Annex 5

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Requirements to be met by filler materials used for rail joint welding and rail resurfacing by welding

1. Foreword

The content of Annex 5 was prepared by DB Netz AG, Headquarters, Rail Technology Competence Unit, and agreed upon and approved by the German Federal Railway Authority (EBA).

2. Fundamental requirements

Detailed specifications regarding the use of filler materials for resurfacing welding work on rails and other parts of the permanent way and for the welding of rail joints are provided in DB Guideline 824.

Before filler materials are used for DB Netz AG's regular operations, operational testing shall be carried out by DB Netz AG. The operational testing period is normally 5 years or 100 million tonnes of load, or a period determined on an individual basis by the Rail Technology Competence Unit of DB Netz AG.

Once the filler materials have passed the suitability test and operational testing, DB Netz AG's Rail Technology Competence Unit shall approve the filler materials for DB Netz AG's regular operations and a certificate shall be issued to this effect.

The certification of the filler materials shall be carried out by DB Systemtechnik, DB Netz AG, Rail Technology Competence Unit or by a recognised EBA inspection expert in the field of permanent way welding.

The following sections set out the requirements for suitability testing for filler materials for rail resurfacing by welding and other parts of the permanent way and for the welding of rail joints.

3. Approval and release of filler materials for arc build-up welding in accordance with DIN EN 15594

3.1 Fundamental requirement:

The approval and release of filler materials with the associated welding procedure specifications [WPS] is generally compatible with the requirements of EN ISO 15613. Due to the specific requirements regarding the resistance (durability) of repair welds and use in the permanent way, e.g. rolling contact fatigue, the approval and release test must be carried out in accordance with this specification.

3.2 Information from the manufacturer:

- Toxicity threshold
- Rail steel grade in accordance with EN 13674-1
- Covered electrode classification in accordance with EN ISO 3580
- Wire electrode classification in accordance with EN ISO 14341
- Chemical analysis and batch analysis
- Storage requirements with manufacturer recommendations
- Current range/voltage range/polarity
- Dimensions, length and diameter
- Tubular cored electrode spool size and efficiency
- Drying requirements
- Description of the identification system
- Ideal application methods
- Durability of vacuum-packed covered electrodes

3.3 Batch testing by the manufacturer:

The batch testing characteristics are:

- Concentricity/roundness and dimensions
- Chemical composition
- Consumption, e.g. filler wire guides

3.4 Test arrangements

3.4.1 Test overview

- Mechanical testing
- Chemical analysis of the pure welding material with batch review
- Hardness
- Welding reliability (under laboratory conditions)
- Freedom from cracks
- Weld metal porosity
- Craters
- Open circuit voltage (OCV) requirements
- Welding parameters, defined in a WPS
- Number of defects, size of defects

3.4.2 Statements on the general weldability

The testing body must prepare a written statement on the general weldability that includes the following:

- Build-up weld shape
- Cratering
- Spatter
- Slag characteristics
- Ignitability and re-ignitability
- Other relevant information

All tests must be carried out on the rail material for which the approval/release is to be obtained. These tests must be carried out for a single run, for single-layer build-up welding and for five-layer build-up welding.

Testing on a single run is used to check for cracking after grinding.

Testing on single-layer build-up welding is used to assess the impact of the build-up welding on the rail steel.

Testing on five-layer build-up welding is used to assess the impact of the welding material in the individual layers of the build-up welding.

Microsections and hardness measurements according to Brinell and Vickers are carried out on single-layer and five-layer build-up welding. The macro Brinell hardness test is used to assess the surface: HBW 2.5/187.5. HV 30 over the welds, HV 0.2 in the fusion line with 10 offset impressions.

The test piece for five-layer build-up welding must be ground to a finish and subjected to ultrasonic testing.

3.5 Laboratory tests

The aim of the laboratory tests is to prove the suitability of the filler materials for successful repairs on approved rail steel grades.

The following build-up welds are required for the laboratory tests:

- Single build-up weld on the rail: one test piece as per Fig. 17
- One layer on the rail: one test piece as per Fig. 17
- Five layers on the rail: one test piece as per Fig. 17

The test pieces are created with stringer beads. The number of beads depends on the width of the test piece (rail head), but there should be at least five.

The welds must be subjected to magnetic particle inspection (MPI) in accordance with EN 1290 or dye penetrant testing (DPT) in accordance with EN 571-1.

3.5.1 Description of the specimen for laboratory testing

Figures 17 and 18 describe the requirements for the test piece with regard to the dimensions, preparation details and the locations of the measuring points for measuring the preheating.

The preheating must extend 75 mm from the prepared area (point A).

The preheating must extend over the entire thickness of the rail head (point B) and must be in the range of 400 °C to 450 °C; the interpass temperature must not exceed 500 °C and must not fall below 400 °C.

Length C of the test piece must be at least 600 mm.

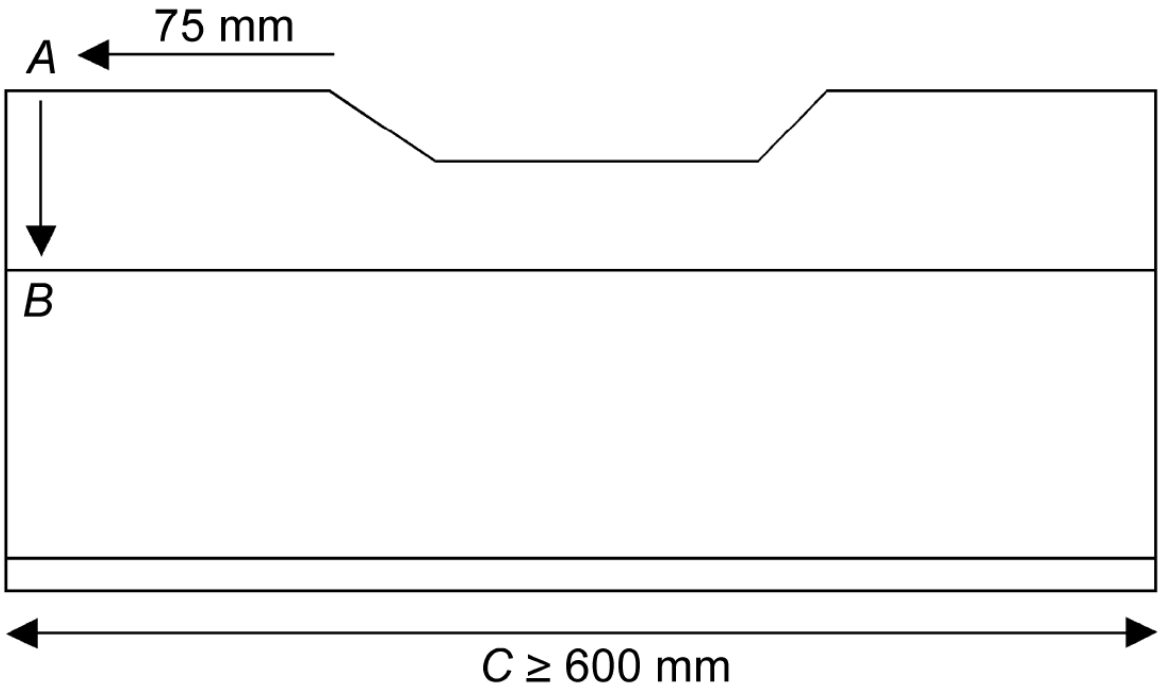
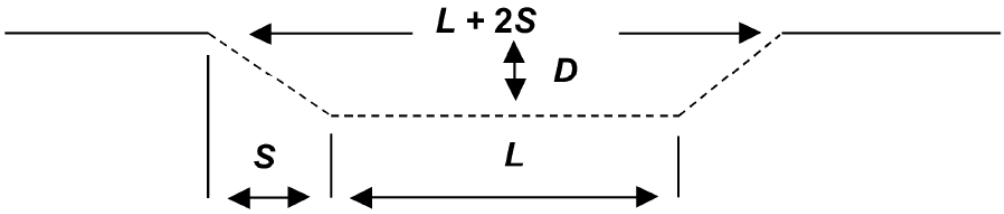


Figure 17: Example of a test piece

For the tests, the transverse prepared area must extend across 100% of the rail head width.



Legende

D Tiefe des Ausarbeitung
$S \geq 5D$
$L + 2S \geq 200$ mm

Fig. 18: Example of prepared area on a test piece

The dimension D must be large enough so that the surface of the last layer is even with the surface of the surrounding rail.

For DB Netz AG, the distance L + 2S is set at 250 mm. Welding must be carried out from left to right. The edge zones (S) are not used for testing. The test specimen is taken from the centre of area L.

3.5.2 Testing a single run

3.5.2.1 Objective

This test is used to verify the compatibility of the filler materials with the rail steel. No preparation is required for this build-up weld.

3.5.2.2 Description

The test piece of the corresponding steel grade must be at least 600 mm long. The running surface of the test piece must be lightly sanded to remove any rust. The test piece must be preheated in accordance with the preliminary welding procedure specification (pWPS) and the location of the preheating measurement must be selected in accordance with **Section 4.1**.

3.5.2.3 Inspection and assessment of the build-up weld

The build-up weld must be cleaned, and slag and spatter must be removed. The build-up weld must first be visually inspected "as welded".

After the visual inspection, the build-up weld must be ground down until it is 0.5 mm to 0.8 mm below the rail surface. After grinding, the build-up weld must be subjected to magnetic particle testing (MPI) or dye penetrant testing (DPT). The build-up welding must comply with the specifications set out in **Section 4.7**.

If the build-up weld fails the MPI or DPT, testing must be terminated. The approval of the welding consumables must be rejected for this steel grade.

3.5.3 Test for single-layer build-up welding

3.5.3.1 Objective

This test is used to examine the impact of single-layer build-up welding on the rail material and to check for homogeneity.

3.5.3.2 Description

The test piece of the corresponding steel grade must be at least 600 mm long. The rail must be prepared in accordance with **Section 4.1**.

Only in the case of MMA electrodes must the length of the joint preparation be calculated in such a way that the full length of the electrode minus 80 mm is used. This length can be derived from the individual build-up weld on the rail.

3.5.3.3 Inspection and assessment of the build-up weld

The build-up welding must be cleaned, slag and splatter must be removed, and the surface must be checked using MPI or DPT. The build-up weld must be divided as set out in **Section 4.5** and prepared for hardness testing and metallurgical examination. All results must comply with the requirements set out in **Section 4.7**.

If the build-up weld fails the MPI or DPT, testing must be terminated. On completion, the rail must be ground to the rail head profile.

3.5.4 Test for multi-layer build-up welding

3.5.4.1 Objective

This test is used to determine the integrity of the metal used for multi-layer build-up welding on rails.

3.5.4.2 Description

The test piece of the corresponding steel grade must be at least 600 mm long. The rail must be prepared in accordance with **Section 4.1**.

Only in the case of MMA electrodes must the length of the joint preparation be calculated in such a way that the full length of the electrode minus 80 mm is used. This length can be derived from the individual build-up weld on the rail. For completion, the build-up welding must consist of at least five layers and the rail must be ground down to match the rail head profile.

3.5.4.3 Inspecting and assessing build-up welds

The build-up weld must be cleaned, slag and splatter must be removed, and the surface must be checked using MPI or DPT. The build-up weld must be divided and prepared for hardness testing and metallurgical examination as set out in **Section 4.5**. All results must comply with the requirements set out in **Section 4.7**.

If the build-up weld fails the MPI or DPT, testing must be terminated.

3.5.4.4 Report on the welding tests

The welder must document the following:

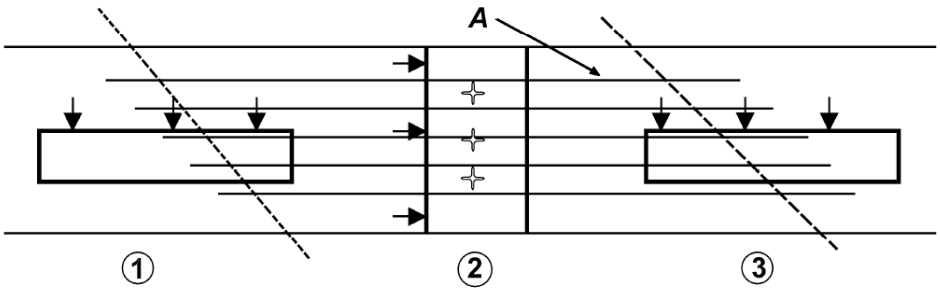
- The behaviour of the electrode during welding
- The ignition behaviour (ignitability and re-ignitability)
- Smoke production
- The removability of slag and spatter
- Cratering

3.5.5 Preparing, examining and testing test pieces

3.5.5.1 Labelling test pieces for examination

A number of test pieces with single-layer and multi-layer build-up welding are required. Figure 20 describes the separation cuts (thick lines) for sampling and the locations for the hardness tests (stars).

The arrows indicate the surfaces for the location of the macro/micro examinations.



Legende

① Länge mindestens 100 mm (es muss mindestens 10 mm in den Bereich der ungeschweißten Schiene vor Beginn der Auftragschweißung hineinreichen); die Tiefe muss mindestens die Tiefe des Ausarbeitung +10 mm sein

② Breite mindestens 20 mm; die Tiefe muss die Tiefe des Ausarbeitung +20 mm sein

③ Länge mindestens 100 mm (es muss mindestens 10 mm in den Bereich der ungeschweißten Schiene nach dem Ende der Auftragschweißung hineinreichen); die Tiefe muss mindestens die Tiefe der Ausarbeitung +10 mm sein

A schematisches Beispiel eine Auftragschweißung

Figure 19: Location of the macro/micro examinations

3.5.6 Hardness testing for the build-up welding and the non-welded rail

This applies to single-layer and multi-layer build-up welding.

- Surface hardness test

To determine the hardness on the surface of the build-up weld, the hardness must be measured at three points using test method HBW 2.5/187.5 in accordance with EN ISO 6506-1.
Specimen 2 in Figure 19 indicates the locations for the hardness measurement. The hardness measurement must be taken in the centre and the measuring points must be 10 mm apart. The hardness must be expressed as the mean value of the three measurements.

- Hardness testing in build-up welding

The hardness profile for the build-up weld must be determined in the vertical axis of the build-up weld using the HV10 test method in accordance with EN ISO 6507-1. The indentations must start 3 mm below the rail head and must be recorded 1.5 mm apart along the centre line of the rail profile. Hardness impressions of the unaffected base rail must extend into the area of the unaffected parent material (at least five characterising indentations). Specimen 2 from Figure 19 is to be used for this test.

Figure 20 describes locations for hardness testing in build-up welding.

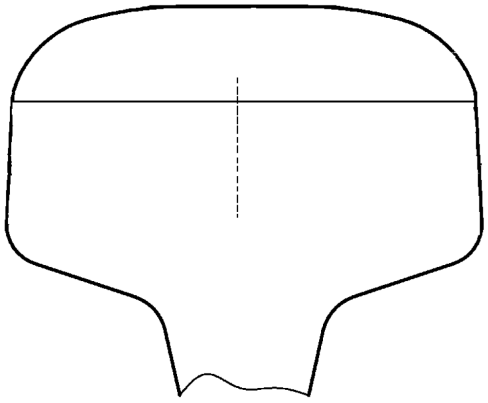


Figure 20: Example of locations for hardness testing

3.5.6.1 Macro and micro testing

In preparation for the examination, the test piece must be polished free of grooves and then etched with a nitrate-like solution (2% or 4% nitric acid in alcohol). Other etching processes are not permitted.

3.5.7 Acceptance criteria

3.5.7.1 Hardness

The acceptance criteria for hardness are listed in Table 09.

Steel grade	Position	Single layer	Multi-layer
R260	Surface	max. 380 HBW	290 HBW to 340 HBW
	Build-up welding	Not applicable	max. 400 HV10
R350HR	Surface	max. 400 HBW	340 HBW to 390 HBW
	Build-up welding	Not applicable	max. 400 HV10

Table 09: Hardness requirements for the surface of the build-up welding

The same filler materials must provide acceptable hardness values for single-layer and multi-layer build-up welding.

3.5.7.2 Macro and micro testing

The maximum permissible porosity for rail welding is significantly lower than that for manufacturing in general. This is due to the chemical composition and the cyclical load sustained during operations.

Defects must be assessed on the cross-section of the specimen (test piece 2) and on longitudinal sections (test pieces 1 and 3) over a total length of 100 mm.

The acceptance criteria for macro/micro analyses are shown in Table 10.

Defect type	Acceptance criteria
Cracks	Not permissible
Crater cracks	Not permissible
Individual pores	0 mm to 0.12 mm, unlimited
	0.12 mm to 0.3 mm, max. 3 per test piece
	0.3 mm to 1 mm, max. 1 per test piece
	>1 mm, not permissible
Pore groups[a]	Max. 0.4 mm, max. 3 groups per test piece
Linear pores[b]	Not permissible
Extended cavities / wormholes	Not permissible
Solid inclusions	None obvious in the polished test pieces
Lack of fusion	Not permissible
Differences	Not permissible
a Pores are categorised as groups if the distance between two pores is smaller than the diameter of a pore.	
b Linear pores are defined by the arrangement of three or more pores in one plane.	

Table 10: Acceptance criteria for macro and micro analyses

At 100x magnification, the test piece must not show any signs of retained martensite. At a magnification of 100x or above, signs of retained martensite are to be ignored.

3.6 On-track tests

3.6.1 General

The on-track tests must be carried out on a rail made of the steel grade to be approved.

The build-up welding must be carried out in accordance with the requirements of the WPS.

The test welds should be carried out in the centre of the rail head. The rail should be loaded with mixed traffic at 160 km/h and a load of at least 60 Tlt/t. The tests can be analysed on simulated defects over the full width of the rail head. Tracks with material breakouts can be examined visually and using ultrasound. The evaluations can be recorded 14 days before the welding. The test vehicles must be free of obvious and internal defects.

A description of the site can be created to describe the rails used, the insulated rail joints and the condition of the rails in the area extending 4.5 m on both sides of the test welds.

This description can include the flatness measurement and the intended centre line of the weld, 500 mm on both sides of the weld. Under no circumstances may the flatness deviation exceed 0.2 mm.

For the on-track tests, the welding conditions, the number of prepared areas, the route categories, the dimensions of the prepared areas, the test distances and the average tonnage must be recorded.

3.6.2 Preparation details

The details of the prepared area must comply with the specifications set out in **Section 4.1**.

In the case of transverse prepared areas, the prepared area must extend across the entire width of the rail head.

3.6.3 Scope of testing

The tests must include the following:

- a: Testing for surface cracks
- b: Detection of localised deformation (wear or plastic material deformation) by checking the levelness of the build-up weld with the base rail over a length of 1.0 m
- c: Soundness of the weld

3.6.4 Test methods

- For test a: visual inspection and MPI or DPT
- For test b: straightedge and feeler gauge or electronic straightedges
- For test c: Ultrasonic testing (UT) in accordance with the requirements of the railway authority (rail company)

3.6.5 Requirements for the track test pieces

Two types of repair welds are necessary to analyse the impacts:

Two types of prepared areas are required to examine affected and unaffected welding material:

- Four test pieces with one layer
- Four test pieces with × layers (at least five layers)

3.7 Acceptance criteria

3.7.1 Rail evenness

If a flatness deviation of more than 0.2 mm, measured over a length of 1 metre, is detected after a load of 5 million tonnes, the test piece must be rejected.

3.7.2 Surface defects

No visible defects are permitted when carrying out magnetic particle inspection (MPI) or dye penetrant testing (DPT).

3.7.3 Premature wear of the weld

Deviations in the running surfaces of more than 0.2 mm over a test length of 1 m in the rail cross-section compared to the measurement after the first day are not permissible.

After completion of the test welds, any defects that occur that are not related to the weld shall be excluded from the metrological evaluation of the build-up welds.

3.7.4 Frequency of testing

The on-track tests must be carried out over a period of five years or a track load of 100 million tonnes and must be carried out at least after the first day, after the first month, after six months and then annually or as determined on an individual basis.

Records of track inspections must be kept for evaluation purposes.

3.8 Analysis, results reports and decisions based on the track tests

3.8.1 General

On completion of all on-track tests, the body carrying out the test must draw up a report containing the following points:

- List of all general information
- Records of the track inspections
- Proposal of the issuing body regarding the filler materials and WPS

3.8.2 List of all general information

- Authorising rail company
- Route category
- Route description
- Condition of the rails before welding (ultrasonic testing)
- Rail designation
- Location
- WPS (manufacturer of the filler material/identification/dimensions /classification)
- Name of the engineer responsible for the on-track testing

3.8.3 Records of the track inspections

The test report after each test must include the following:

- Presence of any cracks
- The geometric deviations in the longitudinal and transverse directions and the deformations
- Soundness of the weld as determined by an ultrasonic examination

3.9 Decision regarding the filler materials and WPS by the body carrying out the tests

The body carrying out the tests must state in this report whether the filler material and the associated WPS meet the acceptance criteria.

3.10 Declaration of conformity for filler materials

All filler materials used after the track tests must be available with the same quality, performance and characteristics as the materials used in the tests and shall be supplied in accordance with EN ISO 544. The labelling of the filler materials used in production must reflect their conformity with the filler materials used in the tests.

4 Approval and release of filler materials for arc joint welding

4.1 Fundamental requirements

The fatigue resistance of welded joints on rail steels is tested using the constant-amplitude fatigue test. The test must be carried out on a rail joint that matches the form of the rail and the steel grade for which the approval/release is to apply.

The quality of execution of the weld to be tested must match the subsequent actual condition (production on the track/in the workshop).

Mechanical post-treatment of the bead transitions, in deviation from the series, is not permissible.

4.1.1 Fatigue test

The fatigue resistance must be determined using the "past-the-post" test method.

4.1.1.1 "Past-the-post" test method

Three test pieces are required. The weld must be within ± 10 mm of the centre of the test piece.

a) Each test piece must be positioned in the test device in such a way that the centre line of the weld is within 3 mm of the centre line of the stamping tool.

b) The maximum stress to be applied is 200 MPa, the minimum stress is set at 25 MPa. The test pieces must not be more than 100 mm longer than the outer span.

No defects may occur during the application of five million vibrations.

c) The weld is loaded with a sinusoidal, cyclical load so that the maximum and minimum stress values are reached. The specified values must be kept within 2% of the required nominal value. The fatigue test is carried out either until fracture occurs or until five million load cycles have been reached.

If the test piece fractures, the result must be documented as a failure. If the test piece remains intact, it is documented as "fatigue-tested".

4.1.2 Documentation

The following values must be documented for each test series:

- The inner and outer span of the test rig
- The distance between the centre line of the stamping tool and the support points
- The nominal stress converted to the outer bending curve

The following must be documented for each test:

- Whether the test piece has failed the test or is documented as "fatigue-tested"
- In the event of failure, the location of the fracture

5 Approval and release

The application for approval for the railway infrastructure sector must be submitted to the German Federal Railway Authority, Sgb. 215, Arnulfstrasse 9/11, 80335 Munich, Germany.

All necessary documents must be enclosed with the application:

- For filler materials for arc build-up welding on rails, according to Section 2 and Section 3
- For filler materials for arc joint welding on rails, according to Section 2 and Section 4

The German Federal Railway Authority issues a U-EBA mark with the approval.

The application for approval for use at DB Netz AG must be submitted to DB Netz AG, headquarters, Rail Technology Competence Unit, Adam-Riese-Strasse 11-13, 60327 Frankfurt am Main.

All necessary documents must be enclosed with the application:

- Authorisation for operational testing or approval from the German Federal Railway Authority
- For filler materials for arc build-up welding on rails, in accordance with Section 2 and Section 3
- For filler materials for arc joint welding on rails, in accordance with Section 2 and Section 4

If a filler material has a CE marking, EBA approval is not required; release for use by DB Netz AG must be applied for in all cases. If a filler material is included and named in DB Netz AG's 824 guidelines, the named filler material shall be deemed to be approved.

5.2 Changes, name changes, changes to product designations

All changes, e.g. changes to the name or company name of the manufacturer, changes to product designations etc., must be reported to the approval and release bodies and a corresponding renewed approval or release must be applied for.

The changes and any conformity with the previous product must be demonstrated to the approval and release bodies using suitable documentation. These must be confirmed by one of the bodies named in Section 4.1.3.

5.3 Quality assurance

In order to demonstrate consistent quality, the manufacturer's, supplier's or dealer's own internal production control must be monitored at least once a year by an accredited testing centre in accordance with system 2+ and evidence of this must be provided to DB Netz AG, Rail Technology Competence Unit, in the form of a monitoring report and the manufacturer's checklist.

If the manufacturer, supplier or dealer refuses to comply with monitoring, DB Netz AG's Rail Technology Competence Unit reserves the right to withdraw approval.

5.4 Costs

All services mentioned, such as

- product testing/evaluation,
- quality monitoring within the framework of the WPK,
- approval,
- release
- and field testing,

are subject to a charge. The cost rates can be obtained from the respective service provider. All costs shall be borne by the applicant.