DELIVERABLE **D4.1, D4.2, D4.3 and D4.4 - Study of worst case conditions**

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Version	Date	Contributors	Sections Affected
0.1	31.10.2014	All	

1. DEFINITION OF THE WORST CASE CONDITIONS REGARDING OPERATIONAL CONDITIONS OF ECB

The main objective this section is to define the worst case conditions by an ECB regarding operational conditions of ECB.

The conditions are not set on the basis of known worst situations but on a thorough understanding of all the possible situations, by means of the information of WP2.

Realistic representative worst case conditions have to be established, and they will then be the inputs for the requirements for the test site, test procedure and test setup, which will be developed and executed in WP5.

1.1 INFRASTRUCTURE

In TSI HS INF 2008 (see §4.2.13) longitudinal forces arise from traction and braking forces. These forces are defined in the High-Speed Rolling Stock TSI. "The maximum deceleration of a train must not exceed 2.5 m/s² "(TSI HS RST, § 4.2.4.5 and § 4.2.3.4.3). This requirement accomplished by ECB. The ratio between mass of train and the brake force of ECB comes to much lower deceleration.

The brake force of the ECB that may be executed on the track is limited depending on the brake mode, TSI HS RST § 4.2.4.5.

1.1.1 Track / rail heating

a) Ballasted track

The lateral stability of ballasted track (no track buckling) is mainly described by the critical rail temperature (CRT). This is a cross section averaged temperature of rail. This is higher than the local expected averaged rail temperature. The difference between the critical rail temperature and the local expected rail temperature is used as safety of the system. The local expected averaged temperature considers the maximum of environment temperature and the maximum heat coming from sun radiation as worst case conditions. The thermal difference is usable for ECB brake applications. For more details see ECUC D2.2 chapter 5.1.

b) Ballastless track

The criteria of averaged rail temperature are not used to evaluate the lateral stability of ballastless track. Following the maximum averaged rail temperature is not limited and the use of ECB is not restricted. For more details see ECUC D2.2 chapter 5.2.

1.1.2 Forces on track / rail

a) Rail

During operation of ECB vertical and longitudinal forces act on rail.

The brake force is acting in longitudinal direction. The brake force interact with the rail the in two forms - the longitudinal force and the heating of rail.

The vertical force is acting between the wheels and rail. In case of emergency brake application the vertical forces could have an averaged level of 20 kN per rail / per meter. The level depends on kind of brake application, type of ECB and speed.

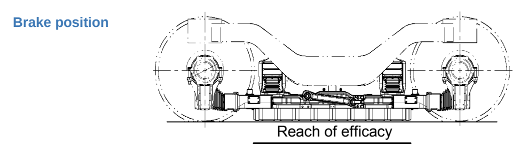

Figure 1: Vertical force between wheels and rail

During a brake application the ECB could touch the rail due to dynamic acceleration. This fact is considered in the definition of loads of interfaces and the earthing of ECB.

b) Rail mounted equipment

The force acting on rail mounted equipment can estimated by the level of magnetic stray field. On the one hand the worst case conditions defined by the minimum static air gap and emergency brake application and on the other hand the worst case conditions are depending on the position of the equipment related to the head of rail.

c) Non magnetic parts of switches

The physical principle of ECB assumes ferromagnetic properties of rail and a conductivity of rail. In case of non magnetic sections of rail the ferromagnetic property is changed. Thereby the attraction force and the brake force would decline.

ECB systems with pneumatic load relieving achieve a balance between attraction force and relief force. In case that the relief force is greater than the attraction force is possible that the ECB moves to release position. The position of ECB should be monitored. The ECB control identifies this situation and a routine of brake control brings back the ECB in brake position.

1.1.3 Gauge

The geometrical dimensions of ECB shall fulfill the cinematic gauge of EN 15273-2 for lower parts (60 mm below top of rail). The test should consider the release position and the brake position. See ECUC D2.3 chapter 3.3.

1.1.4 EMC

The interferences of ECB with signalling devices can be separated in 3 aspects.

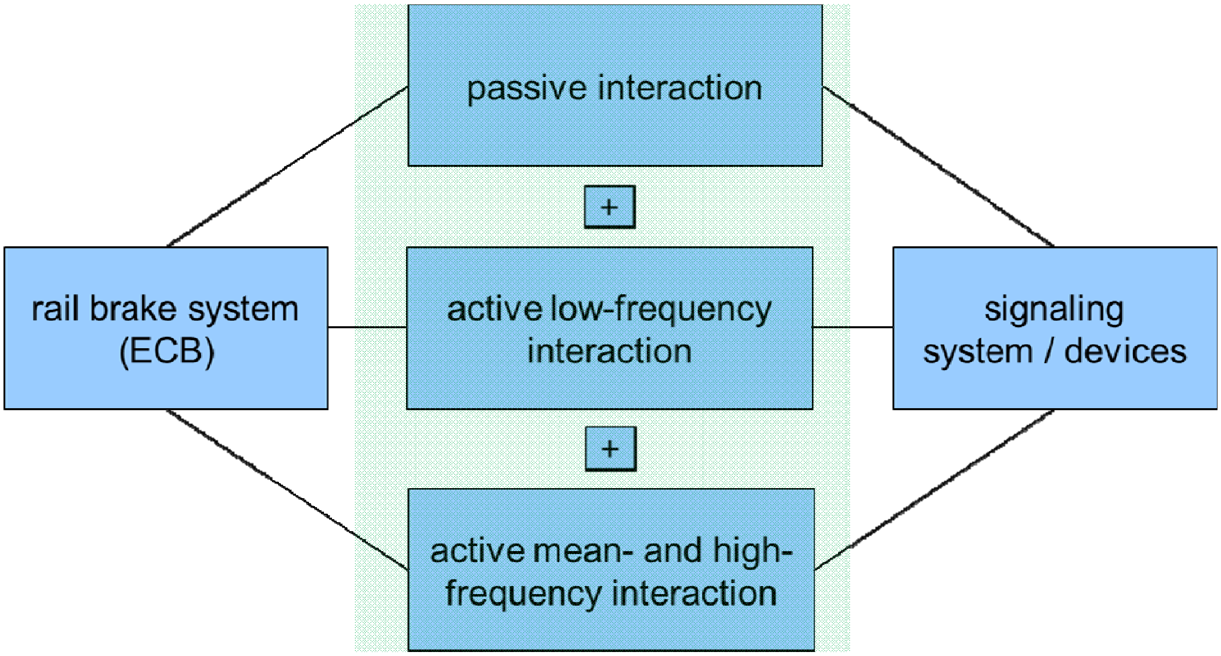

Figure 2: Cases of EMC interferences

1. Passive effect

Magnetic fields generated by signalling system apertures are altered due to the compact metallic ECB mass. The worst case conditions are described on the one hand by the minimum air gap and on the other hand by the lateral position of the ECB, see section 1.1.3.

2. Low-frequency magnetic fields

The low-frequency magnetic fields caused by the ECB for generating the braking effect and the ECB movement at the same time interact with signalling devices alongside the rail.

The two important parameters are the strength of direct current magnetic stray field and the pole pitch of ECB. By use of pole pitch of ECB and the speed of train, the frequency of the magnetic stray field can be calculated. Worst case conditions would be given in case of resonance with working frequencies of signalling devices.

3. Active mean frequency interaction

Interactions between mean-frequency magnetic fields which are mainly generated by the electric power supply of the braking device. The worst case conditions would be given by specific properties of the power supply of ECB.

1.1.5 Management of rail temperature

The idea of management of rail temperature is that the actual environment temperature is in same level as the considered maximum of environment temperature only on very few days over a year. The difference between the considered maximum of environment temperature and the actual temperature could be used for ECB service brake applications in a lot of days. See also chapter 1.2.3.

1.2 OPERATION

1.2.1 Operational cycle

The operational cycle has to be analyzed for the train and ECB and for the infrastructure.

1) Train / ECB

The operational cycles are necessary among others for thermal calculation of ECB. The description of operational cycles should be included following specifics:

- Brake mode (emergency brake application or service brake application),
- Range of speed,
- Time interval of ECB brake application,
- Line Gradients
- The overall energy dissipation provided by the ECB

2) Infrastructure

The operational cycles are necessary among others for calculation of rail heating. The description of operational cycles should be included following specifics:

- Time interval of trains
- Line Gradients
- Expected brake force by ECB (emergency brake application or level of service brake application)

1.2.2 Environment

The range of environment temperature of operation is compliant to EN50125, categories A1 (altitude up to 1400 m) and T3 (-25°C up to 45°C).

1.2.3 Approval for use of ECB

The approval of use of ECB is depending on the compatibility of track, track equipment and signalling devices with the ECB.

1.2.3.1 Common approval

The train should be equipped with a train control system (for example LZB or ETCS) that is able to enable or disable the ECB according to the sections of lines which allow the use of ECB for only emergency brake applications or emergency and service brake applications. These information is usually given in the infrastructure register. This information should be transmitted automatically to the train by train control systems.

Additionally it should be possible to enable or disable the ECB by manual operation of train personnel (e.g. the train driver).

A brake test of the ECB every 24 hours should be mandatory.

1.2.3.2 Condition based approval/management of rail temperature

The operation of ECB is limited due to the heating of the rail caused by the use of the ECB.

It would be an advantage if the difference between maximum and actual temperature could be used for additional ECB brake applications. This information shall be transmitted to the train by train control systems (for example LZB or ETCS).

1.3 TRAIN / ECB

1.3.1 Range of speed / Speed of train

The ECB have not limitation regarding to maximum speed. The ECB operates up to the maximum speed of the train.

The minimum speed is defined in TSI HS RST: (see §4.2.4.5). The ECB only operates a speed more than 50 km/h.

In the interfaces between the ECB and the bogie the mechanical loads over the full range of speed should be considered.

1.3.2 Power supply / power consumption

The actual ECB requires pneumatic energy and electric energy to operate

a) Pneumatic power supply

The pneumatic energy is necessary to move the ECB by actuators from release position to brake position and reverse from brake position to release position. These actuators can also be used to build a vertical force against the attraction force. The existent types of ECB use pneumatic energy for vertical displacement.

The main requirements are the level of pressure, the pneumatic volume per ECB and per application and the operation cycle.

The worst case condition for pneumatic power supply shall be defined by

- the air consumption of an emergency brake application from maximum speed to standstill
- and the maximum level of pressure on main brake pipe
- and the numbers of application per time.

The worst case condition for ECB should be considered the loads by maximum pressure and the numbers of applications. According to EN15734-1, the air supply is ensured via a local reservoir which size considers three successive application cycles without refilling.

b) Thermal limits of ECB

The current through the coils generates the magnetic field for brake application and the current heats the coils. One of the properties of ECB is the maximum temperature of coils. The worst case conditions should consider:

- the maximum environment temperature and
- the standardised operational cycles, see section 1),

or

- the minimum of operation temperature of train and
- the maximum operation time of an emergency brake application, see chapter 1).

c) Electric power supply

The electric energy is necessary to generate the magnetic field and thereby control the brake force of the ECB.

The worst case conditions for the electric power supply are described by a collective of loads which include:

- the maximum of power consumption of an ECB,
- the mode of operation described by duty type (DIN VDE 0530),
- time cycles of operation,
- the number of ECBs which are controlled by one power supply,
- and the power supply operation modes under different power line conditions (AC, DC, no connection).

The electric power supply should have a diagnosis system so that the ECB power circuit is monitored by level of isolation and earth failures.

The worst case condition for ECB should consider the following parameters:

- maximum voltage level,
- maximum voltage rise,
- connection to earth,
- maximum current level.

1.3.3 Mechanical forces

The definition of worst case conditions of mechanical forces should consider on the one hand the release position of ECB and on other hand the brake position.

The worst case condition in release position should consider

- the mass of ECB,
- acceleration EN61373 category 2,
- shock EN61373, category 2.

The worst case condition in brake position should consider

- brake force during emergency brake application with a minimum static air gap, see D2.3 Table 7,
- attraction force during emergency brake application with a minimum static air gap,
- the mass of ECB and the quasi static acceleration EN61373 category 3
- maximum vertical force due to deflection of integral beam from maximum of static air gap through to contact to rail.

1.4 MAINTENANCE

1.4.1 Interval of air gap adjustment

The air gap between the ECB-magnet and the rail has an influence on the performance of ECB and the compatibility with the infrastructure.

The interval of adjustment of air gap depends on the wear rate of the wheels. During the service of the train the wear of wheels reduce the diameter of the wheels and therefore the air gap is shortens. The air gap should be adjusted if the minimum air gap is achieved.

The air gap should be also adjusted in any cases of displacement of wheel sets or reprofiling of wheels.

1.4.2 Air gap

The air gap between rail and ECB-magnet has influence on attraction forces, brake forces and EMC.

The worst case conditions are depending on the following aspects

a) Brake force

The brake force reduces if the air gap increases. The maximum of allowed air gap represents the worst case condition to validate the ECB brake force. In practise present the new adjusted air the maximum air gap.

b) Attraction force

The attraction force increases if the air gap decreases. The minimum of allowed air gap represents the worst case condition to validate the vertical loads on interfaces of bogie and the vertical loads on rail and track equipment.

c) EMC

Present experience from running test showed that the greater interaction between ECB and signalling devices when the air gap is minimum. See also section 1.1.4.

2. DEFINITION OF THE WORST CASE CONDITIONS FOR SIGNALLING SYSTEMS

The main objective of this section is to define the worst case conditions by an ECB regarding track side installed signalling systems and components.

The definition of the worst case conditions (immunity limits) for the signalling system considers different possible operational and quality of service scenarios. This will include constructive and operational conditions but also transient phenomena and default conditions.

The conditions are set on the basis of known worst case situations and on a thorough understanding of all the possible situations by means of the information of WP2 as well as on models and simulation results of WP 3.

Realistic representative worst case conditions have to be established, and they will then be the inputs for the requirements for the test site, test procedure and test setup which will be developed and executed in WP5 as well as specific requirements on the analysis and assessment of the measurement results of WP5 .

2.1 INFLUENCED SIGNALLING SYSTEMS

2.1.1 Axle counters and wheel sensors

As already described in deliverable D2.1 axle counters and wheel sensors can significantly be influenced and disturbed by emitted magnetic fields (x, y, z-direction) within the working frequency range of the axle counter detector or wheel sensor (generation of further non existing axles/delete of existing axles). Furthermore as result of the magnetic saturation of the rail the magnetic behaviour of the rail changes and the typical characteristic curve of axle counters will vary significantly. All these effects could lead to a miscount of axles.

Based on these significant effects, following worst case situations could be defined:

a) High magnetic fields within the working frequency range of axle counters generated by
  - dominant current levels based on modulations / noise of the ECB power supply system (e.g. DC-voltage-link of the train) within the working frequency range of axle counters
  - dominant current levels generated by resonance effects of parasitic electrical resonance circuits (e.g. cabling, environment) within the working frequency range

of axle counters. The resonant effects have not been found to be mainly dependent on the train in which a specific ECB is installed, but on the position within the train and the separation among the magnets that make up the ECB. This defines the cable length and therefore the parasitic capacitance that will have a major impact on the resonant frequencies.

- high transient current levels with significant duration
- low air gap between ECB and axle counter head in combination with significant currents within the working frequency range of axle counters.

b) Very high magnetic fields which lead to a magnetic saturation or change of the magnetic characteristic of the rail generated by

- high operation current of ECB (e.g. 95 A)
- low air gap between ECB and rail head in combination with a higher operation current.

The magnetic fields resulting from disturbances or modulations from the ECB power supply may be significant at the first ECB-pole, directly connected with the positive pole. However this is due to the specific architecture of the power supply considered by the manufacturer, in which there exists an asymmetry between the positive and negative ports. Magnetic fields resulting from resonance effects with parasitic electrical circuits could have their maximum level at different positions.

2.1.2 Speed detection (GPE)

The trackside installed balises of the GPE system could be influenced and disturbed by magnetic fields within the area of the working frequency of the balises (Indusi 500 Hz, 1000 Hz, 2000 Hz). Furthermore low frequency “saturation effects” could occur by very strong magnetic fields, which could prevent the detection of transmitted signals.

As the magnetic field in the area of the balises will get a maximum at the minimum distance of the ECB to the rail, the minimum air gap, the maximum operation current of the ECB (e.g. 95 A) and a high current flow in the ECB coils at the working frequency of the balises - could be seen as a possible worst case situation.

2.2 NON INFLUENCED SIGNALLING SYSTEMS

Chapter 3.2 of D2.1 defines numerous signalling systems (e.g. loops of level crossing, cables, PZB / LZB / TVM, hot box detectors), which have shown at specific tests or up today in real operation no or no significant influence or disturbances. As it was decided, that it will be not necessary to consider this systems in the ECUC-project in detail no worst case conditions will be deviated for this systems, too.

2.3 SIGNALLING SYSTEMS WHICH CAN POSSIBLY BE INFLUENCED

2.3.1 Euro balise, KVB (Contrôle de vitesse par balise)

The balises are powered by magnetic fields in the frequency range of app. 27 MHz and transmit information to the train via magnetic fields in the frequency range of app. 4 to 4.5 MHz. Tests and examinations carried out in the year 2000 with a euro balise have shown, that euro balises will still work proper and reliable also after the influence by an active ECB.

Significant influences and disturbances may result by strong magnetic fields in the working frequency ranges of the balises (up-link and down-link). ECB will typically have no significant currents and magnetic field emissions in this high frequency range. Influences may occur by short duration high magnetic field pulses (like transients) resulting from the single poles by the overrun of the balises with high speed. This short pulses or waves could have broadband emissions which – at the end – could include significant magnetic field emissions at the higher frequency ranges, too.

2.3.2 Track circuits

As the results on single types of track circuits (UM71, FTGS) show no significant influences of ECB on track circuits no specific worst case requirements are known on track circuits. Track circuits may be influenced by disturbances of the current flow of the track circuit device in the rail. In this context disturbances in the ranges of the track circuit working frequencies may be significant as well as very high transient currents which may be extended over a longer period of time. Minimum air gap and maximum current flow in the ECB coils can be seen as the worst case conditions.

3. DEFINITION OF THE WORST CASE CONDITIONS FOR RAIL HEAD

The main objective of this section is to define the worst case conditions by an ECB regarding rail head.

In this task the contributors will define the worst case conditions for the rail head considering different possible operational and quality of service scenarios. The contributors will consider the effects of ECB in the infrastructure characteristics.

The conditions are set on the basis of known worst case situations and on a thorough understanding of all the possible situations by means of the information of WP2.

Realistic representative worst case conditions have to be established, and they will then be the inputs for the requirements for the test site, test procedure and test setup, which will be developed and executed in WP5.

This task considers the following:

- Temperature limit of track
- Succession of trains
- Speed limit of line section
- Maximal brake power of trainset
- Material of rail
- Weather conditions
- Quality of track bed
- Rail type / gauges
- Non magnetic switches
- Load cases for track / track equipment
- Approval for use of ECB for emergency and / or service brake
- Air gap adjustment
- Operational cycle

The purpose of the testing is to validate the Thermal modelling work that has been undertaken so that the model can be applied to accurately predict the effects of ECB operation and develop operational limits for the safe use of the ECB over different types of track.

The thermal modelling that has been performed is divided in three parts:

1. Modelling of the rail temperature as a result of the passage of a single train.
2. Modelling of the rail temperature from the passage of multiple trains in various service patterns.
3. Modelling of the effect of ECB on the structural integrity of the rail (not yet complete).

The testing proposed will be performed on a dedicated test site which is not on the operational railway, as such it will not be possible to simulate a full service pattern over the test site. The aspect of the thermal model that can be realistically validated by testing in this scenario is the first, i.e. the rail temperature due to passage of a single train.

To validate the model, ideally the conditions for the rail head should reflect the conditions that were used for the modelling. Therefore this document presents a summary of the parameters that were applied during the thermal modelling so that these can be considered in the context of the test site.

It is also hoped that other aspects of the ECB interaction with infrastructure can be investigated during the testing, specifically:

- Operation of the ECB over insulated rail joints (IRJs)
- Interference effects on track circuits.

Test site conditions that would be required to allow investigation of these aspects are also discussed.

3.1 Modelled Conditions

3.1.1 Track Temperature Limits

In the FE simulations the following nominal values are considered for ambient temperature and rail initial temperature:

- Temperature of surrounding air: 27^{o}C
- Initial temperature of the rail: 27ºC

Measurements have shown that the temperature of rail can be approximately 20^{o}C higher than the ambient temperature on a sunny day. Simulations have been conducted reflecting also a temperature shift between rail and ambient temperature. More precisely, the following scenarios have been taken into account (in green, nominal ambient and rail temperature):

		Cold days	Mild temp days	Hot days
Ambient temperature		8ºC	18ºC	**27ºC**
Rail temperature	No sun-ray (+0ºC)	8ºC	18ºC	**27ºC**
	Sun-ray	15ºC	28ºC	37ºC
	Severe Sun-ray	----	----	47ºC

Table 1. Considered temperature scenarios in the simulations

Maximum allowed temperatures are dependent on the track type and they consider temperature increases due to exposition to the sun (estimation of temperature increases due to sun-radiation are given in Table 1 above for different type of days) and temperature increases due to the use of ECB.

3.1.2 Maximum Brake Power of Trainset

The power of the trainset used in the thermal modelling was as follows:

- 2/3 service brake 105kN
- Full service brake 170kN
- Emergency brake 360kN

3.1.3 Succession of Trains

The thermal model considered the following service patterns:

Braking	Total Brake Force per Train (kN)	Frequency (trains per hour)	Interval (minutes)
2/3 service	105	8 / 10	7.5 / 6
Full service	170	6 / 8 / 20	10 / 7.5 / 3
Full service + emergency	170 + 360	Service brake every 2 minutes for 20 mins (10 trains) + 2 emergency braking applications	

Table 2: Modelled Service Patterns

The Brake Force corresponds to the total force per train. If an 8-vehicle ICE3 train is considered, it contains 4 ECB equipped vehicles, a total of 16 magnets.

3.1.4 Speed Limit of Line Section

Train speeds of 150km/h, 200km/h, 250km/h and 300km/h used for the modelling. These values were selected previous to the measurement campaign (where train velocities are selected according to operating conditions) and they cover more or less the whole range of use of ECBs (recommended between 100-350 km/h).

Results show train speed is not as significant with respect to rail heating as braking force and train frequency. Detailed results presented for 200km/h (marginally worst case modelled).

3.1.5 Material of Rail

All modelling was performed using steel rail with the following parameters:

- Young's modulus: 2.1E11Pa
- Poisson's ratio: 0.3
- Thermal conductivity: 40-50W/mK

3.1.6 Weather Conditions

The model assumes the nominal temperature of the surrounding air to be 27^{o}C. Nevertheless, according to Table 1 different ambient temperatures have been considered to differentiate between cold and hot days.

The model also assumes a value of 10 Watts/m^{2o}K for the film coefficient to model the evacuation of heat through the lateral surfaces of the track due to convection mechanisms. The value of the film coefficient is reported in literature to be between 5-25 Watts/m^{2o}K for still air.

3.1.7 Rail Type

The thermal modelling assumes UIC60 rail.

3.1.8 Non-magnetic Switches

In the UK the vast majority of switches are manufactured from standard pearlitic steels and as such are magnetic. Crossings are commonly austenitic manganese castings which are non magnetic.

3.1.9 Load cases for track/track equipment

Measurements should be taken to investigate the effect of ECB operation on the stress suffered by the rail. A specific scenario that should be investigated through the monitoring of rail stress is that of rail creep in which repeated braking at the same location in the same direction can cause stress as the rail tends to bunch up ahead of the braking point and become tensioned behind it.

The most suitable method for monitoring the rail stress is by use of strain gauges. These can be fitted to the web of the rail at a number of locations and continuously monitored, the gauges are bonded or spot welded onto the rail. No intervention is necessary for the measurements. The only complication is that strain gauges only measure changes in stress therefore to obtain absolute stress values it is necessary to provide a calibration point at which the rail stress is known. This is normally achieved by cutting the rail to zero the stress, the gauges are then applied and the rail re-stressed and welded.

Other methods of measuring rail stress are not suitable for continuous monitoring and therefore the use of strain gauges is preferred for this application.

3.1.10 Approval for use of ECB for Emergency and/or Service Brake

The thermal modelling considers 2/3 service, full service and emergency braking.

3.1.11 Air Gap Adjustment

The air gap assumed for the thermal modelling is not stated. The model obtains the heat input into the rail by assuming that all kinetic energy of the train is converted into heat (breaking force*velocity). All the generated heat is directly introduced as an input in the head of the rail, ignoring the air gap between the head of the rail and the ECB. The air gap is, thus, neglected when thermal simulations are performed. The consideration of the thermal gap could lead to some heat losses (difficult to predict), not considered to be in the safe side of the results.

The low frequency magnetic flux calculation used air gaps of 3mm, 5mm, 7mm & 9mm.

3.1.12 Operational Cycle

The operational cycle is as defined in section 2.1.2 for the succession of trains.

3.2 Track Limitations

3.2.1 Ballasted track

If the test site is located on ballasted track then it will be necessary to restrict the use of ECB to ensure that the rail temperature remains within acceptable limits. The requirements for use of ECB over French ballasted track are shown below:

France – HS East European line		
Quantity of trains in one hour	For ECB < 105kN (2/3 TSI)	For TSI ECB < 180 kN
If rail temperature 40°C ≤ Θ ≤ 45 °C	8	5
If rail temperature 45°C < Θ	1	1

Table 3: Ballast Track Restrictions (East European line)

France – HS Rhein-Rhone line		
Quantity of trains in one hour	For ECB < 105kN (2/3 TSI)	For TSI ECB < 180 kN
If rail temperature 41°C ≤ Θ ≤ 45 °C	10	6
If rail temperature 45°C < Θ	2	1

Table 4: Ballast Track Restrictions (Rhein-Rhone line)

Use of ballasted track for the test site will require that the use of the ECB be restricted, limiting the range of operation that can be tested. For this reason the use of a test site on ballasted track is not recommended.

3.2.2 Non-Ballasted track

There are currently no restrictions on the use of ECB on non-ballasted track.

3.3 Test Requirements

3.3.1 Track Type

The test site should be on non-ballasted (slab) track with UIC60 rail.

3.3.2 ECB Operation

The ECB should be operated at the following levels:

- 2/3 service brake 105kN
- Full service brake 170kN
- Emergency brake 360kN

3.3.3 Train Speed

A train speed of 200km/h should be used if possible however the modelling suggests that train speed is not significant and a speed of 150km/h could be used if necessary.

3.3.4 Temperature Measurements

The model calculates temperature values at all the points in a section of the rail (see figure below), although results have been detailed and compared in the 5 reference points stated in the figure.

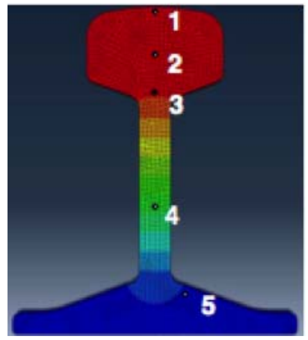

Figure 3: Rail Temperature Reference Points in the Model

In the measurement campaign temperatures should be measured in the surface of the rail. They will be compared to simulation results at the corresponding points of the FE model. The measurement of temperature at 3-4 different points is suggested (see figure below):

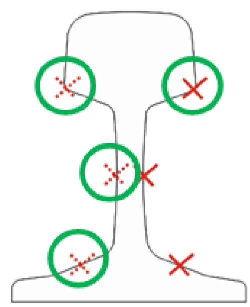

Figure 4: Suggestion of Rail Temperature Measurement Points

Measurement of ambient temperature is necessary, as rail as the rail temperature before ECB is applied.

3.3.5 Stress Measurements

Stress monitoring is to be conducted at one position of the rail, where repetitive use of ECB is expected.

3.3.6 Insulated Rail Joints

UK lines employ DC track circuits with Insulated Rail Joints (IRJs) providing separation between circuits. Concerns have been raised about the operation of ECB across IRJs, specifically in relation to the risk of drawing an arc across the IRJ. The ECB is located in between the axles of a bogie and therefore each axle will provide a low impedance path between each rail on either side of the IRJ while the ECB is passing over it. This mechanism should prevent the development of any significant voltage either across the IRJ or across track circuit receivers. This can be confirmed by testing.

The test site should therefore include an IRJ that can be instrumented to allow measurement of voltage across the joint. A suitable arrangement for inclusion in the test site is shown below, this has a track circuit receiver connected either side of the IRJ.

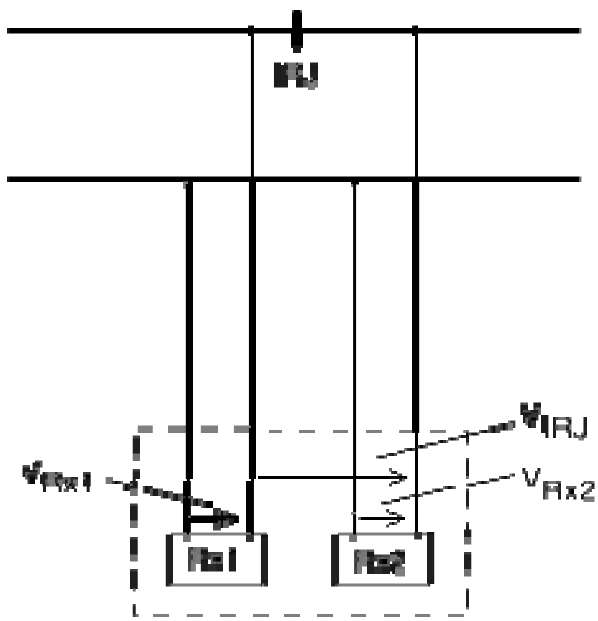

Figure 5: IRJ Voltage Measurement

The voltage across the IRJ would be measured at the terminals of the track circuit receivers with the instrumentation contained within the location case. Additionally the voltage across each receiver could be recorded which will give useful information regarding the potential for interference with track circuits as a result of ECB operation.

Sampling frequency for measurements should be 24kS/s to ensure that interference for all UK track circuit types can be assessed.

4. DEFINITION OF THE WORST CASE CONDITIONS FOR ROLLING STOCK

The main objective of the present section is to define the worst case conditions by an ECB regarding rolling stock. The conditions are set on the basis of known worst case situations but on a thorough understanding of all the possible situations by means of the information of WP2.

Realistic representative worst case conditions have been established, and they will used as inputs for the requirements for the test site, test procedure and test setup, which will be developed and executed in WP5.

4.1 BOGIE

The mechanical load capacity of the bogie must be designed for the dimensions, the mass and the forces of the ECB.

The interfaces between the ECB and the bogie should consider the mechanical loads over the full range of speed.

The definition of worst case conditions of mechanical forces should consider on the one hand the release position of ECB and on other hand the brake position.

The worst case condition in release position should consider

- the mass of ECB,
- acceleration EN61373 category 2,
- shock EN61373, category 2.

The worst case condition in brake position should consider

- brake force during emergency brake application with a minimum static air gap, see D2.3 Table 7,
- attraction force during emergency brake application with a minimum static air gap,
- the mass of ECB and the quasi static acceleration EN61373 category 3
- maximum vertical force due to deflection of integral beam from maximum of static air gap through to contact to rail.

4.2 BRAKE CONTROL

The brake control system should be able to activate the ECB according to the required brake force.

The existing ECB is controlled by a central brake control system which allows the traction control system to switch the ECB current on or off. The communication between the control systems works via MVB.