country to country, in the application of nuclear fission energy fuel reprocessing is essential. Further, the best way to handle spent fuel and to take care of nuclear waste is to reprocess the spent fuel.

6. There are many candidate systems which may be called upon to supplement or eventually replace our presently largely light water reactor technology. These include fast breeder reactors, high temperature gas reactors, heavy water reactors and homogeneous reactors. Development of these systems should be pursued vigorously on an international basis, although not necessarily all systems in all countries.

7. Practical consideration of the ability to produce and deploy reactors in the numbers necessary dictates that currently successful systems be sustained and their installation encouraged by governments until and unless advanced systems are fully available and acceptable, technically, economically and industrially.

8. The plutonium-uranium fuel cycle has particular advantages in fast spectrum reactors and the uranium-233 thorium fuel cycle in thermal reactors. Both will need to be developed, including all necessary steps for full implementation.

9. Impressive progress has been achieved towards proving the scientific feasibility of fusion systems based on the principles of magnetic and inertial confinement. Progress has been made also in hybrid systems which suggest, on a longer timescale, economic feasibility. Development of these systems, already involving a considerable degree of international cooperation, should be pursued vigorously on this basis, again, not all systems in all countries. However, the possible successful development of fusion technology should not delay the prudent and necessary deployment of fission technology. It is possible that the first application of fusion technology will be in a hybrid fission-fusion complex.

10. It is recognized that the deployment of fission power or hybrid fusion-fission on a large scale poses problems of safeguard of material against potential diversion and, thus, proliferation of nuclear weapons. We are confident that the international community can and should take the political, institutional and technical measures which will be effective in diminishing the risk of proliferation while retaining the economic advantages of nuclear power. Therefore, we do not believe the risk of proliferation should deter the use of nuclear energy.

11. The probability that accidents in existing reactors will cause harm is acceptably small and we believe, with proper use of experience, that this will diminish even as the number of reactors increases.

12. Solar energy may have a part in the mixed energy system of the future. The extent of its penetration will depend largely on economic considerations. It is difficult to determine finally what these economic parameters will be without practical experience on a substantial scale; at present, the parameters appear to be adverse.

13. Meeting the energy demand of the still rapidly rising world population with legitimate expectations of a higher standard of living calls for largescale mobilization of labor, materials, capital, and technical and managerial skills. It should be governments' constant preoccupation to accomplish this economically and effectively to avoid overtaking the world's productive capabilities and resources of these necessities.

14. There is an urgency to the world energy problem which, especially in view of the long lead-times, brooks no delay in determining and executing national programs and in seeking international cooperation to take up the tasks and share the benefits equally.

Signatories

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Soviet Scientist: If We Coordinate Efforts, Fusion Can Be Achieved

Following are excerpts from the presentation of Nikolai G. Basov, of the P.N. Lebedev Physical Institute, USSR Academy of Sciences, Moscow, to the Nov. 7 to 11 meeting of nuclear scientists and industry representatives organized by the University of Miami Center for Theoretical Studies and held in Fort Lauderdale, Fla.

It is a great pleasure for me to give a talk at such a representative forum of scientists. I would like to speak about physical investigations which have been underway at the Lebedev Physical Institute since 1962. This direction in laser physics is developing at the present time in many laboratories, and it has now become one of the most popular and active fields of physics, which can be considered as one of the serious directions in solving the energy problem. I am speaking about laser induced fusion. We consider the task of this talk solved, if the participants of the present meeting could see not only our results and conclusions and one of the possible ways of solving the energy problem, but at the same time the vital necessity to concentrate the efforts of scientists and to coordinate the investigations in this field on a larger scale than we have now.

The principle of energy production in laser induced fusion is as follows. The pellet containing thermonuclear fuel is irradiated spherically by the laser light. Laser radiation absorbed by the pellet heats the target, and the outer part of the target, a so-called "corona," expands in the direction of the laser beams. Due to the law of conservation of momentum, the inner part of the target moves to the center of the pellet, and becomes highly compressed and heated. Thermonuclear reactions are developed in this part of the target, the microexplosion occurs, and the fusion energy produced in this way should be used in a special reactor for the generation of electrical energy. In the case when we can produce more energy, which is necessary for laser pumping, we can use the rest of fusion energy in industry or national economy....

What types of lasers would be suitable for the laser fusion power station in the future? One can give a negative answer to this question, because today no lasers are able to operate with repetition frequency of 1 cycle per sec. during a year. However, the answer can also be positive, because there are no physical restrictions to realization of such laser operating conditions. Moreover, many physicists consider this regime to be quite achievable. Realization of such lasers is a severe problem, which demands, in my opinion, the concentration of efforts on an international scale.

As we know now the scientists from Livermore laboratory also agree with a principal feasibility of achievement of high fusion yield.

As I have already mentioned, the problem of designing thermonuclear reactors is of great importance. Although at the present time there is not enough data for the engineering design, it is necessary to work on this kind of project, because it will help to discover the lasers and targets needed for the creation of laser fusion power stations. We have such a preliminary project, which was worked out jointly with Moscow High Temperature Institute, headed by academician A.E. Sheindlin. Now I shall report some characteristics of this project. We know that similar projects are also being designed in the USA and Western Germany....

...Efficient transformation of thermonuclear microexplosion energy in one of the types of energy used (electricity, heat, chemical energy, or energy of secondary nuclear fuel) is a complicated engineering problem. In principle, the thermonuclear microexplosion giving rise to monoenergy particle flux is a unique source of low entropy energy. However, it is extremely difficult to offer adequate schemes for transformation of this energy using technological possibilities of the present day or even of the nearest future....

A specific feature of laser thermonuclear installations consists in rather high expenses of electric energy for proper needs. So, at laser efficiency of 5 percent, the gain coefficient of the reactor is 100, and the efficiency of energy conversion is of 0.4. In this case the proper energy needs for laser thermonuclear power stations (LTSP) are equal to the electric energy delivered to the consumer. Such a high value of proper needs for the laser power station is an order of magnitude higher than a similar value for the up-to-date thermal electric power stations. It reduces considerably the economical index of the laser power stations. Therefore for LTPS the problem of using the heat scattered by the laser facilities is extremely important. In our project we have provided a high value of laser energy conversion into electrical energy with the use of a heat transformer. The idea is based on the application of the C02 laser, in which C02 gas moves with high velocity through the active volume. The temperature of slowing down is of 700°K, and the static temperature in the active region is less than 423°. These parameters allow us to limit the population of the lower laser level and to obtain a sufficient gain coefficient of the laser media. On the other hand, it is possible to use the energy scattered during pumping effectively. The scheme of LTPS assumes the usage of the laser heat at the first stage of the heat exchanger, that is the usage of the steam generator for heating the water from 543°K to 622°K. The use of the laser heat makes it possible to increase considerably the electric efficiency of LTPS and to improve the economic index. In our project of a thermonuclear power station, we have tried to combine a unique heat source in the form of a laser thermonuclear reactor with a standard industrial steam turbine....

The economics estimates show that the evaluation of one kW of electric power in laser stations essentially depends on the capital investments in the laser facility, and these are twice as high as the corresponding values of conventional atomic stations. But this value is comparable with that for breeders.

In our opinion, the most promising seems to be a hybrid type of the reactor with the blanket of fissionable materials.

By using the energy of fission it's possible to reduce the requirements of the laser facilities, in particular, to decrease the laser efficiency down to 0.2 percent or to reduce the pulse energy. One can also increase the resource of the entire facility, that is decrease the pulse repetition frequency, or simplify the target design, and reduce the cost of the target preparation. The hybrid laser reactor will be a generator of nuclear fuel. It can start to operate with low-enriched fuel.

I shall report some data of the power station on a hybrid laser reactor designed in Lebedev Institute in cooperation with the Institute for High Temperature. In this project we have not changed the energy of the nuclear microexplosion. But we suppose that laser efficiency is lower, say 3 percent, and the used target is simpler in design, and produces a thermonuclear yield of 40. Moreover, the principal idea is based on the use of helium as a heat carrier, which leads to rather high dimensions of the reactor and to the increases in the duration of the fuel burning up. We also suppose that 50 percent of fissionable material should be burned up, and then buried without reprocessing. Nuclear and thermonuclear energy is transformed into electrical energy by means of a helium turbine and a standard steam turbine.

The reactor has a cylindric shape, the "wet" wall is used, the content of fissionable material in the blanket is about 300 tons of natural uranium carbide.

Of great interest are the data on time dynamics of the basic reactor parameters. It is desirable to have a time-constant electric power output of the station. Therefore the increase in the energy gain coefficient of the fissionable blanket due to plutonium storage can be compensated by a decrease in the microexplosion repetition frequency. As a result, the resources of laser and other facilities increase....

Our project of the thermonuclear power station LTB-500 has been presented in the report entitled "Fast fission and fusion reactors" of the International Institute of Applied System Analysis, in Vienna. In that report a detailed analysis has been made of various applications of different types of reactors in the areas of energetics, economical estimates, the problem of radioactive waste, risky and accidental situations, fuel and material resources and so on.

In this respect a hybrid laser reactor is not a specific system. But compared to breeders, the laser hybrid reactor is in a subcritical state, and unlike breeders doesn't need systems for controlling the subcriticality. The hybrid reactor, in contrast to the breeders, can use fissionable materials with any degree of enrichment, in particular, it can operate on natural uranium. For such reactors there's no problem of redoubling the fuel.

We believe that future nuclear energetics should develop in different directions, in order to meet various requirements of national economy. One of the applications of thermonuclear stations is the production of fuel for breeders. If we don't intend to produce electric energy on such a system, that is if we consider a near-to-zero efficiency reactor, then it's possible to reduce requirements toward lasers and targets. At present we perform such investigations....