

**THE CASE-HARDENING OF STEEL; AN  
ILLUSTRATED EXPOSITION OF THE  
CHANGES IN STRUCTURE AND  
PROPERTIES INDUCED IN MILD STEELS BY  
CEMENTATION AND ALLIED PROCESSES**

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The Case-Hardening of Steel; An Illustrated Exposition of the Changes in Structure and Properties Induced in Mild Steels by Cementation and Allied Processes by Harry Brearley

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**HARRY BREARLEY**

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## THE CASE-HARDENING OF STEEL

**THE HEAT TREATMENT OF TOOL STEEL**

An Illustrated Description of the Physical Changes and Properties induced in Tool Steel by Heating and Cooling Operations.

By **HARRY BREARLEY**

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OF STEEL

*AN ILLUSTRATED EXPOSITION OF THE CHANGES IN  
STRUCTURE AND PROPERTIES INDUCED IN STEELS  
BY CEMENTATION AND ALLIED PROCESSES*

LIBRY OF  
CALIFORNIA

BY

HARRY BREARLEY

*WITH ILLUSTRATIONS*

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TO THE  
UNIVERSITY OF  
CALIFORNIA

TO  
MY FIRESIDE CHUM



## PREFACE

THE following descriptions and explanations were written mainly for the use of those actively engaged or interested in the commercial production of case-hardened objects. For that reason the chapters are arranged so as to appeal at once to the workshop experience and observations of craftsmen, to whose friendliness the author is indebted for many of the specimens from which the illustrations were made. It was not found possible, however, to separate the subject into practical and theoretical divisions, nor is any such distinction desirable.

Though no apology may be needed for introducing a number of micro-photographs, a few words of explanation may be allowable. We are accustomed to discriminate between certain kinds of materials by the appearance of fractured surfaces; the tool steel trade was built up on refined discriminations of this kind long before chemical analysis or the modern refinements of heat treatment had been developed to any serviceable extent. The observation of polished and etched surfaces is nothing more than an extension of this old and useful practice, and quite a remarkable amount of information can be extracted from such surfaces by means of a hand lens magnifying only five or six diameters, and sometimes even by the unaided eye.

It is unfortunate, though perhaps not altogether unavoidable, that microscopic demonstrations should be obscured by a jargon of ambiguous names. But the examinations themselves are not in the least ambiguous; on the contrary, they are along the line of least resistance for whoever wishes to study the principles underlying metallurgical handicrafts, and provide unrestricted opportunity for direct observation, which may be interpreted

according to one's personal experience. The necessity for such observations lies mainly in the planning of schemes for attaining some desired end, and in the quest of the intelligent mind after the why and wherefore.

An explanation based on the mechanical structure of an object is intelligible, because most minds can appreciate the elements of design and pass judgment on the composite properties of materials. Many kinds of steel have a mechanical structure which, when suitably magnified, is as obvious as that of reinforced concrete. It is in terms of such structures that the properties of case-hardened steels must be explained. For that reason micro-photographs will be freely used in the following pages; and for the same reason the assistance offered by microscopic methods, whatever means of magnification are available, should not be ignored in workshop practice.

The first edition of this book appeared in 1914, but it has been for some years out of print. Meanwhile the great stir about steel specifications caused by the war impressed new ideas about steel and its heat treatment on most engineering firms, much to their benefit in all respects, except, perhaps, in relation to case-hardening steels. In these many changes followed in rapid succession, resembling somewhat in exposition and effect the advertisements of a patent medicine vendor. As a legacy there remains a tangle of truth and falsehood which only time and patient observation can straighten out. In venturing to question the value of notions which some readers may cherish, the author has written as clearly as he knows how, and perhaps a trifle dogmatically. It should, however, be understood that no man's word is law in an experimental craft like case-hardening. Nothing but good can come of criticism which induces the case-hardener to reweigh his compromises and test his beliefs.

The author is greatly indebted to his colleagues, J. H. G. Monypenny, who kindly read the proofs and compiled the index, and Harry Nicholds, who made drawings and photographs for illustrations.

## CONTENTS

	PAGE
PREFACE - - - - -	v
<b>PART I</b>	
HISTORY AND MEANING OF CEMENTATION	
CASE-HARDENED FILES—CEMENTATION AND CAST STEEL— SHEAR STEEL—STRUCTURE OF STEEL—PEARLITE— CEMENTITE - - - - -	1
<b>PART II</b>	
STRUCTURAL CHANGES IN THE CORE	
OVERHEATING—REFINING—CHANGES ON HEATING—COM- PLETE DIFFUSION—CHANGES ON COOLING—DOUBLE QUENCHING - - - - -	8
<b>PART III</b>	
FIBRE AND LAMINATION IN THE CORE	
WHAT IS FIBRE?—FIBROUS CORES—FINAL QUENCHING— FIBRE STEELS—TRANSVERSE CRACKS—LAMINATION— SLAG STREAKS - - - - -	26
<b>PART IV</b>	
PROPERTIES AND DEFECTS OF HARDENED CASES	
FREE CEMENTITE—REFINING THE CASE—SUPER-CARBURI- SATION—SLAG STREAKS—HARMFUL FIBRE—SOFT SPOTS—TROOSTITE—GRINDING—STREAKY TROOSTITE —CRACKS AND SPLINTERS - - - - -	36
<b>PART V</b>	
THE CARBURISING OPERATION	
FURNACES—BOXES—CONDUCTIVITY OF MIXTURES—SOFT PLACES—CARBURISATION—ACTION OF GASES—DECAR- BURISATION BY GASES—A CRUCIAL EXPERIMENT— SLOW COOLING—DEPTH OF PENETRATION—PENETRA- TION CURVES—PHOTO RECORDS OF PENETRATION - - - - -	55
<b>PART VI</b>	
CASE-HARDENING STEELS	
MACHINED SURFACES—CAUSE OF ROUGH FINISH—FREE CUTTING—CARBON STEELS—MANGANESE STEELS— CHROMIUM STEELS—NICKEL STEELS—NICKEL CHROME STEELS—SPECIFICATIONS - - - - -	72