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Fusion Energy Foundation

World Development and Transition to a Fusion-Based Economy

Special FEF Conference Issue

Newsletter

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Backcover: The Alcator magnetic confinement fusion experiment located at the Francis Bitter National Magnet Laboratory.

Fusion Energy Foundation Newsletter

Vol. 1, No. 6
June 1976

Editor-in-Chief, Dr. Morris Levitt
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Editorial

World Development and the Transition To a Fusion-Based Economy

The significance of the Fusion Energy Foundation Conference, titled "World Development and the Transition to a Fusion-Based Economy," is best seen in the light of numerous recent conferences which have promoted the discredited concepts of Zero Growth and Malthusianism. In contrast, the issue which we address here is the concept of Progress.

The simple truth needs to be reemphasized that the very existence of human culture depends on progress in science and its technological applications. The very fact that the conception of scientific progress has come under attack through such catch words as de-industrialization, deurbanization, and depopulation is indicative of the present situation. What is not understood, however, is that reversion to primitive means of production is being proposed for the advanced sector, not just the Third World. Even the nominally pro-growth programs such as the U.S. Energy Research and Development Agency policy for the future fail to take adequate account of the rate and quality of scientific and technological advances required for overall development.

The truth is that, even relative to existing, readily available resources, we are at a crisis point because of the failure to apply advanced technologies or to raise the skill and technological levels of populations on a broad scale. This, of course, cannot be done when investments increasingly flow into speculation or debt service, instead of into expansion and improvement of the industrial and agricultural sectors.

We are, moreover, at the point of utilization of land, energy, and other material resources where a simple expansion of productive capacities would readily deplete the most accessible resources as they are presently defined. Immediate economic expansion, necessary to reverse the present related production and ecological collapses, must therefore be seen not as an end in itself, but rather as the transitional phase to a higher-order mode of production. For reasons we have cited many times before and resummarize in this issue, the keystone of any more qualitatively advanced productive order must be fusion power and fusion-related technologies.

In fact, even the most positive form of implementation of an ERDA-type energy policy would be unsatisfactory. As Soviet physicist P.L. Kapitsa points out in an article excerpted in this issue, the basis for economic development is a qualitative improvement in energy production and conversion technologies such that there is a resultant increase in energy-density flux. Unless this criterion is met, the productivity of human society as a whole cannot be improved, and sooner or later productive plant and raw materials will be irreversibly depleted. Under present conditions, the process of collapse can be measured in years.

The point is that progress can't be maintained with patch-work tactics, but requires a development strategy. As a case in point, the achievements and potentiality of the present system of production are the result of the development and application of the three main branches of classical physics — Newtonian mechanics, thermodynamics, and Faraday-through-Maxwell's electromagnetic theory — in conjunction with industrial chemistry. The most striking feature of our present system is the interaction between the broad productive base and the most concentrated form of large-scale energy flow, electricity.

It is worth briefly looking at how that came about and how the onset of fusion signifies the supersession of conventional electricity or presently low efficiency quantum electronic devices such as the laser (which itself has barely been applied to production) by the fusion-based generation of electricity and the electromagnetic phenomena and interactions of the plasma state.

In the latter part of the 19th century the prerequisites for an electrical grid appeared. This can be traced to the economic and technological changes set in motion by the tremendous investments made in railroad systems at mid-century, key scientific and technological developments, and the evolution of a significant force of skilled industrial workers and scientific-technological cadres. The wild expansion of railroads was accompanied by increases in coal mining and iron production, but most significantly by the revolutionizing of steel making and the takeoff of that industry through the invention of such processes as that of Bessemer and Gilchrist-Thomas.

Steel making and engineering advances in machine-tooling were crucial for electricity production by making possible the production of high strength components for steam turbines which could operate at much higher velocities than the earlier iron and brass steam engines. The turbines themselves were much more the product of applied thermodynamics than the trial and error steam engine, being designed to maintain a high temperature differential between imput and exhaust.

The turbines were coupled to electrical generators based on the production of voltage and current by rapid rotation of a current-carrying coil in a strong magnetic field. The major engineering development here was the notion of using part of the current generated to power the components of the generator itself.

At the turn of the century the efficiency of electricity production was only 5 per cent and the total produced relative to all energy production was small. Since the 1920s, however, production has grown exponentially, increasing by a factor of 15 to constitute about 27 per cent of the total energy input to homes, industry and transport. Simultaneously, technological advances in increasing the temperature of super-heated steam and increasing the scale of power plants has raised the efficiency of electrical generation to about 35 per cent.

The point here is that one cannot assess the role of electricity in terms of its own conversion efficiency, though that is obviously an important economic factor. Rather, it is the strategic application of electricity in domestic consumption, machine motors, industrial processing as in steel and aluminum, and in electronic control, communication and computational devices which determines an increase in the overall productivity of society and the ability to increase and control energy throughputs in general.

As indicated, the coupled advances in overall productivity, energy throughput, and concentrating energy forms have been largely based on 19th century advances in physics. This physics, and the 20th century quantum theory which has had some significant impact directly on production and indirectly through communications and computers, involves "averaging" over or simply ignoring the interaction that is actually most fundamental in physics: that between field and particle aspects of any physical process.

With the need for the unique energy focusing and flux throughput properties of fusion plasmas, however, humanity requires an advance in scientific cognition appropriate to the control of plasma processes. That cannot be had from physics as it is now conceptually constituted. We must go beyond the thermodynamic principles of high temperature efficiency, beyond the electromagnetic theories of particle and collective plasma behavior, to develop the science of high-density matter-field interaction on which such new technologies as ore reduction through shock-ionization and plasma photo-chemistry will be based. With respect to these technologies, our present theoretical knowledge can be compared to the state of metallurgy before the development of modern chemistry and solid state physics.

In short, we will soon need a science and a general level of scientific cognition appropriate to production technologies based on understanding the behavior of plasma, the fourth state of matter. Only then can we move rapidly, as we must, to an economy in which plasma technology is decisive.

The policies necessary for human survival and development can be determined scientifically, and must be implemented through new international economic arrangements. That requires both scientific rigor and political spine. The Fusion Energy Foundation is committed to promoting the first — from the contents of this special issue of our newsletter, which serves as the program for the Chicago Conference on "World Development and the Transition to a Fusion-Based Economy," to the initiation of the International Journal of Fusion Energy as a focal point for needed theoretical syntheses and advances in plasma physics.

If you have the courage to face the truth about the present historical conjuncture — the real danger of extinction as opposed to the tremendous potentiality for transition to a fusion-based economy — you will also have the courage to act on the basis of that truth.

On Trends in Nuclear Fusion Research

Reprinted here is the concluding section of an assessment of fusion research prepared for the Fusion Energy Foundation in fall 1975 by Dr. Bo Lehnert. Dr. Lehnert is the Director of the Division of Plasma Physics and Fusion Research of the Royal Institute of Technology in Stockholm, Sweden.

...We summarize the present state of nuclear fusion research in the following paragraphs.

Plasma Physical Problems

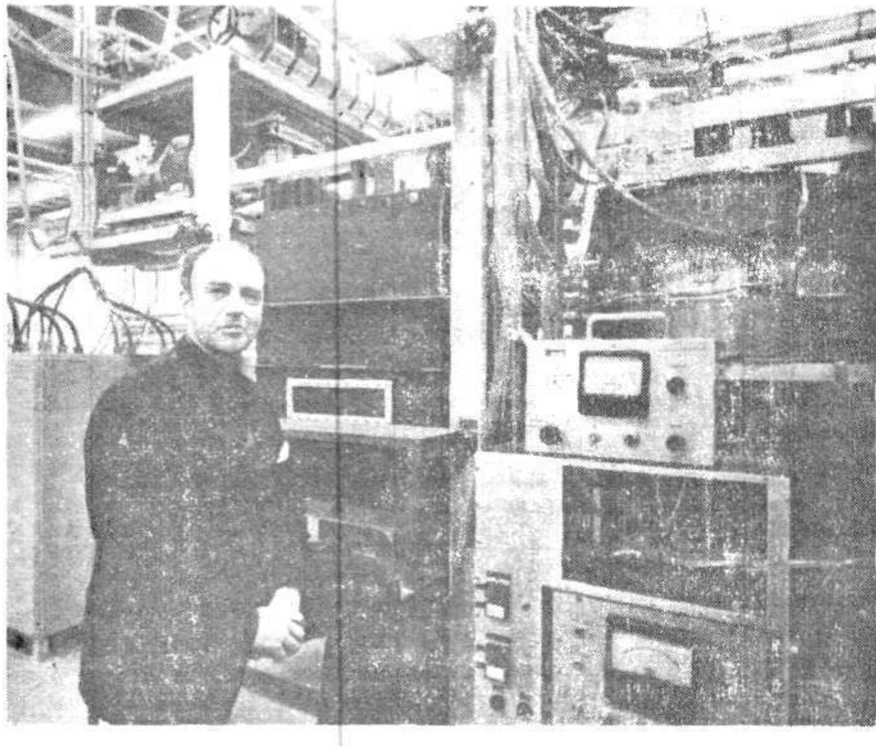
Among the basic plasma physical problems, considerable progress has been made in establishing the foundations of plasma theory and connecting theory and experiments. In particular, a great number of plasma instability and wave modes have been thoroughly investigated; "Bohm-diffusion" has been suppressed in many cases; nonlinear theory has made considerable progress; numerous stabilization methods have been developed; and a considerable number of promising heating methods based, for example, on imposed high-frequency fields, and on neutral and charged particle beams, as well as on turbulence, have been tested in the laboratory. Further important results have been achieved by means of computer calculations; the plasma diagnostic techniques have been largely extended; and several approaches to the fusion reactor appear to have a fair chance of success.

There also remain a number of important basic problems to be further tackled, such as the energy loss mechanisms in complicated field geometries and under non-linear conditions of instability growth, the effects of plasma impurities in closed magnetic bottles, plasma-neutral gas interaction, and the radiation losses from a magnetized thermonuclear plasma. Before reaching the final goal, it also has to be understood how to confine, stabilize, and heat a plasma in a way to avoid all undesirable loss mechanisms in one and the same confinement system, thereby also satisfying all other technical requirements.

With special devices such as Tokamaks, Stellarators, theta pinches, magnetic mirrors, and some other systems, considerable progress has been made on the way to high plasma temperatures and long confinement times under stable plasma conditions. Nevertheless, in every single experiment performed so far, there remains an increase of one or several orders of magnitude in one or the other of the parameter values T and 0 before the necessary conditions of a practically operating fusion reactor can be realized. Thus, the general development of fusion physics and a search for new approaches should at this stage be considered at least as important as maximum experimental parameter data obtained by means of individual devices.

A considerable part of the international fusion research program is now devoted to large experiments with magnetic bottles having a main toroidal field component, as well as to a number of large laser fusion experiments. It is outside the frame of the present review to discuss all these investigations in detail. Here attention should be drawn only to some features of the magnetic bottles just mentioned. When developed into full reactor scale, such systems are faced with the following problems:

(1) So far only small total beta values have been reached in Tokamak and Stellarators. This leads to a number of plasma physical and reactor-technological drawbacks. First, very large magnetic field energies become necessary at the plasma pressures prevailing in a full-scale system. Second, the existence of a relatively weak poloidal field component results in slightly screw-shaped field lines, in their turn leading to long magnetic



Dr. Lehnert at the Royal Institute.

connection lengths between "bad" and "good" regions. This makes the confinement vulnerable to a number of instabilities. Third, the large required total magnetic field strength becomes unfavorable with respect to cyclotron radiation losses. Fourth, large magneto-mechanical stresses arise on the coil system, at the same time as super-conducting windings become necessary for the Ohmic coil losses to be reduced to an acceptable low level. Fifth, the rotational transform and the magnetic surfaces become sensitive to small disturbances, in a way which may affect the symmetry of the magnetic field and the plasma geometry.

(2) The complicated diffusion processes and other loss mechanisms which involve "banana" effects and trapped particles are not fully understood at this stage. The losses in Tokamaks and Stellarators are larger than those so far predicted by the theory of a stable and steady state, but become consistent with anomalous transport processes due to instabilities.

(3) The critical ion density limit has not, for certain, been exceeded in Tokamak experiments.

(4) The problem of steady-state Tokamak operation by means of a "boot-strap" mechanism has not yet been settled. It is true that, if the impurity problem of closed bottles cannot be solved, pulsed operation should in any case become necessary. On the other hand, such operation may reduce the chances of achieving a practically useful reactor.

(5) The coil windings which generate the toroidal magnetic field introduce complications in the replacement and repair of construction details.

During recent years considerable progress has been made in fusion reactor technology, that is, concerning superconducting coils, material problems including damage by meutron radiation, blanket construction, and model studies of full-scale systems. In particular, the detailed study "UWMAK" at the University of Wisconsin should be mentioned, as well as associated calculations on the afterheat problem and the suggestion of using a graphite "curtain" to reduce the damage of the "first wall".

Nevertheless, this is just the beginning of a long and laborious road to the final goal where such problems now are faced as those of the interaction between the plasma and the "first wall," of sputtering and blistering, of refeuling and removal of ashes, of the cooling system and its working fluids and gases, and last, but not least, of repair and replacement of radioactive construction details.

The Future

At the present stage many of the basic problems of fusion research have, in fact, been solved, and there is no indication that remaining problems could not be successfully tackled if sufficient resources become available. However, it also has to be stressed that *none* of the approaches described in this review will for certain lead to the fusion reactor, even if several schemes for the moment appear to have a chance to do so. Consequently, the present concentration of the main activities and resources of the world's fusion research to rather narrow lines and to a few large projects at the expense of basic investigations is not reconcilable with a corresponding necessary knowledge in fusion physics and technology. In the case that none of these large projects is able to keep the promise of being a solution of the reactor problem, fusion research as a whole may end up in a difficult political dilemma. This situation is partly a result of attempts to accelerate fusion research toward its final goal under the contemporary constraint of limited resources. Needless to say, a substantial increase in available funds would at once cure this situation.

However, even at the present economical level, the efficiency of future research programs could be improved by means of the following measures:

(1) The large and intermediate-size experiments with devices of a more "conventional" Tokamak, Stellarator, pinch, and mirror type, should be reduced in number as far as possible. Unncessary duplication can partly be avoided by means of improved coordination of projects on the international level. Only a few large devices with strong fields, such as Tokamaks planned for studies of the not-fully-understood scaling laws, should be further developed.

(2) Experimental investigations on modified toroidal devices and other schemes also within extended parameter ranges should be encouraged.

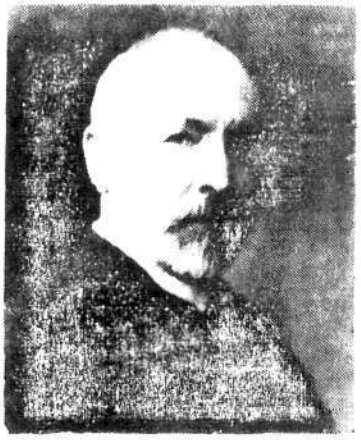
(3) Without affecting the total budget of larger experiments to any greater extent, more resources can be given to basic research conducted on broad lines and by means of moderate-size experiments.

(4) A systematic search for more alternatives to the present lines of approach should be continued. New ideas, as well as reconsiderations of earlier ideas from new angles, may even become necessary for a future success of fusion research.

In any case, the goal of fusion research ought to be too important to society for half-measures to be undertaken in the form of redistributions of insufficient funds. The real and necessary action to be taken now consists of a "crash program" with basic research and new ideas being strongly represented along broad lines and being conducted by all the manpower which is practically available.

The Concept of the Transfinite

by Uwe Parpart



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Top Soviet Scientist: Fusion Is Necessary for World Growth

In an article published earlier this year a leading Soviet physicist emphasized that the USSR's commitment to achieving controlled thermonuclear fusion as rapidly as its resources permit springs from the primary necessity of increasing the productive capability and "material well-being" of populations. The following excerpts from this article by P. L. Kapitsa, a leader in Soviet physics for nearly the past half-century, are the first English translation of this important statement in the Western press.

Kapitsa first presented his article in an Oct. 8, 1975 speech to the Soviet Academy of Sciences, in honor of the Academy's 250th anniversary; it was then published in the USSR in February in Successes of the Physical Sciences (Vol. 118, Issue 2). His point is particularly timely now, however, when the Atlanticist political forces are stridently demanding genocide through "limited growth," under whatever slogan, and when some leading Soviet circles are foolishly allowing themselves to be hoodwinked into at least passively supporting such triage policies.

Kapitsa develops and applies a rigorous criterion for gauging the appropriateness of any energy-producing technology for the solution of the problem posed by the imminent depletion of the resource-bases for present energy-producing technologies. His criterion is whether or not a proposed technology provides an increased throughput, or flux, of energy density at least sufficient to power a mode of production more productive and efficient than the present industrial system. He demonstrates that only controlled thermonuclear fusion suitably satisfies this condition.

Kapitsa's article is significant evidence of the clarity among at least leading Soviet scientific circles on the crucial energy question, particularly in contrast to the "pluralist" tolerance of U.S. scientists for phony "alternative" energy sources advocated by such Atlanticist-controlled agencies as the U.S. government's Energy Research and Development Administration.

The second significant feature of Kapitsa's formulation is that it permits proper location of the necessity for qualitative advances in plasma physics theory, again in sharp contrast to the deliberate destruction of such basic research in the U.S., and the application of such advances to fusion reactor design. Needed energy conversion and throughput rates can only be achieved in hot, dense plasmas, and such plasmas exhibit "turbulent" (i.e., complex oscillatory and self-interactive) behavior which lies outside the present scope of mathematical physics. This, for Kapitsa, is the area of research on which maximum effort should be focused. Thus the realization of fusion reactors is seen to be a by-product of the most fundamental theoretical investigations of the frontiers of physics.

It is generally realized that the basic factor determining the development of people's material culture is the creation and utilization of energy resources...The role of energy in the national economy is well illustrated by the curve in Figure 1. On the horizontal axis is the per capita value of the Gross National Product for various countries, and on the vertical axis is a per capita representation of energy resources. Within the limits of normal flunctuation, it is apparent that there exists a simple proportionality. Therefore, if people are deprived of energy resources, their material well-being will undoubtedly fall.

The generation, transformation, and conservation of energy are indeed fundamental processes studied by physics. The basic law established by physics is the law of the conservation of energy. On the basis of this law, a global crisis in obtaining energy is predicted...and therefore the energy problem has become problem number one for technology and science. In the leading countries, great means are presently being spent on scientific and technological research in this area. The main line of this research is generally being conducted with a narrow technological approach, with insufficient consideration of the laws established by physics. Life has shown that the efficiency of research is significantly higher if it is conducted with a deeper consideration of the basic laws of physics. In my statement I want to note those physical laws which should play a leading role in the resolution of energy problems....

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

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

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

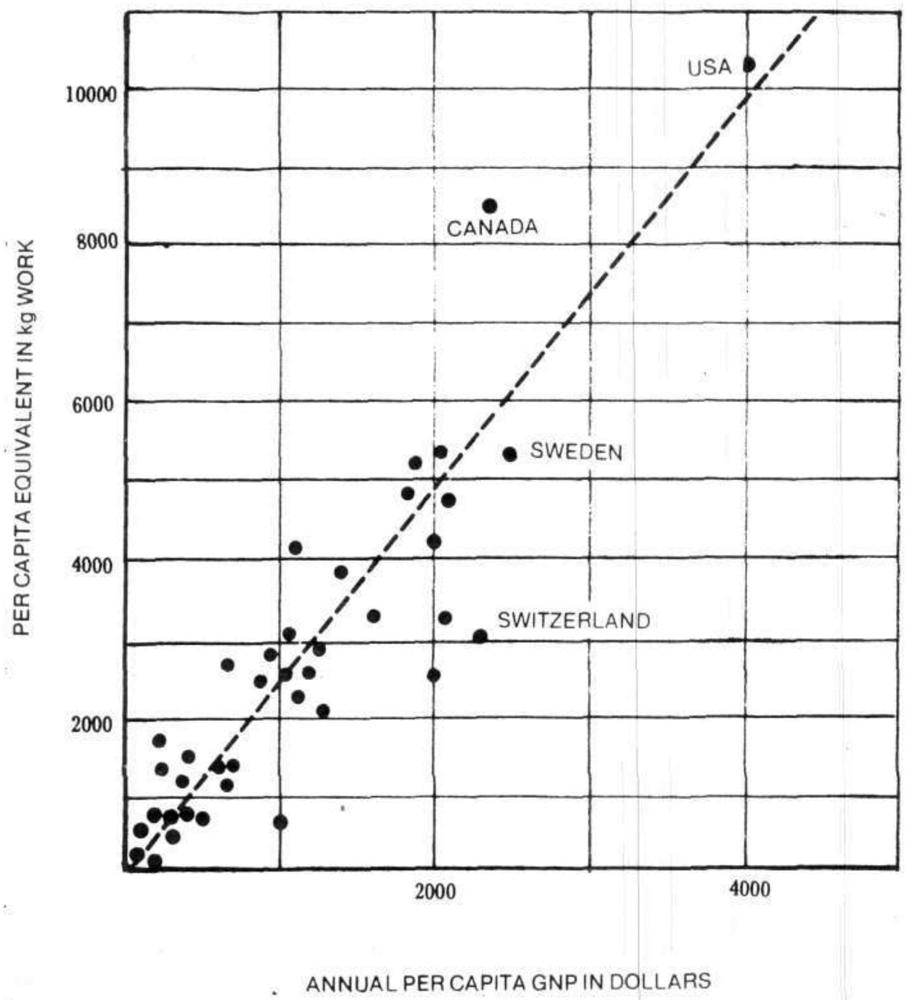
where v is the velocity of diffusion usually equal to the speed of sound, F can be either mechanical or thermal energy, and U is a vector. In stationary processes, div U (the variation of energy flux from place to place in the medium — ed.) determines the magnitude of energy transformation into another form. The vector U turns out to be quite appropriate for studying processes of energy transformation. It was first proposed 100 years ago, in 1874, by the Moscow physicist N.A. Umov. A decade later, G. Poynting derived the same vector to describe the energetic processes in an electromagnetic field. Therefore we call it the Umov-Poynting vector....

Analysis (using the Umov-Poynting vector — Ed.) shows that limitation of the density of the energy current makes it necessary to reject several very effective processes for transforming energy, for purposes of large-capacity energetics. Thus, for example, in gaseous elements where direct transformation of chemical energy of oxidation of hydrogen into electric energy takes place, this process can be carried out with efficiencies as high as 70 per cent. But the possibility of using gaseous elements for large-capacity energetics is limited by the extremely low speed of the diffusion processes in electrolytes; therefore, according to expression (1), the density of energy is in practice very low and only 200 watts can be gotton from a square meter of electrode. For 100 megawatts power, the working area of the electrodes reaches a square kilometer, and there is no hope that the capital expenditures on construction of such a power station could be justified by energy it would generate....

(Kapitsa shows that this is also the case for proposals ranging from his teacher Ioffe's electrostatic generator to tapping bio-chemical processes.)

At the present time the greatest interest is focused on those methods of energy generation which to not depend on the quantity of energy stored in various types of fuel stored over past centuries. Of these the main one is the direct transformation of solar energy into electric or mechanical energy, on a large scale of course. Again the realization in practice of this process for large-capacity energetics is connected with the limited magnitude of energy density. Optimal calculations have shown that the power from one square meter of surface irradiated by the sun will on the average not exceed 100 megawatts, it is necessary to take the electric energy from an area of one square kilometer. Not one of the methods yet proposed for transforming solar energy can do this in a way that the capital expenditures would be justified by the energy obtained. For this to be profitable, it is necessary to lower the expenditures by several times, and the way to do this cannot even be forseen at this point. Therefore it must be considered that the practical direct utilization of solar energy on a large scale is unrealistic....

(Kapitsa notes that the same is true for geothermal and wind schemes.)



As is already being generally recognized, all hope to solve the global energy crisis is connected with utilization of nuclear energy. Physics gives every basis to consider this hope well-founded.

As is known, nuclear physics gives two directions for solving the energy problem. The first of these is well developed and is based on obtaining a chain reaction in uranium, as its nucleus collapses and neutrons are given off. This is the same process which takes place in an atom bomb, slowed to a stationary condition....But it is also well known that three basic difficulties must be overcome on the road to their further wide-spread development and transfer of the whole country's energetics to atomic energy.

1) The wastes from uranium decay are highly radioactive, and to dispose of them reliably presents great technological difficulties, which are as yet without recognized solution....

2) A big atomic power station, with millions of kilowatts power, presents a great danger to the environment and especially man. In case of an accident or sabotage, the exploding radioactivity would destroy everything living over an area of many square kilometers, no less than did the Hiroshima atom bomb. This danger is now considered so great that in the capitalist world not a single insurance company will take on such a risk.

3) The widespread use of atomic energy will also lead to a wide proliferation of plutonium, which is necessary for the nuclear reaction. Such a distribution of plutonium throughout all the countries in the world will make the control over atomic weapons proliferation more difficult....

It must be admitted that the best way out of the situation is obtaining energy through thermonuclear fusion of deuterium and tritium nuclei. It is known that this process takes place in the hydrogen bomb. And finally, the supply of deuterium in nature, in the oceans, is even greater than that of uranium.

But the difficulties in making a controlled thermonuclear reaction have not yet been overcome. I will speak about them in my report, because as it now turns out these difficulties are basically also related to the creation in a plasma of energy flows of sufficient power. I will go into this in somewhat more detail.

It is well known that to usefully obtain thermonuclear energy, the ions in the plasma must have a very high temperature, more than 100 million degrees. The main difficulty of heating the ions is connected with the fact that the heating of the plasma results from action of an electric field upon it, and in this practically all the energy is received by the electrons, which due to their small mass are poor transmitters under impact, of energy to the ions. Calculations of energy transfer from electrons to ions in plasma, with their coulomb interaction, were already theoretically well described in the 1930s. L.D. Landau gave the expression for that interaction, which remains accurate to this day....

The small magnitude of energy transferred to the ions is especially manifest in the Tokamak thermonuclear installations, which are the most widely developed at this time. In the Tokamak the ions are held in a limited volume by a strong magnetic field and the heating process is conducted by electrons, which are initially heated to very high temperatures by a short impulse charge, then transfer their energy to the ions. Under the conditions accepted in current Tokamak plans, the time in which the electrons will give their energy to the ions will reach 20 to 30 seconds. It happens that in this period the greater part of the electrons' energy is given off in plasma radiation loses. Therefore efficient ways are now being sought to transfer the energy from the electrons to the ions in a more prolonged action. This can be either a high-frequency heating or the injection of fast neutral atoms of deuterium, or the dissipation of magneto-acoustical waves. All of these methods of heating, of course, make Tokamak-type reactors considerably more difficult to construct....

It is obvious that the efficiency of energy transfer between electrons and ions grows with density. Therefore we propose that in heating solid condensed tritium or deuterium with a laser impulse, the initial density will be very great, several times higher than in the Tokamak, and it will be possible to heat the ions in a short space of time by impulses. But calculations have shown that, although the heating time is reduced to one 100 millionth of a second, it is still insufficient, because in this time period the unconfined plasma pellet flies apart to a considerable distance.

As it is known, methods are now being sought for laser fusion conditions of collective interaction of the electrons with the ions, e.g. creation of shock waves, which by adiabatic (no heat transfer — Ed.) compression will more rapidly raise the temperature of the ions than by coulomb interaction.

The main obstacle at the present time is that physical processes in plasma are as yet not studied sufficiently deeply. The theory which is well developed here relates only to the unturbulent state of plasma. Our experiments on a freely flowing plasma flux, obtained in a high-frequency, high-power field, have begun to show that hot plasma, in which the electrons have a temperature of several million degrees, is in a turbulent state in the magnetic field. As is known, even in regular hydrodynamics turbulent processes are not fully described quantitatively, and basically all calculations are based on a theory of approximations (to linear theory — Ed.). In plasma, without doubt, the hydrodynamic processes are significantly more complex, and therefore it will be necessary to take another route.

There is no basis for considering that the difficulties of heating ions in plasma will not be overcome, and I think that the thermonuclear problem of achieving large powers will be solved in time.

The basic task facing physics is the deeper experimental study of the hydrodynamics of hot plasma, since this is necessary to make a thermonuclear reaction under high pressures and in strong magnetic fields. This is the great, difficult, and interesting task of modern physics. Its solution is closely connected to the solution of the energy problem which is becoming decisive for our epoch. Of course, this is the number one problem of physics.

Engineers Map Auto-to-Tractor Conversion to Fight World Holocaust

by Eric Lerner

Detailed plans for the conversion of U.S. auto plants to tractor production have been drawn up by a team of Midwestern engineers. The plans come at a moment when the expanded food production made possible by agricultural mechanization is urgently needed for the reversal of the expotential spread of disease.

The U.S. Labor Party has warned that without a substantial increase in food production to increase nutritional levels and thus increase disease resistance of the world population, it will be very difficult to avoid devastating disease epidemics by this fall or winter. Existing food reserves usable for human consumption amount to about 50 million tons, adequate for only one-third of the nutritional increase needed for substantial increases in disease resistance.

In order to produce the additional 100 million tons of grain minimally needed between now and the 1977 harvests, the September planting in the southern hemisphere, especially the immensely rich and unused soils of the Argentine Rio de la Plata region, must be massively expanded. For this tractors, three quarters of a million of them, are required above all. With present U.S. and Western European tractor production operating at less than replacement rates for existing tractors, the necessary massive new production can come only from crash conversion of the auto industry. At the same time, the implementation of the agricultural development plans which are the core of any competent peace settlement in the Mideast similarly require hundreds of thousands of tractors from converted auto factories.

To stop the threats of thermonuclear war and ecological catastrophe, the auto plants must be converted. The prerequisites for their use — Third World debt moratoria and agricultural development agreements — must be set in motion.

Responding to to this urgent need, machine designer Jack Seiler, assisted by a small team of Midwest auto engineers has drawn up preliminary plans for the crash program of auto conversion. Seiler, who works for the Advanced Machinery and Engineering Company (a machine tool manufacturer), had previously worked on the design of machine-tool transfer lines (automatic series of machine tools) for the huge Kama River Truck complex built in the Soviet Union with Western machinery. He got help from other engineers by telling them, "These people in the Third World can produce food, but they need our tractors — let's produce them!"

This is the first time that specialists outside the U.S. Labor Party have prepared programs to meet the requirements of the Labor Party's International Development Bank policy for world reconstruction.

The Crash Program

Seiler's plan outlines the precise steps for conversion and the time and manpower requirements involved. The first phase, occupying a small team of top agricultural and automotive engineers for about week, will be the selection of the existing tractor design most suitable for use in Third World countries and most readily produced — a "peasant-proof tractor."

"What you want is a simple, rugged machine which can run on practically no maintenance," Seiler explained. He used as an example the Lantz Bulldog, a tractor designed by pro-communist engineers in pre-Nazi Germany for use in then dismally backward Eastern European agriculture. "This machine wasn't fancy, but if even one cylinder was still working, you could plow your field with it — it would run for years without major maintenance."

Simultaneously with this selection, the engineering cadre of the next phase must be organized in at most a couple of weeks. Three or four thousand competent engineers must be drawn off the unemployment lines and grouped into a concentric circle structure, beginning with a handful of top experienced engineers as organizers, who in turn will direct a hundred or so senior engineers and designers, themselves the heads of teams of less experienced but competent engineers and technicians.

In the second phase, a task force of 250 technicians and engineers will inspect and study the transfer lines, assembly lines, and foundries available for conversion. On the basis of this study, a decision will be made about which idle lines to use and which partially used lines to consolidate auto production on, to free the rest for tractors. Seiler estimates that today, even with the small increase in auto production, fully 40 per cent of all productive facilities remain idle. Ten transfer lines and the associated assembly lines and foundries for parts casting will be selected at this point for conversion. For all lines this phase will involve about 10,000 manhours, or about a week's work.

The third phase, the main design of conversion of the transfer lines and assembly lines, will then begin. Seiler's plan concentrates on describing in some detail the most difficult task, that of converting the complex automatic machine tools which machine the engine block, but simultaneous efforts will involve the simpler assembly lines where such changes are necessary, the foundries where the parts are cast, and

so on. The selected tractor design will be used to decide how each part is to be machined and to select appropriate tools and automatic settings for machining them. Then transfer lines will be laid out and fixtures to hold the work and machining heads will be designed. Based on studies of the cycle time (repetition rate) of machine tools, all electrical schematics will be revised and existing controls rewired.

Finally the transfer line, made up of hundreds of machining stations, will be studied to alleviate bottlenecks by adding additional machines performing the same task, maximizing the ultimate production rate. For the transfer lines, this phase will mean about 100,000 manhours of work, and the job as a whole should take roughly two weeks for the total engineering manpower available.

At this point, the components for the redesigned transfer lines must be manufactured where they are not already available in the existent lines. This means a crash mobilization, prepared in the preceding month, of various specialized foundries and machine shops for rapid production of these key components. This phase, lasting a minimum of two weeks, will overlap with the final phase, that of actual conversion.

In this final phase, the previously organized engineers will become the supervisors of a larger workforce of 7,000 to 8,000 highly skilled machinists hired and organized during the preceding period. Working in shifts around the clock, this integrated task force will rework the machine tools' pneumatic, hydraulic, and electrical controls, rebuild the machining heads and holding fixtures, relocate the machining stations in the line, and install new motors where larger power is required. Simultaneously, other parts of the task force will be implementing the planned changes in assembly lines, foundries, axle and parts lines. For all lines some 500,000 hours of work, or another two weeks, will be required to finish the job.

War-Time Mobilization

Seiler emphasized that such an extreme crash program would be possible only with the highest degree of motivation, comparable to that of the war-time conversions at the start of World War II. "The leadership and team work of such a project must be absolutely top-notch — the task force must work like a well-oiled machine" if anything close to this timetable is to be realized, he said. If not, time is wasted in blunders and uncoordination.

Seiler's plan demonstrates that conversion from auto to tractor production could be carried out in two months, start to finish. But without this mobilization, absolute priority for all parts obtained outside the industry, and general, top-down organization, "this thing would inevitably take six months or more." Those conditions must be a product of the political mass organizing which alone can bring the tractor plan into implementation in the first place.

Once completed, the new converted factories would begin to churn out tractors, simple, big but sturdy and capable of doing the job, at a rate of 350,000 a month in the U.S. alone, and a similar additional number if 40-50 per cent of Western European factories are converted (like the plants that Italian FIAT boss Agnelli is shutting down). Seiler's firm estimates of a conversion ratio of one tractor for each car produced is nearly double the estimate made by the Labor Party last year on the basis of a much less thorough engineering analysis.

If conversion were underway by June 1, tractors could be rolling off the lines by the early August, and, by mid-September, plowing up Argentine and other Third World fields or on their way to the Mideast. Each tractor would enable the production of some 150 tons of food on 75 hectares of land. For each day this conversion is delayed, **3 million tons of food** will not be produced, and **700,000 people will die** of starvation or disease over the course of the next year.

Eric Lerner is a leading member of the research and development sector of the U.S. Labor Party. He has done extensive research on global economic development and the threat of ecological holocaust.

Aspects of a Fusion-Based Economy

by Jon Gilbertson

A small handful of scientists and engineers in the United States, along with an even smaller handful of money, has been involved in looking at what a fusion-based economy would mean. Most of the effort to date involves getting an overview of the possibilities for integrating industrial processing around fusion reactors and identifying the various ways for accomplishing this integration. The results of even these cursory studies have made it very clear that fusion reactors not only represent an inexhaustible source of energy for mankind in the conventional sense, that is, heat and electricity, but in addition provide a vast resource of new energy forms through the plasma medium often referred to as the "fourth state of matter."

This medium, the fusion plasma, will totally revolutionize and transform industry to the form necessary to permit human society to make that leap forward to the next higher manifold required for our survival beyond the year 2000. Absolutely necessary for this transition over the next two decades will be unprecedented rates of consumption worldwide, and particularly in the advanced sector, of the conventional energy resources such as oil. In the latter half of this period, fusion reactors will be providing significant amounts of thermal and electrical energy as well.

The integration of industrial processing around fusion reactors will occur in essentially two phases. The first will be the upgrading and advances in processing that will result with the availability of large amounts of thermal and electrical energy. This will directly involve the conventional heavy, chemical, and material processing industry, particularly those processes that will require future power inputs greater than 100,000 MWt. These include iron ore production, aluminum production, ammonia production (particularly fertilizer), cement production, and hydrogen production.

Total thermal and electrical power requirements for these applications in the United States have been estimated by Steinberg, et al. (1) to reach 2.1×10^6 MWt and 768,000 MWt respectively after the year 2000, and these are likely to be low predictions. In addition, fusion reactor thermal energy can be applied to processes that are not presently utilized because large sources of cheap thermal energy are not now available. These are high temperature processes operating at 1500^0 C or higher and include, for example, acetylene production, nitrogen fixation, carbon dioxide decomposition, and water decomposition.

The second phase of industrial integration will occur through the use of the high-temperature plasma directly and the new energy forms that are made available. Since this will represent the real transformation of industry as we now know it, many of the future possibilities are unknown at this time and will be discovered over the next time period. Some work has been done, however, again by a vanguard handful of scientists and engineers, and has already opened the door to some mind-boggling prospects for future skilled industrial workers.

The nucleus of these prospects is an original study performed by Eastland and Gough in 1970 (2) on a new approach to pollution and energy use based on the idea of using a "fusion torch," that is, high-temperature fusion plasma. This concept has since been expanded by Sabri (3), Steinberg, et al. (4), and Eastland and Gough (5) to several areas of industry using the large amounts of plasma energy in the form of high energy particles, neutrons and gamma rays, and electromagnetic radiation. Some of the industrial applications of these energy forms include: production of primary metals such as iron and aluminum; synthetic fuel production (that is, hydrogen and methanol); chemonuclear production of basic industrial chemical compounds such as carbon monoxide, hydrogen peroxide, ethylene, formaldahyde, and nitrogen dioxide; photochemical reactions in general; ozone production; desalination of H_2O; and element reprocessing and matter recycling. In addition, separation of basic atomic species from ores and other materials vaporized by direct plasma interactions by using rotating plasmas has been proposed.

From the research completed thus far it is clear that the advent of fusion reactors will open the door to the development of integrated, multi-component chemical and material complexes which were heretofore unknown and impossible. The following example of such an industrial complex was developed by Steinberg and Jordan (6) and would combine the production processes of steel, methanol, and ammonia as well as electrical power.

Steel-Methanol, and Ammonia Production: A Multi-Component Industrial Complex

The first step toward economic recovery is to determine goals in the production of the most basic industrial commodity, steel. The current debt-imposed collapse of the steel industry in the advanced sector and particularly in the United States, is well recognized by the working class and a few enlightened industrialists as a result of the U.S. Labor Party organizing and publications. *(7)* Basic processes and technology within the U.S. steel industry have changed very little over the past century and are currently no more than a crude scale-up of the technology of at least 100 years ago. Therefore, the potential advances and breakthroughs that will occur in the steel industry once it is integrated within the technology available through fusion reactors is a particularly important focus.

Such an integrated industrial complex, shown schematically in Figure 1, not only produces large quantities of steel, but also processes large amounts of ammonia for the production of fertilizer, as well as methanol for use as liquid fuel. Production of iron is based on the "Jordan Blast Furnace Concept," an advanced process that could be incorporated into steel production today (see below) and would immediately double the output of iron. Steel is manufactured in the complex from two processes: the Basic Oxygen Process (BOP) which is the dominant method in use today, and the Electric Furnace, which now produces less than 20 per cent of the U.S. steel output because it requires large inputs of electricity. The production of ammonia fertilizer and methanol liquid fuel in the integrated industrial complex is also by

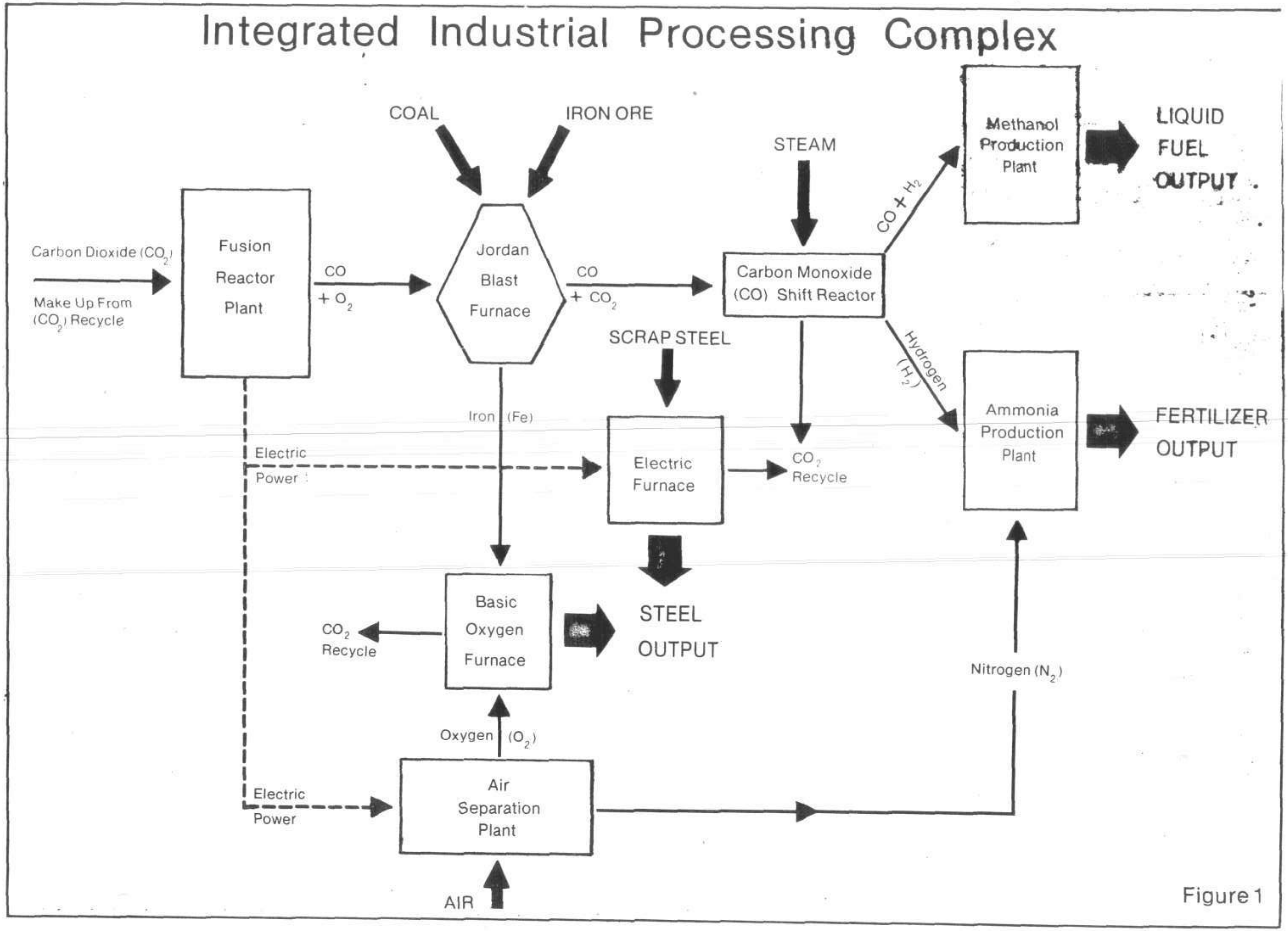

Integrated Industrial Processing Complex
Carbon Dioxide (CO_2)
Make Up From (CO_2) Recycle
Fusion Reactor Plant
CO + O_2
COAL
IRON ORE
Jordan Blast Furnace
CO + CO_2
STEAM
Carbon Monoxide (CO) Shift Reactor
CO + H_2
Methanol Production Plant
LIQUID FUEL OUTPUT
Hydrogen (H_2)
Ammonia Production Plant
FERTILIZER OUTPUT
SCRAP STEEL
Iron (Fe)
Electric Power
Electric Furnace
CO_2 Recycle
STEEL OUTPUT
Basic Oxygen Furnace
CO_2 Recycle
Oxygen (O_2)
Electric Power
Air Separation Plant
AIR
Nitrogen (N_2)

Figure 1

currently used processes; however, the integration of these processes with a fusion reactor opens the door to their large-scale expansion and use. Overall, the integration of these multi-component industrial complexes with a fusion reactor allows production capacities that are not now possible.

The industrial complex shown in Figure 1 uses fusion energy in two forms, electricity through the conversion of heat via steam turbines, and radiation through the production of high energy gamma rays via neutrons produced in the fusion process. The fusion reactor is cooled by carbon dioxide (CO_2), which flows through the blanket regions of the reactor. Not only is the thermal energy removed by the CO_2, in addition, disproportionation of a portion of the CO_2 to carbon monoxide and oxygen by gamma radiation occurs; that is, $2CO_2 \longrightarrow O_2 + 2CO$. The oxygen and the carbon monoxide is then separated from the carbon dioxide and fed directly to the blast furnaces where iron is produced by the Jordan process. The carbon dioxide remaining, plus additional carbon dioxide make-up from the steel making process is cycled back into the fusion reactor as primary coolant.

Because of the large amounts of inexpensive electricity available from the fusion reactor, the steel making operation can incorporate two basic energy-intensive processes, the oxygen furnace and the electric furnace. Each of these processes has its own special advantage in steel making, and the capability to use both at roughly the same output in tons per year of steel permits optimal operation. As applied to this integrated processing scheme, the electric furnace is the best process for converting scrap steel to reusable steel, while the basic oxygen furnace best converts blast-furnace iron to steel. The air separation plant that produces the oxygen for the basic oxygen furnace also separates nitrogen from the air, which is then used in the production of fertilizer in another part of the production complex.

A breakdown of the fusion reactor energy distribution to these industrial processes is shown in Table 1. Also indicated is the output of product in tons per year of the various processes within this multi-component complex. As shown in Table 1, most of the energy from the fusion reactor 92.7 per cent, goes into radiative disproportionation of carbon dioxide for production of carbon monoxide and oxygen, while the electric furnace uses 7.0 per cent and the air separation plant less than 0.3 per cent of the fusion reactor energy.

The balance of this integrated industrial complex consists of the production of liquid fuel (methanol) and fertilizer. Carbon monoxide which is produced in the fusion reactor is mixed with equal amount of carbon monoxide produced in the blast furnace operation itself and used as raw material feed to those industrial processes.

For the production of methanol, the carbon monoxide is mixed with steam in a shift converter, resulting in the production of hydrogen and carbon dioxide that is then carried by the unconverted carbon monoxide to the CO_2 solvent separator. This process removes the CO_2 from the mixture, where it is recycled back into the fusion reactor, while the hydrogen and carbon monoxide is channeled through a catalytic converter, producing methanol.

Ammonia is produced by a similar process, except that the carbon monoxide is completely converted to hydrogen and carbon dioxide via the steam shift converter. Therefore, removal of the CO_2 for recycle will leave only the hydrogen, which is subsequently mixed with nitrogen from the air separation plant, then passed through a catalytic converter to result in ammonia fertilizer.

This integrated processing complex clearly illustrates the relatively early industrial capabilities and breakthroughs possible during the transition to a fusion-based economy. Furthermore, this is only one example of the many possibilities for industrial integration that have already been identified by researchers in this area. It is clear, even from the industrial complex described here, that we need not worry about the necessity of rapidly using up all our current reserves of coal, oil, and natural gas in order to make the transition to fusion. Natural gas, which is now the primary raw material used in the produciton of ammonia fertilizers, can be fully committed immediately to large-scale fertilizer production based on world consumption requirements, since a future fusion economy will provide a means for even larger-scale fertilizer production through utilization of nitrogen and hydrogen, from air and water, respectively.

Similarly, oil and coal can be fully committed now as an energy resource to be exhausted during this transition period since the essentially infinite resources of fusion energy will completely replace future thermal and electrical power needs. Furthermore, the future requirements of liquid fuel for automobiles, diesels, and so forth, can easily be met by the production of methanol from hydrogen and carbon monoxide using several alternative forms of energy from the fusion reactor.

Other necessary heavy industrial materials and chemicals can be produced by similar methods based on future developments in fusion technology and will be described in later articles.

The Jordan Blast Furnace Concept

It is not necessary to wait until large fusion power plants are operating in order to greatly increase the industrial output of steel, fertilizer, liquid fuel, and other materials and chemicals. The process of beginning to create integrated multi-component complexes can begin immediately in combination with a commitment to developing fusion power.

The most obvious example of what could be done now in the steel industry is based on research that was completed ten years ago by Jordan. *(8)* He developed a relatively simple alternative to the age-old hot-air blast furnace currently used in producing iron. The concept involves altering slightly the operation of a conventional blast furnace to both double the liquid iron output and greatly increase the use value of the "top gas" exhaust from the furnace. Jordan replaced the hot-air blast to the furnace with a mixture of oxygen and carbon dioxide. This serves both to increase the heat of combustion in the furnace and to enrich the top gas, which could then be cleaned and converted to either ammonia fertilizer or methanol, — a first approximation to an integrated industrial complex. Part of this top gas would also be used to generate power to run the blast furnace.

Considering, for the moment, the steel-making industry alone, this would mean a doubling of the iron output from currently used blast furnaces with only the relatively simple modification in the plant of providing a source of oxygen via an oxygen-separation plant. Furthermore, the cost of providing this oxygen supply is reported to be less than the cost of the equipment required to heat and inject the hot-air blast in a conventional furnace. In order to accomodate the doubled iron output from this furnace in the steel-making end of the plant, the steel-producing furnaces and processing equipment would necessarily also have to be doubled.

The question of why such alterations, obviously advantageous, both from an economic and productivity standpoint, have not been made must be addressed, even though the answer, given the past and current states of economic collapse of the advanced sector, is obvious. In discussions with a division chief of the U.S. Steel Corporation who was Jordan's supervisor at the time the Jordan process was developed, he indicated that "Jordan was a bit ahead of his time as far as U.S. steel was concerned." The division chief admitted that Jordan's concept "was technically feasible and, in fact, present plant and equipment could be converted without too much trouble or great expense." Yet, when the division chief was asked why the Jordan process wasn't being implemented, he said, "They had more economical ways of operating the blast furnace and, furthermore, with the relatively fixed rates of steel production, the concept is not economical."

It is clear that the steel industry's self-proclaimed steady-state operation is rapidly propelling its decline. At a time when the developing nations need a rapid influx of steel products through heavy construction, farm equipment, industrial machines, and machine tools, U.S. Steel Corporation executives plan for "fixed rates of production." Interestingly, even the inventor of the advanced technology has a limited view of what holds back advances necessary for the world development he advocates. When contacted recently, Jordan apologized for the error of U.S. Steel, saying that "the trouble with them was that they had never been out there in the mill and really didn't know how the mill worked." Now working as a consultant-inventor, Jordan continues to follow the developments in fusion. "Fusion is definitely the way to go, in the long run" he said.

Based on the Jordan process alone, vast increases in steel production can be implemented almost immediately. Such near-term advances will be necessary in order to provide the steel required to produce tractors and farm equipment for advanced-sector and Third World agricultural development. Exactly how the U.S. auto sector can be rapidly converted to tractor production is described in Eric Lerner's article in this Newsletter. As the editorial in this issue lays out, there is no time to lose in implementing debt moratoria and turning around the devastating collapse in technology and production.

Jon Gilbertson has worked as a nuclear engineer for 15 years with a leading Northeastern nuclear design and construction firm. He is on the research staff of FEF.

Footnotes

(1) Meyer Steinberg, Morris Beller, and James R. Powell, "A Survey of Fusion Power Technology to the Chemical and Material Processing Industry," Brookhaven National Laboratories - 18866, May 1974.

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

(3) Z.Sabri, "A Study of the Feasibility of Fusion Torches," Ph.D. Dissertation, University of Wisconsin, 1972.

(4) Steinberg, et al., op. cit.

(5) B.J. Eastlund and W.C. Gough, "The Fusion Torch—A New Approach to Pollution and Energy Use," American Institute of Chemical Engineering, No. 104, 1970.

(6) R.K. Jordan and Meyer Steinberg, "Applications of Controlled Thermonuclear Reactor (CTR) Fusion Power in the Steel Industry," Brookhaven National Laboratories - 19885, March 1975.

(7) U.S. Labor Party Presidential Campaign White Paper on Steel Production, New York: New Solidarity International Press Service, May 1975.

(8) Research completed at U.S. Steel in 1966 by R.K. Jordan, to be published by Pennsylvania State University.

CTR ENERGY APPLIED TO A STEEL-METHANOL-AMMONIA COMPLEX

Process	Raw Mat.	Products	Capacity tons/yr	Unit Energy Req.	MW (Power)	MW (t)
Electric furnace	Fe scrap	Steel	2×10^6	600 kwh(e)/ton steel	172	430
CTR disproportionation	CO_2	CO, O_2	2×10^6 1.3×10^6	20,000 kwh(t)/ton CO		5700
Jordan-Concept furnace	Fe ore, coke, O_2	Iron	2×10^6			
BOP shop	Iron, O_2	Steel	2×10^6			
Air sep'n. for BOP. for NH_3	Air, O_2N_2	Oxygen, Nitrogen	2×10^5 7×10^5	300 kwh(e) t O_2	8.6	21.5
Methanol	CO	Methanol	6.6×10^5 (200×10^6 gal.)			
Ammonia	CO	Ammonia	8×10^5			

Table 1 shows a breakdown of the fusion reactor energy distribution to the aforementioned industrial complexes.

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What ever the significant, hard-won progress and even breakthroughs in fusion to date, it can still all mean nothing — unless there is a political commitment to carry it through to fruition and a climate supportive of wide-ranging research.

The **IJFE** will be one of the few journals designed to be read from cover to cover because it provides what fusion scientists and non-specialists need in addition to updating on more technical developments: an ongoing **synthesis** of fusion research. To get efficient fusion reactors, there must be continuous mutual interaction of improvements of theory and devices — not simply improvements in the theory of existing devices. And there must be an understanding in Congress and elsewhere of the process of converging on various solutions that repay the original investments many times over to justify support for a growing research effort before payoff.

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Directly related to this function of the Journal are the more general activities of the FEF, which has been the most important institution — aside from the front line researchers — for the survival and development of fusion research. Subscribing to the Journal helps to finance and extend the influence of the FEF, which gives fusion scientists a social potency they are otherwise lacking individually.

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New Physical Concepts in Plasma Physics

The following comments on the present state of plasma research are excerpted from a review paper by V. N. Tsytovich, of the P. N. Lebedev Institute in the Soviet Union. The paper, "Strong Interactions of Relativistic Beams with Gas and Plasma," was delivered at the 17th International Conference on Phenomena in Ionized Gases, Eindohoven, the Netherlands in August 1975. Tsytovich's conference presentation was reprinted in its entirety in Physica, *published by North Holland and Co.*

Readers without a background in plasma physics should not be deterred from reading Tsytovich's comments because of the mathematics in the middle section; Tsytovich discusses the physical import of the formalism in detail.

The Tsytovich article, which sparked great excitement among American physicists, poses in a sharp form the question of the state of conceptual knowledge in plasma physics today. As Tsytovich notes, this problem is especially acute for the case of the strongly turbulent plasmas. In the following article, "What is a Plasma?" Dr. Steve Bardwell of the Fusion Energy Foundation staff challenges Tsytovich's speculation that an adequate formulation of a theory of a strong turbulence can be found in a statistical approach.

The present relativistic electron beam parameters are flexible in a broad domain: the currents reach values of 50-100 KA and even up to several MA; the beam electron density is on the order of 10^{12} to 10^{13} particles per cm^3 and even higher: the particle energy of the order of 100 keV up to 5 MeV, and the duration 100 to 50 ns. The energy in these beams and the power are relatively high, and in the case when this energy is transferred to the gas or plasma a powerful pulsed action occurs. Since the duration of the interaction is small, the interaction must be connected with collective processes. Many data existing today on the interaction of powerful relativistic beams with gases and plasmas indicate that one is faced with new physical problems and that the previously developed concepts on the collective beam-plasma interaction are not sufficient to describe the new physical phenomena.

Notwithstanding the short interaction time, the effects observed are very pronounced and of great importance. They include: (a) the rapid ionization, (b) the appearance of large potentials in a plasma, (c) the effective heating of dense plasma, (d) the acceleration of ions in the direction of the beam up to energies essentially higher than the beam electron energies, and (e) the creation of non-equilibrium electron and ion distributions with appreciable extra-thermal tail particles, etc. Therefore, the collective processes, if they are responsible for the observations mentioned, must be strong collective processes.

The above are the most impressive phenomena in the strong interaction of powerful relativistic electron beams with gases and plasmas, the physics of which is not quite clear. The main question is, is it possible to use the present concepts of collective plasma processes or are we faced with completely new physics which calls for new concepts. By the present concepts, we mean the standard schemes of collective mode of excitation due to some instabilities and their saturation by nonlinearities. By the new physical concepts we imply the initiation of such new collective motions which are not possible in the plasma without some powerful action on it. One can concieve, for example, of new objects, like clusters of collective modes, which have already been named solitons, cavitons, spikons, relatons,and so on. We may note that the interest in such objects was stimulated by extensive, mostly numerical (but not experimental) investigations. Reports concerning such new objects, found in numerical simulation of beam-plasma interactions, appear in the literature, but the numerical simulation cannot give an answer to the three-dimensional problems which are of interest for the experiments.

Often these problems are connected to the problem of so-called strong Langmuir turbulence, the theory of which is, at present, only at a rudimentary stage, notwithstanding (or perhaps due to) the extensive efforts made in the last few years to solve this problem by numerical methods. It seems that the transition of a plasma to a state of strong turbulence is, in a sense, similar to a phase transition in which the different collective modes, coalesce, forming some kind of cluster. Plasma physicists are at present only starting to understand the general properties of this new plasma state. The interaction of intense relativistic beams with plasma present one, but not unique, method that induces such a transition. Similar transitions can occur if the plasma is subjected to strong radio frequency waves, or laser beams. Therefore, the problems of strong beam-plasma interactions and the laser-plasma interactions are frequently discussed together. In the following we try to draw attention to the specific effects connected with powerful relativistic electron beams and to some general problems, underlining the unsolved questions.

One of the most effective collective interactions of the relativistic electron beam with a plasma is the excitation of Langmuir oscillations. The level of Langmuir oscillations is usually high enough to create modulational instability. Let us first take up the modulational instability of intensive Langmuir oscillations in the absence of the beam, or with the beam present but in the domain of phase velocities, that is, when the beam itself does not influence the modulational instability and is simply a source of Langmuir oscillations.

The modulational instability is created due to the high frequency pressure of Langmuir oscillations which are practically trapped in the fluctuation of plasma density rarefaction (see Figure 1). If the high frequency pressure becomes sufficient to increase the density rarefaction, more waves will be trapped which will then increase the high frequency pressure, that is, rarefaction will develop further. This effect was first pointed out as far back as 1964 but extensive investigation was postponed until 1972 when attention to this problem was greatly stimulated again by some numerical simulations and numerical computations. The numerical simulations, performed specifically for the case of relativistic beams, showed that the modulational instability plays a very essential role.

The linear theory of the modulational instability is in a very well-developed stage. In the simplest case, one can use the equations following from the Poisson equation, taking into account the first non-linear terms proportional to the square and cube of the electric field of Langmuir oscillations:

$$\operatorname{div}\left(2i\omega_{pe}\frac{\partial}{\partial t} + 3v_{Te}^2\Delta\right)E\,(r,t) = \operatorname{div}\left(\omega_{pe}\frac{\delta n}{n}E\,(r,t)\right), \qquad (1)$$

$$\left(\frac{\partial^2}{\partial t^2} - v_s^2\Delta\right)\delta n = \Delta|E\,(r,t)|^2/4\pi m_i,$$

where $\mathbf{E}$ is the amplitude of the electric field strength equal to $E\exp(-i\omega_{pe}t)$; $\omega_{pe} = (4\pi n_0 e^2/m_e)^{1/2}$ is the electron plasma frequency, and $v_{Te} = (T_e/m_e)^{1/2}$ is the thermal electron velocity. In the first equation, the term $3v_{Te}^2\,\Delta E$ describes the electron thermal motion, and the right-hand side of equation (1a) describes the influence of the density rarefaction. In equation (1b), the left-hand side describes the transportation of a density disturbance δn with sound velocity $v_s = v_{Te}(m_e/m_i)^{1/2}$ and the right-hand side describes the increase of a density rarefaction under the action of high frequency pressure of Langmuir waves. It is possible to show that the system of equations (1) is an approximation of more precise equations which take into account all the non-linearities, including the term proportional to the cube of the electric fields, if the following inequalities are satisfied:

$$t \gg \omega_{pi}^{-1}\,;\quad l > 10v_{Te}/\omega_{pe} = 10r_d\,;$$

$$\omega_{pi} = \omega_{pe}(m_e/m_i)^{1/2}.$$

Let us consider the main consequences of the development of the modulational instability. From the simple physical picture (see Figure 1) it is obvious that in the first stage the density rarefactions are increasing spontaneously. In the second stage new collective objects or motions can be formed.

The simplest are the Langmuir solitons. Apparently, solitons can exist only for one-dimensional motions. Equations 1a and 1b have a self-consistent non-linear solution corresponding to motion with a constant velocity V_0, which can be called a soliton.

Shown in Figure 2 are the subsequent stages of soliton formation from an initially homogeneous field, which were calculated by numerically solving equation 1. The velocities of solitons cannot exceed the sound velocity V_s since for $V_0 > V_s$, the density rarefaction cannot keep up with the field increment. Analysis shows that the one-dimensional soliton in the absence of a very strong magnetic field, is unstable for three-dimensional disturbances.

Investigations of the development of the modulational instability in three-dimensions, even in the frame of the simplest equations (1), is an essentially more complex problem. In the case of three-dimensional motion there exist two possible final results of the development of density rarefaction: (1) the development of density rarefaction will be stopped by non-linearities; (2) the effective size of the density rarefaction will decrease down to the values of the order of the Debye length r_{De} and the energy of the Langmuir oscillations will be absorbed by fast electrons. For the second possibility the rather inapt tern. Langmuir collapse was coined and the objects formed were called cavitons.

The main part of the collapse is supersonic. But in this case the domain of the validity of equations 1a and1b on which all the conclusions about collapse were based, is essentially reduced. This shows that collapse is impossible. In

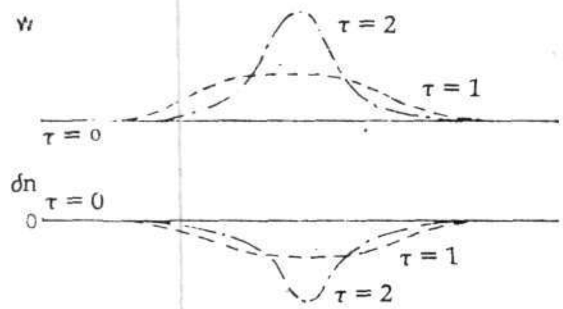
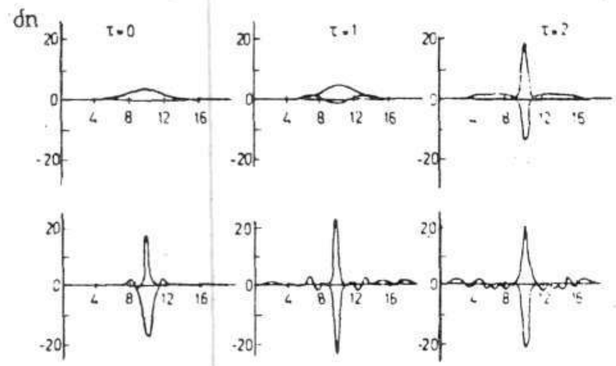


Figure 1 The development of modulational instability. Figure 2: The results of numerical calculation of the formation of solitons during the development of modulational instability.



connection with this conclusion, recent numerical simulations results are of interest, as they show that the process of increase of density rarefaction is stopped at

$$r = (6 - 5)r_d$$

The objects formed were named spikons.

The plasma state in which solitons, spikons, and cavitons exist simultaneously sometimes is considered a model of a new physical state, often called a state of strong Langmuir turbulence. But in a state, easily excited by relativistic beams, evidently the interaction between the new collective motions described (solitons, spikons, etc.) becomes essential and this interaction destroys their individuality. To describe this state a new statistical approach is needed.

As already mentioned, research related to the new physics of strong turbulence and new dynamic collective processes is still in its initial stage. There is no doubt that these problems will be in the center of modern physics for a long time. However, there is hardly any hope that the use of computers, that played such an important role in the stimulation of the initial research in this field, will play any significant role in the future and be of use for the interpretation of the experiments. only three-dimensional theoretical concepts will be able to give an appropriate description and the theory of strong turbulence, as we believe, must be developed on the basis of a statistical description. A program for founding a theory of strong turbulence by investigating particular dynamic motions like solitons, cavitons, spikons, and so on, apparently cannot be consistent not only because it is practically impossible to take into account all the real variety of such phenomena, but also due to the fact (and this is more essential) that the interaction of these dynamic motions qualitatively changes their properties. Therefore, we think that the approach in which three-dimensional statistical principles are used to describe the modulational disturbances can be regarded as a first step toward a theory which is required for an adequate description of this new plasma state.

Frontiers of Science in Plasma Physics

The following article by Dr. Steven Bardwell, a plasma physicist on the FEF staff, provides an introductory survey of the range of plasma phenomena that most suggest the need for new conceptions to grasp the interactions characterizing the plasma state. This preliminary work will be followed in the future by more detailed studies on the evolution of thermodynamic, electromagnetic, plasma, and quantum theories to locate the most important areas for deeper theoretical investigation. The purpose of this work will be to begin the specification of types of experiments that probe "into" the interaction responsible for the remarkable properties summarized here.

by Dr. Steven Bardwell

More than 99.9 per cent of the matter in the known universe exists in a plasma state. This preponderance of matter, furthermore, exists in a range of temperatures and densities that defies imagination.

We can get a good, though approximate, measure of the tremendous range in physical states by comparing the energy density of the known plasmas. For the interstellar plasma, with a density of about one particle per cm^3 and a temperature of several thousand degrees Kelvin (which has existed for tens of billions of years) to a laser-induced plasma, with a temperature of 10 million degrees and a density of 10^{26} particles per cm^3 (which exists only for billionths of a second), there is a range of energy density (calculated approximately from the product of the temperature, θ, and electron density, n_e of 10^{30}. That is a number whose largeness is difficult to appreciate; but for comparison, 10^{30} grains of sand would fill the volume occupied by a sphere the size of the earth!

Most important for the questions examined here, that range of energy density not only is a quantitative measure of the different kinds of plasmas that can exist, but also provides insight into the qualitative diversity of the plasma state. These different "phases" of a plasma, as different as a solid and gas in un-ionized matter, give rise to an incredibly rich variety of plasma phenomena. It is my contention here that this variety of phenomena includes effects that cannot be sufficiently described by present physical theory. In fact, as this brief and non-technical survey attempts to show, research into singular and ordered phenomena — which I argue are the characteristic kinds of behavior of plasmas — shows that the present physics cannot generate a coherent description of these globally ordered phenomena within the essentially microscopic and entropic conceptions that underlie contemporary physical theory. The implied directions in which scientific research must go are evidently much more social and political questions, as I will show.

Figures 1 and 2 are strikingly different pictures of the evolution of a system of "fluid-like" turbulence. The first (Figure 1), a time-series of photographs of a jet of water entering a previously undisturbed bath of water, shows dramatically what is certainly the intuitively expected evolution of this form of initially ordered energy being deposited in the fluid. The large, beautifully symmetric vortices that are formed as the fluid jet first enters the liquid bath rapidly decay into smaller and more chaotic turbulence, with the end result that the scale of turbulence becomes microscopic, eventually leaving its mark only in the form of slightly increased molecular motion (that is, the fluid bath is slightly hotter).

The next series of photographs (Figure 2) shows the inferred evolution of a large (about 1,000 light years in diameter) body of plasma turbulence. The progression is clearly from a relatively disordered state of the elliptical nebulae to a spiral galaxy. Even more amazing, there is very strong evidence that the evolution of laboratory plasmas is similar: that the deposition of energy in a plasma results in the "spontaneous" transition of the plasma system from a state of relative disorder to one of greater order. Two

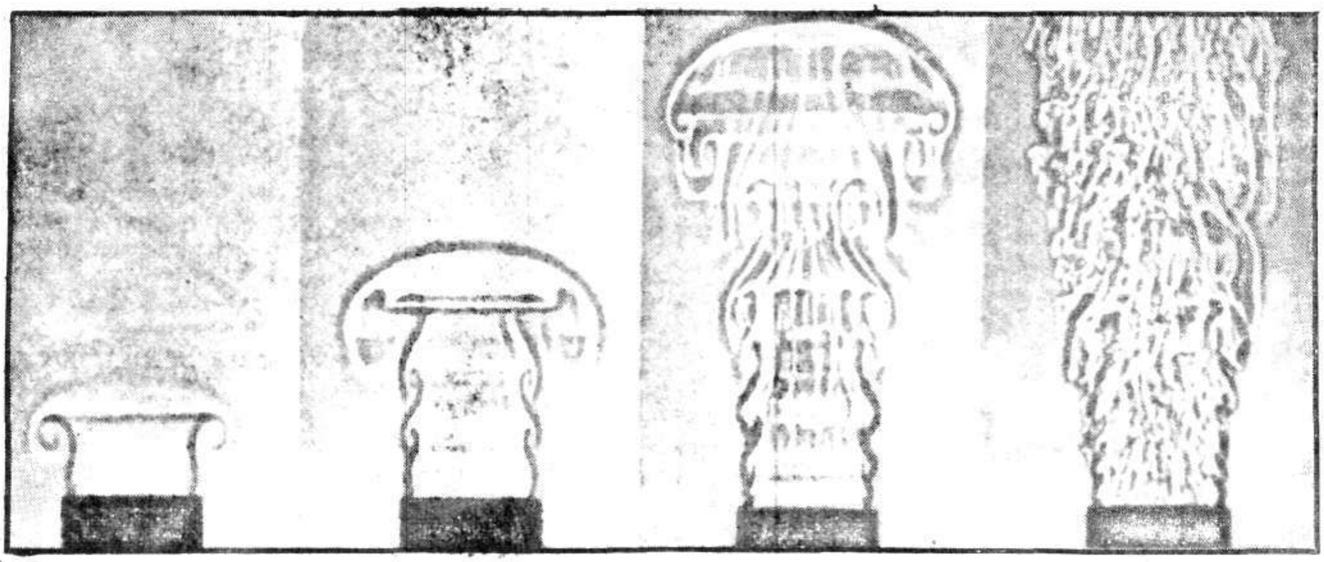


Figure 1: Fluid turbulence — a time-series of photographs from (left to right) of a jet of water entering a previously undisturbed bath of water. The initial symmetric vortices decay into chaotic turbulence.

examples of this are **immediately accessible**: the case of strong Langmuir turbulence, which is characterized by intense, highly localized fields that the plasma creates out of the otherwise random energy, and the case of magnetically confined plasmas which, in a dynamic state, are highly structured into tightly wound, very dense threads of current and magnetic field.

I will describe these experiments in more detail below, but the striking kind of behavior that a plasma regularly exhibits is emphasized by imagining the same sort of phenomena happening in a more down-to-earth situation. V.N. Tsytovich, in an article excerpted above, describes the equivalent of the following sequence of events: Shine a flashlight in a darkened room; instead of the expected diffuse spot of light appearing on the opposite wall of the room there appear several intense spots of light, that have concentrated the energy of the flashlight into spots whose intensity is thousands of times the intensity of the original beam. Fortunately, it doesn't happen!

Or, parallel to the occurrences in a Theta-pinch plasma machine, imagine that the result of turning on a radiator in a room is the production of violent blasts of hot air with temperatures several times that of the radiator! As bizarre as that would be in a cold room, it is the well-documented result of the propagation of an electric field in many magnetically influenced plasmas.

The fact that these kinds of globally ordered and strikingly coherent phenomena are not at all unusual in high-energy plasmas constitutes a serious challenge to presently known plasma physics and, a fundamental challenge to the roots of plasma physics in, especially, Maxwell's equations and elaborations of mechanics (either of the sort of Liouville's equation, or, more rarely, quantum mechanics). This is obviously not to say that a number of ad hoc assumptions could not be found that would phenomenologically describe this behavior; that, in fact, describes much of the theoretical work that goes on in plasma physics in conjunction with laboratory work. The question is, can presently understood physical concepts account in a coherent way for these very basic (not at all derived) kinds of collective effects. Before trying to answer this question, it is necessary to look more closely at the three classes of phenomena referred to above (strong Langmuir turbulence, the vortex filaments observed in a magnetically active plasma, and the existence of galaxies) to better identify in a rigorous way these difficulties in plasma physics.

Strong Langmuir Turbulence

In a plasma in which the energy in the collective motions of the plasma is of the same order as the thermal energy density, when $n_e\,\theta \approx 10\,(\varepsilon_{\text{collective}})$, the plasma exhibits fundamentally different effects than it does in the domain of weak turbulence: $n_e\,\theta \gg \varepsilon_{\text{collective}}$. Perhaps the most striking of these, in a non-magnetized plasma, is the appearance of very sharp concentrations of ε in space and corresponding density variations. The concentrations of collective mode energy have been named solitons or spikons, and the accompanying density depressions, cavitons. The enhancement of ε of these collective modes can be many orders of magnitude above "equilibrium" level, and the persistence and individuality of these structures are astounding. I will not go into detail in regard to the hypothesized physical effects responsible for these solitons, and so on, but refer to the above article by Tsytovich for more details.

Tsytovich makes the point very convincingly that strong Langmuir turbulence faces plasma physics with a number of well-documented experimental and theoretical phenomena that are so unlike the results of previously linear treatments of a plasma, that the underlying assumptions of that theory are called into question. Specifically, I would raise one aspect of the theory of plasma turbulence that seems to be at the root of the formation of solitons and the like, but that is conceptually unexpected. This is the observation of phase coherence effects. The actual dynamics of the decay of the turbulence that give rise to strong Langmuir turbulence are similar to the fluid turbulence pictured in Figure 1 — there is a transfer of energy from longer scales to shorter.

Figure 2a

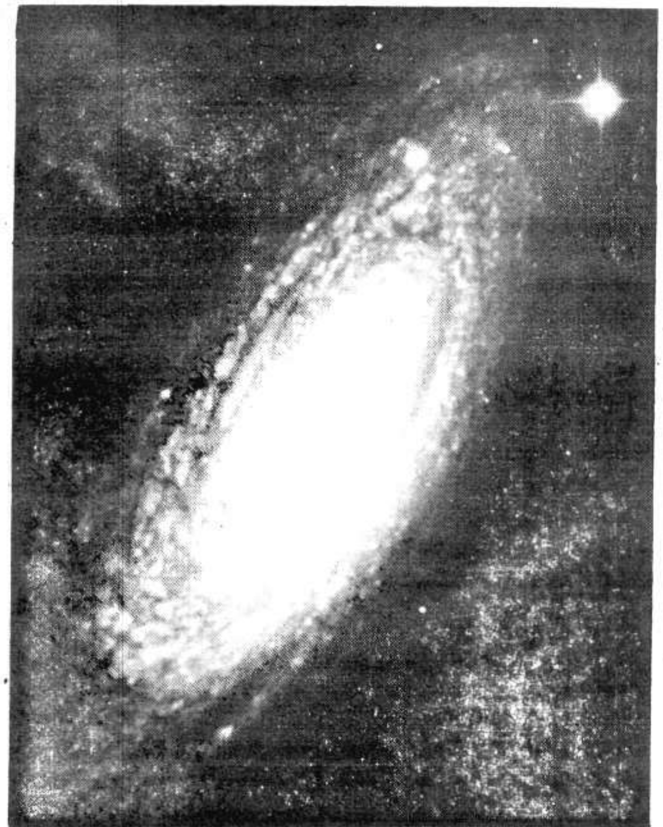


Figure 2b

The same is true of the modulational instability that is at the root of Langmuir turbulence (see Tsytovich's paper), but, the phase in the case of the fluid turbulence quickly becomes uncorrelated with wave lengths, and the result is random fluctuations. However, in the case of the Langmuir plasma turbulence, there is a "remembering" of phase. This results in the constructive addition of the small-scale turbulence in such a way that very sharp spacial distributions of wave energy become the predominant feature of a strongly turbulent plasma. This observation of solitons, and so on, has sparked some very detailed work on the modulational processes, with the general result that what was initially thought to be well understood (that is, even the linear stages of the formation of these structures) is increasingly fraught with difficulties. I would refer here to recent work by Morales and Lee, and DuBois and Bezzerides. (1)

Plasma Vortex Filaments

Similar and even more suggestive difficulties are presented by the observation of highly structured vorticial filaments that appear in careful observation of the current sheet in a Theta-pinch machine. Here, rather than an amorphous propagation of energy through the plasma when the capacitor is discharged into the plasma, a very beautiful set of interlocking "threads" form, whose energy density is on the order of a million times greater than the immediately adjoining parts of the current sheet. Bostick and his coworkers (2), who have done the most detailed experimental work on these plasma vortex filaments, have observed a variety of types of vortical structures, but I will confine what I say here to the vortex filaments that form perpendicular to the guidefield of the machine, so-called paramagnetic vortex filaments.

These filaments have a detailed internal structure, which consists of parallel spirals of magnetic field, current, fluid velocity, and vorticity, giving rise to a Lorentz and Magnus force-free configuration. The physics behind the formation of these structures seems to be that of a non-linear Alfvén wave — that is, that an Alfvén wave in some non-linear stage becomes a vortical disturbance (certainly the force-free arrangement of fields is reminiscent of an Alfvén wave). However, the deeper reasons behind the amazing regularity and repeatability of these structures have raised fundamental questions.

The most profound work done on this is by D. Wells (3), who has developed a generalized fluid approach to the dynamic equilibria in plasmas. Formally, this has necessitated the inclusion of the momentum transport term in the fluid equations, since there is a zero-order velocity in the problem. The increased complexity and nonlinearity of the resulting system of equations have resulted, however, in a conceptual change in the approach to the whole question of plasma equilibrium that is important but unsolved by Wells' work. Very specifically, Wells uses global considerations for these dynamic fluid problems that introduce in a fundamental way the questions of coherence and order in the described plasma. Wells' papers deal with these questions in a physically appealing way, but do not answer the fundamental conceptual questions about the source of the ordering constraints and boundary conditions that are necessary to arrive at his very general results about the low-lying energy states for a plasma system as a whole (the various vortical structures). Wells seems to have taken this important question very nearly as far as is

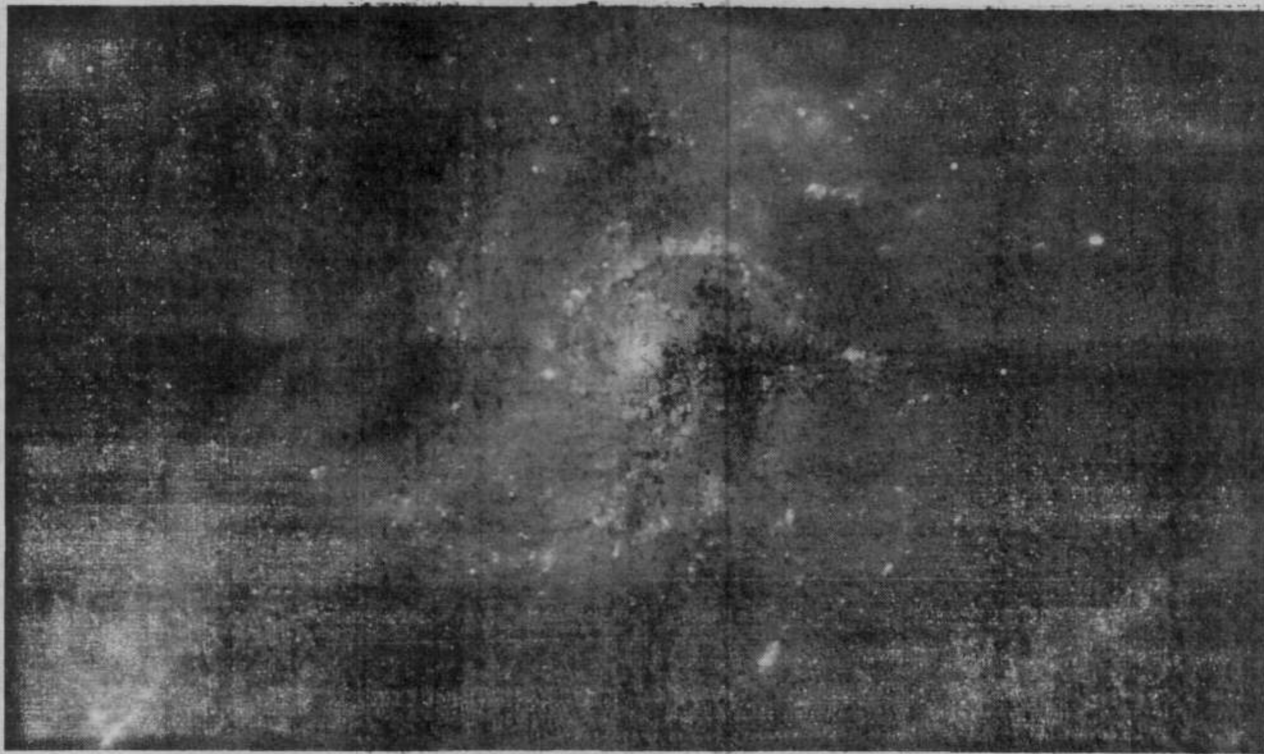


Figure 2c Plasma Turbulence: The disordered state of the elliptical nebulae progresses to a highly ordered spiral galaxy.

possible without a serious challenge to presently understood physics.

Galaxies

However esoteric and refined the previous speculations have been in regard to the difficult problems that face plasma physics, these problems are minor compared to the almost unapproachable difficulties presented by the unquestionably ordered and structured distribution of matter in the universe as a whole. As the pictures of the galactic structures (Figure 2) faintly suggest, the tendencies that exist for a plasma to assume ordered and globally coherent states are not minor in either length or time scales. Something very fundamental is at work here!

The general order of the problem is obvious if we consider that the galaxies occupy about one-millionth of the space in the universe and that the density inhomogeneities are on the order of one particle per cm^3, compared to stellar densities of 10^{24}particles per cm^3. In any case, it is difficult to imagine the condensation of galactic- or stellar-type structures out of any terrestrial environment; a room filled with smoke normally does not condense into granules of carbon that spin about each other in tight, symmetrical vortices.

The problems of constructing any satisfying cosmology that also can account for even the few empirical observations of the galaxies are well known. The most sophisticated attempts to do so in the context of plasma physics, the so-called turbulent theory of galaxy formation — due to a group of Soviet scientists, Orzenoi, Chernin, and Chibisov (4) — does no better in answering these questions. Even so, it is intriguing that with only a few assumptions about time scales and density scales they are able, with a plasma, to create order out of disorder.

But doing so creates more difficulties than it removes. The question I want to concentrate on here, that of accounting for the remarkable persistence of ordered structures in a plasma, is addressed *only* by *accident in this turbulent theory*, and then only as a fact so obvious that it underlies all the ad hoc assumptions that are used to "explain" the angular momentum and density inhomogeneities.

Some Speculations

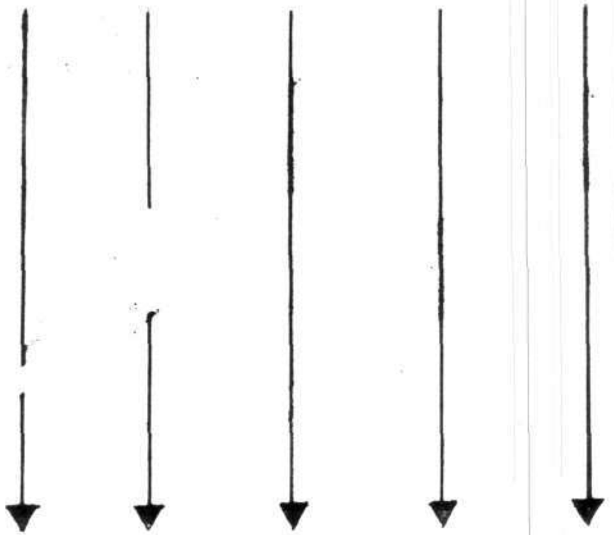
The disparate problems that the above phenomena present to a physicist all point in a similar direction for resolution. And, as painful as it is, this is in the direction of a reexamination of the problems that to a great extent have been ignored since the conceptual

SHORT GLOSSARY OF PLASMA PHYSICS TERMS

ALFVEN WAVES: A low frequency wave motion which occurs in a plasma with a magnetic field. This wave motion is associated with a "plucking" of the magnetic field lines, and the oscillation is of the magnetic field line and the element of the plasma associated with it.

LANGMUIR WAVES: The characteristic, high frequency wave motion possible in an unmagnetized plasma. This wave motion is an electrostatic disturbance of the plasma in which the electrons oscillate about the essentially stationary ions. Also called "plasma waves."

TURBULENCE: A general term for a non-equilibrium motion of a fluid or plasma. It is an especially important concept when this motion is in the form of collective oscillations of the fluid (like waves or vortices) or plasma (like Langmuir waves). A distinction in plasmas exists between "strong" and "weak" turbulence, strong turbulence occurring when the energy in the collective motion of the plasma is comparable to the thermal (or random) energy of the plasma.



A schematic anatomy of a high-amplitude non-linear Alfven wave. The vertical lines represent the background magnetic field. The left- and right-hand spindle-like filaments show that the convected force-free mass is made up of parallel constituents including the local magnetic field, electrical current density, fluid velocity, and fluid vorticity.

upheavals that physics underwent in the early part of the 20th century. Most fundamental in this regard is the question of the real nature of the particle-field interaction. In plasma physics, more critically than in any other field of physics, a competent understanding of the phenomena depends on a detailed understanding of what sort of singularity a particle is, how its existence is consistent with continuous fields, and how the particles and fields interact to form a "greater whole" that makes up a plasma. These are questions (even in their simplest form of making Maxwell's equations consistent with the existence of an electron) that are not answered by present-day physics; actually, the questions are rarely asked. The heroic attempts to resolve the quandries about fields and particles that quantum mechanics represents, are, by and large, avoided by plasma physicists; but such a solution is key to attacking the problem in plasma physics in an effective way.

In another way, the difficulties presented here bear on the fundamental problems faced by physical science. Almost never have basic advances in a science been made by a head-on attack against the most glaring inconsistencies that slowly became evident. Rather, a combination of two interconnected but usefully separated occurrences came about:

(1) On the one hand, unresolved difficulties in science, which were profitably ignored in some previous research, come back to haunt the science when it is pushed into new domains. This seems to be the significance of the evidence presented above in plasma physics. All of contemporary physics is based on a structure that is fundamentally unable to explain anything but systems that, subject to the Second Law of Thermodynamics, "run down." While this is certainly inconsistent with the existence of living beings, it has been a useful approximation; and certainly the technology built on this science has been immensely successful (at least until recently). Plasma physics seems to be presenting evidence in the inanimate world that this basic perception of the direction and quality of "spontaneous" processes in matter is not sufficient to describe non-living matter as well as living matter.

Put differently, no biologist would attempt to describe any level of living system, from a cell to an ecology, without his underlying methodology being that of the possibility of development and differentiation. In the physical sciences, however, the opposite has always been the basic assumption; the law of increasing entropy is one expression of this. Parenthetically, the article in this Newsletter by P. Kapitsa offers an insight into a connected feature of the problem; as Boltzmann showed in his H-theorem, under a wide variety of circumstances, the conservaton of energy implies the second law. Putting together Kapitsa's insight into the importance of energy flow, as opposed to static forms of energy, a reconceptualization of the idea of energy is almost certainly demanded. The difficulties that plasma physics creates with a consistent entropic formalism means that the energy concept on which it is based must be reexamined.

To restate the first point, the new and striking evidence of qualitatively different types of behavior in a plasma, behavior that is of a global, ordered kind, in itself challenges the roots of present physics. Even more, it points in the direction of a solution exactly in the areas of phenomena for which this coherent behavior is not an anomaly, but is, rather, the heart of the matter. This is why Tsytovich's sense that a statistical approach to the problem of strong turbulence is insufficient. The methodological center of kinetic theory and of many-body theory more generally, is statistical; and in such an approach even the most mundane global processes, such as phase changes, are very difficult to describe. Without a more basic reconceptualization of the role of ordering in these physical sciences, these phenomena are inexplicable.

(2) The actual working out of these new approaches to plasma physics specifically, and science in a broader sense, are not at all unconnected with the social context in which they have occurred. There is an uncanny parallelism between the necessity for the development of fusion, the appearance of fundamental difficulties in plasma physics, and the generation of social currents that are attacking social problems along the lines indicated above — that is, the necessity of conceptualizing humanity as a developmental entity. The coming-into-being of a fusion-based economy is not just the development of a new technology: Much more profoundly, it is a transition in scientific world view from one based on a technology that came out of Newton and Maxwell to one based on the scientific conceptions underlying a working plasma physics.

Several articles in this Newsletter emphasize one or another aspect of this observation; the point is critical if we are to begin to reformulate the basic questions of plasma physics.

Notes

(1) B. Morales and Y. Lee, Physics of Fluids, *19*, 690 (1976). B. Bezzerides and D.F. DuBois, Physical Review Letters, *36*, 729 (1976).

(2) W.H. Bostick and D.R. Wells, Physics of Fluids, *6*, 1325 (1963). W.H. Bostick, et al., Physics of Fluids, *6*, 2078 (1963).

(3) D.R. Wells and J. Norwood, Journal of Plasma Physics, *3*, 21 (1969). D.R. Wells, Journal of Plasma Physics, *4*, 645 (1970).

(4) L.M. Orzenoi and A.D. Chernin, Soviet Astronomy — AJ, *11*, 907 (1968).
———— Soviet Astronomy — AJ, *12*, 901 (1968).
L.M. Orzenoi and G.V. Chibisov, Soviet Astronomy — AJ, *14*, 615 (1971).
———— Soviet Astronomy — AJ, *15*, 923 (1972).
See also the review article by B.J.T. Jones, Review of Modern Physics, *48*, 108 (1976).

The State of Research and Development in the United States

by Charles B. Stevens

The destruction of science in the United States and the resulting collapse of scientific research and development has gone so far as to provoke public alarums from science policy makers. There is indeed cause for alarm, and for reasons more fundamental than those raised by these bourgeois spokesmen. The degeneration of the United States' research and development capabilities, if allowed to continue, will leave the world's largest scientific community and the world's most highly skilled workforce gutted, totally unprepared and unable to take up the global task of reconstruction on which humanity's future depends.

Dr. Jerome Wiesner, former science advisor to President John Kennedy and current president of the Massachusetts Institute of Technology, detailed the collapse of science and technology in the U.S. in the opening speech to a science conference held in Washington, D.C. in April of this year, titled, "Technological Innovation and Economic Development: Has the U.S. Lost the Initiative?" Given the failure to utilize even existing technology, Wiesner told the conference, "there is little incentive to invest in still more advanced technology." At a meeting of the National Association of Science Writers April 27, Senator Edward Kennedy (D-Mass) argued along similar lines for increased U.S. research and development efforts.

The exponential collapse of U.S. Reaseach and Development pointed to by Wiesner and Kennedy was empirically documented in the December 10, 1975 report to the President on "Science Indicators 1974" by the National Science Board and the National Science Foundation. That this report ignores such essential questions as the relationship between the skill level of the U.S. workforce in general and the characteristics of scientific work in particular is not surprising, given that the National Science Board includes the heads of such leading Atlanticist think-tanks as the Rand Corporation and the Hoover Institute on War, Revolution, and Peace. But the report makes clear to any informed reader the abysmal state of Research and Development in the United States — one important secondary reason why think-tanks like Rand are pushing for thermonuclear confrontation with the Soviet Union before the U.S. is hopelessly strategically outrun, that is, within the year.

Downward Trend

The voluminous data in "Science Indicators 1974" can be summarily represented in just one chart, at least in relative terms: a time graph showing a horizontal line with a slight upward hump in 1965 and a deeply descending tail as the mid-1970s are approached. In other words, all indicators point to a slight rise in United States Research and Development in the mid-1960s and, with the onset of the depression of the 1970s, a sudden collapse — even in absolute terms.

But if we scratch beneath the surface and look back to the 1950s, we discover that scientific Research and Development in the United States actually stagnated throughout the 1960s. We further see that the vast bulk of scientific work has been directly or indirectly oriented to the military-defense sector, meaning that even during the "growth period" of the 1960s these efforts were largely swallowed up in worthless military boondoggles, and never represented more than a **potential** for the development of real production.

In addition, the report notes that the number of small, private companies, the source of a relatively high proportion of significant scientific breakthroughs in the 1950s, declined throughout the 1960s toward zero in the 1970s — as has the number of breakthroughs! What this charts is the dwindling possibility of applying scientific advances to production, as smaller companies succumb to the bankruptcy of the economy as a whole. At the same time the deliberate cannibalization of such firms has been pursued more and more ruthlessly over the past decade as part of the imposition of iron Atlanticist political control over U.S. science, with the result that the tremendous potential of U.S. science is being obliterated.

Some General Measures

The United States, France, and Great Britain are the only major industrial nations whose Research and Development expenditures as a per cent of Gross National Product have been declining over the past ten years. The number of scientists and engineers engaged in Research and Development per 10,000 of population in the United States has in the mid-1970s returned to the level of the early 1960s, about 25 per 10,000. During the same period the figure for the USSR has risen from about 19 per 10,000 in 1963 to more than 37 per 10,000 in 1973. In absolute terms the Soviet Union has approximately twice the scientists and engineers engaged in Research and Development as the United States, that is, 931,000 compared to 523,100 as of 1973. While gross numbers do not necessarily correspond to quality, it is documented that the USSR has been able to qualitatively outdistance the United States in specific crucial areas of science and technology such as fusion research. Recent Soviet achievements in electron beam fusion demonstrate that they are able to rapidly overtake the U.S. in areas in which the U.S. has long been hegemonic and, based on existing technology, should have remained so for some time to come.

This is further confirmed by the fact that the technologically most advanced sector of the U.S. economy, the only area which is not totally wallowing in obsolescence is the aerospace-defense sector. In particular the missile-aviation manufacturers have intensities of Research and Development in which Research and Development personnel approach 10 per cent of the total workforce. As the U.S. Labor Party has documented, if this sector were converted to new industries producing to meet real human needs, within four to five years the total industry of the United States could be technologically upgraded to the point that its annual output would grow at rates of 100 per cent per annum, with the entire working population converging on skill levels which are now thought of as reserved for advanced technologists and scientists.

The Collapse

During the 1950s the total number of scientists and engineers doubled, rising from about 600,000 to nearly 1.2 million. In the 1960s the relative gain was only half as great, from about 1.2 million to 1.7 million. There is also a decline in the proportion of these scientist and engineers engaged in Research and Development; but these obviously key facts are nowhere directly given in the "Science Indicators" report.

While the number of those receiving undergraduate degrees in the sciences as a percentage of all undergraduate degrees remained relatively constant over the past decade, the relative number in the physical sciences (both physics and chemistry) and engineering has fallen by 50 per cent as compared to a 50 per cent rise in "social science" degrees. In enrollments for advanced (Ph.D. and Masters) degrees, the proportion for sciences as a whole did not remain constant — it dropped from 38 per cent in 1960 to 28 per cent in 1972.

A good measure of the quality of doctoral science programs graduates is given by the amount of money per capita spent on their education. Since 1966 the amount spent in constant 1967 dollars on physics Ph.D's has dropped from $24,500 to $14,900. Other fields also experienced a similar tendency, although not so precipitous a drop.

Finally, the National Science Board gloats over the fact that while the United States has lagged behind all other major industrial nations in terms of application of technology to increase productivity, as measured in terms of increases in output per hanhour, the U.S. did outdistance every other country in the capitalist advanced sector in maintaining lower "unit labor costs" throughout the onset of the depression. This translates into the tremendous increase in speedup and other forms of direct cannibalization of the U.S. workforce.

Charles Stevens is on the research staff of the FEF and the research and development sector of the U.S. Labor Party. He is a leading U.S. reporter in the area of fusion power.

The Choice at Habitat: Genocide or Development

Resolution Presented by the International Caucus of Labor Committees at the United Nations Habitat Conference

INTRODUCTION:

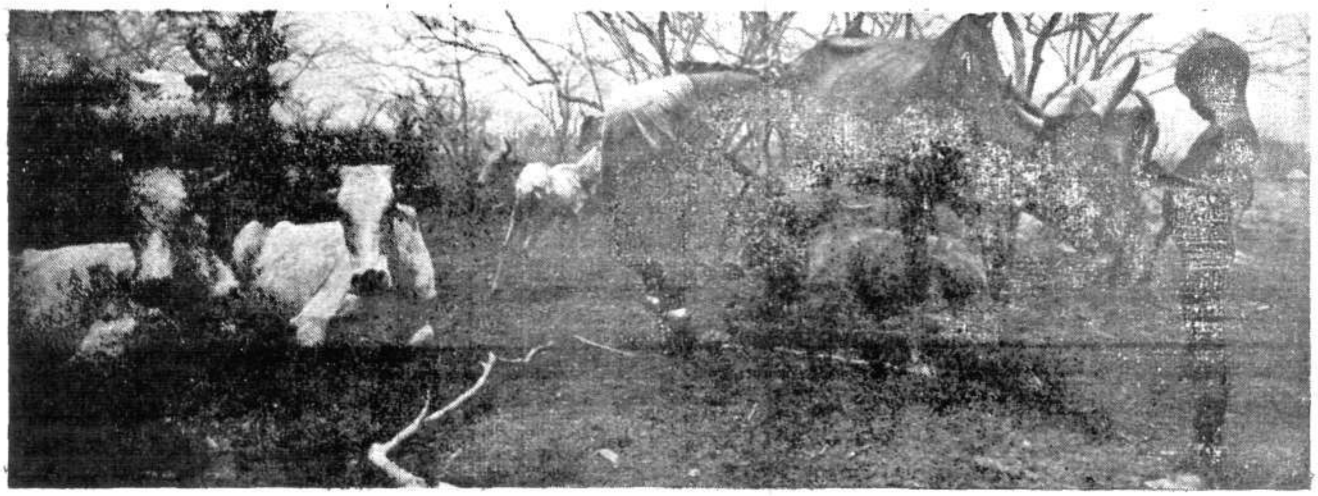
Organizers from the U.S. Labor Party and the North American Labor Party circulated the following resolutions among governmental and nongovernmental delegates at the United Nations Habitat Conference held in Vancouver, British Columbia May 30 to June 11.

The proposed agenda for Habitat, endorsement of the World Bank programs for deurbanization and labor-intensive agriculture, and the establishment of a "human settlement" organization to carry out these plans met with strong opposition from developing sector and East bloc delegates. Mexican President Luis Echeverria led off the fight for development and technology in a speech May 31 that called for the immediate implementation of the new world economic order. Subsequent speeches by the Cuban, Rumanian, and Tunisian delegates echoed Echeverria's call, denouncing zero growth and identifying the new world economic order as the only solution to world urban problems. A broader group of countries — including Pakistan, India, Egypt, Ghana, and the Soviet Union — spoke against the proposal for a human settlement organization.

At the time of this writing, the Group of 77 (developing nations) submitted a new draft declaration of principles to replace the original drawn up by Habitat chairman Enrique Pensalosa. The additions, directly reflecting Echeverria's speech, deal almost exclusively with the new world economic order, the necessity for rapid industrial and technological development, and nuclear disarmament. While not calling outright for debt moratoria, the new draft emphasizes that the international comunity "should provide the necessary financial and technical assistance, and see new effective ways to promote them."

Throughout the world today a tremendous battle is being fought, a battle which all the delegates to the United Nations conference on human habitation are now a part of, whether they like it or not. On one side are the advocates of genocide, of a new Nazism, of a Final Solution to the population problem. The Club of Rome, the World Bank, the Inter-American Development Bank, and, above all, the New York international banking circles that stand behind and control these institutions have made their policies clear. In order to collect their debt, the enormous parasitic mass of $5 trillion which is strangling the world economy, they are perfectly willing to destroy whole populations, to reduce the human race by one billion people (as recommended by John D. Rockefeller III), to recreate Auschwitz on a global scale. Their slogans are "labor-intensive development," "organic growth," "appropriate technologies," "energy conservation," "decentralization." The real policy that lies behind these slogans is the looting of the entire world, especially the developing sector, to enforce the payment of debt service. As stated by New York banker George Ball: "The Third World cannot afford to industrialize — they can only pay their debts with labor-intensive agriculture."

This policy is being carried out now — for example, through Enrique Penalosa's Inter-American Development Bank (IADB) "development plans," in which hundreds of thousands of peasants are worked to death in the jungles of Honduras and Brazil to produce exports, and through the World Food Program, in which 23 million workers and



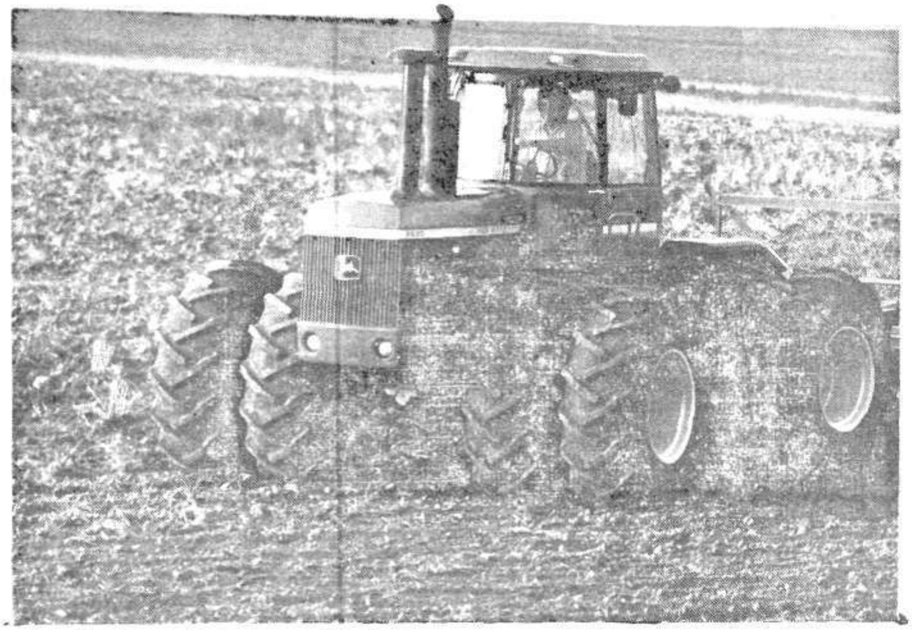
"Once completed, the new converted factories would begin to churn out tractors, simple, big, but sturdy and capable of doing the job, at a rate of 350,000 a month in the U.S. alone ..." Each tractor would enable the production of some 150 tons of food on 75 hectares of land. For each day this conversion is delayed ... 700,000 people will die of starvation or disease over the course of the next year."

peasants around the world slave for a daily ration of 1,700 calories.

World Bank President Robert Strange McNamara and the other fascists behind these programs have planned the Habitat Conference as another opportunity to organize for their schemes. Here in Vancouver, they are attempting to push through programs of deurbanization, of deindustrialization, shipping millions of urban dwellers to the countryside, of blocking any real urban development under the cover of "self-reliance" and "local control."

On the other side of the battle are those forces in the developing countries and within the working class of the advanced countries who are fighting for a New World Economic Order based on an International Development Bank, for actual development, for a general debt moratorium. The courageous fight of the Mexican government of Luis Echeverria for a debt moratorium for all developing countries as the basis for recovery from the world depression has been the cutting edge of this fight in the Third World. Those pro-development forces, including that large part of the North American working class organized by the U.S. and North American Labor Parties, are determined not to allow the banks' debt to condemn the human race to extinction.

We call on the participants of this conference to fight for the adoption of the following proposed resolution, whose principal points are summarized below:



I. The immediate cause of both the present crisis in the world's urban areas and the general depression affecting the entire world economy is the tremendous parasitic burden of $5 trillion in debt hanging over the cities and the developing countries.

II. To resolve this crisis, there must be a general debt moratorium on all municipal and developing country debt: an International Development Bank must be set up to finance development.

III. All development policies must have as their primary goal the increase in the productivity of human beings and the provision of the necessary levels of consumption, education and technology required by that goal; all such development policies must be premised on the rapid development of nuclear fusion power to provide the unlimited energy and resources needed for development.

IV. Urban development must be based on the use of the most productive capital-intensive methods available, utilizing the idle capacities in the advanced countries and those wasted on armaments to aid in the reconstruction of expanding developing-sector cities.

V. The conference condemns all labor-intensive "development" schemes as genocidal methods of debt collection. Any reduction in human productivity must lead to a reduction in human consumption and global catastrophe.

I. The Crisis of the Cities

The present crisis in the world's urban areas is inseparable from the general depression affecting the entire world economy. The immediate cause of both this general depression and the catastrophic impact it is having on the cities is the tremendous parasitic burden of $5 trillion in debt. As a result of the diversion of financial resources to the ever increasing demands of debt service to the International Monetary Fund, World Bank, Euro-dollar Market and the major New York City banks, vital municipal services — sanitation, water supply, fire protection, healthcare, education — have been destroyed and housing construction has totally collapsed. The developing countries, crippled by more than $300 billion in debt, have been forced to slash imports and have been unable to purchase from the advanced countries the capital goods and other goods and other materials for the construction of decent, livable cities. The general rapid contraction of trade caused by the complete bankruptcy of the entire world monetary system has led to massive unemployment levels in both advanced capitalist and developing sectors.

As a result, the cities of the world are now being turned into hellholes breeding every epidemic disease on earth, destroying the minds and bodies of their inhabitants. Rats are overrunning every major city in Western Europe, North America and the Third World, outnumbering humans by as much as 10 or 20 to 1 and bringing with them the immediate threat of catastrophic epidemics of plague. Sewerage systems have broken down, allowing the spread of cholera and typhoid. Parasitic diseases like chagas rage in the filthy favelas and shantytowns of Latin America, Africa and Asia. Millions of debilitated, starving and overcrowded workers and their children die of meningitis, influenza, and a dozen other preventable diseases. Without immediate counteraction, this situation will make a general biological catastrophe — a self-feeding spiral of global pandemics — inevitable, a catastrophe that will leave the cities depopulated as at the time of the Black Death in Europe, and civilization extinct.

To prevent this catastrophe, immediate steps must be launched to reverse the economic crisis and to start rapid urban development in the context of general economic recovery.

II. Necessary Financial Policies

Without fundamental changes in the present international financial relations and institutions, development is impossible. The first essential step toward reversing the present collapse must be a general debt moratorium, particularly including all municipal debt and all debts of developing sector countries. The Conference fully supports the courageous fight of the Mexican government of Luis Echeverria and the other developing countries for debt moratorium. **In view of the failure of the recent United Nations Conference on Trade and Development IV in Nairobi, Kenya, to resolve this vital issue, this Conference calls for an immediate moratorium on all Third World debt.**

On the basis of freeing the world economy from the burden of the mass of debt, a thorough reorganization of the major institutions of international credit must be at once initiated. A new credit institution, an International Development Bank, must be created, jointly controlled by the developing sector, the socialist countries and the advanced capitalist states, whose purpose is the financing of development. This new institution must have the authority to provide long-term (10-20 year) low- or no-interest credit for urban, industrial and agricultural projects in all sectors of the world and should be provided wtih authority to issue approximately $100 to $200 billion in credit in the first year of its operation. Only on this basis can the mammoth joint projects of urban construction and development that are necessary be undertaken.

Such a new institution is immediately required and **the Habitat Conference calls for the establishment of an International Development Bank as a replacement for the presently bankrupt IMF and World Bank.**

III. Fundamental Development Policies

The only criterion from which correct development policies can be formulated is that of maximizing the creative and productive powers of the human race as a whole — the productivity of labor. Contrary to the vicious lies of the Zero Growth or "organic growth" propagandists,

Dr.Morris Levitt

Dr.Steven Bardwell

VIDEO TAPE

Special

Fusion

A half-hour videotape special on the state and prospects of fusion research is now available for sale or rental from New Solidarity World News. The show features Fusion Energy Foundation Director Dr. Morris Levitt presenting an up-to-date report of breakthroughs in controlled thermonuclear reactions research. Levitt describes how this has dramatically moved up the "time-table" for functioning fusion reactors, and elaborates the concept of the fusion-based economy of the future.

Plasma

A series of three classes is available on "Plasma: The Fourth State of Matter," presented by Dr. Steven Bardwell. The lecture series elaborates the evidence presented in Bardwell's article that the behavior of plasma challenges the roots of present physics and explores a reformulation of the basic questions of plasma physics.

For information: New Solidarity World News, GPO Box 1972, New York, N.Y. 10001 human survival is possible only on the basis of a continual advancement of technology. Since at any given level of technology, resources tend to be relatively limited, the replacement of existing techniques with qualitatively new ones is at every point in human history an absolute imperative. These more advanced technologies require more highly skilled individuals to man them and the creation of such more skilled individuals requires higher levels of consumption and increased leisure time for education. These requirements of higher per capita consumption combined with the reduction of working time necessitates a general increase in the productivity of labor, a general replacement of human labor with machinery and energy. This general increase in labor productivity and capital intensivity of industry are simultaneously necessitated by the need to provide an expanding proportion of the total labor time available to society for the development of new technologies and their implementation and thus to reduce the time involved in mere maintenance of existing levels of consumption and existing plant and equipment.

For these reasons, all development policies must have as their primary goal the increase of the productivity of human beings and the provision of the necessary levels of consumption, education, and technology required by this goal.

At the present point in human development, the mere continuation of the present fossil-based economy will lead to a rapid exhaustion of these resources, especially under conditions of actual world economic development. Therefore, all global development policies must have as their fundamental premise the most rapid development of nuclear fusion power as the only possible unlimited and economical energy source to replace the present fuels. Since the construction of a fusion-based economy over the course of the next 15 to 20 years will involve the most fundamental revolution in technique in all branches of production, the aim of development policies in the transitional period toward a fusion economy must create a labor force of sufficient skill to man such an advanced economy.

IV. Urban Development Policies

The world's cities must be developed as environments capable of producing in the working population the skills for not only the highest levels of today's technology, but for tomorrow's fusion-based technology as well.

In the advanced countries, this means restoring on an emergency basis the vital services — sanitation, sewerage, hospitals, fire protection — necessary to prevent the spread of disease, massive expansion of educational facilities for both children and adults and immediate beginning of rebuilding of slum areas, on the basis of thorough modernization. Over the longer run, the goal of advanced world urban development should be the provision of decent and modern housing, rapid mass transportation and other services for the entire population within the decade.

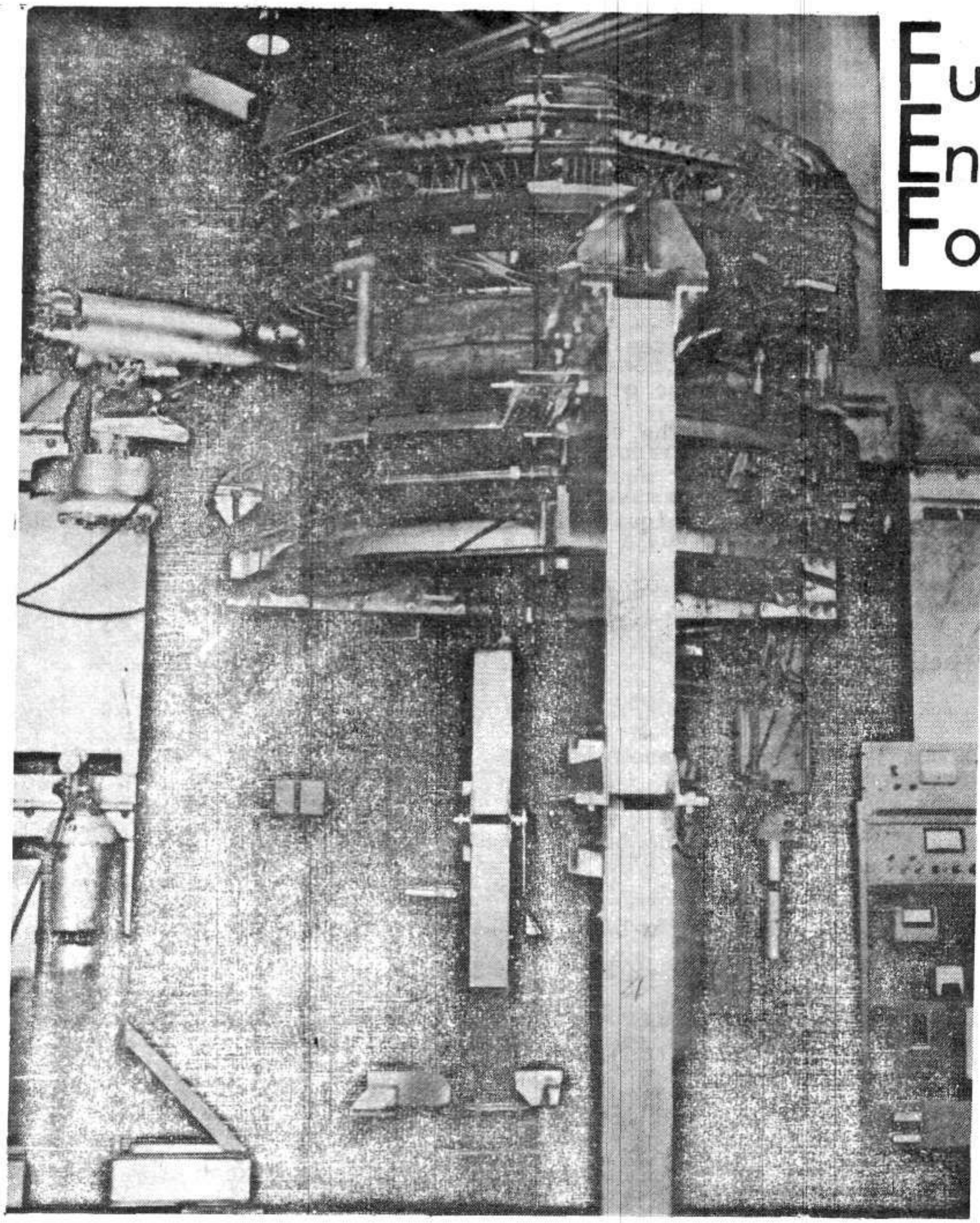
In the developing sector, urban development can be planned only in the context of assimilating the large rural urban migration made possible through the rapid mechanization of agriculture. Such mechanization is essential both from the standpoint of increased food production and the necessity of liberating the majority of the world population from back-breaking toil which denies them the opportunity for developing the skills required by a modern society. In this context of rapid assimilations of peasant populations, the cities of the developing sector must not only be rapidly brought, on an emergency basis, to a minimal level of functioning of basic services (transportation, sanitation, sewerage, water supply) necessary to prevent chaos and epidemics, they must be rapidly expanded to absorb much larger surrounding populations.

The sheer magnitude of this task ensures that it can be carried out only by the maximum use of mass production techniques for housing construction and the most intensive use of the worldwide division of labor. On the basis of rapid expansion of trade among the advanced capitalist states, the developing countries and the socialist states, the now idled or wasted capacities of the capitalist countries, emphatically including those now engaged in armaments production, can be mobilized for the fulfillment of the titanic task of construction Third World cities. The large and idle lumber and wood-processing industry of the Vancouver-Seattle region, for example, together with the capacities of the Northwestern U.S. defense industries, could provide annual production capacities of tens of millions of pre-fabricated or semi-prefabricated housing units to be constructed in the cities of Africa, Latin America and Asia. The involvement of large numbers of developing country urban populations in the tasks of construction will provide opportunities for the assimilation of skills transitional to those required in industry.

As development proceeds, more and more of the production of housing and related products will be shifted to the developing countries themselves, on the basis of importation of capital goods from the advanced capitalist and socialist sectors, thus providing the nucleus of a more and more diversified industrial development in the developing urban centers.

V. Condemnation of Fascist Policies

In view of the absolute necessity for the implementation of the above policies, the Habitat Conference condemns unequivocally the fascist programs put forward by the World Bank, the Club of Rome, the International Labor Organization and others at this Conference which advocate "labor-intensive development" and "limited" or "organic" growth. The backers of these plans claim to have the utmost concern for the urban and rural poor, who must be provided with employment opportunities by the elimination of all industrial technology for the development sector and its replacement with labor-intensive techniques, the slowing of necessary urbanization and mechanization of agriculture and their replacement with agrarian slave-labor schemes to boost exports. The Conference notes that the great concern of the president of the World Bank and principal author of these schemes, Robert McNamara, for the poor of the world was adequately demonstrated during his term as U.S. Secretary of Defense, during which he supervised the elimination of one to two million Vietnamese poor by the methods of napalm and artillery fire. The Conference further notes that the actual effect of any plan which brings about a massive reduction in the productivity of labor is necessarily a massive reduction in per capita consumption and standards of living. In the current already catastrophic conditions of the Third World, this program amounts to genocide on a scale undreamed of by the Nazis. The actual aim of these programs is purely the elimination of necessary capital imports to the Third World and the maximum collection of debt owed to the dominant U.S.-based financial institutions. The participants of this Conference pledge their full resources to stopping the implementation of these schemes and removing the perpetrators of them from all positions of power.



Fusion Energy Foundation

The Fusion Energy Foundation was founded in November 1974 at a meeting attended by representatives of the U.S. Labor Party, the United Nations and the International Atomic Energy Agency, scientists who have made significant contributions to fusion research, and interested laymen.

The purpose of the FEF is to provide a forum of independent, high-level scientific discussion of fusion from the standpoint of comprehensive policy making.

We need your financial support.

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