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Cleanroom Technology

Fundamentals of Design, Testing and Operation

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JOHN WILEY & SONS, LTD
Chichester • New York • Weinheim • Brisbane • Singapore • Toronto

Published by John Wiley & Sons Ltd,
Baffins Lane, Chichester,
West Sussex PO19 1UD, England
National 01243 779777
International (+44) 1243 779777

e-mail (for order and customer service enquiries):
cs-books@wiley.co.uk

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http://www.wiley.com

Other Wiley Editorial Offices

John Wiley & Sons, Inc., 605 Third Avenue,
New York, NY 10158-0012, USA

WILEY-VCH Verlag GmbH, Pappelallee 3,
D-69469 Weinheim, Germany

Jacaranda Wiley Ltd, 33 Park Road, Milton,
Queensland 4064, Australia

John Wiley & Sons (Asia) Pte Ltd, 2 Clementi Loop #02-01,
Jin Xing Distripark, Singapore 129809

John Wiley & Sons (Canada) Ltd, 22 Worcester Road,
Rexdale, Ontario M9W 1L1, Canada

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

ISBN 0 471 86842 6

Produced from computer files supplied by the author
Printed and bound in Great Britain by Biddles Ltd, Guildford and King's Lynn
This book is printed on acid-free paper responsibly manufactured from sustainable forestry,
in which at least two trees are planted for each one used for paper production.

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Preface

The dirt and bacterial-free conditions provided by cleanrooms are essential for much of modern manufacturing industry. Without clean conditions, products get contaminated and either malfunction or become hazardous to people. In recent years there has been a considerable increase in the number of cleanrooms. They are now used for the manufacture of items used in computers, cars, aeroplanes, spacecraft, televisions, disc players and many other electronic and mechanical devices, as well as the manufacture of medicines, medical devices and convenience foods. This rapid increase in the use of cleanrooms has created a demand for good quality information about cleanrooms that is free from the 'hype' of sales and marketing jargon. Information is also required to teach production personnel about their working environment, and how to conduct themselves within the cleanroom to minimise contamination.

Cleanroom technology can be divided into three parts: design, testing and operation. Cleanrooms have to be first designed and constructed; they then have to be tested to ensure they achieve their design specification and continue to do so; finally they have to be operated in such a way as to minimise contamination. This book covers, in a holistic way, these three main facets of cleanroom technology.

This book has been written using the principals generally accepted within cleanroom industries. However, I have found many areas where no sound advice exists and have had to develop guidance using my knowledge and experience. Because of this, I have tried wherever possible to give the scientific reasons for the contamination control measures suggested, so that the worth of my opinions may be judged. However, many of the principals are one man's opinion, and this should be borne in mind.

This book is intended for anyone involved with cleanrooms who wishes an overview of the fundamentals of cleanroom design, testing and operation. However, it is inevitable that with my teaching background I would wish to help those who instruct, or are about to instruct, the subject of 'Cleanroom Technology' either at college, or to their cleanroom personnel. I hope the information given in this book is helpful in achieving these requirements.

Acknowledgements

During my many years of involvement with cleanrooms I have been fortunate to meet many of the people who pioneered and developed cleanroom technology. Many of them I now consider as friends. From these people I received information that assisted me during my career; it is from my career experience that this book has been written. It would be impossible to name all of these people, and they must forgive me if they see an idea that they know was theirs. I must confine myself to acknowledging the help of those people who directly contributed to this book. This contribution has been in the nature of: being a co-author of an article that I have used when writing this book; reading and commenting on a chapter; helping in producing photographs. These people are (in alphabetical order) Neil Bell, Chuck Bernt, Roger Diener, Gordon Farquharson, Gordon King, Lynn Morrison, Bob Peck, Martin Reeves, Hal Smith and Neil Stephenson. I should also like to acknowledge the support of the Scottish Society for Contamination Control.

The photographs on the cover of this book are reproduced by permission of Aberdeen City Council, Library and Information Service, Pentagon Technology, Analog Devices and Evanite Fiber Corporation. The permission to use other photographs, tables and drawings used within the book is acknowledged at the end of each chapter. Isabelle Lawson produced most of the drawings in this book, and Barbara McLeod read and commented on the script.

1

Introduction

1.1 What is a Cleanroom?

It is clear that a cleanroom is a room that is clean. However, a cleanroom now has a special meaning and it is defined in the International Organization for Standarization (ISO) standard 14644-1 as:

> *A room in which the concentration of airborne particles is controlled, and which is constructed and used in a manner to minimise the introduction, generation, and retention of particles inside the room and in which other relevant parameters, e.g. temperature, humidity, and pressure, are controlled as necessary.*

The first two thirds of the definition is, in essence, what a cleanroom is. It is a room that minimises the introduction, generation and retention of particles. This is achieved, firstly, by supplying it with exceptionally large quantities of air that has been filtered with high efficiency filters. This air is used to (1) dilute and remove the particles and bacteria dispersed from personnel and machinery within the room and, (2) to pressurise the room and ensure that no dirty air flows into the cleanroom. Secondly, a cleanroom is built with materials that do not generate particles and can be easily cleaned. Finally, cleanroom personnel use clothing that envelops them and minimises their dispersion of particles and micro-organisms. These and other similar measures that minimise the introduction, generation and retention of contamination in a cleanroom are discussed in this book. Cleanrooms can also control the temperature, humidity, sound, lighting, and vibration. However, these parameters are not exclusive to cleanrooms, and are therefore not discussed in any detail in this book.

Figure 1.1 A cleanroom with personnel wearing special cleanroom clothing.

1.2 The Need for Cleanrooms

The cleanroom is a modern phenomenon. Although the roots of cleanroom design and management go back for more than 100 years and are rooted in the control of infection in hospitals, the need for a clean environment for industrial manufacturing is a requirement of modern society. Cleanrooms are needed because people, production machinery and the building structure generate contamination. As will be discussed later in this book, people and machinery produce millions of particles, and conventional building materials can easily break up. A cleanroom controls this dispersion and allows manufacturing to be carried out in a clean environment.

The uses of cleanrooms are diverse; shown in Table 1.1 is a selection of products that are now being made in cleanrooms.

Table 1.1 Some cleanroom applications

Industry	Product
Electronics	Computers, TV-tubes, flat screens
Semiconductor	Production of integrated circuits used in computer memory and control
Micromechanics	Gyroscopes, miniature bearings, compact-disc players
Optics	Lenses, photographic film, laser equipment
Biotechnology	Antibiotic production, genetic engineering
Pharmacy	Sterile pharmaceuticals, sterile disposables
Medical Devices	Heart valves, cardiac by-pass systems
Food and Drink	Brewery production, unsterilized food and drink

It may be seen in Table 1.1 that cleanroom applications can be broadly divided into two. In the top section of Table 1.1 are those industries where dust particles are a problem, and their presence, even in sub-micrometre size, may prevent a product functioning, or reduce its useful life.

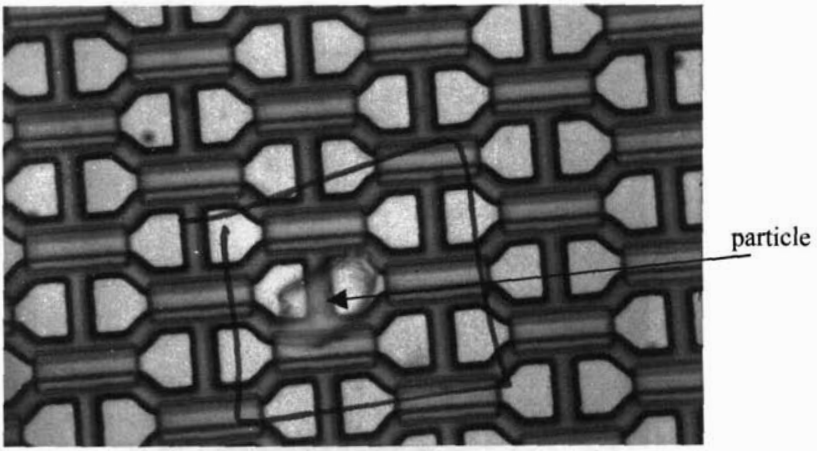

Figure 1.2 Contaminating particle on a semiconductor

A major user of cleanrooms is the semiconductor fabrication industry, where processors are produced for use in computers, cars and other machines. Figure 1.2 shows a photomicrograph of a semiconductor with a particle on it. Such particles can cause an electrical short and ruin the semiconductor. To minimise contamination problems, semiconductors are manufactured in cleanrooms with very high standards of cleanliness.

The bottom section of Table 1.1 shows manufacturers who require the absence of micro-organisms, as their growth in a product (or in a hospital patient) could lead to human infection. The healthcare industry is a major user of cleanrooms, as micro-organisms or dirt must not be injected or infused into patients through their products. Hospital operating rooms also use cleanroom technology to minimise wound infection (Figure 1.3).

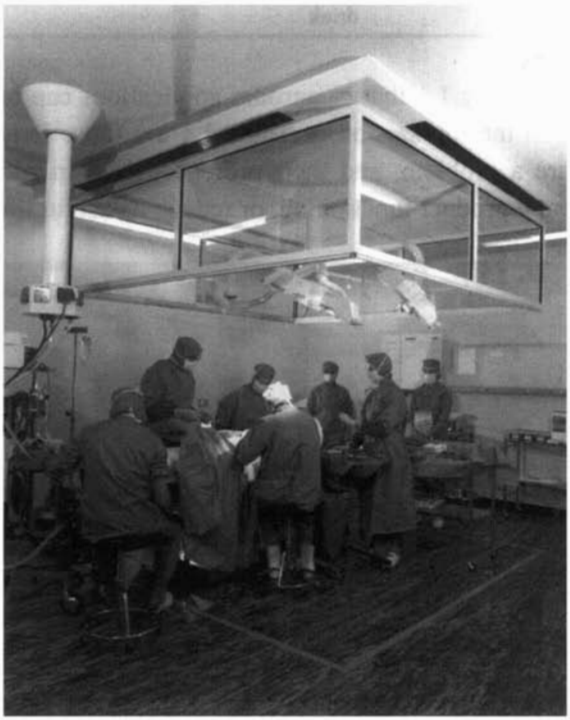

Figure 1.3 Unidirectional flow system in an operating room

It may also be seen from Table 1.1 that many of the examples are recent innovations and this list will certainly be added to in the future, there being a considerable and expanding demand for these type of rooms.

1.3 Types of Cleanrooms

Cleanrooms have evolved into two major types and they are differentiated by their method of ventilation. These are *turbulently ventilated* and *unidirectional flow cleanrooms*. Turbulently ventilated cleanrooms are also known as 'nonunidirectional'. Unidirectional flow cleanrooms were originally known as 'laminar flow' cleanrooms. The unidirectional type of cleanroom uses very much more air than the turbulently ventilated type, and gives superior cleanliness.

The two major types of cleanroom are shown diagrammatically in Figures 1.4 and 1.5. Figure 1.4 shows a turbulently ventilated room receiving clean filtered air through air diffusers in the ceiling. This air mixes with the room air and removes airborne contamination through air extracts at the bottom of the walls.

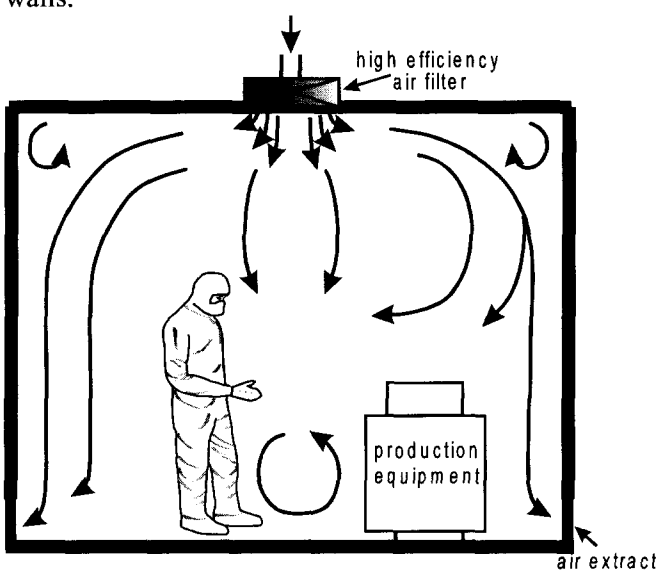

Figure 1.4 Conventionally ventilated type of cleanroom