POWER PLANT MATERIALS

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Keywords: Materials, Metals, Alloys, Nuclear Reactors, Material Properties

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Summary

The most common materials found in critical power plant applications are the metals, the properties of which are determined by the size, composition and distribution of the crystal grains making up the microstructure. For plain carbon steel, the microstructure is fashioned by adjusting the carbon content, heat treating and mechanical working.

Enhanced physical properties and corrosion resistance are obtained in the low-alloy steels by alloying with elements such as manganese and chromium to less than 5 weight percent; the stainless steels require above 12 weight percent chromium - often with nickel and lesser amounts of other additives such as molybdenum or niobium.

For some high temperature applications, nickel alloys may be required. Their oxidation resistance is provided by chromium, while molybdenum can be added for extra protection in very aggressive environments. A major application of nickel alloys in the power industry is the tubing of steam generators in nuclear reactors such as the PWRs and CANDUs.

Zirconium alloys, such as the Zircaloys (having about 1.5 weight percent tin as the main additive) or Zr-2½ Nb have their greatest use in the power industry for in-core components in nuclear reactors, where their neutron transparency and corrosion resistance make them suitable for fuel sheaths or pressure tubing in water-cooled systems. In the carbon-dioxide-cooled Magnox reactors, the fuel sheathing is of magnesium having improved mechanical properties imparted by alloying, mainly with about 0.8 weight percent aluminum.

Copper has an important role in electrical equipment because of its high electrical conductivity; the accompanying high thermal conductivity also makes its alloys important for heat exchanger tubing. The brasses, resulting from alloying with zinc, are used extensively in cooling water systems and for condensers. For more corrosion-resistant material, the cupronickels resulting from alloying with nickel may be employed. For best corrosion resistance in condensers - especially those in sea-water service - or for cooling water heat exchangers when copper must be avoided, titanium is recommended.

Finally, the non-metals such as ceramics and polymers find not only traditional uses as insulators and construction materials (e.g., cable insulation, concrete for buildings and fiber-reinforced plastic for piping and storage tanks) but also growing applications as specialized materials in components such as corrosion-resistant heat exchanger tubes and machine parts.

1. Introduction

The performance of power-producing systems has always been limited by the properties of engineering materials. Since the early days of industrial steam generation in the seventeenth and eighteenth centuries, for example, the ever-increasing need for power for new factories created a steady demand for larger boilers and more severe steam conditions. Materials development could not keep pace and catastrophic failures of equipment occurred frequently.

As late as the end of the nineteenth century, hundreds of steam plant explosions accompanied by large numbers of casualties were being recorded every year in Europe and North America. The causes were generally linked to the failure of riveted joints or poorly worked steel plate in fire-tube boilers. The innovation of the water-tube boiler and the understanding of localized corrosion of steels in high-temperature water were major factors that led to much safer equipment - even as operating conditions continued to become more severe.

Today, the risk of catastrophic failure of a power-producing system is low. This can be attributed to the strict safety standards that are imposed on component designers and manufacturers as well as on plant operators. The setting of these standards clearly involves a thorough knowledge of the properties of the materials of construction and an understanding of their behavior in the local environment. That environment may itself be adjusted for overall optimum performance by specifying its chemistry. The prime example of such chemistry control is the specification of a minimum alkalinity level in the feedwater systems of steam raising plants, which is necessary to minimize corrosion of piping and components and to keep systems clean.

While the current performance record of power plants is generally good, technology is not standing still. The push for bigger returns on capital investment and the accompanying trends towards higher plant efficiencies and longer component lifetimes lead to even more severe operating conditions in power systems. Inevitably, the demands on materials escalate. As described in *Fossil Fuel Plant Materials and Chemistry* and *Nuclear Reactor Materials and Chemistry*, the predominant materials of construction in steam-raising equipment are the metals. Their interaction with the operating environment very much dictates the chemistry control practised by plant operators.

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Bibliography

Stultz S.C. and Kitto J.B. (1992). Steam; Its Generation and Use. 40th Edition, Babcock and Wilcox Co., 1992. [This 982-page volume is the 40th in a series that began in 1875. After a historical introduction it deals with all the technical aspects of steam, including physical properties, heat transfer characteristics, etc., and of equipment for raising steam, including fossil-fired boilers and nuclear reactors. The materials commonly found in steam plants are dealt with in one chapter, involving metallurgical considerations and mechanical properties, and the application aspects are covered to some extent in chapters on structural analysis and design, manufacturing and construction. The treatment of the subject matter is comprehensive and can be understood by anyone with a technical background.]

British Electricity International, London (1992). Modern Power Station Practice. 3rd Edition, Incorporating Modern Power System Practice. Volume E, Chemistry and Metallurgy. Pergamon Press, 1992.[This edition comprises twelve volumes dealing with all aspects of the electricity generation and transmission capability of the (former) Central Electricity Generating Board in the U.K. The volumes cover subjects ranging from station planning and design to operation of the distribution system. Volume E - Chemistry and Metallurgy - treats practices in fossil-fired boilers, from the points of view of system monitoring and operation to inspection and cleaning, in 576 pages. The metallurgy of the important metals (including non-ferrous metals and alloys) is outlined and the characteristics and uses of non-metals (including ceramics and polymers) are presented. The treatment of the subject matter is extensive and thorough and provides an excellent reference text. It should be of value to anyone with a technical background.]

Biographical Sketch

Derek Lister, B.Sc. Tech., M.Sc. Tech., Ph.D., M.I.Chem.E., C.Eng., F.C.I.C., was born in Nelson Lancashire, England in 1939. He was educated at the local secondary technical school, the University of Manchester and the University of Leicester, obtaining his bachelor's and master's degrees in chemical engineering and his Ph.D. in physical chemistry. He spent three years with the Atomic Power Division of English Electric Co., developing Magnox and AGR nuclear fuel, and four years as a Research Fellow at Leicester University, studying crystal growth and electron spin resonance, before joining Atomic Energy of Canada Ltd. at the Chalk River Nuclear Laboratories in 1969.

After a short period in CANDU nuclear fuel development he became involved in research into reactor chemistry. This was concerned mainly with chemistry control and corrosion in CANDU reactors, though contract research was done for the U.S. nuclear industry as well. He became Senior Scientist and, in 1992, when Manager of the System Chemistry and Corrosion Branch, he was awarded the NB Power/AECL/NSERC Industrial Research Chair in Nuclear Engineering at the University of New Brunswick and moved to Fredericton.

At UNB, he contributes to the Option in Nuclear and Power Plant Engineering in the Chemical Engineering Department and to other undergraduate courses. He has designed and constructed a research laboratory containing high-pressure, high-temperature equipment for studying reactor and power plant chemistry and corrosion and carries out research for the Canadian and overseas nuclear industries. He has published extensively in the fields of reactor chemistry and corrosion and heat exchanger fouling. He is now Chair of the Chemical Engineering Department as well as holder of the research chair and holds technical advisory positions on several national and international bodies. He enjoys skiing, tennis, drawing and painting and French and English literature.