

the author states: "In a large number of places and over fairly long lengths the irregularities are within the range of only 1 mm; irregularities ranging between about 1 mm and 2 mm occur only over very short distances, and irregularities in excess of 3 mm are hardly present at all". The argument is impressive, but as the author of this

paper is careful to add: "... causes of irregularity of the concrete surface must be sought both in the constructional technique employed, i.e. the machines and their operation, and in failure to comply with the technological conditions applicable to any concrete used for pavement construction".

PHYSICS AT EINDHOVEN

THE oldest section of the Philips Research Laboratories was built at Eindhoven in 1924 in what was then a quiet rural district, but to-day it is hemmed in by the Philips factories and is surrounded by a busy town environment. The conditions are no longer suitable for advanced research work, and in 1958 it was decided to replace the Laboratories by a complex of new buildings in better surroundings. A site of about 275 acres at Waalre, a few kilometres south of Eindhoven, was obtained and buildings to accommodate a staff of some 3,000 by 1970 are to be built. The complex is to consist of four sectors, each sector comprising one large laboratory block, a workshop, subsidiary buildings for special experiments, a reading room, lecture theatre and canteen. There will be, in addition, at the centre of the site a building containing offices and general services, including a large restaurant, a central library and a spacious auditorium, suitable for large meetings and congresses. The laboratory block of the first sector has been completed and was recently taken into service. To mark the occasion a symposium attended by a large number of distinguished guests representing research establishments in many countries was held at Waalre during September 26-27. Three main lectures were given and fifty papers on specialized topics were read by members of the staff of the Laboratories.

The September issue of the *Philips Technical Review* (24, No. 11/12; 1963) is devoted to a description of the symposium, together with a photograph of the main eight-storey laboratory block and a descriptive article by M. J. Jansen Gratton of the planning of the new complex of buildings. Prof. H. B. G. Casimir, the director of all the research activities of the Philips industries, gave a brief introductory address, and delivered the first lecture, entitled "Some Main Lines of 50 Years of Philips Research in Physics", in which he briefly reviewed various subjects of research at the Laboratories relating to gas discharges, ferromagnetism, solid-state physics and

network theory. F. de Jager, in his lecture on "Modulation, Yesterday and Tomorrow", described how the ever-increasing demands on communication links have led to the introduction of new methods of modulation. Frequency modulation, pulse-code modulation and delta modulation are discussed and, looking into the future, de Jager considered that during the next fifty years the combination of results found in information theory and in perception research will lead to the design of still more effective methods of modulation. The contributions of the Philips Research Laboratories to solid-state chemistry was the subject of the third main lecture, and H. J. Vink briefly reviewed four areas of activity—crystal chemistry, internal charge compensation, gases and metals, and thermodynamics.

In addition to the texts of these talks, the *Review* contains summaries of the papers, and of the two demonstrations set up in the Laboratories. The papers are classified under four headings—fundamental, devices and materials, systems and measuring, and biochemistry and perception. The two demonstrations are of particular interest. The first, by G. Prast, showed the recent application of a modification of the Philips-Stirling thermodynamic cycle which has enabled the production of a gas-refrigerating machine for the temperature of liquid hydrogen*. The addition of a Joule-Thomson circuit can extend the temperature range towards the helium region. The second demonstration, by E. F. de Haan and S. L. Tan, was of the 'Plumbicon', a pick-up tube similar to the 'Vidicon', but using the photoconductive properties of lead monoxide. A colour camera for television broadcasting using this tube has been constructed and is claimed to be four times more sensitive than a 3-in. image 'Orthicon' colour camera, with an improved signal-to-noise ratio and a higher range of contrast.

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* A more detailed description has now been published in *Cryogenics*, 3, 156; September 1963.

CARBIDES IN NUCLEAR ENERGY

TWO hundred and fifty delegates from eighteen countries attended a symposium held at the United Kingdom Atomic Energy Research Establishment, Harwell, during November 5-7, at which sixty-seven papers were presented, dealing with many diverse aspects of the carbides of uranium, plutonium and thorium. The papers were divided into four separate sections, which were concerned with phase diagrams (Sessions 1 and 2), fabrication (Sessions 3 and 4), chemical and physical properties (Session 5), and irradiation behaviour (Session 6).

In the first two sessions, the earlier papers were concerned with features of the uranium-carbon diagram, the exact form of which remains in doubt. It was suggested by Magnier and Accary, of Saclay, that the shape of the uranium-rich boundary of the UC phase implies the existence of a phase of higher uranium content than UC. There seems to be little direct experimental evidence for this new phase, and some contributors to the discussion

were not convinced of its existence. Two papers dealt with the orientation relationships between UC₂ and a parent UC matrix as determined by X-ray diffraction and electron diffraction and microscopy; the results were in good agreement. Imoto has shown that the high-temperature form of uranium dicarbide only exists for a carbon/uranium ratio less than 1.86, whereas the low-temperature tetragonal form probably exists at the stoichiometric ratio.

Papers on plutonium-carbon alloys tended to confirm earlier work on the plutonium-carbon phase diagram and on the rate of self-irradiation damage of the various plutonium carbides; the complex behaviour of alloys with carbon contents between 40 and 50 atomic per cent, where Pu₃C₂ and PuC_{1-x} coexist, was also emphasized. Work on the uranium-plutonium-carbon system at carbon contents above 50 atomic per cent was described by Dalton, who has shown that the M₃C₃ phase is rapidly

stabilized up to a peritectic temperature of about 2,250° C by replacement of uranium by plutonium. It has also been established that U_2C_3 and Pu_2C_3 form a continuous series of solid solutions at temperatures below 1,700° C.

The importance of the oxygen and nitrogen contents of carbides was dealt with in papers from France and the United Kingdom, and general agreement was found on the factors affecting the solubility of oxygen in UC and (UPu)C. Approximately one-third of the carbon atoms in UC can be replaced by oxygen atoms with the formation of $UC_{1-x}O_x$ phases. Higher solubility of oxygen was observed as the plutonium content in (UPu)C alloys was raised. A paper by Pascard gave a considerable amount of data on the phase relationships in (UPu) (CNO) alloys with particular reference to $MC-MN-MO$ compositions. These papers provoked extensive discussion, and it was apparent that even more attention must be directed to the effects of dissolved oxygen and nitrogen in the future, particularly in the case of sintered materials which tend to have higher oxygen and nitrogen contents than are melted materials.

Two papers in this section, from workers at the Battelle Memorial Institute, dealt with phase relationships in carbide systems with transition or refractory metals. Alexander's paper reviewed the thermochemical data on the carbides of the refractory metals and of uranium, and made predictions as to the compatibility of uranium carbides with the relevant refractory metals. Work by Chubb on the phase relationships at 1,500° C and above in the systems of uranium and carbon with molybdenum, rhenium, tungsten, niobium or yttrium showed that tie lines of the type UC-X are observed with the first three of these elements but not with niobium or yttrium where U-MC tie lines occur. Farr reported results on the melting points of the UMC_2 compounds with molybdenum, tungsten and technetium, and a new compound of the U_2MC_2 type was found in the systems containing iridium and rhodium.

Two papers from the University of Sheffield and Harwell were concerned with the uranium-chromium-carbon, uranium-nickel-carbon, uranium-iron-chromium-carbon and uranium-plutonium-iron-carbon systems. The danger of predicting phase diagrams was emphasized by the behaviour in the uranium-iron-chromium-carbon system where UC-Fe and UC-Cr pseudo-binaries exist, but for the iron-chromium solid solution containing 30-80 per cent chromium reaction occurs with UC to produce UF_2 and Cr_2C_6 . In the quaternary system uranium-plutonium-iron-carbon, a ternary phase of approximate composition $Pu_3Fe_2C_6$ exists in which plutonium may be replaced extensively by uranium. In the discussion, French workers reported the existence of the phase $UNiC_2$ which is isomorphous with UF_2C_2 and $UCoC_2$.

Final papers in this section discussed the ternary phases in the UC-SiC and UC_2 -SiC systems and in the UC-US system. Extensive solubility of UC in US is observed, but there is only limited solubility of US in UC. U(CS) alloys have many of the attractive properties of UC and also appear to be more compatible with potential fuel casing materials than is UC.

Of the ten papers presented in Session 3, five were largely concerned with the preparation of carbide by the carbothermic reduction of uranium or mixed uranium-plutonium oxides and the others with the sintering of powders prepared from this material, or from arc-melted carbide. Preparation of carbide free from oxygen requires temperatures of 1,600°-1,800° C. This is due, in part, to the solubility of oxygen in UC, which leads to the formation of a phase corresponding approximately to $UC_{1-x}O_x$ as an intermediate in the UO_2 -C reaction. The occurrence of such a phase may be of help in preparing single phase material. After initial trials, control of carbon content to better than ± 0.1 wt. per cent can be attained. Generally, the reaction product has a bulk density of

6-8 g/cm³. It was reported that, by careful control of the processing conditions, $\frac{1}{2}$ mm diameter uranium-carbon spheres with bulk densities of ~ 12 g/cm³ have been produced at Springfields directly from $UO_2 + C$ without using sintering temperatures above 1,600° C.

The presence of plutonium in amounts up to 30 per cent of the total metal content does not appear to affect the course of the reaction, but in amounts of 50 per cent or greater the reaction was more complex, sesquicarbides being formed. Volatilization of plutonium during small-scale work was reported, but it was thought that the effect was unlikely to be troublesome in large-scale runs. The use of argon to remove carbon monoxide from the oxide and carbon reactants has been studied both in static and in fluidized beds. Reduction to products having carbon contents which could be controlled to ± 0.05 wt. per cent and oxygen contents as low as 0.2 wt. per cent has been achieved at temperatures between 1,500° and 1,650° C. The use of flowing inert atmospheres appears to be more suitable than vacuum for development into production plants having a continuous throughput.

Considerable progress has been made in the development of techniques for sintering uranium carbide bodies to greater than 95 per cent theoretical density. In the past two years, sintering temperatures have dropped by 400°-500° C and high-density pellets are now made by compacting fine, $\sim 1\mu$, powders which have been protected against surface oxidation; oxygen in solution is not detrimental to the sintering process, and only heavily oxidized powders show a change in carbon content during sintering. Intensive milling is required for the preparation of such fine powders from arc-melted carbides, but the carbon-reduced oxide clinker is pulverized more readily.

A binder/lubricant is desirable for all but small-scale pressing of pellets, but care in its selection is required if the carbon content of the sintered material is not to be affected. Sintering aids were not generally used in the work reported in this session, but densities greater than 97 per cent of theoretical were claimed for powders sintered with UAl_3 additions at 1,350°-1,400° C *in vacuo*. However, the success of this method requires the use of hypostoichiometric powder, since material which contained UC_2 sintered to low densities and retained large amounts of aluminium.

The first two papers in Session 4 were concerned with the sintering of U-C and (UPu)-C at 1,400°-1,600° C using nickel as a sintering aid. Both showed that the addition of 0.1-0.4 wt. per cent nickel enabled sintered densities of 95-97 per cent theoretical to be reached with powders which would only sinter to ~ 90 per cent theoretical under the same conditions in the absence of nickel. The reason for the beneficial effect of nickel remains obscure, but it appears to inhibit the composition changes which otherwise occur during the vacuum sintering of oxidized carbide powder.

A paper on the preparation of (UPu)C by the reaction of the metal powders with hydrocarbon gases showed that this process can produce sinterable carbide powders and that the degree of carbon content control is similar to that in processes involving the carbothermic reduction of oxides to carbides.

It was evident that there is widespread interest in arc melting and casting as a preparation and fabrication method for uranium carbide and that workers in several countries have developed this method to a stage where the manufacture of tonne quantities of cast rods can be undertaken. Research in this field has been concentrated mainly in two directions: first, to discover those conditions by which crack-free casts can be produced; and secondly, to increase the rate of casting by the use of semi-continuous furnaces in which a day's supply of melting stock can be held and fed to the melting crucible as required. An interesting development is the use of an electron beam to melt the carbide, which is continuously cast in a water-cooled mould, the upper region of which

contains the molten pool of material which is continuously replenished by a steady supply of granulated feed stock.

The fabrication or coating of small spherical carbide particles was the subject of three papers. One of these described the experimental work leading to the formation of uranium carbide granules by the agglomeration of fine powders on a vibrating sieve apparatus using an organic binder. Another, by Gibson, of the Vitro Corporation, dealt with a tonne-scale method by which spheres of (UZr)-C having very low impurity contents were formed by a high-energy arc discharge, one of the electrodes containing carbon and the metallic oxides, which reacted extremely rapidly in the arc flame to produce molten spheres of the mixed carbide. The third paper was concerned with a fluidized bed system by means of which dense carbon or silicon carbide coatings were applied to small UC₂ spheres in order to retain the fission products produced when such carbide particles are used as fuel in the *Dragon* reactor.

Fuel-to-can bonding was the subject of a paper in which experiments on bond formation between U-C and (UC)-Fe cermets and various canning metals, together with the results of thermal cycling tests of the bonded materials, were described. Bonds of this type are of interest since they might enable fuel elements to operate at lower centre temperatures than can be attained with gas bonding at the same heat rating. Finally, a glimpse of more sophisticated reactor systems was afforded in an account of the fabrication and irradiation in the *Pluto* reactor of (UZr)-C rods for the direct conversion of heat from fission processes into electricity.

In the section dealing with the chemical and physical properties of carbides, two papers from C.E.N., Grenoble and Saclay, described the chemical reactions of uranium-carbon alloys with water and acids. It was claimed that reactions with both neutral and acid media can be used as a basis for uranium and carbon analysis since the reaction products are markedly dependent on the UC₂ content. The second paper indicated that corrosion rates depend on the water and water vapour contents of non-aqueous liquids and gaseous media, respectively. The general conclusion was that atmospheric corrosion of uranium-carbon alloys is a stress corrosion phenomenon which is probably influenced by internal stresses and pre-existing surface cracks. Antill and Peakall have studied the oxidation kinetics of a UC-10 wt. per cent Fe alloy and 90 per cent dense sintered U-C in steam, carbon dioxide and water. In all these environments, the UC-Fe alloy was appreciably more resistant than the sintered carbide. For the reactions in steam, the improvement of UC-Fe over sintered U-C was explained in terms of the likely chemical reactions. It was suggested that with sintered U-C the protons released at the oxide film-gas interface may diffuse into the specimen to form molecular hydrogen at discontinuities. By this means, high pressures may be built up resulting in rupture of the specimen. Iron could exert a beneficial effect if it facilitated the removal of protons near the surface by means of a catalysed reaction, to form molecular hydrogen or gaseous hydrocarbons.

Two papers by Milner and co-workers at Harwell described techniques which have been developed for the determination of both major and minor constituents in actinide carbide ceramics and cermets. It was clear throughout the symposium that the accurate analysis of carbon and oxygen contents is extremely important and requires rather special techniques if the necessary accuracy is to be achieved.

A number of papers were presented on the high-temperature properties of uranium, plutonium and thorium carbides. One of these was given by Krikorian, of Livermore, who described determinations of the vapour pressure of thorium over ThC₂. These determinations were unusual in that they used emission spectra for the detection of species in a high-temperature system. In

this work the emission intensity of atomic thorium above carbon-saturated ThC₂ was used as a measure of the thorium vapour pressure, by applying the second and third laws of thermodynamics. This technique has two important advantages over the mass spectrometric method, since higher gas pressures can be used and the detection system can be isolated from the source material. This is of considerable importance in work with actinide carbides where it is desirable to isolate radioactive materials from the detection system.

In another paper in this section, Potter presented results for the vapour pressure and volatility of PuC between 1,500° and 1,565° C determined by a transpiration method. Discrepancies were observed between this work and previous work, for the value of the heat of vaporization, and it was suggested that variations in the carbon content may greatly influence the volatility of PuC.

Many authors described measurements of the thermal conductivity, electrical resistivity and thermal expansion of U-C and (UPu)-C alloys. Both the radial flow and the thermal diffusivity techniques have been used to measure the thermal conductivity of U-C. Using the diffusivity technique, Wheeler has shown that, between 1,500° and 1,900° K, the conductivity increases significantly in compositions near to stoichiometric. Further work is necessary to determine the variation of this property with composition at high temperatures.

Workers at Los Alamos have shown that in the range 200°-450° C, replacement of uranium by plutonium in (UPu)C solid-solutions results in a decrease in thermal conductivity. However, since the temperature coefficient of thermal conductivity is positive and increases with increasing plutonium content, it is possible that at fuel operating temperatures the thermal conductivity of some plutonium-containing carbides may not be significantly different from that of UC.

Compatibility work on U-C and (UPu)-C compositions was reported in several British and American papers. For U-C with gas bonding, stoichiometric and hypostoichiometric alloys are unreactive to type 304 stainless steel at temperatures below 800° C and 700° C, respectively. There is the possibility of uranium migration in the hypostoichiometric material under the influence of temperature gradients, which may lead to reaction at the fuel/can interface. Carbides which are hyperstoichiometric with respect to carbon are compatible with type 304 stainless steel in the presence of a gas bond at temperatures up to 600° C, but a sodium bond accelerates carbon transport to the steel, giving an observable amount of reaction.

For (UPu)-C, Batey has found that after tests for 700 and 2,100 h, at 650° and 800° C, nominally stoichiometric carbide is compatible with 316L stainless steel, but hyperstoichiometric carbide reacts. The most favourable fuel/can combination seems to be stoichiometric carbide, sodium or gas bonded to stainless steel.

Costa, from Fontenay-aux-Roses, described some resistivity and thermoelectric power measurements on uranium, plutonium and thorium carbides. This work shows that ThC becomes superconducting at 9° K and that PuC undergoes a magnetic transformation at 100° K. Analysis of these results together with the values of the density of states at the Fermi surface has led to the proposal that ThC is analogous to a transition metal carbide, with a narrow *d*-band, while PuC is analogous to a rare earth carbide with some highly localized *f*-electrons.

In the last session, five papers, which were concerned with the irradiation behaviour of U-C and (UPu)-C fuel materials, were presented. First, more basic investigations carried out by workers at Dounreay on the nature of radiation damage in UC have given a reasonable picture of the damage process at low neutron doses and at low temperatures. The results of electrical resistivity, lattice parameter and X-ray line broadening investiga-

tions in UC, UC₂ and U₂C₃ were described, and led the authors to conclude that both vacancies and interstitials or clusters of these are formed, and that there appears to be a definite saturation effect at low burn-up. At higher burn-up the damage is more complex and there is an indication that the defect aggregates are more stable.

Irradiation experiments on miniature fuel elements at centre temperatures between 700° and 1,400° C and burn-ups between 1,000 and 30,000 MW days/tonne were reported by authors from the Argonne, United Nuclear and Harwell Laboratories. In general, the release of fission gas from single phase UC and (UPu)C fuel is low, and in some cases it is much less than the amount that would be expected from recoil alone. Work on U-C has shown that the release of fission gas is influenced by the nature of the second phase present as a result of deviations from the stoichiometric amount of carbon, hypostoichiometric alloys releasing much more gas than hyperstoichiometric alloys. Irregular cracking has been observed in many irradiated carbide samples, but it is not clear whether these cracks are present prior to irradiation. The presence of these cracks does not seem to have had any deleterious effects and no significant changes in microstructure have been reported.

Electron microscopy of irradiated carbides has brought to light the precipitation of fission gas bubbles in the free uranium areas in hypostoichiometric uranium-carbon alloys. This suggests that the free metal behaves like

bulk uranium and may be responsible for swelling in hypostoichiometric alloys.

Sayers described the irradiation behaviour of coated particle fuels to the very high burn-up of 14 per cent. The results provided useful information on the irradiation behaviour of UC₂, which can retain fission gases and hold 99 per cent of the amount generated even in particles with failed coatings. A spearhead form of attack, resulting in the formation of characteristic V-shaped cracks extending radially outwards into the pyrocarbon coatings, was reported. This is believed to result from the irradiation-induced shrinkage of the low-density pyrocarbon.

The symposium will undoubtedly prove to be important in the development of carbide fuels for nuclear reactors. The large number of papers presented and the widespread interest in the conference give a clear indication of the eagerness with which the arrival of carbides as viable fuels is awaited. It is now apparent that carbides of controlled composition can be made by any of several variations of two basic routes and that rather detailed investigations of all the relevant phase equilibria and physical and chemical properties are now being undertaken. However, it is always the case that the final proof of any nuclear fuel material arrives at a much later stage than this. The irradiation results that have appeared are, on the whole, extremely promising, but it remains to be demonstrated that carbides are superior in overall performance to oxides.

BIOCHEMISTRY IN SPAIN

THE development of biochemistry in Spain over the past two decades has been hindered by various factors, notably the isolation of the country during and after the Spanish Civil War and the Second World War, the loss of talent through emigration of a large proportion of the more promising scientists, and the inadequacy of the educational programmes, particularly in the medical schools, where the teaching of biochemistry is still largely in the hands of physiologists.

The establishment of some units for biochemical research in the 'fifties, under the sponsorship of the Consejo Superior de Investigaciones Científicas (C.S.I.C.), was the starting-point of steady improvement in that area. Several factors which have positively contributed to this development are the increasing flux of young biochemists from Spain to the United States, Great Britain and other countries for further training and the support provided by the private Foundation 'Juan March' and, more recently, by the U.S. Public Health Service to some local groups. Moreover, whereas biochemistry was formerly taught at the undergraduate-level only in the university faculties of pharmacy, some new chairs of biochemistry have now been created in faculties of science.

A first meeting of Spanish biochemists, under the auspices of the C.S.I.C. and the International University Menéndez y Pelayo, was held at Santander in July 1961, and a second meeting, under the sponsorship of the C.S.I.C. and the University of Santiago de Compostela, was held in Santiago during August 1-3.

The latter meeting was attended by about a hundred scientists, thirty of whom presented papers dealing with their recent work in Spain or abroad. Five formal lectures were delivered by Prof. M. Lora Tamayo, professor of organic chemistry in the University of Madrid and Minister of Education, on the active site and the mechanism of action of phosphatases; Dr. A. Sols, head of the Department of Enzymology of the Instituto Marañón, C.S.I.C., Madrid, on metabolic control of enzyme activity; Prof. J. Oró, University of Houston, Texas, on the synthesis of biochemical compounds under prebiotic-like conditions; Prof. L. F. Leloir, Institute of Biochemical

Research, Buenos Aires, on sugar nucleotides and polysaccharide synthesis; and Prof. S. Ochoa, New York University, on the genetic code. Communications were presented by Drs. F. Alvarado, C. Asensio, J. L. R.-Candela, F. Escobar, Gertrudis de la Fuente, Carmon García, C. F. Heredia, M. Losada, F. Mayor, Gabriela Morreale, Monique Novaes, A. Paneque, D. Rodriguez, Margarita Salas, J. Vicente, J. R. Villanueva, E. Viñuela and F. Vivanco (Madrid); Drs. F. Calvet, E. Cuenca, P. Puig-Muset, and M. Rosell (Barcelona); Drs. J. A. Cabezas and B. Regueiro (Santiago); Dr. E. Montoya (Granada); Dr. E. Santiago (Pamplona); Dr. F. Sabater (Long Ashton, Bristol); Dr. D. Vazquez (Cambridge); Dr. C. Osorio (Birmingham); and Dr. T. Jauregui-Adell (Paris). Prof. C. Jimenez Diaz, the noted Spanish clinician, gave a résumé of the meeting at its closing session and emphasized the increasing impact of biochemical investigations in the advance of clinical research.

At the request of the Spanish National Committee for Biochemistry (Spain's representative body on the International Union of Biochemistry), a group of biochemists, as charter members, formally founded a Spanish Society of Biochemistry in Santiago. The first Council of the new Society was appointed as follows: Dr. A. Sols (*president*), Prof. F. Calvet (*vice-president*), Dr. J. Rodriguez Villanueva (*secretary*), Dr. M. Losada (*treasurer*), Dr. E. F. Alvarez, Prof. J. Garcia Blanco, Prof. F. Mayor, Prof. J. L. Rodriguez-Candela, Prof. S. Santos Ruiz, Dr. F. Vivanco (*officers*), and Dr. C. Asensio (*secretary elect*). Prof. C. Jimenez Diaz, Prof. L. F. Leloir, Prof. M. Lora Tamayo, and Prof. S. Ochoa, were appointed honorary members. The address of the new Society is: Centro de Investigaciones Biológicas, Velázquez 138, Madrid 6, Spain.

The Society aims at furthering the progress of biochemistry in Spain by holding scientific meetings and by the intensive promotion of relations between biochemists in Spain and abroad. To this end the Society will seek admission in the newly created European Federation of Biochemical Societies.

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