For almost a century now, the long-life members of the carbon materials family, the industry giants as it were, (i.e., graphites, synthetic graphites, delayed coals, activated carbons, and carbon blocks) have undergone a renovation and improvement. But that is not all: the search for new, novel carbon forms never ceases (Figure 1). It would appear that there is no end to the way these graphites (continued, page 6).

Power Station Refurbishment: Opportunities for Coal

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INTRODUCTION

The U.S. has a substantial inventory of aging coal-fired power stations. As these stations near the end of their designed life, utilities have to decide how to maintain capacity. The planning, permitting, and construction of a new, modern power station typically takes about 10 years. It is often difficult to convince communities that it is appropriate to build a power station “in their back yard” and the permitting process is frequently protracted by the intervention of environmental action groups. Political expressions of concern about the effects of power generation on the environment tend to favor plans that reduce power consumption by increasing energy use efficiency.

With a cost of billions of dollars and an operating life of around 30 years, the construction of a new, major league, power station has been referred to as a “bet your net worth” proposition. Utilities are not entirely protected from the financial risk since, if it is found in retrospect that undertaking the project was imprudent, recovery of expenditures by rate increases may be resisted.

(continued, page 4)
Carbon fibers, (continued)

just a "cutting" can be put together to create new carbon materials.

The new materials' success story must be awarded to the PAN fiber. The carbon fiber story actually belongs to the last century with the invention of the electric light bulb. Thomas Edison literally used sewing thread and hair from his wife's head in his early experiments. The continuous improvement in mechanical properties during the last two decades of those PAN fibers has meant that the mesophase-type fiber has not been sold competitively against PAN. The dream of a concentric single-crystal shape as a fiber, free from disclinations and interface defects, with an optical texture (e.g., from variations in mesophase orientation), has not materialized. But it was a brilliant concept and manufacturers have had to settle for less — or have they? Mesophase can be manipulated to control its optical texture (crystallinity). Inter-crystallite interactions can be adjusted, influencing Young's modulus and strength. Thermal management systems are very seriously looking at these fibers, including applications in the Tomahawk fusion reactor. Are we really in the time of a third major influx of capital into carbon technology?

Carbon filaments or whiskers, smaller in dimensions than the fiber, and generated from carbon growing on metal particles, offer a new form of carbon.

They can be grown in normal fiber systems, giving a higher density composite, or form a cermet in their own right. They are comparatively quite graphitic and being hollow, offer enhanced surface accessibility. Their use must be watched carefully. Still in the area of fibers, there is a mixed discipline in the activated, mesoporous carbon fiber. This material offers flexibility in terms of presentation to the adsorbate, e.g., as a cloth, or in frames for liquid purification. Initial incentives were to protect military personnel and equipment during chemical warfare. Domestic markets must be established. It is not only the PAN fibers that have exotic uses in aircraft or possible space stations. A pitch-based fiber is also on the market. It is made of a stabilised petroleum pitch and finds applications in building material, concrete reinforcement, solar collection cells, brake and clutch friction materials, static dispersions, thermal and sound insulators and electrical conductors. Fibers from rayon and similar materials are also used but no longer produced in quantity.

Other, relatively new carbon forms have appeared on (and disappeared from) the market. To return to the concept and applications of mesophase, during the thermal pyrolysis of petroleum and coal tar pitch, at about 400 °C, the mesophase or liquid crystal system appears as a spherical entities from within the pitch. They can reach the size of about 25 μm in diameter before beginning to touch and coalesce. There is a current technology to grow, harvest and utilize these spheres, called mesocarbon microbeads (MCMB), as creating small-grained, high-density, isotropic graphites for example, as required in nuclear reactors. The purity of MCMB manufacturing shows a rapid change in approach to overcome technical difficulties. Initially, the simplest approach is filtration. But to take out particles 35 μm or less and maintain adequate permeability in the filter cake was not possible. There is the approach of pitch pyrolysis under supercritical conditions when the MCMB are formed on pressure release without encasement in unprocessed pitch. Mixing and heating pitch with an insoluble dispersant such as a thermally stable silicious oil, creates MCMB which are more readily separated from the oil due to unprocessed pitch in filtration. Finally, a simplistic approach was found to form an aerosol of pitch droplets, stabilize these, and carbonize to the MCMB stage. The advantages of using MCMB in creating synthetic graphites are: a lower volatility content, a higher density graphite due to isostatic premelting use during graphitization and control over the optical texture (crystallinity) of the graphite by adjustment to the size of MCMB selected.

Excitement was generated in the 1970s over the possibility of using carbon materials as prosthetics, in bone and tendon replacements, and as replacement (continued, page 3)
The development of alumina- and graphite-refractory materials from single-crystal graphite is a success story. Although not a high tonnage product, they have an indispensable role in the metallurgical industry where they are used as ladle nozzles, submerged nozzles, probes and gate valves.

The forward-thinking carbon scientist speaks with enthusiasm about the use of porous carbons as catalyst-support materials. There is no doubt that when supporting platinum they are effective hydrogenation catalysts, but their widespread adoption is still awaited. Is this a case of too much enthusiasm or is there a lack of funding to develop these materials to levels of industrial acceptability? Time will tell.

The ever-optimistic carbon scientists today have their attention firmly attached to two new developments: the diamond-like and graphite film and fullerene. Again, it was the military which gave diamond-like films a push, both in providing hard reflecting surfaces and as a semiconducting material. The fullerenes come to us from outer space and have sparked many imaginations. They are spheres, or spheres within spheres within spheres, or cylinders of carbon atoms arranged in hexagonal and pentagonal array. That is, they have surfaces, certainly not graphite, with pentagonal arrays to accommodate the strain energies (see Carbon 1992, 30 (8) for further details. Being only a molecular weight of ~1,000 atoms and occurring in the debris of high temperature, high energy carbon systems, such as laser ablation of graphite and electrical discharges between carbon deodes, it is not surprising that they have been overlooked for so many years. Perhaps early pronouncements were a little too optimistic. Fullerenes are not carbon blacks, nor are they gas-phase initiators of mesophases. But they are neat and interesting materials with catalyst and lubricant potential and have relevant electronic properties (superconductivity). They can be bonded with platinum and stabilized in water by attaching to a cyclodextrin-type molecule.

The ultimate in imaginative developments of a carbon material is the elastic carbon thread. Yes, it is elastic and quite strong. It is a coiled thread made from spinning together different parent materials. Like so many products of the imaginative mind, all it needs is a market. The world today does not need so many fancy things. Perhaps it needs only aluminium for its drink can, steel for its automobiles, carbon fibers for its aircraft, carbon blacks for its newspapers and activated carbons to keep its food and environment clean and acceptable.

Dr. Jerry March is a distinguished Visiting Professor of Southern Illinois University, Carbogenic and previously worked at the Northern Carbon Research Laboratories at the University of Kansas upon retiring.

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PLANNING DURING UNCERTAIN CONDITIONS

Since the future market is uncertain, it may be appropriate to seek a strategy valid for many scenarios. An important key to success, in such a strategy, is the ability to adapt quickly to change, while taking maximum advantage of the market as it develops. Such considerations may lead utilities to favor schemes which allow capital commitment to be recouped in a program of small, rapidly executed, independently justifiable investments. An overall plan for this approach might include the following:

- Maintain capacity by refurbishing existing power stations.
- Expand capacity by small steps in line with increased demand.
- Make up any supply deficits by suitable contracts with neighboring power producers.

RAPID RESPONSE: TECHNICAL OPTIONS

The possibilities suggested below are low cost only in the sense that they involve tens or hundreds of millions of dollars rather than billions. Similarly 'rapid' implies increasing generating capacity within three years rather than ten. In that context, upgrading existing power stations or the addition of small generating modules may qualify as rapid low-cost options.

Many power stations are coal fired and hence have facilities for receiving, handling, and storing coal. The policy of refurbishment, re-powering, and extension at existing sites therefore favors continued coal use. Power station refurbishment and re-powering is a large topic to cover in a short article but a few examples are given below. These examples describe some of the options open to utilities.

REPOWERING

The cost of extending an existing power station’s life may be no more than 20–30% of the construction cost for an equivalent new facility with comparable service life. The life of a power station might be extended indefinitely by replacing parts as they wear out. Older power plants however tend to be less efficient, less reliable and less environmentally friendly than newer plants. In addition to life extension, efficiency upgrading is desirable, and licensing authorities may impose an obligation to reduce environmental impacts as a condition for permitting the work. To address the problem of reliability.

CATR Director Frank Derbyshire recently gave a presentation to the Kentucky Coal Export Council, which is chaired by Lt. Governor Paul Patton, University of Kentucky President, Dr. Charles Wengerski and Vice President for Research and Graduate Studies, Dr. Irv Magid attended.

Comprehensive information about the plant's reliable life expectancy is necessary. Collecting this information may be expedited by upgrading the control system as the first step of refurbishment.

Control system upgrades

Older power stations may still rely on their original process control equipment. This equipment's original capability would have been limited compared with modern control equipment, and its performance is likely to have further declined by age. Modern, distributed digital controllers, offer more accurate and reliable control. The benefits are: greater thermal efficiency resulting from closer adherence to optimal operating conditions and reduced incidence of component failures by tighter temperature control. Digital control systems also facilitate data acquisition by a central computer. The resulting database is relevant to failure analysis, residual life prediction, predictive plant maintenance and other computer-based management systems.

Re-powering

Substantial plant modification, for example boiler or turbine replacement, is usually described as re-powering rather than refurbishment. Where an old plant has been subject to less exacting emission control requirements, re-powering may invoke the standards of emission control applied to new plants (New Source Performance Standards).

Re-tuning and post combustion emission control equipment is expensive and space to locate the equipment is often not always available. It may be cost effective to replace the boiler using 'clean coal technology.'

Atmospheric circulating fluidized bed combustion, with in-bed desulfurization by lime or dolomite injection and intrinsically low NOx production, is already a well established clean coal technology. As well as being more environmentally friendly than an uncontrolled pulverized coal boiler, relatively small circulating fluidized bed boilers can match the efficiency of much larger pulverized coal boilers which are handicapped by pre-combustion emission control equipment. Pressurized fluidized bed technology (PFBC), a further development of atmospheric fluidized bed technology, is currently being proved at new plants in the U.S., Sweden and Spain.

If emission controls continue to become more stringent, coal conversion (continued, page 5)
Power Station, continued

into a clean gas before combustion may eventually become a practical necessity. The integration of a combined cycle (IGCC) is the new plant or repowering option which offers the lowest achievable emissions per metric tonne of fuel and, of course, high thermal efficiency from relatively small units.

Combined cycle repowering

Where gas supplies are available, the cost and efficiency of an existing coal fired power station may be increased by adding a combustion turbine generating set. Several configurations are possible for such a combination, but the common factor is that improved efficiency is obtained by using the waste heat in the combustion turbine exhaust to assist steam generation for the steam turbine. This technique has been used to augment the performance of many coal-fired power stations in Italy.

Steam turbine upgrading

Older turbines were usually built with more generous design factors than newer, more tightly engineered machines. Many old turbines therefore have considerable potential for cost-effective upgrading. It may be possible to replace the internals, while retaining the casings and foundations. The installation of new blades with modern aerodynamic sections and incorporating, new blade tip steam seal designs may provide efficiency and capacity improvements. In the turbine's low pressure section, aerodynamic design is important not only for the turbine's performance, but also for its reliability. The low-pressure end was designed to avoid inducing vibrations in the long, flexible blades, which can result in premature blade failure.

CONCLUSIONS

Uncertainty about the future market for electricity may reduce the enthusiasm of utilities for large, new power stations. An emphasis on pursuing gas energy to several countries is to improve and extend the life of existing coal-fired power stations. The development of relatively small, low-cost, thermally efficient power modules based on clean coal technology offers utilities the prospect of reducing reliance on conserving existing capacity and adding new capacity in small increments.

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David H. Scott was Operations Manager for By-Products Coal Products Ltd (CPL) in England from 1978-1990. In 1990 he joined IEA Coal Research as member of the Coal Utilisation Department.
In my two years here, I have found that the University of Kentucky Center for Applied Energy Research is an excellent research center with dedicated and intelligent scientists and support staff. But besides the Center’s significant research accomplishments and capabilities, through efforts like Energia, the library’s on-line catalog system, coal quality data base, conference sponsorship and IEA publications distribution, we also bring information and promote interactions on a university, state, national and global scale for those working in the field of energy.

I have thoroughly enjoyed my editorship of Energia. Otherwise, with an English literature major’s background, I might have been unfortunate enough to go through life without knowing the potential of hydroxylation as a route for coal liquefaction. I might have never even have thought about the selective activation of methane.

Comments, suggestions and article/editorial contributions are always welcome from our readers. If you know of someone who might wish to receive Energia, please contact me at (606) 257-0224, fax (606) 257-0302.

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