chain reaction will be inhibited. In such a case, it would be necessary to remove the uranium, extract the fission products, and either to recharge the reactor with new metal or to recover the uranium and to replace it, adding sufficient plutonium or U235 to make it reactive.

Of necessity, all reactors manufacture fission products. At some stage or other, it will ultimately be desirable to remove them. Their disposal may prove to be an awkward problem.

Cost of Power Derived from Atomic Energy

So far as the *immediate* future is concerned, the application of atomic energy to the production of power is not likely to result in a net decrease of over-all costs to the community.

Owing to the difficult and tedious nature of the processes for preparing U235 or plutonium in high concentration, reactors depending on such materials for fuel will be far more costly to run than existing hydro-electric or steam-power plants, and the most favourable comparison at the present time will be given by the natural uranium reactor.

Recently an American committee has made a careful study of the costs of building and operating a natural uranium reactor to deliver 75,000 kW., and has concluded that the over-all cost of power would be only about 25 per cent greater than for a coal-burning power plant. This estimate is based on the assumption of a high operating temperature of the uranium reactor, that is, on the performance of a plant which has not even been designed, let alone built. It does not, therefore, represent the present position, but the possible position in a few years time, when research and development have provided the solution of a number of difficult technical problems. The committee's estimate is nevertheless valuable in indicating the possibilities which can already be foreseen. It is not unreasonable to expect that future development of atomic energy will result in a material reduction of costs, and perhaps make the uranium reactor a direct competitor with other power plants.

At the present moment it seems that the use of atomic power plants would be justified, on a purely economic basis, only in the special circumstances I have previously mentioned, where the power needed to develop resources is either very costly or unavailable, or because of difficulties of transport.

What is needed now is intensive research and development in the technical problems which are involved in the applications of atomic energy. This will not only clarify our present somewhat vague ideas, but it may well be that quite new lines may be opened up.

The Future

In assessing the possibilities of future development it is well to remember not only that the art is in its infancy, but also that the preoccupation of the war years with the military aspects of atomic energy has excluded almost completely the consideration of industrial applications. These military aspects still have, and, until some far-reaching international agreement on the control of such weapons is obtained, are bound to have, a retarding influence on peaceful developments, for the reason that the paramount need for security prevents that wide dissemination of knowledge which promotes free exchange of thought, stimulates discovery, and gives an impetus to invention and development.

At this early stage in our knowledge of these matters one cannot hope to see clearly into the future, but only to discern the probable lines of progress. Upon further investigation some lines we now have in mind may prove fruitless, but if we can be guided by the history of scientific and technical development, it is more than likely that others will give a rich reward. A few short years ago what has even now been accomplished would have been considered an idle dream.

Already a military weapon of unparalleled power has been created; enormous amounts of radioactive material have been manufactured; substances which have, owing to their inherent instability, become very rare or even completely disappeared from the cupboard of Nature, have been built up by individual nuclear transmutations and collected in large quantities; and the first steps have been taken towards the development of these new energy sources for industrial application.

This new enterprise constitutes a far deeper interference with the natural course of events than anything which has been attempted hitherto, and it is a most remarkable example of the powers of physical science and engineering and of our increasing control over the processes of Nature. It is not easy at this early stage to survey in detail the consequences which may flow from this advance in the years to come, but it can scarcely fail in the long run to bring about a new outlook and a new situation as regards human resources.

DR. JAMES HUTTON AND THE MANUFACTURE OF SAL AMMONIAC

By ARCHIBALD CLOW and NAN L. CLOW

THE hundred and fiftieth anniversary of the death of Dr. James Hutton (1726-97), the celebrated geologist, which occurred on March 26, brings to mind a little-known phase in the utilization of the products of coal distillation, the profits from which are said to have secured to Hutton the leisure necessary for his geological speculations.

In his "History of Inventions and Discoveries", J. Beckmann says: "If I am not mistaken, the first manufactories of sal ammoniac were established in Scotland: the oldest of these, perhaps, was that erected by Dovin and Hutton at Edinburgh in 1756".

This refers to a co-partnership formed by Dr. James Hutton and someone variously described as James Dovin, Dairy, or Davie, in Edinburgh according to a plan conceived when they were Edinburgh students. In Kay's "Portraits"², the date of formation is given as before 1749, which may be right, since Hutton went to a Norfolk farm to study agricultural methods in 1752.

The raw material used in this early chemical manufacture was soot, and for a number of years Davie took all the soot collected by Edinburgh 'tronmen'—a chimney sweeps' society formed in 1738³. The process was carried out as follows: "Globular glass vessels, about a foot in diameter, are filled to within a few inches of their mouth with it [soot], and are then arranged in an oblong furnace, where

they are exposed to a heat gradually increased. The upper part of the glass balloon stands out of the furnace, and is kept relatively cool by the air. On cooling, the upper parts of the globes are found to be lined with sal ammoniac in hemispherical lumps, about 2.5 inches thick. 26 lbs. of soot yield 6 of sal ammoniac."

There is a reference to the manufacture of sal ammoniac in Edinburgh, and to green glass globes used in the manufacture, in a letter from John Findlay, secretary to the Duke of Richmond, to George Macintosh, the Cudbear and Turkey red manufacturer, and it seems probable that the vessels used by Hutton and Davie were old vitriol bottles from the Prestonpans Vitriol Works, founded by Dr. John Roebuck and Samuel Garbett in 1749⁴.

The firm of Hutton and Davie was still in existence in 1783, and in that year they began buying sal ammoniac, probably crude, from the tar works established at Culross in 1781 by Archibald Cochrane, ninth Earl of Dundonald.

Dundonald's sal ammoniac was one of the by-products of his tar manufactory. The preliminaries in the negotiations for the sale of the sal ammoniac to Hutton and Davie are referred to in the report that Dr. Joseph Black, professor of chemistry in Edinburgh, prepared for Andrew Stuart, when the latter was trying to ascertain the likely success that might attend the founding of the British Tar Co. After going into the details of prospective profits from the sale of tar and coke, Dr. Black goes on: "There is one article omitted above, which is a quantity of Volatile Alkali formed in the water condensed along with the tar from the vapour of the coals. The volatile alkali, after being somewhat refined from the oil and water can be employed in the manufacture of sal ammoniac: and My Lord having sent a specimen of his prepared or purified alkali to Messrs. Hutton and Davie who manufacture sal ammoniac here, I know that they found it good for the purpose and made his Lordship an offer for a certain quantity annually, the consumption of sal ammoniac being limited. But I do not know what offer they have made, or what profit this article is capable of yielding. They have hitherto extracted their volatile alkali from soot, which is also produced by the condensation of vapour from coals"⁵.

Evidently Lord Dundonald hoped to make a considerable business by working up this side-line, because he wrote Andrew Stuart, his uncle: "My partners and I have it in our Power to render him [Glassford]* very essential service by purchasing from him annually some Thousand Pounds worth of a commodity he manufactures concerning which I shall explain myself more fully when I have the pleasure of seeing him in Scotland"⁶.

The latter refers to the purchase of either sulphuric acid or hydrochloric acid, to be used in the manufacture of sal ammoniac.

Dundonald sent a William Kinnaid, chemist and apothecary, to London in 1784 to learn the best way of making sal ammoniac. Dundonald and his two brothers, John and Alexander, who were already his business associates in the British Tar Co., were to join Kinnaid in the manufacture; but difficulties arose over Kinnaid's wages, and it is said that he did everything he could to sabotage Dundonald's enterprise because he wished to start on his own⁷.

* Glassford of Dougaldston, a principal partner in the Prestonpans Vitriol Co.

The method of manufacture employed by Dundonald was probably that invented by M. Leblanc of St. Denis, near Paris, with this difference, that Leblanc got his ammonia by the destructive distillation of organic matter, whereas Dundonald's ammonia was produced by the action of heat upon nitrogenous matter in coal. The ammonia was combined with hydrochloric acid, which was produced in a brick kiln by the action of sulphuric acid on the sea salt he could obtain from his own pans at Culross⁸.

None the less, soot continued to be used as a raw material, both by Hutton and Davie, and also in a new manufactory which was founded by Charles Macintosh at Glasgow in 1786, in partnership with his father, George Macintosh, of the Cudbear and Turkey Red Works, and a Mr. William Couper, an eminent Glasgow surgeon.

The Macintosh factory continued for a number of years, but it is probable that more scientific methods of making sal ammoniac led to its being closed down⁹. In any event, by 1814, according to Sir John Sinclair, there was only one sal ammoniac works of any size in Scotland, and that was at Bo'ness¹⁰. There Joseph Astley operated a patent process similar to that referred to in the *Annales de Chimie* of 1797 (20, 186), which used 'bittern' from the salt works as a raw material. From this factory sal ammoniac was retailed at £9 10s. 10d. per cwt. Considerable details about Astley's process are given by Thomas Thomson in his supplement to the "Encyclopædia Britannica":

"One process more deserves to be mentioned, on account of its ingenuity and simplicity. It is the invention of Mr. Astley, who has secured the exclusive privilege by a patent, and has a manufactory at Borrowstouness, on the Firth of Forth, and another at Portobello, near Edinburgh. He mixes together animal matter (chiefly woollen rags), and what in Scotland is called *spirit of salt*. It is the mother ley that remains after all the crystals of common salt that can be got have been separated from sea-water. It consists chiefly of muriate of magnesia. This mixture is burned in furnaces, and the produce received in small chambers placed over the furnaces. This produce contains abundance of sal ammoniac, which is obtained pure by sublimation. We conceive the theory of this process to be, that the carbonate of ammonia is formed by the combustion of the animal matter. This carbonate immediately decomposes the muriate of magnesia, and sal ammoniac sublimes. In principle, therefore, it does not differ from Baume's original process, though, in point of economy, it is probably greatly superior to it."

Hutton died in 1797, and Davie not long after. Following Davie's death, it appears that Edinburgh soot was sent to Walker's works at Beverley, Yorks, because we learn that Astley, who is described as an extensive chemical manufacturer in Portobello, was involved in a legal action in the Court of Session through one of his clerks inveigling two or three members of the Edinburgh Tronman's Society (chimney sweeps) into a public house and persuading them to sign an agreement on behalf of the Society to supply Astley with all the soot they collected instead of sending it to Yorkshire¹¹.

The next phase in the utilization of coal by-products is the well-known development of the gas industry in the first two decades of the nineteenth century. The new information which we have set forth concerning the prior utilization of coal by-products throws new light on the economic back-

ground of the gas industry. It also gives a new perspective to the growth of experimental chemistry during the latter half of the eighteenth century; and it is worth bearing in mind that when Joseph Priestley discovered ammonia, he was exploring the properties of a substance of established utility as a saleable by-product of coal.

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NATURE OF VIRULENCE

THE term 'virulence' has sometimes in the past been regarded as an intrinsic property of an infecting agent; that such a view is not entirely in accord with our knowledge of natural and experimental infections was apparent from the discussion on the nature of virulence at the meeting of the Society for Microbiology held in London on December 20. As virulence can only be measured in terms of the effect on the host by a micro-organism, using that term in its widest sense, it is obvious that the interaction between the micro-organism and host by which we estimate virulence will depend on many variables affecting both participants. Much of the discussion related to these variables and their effect on virulence. A very wide field was covered, contributions on the virulence of bacteria, of fungi and of viruses for both plant and animal hosts and of the parasitic protozoa being made by various speakers. It was generally accepted that multiplication of an infecting agent in the body of the host does not alone determine virulence, and that the term 'virulence' necessarily implies structural or functional damage to the tissues of the host.

It is clear that the morphology and physiology of plants are so different from those of animals that virulence of phytopathogens involves mechanisms different from those concerned in virulence of micro-organisms for animals. This point was clearly illustrated by Mrs. Dagny Oxford in her discussion of bacterial virulence in plants; the bacteria virulent for plants, unlike most of the animal pathogens, are free-living, relatively resistant and simple in their nutritive requirements. As most of these species do not split cellulose, they depend for their entry into plant tissues on abrasions or wounds. There may be some correlation of virulence of phytopathogenic bacteria with the power to produce pectolytic enzymes, and in some instances cell-free filtrates of bacterial cultures produce reactions in the plant tissues similar to those caused by the living bacteria. Mrs. Oxford pointed out that the resistance of plants

to bacterial infection is a function of the local tissue cells and does not depend on any humoral mechanism such as operates in the resistance of animals to invading bacteria.

Fungi are, however, more important disease-producing agents in plants than are bacteria, and Prof. E. Gäumann of Zürich made a most interesting contribution in this field to the symposium. The necessary attributes for virulence were discussed in relation to different types of pathogenic fungi, the part played by the host tissues being emphasized. The damage to plant tissue appears in the case of one fungus to be due to a polypeptide which destroys the semipermeability of the plasma boundary layer; but the power to produce this substance *in vitro* is not of itself sufficient to determine virulence. The power to penetrate the plant tissues by the production of certain enzymes and to withstand the reactions of the host tissues are also necessary. In plant infections due to more than one fungus (mixed infections), the resulting disease may be dependent on the interaction of the infecting fungi and may not be controlled by the most virulent strain.

In his discussion on the virulence of bacteria in animals, Dr. D. W. Henderson pointed out that it is difficult to induce parasitism in normally saprophytic bacteria, and that this lack of virulence is due in some instances, although perhaps not in all, to their lack of power to multiply in the living body. In general, toxicity is inversely proportional to the degree of tissue invasion by a pathogenic bacterium. The species of the animal host, its physiological state, and its genetic constitution may all influence the virulence of a bacterial infection. Other points mentioned by Dr. Henderson as bearing on virulence concerned aggressins, route of entry of a bacterium into the body, and the synergistic action of other bacteria. The importance of the last two factors was later referred to by Dr. C. H. Andrewes in relation to the virulence of viruses for animals.

That apparent increase of virulence in a parasitic micro-organism may in fact be due to lessened resistance of the host was exemplified by Dr. J. T. Duncan in his contribution on virulence of ringworm fungi in animals. These fungi are frequently highly parasitic and highly infectious but of low pathogenicity, and the host parasite equilibrium may remain undisturbed for years. On the other hand, some of the normally saprophytic fungi may become highly pathogenic, producing severe systemic disease; and in some of these fungi pathogenicity is associated with the property of dimorphism, the organism being capable of developing, in place of the complex mycelial saprophytic form, a simple form adapted for rapid reproduction and invasion in animal tissues. In the case of such fungi, as with some of the ringworm fungi when implanted on an unusual animal host, high pathogenicity may be associated with low infectivity.

The parasitic protozoa afford instructive examples of variations in the host parasite relationship in relation to virulence. Prof. H. E. Shortt illustrated the state of true symbiosis between certain protozoa and their vertebrate or invertebrate hosts, and from the symbionts and commensals went on to consider the parasitic protozoa. Some of these may multiply without producing disease, but this balanced parasitism might be readily upset. The mechanism by which disease is produced by pathogenic protozoa is not clearly understood; no true toxins are demonstrable, and in some cases disease is due to mechanical