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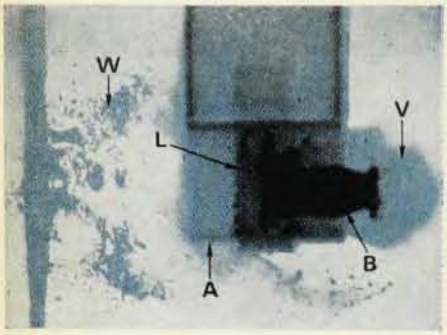

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less) are funded with a minimum of delay for proposal review although larger projects take longer. Lindquist indicated that the approval rate for all proposals is about 18% with most being rejected because they are poorly written and do not meet USOE criteria. He said, however, "This does not reflect the true rate for really innovative and well conceived proposals, which have a very good chance of receiving support from us."

Amasa Bishop assesses US effort in controlled fusion

Few physicists are more closely identified with the US fusion effort than Amasa Bishop, who recently replaced Arthur Ruark as head of the Atomic Energy Commission's controlled thermonuclear program.

We went out to Princeton one Sunday to visit Bishop (he works seven days a week) to gain his views on fusion research in this country. Seated in his shirtsleeves near the complex apparatus and electronic equipment of the Model-C stellarator, he flatly predicted that controlled fusion would be achieved by the late 1970's. With a tone of urgency, he told us of the drastic effects we may expect from inadequate support of plasma research, why he has come back to his old job and how the perspective has changed for both scientists and Congress.

Bishop, like so many other physicists in fusion research, was trained outside the field. He earned his PhD in nuclear physics, and his earliest work was in meson physics and angular correlation of nuclear radiation. But after three years' postdoctoral study in Zürich, he returned to the US to join the highly classified Project Sherwood in its earliest days, when expectations were high for a quick solution to controlled thermonuclear energy. Over the years, Bishop has seen these expectations dashed by the complexity of the plasma state and then rise once again as problems are solved one by one. He left Project Sherwood as its director in 1956 to serve first as AEC scientific representative in Paris and then as head of the US delegation to EURATOM in Brussels. For the last five years he has been engaged in fusion research with the Princeton stellarator. Bishop, who will be 46 in July, lives with his wife and four children in Princeton (Amasa is a family name, accented on the first syllable).

Bishop is returning to Project Sherwood at a significant time. Both the Pake Report (see PHYSICS TODAY, April 1966, page 23) and the Herb Report (see PHYSICS TODAY, March 1966, page 60) have warned of a decline in plasma-physics education and in US leadership in controlled fusion unless support over the next five years is approximately doubled. Soon a funding decision will be made in Washington as to whether our fusion program will become second rate or advance rapidly to the CTR goal. We asked Bishop:

BISHOP

● *What are some of the reasons that caused you to return as director of the AEC thermonuclear program?*

"Probably the main reason is the impact that the Herb report had upon me. I was very much impressed by the extent of the review carried out by the Herb Panel, and I find the conclusions and recommendations in its report to be both dynamic and far-reaching. Since I am very deeply involved personally in the controlled thermonuclear program and convinced of its eventual success, I was pleased to see the Herb Panel arrive at conclusions with which I myself concur almost completely."

● *But considering the continued budgetary curtailments in the program, is this not a discouraging time at which to take over?*

"This is another reason why I de-

cided to come back. I want to see what I can do to help rectify this budgetary limitation. I would like to use the Herb report as a springboard for an intensified program that will move forward as rapidly and as strongly as possible."

● *At this point, what chance do you think the Herb report recommendations have of being implemented?*

"I sincerely believe (and hope) that they have a very good chance. In my opinion, the US effort should be supported at a level which will ensure active leadership in the field."

● *If the Herb Panel recommendations are accepted, would this not result in a restriction of some other programs in the AEC physical research division?*

"This need not be done at the expense of other AEC programs, provided the AEC, Congress and the Bureau of the Budget increase the funding for the controlled fusion effort."

● *Should the budget limitations continue, what do you foresee happening to the program?*

Need new people, devices. We have two major requirements. One is for new people to come in and help invigorate the program; the other is for the construction of new experimental devices that will test the next generation of confinement ideas for hot plasmas. If the level of operating funds is kept constant as it has been for the last four or five years, then our hands are completely tied in trying to achieve either of these two goals. We are, in effect, being forced to continue operation with limited personnel and with equipment that is outmoded. We lack the necessary funds to move ahead at a pace commensurate not only with the importance of the program but also with the encouraging outlook for eventual success."

● *Does the program now have a different perspective from when you first headed it?*

"Yes, definitely so. You see, I came into the program in the very early days when it was highly classified and no one knew what the possibilities were for success. In view of the rapid success that this country had with H-bomb development, where a sizable

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effort overcame great problems, we felt there was a reasonable possibility we could do the same thing with the controlled fusion effort. It was on the basis of this hope, of course, that the whole program was classified."

Difficulties more complex. "Then, about the time of the Geneva conference, in 1958, it became eminently clear that the controlled fusion problem was not going to succumb to an empirical attack, even with a very intensive effort. The difficulties were much more complex than we realized at the beginning. We saw the problem required a full and detailed understanding of plasmas, achievable only through a long-range research effort. It was for this reason that the whole program became declassified in 1958. Today, besides maintaining our long-range goal of achieving fusion, we are also building a solid framework of basic plasma physics and high-temperature plasmas."

● *How has the attitude of the Joint Congressional Committee toward the fusion program on Atomic Energy changed over the years?*

"In the beginning, of course, the Committee members were just as excited as we were about the prospects of rapid success. Then, when it became clear that this was going to be a long-range problem, their perspective and attitude changed also."

● *Will any of the fusion approaches have to be sacrificed if funds are restricted?*

Experiments, not approaches. "I want to speak very specifically on this matter; it is an important point that is often misunderstood. When the program first got under way and we had no real understanding of the problems involved, we set up a number of empirical "approaches" in the field: the pinch approach, the stellarator approach, etc. Since then, we have found that we need a deeper knowledge of plasmas through experimental research to achieve controlled fusion. Thus, the experiments which are being carried out throughout the country should not be considered as approaches to fusion power, but rather as experiments designed to answer critical questions concerning the behavior of plasmas in magnetic fields under a variety of conditions. The answers to these questions—particularly those relating to plasma confinement—are absolutely essential to continued progress in the field. The relevant experiments cannot be sacrificed without slowing the progress toward our goal."

● *Do you believe that government support of the fusion program should be diversified and not concentrated in a single agency?*

"I think that prime responsibility for the development of controlled fusion power is clearly that of AEC. There are, however, other government agencies that have justifiable interests in this field, and to the extent of these interests, their participation in this work is certainly appropriate and welcome."

● *The Herb report speaks of a national center for plasma studies. How do you envision such a center?*

"I think it could serve a number of useful purposes. In the first place, it would be a center where a large variety of plasma experiments would be carried out. These experiments would be unclassified, open to qualified scientists from this country or abroad who care to come and work in the program. This in itself would help to bring in the young blood and new ideas that we so desperately need in this program. Secondly, the assembly of a large number of experiments under one roof would stimulate a cross-fertilization of concepts and techniques, and also facilitate the intermarriage of different types of devices when and as needed. Such a meshing of concepts and experiments is certainly required if we are to move rapidly forward in this program. Thirdly, when the time is ripe for building a large device for a final test of successful fusion experiments, the background and experience for its construction would be on hand at one site, so that we wouldn't lose several years in having to set up such a center from the start."

● *Do you think our education in plasma physics is of a sufficiently high quality?*

"The US is just beginning to develop high quality in the training of scientists and engineers in plasma physics. Many of us moved into plasma physics from other fields (I, my-

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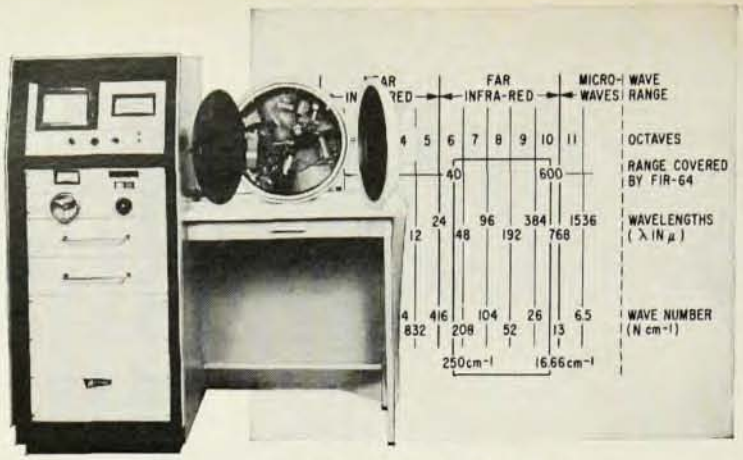

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self, from nuclear physics), and it is only in recent years that scientists are being adequately trained in plasmas. This is a new, young field, and if we are going to move ahead in it, we will need a considerable expansion in the university program."

● *In 1958 you estimated that controlled fusion would be achieved in about two decades. Now, eight years later, do you still believe that this goal is at most twelve years away?*

"Yes, I do. When we speak about proving the feasibility of the program, I sincerely believe that by the late 1970's such proof will have been established. That is, we will have shown that our program is experimentally practicable so that one can move ahead from that point into an engineering-development project for a fusion reactor."

● *Are others in the field just as sanguine as you are on this estimate?*

"Of course you'll get all kinds of opinions from different people. But many of my colleagues in the program feel just as I do."

Three major problems. "Let me be specific. The three major problems in controlled fusion are impurities, heating of plasma, and confinement. Now very significant progress has been made during recent years, particularly in the first two areas. World effort is at the present time being focused on the last major roadblock: that of plasma confinement. Even on this difficult problem, significant progress has been made. One of the most important instabilities, the flute instability, has been suppressed in straight systems by using minimum-B configurations. Progress is being made toward controlling the residual classes of instability.

"Perhaps the thing that gives me the greatest cause for optimism is the fact that we are now developing a rather close relationship between theory and experiment.

"From all these considerations, it is evident that the outlook for success is increasingly encouraging. Thus, in my opinion, it would be most unfortunate if this country, which built a strong foundation in this field during the past 16 years, should now fall back and let other nations achieve the fruits of success." □