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Scientific Conf. on Atomic Energy

– Feb. 55

- Programme of Nuclear Power
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- Supply of Military Aircraft

(Presented to Parliament of England by the Minister of Defence)

# The Supply of Military Aircraft

*Presented to Parliament by the Minister of Defence and the Minister of Supply by Command of Her Majesty*
*February 1955*

LONDON
HER MAJESTY'S STATIONERY OFFICE
SIXPENCE NET

Cmd. 9388

# THE SUPPLY OF MILITARY AIRCRAFT

## I. Introduction

1. Public interest in the supply of aircraft in accordance with the Defence Programme is natural. The country has the right to be assured that the best possible use is being made of the national resources and the large sums of money provided. The desire, however, of any Government to give information must be curbed by security considerations. If every technical difficulty in the development of a particular aircraft is to be publicly discussed, it is impossible to avoid giving information to potential enemies which they are most anxious to possess, both to guide their own development and to enable them to assess our strength. In this White Paper the Government have tried to give the fullest possible information consistent with the national safety. Some general observations on the nature of the problem will be found in the Appendix.

## II. Situation in 1945

2. We entered the second World War with advanced designs of aircraft ready to go into large-scale production. During the war we concentrated primarily on producing large numbers of aircraft of these types and development was mainly directed towards improved versions of existing breeds of aircraft. This policy avoided the dissipation of our resources over a large number of experimental projects and contributed to our air strength. But it meant that at the end of the war very few advanced projects were under development in this country, and we were falling behind in the science of aerodynamics, though not in the field of gas-turbine engines.

3. Consequently, at the end of the war, both the Royal Navy and the Royal Air Force were, with one exception, entirely equipped with piston-engined aircraft, most of which had been in service for a number of years or were developments of well established types. The exception was the jet-propelled Meteor day fighter, an early mark of which came into service in small numbers at the end of 1944.

## III. 1945 to 1950

*Re-equipment*

4. After the war, it was considered that the likelihood of another war was not immediate. It was therefore decided not to take a major step forward in the re-equipment of the Royal Navy and the Royal Air Force with new front-line aircraft until about 1957. During the interim period the Services were to use mainly equipment of types of which they already had large quantities, together with a limited number of new types based on war-time conceptions, the development of which was continued.

5. Meanwhile in 1945-6 requirements were stated by the Services for aircraft of the performance and armament which they considered would be needed for operations about 1957. On the basis of these requirements design of the Vulcan and Victor medium bombers was started in 1947, and that of a swept-wing day-fighter and a two-seat all-weather fighter in 1948. Steps were taken to provide interim bombers to cover the period until the Vulcan and Victor were available (as explained in paragraphs 11 and 12). But although a swept-wing Nene-engined aircraft, comparable in time and performance with the Sabre and the MIG, could have been developed, it was decided not to proceed with an interim fighter of this type.

*Research*

6. The decision was also taken in 1946 that, in the light of the limited knowledge then available, the risks of attempting supersonic flight in manned aircraft were unacceptably great and that our research into the problems involved should be conducted in the first place by means of air-launched models. It is easy to be wise after the event, but it is clear now that this decision seriously delayed the progress of aeronautical research in the U.K.

7. Various research aircraft however were ordered. These included several of delta form to explore the behaviour of this type of aircraft at speeds near that of sound, and two swept-wing single-seat aircraft of fighter type. In 1948 and 1949 a number of small aircraft were ordered to test in the air important features of the designs of the Victor and Vulcan.

8. The general economic and financial situation of the country was a limiting factor; in particular following devaluation in 1949 various other research aircraft for experiments in flight at speeds near that of sound were cancelled for reasons of economy.

9. This limitation also applied to the provision of basic research facilities. During the war only those immediately necessary for its prosecution had been provided. The need for extensive new facilities to deal with the problems likely to be encountered in post-war aeronautical research had been recognised before the end of the war. Plans had been made for their provision, but the execution of these was delayed, owing to the competition of other claims for capital investment and the shortage of steel. The result was that delivery dates for research plant were extremely long, and the necessary building and civil engineering work could only proceed slowly. The overall effect of these difficulties was that during the years from 1945 to 1950 only limited new facilities were created.

*Development*

(a) *Bombers*

10. The Canberra which was first conceived late in 1944 was developed with marked success as the first jet light bomber.

11. In 1946 when the long-term requirement for a medium-range bomber was under consideration, the R.A.F. stated a requirement for an "insurance" aircraft of more orthodox design to be available as quickly as possible. Prototypes were therefore ordered of a straight-wing jet-engined bomber, the S.A.4. The performance of this aircraft was to be substantially below the long-term requirement, to meet which the Victor and Vulcan were later ordered.

12. In 1947 it was decided that a further insurance should be developed in the form of an aircraft superior in performance to the S.A.4 and meeting as nearly as possible the full medium bomber requirement, but of less advanced design than the Victor and Vulcan, so that the development problems should be fewer. This was the Valiant.

13. By the end of 1949 it was thought that such good progress was being made on the Valiant that the latter would be available little if at all later than the S.A.4. In view therefore of the superior performance of the Valiant it was decided to abandon the idea of the S.A.4 as an operational aircraft.

(b) *Fighters*

14. The Vampire which had been developed during the war came into service in 1946. More advanced marks of the Meteor were produced, equipped for a variety of roles. They were greatly improved compared with

the original Meteor and fitted with engines of nearly double the power. They provide an example of highly successful and continuous development of an established type. It is these later marks which are still in service with the R.A.F.

15. In 1948 when Berlin was being blockaded and international tension was growing, production orders for the latest mark of Meteor day-fighter were more than doubled. It was also decided to develop the Venom (evolved from the Vampire with thinner wing and more powerful engine) as an interim day-fighter, and to proceed with a night-fighter version of the Meteor.

16. At the same time the question of ordering an operational version of one of the two swept-wing single-seat research aircraft was considered. It was concluded that this could not be done in either case without delaying other projects of a more advanced nature. In 1949 this was considered again but in view of the financial crisis and consequent drive for economy, no change was made in the earlier decision. Consequently not even a prototype of an operational swept-wing fighter flew before 1951, and no prototype fully representative of the production aircraft before late 1952.

### *Summary*

17. To sum up the position before the Korean War broke out, requirements had been stated by the Services for very advanced aircraft expected about 1957; research had been restricted by inadequate facilities and the decision about manned supersonic flights: some steps had been taken to provide interim bombers to be available before 1957: a calculated risk had been taken to have no interim swept-wing fighters.

## IV. **Effect of the Korean War**

18. In June, 1950, war broke out in Korea. In the light of the new threat of a third World War, plans for re-equipping the Services about the year 1957 had to be reviewed.

19. In the fighter field a substantial production order for the swept-wing day-fighter referred to in paragraph 5 was placed off the drawing board in October, 1950, although its first prototype did not fly until 9 months later. Several hundred more were ordered in the early months of 1951. This was later named the Hunter. It was also decided as an insurance to order off the drawing board an operational version, proposed by the makers, of a research aircraft, the S.535, which it was hoped could get into production before the Hunter; prototypes and 100 production aircraft were ordered in November, 1950, and the production order was increased by 50 early in 1951. This was later named the Swift. Owing to the emergency, production orders for the Hunter and the Swift were placed much earlier in the development phase than would normally be the case.

20. In the same way a production order for the Valiant bomber was placed early in 1951, before the first prototype had flown. At the same time it was decided to order the Sea Venom as an all-weather fighter for the Fleet Air Arm, and again a production order was placed before the first prototype had flown.

21. Clearly the decision to place these orders at this stage meant taking exceptional risks. The overloading of particular firms in the aircraft industry was also a consequence. On the other hand it offered a hope that some of the latest aircraft would be available earlier and could be used in war, even if their operational performance did not completely meet the original requirement.

## V. Progress 1951–1955

(a) *Bombers*

22. The development of the three V-bombers has proceeded steadily. Deliveries of the Valiant have started and will continue during the coming year. Development troubles have been remarkably few for an aircraft of its size and performance, and its introduction marks a major increase in our power to deter an aggressor. Although the Vulcan and Victor are of more advanced design, good progress has been made despite setbacks through accidents to prototypes of each. During the coming year both development and production will proceed with growing momentum.

23. The Canberra, which is in service in large numbers, marked a substantial advance and has proved a successful and versatile aircraft. Development of later marks of improved performance and for different roles has continued.

(b) *Fighters*

(i) *Interim Types*

24. Venom Fighter-Bombers, Venom Night-Fighters and Meteor Night-Fighters have come into service; these aircraft are usefully filling the gap until the latest swept-wing aircraft are introduced. Although they must be regarded as interim types, they have given a worthwhile improvement in performance over the aircraft previously in service in these roles. In particular the two-seater night-fighters with their airborne and ground equipment afford a defence against night attack which we believe is superior to that of any other country.

(ii) *Hunter and Swift*

25. In the case of the Hunter and the Swift serious development troubles were encountered. The decisions of 1950–51 to order many hundreds of these aircraft meant that while development was still in a very early stage, tooling up and other preparations were rapidly pushed ahead for production of swept-wing aircraft with a large number of new features, such as axial flow engines, power controls, heavier armament, and other more complicated equipment. All these had to be introduced and developed together. They had to be tested concurrently. Modification to one feature often meant modification to many others. This had to be done under the handicap that only a few prototypes had been ordered. A single intractable aerodynamic problem from time to time monopolised the flying time of all the available aircraft or grounded them so that all other development flying, including the flight testing of guns, radar and other equipment, had to be put back. For instance for a long time difficulty was experienced in making the Hunter air-brake slow the aircraft effectively without upsetting the pilot's aim. Meanwhile production built up rapidly, and although this enabled early production aircraft to be diverted to assist in development flying, it also meant that increasing numbers of aircraft were coming off the production line while some major features of the design were still unsatisfactory.

26. The first prototype of any mark of Hunter flew in July 1951, the first representative prototype in November 1952. The main troubles have been largely overcome, and substantial numbers of Hunters have already been delivered to the Royal Air Force. There are still certain directions in which the Hunter's performance could be improved; on these development is proceeding. Apart from these there is a problem with the guns: the firing of the guns causes interference with the flow of air into the engine, and when this happens in the rarified atmosphere encountered at extreme altitude, it may lead to the engine stalling; this trouble, which has been experienced in other countries even with more lightly armed aircraft, affects significantly

only certain marks of Hunters. Measures already taken have effected a substantial improvement and further measures are in hand designed to eliminate the trouble.

27. We believe that in the Hunter we have a fine aircraft capable of further development. Its all-round performance and heavy armament mean that it compares favourably with any fighter now in general service in any other country.

28. As explained in paragraph 19, the Swift was based on a research aircraft built primarily to explore aerodynamic problems. Subsequently in the emergency of 1950 it was decided to turn it into an operational aircraft; in addition to introducing armament and all the rest of the operational equipment required for service use, it was decided to replace the Nene engine by the larger and more powerful Avon. The resulting changes from the original design so complicated the process of development as to become the basic cause of many of the difficulties which have been encountered.

29. Production of the first mark with two Aden guns was ordered, as has been stated, in November, 1950; the first prototype did not fly until July, 1952. The second mark with four Aden guns, involving important changes to the wing, was ordered in April, 1951, but a four-gun aircraft did not fly until May, 1953; this was also the first aircraft representative of the Mark 4 which was the mark for which the largest orders were placed for the R.A.F. The aerodynamic performance of all marks proved disappointing and great efforts have been made by all concerned to get the aircraft right. Meanwhile, as in the case of the Hunter, production has been rapidly building up.

30. After a series of exhaustive tests, it has been decided that the Swift Marks 1 to 3 cannot be brought to an acceptable operational standard. Within the past few days, certain modifications have been introduced into the Mark 4. Further tests are taking place to see whether these have produced a sufficient improvement to warrant putting this mark into service with the R.A.F. It will be possible to replace the Mark 4 Swifts by Hunters if necessary. Development is continuing for the time being of other marks designed for certain specialised functions.

(iii) *Future Fighters*

31. In the next financial year, substantial numbers of the Javelin all-weather delta fighter should become available. The development of the P.1 day/night-interceptor, a prototype of which has already flown faster than sound in level flight, will be pressed forward. We are looking ahead to still more advanced projects.

(c) *Other R.A.F. Aircraft*

32. Production models of the Beverley heavy transport are coming off the line. Helicopters for a variety of tasks including the joint Army/R.A.F. Helicopter Unit will be included in the 1955 production programme. A small number of Jet Provosts will be delivered in the next financial year for evaluation as basic trainers. Development of the V.1000 long-distance jet transport is proceeding.

(d) *Fleet Air Arm*

33. The Royal Navy's first jet-propelled aircraft have completed their basic development; the Seahawk day-fighter and Sea Venom all-weather fighter have come into service. Seahawk deliveries will be completed next financial year and Sea Venom all-weather fighters will be coming forward in increasing numbers. Though both are interim types, their performance is far superior

to that of their forerunners; on the other hand they are of less advanced design than the R.A.F.'s swept-wing fighters, and their development troubles have, therefore, been less serious.

34. The Wyvern was first conceived in 1944 as a piston-engined strike aircraft. In 1945 it was decided to fit a turbo-propeller engine. As the first military aircraft in the world with such an engine, it has encountered more than its fair share of development troubles, particularly in regard to the engine and propeller control system. Up to date it has not proved successful for its designed purpose as a carrier-borne aircraft, but work is still proceeding with a view to remedying its defects.

35. The Gannet was originally devised in 1946 as a two-seater anti-submarine aircraft. In 1948 it was re-designed to carry a third crew member, and the production contract was placed in January 1951. Development and production have proceeded smoothly apart from some difficulty with the engine under certain conditions, which has now been overcome. The Gannet is a formidable submarine hunter and will be delivered to the Navy in substantial numbers in 1955.

36. Development for the Navy of the D.H.110 all-weather fighter, and of a twin-engine swept-wing day-interceptor will continue in 1955. Production orders for both types have been placed.

37. Development and production of helicopters for naval use in the anti-submarine, rescue and communications roles will also be pressed forward.

(e) *Armament*

38. Great emphasis has been placed upon the armament element of our new weapons systems. Our latest types of fighters are fitted with four 30 mm. Aden cannon, the most destructive gun armament in service anywhere in the world. They can deliver 10 times as much high explosive per second as the cannon of the Russian MIG.

39. The next step will be to introduce air-to-air guided weapons into our fighter defences. The progress made in developing various different types of these, employing a variety of guidance and homing techniques, will be described in the forthcoming Statement on Defence. Production orders have been placed for one of these types.

(f) *Summary*

40. To sum up, the position in 1955 must be assessed in the light of what a potential enemy may now have in service. The view that the Services are equipped with obsolete aircraft dating from the last war is totally incorrect. This country has an effective air defence against what any potential enemy is at present able to bring against us. By night, the most likely time for attack, we have a better defence than anyone else in the world. With regard to the future, during 1955 our deterrent strength will be built up with the putting into service of the Valiant bomber. Our fighter defence will be strengthened by the equipment of more squadrons with Hunters. We are developing new types of bombers, fighters and naval aircraft to deal with the expected future armament of any potential enemy. As our forces are re-equipped with this new generation of aircraft we shall have the balanced and powerful air fighting forces appropriate to our resources and our standing as a great power.

## APPENDIX

### *Research*

1. Research can be described as the process of creating scientific capital. It comprises all that work, much of it of a very theoretical and fundamental nature, which is not directed specifically to meeting immediate Service requirements. Some of it contributes to the solution of current problems, but much of it goes to build up the fund of basic knowledge needed to meet future requirements. Today's research leads not to tomorrow's aircraft (for they are already being developed today) but to those of the day after tomorrow. An adequate programme of research and the necessary capital facilities for such a programme are therefore vital to success.

2. In the aeronautical field much of the research is done by the experimental establishments of the Ministry of Supply and by other authorities; that done in the industry is also of great importance, and will grow in significance as the additional research facilities which the manufacturers are themselves providing, co-operatively and individually, come into use.

3. The plans for the provision of extensive and up-to-date experimental facilities at Ministry of Supply establishments are now maturing and great benefit will be derived from the new facilities as they come into use. The tempo of aeronautical progress is such, however, that more advanced facilities must be continuously provided, and it must be recognised that their provision will impose a growing financial burden.

### *"Weapons Systems"*

4. An aircraft must be treated not merely as a flying machine but as a complete "weapons system". This phrase means the combination of airframe and engine, the armament needed to enable the aircraft to strike at its target, the radio by which the pilot is guided to action or home to base, the radar with which he locates his target and aims his weapons, and all the oxygen, cooling and other equipment which ensure the safety and efficiency of the crew. Since the failure of any one link could make a weapons system ineffective, the ideal would be that complete responsibility for co-ordinating the various components of the system should rest with one individual, the designer of the aircraft. Experience has shown that this is not completely attainable but it is the intention to move in this direction as far as practical considerations allow.

### *Development*

5. Even before the war development took many years; in the case of the Spitfire it started with the Schneider Trophy Races of 1927–31, which led to the reappearance of the monoplane. The specification from which the Spitfire was evolved was issued in 1935; development proceeded from 1935 and it was not until 1940 that large scale production was achieved. The success of the final production was due in no small measure to the time spent on the development process.

6. Modern aircraft are vastly more complicated; to take only one example, a modern bomber needs 60 times the weight of radio and electrical equipment carried by a pre-war bomber. Clearly the development period up to release to service, though it varies from aircraft to aircraft, can hardly be less than before the war.

7. The starting point of the process of development is the assessment of the defence needs of the country and the strength of a potential enemy. In the light of this a requirement is stated by the Service Department concerned.

The requirement may have to be modified to some extent to take account of the Ministry of Supply's advice as to what it is technically reasonable to aim at in the required time-scale, but the essentials of the requirement are determined by the threat which it is intended to meet. The operational requirement is then translated into a technical specification by the Ministry of Supply. The designer's ability to achieve what is called for by the specification turns largely on the extent to which an aircraft of the performance required can be designed within the framework of the basic technical knowledge available at the time. This reinforces the vital importance of a research programme of adequate size and of the right content.

8. When the specification is issued, designs to meet it are called for from industry. These designs may involve radically different solutions of the problems posed. Those to be developed are selected on their technical merit.

9. The early phases of development involve calculations of stresses and performance, initial drawing office work and the construction of models and rigs for wind tunnel and other testing. This phase overlaps design as the latter is often dependent on the results of these tests. As construction of the first aircraft proceeds, re-design and further tests are needed. Then begins testing of the aircraft—first on the ground and afterwards in the air. Flight testing must be done progressively ; a prototype is gradually subjected to more rigorous and searching tests and manoeuvres. As faults are revealed, re-design and rebuilding are required.

10. When the manufacturer is satisfied that the aircraft has reached a stage when its performance can be evaluated, it is sent to the Aeroplane and Armament Experimental Establishment of the Ministry of Supply, where it is tested and assessed by pilots specially selected and seconded from the Services. If it is not acceptable, it is returned to the manufacturers for improvement. When it is finally brought to an acceptable standard, it is formally released to service. The process of testing and proving every item of a weapons system, however, is inevitably protracted and it is thus the normal practice for the first release to be a partial one, which is extended progressively as the tests proceed. Release to service is not the end of development, for this continues throughout the service life of the aircraft, to remedy faults and improve performance and reliability.

11. During all these processes there must be complete co-operation between the Service, the Ministry of Supply and the manufacturer.

12. Development is the most difficult, as well as the longest, stage. The difficulty increases as the growth of our basic knowledge opens up possibilities of more rapid advances in many fields. It is in development, rather than production, that the difficulties have been encountered which have recently held up the re-equipment of the Services with aircraft of the latest types.

13. These processes are difficult enough if everything goes well and plans remain unchanged. It can be readily realized how much they are complicated by changes during their course in the assessment of the war risk or of the enemy's potential, leading in turn to changes in requirements and plans.

### *Production*

14. When a production contract is placed, plans must be prepared, and materials, special components, sub-assemblies and the like, ordered from subcontractors, who in turn have to plan and set up production. Drawings are made, jigs and tools designed and manufactured, and labour recruited.

15. The complexity of a modern aircraft affects production no less than development ; a modern day-fighter, for example, requires 12,000 to 15,000 production drawings compared with some 6,500 for a wartime fighter. Thus it is seldom possible to get the first aircraft less than 2½–3 years from the time of ordering.

16. The early phases of production, however, must almost invariably overlap the later phases of development although these are often the most critical ; otherwise the time from the formulation of a new operational requirement to the delivery of aircraft in quantity would be 12 years or more, at the end of which the original requirement might well have materially altered so that the aircraft eventually delivered might be already obsolete.

### *Modifications*

17. The length of the development process gives particular point to the difficult question of modifications. There are really two classes of modifications. Within the first class are modifications essential for safety and also those designed to bring an aircraft under development up to an acceptable operational standard ; these modifications are inevitable, and any resultant delay in production has to be accepted. But there is also the continuing need to incorporate during the development of later marks of the aircraft other modifications intended to extend performance beyond that originally conceived. These form the second class of modifications. They present a constant dilemma ; on the one hand they can greatly prolong the useful life of the type: on the other hand if too many are introduced they may cause major changes in design. This second class of modification therefore should be introduced at some convenient point in the production process in order not to delay delivery of earlier versions.

18. The objective is in the case of each mark of an aircraft to incorporate only modifications in the first class, and to defer the second class to a later mark of aircraft. Such decisions are not easy and require the exercise of extremely skilful judgment as to the right timing.

### *Development Batch*

19. In paragraph 25 on page 6 the delays caused in the past through shortage of prototypes have been mentioned. To minimise delay from this cause, it was decided over a year ago that in all appropriate future cases a development batch of a dozen or more aircraft should be ordered, instead of two or three prototypes. The delivery programme for these aircraft will be carefully planned so that the full programme of development testing can be carried out in the most expeditious manner, while the later aircraft of the batch are so phased that the lessons learned on the earlier ones can be applied to them. The production of the development batch will also be so arranged as to lead smoothly into the full-scale flow of production. The first opportunity of putting this policy into practice has been in the case of the P.1, and as was announced by the then Minister of Supply on 1st March, 1954, a development batch of 20 of this aircraft was ordered.

### *" Shorter Steps "*

20. The larger the steps by which development of new types of operational aircraft proceeds, the greater the technical difficulties and the risk of failure. Had an interim swept-wing fighter been fully developed after the war as a combat aircraft, we should have known earlier of many of the problems later encountered on the Hunter and Swift. A policy of shorter steps would mean more frequent but shorter advances. This would not only have the

advantage of easing the technical problems, but would mean that, at any point in time, an up-to-date aircraft would be well advanced in development and in the event of an emergency could be put into production relatively quickly. The extent to which the Services should be re-equipped at each stage would be governed both by the assessment of the international situation and by financial considerations; to establish a technical advance, however, it is not essential to go into full production. Whilst the full consequences of a policy of shorter steps are still being examined, it appears that, despite the possibility of greater expenditure on development, the overall result would be an economy of the nation's resources and an increase in its preparedness at any point.

*Use of Resources Available*

21. The dangers of undue dispersal of the aircraft industry's resources over too wide a variety of projects are obvious, but some measure of insurance is necessary. To take the case of the three V-bombers as an example, it has already been shown in paragraph 12 on page 4 that the Valiant is an interim type ordered as an insurance, which is entering service appreciably earlier than the Vulcan and Victor. Only the latter can fully meet the Royal Air Force's requirement, but at the time they were started both were such advanced conceptions and employed such widely differing approaches that it was a wise precaution to develop them in parallel. Similarly it has been explained how the Swift was ordered in an unforeseen crisis as an insurance.

*Summary*

22. The experience of the last ten years leads to the following conclusions:—

(*a*) Development and not production is the difficult stage in the supply of military aircraft; it is bound to be lengthy.

(*b*) A large research programme is necessary to ensure that development is on technically sound lines.

(*c*) The weapons system concept must govern development.

(*d*) An adequate number of aircraft must be available for development purposes.

(*e*) Modifications which are not essential for safety or to bring an aircraft up to an acceptable operational standard must be so phased into the development and production programme as not to cause delay or undue expense.

(*f*) Owing to the rate of technical advances, it may well prove more economical in the long run to advance by shorter, though more frequent, steps.

(*g*) The system must permit design teams to propound different solutions to the problems posed, but this must not lead to undue dispersal of effort.

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# Statement on Defence, 1955

## I.—INTRODUCTION

**Defence Policy**

1. Overshadowing all else in the year 1954 has been the emergence of the thermo-nuclear bomb. This has had, and will continue to have, far-reaching effects on the defence policy of the United Kingdom. New and revolutionary problems are posed requiring courage and imagination for their solution. Nevertheless our problem is still fundamentally a dual one. We have to prepare against the risk of a world war and so prevent it; it is on the nature of these preparations that the existence of thermo-nuclear weapons has its main effect. At the same time we must continue to play our part in the defence of the interests of the free world as a whole, and particularly of the Commonwealth and Empire, in the " cold war "; and we must meet the many other peacetime commitments overseas arising from our position as a great Power with world-wide responsibilities.

**Nuclear Weapons**

2. In the Statement on Defence, 1954 (Cmd. 9075), Her Majesty's Government set out their views on the effect of atomic weapons on United Kingdom policy and on the nature of war. Shortly afterwards the United States Government released information on the experimental explosion at Eniwetok, in November 1952, of a thermo-nuclear weapon many hundred times more powerful than the atomic bombs which were used at Nagasaki and Hiroshima in 1945. On 1st March, 1954, an even more powerful thermo-nuclear weapon was exploded in the Marshall Islands. There are no technical or scientific limitations on the production of nuclear weapons still more devastating.

3. The United States Government have announced that they are proceeding with full-scale production of thermo-nuclear weapons. The Soviet Government are clearly following the same policy; though we cannot tell when they will have thermo-nuclear weapons available for operational use. The United Kingdom also has the ability to produce such weapons. After fully considering all the implications of this step the Government have thought it their duty to proceed with their development and production.

4. The power of these weapons is such that accuracy of aim assumes less importance; thus attacks can be delivered by aircraft flying at great speed and at great heights. This greatly increases the difficulty of defence. Moreover other means of delivery can be foreseen which will, in time, present even greater problems.

5. If such weapons were used in war, they would cause destruction, both human and material, on an unprecedented scale. If exploded in the air, a hydrogen bomb would devastate a wide area by blast and thermal radiation. If exploded on the ground, the damage by blast and thermal radiation would be somewhat less; but there would be additional extremely serious indirect effects. A great mass of atomised particles would be sucked into the air. Much of it would descend round the point of the explosion; but the rest would be carried away and descend as radio-active " fall-out." The effect on those immediately exposed to it without shelter would certainly be fatal within the areas of greatest concentration of the " fall-out ";

it would become progressively less serious towards the outer parts of the affected region. Large tracts would be devastated and many more rendered uninhabitable. Essential services and communications would suffer widespread interruption. In the target areas, central and local Government would be put out of action partially or wholly. Industrial production, even where the plant and buildings remained, would be gravely affected by the disruption of power and water supplies and by the interruption of the normal complex inter-flow of materials and components. There would be serious problems of control, feeding and shelter. Public morale would be most severely tested. It would be a struggle for survival of the grimmest kind.

6. It is essential that these facts should be known not only to our people but to all the world. All should realise the magnitude of the disaster war would bring. Such understanding may bring home to people in all lands the consequences of war and generate a compelling will to peace, strong enough to enforce itself on the most arbitrary of rulers. That is the first implication of the nuclear weapon. It is one not of despair but of hope. In the hands of the free world, which at present has a marked superiority both in the weapon itself and in the means of delivering it, and which has no thought of aggression, it is a most powerful deterrent. In the Government's considered view this deterrent has significantly reduced the risk of war on a major scale.

7. In these circumstances our immediate duty and our policy are clear. To build up our own forces, in conjunction with those of our allies, into the most powerful deterrent we can achieve. By this means to work for peace through strength. Thus we shall hope to obtain real disarmament and relaxation of tension. But we must also so equip and train our forces and so organise the country as to enable us to survive and to defeat the enemy if all our efforts for peace should fail. Nevertheless our long-term policy remains unchanged.

**Disarmament**

8. The Government will continue to strive for a practical scheme of disarmament as a contribution to the alleviation of international tension and the avoidance of war. Their ultimate aim is abolition of the use, possession and manufacture not only of all nuclear weapons, but also of other weapons of mass destruction, together with simultaneous major reductions of conventional armaments and armed forces to agreed levels which would redress the present Communist superiority.

9. The whole programme would have to be carried out to an agreed timetable, and an essential feature would be the provision of machinery to supervise and enforce agreed prohibitions and reductions. Detailed proposals on these lines have been put forward by Her Majesty's Government in recent years. Until recently there has been no indication that the Soviet Government were ready even to entertain any workable scheme; indeed, there were many indications to the contrary. In September, 1954, however, the Soviet Government announced that they were prepared to accept " as a basis " certain proposals put forward last June by Her Majesty's Government in conjunction with the French Government. But the recent debates in the United Nations General Assembly indicate that they are still not prepared to agree to the essential safeguards provided in these proposals although it is

hoped that in the forthcoming discussions they will be ready to discuss disarmament more realistically. If the free world were to disarm without such safeguards it would incur a double risk. It would be threatened with conventional forces which it could not hope to match; and it would have no guarantee that such forces would not be reinforced by nuclear weapons over the clandestine production of which there would be no adequate control. In short, disarmament must be real and comprehensive, and there must be secure and workable safeguards. Until the Communist world is prepared to accept such a system our " Grand Alliance " must build and maintain its strength.

**Co-operation in the Free World**

10. The deterrent to aggression does not consist in military strength alone. The political unity and resolution and the economic as well as the physical strength of the free world must be maintained. This has been the basis of our policy ever since the clear emergence of the Communist threat after the last war. On it were founded the Brussels Treaty of 1948 and the North Atlantic Treaty of 1949. To this end, too, the agreements resulting from the London and Paris Conferences are of supreme importance. Among other advantages of these agreements is the fact that none of the forces under SACEUR's command can be used for an independent recourse to war. Their ratification will enable Western Germany to make her essential contribution of forces, under suitable safeguards. They will also, by " recognising that a great country can no longer be deprived of the rights properly belonging to a free and democratic people " and by associating the Federal Republic as an equal partner in Western European Union and in N.AT.O., strengthen the solidarity and unity of purpose of both these communities.

11. The United Kingdom's undertaking, subject to the ratification of the agreements and to certain other understandings, to maintain her forces on the mainland of Europe, contributed powerfully to the success of the London and Paris Conferences, and will certainly continue to strengthen the stability and effectiveness of N.A.T.O. and Western European Union. The British initiative was followed (and this was not the least important result of the Conferences) by an expression by Mr. Dulles of the willingness of the United States to consider complementary assurances regarding the continued maintenance of United States forces in Europe.

12. Further evidence of the desire to unite for mutual protection against possible aggression is provided by the conclusion of the South-East Asia Collective Defence Treaty. The development of this organisation, which is about to be further discussed in Bangkok, should contribute much to the stability of this troubled area.

13. Naturally it is within the Commonwealth that we look for the fullest co-operation in defence. The closest liaison is maintained at the Service level with other Commonwealth countries between whose forces there is considerable standardisation of equipment, weapons and training techniques. Besides frequent inter-Governmental consultation, of which the recent meeting of Commonwealth Prime Ministers is an example, regular Service conferences are held and there is close and intimate co-operation with the individual countries concerned over regional planning and strategy.

**The Cold War**

14. Political unity and armed strength would be of little value if the will of the free peoples to maintain, and if necessary defend, their independence and way of life were in doubt. For this reason economic, social and political progress must be maintained and consolidated, particularly in the less developed countries which might otherwise be undermined by Communist infiltration and subversion.

15. It is certainly no part of the Government's policy to abandon resistance to Communist imperialism in the cold war. Weakness and irresolution in the face of limited aggression will not avail to avert a major war. The existence of the nuclear weapon may discourage overt armed intervention by the Communist Powers, such as occurred in Korea, because of the risk that it might develop into unlimited war. But equally it may encourage the indirect approach through infiltration and subversion. We shall therefore, in parallel with our effort to develop the deterrent and to prepare against a major war, strengthen by all means at our disposal, including where necessary the maintenance of adequate conventional forces, our defences against this method of attack. We must play our part with the other countries of the Commonwealth and with our allies in resisting the spread of Communism throughout the world.

16. The United Kingdom is responsible for many dependent territories overseas. We must be ready to defend them against external attack. We have also to protect them, by assistance to the civil power, against internal disruption. The rapid transition through which many colonial societies are now passing in their progress towards self-government creates conditions which are in some cases capable of being exploited by international Communist techniques. This immediately, but as we hope only temporarily, must increase the actual and potential commitments for British forces in support of Colonial Governments and Administrations. At the same time the measures already being taken to strengthen the ability of the Colonial Governments themselves to deal with threats to internal security must be progressively improved.

17. Our reduced commitments in Trieste, Korea and the Middle East now make it possible to rebuild a strategic reserve of land forces in this country. Coupled with the mobility of the Navy and increasing use of air transport, this will greatly increase our ability to exercise our world-wide responsibilities effectively and economically.

**The Deterrent**

18. Apart from these responsibilities, in a situation in which the Communist world maintains large and increasingly powerful armed forces, the strength of our forces and those of our Allies must also be developed and sustained against the possibility of a major war. To this end, increasing emphasis must be placed on the deterrent.

19. This deterrent must rest primarily on the strategic air power of the West, armed with its nuclear weapons. The knowledge that aggression will be met by overwhelming nuclear retaliation is the surest guarantee that it will not take place.

20. This counter-offensive strength is also our most effective defence against aggression should it ever occur. The enormous power of nuclear weapons is such that in war the outcome of the first few exchanges would be of critical importance. Great advantages would probably flow from surprise and from the first assault. In these circumstances the enemy might well initiate the use of nuclear weapons at the outset of hostilities. A prompt and overwhelming counter-offensive with the most powerful weapons available offers at present the surest means of limiting the scale of such attacks.

21. But we cannot rely only on strategic air power. Our policy must aim at impressing on the potential enemy that a sudden attack even with nuclear weapons would not be conclusive. It must also demonstrate that we have both the will to survive and the power to ensure victory. The vast conventional forces controlled by the Communist world include a large and growing Navy. On our side, we must have a Navy capable of dispersal and concentration at will which, with the allied navies, can seek out and destroy the enemy's naval forces and preserve effective command of sea communications.

22. The Communist world also maintains, and can continue to maintain, a great preponderance of conventional land forces. These, moreover, operate on internal lines of communication. The Soviet Union and her Eastern European Satellites have some six million men under arms backed by enormous reserves. On the German front the Soviet Army could be increased to well over 100 divisions within 30 days. Over the whole field of deployment East and West the Soviet and satellite land forces could be raised to the level of 400 divisions. Even allowing for the essential German contribution the free world cannot put into the front line anything comparable to this strength in conventional forces. The use of nuclear weapons is the only means by which this massive preponderance can be countered. But with their aid and with the German contribution we can adopt a forward strategy on the ground in Europe and so defend the Continent, instead of contemplating again the grim process of liberation. If we do not use the full weight of our nuclear power, Europe can hardly be protected from invasion and occupation—with all that this implies both for Europe and the United Kingdom.

23. It was for these reasons that the Council of the North Atlantic Treaty Organisation, at its meeting in Paris in December, 1954, approved a report by the Military Committee on the most effective pattern of N.A.T.O. military strength which assumed the use, in a major war, of nuclear weapons. The report will, henceforward, form the basis of N.A.T.O. defence planning and preparations. Decisions on putting such plans into effect are specifically reserved to Governments.

24. Thus, until the Soviet Union agrees to participate in a secure system of disarmament, the free nations must base their plans and preparations on the assumption that if a major war were precipitated by an attack upon them they would have to use all the weapons at their disposal in their defence. The consciences of civilised nations must naturally recoil from the prospect of using nuclear weapons. Nevertheless, in the last resort, most of us must feel that determination to face the threat of physical devastation, even on the

immense scale which must now be foreseen, is manifestly preferable to an attitude of subservience to militant Communism, with the national and individual humiliation that this would inevitably bring. Moreover, such a show of weakness or hesitation to use all the means of defence at our disposal would not reduce the risk. All history proves the contrary.

**The Tasks Before Us**

25. We must therefore contribute to the deterrent and to our own defence by building up our own stock of nuclear weapons of all types and by developing the most up-to-date means of delivery. We must, moreover, in making our plans for dealing with aggression against our alliance, not flinch from the necessity to use these weapons. For in the knowledge of our resolve lies the best hope, and it is a real hope, that it may never be put to the test.

26. Meanwhile, the development of nuclear weapons does not mean that the use of naval and land forces in a major war is now obsolete or outmoded. Naturally their weapons, organisation, tactics and training will be profoundly affected. But the Navy is still required to contain and destroy enemy forces at sea so as to allow free movement of supplies and troops and to give both our land and air forces support in their operations. We still need troops on the ground to hold the enemy well to the East in Europe in the vital initial stages of a war. This would give time for the effects of our strategic air offensive to be felt. It would also hold back from the United Kingdom the threat of shorter-range aircraft and ground-to-ground missiles. The presence of a firm shield of troops and tactical aircraft similarly reduces the danger that the Communists might be tempted to try to over-run Europe with conventional forces in the hope that the West would refrain from using nuclear weapons in its defence or that it could be used as a pawn in a shameful negotiation. It is from this point of view that a German defence contribution is militarily so important.

27. At the same time we must make all possible provision for the defence and continued functioning of the home base. This will demonstrate that we have the will to survive and have no intention of surrendering even if it should come to nuclear warfare. For this purpose the R.A.F. Fighter Command must be armed with the most powerful aircraft and weapons we can develop and maintained at a high state of readiness. Home defence is no less vital than before. It is true that its character has changed. It is no longer a question of dealing with local and isolated incidents. The whole country, the Services no less than the civilian population, is involved and must be organised accordingly. For this work the Services must themselves be trained, local civilian organisations developed, and a link provided between the two. The Government have therefore decided to form a Mobile Defence Corps as part of the Army and R.A.F. reserve forces.

28. We also need defensive strength to take toll of the enemy if he attacks. To this end the Reserve Army, apart from its overseas commitments to N.A.T.O. and for other purposes, will continue to play a vital rôle. Within our resources, full preparedness in all these fields is not possible. We must apply flexible and carefully assessed priorities.

29. The discharge of our many overseas commitments in cold war conditions must continue to absorb a large share of the resources which we can make available for defence. For the rest we must, in our allocation of resources, assign even higher priority to the primary deterrent, that is to say to the production of nuclear weapons and the means of their delivery. Other elements of our defence effort must be adjusted to conform to these priorities and we must, in particular, eliminate those parts of our forces which have become or are becoming obsolete in modern conditions. We must have regard also to the kind of war in prospect; and here the governing factor is the critical importance of the initial phase. We cannot, however, be sure that the initial phase will be decisive; certainly all our efforts must be directed to securing that it is not decisive against us. Some provision, though on a lower priority, must therefore be made for continuing operations after the initial phase, particularly at sea.

**Conclusion**

30. To sum up; there are inescapable difficulties and dangers in this period of uneasy truce with the Communist Powers whose aims and policies are fundamentally opposed to our own. The monolithic nature of the Communist system seems to remain basically unaltered. Its military strength continues to grow at an impressive rate. On the surface Communist policies may appear, from time to time, more accommodating. But Communist actions have so far provided no real ground for believing that the threat to the free world has sensibly diminished.

31. These difficulties may, however, be overcome if we are patient and resolute, and these dangers avoided if we are united, vigilant and prepared. We must not be lulled into a false sense of security, nor frightened into a state of paralysis, nor provoked into hasty or ill-considered action.

32. Above all, if the free world stands together determined if necessary to defend itself with all its resources, then the nuclear weapon, in the words of the Prime Minister, " increases the chances of world peace far more than the chances of world war." There seems reason to hope that this will remain true even when the present great predominance of the West both in stocks of nuclear weapons and in the means of delivering them has been reduced. In fact, from a universal realisation that the results of a major war can only be utterly disastrous for both sides may emerge a new hope. The armed truce of recent years may develop through " co-existence " into real peace.

## II.—THE PROGRAMMES OF THE SERVICES

33. This broad review of the strategic implications of the thermo-nuclear weapon does not radically alter the rôle of any of the three fighting Services. Each has a contribution to make to the three main aims of our defence policy—to build up the deterrent against aggression, to fight the cold war, and to prepare for a major war in case it should come to that.

34. Their rôles in these three contexts are not competitive but complementary. Moreover, particularly in considering their preparations

for a major war, we must always remember that we shall not fight alone but as a member, though a leading member, of a great alliance. Thus, within limits, the pattern of our own forces must conform to that of the whole.

35. The main contribution to the deterrent is made by the Royal Air Force whose primary task now is to build up the V-Bomber force, with its nuclear potential, to the highest possible state of efficiency and preparedness. The first squadrons of V-bombers will be introduced during this year.

36. The Navy also makes its contribution of heavy carriers to the allied striking fleet whose great mobility and offensive power, to be augmented by guided missiles and by the other modern equipment which is under development, will add powerfully to our ability to hit the enemy either independently or in support of allied land forces and land-based air forces.

37. The importance of strong land forces prepared for instant action in the defence of Western Europe has already been explained. Elsewhere they are no less an essential part of the deterrent.

38. The main burden of the cold war and of our other peacetime military commitments in the Colonial Empire is borne by the Army whether in active operations against Communist guerillas in Malaya, in helping to restore law and order as in Kenya, or in maintaining confidence and stability elsewhere, for example in the Middle East. For these purposes conventional forces and conventional arms are required.

39. The Army is now able to re-build a strategic reserve in the United Kingdom. This has for long been a primary aim of our defence policy; it is essential both in the cold war and in our preparedness for a major war. In the cold war it can be used promptly to restore situations which might otherwise grow into serious or lasting commitments. It will also reduce the present high proportion of overseas service in the Army. In this way, through concentration and the better training facilities available in this country, it will increase the standard of efficiency.

40. The traditional task of the Navy in peace-time is, as it always has been, to sustain our foreign and colonial policy. The presence of Naval forces is often sufficient to provide a steadying influence. The Navy is moreover essential to the support of our strategic reserve. And in limited conflicts of the Korean type it can provide quickly, by reason of its mobility, powerful assistance to the land battle.

41. The value of the R.A.F. in the cold war is exemplified by the squadrons now engaged in active operations both in Kenya and in the Far East. In Malaya the Naval Helicopter Squadron continues to give valuable assistance. The overseas commands of the R.A.F. are receiving new equipment and will continue to maintain close liaison with other Commonwealth Air Forces. Great emphasis is placed on mobility, and the ability to reinforce overseas theatres with all types of aircraft at short notice is constantly improving. Special attention is being paid to the re-equipment of Transport Command so as to provide increased mobility for the strategic reserves of both land and air forces as well as greater capacity for co-operation with the Army in tactical airborne operations.

42. These are the various tasks of the Services in peace, or cold war. Their performance requires continuous effort and patient vigilance. But, if it should come to global war, or hot war, the tempo will change dramatically. In the critical initial stage the primary rôle will fall to the Air Force. But the tasks of the Navy and of the Army will also be vital. Above all, the highest possible state of readiness in all the three Services is essential.

43. We rely upon the striking power of the Air Force for an immediate and decisive counter-blow; for a major contribution to the defence of this country against air and sea attacks; and for air support to the allied front in Europe.

44. The threat of nuclear attack presents grave problems to our air defence forces. The control and reporting system in the United Kingdom, the overhaul of which was begun at the outset of the rearmament period, and which is already highly developed, will be further improved. The expansion of Fighter Command has been completed. Its re-equipment is now proceeding. The balance of the Command will be improved by a further increase in the proportion of all-weather radar-equipped fighters. High priority continues to be given to the development of guided missiles. Orders have been placed for air-to-air guided weapons and progress is being made with the development of other types.

45. The 2nd Tactical Air Force will be maintained at the highest possible efficiency in support of the front in Europe. Improvements will be made in this force so as to increase its fighting capacity. Coastal Command will be strengthened by the addition of some Seamew aircraft for short-range anti-submarine reconnaissance.

46. Throughout the R.A.F. means to improve the state of immediate readiness are constantly being studied and applied. To this end, aircrew with recent flying experience in operational squadrons are now chosen as immediate reserves. Changes are being made in the organisation of the Royal Auxiliary Air Force. Reserve ground personnel are being organised into reserve flights for individual regular stations. They will report to these stations immediately in emergency or on mobilisation.

47. Our Army in Europe, which will be maintained at a strength of 4 Divisions, is being organised, trained and equipped with a wide variety of up-to-date weapons. But the threat of hot war is not limited to Europe. The Army must plan and prepare for eventualities which may arise in the Middle East or the Far East as well.

48. The main effect of nuclear weapons on the land battle is greatly to increase the need for flexibility so as to be able to move from dispersion to concentration as quickly, and with as little confusion, as possible. Greater elasticity of outlook by commands at all levels will be required; the organisation of fighting units and their equipment also need modification. Experimental organisations and a revised scale of weapons and equipment, including transport, are being worked out. These will be tried out in manœuvres this year. The organisation of supporting arms and services will also have to be adjusted to enable them to back up the fighting units.

49. In the field of anti-aircraft defence it has become obvious that anti-aircraft guns are no longer effective against the speed and height of aircraft carrying thermo-nuclear weapons in attacks on area targets. Consequently, as already announced, the A.A. Command structure in the United Kingdom is being abolished. Anti-aircraft guns will still, however, be needed in the field and for the local defence of certain vital targets against which the most likely threat is from precision bombing.

50. In a major war, the task of the Navy would be to secure the sea communications without which we cannot for long survive. For this purpose we need ships and naval aircraft equipped with the latest weapons, well trained and ready to fight from the outset of war. Special attention is therefore being given to immediate readiness. In particular, a radical reorganisation of the Reserve Fleet is now in progress. The emphasis will be put on those ships which are, or can be made, ready for almost immediate service in an emergency and all these will be refitted and maintained at the shortest possible notice. Consideration is also being given to the further dispersal of the Reserve Fleet both within and outside the United Kingdom.

51. The new developments must clearly have an important effect on the character of the tasks to be undertaken by the forces stationed in the United Kingdom in the initial stage of a future war. Even under conditions of nuclear attack some of these will be engaged on Service duties of absolute priority, for example, in the bomber counter-offensive; in the air defence of the United Kingdom; in getting the Navy to sea; in reinforcing, to the extent that is practicable, overseas theatres of war and in particular the Western front in Europe; and in protecting this island against airborne invasion. The Territorial, as well as the Regular, Army will have a vital rôle to play. It is clear, however, that Service units at home not directly employed in operations would have to be used largely to aid the civilian population. Plans to enable them to carry out this task are, therefore, being developed. Section VIII of this Statement deals with these plans in more detail and outlines the proposed functions and organisation of the Mobile Defence Corps.

52. Within the limit of our resources, therefore, we are planning for a better equipped and maintained Active Fleet and a reduced but much more highly prepared Reserve Fleet; a smaller, better disposed, more mobile Army; and a more powerful Air Force including, in particular, an effective strategic bomber force. All these forces must be armed with the most modern weapons.

## III.—FINANCE

53. Despite the economic progress of the United Kingdom in the past year, the importance of maintaining a proper balance between the demands of defence and other claims on our resources necessarily imposes a financial limitation on the defence programme. As explained in the Statement on Defence 1954 our balance of payments is also affected, directly by our

overseas military expenditure and indirectly through the diversion of production resources from exports and capital equipment. The defence programme has been reviewed over the past year in the light of these considerations, as well as of the strategic background outlined above.

54. There are two further relevant factors. The first is the progressive reduction in the external economic aid on which we have hitherto been able to rely. The second is the probability that, from about the beginning of the financial year 1956–57, the bulk of the local costs of our forces in Germany will no longer be met by contributions from the Federal Republic and will fall on our own Defence Budget. Both have budgetary and balance of payments implications.

55. In addition, the Defence Estimates for 1953–54 were, and those for 1954–55 will be, considerably underspent mainly because of development difficulties associated with the newer equipments and also because of unavoidable delays in works services. The experience gained in the last two years of a whole range of factors which condition the rate of expenditure in these fields has been taken into account in preparing the estimates for 1955–56.

56. Taking all these factors into account, the total of the Defence Budget proposed for 1955–56 (not allowing for receipts from American Aid) is £1,537·2 million compared with £1,639·9 million for 1954–55. Allowing for American Aid the figures are £1,494·2 million for 1955–56 compared with £1,554·54 million for 1954–55.

**Summary of Estimates 1955–56**

57. The following tables compare the estimates for 1955–56 with those for 1954–55. An analysis of the 1955–56 figures is provided in Annex II.

NOT ALLOWING FOR RECEIPTS FROM AMERICAN AID

£ million

| | *Estimate 1954–55* | *Estimate 1955–56* |
|---|---|---|
| Admiralty ... ... ... ... ... | 367·0 | 347·0 |
| War Office ... ... ... ... ... | 561·0 | 484·0 |
| Air Ministry ... ... ... ... | 537·0 | 540·4 |
| Ministry of Supply ... ... ... | 151·0 | 147·5 |
| Ministry of Defence ... ... | 23·9 | 18·3 |
| | 1,639·9 | 1,537·2 |

ALLOWING FOR RECEIPTS FROM AMERICAN AID

| | £ million | |
|---|---|---|
| | *Estimate 1954–55* | *Estimate 1955–56* |
| Admiralty ... ... ... ... ... | 353·00 | 340·5 |
| War Office ... ... ... ... ... | 535·00 | 474·0 |
| Air Ministry... ... ... ... ... | 491·64 | 513·9 |
| Ministry of Supply ... ... ... ... | 151·00 | 147·5 |
| Ministry of Defence ... ... ... | 23·90 | 18·3 |
| | 1,554·54 | 1,494·2 |

**American Aid**

58. The total of £1,537·2 million for the Defence Budget includes provision for expenditure in 1955–56 representing £43 million of the sterling equivalent of aid from the United States of America. This aid, which is of four types, has been allotted as follows:—

| | £ million | | | |
|---|---|---|---|---|
| | *Navy* | *Army* | *Air Force* | *Total* |
| Defence Support Aid ... ... | 3 | 5 | ... | 8 |
| Agricultural Commodity Aid ... | 3·5 | 5 | ... | 8·5 |
| Special Aircraft Purchase ... | ... | ... | 16·5 | 16·5 |
| Additional R.A.F. Programme ... | ... | ... | 10 | 10 |
| | 6·5 | 10 | 26·5 | 43 |

The nature of Defence Support Aid and Agricultural Commodity Aid was described in paragraph 21 of the Statement on Defence 1954. Receipts in these categories in 1954–55 will be lower than expected and the amounts provided for 1955–56 represent the balances outstanding, together with £6 million of Defence Support Aid previously allotted to the United Kingdom and expected to accrue in 1955–56. The provision for Special Aircraft Purchase (£16·5 million) is made up of two elements. First, the £30·36 million provided in the 1954–55 Estimates and described in paragraph 21 of Cmd. 9075 will not all be received in that year, and the 1955–56 provision therefore takes account of the balance still to be received. Secondly, legislation passed by the United States Congress in 1954 provides that surplus agricultural commodities to the value of $35 million may be sold to the United Kingdom and the sterling proceeds used by the United States Government for payments in respect of military aircraft manufactured in the United Kingdom and required by the United Kingdom forces for the defence of the North Atlantic area. The provision of £16·5 million includes those receipts estimated to accrue in 1955–56 under this new arrangement, upon which, however, final decisions remain to be taken by the two Governments. The remaining item of aid is £10 million in respect of aircraft and equipment to be bought, under contracts already placed, from Her Majesty's Government by the United States Government, and to be made available to the Royal Air Force in support of the expansion and modernisation of that Service. The £10 million covers the initial part of a programme from which receipts are to be spread over approximately three years.

## IV.—MANPOWER

### Active Forces

59. **Regular Recruitment and Strengths.**—The following table gives the number of male regular recruits entered in each Service in each of the financial years 1951–52 to 1953–54, and the number which it is estimated will be entered in the financial years 1954–55 and 1955–56:—

MALE REGULAR RECRUITS

| | *Actual* | | | *Estimated* | |
|---|---|---|---|---|---|
| | *1951–52* | *1952–53* | *1953–54* | *1954–55* | *1955–56* |
| Navy ... | 11,100 | 10,100 | 9,100 | 8,100 | 8,100 |
| Army ... | 32,700 | 50,800 | 41,300 | 39,000 | 39,000 |
| R.A.F. ... | 41,200 | 38,600 | 30,700 | 27,000 | 26,100 |
| Total ... | 85,000 | 99,500 | 81,100 | 74,100 | 73,200 |

60. The following table gives the male regular strength of officers and other ranks at April 1953 and April 1954 and the estimated strengths (allowing for normal outflow and wastage, and for present regular recruiting trends) at April 1955 and April 1956:—

MALE REGULAR STRENGTH

| | *Actual* | | *Estimated* | |
|---|---|---|---|---|
| | *1 April 1953* | *1 April 1954* | *1 April 1955* | *1 April 1956* |
| Navy ... ... | 133,700 | 121,000 | 114,700 | 108,400 |
| Army ... ... | 211,300 | 216,900 | 222,900 | 203,000 |
| R.A.F. ... | 188,900 | 186,500 | 181,100 | 171,900 |
| Total ... | 533,900 | 524,400 | 518,700 | 483,300 |

61. In the Statement on Defence 1954 (paragraph 29) it was pointed out that because so large a proportion of the regular recruits of the Army and R.A.F. entered on the new three and four-year engagements, there was considerable difficulty in building up and maintaining a " hard core " of men of long service and experience. It was essential, for this purpose, that a good proportion of the short-term regular recruits should prolong their service. It was mainly to provide inducements for prolongations of service that selective increases in service emoluments were introduced in April 1954 (Cmd. 9088). The results of these pay increases cannot yet be finally assessed. In the Navy, which is particularly concerned that as many men as possible should extend their medium term seven-year engagements, the results so far are not encouraging. In the Army, while prolongations by men serving on the older (five-year and longer) engagements have shown a welcome increase, it is still too early to assess the effects on men serving on the three-year engagement. In the R.A.F. the results have been distinctly better, and there has been a definite improvement in the trades of highest skill as a direct result of the April 1954 pay increases. It remains, however, our principal manpower problem to induce adequate numbers of men to prolong their engagements. If it is not solved, not only will it be necessary

to devote excessive resources to training, movements and administrative overheads inseparable from too high a proportion of short-service men, but the general level of skill and experience in the Services will inevitably suffer.

62. **National Service Requirements.**—On present estimates of regular recruiting and prolongations of engagements, the Services will require in 1955–56 to enter about 198,000 national service men, or men who undertake regular engagements in lieu. These are allocated as follows :—

| | |
|---|---|
| Navy ... ... ... ... ... | 7,500 |
| Army ... ... ... ... ... | 130,500 |
| R.A.F. ... ... ... ... ... | 60,000 |

63. **Total Size of Active Forces.**—During 1955–56 the total strength of the active forces is expected to decline by about 35,000 to about 788,000. In the following table, total strength at April 1954 is compared with estimated strengths at April 1955 and April 1956. A detailed analysis is given in Table 1 of Annex 1.

TOTAL ACTIVE STRENGTH

| | *Actual* | *Estimated* | |
|---|---|---|---|
| | *1 April, 1954* | *1 April, 1955* | *1 April, 1956* |
| Regulars ... ... | 524,400 | 518,700 | 483,300 |
| National Service ... | 298,300 | 283,400 | 285,500 |
| Women ... ... | 23,100 | 21,200 | 19,200 |
| | 845,800 | 823,300 | 788,000 |

**Reserve and Auxiliary Forces**

64. The strength of the reserve and auxiliary forces, including part-time national service men, increased during 1954 from about 571,000 at 1st January, 1954, to about 647,000 on 1st January, 1955. The number of volunteers increased from 114,000 to 117,000.

65. The total strength of the national service reserve increased from about 457,000 at 1st January, 1954, to about 530,000 at 1st January, 1955. It will remain at about this latter figure for the further five years ending in 1959, for which Parliament has sanctioned the continuance of the current national service scheme, since the numbers completing their period of obligatory part-time service will be about balanced by new entries into the reserve on completion of colour service. The number of men who had undertaken a voluntary engagement in the reserve and auxiliary forces in lieu of part-time training liability increased from about 62,500 to about 64,500 during 1954.

66. Table 2 of Annex I compares the strength of the volunteer reserve and auxiliary forces at 1st January, 1954, and 1st January, 1955.

**Future of the National Service Scheme**

67. The Government have naturally considered whether any of the changes in defence policy which flow from the development of nuclear weapons affect the current scheme of national service.

68. Apart from building up trained reserves for an emergency, national service makes an essential contribution to the efficiency of the active forces in two main respects. First it provides the number of men necessary to ensure that the active forces are able to carry out their commitments; secondly it provides skilled men and junior leaders, both officers and non-commissioned officers.

69. Some redeployment of our forces will take place following reductions in strength in Korea and the Middle East and the withdrawal of the Trieste garrison. But there will be a considerable reduction in regular strength during the course of 1955–56; and it will still be necessary for us to maintain strong forces in many parts of the world. The building up of an adequate strategic reserve in the United Kingdom is an essential feature of our policy. Any appreciable reduction in the present period of two years' colour service for national service men would mean that there would not be sufficient numbers of fully trained men to fulfil our commitments. Moreover the ratio of productive service to time under training would be reduced. In general, our forces would be less effective and less efficient. The Government would therefore be failing in their duty were they to propose, at the present time, any reduction in the current period of whole-time national service.

**Colonial Forces**

70. At the present time the Malay Regiment, the Federation Regiment and a Battalion of the Fiji Regiment, in addition to the Royal Malayan Navy and the R.A.F. Regiment (Malaya), are actively engaged against the terrorists in Malaya. Six King's African Rifles Battalions are in Kenya, the seventh provides the garrison of Tanganyika and Mauritius, and two companies are in Uganda. The Kenya Regiment, the East Africa Independent Motor Squadron and the East African Heavy Anti-Aircraft Battery are also serving in Kenya.

71. The present strength of the armed forces raised by the Colonial territories is about 63,000. This figure is expected to fall to about 43,000 by March 1956 as pioneer units hitherto employed in the Middle East are disbanded. In addition, in certain Colonial territories local personnel are enlisted in the United Kingdom forces. These now number 14,000. The number of United Kingdom Officers and N.C.O.'s providing the necessary leadership and cadres for the organised units of the Colonial forces is about 5,000.

## V.—RESEARCH AND DEVELOPMENT

72. The financial provision for research and development in 1955–56 is about the same as in 1954–55.

73. As has already been stated, until there is international agreement on effective disarmament, our defence policy will continue to be based primarily upon the maintenance of the nuclear deterrent to aggression. This is reflected in the defence research and development programme. The work

carried out in previous years is coming to fruition in a steadily growing stock of nuclear weapons. Further work is proceeding with the object of increasing the variety and power of these weapons.

74. The development and production of manned bombers, which are at present the primary means of delivering nuclear weapons, are proceeding satisfactorily. The manned bomber may eventually be supplemented by the ballistic rocket and we are therefore working on the development of such a rocket as an addition to our deterrent strength. We are also considering methods of defence against this form of attack.

75. For the air defence of the United Kingdom, the development of high performance manned fighters and guided missiles will continue. The development of new fighter aircraft has been passing through a stage of great difficulty. This matter is discussed in a separate Statement on the Supply of Military Aircraft (Cmd. 9388).

76. The main effort in the development of guided weapons is devoted to providing defence against bombers flying at high speeds and at great altitudes. Against this threat heavy and medium A.A. guns will in the future be of little value. The future air defence system of the United Kingdom will have as its main components the manned fighter and the ground-to-air guided weapon. The balance between these weapons will vary with new developments, but it is clear that for a long time to come both will be needed to combat the bomber threat. The effectiveness of our manned fighters will be increased by fitting air-to-air guided weapons capable of engaging enemy aircraft at longer ranges and with a much greater certainty of success than is possible with aircraft armed only with cannon. Development of these air-to-air guided weapons, incorporating a variety of techniques, has reached an advanced stage.

77. The surface-to-air guided weapons which are under development for use from the land and from ships are of greater complexity than air-to-air missiles, and the time required to develop an effective operational weapon system is necessarily longer. Nevertheless good progress has been made and numerous trial firings are taking place both in this country and in Australia.

78. The Long Range Weapon Establishment and the Woomera range, set up in Australia under the Joint United Kingdom/Australia Guided Weapon Project, are playing a rapidly increasing and essential part in the later stages of development and testing of both air-to-air and surface-to-air guided weapons.

79. There is close collaboration with the United States in the guided weapon field. Comprehensive arrangements have been made for the exchange of information and of visits by technical personnel. The nature of the potential threat from the air to the two countries differs in many significant aspects. As a result, the weapons required by each country must often have different characteristics. Nevertheless, we derive great advantage from the larger development effort and the more extensive resources that the United States have been able to devote to the subject, and at the same time we make a valuable contribution of our own.

80. New possibilities for development of guided weapons are opening up with great rapidity. In planning the programme for the equipment of the Services, it is essential, therefore, to avoid the danger of devoting our necessarily limited resources to the development and production of weapons employing techniques which will quickly become obsolete owing to the advent of new knowledge.

81. It may be asked why we are not as advanced as our American allies. The simple answer is that we did not start until three years after them. The experimental establishments and the firms associated with the guided weapons programme have every reason to be proud of the work they have done: it will stand up favourably to comparison, both in quality and in rate of progress, with any in the world.

82. In framing the research and development programme of the Navy, its offensive and defensive rôles have both been closely studied. The work of improving high speed submarines of great underwater endurance, long range aircraft and weapons for use against fast and heavily armed cruisers has made considerable progress, and technical advances of high operational importance are at this moment being achieved. The development of shipborne guided weapons systems is well under way. The success of recent developments in aircraft carriers and their equipment will make it possible to use at sea heavier and faster fighter and strike aircraft, the latter being capable of carrying atomic bombs.

83. The research and development programme as a whole has recently been fully reviewed taking account of the existence of nuclear weapons. Though at first sight it might appear that the introduction of these devastating weapons would permit wholesale reductions in our activities in other directions, there are many military situations in which the use of nuclear weapons would be unsound, and it is still necessary for us to maintain our effort in the development of other weapons. Moreover, many of the projects on which we are expending a great deal of work at the present time are unproven, and with so much at stake it would be wrong prematurely to abandon all other lines of development.

84. The Statement on Defence 1954 pointed out that, because of their extreme complexity and novelty, the time taken to put the newer types of weapons through all the various stages of research and development into production "tends to be very much longer than in the past." It can be dangerous and misleading to ignore this fact. It is a mistake to assume, because it is announced that nuclear weapons, guided missiles and supersonic aircraft, for example, are under development, that they are practically ready for use in operations. This applies to all other countries as well as to the United Kingdom.

## VI.—PRODUCTION

85. Expenditure on production was a good deal less than the estimate in 1953–54 and there will again be underspendings in the current financial year. It is now apparent that, in framing the estimates for both years, an inadequate allowance was made for the development difficulties associated

with the newest equipment. For this reason and also because the production of some types of equipment can in present circumstances be reduced, the total amount to be provided for defence production in 1955–56 is estimated at about £600 million.

86. There have been no serious production as distinct from development difficulties. In general the current rate of development leads, if we are to keep pace, to relatively short runs of production. This factor, added to technical complexities, makes the organisation of production by no means easy. The problem to-day is less one of mass production of relatively simple equipment, than of the " tailor-made " production of relatively small quantities of highly complicated equipment.

87. The production programmes of the three Services in 1955–56 will be described in detail in the memoranda accompanying their respective Estimates. The following are among their principal features.

88. In the Navy the design of a new system of power-operated armament has been sufficiently proved to make it possible to resume work on the three Tiger-class cruisers which will have exceptionally high fire-power. The submarine new construction programme will continue; a high-speed experimental submarine will, it is expected, be completed in 1955–56. An experimental guided weapon ship, converted from a maintenance ship, is nearing completion and her trials are planned to begin in 1956. In the meantime, action is being taken to enable a start to be made at the earliest practicable date on the construction of a class of guided weapons ships which will replace our older cruisers. Increased effort will be devoted to refitting ships of both the active and reserve fleets to improve their efficiency and readiness. Economies in the provision of naval aircraft will flow from the reduced accident rate expected with the introduction into our carriers of the angled deck and the mirror landing device.

89. The long-term plan for the re-equipment of the Army will continue. During the year the first of a new range of wireless sets will be issued; new L.A.A. guns, new radar for the field forces and new sub-machine guns will also reach the troops. Large-scale trials of the F.N. rifle will be carried out both at home and overseas.

90. The re-equipment of the Royal Air Force with more modern and advanced types of aircraft and equipment will be accelerated in 1955–56. The first stage of the expansion and modernisation of the radar network in overseas theatres will be completed and a start will be made on the next stage of the programme both for the United Kingdom and the Continent.

91, **Offshore Procurement.**—Contracts to the value of about $200 million were placed in the United Kingdom in 1954 under the off-shore procurement programme for the purchase by the United States of military equipment for N.A.T.O. countries, bringing the total value of such contracts up to $650 million. The main items covered were aircraft (Hunters, Javelins and Sea Hawks), ammunition, Centurion tanks and electronic equipment.

92. **Military Aid from the United States and Canada.**—We have continued to receive equipment under the United States Mutual Security Act, some being produced in this country under the off-shore procurement programme. The United States has also assisted in expanding our capacity for the manufacture of propellants and explosives by providing the plant under off-shore contracts while we bear the cost of the buildings.

93. The Canadian mutual aid programme has continued. Among the items received by the United Kingdom are anti-aircraft radar, ammunition, propellants and explosives.

## VII.—CO-OPERATION WITHIN THE COMMONWEALTH AND WITH INTERNATIONAL ORGANISATIONS

### Commonwealth

94. Close co-operation and day-to-day consultations on defence matters between the United Kingdom and the other Commonwealth countries continue at all levels.

95. During the recent conference of Commonwealth Prime Ministers opportunity was taken not only to review the international scene but also to hold a series of meetings on regional defence problems. These meetings covered the main areas in which the forces of Commonwealth countries may have to be deployed in the event of war. Each was attended by representatives of those Commonwealth countries whose forces might in war be operating in the particular area under discussion. Their purpose was to enable the representatives of those countries to join together in reviewing the plans for the defence of each area and most useful progress was made.

96. It was announced last autumn that, consequent on the reduction of the American forces in Korea, it had been agreed that the Commonwealth land forces in Korea should be reduced by two-thirds. This reduction is nearly completed. The forces remaining will continue as a separate Commonwealth formation. In the Middle East and the Far East units from other Commonwealth countries have continued to serve alongside United Kingdom forces.

### North Atlantic Treaty Organisation

97. At their meeting in Paris in December, 1954, the North Atlantic Council, in addition to considering the report on the most effective pattern of N.A.T.O. military strength referred to in paragraph 23, also considered the Annual Review for 1954. They noted that there had been an increase in the strength of N.A.T.O. forces and further steady improvements in their efficiency over the past year. This improvement in quality resulted from increases in operational and support units, from the supply of large quantities of new equipment and from large-scale combined exercises.

98. The Agreements signed in Paris in October, 1954 (Cmd. 9304) provide for a number of organisational changes which will strengthen the cohesion and unity of N.A.T.O. forces on the Continent.

**Western European Union**

99. The Paris Agreements also revise and extend the Brussels Treaty of 1948 and provide for the accession of Germany and Italy to the Western European Union. On the political side they mark a further movement towards the unity of Europe. On the military side this organisation will control the level of armaments and the size of the forces of member countries on the Continent and will thus provide the instrument for a controlled rearmament of Germany.

**South-East Asia Collective Defence Treaty**

100. In September, 1954 a collective defence treaty for the South-East Asia area was signed by the Governments of Australia, France, New Zealand, Pakistan, the Philippines, Siam, the United Kingdom and the United States. The Foreign Ministers of these Governments are to meet shortly in Bangkok to consider arrangements for the fulfilment of the provisions of the treaty and to exchange views on matters affecting the peace and security of the treaty area.

## VIII.—HOME DEFENCE

101. Home defence measures, by demonstrating the country's determination to resist aggression in all its forms, buttress the resolution needed to sustain an effective deterrent policy. Against the thermo-nuclear attack of the future the best defence of the civil population in this small, crowded and vulnerable island is to try to ensure that it never materialises. But we must also in common prudence continue to provide financial and other resources for a measure of insurance in case we should fail in our main aim of averting war. The extent of these precautions and the speed at which they should be put in hand will vary from time to time with changes in the international situation and with the progress of our defence effort.

102. An outline has been given in paragraph 5 of the effect which the use of thermo-nuclear bombs would have. The very grimness of this prospect is a potent influence in restraint of war. Yet if war should come despite our efforts to prevent it, there is still much that can and must be done to mitigate the effects of a thermo-nuclear attack.

103. The new form of this threat to our security calls for a complete overhaul of our home defence plans. These must be conceived not in terms of our experience in the last war nor even of the threat posed by the atomic bomb. The advent of the hydrogen bomb calls for an entirely new approach. But the Government have not yet been able, with the information in their possession, finally to assess the implications of the latest weapon developments. This applies particularly to the extensive radio-active contamination which may be caused by the "fall-out" from a hydrogen bomb burst at ground level. Until an appreciation has been completed, it would be unwise to embark upon measures which may later prove to be misdirected.

**Civil Defence Services**

104. We are not, nor shall we ever be, able to forecast the precise effect or the extent of any nuclear attack against this country. Some areas would be destroyed, some would be on the fringe of devastation, others would escape direct damage by blast and heat. Still less can we forecast the pattern of radio-active contamination which might result from the attack. It would be quite wrong for people to assume that their neighbourhood would be sure to receive a direct hit and that they would therefore be unable to help themselves or others. It would be equally mistaken to assume that any part of the country would escape the effects of the attack and have no need of help. We are all in it, and we must all learn to help ourselves and to help each other.

105. Obviously the need for rescue, fire-fighting and welfare operations would be as great as ever. The presence of radio-activity would have to be detected and measured, and the necessary warning given to the public. The first call would have to be met by the civilian services on the spot organised by the local authorities, with the help of the Civil Defence Corps, the Industrial Civil Defence Service, the Auxiliary Fire Service and the Women's Voluntary Services, and by the National Hospital Services (including the National Hospital Service Reserve) supported by the voluntary aid societies. Every individual citizen would be needed; common sense and good neighbourliness demand that everyone should be ready to take part.

**The Rôle of the Armed Forces**

106. But the local services, though vital, would not in themselves be sufficient. They would need to be supported by all the formed and disciplined bodies of the armed forces that were available in this island. The Government have therefore decided that all members of the armed forces, including the Home Guard, will in future receive training in elementary civil defence duties as part of their normal military training. This will enable them to play an effective part in assisting the local civil defence services, in addition to carrying out their active operational rôle.

**The Mobile Defence Corps**

107. For this purpose an effective link is needed between the local civil defence forces and the organised bodies of the armed forces. This must be a disciplined body under direct military control, consisting of Service personnel and capable of rapid deployment in support of the local civil defence services wherever the need is greatest.

108. To provide this vital link the Government have decided to establish a Mobile Defence Corps specially trained in, and equipped for, fire-fighting and rescue and ambulance duties. The scope of these duties may be enlarged in time in the light of experience. Initially the aim will be to build up during the next three or four years a force of 48 reserve battalions, each of a minimum strength of about 600. Some of these will be trained and equipped to perform fire-fighting duties, others to perform rescue and ambulance duties. In an emergency these battalions, which will be distributed over the whole country, would be mobilised like any other unit of the reserve forces.

109. Men will be selected for the new Corps from the Army and R.A.F. and will receive one month's whole-time training during the course

of their active service. Special training depots will be opened in various parts of Great Britain and the intention is that about 10,000 men a year will receive whole-time training at these depots. Sufficient accommodation will be ready to receive the first intake of whole-time trainees towards the end of this year. On completion of their active service these men will be posted to reserve battalions as near as possible to their homes. They will carry out their 15 days' annual reserve training with their battalions.

110. As the new scheme develops the Government will consider the practicability of expanding the number of reserve battalions.

111. General responsibility for the new Corps will rest with the War Office, but a certain proportion of the training depots and of the reserve battalions will be manned by the R.A.F. In the event of mobilisation the reserve battalions would come under the operational control of the local Army Commander who would deploy them in consultation with the civil defence regional authorities.

112. The permanent instructional and administrative staffs required at the training depots will be found from within the active Army and R.A.F. and by the employment where appropriate of civilians. The more senior officers and N.C.O.s. of the reserve battalions will have to be found from volunteers and the Government are confident that adequate numbers with the necessary Service experience will see in this new development an opportunity for serving their country in a vital and exacting rôle.

**Scheme for Training R.A.F. Class H Reservists in Civil Defence Duties**

113. As a supplement to the Mobile Defence Corps the scheme announced last autumn for giving national service reservists part time training in civil defence duties under the Civil Defence (Armed Forces) Act, 1954, will be continued though in a somewhat modified form. All the men concerned will be trained in fire-fighting duties. In the event of war they would perform those duties with the fire service, which, as has already been announced, would be under unified and central control. The fire service would thus be able to carry out a rapid and very necessary expansion. One training depot will be ready this summer. It will accommodate about 10,000 reservists a year for their first period of basic training. A second depot will be needed for the more advanced instruction to be given to reservists in their second year's training.

**Evacuation and Shelter**

114. Besides reviewing the rôle of the armed forces in home defence the Government are also re-examining all civil defence policies, notably those on evacuation and shelter. These must now take account not only of blast and heat but also of radio-active "fall-out." The distinction between evacuation, neutral and reception areas will be far less easy to make than in the past, since the effects of "fall-out" might be felt over wide areas of the countryside and the relative safety of rural areas correspondingly reduced. Nevertheless some areas, primarily those with the greatest concentration of population and industry, would still be more vulnerable than others.

There would therefore be some advantage in spreading the risk by a measure of dispersal so long as this enabled the community to continue to function effectively.

115. Within a few miles of the point of burst it would be quite impracticable to provide protection against the violent explosive power of a hydrogen bomb. But beyond the area of devastation by blast and heat a considerable degree of protection against the effects of " fall-out " during the period of intense radiation could be secured by shelter which need not be of very elaborate construction, for example by a trench with overhead earth cover. This would have to be allied with disciplined behaviour on the part of the population and with the strict observance of suitable precautions after the attack.

116. Further study of the implications of " fall-out " must, however, be carried out before the Government can decide the best policies both for shelter and evacuation.

**Casualties and Homeless**

117. A single hydrogen bomb explosion on a built-up area would take very heavy toll of life and leave very large numbers of people injured and homeless. To the increased casualties resulting directly from the greater destructive effects of the hydrogen bomb there would have to be added the large numbers of people affected or suspected of being affected by radioactivity. Planning of the casualty services must, therefore, take account of this tremendously increased burden.

118. The need to care for those who have had to leave their homes, whether in the course of evacuation or through the destruction or contamination of their houses, would present a formidable problem in providing billets and rest centres. Full use would have to be made of every type of building in the areas to which the homeless were moved, and emergency feeding arrangements would have to be provided. Plans prepared in advance to deal with such a situation would have to be supplemented on the widest possible scale by improvisation and by readiness on the part of local authorities and the public generally to do whatever they could to help themselves and each other.

**Communications**

119. The maintenance of communications would be vital, not only to meet the operational needs of the fighting services and of civil defence, but also to make possible the organisation of supplies and movement and to disseminate essential information. The Post Office are, therefore, planning to build up a special network, both by cable and by radio, designed to maintain long-distance communication in the event of attack.

**Ports**

120. A large part of the imports into this country enters through the major ports which are vulnerable to thermo-nuclear attack. Plans have, therefore, been drawn up for the provision of alternative facilities, including the use of smaller ports and harbours. Much practical work has been done to

implement them. These arrangements cover dry cargo and oil and take account of the internal distribution of cargoes once landed.

**Stockpiling**

121. After the initial attack there would doubtless be a period during which the import and distribution of normal supplies of food and materials would be very seriously disrupted. It would be necessary to have available stocks of essential commodities, widely distributed so that they might so far as possible escape destruction or contamination. Those which would be chiefly needed would be food, in the most convenient form for storage and emergency feeding purposes; and oil, which would be required in large quantities for emergency transport and also for other purposes such as heating and cooking. Progress will be made in the coming year in building up reserves of such essential supplies.

**Finance**

122. In the financial year 1955–56, which will be an interim year while policy is being reshaped, £70 million has been provided for defence expenditure by Civil Departments (including loan expenditure by the Post Office). In addition there will be the cost of the Mobile Defence Corps. The Government will keep under review the balance between expenditure on the active forces and on home defence. It is the former which provides for the main deterrent to war and so for the basic security of the civil population. An analysis of defence expenditure by Civil Departments is given in Annex III.

**Conclusion**

123. The new problems posed for home defence by the advent of thermo-nuclear weapons do not admit of simple or immediate solution. What is said here will be amplified by further statements as studies and planning proceed. The Government believe, however, that the country is entitled to know the gravity of the possible threat and to be given an indication of the lines on which they are working to meet it. They are confident that the people as a whole will be ready and willing to play their part in building that will to resist which is an essential part of the deterrent to aggression.

# ANNEX I

## Table 1.—Analysis of Active Strengths

(Figures in thousands)

| | 1st April, 1954 (actual) | | | | 1st April, 1955 (estimate) | | | | 1st April, 1956 (estimate) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Navy | Army | R.A.F. | Total | Navy | Army | R.A.F. | Total | Navy | Army | R.A.F. | Total |
| Regular ... ... | 121·0 | 216·9 | 186·5 | 524·4 | 114·7 | 222·9 | 181·1 | 518·7 | 108·4 | 203·0 | 171·9 | 483·3 |
| National Service... | 7·8 | 221·2 | 69·3 | 298·3 | 9·3 | 203·9 | 70·2 | 283·4 | 10·2 | 200·0 | 75·3 | 285·5 |
| Women ... ... | 5·0 | 8·8 | 9·3 | 23·1 | 5·0 | 8·2 | 8·0 | 21·2 | 4·9 | 7·5 | 6·8 | 19·2 |
| Total ... | 133·8 | 446·9 | 265·1 | 845·8 | 129·0 | 435·0 | 259·3 | 823·3 | 123·5 | 410·5 | 254·0 | 788·0 |

ANNEX I

TABLE 2.—ANALYSIS OF VOLUNTEER RESERVE AND AUXILIARY FORCES AND NATIONAL SERVICE RESERVES

| | Strength at 1st January, 1954 | | | | Strength at 1st January, 1955 | | | |
|---|---|---|---|---|---|---|---|---|
| | Normal Volunteers | Volunteers from N.S. | Part-time N.S. | Total | Normal Volunteers | Volunteers from N.S. | Part-time N.S. | Total |
| *Royal Navy* | | | | | | | | |
| Royal Naval Reserve ... ... ... | 3,738 | — | — | 3,738 | 4,198 | — | — | 4,198 |
| Royal Naval Volunteer Reserve | 9,042 | 1,070 | 439 | 10,551 | 8,910 | 1,674 | 861 | 11,445 |
| Royal Marine Forces Volunteer Reserve | 1,055 | 149 | — | 1,204 | 1,046 | 347 | — | 1,393 |
| Royal Naval Special Reserve ... ... | — | — | 9,629 | 9,629 | — | — | 7,817 | 7,817 |
| Women's Royal Naval Volunteer Reserve ... ... ... ... | 1,252 | — | — | 1,252 | 1,344 | — | — | 1,344 |
| *Army* | | | | | | | | |
| Territorial Army ... ... ... | 60,310 | 55,776 | 136,694 | 252,780 | 65,101 | 54,900 | 177,443 | 297,444 |
| Women's Royal Army Corps (T.A.) ... | 9,569 | — | — | 9,569 | 8,567 | — | — | 8,567 |
| Queen Alexandra's Royal Army Nursing Corps (T.A.) ... ... | 200 | — | — | 200 | 197 | — | — | 197 |
| Army Emergency Reserve ... ... | 10,245 | 3,019 | 123,366 | 136,630 | 11,243 | 4,538 | 143,088 | 158,869 |
| Women's Royal Army Corps (A.E.R.) | 37 | — | — | 37 | 37 | — | — | 37 |
| Queen Alexandra's Royal Army Nursing Corps (A.E.R.) ... ... | — | — | — | — | 25 | — | — | 25 |
| *Royal Air Force* | | | | | | | | |
| Royal Auxiliary Air Force ... ... | 5,745 | 763 | — | 6,508 | 5,631 | 774 | — | 6,405 |
| Women's Royal Auxiliary Air Force ... | 2,415 | — | — | 2,415 | 2,036 | — | — | 2,036 |
| Royal Air Force Volunteer Reserve ... | 9,913 | 1,659 | — | 11,572 | 8,722 | 2,181 | — | 10,903 |
| Women's Royal Air Force Volunteer Reserve ... ... ... ... | 523 | — | — | 523 | 388 | — | — | 388 |
| Royal Air Force Reserve of Officers (N.S.) and Class H of the Air Force Reserve ... ... ... ... | — | — | 124,364 | 124,364 | — | — | 136,314 | 136,314 |
| Total ... ... | 114,044 | 62,436 | 394,492 | 570,972 | 117,445 | 64,414 | 465,523 | 647,382 |

# ANNEX II

Financial Year, 1955–56

## Division of the Defence Budget under the Principal Headings

(£ million)

| 1 | 2 Admiralty | | | 3 War Office | | | 4 Air Ministry | | | 5 Ministry of Supply | | | 6 Ministry of Defence | | | 7 Totals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gross | A. in A. | Net | Gross | A. in A. | Net | Gross | A. in A. | Net | Gross | A. in A. | Net | Gross | A. in A. | Net | Gross | A. in A. | Net |
| 1. Pay, &c., of Service Personnel | 53.82 | 0.73 | 53.09 | 135.84 | 16.22 | 119.62 | 91.96 | 3.00 | 88.96 | 2.80 | ... | 2.80 | 2.97 | ... | 2.97 | 287.39 | 19.95 | 267.44 |
| 2. Pay, &c., of Reserve, Territorial and Auxiliary Forces and grants for administration, &c. | 1.96 | ... | 1.96 | 16.43 | 0.19 | 16.24 | 2.80 | 0.09 | 2.71 | ... | ... | ... | ... | ... | ... | 21.19 | 0.28 | 20.91 |
| 3. Pay, &c., of Civilians ... | 46.48 | 0.56 | 45.92 | 69.30 | 1.58 | 67.72 | 39.82 | 5.08 | 34.74 | 13.93 | ... | 13.93 | 0.76 | ... | 0.76 | 170.29 | 7.22 | 163.07 |
| 4. Movements ... ... ... | 9.11 | 0.16 | 8.95 | 32.12 | 1.31 | 30.81 | 14.93 | 1.43 | 13.50 | ... | ... | ... | 0.27 | ... | 0.27 | 56.43 | 2.90 | 53.53 |
| 5. Supplies— | | | | | | | | | | | | | | | | | | |
| (*a*) Petrol, oil and lubricants | 17.28 | 5.14 | 12.14 | 10.15 | 2.49 | 7.66 | 63.25 | 2.25 | 61.00 | 2.04 | ... | 2.04 | 0.01 | ... | 0.01 | 92.73 | 9.88 | 82.85 |
| (*b*) Food and ration allowance | 12.29 | 2.44 | 9.85 | 44.05 | 9.87 | 34.18 | 19.73 | 1.05 | 18.68 | ... | ... | ... | ... | ... | ... | 76.07 | 13.36 | 62.71 |
| (*c*) Fuel and light ... ... | 4.27 | 1.69 | 2.58 | 7.27 | 1.65 | 5.62 | 7.45 | 2.23 | 5.22 | 1.49 | ... | 1.49 | ... | ... | ... | 20.48 | 5.57 | 14.91 |
| (*d*) Miscellaneous ... ... | 0.57 | 0.23 | 0.34 | 2.14 | 0.13 | 2.01 | 1.40 | 0.30 | 1.10 | ... | ... | ... | 0.12 | ... | 0.12 | 4.23 | 0.66 | 3.57 |
| | 34.41 | 9.50 | 24.91 | 63.61 | 14.14 | 49.47 | 91.83 | 5.83 | 86.00 | 3.53 | ... | 3.53 | 0.13 | ... | 0.13 | 193.51 | 29.47 | 164.04 |
| 6. Production and Research† ... | 195.31 | 28.12 | 167.19 | 155.25 | 16.25 | 139.00 | 292.00 | 38.00 | 254.00 | 667.81 | 564.18 | 103.63 | ... | ... | ... | 837.17* | 173.35* | 663.82 |
| *Production and Research providing for the appropriation-in-aid of American aid receipts*† | *195.31* | *34.62* | *160.69* | *155.25* | *26.25* | *129.00* | *292.00* | *64.50* | *227.50* | *667.84* | *564.18* | *103.63* | ... | ... | ... | *837.17** | *216.35** | *620.82* |
| 7. Works— | | | | | | | | | | | | | | | | | | |
| (*a*) Works ... ... ... | 23.89 | } 1.69 | 22.89 | 33.37 | } 4.70 | 33.32 | 66.01 | } 19.10 | 50.06 | 23.61 | ... | 23.61 | 12.70 | } 0.48 | 12.24 | 159.58 | } 25.97 | 142.1 |
| (*b*) Rents ... ... ... | 0.69 | | | 4.65 | | | 3.15 | | | ... | ... | ... | 0.02 | | | 8.51 | | |
| (*c*) Loan quarters ... ... | 1.68 | 1.68 | ... | 2.00 | 2.00 | ... | 3.80 | 3.80 | ... | ... | ... | ... | ... | ... | ... | 7.48 | 7.48 | ... |
| (*d*) Repayment of sums issued under the Armed Forces (Housing Loans) Acts, 1949 and 1953 ... ... | 0.12 | ... | 0.12 | 0.50 | ... | 0.50 | 0.44 | ... | 0.44 | ... | ... | ... | ... | ... | ... | 1.06 | ... | 1.06 |
| | 26.38 | 3.37 | 23.01 | 40.52 | 6.70 | 33.82 | 73.40 | 22.90 | 50.50 | 23.61 | ... | 23.61 | 12.72 | 0.48 | 12.24 | 176.63 | 33.45 | 143.18 |
| 8. Miscellaneous effective services | 7.35 | 1.83 | 5.52 | 10.00 | 2.12 | 7.88 | 8.70 | 4.33 | 4.37 | ... | ... | ... | 1.98 | 0.05 | 1.93 | 28.03 | 8.33 | 19.70 |
| 9. Non-effective charges ... | 16.73 | 0.28 | 16.45 | 19.68 | 0.24 | 19.44 | 5.91 | 0.29 | 5.62 | ... | ... | ... | ... | ... | ... | 42.32 | 0.81 | 41.51 |
| 10. Totals before appropriation-in-aid of American aid receipts | 391.55 | 44.55 | 347.00 | 542.75 | 58.75 | 484.00 | 621.35 | 80.95 | 540.40 | 711.68 | 564.18 | 147.50 | 18.83 | 0.53 | 18.30 | 1812.96* | 275.76* | 1537.20 |
| 11. *Totals providing for the appropriation-in-aid of American aid receipts* ... ... ... ... | *391.55* | *51.05* | *340.50* | *542.75* | *68.75* | *474.00* | *621.35* | *107.45* | *513.90* | *711.68* | *564.18* | *147.50* | *18.83* | *0.53* | *18.30* | *1812.96** | *318.76** | *1494.20* |

NOTE.—The expenditure by the Ministry of Labour and National Service in administration of the National Service Acts and in connection with the examination of volunteers for Her Majesty's Forces is estimated at £1.43 million.

* To avoid double-counting of payments by the Service Departments to the Ministry of Supply the cross totals of columns 2–6 have been reduced by £473.20 million.

† Includes the cost of development work undertaken by industry under contract, and the purchase of stores and equipment for research and development establishments.

# ANNEX III

## Defence Expenditure by Civil Departments (Net)

| Department | Item | Class and vote | 1955–56 estimate (£ million) |
|---|---|---|---|
| Home Departments... | Grants to local authorities; production of equipment and materials, &c. | Class III, 2<br>15 | 11·81 |
| Health Departments | Grants to local authorities; works (emergency hospitals, &c.); production of equipment and materials | Class V, 4<br>5<br>10<br>11 | 1·60 |
| Housing (including Scotland) | Grants to local authorities, &c.; production of equipment and materials | Class V, 1<br>10 | 0·51 |
| Ministry of Food ... | Grants to local authorities; production of equipment and materials, &c.; maintenance and turnover of food stocks; purchase of additional stocks | Class VIII,<br>10<br>11 | 23·16† |
| Ministry of Fuel and Power and Scottish Home Department | Due functioning of electricity and gas undertakings | Class IX, 6<br>and<br>Class I, 25 | 0·63 |
| Ministry of Fuel and Power | Oil storage and distribution; purchase of oil for stock | Class IX, 6 | 10·85 |
| Ministry of Transport and Civil Aviation | Due functioning of railways, civil aviation and shipping; port facilities | Class IX, 3<br>4 | 2·49 |
| Ministry of Works ... | Storage and accommodation | Class VII, 3 | 0·95 |
| Board of Trade ... | Maintenance and turnover of stocks of materials; balance of 1954–55 contracts for purchase of materials | Class VI, 3 | 4·20 |
| Post Office ... ... | Communications ... ... | Met by loan | 13·00 |
| Other Departments... | Various ... ... ... | — | 0·46 |
| | | Total ... | 69·66 |

† This includes provision of £4·8 million for the transfer of certain trading stocks to the strategic reserve.

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# A PROGRAMME OF NUCLEAR POWER

*Presented to Parliament by the Lord President of the Council and the Minister of Fuel and Power by Command of Her Majesty*
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# A PROGRAMME OF NUCLEAR POWER

## CONTENTS

# A PROGRAMME OF NUCLEAR POWER

1. An important stage has been reached in the development of nuclear energy for peaceful purposes. Hitherto the work in this country has consisted of a military programme, a broadly based research and development programme, and the production and use of radioisotopes. The military programme continues to be of great importance but the peaceful applications of nuclear energy now demand attention. Nuclear energy is the energy of the future. Although we are still only at the edge of knowledge of its peaceful uses, we know enough to assess some of its possibilities.

2. Our future as an industrial country depends both on the ability of our scientists to discover the secrets of nature and on our speed in applying the new techniques that science places within our grasp. The exact lines of future development in nuclear energy are uncertain, but this must not deter us from pressing on with its practical application wherever it appears promising. It is only by coming to grips with the problems of the design and building of nuclear plant that British industry will acquire the experience necessary for the full exploitation of this new technology.

3. The application that now appears practicable on a commercial scale is the use of nuclear fission as a source of heat to drive electric generating plant. This comes moreover at a time when the country's great and growing demand for energy, and especially electric power, is placing an increasing strain on our supplies of coal and makes the search for supplementary sources of energy a matter of urgency. Technical developments in nuclear energy are taking place so fast that no firm long-term programme can yet be drawn up. But if progress is to be made some indication must be given of the probable lines of development so that the necessary preparations can be made in good time. A large power station may take five or more years to complete, including finding the site, designing the station and building it. Some of the special materials needed for nuclear power may take several years to get. Moreover, the main burden of building and designing commercial nuclear power stations will fall upon industry who will have to see that the necessary staff are trained. These are some of the many things that must be started soon if we are not to waste precious years in building up this new and unfamiliar industry.

4. Her Majesty's Government have therefore prepared a provisional programme of nuclear power which covers the next ten years in some detail and gives an indication of the probable developments in the following ten years. It will be constantly modified as time goes on and at each stage final decisions will not be taken until the last possible moment so that new technical developments can be used to the fullest advantage.

## PART I

## THE PROBABLE LINES OF DEVELOPMENT OF NUCLEAR POWER

5. The principle of nuclear fission and the methods by which a nuclear reactor can be used in place of a coal or oil-fired furnace to provide heat for an electric generating plant have been described in various publications.* A short account is given in Annex 1 which also describes

* See particularly "*Harwell: The British Atomic Energy Research Establishment*", London H.M.S.O., 1952, and "*Britain's Atomic Factories*", London H.M.S.O., 1954.

the experimental nuclear power station now being built at Calder Hall in Cumberland and some of the different types of nuclear power station that might be built in the future. The Calder Hall station is the first attempt in the United Kingdom to produce electricity from nuclear energy on a large scale. Future developments, so far as they can now be foreseen, are likely to be directed at two main objectives: using the main nuclear material, uranium, more efficiently; and reducing the capital cost per kilowatt of a nuclear power station, in terms both of the construction of the reactor and of its initial charge.

6. During the next ten years two types of reactor are likely to be brought into use on a commercial scale. The first type will be similar to those now being constructed at Calder Hall, but improvements in design during the period should enable the later models to show a great advance in efficiency compared with the earlier ones. They will be gas-cooled graphite-moderated "thermal" reactors using as fuel natural uranium or slightly "enriched" uranium, i.e. fuel having a slightly higher fissile content than natural uranium. The first improved models could be designed and built so as to come into operation in about six years' time.

7. These first reactors will burn only a very small proportion of the natural uranium placed in them but they will produce, in addition to heat, the element plutonium which does not occur in nature. This plutonium which can be extracted chemically from the used fuel is potentially very valuable: it is a pure fissile material whereas natural uranium contains only one part in 140 of fissile material.

8. The second type of reactor that may be built for commercial operation during the next ten years is a liquid-cooled "thermal" reactor. This type requires more complicated techniques which at present would result in higher costs. But with further development liquid-cooled reactors should be able to give a much higher heat rating* than the first gas-cooled reactors for the same capital cost. They might therefore eventually prove more economic than the gas-cooled reactors although the comparison will depend on how much the gas-cooled type can be improved. They could take any of several forms (see Annex 1) most of which need "enriched" fuel and could use for this purpose the plutonium produced in the earlier reactors in conjunction with natural uranium. The first commercial liquid-cooled reactors might be built during the latter part of the next ten years and begin operating about 1965.

9. Development after 1965 may take various forms: thorium may be used, at first in conjunction with plutonium, as an alternative fuel; "homogeneous" and "fast breeder" reactors may be developed. It has already been decided to build a full-scale experimental model of a "fast breeder" reactor capable of producing power on a site at Dounreay in Caithness. There is no doubt that the commercial reactor that emerges after these developments as the most suitable, whatever type it may be, will have a lower capital cost per kilowatt and a better utilisation of the nuclear fuel than any of the earlier reactors.

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* The heat rating of a reactor is the rate of production of heat from each ton of fuel in the reactor.

## PART II

### THE PROBABLE COST OF NUCLEAR POWER

10. An estimate can be made of the cost of electricity produced by the two types of reactor likely to be in commercial use in the next ten years although it must be subject to a wide margin of uncertainty. Experience of operating reactors at high temperatures and under the high rates of heat extraction required for power is still limited. To the technical uncertainties about the characteristics and performance of the reactors themselves must be added the rather different uncertainties about the supply and value of the nuclear materials required by and produced by a reactor system. In what follows the results of making assumptions on these counts should be regarded as giving only an approximate and not an exact estimate of cost.

**Capital and Overhead Costs**

11. A reasonably accurate estimate of the constructional cost of the first commercial stations can be made. A station of the same type, but designed to produce fissile material for military purposes as well as electricity, is already being built at Calder Hall at a cost of £15–£20 million. Even the first commercial reactors of the Calder Hall type can be expected to show a higher heat rating than those now under construction, so that the capital cost per kilowatt will be lower. A new station might have an electrical output of 100–150 megawatts or even 200 megawatts. We have no experience on which to base an estimate of the working life of a reactor in a commercial station but a life of between 10 and 20 years seems to be a reasonable technical assumption. As nuclear stations will have a higher capital cost and a lower running cost than other stations they will be run as base-load stations at a high load factor (perhaps 80 per cent).* On these assumptions a rough figure for the annual overhead cost for each unit of output can be calculated. The works and operating costs, excluding fuel costs, can be estimated from the experience of operating coal-fired power stations and the military reactors at Windscale.

12. Developments in reactor design such as the introduction of liquid cooling should gradually lead to much higher heat ratings without much increase in capital cost. This would reduce still further the capital cost per kilowatt and thus reduce the overheads.

**Fuel Costs**

13. The fuel cost depends on three things: the cost of the raw material, uranium; the processing cost, including the conversion of ore into fabricated fuel elements, the chemical processing of the used fuel elements and the extraction of plutonium from them; and the "level of irradiation", that is, the amount of heat that can be got from each ton of fuel in the reactor before it has to be taken out.

14. Her Majesty's Government consider that enough uranium will be available for the civil programme over the next ten years, after making the best assessment possible of world supplies and of world requirements for all purposes. The cost of the initial charge of fabricated uranium for one of the early types of station similar to Calder Hall may amount to about £5 million;

* The load factor of a station is the ratio of the average load to the peak load carried by the station in each year. The stations having the lowest running costs are operated on the "base load" (i.e., they are used to supply the demand that is present the whole time) and therefore have a high load factor.

a new charge costing the same will be needed every 3–5 years. The cost of processing uranium, both before and after use, is known from the processes now being worked at the Springfields and Windscale factories for the military programme. In the early stages of a power programme the processing costs will be similar, but big reductions can be expected later when new factories are built.

15. It is expected that it will be possible to extract as much as 3,000 megawatt-days of heat from every ton of fuel.* This is the equivalent of the heat from 10,000 tons of coal. There is as yet no practical experience of this level of irradiation at high temperatures and the metallurgical behaviour of the fuel elements is uncertain. But there are many lines of development which should overcome such metallurgical defects as may appear.

### The Cost of Electricity and the Credit for the Plutonium By-product

16. Some credit should be allowed for the fissile by-product plutonium. It is in many ways equivalent to uranium 235, another form of fissile material. But plutonium can be extracted by chemical means from a power reactor's used fuel for only a fraction of the cost of separating uranium 235 from natural uranium in a diffusion plant. When concentrated fissile material is available in quantity there will be great scope for the design and development of more advanced and more efficient reactors that need "enriched" material and will not operate on natural uranium. For example, most types of liquid-cooled reactor need "enriched" material; and, looking further ahead, concentrated fissile material in the form of either uranium 235 or plutonium is required for a "fast breeder" reactor or for starting a thorium system. In this manner the early reactors will be producing not only electricity but also the capital equipment (i.e. the initial charge of fissile material) for future power stations. Without the plutonium it would not be possible to build up a system of nuclear power stations of steadily advancing efficiency.

17. In the early stages of an expanding nuclear power programme it is to be expected that concentrated fissile material will be scarce and that if there were a free market its price would be high. It will be required for enriching the fuel charge in new commercial reactors, and also for many experimental and development purposes including the fuelling of prototypes of advanced design. Eventually the system will reach the stage where more plutonium is produced than the new power stations require; its "market" price will then fall and it might be used as a substitute for natural uranium rather than as concentrated fissile material. This is unlikely to happen for 15 or 20 years.

18. It is not obvious what is the right value to put on the plutonium produced, although the effect on the net cost of electricity could be considerable. A high value in the early stages of the programme means a lower net running cost for the early reactors but adds a heavier capital charge on to the later ones, which they might well be able to afford because of their higher efficiency. Limits can be set to the value of the plutonium by considering the uses to which it might be put. At worst it could be fed back into a reactor as fuel in place of natural uranium; and since natural uranium contains only one part in 140 of fissile material, plutonium should be worth at least 140 times as much, weight for weight. At best plutonium is not likely to be worth more than the cost of uranium 235 separated from natural uranium in a diffusion plant. There is a wide range between these limits but both values can be measured in terms of thousands of pounds sterling for a kilogram of plutonium. In the early period it is thought right

* See paragraph 8 of Annex 1.

to allow for the plutonium at a rate of many thousands of pounds a kilogram; the value should eventually fall but would have a significant effect on the cost of generating electricity.

19. On the assumptions set out above, and taking what appears to be a reasonable value for the plutonium, the cost of electricity from the first commercial nuclear stations comes to about 0·6d. a unit. This is about the same as the probable future cost of electricity generated by new coal-fired power stations (see Annex 2 para. 10). If no credit were allowed for the plutonium the cost of nuclear power would be substantially more than 0·6d. a unit. Later stations should show a great improvement in efficiency, but the value of plutonium would probably fall considerably during their lifetime. Even so their higher efficiency should enable them to remain competitive with other power stations.

20. These estimates assume that all the plutonium is used for civil purposes, as would be most desirable. No allowance has been made for any military credits.

## PART III

## A PROVISIONAL PROGRAMME

21. Her Majesty's Government consider that the development of nuclear power has reached a stage where it is vital that we should apply it commercially with all speed if we are to keep our position as a leading industrial nation and reap the benefits that it offers. The programme outlined below is provisional and must be considered only as the best indication that can now be given of the probable line of development. Types of stations, numbers and dates are all subject to change.

22. Although the decision to go ahead with a nuclear power programme does not depend on precise comparisons of cost, the outline given above has shown that the cost of nuclear power should not be greatly different from the cost of power from coal-fired power stations. This country has a rapidly growing demand for energy, particularly in the form of electric power, and increasing difficulty in producing the necessary quantities of coal. These facts by themselves would justify a great effort to build up a nuclear power system.

23. The stations will be built in the normal way by private industry for the Electricity Authorities,* who will own and operate them. The Atomic Energy Authority, as the only body with the necessary experience, will be responsible for giving technical advice on the nuclear plant. British industry and consulting engineers have as yet no comprehensive experience of nuclear technology. They will be faced with a major task in training staff, in creating the necessary organisation and in designing the stations. This work has already begun. Owing to its complexity and diversity teams drawn from several firms may have to be formed. The preparatory work will call for great efforts from all concerned, and even so it will not be practicable to start building any commercial stations before 1957.

* These are at present the British Electricity Authority, the North of Scotland Hydro-Electric Board and the Northern Ireland Electricity Board. On 1st April 1955 the South of Scotland Electricity Board will come into existence and the Central Electricity Authority will replace the British Electricity Authority.

24. It is intended that the Electricity Authorities and private industry should obtain as quickly as possible the practical experience in designing and building nuclear power stations that will be the necessary foundation for a big expansion in the later stages of the programme. The Atomic Energy Authority, while giving as much assistance and advice to industry as possible, will remain primarily a research and development organisation and will continue to design, build and operate pioneering types of power reactor. They will also be responsible for buying uranium, fabricating the fuel elements, processing the used fuel and extracting the plutonium from it. There will therefore have to be a continuous process of co-operation and of financial adjustment between the Electricity and Atomic Energy Authorities. The exact arrangements to be made are at present being discussed with them.

**Power Stations**

25. The provisional programme for the construction of nuclear power stations* is as follows :—

(i) The construction of two gas-cooled graphite-moderated stations (each with two reactors) would be started about mid-1957. These stations should come into operation in 1960-1961.

(ii) The construction of two further stations would be started about 18 months later, i.e. in 1958-1959. These would also have two reactors each and would be similar in type to the earlier two stations but should show an improved performance, particularly in heat rating. Each of the eight reactors in these early stations would have a net output of electricity of 50 to 100 megawatts so that the total output from the four stations, which should all be in operation by 1963, would be somewhere between 400 and 800 megawatts.

(iii) The construction of four more stations might perhaps start in 1960, and then a further four 18 months later, say, 1961-1962. These might come into operation in 1963-1964 and in 1965. It is difficult to specify what type of station these would be, but it is probable that each station would consist of only one reactor, which would be much more highly rated than the reactors in the first four stations. The stations begun in 1960 might be developments of the gas-cooled graphite-moderated type. The last four stations might be of the liquid-cooled type which might by then have been developed sufficiently to be economically satisfactory. The total installed capacity of the eight stations in this group should be well over 1,000 megawatts.

26. The ten-year programme would provide a capacity of about 1,500 to 2,000 megawatts. By the end of the ten years this country would probably be needing new generating capacity at the rate of over 2,000 megawatts a year, and the new nuclear stations coming into operation each year would be meeting something like a quarter of this. On the assumption that nuclear stations would be used as base-load stations they would by 1965 be producing electricity at a rate equivalent to that produced by about 5 to 6 million tons of coal a year. Assuming that the programme continued to expand rapidly, this contribution towards the country's energy needs should also rise rapidly thereafter.

* The term " station " is used here to denote the smallest unit that is likely to be built. In practice more than one such station may be built on the same site.

27. The plutonium from the early reactors should begin to become available in 1964 at the rate of several hundred kilograms a year and would be available for enriching the fuel charges in later, probably liquid-cooled, reactors. These reactors would in turn produce plutonium and being more highly rated would produce it more quickly so that it would be available for a rapidly expanding programme of reactors requiring enriched fuel in the late 1960s.

**Ancillary Plant**

28. The present ancillary plant, which has been built and is used primarily for military purposes, will be adequate at first for a commercial programme of this magnitude but some expansion will be necessary later. A new fuel processing and fabricating plant will be needed in due course in addition to the existing factory at Springfields to meet the rapidly increasing demand for nuclear fuel; and a new chemical processing plant will eventually be needed to deal with the large quantities of used fuel taken out of the nuclear power stations. Such slight enrichment as may be necessary for the fuel elements in the early stations can be provided from the existing capacity of the diffusion plant at Capenhurst.

**Cost**

29. The capital expenditure on the construction and installation of the stations in the programme will be considerable. The cost of the first two stations together (comprising four reactors) would probably be between £30 million and £35 million. The next two stations which would have a much higher output would cost perhaps slightly more, while the cost of the last eight stations would be in the region of £125 million in total. The cost of the initial charges of uranium, including fabrication, might amount to a further £40 million. The new ancillary plant that would be required within the 10-year period might cost £30 million. The concurrent capital expenditure on prototype development might be £30 million to £40 million. The cost of the ten-year programme might therefore come to £300 million. The rate of expenditure on the commercial applications of nuclear power would rise steadily during the period and the total over the ten years would amount to more than the £300 million, since it would include expenditure on stations that would not be completed until after 1965 and do not appear in the present programme.

30. This investment will not be a wholly additional demand on the economy. The nuclear power stations will be built instead of other types of station. The investment by the Electricity Authorities in new coal or oil-fired generating capacity over the next ten years would, in the absence of nuclear power, probably be of the order of £1,200 million. With a nuclear power programme there will be a significant reduction in this figure which can be set off against the investment in nuclear power. The National Coal Board should also be able to reduce its investment programme in some ten years time below what would have been necessary in the absence of nuclear power.

31. No accurate assessment can be made so far ahead of the amount of additional investment that the economy will be able to afford. All that can be said is that, given a normal rate of growth of gross national product and given that a reasonable proportion of the increase in resources is made available for an increase in investment, there would not appear to be any great difficulty in accommodating a nuclear power programme on the scale here proposed. It is unlikely that the rate of expansion of investment in the fuel and power industries over the next ten years, even including this programme, will exceed the rate of the expansion in real terms that has taken place since 1948.

**Long-Term Prospect**

32. From about 1965 it may be economically desirable to build nuclear power stations instead of coal-fired stations, even without taking account of any long-term difficulties in the supply of coal. Cheap power is a great asset to any industrial country and the more quickly we can convert power generation to the cheaper system the sooner we can hope for a reduction in the real costs of production.

33. On the provisional programme the new nuclear power stations would by 1965 be meeting a quarter of the total requirement of new generating capacity. How quickly it would be possible to expand the programme to match the whole of this requirement will depend upon the progress made in the first ten years. The programme for this first period may be subject to frequent and major change according to the speed of technical development and the success of the early stations. Any attempt to forecast the developments after 1965 must be even more uncertain.

34. The possibilities of expansion will depend to a great extent on the speed with which the necessary techniques are mastered by industry at large. The Atomic Energy Authority will continue to make new information available and to provide training; with this help industry should acquire wide experience in carrying out a 10 year programme of the type that has been outlined and this would make possible a much greater expansion after 1965. If all went well it might be practicable by the early 1970s to expand the rate of construction of nuclear power stations to match our total requirement of new generating capacity, which by this time might amount to about 3,000 megawatts a year. On this assumption the total nuclear power station capacity installed by 1975 would be of the order of 10–15,000 megawatts, the whole of which could be used for base-load operation. The nuclear power stations would then be producing electricity at a rate equivalent to that produced by about 40 million tons of coal a year.

35. Another possible limitation on the rate of expansion in the later years is the supply of nuclear fuel, particularly the more highly enriched material that will be needed for some of the advanced types of reactor. By the late 1960s the early reactors should be producing plutonium in quantity and this would be available for the later reactors. The provisional programme and the further expansion thereafter will also call for increased supplies of uranium; and no doubt other countries will be increasing their commercial demands at the same time. Recent evidence suggests that uranium is more plentiful than was once thought; considerable workable deposits of medium-grade ore are known while the widespread existence of low-grade ores implies that adequate quantities can be produced from them if necessary. Moreover the expansion in the requirement of uranium should be mitigated by the greater economy in its use that will by then have been achieved and by the possible development of the substitute fuel thorium, which should be available in considerable quantities if it is required. For these reasons Her Majesty's Government are confident that the necessary supplies of raw material will be available to meet the increases in demand.

**Siting and Safety**

36. The history of the development of nuclear energy has made everyone aware of its destructive possibilities and it would be natural to ask whether there were any special dangers associated with nuclear power installations. The first important thing to recognise is that it is impossible for an " atomic

explosion" to take place in a power reactor. If nuclear power facilities are properly designed any accidents that may occur will be no more dangerous than accidents in many other industries.

37. The main hazards in a nuclear power station are caused by the concentration of highly radioactive materials. But these are known dangers which can be guarded against, both by precautions in the design of the reactor itself and if necessary by enclosing some or all of it in a gas-tight container. The reactors that will be built for the commercial production of electricity will present no more danger to people living nearby than many existing industrial works that are sited within built-up areas. Nevertheless the first stations, even though they will be of inherently safe design, will not be built in heavily built-up areas.

38. The disposal of radioactive waste products should not present a major difficulty. The problem is primarily one for the chemical processing plants, which will be few in number, and not for the power stations. The volume of waste will be small and great efforts are being made to determine the most economical methods of storing or disposing of it. There are many valuable uses for it which may be able to absorb a great part of the output. Any material that is discharged will be tested to ensure that it is of extremely low radioactivity, so that it will be harmless and comparable in effect to the natural background radioactivity which is always present.

**International Aspects**

39. Her Majesty's Government have always been in favour of the greatest possible international co-operation in the peaceful uses of nuclear energy, so that full use can be made of this great new scientific development for the benefit of the world. The Government have recently acted as joint sponsor for the proposal before the United Nations, which has now been approved, to set up an International Atomic Energy Agency and have agreed to make available to the Agency 20 kilograms of fissile material. They intend to play a full part in the international scientific conference on the peaceful uses of nuclear energy that is to be held later this year.

40. Physicists and engineers from a number of countries have taken the opportunity of learning nuclear technology by attending schools and courses in this country such as the Reactor and Isotopes Schools at Harwell. So far as resources permit we intend to provide further facilities for nationals of other countries to attend these schools. Other countries will also be helped to build experimental and development reactors which are an essential preliminary to the building of commercial reactors. We are already helping in this way a number of Commonwealth and European countries.

41. We must look forward also to the time when a valuable export trade can be built up. The experience gained by British industry in designing and building nuclear power stations during the next ten years should lay the foundations for a rapid expansion both at home and overseas. At the moment nuclear power generation is still in the development phase; the exact economics of nuclear power stations are uncertain; and the stations when built will still be pioneering projects and will need much skilled attention. But as time goes on the design of the stations will be improved, the cost of electricity from the stations will be known more exactly and, above all, their construction and operation will have become standard engineering practice. We shall then be in a position to fulfil our traditional role as an exporter of skill, to the benefit both of ourselves and of the rest of the world.

## PART IV

## THE PLACE OF THE PROGRAMME IN THE GOVERNMENT'S FUEL POLICY

42. In a debate in the House of Commons on 9th July, 1954,* the Minister of Fuel and Power, in describing the fuel and power policy of Her Majesty's Government, said that one of its main objectives was to supplement supplies of coal with other kinds of energy—atomic energy as soon as possible and oil forthwith. The previous three Parts of this Paper have given an account of the possible development of nuclear power in this country so far as it can be foreseen now. They express the Government's hopes and views about the scale and timing of the commercial use of nuclear power. It can now be shown how this possible development would fit in with the energy requirements of this country and with the supply of other fuels.

### Electricity

43. The use of electricity has grown rapidly in all countries ever since it was introduced commercially in the 1880s. The average increase has been about 7 per cent. a year which means that consumption has doubled every 10 years. This cannot be expected to go on for ever but so far there is no sign that the demand for electricity is even beginning to approach saturation point either in this country or anywhere else, even in countries with a much higher consumption a head than ours.

44. An estimate of the demand for electricity in Great Britain during the next 20 years is given in detail in Annex 2. The demand is expected to continue to grow rapidly although at a slower pace than before. It is likely to be some 3½ times the present level in 20 years' time. To meet this growth in demand, with the opportunity it will offer for higher productivity and efficiency throughout the economy, it is estimated that the installed generating capacity, which averaged 20,000 megawatts in 1954, will have to be increased to 35–40,000 megawatts by 1965 and to perhaps 55–60,000 megawatts by 1975. If the provisional programme suggested above were completed—in practice it is certain to be modified one way or the other—it would provide 1,500 to 2,000 megawatts of nuclear power by 1965 and somewhere between 10,000 and 15,000 megawatts by 1975. The nuclear power stations would be operated on base load and would supply a higher proportion of the total power than the ratio of these figures would suggest.

### Coal Supplies

45. Without nuclear power the rate of consumption of coal (or its equivalent as oil) by the power stations alone would increase on the assumption in the last paragraph by perhaps 2½ times over the next 20 years, reaching about 65 million tons a year by 1965 and 100 million tons a year in the 1970s, and would at that time be rising by 4 or 5 million tons a year. On the basis of the provisional programme of nuclear power, the coal required by power stations would level off in the region of 60 to 70 million tons a year during the course of the 1960s. This levelling off in the demand for coal for power stations would come none too soon to help with the difficulties of finding manpower for the mines and of producing at reasonable cost enough coal for the other users of solid fuel whose demand would have been steadily rising meanwhile.

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* House of Commons Report. Vol. 529 : No. 145, col. 2517.

46. Since the war the production of coal from deep mines has increased from 175 million tons in 1945 to 214 million tons in 1954. But the demands of our expanding home industries have been rising even faster. We have had to supplement output from the deep mines by opencast coalmining and by importing coal, and even so supplies for the householder are still restricted and there is not enough for exports. The National Coal Board have in hand a large programme of capital investment which has gone ahead rapidly in the last year or two; but a great part of this will be needed to maintain the output of the mines at the present level. Greater efficiency in the use of coal and substitution of oil for coal in certain processes including electricity generation will give some limited relief, but the increasing demand for fuel cannot be met without exploiting to the full any new and economic technique available.

47. The provision of enough men for the mines is one of our most intractable problems and is likely to remain so. In order to meet the present demand for coal recourse has been had to voluntary Saturday working as well as to opencast production and to imports: but the demand continues to increase. Any relief that can come from other sources of energy such as nuclear power will do no more than ease the problem of finding and maintaining an adequate labour force. There can be no question of its creating redundancy. The mining industry will in any case remain one of the major employing industries of the country, but it may hope to be relieved by the advent of nuclear power of the excessive strains which are now being put upon it.

## PART V

## CONCLUSION

48. Our civilization is based on power. Improved living standards both in advanced industrial countries like our own and in the vast underdeveloped countries overseas can only come about through the increased use of power. The rate of increase required is so great that it will tax the existing resources of energy to the utmost. Whatever the immediate uncertainties, nuclear energy will in time be capable of producing power economically. Moreover it provides a source of energy potentially much greater than any that exist now. The coming of nuclear power therefore marks the beginning of a new era.

49. As a leading industrial nation our duty, both to ourselves and to other countries, is to establish this new industry of nuclear energy on a firm foundation and to develop it with all speed. It is a major industrial development that will bring with it revolutionary changes in technique. We shall only learn the new techniques by pressing forward with the practical applications wherever we can and in spite of the many uncertainties surrounding each enterprise.

50. The programme that is described here is provisional and will be altered in many ways in the course of time. But it is hoped that it gives a clear enough picture of the probable scale, scope and timing of developments to put nuclear power in its proper perspective and to show how it will fit in as one of the sources of energy that will be available to meet the rapidly growing needs of our expanding economy.

51. The large-scale production of nuclear power cannot be brought about quickly. The first commercial, as opposed to experimental, stations will not be in operation for at least five years. But if proper preparations are made now it will be possible for nuclear power to be produced commercially in significant quantities within ten years. The experience gained from building and operating stations during these ten years should make possible a much more rapid expansion thereafter at home and abroad.

52. New technical developments that cannot at present be foreseen may perhaps lead to a more rapid improvement in the performance of stations than has been assumed. If so we should be in a good position to take advantage of such developments. On the other hand the provisional programme may turn out to be too optimistic : the stations may take longer to design and to build ; they may cost more ; the amount of development work needed may have been understimated. If any of these things happened nuclear power would come later or be more expensive than the programme suggests. Her Majesty's Government consider that these risks must be accepted.

53. This formidable task must be tackled with vigour and imagination. The stakes are high but the final reward will be immeasurable. We must keep ourselves in the forefront of the development of nuclear power so that we can play our proper part in harnessing this new form of energy for the benefit of mankind.

## ANNEX 1

## THE GENERAL PRINCIPLES OF NUCLEAR POWER

### The Nature of Nuclear Reactions

1. Mankind relies at present on two main sources of energy:—

(*a*) Chemical reactions (where energy is released mainly in the form of heat derived from the burning in air of such organic substances as wood, coal, and oil), and

(*b*) naturally occurring movements of large masses of matter (winds, and water falling under gravity).

The source of energy with which we are now concerned is fundamentally different from these forms of energy, although they are all ultimately derived from solar energy, which is itself a product of nuclear reactions taking place in the sun.

2. The atoms of which matter is composed, of which there are about 100 different kinds, are all constructed on the same pattern: they consist of a dense central nucleus which carries a positive charge and is surrounded by a field of negatively charged electrons. The nucleus itself is made up of positively charged protons and uncharged neutrons. The number of protons, which equals the number of electrons, determines the chemical properties of the atom; while the total number of the particles in the nucleus (protons and neutrons) determines its mass. A change in the number of neutrons affects the mass of the atom but leaves its charge (and therefore its chemical nature) unaltered. Chemically identical atoms, that is, atoms having the same charge but different masses, are called isotopes. Uranium 235 and uranium 238 are different isotopes of the same chemical element uranium, the number after the name of the element indicating the mass of the atom, i.e., the total number of protons and neutrons in the nucleus. Isotopes may be stable or they may be radioactive, i.e., tending to change spontaneously into other atoms or isotopes while at the same time emitting particles or radiation. A change in the number of protons, on the other hand, affects the charge of the nucleus and therefore the chemical nature of the atom. The new chemical element produced by such a change may also be stable or radioactive. The radioactivity of different elements plays an important part in nuclear energy.

3. The commonest type of interaction between atoms affects only the electrons; the nucleus remains untouched. Reactions of this kind, of which the burning of coal is one example, are called chemical reactions and the energy they release or absorb is relatively moderate. The energy and heat processes involved in a modification of the nucleus of an atom are about a million times greater. The purpose of nuclear fission or hydrogen fusion is to achieve the release of energy on this scale. A controlled hydrogen fusion reaction is not at present in sight, but the control of nuclear fission is well established.

4. Nuclear fission takes place when a free neutron, the uncharged constituent of the nucleus, is made to strike the nucleus of a fissile element, e.g., uranium 235. The three main results are as follows:—

(*a*) The nucleus splits into two "halves" which fly apart releasing energy which appears as heat.

(*b*) Several new neutrons are released by the affected nucleus. These can serve a variety of purposes: —

(i) Some of them may collide with other fissile nuclei, repeat the process of fission, and so establish a chain reaction, which can be controlled to provide a continuing release of energy.

(ii) Others may be captured by the nuclei of neighbouring non-fissile atoms, such as uranium 238. This then becomes uranium 239 which is radioactive and changes rapidly to plutonium 239. Plutonium 239, by contrast with uranium 238, is fissile, that is, it will itself undergo fission when struck by a neutron.

(iii) Finally, some neutrons may be a total loss, in the sense that they may be absorbed or lost in ways which make no contribution either to the chain reaction or to the production of fresh fissile material.

(*c*) The two " halves " into which the original nucleus splits are called fission products. In general they are radioactive and because they are potentially harmful to life and may be destructive of materials it is necessary to keep control of them for a long time ; but fortunately their bulk can be made quite small.

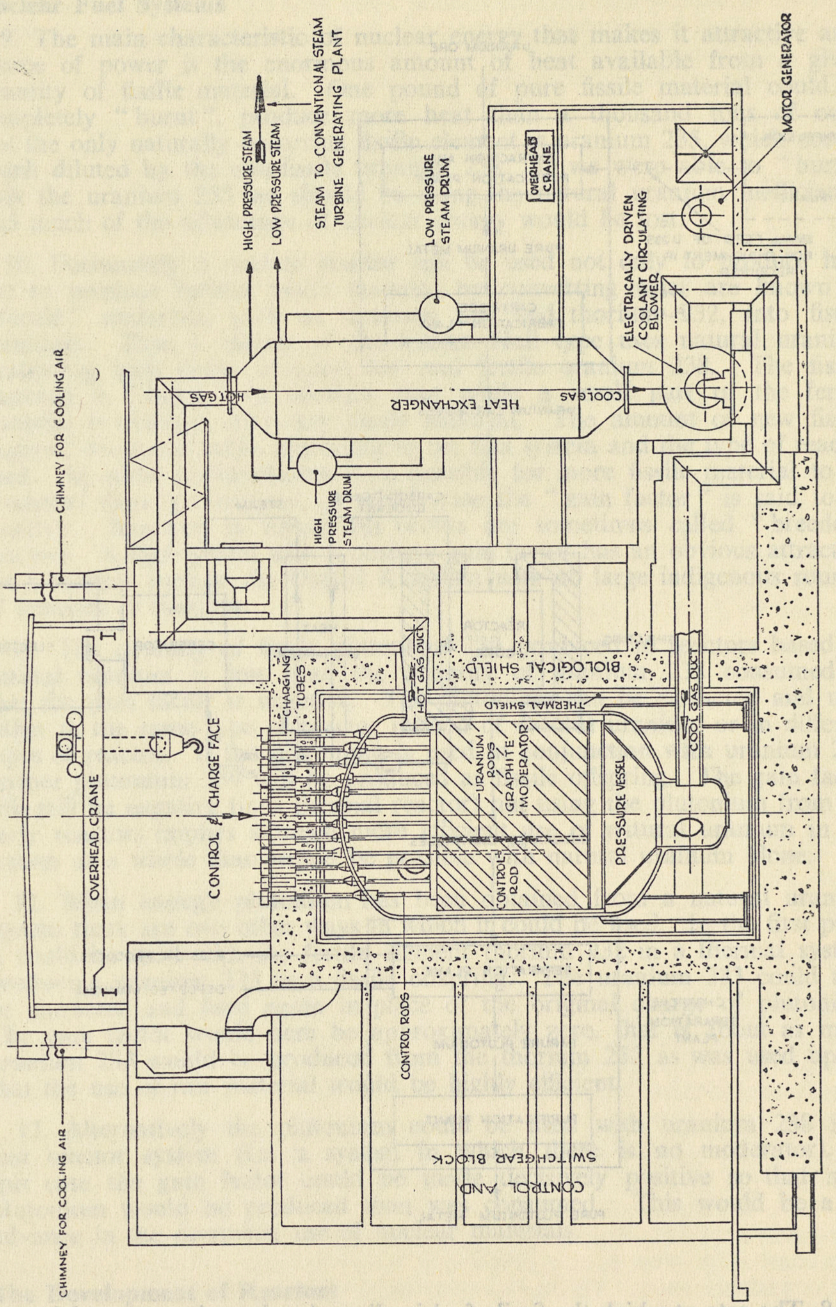
5. The heat from the fission of the nuclei can be used to produce steam to drive an electric generating plant. The reactor, i.e. the plant in which fission takes place, is thus the equivalent of the coal or oil-burning furnace of existing power stations.

**A Typical Nuclear Reactor**

6. The practical application of these basic principles can be illustrated by the reactors two of which form part of the experimental power station now being constructed at Calder Hall. This kind of reactor, which is illustrated in Chart I, consists of a mass or core of graphite which is called the moderator. This core is built up from many thousands of separate and accurately machined graphite bricks ; it contains numerous vertical channels ; and it is enclosed in a pressure shell of steel surrounded by a shield of concrete. The fuel is natural uranium which consists to a small extent (one part in 140) of fissile uranium 235 and to a much greater extent of non-fissile uranium 238. It is fabricated into rods which are sealed in metal cans and placed in the vertical channels within the graphite core ; and nuclear fission takes place in these rods, the surplus neutrons emitted travelling about in the graphite and uranium until they produce further fissions or are absorbed to form plutonium or are lost. The heat that is liberated is removed by the circulation of carbon dioxide gas under pressure through the core. The graphite " moderates ", or reduces, the average speed of the neutrons produced by the fission reaction to the low value known as the thermal level. A reactor with a moderator is therefore called a " thermal " reactor. If there were no moderator a large proportion of the neutrons would be absorbed by the relatively abundant uranium 238, which captures fast neutrons more readily than does the uranium 235, and the chain reaction would come to an end. The fission process is controlled at a fixed level of activity by moving rods of neutron-absorbing material in or out.

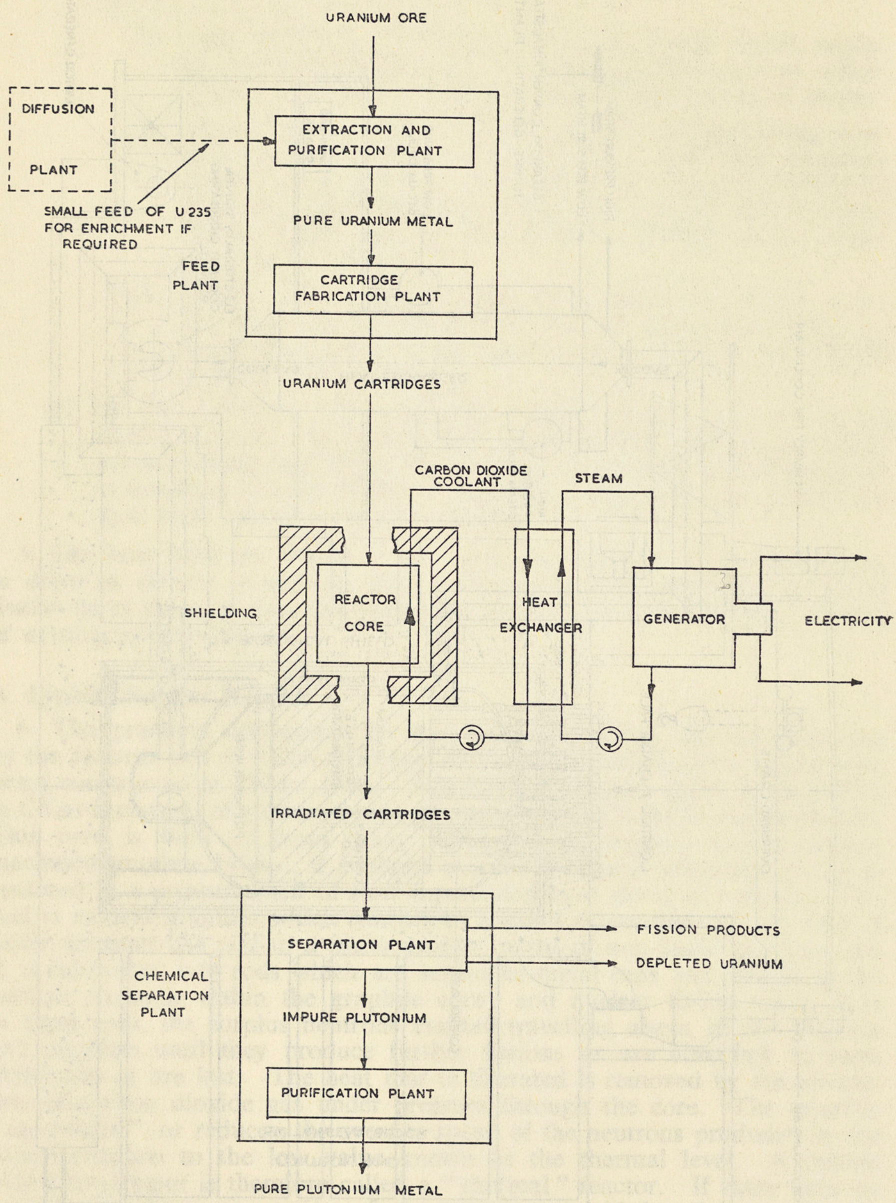
7. As the nuclear reaction proceeds some of the fissile uranium 235 is gradually used up ; a small fraction of the uranium 238 is converted by neutron capture into its fissile offspring plutonium 239 ; structural changes take place in the fuel rods owing to the neutron bombardment to which they

**Chart I.—A gas-cooled Power Reactor**




are subjected ; and fission products accumulate. Eventually the fuel has to be removed and fresh fuel supplied. The irradiated fuel from the reactor has to be chemically processed in order to separate out both the valuable plutonium 239 and the depleted uranium, which now has a smaller proportion of uranium 235 than is present in natural uranium. Chart II illustrates diagrammatically the processes associated with the operation of a Calder Hall type reactor.

**Chart II.—Nuclear Power Unit and Ancillary Plant**




8. The rate at which the fissile fuel is allowed to burn is expressed in terms of the output of heat, i.e., in megawatts per metric tonne of fuel. The fraction of fuel burnt depends on how fast it burns and how long the fuel element remains in the reactor. If one tonne of fuel burning at a rate of 3 megawatts remains in a reactor for 1,000 days, the level of irradiation achieved is 3,000 megawatt days per tonne (MWD/T).

**Nuclear Fuel Systems**

9. The main characteristic of nuclear energy that makes it attractive as a source of power is the enormous amount of heat available from a given quantity of fissile material. One pound of pure fissile material could, if completely "burnt", produce more heat than a thousand tons of coal. But the only naturally occurring fissile element is uranium 235, which occurs much diluted by the non-fissile uranium 238. If we were able to "burn" only the uranium 235 we should be using the natural uranium inefficiently and much of the advantage of nuclear energy would be lost.

10. Fortunately a nuclear reactor can be used not only to produce heat but to produce further fissile material by converting what are known as "fertile" materials, such as uranium 238 and thorium 232, into fissile materials. Thus a reactor of the Calder Hall type uses natural uranium containing both fissile uranium 235 and fertile uranium 238. The fissile material is "burnt" to produce heat while a small part of the fertile material is changed into new fissile material. The amount of new fissile material produced varies according to the fuel system and the type of reactor used. In some circumstances it is possible for more fissile material to be produced than is consumed, in which case the "gain factor" is said to be positive. Reactors in which this occurs are sometimes called "breeder" reactors. A fuel system with a positive gain factor has an obvious attraction for a country such as the United Kingdom with no large indigenous sources of uranium or thorium.

11. The quantity of fissile plutonium 239 produced in reactors based on natural uranium is less than the quantity of uranium 235 consumed so that the gain factor is negative. The plutonium can be extracted and used either in the same type of reactor instead of natural uranium or in different types of reactor. If the plutonium is used in conjunction with uranium 238, further plutonium 239 will be produced as fissile offspring. The gain factor will still be negative (in a thermal reactor) but using the plutonium from the early reactors implies a much more efficient use of natural uranium in the system as a whole than would be possible with natural uranium alone.

12. When enough plutonium has been obtained from a natural uranium system there are two other ways in which it could be used. In the first place it could be used with the fertile element thorium 232 in a thermal system, producing uranium 233 as a fissile offspring. The uranium 233 could then be extracted and used again in place of the original charge of plutonium. The gain factor would here be approximately zero, that is about as much uranium 233 would be produced from the thorium 232 as was used up, so that the use of raw material would be highly efficient.

13. Alternatively the plutonium could be used with uranium 238 in a fast reactor system (i.e. a system in which there is no moderator). In this case the gain factor could be made decisively positive so that more plutonium would be produced than was consumed. This would be a big advance in the economic use of nuclear materials.

**The Development of Reactors**

14. There are four types of atom that can be used as moderator in a thermal reactor: carbon, light hydrogen, heavy hydrogen, and beryllium. Carbon, in the form of graphite, is likely to be the most practical moderator in the immediate future. Light hydrogen in light water (ordinary water) is a possible alternative for reactors producing power on a large scale. These two have obvious advantages over the others from the supply point

of view. A reactor also needs a coolant ; and here too a range of possibilities is open comprising at present a gas such as carbon dioxide or helium, heavy water, light water and molten sodium metal. Carbon dioxide and light water are the most probable choices for this country in the next few years.

15. The only reactor for commercial power production that is within our present technical reach in terms of design and construction in the near future is the type now being built at Calder Hall, using graphite as the moderator and a gas, probably carbon dioxide, as the coolant. The first reactors of this type designed specifically for the commercial generation of electricity could be built beginning about 1957, and begin operating in about 1961. The heat rating would be relatively low so that the capital cost for each unit of electricity sent out would be high.

16. The next step in the design of thermal reactors would be to increase the heat rating. Higher ratings should be obtainable from advances in the design of the gas-cooled reactors. Alternatively a liquid could be substituted for a gas as the coolant but this gives rise to more complex technological problems and, unless heavy water is used, requires a higher concentration of fissile material in the fuel than is present in natural uranium. This higher concentration could conveniently be provided by the plutonium produced in the early reactors. These enriched reactors could themselves produce plutonium 239 which could then be used for enrichment in further liquid-cooled reactors, or for starting a thorium system or a fast breeder reactor, or could be fed back into the same reactors instead of natural uranium.

17. A large-scale prototype of a liquid-cooled thermal reactor could probably be constructed and fully tested by about 1963. This might enable commercial reactors of the same type to be completed by about 1965, by which time plutonium would be beginning to come from the early Calder Hall type reactors. One type that could probably be produced on a commercial basis by that date is a light-water reactor, using light water under pressure both as coolant and moderator. Other possibilities are liquid-sodium-cooled graphite-moderated reactors and heavy-water reactors.

18. The design of a thermal reactor might be still further simplified, with a saving in capital cost, if its fissile material were supplied in the form, not of solid metal rods, but of some kind of solution or suspension which could also serve as coolant and moderator. A homogeneous reactor, as this type is called, should also have lower operating costs since there would no longer be any need to fabricate solid fuel elements and encase them in protective material to prevent chemical and corrosive attack by the coolant. It might have a small positive gain factor. It is unlikely that a prototype of a commercial station could be constructed until at least the mid-1960s.

19. In order to obtain breeding of plutonium with a large positive gain factor, a fast reactor will be required, i.e. a reactor without a moderator in which the neutrons are permitted to cause fission of the fuel while they still have a considerable fraction of the energy with which they are born. The small core of a fast reactor presents many difficult technical problems, associated both with heat transfer and with the effect of high temperature on the fuel elements. The solution of these problems will take time. The design of an experimental model of a fast reactor capable of producing power is already in hand. This will be built at Dounreay and will produce data and experience for further developments. A prototype of a commercial station is not, however, likely to be tested until 1965 at the earliest ; and production plants could not be expected to be in operation until the 1970s.

## ANNEX 2

## THE PROBABLE DEMAND FOR ELECTRICITY 1955-1975

1. Various methods can be used for estimating the future demand for electricity. One method is to take the past trend in electricity consumption and fit a curve to it which is then extrapolated over the next 20 years. This method subsumes all the main factors which influence the growth of demand. In the absence of any major and sudden change in the structure of the economy, the projection of the curve should provide a reasonable estimate of the size of the demand in 20 years' time. The curve and an extrapolation of it are shown in Chart III.

2. A second method is to make a more detailed analysis of the individual sectors of demand and of the factors which influence their growth. For instance the expansion of industrial demand can be related partly to the expected growth of industrial production and partly to the known trend towards the use of electricity in substitution for other fuels in industry. The forecast of domestic consumption is based on the known trend of the rapid expansion in the use of electricity in the home and on the farm, and on the expected growth in the number of consumers. Similar estimates can be made for the increase in commercial demand and in the demand for traction purposes.

3. These two methods produce much the same result, which is summarised in the following table:—

ELECTRICITY CONSUMPTION IN GREAT BRITAIN

*Milliard units (Thousand million kilowatt hours)*

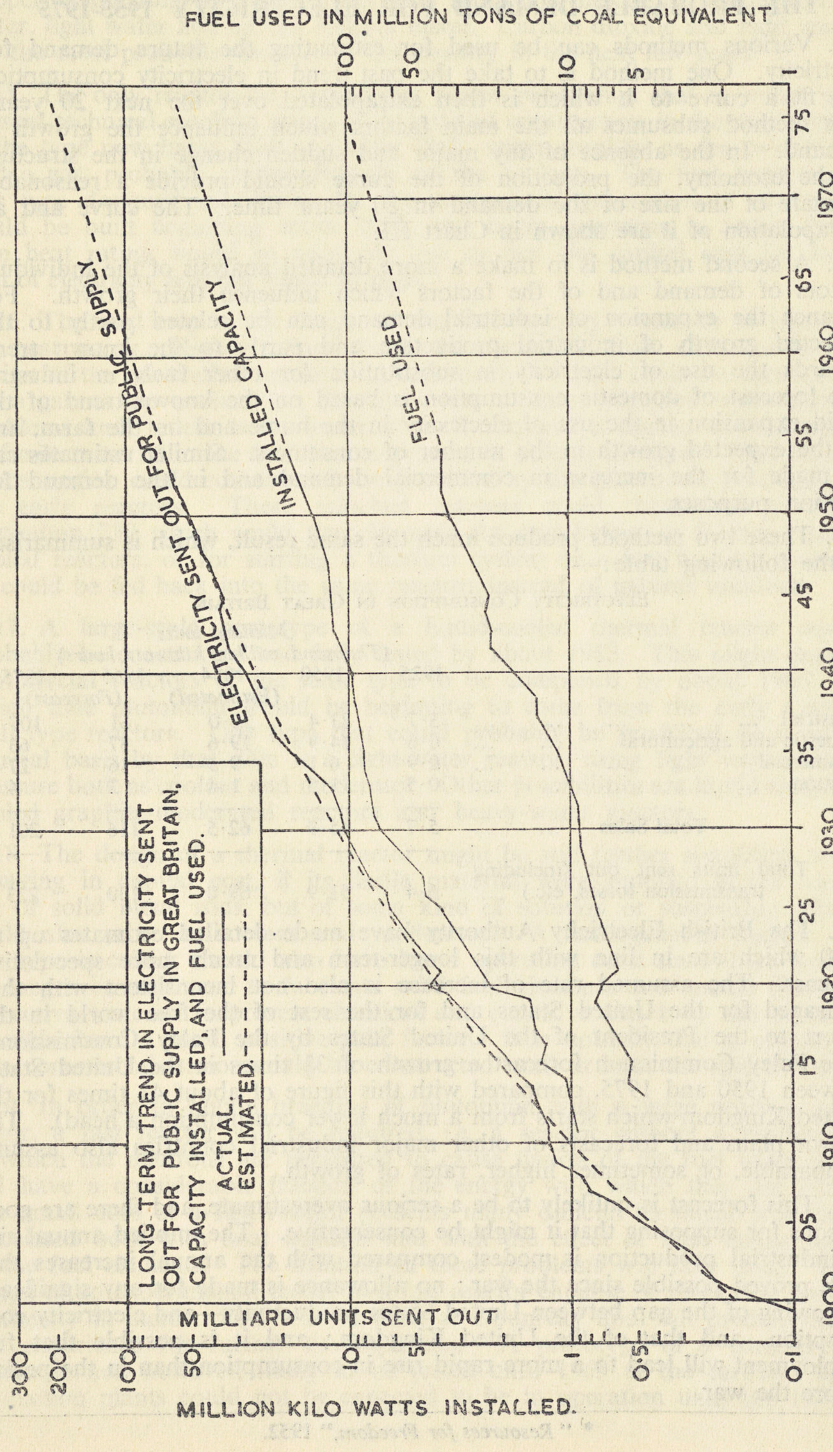
| | 1925 | 1950 | 1954 (*Estimated*) | 1965 (*Forecast*) | 1975 (*Forecast*) |
|---|---|---|---|---|---|
| Industrial ... ... ... ... ... | 3·7 | 23·4 | 32·0 | 61 | 107 |
| Domestic and agricultural ... ... | 0·6 | 14·9 | 19·6 | 37 | 63 |
| Commercial ... ... ... ... | 0·9 | 6·1 | 9·5 | 16 | 27 |
| Traction ... ... ... ... ... | 0·5 | 1·5 | 1·4 | 2 | 4 |
| Total Sales ... ... | 5·7 | 45·9 | 62·5 | 116 | 201 |
| Total units sent out (including transmission losses, etc.) ... | 6·4 | 51·9 | 69·0 | 130 | 223 |

4. The British Electricity Authority have made detailed estimates up to 1960 which are in line with this longer-term and much more speculative forecast. The assumed rate of increase is also not inconsistent with that envisaged for the United States and for the rest of the free world in the report to the President of the United States by the Paley Commission.* (The Paley Commission forecast a growth of 3½ times in the United States between 1950 and 1975, compared with this figure of about 4½ times for the United Kingdom which starts from a much lower consumption a head). The known plans and forecasts of other major industrial countries also assume comparable, or sometimes higher, rates of growth.

5. This forecast is unlikely to be a serious overestimate, and there are good reasons for supposing that it might be conservative. The implied annual rise in industrial production is modest compared with the annual increases that have proved possible since the war ; no allowance is made for any significant narrowing of the gap between United States productivity—and electricity consumption—and that of the United Kingdom ; and it is possible that full employment will lead to a more rapid rise in consumption than in the period before the war.

* "*Resources for Freedom,*" 1952.

## Chart III.—The Demand for Electricity



6. Nevertheless the implication of even these conservative estimates is that in about 20 years' time electricity consumption should be running at about 3½ times the present level. The rate of growth, which in recent years has averaged 7 per cent. a year, would on these estimates fall to about 6 per cent. a year in the early 1960s and to about 5 per cent. a year in the early 1970s.

### Generating Capacity Required

7. The growth in the industry's capacity over the last 30 years, and the efficiency with which its plant has been used, is illustrated by the following table:—

CAPACITY OF PUBLIC ELECTRICITY SUPPLY SYSTEM

| *Year* | *Capacity installed at end of year (thousand megawatts)* | *Number of units sent out per kilowatt installed* |
|---|---|---|
| 1925 ... ... ... | 4·4 | 1,422 |
| 1935 ... ... ... | 8·1 | 2,049 |
| 1945 ... ... ... | 12·3 | 2,853 |
| 1950 ... ... ... | 15·1 | 3,442 |
| 1954 ... ... ... | 20·7 | 3,342 |

In 1954, the industry had an average of 20,000 megawatts of installed capacity, and its maximum available capacity during that year (after allowing for break-downs, overhauls, &c.) was 80 per cent. of this figure. A further improvement in plant utilisation may be expected through a reduction in the time required for repairs and a closer integration of the system, so that by 1975 it might be over 85 per cent. The average load factor in 1954 was 49 per cent. : and some improvement may be possible, perhaps raising it to 52 per cent. by 1975.

8. On these assumptions the total generating capacity required in 1975 would be of the order of 57,000 megawatts installed. Allowing for some 2,000–4,000 megawatts of hydroelectric and pumped-storage plant and for 10,000 megawatts of existing plant still in operation, this implies the installation in the next 20 years of new plant equivalent to about 45,000 megawatts installed, or 40,000 megawatts sent out—a programme which, on the basis of coal-fired power stations alone, would cost about £2,500 million. On the present B.E.A. programme the capacity installed each year should already have reached about 2,000 megawatts sent out by 1960 ; on the forecasts used here it might well have to exceed 3,000 megawatts sent out during the 1970s.

### Coal Required for Power Stations

9. The thermal efficiency of coal-fired power stations has improved rapidly in the last few decades, as the following table shows:—

EFFICIENCY OF STEAM STATIONS OF THE PUBLIC ELECTRICITY SUPPLY SYSTEM

| *Year* | *No. of lb. of coal used per unit generated* |
|---|---|
| 1925 ... ... ... | 2·43 |
| 1935 ... ... ... | 1·54 |
| 1945 ... ... ... | 1·42 |
| 1950 ... ... ... | 1·37 |
| 1954 ... ... ... | 1·26 |

The figure for 1954 corresponds to an average thermal efficiency of about 23·6 per cent. The best modern stations already have a thermal efficiency of of 30 per cent., and it is possible that the average efficiency in 1975 might be as high as 30–32 per cent. On the basis of the figures given above and if the calorific value of the coal used by the industry continues to be no less than it is now, the total fuel equivalent required by the power stations would be about 65 million tons in 1965, and might rise by 1975 to a figure in the region of 100 million tons. A proportion of this coal is expected to be replaced by oil; but in round terms it may be assumed that 20 years hence, in the absence of nuclear power, the power stations would be consuming about 100 millions tons of coal, i.e., about 2½ times as much as at present, and twice the 50 million tons now estimated for 1960. By 1975 the rate of consumption might be rising by about 4–5 million tons a year.

**The Cost of Generating Electricity**

10. The cost of generating electricity in a modern coal-fired power station, operating at a high load factor and having a thermal efficiency of about 30 per cent., is about 0·6d. a unit, made up as follows:—

| | *Pence per unit* |
|---|---|
| Fuel cost (including handling) ... ... | 0·38 |
| Other costs including interest and depreciation ... ... ... ... | 0·22 |
| | 0·60* |

How this will vary in the next ten or twenty years is uncertain but on balance it seems unlikely that the cost of electricity will show any great change compared to other prices. It is possible that the pressure on coal supplies will tend to force up the price of coal used by power stations. On the other hand new stations will be more efficient so that less coal will be required for each unit, and there will be other developments that should also reduce costs. Examples are: bigger generating units, simpler buildings, higher temperatures and pressures in the boilers and higher load factors. It seems reasonable to assume for practical purposes that the cost of generating electricity from new coal-fired stations used as base-load stations will continue to be in the region of 0·6d. a unit.

* The average cost of supplying the consumer is about 1·3d. a unit which includes the cost of transmission and distribution and also the higher cost of operating the less efficient stations at peak periods.

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