Assessment Overhead
Contact Line Langset - Kleverud

13.04.2017
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### Abbreviation and Acronyms

<table>
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<th>Abbreviation / Acronyms</th>
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<tbody>
<tr>
<td>BN</td>
<td>Bane NOR – Norwegian infrastructure manager</td>
</tr>
<tr>
<td>CA</td>
<td>Catenary wire</td>
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<tr>
<td>Candrop</td>
<td>Calculation software for cantilevers and droppers</td>
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<td>CW</td>
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<td>DIN</td>
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<td>EBA</td>
<td>Eisenbahn-Bundesamt CERT Deutschland (Railway Federal Authority Certification of Germany)</td>
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<td>EBC</td>
<td>Eisenbahn-Bundesamt Deutschland (Railway Federal Authority of Germany)</td>
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<tr>
<td>EN</td>
<td>European Standard published by European Committee for Standardization or national organization for standardization</td>
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<tr>
<td>INFRANORD</td>
<td>Installation company</td>
</tr>
<tr>
<td>ISO</td>
<td>International Standard published by International Organization for Standardization</td>
</tr>
<tr>
<td>kN, N</td>
<td>Kilo Newton, Newton</td>
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<tr>
<td>mm</td>
<td>Millimetre</td>
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1 Conclusion

Between Langset – Kleverud a new line with an overhead contact line system was built from year 22. July 2013 to 30. November 2015. The used overhead contact line system S25 is in Norway a common system for high-speed lines up to 250 km/h. It was installed the first time in year 1998 from Lillestrøm to Gardermoen for the Airport Express up to 250 km/h operational speed.

The overhead contact line system S25 bases on the German overhead contact line system Re250. In Germany, all high-speed lines up to an operational speed 250 km/h were equipped with this overhead contact line system.

For the two transition tension lengths between overhead contact line system S35 and S25 it was used the overhead contact line system S20 for a maximum speed of 200 km/h.

The German Railways, Deutsche Bahn AG, uses system Re250 since more than 25 year with positive experiences on their high-speed lines. Also, the system S20 bases on the German System Re200 which using the German Railway for more 45 years successfully.

Also in Norway, the Bane NOR operates these overhead contact line systems for more than 20 years very successfully.

The experiences show using the correct components, design parameter and installation procedures the systems S20 and S25 work with a high availability.

The overhead contact line for the double track section Langset – Kleverud was checked during an approval test by BN. The results of the approval tests show some weaknesses in the BN drawings, design and installation.

The present report based on the assessment which invested in the nights from 25. to 28. March 2017.

The operational speed can be not increased up to 250 km/h without removal of the priority of findings. These are

1. changing of ten tension lengths of contact wire regarding the existing bumps kinks and bends of contact wire together with the installation of the correct droppers BzII 10 mm²,
2. removing of the other existing bumps kinks and bends in the other contact wire tension lengths they are not changed together with changing of the used 12 mm² dropper wire to 10 mm² dropper according to BN regulation.

During the removals according to item 1 and item 2, it should be take part a competent colleague of BN to supervise the removal work of company. He should confirm in written the work was done correctly. After the execution of these removals according item 1 und item 2 BN should undertake a contact wire position measurement and a contact force measurement with at least operational speed of 250 km/h plus ten percent. If the results are according to the requirements of
standards and technical rules of BN the operational speed can be increased to maximum 250 km/h respectively 200 km/h.

2 Introduction

In the nights from 25. to 28. March 2017 during an inspection the overhead contact line system S20 and S25 was checked regarding its conformity to the requirements of Standards and BN regulations.

For the inspection, it was used a maintenance inspection railway vehicle. During the inspection, the results were documented by Figures and as a report (Annex 1).

The inspection was undertaken by an independent expert of the German Railway Authority EBA and the German Railway Authority for Interoperability EBC. The inspection was attended by the BN site manager, BN technical inspector, INFRANORD Mr. and INFRANORD project leader.

3 Findings

3.1 Structure of findings

The findings are structured in

- system drawing findings
- components findings
- layout design findings
- overhead contact line installation findings
- pole findings
- foundation findings

3.2 System drawings

3.2.1 Generell

I recommend to improve the following drawings to avoid misunderstandings and mistakes in the current projects. The suggestions result from findings during the inspections at the overhead contact line Langset - Kleverud and experience from other projects.

3.2.2 Distance between dropper and lower z-rope clamp

The z-rope clamp is a heavy point in the contact wire. Avoiding contact force peaks and higher contact wire wear the lower z-rope clamp should be at least 250 mm in distance of the next dropper.
Figure 2.2: Distance between z-rope clamp and dropper.

The missing distance between dropper and lower z-rope clamp is a finding in the system drawings and the missing value of 250 mm should be included very urgent.

3.2.3 Upper fixation point of registration tube dropper

The upper fixation point is differently. For the pull-off supports the registration tube dropper is fixed at the cantilever tube hook (Figure 2.3a). Other sides for the registration tube dropper is fixed at the catenary clamp hook (Figure 2.3b). In the last case because of the Y-stitch wire there is no other possibility for fixing the registration tube dropper. The catenary clamp was moved for adjusting the catenary wire radial position. In this case the registration tube inclination changed and the contact wire height changed. This should never happen for the small tolerance of a high-speed overhead contact line system.

Figure 2.3a: Existing registration tube dropper at the pull-off support.
**Figure 2.3b:** Existing registration tube dropper at the push-off support.

**Figure 2.3c:** Suggested solutions. a) pull-off support, b) push-off support

Figure 2.3c shows the possibilities for avoiding the changing of contact wire height. If the possibility exists for moving the catenary wire clamp by ±300 mm then the possibility will be used. With the suggestion in Figure 2.3c variant a) and variant b) the movement of catenary wire clamp is independent of the fixation of registration tube dropper.

The incorrect upper fixation of registration tube dropper is a finding in the system drawings and should be fixed very urgent with view to the other present projects.

### 3.2.4 Upper fixation of registration tube dropper

Drawing EK.707394 has to be improved. The fixation of registration tube dropper is not in the Y-stich wire in Norway only in Germany (see Figure 2.4).
According to drawing EK.707394 there is no the possibility for an adjustment of catenary clamp ±300mm. This possibility according to drawing EK.707394 shown in Figure 2.4 did not exist in Norway.

The incorrect upper fixation of registration tube dropper is a finding in the system drawings and should be fixed very urgent for avoiding of misunderstandings in other present projects.

3.2.5 Current carrying connections for registration tube dropper

In high-speed lines in Germany, Spain, Netherlands, China and Turkey it is used the current carrying registration dropper because of the high short circuit power. Therefore, the infrastructure manager has only positive experiences with current carrying dropper connections. Due to the high short circuit power and the positive experiences of the high-speed infrastructure manager it will suggested to use the current carrying registration tube dropper for Bane NOR.

The mentioned countries above have slab tracks. Due to the slab track, there are no necessaries to adjust the catenary clamp. In these countries, it is strictly forbidden to move the catenary clamp.

But Bane NOR uses the overhead contact line system S25 on ballast tracks. Therefore, it is necessary to adjust the catenary wire position on ballast tracks. Therefore, it will be recommended to use the current carrying dropper for S25. In this case, it needs to produce a drawing according to Figure 2.5a.

Figure 2.5b a) and b) shows the upper current carrying dropper fixation in high-speed lines as a common solution.

Figure 2.5.c shows the lower current carrying dropper fixation at the registration tube.
Figure 2.5a: Missing drawing for the current carrying registration tube dropper.

Figure 2.5b: Upper fixation of registration tube dropper with current carrying connection for (a)) push-off support and (b)) for pull-off support.
Figure 2.5c: Lower fixation of registration tube dropper for a *current carrying connection*.

This is a finding in the system drawings and it should be fixed with view to the present running projects.

### 3.2.6 Span length drawing

The drawing EK.707390 should be improved to avoid misunderstandings (see Figure 2.5).

![Diagram](image)

**Figure 2.5**: The arrows should be included for the dimension of 0,19 m.

The drawing is a bit confusing. Therefore, it should be used arrows separately for the 0,19 m and 0,45 m values to avoid misunderstandings.

### 3.2.7 Grease on threads

During the inspection of screws, it could be seen there are no grease at the screw threats. There is no requirement in the Bane NOR regulations. The type of grease should be explained in the regulations of Bane NOR. According to the grease type of Germany it should be used for screws of A 2 and A4 und CuNiSi an anti-friction coating on chlorinated paraffin basis. For all other screws and nuts it should use lithium soap greases e.g. K 2G.

The missing requirement for grease type is a finding in the system drawings and in the technical regulation and it should be included urgently due to the other running electrification projects.

### 3.2.8 Position of diagonal bolt position

The bolts have to be in the upper direction, not in the down viewing direction as shown in Figure 2.8. Therefore, the existing drawing EK.707399, EK.707400, EK.707401, EK.707402, EK.707403, EK.707405, EK.707407, EK.707408, EK.707409, EK.707410, EK.707411 should be corrected by adding the bolts in the upper direction.
3.2.9 Missing torques in drawings

Drawing EK.707220 contains the used clamp with M16 U-bolts as shown in Figure 2.9. In this drawing the link to drawing EK.707169 with the required correct M 16 U-bolt type is missing due to avoid mistake of using the wrong U-bolt type with the wrong torque.

The position of bolts of diagonal tube should be in the upper position due to a loose screw will be not falling down. It should be change in the drawings mentioning above.
In drawing EK.707169 has to be included the required torque 70 Nm according to Siemens requirements. Now there is no information what torque having to be used for clamp according to drawing EK.707220 and Figure 2.9 during the installation.

Figure 2.9: Clamp with U-bolts for fixing the diagonal tubes at the soffit pole.

3.2.10 Torsions angle of poles

The requirement of a minimum the minimum torsions angle 6° is missing in the BN drawings. The requirement of 6° comes from the German requirement according to drawing Ebs 02.03.20. It has to be included in the BN drawing.

3.2.11 Drawing for E-press clamp

There is no drawing for the E-press clamp for S25. There is only the E-press clamp according drawing EK.707327 for system S20 and not for System S25.

3.3 Design findings

3.3.1 Distance between Y-stitch and top anchor tube

For the candrop calculations the user did not realize that the Y-stitch wire is too close to the registration tube dropper and top anchor tube. The requirement of having enough distance works with a 18 m Y-stitch wire according to drawing EK.707398. As a result, the Y-stitch wire is too close to the top anchor tube (see Figure 3.1). The candrop user has to change the dimensions, check the results and has to present the updated calculation to INFRANORD after review by Bane NOR.

a) b)
Figure 3.1: Y-stitch wire are too close to the catenary wire support. a) stitch wire touches the hook of registration tube dropper, b) stitch wire is covered by a plastic protection due to the stitch wire touches the top anchor tube

This is a design mistake by wrong candrop calculation. It has to use a 18 m stitch wire. After recalculation of Y-stitch wire and support droppers it has change the Y-stitch wire and the droppers at the support.

In the candrop software it should include a warning signal for the user if the Y-stitch wire is closer than 150 mm to the registration tube or top anchor tube.

3.4 Installation findings

3.4.1 Internal assessment of INFRANORD

Because of unusual high number of findings, the protocol of internal assessment of INFRANORD needs to presented and reviewed by the independent expert. I ask INFANORD to present this protocol until 06. April 2017.

I doubt there was an internal quality assessment of INFRANORD due to the unusual high number of findings.

3.4.2 Contact wire bumps, kings and bends

In the overhead contact line tension lengths

- Right track: L14, L18 (19,4% existing wear!), L20, L22, L24, L38
- Left track: L15, L21, L23, L27

are bumps, kinks and bends. Therefore, the contact wire has to change for the above mentioned tension lengths.

So, the measured thickness of contact wire is only 11,25 mm instead 13,2 mm of a new contact wire thickness in tension length L20. That means the contact wire has a wear of 10,5 %. In tension length L18 is was measured a 19,4% contact wire wear. The extremely high punctually contact wire results from the contact wire bumps, kings and bends which could be seen in the nightly inspections.
Without adjustments, the contact wire can be operated for another 1,5 year (10,5%) respectively 0,5 year (19,4%) with the same train head way up to now and the same operational speed of 130 km/h up to now. The life time of contact wire will be shorter for the nominal operational speed of 200 km/h. The bumps are approximately 1,5 years old. The existing punctual contact wire wear points to this operational time. It is not possible to produce so high contact wire wear after 8 months or less. Therefore the bumps are at least 1,5 year old and it happens during the installation.

Figure 4.2a: Bump in the contact wire as an example for the extremely high number of bumps.
From my point of view and my experiences the number and height of contact wire unevenness are unusual in worldwide overhead contact line installations in high-speed lines. If somebody doubts the statement above I suggest another inspection to demonstrate and explain the reason for the bumps to INFRANORD.

The bumps, kinks and waves resulting from a not correct installation procedure with not correct tools during the installation. The bumps are not from third parties.

The findings are installation mistakes. The bumps, kinks and waves must to be removed by changing of ten contact wire lengths mentioned above and by removing of the residual bumps, kinks and waves in the residual contact wire lengths.

### 3.4.3 Dropper type Bzll 12 mm²

The dropper type Bzll 12 mm² can be not used for the high-speed overhead contact system S25. The experiences from other countries with high-speed lines show the Bzll 12 dropper type tends to break close to the lower dropper clamp (Figure 4.3).
The material copper bronze II distributes by its material features and it is close to its strain limit for speeds of 160 km/h, especially for short droppers in tunnels. Due to those experiences the Bane NOR requires BzII 10 mm² dropper type like Germany. Otherwise the 12 mm² dropper could break for operational speeds of 200 km/h and higher speeds. Therefore, the decision of a 130 km/h speed limit was correct and I confirm this decision afterwards.

It has to substitute the 12 mm² dropper types against to the 10 mm² dropper. I recommend to substitute the dropper together with changing process of ten contact wire lengths.

For the dropper substitution in the residual tension length the dropper should be substitute together with contact wire adjustment regarding the bumps and waves.

The use of the wrong dropper is an installation mistake. The use of the correct dropper is stated in the technical regulation and drawings e.g. EK.707243.
3.4.4 Position of current connections at steady arm

The correct position is essential for the life time of current connection part 5 and 6 in Figure 4.4b. Therefore, it has to be installed in the position according to drawing EK.707474 shown in Figure 4.4b.

**Figure 4.4a:** Existing position of current connection at steady arm.

**Figure 4.4b:** Required position of current connection at steady arm according to drawing EK.707474.
Figure 4.4c: Correct installed of current connection at steady arm at Gardermoen line as required according to drawing EK.707474.

This is an installation mistake. It has to be removed by adjustment of jumpers.

3.4.5 Length of crossing bar at switches

The measured length of crossing bar at four switches at km 79 was 2.65 m and with two holes for fixing the droppers (Figure 4.5a). According to the drawing EK.707473 the maximum length of the crossing bar is 2.5 m without two holes.

The used crossing bar can be keep in the crossing but it has to be installed two droppers at each crossing bar.

Figure 4.5a: Used crossing bar type for overhead contact lines above switches crossings.
Figure 4.5b: The requirement for crossing bar according to drawing EK.707473.

If it will be used a crossing bar according to Figure 4.5a then it has to fix the crossing bar with droppers (Figure 4.5c)

Figure 4.5c: The crossing bar with correct installed droppers.

This is an installation mistake. It has to be negotiated with Bane NOR if the existing crossing bar could keep. If the Bane NOR confirm this then it has to be installed two additional droppers for the crossing bar.
3.4.6 Soffit pole for S25 cantilever in tunnels

The diagonal tube uses clamps with hooks (Figure 4.6a). According to drawing EK.707423 there is no hook at the clamp. But the drawing is not quite complete.

For the used application in the tunnels there are a new BN project drawing number EK.109731. According to this drawing and drawing EK.707423 there is no hook at the clamp.

![Figure 4.6a: Used soffit pole bar clamp with hook in tunnels.](image)

This is an installation mistake. It has to be ask the Bane NOR if the clamp with the hook can be keep at the tunnel cantilevers.

3.4.7 Upper fixation of anchor rope

The upper fixation of mast anchor rope did not correspond to the drawing EK.707162 (see Figure 4.7a). The correct fixation according to drawing EK.707162 is shown in Figure 4.7b.
Figure 4.7a: Existing not correct upper fixation of mast anchor rope.

Figure 4.7b: Correct upper fixation of mast anchor rope according to the drawing EK.707162.
This is an installation mistake. It has to be removed the wrong fixation and changed by the application shown in Figure 4.7b. If this will be not changed it will break and the pole is moving down (see Figure 4.7c).

Figure 4.7c: The experiences show the consequences of broken fixation.

3.4.8 Cupal plates in catenary clamps

The cupal plates should be closed according to drawing EK.707258 (see Figure 4.8a). See the existing installation in Figure 4.8b.

Figure 4.8a: Correct position of cupal plates.
**Figure 4.8a:** The Cupal plates are not correct installed in catenary clamp.

This is an installation mistake. It has to be removed. If not the catenary wire will break by electrolytical corrosion.

### 3.4.9 Split pins used at the cantilever

The used split pin is not according to the F-number 251.908.410 (see Figure 4.9a).
Figure 4.9a: The used wrong split pin is too big.

Figure 4.9b shows the difference between the correct split pin (above) and the used wrong split pin (below).

Figure 4.9b: The split pin according to F-number 251.908.410 (above) and the used wrong split pin (below).

Due to using the wrong type of split pin it has to be negotiated with the Bane NOR if the split pin can be keep. On basic to present Bane NOR the material data and the agreement of Bane NOR it could be decided the split pin can be keep in the overhead contact line.
The use of the wrong split pin is an installation mistake.

3.4.10 Colors at screws in end terminations

The meaning of colors of end terminations are not clear (see Figure 4.10 a) to c)). There is an explanation necessary.

**Figure 4.10a:** Bolts with colors.

**Figure 4.10b:** Bolts with colors.
The material type cannot be checked of bolts and nuts. Therefore, it is an explanation necessary for the type of material. It has to be confirmed that the right material was used.

3.4.11 Loose nuts at cantilever

A screw is fix if the nut of the screw is fixed by an torque wrench with the required torque. This was definitely not done with the nut shown in Figure 4.11.

Figure 4.11: The counter nut at cantilever was not fixed.
Therefore, the nuts and screws have to be fixed by a torque wrench.

Loose nuts and screws are installation mistakes. All nuts have to be checked.

**3.4.12 Sag of feeder cables to the overhead contact line**

The feeder cables from switch to overhead contact line should have a sufficient sag according to drawing EK.800054. This is not given at pole in Figure 4.12.

![Figure 4.12: Not sufficient sag of feeder cable.](image)

This is an installation mistake and it has to be removed.

**3.4.13 Wire end at catenary and contact wire**

The wire ends are too long (see Figure 4.13a). It have to be cute according to the drawing e.g. EK.707320 (see Figure 4.13b). But each drawing of Bane NOR has the same requirements as EK.707320.

![Figure 4.13a: The end is too long and it should be no longer as required in drawing EK.707320.](image)
Figure 4.13b: The end is too long and it should be no longer as required in drawing EK.707320.

Figure 4.15c: Correct cute ends according to drawing EK.707320.

The too long wire ends are an installation mistake and have to be corrected.

3.4.14 Wrong contact wire clamp type

Sometimes it was used the wrong contact wire clamp type (see Figure 16a). The correct contact wire clamp type is shown in Figure 16b.
Figure 4.14a: Wrong contact wire clamp type.

Figure 3.14b: Correct contact wire clamp type according to drawing EK.707472.

Figure 3.14c: Contact wire clamp type according to drawing EK.707472.
The use of the wrong contact wire type is an installation mistake and it has to be removed.

3.4.15 Connection of jumper at contact and catenary wire

Current connection between catenary wire and contact wire has to be pressed with a C-press clamp according to drawing EK.707328 and an E-press clamp according to drawing EK.707327. This is not given in the inspected overhead contact line (Figure 4.15a).

**Figure 4.15a:** Wrong current connection at contact wire close to the section insulator.

**Figure 4.15b:** Correct pressed C-clamp current connection at catenary wire at another Norwegian S25 project.
Figure 4.15c: Correct pressed E-clamp at contact wire at another Norwegian project.

The use of the wrong screwed clamp is not complied with the C-press clamp according to drawing EK.707327 and E-press clamp according to drawing to EK.707327 is an installation mistake.

![Correct pressed E-clamp at contact wire](image)

**Figure 4.15d:** Correct pressed clamps: a) C-press clamp type f for catenary wire BzII 70 mm² according to drawing EK.707328, b) E-press clamp for contact wire AC-120-CuAg according to drawing to EK.707327.

3.4.16 Position of bolt at Cantilever

The bolts at cantilever tube have to be in the upright position as shown in Figure 4.16a) and b).
Figure 4.16a: Bolts in the upright position as an example at Gardermoen line.

Figure 4.16b: Bolts in the upright position as an example at Gardermoen line.
3.4.17 Plastic caps and wind stays in tunnel

In tunnels, it is not necessary to install plastic caps at tubes and wind stays (see Figure 4.17).

Figure 4.17: In tunnel, there are wind stay and plastic caps at Langset – Kleverud.

The installation of plastic caps and wind stays is an installation mistake.
3.4.18 Distance at the end of registration tube

The distance between end of registration tube a fixation of registration tube has to be 200 mm for pull-off support according to drawing EK.707399 and EK.707400.

This is not given at the cantilever shown in Figure 4.18a.

**Figure 4.18a:** The distance between end of registration tube a fixation of registration tube is too small.

**Figure 4.18b:** The distance between end of registration tube a fixation of registration tube has to be at least 200 mm according to drawing EK.707399.

The cutting of cantilever tubes is part of installation. Therefore, the too short registration tube is an installation mistake.

3.4.19 Moving of soffit pole clamps
The clamp according to drawing EK.707303 for soffit pole clamp bolt has to be fixed with a torque of 70 Nm for M16. The torque is missing in drawing EK.707303.

This was not given at soffit pole in Figure 4.19.

Figure 4.19: Moving soffit pole clamps at pole number 81-40.

It could be seen during the approval test a lot of loose screws having torques not according to the requirements. The right torques at soffit pole brackets are the basic for the correct and safe installation. The existing torques at bracket clamps were lower than 70 Nm. This could be seen during the approval test by Bane NOR. There are some videos demonstrating the loose screws. This is the reason for the downwards movement of bracket clamps of cantilever.

The not fixed screws at soffit poles are installation mistakes.

3.4.20 Adjustment of balance weights at tensioning device

The adjustment of balance weights has to be carry out according to drawing EK.707487. According to Figure 4.20 the correct adjustment was not given.
Figure 4.20: Balance weights are not correct adjusted depending on the temperature.

The balance weights are too low. For the S25 as a 70K overhead contact line system the existing temperature of around 5°C the weight should be close to the middle position (see drawing EK.707487).

The wrong adjustment of balance weights is an installation mistake.

3.4.21 Rusty bolts for fixation of aluminum traverse at tunnel wall

The bolts in the tunnel fixing the soffit pole traverse are rusty. Actually, stainless steel should be not rusty. Therefore, it has to be present the material certification of bolts.
Figure 3.21: Rusty bolts in the tunnel fixing the soffit pole traverse.

Stainless steel should not corrode. But the bolts fixing the soffit poles at the tunnel ceiling are rusted.

The material features should be checked

3.4.22 Grease at threats of screws

Figure 3.22: Missing grease at each stainless-steel threat.
The grease for the screw threat is important for untighten the screws. Otherwise stainless steel screws are cold welded. In this case, there is no possibility to lose the screw.

This is an installation mistake and it has to be removed.

### 3.4.23 Inclined droppers

The droppers have to be installed in the vertical position. Otherwise the contact wire height is not constant. The tolerance is given according to drawing EK.707159 with a maximum angle of 15°. The position of dropper showing in Figure 4.23 is outside the tolerance.

Figure 4.23: Inclined dropper is outside the tolerance.

### 3.4.24 HV cable without protection

Each high-voltage cable has to protect by a metal protection. This not give for the 15 kV 16,6 Hz cable shown in Figure 4.24.
Figure 4.24: HV cable without metal protection.

The missing metal protection of the MV - cable is an installation mistake.

3.4.25 Balance weights in Tunnel

The balance weights in the tunnel have different number of weight and have to be checked and corrected. Otherwise the tensile force in contact and catenary wire is not given and the interaction between overhead contact line and pantograph does not fulfil the requirements according to the Norwegian technical regulations.

The different number of balance weights is an installation mistake.

3.4.26 Distance between tensioning device to first dropper

The distance between tensioning device to first dropper has to be 20 m according to drawing EK.707398. This requirement is not given throughout.

The distance is important for touching a cracked wire to the ground. Otherwise the wire can be hanging in the air and there is no circuit breaker trip.

The not correct distance is an installation mistake.
3.4.27 Adjustment of cantilevers depending on temperature

The cantilevers have to be adjusted according to the temperature. According to drawing 4-02.05.33 (Figure 4.27) the cantilever adjustment has to be carried out.

![Figure 4.27: Adjustment of cantilever depending on temperature.](image)

The not correct adjusted cantilevers depending on the temperature is an installation mistake.

3.4.28 Contact wire height

Contact wire height has to be adjusted according to the tolerance of contact wire height. The tolerance are stated in "Kontaktledning/Prosjektering og Bygging/Kontaktledningsutforming/Vedlegg/Mekanisk utforming System 25, Mekanisk utforming System 25".

The tolerance are:

- g) Montasjenøyaktighet: Kontaktledningen skal monteres i henhold til angitte toleranser.
- Utførelse: Kontakttrådhøyde (hkt) ± 30 mm utjevnet over 3 spennlengder, maksimalt ± 20 mm mellom to utligger
- Utførelse: Bærelinehøyde (hbli) ± 50 mm
- Utførelse: Sikksakk ± 30 mm
- Utførelse: Utliggerens posisjon i kontaktledningens lengderetning ± 50 mm
The contact wire position measurements on 04.11.2016 for track Minnesund – Espa and on 04.11.2016 for track Espa - Minnesund can be not used for evaluation of contact wire height. The measurement of Roger 1000 does not fulfil the minimum requirement to a measurement for high-speed line and standard overhead contact lines (Figure 4.28a). Therefore, it is not possible to confirm the compliance the agreed tolerances above.

**Figure 4.28a:** Measurement record of contact wire height by Roger 1000.

**Figure 4.28b:** Measurement and evaluation record of contact wire height by the German measurement device.
With the measurement of Roger 1000 there is no possibility to evaluate the contact wire position measurement (Figure 4.28a).

I recommend the measurement of contact wire position again with a measurement device that fulfil the minimum requirements as shown in Figure 4.28b.

3.5 Poles

The twisted poles have to be measured how the torsions angle is. Is it lower than 6,0° in height of contact wire then the pole can be remain (see Ebs 02.03.20). If the angle is more than 6,0° than the pole has to be changed against a stronger one.

The requirement of the minimum torsions angle 6° is missing in the BN drawings. The requirement of 6° comes from the German requirement according to drawing Ebs 02.03.20.

3.6 Foundations

The movement of foundation after erection is a known process. Therefore, the anchor bolt allows an adjustment of poles. The adjustment of poles is part of the installation of overhead contact lines and has to be done by the installation company. But the adjustment of contact wire height and stagger has to be done with the cantilever and not with the pole adjustment. If a pole moves downwards there is no locally contact wire wear as could be seen in the inspection.

I am not able to evaluate if Bane NOR’s or INFRANORD’s measurement of foundation is correct.

4 Priority of removals

I suggest the following priorities:

1. Update of drawings
2. Candrop calculations for Y-stich wires
3. replacement of ten tension lengths of contact wire together with the droppers
4. removal of contact wire bumps, kinks and wave of the residual contact wire lengths together with replacement of droppers
5. removal of findings from clause 3.4.4 to 3.4.28

The removal work has to include the findings of the protocol EK.112681-000.

5 Letter of INFRANORD on 06.04.2017
I got this letter on 07.04.2017. This one day after the agreed date of the agreement between Bane NOR, INFRANORD and Expert Consultancy. But the issues of INFRANORD are answers in the present report.

Igensdorf, 13.04.2017