ture (50%) and forestry (34%). Figures produced by S. W. Pardoe (National Coal Board Opencast Executive) implied that coal from opencast mining is currently about £2 per ton cheaper than deep mine coal and that in this field again the sites can be advantageously restored, mainly to agriculture. A. D. M. Penman (Building Research Establishment) pointed out, however, that the volume of world mining is doubling every 14 years and the demand for construction on all types of previously opencast land has led to a joint research programme with the Coal Board. Discussion from the floor disclosed that there is no stability relationship between age and depth of backfill. Moreover, ingress of water is commonly believed to induce the sudden settlements recorded on some backfilled sites and Penman suggested that flooding might be one method of improving compaction.

With respect to site investigations in redevelopment areas both K. W. Cole (Ove Arup and Partners), who cited case histories to emphasize problematical foundation situations in glacial deposits and areas of shallow mine workings in the North-East, and M. I. Beeby and L. Threadgold (Exploration Associates Ltd) made a plea for improved procedures and organization. W. R. Dearman (University of Newcastle upon Tyne) considered that geotechnical maps could lead to more rational site investigations and demonstrated several types drafted from collated geotechnical information pertaining to Tyneside.

Coastal reclamation was brought into sharp focus by G. B. M. Oliver (National Ports Council) who explained that because the parts are required to operate commercially there is no great incentive to utilize maintenance dredgings for land reclamation; disposal at sea is usually cheaper. Emplacement of dredging muds from estuaries was discussed by P. R. Vaughan (Imperial College, London) who showed the value of underdrainage and controlled drying. He forecast that hydraulic fills of this type could produce in less than a decade usable ground no worse than many existing alluvial deposits. Other speakers, including A. C. Meigh (Soil Mechanics Ltd), advocated dynamic compaction for granular soils down to coarse silt size as well as for other types of fill. This technique involves dropping a heavy weight on to the ground surface from a great height.

Feasibility studies for a number of coastal reclamation schemes including Maplin were described, and T. D. Ruxton (Binnie and Partners) mentioned that the long period required for the evaluation of some schemes in Britain was often due to hydraulic seepage problems. G. G. Pickton (Department of the Environment) remarked that a scheme involving the reclamation of 30,000 acres at Maplin had been formulated in the eighteen fifties at a cost of £3,738!

E. L. Streatfield (Cremer and Warner) in his introduction to the session on groundwater pollution said that the proportion of indisputable toxic industrial waste is just over 2%, and a further 5% may fall into this category. Preliminary results from a multi-authority review of 2,494 landfill sites in England and Wales were presented by D. A. Gray and J. D. Mather (Institute of Geological Sciences). This desk study has revealed that only fifty-one sites present a risk to aquifers and of the 714 locations examined by the river authorities only eighty were classified as unacceptable.

NUCLEAR PHYSICS

Reaction Times

from our Nuclear Theory Correspondent

It is usual to divide nuclear reactions into two stages: the first is the direct interaction of the incident particle with the target nucleus, and this takes place in the time it takes for the particle to cross the nucleus, usually about 10^{-22} s. After the direct stage, the remaining nucleus is in an excited state in which the energy is shared statistically among all its nucleons. Many interactions can take place among them, and eventually it happens that a nucleon or group of nucleons near the nuclear surface receives enough energy for it to escape, and this continues until the remaining nucleus is left in its ground state. This process is the decay of the compound nucleus, and takes a much longer time, of the order of 10^{-14} to 10^{-18}.

The theories of the direct and compound stages of the nuclear interaction are now quite well understood, and it is possible to calculate the angular and energy distributions of the particles emitted in each stage, and to compare their sum with the experimental observations.

The time delay between the two processes naturally raises the question whether they can be observed individually, but because the most refined electronics cannot resolve times shorter than about 10^{-9} s, it is quite impracticable to do it directly. A very ingenious way of doing this indirectly has, however, been developed recently, and Professor G. M. Temmer and his colleagues at Rutgers University and Bell Laboratories reported at a recent conference that they have used it to resolve the direct and compound contributions to the elastic scattering of protons by germanium-72 (*Proc. int. Conf. nucl. phys., Munich, August 27–September 1, 1973;* North-Holland, Amsterdam, 1973).

The method depends on using a crystal as a target so that the nuclei are in a regular spatial array. If a nucleus in a regular crystal emits a particle along the direction of one of the crystal axes, it will collide with the next nucleus and be scattered. Thus particles emitted in these directions are blocked and cannot escape from the crystal. If, however, the emitting nucleus moves from its original position, a particle emitted along the crystal axis will travel between the lines of nuclei and so escape. A struck nucleus recoils and the distance it travels before emission depends on the time between the initial impact and the decay; this is different for a direct and a compound process. In a direct process the target nucleus does not have time to move, but in a compound nucleus process it may move sufficiently far from its equilibrium position to increase the chance of escape of a particle emitted along a crystal axis.

The figure shows the intensities of particle emission as the detector moves across the line of the crystal axis, and the dip due to blocking is clearly seen. This was done for emission angles of 35° and 145°, and a small difference between them can be seen. The direct process contributes proportionately more at the forward angle of 35° than at the backward angle of 145°, and the amount of this difference allows the mean lifetime of the compound nucleus to be determined; the result is found to be about 1.4×10^{-16} s. The three sets of measurements illustrated refer to energies on and off the isobaric resonance at 5 MeV and at an energy above the (p,n) threshold. At this last mentioned energy so many reaction channels are available for the decay of the compound nucleus that the compound elastic process is negligible. Thus the direct reaction dominates at both angles, so the transmission curves are the same.

This very ingenious measurement makes possible a series of refined tests of nuclear reaction theories in an entirely new way and marks a notable advance in nuclear physics techniques.