Inspection of Metals, Volume II:

DESTRUCTIVE TESTING

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INSPECTION OF METALS by Robert Clark Anderson

Volume I: Visual Examination
Volume II: Destructive Testing

In preparation:
Volume III: Nondestructive Testing

Preface

This is the second of three volumes devoted to the inspection of metals. The series is dedicated to the better understanding of the behavior of metals through examination and testing. It is hoped that these volumes will become standard reference works in the inspection departments and metallurgical laboratories of all metalworking facilities, and perhaps will even be used as teaching aids.

It is further hoped that this material will act as another stepping-stone toward the long-sought goal of defect-free parts and equipment — a goal that in turn would reduce costly service failures and their toll of property damage and human suffering.

Like most books, this volume is a blend of personal experience and the work of many predecessors. Wherever possible, the work of others has been recognized and credited. If in any case such credit has been omitted, it has been omitted solely by error.

I would be remiss if I failed to recognize the help of the many persons who provided encouragement and lent assistance in the research, typing, proofreading, editing, preparation of photos and drawings, and printing. I would like particularly to recognize my wife, Aileen, for typing, editing, proofreading, and prodding me onward. My sons Stephen and Randall, co-

workers and second-generation metallurgists, were both of great help in advising me and in proofreading and editing the text. I also wish to thank Dr. Walter Bradley of Texas A & M University for assistance in the preparation of the chapter on fracture mechanics. The Metallurgical Supply Co., Inc., offered access to a great assortment of equipment and literature for photography and data acquisition. Employees who assisted above and beyond the call of duty were Dr. Ed Bravenec, Stan Cooper, Al Deaver, and Jill Cummins, who helped put it all together. Harvey Mohr of H. O. Mohr and Associates assisted with the chapter on pressure testing, as did Obert Nordin. Jack Braverman and others from ASM International gave much-needed encouragement and kept me moving forward when things slowed down. There are many others who also deserve my heartfelt thanks. It is gratifying that so many people are so willing to give their time and share their knowledge.

Contents

CHAPTER

1

Introduction

The purpose of this volume is threefold. First, the information on the most common and widely used destructive tests (much of which can be found scattered through other books) will all be located in one place. Second, these tests will hopefully be described in simple usable form, uncomplicated by excessive technical jargon. Third, it is hoped that the "tricks of the trade," learned the hard way, through many years of practical experience, will make these testing procedures more usefully understandable.

Most of the tests described are not only commonly used, but also relatively simple to perform. There is, however, a shortage of information on such questions as:

1. What does the test do?
2. What do the test results really tell you?
3. How do you know when test results are in error?

In each chapter an effort will be made to include the following information:

1. A brief history and background of the testing procedure.
2. A description of the test.
3. How the test is performed.

4. Equipment available for performing the test.
5. Technical considerations including interpretation of results, sources of error, and helpful hints.
6. Applicable specifications and conversion tables.
7. Calibration of equipment and quality-assurance aspects.

It is recognized that there are a multitude of variations on each basic test method. There are also many testing procedures that are not commonly used. It is beyond the scope of this book to list each and every destructive test and each subvariety of the common tests. Some specialty tests along with some specialty equipment will be covered, but only to a limited degree.

It is hoped that by following this approach of providing good, basic, helpful data on the most commonly used destructive test procedures, this volume can become a readily used reference source. It is written to be useful both for those new to the field and for people with considerable training and experience. It is also hoped that it will be useful in avoiding the many pitfalls experienced by those who perform such tests. The ongoing theme of the three volumes of this "Inspection of Metals" series is "a better understanding of the behavior of metals through examination and testing." A clear and thorough understanding of testing procedures is one way of achieving the goal of superior quality control. This is the type of quality that is so badly needed for survival in today's multinational competition.

The term "destructive testing" is the subject of much controversy. As a case in point, the following is a description of a recent experience:

> A part failure occurred which resulted in a serious lawsuit with sizable demands. The plaintiff was the owner and possessor of the broken parts. The defendant, a large manufacturer of considerable reputation, made demands of the plaintiff to obtain the parts for examination. The plaintiff realized the defendant had the right to such an examination. The plaintiff was concerned, and rightly so, that the defendant might alter or destroy these parts as part of his examination procedure. This would prevent their being used as evidence at the time of trial. An agreement was worked out in the presence of the judge whereby the plaintiff would release the parts for a certain period of

> time if the defendant would agree to perform no destructive testing. This agreement was signed by both parties in the presence of the judge. At a later date, the parts were returned to the plaintiff. The parts had been subjected to hardness tests and a sizable segment had been removed from both sides of the fracture for microscopic examination. When questioned, the defendant claimed such cutting was not really destructive examination since the pieces were still present.

This case is presently under consideration by the court.

What constitutes destructive testing? Is a Brinell hardness test impression destructive testing? How about a Rockwell hardness impression — does this represent destructive testing? Does a microhardness test impression, which is not even visible to the naked eye, qualify as destructive testing? For the purpose of this volume and series, the following definition is proposed for the term "destructive testing." It is hoped that this definition will be universally accepted.

> **Destructive testing** – Any test which alters the shape, form, size, or structure of the material being tested.

There is sound reasoning behind this definition. Small indentations such as hardness-testing impressions can act as stress raisers, causing crack initiation under subsequent load applications. Worse still are the hardness impressions in crack-sensitive materials that may in themselves initiate cracking (Fig. 1). In determination of the cause of a failure, a highly localized point of origin may hold the key. Even a microhardness impression made at that point could make the determination difficult or impossible.

When two dissenting parties are involved in determining the cause of a failure, there are various procedures which allow for destructive testing at the proper stage of the examination. Each party can separately perform nondestructive examinations (in accordance with the stated definition) such as visual examination, photographic studies, and the like. They can then agree on how and where destructive tests will be made. As an alternative, testing can be done jointly, with each party reserving the right to draw its own conclusions.

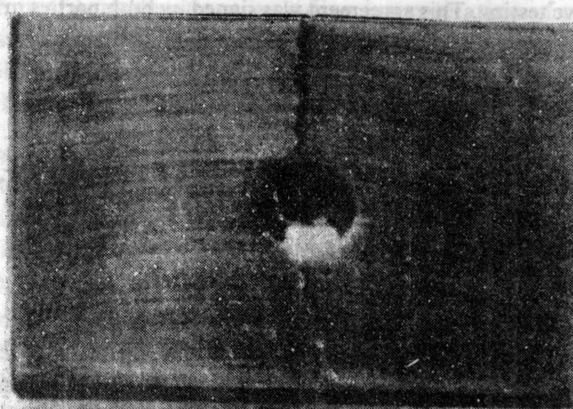

Fig. 1. Example of a Brinell hardness impression that produced a crack in the tested material.

A final item that we should mention before getting into the specifics of destructive testing is calibration of equipment. A test can be no more accurate than the capability of the equipment being used to run the test. Calibration equipment is highly specialized and can be expensive. It is generally desirable to utilize the services of a company specializing in such calibration work. This also provides an independent opinion, which is desirable in the case of test-result controversies. Such calibration may be necessary only once or twice a year, unless problems develop. This frequency depends on quality of equipment and frequency of use. It also depends on the care exercized by the operator. Dated certificates of calibration should be displayed prominently near the equipment or be readily available for inspection.

During the interim periods between visits from the calibration service, there are various methods of ensuring that the equipment is staying within its calibration limits. Use of known-value test samples, such as hardness test block standards, will alert the operator to equipment inaccuracy. A log book of such standard testing should be kept. This not only shows that such tests have been performed regularly but also shows the trend of change which may occur over a period of time. A good working knowledge of the equipment plus the sense and feel that develop from regular usage often provide warnings of impending problems. Cleanness, proper maintenance and, wherever possible, limiting the use of the equipment to a single well-trained operator (or to as few operators as possible) help assure reliable, repeatable results.

A quality-assurance manual can and should spell out all of these considerations. It may specify calibration requirements, routine maintenance intervals, and interim standard testing procedures.