several thousand amperes round the loop of buoyant cable.

The degaussing of ships, at first effected by a single-turn coil embracing the hull, was, after considerable research, shown to be practicable with multi-core cable fitted inside the hull.

H.M.S. *Belfast*, damaged by a magnetic mine explosion in October 1939, exhibited extensive damage to electrical equipment from underwater shock. The shock accelerations and displacements resulting from non-contact under-water explosions were of a much higher order than those against which the equipment had been designed, and an extensive programme of experiment and of redesign of electrical equipment and of shock-proof mountings was undertaken.

The loss of the *Ark Royal* in November 1941 brought to light further important factors in the vulnerability of the electrical systems of warships. A hit by a single torpedo had the disastrous result of flooding one boiler room and the main switchboard room. The remote control of circuit breakers from the main switchboard was based on a system which the flooding rendered completely inoperative and services could not be restored although power was available for some time. Even the power supply was dependent, as the generators were driven by steam turbines, on the ship's main boilers. The redesign of the control system introduced relay control, energized from independent local supplies, and auxiliary diesel generators were provided.

Electrical actuation in the training and elevation of anti-aircraft guns was initiated in 1939, utilizing the rotating amplifier machine known as the 'metadyne', controlled by a magslip-data transmission system to which reference has already been made.

The introduction of radar for range-finding produced automatic following of the radar aerial so that the aerial, the gun director and hence the gun automatically followed the target. Fully automatic following of the target was achieved by designing the radar to provide its own misalignment signal and feeding the necessary additional information from the fire control computer and the stabilizer.

The action information centre has become the most concentrated part of the electrical installation of a warship. It is the focal point for radar and asdic information, for external and internal communication, aircraft and weapon direction and for navigation.

Alternating current was adopted in 1948 for all ships larger than mine-sweepers. Simplicity, reliability and the necessity to save space and weight in the large and complex electrical systems required made the advantages of alternating current supply overwhelming.

A supply frequency of 60 c./s. was adopted for the 440 V. three-phase system. The higher frequency of 60 c./s., in place of the standard power frequency of 50 c./s., had the great merit of a substantial reduction in the size and weight of machines and a higher maximum speed of 1,800 revolutions per minute. There was the added advantage of a common standard with the U.S. Navy. There is, of course, the disadvantage of more complex equipment where continuous variation of speed is required. Automatic voltage regulation is required, and a standard type of automatic voltage regulator utilizing a magnetic amplifier has been developed which can be used with generators of 150-kW.–1,500-kW. capacity.

Nuclear propulsion has revolutionized the performance of the submarine, which becomes at last a true submarine rather than just a submersible vessel. The nuclear submarine must, however, still have a battery for starting up and emergency standby although of smaller size than that for the conventional submarine. Because of the possibility of prolonged submerged operation, some of the battery problems encountered with conventional submarines became of even greater importance. The evolution of hydrogen on open circuit can be reduced by the use of grid alloys having a very low antimony content. Antimony-free grids would at the same time eliminate the production of the highly toxic gas, antimony trihydride, or stibine.

The electrical installation of the nuclear submarine is in fact much like that of the surface vessel with the addition of an electric drive of small power for emergency use. As in the surface vessel, an increasing amount of electronic and servo equipment is required, and there is in addition the equipment for reactor control and instrumentation. It is in the submarine, because of the acute limitation of space, that semiconductor devices offer special promise in their future application.

J. Greig

POWDER METALLURGY

An international conference on "Powder Metallurgy", sponsored by the Metal Powder Industries Federation and the Metallurgical Society of the American Institute of Mining and Metallurgical Engineers, was held in New York during June 13–17. At sessions throughout the first three days, papers were presented by authors and briefly discussed. Visits to plants were made during the last two days. The meetings were well managed and held to a precise time schedule which allowed little time for informal discussion. The hall, with a seating capacity of about four hundred, was filled for every session.

Dr. P. Schwarzkopf, honorary chairman of the conference, opened it with a review of a half-century of modern powder metallurgy, which he considers to have developed since Coolidge's paper of 1910 on the powder metallurgy of tungsten. He regards earlier powder metallurgy, such as that in pre-history, that by the Incas, and the British and Russian work on platinum, as detached from the development of modern technology to which they made little contribution. Powder metallurgy was a forgotten art at the start of this century, although in 1898 Welsbach patented its use to make osmium filaments. Coolidge's tungsten filaments were the first really usable product of modern powder metallurgy. Cemented carbides manufactured by powder methods came in 1922.

Work on the nature of the sintering process appeared in 1922 when Sauerwald published his first paper on the subject, which he thought of as a recrystallization process. Important later work on the theory of sintering included Russian papers published in 1945 and the work of S. P. Slater and G. C. Kuczynski. In recent times the latter worker has dominated thinking in this field.

Several papers at this conference made it clear that work on the theory of sintering is once again coming to life. It is now appreciated that we must not seek one dominant sintering mechanism for all materials, or even for one material at all stages of the sintering process, or in all circumstances in which sintering takes place. Kuczynski (University of Notre Dame) emphasized this by stressing the convenience of considering separately the two extreme stages of sintering when seeking to explain what occurs: these are: (1) the formation of necks between particles at the start of sintering, and (2) the disappearance of isolated pores towards the end of the process. The first stage is now fairly well understood, but the second is more complex and difficult to cope with. Unbalanced forces in the necks lead to flow of material in a viscous or plastic manner. He has shown that, if x is the diameter of the neck between sintering particles, and a the diameter of the particles, x^n/a^m is a function of time and the values of n and m are characteristic of the sintering mechanism which is operating:

$n =$	2	3	5	7
$m = 1$	Viscous or plastic flow	Evaporation and condensation	—	—
2	—	—	Volume diffusion	—
3	—	—	—	Surface diffusion

Recent observations of the sintering of copper wires twisted together show that volume diffusion is in this case the main mechanism. Kingery has shown it to be evaporation and condensation in sodium chloride. In glass it is viscous flow. Sintering of nickel at 1,400° C. is due to volume diffusion and that of iron at 850° to surface diffusion. Kuczynski described a very pleasing experiment on the sintering of copper-8 per cent indium. Indium diffuses more rapidly than copper in this alloy and where its concentration rises an indium-rich δ-phase forms. This phase was found in the necks between sintering particles, an observation confirming that diffusion is a mechanism of the sintering in this case.

The importance of grain boundaries is not yet clear. A. L. Pranatis and L. L. Seigle examined the sintering of iron, copper and nickel and observed the radius of the neck between particles to be proportional to time whether boundaries were present or not. However, they found that reduction did not occur in the volume of isolated voids in nickel at 1,400° C. unless boundaries ran into them, whereas B. H. Alexander and R. W. Baluffi observed shrinkage of voids within metal single crystals.

A few years ago M. Eudier reported that additions of hydrogen chloride to the sintering atmosphere accelerated the sintering of iron powder and improved the properties of the product. More recently J. Vacek described the spectacular effect of a trace of nickel in causing tungsten to sinter at half the temperature required for pure metal. Considerable interest was shown in such activated sintering, the practical significance of which is clear. That the nature of the sintering atmosphere may determine which sintering mechanism dominates a particular case was illustrated by Kuczynski's observation that single crystal particles of alumina sinter by volume diffusion when heated in helium containing a little oxygen, but by viscous flow in dry hydrogen.

J. Wulff (Massachusetts Institute of Technology, Cambridge, Mass.) has studied the effect of nickel on the sintering of tungsten. He reminded the conference that this remarkable effect was known to von Bolton long ago, but has been overlooked until very recently. Wulff found that additions of nickel are increasingly beneficial so long as a monatomic layer over the tungsten particles is being built up, but not after sufficient metal for this is present. He attributes the effect to diffusion of tungsten through the nickel. F. Eisenkolb (Technische Hochschule, Dresden) found additions of about 2 per cent of calcium fluoride to iron or steel powder to improve its sintered strength, but that larger additions reduced this.

It would be very interesting to know what effect these additions have on the Kuczynski coefficients of the sintering metal.

Kuczynski recalled attention to phenomena when two metals sinter together. Thus when copper and nickel are in contact at 1,020° C. the copper particles shrink and pits form in them near junctions with nickel, while the nickel particles expand. This is explained by the more rapid diffusion of copper than of nickel.

G. A. Geach and A. A. Woolf (Associated Electrical Industries, England) have examined a number of pure crystalline organic materials of widely differing molecular shapes and found that these did not sinter at 0·8 of the absolute melting points, although they show creep deformation at lower temperatures. It is not clear whether this should be attributed to an absence of self-diffusion of large molecules or to the low surface energy of such materials. Although nylon sinters it is interesting that it does so more slowly if the threads are stretched so that the material becomes more crystalline. It was reported that in commercial practice amorphous precipitated nylon is found to sinter more effectively than ground material.

Developments were reported in many techniques of powder metallurgy. Although hydrostatic pressing of powder in a rubber sack was patented in 1913 much attention is now being given to this method. H. H. Hirsch and C. E. van Buren (General Electric Co.) reported that pressing vessels up to 20 in. in diameter and several feet long now exist, and that pressures up to 50 t.s.i. can be used, although it is now known that for each material there is a pressure above which little advantage is gained (30 t.s.i. for tungsten, 4·5 t.s.i. for alumina). Isostatic pressing to finished form in shaped moulds of rubber or reversible gel is extending, and may lead to economy when only moderate numbers of parts are required. Slip casting of metal powders in porous moulds is also being developed, and A. Poster (Sylvania Electric Products) described freezing the mould at 29° F. to remove the casting safely, and then drying it for two days in fuller's earth because rapid drying damages the surface. Hot extrusion of metal powder is particularly valuable when pyrophoric powders, or those involving a health hazard, are pressed while in a closed can. Developments in the direct rolling of metal powder to strip which were described included the use of heated rolls. Rolls of very large diameter are desirable for compacting powders, and an interesting technique described used two rings of large diameter of metal which were threaded about the 8-in. rolls of a smaller mill and operated as large rolls.

The use of an explosion to drive the ram of a mould pressing powders will give pressures of 10^6 p.s.i. for microseconds: R. A. Cooley (Propellex Division, Chromalloy Corp.) reported improved properties of products pressed in this way. A remarkable result claimed is nickel of density one per cent higher than the crystallographic value.

A large amount of work on dispersion-hardened materials was reported, and at present interest is greatest in materials based on aluminium, copper or nickel. It appears that the dispersed phase should be hard and that interfacial energy between it and the matrix should be low: thus thoria particles in titanium alloys have little effect unless the alloys wet the particles. Dispersed particles should be of irregular shape, not rounded, for greatest effect. F. V. Lenel and G. S. Ansell (Rensselaer Polytechnic) stated that the yield stress of these materials is determined by the stress which fractures a dispersed particle, and that it is inversely proportional to the square root of the spacing between particles.

SAP alloys (aluminium strengthened by dispersed oxide) are now known which can be rolled either hot or cold or which can be drawn and pressure-welded.

M. Eudier (Metallurgie Française des Poudres) reported that a controlled oxidation of nickel before sintering raises the density achieved, and he explained that the effect is due to filling of certain pores with oxide and later reduction of this without re-formation of cavities.

The powder metallurgy industry is expanding rapidly. The use of iron powder showed an upsurge during 1954–55, and in 1960 was three times that in 1956. Application of powder methods to beryllium is now important, and the plant to handle a large amount exists. Consolidation of powder in cans by quick blow-forging is important and disks 12 in. in diameter by 1·5 in. thick are made in this way. Beryllium foam made from fine powder, and the production by hot pressing of metal beryllide parts which have high thermal conductivity, are novel developments. Very large pieces can now be manufactured by powder methods: F. Emley (Westinghouse Electric Corp.) noted equipment for hot-pressing beryllium billets up to 60-in. diameter, and the production of molybdenum billets 40 in. × 3·5 in. × 3·5 in.

G. A. GEACH

SOIL FAUNA IN RELATION TO SOIL FORMATION AND FERTILITY

THE study of soils has for long been the province of pedologists, chemists and microbiologists, and, apart from isolated instances, it has only been during the past fifteen years or so that the subject has attracted attention from zoologists in Britain. During the 1955 Easter School held by the School of Agriculture, University of Nottingham, many soil zoologists from Europe as well as Britain were brought together. This was succeeded during 1958 by a three-day international colloquium held at Rothamsted Experimental Station and devoted to "Progress in Soil Zoology". These have given new stimulus to the subject, and the recent symposium on "Soil Fauna in Relation to Soil Formation and Fertility", held by the Association of Applied Biologists, indicates the still growing interest which soil zoology is arousing. This symposium was held on October 14 at the British Museum (Natural History), where the new lecture theatre is eminently suitable for such meetings.

The theme was introduced and summarized by G. V. Jacks, director of the Commonwealth Bureau of Soils. He started by giving numerical evidence of the increasing number of publications on soil zoology appearing in *Soils and Fertilizers*: during 1937–40 there were three, during 1953–56 thirty, and during 1956–59 ninety. The part played by biological processes in determining soil fertility was then put in perspective. Under natural conditions soil animals are complementary to plants and necessary for operating the cycle of nutrients effectively. They are important factors in breaking down plant litter, mixing it with the soil and creating the porous texture characteristic of good soils.

The first paper was given by Dr. D. A. Osmond and Mr. P. Bullock, of the Soil Survey of England and Wales, on "Soil Fauna in Relation to Pedology". The condition of a soil is the result of many factors of which the fauna is but one. The influence of animals is difficult to assess in arable land, but may be very great in grassland and forest soils. Their effects range from the burrowing of mammals to the incorporation of quantities of plant material into the soil by the mesofauna. Dr. Osmond then described different soil-types with the aid of photographs of thin sections. Peat represents one end of the scale where plant matter is virtually unattacked by the fauna, and with increasing faunal influence one passes through moder and mull soils, finally culminating in the vermisols possibly found in parts of north England which are the result of intense earthworm activity.

The mechanics of earthworm influence were pursued by Dr. F. Raw, from Rothamsted Experimental Station, by a consideration of leaf burial in apple orchards. Comparisons were made between sprayed and unsprayed orchards, some under arable cultivation and others under grass. For sampling earthworm populations dilute formalin was found more efficient than permanganate, and in the seven orchards investigated six dominant species were found. Of these, pot experiments showed that only *Lumbricus terrestris* was responsible for pulling leaves into its burrows. Quantitative studies showed, moreover, a close relationship in the grass orchards between weight of *Lumbricus terrestris* populations and the percentage disappearance of leaf litter from cages. The rate of disappearance was inversely proportional to the amount of surface vegetation, being greatest in the arable orchards.

In grass orchards which had been sprayed with a copper fungicide for many years, the earthworm fauna was reduced to a single species living in the surface litter. Here leaf decomposition was very slow and the soil profile had typical mor characteristics.

Some aspects of work being carried out at the University College of North Wales, Bangor, were described by J. Hobart and A. J. Hayes. The former gave a paper on the distributional patterns of soil mites in pure and mixed stands of conifers. In the apparently uniform habitat of a Douglas fir plantation (*Pseudotsuga taxifolia* Britt.), only eight out of thirty-two common species of mites (adults) did not show a significantly aggregated distribution. Samples were taken along radiating transects from trees, and several species of mites were found to have very definite and different preferences for particular radial distances. These may be due to differences in the