Rolf Steinhilper

Born in 1953, he graduated as a Mechanical Engineer in 1978 and received a Dr.-Ing. (PhD) Degree in 1987 at the University of Stuttgart, Germany, with his thesis “Product Recycling in Mechanical Engineering”.

In the past twenty years his work has involved management training, industrial engineering, consultancy and applied research for major international companies in Europe, USA and Canada, Japan, China and Taiwan in the fields of manufacturing and remanufacturing.

Current work includes lecturing on recycling and remanufacturing at Stuttgart University. He has published ten books and more than 250 papers.

In 1993, Rolf Steinhilper has been awarded the European Océ-Prize for his comprehensive technological and logistical concepts for product recycling.
Remanufacturing
The Ultimate Form of Recycling

Rolf Steinhilper

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Remanufacturing Industries Council International
Automotive Parts Rebuilders Association
Fraunhofer Demonstration Center Product Cycles

The inner title photo shows
the assembly area
of Precision Alternators and Starters
Fairfax, VA

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Foreword by the Author

Remanufacturing – the ultimate form of recycling: My writing this book was inspired and supported by great men. Without their encouragement and critique I doubt it would have yet been begun.

First I want to thank my father Ulrich Steinhilper who, when I was only six years of age, not only taught me to ride my first bicycle, but also to "recycle" the components – I learned how to patch the tire inner-tube! Out of this my first practical experience a gradually expanding range of skills developed, which, by the time I was beginning my studies as a university student, equipped me to repair cars. At one and the same time I had my first contact with remanufactured products like brake shoes, clutch assemblies and alternators.

Moving from my education to the world of work, I want to record my thanks to Professor Hans-Jürgen Warnecke, President of the Fraunhofer Institutes for Applied Research. Twenty years ago he had the foresight to support my proposal to start research and to offer consultancy in the field of remanufacturing. This has led to the service we provide today in five Fraunhofer-Centers “Product Cycles“ established in the key industrial areas of Germany.

At an international level, sincere thanks go to Professor Robert T. Lund from Boston University, as well as to Mr. William C. Gager who gives his introduction on the next page. They invited me to share in their development of remanufacturing on an international scale, both in science and in industry. Thus in 1982, my first visits to M.I.T. established a really friendly and open relationship with experts from all points of the globe.

Closer to home, in Europe, I want to thank Fernand J. Weiland for his support and for the preface overleaf. My heartfelt thanks go to my colleagues at the Fraunhofer Institute for their help and support, to the companies who waived copyright or supplied the illustrations and graphics for the book, and to Mrs. Susanne Bacher who, as always, has supplied the illustrations and graphics.

Last, but by no means least, I must thank the readers of this book for their interest in the further advancement of the great concept of remanufacturing.

Rolf Steinhilper
Head of the Fraunhofer Centers “Product Cycles“, Fraunhofer Institute IPA Stuttgart, Germany - 1998
Introductory Remarks
by William C. Gager

Remanufacturing and rebuilding is a process that has been around for over 60 years to restore old products to like new performance and save energy, natural resources, landfill space and reduce air pollution by less re-smelting. This industry also creates hundreds of thousands of jobs and new tax-paying businesses.

By extending product life and by giving products numerous lives, remanufacturing saves 85% of the energy that went in to manufacturing the product the first time. A product can always be resmelted but if we can add numerous lives to that product before it gets resmelted we have really helped save our environment and benefit society.

Public policy makers and scientists are becoming more concerned about the consequences of global warming and sustainable development. We all know that there is only a certain amount of natural resources on this planet. The closer we get to “zero waste”, the more future generations will enjoy the same material wealth that we enjoy today.

The days of throw-away products and single use products are over with. It’s time to move forward with more and more remanufacturing.

William C. Gager
President, Automotive Parts Rebuilders Association
Chairman, Remanufacturing Industries Council International

Preface
by Fernand J. Weiland

I am very grateful to Dr. Steinhilper for writing this very interesting book. The image of the European remanufacturing industry will be greatly improved as a result of him acknowledging and communicating the important contribution we are making to the environment, economies and the labour markets in Europe. Because of these important values this young industry, which is growing fast, deserves enhanced support and better recognition from the media, politicians and all persons concerned with a cleaner environment.

Fernand J. Weiland
Director of the European Division
of Automotive Parts Rebuilders Association
Remanufacturing: Rebuilding the Future

What is Remanufacturing?

Remanufacturing is recycling by manufacturing “good as new“ products from used products.

Remanufacturing has many names. Rebuilding, refurbishing, reconditioning, overhauling are also frequently used terms. Increasingly, however, remanufacturing is becoming the standard term for the process of restoring used durable products to a “like new“ condition.

Remanufacturing also has many meanings. Remanufacturing involves a broad scope of participants in modern products’ life cycles. Each participant has his special focus. There are various significant characteristics and effects:

Figure 1: Remanufacturing is the Ultimate Form of Recycling. It Receives and Deserves Support from More and More Organisations

Characteristics and Effects
From an *environmentally conscious citizen’s* viewpoint, the main reason for being interested in remanufacturing will certainly be their appreciation for recycling as a key principle of “making peace with nature“ and securing a sustainable future.

A *business strategist* might discover that remanufacturing rewards the world of manufacturing with new business opportunities in the after sales service market enabling one to offer their customers new solutions with a minimum total cost of ownership.

The *waste manager* will be delighted how remanufacturing can serve to turn around their costly disposal processes into product loops creating profits.

The *innovative manufacturing engineer* will identify the five steps of remanufacturing, from disassembly, cleaning, inspection via parts reconditioning until reassembly and final testing. He will see them as an expansion of the technologies he is familiar with, accompanied by new challenges especially in the first steps.

Any *maintenance expert* would certainly point out, that remanufacturing is the most effective way to perform servicing and repairing tasks to both the worker’s and customer’s satisfaction.

*Politicians* and *government officials*, whether on federal, state or regional levels, will agree that remanufacturing is a unique strategy for new business development and creating jobs in their surrounding communities.
Economists will honour remanufacturing enterprises as members of the esteemed community of “hidden champions” of industry, playing an important role not only for today’s but also future industries’ survival.

The environmentally responsible industrial professional at once will recognize that remanufacturing is the key link in an integrated green technology chain to perform his new “cradle to grave“-product and recycling responsibilities and liabilities successfully.

For the consumer, remanufacturing is not just the most ecologic but also the most economic way of having access to state-of-the-art technology products at affordable prices but always the up-to-date quality of new products.

Success and also risk assessment analysts will describe remanufacturing as an approach to successfully repeat, replay (and to an interesting extent even replace) those manufacturing technologies, which so far only created a product’s first life cycle. Remanufacturing offers a product many life cycles – it is the enabling technology for “cradle to cradle“ product loops.

Scientists will plainly state, that remanufacturing is the most efficient and effective way to save resources, whether energy or materials, of any form of recycling.

Finally, you don’t need to belong to the small party of idealists to esteem remanufacturing not just as a principle for the “rebirth“ of a product, but also as the birth of an idea how to give new breath to the ideals of a sustainable future for our planet and civilizations.
To a certain extent this full dozen of various views of remanufacturing – in number and in sequence – already reflects key messages of the twelve chapters of this book. More important of course they also in practice offer plenty of benefits and growth potential to industry and society.

Therefore it is no surprise that in today’s world one can already discover an impressive range of application examples representing remanufacturing as the ultimate form of recycling.

Remanufacturing has its roots and displays a long tradition already since the very first moves and outcomes of the industrial age like steam engines, railways, power generation and electrical equipment, machine tools etc. Furthermore remanufacturing always has been a strong partner throughout the uprise of the automotive sector, which undoubtedly was the main industrial driving force so far. Remanufacturing will continuously strengthen its important role in the automotive industry.
Looking ahead, remanufacturing will certainly also keep up with the most up to date technologies and products, offering new opportunities and incentives also within the fast moving electronic industries with their computers, communication and multimedia products.

It is a surprise, however, how little the good news about remanufacturing has made its way into the awareness of consumers and professionals so far, or how limited their influence to decision making in industry or society still appears to be. It seems, however, that just recently there has been an awakening no longer to leave aside the chances of remanufacturing as a brilliant idea for a proactive integration of technology and environment, serving both new markets as well as a responsibility for the nature and the future of our society.
Product Retirement: “You Only Live Twice“?

Industrial production and productivity, especially in the automotive sector, has made impressive progress since the early days, when engineers Daimler and Benz put their very first motor car onto the cobble stone roads a century ago. Henry Ford rolled out his first Model T in 1908 and manufactured the first ten million of them – the main portion of those days’ world car market – in the sixteen following years. Who would have expected, that such a production volume nowadays is just a matter of ten weeks worldwide – with products offering a multitude of functions and features compared to Tin Lizzy?

While looking back, the quantities of products entering the market have certainly been difficult to foresee, but it is an easy task looking ahead to forecast the product volumes returning from their markets, as cars retire after an average lifespan of around ten to twelve years.
There are 170 million cars on America’s roads, 150 million cars in Europe, and around the same quantity all over Asia. For an attempt to imagine them lining up when retiring from their useful lives within the next ten years, the equator line of our globe is not long enough.

A 150 million car queue would circumspan our planet approximately ten times, or for a better imagination, in fact reaches from the earth to the moon, as an artist’s impression illustrates.

Even faster revolutions and innovations have speeded up the electronic sector. During the first semiconductor experiments in Silicon Valley who would have forecasted, that the personal

**Figure 4:**
150 Millions of Scrap Cars Illustrated

---

**Reaching the Moon with Scrap Cars?**

**Overtaking Car Production**
computer industries will need just a few decades to reach and then to exceed the car production quantities in numbers (now 60 millions of PCs / 50 millions of cars per year) and that on top of the computer industry as such also today’s cars contain several computers for electronic engine, safety, comfort control and more?

Meanwhile, the amount of electronic products returning from the market has just started to demonstrate its dimensions. It will certainly not line up like the cars, but it already piles up to hills soon reaching fearsome mountain sizes. In every big city the illustrated pile of waste electronics and monitors, whether from PCs or TVs together with other timed out electronics like telephones, fax machines, printers etc., which counts in hundreds of thousands annually, would make any skyscraper look like a toy.

Unfortunately, however, the slogan “you only live twice“ has up to now only become common as a famous movie title. High-tech products only live once – but it is in fact becoming common, that the traditional one-way-system from the manufacturer to the market has to be replaced by a cyclical system.

Figure 5: Any Big City’s Annual Office Electronics Scrap Illustrated
Industry’s Responsibilities

In Europe and in Asia laws are becoming effective, that put the responsibility for the full life cycle of a product, including their take back and recycling, completely onto the manufacturer’s shoulders.

Bearing this responsibility has meant considerable efforts for building up completely new collection and recycling networks already in the packaging products sector and meant a heavy workload for all parties involved.

In the high-tech products sector, it is strongly recommended not just to use one’s shoulders and muscles but in particular one’s head and brain to develop an overall concept of product responsibility all across manufacturing, product use and retirement / recycling.

First Experiences

Intelligent Solutions

Figure 6: Today’s Industry’s Responsibility throughout the Product Life Cycle
Established Recycling Processes

When manufacturers started to study adequate product recycling processes, of course the first approach was to rely on existing technologies. This can be compared with the approach of the early car makers, who met the challenge of a manufacturing technology for the first time (the very first task in the bottom left of the previous figure) one century ago. As the technology of manufacturing horse coaches existed, during the first years most cars really rolled out as motor coaches – but the experience was, that they were not manufacturable in large quantities at affordable prices. New developments and innovations became necessary and had to take place further on, which in fact has happened.

One hundred years later, the same applies to attempts only to use the existing scrap processing technologies for product recycling, whether cars, appliances, computers or other high-tech waste is being considered. The classic procedure is no longer affordable, in particular since it is no longer true, that retired products are mainly a source of recovering metal.

Figure 7: Regarding Retired Products just as Metal Scrap
Regarded mainly as metal scrap, retired cars over decades have primarily put into a powerful, up to 5000 horse power shredder, which cuts them into small pieces within a few seconds.

However, after the shredder process, only the metals can be recycled, that means resmelted together with new metal from ore, in the mining and steel industries.

For this purpose, however, a magnetic separator is necessary, which concentrates the steel and iron fraction which then can be shipped to the blast furnaces of the steel industry.
Economic and Environmental Problems

This fraction and also the “rest“ (that is up to one third of the original product weight), when cars are being recycled (and more than 50 % of the original product weight, when electronic equipment is being recycled) provide both economic and environmental problems.

At first, they lead to high working cost for a manual sorting out of unwanted materials and components which arrive together with the magnetically separated steel and iron fraction – such as rubber parts from steel-belt-tires, copper windings around electric motor iron rotors, plastics with metal inserts etc.

Furthermore, and worse, the mixed non-metal fraction of dirt, dust, rubber, glass, plastics, foams, textiles, stuck with engine and gearbox oils, toxic braking liquids etc. (recently also toxic chemicals from airbag gas generators), which reach one third of the original products’s weight and volume (or of the queue from the earth to the moon, remember the comparison illustrated earlier), wait for further treatment.
Until recently, this so-called “shredder-fluff“ had been brought to landfills together with more or less harmless household waste – endangering and intoxicating the groundwater and the atmosphere – a procedure, which is now forbidden by law in Germany and may be soon in other countries too.

Environmentally responsible product recycling today and in future therefore starts with careful preparation and disassembly processes to recover most of the mentioned fractions, valuable parts or materials and / or hazardous components and substances, so that they will not end up in a mixed toxic and non recyclable fraction.

To enforce this move towards cleaner technologies, the automotive, appliance and electronic industries are becoming obliged by law or are preparing themselves to take back and recycle their products. In Germany, the automotive and the electronic industries recently have declared voluntary self commitments to do this.
The most significant progress during this efforts will be achieved, if the tracks of the established scrap recycling technologies are left and new innovative approaches and processes for future product recycling solutions are developed.

**Cleaner Technologies**

In addition to thousands of remanufacturing companies, who already disassemble products, hundreds of disassembly workshops have started or will soon start operation in all industrialized countries.

The pioneers can be located in the automotive, appliance and electronics industries as well.
Figure 15: Disassembly Line for Cars

Figure 16: Disassembly Workshop for Household Appliances

Figure 17: Disassembly Line for Television Sets
In the disassembly lines or workshops, four groups of parts are recovered from the retired products, before their remainings can then be passed to the shredder process.

**Group 1:** Parts of valuable materials, for example from cars:
- lead batteries
- brass radiators
- aluminium wheels

from electrics and electronics:
- gold contacts
- copper wiring etc

**Group 2:** Parts made of (mainly non metal) materials, which otherwise would end in the non recyclable shredder fluff, for example from cars:
- rubber tires
- plastic bumpers
- windshield and window glass

from electrics and electronics:
- plastic housings, keyboards etc
- insulation materials etc