UNITED KINGDOM ATOMIC ENERGY AUTHORITY

FIRST ANNUAL REPORT 1954-55

LONDON
HER MAJESTY'S STATIONERY OFFICE
TWO SHILLINGS NET

95

UNITED KINGDOM ATOMIC ENERGY AUTHORITY

FIRST ANNUAL REPORT

For the Period
19th July 1954—31st March 1955

Presented to Parliament in pursuance of Section 3 (5) of the Atomic Energy Authority Act, 1954

Ordered by The House of Commons *to be Printed*
25th October 1955

LONDON
HER MAJESTY'S STATIONERY OFFICE
TWO SHILLINGS NET
95

United Kingdom Atomic Energy Authority,
St. Giles Court,
London, W.C.2.
26th July, 1955.

MY LORD,

I have the honour to submit, in accordance with Section 3 (5) of the Atomic Energy Authority Act, 1954, the first Annual Report of the United Kingdom Atomic Energy Authority. This Report covers the period from 19th July, 1954 to 31st March, 1955.

I have the honour to be, My Lord,
Your Lordship's obedient Servant,

E. Plowden.
Chairman.

The Most Hon. The Marquess of Salisbury, K.G.,
Lord President of the Council,
Privy Council Office,
Whitehall, S.W.1.

Note by the Lord President of the Council.

In accordance with Section 3(5) of the Atomic Energy Authority Act, 1954, and following the advice of the Authority, an annexe to this report has been withheld from publication in the interests of national security.

Salisbury.

Privy Council Office
27th September, 1955.

CONTENTS

	Page
CHAPTER I. **Introduction**	1
CHAPTER II. **The Authority**	2
Origins	2
Membership and Functions	3
Organisation	3
Finance	4
Estimate 1954–55	4
Estimate 1955–56	4
Contracts	4
Patents Policy	5
CHAPTER III. **The Materials: Uranium, Plutonium, Thorium and Heavy Water**	5
Uranium Procurement	5
The Combined Development Agency	6
Sources of Supply	6
Uranium Fabrication	7
Fuel Element Production	8
Uranium hexafluoride	8
Production of Fissile Material	8
Uranium 233 (from Thorium)	9
Heavy Water	9
CHAPTER IV. **Reactors: Construction and Development**	10
Reactors under Construction	10
Calder Hall	10
Dounreay	11
Harwell	12
Reactor Research	12
Leo	12
Homogeneous Reactor	13
Slurry System	13

	Page
CHAPTER V. **The Programme for Nuclear Power**	13
The provisional programme	13
The Authority's part in the programme	14
Collaboration with Industry	14
A.E.R.E. Reactor School	15
CHAPTER VI. **The Isotope Programme**	15
Isotope Consignments	16
Supply Prospects...	16
Developments in Usage	17
CHAPTER VII. **The Weapons Programme**	18
CHAPTER VIII. **Progress in Research**	18
Physics	19
Chemistry and Chemical Engineering...	19
Metallurgy	20
Reactor Studies	22
Electronics	22
Extra-Mural Research	23
CHAPTER IX. **Health, Waste Disposal and Safety**	23
Health	23
Waste Disposal	23
Liquid Waste	24
Solid Waste	24
Gaseous Waste	25
Present and Future	26
Safety	26
Genetic Effects	26
CHAPTER X. **The Authority's Staff**...	26
Retention	26
Recruitment	27
Lodging Allowances	28
Equal pay...	28
Staff and Industrial Relations	28
Training	29
Pensions	29
Living Conditions	29
Housing	30
Hostels	30
Schools	30
Transport	30

	Page
CHAPTER XI. **International Aspects**	31
The Commonwealth Countries...	31
Canada	31
Australia	31
New Zealand	32
India...	32
Pakistan	32
South Africa	32
United States	32
International	32
European Council for Nuclear Research (C.E.R.N.)	32
European Atomic Energy Society	33
European Countries	33
France	33
Denmark	33
Belgium	33
Other European Countries	33
APPENDIX 1. Atomic Energy Authority Establishments and Senior Staff as at 31st March, 1955	34
APPENDIX 2. Conferences and Symposia held at the Atomic Energy Research Establishment during the period 1st August, 1954 to 31st March, 1955	35

UNITED KINGDOM ATOMIC ENERGY AUTHORITY

REPORT

for the year ended 31st March 1955

CHAPTER I

INTRODUCTION

1. This is the first annual report of the United Kingdom Atomic Energy Authority. The fact that it is a first report indicates the Authority's recent origin; what it does not show is that although the organisation may be new the endeavour and purpose behind it already have a notable past. For reasons which are given in the next chapter, Her Majesty's Government decided to transfer responsibility for atomic energy matters from the Ministry of Supply to a non-departmental body. After the transfer, most of the staff who had contributed to the success of the project in the past continued to serve the new organisation. Thus the Authority came into being with the important asset of many years' experience and achievement.

2. The report covers the period from 19th July, 1954, when the Authority came into being to 31st March, 1955. In order to make this first report more self-contained some background information has been given about events before the setting up of the Authority and about the nature of the scientific and industrial processes that go on at the various Establishments.

3. Much of the work done on atomic energy is subject to strict security. Hence this report cannot contain a full account of the Authority's activities. Within the necessary limits every attempt has been made to present as complete a picture as possible. In the main it is a reasonably non-technical picture but there are certain areas of work of such a technical nature that they can be included only in their own terms. Wherever practicable these terms have been simplified for the layman. Nevertheless there is a stage when simplification leads to inaccuracy. This stage, it is hoped, has been avoided even at the cost of some inconvenience to the non-technical reader.

4. A great part of the Authority's activity in research, development and production is of common application and does not depend upon specific end-use. The visible products of this activity are, however, clearly divided between civil and military applications. In the civil field, the period under review has seen the publication of the Government's Nuclear Power Programme (Cmd. 9389) while, on the defence side, the Defence White Paper (Cmd. 9391) included the announcement of the Government's decision to proceed with the development and production of thermo-nuclear weapons.

5. These two developments are the conspicuous features of the period covered in this report, but the report reveals the continued growth, in all aspects, of a project which has been expanding, since its inception in 1945, at a rate which few, if any, industrial enterprises would consider feasible. The programmes that the Authority have undertaken are closely geared to a timetable; the principal threat to the fulfilment of these programmes in accordance with the timetable is lack of skilled manpower. Her Majesty's Government have never hesitated to furnish the money needed for buildings, plant and equipment for the atomic energy programme; material shortages have never been insuperable; but the difficulty of recruiting and retaining sufficient skilled scientists, engineers and craftsmen has been acute throughout the ten years of the project and shows no signs of becoming easier.

6. The Authority are in competition with industry (and notably with sections of industry that are themselves building up staff in order to enter the field of nuclear energy) for staff to carry out their development programmes; and, as a body dependent upon public funds, the Authority have not the same freedom of manoeuvre as industry in the matter of salaries. They are aware, of course, that the shortage of technological skill is nationwide, and that steps are being taken to alleviate it. They feel it essential, however, to put this subject in the forefront of their report because the development of atomic energy is unique in the variety of specialised skills which it demands. This demand is not at present being met.

CHAPTER II

THE AUTHORITY

7. The United Kingdom Atomic Energy Authority came into being on 19th July, 1954, under the provisions of the Atomic Energy Authority Act, 1954, and took over the existing Establishments on 1st August, 1954.

Origins

8. After the end of the war, responsibility for work on atomic energy was transferred from the Department of Scientific and Industrial Research to the Ministry of Supply. This arrangement was given statutory form in the Atomic Energy Act, 1946, and continued in force until 1st January, 1954, when, by an Order in Council, transfer of functions was made from the Minister of Supply to the Lord President of the Council.

9. This second transfer was the outcome of a decision in principle announced to the House of Commons by the Prime Minister on 28th April, 1953, that responsibility for atomic energy should in due course be handed over to a non-departmental organisation under Government control. The Prime Minister announced also that in order to devise a plan for the creation of this organisation the Government had appointed a Committee consisting of Lord Waverley, the late Sir Wallace Akers and Sir John Woods.

10. The main recommendations of the Waverley Committee were summarised in an appendix to " The Future Organisation of the United Kingdom Atomic Energy Project " (Cmd. 8986) which was presented to Parliament in November, 1953. The White Paper stated that the Government had accepted the Committee's recommendations for the establishment of an Atomic Energy Authority and that the necessary administrative preparations were under way. The Committee had suggested that the Lord President appeared to be the most suitable Minister to be responsible to Parliament for the finance provided for the Authority and for the policy directions given to them; and it was as a step towards implementing this recommendation that the Order in Council was brought into operation on 1st January, 1954. A Bill was also introduced to provide for the setting up of the Authority; this Bill received the Royal Assent on 4th June, 1954. During the seven months' interval from 1st January until the establishment of the Authority responsibility for atomic affairs was in the hands of a Department of Atomic Energy responsible to the Lord President.

11. The reasons that led the Government to decide on the creation of a non-departmental organisation were given in Cmd. 8986 (paras. 8-9):—

" As the industrial uses of atomic energy become relatively more prominent, the case for a form of control of the project which is more akin to the structure of a big industrial organisation than to that of a Government department becomes increasingly strong ; and it will, in the Government's view, become stronger with the increase in the need for closer contact and co-operation with industry, including the nationalised industries, and the widening application of atomic techniques.

" It is considerations such as these which have led the Government to conclude that the most rapid and economical development in this field will be secured by transferring responsibility from the Ministry of Supply to a non-departmental organisation with the necessary executive power, within the framework of an approved policy and under a financial ceiling, to settle day-to-day problems. They believe that the necessary flexibility and speed of decision can best be obtained from the Board of an organisation run on industrial lines, and with no responsibility outside the field of atomic energy. They have noted that all the other countries working in this field have adopted some special form of organisation, outside the normal framework of an ordinary Government department."

Membership and Functions

12. The Atomic Energy Authority Act provides that the Authority shall consist of a chairman and not less than seven nor more than ten other members, all of whom are to be appointed by the Lord President. The Chairman is Sir Edwin Plowden, K.C.B., K.B.E., and there are at present seven other members viz.:—

Sir John Cockcroft, K.C.B., C.B.E., F.R.S. (Member for Scientific Research)
Sir Christopher Hinton, F.R.S. (Member for Engineering and Production)
Sir William Penney, K.B.E., F.R.S. (Member for Weapons Research and Development)
Sir Donald Perrott, K.B.E. (Member for Finance and Administration)
The Rt. Hon. Lord Cherwell, C.H., F.R.S.
Sir Luke Fawcett, O.B.E. } Part-time Members
Sir Ivan Stedeford, K.B.E.

The Secretary of the Authority is Mr. D. E. H. Peirson.

13. The full-time members of the Authority, together with the Chairman, form a Management Committee known as the Atomic Energy Executive.

14. The functions of the Authority cover the whole field of atomic energy and radioactive substances.

15. The 1954 Act lays down that it is the duty of the Lord President to secure " that, in the conduct of the affairs of the Authority, the proper degrees of importance are attached to the various applications of atomic energy ". After consultation with the Authority the Lord President may give them such directions as he thinks fit, but he " shall not regard it as his duty to intervene in detail in the conduct by the Authority of their affairs unless in his opinion over-riding national interests so require ".

Organisation

16. Since the beginning of Britain's post-war atomic energy project the work has been divided among three principal groups: research, production, and weapon development. Under the Authority this form of organisation still obtains. A list of senior appointments made by the Authority, and of the Authority's Establishments, as at 31st March, 1955, is at Appendix 1.

17. During the period under review, a new outstation was under construction at Bracknell in Berkshire ; when completed, this will serve as a general workshop for A.E.R.E. The Fort Halstead outstation of the Weapons Group was in the process of being given up, the staff being transferred to Aldermaston.

Finance

18. The Authority differs from other nationalised undertakings in that it depends for its funds upon money voted by Parliament. This money is paid to the Authority by the Office of the Lord President (Atomic Energy) subject to Treasury consent. It is paid, not as a lump sum, but under a number of subheads, and excesses on any one of these can be met from savings on other subheads only with Treasury consent. In the period under review approval was given to use savings on stores and material purchases and on works services to meet additional purchases of land and to provide increased loans to uranium producers. Unspent balances are surrendered to the Exchequer at the end of the financial year.

19. One other source of revenue which should be mentioned is the sale of natural and artificial radioactive isotopes to customers in Britain and many other countries throughout the world (see Chapter VI).

20. Miscellaneous receipts, including those mentioned in the above paragraph, may be appropriated in aid of the Authority's expenditure subject to the Lord President's direction and the approval of the Treasury.

21. *Estimate, 1954–55 :* The Estimate for the financial year 1954–55 was presented to Parliament in February, 1954. This was for a net total of £53,675,000 to cover " the salaries and expenses of the Office of the Lord President of the Council (Atomic Energy Department) for the administration of the supply of atomic energy and radioactive substances ".

22. In July, 1954, a revised Estimate was presented to Parliament, for the same net sum as before but with token provision to enable the Lord President to make grants and loans to the Authority from 1st August, 1954. This received Parliamentary approval on 22nd July, 1954.

23. A Supplementary Estimate was presented on 7th February, 1955. This made provision for grants and loans to the Authority and for the diversion of savings to meet additional expenditure as described in paragraph 18.

24. *Estimate, 1955–56 :* An Estimate of the Authority's expenditure in 1955–56 was presented to Parliament on 17th February, 1955, and showed a total of £50,562,000 as the net sum required.

25. The actual expenditure for the financial year 1954–55 will be included in the Appropriation Account of the Office of the Lord President (Atomic Energy) which, after examination by the Comptroller and Auditor General, will be presented to Parliament and published. For their own purposes the Authority have maintained the commercial accounting system already in existence at some of their establishments and are extending it to cover the whole of the Authority's activities.

Contracts

26. The purchase of all the stores, plant, services, etc., required by the Authority is carried out by Contract Branches at the three Groups, to whose senior officers wide delegated powers have been given. There is a Director of Contracts at the London Office who is responsible for general contract policy.

27. Up till the formation of the Authority, orders for all buildings and maintenance work at the different establishments were the responsibility of the Ministry of Works. It was decided that such work should be taken

over by the Authority as soon as conveniently possible, and an immediate start was made by setting up a Works Contracts Branch as Risley to deal with all building projects for new work or maintenance in the Industrial Group. This was done in September, 1954. Since that date arrangements have also been made at A.E.R.E. and A.W.R.E. to take over from the Ministry of Works all maintenance work at those establishments with effect from 1st April, 1955. New works at these establishments will be taken over at a later date.

Patents Policy

28. The many inventions that have arisen out of the work of the three Groups have created for the Authority a substantial holding of patents and patent applications. Until recently the utilisation of atomic energy inventions has been largely confined to the Authority themselves, but the programme for nuclear power will extend their use to industry and to the electricity authorities. Some of the inventions also have general applications in the chemical, engineering, metallurgical and instrument fields. Where inventions are not secret, the Authority follow a policy of granting non-exclusive licences to suitable United Kingdom recipients unless, exceptionally, the invention can be more appropriately exploited by the National Research Development Corporation.

CHAPTER III

THE MATERIALS: URANIUM, PLUTONIUM, THORIUM, AND HEAVY WATER

29. The radioactive element uranium is the life-blood of any atomic energy programme. The task of procuring ores and concentrates of this metal, as well as of some other important minerals such as thorium and beryllium, is carried out by the Metals Branch of the London Office which works in close collaboration with the Industrial and Research Groups. Because the large demand for these metals has developed only in the last decade this work involves more than the negotiation of contracts with the overseas suppliers. It is also necessary to keep in touch with developments in uranium mining all over the world and to be able to assess the merits of new prospects and offer technical and, on occasion, financial assistance. Accordingly the Metals Branch has available to it, apart from its own specialist staff, the advice and help of a number of organisations. These are:

the Atomic Energy Division of the Geological Survey and Museum;

the Radiochemical Group of the Chemical Research Laboratory;

and the Chemistry, Chemical Engineering and Electronics Divisions, A.E.R.E.

30. The first two are units of the Department of Scientific and Industrial Research which have been closely associated with the project from its earliest days, and which are working under contract to the Authority.

Uranium Procurement

31. During the last few years, a world-wide search for new deposits of uranium has begun, and much effort is being put into the study of improved methods of extraction. It is now realised that while minerals bearing small quantities of uranium are fairly plentiful, the low metallic content and the difficulties of treatment still rule out most of them as economic sources. Considerable effort has therefore been necessary to ensure that uranium was available to meet essential defence and research requirements. The various procurement programmes which have been initiated during the last few

years are now bearing fruit and an easier supply position seems probable over the next decade.

32. *The Combined Development Agency :* In 1944 the Governments of the United Kingdom, the United States and Canada, set up an organisation to secure uranium for the joint war effort. This war-time arrangement survives, with modifications, as the Combined Development Agency, from which the British atomic energy project has so far drawn all its supplies of uranium. The Agency makes contracts for the supply of uranium which in due course is allocated between the United States Atomic Energy Commission and the Authority according to need ; Canada as an important uranium producer has no need of external supply arrangements.

33. In most countries ownership of uranium is vested in the government and it follows that Agency contracts for its supply usually involve agreements between Governments, although the mining and treatment of the ores is usually carried out by industry, as it is for instance in South Africa.

34. The Agency does not normally undertake prospecting for new uranium deposits on its own account and only rarely has it provided capital for this purpose. Its main contribution to the task of providing uranium has been the encouragement given to producers through the assured market offered by Agency contracts and as part of its procurement programme it has provided the considerable capital sums necessary for the development and exploitation of deposits. In some cases the Agency has also been able to help by initiating research programmes and by lending technical staff.

35. The main contracts on which the Agency, and hence the Authority, depend for uranium supplies were negotiated for the United Kingdom by the Atomic Energy Division of the Ministry of Supply ; since 1st August, 1954, these have remained the basis of the Authority's purchasing programme. Nevertheless the ever-growing demand for uranium has required continuous efforts to secure adequate supplies ; for this reason the Authority's purchasing arrangements are always under review.

36. *Sources of Supply :* prospecting for uranium in this country has not resulted so far in the discovery of any deposits that can be exploited economically. The Authority rely on the following overseas sources:

Belgian Congo : the deposit of uranium and radium-bearing minerals at Shinkolobwe in the Belgian Congo has been renowned for many years for its great size and the unusually high grade of the ore, which is in a form (pitchblende) particularly amenable to treatment. The Shinkolobwe mine continues to be the world's largest individual uranium producer and it is still a most important source. Its current output of uranium ore and concentrate is contracted to the Combined Development Agency to which it was one of the earliest suppliers. Congo uranium ore has played a major role in the establishment of the British project and continues to form an important part of the Authority's supplies.

South Africa : the realisation that the small uranium content of the gold ores of the Rand (and latterly of the Orange Free State) could be exploited economically as a by-product of gold has made it possible for the Union of South Africa to provide a considerable supply from deposits that would be prohibitively expensive were the uranium alone to be worked. The low uranium content of the ore makes it necessary to upgrade the ore considerably before shipping it as a concentrate in order to avoid heavy transport charges to the United States and the United Kingdom. This requires elaborate treatment plants at the mines which have added much to the cost and complexity of the operations. They have also called for a large capital investment by the Combined

Development Agency. The Authority's share in this up to 31st March, 1955, has involved the conclusion of loan agreements with twenty-two gold-uranium producers.

Australia: it is only within recent times that the existence of uranium in Australia in economically workable quantities has been proved.* The Australian Government has taken steps to stimulate private prospecting in various ways and as a result a number of occurrences of uranium have been discovered. At the moment two deposits are producing or are about to produce uranium: Rum Jungle and Radium Hill. The operations at Rum Jungle, near Darwin, are carried out by a private company, Territory Enterprises (Proprietary) Ltd., acting as agent for the Australian Government. The uranium produced here is sold by the Australian Atomic Energy Commission to the Combined Development Agency. The operations at Radium Hill, on the other hand, are carried out directly by the South Australian Government with whom also the Agency has a contract for the purchase of uranium. The Agency has been able to provide substantial help to both these enterprises by way of capital and, from time to time, by technical assistance.

Portugal: the only source of uranium in Europe that is available to the Agency is in Portugal. Under the terms of an agreement between the United Kingdom and Portuguese Governments, uranium has been produced there for some years past.

The British Colonies: although no large economic occurrences of uranium have so far been reported in the British Colonial territories their potentialities make them worthy of mention. The Authority, although not directly financing prospecting in these areas, have taken measures to encourage the search for uranium. The Atomic Energy Division of the Geological Survey and Museum has co-operated with the Colonial Geological Surveys, has publicised special prospecting techniques, and has offered to examine and report upon samples sent in by prospectors: this latter work has now reached considerable proportions. A.E.R.E. has produced, and continues to develop, a range of electronic instruments for prospecting and many of them have been sold to Colonial Governments, mining companies, and individual prospectors.

The continued flow of samples to the Geological Survey and Museum suggests that interest in uranium exploration is well maintained. Another encouraging feature is that a small uranium ore body which is probably suitable for economic exploitation has been discovered at the Nkana Mine in the North Rhodesian copperbelt. The Authority, at the end of the period under review, were negotiating an agreement for the purchase of the uranium with the Rhokana Corporation which owns the mine.

Uranium Fabrication

37. When the uranium arrives in this country as an ore or concentrate it is sent to the Springfields factory of the Industrial Group. The operations carried out there to produce uranium metal can be divided broadly into three stages: first there is an ore-crushing and multiple purification process leading to ammonium diuranate; then the diuranate is converted to uranium tetrafluoride in the "Dryway" plant; finally the tetrafluoride is reduced to metal billets by mixing it with calcium and firing it in a mould.†

* From Australia the Authority also obtains beryllium which is used for research purposes in connection with nuclear reactors.

† For a detailed account of the operations at Springfields see "Britain's Atomic Factories" by K. E. B. Jay, (London, H.M.S.O., 1954).

38. The Springfields plant was constructed at the end of the war to meet an urgent military requirement for the plutonium which is produced from uranium. As a result of this urgency the transition from test-tube experiment to pilot plant operation and forward to full-scale production had to be telescoped. This has meant that although the factory has worked satisfactorily it is capable of improvement at all stages. The initiation of the nuclear power programme (see Chapter V) will involve a great increase in the amount of uranium processed and the creation of capacity for this higher throughput will be used as an opportunity to improve the whole process.

39. During the period under review the upgraded South African concentrate which was mentioned earlier in this chapter has been passing through the Springfields factory. Because of the preliminary operations in South Africa, this concentrate is much purer than the Belgian Congo ore for which the plant was originally designed; in consequence, one step in the purification stage can be omitted. Furthermore there is no need to use the ore-crushing plant at the outset of the operations, and this plant has been used to crush accumulated waste slags from the reduction stage to enable the uranium in them to be recovered. Thus the cost and complexity of the South African end of the operations are to some extent compensated for by a simplification at Springfields.

40. *Fuel element production:* when the metal billets have been formed in the mould the next stage is to convert them into cartridges for use as fuel elements in a pile. To do this, the billets are formed into rods which are then machined to size, put into metal cans and sealed. After sealing, the cans are subjected to a variety of tests to ensure that they will withstand pile conditions of temperature without leaking. So far, Springfields has been making fuel elements for the Windscale piles and for BEPO at Harwell; during the period under review, construction of the canning line for the Calder Hall reactor fuel elements was begun.

41. *Uranium hexafluoride:* in addition to the production of cartridges, Springfields manufactures uranium hexafluoride for the diffusion plants and reconverts it after it has been processed at Capenhurst. The starting point for the manufacture of hexafluoride is uranium tetrafluoride, which is fluorinated to produce the desired gas. The returned hexafluoride has frequently to be blended with either natural or depleted material to give uranium with the desired proportion of the all-important 235 isotope. This operation gives rise to a serious problem in factory management to ensure that there is no accidental mixing, either in process or scrap, of material of different enrichments.

Production of Fissile Material

42. There are three known fissile isotopes, uranium 233 and 235, and plutonium 239; of these only uranium 235 occurs naturally, the others being produced by the action of neutrons on thorium 232 and uranium 238 respectively when they are irradiated in reactors.

43. Natural uranium contains only 0·7 per cent. of the 235 isotope and to obtain this fissile material in concentrated form it has to be separated from the remainder, which consists of the 238 isotope. This is extremely difficult since they are chemically identical. The method used is diffusion through a porous membrane, which makes use of the different rates of diffusion of the two isotopes due to their different masses. For this a gaseous compound of uranium is needed and the only suitable one is uranium hexafluoride. The diffusion process is carried out at Capenhurst Works, near Chester.

44. To produce the artificial fissile material, plutonium 239, natural uranium fuel elements are put into the reactors, or piles as they are commonly called, at Windscale. Here some of the uranium 235 is consumed and some of the uranium 238 is converted to plutonium 239. As a result the proportion of the 235 atoms is somewhat decreased but the irradiated material still contains a good deal of this fissile isotope, though not enough to keep a chain reaction going in the piles. To enable it to be used again a Low Separation Diffusion plant has been built at Capenhurst in addition to the main plant, and in this the uranium which has been depleted in its fissile content can be restored to its original constitution by carrying out a partial separation from the uranium 238 atoms. This permits much greater economy in the use of uranium, since the restored material can be put through the pile again and used to produce more plutonium instead of being unusable. This Low Separation plant has worked satisfactorily during the period.

45. The piles at Windscale have worked efficiently during the period and the planned amount of plutonium has been produced. One interesting development has been the use of a television camera, which was lowered into a part of the pile where the activity was too great to permit access, in order to investigate the conditions of the structure. Photographs were taken of the pictures on the screen and these gave the engineers a permanent record of what they saw. Certain minor defects were discovered and methods are being devised to rectify them.

46. The primary separation plant at Windscale has also worked without trouble. This is the plant where, first, the irradiated cartridges are dissolved in acid, then, the highly active fission products are removed from the solution, and finally, the plutonium is separated from the residual uranium. It is noteworthy that although this plant was built on the assumption that once it had started working nobody would be able to enter it again on account of the activity, the factory staff have succeeded in devising methods of decontamination which allow access for limited periods. This has made possible a number of modifications which have increased the capacity of the plant.

47. From the primary separation plant the plutonium-bearing solution has to pass through further purification stages before it is produced as a metal. For this purpose a new and improved plant has been constructed and has been brought successfully into use.

48. *Uranium* 233 (*from Thorium*): plutonium is the first of the two artificial fissile elements; the second is uranium 233. This fissile isotope of uranium is made by the neutron bombardment of thorium; it is, in fact, the means by which thorium becomes a source of nuclear power. Thorium is a reasonably abundant raw material and no undue difficulty is foreseen in procuring the supplies that will be needed in the future. Research is being carried out by A.E.R.E. and by the Research and Development Branch of the Industrial Group to improve knowledge of thorium and of the production of uranium 233. A pilot plant has been used to process several tons of irradiated thorium for the extraction of uranium 233 for use in experimental work.

Heavy Water

49. Heavy water is a possible moderator and/or coolant for more than one type of reactor, and its use facilitates a number of developments in reactor technique. Natural water contains about 0·015 per cent of heavy water, and it has been known for a long time that distillation can be used

to separate the "light" and "heavy" water. The problem, therefore, is not the acquisition of the raw material, nor the method of its separation, but its processing on a commercial scale. To do this, large quantities of heat are required and heavy capital expenditure is necessary. Conventional distillation columns and heat derived from coal-fired boilers lead to such high costs that water distillation is at present uneconomic in this country. However, if there is a low-cost source of steam, and if the plant cost can be reduced by the development of high efficiency distillation equipment, it is possible to obtain heavy water at an attractive price.

50. These conditions can be fulfilled. Geothermal steam in New Zealand offers a source of low-cost steam; and experimental work at A.E.R.E. has led to the development of distillation column packing of such high capacity that the capital cost could be brought down nearly to half that which would be incurred with a conventional "bubble-cap" type of packing. The new packing is known as "Spraypak". It has moreover been found practicable to combine a distillation plant with a steam-driven turbo-generator station; this can be done in such a way that about one third of the energy in the steam is used for distillation and the remaining two-thirds for the generation of electricity.

51. The scheme for a combined heavy water distillation and electricity generating station was discussed with the New Zealand Government, who had already been considering plans for the harnessing of geothermal steam to power production. Towards the end of 1954 an agreement was signed between the New Zealand Government and the Authority whereby a joint company, Geothermal Development Ltd., was set up with the object of building a plant at Wairakei in the geothermal region of the North Island. The capital cost of this plant is estimated at £6 million, of which £2 million will be provided by the Authority for the heavy water plant and £4 million by the New Zealand Government for the electrical power equipment. It is expected that the first heavy water will be produced from it towards the end of 1957, and that electrical power generation will follow a few months later. The heavy water will be bought by the Authority. Meanwhile supplies have been obtained from Norway and some further quantities are to be purchased from U.S.A.

52. The new distillation column packing, "Spraypak," was developed with a heavy water plant in mind; but it is potentially useful in the general field of distillation. As a result of enquiries received from industry, licences have been granted not only to British firms but also to firms in the United States, France and Italy and other licences are in course of negotiation. "Spraypak" has already been used in a stabiliser column in a petroleum refinery in the United States and other installations are in prospect.

CHAPTER IV

REACTORS: CONSTRUCTION AND DEVELOPMENT

53. This Chapter describes the various reactors that the Authority have under construction, and outlines the studies that are being made for future designs.

Reactors under construction

Calder Hall

54. One of the major items in the Authority's capital expenditure has been the continued construction of the prototype power station and factory at

Calder Hall. As originally planned this factory will have two reactors*, the heat from which will be used to produce steam to drive turbo-alternators; the generated electricity will then be fed into the Central Electricity Authority's distribution system. The reactors, which are graphite-moderated and cooled by carbon dioxide under pressure, will also produce plutonium for military purposes.

55. Each reactor is contained in a pressure shell of mild steel about 40 feet in diameter and 60 feet high, and this pressure vessel is housed in a concrete biological shield several feet thick with a heat exchanger at each corner. Between the two reactor buildings is the turbine hall containing conventional turbo-alternator sets and their ancillary equipment.

56. To enable the same construction equipment, such as lifting tackle, to be used for both reactors, and to avoid too great a load on manufacturing capacity, construction of one reactor was programmed to proceed slightly in advance of the other. By the end of the period under review one pressure vessel had been completed, stress-relieved, and tested. The massive concrete housing had been finished and three of the four heat exchangers had been put in position; these exchangers are delivered to the site in sections and then welded together before being lifted into position on their "stools". The pressure vessels, being larger still, arrive on the site as plates which are then welded into four sections: a bottom dome, two rings and a top dome. These sections are then lifted into the reactor house and finally welded together inside. Despite this piecemeal assembly, it is sometimes necessary to raise sections weighing up to 100 tons over 100 feet into the air.

57. The turbine hall had nearly been completed at 31st March, 1955, and the installation of equipment had begun. The first cooling tower had reached a height of 126 feet.

58. The Authority expect that by 1957 they will be supplying electricity from Calder Hall to the C.E.A.

Dounreay

59. The Dounreay establishment in the extreme north of Scotland is intended to house several reactors of experimental or advanced types, together with the plants for fabricating their fuel elements and treating them after irradiation. The first commitment there—the construction of a fast "breeder" reactor—had begun by the end of March, 1955.

60. The breeder reactor will use highly enriched fuel, either uranium 235 or plutonium; there is no moderator and therefore the core is very small. In order to remove the heat from this small volume it is necessary to use a liquid metal as coolant. Surrounding the core is a "breeder blanket" which will consist of cartridges containing either uranium 238 or thorium, and the spare neutrons from the reaction in the core will convert the "fertile" materials in this blanket into fissile material—plutonium, in the case of uranium 238, or uranium 233, in the case of thorium. In this way it is expected that more fissile material will be produced than is consumed in the reactor.

61. Owing to the small core size, there is a risk that an accident in the reactor might lead to a rapid rise in temperature which in turn might cause the melting of the fuel elements. If this should happen there might be an escape of fission products from the core. To prevent these from being dispersed outside the reactor, it will be enclosed in a steel sphere about

* Since the end of the period covered by this Report, an expansion of the Calder Hall plant has been announced.

140 feet in diameter. The foundations for this sphere were being laid at the end of the period under review; fabrication of the sections for the shell itself had also started.

Harwell

62. In addition to the reactors under construction at Calder Hall and Dounreay, two others are being built at Harwell for research purposes. Work on one of these did not begin until May, 1955; nevertheless it may be mentioned in this Report in order to complete the general picture of the Authority's current reactor programme.

63. *E.443:* the furthest advanced of the research reactors (E.443) is now known as DIDO. It is designed to produce a high neutron density or "flux" to a maximum of 10^{14} neutrons/sq. cm./second. Heavy water is used as the moderator and the coolant and a highly enriched uranium aluminium alloy as the fuel. DIDO will be used for a wide variety of experimental and development work in connection with the nuclear power programme (see Chapter V).

64. The design and construction of this reactor, which is scheduled for completion by mid-1956, is being carried out by the Ministry of Works and Head Wrightson Processes Ltd., under the direction of A.E.R.E.

65. *PLUTO:* the second of the research reactors is PLUTO. Basically it is of the same type as DIDO, but with redesigned experimental facilities for extensive materials testing. It will be used entirely for the testing and development of fuel elements and their associated coolants and auxiliary equipment, such as special pumps, heat exchangers, valves, etc. It will allow for the building in of six test "loops" designed to simulate the actual operation of some future power reactor. Work on Pluto was only begun in May, 1955, and the reactor is not expected to come into operation until the end of 1957; its potentialities will be discussed at greater length in a future Annual Report.

Reactor Research

66. In addition to the work done on reactor construction there has been much research into methods of improving existing types and developing new ones. Full use has been made of the research reactors, GLEEP, BEPO, ZEPHYR (Zero Energy Plutonium Fast Reactor), and DIMPLE (Deuterium Moderated Pile-Low Energy). More plentiful supplies of fissile material have made it possible to extend the scope of the exponential and critical assembly experiments which are necessary to obtain the nuclear physics data for new types of reactor.

67. *LEO* (*Low Enrichment Ordinary Water*)*:* of the various moderators available for use in reactors ordinary (or light) water is particularly interesting because of its cheapness and availability and because it can also serve as the coolant. A reactor of this type consists essentially of a pressure vessel to contain the water, into which are inserted, in a regular lattice array, rods of the enriched uranium fuel. These rods must be sheathed in a corrosion-resistant material in order to prevent attack on the uranium by the water, and also to prevent too much radioactivity from the fuel from entering the water. One of the main metallurgical problems is the development of this sheathing material. Stainless steel is one possibility but has the disadvantage of being a strong neutron absorbent unless it can be used in very thin-walled tubes. Another possibility is zirconium; here again there is a disadvantage, this time of cost. Other alloys are promising.

68. Preliminary investigations of light-water reactors began at A.E.R.E. several years ago with the examination of possible experimental systems on a small scale. This work has subsequently extended to a survey of schemes whereby power might be produced as economically as possible in units each producing 100 megawatts or more of electricity. Early in 1954 it was decided to proceed to the next stage of a detailed design study now known as LEO. This work is still in progress.

69. It is tentatively thought that it is advisable to generate saturated steam by the reactor heat and then to superheat this steam in a separate unit fired by conventional fuels. The reactor supplies about three-quarters of the total heat consumed, and this " mixed " system can achieve a thermal efficiency approaching that of modern coal-fired power stations at a reasonable capital charge per kilowatt generated. Particular attention is also being paid to simplicity of layout in order to keep all capital charges to a minimum.

70. The design study of LEO is being carried out at Harwell by A.E.R.E. in collaboration with the Industrial Group of the Atomic Energy Authority, Babcock & Wilcox, and the English Electric Company. A representative of the Central Electricity Authority has been acting as a consultant.

71. *Homogeneous Reactor :* among the new types being studied is the homogeneous reactor. In this, the fuel is used in the form of a solution or fluid suspension, instead of solid metal rods. The solvent is the moderator and cooling is achieved by circulating the whole solution.

72. *Slurry System :* studies are also being carried out on liquid metal slurry systems in which the fissile material is dissolved, or carried in particles, in some liquid metal. Both the homogeneous and slurry systems offer a number of advantages over the solid fuel type of reactor. Among others they do away with the need for fabricating cartridges ; and they make it possible to achieve greater utilisation of the fuel by continuous removal of fission product poisons.

CHAPTER V

THE PROGRAMME FOR NUCLEAR POWER

73. During the period under review a most significant stage was reached in the development of atomic energy for peaceful purposes. The rapid advance in technique and the experience gained in designing the Calder Hall station made it possible to consider a programme for the commercial production of power from nuclear energy.

74. To this end studies were made in conjunction with the Government departments concerned and with the Central Electricity Authority, on the basis of which the Government prepared a provisional programme of nuclear power. The programme was set out in a White Paper (Cmd. 9389, " A Programme of Nuclear Power ") which was presented to Parliament in February, 1955.

The Provisional Programme

75. The provisional programme is for the construction of twelve nuclear power stations during the next ten years. The programme caters for two stations to be started in 1957 which should come into operation in 1960–61. These would be followed by two more stations which would be started about eighteen months later. Each of the four stations would use two gas-cooled graphite-moderated reactors (improved versions of the Calder Hall type), and by 1963, when all should be in operation, they would have a total output of between 400 and 800 megawatts.

76. The construction of another four stations might start in 1960 and be followed by a further four 18 months later. These might be expected to come into operation in 1963–64, and in 1965; some of the last four might perhaps use more advanced reactors of the liquid-cooled type. The total installed capacity of these eight stations should be well over 1,000 megawatts.

77. The proposals set out in the White Paper therefore envisage the construction of nuclear power stations with a capacity of about 1,500 to 2,000 megawatts during the next ten years. On the assumption that they would be used as base-load stations which have little "idle time", they would be producing electricity equivalent to that produced by 5 to 6 million tons of coal annually. Under the programme, by 1965 the new nuclear power stations being brought into use each year would make up about one quarter of the total new generating capacity that was needed.

78. The programme would eventually require some expansion of the present ancillary plant. A new fuel-processing and fabricating plant would be needed in due course in addition to the existing factory at Springfields, and a new chemical processing plant would be needed to deal with the large amounts of used fuel taken out of the nuclear power stations. The total cost of the programme including the ancillary plant and the uranium charges was estimated at £300 million in the White Paper.

79. The White Paper also gave some indication of the way in which nuclear power might develop in the years after 1965. Any such forecasts are necessarily most uncertain, but if all went well it might be practicable, by the early 1970's, to expand the rate of construction of nuclear power stations to match the total United Kingdom requirement for new generating capacity which by that time might amount to 3,000 megawatts a year. On this assumption the total nuclear power 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 an annual rate equivalent to that produced by 40 million tons of coal.

The Authority's Part in the Programme

80. Although the Authority's general function covers the whole field of atomic energy, there is a specific limitation set in the matter of nuclear power. On 29th July, 1954, the Lord President issued a direction to the Authority that the production of power from nuclear energy on a commercial basis was to be carried out by the electricity authorities. The stations proposed will be built by private industry for these authorities who will own and operate them. The Atomic Energy Authority's part in the programme will be the responsibility for giving technical advice on the nuclear plant. They will also have to give considerable help in the training of the staff of industrial firms and consulting engineers. This work began during the period under review.

81. *Collaboration with Industry:* various industrial firms have been given some opportunity of acquiring valuable experience in the nuclear power field through the design and construction contracts for the Calder Hall reactors and for the research reactors mentioned in the previous Chapter. Other firms have been given contracts for design studies of even more advanced types of experimental reactor. Industry will be used to the fullest practical extent as further experimental projects mature.

82. The power programme is backed by a collaboration scheme with the Central Electricity Authority and with industry. A substantial number of engineers from the staffs of the C.E.A., of consulting engineers, and of several

heavy electrical plant manufacturers, boiler makers and other firms are engaged in this scheme and on the design of improved versions of the Calder Hall reactors. The industrial firms concerned have been formed into four teams each led by one of the heavy electrical plant manufacturers, namely: Associated Electrical Industries; General Electric Company; English Electric Company; C.A. Parsons.

83. *A.E.R.E. Reactor School:* the training aspect of the Authority's responsibility is exemplified by the Reactor School at Harwell. At the beginning of last year it was felt desirable to start a training school for new professional staff at A.E.R.E., and one to which seconded representatives from industrial firms could be sent for initial training in atomic techniques. A trial course was held in May, June and July, 1954, which was attended by 25 students, all drawn from attached staff.

84. The Reactor School was formally opened on 26th September, 1954, and during the following six months it gave instruction to a total of 82 students. Of these, 32 came from the four industrial teams, nine from the C.E.A., and the remainder from various industrial organisations connected with the nuclear power programme. Each course includes about 90 lectures over a period of twelve weeks, together with practical work, colloquia, and tutorials. The emphasis of the course is on the gas-cooled graphite-moderated natural uranium type reactor.

85. As announced in the United Nations General Assembly, on 5th November, 1954, the School will be opened to overseas students for unclassified courses from September, 1955. The first of these "open" courses was fully enrolled at an early date.

86. Apart from the Reactor School, an increasing number of industrial firms are keeping in touch with particular developments in the atomic energy field by making arrangements to attach staff to A.E.R.E. These developments cover electronics, metallurgy, and the application of radiation to industrial processes, as well as all aspects of power production.

CHAPTER VI

THE ISOTOPE PROGRAMME

87. While atomic power is now the principal objective on the civil side of the Authority's work, exploitation of the first material fruits of nuclear development—radioactive isotopes—continues at a rapid pace. Applications of these novel substances now range through many departments of medicine, of industry, and of scientific research, and the purpose of the Authority's isotope programme is to encourage these developments by supplying the materials and promoting their use.

88. The production and distribution of radioactive materials derived from reactors in the United Kingdom is the joint responsibility of the Isotope Division at Harwell and the Radiochemical Centre at Amersham, both within the Research Group; and the Industrial Group is now also taking part in one of the larger chemical operations. To foster the uses of these materials, there are the Isotope School at Harwell and advisory services at both the Radiochemical Centre and Harwell.

89. Since British radioisotopes first became available on a substantial scale in 1948 when the BEPO reactor started operation, the work of production and distribution has developed into a considerable business whose scope is now world-wide. As will be seen from the accompanying table the combined output during the year ending 31st March, 1955, was 18,835 consign-

ments, an increase of 16 per cent. over the calendar year 1953. Of this total 35·6 per cent. was exported, and the main buyers were the United States, Canada, France, Germany, and Sweden; some 40 countries in all used British isotopes last year. In addition to these direct exports, many radiation sources were supplied to British manufacturers of scientific instruments and industrial radiation equipment, and were subsequently sold abroad by them.

ISOTOPE CONSIGNMENTS

(Year ending 31st March, 1955)

	From Harwell	From Amersham	Combined Total
To United Kingdom:			
Hospitals	1,935	4,626	6,561
Universities	622	698	1,320
Industry	1,052	340	1,392
Government Departments	332	238	570
Atomic Energy Authority Establishments ...	1,867	248	2,115
Others	142	40	182
U.K. Total	5,950	6,190	12,140
To Overseas:			
Commonwealth Countries	193	468	661
Other Countries	2,687	3,347	6,034
Overseas Total	2,880	3,815	6,695
GRAND TOTAL	8,830	10,005	18,835

The value of the radioactive products sold during the year ending 31st March, 1955, was about £450,000.

Supply Prospects

90. In considering the present state of the supply of radioactive materials it is convenient to make a division according to quantity: amounts up to a few curies, which include most of the established uses of radioisotopes; the amounts of some thousands of curies, i.e. "kilocuries", for industrial and medical application of the near future. Generally speaking it may be said that at the curie level production is keeping pace with demand. Several of the more important isotopes which are made by chemical extraction from irradiated materials—these include phosphorus 32, iodine 131, and carbon 14—are now produced by a routine process at Amersham. A group of new process buildings was completed structurally in the spring of 1954 and equipped with plant specifically designed for the production and dispensing of radioactive isotopes. As a result of these new facilities there have been substantial economies in staff, the safety of the operations has been much improved, and the specific activity of the products is now higher than was possible before.

91. The most powerful sources so far produced have been of cobalt 60. But for kilocurie amounts of isotopes, such as are now envisaged in some medical and industrial applications, the source will be fission products. Up to the present time these materials, which have been accumulating in the form

of residual solutions from the extraction of plutonium, have been a liability; their intense radioactivity makes it necessary to provide permanent and costly storage for them. Fission products contain some twenty elements in the middle section of the periodic table, including the rare earths, and complete separation of them on an industrial scale would be a formidable problem. However, only two of them are of considerable importance so far, caesium 137 and strontium 90, and a pilot plant for separating these two on the scale of about 100 curies per annum has been operating at Amersham. Based on this experience the Research and Development Branch at Windscale is now constructing a plant which is designed to produce concentrated sources of these elements with activities in the region of 1.000 curies. The first kilo-curie source of caesium 137 will be sent, during the second half of 1955, to the Royal (Cancer) Marsden Hospital in London where it will be used for radiotherapy. Such units are expected to have considerable technical and economic advantages over the orthodox X-ray machines, and in time they will probably replace them.

92. The separation of fission products on this large scale will also contribute in time to a solution of the problem of waste disposal, for the isotopes caesium 137 and strontium 90 are the ones that make permanent storage necessary on account of their long life. If they could be removed completely the remainder of the fission products would decay within a reasonable time and when the activity had reached a safe level they could be discharged to sea (See Chapter IX).

Developments in Usage

93. Although the use of separated fission products at the kilocurie level is still only in prospect, there has been a marked increase in the use of smaller amounts for industrial and medical purposes. To meet this demand much effort has been devoted to the design and manufacture of radiation sources in which the fission product isotopes can be used in a form that is both safe and efficient. The improved supply of high quality beta-ray sources has enabled British manufacturers to gain some big orders for electronic equipment, and several hundred thickness gauges have been exported. Foils containing the beta-emitter strontium 90 are now being used on a considerable scale in the textile industry for eliminating troubles arising from static electricity in the weaving of artificial fibres. Similarly, the gamma-emitting isotope caesium 137 is coming into use for industrial radiography now that it can be supplied in capsules for this purpose.

94. In most tracer investigations the chemical form of the isotope is of paramount importance, and a particular "labelled compound" must be used according to the purpose of the experiment. The synthesis of compounds of the very important isotope carbon 14 has continued at Amersham; about 40 new compounds were prepared during the year, bringing the total number available for general distribution up to 130. The compounds of carbon 14 are generally stable enough to be stored until they are wanted, but compounds of several other isotopes which are short-lived must be prepared specially for each user and it is clearly important that methods of preparation shall be quick and efficient. Improvements in technique have made many of the commoner compounds of such isotopes as phosphorus 32, iodine 131, and sulphur 35, more readily accessible than before.

95. Those engaged in biological researches are still the predominant users of labelled compounds, but the radioactive tracer method is of wide application and there is now evidence of a growing interest within industry generally. The number of laboratories in the United Kingdom now using tracer methods is thought to be about 100. Some typical applications are to be found in

the technology of detergents and other surface active compounds, of petroleum fuels, and in the manufacture and use of systemic insecticides.*

96. The use of human serum albumin labelled with radioactive iodine 131 has become widespread in the United States for medical diagnosis, particularly the determination of blood volumes and the study of the circulation in human patients. With the assistance of the Ministry of Health and of the Medical Research Council a regular supply has recently been made available to doctors in the United Kingdom through the Radiochemical Centre at Amersham.

CHAPTER VII

THE WEAPONS PROGRAMME

97. During the period under review the Authority fulfilled the directives of Her Majesty's Government concerning research and development on atomic warheads and the production of fissile material. As already mentioned in Chapter I the Defence White Paper (Cmd. 9391) announced the Government's decision to proceed with the development and production of thermonuclear weapons.

CHAPTER VIII

PROGRESS IN RESEARCH

98. To support their civil and military programmes the Authority must provide scientific knowledge of the highest quality, backed by extensive research and research facilities. The designers of plant, equipment and weapons must have available the results of tests and trials of the materials and the systems they wish to employ and a constant search must go on for improvements in these materials and systems. The widest possible examination must be made of more advanced methods of generating atomic power and of processing the fuel used in reactors. Some of these methods, when their difficulties are solved, may prove much cheaper and more convenient than those which are at present under development. Research must also be carried out on the by-products of an atomic power programme, such as isotopes and the radiation from the fission products produced in reactors, which have important industrial applications.

99. The Authority have at A.E.R.E. Harwell their major establishment for pure and applied research. In the Industrial Group they maintain a Research and Development Branch mainly devoted to applied investigations and at A.W.R.E. they conduct research, both fundamental and applied, for the weapons programme. The activities of these laboratories are closely co-ordinated and research on specific projects is frequently shared among all three groups.

100. Reference has been made in Chapters IV and VI to the design of nuclear reactors and to the application of research to the production and use of radioactive isotopes. Applications to public health and safety are dealt with in Chapter IX. For the large field remaining all that can be done is to indicate the scope of the research programme and to select a few illustrative examples.

* For a more detailed description of some of the latest uses of radioisotopes see "Atomic Energy Research" by K. E. B. Jay (Butterworth Scientific Publications, London, 1955). This is an official publication of the Authority.

Physics

101. The first science basic to the atomic power and weapons programme is physics, including mathematical physics. Since the particles actuating reactors are neutrons arising from atomic fission and producing further fissions and further fissionable atoms, much research must be carried out to determine the exact nature of the interactions of neutrons of different speeds with a variety of elements. To extend the facilities available for this purpose, a novel and much more powerful source of neutrons for use in the laboratory (the " neutron project ") is being developed at A.E.R.E., in which the multiplying effect of a uranium target bombarded by neutrons resulting from a powerful pulsating electron beam (25 MeV at 1 amp) is used to enable measurements to be extended and made more accurate. The first stage of a working equipment is to be installed in the autumn of 1956.

102. The Authority consider it essential also to foster a programme of fundamental research into the study of the unresolved problem of the forces which bind together the elementary particles in atomic nuclei. The 110-inch synchro-cyclotron at Harwell has been in use since 1949 to produce beams of fast particles for such studies and was the first high energy machine to operate in Europe. In the meantime other countries have developed or are planning particle accelerators of much higher energy and consideration is now being given to the design of a new machine which will provide for this country, in association with the Universities, a facility which is seriously needed to keep us in the forefront. The exact form that this new accelerator will take has not yet been decided and awaits the results of complex calculations. The machine most exhaustively studied has been a 600-million-volt proton linear accelerator of which a 50-million-volt pilot section is under construction. But in view of the rapid advances being made in the field of high energy particle acceleration it has been decided to examine the problems involved in the design and construction of machines of still higher energy before proceeding further.

103. Important though they are for fundamental studies in physics as applied to atomic energy, these two projects occupy only a small fraction of the staff and facilities available for work in this field. Since their subject covers in great detail the whole of radioactivity and of radiation, the physicists must have expert knowledge and special equipment over a very wide range. Amongst the new machines recently built is one to separate milligram quantities of the chemically inseparable isotopes of heavy elements such as plutonium, americium and neptunium by magnetic methods to enable studies to be made of their reactions with neutrons and other particles.

Chemistry and Chemical Engineering

104. The science of chemistry is also fundamental to the Authority's programme. The strong radiations in atomic reactors lead to the production in appreciable quantities of elements of whose chemistry very little is known. The chemical behaviour of elements such as ruthenium, polonium, protoactinium, actinium, neptunium, americium and curium may be as important to the programme as is that of uranium, thorium and plutonium and much research on them must be conducted.

105. The chemist is also required to explain and predict what happens when chemical compounds are exposed to intense radiation from neutrons and gamma rays. This growing field of radiation chemistry, in which major chemical changes can be produced without changes in temperature or pressure, requires intensive exploration. Studies have shown that important chemical and structural changes can be brought about in materials irradiated

by powerful radioactive sources. Amongst these are improvements in the heat resistance and other physical properties of plastics and in the properties of lubricating oils. These investigations may well lead to a further large industrial demand for the separated fission products referred to in Chapter VI, to which must be added their probable employment in the sterilisation of food and of food wrappings and containers.*

106. From the many fundamental chemical investigations being undertaken have come some valuable new scientific techniques and new instruments of general application. One example is the extremely sensitive analytical technique of radio-activation, in which the amounts of minute traces of impurities can be determined by exposing the material in a reactor and converting these impurities into radioactive forms. They can then be identified and measured by the rays they subsequently emit.

107. One new instrument of value outside its original application is an infra-red spectrometer developed for recording continuously the percentage of heavy water in a mixture of light (i.e., ordinary) and heavy water. Another is an analytical device known as the square-wave polarograph which can rapidly measure minute traces of impurities in materials.

108. Research in technical chemistry and in chemical engineering is fairly evenly divided between the three main groups of the Authority, the longer range studies being mainly carried out at A.E.R.E. The Research and Development Branch of the Industrial Group has dealt successfully with the development of new solvent processes for the extraction of uranium from its ores and with the application of the so-called "fluidised bed" technique to the processes used in the Industrial Group. Essentially this technique facilitates chemical reaction between a solid and a liquid or gas by using the solid in the form of a bed of finely divided particles through which the second material is blown and which owing to its finely divided state behaves like a fluid.

109. Processes for the extraction of metals from low-grade ores are studied at a section of the Chemical Research Laboratory of the D.S.I.R. at Teddington, mineral dressing work is done at Harwell and the development of methods for the production of uranium metal is carried out mainly in Springfields. The chemical technology of other metals is studied by the Authority, where appropriate, or by outside contractors under research contracts. Considerable chemical engineering development work is done by the Industrial Group at Windscale while a wide range of plant development and basic design studies is carried out at Harwell. Most of the large amount of chemical research work involved in the weapons programme is carried out at A.W.R.E.

Metallurgy

110. Metallurgical research in the Authority begins with the extraction of metals from the ore; then follow the fabrication of metals, alloys and ceramics and determination of their physical and chemical properties; the effects of irradiation on materials, particularly the fuels of reactors, and the high-temperature processing of irradiated fuels. In each of these fields developments can have a profound influence on the economics of nuclear power, on the ease with which reactors can be operated and on their safety.

111. The metallic materials of atomic energy have introduced new names to the public—uranium, plutonium, thorium, zirconium, beryllium. These metals, which until atomic energy required them were comparatively rare

* To provide further facilities for the practical application of this work and to assist industry with advice and tests, a Technological Irradiation Group was established as part of the Isotopes Division of A.E.R.E. in April, 1955.

in an industrial sense, have now to be extracted from their ores (or in the case of man-made plutonium, from irradiated uranium) on a large scale. Although existing methods for producing them have served well, there is a continuing search for cheaper processes which will yield metals of superior quality. During the past year a new method using only cheap chemicals and simple equipment, in which the oxides of uranium, thorium or beryllium are converted to the appropriate chlorides, from which in turn the metal can be extracted, has been tried on a pilot scale with success. By changing the conditions of reduction the metals can be obtained in the form of powders of varying shape and size, which affords the metallurgist some freedom and flexibility in fabrication and provides the engineer with materials whose properties can be modified.

112. The metals having been made, they have to be worked into the shapes required by the engineer, and this is not always easy. Research has to be carried out on arc-melting them in special atmospheres, on extruding or rolling them in enclosing sheaths of cheap, chemically resistant metals and on powder metallurgy methods of fabrication. All this work is yielding techniques of increasing application in the manufacture of reactor fuels and of the special canning materials which contain them.

113. Since the materials in a reactor must not corrode in the coolant, the finding of corrosion resistant alloys stands high on the list of research requirements. The coolant can be an oxidising or reducing gas, high temperature water, or a liquid metal like sodium or bismuth. One example of present research interest relating to water-cooled reactors may be quoted. Zirconium-tin alloys are particularly resistant to water corrosion at 300° C. This material is, however, expensive and its technology has to be learned. An aluminium alloy which could give similar service would be an attractive alternative. It has recently been established that such an alloy can be made with useful corrosion resistance up to 300° C. for short periods (about 200 hours) and this may be the precursor of aluminium alloys for future power reactors using water as coolant.

114. The key component in a reactor is the fuel element, and its behaviour under irradiation constitutes a major problem of atomic energy. When a uranium or plutonium atom splits, the resulting pair of atoms hurtle through the lattice of the solid with high energy and disrupt the orderly array of atoms in their path. Even when the fission products come to rest they still affect the metal because two atoms different in nature from uranium or plutonium have to be accommodated where only one atom existed before ; since some of the fission products are gases, xenon and krypton, the effect of these when they aggregate in " pockets " in a solid can be profound. The phenomenon of fission can make uranium metal grow, contract or crack, wrinkle the surface or blow it up like a sponge. How to control these effects by modifying the metallurgical structure of the fuel or its design is an important item in the research programme of the Authority. One example will show how a solution to one of the effects has been obtained. The wrinkling of the surface of uranium is related to the grain size. The grain size of metals can be modified by heat treatment or by alloying. The techniques for achieving this have been worked out and are being used as part of the manufacturing techniques in the factories.

115. Solid fuel elements are at present used in most reactors but have other disadvantages besides their susceptibility to irradiation damage. Their charge and discharge from the reactor complicates engineering design and the cost of processing them before and after irradiation is a significant item in nuclear power economics. These disadvantages might be avoided if the

fuel could be liquid at operating temperatures. Uranium and plutonium solutions in molten bismuth, lead and other metals are known ; these solutions are, however, dilute and increased concentrations can only be achieved by using mixtures known as slurries. These, although not true liquids, behave like fluids under certain conditions and may be of interest in future reactor designs. The growth, settling and distribution of the solid particles of a slurry and their interaction with the liquid medium are therefore under continued study.

116. Solid fuels, however, need not be metallic and ceramic compounds with high melting points (about 3000°C) are of some interest. These are generally brittle and methods of making them more resistant to shock are being studied. This may be done by preparing cermets, i.e. mixtures of metals and ceramics appropriately distributed. Some interesting possibilities are uranium-thoria, silicon-uranium oxide and uranium-uranium carbide.

Reactor Studies

117. Something about the research needed for the design and development of new types of power reactor has already been said in Chapter IV. It begins with a " feasibility study " in which engineers, physicists, metallurgists and chemists co-operate to seek feasible solutions to a great variety of problems. The proposed system must not only be one which is workable and economic as a piece of engineering " hardware " ; it must also stand up to the conditions which arise when it is running as an atomic reactor bathed in intense radiation at high temperatures. The degree of corrosion and deterioration of working components must be carefully estimated, for it is not an easy matter to change a valve or a pump in an atomic reactor, even when it has been shut down. Thus power reactor design studies call for special physical and engineering researches and for prolonged tests on the research reactors described in Chapter IV.

118. Since it is intended to use a liquid metal as the coolant for the fast reactor and liquid metal coolants may possibly be used in other reactors, research has been carried out on some of the problems involved. These have included the development of new kinds of pumps for the circulation of liquid sodium or sodium-potassium alloy, the clearing away of unwanted oxide films and the transfer of the heat taken from the reactor by the liquid metal to water which will generate steam for a turbo-alternator.

Electronics

119. Work in the atomic field cannot proceed far without the aid of the ubiquitous electronic instruments. They are required on a large scale for the control of atomic reactors and processing plants. They are needed to study the performance of atomic weapons, to search effectively for uranium-bearing ores in remote countries and to protect the health of plant workers. The development of this wide range of electronic instrumentation has meant a considerable research programme, in which the Authority have collaborated with members of the Scientific Instrument Manufacturers Association. It is now possible for outside users to purchase most of the more widely used instruments direct from industry and a growing export trade has developed.

120. An example of one of the more elaborate applications of electronics is afforded by the electronic analogue computer being developed at A.E.R.E. to simulate the operation of a large atomic power station by showing directly and so without the need for elaborate calculation how the essential factors involved change with time and interact with one another. With this machine it is hoped to be able to predict the performance of such a station under very varied conditions and to study the effects of alterations in design.

Extra-Mural Research

121. One of the special functions of the Authority, as stated in the 1954 Act is "to make arrangements with Universities and other institutions or persons for the conduct of research into matters connected with atomic energy or radioactive substances". This extra-mural research and development has made a major contribution to the work of the Research and Industrial Groups during the period under review. A great many research contracts have been placed with industrial firms and much help has been obtained from the Universities in the form of laboratory investigations and through the advice given by expert consultants.

CHAPTER IX

HEALTH, WASTE DISPOSAL AND SAFETY

122. There are risks in atomic energy work, as there are in any scientific or industrial venture. But they are risks that are as easily measurable, and as well understood, as those in any other undertaking and can be guarded against accordingly. The Authority take the utmost care to protect their staff and the public from any possibility of harmful effects from their operations.

Health

123. The Medical Service of the Authority is concerned with the various aspects of occupational health and hazards in each of the Groups. Advice from the medical point of view is given on toxic and other environmental hazards and on the protection of workers required. This advice is given both for current work and for planned future developments. Treatment of accidents and illness at work is provided and a continual survey of the health of all staff is maintained by means of periodical medical examinations.

124. The lost time accident rate, both in frequency and severity, is low and compares favourably with the Factory Department figures for other industries. It is on a par with the rate for the light engineering, electrical and radio industries. During the period under review there have been no fatal accidents; indeed throughout the whole history of the project there has been only one fatality among the operating staff, and that was due to a fall from a platform.

125. The general health of the staff has been well maintained and the sickness absence rate has remained low.

Waste Disposal

126. In common with most other industrial operations, the activities of the Authority lead to the production of quantities of waste material for which storage or disposal arrangements have to be made. Some of the waste is radioactive and precautions have to be taken with this material similar to those necessary with toxic chemical waste in other industries. The disposal of this radioactive waste has been the subject of much thought and several methods have been developed which enable it to be dealt with safely. A great deal of work is still in progress, however, for this is an active and expanding branch of chemical technology.

127. Under the provisions of the 1954 Act the disposal of radioactive waste can take place only with the prior authorisation of the Minister of Housing and Local Government and the Minister of Agriculture, Fisheries, and Food. These Ministers have the power to appoint inspectors who have the right of entry to see that the authorisations are complied with.

128. The recommendations of the International Commission on Radiological Protection and of the Medical Research Council have been taken as a basis for fixing the authorised discharges. These bodies have recommended maximum permissible levels for exposure to radiation and for radioactivity in air, drinking water and the human body. The levels have been arrived at from extensive experimental work in many countries and from more than 50 years' practical experience with X-rays and radium ; the Commission has said that exposure to these levels "is not expected to cause appreciable bodily injury to a person at any time during his lifetime". These levels are intended to apply to persons exposed to radiation during the course of their job, and the Commission has recommended that where large populations are exposed to radioactivity a further safety factor of 10 should be applied in order to ensure complete protection to the general public.

129. Another margin of safety is provided by the fact that some of the agreements on the discharge of radioactive waste, having been negotiated several years ago, are based on the even more rigorous safety factors that were then considered desirable. For instance, when radioactivity is discharged to the River Thames, which is one of the main sources of London's drinking water, the Medical Research Council has recommended a safety factor of 100 coupled with the requirement that the specification must be met at the point of entry and not at the point of withdrawal. These recommendations have always been complied with.

130. *Liquid Waste :* High-activity liquid waste, arising mainly in the chemical separation of fission products from spent nuclear fuel, is stored in specially designed tanks. In some cases, when the radioactivity decays reasonably quickly, the liquid need only be stored until the activity is low enough to permit disposal either directly or after treatment.

131. Many of the Authority's establishments have to handle large volumes of low-activity liquid waste, and this is dealt with by dispersal either to sea, rivers, or sewers, after treatment to reduce the activity level to that permitted under the statutory authorisations and to ensure that the effluent is suitable for discharge on general chemical grounds.

132. The Authority are required to analyse samples of all liquid effluent discharged and to keep records and duplicate samples for inspection by the representatives of the Ministries concerned.

133. The authorised discharges to rivers that are sources of drinking water are based on the premise that any member of the general public may consume, throughout his life, 2½ litres (about 4½ pints) a day of the raw river water immediately below the discharge points. In those cases, as at Windscale, where discharges are made to sea through pipe-lines, considerable research and field tests have established rates of discharge which can in no way affect either the health of the public or the industries concerned—in particular fisheries and the use of seaweed.

134. *Solid Waste :* Two methods are used at present for dealing with high-activity solid waste: storage and deep-sea disposal. In practically all cases combustible material is first reduced in bulk by burning under controlled conditions. If storage is used, the storage accommodation is specially designed and sited so that no contamination of drinking water supplies can take place. In the case of sea disposal the waste is carried out into the Atlantic beyond the Continental Shelf. In addition to the highly active waste, material is included in this remote dumping which, if not placed in drums, would float ; also included are some scrap materials whose salvage would be undesirable.

135. The waste is contained in concrete blocks, surrounded by a mild steel outer shell. These blocks are designed to sink to the sea-bed, where they will gradually disrupt over a period of many years; during this period the activity itself will be dying out by the natural laws of radioactive decay. The disposals are carried out in water more than 2,000 fathoms deep, several hundred miles from the British coast, and in areas approved by the Minister of Agriculture, Fisheries and Food. The depth is far below that of any possible trawling operations. Each cargo is accompanied by a responsible officer of the Authority who certifies to the Minister the total tonnage dumped and that all the containers sank; he also supplies an extract from the ship's log giving the area of dumping.

136. Low-activity solid waste includes equipment from laboratories and sludge derived from the treatment of low-activity liquid waste. Permanent controlled storage of this waste is neither necessary nor economic, because little or no health hazard is involved. The main danger is the possible re-use of salvaged material in equipment used for radioactivity measurements. Controlled burial of this waste, apart from sludge, is carried out provided that the location is geologically satisfactory and that no contamination of underground water supplies is possible. Burial is particularly suitable for these materials which are in an insoluble form.

137. Under the authorisations granted, regular sea disposal of low-activity waste is made in the recognised dumping areas off the British coasts, which are used for the disposal of surplus Service material, such as unstable ammunition. The controls exercised are similar to those for the Atlantic disposals and each cargo is accompanied by a responsible officer of the Authority. Trawling is not normally carried out in these dumping areas but the activity in question is so low that even if a drum, or its contents, were brought to the surface and handled by a fisherman no possible harm could be done to him.

138. Last year it was the intention of the Authority to dispose of certain low-activity solid waste down a number of disused mine-shafts in the Forest of Dean. The rigorous precautions described above would have been observed and the Authority were completely satisfied that there would have been no harmful effects. However, the Authority were unable to secure permission from the owners of the mines, and therefore, although they were satisfied that there was no risk, abandoned the proposal.

139. *Gaseous Waste:* The main source of gaseous waste is the air used to cool the fuel elements in the air-cooled reactors. The removal of the short-lived radioactive argon from the air stream is not usually practicable; instead the principle of dispersal is used. In some cases stacks of more than 400 feet high are used to ensure adequate dilution. The air discharged from laboratories or plants may also contain radioactive dust particles, liquid droplets, or mist. In some instances this may be dispersed safely, but in other cases safety is achieved by removing much of the dust before the air is discharged. For this purpose filters, electrostatic precipitators, or centrifugal precipitators are used. The collected dust and contaminated filters are dealt with as liquid or solid waste.

140. The atomic energy project has, from the start, monitored its gaseous effluent either at the outlets or in the surrounding district. The Authority are now required by law to take samples either at the point of discharge, or of soil and vegetation in the neighbourhood, to satisfy the authorising Ministries that human beings, farm animals and crops will not be affected by the effluent. They are also required to keep the activity of the gaseous waste down to as low a level as is practicable. It is worth noting that stringent

control of discharged activity is also needed to prevent interference with the technical work of the Authority, and in most cases this factor limits the activity discharged even further.

141. *Present and Future*: The methods for disposal of radioactive waste described above enable the Authority to get rid, as far as necessary, of all that arises from their present work. The precautions taken are such that there can be no conceivable hazard to human beings, agriculture, or fisheries. The statutory requirement for each disposal operation—of prior authorisation by the two Ministries—ensures that the safety aspects are continually kept under review and provides a safeguard that the conduct of the operations is not at any time contrary to the public interest. In most of the methods used the factor of safety can be shown by calculation to be very large indeed, and entails considerable expenditure. Efforts have therefore been made to find cheaper methods of safe disposal (as, for instance, by carefully controlled burial rather than by discharge to sea) and there is undoubtedly room for further development in this direction.

142. With regard to the future, intensive research on manipulation, chemical separation, storage and disposal of fission product waste has already shown that no insuperable difficulties will be encountered with the progress of the nuclear power programme.

Safety

143. The publication of the power programme included some remarks on the siting and safety of the proposed stations. (Cmd. 9389, paras. 36 and 37):—

> " . . . 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.
>
> ". . . 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."

Genetic Effects

144. The Authority collaborate closely with a Radio-biological unit of the Medical Research Council, under Dr. J. F. Loutit, which is located at Harwell.

CHAPTER X

THE AUTHORITY'S STAFF

Retention

145. In accordance with the White Paper on " Future Organisation " (Cmd. 8986) the entire staff, both industrial and non-industrial, who had been in the service of the Department of Atomic Energy before Vesting Day [save only for a few who remained to form the Office of the Lord President (Atomic Energy)] were seconded to the Authority on 1st August, 1954. One of the Authority's first tasks was to determine their terms and conditions of employment in order that the seconded staff might make their decision whether or not to stay with the Authority ; a great deal of preliminary work had, of course, been done in the months preceding Vesting Day.

146. The White Paper had recognised that the Authority would require to have some flexibility with regard to the conditions of employment of their top staff. It is in the higher ranges, accordingly, that the Authority have made the most significant changes. Three salary bands have been established for managerial staff, and within these bands officers will have their salaries assessed periodically according to individual responsibility and merit.

147. So far as the rest of the non-industrial staff was concerned, some change from Civil Service salaries was necessitated by the introduction of a contributory pension scheme. (The Superannuation Acts provide for non-contributory pensions for Civil Servants, but it was felt that the Authority should follow the general pattern of industry, including nationalised industry, and establish a contributory pensions scheme). But the Authority were under injunction to avoid terms and conditions widely divergent from those of the Civil Service. For almost all the non-industrial grades the Authority have therefore, laid down salary scales consisting of the appropriate Civil Service scales plus the amount necessary to provide for pension contributions.

148. For the industrial grades, whose pension provision remains non-contributory (see para. 165 below) the Authority have initially adopted the wage rates paid to industrial employees in Government establishments.

149. The Authority have adopted the majority of the Civil Service provisions in such matters as hours of work, leave, sick leave, etc. Some changes have been made where regulations appropriate for Civil Servants were unsuited to the circumstances of a statutory body such as the Authority ; and further changes will continue to be made from time to time after proper consultation with the Staff Associations concerned.

150. Offers of employment have been issued by the Authority, on the general lines described above, to all their seconded staff, and also to ex-Ministry of Works staff in so far as the functions formerly carried out by the Ministry of Works have been taken over by the Authority, and to those members of the War Department Constabulary and Admiralty Constabulary who had been serving at atomic energy establishments and who, with effect from 1st April, 1955, formed the nucleus of the Authority's own constabulary. Each individual has until 1st February, 1956, to make his decision ; those established Civil Servants who elect not to accept the Authority's offer will be eligible for reposting in the Civil Service.

151. By the end of the period under review, all but a handful of the senior staff had accepted employment under the Authority. Similarly, the great majority of the industrial employees had signed on. Offers of employment to the junior non-industrial staff did not issue until 1st February, 1955. By 31st March 50 per cent. had replied ; 44½ per cent. had accepted and 5½ per cent. had rejected their offers.

Recruitment

152. The Authority's recruitment difficulties have been emphasised in Chapter I (paras. 5 to 6). The staff which the Authority took over on 1st August, 1954, was materially below the required level for the programmes then in hand. Since that date the programmes, both military and civil, have been enlarged with a consequent increase in labour requirement ; and to normal wastage has been added the exceptional wastage referred to in the preceding paragraphs. Moreover, most of the Authority's establishments are in comparatively isolated areas ; the labour resources of the surrounding localities have long since been exhausted.

153. It has been necessary therefore for the Authority to devote a great deal of effort to the problem of recruitment. Public advertisement of vacancies is only the first and obvious step. In addition, close contact has been established with Universities, schools and technical colleges; recruiting teams from the Authority have carried out a large programme of visits, experience having shown that personal contact is infinitely more profitable than the written approach. Despite this considerable diversion of effort, the net increase in the Authority's labour force is disappointing, and two conclusions are unavoidable: —

(*a*) There is a serious national shortage of most types of scientists and engineers and of many technical and craft grades.

(*b*) The Authority have not the same freedom of movement as industry in the matter of salaries.

154. An organisation expanding at a normal rate trains its future managers and executives from among its own staff. The Authority are doing this to the utmost extent possible; but the weight of new commitments has forced them to look outside for a large number of senior staff, and it is not easy to attract men who have long settled in other employment and most of whom would have to sacrifice valuable pension rights on changing jobs.

155. This difficulty is to be expected. The Authority's difficulty in recruiting the younger engineers and technicians who are needed to form the base of the pyramid today and to provide the leaders in years to come is more disquieting. In the Industrial Group in particular, recruitment of professional and scientific staff has done no more, over the last eighteen months, than keep pace with wastage: there has been no increase in manpower to match the increased programmes, both civil and military. Inadequacy of staff is a constant threat to the achievement of the Authority's programmes; and there is always the fear that even if the dates are achieved (as so far they have been) details will have been skimped that will be the cause of operating troubles for the future.

Lodging Allowances

156. In order to encourage recruitment, the Authority pay lodging allowances to married recruits in certain junior grades until such time as they are able to get their families moved to their new places of employment.

Equal Pay

157. The Authority have accepted the principle of equal pay for women and have introduced a scheme comparable to that agreed to for the Civil Service. The first instalment of the seven-year process has been made.

Staff and Industrial Relations

158. The U.K.A.E.A. Whitley Council for non-industrial staff is on standard Civil Service lines. It was taken over by the Authority, in agreement with the staff representatives, from the Department of Atomic Energy. Similarly local Whitley Committees already in existence at the Groups were continued without much change. In accordance with the 1954 Act the Whitley Council, its special negotiating committees (or "joint working parties"), and the various staff associations individually have played a substantial part in working out the new conditions of service; they will continue to do so. The Joint Working Party on the Principal Superannuation Scheme illustrates how valuable this kind of co-operation can be. Another example is the joint study of training and welfare provisions which is now going on. Also, in accordance with the requirements of the Act, arbitration machinery is in course of negotiation.

159. On the industrial side the draft constitution for a Joint Industrial Council was, at the end of the period under review, being discussed with the headquarters of the trade unions. The constitution has been agreed since the period covered in this report. At the establishments Joint Works Committees set up by the Ministry of Supply have continued to function satisfactorily.

Training

160. The Authority inherited an admirable system of staff training from the Ministry of Supply, and they are taking steps to extend this, wherever possible, as a long-term method of overcoming recruitment difficulties. Junior employees in the scientific and technical grades are given assistance to obtain technical qualifications by attendance at technical colleges and universities, partly in official time. Moreover, the Authority offer bursaries for full-time university education to the best of their junior scientific staff.

161. The Authority have continued the Ministry of Supply apprenticeship schemes which were already in operation at their establishments. These schemes cater for the training of craft and student apprentices and also, in certain cases, for the training of students prior to entrance to a university. In 1954 80 craft apprentices and 15 student apprentices were recruited.

Pensions

162. The Principal Superannuation Scheme for non-industrial staff has been worked out by agreement with the Government Departments concerned and with the staff representatives to provide a scheme of pensions and benefits broadly similar to those given to established Civil Servants. It is contributory, and compulsory for all full-time non-industrial staff other than those excluded by the age limits or those who are covered by other arrangements.

163. The Minimum retiring age is 65 for men and 60 for women, but initial entrants who were established Civil Servants retain their right to retire at 60 and their right to certain other privileges. There is considerable provision for interchange with other schemes and, unlike the Civil Service, there is provision for buying added years of reckonable service and purchasing earlier qualifications for benefits.

164. Some officers have an option to retain their membership of other schemes—for example, the Federated Superannuation System for Universities, the Federated Superannuation Scheme for Nurses and Hospital Officers, and the Department of Atomic Energy (formerly Ministry of Supply) Special Classes Scheme.

165. Those industrial employees who were in the service of the Department of Atomic Energy before Vesting Day retain their previous rights to pension on a non-contributory basis, by analogy with the Superannuation Acts.

Living Conditions

166. The Authority have a responsibility for ensuring that their work is not hindered by the absence of reasonable amenities and facilities for their staff. Most of the establishments are large and are in comparatively undeveloped rural areas. A considerable proportion of the staff—indeed most of the skilled staff—have been recruited from other areas where they were accustomed to urban amenities. The influx of so many people in a relatively short time has aggravated the problems of the local authorities; both the Ministry of Supply in the past and the Authority to-day have therefore accepted a large share of the responsibility for providing housing and other

services. If they had not done so the atomic energy project could not have developed as rapidly as it has.

Housing

167. The local authorities are responsible for providing houses for the Authority's locally recruited staff; The Authority's own housing problem therefore depends on how many staff are recruited from elsewhere. This does not mean that local authorities have done nothing to meet the needs of employees from outside their areas: they have provided about 1,000 houses for them, they are building more than another 350, and it is hoped that they will eventually be able to provide a further 500. Nevertheless, the help that local authorities can give depends very largely on individual circumstances; frequently they are unwilling to allocate houses to new residents employed by the Authority before the needs of older residents have been met. The Authority have therefore followed the policy of the Ministry of Supply and the Department of Atomic Energy and have provided houses themselves where local authorities have been unable to do so.

168. On 1st August, 1954, the Authority took over 2,650 houses, of which all but 186 had been built since 1946; by 31st March, 1955, they had completed a further 100 houses, had 470 in course of construction and had 900 planned. The great majority of these houses are similar in type to local authority houses and the rents are comparable. A small number of larger houses with higher rents have also been provided for senior staff.

Hostels

169. The impossibility of finding a sufficient number of suitable lodgings for unmarried staff reasonably near the establishments has forced the Authority to continue to provide hostels. On 1st August, 1954, they took over nine hostels with accommodation for 1,050 employees; this will shortly be increased to 1,350. In addition a small hotel has been acquired for conversion to a hostel at Dounreay.

Schools

170. Responsibility for providing primary, secondary, and further education—apart from specialist education in the establishments themselves—rests with the Ministry of Education, the Scottish Education Department and the local education authorities. The problems which have faced the local education authorities at the establishments are similar to the problems which have faced them elsewhere; shortage of teachers and accommodation, shortage of places in secondary grammar and secondary technical schools in some areas, and the high birthrate in the immediate post-war years. The problems are aggravated by the fact that a very high proportion of the Authority's employees are young married people and the birthrate at some of the establishments is twice the national average. The Authority have helped local education authorities by allowing them to use establishment buildings or by reserving sites for schools.

171. Despite the difficulties, the main problems of providing adequate educational facilities for the Authority's employees and their children have now been solved in most areas in which the Authority are concerned.

Transport

172. It is the Authority's policy that staff should be transported to and from their homes as far as possible by public services. Public operators are encouraged to extend their scheduled services to meet employees' needs.

Where they are not prepared to do this the Authority normally hire coaches for given runs from the public operators. In some cases, however, coaches cannot be provided at economic rates and the Authority have to run their own buses, as did the Ministry of Supply. The Authority own 134 buses, but a number of these are used only for internal services at the establishments.

173. Excluding buses, the Authority have 514 vehicles of all types. As with staff, so with the transport of goods: public carriers are employed as much as possible. It is sometimes necessary, however, for reasons of security, speed, or the type of load (e.g. radioactive materials) to use the Authority's own transport.

CHAPTER XI

INTERNATIONAL ASPECTS

174. The previous chapters of this Report have shown that the United Kingdom has built up a great fund of experience in atomic energy. This knowledge is obviously of great value to other atomic energy organisations, and within the limitations set by available resources and strict security the Authority have given assistance to other countries. They have continued the co-operation which was begun before they were appointed and they have negotiated, or are in course of negotiating, a number of new arrangements. All these arrangements provide for the exchange of information and some of them provide also for the supply of materials; except in the case of the U.S.A. they are concerned exclusively with the peaceful applications of atomic energy.

The Commonwealth Countries

175. The atomic energy project in the United Kingdom and the projects in various Commonwealth countries have worked in close collaboration during the period under review. Commonwealth students are coming in increasing numbers to A.E.R.E. for training at the Isotope and Reactor Schools; the closest touch has been maintained between the Authority's scientists and their colleagues in the Commonwealth; and, at a more formal level, the Authority have had many discussions with the Commissions and Boards that have been set up in the Commonwealth Countries.

176. *Canada:* contact with Canada has been close ever since the early war years. Canadian scientists have had full access to research and development work on nuclear power at Harwell, and the staff of the Authority and their predecessors have gained great benefit from contact with Canadian scientists and from attachments to the Canadian atomic energy establishment at Chalk River, Ontario. At Chalk River there is the NRX reactor—a high flux reactor using natural uranium as fuel and heavy water as a moderator —which has provided unique opportunities for testing various materials and fuel systems. The British project has been able to use this reactor for investigation of some of its own technical problems.

177. *Australia:* reference to collaboration with Australia as a source of uranium and beryllium has already been made in this report. In the summer of 1954 the Authority undertook to help Australia design and build a reactor similar to DIDO, and in due course to supply fuel elements for it and to process these when they are spent. For her part Australia will make available to the Authority information gained during the operation of the reactor. The United Kingdom will also provide technical information required for the development of the Australian programme, and a number of Australian scientists are now receiving training in the Authority's establishments.

178. *New Zealand:* the agreement between the Authority and the New Zealand Government for the construction of a heavy water plant operated by geothermal power has been described in Chapter III.

179. *India:* the Authority have discussed with the Indian Department of Atomic Energy the drawing up of a programme of research and development to be carried out in India, so framed as to avoid duplication of effort and to ensure the maximum degree of co-operation and mutual assistance. The Authority have offered to assist in the design and construction of a research reactor to be built in the near future and of a larger research reactor which may be built at some later date, and will make available fuel and other facilities needed for carrying out the agreed programme.

180. *Pakistan:* Pakistan has recently set up a committee to administer her atomic energy project. The Authority have offered to give help in training staff and in supplying equipment and radioactive isotopes.

181. *South Africa:* South Africa intends to send a small mission to study the British project and to hold preliminary discussions on the type of development programme which might suit her needs.

182. The extent of the collaboration described above is related to the stage of development reached in each country. But in all cases the aim is the same: that the Authority and the Commonwealth country concerned should give each other all practicable help to further their projects for their mutual benefit and for the benefit of the Commonwealth as a whole.

United States

183. Collaboration with the United States, with which the United Kingdom is associated in the Combined Development Agency (see Chapter III), began in the war years and has continued since so far as has been compatible with U.S. legislation. The United States Atomic Energy Act of 1954 allowed scope for increased co-operation with other countries, and the Authority have given technical advice to Her Majesty's Government in the negotiations for bilateral agreements between the United Kingdom and the United States.*

International

184. The United Kingdom was a joint sponsor of the resolution of the United Nations' General Assembly to establish an International Atomic Energy Agency and has played a prominent part in the negotiations to give effect to that resolution. Her Majesty's Government have announced that they will contribute 20 kilograms of fissile material to the Agency when it is formed.

185. The International Conference of Scientists, also sponsored by the United Nations, will meet at Geneva in August, 1955, to discuss the peaceful uses of atomic energy. Sir John Cockcroft was appointed one of the Vice-Presidents of the Conference, and the Authority have been responsible for arranging the British representation at it.

186. *European Council for Nuclear Research (C.E.R.N.):* a Convention, subsequently ratified by all the signatories, was signed in Paris on 1st July, 1953, by twelve European countries, including the United Kingdom. They are: Belgium, Denmark, France, German Federal Republic, Greece, Italy, Netherlands, Norway, Sweden, Switzerland, United Kingdom of Great Britain and Northern Ireland and Yugoslavia. The Convention provided for the setting up of a European Council for Nuclear Research, known as C.E.R.N. from the initials of its French title.

187. The Council has the broad aims of planning and organising co-operation in fundamental nuclear research, and the more particular aim of

* Civil and military agreements with the U.S.A. have been concluded since the end of the period under review.

establishing at Geneva an international laboratory equipped with the elaborate and costly apparatus essential for such research. The construction and equipping of the laboratory is expected to take seven years. The Authority are giving substantial assistance in the design and construction of the apparatus which is to be built by the secondment of key staff.

188. The financial liability of member countries is laid down in the Annex to the Financial Protocol to the Convention. The contribution of Her Majesty's Government will be about £350,000 per annum for the seven-year construction period, and about £180,000 per annum thereafter.

189. The first session of the Council was held at Geneva on 7th–8th October, 1954, and was attended by Sir John Cockcroft as a Council Member representing Her Majesty's Government, and by Mr. D. W. Fry (Chief Physicist, A.E.R.E.). Sir John Cockcroft was appointed a member of the Scientific Policy Committee for a term of two years.

190. *European Atomic Energy Society :* this Society was founded in 1954 with the aim of promoting co-operation in nuclear research and engineering in the unclassified field. Its members are Belgium, France, Italy, the Netherlands, Norway, Sweden, Switzerland and the United Kingdom. The Society has a Council consisting of one member from each of the participating countries, who may attend meetings with a deputy. Sir John Cockcroft was elected the first President of the Society. The Council meets about once a year and at its meeting in Brussels on 21st December, 1954, the Authority was represented by Sir John Cockcroft and Dr. J. V. Dunworth (Head of the Reactor Physics Division, A.E.R.E.).

191. There is also a Working Group to conduct the business of the Society between meetings of the Council. From time to time this Working Group organises small technical conferences to discuss particular topics, and these conferences are held at various European centres, including Harwell.

European Countries

192. The Authority have maintained and extended the informal contacts with atomic energy organisations in European countries which had been built up before 1st August, 1954, and in addition have entered into negotiations with a number of countries for the conclusion of collaboration agreements covering specific subjects.

193. *France :* in February, 1955, the Authority and the French Commissariat of Atomic Energy concluded an agreement for the exchange of unclassified information between the two organisations on a range of subjects. In addition, the Authority agreed to assist the Commission by giving advice and supplying experimental quantities of various materials.

194. *Denmark :* towards the end of 1954 the Danish Atomic Energy Commission informally intimated that it would shortly approach the Authority for assistance in the design of a research reactor and the supply of nuclear fuel elements for it, and a Danish mission visited Harwell at the end of March, 1955, to initiate the negotiations*.

195. *Belgium :* the Authority have entered into negotiations with Belgium for a programme of collaboration in furthering the peaceful applications of atomic energy by the exchange of information.

196. *Other European Countries :* interest has been shown in the Authority's activities by a number of other European countries, for example the Netherlands, Norway, Italy, Yugoslavia, Sweden, Switzerland and Portugal. In some cases, negotiations for collaboration agreements are proceeding.

* An agreement has since been concluded with the Danish Atomic Energy Commission

APPENDIX 1

ATOMIC ENERGY AUTHORITY ESTABLISHMENTS AND SENIOR STAFF AS AT 31st MARCH, 1955

(The names of the Chairman, Members and Secretary of the Authority are given in Chapter II)

LONDON

E. J. S. Clarke, T.D.	Principal Officer in Charge Metals.
C. J. Highton	Principal Legal and Lands Officer.
W. F. Jenkins, C.B., C.B.E.... ...	Principal Finance Officer.
J. A. Jukes	Economic Adviser.
E. H. Underwood, O.B.E.	Director of Public Relations.

INDUSTRIAL GROUP

(Headquarters, Risley)

W. L. Owen, C.B.E.	Director of Engineering and Deputy to Managing Director.
K. B. Ross, O.B.E.	Director of Operations.
L. Rotherham	Director of Research and Development.
D. A. Shirlaw, C.B.E.	Director of Administration and Accounts.
D. D. W. Cole, C.B.E.	Deputy Director (Operations).
P. T. Fletcher	Deputy Director (Engineering Services).
T. L. Viney	Assistant Director (Works and Buildings).
J. B. W. Cunningham	Chief Engineer (Thermal Reactor Design).
H. V. Disney	Chief Engineer (Diffusion Plant Design).
J. W. Kendall	Chief Engineer (Fast Reactor Design).
C. J. Turner, C.B.E.	Chief Engineer (Chemical Plants Design).
W. Davies, O.B.E.	Chief Construction Engineer.
J. C. C. Stewart	Principal Technical Control Officer.
Dr. A. S. McLean	Group Medical Officer.

Production Factories:

Springfields: Works General Manager, Dr. H. Rogan.
Windscale: Works General Manager, H. G. Davey, O.B.E.
Capenhurst: Works General Manager, S. F. Hines, O.B.E.

Experimental Stations:

Calder Hall: Works Manager, K. L. Stretch.
Dounreay: Officer in Charge of site, T. G. Williams.

Research and Development Laboratories:

Springfields: Laboratory Manager, L. Grainger.
Windscale: Laboratory Manager, D. R. Mackey.
Capenhurst: Laboratory Manager, Dr. H. Kronberger.
Culcheth: Laboratory Manager, Dr. A. B. McIntosh.

RESEARCH GROUP

Atomic Energy Research Establishment, Harwell

Dr. B. F. J. Schonland, C.B.E., F.R.S.	Deputy Director.
G. Raby, C.B.E.	Deputy Director, Engineering.
Dr. H. M. Finniston	Chief Metallurgist.
D. W. Fry	Chief Physicist.
Dr. R. Spence, C.B.	Chief Chemist.
D. R. Willson, M.B.E.	Secretary.
Dr. K. Williams	Group Medical Officer.

Radiochemical Centre, Amersham.

WEAPONS GROUP

Atomic Weapons Research Establishment, Aldermaston

W. R. J. Cook, C.B.	Deputy Director.
C. A. Adams	Chief of Research.
J. E. Adamson	Principal Administrative Officer.
Admiral P. W. B. Brooking, C.B., D.S.O., R.N. (Retd.).	Assistant Deputy Director.
J. R. V. Dolphin	Chief Engineer.
Dr. J. V. Lynch	Group Medical Officer.

Fort Halstead (Research and Development):

Dr. A. M. Davis, C.B.E. ... ... Deputy Director.

Woolwich Common (Electronics Engineering):

C. Smith ... ... Officer in Charge.

Proof Range:

E. H. Mott, O.B.E. ... ... Senior Superintendent.

APPENDIX 2

CONFERENCES AND SYMPOSIA HELD AT THE ATOMIC ENERGY RESEARCH ESTABLISHMENT DURING THE PERIOD 1st AUGUST, 1954 TO 31st MARCH, 1955

U.K.–Canada Technical Conference on Atomic Energy, 28–30 September 1954.

Canada, U.K., U.S.A., Tripartite Declassification Conference, 4–6 October 1954.

Conference on Electronics applied to Nucleonics, 4–6 December 1954.

Symposium on the Uses and Development of Radioisotope Testing, 18–20 January 1955.

European Atomic Energy Society Conference, " Radiological Safety and Siting Problems of Nuclear Reactors ", 23–25 March 1955.

Physical Society Spring Meeting, " Neutron Physics and Nuclear Energy Levels ", 31 March–2 April 1955.

(31348) Wt. 1022—894 K40 11/55 D.L.

PRINTED AND PUBLISHED BY HER MAJESTY'S STATIONERY OFFICE
To b purchased from
York House, Kingsway, LONDON, W.C.2   423 Oxford Street, LONDON, W.1
P.O. Box 569, LONDON, S.E.1
13a Castle Street, EDINBURGH, 2   109 St. Mary Street, CARDIFF
39 King Street, MANCHESTER, 2   Tower Lane, BRISTOL, 1
2 Edmund Street, BIRMINGHAM, 3   80 Chichester Street, BELFAST
or from any Bookseller
1955

Price 2*s* 0*d* net

PRINTED IN GREAT BRITAIN