German airplanes broke the world's speed records twice in 1939—a Heinkel in March at 464 miles per hour and a Messerschmitt in April at 469 miles officially and 481.4 unofficially—the momentary speeds developed have been accepted as inherent in the liquid-cooled engine used. This is an entirely false inference.

At the time that the Germans were claiming the world's speed record, moreover, American planes equipped with American air-cooled engines of similar rated power output were making a high speed in normal flight of about 330 miles per hour, while British planes with liquid-cooled engines of the same power output were credited with 360 or more miles per hour. The case for the liquid-cooled engine seemed to be very convincing. Yet it was based on a false conception of the aerodynamics of the matter. There was also an element of propaganda in it.

The test of war has shown that the German fighting planes have a real speed of about 350 miles per hour and that their British opposite numbers make the same speed or a little more. In the meantime, progressive improvement in the installation of the American air-cooled engines has brought up the speed of our fighter planes.

The National Advisory Committee for Aeronautics in its Langley Field wind tunnel has developed means of streamlining (ducting and cowling) the American radial air-cooled engine, so that its drag can be made as low as that of the best liquid-cooled engine installation. Thus recent technical progress has enabled American airplane builders to demonstrate airplanes with larger air-cooled engines at speeds exceeding 400 miles per hour. There now appears to be nothing to choose, as to speed, between the two types of engines when each is properly installed. This statement could have been true several years ago, but the results of research were available only recently.

The largest liquid-cooled European type engines now used by Germany and England develop about 1,200 horse power, and this year—1941—we shall have similar engines in quantity production here. Two new types of American air-cooled engine are already developed and in production in the 2,000 horse-power size. Nowhere else in the world are engines of such power available. The demand for armor, protected gasoline tanks and heavier armament can safely be predicted to make the 1,200 horse-power engine inadequate in the near future on account of the increased weight involved. Also there is always a demand in war for more speed. This country, however, can meet these demands by the development of a 2,000 horse-power fighter to compete with the 1940 European 1,200 horse-power plane. We have the engines and the knowledge of how to install them for high speed.

Production for war is not like production for domestic consumption. The business man trained in commerce may insist on "freezing" the design and going into production for three years on the same article in order to recover his investment in engineering costs. In war, technical progress on the part of the enemy can make such a three-year program disastrous.

We now have the interesting situation of a very large production program for 1,200 horse-power fighter airplanes based on European liquid-cooled engines which is getting well under way at about the time our own engineers present us with two 2,000 horse-power engines, and our scientists show us how to streamline them in an airplane installation to secure extremely high speed.

The position seems to be that we are using our great productive capacity for an immediate program of fighting airplanes that are the equal of anything known in Europe, and yet we have the potential ability to make obsolete all fighter airplanes in the world to-day, including our own. This position has come about by recent technical progress in engines and fuels, combined with new knowledge of the aerodynamics of air flow. When we should take advantage of this recent technical progress is a delicate question involving a balance between strategic and tactical considerations. It is the old dilemma of quantity now versus quality later and can be decided wisely only when we know whether it really is later than we think.

PROFESSOR LAWRENCE AND THE DEVELOPMENT OF THE CYCLOTRON[1]

By Professor R. H. FOWLER
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I HARDLY need remind this distinguished gathering that it is the father of the cyclotron whom we are delighted to honor to-day. When I first met Lawrence, in June, 1931, the cyclotron was a very small baby. In fact, the only examples that had been made to work up to that time were still barely out of the sealing wax and string stage in which all good physical apparatus is first realized in material form. My memory of that

[1] An address on the occasion of the presentation of the Duddell Medal of the Physical Society of London at the dinner of the American Physical Society and Section B of the American Association for the Advancement of Science, Philadelphia, December 27. The medal was to have been presented by Lord Lothian. In view of his death the presentation was made by Mr. Neville Butler, chargé d'affaires of the British Embassy.

first visit tries to tell me that Lawrence was then working with pole pieces of about 8 inches diameter. Perhaps there never was exactly such a stage. We all know anyhow that these baby models culminated the following year in a model with 11-inch pole pieces with which million-volt hydrogen ions were generated and used to verify the artificial disintegration of lithium, then just recently discovered by Cockcroft in England.

Lawrence, however, had already at that time more exciting developments in view, which I vividly remember. The derelict Poulsen arc magnet had already been located near Palo Alto and was even then on its way to Berkeley to form the backbone of the first of that whole series of adult cyclotrons with which Lawrence's work and ideas have enriched physical science. I well remember how Lawrence, in showing me round his laboratory, outlined to me the program that he had primarily in mind—not so much to investigate himself a particular physical phenomenon, as to build a new and more powerful tool and make it available to physicists in general—a tool that would be of the utmost value in all that wide range of physical phenomena which demanded, and still demands, bigger and better guns shooting more and more powerful projectiles to explore the innermost structure of the atomic nucleus.

I remember registering joyfully at the time what a wise choice of program this might, with luck, turn out to be, and how it would appeal to Rutherford, who had himself been driving ahead for some years on other developments with the same objective of producing bigger and better atomic guns. I remember, too, his interest when I reported Lawrence's plan to him on my return to England in the following month.

Well the luck *was* good—though of course it wasn't luck at all, but hard work, good physics, good engineering and deep insight into things which built the series of cyclotrons based on the old Poulsen arc magnet until its whole 37-inch diameter pole pieces were utilized to the full. It was these qualities, with good team work, which finally disentangled and interpreted the flood of important observations made with its use. If there was any element of luck about the affair it was perhaps that in the early experiments with deuterons (made possible by the success of G. N. Lewis in 1933 in concentrating heavy hydrogen) the resulting powerful neutron sources in the cyclotron did not damage the health of any of the workers before their danger, or even their existence, was recognized.

Lawrence's own development of the cyclotron, achieved and projected, have naturally not stopped with the 37-inch maximum allowed by the old Poulsen arc magnet, still working in the old Radiation Laboratory at Berkeley. This was followed by the 60-inch instrument of the William H. Crocker laboratory capable of producing a 100-microampere beam of 16-million volt deuterons or 32-million volt particles. Nor is Lawrence content to stop there, for a further instrument is under construction of such colossal size and power and promise of performance that I, who have not yet had the good fortune to see the plan, hesitate to describe it to you and must hope that Lawrence himself will do so in his reply.

I have not thought it necessary in this assembly of physicists and at this date to describe a cyclotron. We all know how it works in principle and realize what great pains and genius have been necessary to make it work in practice. But I would like to make one or two remarks about the outstanding contribution it is making, not only to physical science, but over the whole scientific field. In the range of usefulness of its products it is unsurpassed by any other tool at our disposal, with the possible exception of the microscope. It is, at the present moment, our most potent means of producing powerful neutron sources and by this means of making a large variety of new nuclei, providing us with new isotopes of the ordinary chemical elements in significant concentrations, which are in general unstable with a large variety of mean life. This wealth of new nuclei manufactured under known condition is itself of the greatest value to physicists in reducing to order our knowledge and our theories of the structure of the nucleus, just as the knowledge and theory of the outer structure of the atom was reduced to order, it seems only the other day. In this new study the cyclotron is the tool playing the part of the spectroscope of yesterday. But the wealth of new unstable isotopes of ordinary chemical elements does more than this. It enables us to study the sequences of chemical and biological processes with marked atoms such as carbon, perfectly normal except for their nuclear laundry mark. It enables also strong radioactive preparations of ordinary substances to be used in medicine in a way hitherto undreamed of. Important as the study of nuclear physics is in itself, these contributions to medical and biological science must be rated as of overwhelmingly higher potential value, and it is in virtue of them that I believe that Lawrence's work in developing the cyclotron takes its outstanding place to-day. In various parts of the world from Berkeley via Boston to England and thence via Moscow to Japan between 20 and 40 cyclotrons are already at work, a magnificent realization of Lawrence's dream.

We hail Lawrence, therefore, as one of the great tool makers of our time for his gift to us of the cyclotron. Looking back as a physicist, or if you prefer more strictly as an atomic physicist, over the years within my own experience, I can think of few new tools of comparable importance primarily developed by one individual. The cloud chamber of C. T. R.

Wilson is certainly one, and perhaps the mass spectrograph of Astor. Other great tools, for example, optical and x-ray spectrographs, have been from the first the work of many independent hands. But when one contemplates the wide fields which are coming to depend on the cyclotron one is tempted to believe that it will prove to be *the* great tool of our times. Incidentally, to be frivolous for a moment, it is the one major tool of which, to my knowledge, the Cavendish Laboratory ever made a Chinese copy.

A great toolmaker is a high estate, but we should do Lawrence scant justice if we did not hail him as a great team leader too. He has inspired and driven a remarkable team of workers—in these days in enterprises of such magnitude and complication the power to organize such cooperative efforts and to get the best from a team is an essential quality in the outstanding physicist. At least one major discovery is credited in the Cavendish to the toe of Rutherford's boot. I fancy that Lawrence's boot has an equally good toe and have no doubt that he uses it with judgment—I hope with equal success—as the great team leader must.

The English-speaking democracies may well contemplate with some pride the part that their outstanding scientific leaders have played in building modern science, and not least that wing of the building devoted to physics and engineering—which physicists, chemists, engineers and an odd mathematician or two have combined to glorify. Each of us will have our own pet list of heroes in this group. All these lists will be different and I shall not invite criticism by giving you mine. But I think we shall all soon agree that on this list the father of the cyclotron will hold an honored place.

Physicist, engineer, team leader, good colleague, Comstock Prizeman, Nobel Laureate, on my own behalf and, not greatly daring, on behalf of the members of the Physical Society of London, Ernest Lawrence, I wish you well.

SCIENTIFIC EVENTS

THE SIXTH LERNER-AMERICAN MUSEUM BIG GAME FISH EXPEDITION

UNDER the leadership of Michael Lerner, field associate in ichthyology of the American Museum of Natural History, the sixth Michael Lerner-American Museum Big Game Fish Expedition left Miami, Fla., on January 7 by Pan-American Airways for Talara, a small oil camp on the northwest coast of Peru, which will serve as a base for fishing operations. Mr. Lerner states that "The main objective of this year's expedition will be to investigate the habits of marlin reported to be found at this season of the year off Peru, with the purpose of finding further clues to its breeding places and breeding behavior."

To meet the special requirements of this type of big game fishing, Mr. Lerner has obtained the use of a 39-foot deep-sea fishing launch, the *Alone,* which has been shipped to Talara aboard a Grace Line steamer to be in readiness for the arrival of the expedition.

From its base at Talara, Peru, near the Ecuadorian border, the expedition will cruise along the Peruvian and Ecuadorian coasts, fishing to an offshore distance of one hundred miles, and making a study of the currents in which the large fish are apt to be found feeding on the smaller fish. Talara was one of the base camps for last year's expedition, when quantities of swordfish, manta, sharks and whales were found feeding in the rip where the warm current El Nino enters the cold Humboldt current.

"The breeding places and breeding behavior of all marlins are still unknown," said Mr. Lerner. "Our expedition of last year found evidence contradicting a prevalent report that both marlin and swordfish off Chile were in spawning condition. Our examination of the fish caught at that time showed all forty specimens examined to be adult female fish in a totally inactive state, as was the case with swordfish caught on two previous expeditions to Cape Breton and with marlins caught off the Bahamas."

Since this series of expeditions was inaugurated in 1936, specimens of swordfish and marlins in the North Atlantic, the Bahamas, Australia, New Zealand and off the west coast of South America have been collected but the breeding places of both remain a mystery.

It is also planned to collect specimens of a large squid found off the northwestern coast of South America. These appear at the surface at night in enormous numbers. Live specimens will be gathered and shipped back to New York in a large specially constructed tank for scientific study at the American Museum.

WORK OF THE UNITED STATES GEOLOGICAL SURVEY

A CONSIDERABLE part of the United States Geological Survey's geologic staff has been engaged for many months past in field investigations of deposits of the strategic minerals—manganese, mercury, antimony, tin, chromite, tungsten, nickel and mica. Examinations completed or under way cover areas in a dozen states and Alaska. Nine of the resulting reports have been published, others are in press, and still others are in preparation or await additional office and