BIOGRAPHICAL MEMOIRS

Henry Thomas Tizard, 1885-1959

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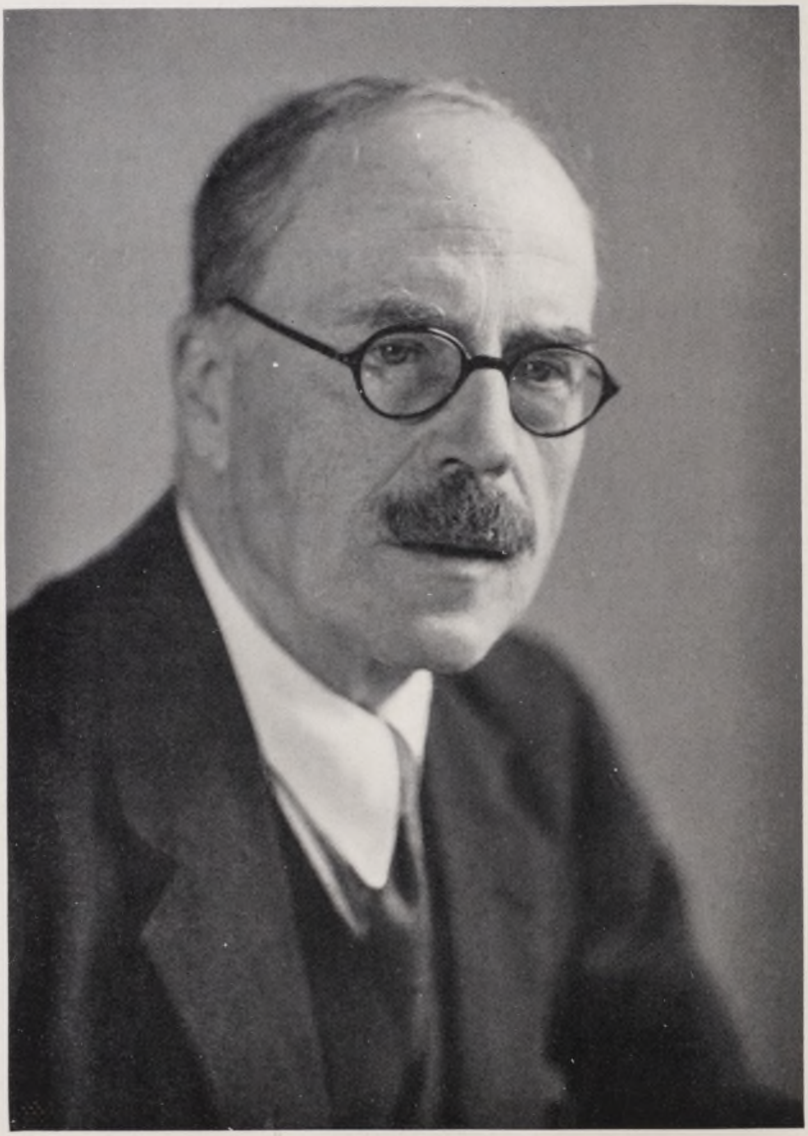

H. T. Tizard

HENRY THOMAS TIZARD

1885-1959

Henry Thomas Tizard was born at Gillingham, Kent, on 23 August 1885. His father, Capt. Thomas Henry Tizard, R.N., C.B., F.R.S., was in the hydrographic service of the Navy, of which, in 1891, he was appointed Assistant Hydrographer. His mother was Mary Elizabeth Churchward. H.T.T. was the only son. He had two older and two younger sisters. His father lived until 1924 and his mother until 1931.

On his father's side, his grandfather was a ship owner and coal merchant at Weymouth. H.T.T. believed that the Tizards were originally Huguenots, who settled in Weymouth early in the 17th century. He had no record of their activities. On his mother's side, there is evidence of engineering among his ancestors. His grandfather was a civil engineer, first at Malta Dockyard, and later at Pembroke Dockyard. A relatively remote ancestor (1628-1700) on this side was Sir Paul Rycaut, F.R.S., (elected 1666). Little is known about him. He was an author and traveller.

H.T.T. had a good memory, particularly for the events of his early childhood—memories of the dockyard at Chatham, and the building of ships, and of sailors encouraging him to climb a rope ladder up a mast.

When his father moved to the Admiralty in 1891, the family lived at Surbiton, and here he went to his first school, 'Enfield House', kept by three maiden ladies. The mathematics master, Verey, he described as a magnificent teacher —to whom he owed more than he could tell. Indeed, he attributed much of such success as he had in later life to his grounding in mathematics at this school, where he remained for eight years.

Following the tradition of his father's family, he expected to enter the Navy, but in 1899, when due for the Entrance Examination, he discovered a blind patch in his right eye. A specialist said that it would probably clear, which it eventually did. But the Navy being now out of the question it was decided that he should sit for a Scholarship at Westminster. His good mathematical training at his Preparatory School earned him an Exhibition. He was soon awarded a Scholarship, without which it was apparently unlikely that the family finances would have enabled him to remain at Westminster.

He was fortunate in finding a good teacher of chemistry, though physics was sadly neglected. He paid a tribute to the teaching of mathematics, particularly to H. E. Piggott straight from Cambridge. He believed later that he should have been advised to try for Cambridge, where, in the excitement of the times following the discovery of the electron, he would have found the incentive which his temperament needed. He was apparently dissuaded by

his housemaster from trying for a 'close' Scholarship at Trinity College, Cambridge, on the grounds that they were not given to scientists!

In 1903 he was elected to a demyship at Magdalen College, Oxford, and went up for the Michaelmas Term, 1904, when for the third time he found himself with a first-class teacher of mathematics, A. L. Pedder. He was placed in the First Class in Maths Mods. in 1905.

At this point the influence of his science teacher at Westminster, E. C. Sherwood, whom he regarded as a good teacher of chemistry though he knew very little physics, asserted itself, and he forsook mathematics for chemistry. Here his tutor was N. V. Sidgwick (later F.R.S.), of Lincoln, one of the strongest and most lasting influences of his life. Tizard's obituary of Sidgwick (*Obit. Not. Roy. Soc.* **9,** 237,1954) is an outstanding example of his command of language—a tribute to a great man rather than an obituary.

He sat for the Final Examination in Natural Sciences (Chemistry) in 1908. He remarked that chemistry at Oxford owed little to the then aged Professor. The University laboratories were in a poor state, and most of his practical work was done in the better equipped laboratories of some of the colleges (Balliol, Magdalen and Trinity). The practical teaching was good, but lectures were uninspiring. He learnt practically no physics. There were keen younger men on the staff, but there was little stimulus from the seniors. But with typical fairness, he recognized that his unfavourable judgement of the teaching of science at Oxford may have been due partly to shortcomings on his own part, bearing in mind the names and careers of his contemporaries.

It was during his Finals that, for the first time, he was sorely tried by ill-health. He had been satisfied with his performance in the theoretical papers, but the practical examination, taking the whole of the next week, found him with a high fever, and a temperature of 104 °F. He was removed to a nursing home, where the crude methods of those times succeeded in reducing his temperature but left him unable to tackle the paper on the second day, although he had the presence of a nurse to support him. He was grateful to the External Examiner for suggesting that he should go back to bed. On the third day he managed to put in three hours and on the fourth day the full six. In the list, he was given a First Class.

Sidgwick advised him to go to Germany, where Nernst had promised him a place in his laboratory. He managed to raise £130, from the College and from his father, which had to suffice for a year in Berlin. He spent the semester 1908-1909 there, Nernst having put him on to the condensation of acetylene to benzene. In the light of his results Tizard described it as a hopeless task, and he had much the same to say about another project on which Nernst put him early in 1909. It came to nothing. He had nothing publishable to show for his work, and decided not to risk the waste of another year. Nevertheless he recognized that he learnt a great deal of value in Nernst's laboratory. It was here also that he first met F. A. Lindemann.

He returned to Oxford and N. V. Sidgwick in the summer of 1909 and later spent some time in the Davy Faraday Laboratory at the Royal Institution,

where he started work on the sensitiveness of indicators. Four of his papers appeared in the *Transactions of the Chemical Society* and his lecture to the British Association at Portsmouth on the subject was published in the *Report of the British Association* in 1911. In this year, he was elected to a Fellowship at Oriel, where for the first time he had found himself relatively well off. His total income amounted to something over £500 a year, which with free rooms and free dinner was affluence.

At Magdalen, during the summer of 1910, he met Kathleen Eleanor Wilson, daughter of Arthur Prangley Wilson, a mining engineer, and of Edith Alexandrine (Hill). Although it was not until 24 April 1915 that they were married, they had waited only for a suitable opportunity. Having no private resources, he was concerned about finance.

He suffered an attack of fever in 1912, similar to the one which had nearly robbed him of a First in his Chemistry Finals in 1908. But he nevertheless regarded life at Oxford as too comfortable and by 1913 had vowed that he would not stay longer than five years, and would then go 'into the wide world and earn an honest living'. He often wondered if he would have kept his vow if the war had not intervened. It was at this time that he first met what eventually became the greatest interest in his life, the part of science in national affairs, and particularly in defence. Hitherto he had taken no interest in the matter, although he shared the general excitement about the development of aviation.

There was first a short interlude. In the summer of 1914 he went to Australia as a member of the British Association. The Australian Government had provided free passages for about 100 well-known British scientists and, at the last moment, when one of them was suddenly unable to go, a friend suggested Tizard as a substitute. On board the *Euripides*, in addition to N. V. Sidgwick, were a group of great men of science—all Fellows of the Royal Society—Professor H. B. Dickson, Sir Thomas Holland, J. E. Petavel, Professor Seward and, above all, Sir Ernest Rutherford. Thirty years later, and eight years after Rutherford's death, Tizard broadcast one of the best of his Addresses, 'I knew a man—Lord Rutherford'. There were 13 years difference between them in age, but they formed a friendship on board the *Euripides* which ended only with Rutherford's death. Owing to the outbreak of war, Tizard had little time in Australia, but returned more than once in later years. The Commonwealth fascinated him, and he was the kind of man the Dominions understood and welcomed.

He returned to England early in October, and joined the Royal Garrison Artillery at Portsmouth in November 1914, but soon came to the conclusion that he could make a better contribution than by training territorials on anti-aircraft guns in Hilsea Lines. With the help of a friend, he managed to arrange a transfer to the Royal Flying Corps, as an Assistant Equipment Officer, 2nd Lieut., to undertake experimental work at the Central Flying School at Upavon, Wiltshire.

It was here that I first met Tizard. I was engaged in experimental work

on aircraft in flight at the Royal Aircraft Factory, Farnborough (now Royal Aircraft Establishment), and the 'testing of the performance of service aircraft', which was a very broad description of the work of the Experimental Flight at the Central Flying School, had much in common with the Factory's work related to the design of aircraft. In the Commandant of the C.F.S., Commodore Godfrey Paine, R.N., Tizard recognized 'a very good commandant—he knew no science, but had a scientific spirit and encouraged experiment'. Among those whom Tizard had in his team were: G. M. B. Dobson (later F.R.S.), R. B. Bourdillon (whom Tizard had met in Oxford in 1911), and I. O. Griffith. Work in flight on the problem of the errors in sighting caused by the lag of the bomb behind a parabolic path, due to the resistance of the air to its flight, convinced Tizard that the error due to this cause was much less than the errors in flying the aircraft. He persuaded Paine that he could be of much more use if he learnt to fly himself. Permission was given 'so long as you go up only in weather which is too rough for cadets'. He qualified after $3\frac{1}{2}$ hours dual instruction, and 2 hours solo.

Tizard loved flying as a pilot, and was generally in the highest spirits when in the air. Later he felt less confident and came to the conclusion that his uneasiness was due to too much flying over 15000 feet with no oxygen.

In January 1916 he became a fully qualified pilot, and flew to France where he met General Trenchard. The main purpose of the visit was to investigate the results of bombing. But by this time his interest was moving towards the wider problems of determining the performance of military aircraft, particularly in view of the improvements which were at last being made, and of the increasing importance of the aircraft for fighting and reconnaissance. Aerial photography and radio were developing. Cloud flying was becoming of great importance, and revealing new problems. He was much impressed by the first modern aircraft he flew, the Royal Aircraft Factory's BE2C, 'a wonderful machine to fly after experience with Maurice Farmans' (on which we both had learnt). 'It was completely stable, easy to fly in the clouds and easy to land.' He became convinced that these qualities were of outstanding value in military aircraft.

But it was also necessary to be sure that improvements in performance (speed, rate of climb, and ceiling) were real and not mythical. He was not content to rely on personal estimates about things which could be measured. He was not satisfied with the instruments available, and proceeded to stimulate the development of better equipment. G. M. B. Dobson devised instruments which measured directly rate of climb and the rate of consumption of fuel. Tizard also appreciated the great advantages of the new aircraft compass devised by Keith Lucas, F.R.S., at Farnborough. But he felt frustrated by what he regarded as the failure of the War Office authorities in London to appreciate the need for more experimental work, with the object of producing not merely better aircraft, but *better weapons*. They seemed to him to have little understanding of engineering, and even less of science.

Once again, towards the end of 1915, he met a man who permanently

influenced his outlook on life. Bertram Hopkinson, F.R.S., had temporarily left his Professorship of Mechanical Sciences at Cambridge and joined the Department of Military Aeronautics at the War Office, with responsibility for the design and supply of bombs, guns and ammunition. Hopkinson made a profound impression on Tizard, an impression which deepened as time passed, and he came to know him intimately. Hopkinson's judgement was mature, he knew how to get the best out of people working under him, advised rather than ordered, and treated his staff as pupils rather than servants.

The two pages which Tizard contributed to Hopkinson's Obituary (*Proc. Roy. Soc.* A, **95,** XXVI (1919)) and his broadcast (5 March 1937) in 'Talks for Sixth forms', in a series entitled 'Someone who has influenced me in my life', are eloquent tributes to a man whose early death was a grievous loss to science, to engineering, and to aeronautics. For the first time, aeronautics was recognized by those in authority in the fighting Services as an essential element in defence. Its future, and possibly even the safety of the country, would depend upon finding the right man to head its research and experiment, a man in whom all would have confidence, on whose judgement they could rely in making the great decision—in Tizard's words—'What is best to do, among the so many things that might be done.'

Hopkinson had already decided on some things that *must* be done. The first was to move the whole of the experimental element at Upavon to more suitable surroundings away from the embarrassments inseparable from 'School' flying, and to provide better resources. In May 1916, he decided to move the Armament Experimental Flight to Orfordness in Suffolk, and in July 1916 to move the Aircraft Testing Flight to the adjoining airfield at Martlesham Heath. Tizard moved with them, was promoted to Captain, and made responsible for directing the scientific and experimental work of the whole station.

He moved his family to Woodbridge (his eldest son John Peter Mills had been born on 1 April 1916 and his second son Richard Henry was born on 25 June 1917 shortly after the move to Woodbridge). Although he was at Martlesham for only a year, Tizard looked back on his time there as one of the most enjoyable of his life. His brother officers and the staff at Martlesham were 'a happy friendly crew'. He was sufficiently experienced in flying as a pilot to get more than mere pleasure out of it and, with Hopkinson's enthusiasm and strength to stimulate him, he knew that he could make a significant contribution to the needs of defence in the air.

He flew a new Sopwith 'Dolphin' to France to be compared with the S.E.5's in the famous 56 Squadron. He noted that such advances in the understanding of aerodynamics as were made during the war had little practical effect on the performance of aircraft, compared with the development of the internal-combustion engine. This early appreciation of the overwhelming need to improve the output of an aircraft's power unit, per pound of its weight, determined the pattern of much of his later work for aeronautics.

Aeronautics had to wait some ten years for the full impact of two major discoveries in aerodynamics, though both were lying dormant during this time. Bearing in mind that these years included the 'hungry 20's' and the influence of the aftermath of war, it is fortunate that the inspiration of a few great men came to our rescue. From 1930 on it can fairly be said that both aerodynamics and thermodynamics advanced in parallel, producing in combination improvements which were of a different order of magnitude from what either could have achieved alone.

At Martlesham the front line was not far away. A Zeppelin raided Harwich and Ipswich. On 1 July 1917 Tizard took a new Sopwith 'Camel', with untested guns and ammunition, against a formation of German bombers attacking London. He managed to climb to their level in time to attack one of the rear machines from the tail. He fired a short burst without any visible effect—after which both guns jammed!

During 1917 he drew from his work at Upavon, and its further development at Martlesham, enough material to give to the Royal Aeronautical Society on 7 March 1917 a paper on 'Methods of measuring aircraft performance', primarily in order to emphasize that seriously misleading conclusions could be deduced from measurements, owing to the difficulty of allowing for variations in atmospheric conditions, particularly up or down currents. There was at the time much collaboration between the Testing Squadron, both at Upavon and Martlesham, and the Royal Aircraft Factory, where the same type of problem was met in similar experiments associated with the process of design. The following extract from Tizard's lecture sums up the views of both teams:

'So far as England is concerned, I believe that the general principles of what may be called the scientific testing of aeroplanes were first laid down at the Royal Aircraft Factory. Our methods of reduction were based on theirs to a considerable extent, with modifications that were agreed between us; they have been still further modified since, and recently a joint discussion of the points at issue has led to the naval and military tests being co-ordinated, so that all official tests are now reduced to the same standard. It should be emphasized that once the methods are thought out scientific testing does not really demand any high degree of scientific knowledge; in the end the accuracy of the results really depends upon the flyer, who must be prepared to exercise care and patience unnecessary in ordinary flying. Get careful flyers whose judgement and reliability you can trust and your task is comparatively easy; get careless flyers and it is impossible.'

In the Autumn of 1917 Tizard became restive. He felt unwell, and attributed this to the cumulative effect of high flying, 17000 feet or even higher, without oxygen. He had a blackout in an S.E.5 at 17000 feet due, not to high accelerations imposed by manœuvres, but to sheer lack of oxygen. He had just time to throttle back before he passed out. He came-to with the aircraft out of control at 5000 feet, but recovered rapidly and had no difficulty

in righting the machine, and landed safely.* Aircraft testing, now routine, no longer appealed to him, so he turned his attention to cloud-flying. There was a proposal afoot to form a special cloud-flying bombing squadron in France and that Tizard should join it, though in what capacity is uncertain. Both this, and his uncertainty about the future of the Experimental Station at Martlesham decided him, in October 1917, to move his family from Woodbridge and to settle them in Oxford.

In the event, he was invited by Hopkinson to go to London as his Deputy. He became Assistant Controller, Research and Experiment, was promoted to Major and, in 1918, to Lt. Colonel. This was Tizard's first experience of what has always seemed to me to be his natural place in the world—Headquarters. However, it was not until 1920 that he took the step which ended in his abandoning science as a personal activity, and turned his whole mind and energies to science as a national asset and to the problems of its application to the needs of industry and of defence.

In the time since Hopkinson had first appeared on the scene at Upavon (November 1915) the Headquarters organization had changed radically. The responsibility for aircraft had passed from the War Office to the Ministry of Munitions, whose Minister was Mr Winston Churchill (now Sir Winston Churchill, F.R.S.). On the aircraft side the head was William Weir (later Lord Weir), Director General of Aircraft Production. Under him, the Head of the Technical Department was his brother Brig. Gen. James G. Weir, to whom Hopkinson was Deputy.

Tizard spent much time visiting Experimental Stations, usually by air, and flying himself. He learnt that, for a pilot who does not keep himself in *daily* practice, this method of transport is not to be recommended. His only real crash in his flying career was a forced-landing in an S.E.5 in the dusk, when he hit a tree in a field, finding it a convenient shock absorber.

His attention was inevitably drawn to the serious situation which arose during 1917 owing to the attacks of German submarines on tankers bringing in petroleum fuels. The shortage of aircraft petrol became acute, particularly because it was derived entirely from Pennsylvania oil. For some reason, which apparently nobody understood, this was particularly suitable for aircraft engines. It consisted almost entirely of aliphatic hydrocarbons. Tizard decided that tests should be made at Martlesham with a mixture of standard aircraft petrol and benzol from gas-works. Everyone was surprised to find that this mixture suited aircraft engines even better than the standard aircraft petrol. Unfortunately the benzene in gas-works benzol tended to freeze out of the mixture at low temperatures, although other aromatic compounds did not. But there was a fair supply of toluene from Burma. Most of this was used for explosives, but enough of the residual aromatics could be spared for the fuel for aircraft engines. This almost accidental discovery was largely

* When I read this note, I thought of my own experience. I seldom reached 17000 feet in 1916-1919. But by 1941 oxygen, like the parachute, was available in all service aircraft. I was trained to breathe it from the ground upwards—just to be sure that the system was working, and that lack of oxygen did not make me forget to turn it on!

responsible for Tizard's continuing interest in fuels for aircraft engines, and so for one of his most important contributions to aeronautics, of which a fuller account is given below.

By the middle of 1918 doubts about the outcome of the war had fallen to a point where planning for life after the war had become active. The importance of aeronautics to defence was now recognized. We could no longer afford to ignore it in peace-time, since to do so would place us in a position of great danger in the face of a threat of another war. Moreover, its significance for the future prosperity of the country, as a means of transport in peace-time, was at last becoming a matter for action.

The outstanding success of Hopkinson, in stimulating and directing research and experiment, had led to the preparation of plans for the establishment of a National School of Aeronautical Engineering of which he was to have been the Head. But he had learnt to fly and, for the same reasons as persuaded Tizard, he used aircraft as a means of transport, piloting himself partly because he enjoyed it, and partly because it helped him to realize the things that matter in the air. On 26 August 1918 when returning from Martlesham in poor weather which deteriorated to complete cloud-cover over London, it seems that he tried to descend through the clouds, lost control and probably allowed the aircraft to spin from which he could not recover.

It fell to Tizard to take over Hopkinson's position in London. He was however attacked by the influenza plague, which was widespread in the Autumn, and did not recover until December. He was demobilized in the Spring of 1919, and returned to Oxford.

In later years we sometimes talked about the influence of war on our lives. We agreed that war simplified everything, because all personal plans, ambitions, likes and dislikes become of little significance, compared with the one overriding objective. But for both of us there was a difference between 1914/1918 and 1939/1945. In company with many others, I had found far greater stimulus in the second war than in the first, mainly because in the second aviation came into its own, in spite of the neglect from which it had suffered in this country until a date which was far too near to 1939 to be comfortable for anybody. For Tizard the second war led in some ways to personal disappointment, though I do not believe that he felt that he had been misused or ignored. The material from which much of this memoir has been composed was written by him in or shortly before 1959, the last year of his life. I can find in it nothing to justify a different conclusion. Of the period 1935 to 1952, however, with all its tortuous paths of assertion and contradiction, rumour and denial, I am less qualified to speak from personal knowledge than is Professor R. V. Jones to whom I am greatly indebted for his account of this part of Tizard's life.

But for the first war let Tizard speak for himself: 'The war did me a great deal of good. It pulled me out of the ruck at Oxford. It forced me to do things which I should never have done of my own accord in peace-time, but which I found in practice much easier than I imagined. It brought me into close and

friendly contact with all sorts and conditions of men and it made me realize that a purely scientific education *was* of value for men who had to deal with the practical affairs of life. Of course I was one of the lucky ones.'

There was, however, one difference between the two wars which affected all who took part in both, and that was in our relative ages. At the end of 1918 Tizard was 33. Twenty-seven years on, at the end of World War II, the prospect which faced us seemed very different—obscure, with a darkening horizon. We were in much the same position as everyone else, but we noticed that the younger men worried less than we did.

Be that as it may, after the first war, Tizard returned to Oxford, to his Fellowship at Oriel and to chemistry. He committed himself, with some doubts, to give a full course of lectures in physical chemistry which, judged by remarks made to him in after years, were successful.

He resumed his research on chemical indicators, but his most successful and most valuable research was on the influence of the chemical composition of the liquid fuel on the thermodynamics of the spark-ignition engine. Tizard's interest in this problem was first aroused by his experience at Martlesham in 1917, mentioned above. Owing to the great importance of this question to the fuel-oil industry, the interest of Sir Robert Waley-Cohen of the Asiatic Petroleum Company (Shell) had been attracted by the parallel work of H. R. Ricardo (later Sir Harry Ricardo, F.R.S.). The outcome of this was very substantial financial support from Shell for a programme of research, at a laboratory set up by Ricardo at Shoreham. In this Tizard participated, bringing with him D. R. Pye (later Sir David Pye, F.R.S.), who had been a member of the team at Martlesham.

The relationship between the three leading spirits, and in particular the parts played by Tizard and by Pye, are admirably described by Sir Harry Ricardo in a letter to Sir Harold Hartley, F.R.S., from which I have their permission to quote below:

'Our terms of reference from the Shell Co. were to investigate all the properties of a fuel which could influence the performance of a spark ignition engine and to evaluate their relative importance, that of detonation being only one. I told Sir Robert that to do this we should need the help of one or more really first class physicists and he readily approved my suggestion that we should retain Tizard and Pye as consultants. Tizard stipulated that the results of any such investigation should be published; to this Sir Robert generously agreed provided that no publication was made until 18 months after the Shell Co. had received our report.

'It would have been impossible I think to have found a more ideal collaborator than Tizard. He entered into the project with zest and was always full of valuable and ingenious suggestions.

'During the last year of the war Tizard and I were in constant touch discussing how we would set about the research and what equipment we would need. We found ourselves in complete agreement in mapping out a plan of campaign to be started as soon as the war was over and our laboratory was

ready. It had long been my ambition to have a really versatile research engine in which, among other things, the ratio of compression could be varied while running and therefore without disturbing any temperature or other physical conditions, and I had already prepared scheme designs for such an engine. Tizard agreed with this but advocated that we should design and build another unit using the same variable-compression cyclinder and mechanism but in which the piston would make only one rapid stroke and then be locked at top dead-centre. With this machine, with the help of Hopkinson's optical indicator and by finding the critical ratio of compression for each fuel, we could study the unstable conditions when on the verge of spontaneous ignition. This machine, always known as the "Sphinx" because of its peculiar shape, proved very useful as an adjunct to the variable-compression engine.

'All this was in 1917-1918. The war was still on and all of us were engaged on various war services. We had however many opportunities to meet and discuss matters.

'It was agreed that as soon as the war ended and we were released from our various duties, Tizard and Pye would return to Oxford and jointly prepare a very full thesis setting out all the physical characteristics of all the light hydrocarbon fuels and also other possible volatile liquid fuels such as Alcohol, Acetone, Ether, Carbon Disulphide, etc., while I and my colleagues would supervise the building of our new laboratory at Shoreham and the construction by Messrs. Peter Brotherhood of both the variable-compression engine and the "Sphinx" together with the collection of such other test equipment as we should need. By the summer of 1919 all was ready. Tizard and Pye had prepared a really monumental analysis of all the physical properties of the fuels such as specific heats and dissociation of the gases before and after combustion at all temperatures up to 2500 °C. For this they drew on all the known data supplemented by their own researches at Oxford. In the course of it they investigated all such factors as the total energy per cubic inch of combustible mixture, the latent heat of evaporation, the change in specific volume before and after combustion, the temperature coefficient, etc., and pointed out how each and all of these factors might be expected to influence the performance of an engine, some of which, notably the very important influence of the latent heat, had not at that date been appreciated.

'By the summer of 1919 all was ready to start work. The variable compression engine was installed together with the necessary test gear. The Shell Co. had provided us with all the samples of both commercial fuels and pure substances we needed, together with a bulk supply of a specially prepared fuel from which all the aromatics had been removed to serve as a basis of comparison with all the others.

'Tizard came to Shoreham and we all set to work in real earnest. Brotherhood's had made a superb job of the variable compression engine and it proved a really precious instrument, not merely as a knock-rating unit but

for evaluating the importance or otherwise of the other physical properties of the fuels, some of which had a more important influence on the performance of the engine than any of us had anticipated. For the next eighteen months Tizard spent most of his time with us at Shoreham while Pye remained for the most part at Oxford, but none the less spent several months with us at Shoreham during which he concentrated on the "Sphinx" to which he had become very much attached, and which, some years later, he took with him to Cambridge.

'It is difficult to point to any one achievement of his (Pye's) except of course his analysis of the properties of fuels, but Tizard's help in devising ingenious tests and his astuteness in analyzing the results and drawing from them the right conclusions were invaluable. For the most Thornycroft and I carried out the actual engine tests and Tizard and Pye the analytical work. As had been expected we confirmed that the incidence of detonation was the most important single factor limiting the performance of the petrol engine, and, at Tizard's suggestion, we expressed this in terms of Toluene Number, that is to say, the proportion of toluene (the least prone to detonate of any hydrocarbon fuel we had tested) which had to be added to η heptane (the worst) to match the fuel under test, for we had established a straight-line relationship in the blending of these two. Several years later the Americans substituted iso-octane for toluene and today the expression "octane number" has become universal.

'During the course of this research we all learned a great deal about the behaviour and appetite of the petrol engine and were able to advise the Shell Company as to its diet.

'By the end of 1920 our programme of research was almost completed and from Tizard's point of view was losing its scientific interest, for it was degenerating into the routine testing of shipments of fuel from various parts of the world. The upshot of all this research was then published very fully in two series of articles "The character of various fuels" by Tizard and Pye (1924) and "The influence of various fuels on the performance of the petrol engine" by Thornycroft and myself. Shortly after this Tizard suffered a very severe attack of influenza, which put him out of action for several months, and that was the end of our active co-operation though we kept in close touch as friends for the rest of his life.

'As a collaborator on research of this kind Tizard was quite ideal—he had a vast fund of knowledge, was full of ingenious ideas backed by a thoroughly practical outlook. As a friend his personal charm and sense of humour was always a delight and he was never dull.'

Tizard himself summed up the results of the work as having established the following three main conclusions:

1. At a given compression ratio, the nature of the liquid fuel did not materially influence the maximum power developed. In practice, the best fuel was that which showed the least tendency to knock.

2. The efficiency of the engine, measured by the specific fuel consumption, was highest with a weak mixture.

3. The maximum power developed, at a fixed compression ratio, was constant over a wide range of rich mixtures. This was explained by the dissociation of carbon dioxide at high temperatures.

Tizard noted that it was interesting to reflect that 'but for the dissociation of carbon dioxide, it would have been very difficult, if not impossible, to design a practical multi-cylinder petrol engine'.

During 1919 and until September 1920 Tizard spent a good part of his leisure time on this work, which resulted in six published papers, mostly in collaboration with others. The most striking products of the later phase of this research were published in papers whose authorship is shared with Pye. Indeed, in this work, probably the greatest contribution of either of the authors to an advance in understanding of a problem of high significance, both theoretical and practical, the names of 'Tizard and Pye' are regarded as inseparable.

In February 1920 he was appointed University Reader in Thermodynamics (Chemistry) and in April was re-elected for seven years a Fellow of Oriel. It seemed that he was settled in Oxford after all. But once more he was forced to consider whether his feet were set on the right path. Within a few months he was invited by Sir Frank Heath, the Secretary of the Department of Scientific and Industrial Research, still a relatively new Department, to join him as an Assistant Secretary. He had doubts about the suitability of the Oxford climate for his tiresome and uncertain health, which made him think hard. But what really decided him to accept was that he had come to the conclusion that he 'would never be outstanding as a pure scientist—younger men were coming on—all with greater ability in that respect'. His war experience had taught him the immense importance of the application of science to national affairs. The financial problem of educating his children weighed on his mind, and he decided it was better to have a relatively stable position, a good salary with prospects, than a Readership, whose emoluments were only about half as much, though he could (and at that time in fact did) augment them by an equally remunerative consultancy.

He stayed long enough in Oxford to examine in Final Schools in 1920, 'when I gave First Classes, *inter alia*, to C. N. Hinshelwood, E. J. Bowen and Sydney Barratt (not a bad lot!).'

Tizard resigned his Fellowship on 30 June 1920, leaving with a 'lively feeling of gratitude to Oriel', and moved his home to Wimbledon. He suffered another sharp attack of influenza, seemed to recover fairly quickly, and then went slowly downhill for months. He was well enough to join the D.S.I.R. in September 1920.

His summary of the origin and background of the D.S.I.R., and its history up to the time when he joined, is interesting not only for what he says of the Department but for the light it throws on the way in which his mind grasped a problem of this kind. He regarded Germany, at the beginning of the

century, as the most highly educated country in the world, supreme in science, and with a lead in chemistry so long that it seemed impossible ever to catch up. In the crucial twenty years before 1914 there had been few signs of any appreciable influence of science on the mind of Government in England. Within three weeks of the outbreak of War the Board of Trade had appointed a Committee, under Lord Haldane, 'to consider and advise as to the best means of obtaining, for the use of British industries, sufficient supplies of commercial products, colours and dye stuffs of the kind hitherto imported from countries with which we are at present at war'. But little scientific work of importance to industry could be started in the years from 1916 to 1918.

Early in 1920 it was decided that steps should be taken to co-ordinate the scientific work of the Defence and Civil Departments, by means of 'Co-ordinating Research Boards'. Four Boards had been established, for Chemistry, Physics, Engineering, and Radio Research. Their Chairmen were: Sir Richard Threlfall, F.R.S., Sir Joseph J. Thomson, F.R.S., Sir Charles Parsons, F.R.S., and Admiral Sir Henry Jackson, respectively. Tizard's task in 1920 was to take charge of these Boards. Their terms of reference were 'to organize the scientific work that was devoted to the fighting services so as to avoid unnecessary over-lapping, to secure the utmost economy of personnel and equipment, to facilitate the interchanging of scientific knowledge and experience between all the Departments concerned, and to provide single direction of financial control for all work of a fundamental nature of civilian as well as military interest'. It is not surprising that Tizard regarded these terms of reference as a mistake. How could committees in civilian departments organize work for the fighting services? So far only one service department—the Admiralty—had appointed a Director of Scientific Research and that not until 1920. This was F. E. Smith (later Sir Frank Smith, F.R.S.). Tizard's personal experience of research in war time, and of its relation to a fighting service, had given him clear ideas of how such work should be organized. There should be a Director of Scientific Research in *each* service, who would exert his influence over the whole service, who would ensure that the Research and Experimental Establishments studied the true needs of the service, and that their effort was centred on things that mattered. He was almost quoting Hopkinson.

In due time, the 'co-ordinating' functions of these Boards were abandoned, and simpler, less formal, methods adopted.

Tizard took a keen interest in the Radio Research Station at Slough whose Director was R. A. Watson Watt (later Sir Robert Watson-Watt, F.R.S.). It was from the work done there that radar emerged in 1935.

He was instrumental in obtaining from the Physics Board a grant of £500 a year for the work being done at the Cavendish Laboratory by Dr Kapitza (later F.R.S.), under Lord Rutherford, on the production of magnetic fields of very high intensity.

On the service side, he continued to press the Departments to take a more

enlightened view of the functions of a Director of Scientific Research. He argued the point with Sir Geoffrey Salmond, the Member of the Air Council for Research and Development, who offered him the post of Director of Scientific Research at the Air Ministry, which he declined because he considered the salary was too low. Moreover, the terms of reference excluded armament and bombing, an omission to which he attributed the inadequacy of our bombs in 1939. He was convinced that the Directors of Scientific Research of the services were never used in the right way in peace time. In this he may well have been right. But nearly all his experience of research had been in war, when the relationship between Headquarters in London and the Services' Research Establishments was more flexible and less irksome than it became in peace. Perhaps he did not regret that the problem which he now faced was apparently relatively straight-forward and simple—the peace-time direction of Government-maintained or Government-aided scientific research in aid of the country's industries. But it is doubtful whether he found it so.

In October 1922 he became Principal Assistant Secretary, and in June 1927 he succeeded Sir Frank Heath as Permanent Secretary. During these years he became aware of the causes of the difficulties which faced the Department. He came to value the Advisory Council and made friends of its members. He had a particular regard for the Chairman, Sir William McCormick, F.R.S., of whom, in collaboration with Sir Richard Threlfall, F.R.S., he wrote an outstandingly fine obituary notice, which contains probably the best history which exists of the State's growing interest in, and support of, scientific and industrial research. Tizard did not agree with Sir Joseph Thomson about the kind of research which Industrial Research Associations should undertake, but he regarded him as the outstanding Member of the Council, to whom everybody deferred. Sir Richard Threlfall became his closest friend on the Council—'took me to Vyrnwy and taught me to fish—far bigger and wiser than most public men I have met—all my impressions of him are happy'. To him Sir William B. Hardy, F.R.S., 'with his black beard and commanding air, looking rather like an Elizabethan pirate, was one of the great men of his time. I never met a man so exactly fitted by knowledge and intellect and force of character to be a leader in industrial research.' Sir Joseph E. Petavel, F.R.S. was Director of the National Physical Laboratory—'the best I think the N.P.L. has ever had. But then he was an engineer, the only engineer ever appointed Director N.P.L. The post is officially the gift of the Lord President, but in practice is left to the Royal Society to appoint, which prefers a physicist.'

He was beginning to feel sure of himself in his new environment. He had been elected a Fellow of the Royal Society in 1926 and in 1927 was awarded the C.B. His health still worried him, but after an attack in 1922 (not long after the birth on 15 May 1922 of his third son, David Andrew Thomas) he fortunately consulted a doctor who told him he could find nothing wrong with him except that he was worrying about his wife and family. From this

time onwards until about 1950 it seems that his health did not trouble him so much.

Shortly before he left Oxford in 1920, Tizard had been invited by the Secretary of State for Air to join the Aeronautical Research Committee (since 1946 'Council') as an independent member. In 1921 he became the official representative of the D.S.I.R. on the Committee. His membership was almost continuous for the following twenty-two years. Indeed, though the field of his interests and influence inevitably widened, his early association with aeronautics, in years when flying itself was still in its infancy, provided an invaluable foundation of practical experience for many of his most significant contributions to the problems which faced the country.

All of these had one element in common. We were signally failing to make fruitful use of the knowledge which our own research was providing. We were falling behind other countries. We had men of science, with power of insight and judgement, but they lacked influence. Of Tizard's influence on aeronautics there was never any doubt. On 29 May 1925 he gave the Wilbur Wright Lecture before the Royal Aeronautical Society on 'Fuel economy in flight'. It showed a remarkable grasp of a complex problem, and a characteristic power to pick out the points in which substantial progress in the whole aircraft could be expected, in order to put the significance of possible improvements in fuel economy in proper perspective.

In the same year, on 2 October 1924, he became Chairman of the Society (a position which in 1927 was combined with that of President) and delivered an Inaugural Address with one of the shortest and most striking titles which the Society has ever known—'Commonsense and aeronautics'. He described the title as 'provocative' but explained that in this context 'commonsense' had its literal meaning 'the intelligent thoughts of the ordinary man'. He asked and answered:

> 'What does the ordinary intelligent taxpayer think about aeronautics? Perhaps his chief thoughts can be summarized as follows:
>
> (1) The Air Force is a necessity; but let it be as efficient and economical as possible.
> (2) Civil aviation is a luxury.
> (3) Flying is unsafe.'

The economics of air transport, and its relationship to defence, were summed up in words which might have been written of the present day:

> 'All activities that consume more than they produce are luxuries, unless they bear within them the promise of greater productivity in the future. We are passing through a period when every item of unproductive national expenditure has to be scrutinized with more than usual care. That expenditure on civil aviation has escaped a really critical scrutiny I attribute to two causes—one that many people have a vague idea that it is a necessary factor in the aerial defence of the country; the other that the public mind is preoccupied with more important matters. All the more reason why we who

honestly advocate expenditure on civil aviation should examine our motives and methods and ask ourselves whether they can be justified . . . The majority of you will probably agree that only on one condition will civil air transport become a real part of the economic life of the nation, and at the same time a real factor in the defence of the country. The one condition is that it pays its way. So long as it is carried on at a loss, so long will it be negligible for defence purposes. Machines developed for civil purposes will never be of more than trivial importance in aerial warfare; what will be of importance is the development of a large and healthy industry, and the adoption of aircraft by a considerable section of the community, either as a normal means of transport, or as an indispensable adjunct to other industries. Neither of these events will come about until civil aviation pays its way.'

He added that:

'If you accept these statements, there is only one logical conclusion, It is that air transport cannot yet be regarded as a business; it is simply a large scale experiment. It may be regarded as a natural and necessary consequence of research and experimental work in the laboratory and workshop . . . All industrial research that has a promising issue on the small scale must be tried out carefully on the large scale before its conclusions can be finally adopted. Often it is only on the large scale that those modifications and improvements are introduced which make the difference between success and failure. For air transport to have any prospect of success, it must be operated on the same sound principles that many years' experience have shown to be essential in the conduct of other industrial research.'

Finally:

'Flying is unsafe. Here the commonsense view is undoubtedly right. It *is* unsafe. Not dangerous but unsafe. About as unsafe, let us say, as mountaineering, but hardly as unsafe as motor-racing. It is no good trying to conceal from oneself, and from the taxpayer, that air transport is not a perfectly safe means of transport when we know that it must be made 100 times safer before it can be a reasonable commercial proposition. Considering the nature of the aircraft engine, it is astonishing how reliable it is; considering the newness of the science, it is astonishing how stable and strong an aeroplane can be made; but it is equally true to say that no effort must be spared in making the one more reliable, and the other more stable and foolproof.'

In 1933, Tizard was appointed Chairman of the Aeronautical Research Committee. He was unquestionably the best man for a task which rapidly became both difficult and important. Aeronautical activity in the country expanded rapidly in face of the threat of war. By 1936 we were trying desperately to make up for lost time, to improvise means of doing what we ought to have done five or ten years earlier. To some it might seem an odd time in which to undertake research, and to seek the guidance of a committee which

was not apparently designed to stimulate action, or to make recommendations on urgent matters of policy when the evidence was inadequate and the future obscure. It is, however, precisely in such times that a man with Tizard's powers of judgement and leadership is invaluable. It was a time when it was overwhelmingly important that we should choose right among the many things we were invited or urged to do. He showed several times in his life that he could lead opinion in fields in which he could hardly claim to be a professional expert.

A similar problem had faced Bertram Hopkinson twenty years before, as Tizard showed in his broadcast on 5 March 1937 (see p. 317, line 11). Tizard was not, as Hopkinson had been, at the head of Research and Experiment. But he knew that as Chairman of the Aeronautical Research Committee he was possibly more strongly placed. His understanding of aeronautics was deeper than Hopkinson's had been, his experience was greater, and his power of judgement was outstanding. There were times when he seemed to regard the Committee as a forum in which to test his own ideas. But the recommendations were the Committee's and with a Chairman of Tizard's personality and reputation it was often possible to ensure action before it was too late.

I have vivid memories of these years with Tizard. I was a member of various Sub-Committees of the A.R.C. from 1920 onwards. and of the Engine Sub-Committee (of which he was almost perpetual Chairman) from 1928, so that I never lost touch with him. I was a member of the A.R.C. from 1930 for most of the years until 1946, and saw in him in action at this level.

Using the words of Dr R. S. Hutton:

'I was immensely struck with the way in which Tizard handled this Committee. It was at a time when rapid and great strides had to be made in the speed and size of aeroplanes. After briefly outlining some immediate problem as he saw it, he asked for proposals from the experts. When no one was prepared to start, Tizard himself gave an imaginative sketch of some ideas and then members of the Committee one after another responded. I remember this vividly and always have felt that it was this contribution of Tizard's which really led the way to some of the big advances on the material side of flying which led to our success in the Battle of Britain.'

In October 1929 Tizard resigned from the Department of Scientific and Industrial Research and became Rector of the Imperial College of Science and Technology, an appointment which he held until 1942. His period of 'war service' began in 1935, and his Chairmanship of the Aeronautical Research Committee lasted until 1943. He carried the heavy load of three distinct tasks without signs of distress, and did some of the best work of his life in all fields.

At the College he set an example to all. After more than a full day's war work, he would get back to the College at midnight, rouse the Secretary, Mr G. C. Lowry, from his bed, and work until 3 or 4 a.m. giving decisions

which, to quote Mr Lowry, 'almost without exception proved absolutely right. He was probably the first Rector who combined with intellectual ability and great personal charm such a high degree of organizing and administrative capacity, with a knack for quick understanding and a willingness to enter into detail.'

On the question of Tizard's qualities as an administrator, about which the professional historian may well find it difficult to judge in the light of critical remarks which have appeared in the Press, it should perhaps be said here that most of these can be traced to a failure on the part of the critics to agree on a definition of 'administrator'. It is difficult to believe that Tizard regarded himself as a born 'superintendent' or a good 'manager'—a 'director' perhaps, a 'boss' never, a 'chairman' undoubtedly. He was a master of the searching question*. He had the patience to listen, the power to think, the ability to decide, the courage to change his mind. He had little interest and less belief in size for its own sake†. But he was convinced that the Imperial College was destined to be the first of the Technological Universities upon which the future prosperity of the country would largely depend, and he spent himself unsparingly in devising ways of securing a sound foundation for its future expansion. He was constantly looking ahead.

In Mr Lowry's eyes he was clearly a hero, and to their Secretaries few men are heroes. But it is probably in the words of Dr H. J. T. Ellingham (Fellow of the Imperial College, and now Secretary of the Royal Institute of Chemistry) that we find the best appreciation of his strength and weaknesses.

'Obituary notices and other communications that have so far appeared have not brought out fully all the qualities of Sir Henry Tizard, and some of the characteristics not mentioned, or referred to only obliquely, may be among those that made his tenure of office as Rector of Imperial College so successful and memorable. Indeed it was during his wise administration of its affairs that the College took an important leap forward, and its present status owes much to the seeds that he sowed.

'Tizard had the great gifts of being able to talk on seemingly equal terms to people of all kinds and ages, and to find out what they thought about things. The views of professors, of students—and of office messengers—on matters relating to their jobs (or on other topics) appeared to be of absorbing interest to him. He regarded each as an individual worthy of his attention, and he had a happy knack of throwing out the challenging remark that would stimulate response. It is not surprising therefore that he kept his finger so effectively on the pulse of the organization.

'Though a firm disciplinarian when occasion warranted, he found it difficult to keep the twinkle out of his eye when the case had been settled. This does not mean that he suffered fools gladly: far from it, but he was still

* I owe this to Sir Basil Schonland, F.R.S.

† I can hear him now, on one of his infrequent visits to Farnborough in 1941-1946, when I was the Director of the Royal Aircraft Establishment—'Places like this are far too big. Not more than 500, all told, including the cleaners—if you want to do any research.'

less well disposed towards the pretentious and those who sought to claim unjustified privilege. For himself he claimed nothing more than the bare necessities for carrying out his duties, and at one time during the war was horrified to discover that an official car was being kept continuously at his disposal; thereafter, for ordinary journeys he used a 'bus, and hoped that the chauffeur would be given more useful employment.

'Tizard had a flair for inspiring people with some of his own enthusiasm for getting things done. The encouragement that he gave to younger men in the Services, as well as in academic life, is perhaps his greatest contribution to progress. The fact that he did not always work through the "usual channels" sometimes caused heartburnings in the upper hierarchy, but even this was perhaps a useful stimulus to entrenched authority. In any event, he liked shaking up the complacent and he had no compunction in doing so during the war.

'Mention has already been made of Tizard's originality of mind. He was always throwing off ideas about all sorts of things, and producing in those who picked them up an urge to put them into effect. Even in the darkest days (and nights) of the war, when Tizard carried so many heavy responsibilities, his flow of ideas about the work of the College and its future was uninterrupted. Indeed, even when laid low with one of his occasional bouts of influenza a series of illuminating jottings would appear on a bedside pad. And Tizard's ideas were seldom commonplace. Many were highly unorthodox, or at least had an unusual twist to them; some that turned out to be impracticable he was ready to discard, though with some reluctance if he thought that they were of a kind that it would have been fun to try.

'Faced with alternative courses of action Tizard was usually prepared to make a quick and clear cut decision. It may be that his choice was sometimes influenced by a "hunch", but the workings of his mind were so well integrated that his hunches were often as well based as the carefully thought out conclusions of other men. At any rate most of them worked, and it certainly seemed that he had an innate capacity for seeing things in their true proportions—even through brick walls.'

I have been fortunate to enlist the help of Professor R. V. Jones, C.B., C.B.E., who has written the story of Tizard's work from 1935 to 1952 (which follows). Of this period Professor Jones had intimate personal knowledge owing to his position then in the Air Ministry, on the Air Staff, as Director of Intelligence, and as consultant to the Ministry of Defence.

Tizard's Task in the 'War Years' 1935-1952

By Professor R. V. Jones

After 1933 it became increasingly obvious that the policy of Nazi Germany was likely to lead to war, and that Great Britain would have to defend herself

against the attack of the German Air Force. There had been informed pressure, led by Winston Churchill and F. A. Lindemann, against Baldwin's counsel of despair in 1933 that 'the bomber will always get through'. As a result, a renewed scientific appraisal of the problems of air defence would almost certainly have taken place in one form or another—the national need was far too strong and too widely felt to be ignored.

In the event, two distinct bodies were set up to undertake the appraisal. The first was the Committee for the Scientific Survey of Air Defence, conceived by the Director of Scientific Research of the Air Ministry, H. E. Wimperis, and his scientific Assistant, A. P. Rowe. They advised the Secretary of State for Air to invite Tizard, already well known for his qualities as a stimulating chairman with a long experience of aeronautical technology and test flying, to be chairman of this new committee, which met for the first time on 28 January 1935. The second body to be formed was the Air Defence Research Sub-Committee of the Committee of Imperial Defence. This first met on 10 April 1935; its formation, which was probably directly due to the pressure of Churchill and Lindemann, had taken longer than that of the C.S.S.A.D. Tizard was appointed a member of the C.I.D. Sub-Committee from the start; as it worked out, this body became more concerned with the political and military decisions required to implement the air defence programme of research and development, while the C.S.S.A.D. (the 'Tizard Committee') was concerned particularly with the research itself.

The original independent members of the committee under Tizard were Professor P. M. S. Blackett, F.R.S., and Professor A. V. Hill, F.R.S.; Wimperis was also a member. Lindemann was invited to join the committee, but he delayed accepting, on the advice of Austen Chamberlain; after his position had been clarified in a Parliamentary Debate on 7 June 1935, he accepted the invitation. It is probable that Lindemann could not overcome the suspicion (which appears incidentally to have been unfounded) that the Air Ministry and Tizard had conspired to frustrate his own proposal to place the scientific appraisal directly under the Committee of Imperial Defence. He argued that since the Air Ministry had given Baldwin the notorious advice only a year or so before that the bomber would always get through, it was too committed to take a fresh viewpoint. His membership of the Tizard Committee was therefore thoroughly uneasy, both for himself and for the other members of the Committee, and procedure became so difficult that in July 1936 Blackett and Hill resigned. The Air Ministry thereupon re-formed the Committee without Lindemann, whose behaviour had been unquestionably awkward, although it must be said that his contributions were much more positive than some accounts have made out.

The unhappy quarrel between Lindemann and Tizard cannot be ignored, but it should not be allowed to loom out of perspective. It is not clear whether the air defence controversy was the original cause of the trouble between the two men, or whether the difference had started earlier. Tizard himself

recorded in his unpublished autobiography that he thought that Lindemann had been previously upset by not being appointed to the Aeronautical Research Committee. Here Tizard's usually good memory appears to have been at fault, since the records show that Lindemann was in fact a member of that Committee, and Tizard—in trying to explain to himself the cause of the quarrel—seems to have imagined an explanation contrary to the facts. This may well be evidence of the pain that the quarrel caused him.

Shortly before the Tizard Committee first met, Wimperis had asked R. A. Watson Watt, then Superintendent of the Radio Division of the National Physical Laboratory, to look into the possibility of destroying aircraft by projecting a beam of electromagnetic radiation. Watson Watt replied in a note which dismissed this possibility on energy considerations, but which went on to hint that there might be enough energy reflected from an aircraft, with radio field strengths that could readily be created, to give an echo that could be detected by a radio receiver on the ground. Wimperis told the gist of this note to the Tizard Committee at its first meeting, on 28 January 1935; Watson Watt produced a full memorandum on 12 February, and a practical trial was urgently and successfully made near Daventry on 26 February. This success transformed the prospects of defending Britain from air attack, since it promised to fulfil the first requirement of a defence system, that the course of the attacking aircraft should be known accurately and quickly enough for it to be intercepted.

Radar, or R.D.F. as it was then called, would have come into existence irrespective of the formation of the Tizard Committee: the state of radio technology was ripe, and the need was obvious. Within a short time radar was invented in several different countries. The fact that its operational employment proceeded at its greatest rate in Britain was due in part to the facts that our need and our opportunity for a successful defence system were greater than those of any other country. Having said this, we must also realize that despite the need and opportunity, the development and employment of radar could very easily have gone wrong: the early apparatus was far from reliable and it was to some extent an act of faith to expend comparatively large sums before the system was fully proved. The success of radar appears very obvious in retrospect, in a world now technologically alert, but things looked very differently to an administration to which science and technology were mainly background mysteries. It was a tremendous step from the trial of 1935 to the fully operational system of 1939, and very great credit is due to those who brought about the technical development, persuaded the government to pay, and worked out with the Royal Air Force the way in which a radar-based defence system was to be operated. The men primarily responsible were Watson Watt and his associates at Bawdsey, and Tizard and his colleagues in London.

A new technique such as radar can be successfully employed in operations by an armed service only if the officers of that service understand how to use the new technique, and are prepared, if need be, to remodel their previous

concepts of organization and tactics. There was in the Royal Air Force in 1935 a cadre of officers of exceptional outlook, who were prepared to work with the scientists with the utmost urgency towards the development of the new air defence system. Tizard was fortunate in having on the one side Watson Watt and his colleagues enthusiastically pressing the concept of radar, and on the other a most receptive body of Royal Air Force officers. Tizard's first contribution was to bring the latent possibilities of this situation to reality. As an administrator who was also a man of science and who had been a serving officer, he saw to the full both the need and the scope for co-operation; and he was exceptionally fitted to lead the balanced development of techniques and operational application that would be necessary if Britain was to have a successful air defence system in the shortest possible time.

The nature of Tizard's contribution may be best brought out by the contrast between the British and German approaches to the development of radar. The appropriate technique was invented in Germany within a very few months of its invention in Britain; and in some respects (but not all) German radar equipment was technically superior to the British in 1939. In Germany, however, there was very little of the interplay between the scientists and the serving officers that developed in Britain under Tizard's stimulation, and the German scientists and engineers developed radar equipments that were primarily measuring instruments in which more attention was paid to absolute accuracy than to operational value. These equipments were taken over by the German Services, who seemed to evolve their method of employment almost independently of the scientists who had developed them. Thus, there appears to have been no scientist in Germany who fully understood the needs of the German Air Force, and no officer in that Service who appreciated what science could reasonably be asked to do for it. Radar, with its long range, was regarded by the German Air Force up to 1941 as a means of economizing in visual Observer Corps posts, and the radar stations were grafted on to the Observer Corps organization. In Britain, by contrast, it was realized that the main difficulty in defence against air attack before the invention of radar was the need to fly standing patrols of fighters. By the time visual observer posts had reported the raiders, it would be too late to send up fighters from the ground. Radar, with its longer warning of the approach of the raiders, did give enough time for fighters to be sent up from the ground to intercept them, and for these fighters to be sent to the right region for interception. By removing the dual uncertainties of time and place of attack, radar allowed a great economy in fighters, and this was a much more important economy than that in observer posts.

Air defence thinking was thus much more fundamental in Britain under Tizard than it was in Germany under the officers of the German Air Force. Once radar was seen to be the key to the defence system, it was logical to base the whole system on it. A specially rapid reporting network had to be set

up, so that as little as possible of the valuable warning time should be lost; and radio communications with the fighters in the air had to be brought up to a new standard. Moreover, the technique of interception based upon radar plots had to be worked out. This provided one of the best examples of Tizard's foresight and stimulation.

In 1936, before the radar defence chain existed, Tizard persuaded the Royal Air Force to assume that the chain was in being, and that it would provide the appropriate plots of a raiding aircraft. The situation could be simulated by flying an aircraft along a predetermined raiding course, and feeding its 'plots' to the defence system. It could then be evaluated by practical trials whether the data were sufficient to permit successful interception, and whether one interception technique was more suitable than another. The trials were conducted in 1936 from Biggin Hill, and the serving officers involved still retain warm memories of Tizard's personal impact while the interceptions were being carried out. He would talk to anyone, civilian or serving officer, of whatever rank, if he could thereby gain contact with first-hand experience, or find a new suggestion for solving a problem. As a result of the trials, Britain had not only the radar equipment on which to base her air defence system in 1939; she also had the whole system, manned by a body of men who knew how to use it.

The interplay between science and the services, which Tizard so stimulated and fostered, was vital to the survival of Britain in 1940. It would often happen that the serving officer would express a requirement that could not be met exactly by the scientist. In Britain, the latter was able—by virtue of the co-operation that had developed—to point out that if the serving officer could modify his requirements, an apparatus might be produced which would serve the purpose. Moreover, the scientist might conceive of an apparatus for which the serving officer had previously felt no need, but which could offer a completely new possibility in warfare. Many ideas were, of course, tried and failed; but the prospects of a fair trial were better under Tizard than they had ever been before, and the successful exploitation of such ideas as radar in its many forms, and also the jet engine, is evidence enough of his leadership and judgement.

In 1937 the Committee for the Scientific Survey of Air Offence was formed along the same lines as its Defence counterpart, again with Tizard as Chairman. Tizard himself recorded that, in comparison with the C.S.S.A.D., 'it did not meet with such an enthusiastic welcome from the Air Force. As a result its influence before the war was small.' As already mentioned, at this time Tizard must have been almost fully occupied with his Chairmanship of the C.S.S.A.D. and the A.R.C., and with the Rectorship of Imperial College. He had insufficient effort left over to reorientate the minds of those officers responsible for offensive operations; this was a more difficult task than the defensive one had been, partly because offensive thinking was repugnant to the country as a whole, and partly because the Royal Air Force did not realize its navigational shortcomings, which showed up only after a year of

war experience. If Tizard had been free of all other commitments, he might have been able to stimulate the scientific development of air offence almost as much as he had done for defence; but the comparison shows that even Tizard could be effective only when an armed service was prepared to face its own weakness.

If much of this Memoir has been concerned with the co-operation fostered by Tizard, it is because this was the greatest lesson to be learnt from his example, and he would have welcomed this opportunity of underlining it. In his own words:

'The first time, I believe, that scientists were ever called in to study the needs of the Service as distinct from their wants, was in 1935, and then only as a last resort. The Air Staff were convinced of the inadequacy of existing methods and equipment to defeat air attack on Great Britain, and a committee was established for the scientific survey of air defence. I want to emphasize that this committee, although it consisted on paper only of scientists, was in fact from the first a committee of scientists and serving officers, working together . . .

'When I went to Washington in 1940 I found that radar had been independently invented in America about the same time as it had been invented in England. We were, however, a very long way ahead in its practical applications to war. The reason for this was that scientists and serving officers had combined before the War to study its tactical uses. This is the great lesson of the last war.'

While the fostering of radar in its many forms and applications was the outstanding contribution of the Tizard Committee, the Committee initiated several other developments in the British defence system. Operational research grew out of the partnership with the Royal Air Force over radar, and afterwards spread to the application of scientific method to all forms of military activity. Discussions in the Committee also revealed how little was known about the German applications of science and technology to warfare. Tizard thereupon persuaded the intelligence organization, a naturally secretive body, to accept a scientist to work with it. This was the start of scientific intelligence, which was afterwards taken up by other major powers: and if scientific intelligence played a useful part in 1940 and later, the credit for its primary stimulation is Tizard's.

The Tizard Committee had been strengthened in 1936 by the addition of Professor E. V. Appleton, F.R.S., to its membership, and in 1939 of T. R. Merton, F.R.S. In May 1939, uranium oxide was discussed in connexion with the possibility of making a nuclear bomb, and Tizard tried semi-officially to obtain for the British Government an option on each ton of ore extracted from the Shinkolobwe mine in Katanga. While Tizard seems never to have believed that a nuclear bomb would have any serious influence on the 1939-1945 war (and even in early 1945 he could hardly believe that such a bomb would ever be feasible) he gave good support to the

early evaluation of its possibilities. This was characteristic of his approach: he was prepared to look at any suggestion, and to keep his mind open until proof or disproof was forthcoming. With infra-red detection, for example, despite his initial doubts of its success, he had recommended in 1937, 'that the experiments now being conducted at Oxford on infra-red radiation should continue in the hope that they will have an application to air defence other than the detection of aircraft from the air'. Since these experiments were taking place in Lindemann's laboratory, the recommendation speaks for Tizard's open-minded approach.

The return of Winston Churchill to the Admiralty in 1939, bringing with him Lindemann as his adviser on scientific and economic matters, foreshadowed difficulties for Tizard and his Committee. Tizard himself accepted an appointment as Scientific Adviser to the Chief of Air Staff, and friends tried to close the breach between him and Lindemann. Tizard was anxious for a rapprochement, and Brigadier Charles Lindemann actually persuaded the two men to shake hands in the Athenaeum. But Lindemann could not forget his earlier suspicions, and Tizard found his position in Whitehall increasingly difficult after Churchill became Prime Minister.

Tizard contemplated resignation in June 1940, but this step was allayed by developments in Washington. Some time before, Tizard had suggested that scientific co-operation with the United States should be fostered by attaching a scientific adviser to the British Ambassador in Washington, Lord Lothian; the latter had already suggested to the British Government that an interchange of scientific information and service experience should take place between the two countries. A. V. Hill therefore went out as an Attaché to Washington in May 1940 but, finding that he had an insufficient mandate to release information, he came back to London to press for stronger action. As a result, Tizard was asked to head a mission; Tizard wrote his own terms of reference, which were approved by the Prime Minister:

'To tell them what they want to know, to give all assistance I can on behalf of the British Government to enable the armed forces of the U.S.A. to reach the highest level of technical efficiency.'

Other members of the Mission included J. D. Cockcroft, F.R.S., and R. H. Fowler, F.R.S. They carried with them many technical secrets, including the 10 cm magnetron and the proximity fuse. They also carried, perhaps without specifically realizing it, the great secret of co-operation between science and the services. The impact in September 1940 of the Tizard Mission on military and scientific thinking in the United States was immense. The revelation of so many secrets without guarantee of an adequate return was an act of balanced courage, in which Tizard's judgement must have been a predominant factor. Thereafter there remained, except perhaps in the field of nuclear energy, an exemplary co-operation between the two countries on scientific matters throughout the war.

Tizard told a story of one experience on this Mission, concerning two of

the many inventors who besieged him with suggestions to help Britain to win the war. These two inventors claimed that they had an aircraft that carried a lethal ray which could destroy a town, and they were prepared to sell the secret to Britain for one million pounds. Tizard asked them if they could immediately provide a demonstration on a not-too-difficult target, say Brest. They replied that they could not do so, since they kept the aircraft hidden in Alaska for security. Finally, they agreed that the destruction of Brest should be possible in a week's time, but only if Tizard would first provide a million pounds. Tizard thereupon wrote on Embassy paper, 'In the event of Messrs. A. and B. destroying Brest within ten days, the British Government undertakes to pay them one million pounds free of tax.' The inventors were not seen again, but there was some disquiet at the Embassy because Treasury sanction had not been obtained in advance.

Tizard returned to London early in October 1940, but he played a decreasing part in operational matters. He moved to the Ministry of Aircraft Production towards the end of 1940, and became responsible for research and development there. When this Ministry was reorganized in July 1941, he held a roving commission in regard to scientific research, and represented the M.A.P. as a member of the Air Council. Here he found, as is not uncommon even at the highest level, that much of the time was spent on minor administrative matters; he related that at one meeting of the Council the main business was to inspect competing designs for W.A.A.F. underwear. One development inspired by him was the sending of a mission to North Africa under the leadership of S. Zuckermann (later Sir Solly Zuckermann, F.R.S.) to assess the results achieved by British weapons. In this period Tizard fulfilled the functions of an 'Inspector General' for science, in a manner very similar to that sometimes carried out by retired Commanders-in-Chief. The Chief of Air Staff would call on him to undertake a specific investigation—for example, into the merits of unifying all the scientists in the Air Ministry under a single control, or into the measures to be taken to offset the premature loss of our radio-navigational equipment to the Germans.

In general, Tizard's advice was sought, respected and acted upon by the Air Staff much as Smuts's was by the War Cabinet. His tasks were not, however, enough to satisfy him, particularly when his advice on major issues was likely to be outweighed by that of Lindemann. A controversy regarding bombing effort sprang up between them early in 1942. The importance of this particular controversy can easily be exaggerated; it was not simply a matter of Lindemann wanting sadistically to bomb German towns, and Tizard opposing it on humane grounds, with Lindemann losing the scientific argument but winning the political battle and thereby determining Cabinet policy. Tizard did not, he wrote, fundamentally disagree with the bombing policy, but he thought that it could not be carried out effectively with the forces likely to be at the disposal of the Royal Air Force; and he was very concerned that in concentrating the bombing effort against towns, we should

fail to use sufficient aircraft against enemy ships of war, and that we should thus lose command of the seas. Tizard's view appears in retrospect to have been more balanced than Lindemann's, but it would be wrong to assume that either view was a decisive factor by itself in the bombing policy. The issue, which was basically between offensive and defensive uses of bombing resources, was fought out between many protagonists, political, military and scientific. Lindemann and Tizard could both express their arguments unusually well, and could give quantitative weight to some of the factors; these qualities brought them to the opposing forefronts of the controversy. This is not the place to argue out the full merits of the two sides; it is sufficient to record that as far as Tizard was concerned, his judgement was sound, and that any impatience that he may have felt regarding the neglect of his advice is understandable.

Shortly after this dispute, Tizard left his M.A.P. appointment to become President of Magdalen. There is some evidence that Lindemann (by that time Lord Cherwell) aided him in the election. The four years for which he held the Presidency (1942-1946) were, of course, quite abnormal ones for the College. He initiated several administrative reforms, including a re-organization of the Bursary, a revision of the relations between the College and its Schools at Brackley and at Oxford, and an expansion in the number of undergraduates. He was brilliant in his concepts of what the College should be but, having held posts of great authority, he found it rather difficult to pilot controversial business through a highly democratic body of Fellows. A colleague has noted that he would drop his own ideas at any sign of opposition; this same quality had at times been evident in his defence work.

Tizard continued to be called in on various matters of official business. He went to Australia in 1943 to advise the Australian Government over a wide range of military and civil scientific research organization. Early in 1945, he was Chairman of a Chiefs of Staff Committee on the future of Weapons, and in 1946 he was re-called to full-time Government service, there being now no obstacle since Cherwell had returned to Oxford in 1945.

As science had come to play an increasing part in the war, it had needed a forum in which all the scientific effort could be co-ordinated. At first this was effected by the Deputy Chiefs of Staff Committee, which was attended by these officers and by senior scientists associated with the Service Ministries. Early in 1945 a committee was formed under Cherwell's chairmanship to take over the scientific functions hitherto carried out by the Deputy Chiefs of Staff Committee, but Cherwell ceased to be Chairman after the General Election of that year. In the reorganization that followed the separation of the Ministry of Defence from the Premiership, the successor to Cherwell's committee was the Defence Research Policy Committee. At the same time, a roughly parallel committee for civil aspects of science, the Advisory Council on Scientific Policy, was set up by the Government. Tizard was invited to the Ministry of Defence, and to become Chairman of both the D.R.P.C. and the A.C.S.P.

Tizard was easily the best man for the new post, which he had to steer through a peculiarly difficult time. The Ministry of Defence was uncertain of its philosophy and of its position with respect to the three Services. The whole defence system was re-orientating itself towards the new technological situation created by such developments as nuclear energy and rockets, with Britain having to accept a more subdued part in the world's affairs and carrying through a social upheaval at home, in the face of a series of crises typified by the Berlin blockade. This was a far more complex situation than anything that had had to be faced before or during World War II, and without the ready test that war provides of whether a particular decision is right or wrong. It is therefore not easy to assess even now, after a lapse of ten years, the success either of a policy, or of an individual's personal decisions.

One handicap that Tizard faced was that the D.R.P.C. was not allowed to concern itself with the development of nuclear weapons. This restriction, which persisted for some years after the first Russian nuclear explosion had been reported, was a discouragement to conspective thinking about national defence. The dichotomy between 'nuclear' and 'non-nuclear' aspects of defence led to much frustration of the latter because of the abnormal priority and secrecy given to the former. Tizard may well have found his position unsatisfactory on this account.

Tizard gave the D.R.P.C. the best possible start in these difficult circumstances. His prestige with the services was immense, he was a skilful chairman, and he was a good judge of men. He was particularly well matched to the task of presiding over the periodic meetings of the Commonwealth Advisory Committee on Defence Science, and he much enjoyed the social contacts which these meetings afforded with scientists and serving officers from all over the Commonwealth. The organization of the D.R.P.C. has survived substantially in the form in which he left it on retirement in 1952, and the co-operation that he so effectively fostered between science and the armed services remains as an inspiring example.

His main achievements as Chairman of the A.C.S.P. were to convince the Government of the value of the advice that the Council could provide, and to overcome the suspicion with which the Council was at first viewed by some Government Departments and Research Councils. He insisted on science taking its proper place in Government Departments, and he developed a policy, which is still accepted, regarding the relations between the scientific work of the Departments and that of the Research Councils. In other hands, the A.C.S.P. might well have foundered; in Tizard's it became a workable entity occupying an important place in Government.

He retired from the Advisory Council on Scientific Policy in 1952, having given in the six years of his chairmanship increasing attention to the organization and application of science in peace. While at the Ministry of Defence he undertook several major visits to Commonwealth countries and the United States, and his visits were as much concerned with the broader aspects of science as they were with defence. He had had much to do with these

aspects in his work at the D.S.I.R., and he evidently felt them particularly attractive and rewarding in the post-war years.

Tizard's outstanding service to Britain and to the Dominions was recognized by his advancement in 1937 to K.C.B. and in 1949 to G.C.B. From the United States, where his fame was as high as in his own country, he received in 1947 the Medal for Merit.

During the period 1933 to 1956 Honorary Degrees were conferred on him by a number of Universities, he was elected to Honorary Fellowships of Colleges in Oxford and in London, and received the Gold Medals of three Societies.

[*End of Professor R. V. Jones's Contribution*]

As Foreign Secretary of the Royal Society from 1940 to 1945, Tizard was one of the closely knit group of Officers who guided and administered the policy of the Society through the war years. With Sir Henry Dale, Sir Thomas Merton, A. V. Hill and Sir Alfred Egerton in those days when meetings were at a minimum, decisions and action had to be taken rapidly and firmly, and frequently one or other of the Officers was abroad on a special mission, the functions of a Foreign Secretary were less called upon and duties were apt to be interchanged. Nevertheless in the field of foreign relations the exchange of information on scientific and technical problems primarily arising out of the war brought to London scientific representatives from the various Dominions as well as from the United States and allied countries with whom the international connexions of the Royal Society were maintained and strengthened. Under Tizard's chairmanship the International Relations Committee in 1943 considered the whole question of the post-war organization of international scientific co-operation with special reference to the future of the international unions and the Society has not looked back on its resolve to give the fullest support to the International Council of Scientific Unions and the federated bodies. During his Foreign Secretaryship the Council set up a Cultural Relations Committee with Tizard as chairman to advise on the development of cultural relations with foreign countries with particular reference to the post-war period of reconstruction and, following recommendations of this committee, visits were later made by Royal Society representatives to the national academies of certain countries then newly liberated from alien occupation, and means were explored for assisting the rehabilitation of science and research. One of the means adopted was the provision of scientific apparatus through the Horace Darwin Fund for research institutions abroad.

In 1945 as a result of representation by the Council to the Secretary of State for Air and the First Lord of the Admiralty that aircraft could be profitably used to promote general scientific research after the war, a new joint committee, called the Advisory Committee on Airborne Research Facilities was set up 'to consider proposals for the use of naval and R.A.F. aircraft and facilities for assisting scientific research and to make

recommendations to the Council of the Royal Society, the Lords Commissioners of the Admiralty and the Air Council'. It consisted of representatives nominated by the Council, the Admiralty, the Air Ministry and the Ministry of Aircraft Production, with Tizard as its first chairman. This committee did useful work and continued until its functions were merged with those of the present Defence Services Research Facilities Committee.

In March 1952 Tizard retired finally from the public service. From letters which he wrote to Professor A. V. Hill, F.R.S., it is clear that he was burdened by what he describes as 'my perennial attacks of fever—a curse in my life.' These did not deter him from visiting Pakistan and India in this year, as a representative of the British Association, in company with Professor Hill. On his return, he developed a heavy cold which gave him great trouble and he began 'to think that I am a broken down old gent, mentally and physically'. Characteristically, the same letter goes on to say 'I am now busy writing a Messel Lecture for the Society of Chemical Industry.' In August 1952 he said: 'Three half-fainting fits recently have convinced me that I have been stretched beyond the elastic limit in recent years. I have been trying to hide this from myself but can do so no longer. The doctor says, however, that I should be a reasonable member of society after a rest.'

He took a rest, and was soon active again. He became a Director of several chemical companies: Glaxo Laboratories, Albright & Wilson, Blair Knox, Marchon Products and Solway Chemicals. The income from these relieved some of the anxiety about money from which he was seldom free.

He visited Canada in September 1954 as guest of the Defence Research Board and again in 1956 as guest of the National Research Council. His last voyage abroad was to the U.S.A. in 1957, when he attended the 50th Anniversary of the Founding of the State of Oklahoma.

The bibliography which concludes this memoir gives the dates and titles not only of papers describing Tizard's research work, but also of a number of papers of a different kind, which in his case give a far better impression of the man and his work. From one or two, comparatively long extracts have already been given. There is not space to do justice to the content of all his published lectures and addresses, but all may be read with advantage, and with pleasure. In 'Science and democracy' (1951) he took the opportunity provided by an American audience to let his mind run free over an imaginary future, when a world-Government was striving, without much success, to remedy some of the weaknesses of the world as we know it. He asks:

'Why are we scientists and technologists so anxious about the social implications of our work? There are two main reasons. The first is the haunting, but perhaps unjustified fear that, if ever war comes again on a large scale, the misapplications of the powers of science will be so frightful as altogether to destroy civilization as we know it. The second is that while the application of scientific knowledge has brought such great benefits to mankind, it has not brought a fraction of what, in our opinion, should have been possible.'

His Messel Memorial Lecture before the Society of Chemical Industry in 1952, 'The strategy of science', contains the most valuable and provocative of his surveys of the place of science in the nation's life. He concludes that:

'. . . the springs of enterprise are running down, and unless industry is able and allowed to increase its capital expenditure, and does it wisely, it is idle for scientists to complain that their discoveries are exploited elsewhere. At present the responsibility for deciding whether any branch of industry shall spend anything on new ventures rests largely with civil servants in government departments. How can they exercise it properly? It is not their fault; it is their misfortune.'

and that:

'. . . just as success in pure science rests in the choice of the right problem to attack, so does success in industrial adventure. When money resources are limited it becomes all the more necessary to concentrate the scientific resources. Strategy is all important.'

Finally, he agrees with Benjamin Franklin's confession:

'For having lived long, I have experienced many instances of being obliged by better information or fuller consideration to change my opinion even on important subjects, which I once thought right but found to be otherwise. It is therefore that the older I grow the more apt I am to doubt my own judgment, and to pay more respect to the judgment of others.'

Nevertheless, he holds to certain convictions:

'It is more important now to strengthen our technology than to expand our science; more important to do things than to write about how they might be done. Science is not enough. We haven't any money, so we've got to think.'

The last in this category, 'A scientist in and out of the Civil Service', the Haldane Memorial Lecture delivered at Birkbeck College in 1955, is in the nature of a pocket autobiography. It suggests an answer to the question —Why did Tizard leave the D.S.I.R. in 1929 for the Imperial College? He was convinced that neither research under the D.S.I.R. nor research in industry could produce results justifying the expenditure unless we could ensure a large increase in the right kind of men, technologists as well as men of science. He spoke eloquently on the need to ensure that research workers in both fields should live and work cheek by jowl with those in whose interests they were working.

In the last few years of his life (1955 to 1959) he occupied himself with trying to get his papers in order, and with completing the 'personal record' for the Society, which he signed in May 1959. This record can fairly be described as faultless both in length and in choice of material. It is significant that he made no mention of Lindemann, except the bare facts, related above by Professor R. V. Jones, associated with the C.S.S.A.D. in 1935/1936.

It concludes with two short paragraphs addressed:

'To the writer of my Obituary Notice'

'I am sorry for you: but still you have these notes to help you. I had nothing of the kind to help me when I was engaged on the laborious task of writing the obituaries for which I was responsible. I even had to consult Parish registers to make certain of some dates!

'I am now engaged in writing the story of my life for the private information of my family. It has not got very far yet: but if it gets finished before my death, you will be able to get more details, if you need them, from my son, Dr J. P. M. Tizard.'

The story, which is rather a collection of memories of the first half of a long life than a serious autobiography, covered only the years to about 1927, though in places it contained references to later events. It adds little to the 'personal record' concerning the events that made up his scientific and professional life, but it brings into relief the years up to 1904. When Tizard went to Westminster in 1900 his inborn talent for mathematics left him with time to feel the influence of the arts at a school which was predominantly classical. When he was in the Modern Sixth, he challenged the Headmaster: 'Why are we taught no English on the modern side?' A chosen few were sent to John Sargeaunt—to whom he was ever after grateful for informing and encouraging his love of his own language and its literature.

And 'Westminster was a splendid school for boys of sensibility.' Near-by, in the Abbey and the Houses of Parliament, he watched the pageant of history. Queen Victoria's funeral passed: Edward VII was crowned: from the Strangers' Gallery the privileged King's Scholar observed the workings of the machinery of democracy. No wonder the magic of Oxford had its way with him— 'the beauty of the place, particularly Magdalen, sunk into me'. It is in keeping with his genius for surprising us that all his life he was a strong advocate, not of courses in arts for men of science—but of courses in science for men of the arts and the humanities.

He delivered the Rutherford Memorial Lecture before the Chemical Society on 29 March 1939, certainly the most quotable of all his addresses. But it was of words he had used of Sir William McCormick that I thought, at the Memorial Service in King Henry VII's Chapel in Westminster Abbey on 19 November 1959:

'His work for science was done before he died, as well and as thoroughly as any man's work was ever done.'

Tizard died of a cerebral haemorrhage, after an illness which lasted only a few hours, at his home 'Keston', Hill Head, Fareham, on 9 October 1959.

I have already mentioned on p. 331 my indebtedness to Professor R. V. Jones for his help in dealing with what is possibly the most significant part of Tizard's life. I wish particularly to acknowledge his help in many

discussions we have had about points where information was conflicting or even lacking.

Professor Jones wishes to acknowledge the generous help he has received from those whose names follow:

Sir Edward Appleton, F.R.S.
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Mr R. W. Gandy
Dr J. H. E. Griffiths, O.B.E.
Mr L. A. Jackets, M.B.E.
Sir Ben Lockspeiser, F.R.S.
Sir Thomas Merton, F.R.S.
Air Chief Marshal Sir George Mills
Sir Harold Roxbee Cox
Dr A. P. Rowe, C.B.E.
Lord Tedder, G.C.B.
Sir Alexander Todd, F.R.S.
Sir Robert Watson-Watt, F.R.S.
Mr A. J. D. Woods, C.B.E.

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I have to thank also all those mentioned below who have generously given me their help in the form either of letters or discussions, or both. Without these I should not have been able to write what I have throughout attempted, a story of Tizard's life which would do justice, within the space at my disposal, to the man and his work for science and for his country.

I am specially grateful to Sir Harold Hartley, G.C.V.O., F.R.S., not only for giving me freely of his own memories of Tizard over 55 years, but also for allowing me to see and to quote from letters from some of his friends who were also friends and colleagues of Tizard, namely:

Sir Harry Ricardo, F.R.S.
Mr R. E. Threlfall
Sir Patrick Linstead, F.R.S.
Mr G. C. Lowry
Dr H. J. T. Ellingham
Mr G. R. D. Hogg
Dr R. S. Hutton
Dr L. E. Sutton, F.R.S.
Dr D. G. James

To Professor P. M. S. Blackett, F.R.S., I must express my acknowledgement of the help I have derived from his Tizard Memorial Lecture before the Institute of Strategic Studies, 11 February 1960 'Tizard and the science of war' (*Nature, Lond.* **185,** 647, 1960).

Professor A. V. Hill, C.H., F.R.S., kindly lent me certain letters which passed between him and Tizard, which threw much light on the last years of Tizard's life.

I am indebted to Dr D. C. Martin and Miss Phyllis Boatwright of the Royal Society's staff for the notes on Tizard's work as Foreign Secretary of the Society from 1940 to 1945.

Finally, I must thank Dr J. P. M. Tizard and Dr Noble Frankland for allowing me to read and take notes from the unfinished 'Autobiography' upon which Tizard was engaged until well into 1959.

W. S. Farren.

Public Honours

Air Force Cross, 1918
Companion of the Bath, 1927
Knight Commander of the Bath, 1937
Knight Grand Cross of the Bath, 1949
Medal of Merit, U.S.A., 1947

Honorary Degrees

D.C.L. Durham University, 1943
Ll.D. Queensland University, 1943
D.Sc. Leeds University, 1945
Sc.D. Cambridge University, 1946
Ll.D. Edinburgh University, 1946
Ll.D. Sheffield University, 1948
D.Sc. Belfast University, 1949
D.Sc. Reading University, 1951
D.Sc. Manchester University, 1952
D.Sc. University of London, 1956

Honorary Fellowships

Oriel College, Oxford, 1933
Imperial College, London, 1942
Magdalen College, Oxford, 1947
University College, London, 1954

Medals and Awards

Gold Medal of Royal Society of Arts, 1944
Gold Medal of Franklin Institute, 1946
Messel Gold Medal of Soc. Chem. Ind., 1952

Membership of British Scientific Societies

Member of Chemical Society, 1909

Member of British Association, 1911
President of Section 1, 1934
President of Association, 1948

Fellow of Royal Society, 1926
Member of Council, 1933/1934 and 1940/1941
Foreign Secretary, 1940/1945
Vice President, 1940/1941 and 1944/1945

Fellow of Royal Aeronautical Society, 1917
Hon. Fellow, 1951
Chairman, 1924

Member of Faraday Society 1919
Life Member from 1953

Fellow of the Royal Society of Arts, 1929
Vice President, 1929/1932

Founder Fellow, Institute of Physics, 1920

Hon. Fellow, Royal Institute of Chemistry, 1952

Hon. Membership of Institute of Chemists, India, 1938
Hon. Fellow of Australian Institute of Mining and Metallurgy, 1948
Hon. Member of Institution of Mining and Metallurgy, 1951
Hon. Member of Pakistan Assoc. for Advancement of Science.

Foreign Societies

Fellow of Institute of the Aeronautical Sciences, U.S.A., 1932
Foreign Honorary Fellow, 1950
Foreign Member of Deutsche Luftfahrt Forschung, 1937
Hon. Member of Franklin Institute, U.S.A., 1946

Other distinctions

Elected Member of Athenaeum Club, under Rule 2, 1930
President of Science Masters Association, 1934
President of Fourth Empire Mining and Metallurgical Congress, 1949
Trustee of the British Museum, 1937/1959
Pro-Chancellor, Southampton University, 1952
Prime Warden of the Goldsmiths Company, 1955/1956

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1910. Mechanism of tautomeric change. *Proc. Chem. Soc.* **26,** 125.
1910. (With N. V. Sidgwick.) The colour and ionization of cupric salts. *Trans. Chem. Soc.* **97,** 957.
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1912. (With R. T. Lattey.) The velocities of ions in dried gases. *Proc. Roy. Soc.* A, **86,** 349.
1912. (With J. S. Townsend.) Effect of a magnetic force on the motion of negative ions in gas. *Proc. Roy. Soc.* A, **87,** 337.
1913. (With J. S. Townsend.) The motion of electrons in gases. *Proc. Roy. Soc.* A, **88,** 33.
1917. Methods of measuring aircraft performances. *Aeronautical Society's Reprints*, No. 2.
1920. (With J. R. H. Whiston.) The effect of a change in temperature on the colour changes of methyl orange, etc. *Trans. Chem. Soc.* **117,** 150.
1921. (With A. R. Roeree.) The volumetric estimation of mixtures of acids and of bases, etc. *Trans. Chem. Soc.* **119,** 132.
1921. (With A. G. Marshall.) The determination of aromatic hydrocarbons in mixtures of hydrocarbons. *J. Soc. Chem. Ind.* **40,** 20T.
1921. The causes of detonation in internal combustion engines. *Proc. N.E. Coast Inst. of Engrs Shipbuilders.* May.
1922. (With A. G. Marshall.) Method for the determination of the vapour pressure of hydrocarbon fuels and the estimation of dissolved air. *J. Instn Petroleum Tech.* **8,** 217-223.
1922. (With D. R. Pye.) Experiments on the ignition of gases for sudden compression. *Phil. Mag.* **44,** 79.
1924. (With D. R. Pye.) The character of various fuels for internal combustion engines. *Auto. Engr*, **11,** 55, 98, 134: also printed in the *Report of the Empire Fuels Committee.*
1924. Fuel economy in flight. *J. Roy. Aero. Soc.* **28,** 604.

1926. (With D. R. Pye.) Ignition of gases by sudden compression. *Phil. Mag.* **1,** 1094
1926. Explosions in petrol engines. *Trans. Faraday Soc.* **22,** 352.
1927. (With R. W. Fenning.) The dissociation of carbon dioxide at high temperatures. *Proc. Roy. Soc.* A, **115,** 318.

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1911. Revised and largely retranslated 6th German edition of Nernst's *Theoretical chemistry*, for third English edition, pubd. by Macmillans.
1938. Co-Editor: *Science of Petroleum*, O.U.P.

Special Lectures

1929. The Mather Lecture: Science and the new industrial revolution. *J. Textile Inst.* **4.**
1932. First Hinchley Memorial Lecture: Chemical engineering and the aircraft industry. *Trans. Inst. of Chem. Engrg*, **10,** 87.
1934. Presidential Address to the Science Masters Association: Science and the industrial depression. *School. Sci. Rev.*, No. 59. p. 257.
1934. Presidential Address to Section L. of British Association: Science in the universities. *B.A. Reports.*
1938. First Perin Memorial Lecture: Industrial research, present and future. Publ. by the Tata Iron and Steel Co. January.
1939. Rutherford Memorial Lecture to the Chemical Society. Delivered 29 March, Publ. *J. Chem. Soc.* October 1946.
1948. Presidential Address to the British Association: The passing world.
1951. Arthur Dehon Little Memorial Lecture at Mass. Inst. Technology: Science and democracy. Publ. by M.I.T.
1952. Messel Memorial Lecture: The strategy of science. *Chem.* & *Ind.*, p. 788.
1955. Haldane Memorial Lecture: A scientist in and out of the Civil Service. Birkbeck College.

Other (selected) Addresses

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1931. The British fuel problem: future possibilities. *Chemistry at the Centenary Meeting, Brit. Assoc.*
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