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Plant and Machinery Failure Prevention

- ✔ Zero-failure performance measures
- ✔ Nature/causes of failures
- ✔ Do's and don'ts to prevent equipment failures

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Plant and Machinery Failure Prevention

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To
His Holiness Shri Sadyojat Shankarashram Swamiji
of
Chitrapur Math, Shirali
N. Kanara, Karnataka
India

Foreword

The phenomenal success of A.A. Hattangadi's first book, *Electrical Fires and Failures*, is an indicator not only of its high quality but also of the acceptance of reliability concepts and practices in India and abroad. The fact that the sales of this book were higher in USA than in India, is not a reflection on insufficient appreciation of the need and importance of reliability engineering in our country. It is just that the book's merit has been recognised in USA. Though the book is meant for front-line supervisors and engineers, it is also eminently suitable as a rigorous and excellent textbook on reliability engineering. This emerging branch with unlimited applications will progressively gain acceptance as an integral part of courses on design, manufacturing, operation and maintenance of plant and machinery.

It is with this background that Hattangadi has written this new book on *Plant and Machinery Failure Prevention* for design and maintenance engineers. The book starts with an assurance that Zero-Failure Performance, with regard to electrical and mechanical equipment is an attainable goal. It calls for the determination of failure modes and mechanisms, followed by appropriate corrective measures. The author in his characteristic learning approach writes about the need for an encyclopaedia of component and equipment failures, and provides it within the span of sixty six chapters and discusses the various categories of failures. These chapters reveal the distilled quintessence of his long experience in the electrical department of Indian Railways.

The book further highlights two lessons for design and maintenance engineers. One, there is no such thing as a 'trivial' component or detail of any equipment and machinery because the damage due to its failure may be enormous or even horrendous. Second, there is a need for the training at every level in reliability engineering for learning about failure modes and mechanisms, investigation procedures and degradation processes of mechanical and electrical components.

The author also brings out two facts about reliability engineering:

- It is always possible to determine the true or root causes of failures, and
- Natural phenomena and laws are totally consistent, precise and reliable.

On these two valid assertions is based his faith in the possibility of attaining Zero-Failure Performance if the root causes of failures are correctly determined. The author makes a bold statement that natural laws and phenomena govern failure processes and enumerates

those that cover 95 per cent of all failures. He finally makes a very simple but weighty statement that understanding failures is very often a matter of common sense.

A majority of failures are due to design deficiencies and only some due to maintenance lapses. It appears paradoxical but it is also true that both failure mechanisms and normal operations observe the same natural laws.

The greatest value of this book lies in its presentation of numerous case studies and the measures taken to reach Zero-Failure Performance which should ultimately lead to confidence building among engineers in their work.

As an academic, with over fifty years association with technical education, I feel that this book will prove to be an excellent reference material for all students of reliability engineering and serve as a gold mine of rarely recorded case studies.

I am sure Hattangadi who had a scholastic career of exceptional brilliance will be remembered not only as an outstanding engineer but more for his pioneering contribution in providing a new direction to thought processes and concepts in reliability engineering. His two books will help bring about abiding awareness of the need to achieve Zero-Failure Performance amongst designers, manufacturers and maintenance engineers.

Sadanand B. Kumta
Former Director of Technical Education
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Preface

Nevil Chute, the British Aeronautical Engineer and Novelist has written many novels that combine romance, adventure, mysticism, philosophy and even engineering, in delightful and unforgettable tales. In one of his novels, he defines an engineer as:

An engineer is one who can build for a shilling
what any fool can do for a pound

In early twentieth century, that was a very appropriate and perceptive definition. Engineers have striven continually to reduce the sizes, weights and costs of their creations. This has brought incredibly complex structures, devices and appliances within the reach of the common man. The new technologies are important not only for our comforts and entertainment but also for our survival. However, all this technological progress on the one hand and our growing dependence on it on the other, has thrown up a new challenge for engineers.

It is no longer sufficient to design and build machines and structures at the lowest possible cost; they must also be totally safe and reliable. However, Nevil Chute's definition of an engineer still remains valid and relevant if we take into account the total life-cycle cost including repair costs and costs relating to consequential damages and losses of revenue arising out of failures of the engineer's creations. Often these other costs are far greater than the initial cost of the equipment.

Reliability engineering developed as a distinct discipline in the post-World War II era. The US defence establishment provided the required impetus to its growth. Very wisely they de-classified much of the basic work done for them in this field and placed it in the public domain. Reliability of all kinds of hardware and equipment improved by leaps and bounds thereafter. A discipline that started off with studies in the failures of equipment used by the defence establishment for fighting wars, now finds application in all kinds of plant and machinery, rolling stock, aircraft, home appliances, etc.

It is now possible to aim at Zero-Failure Performance for most of the electrical and mechanical equipment in service of railways, airlines, road transport, power stations and also in industrial/agricultural machines, telephones, home/office appliances, etc. The common man in the developing countries and even some maintenance engineers may find it hard to believe this claim. Chapter 1 specifically tries to remove these doubts.

During my 34 years of service on the Indian Railways and 16 years thereafter as a consulting engineer, I came across a number of curious features of the equipment failure scene. These are as follows:

(a) Many equipment failures including those with serious consequences are caused by visible or measurable defects that are not recognised as such. Some of these are apparently trivial.

(b) There is little published material about defects and failures—trivial or otherwise. Although a great deal has been written about phenomena like metal fatigue, metal creep, partial discharge, etc. it is all at post-graduate level. Front-line engineers and technicians are not exposed to even the main conclusions of such topics.

(c) There is little communication between practising maintenance engineers on the subject of failures of equipment. Similar failures continue to occur repeatedly in different organisations.

(d) Whereas some types of failures are eliminated in some units, they continue to occur in other units. Sometimes they start occurring in the same units after changes in maintenance staff.

(e) While the number of types of equipment now in use runs into tens of thousands, the number of common failure modes and mechanisms is less than ten.

I feel, that an encyclopaedia of all equipment failures which highlights all the failure modes and failure mechanisms, including the apparently trivial ones, and which is updated periodically, would help designers to review their designs before authorising bulk manufacture. It would also help maintenance engineers to reach the correct solutions quickly when confronted with repetitive failures of equipment caused by design or maintenance deficiencies. It would further help them to train the younger entrants into the profession in avoiding all kinds of defects that may otherwise be ignored, by explaining the mechanisms of failures caused by such defects.

This book is the result of that feeling. It condenses in a few hundred pages the lessons learnt over many years of experience in the operation and maintenance of a wide variety of electrical and mechanical equipment. I am sure there are many others who could add valuable material to this compendium from the wealth of their own experience.

Although this book is based mainly on observations and experience in the Indian Railways, the analyses and recommendations in this book are relevant to manufacturing industries and also to other forms of transport. The plant and machinery used in railway workshops, power stations and production units are identical to those in other industries. Moreover, the materials, components and devices used in locomotives, coaches and wagons are very similar to those used in stationary installations. For instance, split pins and cotters, threaded fasteners, shafts/axles, bearings, etc. mentioned in the titles of Chapters 7 to 66 are used not only in railway rolling stock and installations but also in general industries. The

only exceptions are Chapters 60 and 65 regarding track overhead equipment and pantographs. But even here it will be seen that the components used therein, and their failure modes/mechanisms are not different from those elsewhere.

I hope this book will serve as a reference book for design and maintenance engineers. It would be of special interest to the young engineers entering these professions. To facilitate search, I have grouped the entries component-wise. Although there are thousands of types, makes and models of machinery which include these components, the modes and mechanisms of failures are not only the same for all but also relatively very small in number.

Chapters 1 to 6 deal with general principles, which are applicable to all failures and all the preventive measures discussed in detail from Chapters 7 to 66.

Chapter 4 is about investigation methods. Often young engineers just out of technical schools or colleges are made incharge of maintenance of electrical and mechanical equipment. While they know the constructory details and the theory of operation of the machines in their charge, they are ill-equipped to investigate failures. Chapter 4 will be useful for young engineers, without any experience, to face the task of undertaking investigations into failures of all kinds of mechanical and electrical equipment and components. The methods described in the chapter and a reference to the appropriate equipment chapters and sections that follow will help him to apply his theoretical knowledge to the problems at hand.

Chapters 5 and 6 are about mechanical and electrical degradation processes that are involved in most failure mechanisms. Insight into these phenomena is essential for all those who are investigating equipment and component failures.

The remaining Chapters 7 to 66 deal with different mechanical and electrical components, equipment and systems. These 60 chapters are largely independent of each other with very few cross-references. It is not necessary for the maintenance engineer and manager to read all the chapters in the book but it is desirable that he reads Chapters 1 to 6 fully before going on to the first and the last sections of each of the remaining 60 chapters. He may then return to the relevant chapter as and when required.

The entries in this book are based on my memory, my records, discussions with my colleagues and staff. If I do not give the source or local particulars it is because no one really wants to discuss what is usually perceived as one's own failure in having allowed an expensive failure to occur in the first place. Manufacturers are even more reticent for obvious commercial reasons. When the cause of a failure is trivial and the effects are horrendous, there is usually a conspiracy of silence in regard to the true cause of the failure.

If any readers disagree with something I have said in this book, or if they do not find in it what they need to know, or if they go on to devise their own solutions to their problems, I would request them to write to me at: hattangadianant@hotmail.com.

I am grateful to the large number of engineers, supervisors and workers in the electrical department of the Indian Railways, who knowing my interest in this subject kept me informed of their problems and their successes in the field of Reliability Engineering. In particular, I am indebted to my friend S. Natarajan, Former General Manager of South-Eastern Railway, who went through the manuscript and made many useful suggestions.

And above all, I am grateful to my wife Kumud, who encouraged me to write this book and to my son Arun, who went over the manuscript and made many useful suggestions.

A A Hattangadi

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