Reuse of Components and Products: "Qualified as Good as New"

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Abstract

Apart from benefits for environmental protection, reuse of components and products offers attractive economic advantages, provided that components are "qualified as good as new," which (in this chapter abbreviated as "quagan") entails a new concept first introduced in the international standard IEC 62 309. This standard has been initiated by the authors of this chapter, who have worked out the quagan concept to overcome prejudices against and to promote reuse of components and products.

Nowadays electronic components in most products have a considerably longer life expectancy than required. Thus, a quagan component, deployed in a second life in a new product, can have a higher reliability degree than the new ones because of a simple fact: Early failures have been already eliminated by its "previous life." Taking this into account, it is evident that quagan concept supports the interest of manufacturers, customers, and society at the same time.

- *Manufacturers* can make a profit by taking back used products and making them "quagan" (a process we call "quaganized"), using the same test procedures as they have for the new ones and, at the same time, fulfill legislative requirements concerning environmental protection.
- *Consumers* get updated products for a lower price with the warranty granted for new products.
- *Government* achieves higher recycling rates.

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To convince quagan consumers of getting a technically up-to-date product, the quality procedures, including the ones to fulfill the safety requirements, and their documentation must be visible. The purpose of this chapter is to provide guidelines in accomplishing this.

As a first step, quality requirements for “qualification as new” are discussed. This is not trivial because of the necessity to extend the common perception of “new products” to those products containing “as good as new” components. It is likely that this will also lead to changes in the state of the art of legal understanding of the notion “new” because it usually implies using only new components in new products. However, the fact might help here that some products, for example those in the electrical and electronic (E&E) industries, have long contained not-new components that have been already artificially pre-aged due to accelerated testing to avoid early failures.

As a next step, this contribution explains how a manufacturer has to plan for several product generations in advance because, the products sold – if required by law or voluntarily – will return to the plant at some point after the end of their lifespan. Many processes have to be installed and planned in advance; for example, a tight connection to customers, value analysis of attractive, high-value components, their cleaning, restoration, and qualification. Last but not least, these processes have to be documented to inform all parties involved.

This chapter explains also how “design for recycling” can work and what should not be reused. Recommended for recycling are the simple and easily testable, modular components. Up to 25% of a product can be reused, but often only a single component makes up the core of recycling because of its monetary value. However, the value chain should also include spare parts that can be extracted, and materials to be selected for high-quality recycling.

Finally, the state of the software of more complex product systems and their upgrading process is also important. Therefore, refurbishment rules that necessitate hardware and software upgrading should best avoid environmentally contra-productive instructions, for example, the unnecessary charging of batteries or energy consuming load/store instructions in programs. A corresponding standard to the IEC 62309 for software reuse is in the planning.

To sum up, the reader of this chapter will learn that a good concept such as refurbishment is not enough to achieve sustainability. Sustainability includes the trust of all participants in the process and assistance with potential legal problems, thus bringing advantages to all participants.

1 Introduction

Reuse of electro and electronic (E&E) *components* and products is a very sustainable process because of the following facts:

- Residual values within the components can be activated.
- Resources can be saved; the environment can be protected.
- Recycling ratios can be increased.
- *Customers* get high-grade products at a considerably lower price.

- Producers can extend their production to different markets; negative impacts on existing markets can be avoided.
- Plants can be utilized in a more effective way.
- Government can better reach targets for environmental protection.

The standard IEC 62309 (2004) was developed to promote the reuse of electronic components. However, some further barriers still have to be overcome for a broader application of *reuse*. After discussion with industrial organizations, NGOs, applicants, legal and *quality* experts, the main problems have been identified in

- Lack of definition of the state of *quality* of used components
- Unsecure legal situation for customer and producer
- Anxiety about hidden failures
- Different legal situations in various markets and countries

To overcome the obstacles mentioned above, the development of the international standard IEC 62309 had been initiated in 2001 and was released in 2004, which established a framework for minimum requirements for customers and producers. One of the merits of this standard is the definition of *quality* requirements for *qualification as good as new,* which extends the perception of "new product" to those containing *qualified as good as new(quagan)* components.

The standard particularly covers E&E products which preferably contain components that are artificially pre-aged due to accelerated aging to avoid early failures.

2 A New Approach

The idea of reusing components also for the manufacturing of new products arose many years ago in the copy machines industry. One of the most prominent companies involved was Xerox. In spite of their good ideas, as compiled in their internal company rules they did not initiate an international standard to promote internationally comparable criteria for reuse.

The easiest way for a producer to practice reuse is to include all potential "quaganable" components in the production line. In such a case the refurbished components can be checked in the incoming inspection and be transferred directly to the production line of the new product. To promote the idea of *reuse* of the *quagan* components, the following processes were subject of standardization:

- Qualification of *quagan* components
- The definition of a new product with *quagan* components
- *Documentation* and information
- *Guarantee*
- *Environmental aspects*

3 State of the Art

Legal definitions for new products are different for various product groups. Especially for new cars a great deal of legal decisions has been published. The situation in the E&E industry is entirely different. There, thermal pre-aging is usually applied to new components and some products to avoid early failures. The new products built using these components also intentionally contain "not-new" components. From the viewpoint of *quality* and *reliability* science, it can be expected that products containing reused components whose remaining operational lives are still within the range of the application period behave similarly; that is, they are of higher *quality* than the products that are produced using only new components, as was already noted by Xerox in one of its Environmental Performance Reports (Xerox 1995).

3.1 Products Preferred for *Quagan*

Generally speaking, all kinds of products can contain components which are potentially *quagan*. There might be a refurbishing step in between. Capital goods are usually a better choice because they are often in a better state than cheap consumer goods. The age of the product is often not decisive for a possible reuse. Components of 30-year-old trains might be reusable. This might be true of computer components after approximately 3 years of usage; whereas reusable components of cellular phones are available after a single year. Further examples of capital goods with reusable components or complete devices are optical machines, medical devices, and telecommunication equipment. The list of consumer products with potentially quaganable components is long and includes IT products; for example, computers, printers, servers, cellular phones, and also household appliances. One problem here is that those products might often not be in a good condition when collected by municipal waste collectors and bulkily stored in their stations. Usually some valuable plastic goods are also available that do not change their properties much and can be quaganable. There is another *quagan* components market for original *spare parts*. Forerunners in this field can be found in the automotive industry.

The requirement for "quaganation" is that the *remaining working life* of the component be at least the designed life of the new product. A manufacturer also has to plan for several product generations ahead because the *quagan* components will return after some years. Unfortunately, this represents a risk that a change of technology excludes a reuse.

Figure 24.1 illustrates the fact that the state of "as-new" can be described in a much easier way than the state of "used" because the only comparison for "new" is the original specification. This also includes the estimation of the value of the component. All of the other states of used can be specified in many ways which might not necessarily be transparent to the customer.

The life of a *quagan* component ends if its *remaining working life* is shorter than the *new designed life* for a new product. This situation is shown in Fig. 24.2.

Apart from the *quality* criteria for *quagan* IEC 62309 contains several examples for *reliability* determination and test methods. The standard requires all processes involved and available information on customers be documented. *Documentation* also covers the *quality* information according to ISO 9001 (2008), including test results (see Chaps. 4.2.4 and 8.3 of ISO 9001). Thus, the customer is informed

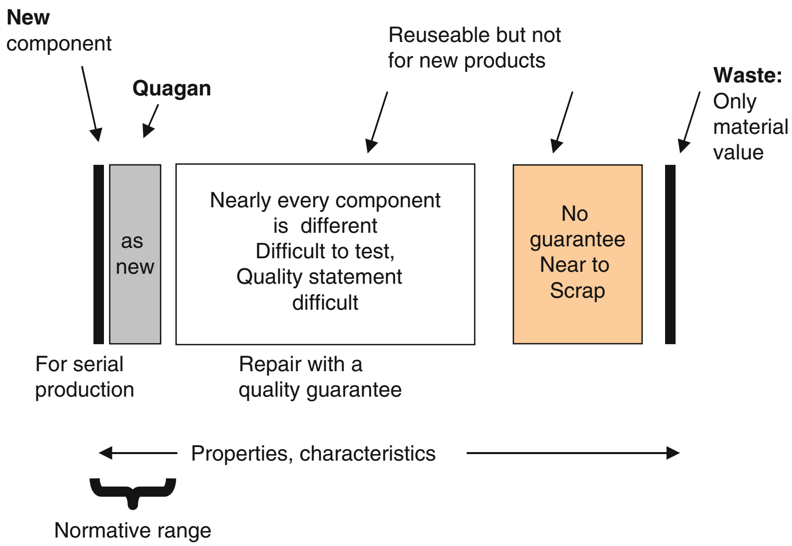

Fig. 24.1 The range of definition for quagan

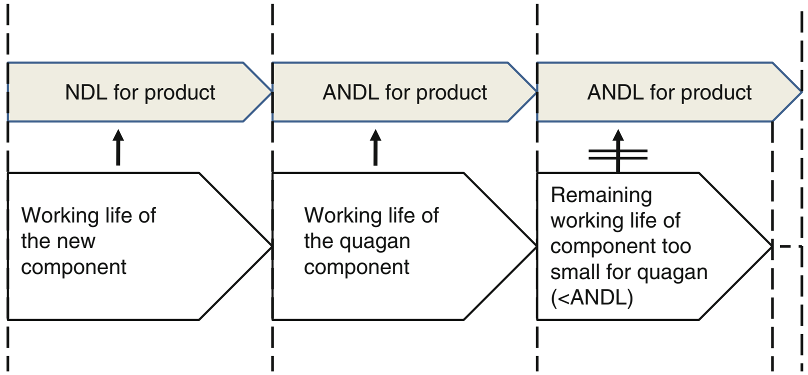

Fig. 24.2 Relation between the designed lives for several product generations and the designed lives of components (cf. IEC 62309). Legend: NDL: new designed life; ANDL: as-new designed life

about the fact that the new product he or she buys contains *quagan* components. This information describes also what has been done to realize quagan in order to avoid any *quality* risks and to assure that the *guarantee* is the same as for a product consisting entirely of new components.

To avoid misunderstandings which might be caused by the artificial word *quagan* the *customer* can also be explicitly informed by a statement that the product "is a new product containing components qualified as good as new in accordance with IEC 62309."

3.2 Criteria for Components to be Qualified as *Quagan*

Quagan components can be parts such as housing, cables, or connections. Electronic components can only be reused as *quagan* if their failure behavior over time and the history of the *component* are known. The “bathtub” curve for the failure behavior cannot be applied without knowledge of the exact behavior of the component and some additional data.

If the customer agrees minor differences to a new component can be accepted including some external, non-functional features such as a shift in the color of a rack. Not acceptable for *quagan* components are environmental risks such as hazardous substances or too high energy consumption.

The costs for the preparation of *quagan* components, for example, logistics, testing, replacement of worn elements, and refurbishment should not be higher than the value of the component. Otherwise, understandably, the component will be recycled. See Fig. 24.3 which explains *cost* aspects.

In addition to the drop-off in prices, the *costs* of logistics, cleaning, and testing also have to be considered; refurbishment is not always necessary. The final price for the *quagan* component is not easy to calculate because a further price drop-off can occur in storage, a risk for a technology change can arise and, last but not least, potential savings of the *reuse* are to be shared with the *customers* who expect a fair price reduction.

Quagan components can also be used as *spare parts*. If an overabundance of components is available sales on the spot market is also possible. It also happens that

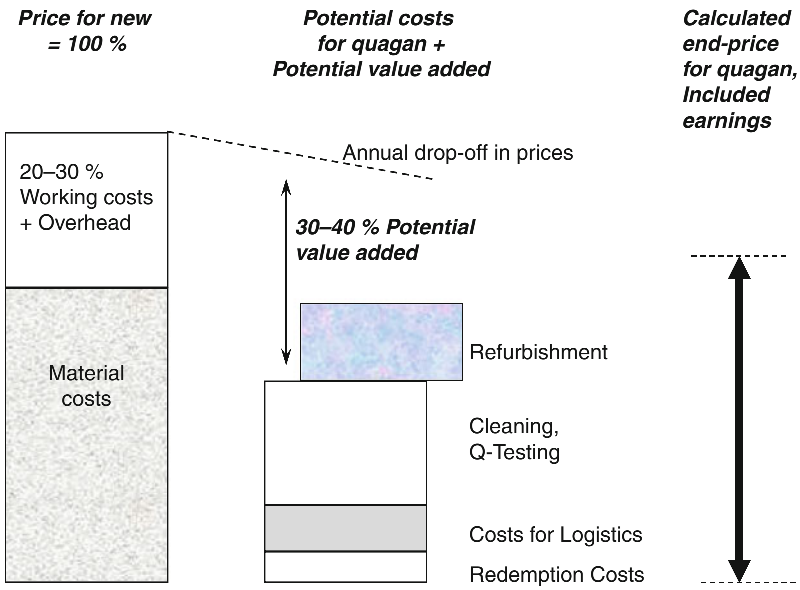

Fig. 24.3 Example for costs of a new component compared to the potential costs of refurbishment and the calculated final price of a quagan component

some components are running out, for example, in plants where longtime service contracts are common. Then, years later the production of new components will have to be re-initiated with a special manufacturer, which might cause extreme high *costs*. In such cases, the required components suddenly become overvalued. To avoid this, a trace-back system can be established with *customers*. This enables a tighter connection to *customers* to motivate them to return old products and provides the opportunity to offer them new ones.

3.3 *Software* Becomes Important

In IEC 62309 *software* dependability aspects are excluded; the standard describes only the requalification of hardware. Nevertheless, nowadays almost any complex product contains software. Together with the refurbishment the *software* needs to be regularly upgraded. Moreover, compatibilities to interoperating components have to be checked. Complex IT products including medical devices are to be accompanied by a *Device History Record (DHR)* which identifies the present state of their *software* and lists devices that are compatible with the new software upgrade. After every upgrade a *Device Master Record (DMR)* is issued that documents the new state of the software landscape to enable a continuous service.

A *software* application can consume a considerably high amount of energy in the product it is embedded in. Thus, upgrades are to be checked for their energy consumption. Annex A compiles recommendations for the reuse of *software* that are not all necessarily environmentally protective. They are, however, useful to achieve further improvements. Trends in legislation expect a manufacturer to integrate means and measures for environmental protection, including energy saving aspects, whenever a new release of the *software* is due during the lifetime of a technical system. In cases in which the hardware of a product is kept largely unchanged and the system is routinely checked for quality purposes, DHR and the DMR become valuable documents. DHR lists updates, whereas DMR describes the total documentation of the manufacturer. After comparison of the requirements and the present state, the necessary installations and updates are managed to *guarantee* the system to be resold is state of the art. The state to be achieved is the same as if they were being put on the market for the first time. For details see the European association of manufacturers of medical devices, COCIR (2009).

3.4 Environmental Targets Must Be Achieved

Legal regulations as to the *RoHS* (RoHS 2003), *RoHS 2* (RoHS 2 2011) and the *WEEE Directives* (WEEE 2003) in Europe require not only collection and recycling targets, but also the *reuse* of components, even if not explicitly specified. At the moment the targets present no problem in being reached without *reuse* but most likely they are going to be set higher. However, not only legal demands but also common sense should avoid the waste of valuable resources. Especially original manufacturers can recreate these values which might also constitute a clear benefit to the reduction of the weight of their waste deposition.

The diversity of materials must and can be reduced to simplify refurbishment and *reuse*. The volume of valuable materials collected must be economically attractive to make the recycling processes run. Many technically and economically practical solutions have been developed; however, there is still a lack of collected material.

The *cost* of recycling depends on the number of different materials or components to be reused or refurbished; the more there is of them, the more expensive the process. Remaining materials and components that cannot be recycled will be dumped or deposited if they cannot be thermally destroyed, that is, burned down to disposable residue.

Note that a great amount of used thermoplastics can be quaganized at considerably less *cost* than the cost of a new thermoplastic. The more expensive a new thermoplastic is like PA, PBT, PC, PPS, or PPO, the less the costs for collection, testing, and regranulation of a quaganized thermoplastic play a role for the resale. It is still cheaper than the new material. But a limit is reached if the price for collection, testing, and re-granulation becomes higher than that of the new plastics. This limit is often at or a bit above the price of new ABS; new PE and PP are usually cheaper than the whole process for refurbishment costs. Utilizing the energy in these plastics is then the best way to recycle them.

4 The Legal Situation

Recycling targets for ten special E&E product categories are set in the *WEEE Directive*. In the new WEEE Recast (2008), these targets are to be increased. Similar legislation exists for other product groups, such as the automotive industry. *Reuse* has been also set at the second highest place in political ranking, as expressed in the new *Waste Framework Directive* (Waste Framework 2008).

Car manufacturers have to reach a recycling level that is theoretically achievable. Similarly, manufacturers of E&E products are recommended to estimate the degree of recyclability of their products although this is not yet legally required. So the companies are expected to be able to answer questions from customers and the public. The easiest way is a disassembly and recycling analysis offered by many qualified recyclers often free of charge.

Limitations also have to be expected by the presence of hazardous substances like those described by the *RoHS Directive* for E&E products. Such regulated substances will no longer be allowed in new products or in new products with *quagan* components. This can end a recycling circle over several product generations.

Reduction of energy consumption is one target of the *Ecodesign* Directive (Ecodesign 2009) covering almost all products sold with volumes above 200,000 pieces in Europe. Restrictions are manifold and additional ones are continuously being published with the progress of studies and implementing measures. Environmental information about products is required if a product is affected by the *Ecodesign* Directive. As a tool the Ecolabel standard according to ISO 14 021 (1999) can be used. The information about the content of *quagan* components and their contribution to the product's effects on the environment can also be placed in this declaration. In cases involving *quagan* the impact by the product itself is the same as that of a new product, but the resources saved can be subtracted.

5 Sustainability in the Processes

If the entire reuse process as explained in Fig. 24.4 is optimized the process becomes sustainable. Ideally, the new product is supplied when the old one is returned to the manufacturer (1), where disassembly, and refurbishment is carried out. Components can be integrated into the production or sent to suppliers (2a) or (2b). In the ideal case the material could be completely reused by suppliers (3a) for the same or other purposes or in their own production (3b).

As described in Sect. 7 these processes can be optimized using the *Design for Recycling (DfR)* approach. Inefficient components/products or environmentally incompatible components/products will be eliminated.

6 Qualification Criteria and Process

For reasons of *quality* assurance, the entire process of qualification from *take-back* and evaluation of the component, disassembly and testing until *reuse* in a new product or as *spare parts* must be described and include a *quality* management system according to ISO 9001. Also an environmental management system according to ISO 14 001 (2004) should be available. Part of the management system must be a *DfR* process and a planning system for several product generations. COCIR has listed in its guide *Good refurbishment practice* (COCIR 2009) many more management processes to be installed to avoid risks with *reuse* that include an early

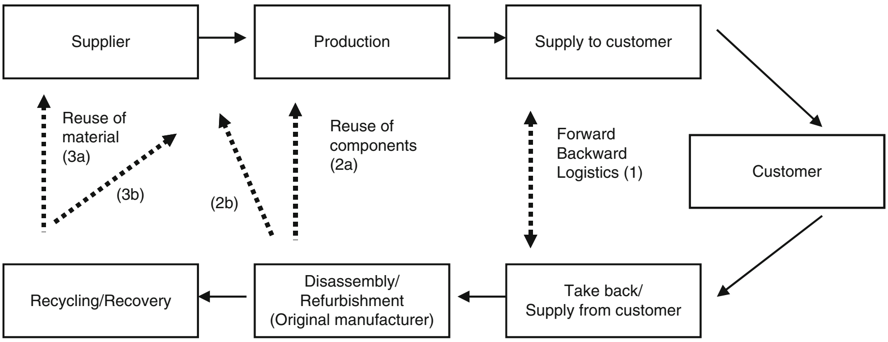

Fig. 24.4 A sustainable, logistic path of a component and a product to a customer and back to the manufacturer and supplier

warning system if unforeseen failures suddenly occur. Included in the qualification processes are

- The history of the component
- *Test procedures*
- A description of the state of the component
- Environmental evaluation and exclusion criteria
- *Software* evaluation, state of *software* and compatibility
- *Documentation* (internal and external for *customers* and information of the public information, for example, about *environmental aspects*)

As depicted in Fig. 24.2 the state of "as-new" is very close to completely new but is often achieved after pre-aging. Some deviations as to color change or a second coating are allowed. Also components showing wear could be reused if their *remaining working life* is longer than that of the product (see Fig. 24.3).

Environmental criteria not only cover the evaluation of substances included in the product, but its energy consumption and an evaluation of its *software* as well. Also an environmental management system for all processes is required for a systematic procedure. A plan optimizing *take-back* and recycling until deposition will reduce additional *costs*. Such a plan also has to include the selection of the recyclers, the reporting of recycled quantities, and improvement targets for avoiding too wide a deposition.

Documentation of the component's state, *test procedures*, test results, applied tools, potential repair, etc. are important to establish a trusting partnership with the *customer.* A *customer* might also be interested to know the complete *quality* planning process for a component. Some results might be more internal but some necessary information should be included in general *customer* information at any rate. This might be the component's designed working life, *guarantee*, *environmental aspects*, and of course, price.

7 Design for Recycling (DfR)

One part within the *Ecodesign* process is the *DfR*. *DfR* enables an easier disassembly which also largely means easy assembly. It is often achieved by a modular construction of the product. As easier assembly means lower production *costs*. *DfR* can also be seen not only as a tool for the reduction of the environmental impact but as a synonym for *cost* reduction as well. Besides the required reusable components *DfR* should also enable the easy collection of the valuable materials without impurities for an efficient material recycling. Rules for *DfR* are described in the standard of the Association of the German Engineers VDI 2243 (2002). Some important rules are summarized in Annex B. They are usually integrated into similar lists of companies' design rules as assistance for the development engineers.

The disassembling and refurbishment of the product structure has to be carefully planned in detail. This is important for an expeditious replacement of the desired components not only for remanufacturing but also for shorter service periods. The planning must consider not only one but several product generations. This means

Table 24.1 Relation between building a structure of a product, connections selected materials, and functional units for a three-level hierarchy (extended table version of IEC 62 309) in a *DfR* concept

Level of detail	Building structure	Connections	Materials	Functional units
General	Recycling concept	Non-destructive disassembly	Ability to recycle	Ability to reuse
Product specific	Modularity	Connection category, diversity	Utilization, compatibility	Division into functional units
Component specific	Accessibility	Dismantling depth, dismantling time	Material diversity	Ability to reuse, exchange or repair
Material specific	Separability	Dismantling time	Material selection	Material diversity within function

the type of component must be kept the same even if the product family or the state-of-the-art of technology changes. An efficient *take-back* system has to be installed to get the products back in good condition. Different models are applicable for a *take-back* according to the quantities desired. Leasing is not the only method that enables a return of the product after a certain time. Contracts could also be made to continually offer customers an upgraded version of the product. In addition a close connection to the customer is required and the sales department has to know where the sold products are located. In the case of medical devices an exchange of used products is also agreed upon between major companies to offer a competitor their product if the product is substituted by another one. Depending on the life cycle the *take-back* system and the changes expected in technology have to be considered as well. Some parts of a train coming back after 30–50 years might have only one more life; other parts might have three or more lives.

For the *DfR* the product structure can be split into its functional units, such as engine, chassis, tubes, cables, etc. This procedure is now often standard within the development engineers' community. An extended procedure might now be to construct these units so that the worn-out element can easily be replaced. Also the functional unit can be designed to be so slim that most of the elements not required in the unit are added to another unit that is not interesting for reuse. This can save volume, time, *costs* of transportation and storage.

Level-specific points of view require corresponding rules. In Table 24.1 it is explained what should be done to improve a product for better *reuse*. Three levels are identified: the product, component, and material level. Modularity, for example, on the product-specific level has influence on the connections and the utilization if it is changed. Components should easily be accessible and dismantled. Too much diversity of the materials is not acceptable. Materials should be easily separated. It can be seen from this table that the more detailed a reuse is planned, the more influence it has on product structure, materials, connections, and other things. For every level of detail different characteristics are important.

Recyclers can not only disassemble components, but also store components as *spare parts* if they employ experienced staff. Thus, they can expand into new business fields and offer more interesting jobs.

As mentioned, *DfR* is only one part of *Ecodesign* (cf. Quella, this book, chapter ►Ecodesign Strategies: A Missing Link in Ecodesign). Through *Ecodesign* an overall reduction of the environmental impact should be achieved and experienced over the entire life cycle. Such procedures are described in IEC 62430 (2009). The *Ecodesign* directive will affect also the design because of its legal requirements for energy-related products. The designers taking *DfR* into account should at any rate try to minimize the environmental impact by their product through a complete *Ecodesign* concept. For more general concepts see Wimmer et al. (2010) and Quella (1998).

7.1 An Example of *DfR*

In the following an X-ray tube for computed tomography is used as an example of *DfR*. In Fig. 24.5 a schematic drawing of the old version of the X-ray tube with the bearings integrated in the vacuum system is shown. A very high rotation speed causing high temperatures requires strong cooling.

Only by completely redesigning the product can the problems of an existing construction be solved. In the case of the X-ray tube in Fig. 24.5 many functions were integrated in one housing which makes repair and reuse difficult. Especially the bearings suffered from the vacuum and high-temperature conditions. Whenever the bearings were worn the complete very expensive tube had to be exchanged. So the solution consists in more modules instead of one. For a new tube system, especially the electronics, the cooling system and the radiator were redesigned as separate components, replacing integrated non-modular equipment. The bearings

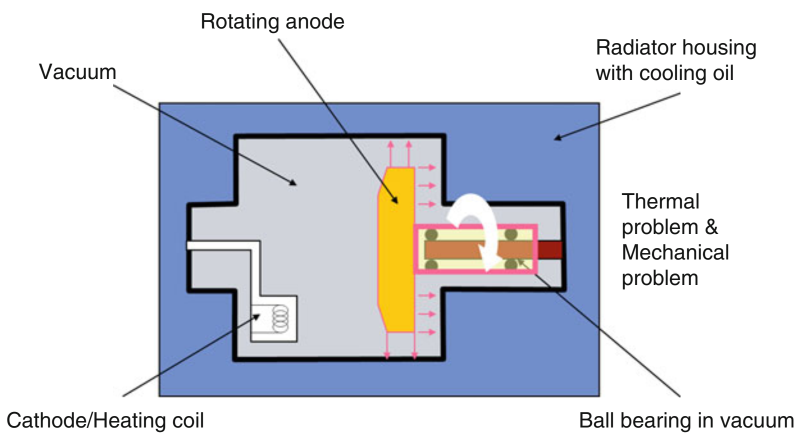

Fig. 24.5 An older model of an X-ray tube. Radiation cooling time is too long. High centrifugal forces lead to an overload of the bearings in the rotating anode (Source: Siemens Healthcare)

Fig. 24.6 Straton X-ray tube. Comparison of new and former product. Result of the new development: 66% material saving, 33% higher scan performance, up to 40% recyclable parts in new tubes (Source: Siemens Healthcare)

in Fig. 24.5 seen in the vacuum chamber were placed outside the vacuum chamber in the new version. Now the worn bearings can be easily replaced. All these components now can be more easily separated, disassembled, and refurbished with strong cost reduction also for the customer.

In Fig. 24.6 some successful changes in the redesigning of an X-ray tube can be seen at first glance in comparison with the old version. The target of several *reuses* for the radiator and cooling was already anticipated during the development of the new system. Reusing material saves costs. In addition body material consumption was reduced by 50% and costs by 40% by switching to an injection molding guide.

8 Conclusions, Future Developments Expected

Many companies have decided to refurbish their valuable products that they take back. A large group of manufacturers belong to the medical sector. They offer many advantages by providing refurbished systems to their *customers*. More refurbished industry products can be found by an Internet search; not all follow the *quagan* concept. Some should be considered with caution.

As special products require special conditions it was necessary to develop special recommendations to convince people in the healthcare sector. COCIR has therefore published rules for *Good refurbishment practice* which in part exceed the requirements of quagan in the IEC 62309.

With the New Work Item Proposal for the reuse of *software* (IEC TC 56 (2009)) the gap between refurbished hardware alone and hardware plus *software* has been closed.

The discussion about the failure curves over time ("bathtub" curve) is still going on, but an updated theory would help to overcome many problems with the *reuse* of electronic components. Before this is achieved it can only be recommended to apply the results of one's own reliability research. If such results are not available a reuse of the components in question can hardly be planned.

In addition, the political situation has strengthened the role of *reuse* and set it at the second highest level in the new *Waste framework Directive*. A stronger promotion of the *reuse* of industrial goods has been announced as a first step.

We are convinced that the potential of *reuse* in the sense of *quagan* is much higher as briefly described in this chapter. In order to extend this concept an overall investigation of exchangeable components in the market is necessary. In addition standard components from different products could be exchanged.

Annex

Annex A: Checklists for the *Software* Upgrade During the Refurbishment Process

A1: State of the *Software* in the Used Equipment

1. Which software upgrades are available and which are compatible with the old and with the upgraded equipment?
2. Which updates have been installed in the old software?
3. Has the compatibility of upgrades or reused software with the remanufactured product already been tested?
4. Which hardware components (new/reused) should be integrated and which new functions should be available in the new product?
5. Is there a need to develop new software program steps for some hardware components that are new in the upgraded/remanufactured hardware product?
6. Is the number of new hardware components to be used with the remanufactured product limited, or must it be limited because problems could occur?
7. Which hardware components cannot be controlled by the old, upgraded or reused software in the new hardware product?
8. Are there different standards used in the components such as transfer rates for data?
9. If a network was used in a production line, for example, is the reused/upgraded product and its software compatible to the network of that specific production line?
10. Can the whole product/system be tested? If, for example, the hardware product/component will be used in a network in a plant or with the Internet what are the framework conditions for the reuse of the software?
11. Can installation media for old data also be used with the updated hardware product (CD, etc.)?

A2: Environmental Aspects of Reused *Software* in New and *Quagan* Hardware Components/Products

1. Is it necessary or possible to integrate energy-saving elements in the software, for example, automatic pull-down to standby?
2. Are loading orders to batteries, capacitors, etc. checked for energy consumption?
3. Which standards are available to estimate comparable modern energy consumption for the equipment according to "Energy Star?"
4. Does the upgraded software cause far greater energy consumption by the upgraded equipment and how can it be reduced?
5. Is the run-time for some tasks too long?
6. Energy consumption in comparison with new hardware equipment; can a too high consumption be reduced by a new software approach?
7. Is a combination of new hardware and software necessary to reduce energy consumption for example, in conjunction with switchable power supplies?
8. Is energy consumption checked for possible impact by components like printers?
9. Can hardware in the upgraded product be substituted by software, such as fax capabilities?
10. Can hardware be simplified, for example, substituting batteries with capacitors?
11. Is it a simple process to test the system (product and software)?
12. Is it easy to use the product and its software?
13. Are there recommendations available for an energy-saving mode in the product?

A3: Aspects of the Harmonization of Hardware State and Possible *Software* States During a Refurbishment Process of Product or System (COCIR 2009)

1. Is the state of the hardware checked that is in place with the reusable system?
2. Usually the DMR of the producer defines the requirements. Which software versions are compatible with the existing state of hardware?
3. Usually the producer's DHR explains which software states are compatible to which hardware states. Is the software update process defined?
4. Usually a recommendation of the producer is available. Is the completed system tested? Hint: sometimes software updates have to be arranged in a certain order of steps.
5. Are all actions in connection with the software update documented?

Annex B: Important General Rules for DfR (Partly Taken from VDI 2243)

(In detail there might be limitations for the applicability of some rules.)

B1: Product Structure

1. Are separable modules according to functional units used?
2. Is there a plan for functional modular structures?
3. Are horizontal structures preferred?
4. Are all potentially reusable components and materials easily accessible, easy to disassemble?
5. Is simple separation of auxiliaries, liquids, cable trees, and electric nets for ease of disassembly allowed?
6. Are E&E components easily accessible and placed on the highest possible disassembly level?
7. Are batteries avoided?
8. Are worn parts readily changeable?
9. Are reusable parts marked?

B2: Materials and Surfaces

1. Are materials marked according to international standards?
2. Are substances avoided detrimental to recycling?
3. Are materials used economically attractive for recycling?
4. Are materials used compatible to the recycling procedures applied?
5. Is the diversity of materials reduced?
6. Is the surface coating compatible with base material for recycling?
7. Are recycled plastics used; are metal inserts avoided?
8. Are halogen-free printed circuit boards used?
9. Is a laser used for inscription if possible?
10. Are easy to clean surfaces used, which do not change color during aging?
11. Is materials' weight reduced by optimizing thickness, by combining, by substituting mechanics with electronics or software?
12. Is unnecessary packaging avoided?
13. Are standardized components used?
14. Are labels avoided or those used compatible with the base material for recycling?

B3: Disassembly and Joint Technologies

1. Are number and variety of joints minimized?
2. Are same joints used everywhere?
3. Is the same disassembly direction applied everywhere, preferable axial in direction of disassembly?
4. Are joints easily soluble and accessible without destroying?
5. Are snap connections used instead of screws?
6. Are connections avoided that cannot be dissolved such as bonding, welding, riveting?
7. Is the application of standard disassembly tools enabled?

8. Are peripheral snap connections applied for printed circuit boards?
9. Are fixing elements for electromechanical components accessible without using electric power?

B4: Removal of Auxiliaries

1. Are liquids able to be removed quickly and completely?
2. Is the possibility of an accessible outlet foreseen?

9 Summary

The applicability of the concept "qualification-as-good-as-new" (quagan) covers components used from short time to long time up to 20–30 years. Real limitations for reuse are only given in a completely new design, in a technology change or in the non-compatibility of software.

The improvement potential in the average is estimated in the range of 25% both in quantity of components and in cost savings. It can be more but depending on product and market also only one component might be of interest for reuse.

Preconditions for reuse as "quagan" are the installation of a take-back system, a skilled recycler, interested and informed customers, and an existing quality management system. A worldwide valid standard such as IEC 62 309 helps to overcome prejudice in the application of the concept by clear and legally acceptable definitions like the integration of "quagan" components in a new product and a trustable framework for the acceptance by the customer.

Reuse meets a growing market as can be seen by more and more offers for refurbished systems in the Internet.

The last missing link in the concept might be an international standard for the integration and/or the reuse of the corresponding software of complex components within the software of a new product. An international standardization proposal has been made (IEC TC 56 2009).

10 Cross-References

►Ecodesign Strategies: A Missing Link in Ecodesign
►Eco-business Planning: Idea Generation Method
►Life Cycle Thinking for Improved Resource Management: LCA or?
►New Business Models for Sustainable Development
►Remanufacturing
►Strategies for Sustainable Technologies: Innovation in Systems, Products and Services
►Supply Chain Management for Sustainability
►Sustainable Consumption
►Sustainable Production: Eco-efficiency of Manufacturing Process

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IEC 62 430, Environmentally conscious design for electrical and electronic products and systems (International Electrotechnical Commission, Geneva, 2009)

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ISO 9001, *Quality Management Systems – Requirements* (International Organization for Standardization, Geneva, 2008)

ISO 14 001, *Environmental Management Systems – Requirements with Guidance for Use* (International Organization for Standardization, Geneva, 2004)

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