FIRST BLACKETT MEMORIAL LECTURE—1976

PATRICK BLACKETT—AN APPRECIATION

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(Delivered 3 May 1976)

Blackett was a brilliant scientist and a brilliant intellectual, a combination of qualities by no means usual. As an intellectual he was an exponent of logical analytical thought. He enjoyed applying his great talents to the analysis of problems of all kinds and was exceptionally skilful in doing so. With most intellectuals there is a danger that they get carried away by the elegance of the arguments which they are able to deploy so they tend to forget that *any* deductive analysis depends on the basic premises from which the argument starts. Blackett was protected against this because he was at the same time an experimental scientist, the whole basis of whose work depends on checking, by experiment and observation, either directly or indirectly, the validity of the basic assumptions made in any research study. In fact, he possessed at the same time the rare combination of great manual skill and mental power. It is not surprising, as we shall see, that his achievements were quite outstanding in a number of quite different fields, in experimental physics, in military strategy and tactics and in the problems of developing countries.

Great as are his individual contributions in these areas, this is by no means all. Blackett was a great organizer. He built up major schools of research at Manchester University and at Imperial College, London. He was much concerned with higher education and was a devoted University teacher.

All his work was characterized by its high distinction. At all times he was content only with the very best. He was not given much to small talk but this doesn't mean he was taciturn. There was much he could, and did, say which was significant and interesting. He was always stimulating and could illuminate the dullest subject with a flash of insight. Naturally he was a very good company.

In appearance he was handsome and possessed an air of distinction. He was always approachable and one of his most endearing qualities was his boyish enthusiasm for any new task which attracted him.

Blackett disliked the conventional and this encouraged him to look deeper into social problems for a better understanding of a complex situation. At no time did he consider himself an establishment figure even when he became President of the Royal Society. Indeed it was a source of some amusement to him to find himself in such a position. Only at a very late stage in his life did he accept any official honours. If it had not been for his reluctance to accept a peerage at the time he would probably have become a Minister in Mr. Wilson's Labour Government in 1964.

He had no time for mindless bureaucracy. Indeed he was unduly harsh at times in his criticism of civil servants. I can well remember his impish grin when relating some of their failings. But he disliked pretentiousness and pomposity at any time.

The many students who worked under Blackett's guidance and supervision had great affection for him although he drove them hard. They acknowledge the inspiration he afforded them as well as the high quality of the intellectual and scientific criticism to which they were exposed. Many of them are in leading positions today.

It should already be clear that Blackett was by no means a cold intellectual. He had great compassion for the underprivileged of this world and often felt frustrated by the difficulty of utilising the power of science and technology to lift from all mankind the bonds of poverty.

A thoroughly human person such as Blackett could not completely free himself from some human failings. Occasionally, but only occasionally, he allowed some degree of prejudice to enter into his analysis of social and political issues. The wonder of it is that this happened so rarely because he tackled such a wide range of problems. He was, in almost every case, prepared to readjust his thinking in the face of evidance.

It would be too much to expect that a deductive analyst with Blackett's genius would also be possessed of strong intuitive powers. While prepared to speculate in science his speculations often proved invalid. On the other hand they stimulated research which led to results of major importance. Moreover as a dedicated scientist he was at pains to seek experimental evidence to check any speculation and when it proved adverse he had no hesitation in rejecting his original suggestion. Furthermore he did appreciate very thoroughly the directions in which scientific research would be most likely to yield results of major importance.

Let us now turn to look at some of his career and achievements in more detail.

Early Years and Background

Blackett was born on 18 November 1897 in Kensington, London. His maternal grandfather served in the British Indian Army and a great uncle was also associated with India as a tea planter. It may well be that Blackett's interest in India owes something to the impressions he gained from these older relatives. On his mother's side there was also a tradition of naval service which influenced the choice of a naval career for Patrick.

At the age of 12 he was interviewed for acceptance as an entrant to Osborne Naval College. His remarkable knowledge and interest in aeroplanes—building model aircraft was one of his hobbies—influenced the interviewing committee who offered him a place at the College which he took up. After two years there he proceeded as was usual to Dartmouth College where he performed very well, being top of his class at the beginning of the First World War.

Instead of some months of peace time training at sea, at the age of 17 Blackett found himself appointed as a Midshipman to H.M.S. "Carnavarvon". He proceeded to Devonport to join his ship but it had already sailed for the South Atlantic and so he joined the ill-fated H.M.S. "Monmouth" which was proceeding to the same destination. If he had stayed aboard he would have gone down with the rest of the ship's crew in the action at Coronel. By good fortune, however, the "Monmouth" met the "Carnavarvon" at the Cape Verde Islands and Blackett was transferred there.

Plate I

Plate II

1st row-sitting —J.A. Ratcliffe, Prof. P. Kapitza, J. Chadwick, Prof. R. Ladenburg, Prof. Sir J.J. Thomson. O.M., Prof. Lord Rutherford. O.M., Prof. C. T. R. Wilson, F. W Aston, C. D. Ellis, P. M. S. Blackett, J. D. Cockroft.

2nd row-standing—P.C. Ho., C. B. O. Mohr, H. S. W. Massey. M. C. E. Oliphant, E. T. S. Walton, C. E. Wynn. Williams, J. R. Roberts, N. Feather, A. O. Davies, K. M. Sporshott, J. P. Gott.

3rd row-standing—W. E. Duncanson, E. Childs, G. T. P. Tarrant, J. McDougall, R. C. Evans, E. S. Shire, E. L. C. White, F. H. Nicoll, R. M. Chandhri, B. V. Bowden, W. B. Lewis

4th row-standing—N. S.Alexander, P. Wright, A. G. Hill, J. D. Paubey, G. Occhiatini, H. Miller

He did see some action at the battle of the Falkland Islands though only to a limited extent as the "Carnavarvon" was little involved.

A little later he was very much involved in the Battle of Jutland. He had been transferred to the battleship "Barham" which suffered considerable damage and casualties. These experiences brought home to him very vividly the horrors of war and undoubtedly influenced his future attitude to political affairs.

During the later stages of the War, Blackett was transferred to antisubmarine duties. This again was an experience which must have influenced his thinking during his work with the Admiralty in the Second World War

Even during these early years in the Navy he had shown a keen interest in technical matters and had been impressed by the crude methods in use for improving the accuracy of gun and torpedo fire. Towards the end of the War, he considered the possibility of joining an instrument firm as an alternative if his first choice of a university career in science could not be realized.

In fact, the Admiralty played into his hands. They introduced a scheme to make up for the education lost by young officers because of the War. This involved a six-month course in Cambridge in general studies. Blackett's first contact with the University was at Magdalene College early in 1919, in naval uniform. Very soon after, he naturally chose to see what the science laboratory, the famous Cavendish Laboratory, was like. In no time at all he decided that this was the place for him. Within three weeks he had resigned from the Navy and become an undergraduate. Obtaining First Class Honours in Part II of the Natural Sciences Tripos in 1921 he was offered a Bye Fellowship at Magdalne College which he accepted. This enabled him to begin his research career at the Cavendish where the influence of Rutherford's arrival was already being felt.

Plate I shows a portrait of the young man taken in 1933. Plate II, taken in the same year, shows him, already with a well-made reputation, among his colleagues in the Laboratory.

Scientific Work

In this lecture, time prevents me from dealing in any comprehensive way with Blackett's scientific researches. Instead, I shall concentrate on his major contributions and activities.

When Blackett joined the Laboratory, Rutherford had already discovered the artificial disintegration of nitrogen by alpha particle bombardment but the nature of the process involved was quite unknown. Rutherford was therefore anxious to obtain Wilson cloud chamber pictures of disintegration events. However, the chance of disintegration per alpha particle was so low that an enormous number of pictures would need to be taken. To make this practicable it was necessary to develop an automatically operating chamber, and so Rutherford assigned to Blackett the task of extending the work already undertaken to this end by Schimizu. This was a fortunate assignment because it enabled Blackett to employ to the full his technical ingenuity and skill. He greatly simplified the design of an automatic chamber and in 1924 his efforts were crowned with success. With a chamber taking 270 photographs per hour on each of which 18 alpha particle tracks were obtained, he took 23,000 photographs in nitrogen containing 20 per cent oxygen. Among these he found eight tracks on which there was clear evidence of a disintegration but with somewhat unexpected features. From the site of the disintegration collision only two tracks emerged, showing that the incident alpha particle was absorbed in the process. One of Blackett's photographs has been reproduced in books and in lectures perhaps more frequently than almost any other concerned with a major experiment.

In 1932 by a happy coincidence the opportunity arose for Blackett to combine his expertise on automatic cloud chambers with the geiger counter technique so as to produce a counter-controlled chamber. This came about through the arrival from Italy of Occhialini who had worked with Rossi on the development of coincidence counting. A counter-controlled chamber was particularly suited to the study of cosmic rays which entered the chamber at random intervals. Much time was therefore saved by ensuring that the chamber was only triggered when a cosmic ray event occurred. Blackett set about the task with his typical enthusiasm and Occhialini remembers the Saturday morning when the integrated system was first operated, photographs were taken and Blackett proceeded to the dark room. He soon emerged shouting with pleasure, "One in each, Beppe, one in each".

This work directed Blackett's interest towards cosmic radiation which indeed became one of his major research activities. At quite an early stage the new counter-controlled system produced exciting results. Operating the chamber in a magnetic field they observed tracks which they showed, by a careful analysis of the data, could only be due to positively charged particles of electronic mass (positrons). This provided detailed confirmation of the earlier observations by Anderson using a chamber with random expansion.

With Chadwick, they observed positrons produced in a lead target by the gamma rays from thorium C″ therefore identifying the source of the previously observed anomalous absorption of gamma rays.

For some time after these initial discoveries Blackett concentrated his research attention on the nature of the cosmic rays. This major change in his research interests happened to coincide with his departure from Cambridge to become Professor of Physics at Birkbeck College in the University of London. He was anxious to build up a research school under his own direction and also felt that the burden of teaching which fell upon him at the Cavendish was becoming so great as seriously to affect his own research work. He lost no time after taking up his new appointment in designing equipment with which the energy spectra of cosmic rays could be determined by use of large magnetic fields. The excellence of his design was matched by his skill in obtaining the resources necessary to build the apparatus which, by the standards of the time, was quite expensive. The observations made with Occhialini suggested that the showers of charged particles produced by cosmic rays in the cloud chamber were mainly composed of pairs of positively and negatively charged electrons. These conclusions were confirmed with the more elaborate equipment at Birkbeck but anomalies were found in the energy spectrum of the cosmic ray particles at an energy of about twice the rest energy of a proton. At that time (up to 1936) it was difficult to understand how the showers of electrons and positrons were produced and Blackett argued that quantum mechanics breaks down at the energies concerned. It is amusing to note that in the course of the debate on this matter, Blackett first met Homi

Bhabha who took the opposite view and, with Heitler, showed how the production of showers was a direct consequence of the quantum theory of radiation. Blackett was prepared to accept this, albeit with some initial reluctance, but still considered that the anomaly in the high energy spectrum was evidence of a failure of the theory. However, he eventually became convinced that an alternative explanation must be sought and, by the end of 1937, accepted the suggestion of Nedermeyer and Anderson that the main consitutents of the penetrating rays at sea level were not electrons but particles with mass intermediate between that of an electron and a proton.

At about this time Blackett had moved to Manchester where he was appointed Langworthy Professor of Physics, succeeding Sir Lawrence Bragg. Within a remarkably short time he had converted the laboratory, which was much more extensive and better equipped than at Birkbeck, from a centre of research in crystallography to one in cosmic rays. Although involved at the time in very subtle arguments about the nature of the rays he nevertheless was able to carry out sweeping changes in the organization, administration and structure of the Department. He took with him much of the equipment and many of his research assistants and colleagues from Birkbeck and before long the Department at Manchester was one of the leading world centres in all aspects of the study of cosmic rays.

Becoming convinced of the existence of the particles of intermediate mass and realising their probable relation to the particles postulated by Yukawa as transmitting the force between nucleons, Blackett concentrated his attention on obtaining evidence about their lifetime. Yukawa has proposed that beta decay proceeds in two stages depending on the decay of the heavy particle first produced into an electron which is observed. With this assumption the lifetime should be about $0\ 5 \times 10^{-6}$s Blackett showed that the decay of the penetrating particles with a lifetime of this order provided an explanation of the temperature effect on cosmic ray absorption in the atmosphere and of the fact that the absorption of cosmic rays depended not only on the mass of material traversed but also on the path length

The onset of the Second World War interrupted his research at this stage. It is interesting to note-however, that Blackett's last publication before the War was a speculation on a possible relation of the lifetime of the heavy particle (which we now know as a meson) to the constant of gravitation. Even at this time his thoughts were turning to wider horizons, to which he was to return soon after the War.

The years of the Second World War naturally brought temporarily to an end the research programme in cosmic rays. Nevertheless, in the first year of the war the seeds of a major post war development were planted. Lovell, who was working on radar defence problems, had observed occasional sporadic echoes which he suggested to Blackett might arise as reflections from ionization produced by cosmic rays. Although detailed analysis made this unlikely, Blackett retained throughout the War the desire to discover the origin of the echoes. This was the motivation for the establishment of Jodrell Bank after the War, leading first to the rapid development of meteor physics and thence to radioastronomy and the giant radiotelescope.

After the War, Blackett did not fully return to personal involvement in cosmic ray research but he retained his interest in the field and inspired a remarkable series of investigations, leading to the discovery of the *V*-particles as they were called at the time. He was also much concerned in the establishment of another large scale research enterprise, the Extensive Air Shower Facilities at Haverah Park, near Harrogate in England.

Before long, Blackett was launched on still another quite different research subject which proved at least as fruitful as his earlier work on nuclear and cosmic ray physics. It all began from a speculation about the origin of magnetism which Blackett found very attractive. I have already referred to his speculation, just before the Second World War, about a possible association between gravitation and particle physics. In the course of some work in which he was investigating the effects of naturally occurring magnetic fields on cosmic rays, Blackett noted that the ratio of the magnetic field to the angular momentum was approximately the same for the earth and the sun, using the currently assumed values for the solar field. It occurred to him that this might be a general feature of rotating matter and he took up this idea with enthusiasm. About the same time Babcock reported the first measurements on the magnetic field of a star, which were consistent with this hypothesis. Encouraged by this, Blackett presented his ideas in a lecture at the Royal Society on 15 May 1947. With great conviction and lucid argument he maintained the interest of a large audience many of whom came unconvinced.

Naturally he was at pains to devise means for experimental tests of the hypothesis by attempting to measure magnetic fields generated by motion of objects of laboratory scale. It was this which opened the way to a new major branch of geophysics, as we shall see. As far as the main hypothesis was concerned, difficulties began to appear quite soon and by 1949 Blackett himself was beginning to have doubts. Nevertheless he continued with the design of a new type of magnetometer of sufficient sensitivity to detect a field of order 10^{-9}G, comparable with that which might arise from the rotation with the earth of a body of mass around 10–20 kg. His ultimate success in developing this instrument was to provide geophysics with a powerful new tool the value of which Blackett was very quick to realize. In a special nonmagnetic hut, known still as "Blackett's Hut", constructed at Jodrell Bank he was able to show that no magnetic field as strong as 10^{-9}G existed in the neighbourhood of a gold cylinder of mass 15 kg thus recording strong evidence against the validity of his original speculation. By this time, however, he had become aware of the possibilities opened up for geophysics if the magnetism of rocks could be measured with instruments considerably more sensitive than hitherto available. The new magnetometer was just such an instrument and Blackett was soon applying it for this purpose. So began a third major phase of his research career. Before describing this, attention must be drawn to the astonishing achievement in instrument design carried out by a man at the age of 50 who had many other preoccupations and responsibilities.

Blackett flung himself into the study of rock magnetism with just the same enthusiasm and energy as in his earlier attack on the problems of cosmic rays. He soon realized from the data obtained quite early on that valuable new information and insight could be gained about the motions of the earth's crust over geological periods of time. Despite his appointment in 1953 to a new and demanding post as Head of the Physics Department at Imperial College, London, he found time for this new activity. As usual he saw the problems on a global basis and organized systematic programmes of measurement in different parts of the earth.

A powerful research group was built up at Imperial College and in 1960 members of this team spent some time at the Tata Institute in Bombay helping to initiate research in rock magnetism in India, a work which proved very fruitful.

The new data on crustal movements gave fresh life to the continental drift hypothesis. From a quite early stage Blackett felt that this hypothesis would prove correct. He took a prominent part in discussions about it and in seeking for other sources of evidence. By 1964 he was convinced and in his last lecture on the subject had the satisfaction of being able to refer to recent evidence that the continental shelf of the east coast of Africa fitted to that of the west coast of South America to an accuracy of better than 50 miles over the entire 4000 miles of coastline. Once again Blackett had made a major fundamental contribution to a branch of physical science. It is typical of a great scientist that he is able to draw from his failure the means for far greater success. Rock magnetism was certainly one of these successes.

Policy in Higher Education and Science

With all his other interests Blackett always played a full part as a University teacher. He was unremitting in the pursuit of excellence and was absolutely convinced of the importance of the association of teaching and research. He realized immediately after the Second World War that it was essential to increase the supply of science graduates. No time was lost in raising by a factor of two or more, the numbers of under graduates specialising in Physics at Manchester. A similar step was taken on his arrival at the Imperial College.

In parallel with the extension of undergraduate schools in science must go the building-up of large and effective research schools. Blackett realized that this meant departing from the current establishment in which there were only one or two professors in even the largest departments. He produced statistical evidence that the professorial complement was far too low and used his powerful influence to create many more professorial posts within the Departments over which he presided, both at Manchester and at the Imperial College. His complete conviction in these matters was of great value to his colleagues in other Colleges in London University, as indeed was his in influence in many other aspects of higher education.

On one occasion when we were examining together a candidate for the D.Sc. and discussing how we should make a judgment Blackett rather typically said that whereas to award a Ph.D. to a candidate who had worked satisfactorily on the subject chosen by his supervisor was almost an obligation, a D.Sc. should only be awarded for real distinction, not measured only by the quantity of the work carried out.

It was always both rewarding and enjoyable to discuss university matters with Blackett as he very rarely failed to have something novel to say. Of building plans for extensions of departments he maintained that one should first work out what was necessary for requirements as present foreseen and then double it. Otherwise as soon as the extension was complete you would again be on the verge of overcrowding.

All were very wise and very true but much easier to implement in the 50's and 60's than in the present times of financial stringency and disenchantment with science and higher education. Blackett was fortunate to take up his post at Imperial College at a time of maximum expansion. The post was made for him and he took full advantage of it. His outstanding ability to carry on many major activities in parallel enabled him to influence strongly the building programme as well as to expand the teaching and research to the full. It is hard to see any way in which his achievement at Imperial College could have been bettered.

Pursuing again his belief in the need to build up large scientific research schools Blackett was a tireless and remarkably effective campaigner for increased resources for science. In the 50's he encouraged the Department of Scientific and Industrial Research to raise the level of support to the Universities for scientific research so high that many predicted that there would be insufficient scientists with promising research projects to use it all. How wrong they were ! British scientists owe a great deal to Blackett for his foresight and pursuasiveness in this matter.

While his personal research interests were in pure science he always encouraged work in applied science and was at pains to devise means both of increasing its scope and effectiveness. This comes out clearly in his work at the Ministry of Technology and elsewhere which we shall return to at a later stage in this lecture.

At all times Blackett was particularly concerned to encourage international collaboration in science. He played a major part in the early days of CERN, the remarkably successful laboratory set up jointly by European nuclear physicists to carry out research in high energy physics.

We shall have more to say later on about Blackett's contributions to policy in higher education and science. Meanwhile we must pass to still another side of his career, his contributions to military tactics and strategy, especially during the Second World War.

Military Tactics and Strategy

Blackett's first major involvement in defence science began with his appointment as a Member of a Committee set up in 1935 by the Air Ministry, under the Chairmanship of Sir Henry Tizard, to consider methods for improving defence against attack by enemy aircraft. This did not prove at first to be a particularly happy experience because of the conflict between Tizard and Lindemann on a number of matters. Blackett and another member resigned at an early stage but the committee was reconstituted some months later without Lindemann and then proceeded to function smoothly until 1939. Its usefulness was greatly reduced when lindemann returned to a powerful position as scientific advisor to the new First Lord of the Admiralty, Winston Churchill.

There is little doubt that Blackett's experiences on the Committee were a factor in the generally critical attitude which he was to take towards Lindemann on many future occasions. In many ways, though, they were incompatible and would have clashed in any case.

Blackett's association with air defence was very natural in view of his childhood interests in aeroplanes. It was equally natural that, when the Tizard Committee ceased to be effective, at the beginning of the War, Blackett should take up duties at the Royal Aircraft Establishment, Farnborough. As a temporary Principal Scientific Officer his work ranged over almost all of the activities of the Establishment but his major personal concern was with the design of a new bomb sight. In this he was able to employ to the full his great skill as an instrument designer. The Mark 14 bomb sight which resulted was used extensively for bomber aircraft both by the British and the Americans.

In August 1940 Blackett became associated with the Anti-Aircraft Command as Scientific Advisor to General Pile. Here the problems were by no means wholly instrumental and we see here the beginnings of the operational research which Blackett was to develop with such success in the later stages of the war. What was often required was advice on the best way of using existing equipment.

The growing seriousness of the submarine attack on the British Merchant Fleet called for the utmost effectivness of Coastal Command aircraft in counter measures. Blackett's group was transferred from the A.A. Command in March 1941 to advise the Commander-in-Chief about operational questions. Blackett insisted on this direct access to those responsible for the actual operations and there is no doubt tht this was an important feature. Substantial gains were made through the advice of the group in which Blackett's analytical skill was clearly manifest.

On of the first of their recommendations which was adopted, was to paint anti–submarine aircraft white instead of black, thereby making them more difficult to to pick up as dark objects against a light sky.

Another, even simpler modification, which was most effective, was to change the setting at which depth charges should be set to explode from 100 feet to 25 feet. At the higher setting, there was a relatively small chance of damaging a submarine when it remained visible so that there was good information about where to drop the charge—the lethal damage radius was only about 20 feet. When the submarine was not visible, there was so little knowledge of its position that little was lost with the smaller setting. On the other hand the chance of damage to a visible submarine was much increased. When the change was introduced, it was so devastating that the German submarine crews believed that a new and more powerful explosive had been introduced !

After nine months with Coastal Command Blackett returned to another of his earlier associations. He joined the Admiralty in January 1942 to set up an operational research group on naval problems. Here again he was at pains to secure that his group must work directly in with those responsible for naval operations and not report through the Director of Scientific Research.

Although formally transferred from Coastal Command, the latter was under the operational control of the Admiralty and the main concern was still anti-submarine warfare. Nevertheless, the scope for Blackett's group was considerably enlarged and it was here that the foundations of the new discipline of operational research were well and truly laid.

Within the Admiralty, Blackett built up a highly enthusiastic and dedicated team, including many brilliant individuals. It was a great reassurance and source of inspiration to those of us battling in provincial establishments to get the right things done in unsympathetic environments and with inadquate resources. An afternoon's visit to the Admiralty to talk with Blackett's men and especially with Blackett himself would bolster one up to further effort.

Perhaps the most important of the many contributions made by the group was concerned with the optimum size of convoys. Blackett noticed evidence that increase in the number of ships in the convoy reduced the risk of loss. This caused him to analyse the situation, taking into account the current German submarine tactics. He was then able to recommend firmly an increase in the number of ships per convoy and persuade the Admiralty to implement it, with very good effect.

This work was the precursor of similar developments in other aspects of military operations and also of the present day discipline of operational research. While ensuring the continuance of this kind of work in the Admiralty and elsewhere Blackett did not involve himself directly in post war operational analysis. Indeed he was critical of those who claimed an accuracy of prediction in operational matters far beyond that justified by the crudity of the input information. Here was the experimental scientist speaking, aware of the pitfalls of thought divorced from experience.

During his period at the Admiralty there was a sharp disagreement between him and the then C-in-C of Coastal Command, Sir John Slessor, about the diversion of bomber aircraft to antisubmarine duties. Blackett circulated a paper, based on analytical arguments, proposing that for decisive success in the antisubmarine campaign 190 heavy bombers should be diverted from Bomber Command. This was hotly contested by Slessor who felt that a pragmatic rather than analytical approach was required. In fact the campaign was won without diversion of so many bombers. Without attempting any judgement it seems likely that there was much to be said on both sides but Blackett was probably encouraged to take an uncompromising line by his strong dislike of the bomber offensive as military strategy.

Here again he found himself on the opposite side to Lindemann (now Lord Cherwell) with whom Blackett and Tizard had been in strong disagreement about the likely effectiveness of an enhanced bomber campaign. It was very difficult to produce convincing arguments on either side and it would be wrong to ignore the subjective factors involved. In retrospect it must be admitted that Blackett and Tizard came nearer to the reality in their estimates but at the time Cherwell's view prevailed. By a curious quirk of fate the consequential rapid development and production of new equipment for bombers led to decisive results in the antisubmarine campaign because of the availability of this equipment for use in Coastal Command aircraft. It is indeed hard to see all the consequences of any particular policy.

Atomic Weapons and Warfare

As a leading nuclear physicist it was natural that Blackett was involved at an early stage in discussions of the possible use of nuclear fission in warfare. In June 1940 a committee was set up within the Ministry of Aircraft Production, under the Chairmanship of Sir George Thomson, known as the Maud Committee. This committee, of which Blackett was a Member, submitted reportsin July 1941 which played a major role in determining the subsequent course of events which led to the development of atomic bombs.

These two reports were remarkably far-seeing and well based except for their prediction of far too short a period required to develop and produce atomic bombs under the prevailing wartime conditions. Blackett alone disagreed and firmly suggested a much more realistic timetable. No doubt his judgment was the better because of his greater experience in wartime activities as compared with those of his committee colleagues who had mainly been concerned with problems of nuclear physics during this period.

Soon after this Blackett became detached from the atomic bomb developments because of his preoccupations with conventional warfare, as recounted earlier.. His judgment on matters relating to the effectiveness of atomic bombs and their influence on global affairs was impaired at first because of this lack of experience of the practical realities which were involved during the later stages of the war—a reversal of the situation which existed at the time of the Maud Committee reports.

Soon after the war ended, Blackett began writing about atomic warfare, taking the line that the existence of atomic bombs did not produce a totally new situation. As late as 1956 he was unconvinced that intercontinental ballistic missiles carrying nuclear warheads were a serious short term possibility although by that time he had realized that nuclear weapons had introduced an entirely new factor into world politics. Thus in a lecture in Cambridge in that year he expressed the following view.

"We should act as if atomic and H-bombs have abolished total war and concentrate our effort on working out how few atomic bombs and their carriers are required to keep it abolished".

Politics and Government

Blackett held strong radical political views. His writings about atomic warfare in the early post-war period were so far to the left of the policy being pursued by the Attlee Labour Government, and especially by the Foreign Secretary (Ernest Bevin) that for some years he was in the political wilderness. However, as early as 1949, Harold Wilson, as President of the Board of Trade, appointed him to the National Research and Development Council (NRDC). Already he had become very interested and concerned about ways and means to improve the performance of British Industry and the NRDC was, in his view, an important step in this direction. In 1950 Blackett joined a group of scientists which met informally to work out an effective policy for science and technology. Gaitskell, as leader of the Labour Party in opposition, attended these meetings at first in person but later was represented by Harold Wilson who continued to attend when he assumed the Party leadership.

Blackett, like many others, considered that the primary problem was to increase substantially the supply of qualified scientists and engineers (QSE's) to work on research and development on industrial problems of applied science. His influence on Labour party policy grew rapidly as his association with Wilson became closer. He was much exercised about the form Government machinery should take in order to infuse British industry with badly needed QSE's.

Eventually, and after many discussions in the group, which now had official standing, Blackett put forward a closely argued document in favour of the establishment of a Ministry of Technology. Wilson, who had in fact suggested that the formation of a new Ministry of this kind was the best way to handle the problems at the Government level, was strongly in support.

The whole election campaign in the autumn of 1964 was fought by the Labour Party with very strong emphasis on technology in industry. After the Labour victory Wilson lost no time in establishing the Ministry of Technology. An advisory Committee on Technology was set up within the Ministry with the Minister as Chairman and Blackett, as Scientific Adviser and Deputy Chairman. Wilson has stated that he would have preferred even closer participation by Blackett as a Minister. To this end he suggested to Blackett that he might go to the House of Lords, thus avoiding the hurly burly of the Commons. However Blackett did not wish to become a peer and carried on from his powerful base in Ministry of Technology.

During this period, I saw a great deal of Blackett in action as in 1965 I had become Chairman of the Council of Scientific Policy within the Department of Education and Science. Blackett was a Member of this Council and we had many discussions together about the many overlapping areas of interest of the two advisory bodies.

It is hard to recall the atmosphere of those first months after the Wilson Government had assumed power. Blackett was at the height of his form, as enthusiastic and vigorous as a school boy, full of ideas and optimism. He hoped for the same kind of success as had followed his work in the Admiralty during the Second War and applied himself and his assistants to analysing the situation as he had done in those earlier times. It was his intention to keep this operational research group small but expert.

The speed with which change could be achieved in the latter years of the war was not attainable in an elaborate Government machinery in peacetime. Furthermore the situation was not similar to the wartime one in which the State, in the form of the Armed Sources, was the customer for the purveyor of analytical operational advice. Industry is a complex of many unrelated, or loosely related entities which cannot be commanded like an army.

Blackett's herculean efforts did not succeed in bringing Britain back to a leading world industrial position but it was a magnificent failure. A great deal of insight was gained about previously neglected factors. Thus it was realized from experience that concentration on research and development (R & D) in technology alone was not enough. There was no correlation between gross national product and R & D expenditure in the different industrialized countries. Major links in the chain essential to make effective use of the effort disposed on R & D had been unrealized and ignored but were now exposed as vital to success.

India and the Developing Countries

Blackett's interest in the underprivileged was stimulated by the great depression and particularly the Wall Street collapse in 1929. His special interests in India, and in developing countries generally, dates from a meeting with Pandit Nehru at an assembly of the Indian Science Congress Association in January 1948. The two got on very well together and Blackett was asked to act as adviser on defence. In 1948 he reported on the form and function which the proposed Defence Science Organization should take. From that time he made frequent visits to India and was often consulted on many aspects of science, education and economies in which he took a keen interest.

He was in close touch with Homi Bhabha and Vikram Sarabhai and I am sure he would have been gratified by the magnificent progress they have initiated. At all times their work has taken account of the special problems of India and especially of the need for building up a sound technical background based in the first instance on concentration of training in only a few centres. During my short tour of India in the past two weeks I have been particularly impressed by the SITE programme in all its aspects and by the high level of technical skill and performance in space and other technology.

In his later years Blackett devoted his analytical powers in large degree to the

problems of developing countries. He drew attention to the fact that the gap between the gross national products of these countries and those of the developed countries was still widening. He also pointed out how difficult it was to improve this situation—the capital requirements alone were very severe.

In the analysis which he presented Blackett took full account of the experience he had gained of British industrial problems and the following quotation from his Nehru Lecture in 1969 shows how far his thinking had developed.

"It is extremely important to consider the whole chain of activities, research, development, design, production, marketing and sales, and post sales service as a single whole. The first stages consume wealth—only the later stages produce it". He then went on to say how relatively expensive were the later stages, both in money and highly qualified manpower and conducted with the following sentence.

"This is why science is no magic wand to convert a poor country into a rich one". Here was someone speaking with the experience that it was also no magic wand for converting a rich country to an even richer one.

In 1969 Blackett finally accepted a Life Peerage and of the four speeches which he made, three, including his maiden speech, were about aid to developing countries.

He maintained his interest in these problems until the very end but India coupled a very special place which makes it so appropriate that this first Memorial Lecture is being given in Delhi.

President of the Royal Society

Blackett's election in 1965 as President of the Royal Society (see Plate III) was a fitting climax to a great career. There is no doubt that it was a source of gratification to him.

During the heady days of the 1960's the role of the Royal Society in national affairs, and particularly its relation to Government, was often debated. Blackett took the view with which many of us, including myself, completely agree. It is that the Society should at all costs preserve its independence while at the same time being prepared to advise and assist in national scientific activities and policy. By preserving its independence the Society could express a critical view and also more readily take the initiative in helping new activities, which it thought desirable, to get started. Through Blackett's close association with both, very good relations were built up between the Society and Government Departments, still maintaining stoutly the Society's independence.

Blackett was also anxious that the Society should play a part in improving the image of Applied Science. He established an Industrial Relations Committee, which has been very active, and moved towards closer cooperation with Engineering Institutions.

Post-graduate education was a target for criticism during Blackett's Presidency and here he played a very valuable part by presenting a balanced view in which he pointed out many advantages of the present system. Although it had become unfafashionable to emphasize the importance of pure science Blackett always spoke out strongly in its support.

Despite the wide range and depth of his many activities he was always at heart a research scientist. Because of this I have spoken rather at greater length on his scientific career and I am sure he would have appreciated this. At the same time I hope I have conveyed something of his extraordinary capacity for effective work in so many different areas of human activity. It is sometimes said that only the very busy have time to take on any additional work. Blackett was an outstanding example.

It is a great privilege to have been a contemporary of such a man, to have known and worked with him in so many of his activities.

ACKNOWLEDGEMENTS

For many of the details presented above I have drawn *heavily on the excellent* Biographical Memoir on Blackett written for the Royal Society by Sir Bernard Lovell. The Proceedings of the Memorial Meeting held at the Royal Society on 31 October 1974 have also been a valuable source.

It is a great pleasure to thank you, Mr. President*, the Officers of the Indian National Science Academy and all others who have been so kind and helpful during my stay in India. I would like particularly to express my gratitude to Dr. Subbarayappa and Mr. Natesa Iyer for their good-natured helpfulness and courtesy as well as their efficiency in making so many detailed arrangements in connection with my visit.

*Dr. B. P. Pal, F.R.S., F.N.A., was the President.