CONTROLLED ATMOSPHERES FOR HEAT TREATMENT

R NEMENYI

Budapest, Hungary

Edited by

G H J BENNETT

University of Birmingham, UK

THE PERGAMON MATERIALS ENGINEERING PRACTICE SERIES

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Editor's Preface

THIS volume has been distilled from a translation of Dr. R. Nemenyi's manuscript and most of the original layout has been preserved.

The aim has been to assemble a useful and practically orientated book for those involved in heat treatment; it is intended to complement some of the "heavier" texts and current literature such as that collected in the ASM/Metals Society 1982 Bibliography series (e.g. 602, Heat Treating Atmospheres) and also to complement those invaluable pocket manuals supplied, for example, by Mahler, Sunbeam and Wild Barfield Ltd.

Thoughts of involvement suggested controlled atmospheres rather than the alternative protective atmospheres as a title for the text, the latter being arguably a more submissive term, and also prompted the inclusion of a few simple calculations to encourage a better quantitative understanding of the various reactions involved in the processes.

There are two points that have to be made: one is that the text is largely and intentionally concerned with bright heat treatments because it was felt that to include any satisfactory treatment of gas carburising, nitriding, vacuum coating and plasma impregnation would have made the book too lengthy; secondly, there are a large number of Hungarian references which are unfamiliar to most of us, however to have ignored them would have been dishonest and maybe in time some of the more important references will get read more widely and/or translated. In accepting responsibility for what I believe to be a good little book I would welcome constructive criticism.

GORDON H. J. BENNETT

Sept 1982 Department of Metallurgy and Materials,
University of Birmingham

Author's Preface

HEAT treatment of metals in protective atmospheres has become of major importance in the last 20 to 30 years. With the older heat-treatment processes it took only one man skilled in metallography to supervise a heat-treatment shop, but the operation of protective atmosphere plant requires a knowledge of automation, control engineering, electronics and chemistry. As, in addition, the basic sciences involved are of a mechanical and metallurgical nature, it can be appreciated that an extremely broad field of knowledge is now involved.

Due to the complexity of the subject, articles were mainly confined to the professional literature. A general work on this subject was last published in 1953 in the U.S.A., but since that time the science has made great progress. By the time this book is published, perhaps yet more up-to-date plant will have been manufactured—but this is a feature of technical progress. In due course many direct-fired furnaces and air atmosphere furnaces now in use will be replaced by ones using protective gases and this book will assist those engaged in such changes.

The usefulness of this book is greatly enhanced by the up-to-date illustrations made available by the courtesy of Ebner Industrieofenbau (Austria, Linz) and Aichelin (West Germany, Stuttgart, and Austria, Vienna, respectively). I take this opportunity to express my sincere thanks to them for their kindness.

R. NEMENYI
Budapest, Hungary

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DR. R. NEMENYI has, in his preface, thanked Ebner's of Austria and the Aichelin Company of Germany and Austria for their invaluable help in providing guidance, data and illustrations. To these are added the West German companies of Degussa, Hartmann and Braun and Maihak together with Applied Research Laboratories of England from whose literature illustrations have been used.

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Sincere thanks are due to Miss Kokila Patel for her devotion to the typing and sorting of the script and to Professor Tom Bell for interfacing so effectively amongst the author, the publishers and the editor.

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Chapter 1

Heat Treatment in Controlled Atmospheres

INTRODUCTION

The need for increased productivity and the meeting of world standards and specifications in technology demand the development of heat-treatment techniques. Heat treatment of metals and alloys used in the engineering industry was often carried out in rather old-fashioned plant, some of the processes involved health and safety hazards, were time consuming, insufficiently productive and often wasteful of energy.

The engineering industry as a whole is characterised by a trend toward mechanisation and automation. With respect to heat treatment plants this trend has been apparent since the 1970s. However, although temperature and atmosphere control are well understood and generally practised, the atmospheres of some heat-treatment furnaces remain uncontrolled.

Quality requirements of products can frequently not be satisfied using these uncontrolled heat treatments; dimensional accuracy, reproducibility, consistency of products and surface carbon content, etc., fall short of the required standard.

The heat treatment of metals, notably steels, in the exhaust gases of direct-fired furnaces which contained larger amounts of carbon dioxide and water vapour was responsible for the poor surface (scaling) and decarburisation since both are oxidising to the iron and carbon at elevated temperatures. This led to the development and use of specific units or gas generators in the early thirties, in which the combustion of fuel was regulated by careful control of the air to fuel ratios. The gas atmosphere produced was often referred to as burnt gas but is now known as exothermic gas. The exothermic gas contains large amounts of nitrogen (from the air) together with smaller amounts of carbon monoxide (CO) and hydrogen (H_2), which are reducing and of carbon dioxide (CO_2) and water vapour (H_2O), which are oxidising, there may also be a small amount of methane (CH_4) present. Two major classes of exothermic atmospheres are recognised, rich and lean. A rich atmosphere is one in which CO and H_2 tend to be higher (10–12% of each) due to a lower air to gas ratio being employed; the lean atmosphere uses a higher air to gas ratio and contains only about 1.5% each of CO and H_2 but over 10% CO_2. Exogas is used for non-ferrous metals and mild steel.

Experience soon established the need to reduce the levels of oxidising CO_2 and H_2O in these atmospheres especially if scaling and decarburisation of high carbon steels were to be avoided during heat treatment. The technological difficulties in effecting this removal to produce prepared exothermic gases (dried and stripped, of CO_2) for use in controlled atmosphere heat treatment processes led in the 1930s to the development of endothermic gas generators. In these the fuel is reacted, using external heating and a catalyst, with only 20 to 40% of the air that complete, exothermic combustion would require to give endogas containing about 40% N_2, 20% CO and 40% H_2. Lean endogas may contain 0.5% CO_2 and rich 1% CH_4 and both will be saturated with water vapour. Endogases are used for ferrous metals. Nitrogen-rich atmospheres can be prepared from exogas and of these the rich prepared nitrogen ($>75\%$ N_2) is used for the annealing and brazing of stainless steel. The lean exogas can produce an atmosphere containing over 95% N_2 and it is therefore essentially inert. The presence of 1–2% of CO and hydrogen make it mildly reducing and this is sometimes referred to as monogas. It is properly lean, dried and stripped exogas but clearly is essentially a monomolecular species gas or monogas. Monogas is used for all steels.

In addition to these prepared atmospheres there are nitrogen/hydrogen-controlled atmospheres prepared from ammonia as well as those obtained from compressed cylinder gases such as nitrogen, hydrogen, argon, etc. These are used for brazing, sintering and stainless steels.

Since the seventies increasing use has been made of vacuum heat treatments in which protection is effected by prevention of the metal objects from being in contact with essentially any atmosphere at all. Originally used for the rarer metals, vacuum heat treatment is finding wide application in many areas.

For heat-treatment purposes, controlled atmospheres were first employed between 1920 and 1930 when copper was annealed in steam because it had been discovered that no further oxidation occurred in

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