CHEMICAL AND PROCESS PLANT

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a guide to the selection of engineering materials

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Introduction to the first edition

The range of materials from which chemical engineers, and others who are concerned with the specification and construction of process plant, can choose, is now very wide and varied. The main purpose of this book is to draw attention to all these materials so that none are overlooked.

The main physical, mechanical and chemical properties and basic costs of each material are given so that an initial appraisal can be made of suitability for a particular project. Many references to the literature and specialist sources of information have been included so that those who need to investigate any aspect more deeply will know where to look and inquire.

Any unusual limitations of a material have been emphasized so that it can be checked whether these will be a serious handicap in particular circumstances. Guidance on the testing of materials has also been given so that reliable data can be obtained in environments for which it does not as yet exist. This is particularly important for non-metals, such as rubbers and plastics, for which the effects of changes in formulations on corrosion resistance, etc., are not so well known as for metals.

The precise specification of construction materials is important and attention is drawn to national and international standards where they exist; the use of these usually results in lower costs and quicker deliveries.

Examples of the use of specific materials have been drawn from many industries including those making organic and inorganic chemicals, petrochemicals, fertilizers, pharmaceuticals, fibres, oils and fats. These are all considered as process industries requiring production plant and equipment for the construction of which the materials described here should be considered.

Introduction to the second edition

All the chapters of the original edition have been revised to include the many developments in metals, plastics, etc., that have occurred in the past seven years. Many changes in national standards and specifications have also been included in the text and tables. The section on brittle fracture has been expanded to cover the considerable progress that has been made in evaluating and selecting materials for low-temperature duties; also a section on fracture mechanics has been added to show how, in the last decade, this technique has been developed into a practical tool for assessing the safety of large vessels and structures.

Information on the costs of materials has again been included to help guide the specifier of engineering materials in the economic consequences of his decisions. Because of the drastic effects of inflation on the prices of all materials these costs are expressed as indices related to basic metals and plastics — carbon steel and polythene — so that the reader may readily convert them to the appropriate values for any time and place.

Acknowledgements

Extracts have been quoted with permission of the following authorities from whom full copies of their standards may be purchased:

British Standards Institution
2 Park Street, London W1A 2BS

American Iron & Steel Institute
1000 16th Street NW, Washington DC 20036

American Society for Testing Materials
1916 Race Street, Philadelphia, Pennsylvania 19103

Alloy Casting Institute Division, Steel Founders Society of America,
Cast Metals Federation Building, 20611 Center Ridge Road
Rocky River, Ohio 44116

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Carbon and low alloy steels

Carbon steels are alloys of iron, carbon and manganese: most steels have a carbon content of 0.1 to 1% and a manganese content of 0.5 to 2%. Low alloy steels contain, in addition, elements such as nickel, chromium, molybdenum and vanadium in amounts up to 12%. Steels with more than 12% of alloying elements are usually classified as high alloy steels (see Chapter 2).

Sulphur and phosphorus are present as impurities in all iron ores and steel specifications contain maximum permissible values for these in order to limit the number of non-metallic inclusions in the steel. New methods for removing impurities from steels such as electro slag refining and vacuum degassing are now used on a commercial scale to produce steels with impurity levels far below those available a decade ago. These steels are more expensive than those produced from basic oxygen furnaces which have now displaced the open-hearth furnace for the large tonnage production of the general-purpose carbon steels. They are thus only justified for critical applications such as offshore installations and vessels in very corrosive environments.

The pressure-vessel steels have more extensive requirements for certification of composition and mechanical properties and may include requirements for tests at elevated and sub-normal temperatures. Structural steels with guaranteed low-temperature toughness values are also available and are now widely specified for critical structures such as large storage tanks, offshore oil rigs and high-pressure pipe lines for oil and gas.

Low-carbon steels (mild steel)

In these steels the carbon content is restricted to a maximum of

0.25%; steels with a higher carbon content are difficult to weld. Low-carbon steel is the most commonly used engineering material because it is cheap, has reasonable mechanical properties and is, in most circumstances, a very ductile material. Typical mechanical properties of general-purpose carbon steel plate, e.g. grade 43A in BS 4360 are:

Tensile strength	430 N/mm^2
Yield strength	230 N/mm^2
Elongation	20%
Tensile modulus	210 kN/mm^2
Hardness	130 DPN
Toughness CVN	30 joules

Note: there is an approximate correlation between the hardness and tensile strength of carbon steels of DPN x (10/3) = tensile strength in newtons per square millimetre.

The tensile or Young's modulus of low-carbon steel at normal atmospheric temperatures is not exceeded by any other steel. Thus, for equipment where rigidity is the limiting factor in design, e.g. storage tanks and distillation columns, high-strength alloy steels have no structural advantage compared with carbon steel. Because of its good ductility, stress concentrations in low-carbon steel structures are relieved by plastic flow and consequently stress analysis of designs in low-carbon steel is not so critical as in high-strength steel and other low-ductile materials.

The fatigue strength of low-carbon steel in air is approximately half the tensile strength. It is reduced by stress raisers such as notches but the effect is not so drastic as with high-tensile steel.

Low-carbon plate and sheet are made in three qualities: fully killed with silicon and aluminium, semi-killed (or balanced) and rimming steel. The extent of the deoxidation or 'killing' of the molten metal determines which type is produced. Fully killed steel is the best quality as most of the impurities are segregated into the top of the billet and can be cropped off leaving clean metal from which plate with very homogeneous properties can be rolled. Fully killed steels are used for pressure vessels requiring very thick plate either because they are large or are operated at very high pressures. Fully killed steel is more expensive than semi-killed steel because of the higher proportion of steel that has to be discarded by cropping. Most general-purpose structural mild steels are semi-killed steels and so are a balance between cost and quality. Semi-killed steels are also used for small pressure vessels. Rimming steels have the minimum amount of deoxidation and are used mainly as thin sheet for consumer applications such as car bodies.

An important development in the production of low-carbon