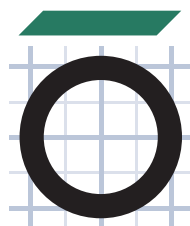


# **ITATECH GUIDELINES ON REBUILDS OF MACHINERY FOR MECHANIZED TUNNEL EXCAVATION**

ITAttech Activity Group Excavation

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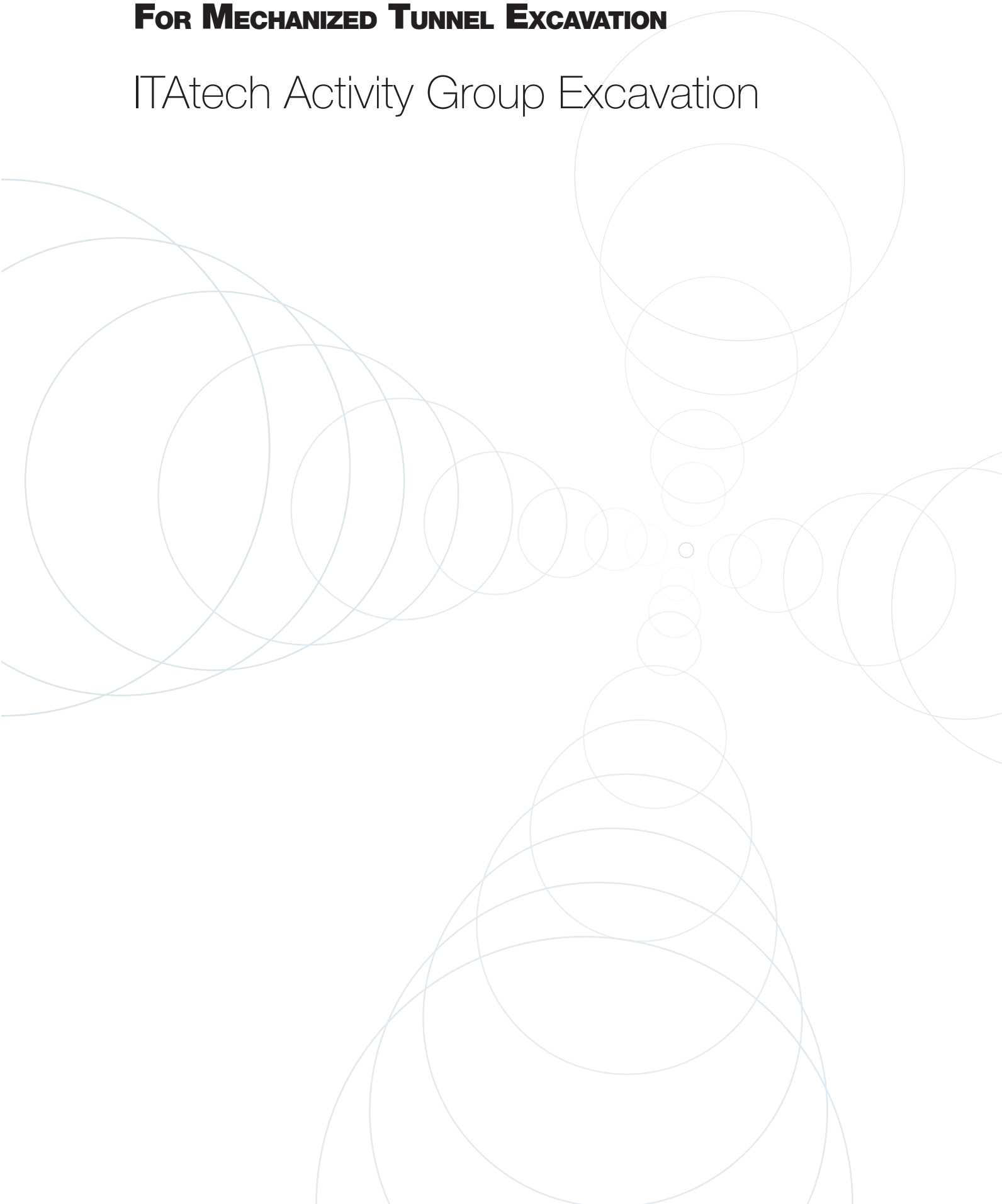


**ITAttech**



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# 1 >> FOREWORD, BACKGROUND, SCOPE

## 1.1 FOREWORD

The use of second hand or rebuilt equipment is quite a common practice in underground construction. For environmental as well as economic reasons the multiple use of equipment has to be considered to be a reliable and safe solution.

The purpose of this ITAttech guideline is to establish definitions and minimum requirements for rebuilding pre-used equipment that can be used for contract specifications of equipment.

## 1.2 BACKGROUND

To date there is no specific guidance available for the tunnelling industry to establish minimum quality requirements for rebuilding pre-used equipment.

In order to achieve a defined level of quality for equipment rebuilds, two rebuild levels and their minimum requirements are established:

- **Remanufacturing**
- **Refurbishment**

*Note: The selection of the appropriate excavation and support system or TBM type for a tunnel project is primarily influenced by the anticipated ground and groundwater conditions. The intended use of the equipment is agreed between the rebuilder and the user taking into account information on predicted ground conditions provided by the user.*

## 1.3 SCOPE

The guideline covers shielded and unshielded Tunnel Boring Machines (TBMs) and their backup equipment along with non-man-accessible Micro Tunnelling Machines (MTBMs) including associated equipment (e.g. California switches, booster pump stations, above ground power packs, control containers or jacking frames).

Were the country of the intended future use of rebuild equipment is different to the country of first use care has to be taken for compliance with national standards and regulations.

The requirements set out in this guideline may be applied to complete machines, individual subassemblies or components of machines.

General requirements are given for hydraulic and electric systems.

Decompression chambers, pressure vessels, refuge chambers and crane systems are not within the scope of this guideline.

The requalification of such components has to comply with the national standards and regulations of the country of intended future use.

*Note: General guidance on refuge chambers can be found in ITA Report No 14, "Guidelines for the provision of refuge chambers in tunnels under construction".*

## 2 >> DEFINITION OF REBUILT LEVELS FOR TOTAL SYSTEMS OR SUBASSEMBLIES

Depending on the requirements of the individual future project (e.g. tunnel length or anticipated duration of use, geological conditions) different options for equipment specification are available.

Equipment can be specified to be all new or rebuilt equipment could be an alternative with corresponding benefits for schedule or economics.

It may not be necessary to specify highest and therefore most expensive level of rebuild. For that reason two levels of the rebuild process are established going back to different stages of the product life cycle (Figure 1):

- Remanufacturing
- Refurbishment

The minimum requirements for each of these rebuild levels are given within the guideline. Individual manufacturers or rebuilders may offer additional measures in order to achieve a specific warranty.

### 2.1 REMANUFACTURING

Systems or subassemblies are employed at a different project in the original configuration

or with modification.

The basic philosophy behind the Remanufacturing process is to establish a full new life cycle for the product with sufficient life to complete the new project.

*Note: Remanufacturing is typically applicable for projects without special challenges where full component lifetime and a “state of the art” set of requirements for the machinery exist.*

Common practice in the industry is also to combine the allowance for the use of remanufactured equipment with the requirement of new condition for a limited number of clearly specified subassemblies or components of a TBM or MTBM. In many cases the components or subassemblies with such “mandatory new” requirement are defined by the project owner, designer or the buyer of the equipment. Also TBM suppliers may offer such combined options for projects allowing remanufactured equipment.

*Note: Such combined configurations are typically applicable for “high profile” projects where extended component lifetime is needed and a special set of requirements for the machinery exists.*

Typically major or core components of machines (e.g. main drive, bearing and seal systems, shield structure etc.), or ground condition related components (e.g. cutter head, rock support installation etc.) are specified as new and specifically built for the project in a list of “mandatory new” components, as listed in the contract specification or supply offer for a machine.

*Note: New means components are of new manufacture and have never previously been used. This can also include new components of older manufacture taken from the spare part stock of previous projects. For new components from stock that are subject to aging (e.g. seals, hydraulic hoses etc.) the remaining life span should be a minimum of two times the anticipated project duration.*

#### 2.1.1 The remanufacturing process

The general remanufacturing process consists of five major process steps (Figure 2) accompanied by a defined quality assurance procedure. The remanufacturing process is in most aspects, similar to the original process of first manufacturing.

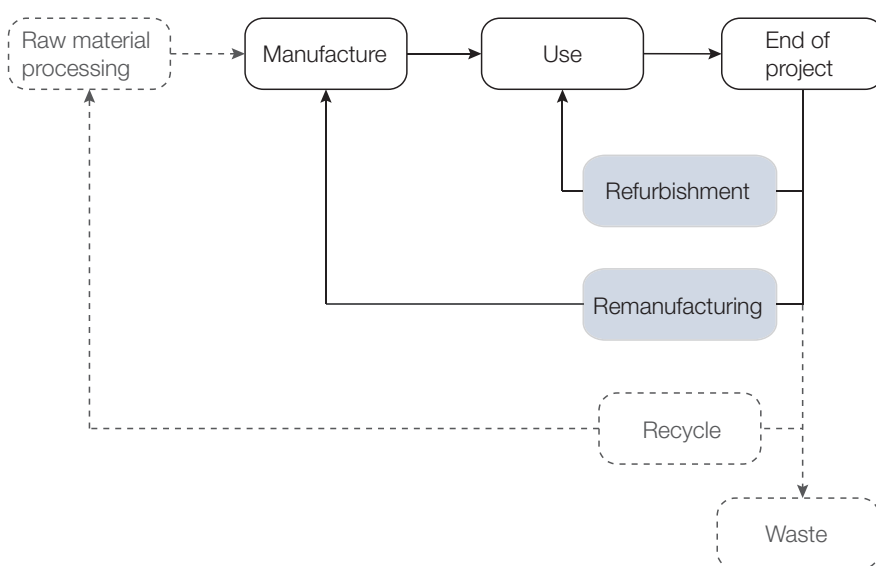


Figure 1: part of the full life cycle process covered by this guideline (full line, black).

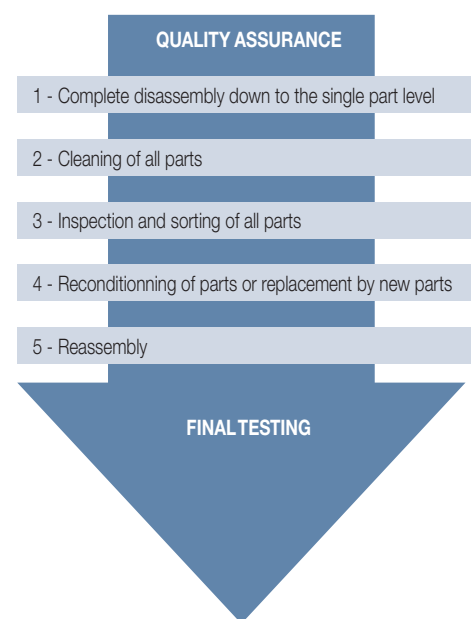


Figure 2: Remanufacturing process steps

## 2 >> DEFINITION OF REBUILT LEVELS FOR TOTAL SYSTEMS OR SUBASSEMBLIES

Step 1: Disassembly goes down to the single part level in the sense of a single part definition during the original first assembly. The disassembly process includes scrapping parts that are apparently not reusable as well as separation of components that are generally not reused such as seals.

Step 2: Cleaning includes removal of muck/soil/debris; de-greasing, de-rusting as well as removing of old paint.

Step 3: Inspection of single parts depends on the nature of the part and is either a purely visual inspection or an inspection by dimensional measurement or other testing (e.g. crack testing methods, electrical test, pressure loss or leakage test etc.). The sorting of parts into reusable, able to be reconditioned or not reusable as a result of the inspection has to be based on predetermined and documented criteria.

Step 4: Reconditioning of parts may involve similar or identical manufacturing steps to those applied during manufacture of the new part. Upgrades or improvements to more recent technical solutions as well as structural reinforcement may be part of the process including replacement of individual parts by new ones.

Step 5: The reassembly process is identical to the process of original first assembly including using the same procedures and tools. The final testing after reassembly follows the identical procedure, test criteria and documentation requirements as after the original first assembly.



Figure 3: Segment erector after remanufacturing ready for final assembly in the TBM

### 2.2 REFURBISHMENT

Systems or subassemblies were previously employed at different projects in the original configuration or with only minor modifications. The refurbishment is predominantly considered to be a “full maintenance” and “repair or replace defective functions or parts” procedure, followed by a final functional test including full test documentation. The basic philosophy behind the refurbishment process is to extend the useful life of the product.

*Note: Refurbishment is typically applicable for projects without special challenges employing machinery that successfully completed a comparable project.*



Figure 4: Gripper TBM after refurbishment ready to be used for the Erstfeld contract of the Gotthard tunnel after completing the Amsteg section of the Gotthard tunnel.

## 3 >> GENERAL REQUIREMENTS

### 3.1 HYDRAULIC SYSTEMS

	REFURBISHMENT	REMANUFACTURING
Hydraulic fluids	New	New
Filter cartridges	Visual inspection	New
Hoses	Visual inspection Replacement when exceeding lifetime limit or damaged	New
Piping	Visual inspection, cleaning	New
Oil reservoirs	Visual inspection, cleaning	Disassembly, cleaning, new seals, reassembly
Hydraulic cylinders	Visual inspection, pressure test	Disassembly, new seals, new wear parts, reassembly, pressure test
Hydraulic motors > 150 cm <sup>3</sup> displacement volume	Visual inspection, functional test	Disassembly, new seals, new wear parts, reassembly, bench test
Hydraulic motors < 150 cm <sup>3</sup> displacement volume	Visual inspection, functional test	Visual inspection, bench test
Hydraulic pumps > 100 cm <sup>3</sup> displacement volume	Visual inspection, functional test	Disassembly, new seals, new wear parts, reassembly, bench test
hydraulic pumps < 100 cm <sup>3</sup> displacement volume	Visual inspection, functional test	Visual inspection, bench test
Valves, valve banks	Visual inspection, functional test	Disassembly, new seals, new wear parts, reassembly, bench test

### 3.2 ELECTRICAL SYSTEMS

	REFURBISHMENT	REMANUFACTURING
Cables > 1000 V	Visual inspection, insulation test	Visual inspection, insulation test
Cables < 1000 V	Visual inspection, insulation test	Visual inspection, insulation test
Cable drums > 1000 V	Visual inspection	Disassembly, cleaning, electrical test
High voltage switchgear	Visual inspection	Disassembly, cleaning, electrical test
Low voltage switchgear	Visual inspection	Disassembly, cleaning, electrical test
Transformers	Disassembly, cleaning, electrical test	Disassembly, cleaning, electrical test
Electrical motors	Visual inspection, electrical test	Disassembly, new bearings, electrical test
PLC hardware	Functional test	Replace obsolete parts, functional test
PLC software	Functional test	New, newest update
Sensors	Functional test	Functional test
Safety related parts	Functional test	New, functional test



## 4 >> SPECIFIC REQUIREMENTS FOR TBMs AND MICRO-TBMs

The specific requirements set out in chapter 4.1 to 4.5 should be respected for remanufacturing as well as for refurbishment.

### 4.1 SHIELD STRUCTURES AND PARTS OF MACHINERY ACTING AS TEMPORARY GROUND SUPPORT

Shield structures and parts of machinery (e.g. roof support structures) acting as temporary ground support during tunnelling operations have to be checked for their ability to withstand the loads imposed by the ground and groundwater for the intended future use taking into account information on future ground conditions as provided by the user.

### 4.2 GROUND SUPPORT INSTALLATION

In unshielded tunnel boring machines where equipment for rock support installation is provided, the existing type and installation area of the rock support elements has to be checked to ensure it is in accordance with the intended future use.

For shielded tunnel boring machines with precast segment installation capability the shield – lining interface as well as the handling capacities and ergonomics of the segment installation equipment has to be checked to be in accordance with the intended future use and segment design.

### 4.3 MAIN BEARING

The main bearing of a TBM is a high value core component of the machine with a long lead time for replacement. Typical design life of a TBM main bearing is 10.000h or more based on assumed loadings established from the anticipated operational conditions of the intended TBM use.

However due to the fact that the majority of main bearings do not come close to reaching the limit of their design life in their first application, multiple use of a main bearing is acceptable given the following requirements:

- The operating hours of the main bearing have not yet reached an estimated 50% of the original design life of the bearing.

- A new lifetime calculation, that takes into account the “as experienced” load conditions and hours of operation in previous use taken from the TBM data recording system and in addition to that, the anticipated load conditions of the future intended use confirms the usability.
- A full bearing inspection and reconditioning as required by the original bearing manufacturer or an equally qualified organization confirms the “ready to use” condition.

The minimum requirements for bearing inspection are:

- Measurement of axial and radial bearing clearance.
- Total dismantling of the bearing and cleaning of all parts.
- Visual inspection of all bearing elements (raceways, rollers, cages, bolting threads and bull gear if an integrated part of the bearing).
- Crack testing of all raceways and bull gear if an integrated part of the bearing.
- Documentation of results and recommendation of required remedial measures if any.

As a minimum all seals (lip seals, O-rings) have to be replaced when reassembling the bearing. Care has to be taken for appropriate corrosion protection.

A feasible option for main bearing reconditioning is regrinding of the raceways and the installation of new rollers. As a maximum value, 0.5mm is typically considered to be the limit for regrind depth. The readjustment of the correct bearing clearance is part of the reconditioning process. Such operations have to be done by a qualified bearing manufacturer and preferably by the original bearing manufacturer.

### 4.4 CUTTERHEADS, TOOLS AND MUCK HANDLING EQUIPMENT

Parts and subassemblies of TBMs that are primary elements of the TBM – ground interaction, excavation and primary muck transport are highly project specific elements with a high exposure to wear. Therefore such elements are less suitable for multiple uses on different projects.

- Cutter tools are considered to be

consumable wear parts and should be replaced by new tools for equipment rebuilds unless a specific OEM rebuild procedure exists as it is common practice for disc cutters.

- Cutter head structures are subject to abrasive wear and high loads affecting the base structure itself as well as the tool sockets which typically are integrated into the structure. Specific test and repair plans and procedures for the individual structure accompanied by a written documentation are mandatory minimum requirements. Fixed wear protection elements should be replaced depending on their condition and considering the intended future use or in any case when 50% of the wear limit has been reached. In addition the design of cutter head structures is strongly related to the anticipated ground conditions of the specific project. Ground related design considerations such as tool types and arrangement, cutter size and spacing, opening ratio, muck flow, distribution of conditioning or flushing ports all have a major influence on the overall structure. Therefore cutter head reuse has to be justified by a qualified comparison of the ground conditions of first use and the intended future use.
- Elements for primary muck processing and transportation such as stone crushers, screw conveyors, TBM belt conveyors or shield slurry piping systems are subject to extensive abrasive wear. Specific test and repair plans and procedures for the individual structures accompanied by a written documentation are mandatory minimum requirements. Fixed wear protection elements should be replaced depending on their condition and considering the intended future use or in any case when 50% of the wear limit has been reached. Replaceable wear protection elements or crushing tools are considered to be consumable wear parts and should be replaced by new elements for equipment rebuilds.

### 4.5 DOCUMENTATION

In addition to the QA documentation accompanying the rebuild and testing process for structures and major components as described in chapter 4.1 to 4.4 documentation should be provided about the previous service life history or previous projects.

## 5 >> QUALIFICATION OF REBUILDER, WARRANTY

### 5.1 QUALIFICATION OF REBUILDER

For complex machinery for the use in tunnel excavation the rebuild process does need a high level of competence. Besides the mechanical and electrical aspects, operational safety is also affected.

- Remanufacturing and refurbishment as defined in clauses 2.1 and 2.2 under the full responsibility or with major support of the original equipment manufacturer (OEM) is the preferred solution. This configuration assures that the original manufacturing know how as well as the entire set of original design and manufacturing documents, schematics, calculations including control software and PLC programming is available for the rebuild process.
- Remanufacturing and refurbishment as defined in clauses 2.1 and 2.2 by equally experienced alternative manufacturer from the same industry is an acceptable solution as long as adequate technical documentation for the equipment is made accessible to the rebuilder.
- Refurbishment as defined in clause 2.2 by other organizations experienced and qualified in the handling and reconditioning of heavy construction machinery is an acceptable solution as long as adequate technical documentation for the equipment is made accessible to the rebuilder.

### 5.2 WARRANTY

Depending on the organization performing or supporting the rebuild process, different levels of warranty for the intended future use of the equipment are common practice in the industry. Typically these conditions are subject to individual negotiation within the rebuild contract.

Warranties for equipment rebuilt by the OEM can reach comparable conditions to new equipment.

## 6 >> REFERENCES

- EN 16191 “Tunnelling machinery – Safety requirements”
- IEC 62309 “Dependability of product containing reused parts – Requirements for functionality and test”
- ISO 16714 “Earth-moving Machinery – Recyclability and recoverability – Terminology and calculation method”
- Rolf Steinhilper: “Remanufacturing”, 1998, Fraunhofer IRB Verlag, Stuttgart
- ITAtech Report No 1 “Guidelines on standard indication of load cases for calculating of rating life (L10) of TBM main bearings”
- ITA Report No 14 “Guidelines for the provision of refuge chambers in tunnels under construction”

