine

by Philip Valenti

THE EARLY HISTORY of the invention of the steam engine shows without doubt that the British Royal Society deliberately prevented the industrial applications of steam power for nearly 100 years. In fact, the Royal Society was so intent on burying Denis Papin's 1690 invention of a paddle-wheel-driven steamship, worked out in collaboration with G.W. Leibniz, that it appropriated his work and created a mythical story of how two British heroes invented the steam engine—a myth that has persisted in the history books until today.

Papin, a member of the Royal Society and part of the Continental republican networks that later produced Benjamin Franklin and the European support for the American Revolution, published many papers throughout England on his ideas and inventions, including steam power. Yet, in 1699, nine years after the Papin-Leibniz steam engine was invented and publicized, the British Parliament awarded an "exclusive patent" to the "fire engine" design of one Thomas Savery—a steam engine design that was proven not to work in full scale.

Still later, in 1712, after the Royal Society appropriated all of Papin's work without remuneration and after Papin "disappeared" in England, another British steam engine hero was created—Thomas Newcomen, an ironmonger reportedly working with Savery. Newcomen is now credited throughout the history books with inventing a steam pump that used a piston and cylinder and was restricted to raising water from mines.

Aside from an improvement 50 years later by James Watt, who created a separate chamber to condense the steam, the so-called Newcomen steam engine was used solely for pumping water at mine sites until the late 18th century. There was no attempt made to develop the explicit designs of Papin and Leibniz for all kinds of labor-saving steam-powered machines. Thus, without any explanation or discussion of extending the steam-power concept, the British deliberately held back for nearly a century the transformation of society that took place when the steam engine was finally applied to manufacturing and then to transportation. (A chronology appears on page 46.)

It seems appropriate, then, that Robert Fulton, the American scientist, painter, and diplomat who later brought many of Papin's designs to fruition, proposed in 1798 that the French use steam-powered warships and a submarine against the "monstrous government" of England to aid in republicanizing the nation and ensuring world peace. Fulton, a humanist in the tradition of Papin and Leibniz, understood perfectly well who the enemy was and what had to be done to free the world from the British stranglehold to pursue industrial and technological development (see box page 44).

The story told here of the steam engine is a striking example of how the British hated the very ideas of Continental Science. To Issac Newton's Royal Society, the Leibnizian world view—the knowledge that man will master the coherent laws of nature and in the process create the means to continually better man's material conditions—was anathema. The society's public show of interest in science was intended only to control scientific developments in the interest of the old aristocratic order.

The fact that Leibniz and Papin developed the steam engine based on a theoretical *conception* of how dynamics and force should operate in a totally new machine, as opposed to Newton's empirical inductive method of mechanics and his hatred of hypotheses, is what the Royal Society sought to suppress from circulation.

Even in the 20th century the British found it necessary to continue the steam engine fight by founding the Newcomen Society here in the United States in 1923. Not only did the Newcomen Society promote the myth that

Newcomen invented the steam engine; it also boldly asserted that Newcomen "may truly be designated the founder of the Industrial Revolution."

With 17,500 U.S. business leaders as members, the Newcomen Society continues to this day to promote the myth that the steam engine as well as American industry came out of the blue by trial and error and mysterious "market forces." (This is a mish-mash they label as "free enterprise.") According to the Newcomen Society publications, such development had nothing to do with the actual source of industrial capitalism—the organization by Leibniz and later by our Founding Fathers of sovereign republics to promote and protect scientific inventions and industry.

In reviewing the original documents—the correspondence of Leibniz and Papin and the Royal Society papers—one cannot help but think of today's antiscience faction and their determination to implement a new Malthusian order by stopping technological development and theoretical science. In this case, a 100-year delay in the implementation of fusion power and full nuclear development would have devastating consequences for mankind. What America needs now is enough 20th-century Benjamin Franklins and Robert Fultons to get rid of the obstructors of progress for good!

The project of discovering and perfecting a source of power capable of effecting a dramatic human advance was first initiated as a national effort by the minister of the young French King Louis XIV, Jean Baptiste Colbert.

The French Academy of Sciences

In 1666, Colbert established the Academy of Sciences at Paris for this purpose, recruiting the Dutch scientist Christiaan Huygens as its first president. Huygens's proposed 1666 program included "research into the power of gunpowder of which a small portion is enclosed in a very thick iron or copper case. Research also into the power of water converted by fire into steam," as well as experiments with vacuum pumps, wind-powered engines, and the communication of force by the collision of bodies.

In 1672, Huygens acquired two young students and collaborators: Gottfried Wilhelm Leibniz, the 26-year-old diplomat, and Denis Papin, a 25-year-old French medical doctor introduced into the Academy by Madame Colbert. Within a year, Huygens and his new colleagues had successfully modified the von Guerike air pump into an engine capable of transforming the force of exploding gunpowder into useful work.

Huygens proposed to create a vacuum within a cylinder under a piston by exploding a charge of gunpowder at the cylinder's base (see Figure 1). After the air was expelled through two valves fitted with leather collars, the collars collapsed, preventing air from reentering the cylinder. The pressure of the atmosphere then was expected to push the piston downwards into the cylinder, the motion

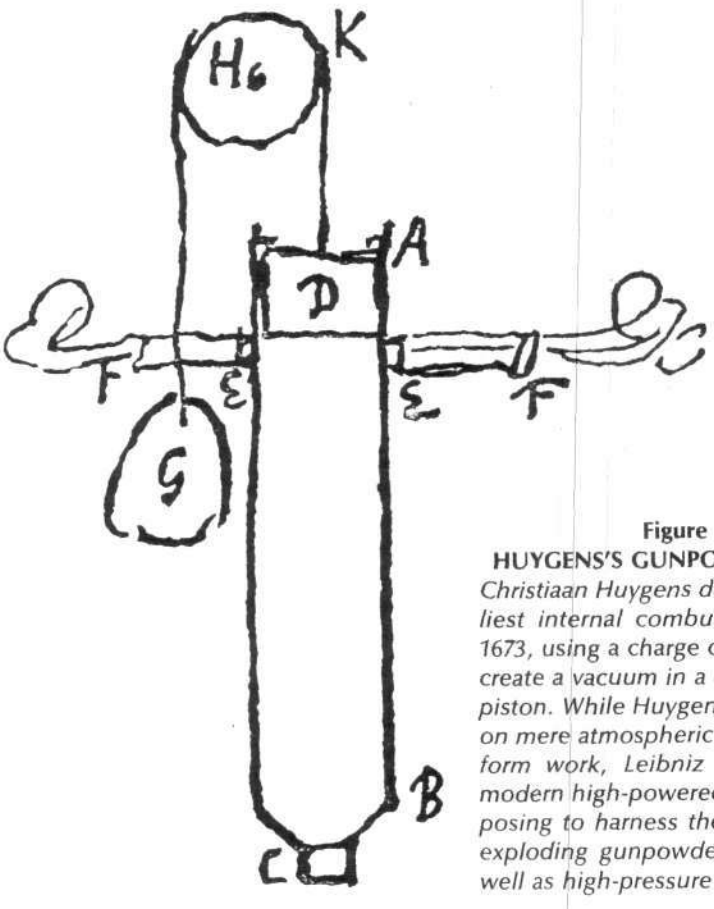


Figure 1
HUYGENS'S GUNPOWDER DEVICE
Christiaan Huygens designed this earliest internal combustion engine in 1673, using a charge of gunpowder to create a vacuum in a cylinder under a piston. While Huygens's device relied on mere atmospheric pressure to perform work, Leibniz anticipated the modern high-powered engine by proposing to harness the direct force of exploding gunpowder or alcohol, as well as high-pressure steam.

Christiaan Huygens

of the piston being applied to perform work. After successfully demonstrating a model gunpowder engine to Colbert, Huygens wrote:

> The violent action of the powder is by this discovery restricted to a movement which limits itself as does that of a great weight. And not only can it serve all purposes to which weight is applied but also in most cases where man or animal power is needed, such as that it could be applied to raise great stones for building, to erect obelisks, to raise water for fountains or to work mills to grind grain . . . . It can also be used as a very powerful projector of such a nature that it would be possible by this means to construct weapons which would discharge cannon balls, great arrows, and bomb shells . . . . And, unlike the artillery of today these engines would be easy to transport, because in this discovery lightness is combined with power.
>
> This last characteristic is very important and by this means permits the discovery of new kinds of vehicles on land and water.
>
> And although it may sound contradictory it seems not impossible to devise some vehicle to move through the air . . . .[1]

While Papin advanced Huygens's work by improving the air pump, Leibniz proceeded, in deliberate fashion, to discover and develop the science of dynamics and its mathematical tool, the differential calculus. Technology-vectored modern science begins with Leibniz's metaphysical discoveries of the 1670-1675 period.

Leibniz wrote that in his youth he freed himself from "the yoke of Aristotle," rejecting scholasticism in favor of the materialist notion of "atoms and the void." Accepting Descartes's concept of matter as mere passive extension, Leibniz attempted to work out a complete physical theory in his 1670 *New Physical Hypotheses*. However, he found that the assumption of a passive, inert matter whose essence consists in merely taking up space resulted in absurdities.

Consider the case, he wrote, of a small body, *A*, moving in a straight line with velocity, *V*. Suppose that *A* encounters a much larger body, *B*, at rest. Leibniz concluded that since there is nothing in the concept of mere extension to account for inertia, the body *A* will carry the body *B* along with it without losing any of its velocity:

> This is a consequence which is entirely *irreconcilable with experiments* . . . . All of this shows that there is in matter something else than the purely Geometrical, that is, than just extension and bare change. And in considering the matter closely, we perceive that we must add to them some *higher or metaphysical notion, namely, that of substance, action, and force* [emphasis in original].[2]

Leibniz proposed to study the forbidden, "impenetrable" interior of things to discover the true cause of phenomena, much as 20th century scientists have explored the interior of the atom and the interior of atomic "particles" like the "proton." He wanted to replace the materialists' occult quality of "hardness" with a notion of "concurrent movement":

> I believe that matter itself, which is homogeneous and equally divisible throughout, is differentiated by motion alone. We see that even fluids acquire a certain firmness when in motion. Thus a vigorous jet of water will prevent anything from breaking into its own path from without with more force than the same water at rest . . . . We learn from the magnet in an elegant experiment, that things which in themselves are separate and, so to speak, sand without lime, can acquire some firmness by motion alone. When iron filings are placed near a magnet, they suddenly become connected like a rope and form filaments, and the matter arranges itself in rows. It is no doubt also by some kind of magnetism, that is, by an internal coordinated motion, that other parts of certain bodies are linked together . . . .
>
> [Since] all bodies are agitated by internal motions, the conclusion is that bodies are firm insofar as these motions are concurrent, but remain fluid insofar as the motions are perturbed and not connected by any system. The result is that every body contains some degree of flexibility and of some firmness alike and that no body is so hard as not to have some flexibility, and the converse.[3]

Next, Leibniz pursued his study of the interior of things on the grounds of the infinite divisibility of the continuum. Discrete, hard atoms cannot exist, he said, because there is no reason for the divisibility of the continuum to stop at any given point; that is, physical atoms violate Leibniz's Law of Sufficient Reason. However, where contemplation of the fact of infinite divisibility led others to reject the very existence of individuals in favor of an all-consuming, continuous, unchanging soup, Leibniz instead discovered the grounds for universal progress and the basis of a new science—dynamics.

For Leibniz, the continuum is not divided merely linearly, like marks on a ruler, but in a manner suggestive of the modern Riemannian conception of nested manifolds, "Worlds within Worlds." As Leibniz develops this in the *Monadology*:

> Each portion of matter is not only divisible *ad infinitum*, as the ancients recognized, but also each part is actually endlessly subdivided into parts, of which each has some motion of its own; otherwise it would be impossible for each portion of matter to express the whole universe.
>
> 66. Whence we see that there is a world of creatures, of living beings, of animals, of entelechies, of souls, in the smallest particle of matter.
>
> 67. Each portion of matter may be conceived of as a garden full of plants, and as a pond full of fishes. But each branch of the plant, each member of the animal,

Gottfried Leibniz

Denis Papin

each drop of its humors is also such a garden or such a pond.

68. And although the earth and air which lies between the plants of the garden, or the water between the fish of the pond, is neither plant nor fish, they yet contain more of them, but for the most part so tiny as to be imperceptible to us.

69. Therefore there is nothing fallow, nothing sterile, nothing dead in the universe, no chaos, no confusion except in appearance . . . .[2]

Such "infinite divisibility," Leibniz said, can account for the "perpetual and very free progress of the whole universe":

> Even if many substances have already reached great perfection, nevertheless on account of the infinite divisibility of the continuum, there always remain in the depths of things slumbering parts which must yet be awakened and become greater and better, and, in a word, attain a better culture. And hence progress never comes to an end.[2]

The Development of Dynamics

Freed from Descartes's concept of passive matter and equipped with a matter containing unlimited resources ("slumbering parts which must yet be awakened"), Leibniz transcended the science of mechanics that had dominated Western thinking since Archimedes. Where mechanics pertained to the passive effects of ancient machines, dynamics was conceived as the science of the active, living force (*vis viva*, or kinetic energy) of "violent actions"—like the explosion of gunpowder and rapid expansion of high pressure steam:

> The ancients, so far as is known, had conceived only a science of inactive force, which is commonly referred to as Mechanics, dealing with the lever, the windlass, the inclined plane—pertinent to the wedge and screw—though there is discussion of the equilibrium of fluids and of similar problems; only the effort or resistance of bodies and not the impetus they have acquired through their action, is discussed . . . .
>
> For I here refer not to any effect, but to one produced by a force which completely expends itself and may therefore be called violent; such is not the case with a heavy body moving on a perfectly horizontal plane and constantly preserving the same force; this is a harmless sort of effect, so to speak, which we can also calculate by our method, but it is not the one we wish to consider now.[2]

Since it is limited to the study of "harmless sorts of effects," mechanics considers the total absolute force of bodies acted upon by ancient machines as directly proportional to the acquired velocity, or $F = mv$. In contrast, Leibniz considered the equivalence of the kinetic energy of a heavy body falling from a given height (violent action) to the work required to raise it to that height, and using Galileo's laws for bodies in free fall, he determined that

Colbert's Academy

the live force of a body in motion is directly proportional to the *square* of the velocity; that is, $F \propto mv^2$.

Leibniz's subsequent statement of the principle of the conservation of *vis viva*—"the cause and total effect are always equivalent in such a way that the effect, if it were completely turned around, could always reproduce its cause exactly, and neither more nor less"—effectively initiated today's technology-vectored science. Most important, Leibniz's practical goal became to free the most violent actions known for the purpose of advancing the material conditions of man. By applying the law of the conservation of *vis viva* to maximize the conversion of the kinetic energy of such actions into useful work, Leibniz envisioned mastering the *direct force* of explosions to power ships, carriages, airplanes, and factories.

The power of Leibniz's dynamic conception and its useful application stands in stark contrast to the mechanical conceptions of the British, who for nearly 100 years restricted steam power to functioning as some sort of exotic lever simply to pump water from mines.

But how could a scientific establishment possibly invent anything useful while insisting, as the British Royal Society did *throughout the 18th century*, that one's preference between measuring force by mv or mv^2 is simply a matter of personal taste, a mere semantic quibble?

From the beginning of his study of the matter, Leibniz had insisted on the practical implications of his dynamics, particularly the issue of mv^2 versus mv, for the construction of machines and the perfection of technology. He wrote in 1695:

> These things are not worthless to consider, nor are they quibblings over words, for they are of the greatest importance in comparing machines and motions. For example, if power is obtained from water or animals or from some other cause, by which a weight of 100 pounds is kept in constant motion so that within a fourth of a minute it can be made to complete a circle of 30 feet diameter, but someone else maintains that a weight of 200 pounds can in the same time complete half the circle with less expenditure of power, his calculation seems to yield a gain; but you ought to know that you are being deceived and getting only half the power . . . .[2]

By 1675, Leibniz had begun to engage the leading French Cartesians in debate over his dynamics and with Huygens's help he succeeded in inventing the differential calculus. At this point, the impact of the reactionary shift in the policies of Louis XIV, which began with the French invasion of Holland in 1672, reached Colbert's Academy. The result was a forced exodus of Protestant scientists several years before Louis's 1685 revocation of the Edict of Nantes. Leibniz left Paris reluctantly to accept a post as librarian in Hanover, while Papin left for England.

Papin's Early Inventions

Working with Hooke and Boyle in London, Papin continued Colbert's project. By 1680, Papin made a major breakthrough toward controlling highly compressed steam in the form of his "New Digester for softening Bones, etc."—a steam pressure cooker. This device consisted of a cylinder with thick walls (as prescribed by Huygens in his 1666 program), in which was enclosed water along with bones, tough meat, and so forth. The whole device was then placed on a fire to cook (see Figure 2).

Although Papin's immediate motive was, as he wrote to Huygens, "to relieve poverty, and to get wholesome and agreeable foods from things that we ordinarily reject as useless," his digester was also a major advance toward

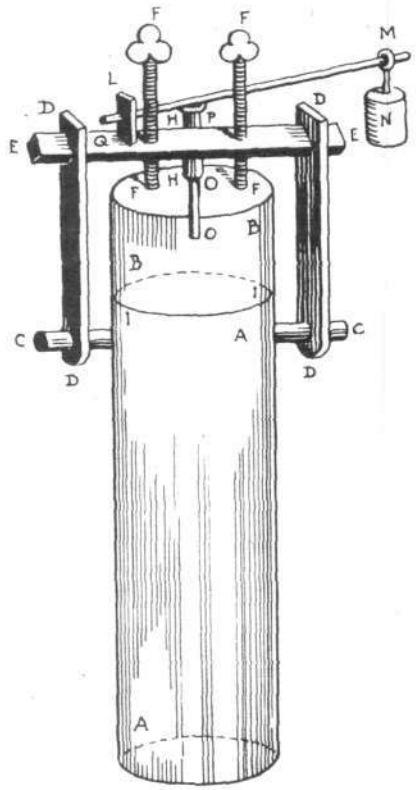


Figure 2
PAPIN'S DIGESTER

Papin wrote a lengthy cookbook for 17th century housewives explaining the operation of his 1680 invention, the steam pressure cooker or "digester." Besides helping to "relieve poverty," Papin's purpose, the digester enabled science for the first time to safely control pressures many times ordinary atmospheric pressure. Papin accomplished this breakthrough by inventing the adjustable safety valve, installed at the top of the cooker.

the steam engine because of a totally new feature—*the safety valve*. This allowed Papin safely to contain pressure many times that of the atmosphere and greater than any pressure previously controlled, limited only by the strength of the cylinder.

That same year Papin was elected a Fellow of the Royal Society, but he was apparently unhappy in London and he soon left for Italy, spending two years as a member of the new Italian Academy of Sciences in Venice. He returned to England, however, and by 1687 he unveiled a new invention to transmit power pneumatically. In order to develop a means of spreading industrialization to areas where water power was not available, Papin proposed two sets of pumps —one set operated by a water wheel, connected by air-tight pipes to another set placed in a neighboring town or suburb. Power would be transmitted by the alternate suction and pressure exerted by the first set of pumps (see Figure 3). This idea was hotly opposed in the Royal Society, and Papin left England to accept a chair of mathematics at the University of Marburg in Hesse, bordering Hanover.

In 1690, Papin published an historic article in the *Acta Eruditorum* of Leipsig, "A New Method of Obtaining Very Great Moving Powers at Small Cost," from which we can precisely date the beginning of the Steam Age. Here, for the first time, Papin proposed using the power of expanding steam to operate an engine. In the new invention, steam replaced the gunpowder charge of Huygens's cylinder, creating a more complete vacuum under the piston and thereby taking advantage of the full force of atmospheric pressure (Figure 4).

Papin's concept was appropriated *in toto* in the Newcomen engine more than 20 years later. However, although Papin mentioned in passing the utility of his invention to "draw water or ore from mines," the article featured a lengthy and detailed discussion of the application of steam power to *propelling ships* equipped with *paddlewheels*:

> So, no doubt, oars fixed into an axis could be most conveniently driven round by my tubes, by having the rods of the pistons fitted with teeth, which would

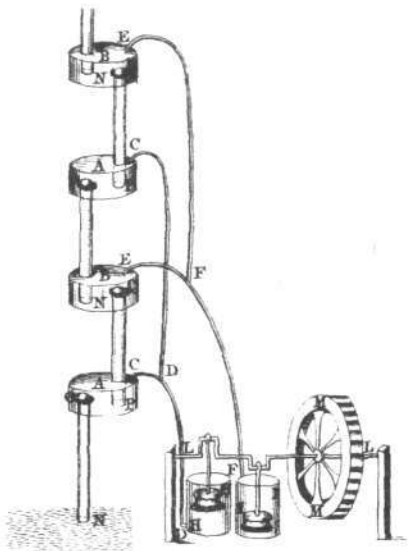


Figure 3
PAPIN'S PNEUMATIC FOUNTAIN

In 1687, Papin illustrated the operation of his pneumatic pump by constructing a model fountain. Water was raised by the alternate suction and pressure exerted by a pair of air pumps. Papin enclosed his model in a container, allowing his Royal Society colleagues to observe the water spouting at the top but concealing its internal mechanism, and he then challenged the Royal Fellows to guess at its design. The Royal Fellows failed to solve Papin's puzzle and were especially embarrassed since they all had earlier agreed that the pneumatic transmission of power was impossible. Papin found himself suddenly friendless in London and decided to leave for Germany later that year.

force round small wheels, toothed in like manner, fastened to the axis of the paddles. It would only be requisite that three or four tubes should be applied to the same axis, by which means its motion could be continued without interruption [Figure 5].

Papin recognized the problem inherent in such atmospheric engines. Since the source of power is not the steam itself but the pressure of the atmosphere, the only means of increasing power is to increase the diameter of the cylinders:

> The principal difficulty, therefore, consists in finding the manufactory for easily making very large tubes . . . . And for preparing that, this new machine ought to supply no small inducement, inasmuch as it very clearly shows that such very large tubes can be most advantageously employed for several important purposes.[1,4]

The Leibniz-Papin Collaboration

With Leibniz's intervention, Papin solved this problem in 10 years time. For Leibniz, the discussions with Papin were a crucial part of his campaign to win hegemony for dynamics among the most talented of European scientists. By the turn of the century, Leibniz had won over Father Malebranche, the leading French Cartesian and head of the Catholic Oratorian order, thus ensuring the future line of development within France leading to Carnot. Malebranche became convinced of Leibniz's dynamics largely on the basis of metaphysical considerations, but Papin was won over during the course of 15 years of experimentation under Leibniz's direction.

Papin began to tackle the problem of "making very large tubes" by studying the means of refining ores more efficiently, and of manufacturing cylinders with appropriately smooth surfaces. This led him to the invention of an improved furnace capable of reaching higher temperatures with a more efficient consumption of fuel. Papin used another of his inventions, the Hessian bellows, to generate a forceful down-draft in his furnace, thereby eliminating smoke and allowing a complete burn (see Figure 6).

By 1695, Papin had adapted this hotter furnace to the rapid production of high-pressure steam by constructing the furnace so that the fire surrounded the water, allowing the maximum surface area of water to be heated directly.

With this discovery, Papin was prepared to initiate a qualitative technological advance—not a linear extrapolation from his 1690 results, such as building larger atmospheric engines, but a proposal to harness the violent force of the *expanding steam*.

In a letter dated April 10, 1698, Papin apologized to Leibniz for not having written sooner, and explained that a new project, commissioned by his employer, the Landgrave of Hesse, had taken up most of his time:

> Monsgr. le Landgrave formed a new plan, very worthy of a great Prince, to attempt to discover where the salt in salty springs comes from. To reach the bottom of

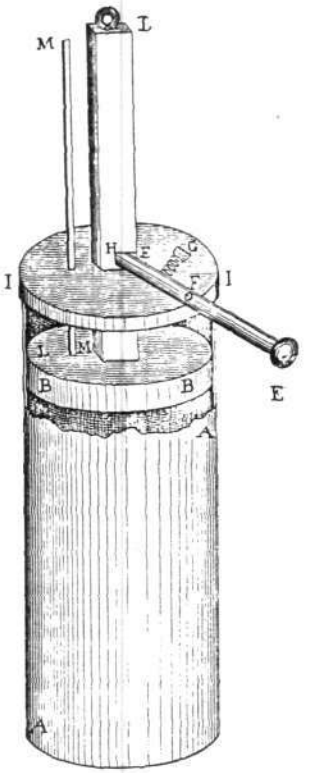


Figure 4
PAPIN'S 1690 ENGINE
The first steam engine using a piston and cylinder was invented by Papin in 1690. Papin proposed to use steam instead of gunpowder to create a vacuum under a piston. Although Papin suggested a means of applying the force of his engine to operate a paddlewheel boat, he realized that the power of an atmospheric steam engine was strictly limited by the diameter of its cylinder.

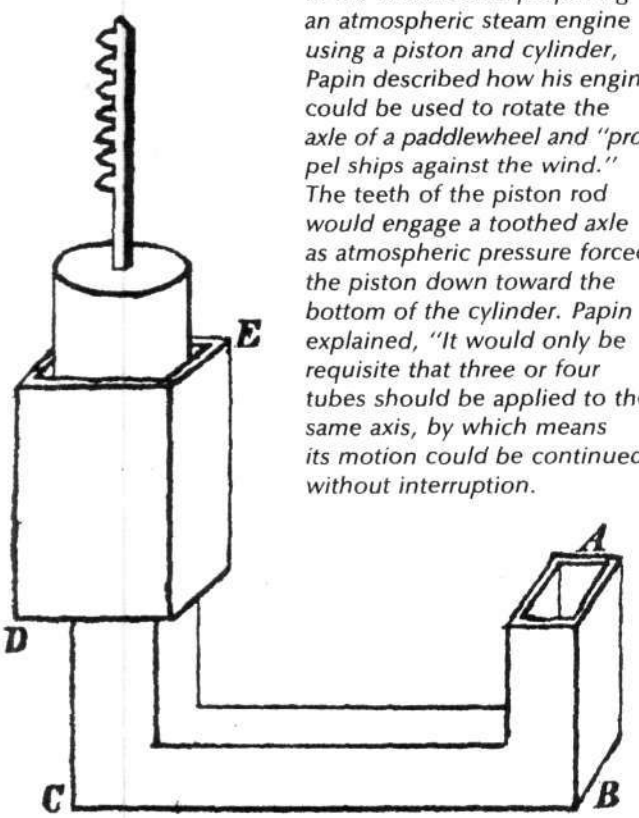


Figure 5
PISTON WITH TEETH FOR USE WITH PADDLEWHEEL
In his 1690 treatise proposing an atmospheric steam engine using a piston and cylinder, Papin described how his engine could be used to rotate the axle of a paddlewheel and "propel ships against the wind." The teeth of the piston rod would engage a toothed axle as atmospheric pressure forced the piston down toward the bottom of the cylinder. Papin explained, "It would only be requisite that three or four tubes should be applied to the same axis, by which means its motion could be continued without interruption.

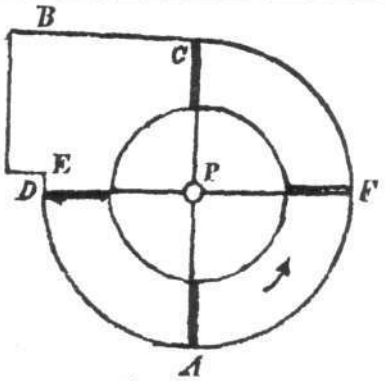


Figure 6
HESSIAN BELLOWS

Papin tackled the problem of manufacturing larger cylinders for his atmospheric steam engine by first inventing a hotter and more efficient furnace to improve the reduction of ores. This furnace utilized a down-draft generated by his "Hessian bellows" (above), which allowed a continuous forceful stream of air to feed the burning fuel. At Leibniz's prompting, Papin applied his hotter furnace to the rapid production of high-pressure steam. This led Papin to abandon the effort merely to scale up his atmospheric engine and instead to begin the crucial project of harnessing the "unbounded" energy of high pressure steam.

this, it would be very advantageous to be able to easily draw out a great quantity of water to a considerable height. I've made many tests to try to usefully employ the force of fire to this task; some succeeded so well that I was persuaded that *this force could be applied to things much more important than raising water.* Consequently, I've given myself totally to this work, knowing the great difficulties always to be met with in such enterprises and which can't be overcome without an extraordinary diligence. I'm presently having a new furnace built of which I've spoken to you before . . . . I'm building it simply to make certain large retorts of forged iron which will be very useful to produce the great effects that I expect from the force of fire. For this furnace I've also built a large Hessian bellows more perfect than those I've made before. And thus one thing leads to another . . . . [emphasis added].

In his reply four days later, Leibniz asked if Papin's method of raising water "is based on the principle of rarefaction which you published before, or if it is based on some other principle; I also have a thought about it, but I want to make a little test of it in order to consult you on its performance."

Papin's historic answer follows (July 25, 1698):

> The method in which I now use fire to raise water rests always on the principle of the rarefaction of water. But I now use a much easier method than that which I published. And furthermore besides using suction, I also use the force of the pressure which water exerts on other bodies when it expands. *These effects are not bounded, as in the case of suction.* So I am convinced that this discovery if used in the proper fashion will be most useful . . . . For myself *I believe that this invention can be used for many other things besides raising water. I've made a little model of a carriage which is moved forward by this force:* And in my furnace it shows the expected result. But I think that the unevenness and bends in large roads will make the full use of this discovery very difficult for land vehicles; *but in regard to travel by water I would flatter myself to reach this goal quickly enough if I could find more support than is now the case* . . . . It gave me much joy to find that you also have some plans to put the moving force of fire to use, and I strongly hope that the little test you told me of succeeded to your satisfaction [emphasis added].

Leibniz's concern for the applications of Papin's work was much greater than simply using the "force of fire" to propel ships and carriages. He saw in Papin's work the *unique experiment* capable of irrefutably establishing the truth of his dynamical science, as well as advancing that science by the process of applying its principles to *the measurement of the thermodynamic efficiency* of Papin's machines. This is the "little test" referred to in the letters above.

Leibniz wrote to Papin (July 29, 1698):

> I understand very well that the force of expanding water will do much more than air pressure will do when the steam is condensed, and this is exactly what I have thought as well in regard to gunpowder . . . . But in regard to water the strain of its expansion will be less violent, [so] it would be good to see if there aren't other fluids which would be even better than water. But water has the advantage that it costs nothing, and is available everywhere. My plan would be to do a test to discover if expanding water can usefully raise more than a column of air. But I lack workers here and I'm too distracted . . . . But I'm now very glad to find out that you've already made the relevant experiment, and that therefore you know approximately what *the force of the steam is relative to the heat and to time* [emphasis added].

Papin replied with a progress report on the construction of his engine, promising that once it was completed:

> I will try also to make observations on *the degree of heat [chaleur] required to make a given effect with a given quantity of water.* But up to the present all that I've been able to do, by the expansion of the steam, is to raise water to 70 feet, and to observe that a small increase in the degree of heat is capable of greatly augmenting the magnitude of the effect. And this convinces me that if these machines are perfected so that very great degrees of heat can be used, one

will be able to create a greater effect with a pound of water than with a pound of gunpowder [emphasis added].

Vis Viva Versus Mechanics

Consider the implications of the Papin-Leibniz discussion once the word *effect* is translated to the modern term *work*. Both Leibniz and Papin agreed that the useful work performed by a heat engine was to be measured by the height, *H*, to which it could raise a given quantity of water (work or effect = MgH). In his dynamics, Leibniz had used the example of the equivalence of the work required to raise a heavy body a given height to the *vis viva* acquired by the body in falling from that height. Whereas in the case of the falling body, the *vis viva* is easily measured by the body's velocity, Leibniz proposed to measure the *vis viva* of expanding steam by its *temperature*. Applying the principle of the conservation of *vis viva*, Leibniz developed the following sort of relation:

vis viva consumed by machine = useful work (height a given quantity of water is raised) + heat lost in overcoming friction + heat lost to superfluous cooling + . . . [other inefficiencies]

With this sort of analysis, Leibniz was prepared to *compare* the thermodynamic efficiencies of heat engines by measuring "the degree of heat required to make a given effect." This also led him to the formulation of his unique experiment: demonstrating that steam can "raise more than a column of air."

Let's look at the case of Papin's 1690 steam engine. Here the atmospheric pressure alone, considered as a "column of air" resting on the cylinder, is responsible for the motion of the piston. The role of the expanding steam is simply to raise the piston back to the top of the cylinder; that is, in Leibniz's phrase "to raise a column of air." Then the condensed steam leaves a vacuum in the cylinder and atmospheric pressure pushes the piston downward once again.

Leibniz proposed to demonstrate that the *direct force* of expanding steam, unlike mere suction, is *unbounded*—that it can "raise more than a column of air" (Aug. 28, 1698):

> There is nothing which merits development more than the force of expansion [*la dilation*]; if one objects that expanded water can do no more than raise a cylinder of air, and that the stronger it [steam] is the higher it [cylinder of air] is raised and that therefore it is sufficient to use the weight of the falling cylinder—I reply that this higher elevation requires more time, allowing the steam to gradually cool, than *a quicker elevation of a heavier weight*. Thus either force is lost or more fire must be used [emphasis added].

Clearly at issue in this "little test" is the validity of the mechanical world view—the universe of inactive force—that threatened to impose itself on emerging technology. Was steam power to be constrained to act passively, slowly pushing and pulling weights like some grotesque Rube Goldberg type of lever or pulley, or was it to be freed in all its violence—maximum *vis viva* to effect a qualitative human advance?

From this dynamical point of view, in fact, Leibniz was by no means convinced that expanding steam was the optimum source of energy for the new technology. For him, even expanding steam was not sufficiently violent or rapid in its action, compared, for example, to exploding gunpowder or, as he suggests elsewhere, to the combustion of alcohol. He argued as well for further work in applying the force of highly compressed air, particularly advantageous for building lighter and more portable engines for vehicles.

The Savery Hoax

Despite the publicity given to Papin's invention, the British Parliament awarded an exclusive patent for "Raising Water by the Impellent Force of Fire" to one Thomas Savery, variously described as a "sea captain" and a "military engineer." The terms of the patent meant that any steam-powered device Papin might invent in England would come under the control of Savery.

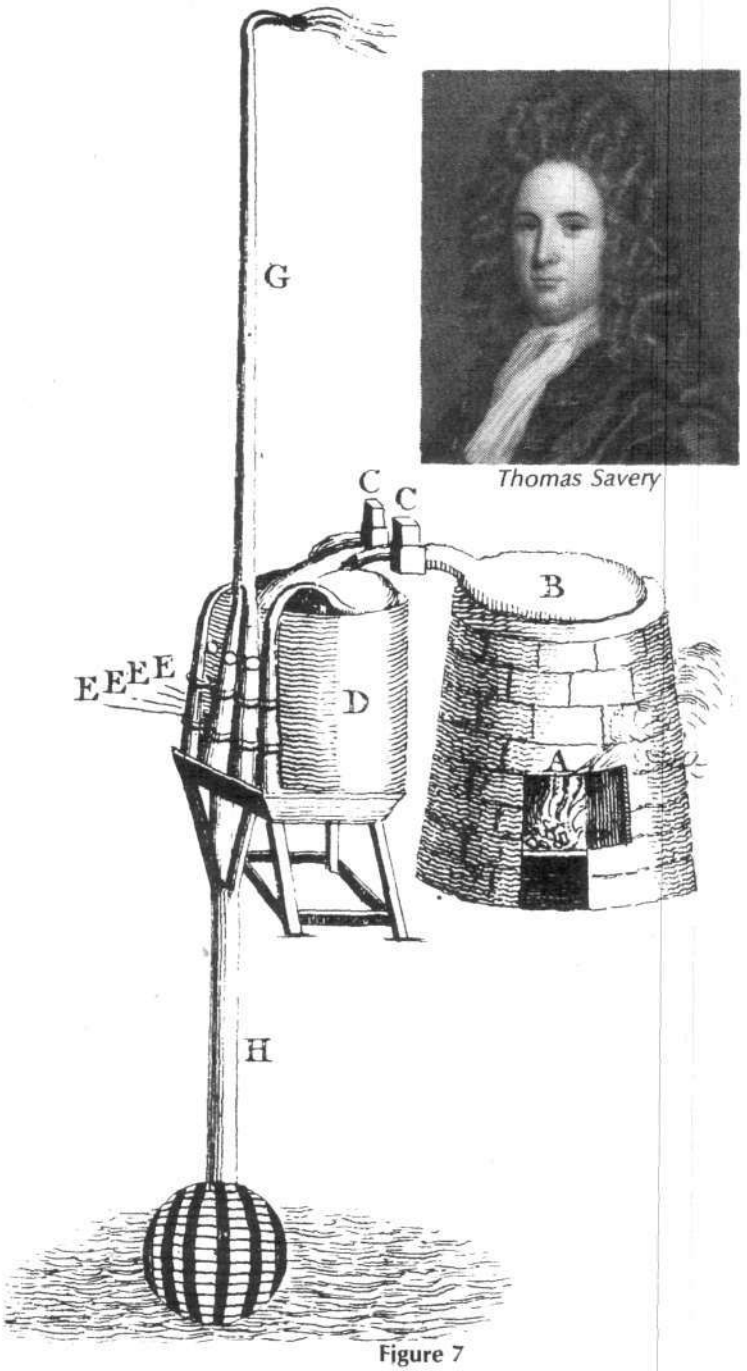
Although news of Savery's patent reached Germany by 1699, it was not until 1704 that Leibniz, via "Hanoverian envoys" in London, was able to acquire some sort of description of Savery's device. Leibniz forwarded a sketch of the English "engine" to Papin, along with an evaluation of its capabilities. Based on further intelligence reports from his envoys, Leibniz concluded—correctly—that Savery's device did not work in full size.

Basically, Savery's engine consists of a chamber connected by a pipe to a source of water below and by another pipe to a separate boiler. Steam enters the chamber from the boiler; cold water is poured on the chamber, condensing the steam and thus creating a vacuum and drawing water up the pipe from below. The steam enters the chamber again, this time for the purpose of pushing the raised water out of the chamber and up another pipe. The steam is then forced to condense once again, creating a vacuum and sucking more water up from below, renewing the cycle (see Figure 7).

For Leibniz and Papin, study of Savery's design provided a unique opportunity to apply and improve their new thermodynamic principles, since Savery was proposing precisely the sort of *containment* of steam power within the conceptual and technological boundaries of mechanics that Leibniz had warned against.

Papin wrote to Leibniz describing experiments in which he had discovered that using Savery's design, an increase in the temperature of the steam actually resulted in a *decrease* of the work performed (July 23, 1705):

> I am persuaded that it will be useless to try to push water to great heights by the immediate pressure of steam: Because when the expanded steam strongly applies itself against the cold water, as is necessary to make it rise to a great height, it isn't possible to



Thomas Savery

Figure 7
THE SAVERY ENGINE

In 1699, Thomas Savery was granted an exclusive patent by the English Parliament covering all conceivable "fire engines," despite the fact that his contraption did not work in full size. Savery claimed otherwise, insisting, for example, that hot steam would not condense upon encountering the cold water in the main chamber of his "engine." Savery further insisted that no engine using a piston and cylinder could ever work because of friction. Nevertheless, Savery's design was guarded as an English state secret, until Leibniz's spies succeeded in smuggling the blueprints to Hanover in 1704.

Source: A. Wolf, *A History of Science, Technology, and Philosophy in the 16th and 17th Centuries*, (New York: The Macmillan Co., 1935).

conserve the force of the steam; but it is immediately condensed by the coldness of the water. And the hotter the steam is the more it violently pushes the valve, in such a way that the valve, being pushed as well by the spring which is behind, causes the water to become very agitated. The water thus agitated is much more likely to cool off a lot of steam than when its surface remains smooth. Thus I firmly believe that this is the reason which makes the elevation of the water decrease when the heat increases . . . .

I therefore believe that the best is to do it so that the steam doesn't directly touch the water, but that it pushes it only by the mediation of a piston which is quickly heated and which consequently only condenses a little steam. And the surface of the piston which touches the steam always stays the same, the new steam which frequently reaches it easily maintains it in a degree of heat all the more great as the steam is hot. Thus there is no fear that the machine's effect will fail to be augmented in proportion to the increase in heat. Experiment has well confirmed my conjecture . . . .

And the more I go forward, the more I wonder at how a small quantity of wood is capable of furnishing such force . . . . But . . . it would be desirable to work at that with more heat than made [now]: seeing principally that the use of this invention isn't limited to raising water, but that it could be applied very well to vehicles and to many other things where force is needed.

Leibniz fully approved of Papin's successful application of his thermodynamics, advising him not to take Savery's claims of success too seriously (Aug. 15, 1705):

> I am delighted that your fire engine advances so well, because when it is brought to perfection, I consider that it will be very useful. Also, it would be a mere trifle if only one-third of the expense would be saved, as the English author believed, since this advantage would be easily absorbed by other inconveniences which such a great alteration of machines would attract. It is very reasonable also to believe that too-diffuse steam applied directly to cold water will condense and lose its force. Consequently, it is better to keep them self-contained [*renfermées*].

According to the Royal Society myth, this sort of reasoning about the steam engine was not supposed to have occurred until about 1769, when James Watt recognized the problem of loss of force because of superfluous cooling of the steam and invented a separate condenser. Watt was motivated in this invention by the knowledge that the Newcomen engine would operate much more efficiently if its cylinder was kept constantly hot while the condenser was kept constantly cold; that is, "it is better to keep them [steam and cold water] self-contained." (Interestingly, Watt was an ally of Joseph Priestley, a victim of the Crown's terror tactics because of his alliance with Continental Science.)

As for Savery and his understanding of the problem, the only written record available is a little pamphlet Savery published in 1702, *The Miners' Friend*, to interest businessmen in his invention. In the chapter titled "The Manner of Working the Engine," Savery describes how a chamber of his engine, *p*, has been filled with cold water raised from a mine, as follows:

> . . . turn the handle of the regulator from you again, and the force [of the steam] is upon the surface of the water in *p*, *which surface being only heated by the steam, it does not condense it, but the steam gravitates or presses with an elastic quality like air*; still increasing its elasticity or spring, 'till it counterpoises, or rather exceeds the weight of the water ascending in *s*, the forcing pipe, out of which, the water in *p*, will be immediately discharged when once gotten to the top . . . [emphasis added].

Incredibly, Savery claimed that the steam is not condensed at all. Since it is probable that he actually knew better, at least from his own failed attempts to scale up the device, such a statement was most likely designed to put something over on some credulous miner.

Beyond the outright fraud involved, consider the manner in which Savery attempted to explain the operation of steam. In groping for some mechanical analogy, he settled for the then-popular occult cause, "gravitation," and the more traditional alternative, "elastic quality." Of course, this primitive mechanical outlook imposed itself on his invention. Although the idea of somehow using the force of steam to push water directly seems to be an advance, in fact, Savery's design predetermined that the more forceful the steam the *less efficient* the engine—a point Papin proved.

As a result, Savery proposed to doom steam to play the role of the ancient horse-driven windlass (hoist) and pulley, slowly *pulling* water up one pipe and *pushing* it out of another, with one significant difference—Savery's "fire engine" was much more expensive.

Savery's fraud was recognized as such by crafty miners and his engine was used mostly to raise water for the fountains of more wealthy aristocrats. As even the British historian A. Wolf admits, "It was costly and dangerous, so the mine owners stuck to horses."

Savery included an interesting comment on ships in his second chapter, "Of the Uses That This Engine May Be Applied Unto," indicating that it apparently had been made clear in England that the authorities would frown on any drastic technological advance in this area. As Robert Fulton later understood, a successful steamship could be the greatest threat to continued Anglo-Dutch commercial and naval superiority.

Savery fearfully noted, "5. I believe it may be made very useful to ships, but I dare not meddle with that matter, and leave it to the judgment of those who are the best judges of maritime affairs."

A few pages later, he added, "As for fixing the engine in ships, when they may be thought probably useful, I question not but we may find conveniency enough for fixing them."

These two timid passages constitute the totality of published British commentary on the steamship during most of the 1700s. Meanwhile, Leibniz had become fully committed to seeing a steam-powered vehicle perfected and built within his lifetime—whether a steam boat, a steam carriage, or an airplane. But while Savery and his colleagues could obstruct science at their leisure in the relative peace and quiet of Gresham College, Leibniz and Papin struggled to advance science as rapidly as possible, living in the direct line of march of an invading French army.

War Pressures

Leibniz had barely dissuaded Papin, pressured by the war situation, from accepting a Royal Society invitation to take up his old post as curator of experiments—an offer made to him, interestingly enough, just after Parliament had granted Savery his exclusive patent in 1699. If Papin had gone to England at that point, all of his experiments in steam power would have come under Savery's legal control.

The situation was so unsettled in Germany that Papin was afraid to visit Leibniz in Hanover for fear that his family would be caught alone in a French attack. He concluded that no continued scientific progress would be possible without an end to the war. He wrote to Leibniz in 1702 describing his experiments with a ballistic air pump capable of throwing "a weight of 2 pounds to a distance of 40 feet" and designed eventually "to facilitate the capture of the strongest [French] positions." Papin argued that this invention not only would help bring peace, but also would be the best enticement for princes and generals to support further research into steam technology.

After a year of strenuous efforts to interest the leaders of the anti-French alliance in his invention, Papin reported to Leibniz (Feb. 25, 1704), "It has been possible since then to receive a reply neither from England nor from Holland; therefore all that I can conclude is that there is only some secret reason why no one wants to accept my proposal."

Leibniz continued to maintain friendly pressure on Papin throughout 1704, insisting that he resume research into applying violent force (particularly that of gunpowder) to the propulsion of ships and to carriages, if not to airplanes. Leibniz argued that such a breakthrough would have the greatest world strategical impact:

> Yet I would well counsel [you], Monsieur, to undertake more considerable things which would force [*forçassent*] everyone to give their approbation and would truly change the state of things. The two items of binding together the pneumatic machine and gunpowder and applying the force of fire to vehicles would truly be of this nature.

Papin finally agreed, and in a letter March 13, 1704 he revealed that he had already built a model paddlewheel boat "which can carry about 4,000 pounds" and that he

had developed a complete theory of rowing "which can also be applied to land vehicles."

By January 1705, Papin had received Leibniz's sketch of Savery's engine. Of course, this had the expected effect on Papin's thinking, as well as on the attitude of the Landgrave of Hesse who took a renewed interest in Papin's work. In March, a newly self-confident Papin wrote to Leibniz:

> I can assure you that, the more I go forward, the more I find reason to think highly of this invention which, in theory, may augment the powers of Man to infinity; but in practice I believe I can say without exaggeration, that one man by this means will be able to do as much as 100 others can do without it. All that I've done up until now has only been to discover the characteristics of this machine and the different symptoms to which it may be subject [a reference to the analysis of the thermodynamic efficiency of Savery's device discussed above]. But Monseigneur from now on wants to apply it to some real use, and his Highness gave me the honor of commanding me to apply this force to turn a mill to grind wheat . . . . And if after the mill we can proceed to apply this invention to ships [*voitures par eau*], I would believe this discovery incomparably more useful than finding longitudes on the ocean, which has been sought for so long.

By the end of 1706 Papin's experiments had convinced him of the explosive strategic potential of steam technology, which he expressed by an analogy to alchemy in a letter to Leibniz:

> Yet it's a great shame that the things from which the Public could derive such considerable usefulness aren't impelled by heat. Because the advantages which this invention could furnish for sea-going vessels alone, without counting those of land vehicles, would be incomparably greater than all expected from the transmutation of metals.

A Genuine Steam Engine

What Papin achieved within two years of receiving Leibniz's sketch of the Savery device was a genuine direct-action steam engine capable of being immediately applied to ships. Papin's engine successfully incorporated the dynamical innovations of 40 years of research that began with the project initiated by Huygens in Colbert's Academy. This achievement is fully documented in Papin's 1707 treatise, "New Method of Raising Water by the Force of Fire," published in Latin and French at Cassel. (This booklet is available today in select university libraries because someone in France had the foresight to reprint 250 copies of it in 1914.)

Papin's engine, shown in Figure 8, works as follows, with each step representing an innovation as a result of dynamical considerations. The engine is to be situated such that there is a constant flow of water into the pipe *G*. In this way, the water to be pumped enters the cylinder *DD* through *H*; the piston *FF* is then raised to the top of the cylinder by the weight of the water.

(1) The copper vessel *AA*, which Papin calls the *retort*, is completely enclosed in a furnace, not shown. The furnace is designed to allow the fire to completely surround the retort, with precautions made to guarantee minimum loss of heat to the outside air.

(2) The retort is supplied with a safety valve *ab* to allow a maximum controlled increase in steam pressure. The robinet, or spigot, *E* is opened, allowing the high-pressure steam to rush into the cylinder.

(3) The opening *L* and the receptacle *II* are provided to allow insertion of hot irons in order to increase the violence of the steam, which is allowed to reach a controlled maximum with attention to the second safety valve *ab*.

(4) The fulminating, expanding steam acts directly against the cold water through the mediation of the piston *FF*, arranged so that the surface of the piston encountering the steam remains hot, while the opposite surface remains relatively cold. The action of the steam on the piston forces the water out through *H* and up through the valve *T*, into the closed vessel *NN*. As *NN* fills with water, the air within *NN* is compressed.

(5) The compression of the air in *NN* is allowed to increase until the robinet at the lower right of the vessel is opened, allowing the raised water to exit forcefully through pipe *XX*.

(6) The resulting high-velocity jet of water encounters an improved paddlewheel, designed according to Papin's *Fig. 2* (shown here in Figure 8). Papin's figure illustrates the advantages of adding many more blades to a mill wheel in order more completely to convert the energy of high-velocity water into rotative motion—the essential concept of a turbine engine.

With this design, technology entered a new, dynamic universe. In a certain sense, it represents a *transition*, in that modern thermodynamic principles are applied to the ancient task of turning a water wheel. However, Papin intended immediately to apply his new engine to power the model paddlewheel boat, which he had constructed three years earlier. Although there is no published explanation by Papin about how he planned to accomplish this, the following is a likely method:

If the engine is fixed to the lower inside hull of a ship so that the pipe *GG* passes through the hull and stands on the outside of the ship below the surface of the water, the engine could easily work to pump water to turn a paddlewheel above the ship's deck. It is also easy to imagine that a Papin well-funded and freed of the immediate pressure to raise water could have quickly figured out how to combine his 1690 design with the new engine, so that a piston rod connected to *FF* would directly transmit the force of steam to rotate an axle, without going through the unnecessary bother of raising water at all.

In the preface to his 1707 treatise, Papin gives Leibniz full credit for providing the necessary impetus to advance

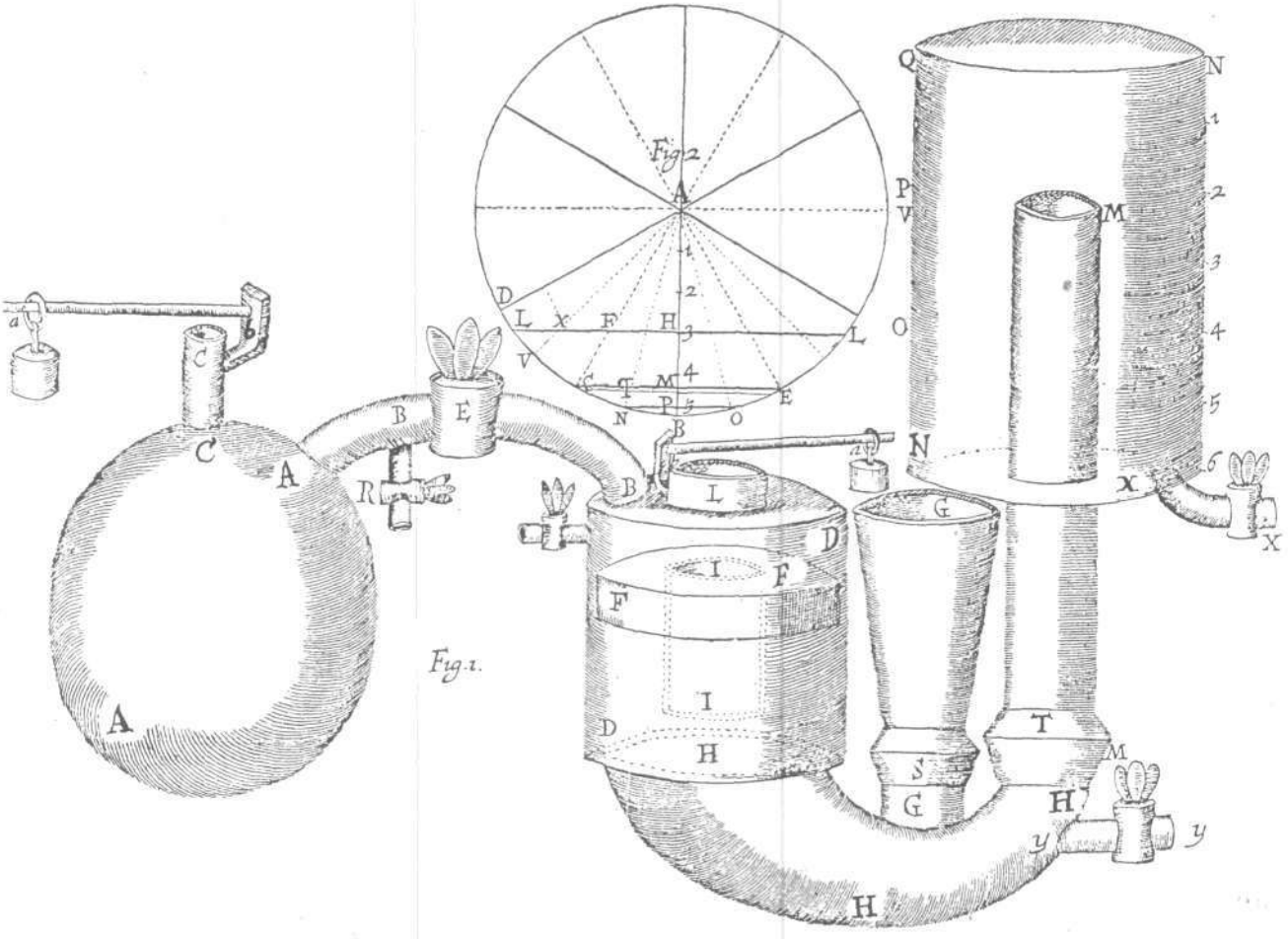


Figure 8
PAPIN'S 1707 ENGINE

Papin invented and successfully operated the world's first direct action steam engine, publishing the results of his experiments in 1707. Papin had also developed a theoretical approach to the construction of ships and to the method of rowing. His study of rowing led him to consider means of maximizing the conversion of energy from a paddle into the forward propulsion of a vessel. He had already constructed a working model paddlewheel boat based on these principles in 1704. Therefore, by 1708 Papin was prepared to combine his steam engine and his paddlewheeler and build the world's first steamboat—100 years before Fulton.

his experiments. In particular, Papin cites two crucial junctures—the 1698 discussions on harnessing the direct force of steam versus mere atmospheric pressure and the 1705 description of Savery's device that Leibniz's spies procured in London.

The quality of analysis in the treatise also shows the effect of Leibniz's firm *theoretical* commitment to live force, combined with Papin's repeated experimental vindications of Leibniz's dynamics over the past 40 years. Papin concluded the first chapter, describing the furnace enclosing the retort:

> 5. The reason which obliges us to have such a great care to augment and conserve the heat [*chaleur*] is because it is the heat which makes all the moving force in this machine. Because otherwise in ordinary pumps it is animals, rivers, the wind or some other thing of this nature which employs their force in order to drive the piston in the pump and expel the water, here it is only the heated steam in the retort *AA* which travels with violence through the pipe *ABB* whenever the robinet *E* is opened, and goes to press the piston in the pump *DD*. And the force of this steam is even greater the more we give it a higher degree of heat.

In chapter 3, Papin commented on the "means to augment the effect of the machine":

> 2. The augmentation of effect of which I have just spoken [that is, increasing the diameter of the pipes,

and so on] is a little thing in comparison to that which could be obtained in augmenting the pressure in the retort *AA*: Because that of which I've spoken until now in order to impel [*pousser*] the water to 64 or 65 feet is equivalent to only two times the ordinary pressure of air: But it's certain that the pressure may be made much greater yet; with digesters or machines to cook bones, which weren't at all completely enclosed in their furnace, as is the retort *AA* here, I sometimes achieved pressures equivalent to 11 times the pressure of air. Thus one may boldly say that the retort, being as well heated as it is and with the aid of hot irons enclosed in the pump *DD*, that pressures may be created much more than 6 times greater than that necessary to impel water to a height of 64 feet: and in such a case one man could create almost as much of an effect as 500 others who have only those inventions used up to the present.

As for Savery's design, Papin described in detail in chapter 5 how the Savery device was inferior to his own "in order that there be no misjudgment in the choice that will be made between Mr. Savery's machine and this one." First, Papin noted that since the retort *AA* is "completely in the fire, it can be heated much more promptly and at less cost than the two vessels that Mr. Savery calls *boillers*."

Second, Papin noted that his piston system ensures that the "steam loses none or very little of its force," compared to the condensation that occurs in the Savery device. Third, Papin described his improvement that "allows the water to enter by its own weight into the pump *DD*, and not by suction" and said, "without this correction, the inconveniences of which I've spoken about in this section would be enough to render the machine completely useless." Fourth, Papin noted the improvement of introducing hot irons to increase the "violence" of the steam. Then, "in order to incontestably prove that the piston *FF* is necessary to raise water to any considerable height," Papin reported that Savery's method completely failed to pump water "into air which had been a bit compressed. . . . Instead, a good effect is always created with the piston, even if the resistance of the compressed air in *NN* is 10 or 12 times greater than that which was impenetrable without the help of the piston."

Leibniz wasted no time in beginning the process of improving Papin's design. In his last published letter to Papin (Feb. 7, 1707), Leibniz not only suggested that the engine be made completely self-acting, and thus more appropriate to moving vehicles, but also proposed practical means of still further increasing the thermodynamic efficiency of the engine by the ingenious use of the so-called waste heat:

> I maintain that for stationary machines or for seagoing vessels, it will be difficult to make anything better along similar lines. . . .
>
> I have a thought that perhaps will not displease you, which is to efficiently use the still-hot steam which leaves the pump when the piston is pushed up. Because it would be a great shame to lose it entirely. I imagine that in leaving it yet has much heat, and enough force to issue forth despite the outside air . . . . Then to make good use here of heat, otherwise superfluous, and at the same time of compressed air, in a manner which perhaps has never been used, I would make a sort of mantle or case *ZZ* around your vessel *QN*, partly filled with compressed air; and within this case I would let the steam enter in such a way that before it streams powerfully into the open air it would be between the case and the vessel. And while it warms this vessel it would as a result contribute towards the work of the compressed air contained therein. I believe that this will be a redoubling of the force . . . . and thus a mediocre vessel *QN* would make a much greater effect. Because it is already certain that heat gives as much force to ordinary air as does compression, and the same heat would give double or triple to compressed air . . . . The continual passage of hot steam would make this vessel extremely hot, almost as if it had been placed on a fire.
>
> I have always had the thought that a great effect could be made and much force placed in a small volume by means of air strongly compressed and then heated. This would be of great use for machines which must be portable.
>
> To say nothing of the superfluous heat of the furnace and the smoke which emerges from it which can be similarly useful among other ways by heating the water of the funnel *G* and of the tube *H* in order that the coldness of this water harms less of the heat in the pump *D* or in the vessel *QN*. . . . Furthermore, I have no doubt that you could, if you so desired, easily arrange that the robinets *E* and *n* are alternately open and closed by the machine without having to use a man for this.

Increased Harassment

Although Leibniz and Papin had succeeded in bringing modern dynamical technology into being, making the industrial transformation of society possible for the first time, they were working within an increasingly aversive environment. Leibniz's persistent international efforts in behalf of what he called the "Grand Design" had brought him into increasing conflict with his employer, George Lewis, the Elector of Hanover and future British King George I, who by 1706 at the latest had been won over by Charles Montague on behalf of the City of London. Leibniz considered his position in Hanover to be tolerable, and even advantageous, only because of his close relationship as a teacher to the Electress Sophia, George's mother, who until her death in 1714 was next in line to become Queen of England.

Even before the publication of his treatise, Papin had reported a sharp escalation in harassment by his unnamed enemies in Hesse. By 1706, there had been almost continual warfare in Europe for 35 years, creating conditions

favorable to the resurgence of feudalist antiscientific forces. As a result, the relative tranquility of London again became attractive to Papin, and he resolved to go to England to demonstrate before the Court and the Royal Society the incontestable superiority of his steam engine over Savery's device.

Papin's plan was to travel to London in his paddlewheel boat, rowing it by conventional means up the Weser River, through Hanover to Bremen, and across the North Sea. Once in London with his model boat and with sufficient means to build an adequate steam pump, Papin planned to operate the world's first steam-driven ship and navigate it up the River Thames. In fact, the main reason which Papin gave to the Landgrave for his desire to leave for London was that only such a seaport had sufficient depth to apply his engine to a ship.

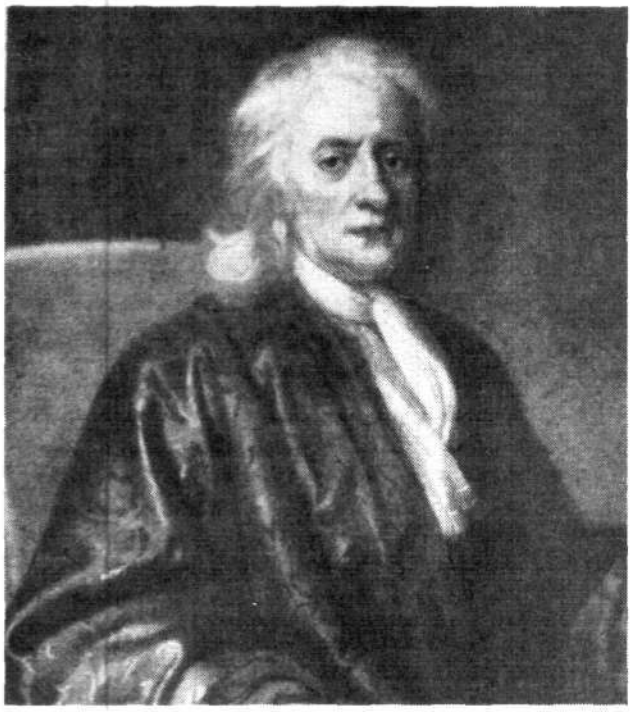
In a letter to Leibniz Sept. 15, 1707, Papin reported on the first successful test of his paddlewheeler:

> At present I will tell you that the experiment of my boat was made and that it succeeded in the manner that I had hoped of it. The force of the river's current was such a little thing in comparison to the force of my oars that it was difficult to recognize that it went faster in descending the current than in climbing it. Monseigneur had the goodness to testify to me of his satisfaction in having seen such a good effect. I am persuaded that if God gives me the grace to arrive safely in London and to make vessels there of this new construction which have enough depth to apply the fire engine to give movement to oars, I am persuaded, I say, that we may produce those effects which will appear incredible to those who will not see them.

In the same letter, Papin renewed a request to Leibniz to help obtain the required permission from the Elector of Hanover for passage up the Weser. Leibniz could expect no cooperation from George but he tried to intervene with his friends among local magistrates along the river. However, Papin got no further than Munden before encountering the ignorant opposition of the Boatmen's Guild, no doubt incited by elements of George's Court. Leibniz received the following report from an official of Munden, Sept. 27, 1707:

> Having been informed by the Doctor Papin, who, coming from Cassel, passed by this town the day before yesterday, that you are presently to be found in this Court [Berlin], I give myself the honor to advise you, Sir, that this poor man of medicine, who gave me your letter of recommendation for London, had the misfortune to lose here his little machine of a paddlewheel vessel, . . . the Boatmen of this town having had the insolence to stop him and to take from him the fruit of his toil, with which he thought to introduce himself before the Queen of England . . . .

Despite the tragic encounter with this "mob of boatmen," Papin continued on to London, only to encounter an even more vicious mob—the British Royal Society, at the time headed by president-for-life Isaac Newton and by Newton's secretary Hans Sloane.



Isaac Newton

Royal Antiscience

When he arrived in England, Papin presented a copy of his treatise to the Royal Society along with the following proposal, recorded in the *Royal Society Register*, Feb. 11, 1708:

> *Proposition by Dr. Papin, concerning a new invented boat to be rowed by oars, moved with heat*
>
> It is certain that [it] is a thing of a great consequence to be able to apply the force of fire to save the labour of man; so that the Parliament of England granted, some years ago, a patent to Esquire Savery, for an Engine he had invented for that purpose; and His Highness Charles, Landgrave of Hesse, has also caused several costly experiments to be made for the same design. But the thing may be done several ways, and the machine tryed at Cassel differs from the other in several particulars, which may afford a great difference in the quantity of the effect. It will be good, therefore, to find out clearly what can be done best in that matter, that those which will work about it may surely know the best way they are to choose. I am fully persuaded that Esquire Savery is so well minded for the public good, that he will desire as much as any body that this may be done.
>
> I do therefore offer, with all dutyfull respect, to make here an Engine, after the same manner that has

been practised at Cassel, and to fit it so that it may be applied for the *moving of ships*. This Engine may be tryed for an hour and more, together with some other made after the Saveryan method. The quantity of the effect should be computed both by the quantity of water driven out of each machine, and by the height the said water could ascend to . . . .

I wish I were in a condition to make the said Casselian Engine at my own charges; but the state of my affairs does not [allow] me to undertake it, unless the Royal Society be pleased to bear the expense of the Vessel called *Retort* in the description printed at Cassel; but after that I will lay out what is necessary for the rest, and I will be content to lose that expense, in case the contrivance of the Landgrave of Cassel doth not as much again as that of Esquire Savery; but in case the effect be such as I promise it, I do humbly beg that my expense, time and pains, may be paid, and I reckon this to amount to 15 pounds sterling. If the Royal Society be pleased to honor me with their commands upon such conditions, the first thing to be done is to let me see the place where the Machine must be set, and I will work for it with all possible diligence and I hope the effect will yet be much greater than I have said: [emphasis in original].[4]

By 1708, the Royal Society had abandoned even the pretense of scientific inquiry, and so its attitude toward Papin's proposal (as well as others) for real technological advance was predictably negative. In Papin's case, the repeated mention of the name Leibniz in his treatise was sufficient to trigger Royal Society killer instincts.

The *Transactions of the Newcomen Society*, Volume 17 (1936-37), contain a succinct account of the fate of Papin's proposition:

> Papin, then at Cassel, submitted with his paper, a request for fifteen guineas to carry out experiments, but the Royal Society, like our own, did not hand out fifteen guineas at a time. Instead, *the matter was referred to Savery in 1708, and in his letter of criticism turning down Papin's design there is a passage in which he damned the cylinder and piston, saying it was impossible to make the latter work because the friction would be too great!* [emphasis added].[5]

Even the Newcomen Society found it necessary to punctuate this account with an exclamation mark.

Papin then argued for his proposal before Newton himself, who rejected it on the pretext that it would cost too much. Papin was then stranded in England without any means of support, completely at the mercy of Newton, Sloane, and Savery, whose exclusive patent covering all conceivable "fire engines" was still in effect. Papin's 1707 "Proposition" was thus the last heard of any practical plan for a steamship or for any application of steam power besides pumping mines until well after the American Revolution.

No record remains of Papin's subsequent activity in England besides a mere seven letters to Sloane, mostly repeated requests for money to carry out a variety of experiments. In his last letter to Sloane, Jan. 23, 1712, Papin complained that a number of his inventions presented before the Royal Society had deliberately not been registered under his name:

> So there are at least six of my papers that have been read in the meetings of the Royal Society and are not mentioned in the Register. Certainly, Sir, I am in a sad case, since; even by doing good, I draw enemies upon me. Yet for all that I fear nothing because I rely upon God Almighty.

The Newcomen Fraud

In 1712, Papin apparently vanished without a trace, not even a death notice. That same year, the witchhunt against the Leibnizians was reaching frenzied heights on the Continent as well as in England, and Thomas Newcomen suddenly appeared to build his fabled fire engine "near Dudley Castle."

Newcomen's engine was simply a scaled-up atmospher-

The Newcomen Society Versus the American System

Although the Newcomen Society was founded in 1920 in England (and three years later in the United States) with the aim of promoting U.S.-British friendship, its real purpose has been to lobby against the American System.

In the tradition of the myth of the Newcomen steam engine, the Newcomen Society has tried to get the country to adopt policies that would make American industry vulnerable to the kind of economic disintegration we are now seeing. This aim has been hidden behind the nice-sounding concept of *free enterprise*. As used by Newcomen, this is the idea that each industry or individual like Newcomen, (if he existed) progressed because it stumbled upon good ideas and developed them by hook or by crook, unfettered by scientific theory or by a national purpose. There is no mention of the national credit policy stressed by the Founding Fathers to create the infrastructure necessary for fostering industrial growth.

The results of this free enterprise ideology can be seen all too graphically in the inability of U.S. industry to come up with a coherent counter strategy to the "controlled disintegration in the world economy" promoted by the Council on Foreign Relations, and its members in the Carter administration (see *Fusion*, October 1979 for details).

The author has invited the Newcomen Society to comment on this article, an event which Fusion *columnist Ben Franklin is greatly looking forward to.*

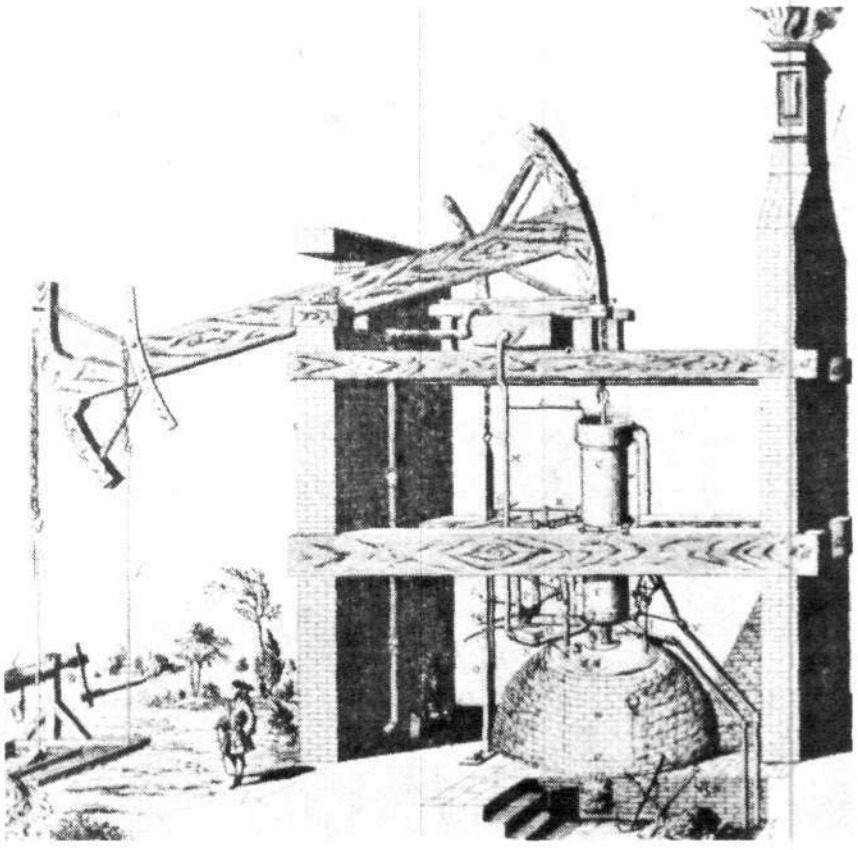


Figure 9
NEWCOMEN'S ENGINE
British historical tradition maintains that Denis Papin mysteriously "drifted into obscurity" in England in 1712. That same year, the "ironmonger" Thomas Newcomen allegedly erected his first engine (shown), limited to pumping water from mines. British historians insist that Newcomen acted entirely alone and that he had no contact whatsoever with any scientist or scientific principles, his work being based exclusively on trial and error ("hypotheses non fingo").

Newcomen published nothing, his exact date of birth and educational background are unknown, and no one knows what he looked like because none of his contemporaries bothered to paint or sketch his portrait. His only extant writings are a few scraps of personal letters to his relatives.

ic steam pump that was based completely on a combination of two of Papin's earlier ideas: (1) the use of steam to create a vacuum and drive a piston (1690); (2) the use of a lever mechanism to transmit power from one pump to another (1687).

In Newcomen's atavistic design, steam enters a cylinder under a piston from a separate boiler (see Figure 9). Cold water is poured over the cylinder or is sprayed inside of it, condensing the steam and creating a vacuum; the piston is forced downwards by atmospheric pressure. In turn, a piston rod pulls down one end of a balance beam that operates an ordinary mine pump attached to the other end of the beam and placed down a mine shaft. Steam reenters the cylinder, merely counterbalancing atmospheric pressure; the piston is then raised back to the top of the cylinder by the weight of the water pump apparatus and the cycle is repeated.

Compared to the level of conception and design achieved by Papin, Newcomen's "exotic lever" is manifestly primitive, a great step backwards. Not only is the force of the engine limited to mere atmospheric pressure, and the design limited to raising water from mines, but Newcomen still insisted on alternately cooling off and heating up the same cylinder, wasting tremendous amounts of steam and consuming massive quantities of fuel. For this reason, his engine was used mainly by owners of coal mines who could afford the fuel. Despite admissions in black and white that Papin was indeed the first to publish the idea of a piston/cylinder atmospheric engine using steam, British historians insist on raising the question, "Did Newcomen know of Papin's work?" To salvage the Newtonian ideology of *hypothesis non fingo*, these mythmakers manufactured an impossible story to the effect that Newcomen lived in total isolation in a small town in "far-off Devonshire." Thus all theory, all science, all metaphysics must have been irrelevant to Newcomen's "invention of the steam engine," the story goes. Since there is no direct first-hand evidence that Newcomen knew anything of the work of "foreigners," Londoners included, these historians argue that this uneducated, "practical" mechanic must have acted alone.

This argument, of course, obscures the fact that there is no direct first-hand evidence that Newcomen knew anything at all and that there is barely enough evidence to allow one to conclude that Newcomen really existed. In fact, there is more written evidence that Newcomen knew of Papin's work than there is written evidence about almost anything else in Newcomen's life.

Volume 17 of the third edition of the *Encyclopedia Britannica*, published in Edinburgh in 1797, contains an article on the steam engine written by Dr. John Robison that is one of the earliest British efforts at rewriting the history of steam technology. Robison, whose political works are favorably reviewed today by the John Birch Society, crudely slandered Papin:[6]

> Papin made many efforts to employ this force [of steam] in mechanics, and even for raising water. It appears that he had made experiments with this view in 1698, by order of Charles Landgrave of Hesse. For

this reason the French affect to consider him as the inventor of the steam engine . . . . Whoever will take the trouble of looking at the description which he has given of these inventions . . . will see that they are most awkward, absurd, and impracticable. His conceptions of natural operations were always vague and imperfect, and he was neither philosopher nor mathematician.

Robison even lied that "Papin's first publication was in 1707," all for the purpose of protecting the mythical British steam invention. However, in trying to concoct some sort of explanation for Newcomen's apparent achievement, Robison was compelled to admit that Papin did indeed influence Newcomen, if even only indirectly. Robison claimed that Dr. Robert Hooke, Fellow of the Royal Society, had written a letter to Newcomen critical of Papin's "boasted method of transmitting to a great distance the action of a mill by means of pipes" (the pneumatic transmission of power).

Robison explained:

> It would appear from these notes that Dr. Hooke had dissuaded Mr. Newcomen from erecting a machine on this principle of which he had exposed the fallacy in several discourses before the Royal Society. One passage is remarkable. "Could he (meaning Papin) make a speedy vacuum under your second piston, your work is done."
>
> It is highly probable that in the course of this speculation it occurred to Mr. Newcomen that the vacuum he so much wanted might be produced by steam and that this gave rise rise to his principle and construction of the steam engine.

This fanciful account was accepted by historians until 1936, when someone decided that even Robison's story ought to be officially discredited and that any mention of Papin should be eliminated from history. This task was undertaken by the Newcomen Society, then 15 years old, which assigned a member to visit the Royal Society archives and look for the "notes of observations" prepared by Hooke for Newcomen that Robison mentioned. Sure enough, more than 240 years later, no paper by Hooke mentioning Newcomen could be found, although the Newcomen researcher noted that "there was another paper on the same subject (Papin) in similar language, which looked like the draft of a letter to someone, but there was no name or address, only a date."

On this bit of evidence stands the Newcomen Society's claim that Thomas Newcomen not only invented the steam engine but "may truly be designated the founder of the Industrial Revolution."[7]

With this scanty information on Newcomen in mind, I'll review the Papin history:

(1) Papin had been a Fellow of the Royal Society since 1680.

(2) He lived in London for nine years between 1676 and 1687.

(3) He published close to 20 articles in the *Philosophical Transactions* of the Royal Society between 1675 and 1687.

(4) In the years 1684-1687, Papin submitted more than 100 reports to the Royal Society in his capacity as curator of experiments, many of them later published in England.[8]

(5) Papin's 1690 Latin article on the atmospheric steam engine was reproduced in his 1695 pamphlet "Recuil de Diverses Pieces touchant quelques nouvelles Machines," which, in turn, was prominently reviewed in the *Philosophical Transactions* of the Royal Society in 1697. (The Newcomen Society concedes that Newcomen himself probably read this review.)

(6) Papin published more than 40 articles in a variety of European scientific journals from 1682-1707, including five separate pamphlets.

(7) Papin returned to England for at least four years, 1708-1712, during which time Papin and his life's researches effectively became the property of the Royal Society.

(8) The legally recognized "inventor of the steam en-

Robert Fulton and the American System

An American lithograph of Fulton and Napoleon in 1804

gine," Thomas Savery, was a demonstrable fraud, and certainly could be of no help to Newcomen since he had condemned the whole idea of a piston/cylinder engine in 1708.

There is no way to avoid the conclusion that the British knew Papin very well—well enough to recognize his work as a political and conceptual threat, closely tied to the fight for human progress waged on the Continent by Leibniz. The calculated result was a near 100-year containment of steam technology, overcome only in the aftermath of the American Revolution—a revolution whose European allies established at the Ecole Poytechnique in France and Göttingen University in Germany, the intellectual centers that continued and advanced the mathematical physics of Leibniz.

The lesson of the steam engine should be evident to today's supporters of advanced technology. The fight is still on and the supporters of nuclear power have to recognize and overcome the same kinds of overt and covert obstacles that were used against Papin.

Philip Valenti, a mathematician, became interested in the story of steam power development during the course of a comparative study of Newton and Leibniz's calculus and philosophy. His is the first English translation of the Papin-Leibniz letters and Papin's 1707 work on the steam engine.

Notes

1. Friedrich Klemm, *A History of Western Technology* (Cambridge, Mass.: MIT Press, 1964).
2. *G. W. Leibniz Selections*, ed. Philip P. Wiener (New York: C. Scribner, 1951).
3. *Gottfried Wilhelm Leibniz: Philosophical Papers and Letters*, ed. LeRoy E. Loemker (Chicago: University of Chicago Press, 1956).
4. *Leibnizens und Huygens's Briefwechsel mit Papin*, ed. Dr. Ernst Gerland (Berlin: Verlag der Koniglichen Akademie der Wissenschaften, 1881).
5. Rhys Jenkins, "The Heat Engine Idea in the 17th Century," *Transactions of the Newcomen Society*, Vol. 17, pp. 1-11, (1936-37).
6. Robison's more well-known work that same year was a Tory propaganda sheet that blamed the Jacobin terror in France on the Freemason circles associated with republicans Lafayette and von Steuben, both of whom fought the British in the American Revolution.

Robert Fulton, the American inventor, brought many of Papin's inventions to fruition more than 100 years later, including the steamship and the submarine, with the added feature of the torpedo. Like Papin, Leibniz, and the American patriots who developed the American System in opposition to British Malthusianism, Fulton was a republican who identified labor power, the human mind, as the real source of a nation's wealth.

In 1798, Fulton made two proposals to the French Republic, one for developing small canals to improve French industry and a second for quickly breaking British naval superiority in order to guarantee "an entire liberty of Commerce."

In a letter to Napoleon Bonaparte May 1, Fulton wrote:

"These plans of improvement and my reflections upon Commerce are elaborations of the following ideas, which I regard as the basis of political welfare, and which seem to me worthy of the consideration of all republicans, and all friends of humanity. Labor is the source of wealth of all kinds; it follows that the more numerous the industrious and useful class, the more a country should gain in riches and comfort. It is therefore to the interest of each nation to draw from its natural advantages every feature possible. To that end Governments must apply themselves above all to internal improvements and seek continually to increase the number of useful individuals; only by eliminating as far as possible the causes of war will men be enabled to devote themselves to industrious works and reduce mendicancy . . . .

"If success crowns the efforts of France against England, it will only remain for her to terminate this long war gloriously by granting freedom to trade and by compelling other powers to adopt this system. Political liberty would thus acquire that degree of perfection and of scope of which it is susceptible and Philosophy would see with joy the Olive Branch of Eternal Peace sheltering Science and Industry."

Fulton's specific proposal for defeating England involved the use of his submarine (*Nautilus*) and torpedo design. On October 27, Fulton proposed to the French Directory, then headed by Lazare Carnot, the scientist and military engineer:

"From the report of the Commissioners named by the Minister of Marine it would appear that the machine and the means which I have proposed to destroy the English fleet are pronounced to be practicable. Permit me then to recall to your consideration the consequences which should result from the success of this enterprise. The enormous commerce of England, no less than its monstrous government, depends upon its military marine. Should some vessels of war be destroyed by means so novel, so hidden and so incalculable, the confidence of the seamen will vanish and the fleet rendered useless from the moment of the first terror. In this state of affairs the republicans in England would rise to facilitate the descent of the French or to change their government themselves without shedding much blood and without any expense to France. With England republicanized, the seas will be free. The liberty of the seas will become a guarantee of perpetual peace to all maritime nations."

New York Historical Society, New York City

Robert Fulton in a self-portrait

7. See Thomas Birch, DD., Secretary to the Royal Society, *History of the Royal Society*, a four-volume supplement to the *Transactions of the Royal Society* published in 1757.
8. Standard reference works now include the updated Newcomen myth. For example: "At the end of the 18th century John Robison propagated the belief that Newcomen's achievement somehow depended upon the applications of scientific principles gained through an alleged correspondence between Newcomen and Robert Hooke . . . . Robison's allegation has been discredited; the records reveal no contact whatever between Newcomen and his contemporaries in science. His invention was a product of a familiarity with technological operations and needs in the mining industry, a close knowledge of contemporary craftsmanship, repeated trials and improvements, and a stroke of luck." (The source is Harold Dorn of Stevens Institute of Technology, writing on Thomas Newcomen in the *Dictionary of Scientific Biography*, Vol. 10, published by the Charles Scribners Sons for the American Council of Learned Societies in 1975.)

Selected References

D. S. L. Cardwell. 1972. *Turning Points in Western Technology*. New York: Science History Publishers.

Heinz Gartmann. 1960. *Science As History*. London: Hodder and Stoughton.

James Patrick Muirhead. 1858. *Life of Watt*, London: J. Murray.

D. Papin. 1707. *Nouvelle Maniere Pour Lever L'Eau par la Force du Feu*. Paris: Cassell (reprinted in France, May 25, 1914).

L. T. C. Rolt. 1963. *Thomas Newcomen*. London: Macdonald.

Thomas Savery. 1702. The Miners' Friend (republished in London: 1829).

Robert H. Thurston. 1878. *A History of the Growth of the Steam Engine*. New York: D. Appleton & Co.

Abraham Wolf. 1935. *A History of Science, Technology, and Philosophy in the 16th and 17th Centuries*, New York: MacMillan Co. 1938. *A History of Science, Technology, and Philosophy in the 18th Century*, London: G. Allen & Unwin Ltd.

Chronology: Steam Power Versus The Royal Society

1666:
Louis XIV's Minister Jean Baptiste Colbert establishes the Academy of Sciences at Paris, appointing the Dutch scientist Christiaan Huygens as the academy's president. Huygens's program includes "research into the power of water converted by fire into steam."

1672:
Papin and Leibniz join the Academy.

1673:
Huygens successfully demonstrates his gunpowder-fueled engine, suggesting that his invention: "permits the discovery of new kinds of vehicles on land and water. And although it may sound contradictory it seems not impossible to devise some vehicle to move through the air."

1675:
Leibniz completes his development of the differential calculus. Anti-Colbert factions force Papin, Leibniz, and later Huygens to leave France.

1680:
In London, Papin continues research into control of high pressure steam; he invents the steam pressure cooker and safety valve.

1687:
Papin proposes the pneumatic transmission of power from water wheels near rivers to remote regions in order to facilitate the rapid spread of industrialization.

1690:
The Steam Age begins with Papin's invention of the atmospheric steam engine; Papin proposes its application to powering a paddlewheel-driven ship.

1692:
Papin and Leibniz begin intensive correspondence.

1695:
Papin publishes a summary of his inventions, including the Hessian bellows, an improved furnace designed to multiply efficiency, the pumping of mines using the pneumatic transmission of power, the atmospheric steam engine, and the "plunging boat" (submarine).

1697:
Papin's summary is reviewed in the *Philosophical Transactions* of the British Royal Society and circulated throughout England.

1698:
Papin constructs a steam-powered atmospheric pump. Leibniz and Papin begin the project of harnessing the *direct force* of high pressure steam; Papin constructs "a little model of a carriage that is moved forward by this force."

1699:
Thomas Savery is awarded an exclusive patent for the "fire engine" by the English Parliament.

1704:
"Hanoverian envoys" to London smuggle Savery's blueprints back into Germany; Leibniz concludes—correctly—that Savery's design could not work in full size.

1707:
Papin publishes a complete account of his direct action steam engine, and tests it successfully against Savery's design.

1708:
In London, Papin proposes that the Royal Society allocate 15 pounds sterling to allow him to construct his engine "and to fit it so that it may be applied for the *moving of ships*. This Engine may be tried for an hour and more, together with some other made after the Saveryan method." Royal Society president-for-life Isaac Newton, backed by Savery, rejects Papin's proposal.

1708-1712:
The Royal Society appropriates Papin's researches without remuneration.

1712:
Papin "disappears." The first Newcomen engine, limited to pumping water from flooded mines, is erected.

1807:
American artist, inventor, and diplomat Robert Fulton achieves the world's first successful steamship voyage with his Hudson River paddlewheeler *Clermont*. Fulton proposes that his inventions, including the submarine and the torpedo, be applied forthwith to destroy the "monstrous government" of England.

Impact Fusion

A New Look at an Old Idea

by Dr. John Schoonover

RESEARCHERS ARE TAKING a new look at the idea of impact fusion, a concept that some fusion scientists feel could soon demonstrate better than breakeven energy production with just a $20 million research investment today. The idea was first proposed in 1963 by Dr. Friedwardt Winterberg, now at the Desert Research Center of the University of Nevada.

The principle of impact fusion is quite simple. A small pellet (projectile) of some solid material is directed at high velocity toward a fuel pellet that is seated in an anvil (Figure 1). The collision produces shock waves that propagate through the fuel, compressing and heating it to the range of fusion conditions.

Most important, there are a number of advantages inherent in this method compared to the more elegant means of achieving fusion that have been under intensive investigation in laboratories around the world. As described in most discussions of fusion experiments, the major technical problems fusion researchers face involve achieving and containing fusion conditions in the plasma core using very small amounts of fusion fuel—the hydrogen isotopes deuterium and tritium. The very high temperatures required, about 30 million degrees Kelvin, and the large product of confinement time and fuel density (called the Lawson criterion), more than 10^{14} per second per cubic centimeter, rule out containment of the reaction in conventional material containers and force researchers to explore many alternative possibilities to achieve these conditions.

The best known fusion alternatives are magnetic confinement and inertial confinement. The first system uses magnetic fields to form a magnetic "bottle" in which the highly ionized fusion plasma is confined, while sufficient energy is pumped into it by neutral beams of energetic hydrogen atoms, by microwaves, or by other processes under investigation. In inertial confinement, a small pellet of liquified fuel is bombarded with highly energy-dense laser beams, electron beams, or intense beams of heavy ions, and the intrinsic inertia of the fuel keeps the com-

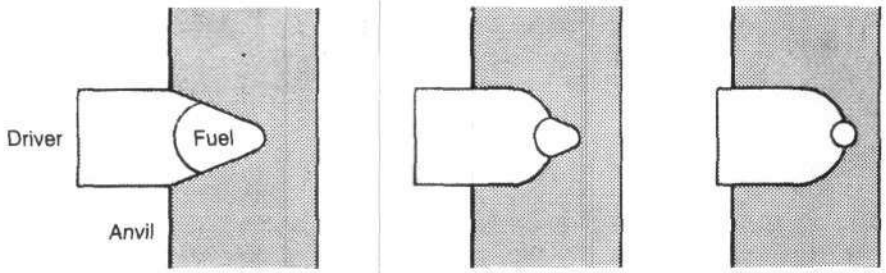


Figure 1
THE PRINCIPLE OF IMPACT FUSION

Impact fusion differs from other forms of inertial confinement fusion in that the driver—a pellet of matter with a mass in the 0.1 to 1.0 gram range traveling at a speed approaching 1 percent of the speed of light—delivers momentum directly to the fuel. In inertial confinement systems driven by laser or electron beams, energy is delivered to the surface of the fuel pellet and this must be converted to momentum for crushing the pellet by heating and ablating the surface material. In impact fusion the driver pellet slams into the anvil/fuel material and the fuel is heated and compressed to achieve the necessary conditions to initiate a fusion burn.

The time sequence in the diagram is from left to right.

pressed mixture together long enough for fusion to occur.

Both these lines of research hold great promise for solving the problem of extracting useful energy from controlled fusion. At the same time, however, both are beset with significant difficulties such as the development of superconducting magnet technology to produce sufficiently strong magnetic fields, the development of efficient highly energetic lasers, and the control of relativistic electron beams.

Impact fusion avoids some of the knottiest problems.

First, the pellet accelerator for impact fusion is simply a modified linear particle accelerator, a well-known technology from many years of high-energy physics experimental use. Second, focusing is not necessary for the pellets, so that sensitive equipment subject to damage by debris from the collison need not be placed in or near the reaction chamber. Third, although heavy ion beam techniques also use extensions of high-energy accelerator technology, there are significant difficulties still to be overcome that are associated with the tendency of the ions mutually to repel each other, and these are not found in pellet acceleration. Last, with the accelerating systems that have recently been proposed, pellets could achieve the required velocities in accelerators with lengths in the range of a few tens of meters, rather than the lengths of a few kilometers proposed for heavy ions.

At the present stage of fusion research, it is impossible to predict the ultimate form of the most practicable energy producing reactors. Consequently, just as aviation engineers traveled a long road through many design variations from the Wright brothers' first aircraft to supersonic transport, we must explore many variants of potential fusion reactor designs, and impact fusion is one of the possibilities that merits serious considerations.

The traditional concept of heat accepted by most physicists is insufficient to deal with the conditions in the high-temperature and high-density regimes associated with thermonuclear fusion. In the conventional approach, heat is viewed as an average expression of the random oscillations —kinetic energy—of bulk matter and the temperature is defined as a measure of the most likely energy of atoms in the ensemble. This is simply heat (energy) in an equilibrium state of high entropy. The pressure of such an ensemble is uniformly distributed in all directions, as is the direction energy travels from the ensemble.

For efficient energy deposition in a fusion fuel pellet, the directionality of the heat must be shaped. That is, the heat content of the matter must appear not as a random high-entropy distribution of molecular motions, but as a highly directional, low entropy, and perhaps even thermodynamically cold motion of the whole ensemble.

Implosion Physics

The impact fusion approach is unique in that it delivers the required momentum for implosion to the fuel pellet. In the other inertial confinement techniques—laser, electron, or ion beams—momentum for the implosion is developed by heating the pellet surface layers, which ablates material and thus provides the momentum needed to crush the fuel pellet.

A projectile with a mass of 0.1 grams traveling at a speed of between 10^7 and 10^8 centimeters per second, about 0.1 percent of the speed of light, carries the necessary energy in the range of 1 to 10 million joules to ignite a fusion fuel pellet. The projectile hits the fuel, which is lodged in a conical cavity in a relatively large anvil, to take one example. The collision sets up a shock wave that propagates through the fuel at the velocity of sound for the material, heating it as it passes (Figure 2).

As the projectile is imbedded into the cavity, it compresses and further heats the preheated fuel to achieve the density necessary for fusion. For preheating to occur, it is important that the sound velocity be greater than the compression velocity. Fortunately this is the case.

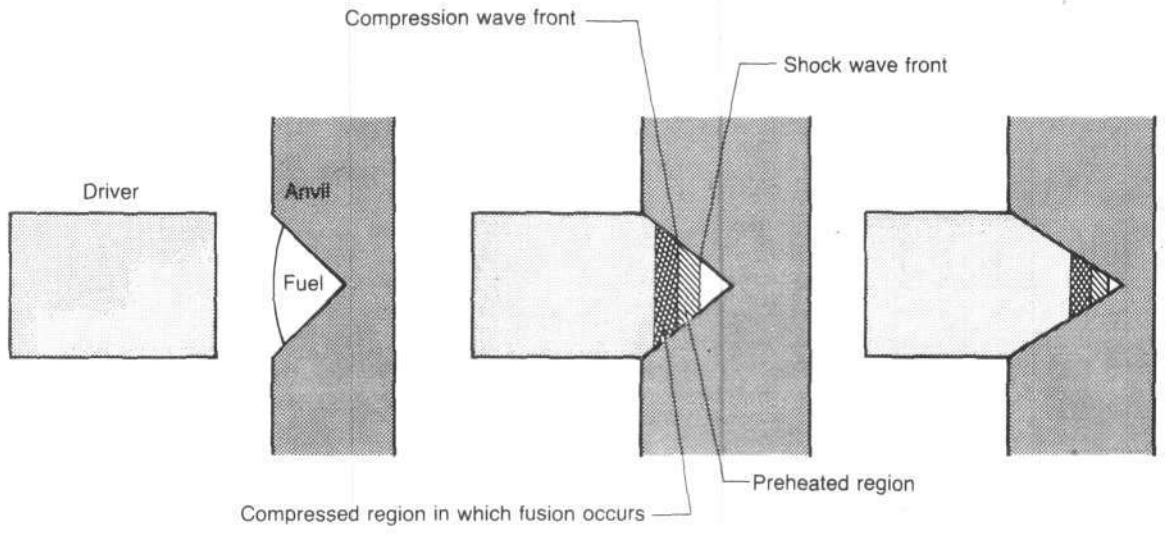


Figure 2
SHOCK WAVE PROPAGATION IN IMPACT FUSION

The conditions under which fusion reactions occur in impact fusion are achieved through a two-phase heating and compression process in the fuel pellet. On impact, the projectile generates a shock wave in the fuel material. This travels at high speed, heating the fuel as it goes. The shock is followed by a more slowly moving compression wave that further heats the fuel while increasing its density to the range in which fusion reactions occur, thus releasing tremendous amounts of energy.

The progress of these two waves is shown in the diagram moving from left to right. The preheated region behind the shock wave is shaded and the compressed region is cross hatched.

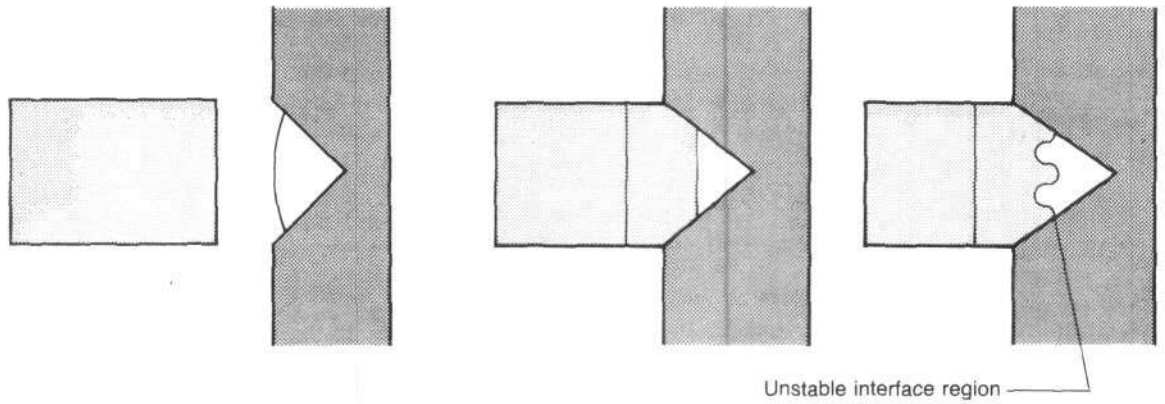


Figure 3
THE RAYLEIGH-TAYLOR INSTABILITY

In addition to the shock wave that propagates into the fuel, another shock wave passes into the material of the driver pellet. This shock wave turns the front part of the driver itself into a plasma. Since the driver plasma is made of heavier material resting on the lighter material in the fuel plasma, the interface region becomes unstable, in effect rippling. This sort of oscillation, called the Rayleigh-Taylor instability, can become progressively larger, causing material from the driver to pass into the fuel, contaminating it and inhibiting fusion. The impact fusion assembly must be designed to minimize such instability.

The fuel can lose energy in a number of ways. The most important of these is *bremsstrahlung*, the X-rays that are produced when electrons collide with nuclei in the ionized plasma during the period following preheating. To compensate for the bremsstrahlung energy loss, the fuel assembly must be designed in such a way that the energy from fusion reactions remains within the fuel mass. This is achieved by assuring that the minimum radius of the fuel after compression is greater than the range of fusion products in the compressed material.

Heat conduction by electrons escaping the fuel also carries away energy. Since the electrons have a small range in the compressed fuel, this effect is restricted to electrons near the surface and presents no significant problem.

If the anvil material has a larger atomic weight than that of the fuel—a condition that is easy to achieve since the fuel is composed of hydrogen isotopes—the initiating shock wave will be reflected rather than passing into the anvil. Consequently, this additional energy is not lost either.

One further complication of some interest arises in the implosion process. In addition to the shock wave propagating into the fuel, there will also be a shock wave in the projectile. As this latter shock wave propagates, it will also convert the region of the pellet adjacent to the fuel into a plasma. This layer, which is supported by the lower density fuel, will develop the hydrodynamic instability known as the Rayleigh-Taylor instability (see Figure 3).

The Rayleigh-Taylor instability works this way. If one were to pour a heavier liquid onto a lighter one in such a way that a smooth surface separated the two, any slight perturbation would begin to disturb this state of unstable equilibrium. At fairly rapid speed, oscillations would develop capable of carrying masses of the heavier liquid into the lighter one. The final result would be that the lighter fluid would float on the heavier.

If such a situation develops too rapidly in the implosion process, it becomes impossible to confine the fusion fuel in an effective manner. The solution to this problem is not obvious beforehand and depends on experimental trials with different fuel, anvil, and projectile shapes to determine the optimum conditions.

Macroscopic Particle Accelerators

Winterberg proposed a simple and straightforward concept for achieving the required projectile velocities in his first paper on impact fusion, published in 1964. Large numbers of quite small spheres were to be charged to the maximum amount they could withstand without breaking down. These would be introduced into a simple linear

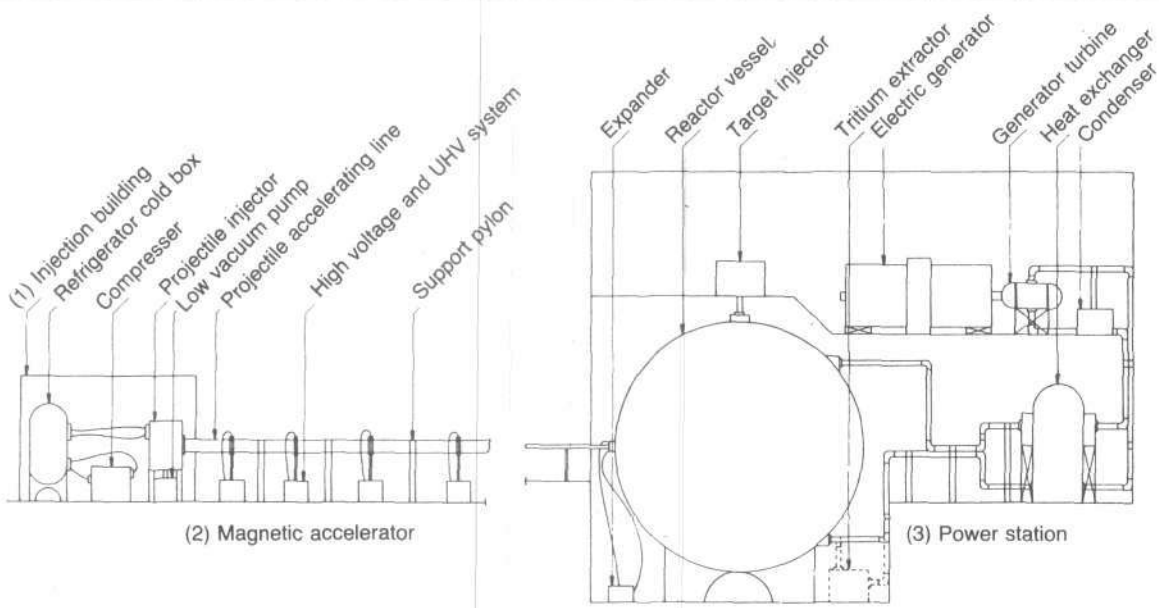


Figure 4
DESIGN FOR AN IMPACT FUSION POWER PLANT

An electric power plant based on impact fusion would be similar to plant designs for other forms of inertial confinement fusion. However, one significant difference is that impact fusion does not require the elaborate and delicate focusing equipment needed to guide laser beams, light ion or heavy ion beams, and electron beams. This design, based on the use of superconducting dipole magnet driver pellets, calls for a magnetic linear accelerator with a length in the range 1 to 2 km. The basic sections of the system shown here are (1) the injection building where driver pellets are prepared for acceleration and injected into (2) the magnetic accelerator, and (3) the power station, where fusion occurs and the energy is extracted to produce electricity or for other useful purposes.

Source: Dr. K. W. Chen, Michigan State University, June 1977.

accelerator of either the Cockroft-Walton or Van de Graff type. If larger particles are desired, more advanced linear accelerators using traveling electric fields in wave guides could be used. (For a discussion of different types of linear accelerators, see "Heavy Ion Fusion: A New Contender for Inertial Confinement" in the February 1979 *Fusion*.)

Even more promising than the electrostatic acceleration technique is the possibility of taking advantage of the properties of superconductors in constructing the projectiles. When immersed in a magnetic field, a superconductor will set up an internal magnetic field that excludes the entry of the external field into the superconducting material. This action creates a pressure on the superconductor, as evidenced in laboratory experiments in which the superconductor apparently defies gravity by floating in empty space.

If the projectiles used for impact fusion are constructed from superconducting materials, an accelerating scheme with an advancing magnetic field can be used to accelerate them. One recent design proposal by K. W. Chen of Michigan State University calls for a series of current loops that generate a local magnetic field that pulls a ferromagnetic projectile forward or pushes a superconductor that has already passed the loop, giving it increased velocity. The position of the projectile is tracked using a laser, which allows the triggering of the dipole fields to be synchronized. The field is designed to maintain the projectile in its trajectory without any transverse drift (Figure 4).

Chen's proposed projectile is a cylindrical dart several millimeters long and 4 millimeters in diameter, with a mass in the range of 0.1 to 1.0 grams. The dense core is a filler composed of uranium oxide (U_3O_8), which is surrounded by 30 layers of the superconducting material, niobium tin (Nb_3Sn). One end of the dart is a pointed cap that acts as a heat shield to protect the superconductor during flight.

After acquiring a speed in the range of 10^7 centimeters per second along a trajectory about 1 kilometer in length, the dart enters the reaction chamber through a hole just large enough to accomodate it. There is no focusing equipment nor other delicate devices in or near the reaction chamber that can be damaged by debris from the blast, which is equivalent to a ton of TNT.

Except for the simplified entry ports, inertial confinement reaction chambers designed for other driver mechanisms would be suitable for use here.

To reach the desired velocities, the two concepts described above require accelerators about 1 kilometer in length. Although construction of such an accelerator is entirely feasible and has been more than surpassed in prac-

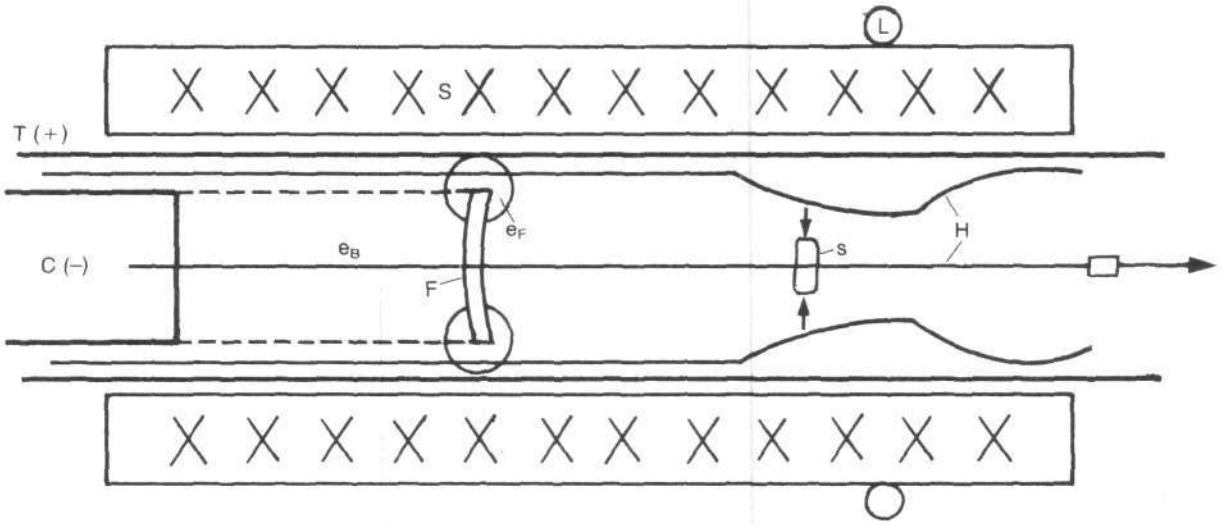


Figure 5

WINTERBERG DESIGN FOR ACCELERATING FOILS TO EXTREMELY HIGH VELOCITIES

The charged metallic foil marked F in the diagram is accelerated by repulsion from the electron cloud, e_B that is generated by the cathode, C-. A magnetic field, H, created by the solenoidal magnet windings, S, surrounding the positively charged drift tube, T+, simultaneously contains the electron cloud e_B and provides stabilization for the foil. It does this by interacting with the magnetic field generated by the circulation of the electron cloud e_F as it travels around the rim of the foil. Once the foil has attained the desired velocity, the fast discharge current loop, L, at the end of the accelerator generates a strong magnetic field pulse that crushes the foil into a slug, s, suitable for driving the fusion reaction.

tice, the concept of impact fusion becomes more attractive the smaller the accelerator and consequently the lower the capital cost to construct the device.

Last year, Winterberg announced the conceptual design for an ingenious accelerator system that would reduce the accelerator length to the range of a few tens of meters for the velocities required. In the Winterberg design, the projectile's drift tube is surrounded by a magnetic solenoid, a cylinder in which the wiring produces a magnetic field that is parallel to the cylinder axis (Figure 5).

At one end of the tube a cathode projects an intense beam of relativistic electrons into the tube. The solenoidal magnetic field acts to insulate the cathode and electron beam from the grounded drift tube by confining the electrons away from the drift tube walls. The projectile, a thin foil, is placed in front of the electron where it absorbs electrons from the beam and then is forcefully repelled before it. The strong electric field generated at the rim of the foil initially causes field emission of electrons, but the strong solenoidal field traps these in the region near the rim, stopping further field emission and creating an annular (donut-shaped) cloud at the edge of the foil.

The motion of the foil through the magnetic field generates a current in this cloud, which, in turn, provides a magnetic moment directed along the solenoidal field axis for the foil and cloud system. As a result, the foil automatically stabilizes itself against tumbling end over end along the drift tube! At the end of the acceleration phase, a fast discharge through an additional current loop generates a momentary strong magnetic field, constricting the solenoidal field and crushing the foil into the pellet before it impacts with the fusion fuel.

The Future

The prognosis for the cost of such an experiment and the construction time is quite good. For example, in a December 1978 paper titled "Magnetic-Gun Igniter for Controlled Thermonuclear Fusion," a prestigious group of scientists—R. L. Garwin, R. A. Miller, and B. Richter—summed up their findings on the superconducting dart concept as follows:

> The idea of a magnetic gun for thermonuclear ignition is not obviously absurd, and it may hold several important advantages in comparison with the particle and light-beam igniters currently being considered. Many problems remain to be solved, but we think the idea is ripe for a serious attempt at an engineering design, perhaps in conjunction with small-scale experiments to discover the most practical way to build a larger scale experiment.

The authors estimate that the magnetic gun accelerator would provide a low-cost driver for fusion reactions, and that small-scale prototypes would be quite cheap to build and test.

Current estimates in the fusion community are that a small section of a macroscopic particle accelerator, capable of attaining speeds up to 10^5 centimeters per second in about 20 meters could be built for a few million dollars. For a commercial-size installation, construction estimates for a macroscopic particle accelerator are in the range of one-tenth the cost for a heavy ion accelerator built to achieve fusion energy production.

Equally encouraging, an experimental accelerator could be built in four to five years from the time an appropriation is authorized for its construction. With parallel development of fuel pellet shapes, it is currently estimated that an impact fusion commercial reactor could be built by about 1990, or shortly thereafter.

There is one other important theoretical consideration in the development of accelerators capable of accelerating macroscopic particles to high velocities. Velocities in the range of 10^8 to 10^9 centimeters per second correspond to nucleon energies in the range 10 KeV to 1 MeV—energies at which it is possible to directly stimulate nuclear reactions. Until now, it has not been possible to cause these reactions except essentially one at a time, using the low ion fluxes available from particle accelerators and neutron fluxes from nuclear reactors.

If such reactions can be generated in bulk, as macroscopic quantities of highly energetic nucleons collide with macroscopic targets, we can look forward to seeing whole new states of highly energy-dense matter self-interactions, demonstrating the general trend of self-organizing properties well known to exist from observation of hydrodynamic and plasma phenomena.

Considering the current dismal failure of nuclear physics to understand the nature of the nucleus in terms of the linearized interactions abstracted from currently available experimental information, the kinds of results to be achieved with high nucleon density accelerators could well lead to a dramatic reconceptualization of the nucleus.

On a completely different level, the impact fusion concept may provide the kind of driver needed for practical interplanetary and interstellar manned space craft. It has long been known that the energy densities available from chemical fuels would be insufficient to achieve the high speeds and large payloads for long-distance space travel. Some form of nuclear energy has been recognized as the necessary alternative, with sequential explosions of atomic or hydrogen bombs as proposed in NASA's Project Orion seen as one answer. The impact driver, as Winterberg has discussed, could be a useful, efficient way of achieving this end.

John Schoonover is director of nuclear physics for the Fusion Energy Foundation.

References

Chen, K. W. (undated.) "Magnetic Linear Accelerator (MAGLAC) as Driver for Impact Fusion (IF)." Michigan State University internal report.

Garwin, P. L., Muller, R. A., and Richter, B. 1978. "Magnetic-Gun Igniter for Controlled Thermonuclear Fusion." Tech. Report No. JSN-77-20.

Winterberg, F. 1964. "On the Attainability of Fusion Temperatures under High Densities by Impact Shock Waves of Small Solid Particles Acelerated to Hypervelocities." *Z. Naturforshg.* 19a:231.

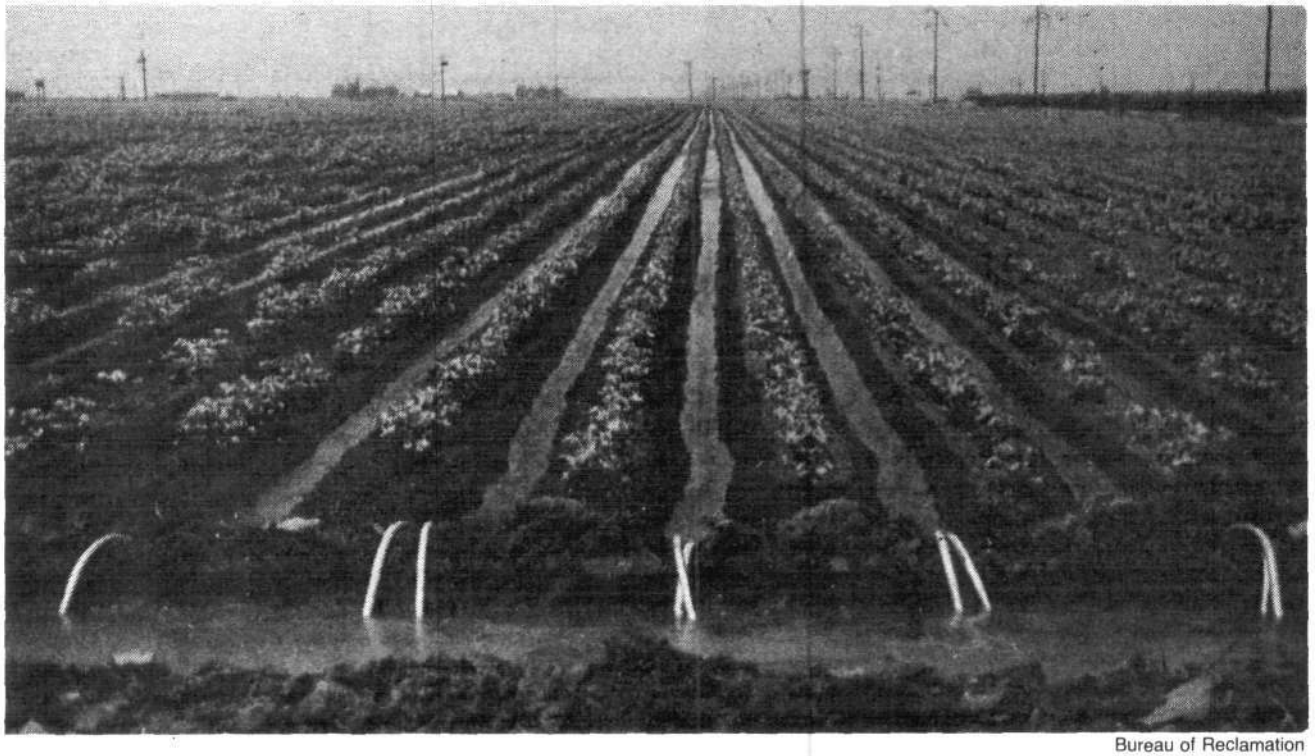
———1968. "Implosion of a Dense Plasma by Hypervelocity Impact." *Plasma Physics* 10:55.

———1978. "Ignition of Thermonuclear Microexplosions by the Acceleration of a Magnetically Insulated Foil to Ultrahigh Velocities." *Atomkernenergie* 31:60.

The North American Water And Power Alliance Proposal

Creating Water Resources for the Year 2000

by Calvin Larson



Bureau of Reclamation

This report by Calvin Larson, Fusion Energy Foundation director of agricultural engineering, is part of an ongoing FEF study of world water resources. Larson presented details of this North American Water and Power Alliance Proposal at a Sept. 19 conference in St. Louis sponsored by the FEF, which is summarized below. An accompanying box describes one of the major battles raging in the United States over modernizing the waterways system, Lock and Dam 26 on the Mississippi River.

* * *

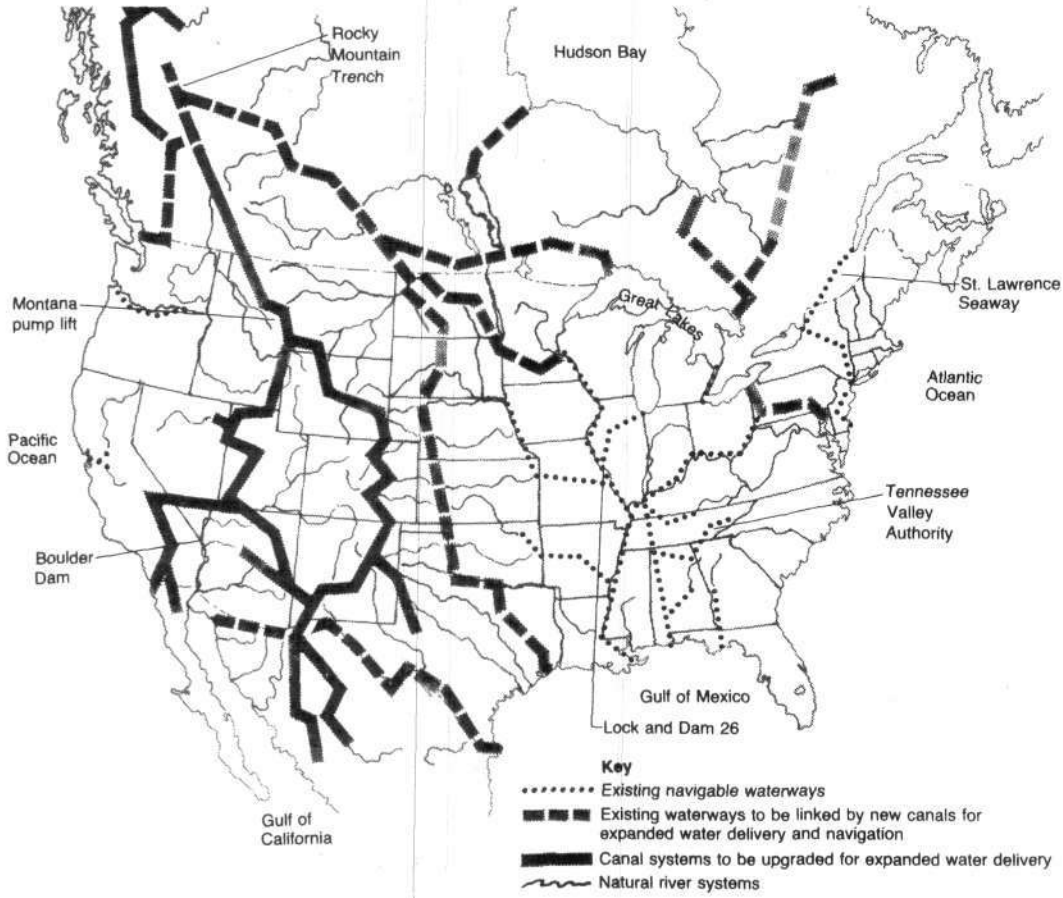
THE POTENTIAL FOR the creation of abundant water resources has never been as great as it is today, despite the cries of the environmentalists to the contrary. Technologies exist to create entire new river systems where there are none now, to collect and store vast quantities of water in underground reservoirs, and to desalinate seawater for use in areas that cannot be supplied by rivers and streams.

Historically man has augmented the hydrologic cycle by building dams and reservoirs to collect precious surface water supply. This technology gave life to the Imperial Valley of California, Arizona's Central Valley, and the Mississippi Valley, which are today the world's most productive farm lands.

The availability of cheap and abundant water supplies for irrigation, along with advancing technologies in fertilizers and pesticides, has given this country the ability to increase agricultural yields beyond those ever dreamed possible. A rural nation with the majority of its population on the land in 1790, the United States now feeds itself and produces a surplus that could feed half the population of the world—using only 4 percent of its workforce.

This transformation of the North American subcontinent came about principally because America's Founding Fathers were committed to the mechanization of agriculture and the upgrading of water-delivery systems to the nation's fertile farmlands.

By the same token, they were committed to linking the breadbaskets of America's heartland with the world mar-



This is the North American Water and Power Alliance (NAWAPA) masterplan for continental water resources development as modified and extended by author Calvin Larson, director of agricultural engineering of the Fusion Energy Foundation. Two major modifications are the bifurcated perimeter canal to be developed around the base of the Rocky Mountains and a Plains States Canal to be constructed between Pierre, North Dakota and Houston, Texas. As in urban water system designs, the gridlike pattern of the extended NAWAPA plan increases the operating flexibility of the system to optimize its multiple benefits and efficiency.

kets that would usefully absorb the nation's growing agricultural bounty. The canal and improved river systems of the 18th and 19th century, many of which are still in use today, speak for the credit policies and economic growth policies the Founding Fathers put into effect to accomplish our national development.

Conservation: Invitation to Disaster

Today, America is suffering from a water mismanagement policy that is rapidly reversing two centuries of development. Under the rubric of "conservation," the Carter administration is encouraging less use of our national water resources, in many cases by increasing the price of desperately needed water beyond the reach of all users.

The administration's commitment to a synthetic fuel program and a coal-based economy is another invitation to disaster. Carter's policy would require the deployment of vast quantities of available water—in several cases the entire supplies of major agricultural states—for synfuels development. Such a program presages bitter fights between farming and industrial communities of the western regions, reminiscent of the battles over water rights in the preirrigation Old West.

Carter's thoroughly misdirected policies have been added on to more than a decade of White House, congressional, and Interior Department blocking of major water project construction. The result is an aggravated shortage in immediately available water supplies for farming or navigation in some regions of the country, coupled with disastrous floods in other regions where needed dams, dredging, and other construction has been postponed.

The case of the Tellico Dam on the Tennessee River, which was held up for over three years by environmentalist intervention, and the overcrowded facilities of Lock

and Dam 26 on the junction of the Missouri and the Illinois Rivers, which have been waiting five years for renovation, are among the most striking.

The North American Plan

The proposal for a North American Water and Power Alliance, a multibillion-dollar western and northeast states water development project that would maximize the resources of the entire continent, has been on the shelf for nearly 15 years.

The North American plan, known as NAWAPA, was proposed in 1964 by the internationally active Ralph M. Parsons Company, based in Pasadena, California, after an investment of $1 million in project design. The essence of the plan is simple: to exploit the natural river systems of the continent, in conjunction with a large-scale engineering effort, to capture the millions of acre feet of water lost through runoff each year and redirect it for use in water-short regions. The project, as it is described here, would take 10 to 15 years to complete—given a mobilization of the skilled labor and engineering resources of the United States, Mexico, and Canada. Its total cost, with the appropriate use of nuclear explosive construction methods, would be about $130 billion at 1979 prices.

The return on this investment would include:

- a near-*doubling* of hydroelectric production in the United States alone;
- a near-*doubling* of irrigated fertile acreage in the states west of the Mississippi River;
- a vast expansion of the continental inland waterway system throughout the U.S. Northeast, Southwest, Midwest, and into Canada;
- a significant increase in ground-water reserves in many overdrafted areas of the country, including the Southwest and the Texas high plains;
- and the augmentation of water flow into the existing river system, alleviating transportation bottlenecks in what are now periods of low natural flow.

A Political Fight Necessary

Despite the obvious benefits of NAWAPA, federal government funding for additional planning was blocked—at the initiation of Washington Senator Henry Jackson—when the plan was first released in 1964, and no action has been taken since. To get NAWAPA moving today requires a major political effort both within Congress and among the progrowth majority of the nation.

The story of the construction of the Boulder (Hoover) Dam on the Colorado River in the 1920s is the story of such a political fight. The completion of the dam was largely due to Congressman Phil Swing of El Centro, California who put forward the need for a multipurpose high dam on the Colorado River for flood control, irrigation, and hydroelectric power—even over the objections of Herbert Hoover, who called the project "politically unfeasible."

To keep the Boulder Dam project alive, Swing fought and defeated a trumped-up scandal on the floor of the House of Representatives, and with his associate Mark Rose of the Imperial Valley Irrigation District, he initiated the national distribution of a fact sheet on the benefits of the plan. Today, Boulder Dam is still considered to represent the most advanced notions of multipurpose water project construction.

The NAWAPA plan—or a similar project—is the next, long-overdue step in continental water resources development.

As of 1975, approximately 390 million acre-feet per year (MAFY) of fresh water were withdrawn from U.S. reserves for use in the United States. About 40 percent was used for irrigation, 37 percent for thermoelectric cooling, 11 percent for industry, 9 percent for domestic consumption in urban areas, and 3 percent for domestic consumption in rural areas.

Of the total, only about 85 MAFY were drawn from ground reserves, the majority of supplies coming from natural lakes, rivers, and reservoir systems. About 110 of the 390 MAFY in use were actually consumed; that is, evaporated, transpired, or retained in manufactured goods. This points to the fact that in 1975, about 70 percent of all water use for irrigation, domestic consumption, and industry was returned to ground water or riverine systems for multiple-purpose reuse.

With this overview, I will discuss the NAWAPA plan from the perspective of how its implementation will augment the total water supply available on a continental scale for a multiplicity of uses and a wide range of benefits to the economy as a whole.

The NAWAPA Masterplan

The North American Water and Power Alliance grid is designed as an overlay to existing continental water systems. NAWAPA's designers have proposed the upgrading of a series of river basins, combining natural hydrographic potential with engineering features for maximum effect. The major engineering projects would be undertaken to collect surplus runoff water from the Rocky Mountains, starting in southern Alaska and into western Montana, to be delivered for use in southern California, Arizona, and Mexico. As the map of the NAWAPA masterplan shows, a major portion of the collected runoff would be diverted east, into channels leading to the Great Lakes and into the Mississippi River.

The beauty of the plan lies in its simplicity. Water now flowing into the Pacific and Arctic Oceans, where it becomes useless, would be diverted to water-short but potentially highly productive areas of the continent. Table 1, which lists the present distribution of water on the continent, shows that the 1.3-million-mile-square area of the NAWAPA project is particularly rich in water resources. With a mean annual runoff of 900 MAFY to be channeled by newly engineered river systems and canals, NAWAPA territory has a unit runoff nearly twice that of the continent as a whole.

The Parsons Company plan proposed the use of conventional methods of diversion—dams, tunnels, contour

Table 1
ESTIMATED WATER RESOURCES OF NORTH AMERICA

Country	Area (MSM)	Population (millions)	Runoff (MAFY)	Unit runoff	
				AF/SM	AF/capita
Canada	6.2	23.4	2,550	411	109
U.S.	5.8	216.0	1,960	338	9
Mexico	1.2	64.6	315	262	5
North America	**13.2**	**304.0**	**4,835**	**366**	**16**
NAWAPA	1.3	—	900	692	—

The NAWAPA catchment area extends in a "T"-shape from southwestern Alaska to Idaho and Montana and from British Columbia to western Labrador. At present, the majority of its 900 milion acre-feet a year of runoff flows unused into the Pacific and Arctic Oceans and Hudson Bay. The major storage facility would be a huge reservoir in the Rocky Mountain Trench, a normal topographical trough that forms the headwaters of the Peace, Fraser, Columbia, and Kootanay Rivers.

The units shown are millions of square miles (MSM) of land area and million acre-feet per year (MAFY) of runoff. One acre-foot is the volume of water that will cover an acre of land 1 foot deep.

The Case of Mississippi Lock 26

Photo FEF

Lock 26 on the Mississippi River is one of the best examples of how underinvestment in America's inland waterways system has begun to create damaging transportation bottlenecks in the agricultural and industrial sectors. Lock and Dam 26 is the strategic shallow-water convergence point for barge traffic from the Mississippi and Illinois Rivers. The lock is located a few miles below their conjuncture on the Mississippi at Alton, Ill., just north of St. Louis.

Barges laden with grain for export and tons of fuel, chemical, and industrial products are now delayed up to two weeks because of the traffic backup at this lock. The average waiting time for passage through the 40-year-old lock system is 10 hours; normal passage time through a lock in good condition is 30 minutes. This means that the bulk of the more than 58 million tons of freight that passes through Lock 26 each year sits in bumper-to-bumper river traffic for many hours before moving on to its destination.

In fact, Lock 26 is the number one bottleneck on the Mississippi, and costs billions of dollars in wasted time, fuel, and missed deadlines and con-

canals, and pump-lifts—to redirect the flow of major northwestern rivers from their normal northerly or westerly course to the sea and onto a course toward storage facilities to be constructed to the southeast. The major storage facility would be a huge reservoir in the Rocky Mountain Trench, a normal topographical trough that forms the headwaters of the Peace, Fraser, Columbia, and Kootanay Rivers. The reservoir would be built at an elevation of approximately 3,000 feet above sea level and would be about 500 miles long, 10 miles wide, and 300 feet deep. Its storage capacity would be approximately 400 million acre feet. (The total reservoir capacity of the United States is now 700 million acre feet.)

From the Rocky Mountain Trench reservoir, water would be directed east and south. To the east, the majority of flow would be by gravity, and would utilize the course of natural rivers in central Canada. Most of the flow to the south would be into new canals, located at the base of the Rocky Mountains at elevations of between 5,000 and 5,500 feet above sea level. A major pump-lift, with a capacity of approximately 135 MAFY and an energy load of about 65 gigawatts, would be required in western Montana to lift this southerly flow into the canals.

In southwestern Montana, the southerly flow along the canal network will branch to the east and west of the continental divide. As shown on the map, the two branches reconnect in southwestern New Mexico. This circumference canal located in Idaho, Utah, Wyoming, Colorado, New Mexico, and Arizona will deliver augmenting water flow to natural river-basin systems originating in those states. These river systems will be either directly intercepted by the main canal, or linked by secondary canals to the new water flow. Major link canals will deliver supplies to southern California, central Arizona, and the high plains area of western Texas.

From southwestern New Mexico, flow will continue into Mexico along both sides of the continental divide and westerly through Nogales into the Gulf of California.

Canals and Storage

The canals of the system will be hydraulically integrated with hundreds of new regulating dams which will intercept, control, and utilize regional river basin runoff in conjunction with the continental supply.

In the Missouri River basin, for instance, five major dams with a storage capacity of 75 MAF and more than 50 smaller dams with a combined additional storage capacity of 110 MAF operate to control an average annual discharge

---

nections. For 10 years, the Army Corps of Engineers has been trying to begin construction of new facilities to replace the dilapidated ones built in 1938; for 10 years they have been blocked by an unsavory alliance of railroad companies and environmentalists.

The Army Corps of Engineers and its allies have been forced to restrict the scope of their proposed renovation to the construction of one large 1,200-foot lock to replace the two smaller ones currently in operation. This will yield only 18 percent greater capacity, from the current 73 million ton maximum to 83 million tons with the new facility. With any increase in freight movement at all, the new facility would be obsolete before it was completed.

What the Corps originally proposed was a new dam and two 1,200-foot locks with a combined capacity of 175 million tons per year, at a current cost of $500 million. The Rivers and Harbors Act of 1962 authorized the Corps to construct such a facility. But in August 1974, 21 western railroads joined the Sierra Club and Isaac Walton League in filing suit in U.S. District Court in Washington, D.C. to stop the project. The suit charged, among myriad other objections, that the project needed specific congressional approval and authorization and that the Corps's environmental impact statement was inadequate. Judge Charles Richey granted an injunction.

The railroads ostensibly joined forces with the environmentalists out of their own narrowly perceived self-interest. Increased volume and efficiency of Mississippi barge traffic would divert significant amounts of freight to cheaper waterways transport, thus "robbing" the railroads of revenue, they said.

On the contrary, studies have shown that when the river transportation system improves, *all forms* of transportation realize an increase in traffic.

A Compromise

After four more years of delay and the death of various congressional authorization bills, a compromise was finally passed last year. It specifically authorized construction of Lock and Dam 26, but imposed a user tax of 4 cents per gallon of fuel consumed, rising later to 12 cents. An appropriation of $20 million was made to begin the first phase of construction late this year.

But one year later, no construction has begun on Lock 26. Although the Corps has submitted supplemental environmental impact statements, the environmentalists are charging that these remain inadequate. The statements don't take sufficient account of the environmental effects of increased water turbulence or on the aquatic life in the few acres of wetlands that would be disturbed, they say.

Currently Judge Richey is involved in a criminal case and has had no time for the Lock 26 matter. In August 1974, Richey had denied the government's motion for a change of venue—and judge—to St. Louis; since then, he has stalled the proceedings in all kinds of ways.

But the Corps's case cannot be helped by the fact that its legal counsel is the Pollution Control Section of the Department of Justice—the same lawyers who have been working consistently with the environmentalists against whom they are supposed to defend the Corps.

Meanwhile, Lock 26 continues to deteriorate. Early in August, when a barge sank in the lock, all traffic ground to a halt for 36 hours.

of 64 MAF from the basin. The NAWAPA plan will deliver an additional 30 MAF of new water that will be controlled and distributed by these existing facilities.

All of the distributions of NAWAPA water will be regulated by centrally located electronic telemetry systems to monitor flows and operate valves by remote control. Such a system has recently been installed in the hydraulic facilities of the Tennessee Valley Authority to optimize the operational response of the system to changing hydrogaphic conditions.

To provide year-round delivery, canals and reservoirs will be designed to operate with up to 7 feet of ice cover without hydraulic impairment. The largest canals will average 800 feet wide by 60 feet deep.

Use of nuclear explosives for the excavation portions of the NAWAPA project would save billions of dollars. Use of atomic explosives for excavation was proven environmentally safe and technologically feasible by the Project Plowshare studies in the late 1950s and early 1960s.

The detailed Project Plowshare report shows the superior design and capacity of a canal constructed with nuclear explosives, as opposed to one built by ordinary engineering techniques. At a 1959 San Francisco conference, the Sandia Corporation presented the results of a computer analysis demonstrating that the construction costs of a new sea-level Panama Canal could be cut from $5 billion to $2.1 billion with the use of nuclear excavation methods. Nuclear analysts estimate that this advanced technology will cut excavation costs on the project to 16 percent of conventional excavation methods, and possibly down to 10 percent as nuclear devices for construction purposes are mass-produced and tested.

Increasing Hydroelectric Capacity

A major benefit of the NAWAPA plan will be vastly increased hydroelectric generating capacity for the United States and its neighbors. Given the commanding elevation of the critical mass of project water, hydroelectric stations integrated with the project could generate some 180 gigawatts of power through new and existing generating units. Approximately 80 gigawatts will be used with the project for pump-lift conveyance of water leaving a net surplus of

Table 2
IRRIGATION, NAVIGATION, AND POWER GENERATING BENEFITS OF NAWAPA, WESTERN UNITED STATES

	Primary Irrigation and Navigation Benefits				
	Water (MAFY)		Irr. land (M acres)		Surplus power
State	1975	New	1975	New	(GWe)
Alaska	—	—	—	—	5.0
Washington	6.2	6.0	1.6	1.5	3.0
Idaho	17.0	5.0	3.8	1.1	2.0
Oregon	6.7	3.0	2.1	1.0	2.0
Nevada	3.5	6.0	0.9	1.5	2.0
Utah	3.9	6.0	1.7	2.5	2.0
California	39.0	15.0	9.0	3.5	2.0
Arizona	7.9	15.0	1.4	2.7	2.0
Montana	12.0	8.0	2.4	1.6	2.0
Wyoming	7.6	5.0	1.7	1.1	1.0
N. Dakota	0.2	5.0	0.1	3.5	2.0
S. Dakota	0.4	5.0	0.2	2.7	1.0
Nebraska	8.2	6.0	5.6	4.0	1.0
Kansas	5.6	5.0	3.0	2.7	1.0
Colorado	10.0	5.0	3.1	1.5	1.0
New Mexico	3.2	8.0	1.1	3.2	2.0
Oklahoma	1.3	4.0	1.0	3.0	1.0
Texas	13.0	15.0	8.6	6.0	2.0
Minnesota	—	1.0	0.1	1.0	1.0
Iowa	—	1.0	0.1	1.0	1.0
Missouri	0.1	1.0	0.3	1.0	1.0
Arkansas	2.7	3.0	1.4	1.6	1.0
Louisiana	2.2	1.0	0.8	1.4	1.0
Mississippi	0.8	1.0	0.4	0.5	1.0
Subtotals	**151.5**	**130.0**	**51.5**	**49.6**	**40.0**

100 gigawatts for other uses (see Tables 2 and 3). Current U.S. energy production is about 450 gigawatts, of which only 70 gigawatts is hydroelectric.

Most important, much of the new energy supply will be made available in energy-poor rural areas of the country, boosting the capacity of the national energy grid to meet the needs of rapidly rising agricultural and industrial production.

The impact of NAWAPA's implementation on irrigated agriculture will be immense, especially in the United States, where irrigated crop land will be nearly doubled (see Table 2). This will move the center of U.S. agricultural production westward, and new transportation facilities will be needed to cope with the increase in western production.

The NAWAPA project itself will help to meet these transportation needs. The plan provides for a network of new waterways that will augment the flows of existing navigable waterways and extend inland navigation in both east-west and north-south directions.

The project map shows the arm of the system extending from Vancouver, British Columbia to the Great Lakes, which will be designed as a seaway for ocean-going vessels, with appropriate dams and locks. From southern Saskatchewan a barge canal will cross North Dakota and link up with the Mississippi River system at Minneapolis. From northwestern North Dakota, a barge canal will connect into the Missouri River, including the Garrison and Oahe reservoirs. This same canal will extend, by pump-lift locks and dams, across the sandhills of western Nebraska and Kansas, and then via the Trinity River system from

Table 3
NAVIGATION AND POWER GENERATING BENEFITS
OF NAWAPA, GREAT LAKE STATES, U.S.

State	New water (MAFY)	Surplus power (GWe)
Wisconsin	1.0	1.0
Illinois	4.0	2.0
Indiana	3.0	2.0
Michigan	4.0	2.0
Ohio	3.0	2.0
Pennsylvania	2.0	1.0
New York	3.0	2.0
New Hampshire	—	1.0
Vermont	—	1.0
Maine	—	1.0
Subtotals	20.0	15.0
TOTAL NAWAPA BENEFITS,NORTH AMERICA		
Total United States	150.0	55.0
Total Canada	60.0	40.0
Total Mexico	40.0	5.0
Total NAWAPA	**250.0**	**100.0**

Tables 2 and 3

Tables 2 and 3 show the water and hydroelectric power benefits of the NAWAPA plan in a first-approximation distribution by states and countries based on estimates of potential productive use and delivery capabilities. The distribution reflects a conservative estimate for a fully developed continental system with an overall capacity of 250 million acre-feet per year. Existing irrigation extractions in the western United States as of 1975—which will be supplemented by new water from the NAWAPA project—are shown for purposes of comparison.

The estimated annual benefits in new mining, manufacturing, and agricutural production are $120 billion in the United States, $35 billion in Canada, and $25 billion in Mexico. A new, detailed hydroelectric and engineering feasibility study—as proposed by the Parsons Company—is required to more clearly quantify the costs and benefits of the plan as a whole.

Dallas to the existing seaport at Houston, Texas. A third major new barge canal will be constructed linking Brownsville, Texas with the Gulf of California via the Rio Grande River.

In the eastern United States, several Great Lakes barge canals, augmented by flow from the NAWAPA project, would once again become major regional transport routes. The old Pennsylvania Canal linking Lake Erie with the Ohio River at Pittsburgh, flowing easterly to Harrisburg and Baltimore, and by feeder canal to Philadelphia, can again be considered for renovation.

Major deepening and widening has been proposed for the New York barge canal, which flows from Lake Ontario into the Hudson, and is still in operation. The construction and improvement of these canals would link eight of the ten major American ports with major inland centers of production.

Several seaway and barge routes would also be opened up into the rich mineral and timber resources of Canada. A new east-west seaway through the plains provinces would access the coal, timber, and grain-producing centers of Alberta and Saskatchewan. Two north-south seaways are

FEF Hosts St. Louis Conference on Energy and Transportation

The Fusion Energy Foundation sponsored a day-long conference Sept. 19 at St. Louis, Missouri's Washington University on the theme "Energy, Transportation, Inland Waterways—Critical Choices for the 1980s." St. Louis was a particularly appropriate site, since the city straddles the nation's major inland waterway, the Mississippi River, and takes great pride in its historic role as the gateway linking America's East and Midwest to the states west of the Rocky Mountains.

The audience of 100 included students, businessmen, and community leaders, who participated in morning and afternoon panel discussions and a luncheon awards presentation.

Calvin Larson, FEF director of agricultural engineering, led the morning panel with a description of the 1964 Parsons Company plan to transform America's waterways by building a new river system that would run parallel to the Mississippi River basin through the Great Plains states, thus eliminating chronic water shortages of the area. Larson described how this plan could boost agricultural productivity and increase the use of barge transport for bulk shipments of commodities for export. The major block standing in the way of this and similar proposals, Larson explained, has been the refusal of the Congress to appropriate funds for feasibility studies in the past 15 years.

Guy Jester, former colonel in the Army Corps of Engineers for the St. Louis district, picked up this line of discussion, stating that the problem facing all water projects is that "private corporations cannot make long-term capital investments. We need projects that can have 50 to 100-year payoffs; the federal government must become involved in this. We've been living off the fat of previous investments."

Jester, who was speaking for the Association to Improve the Mississippi River, then detailed the battle raging over the future of the Alton Lock and Dam 26, the vital link between the Illinois and Mississippi Rivers (see box). Jester warned: "The eco-freaks' vision of the future is of no growth, no employment, and no income . . . the future will be a disaster."

The two other speakers in the morning panel, Frank Spinner, president of the Tower Grove Bank, and Conway Briscoe, 11th ward Republican committeeman, discussed the positive impact a major port development program would have on St. Louis. Spinner explained how such a plan would not only create new employment opportunities, but would expand the city's tax base for further growth. Briscoe put the issue bluntly: "What people have to realize is whether or not this development gets done is entirely a political question."

Celebrating the City-Builders

Next on the conference agenda was a luncheon awards presentation. Roger Maduro, president of the Fusion Energy Club of Washington University, presented the Louis H. Sullivan award for "outstanding contributions to city-building projects" to Gen. Leif Sverdrup, recently deceased founder of the Sverdrup and Parcel Engineering firm and former chief advisor to Gen. Douglas MacArthur. The award was received on behalf of Sverdrup by former St. Louis mayor, John Poelker.

In introducing the award, Maduro quoted Logan Uriah Reavis, an engineer who drew up plans in 1866 for St. Louis to become the capital of the United States because of its unique geographical location along the artery of the Midwest. Maduro told of his relationship to Sverdrup through his grandfather, who had worked with Gen. Sverdrup in 1926 to build the first commercial bridge across the Panama Canal. "America," Maduro concluded, is "a nation that builds nations."

Lyndon H. La Rouche, Jr., 1980 Democratic candidate for the presidency, then took the podium and shocked the audience by declaring: "My friends in Europe are about to implement a new gold-backed monetary system that will spark an era of developing Third World nations to our standard of living." Such a gold-backed system he contrasted to the genocidal "conditionalities" policy imposed by the International Monetary Fund on developing nations, describing the latter: "These policies were first implemented in Nazi Germany under Finance Minister Hjalmar Schacht: they didn't work then and they won't work now!"

LaRouche concluded by warning of the consequences of not pursuing a gold-backed global recovery: "If we don't crank our nation's economy up with a LaRouche presidency, then the prospect of war is a foregone conclusion."

In the afternoon, a three-person panel discussed the crisis in energy policy and the crisis of leadership to get the nation out of the mess.

planned to link Hudson Bay with the east-west seaway—one in Manitoba via Lake Winnipeg and the Nelson River, and one from Lake Huron to James Bay. Finally, a northeastern barge canal will directly link the iron and ore deposits of Labrador and Quebec with the Great Lakes steel mills.

Hydrographic Impact

With vast areas of new land in irrigation under NAWAPA, ground reserves throughout the western states can be expected to increase eventually by as much as 40 MAFY. This is because about 30 percent of applied ground water will percolate into deep ground water systems, replenishing reserves which in many areas, notably in the Texas high plains and southwestern California, are already overdrafted. Another 10 percent of applied water will seep into drainage systems and return to the natural river system.

This augmentation of river flows from project runoff is a second hydrographic benefit of the project and will be especially crucial during periods of low flow during which navigation is constricted on some major waterways. With such augmentation potential, the extension of existing river systems, such as the Missouri and Arkansas (now navigable nearly up to Tulsa, Oklahoma) and the development of new systems, such as the Platte River in Nebraska and the Red River between Texas and Oklahoma, becomes viable. This will provide multiple links between the new Great Plains canal and the lower Mississippi, which is navigable all year round.

A few statistics on waterway development and operations make the point about the eventual high return on the initial major investment in the NAWAPA masterplan. New investments in railroad lines are estimated to be 10 times more costly per ton-mile of freight shipped than investments in waterways. The construction of railroad cars takes over 3.5 times more steel per ton of cargo capacity than a river barge. Energy and power requirements for the operations of railroads are about 1.5 to 2.0 times that for barge traffic.

Expanded use of new inland waterways and cost-efficient barge transportation will also help to relieve congestion in America's crowded deep water ports. The most advanced barge transport has already been containerized and integrated with oceangoing superships like the Lash and the Seabee. Both these ships lift loaded barges directly onto their decks for intercontinental voyages. In effect, these developments will rapidly transform inland barge docks into international ports.

A National Yardstick

Back in 1932, Franklin Roosevelt identified the political necessity for government directed multipurpose water projects as follows:

> Here you have the clear picture of our great government power developments in the United States—the St. Lawrence River in the Northeast, Muscle Shoals [TVA] in the Southeast, the Boulder [Hoover] Dam project in the Southwest, and the Columbia River [Grand Coulee Dam] in the Northwest. And from here, my friends, in each of the four quarters of the United States, there will exist forever a national yardstick to prevent extortion against the public and to encourage the wider uses of that servant of the American people—electric power . . . [that] means cheap manufacturing production, economy and comfort in the farm and in the household.

Abundant water supplies for irrigation have been a major factor in making American agriculture the most productive in the world. Here, the Friant Dam and an irrigation canal, part of the Central Valley project.

Indeed, a few years later, the benefits of such far-reaching infrastructural development was clearly demonstrated during World War II. At that time such "white elephant" dams were used to furnish power and irrigation water for producing food, fiber, nitrate fertilizers, explosives, aluminum airplane fuselages, and, at Hanford, Washington and Oak Ridge, Tennessee, the first successful production of fissile material for atomic power. To support the in-depth war effort, inland waterway navigation for transporting raw materials and finished goods increased from 600 to 1,050 ton-miles in just four years (1940-44), an average annual rate of nearly 19 percent.

Today the same kind of brute force effort is needed to put NAWAPA underway, and the benefit the nation will reap in terms of increased production, trade, and exports are even more important to national security.

New X-Ray Diagnostic Announced

Lawrence Livermore Laboratory

Laser fusion scientists have demonstrated a new scientific diagnostic that will produce a series of revolutions in chemical, biological, and electronic research and technology. Results recently announced by Dr. Philip Mallozzi and his coworkers at Battelle Laboratories in Columbus, Ohio show that intense, short bursts of soft X-rays generated by lasers can be used to examine the atomic actions of a wide variety of materials.

Called extended X-ray absorption fine structure spectrosophy, EXAFS, the new diagnostic makes use of the extremely short burst of X-rays generated by the interaction between the intense beam of laser light and a plasma. EXAFS will permit scientists to make "movies" of how atoms combine and interact chemically and to examine such biological processes as the activity of magnesium in photosynthesis.

The laser-generated short X-rays solve one of the problems with ordinary X-ray sources. Ordinary X-ray sources, such as those used for medical purposes, generate a full spectrum of X-rays, ranging from hard (very short wavelength) to soft (longer wavelength) X-rays. The hard X-rays are generally quite destructive, because they tend to induce chemical and other transformations in the material through which they pass. For this reason, in the most important type of X-ray studies involving three-dimensional examination of materials, only solid crystals can be examined because others cannot withstand the destructive effects of the hard X-rays.

To overcome this problem, scientists have developed special X-ray sources that generate primarily soft X-rays. Particle accelerators, for example, generate a predominantly soft X-ray spectrum by synchrontron radiation of the accelerated electrons. These synchrotron sources are expensive, however, as well as quite diffuse, and samples being studied by this method must be exposed for relatively long periods of time.

Laser Plasma X-Rays

For many years, laser and fusion scientists have been generating short bursts of X-rays when a laser beam interacts with matter. The duration of the X-ray burst is usually on the same scale as the pulse length of the laser beam—several billionths of a nanosecond. Furthermore, the spectrum of the X-rays generated by laser matter interaction can be custom-tailored by creating the proper geometry, shaping the laser pulse, and using the proper materials.

Because the laser-generated soft X-rays are short and intense, they will enable scientists to virtually make movies of how atoms combine and interact chemically. This will be a tremendous boon for the chemical industry, since catalysis and other important chemical interactions can be examined in detail, thus permitting development of alternative industrial processes.

In biology, an entire new world will open up for examination. For example, scientists will be able to measure the effects of trace elements in key biological processes, such as the actions of potassium in nerve cells. The temporal and spatial resolution made possible by the billionth-second-long bursts of soft-rays generated by laser-plasma interaction will permit scientists to make "movies" of these minute amounts of atoms on time scales that allow the exploration of their chemical and other activities.

The short wavelength X-ray is also important in the electronics field to generate very minute and detailed parts of microcircuits on photographic material. Previously, such X-ray application has been limited because of the presence of hard X-rays that penetrate and disrupt the deeper layers of the photo-activated microcircuit material. Laser-plasma generated soft X-rays promise to revolutionize this technology.

—Charles B. Stevens

Cost Cutters Hit Nobel Prize for CAT Scanner

The awarding of the Nobel prize of medicine to the developers of the CAT scanner, the $850,000 symbol of the battle over U.S. medical policy, has drawn predictable criticism from opponents of the device. The Swedish Nobel prize was awarded in mid-October to Allan MacLeod Cormack of the United States and Godfrey Newbold Hounsfield of Britain.

The Computerized Axial Tomography scanner, or CAT scanner, is regarded as the most significant diagnostic revolution in the medical field since the development of X-rays. Using X-rays to photograph cross-sectional pictures (tomograms) of the patient's body, the information for each tomogram is then compiled by computer, creating a pattern on the computer screen that enables doctors quickly and painlessly to diagnose forms of cancer and other disorders previously only diagnosed by exploratory surgery or highly specialized and excruciatingly painful tests.

In Thick of Battle

The widely acknowledged advantages of the CAT scanner, and the promise of still more advanced related technologies like FONAR (Field Focusing Nuclear Magnetic Resonance), which is currently being developed, have put the scanner in the thick of the battle between traditional technology-proud medical forces and those pushing cost-cutting "appropriate medical technologies," right-to-die hospices, and heavy dispensing of drugs in lieu of more expensive medical care.

The Cost-Cutters

Proliferation of CAT scanner technology in the United States would be a sure sign that "the medical profession [has] passed the line of due regard for our increasing medical bills," the *New York Times* editorialized Oct. 15 on the Cormack-Hounsfield award. But, the *Times* admitted, "there are great pressures to use the scanners even more. Patients and doctors want accurate diagnoses. . . ."

The *Times* has also given much play to the views of Senator Edward Kennedy, chairman of the Senate Subcommittee on Health and Scientific Research and a staunch advocate of "appropriate" medical technology instead of more expensive advanced technology and research. For example, the *Times* approvingly quoted Kennedy as saying, "Health technologies contribute enormously to the inflationary spiral, as much as 40 percent of annual increases in the cost of a hospital day can be attributed to their use."

This argument, of course, is false. In a healthy economy the widespread implementation of advanced medical technology would actually lower the cost of medical care.

The CAT scanner's use in the United States has been severely hampered by the policy enunciated by the Kennedy forces. A maze of budgetary restrictions has created ceilings on hospital costs on both the federal and state level, and the cost-cutting decision of Blue Cross-Blue Shield not to reimburse patients for the diagnostic costs of using the CAT scanner have made the diagnostic tool a luxury item.

Although the CAT scanner has been available for five years, only 1,100 scanners have been sold in the United States and 900 in the rest of the world.

—Carol Cleary

Lasers Used to Split DNA Molecules

M. I. Stockmann of the Soviet Institute of Automation and Electrometry in Novosibirsk reported that insertion of a dye in a DNA molecule permitted him to use a nitrogen laser pulse of 200 megawatts per square centimeters to split the DNA chain at a predetermined location. Two-photon absorption by the dye was followed by a transfer of the excitation to the DNA, according to *Laser Focus* Oct. 1979, which published Stockmann's report.

Ultraviolet light has been known to split DNA, but without the introduction of the dye into the chain it had been impossible to split the molecule at a specific bond.

Books Received

The Visible College, Gary Werskey, New York: Holt, Rinehart and Winston, 1979, 376 pp., $12.95.

Disturbing the Universe, Freeman Dyson, New York: Harper and Row, 1979, 283 pp., $12.95.

Janus—A Summing Up, Arthur Koestler, New York: Vantage Books, 1979, 354 pp., $3.95.

Incredible Coincidence, Alan Vaughan, New York: J.B. Lippincott, 1979, 256 pp., $10.00.

Cyril Burt, Psychologist, L.S. Hearnshaw, Ithaca, New York: Cornell University Press, 1979, $18.50.

Theory of Linear Induction Motors, Sakae Yamamura, Tokyo: University of Tokyo Press, 1979, 235 pp., $24.95.

Energy Dictionary, Daniel Hunt, New York: *Van Nostrand Reinhold, 1979, 518 pp.*, $22.50.

Nuclear Power and Radioactive Waste, David A. Deese, Lexington, Mass.: D.C. Heath and Co., 1978, 200 pp., $18.

Advances in Energy Systems and Technology, vol. 1, ed. Peter Auer, New York: Academic Press, 1979, 387 pp., $32.50.

Cutting Energy Costs, R. Dick Larkam, New York: Beekman Publishers, 1977. 126 pp., $24.95.

Energy Technology V: Challenges to Techlogy, Washington, D.C.: Government Institutes, 1978, 1,044 pp., $38.00.

Energy Technology VI: Achievements in Perspective. Washington, D.C.: Government Institutes, 1979, 1,168 pp., $38.00.

Energy Users 1979: A Comprehensive Analysis of the National Energy Act. Government Institutes: Washington, D.C., 1979, 152 pp., $25.00.

Energy Reference Handbook, second edition. Dr. Thomas Sullivan, ed. Washington, D.C.: Government Institutes, 1977, 352 pp., $15.95.

Science of Materials. Witold Brostow, New York: John Wiley and Sons, 1979, 436 pp., $29.50.

Optical Fibers for Transmission. John E. Midwinter. Somerset, N.J.: John Wiley & Sons, Inc., 1979, $24.95.

Letters

Continued from page 5

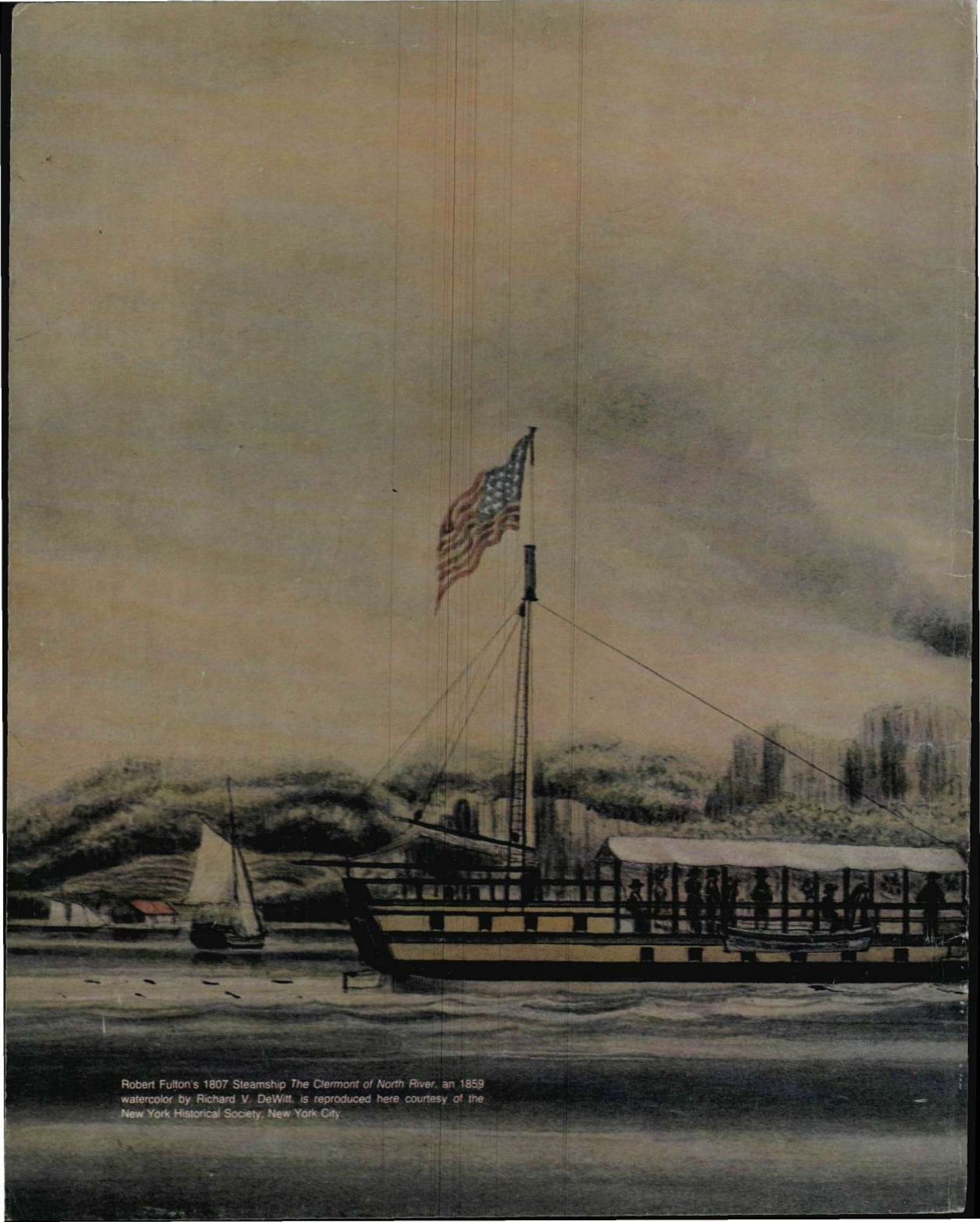
to tribal ways, with local deities and primitive superstitions reminiscent of the time of the Old Dispensation? You know, of course, the alternative to progress is regression. No other alternative exists. If you say that your intentions are sincere and that you are concerned that all men and women lead godly lives, then why have you not acted clearly and decisively to mobilize our citizenry against the plagues of the international dope network, deschooling of public education, and our banal and demoralizing popular culture?

I ask you, noble members of the National Council of Churches: What are you going to do for impoverished humanity, hand out CARE packages? Talk the Gospel to bloated bodies and sleepy minds? How dare you quibble about the questionable dangers of high technology, in agreement with the most immoral of environmentalist rabble, while you feed on its benefits and withhold its blessings from others who are more deprived! How dare you undermine the policies and practices of our constitutional republic, which has the resources and traditions with which to provide the material basis for renaissances of starving cultures throughout the global community . . . .

We cannot pretend ignorance. We are, brethren, called to Knowledge. We are called to fulfill Knowledge's dictates. This requires that secular bodies follow the practices of "ecumenical Christian" conscience; not of Bible thumpers, but of reasonable men and women whose allegience is to the Good, whatever their profession of belief is . . . . And there are no limitations to a man or institution of society of internal moral authority who desire to effectively to do good . . . .

Sam Kahl, Chairman
Parish Council of
St. George Orthodox Church
Portland, Ore.

Comments from readers are welcome. Address correspondence to Fusion *Magazine, Suite 2404, 888 Seventh Avenue, New York, N.Y. 10019.*



Robert Fulton's 1807 Steamship *The Clermont of North River*, an 1859 watercolor by Richard V. DeWitt, is reproduced here courtesy of the New York Historical Society, New York City.