

Translation of Corrosion test report from FORCE 2005

Corrosion test of grease for StAl conductors

FORCE Technology has made a salt fog test of steel plates applied 5 different greases, used for overhead conductors.

The purpose is to judge, which one is best for corrosion protection.

Test samples

Greases

The following greases have been tested:

- 1) Ceritol SV 2KF
- 2) Castrol Rustilo 450
- 3) Castrol Rustilo 431
- 4) Metalube OCG 1000
- 5) Metalube OCG 5000

Plates

1. Sendzimir zinc coated steel plates Z275 (continuous hot-dip zinc coated steel plate with 275 g zinc pr. m² plate, equaling 19 µm at each plate)
2. Aluminum plates Al 99,5 corresponding to alloy AA1050, 100x50x1 mm

Preparation of test subjects

The face of all zinc coated plates was prepared with abrasive sponge (3M) until fully frosted, resulting in the colorless oxide covering to be removed. All plates were then degreased.

The edges of the plates were taped. At steel plates 1-5 was used tape with a thickness of 0.40 mm. At plates 6-10 and at all aluminum plates was used tape with a thickness of 0.45 mm.

The plates was greased with filling knife, and additional grease was swept off with a rail witch was drawn against the tape edges to leave a level layer of grease at the thickness of 0.40 and 0.45 mm thickness. The amount of grease was decided from the plate weight before and after greasing.

Plate number, grease type and amount of grease are shown in table 1 and 2 at both steel and aluminum plates.

Pictures 1-6 is showing the plates before installing in fog chamber.

Salt fog exposure

The salt for exposure is done according to ISO 9227. By this the upwards plate surface is exposed to atomized salt water consisting of 5 % weight NaCl in de mineralized water at a temperature at 35±2 °C and pH-value at 6.5-7.2.

During exposure the plates are placed in plastic containers, the plate faces at a vertical slope of 20°.

Results

The plate surfaces are visually inspected for white and red rust after 216, 511, 1039, 1467 and 2212 hours of salt fog exposure.

Pictures 7-13 are showing face photos of the plates by the inspections. Pictures 14-19 is showing close up photos of the zinc coated steel plates after 2212 hours of exposure.

The exposure was stopped after 2212 hours, and after drying the grease was dissolved and removed with benzene, and at the zinc coated steel plates was loose corrosion products washed off with hot water and brush. The plate surfaces were then visually inspected and the surfaces of the aluminum plates furthermore examined with stereo microscope to check for local corrosion and pits. At the zinc coated steel plates the remaining zinc layer was measured.

Aluminum plates:

The results from the visual inspection during and after the salt fog test is shown in table 4 and, as it is shown here, that even after 2212 hours of salt fog exposure none of the plates have visual signs of corrosion on the grease covered surfaces. Only the reference plate, which is not greased, has a visual amount of superficial corrosion.

The grease is therefore removed with benzene and the surfaces then examined visually and in stereo microscope. The results of the examination are shown in table 5.

These plates are totally non-corroded:

2A, 7A with Castrol Rustilo 450
 5A, 10A with OCG 5000
 6A with Ceritol SV 2KF

The corrosion at the remaining greased plates is superficial and of modest extent, and none of the plates except reference plate A11 have local corrosion or pits in the surface.

Pictures 20-22 are showing photos from stereo microscope examination of the plate surfaces.

Zinc coated steel plates:

In table 3 it shows, that after 1039 hours salt fog exposure there are yet only white rust (white rust = corrosion products from zinc) at the greased zinc coated steel plates. At the reference plate without grease (no. 11), there is red rust at 5 % of the surface already at 1. inspection after 216 hours exposure. At the greased plates the first red rust appear after 1467 hours of exposure at plate 1 (Ceritol SV 2KF) and plate 4 (OCG 1000). After finished exposure only plate 7 (Castrol Rustilo 450) and plate 10 (OCG 5000) are totally without red rust.

Note that Ceritol SV 2KF appears white, and that white rust therefore is difficult to recognize. The slowly development in white rust at plates 1 and 6 should therefore not be attached much importance. The same regards plates 3 and 8 (Castrol Rustilo 431), where the visual judgment of the extent of white rust is remarkably less than what is recognized after removing of grease and washing off corrosion products, as it is later shown. The most important parameter for the durability of the corrosion protection is the time that passes until red rust appears at the steel surfaces of the plates. Red rust appears, when the zinc covering is wasted away in an area at the plate surface.

Appendix 1 shows a graphical presentation of the results of the visual inspections. The ranking of the 5 tested greases protection ability judged based on average red rust percentages are:

1: OCG 5000 (Best)
 2-3: Castrol Rustilo 450
 2-3: Castrol Rustilo 431
 4: Ceritol SV 2KF
 5: OCG 1000 (Worst)

At the plates with the 3 best ranked greases the grease and loose corrosion products was removed, and plate surfaces inspected visually, and thickness of remaining zinc layer was measured after corrosion products at the surface was removed with abrasive cloth. Pictures of the surfaces after cleaning and the measured zinc layer thicknesses are shown in appendix 2.

The examination confirm, that OCG 5000 (plate 5 and 10) has made the best protection, as there are only minor extends of rust starting along the tape edges. At plate 10 the zinc covering at major parts of the plate is without considerable corrosion). The thicker grease film at plate 10 at 0.45 mm is thus having a positive effect at the protection compared to the plate 5, where the thickness of the grease film is 0.40 mm

The better protection from a thicker grease film is also shown by comparing plates 2 and 7 (Castrol Rustilo 450) as the zinc covering at the last mentioned is intact and without considerable corrosion at 50% of the plate surface. Contrary to this the zinc covering at plate 2 is mostly wasted away at the whole surface.

At plates 3 and 8 with Castrol Rustilo 431 the zinc covering is mostly wasted away at the whole surface at both plates, and the protection is therefore considered to be less than with Castrol Rustilo 450. The final judgment of the 5 greases protection ability judged from salt fog test is therefore:

- 1: OCG 5000
- 2: Castrol Rustilo 450
- 3: Castrol Rustilo 431
- 4: Ceritol SV 2KF
- 5: OCG 1000

Conclusion

The protection ability of 5 different corrosion protection greases, witch are considered used for corrosion protection of StAl high voltage conductors, is judged. The protection ability is judged by salt fog exposure of zinc coated steel plates and aluminum plates both covered with grease film in 0.40 and 0.45 mm thickness.

All 5 greases showed good protection ability at the aluminum plates. After 2212 hours of salt fog exposure there was only found minor superficial corrosion at up to 2% of the surface of some test plates. Both aluminum plates with OCG 5000, both aluminum plates with Castrol Rustilo 450 and one of the plates with Ceritol SV 2KF was totally without corrosion.

All 5 greases also showed good corrosion protection of the zinc coated steel plates, compared to the reference plate without grease. The first rust attacks at the greased plates was not found until after 1467 hours salt fog exposure, and the exposure was stopped after a total time at 2212 hours, at witch time just minor starting red rust attacks was found at the plates with the best protecting grease. Based on the inspections and examinations that were made, the ranking of the durability of the corrosion protection of the 5 greases is:

- 1: OCG 5000 (Best)
- 2: Castrol Rustilo 450
- 3: Castrol Rustilo 431
- 4: Ceritol SV 2KF
- 5: OCG 1000 (Worst)

Table 1. Zinc layer thickness and grease mass at Sendzimir zinc coated steel plates

| Plade nr. – fedt type | | Zink-lagtykkelse (μm) | Tape-tykkelse | Fedt masse (g/m^2) | Fedtmasse, gennemsnit (g/m^2) | Afvigelse ¹⁾ |
|-----------------------|---------------------|------------------------------------|-------------------|--------------------------------------|---|-------------------------|
| 1 | Ceritol SV 2KF | 23,0 | tape 1 0,40 mm | 226 | 224 | 1% |
| 2 | Castrol Rustilo 450 | 22,9 | | 212 | | -5% |
| 3 | Castrol Rustilo 431 | 22,7 | | 233 | | 4% |
| 4 | OCG 1000 | 22,0 | | 211 | | -6% |
| 5 | OCG 5000 | 21,3 | | 236 | | 6% |
| 6 | Ceritol SV 2KF | 23,7 | Tape 2 0,45 mm | 372 | 358 | 4% |
| 7 | Castrol Rustilo 450 | 23,6 | | 331 | | -8% |
| 8 | Castrol Rustilo 431 | 21,3 | | 366 | | 2% |
| 9 | OCG 1000 | 21,3 | | 377 | | 5% |
| 10 | OCG 5000 | 23,8 | | 343 | | -4% |
| 11 | - | 22,7 | - | 0 | - | - |

¹⁾ Grease mass deviation from average value

Table 2. Grease mass at aluminum plates

| Plade nr. – fedt type | | Tape-tykkelse | Fedt masse (g/m^2) | Fedtmasse, gennemsnit (g/m^2) | Afvigelse ¹⁾ |
|-----------------------|---------------------|---------------|--------------------------------------|---|-------------------------|
| 1A | Ceritol SV 2KF | tape 0,45 mm | 338 | 368 | -8% |
| 2A | Castrol Rustilo 450 | | 375 | | 2% |
| 3A | Castrol Rustilo 431 | | 349 | | -5% |
| 4A | OCG 1000 | | 362 | | -2% |
| 5A | OCG 5000 | | 361 | | -2% |
| 6A | Ceritol SV 2KF | | 394 | | 7% |
| 7A | Castrol Rustilo 450 | | 388 | | 5% |
| 8A | Castrol Rustilo 431 | | 324 | | -12% |
| 9A | OCG 1000 | | 366 | | 0% |
| 10A | OCG 5000 | | 419 | | 14% |
| 11A | - | - | 0 | - | - |

¹⁾ Grease mass deviation from average value

Table 3. Results of visual inspection of Sendzimir zinc coated steel plates with grease.
 Areal % shows the percentages of surface, where white rust (HR) or red rust (RR) is visible under grease film.
 U-korr. Shows the less and most distance from tape edge, where corrosion is visible under grease film.

| Plade nr. | Fedt-Fab. | 1. inspektion, 216 t | | 2. inspektion, 511 t | | 3. inspektion, 1039 t | | 4. inspektion, 1467 t | | 5. inspektion, 2212 t |
|-----------|---------------------|----------------------|--------------|----------------------|--------------|-----------------------|--------------|-----------------------|--------------|-----------------------|
| | | Areal % | U-korr. (mm) | Areal % | U-korr. (mm) | Areal % | U-korr. (mm) | Areal % | U-korr. (mm) | Areal % |
| 1 | Ceritol SV 2KF | 2 % HR | 0 | 2 ¹⁾ | 0 | 30 | 2-40 | 5 %RR+95 %HR | - | 20%RR+80%HR |
| 2 | Castrol Rustilo 450 | 60 % HR | 7-24 | 95 % HR | 30-40 | 100 %HR | 0-40 | 100 %HR | - | 10%RR+80%HR |
| 3 | Castrol Rustilo 431 | 0 % HR | 0 | 2 ¹⁾ | 0-8 | 10 %HR | 0-18 | 40 %HR | 2-35 | 10%RR+60%HR |
| 4 | OCG 1000 | 50 % HR | 15-27 | 90 % HR | 27-35 | 90 %HR | - | 5 %RR+95 %HR | - | 40%RR+60%HR |
| 5 | OCG 5000 | 40 % HR | 0-17 | 70 % HR | 17-31 | 100 %HR | - | 100 %HR | - | 1%RR+100 %HR |
| 6 | Ceritol SV 2KF | 0 % HR | 0 | 2 ¹⁾ | 0 | 20 %HR | 0-20 | 100 %HR | - | 5%RR+95%HR |
| 7 | Castrol Rustilo 450 | 10 % HR | 0-16 | 80 % HR | 25-35 | 100 %HR | - | 100 %HR | - | 100 %HR |
| 8 | Castrol Rustilo 431 | 0 % HR | 0 | 5 % HR | 0-7 | 10 %HR | 0-22 | 40 %HR | 5-34 | 10%RR+70%HR |
| 9 | OCG 1000 | 20 % HR | 0-15 | 50 % HR | 14-20 | 100 %HR | - | 100 %HR | - | 10%RR+90%HR |
| 10 | OCG 5000 | 10 % HR | 0-15 | 60 % HR | 12-29 | 100 %HR | - | 100 %HR | - | 100 %HR |
| 11 | Ref – uden fedt | 5 %RR+95 %HR | - | 20 %RR+80%HR | - | 80 %RR+20%HR | - | 85 %RR+15%RR | - | 95 %RR+5%HR |

1) Small extend of white rust visible along tape edges

Table 4. Results of visual inspection of aluminum plates with grease.

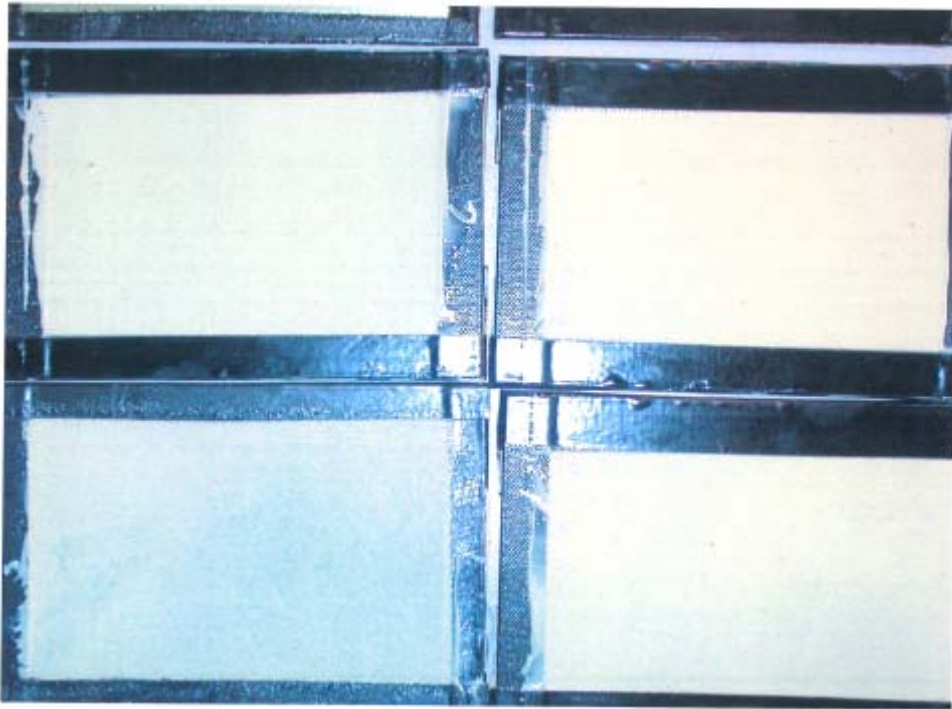
| Plade nr. | Fedtfabrikat | 1. inspektion, 216 t | | 2. inspektion, 511 t | | 3. inspektion, 1039 t | | 4. inspektion, 1467 t | | 5. inspektion, 2212 t | |
|-----------|---------------------|----------------------|-----------------|----------------------|-----------------|-----------------------|-----------------|-----------------------|-----------------|-----------------------|-----------------|
| | | Areal % | Underkorr. (mm) | Areal % | Underkorr. (mm) | Areal % | Underkorr. (mm) | Areal % | Underkorr. (mm) | Areal % | Underkorr. (mm) |
| 1A | Ceritol SV 2KF | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2A | Castrol Rustilo 450 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3A | Castrol Rustilo 431 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4A | OCG 1000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5A | OCG 5000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6A | Ceritol SV 2KF | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7A | Castrol Rustilo 450 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8A | Castrol Rustilo 431 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9A | OCG 1000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10A | OCG 5000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11A | Ref. | 1 ¹⁾ | - | 2 ¹⁾ | - | 2 ¹⁾ | - | 2 ¹⁾ | - | 2 ¹⁾ | - |

1) Few pits in aluminum surface

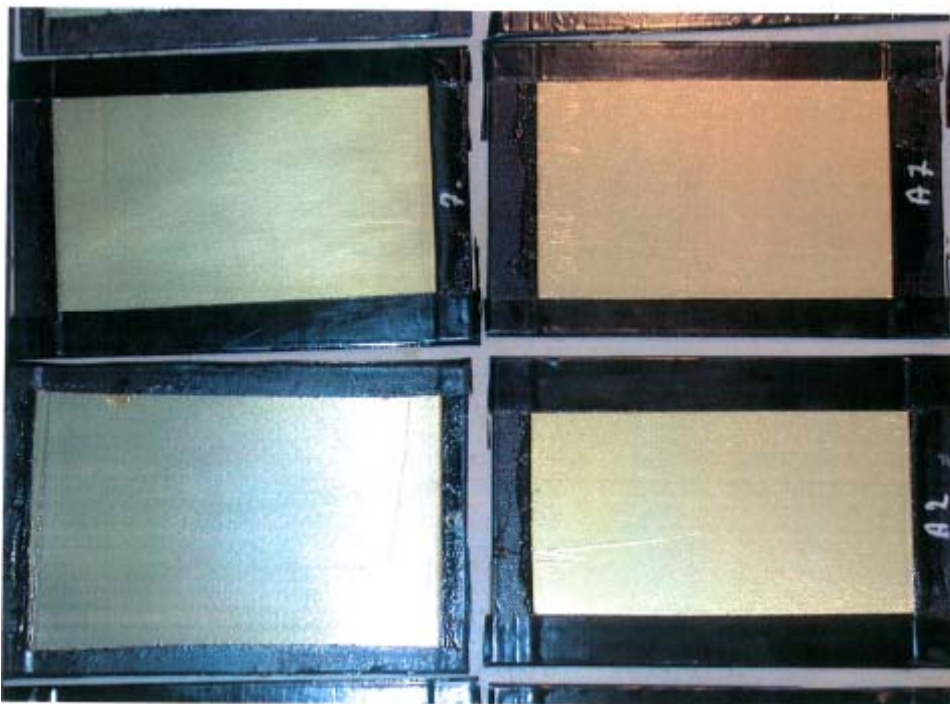
Table 5. Result of examination of aluminum surfaces after finalized salt fog exposure

Surfaces are examined visually and in stereo microscope after removing the grease film.

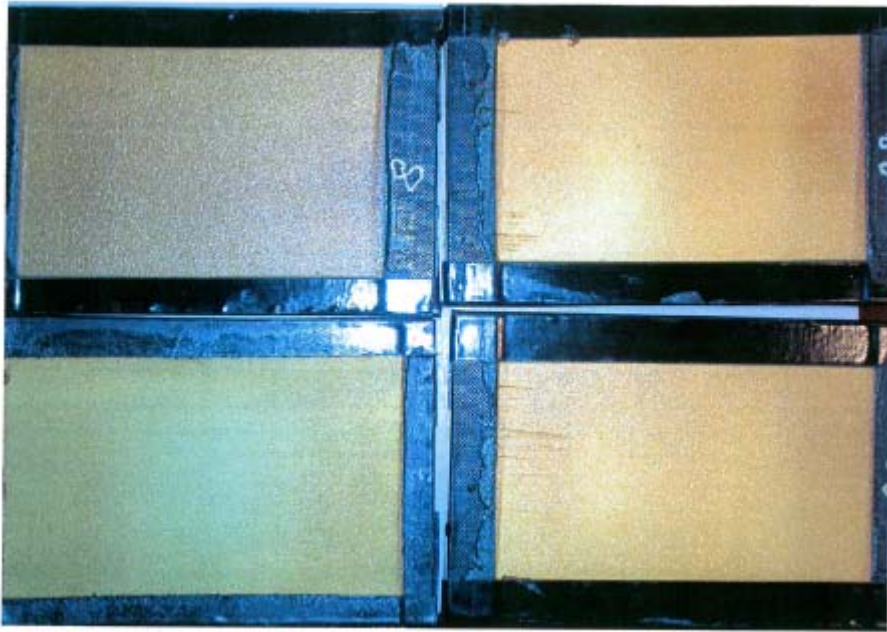
| Testplade | Fedtfabrikat | % af overflade med korrosion |
|------------------|---------------------|--|
| 1A | Ceritol SV 2KF | under 1 %, overfladisk korrosion |
| 2A | Castrol Rustilo 450 | 0 |
| 3A | Castrol Rustilo 431 | ~ 2 %, overfladisk korrosion |
| 4A | OCG 1000 | ~ 2 %, overfladisk korrosion langs tapekant |
| 5A | OCG 5000 | 0 |
| 6A | Ceritol SV 2KF | 0 |
| 7A | Castrol Rustilo 450 | 0 |
| 8A | Castrol Rustilo 431 | ~ 2 %, overfladisk korrosion |
| 9A | OCG 1000 | Under 1 %, overfladisk langs tapekant |
| 10A | OCG 5000 | 0 |
| 11A | Ref. uden fedt | 90 % let overfladisk korrosion og små, spredte grubetæring |



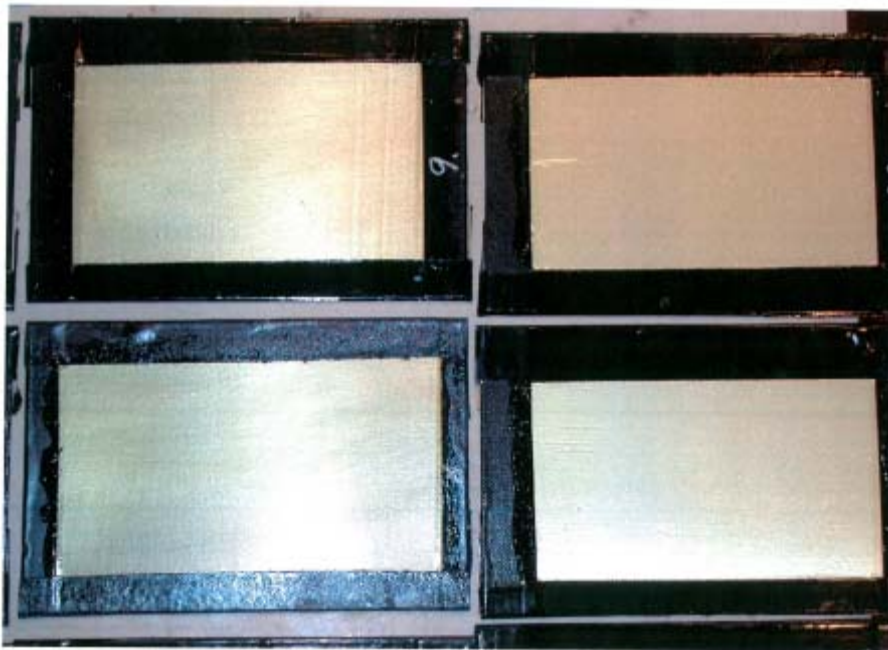
Picture 1. Plates 1, 6, A1, A6 before exposure



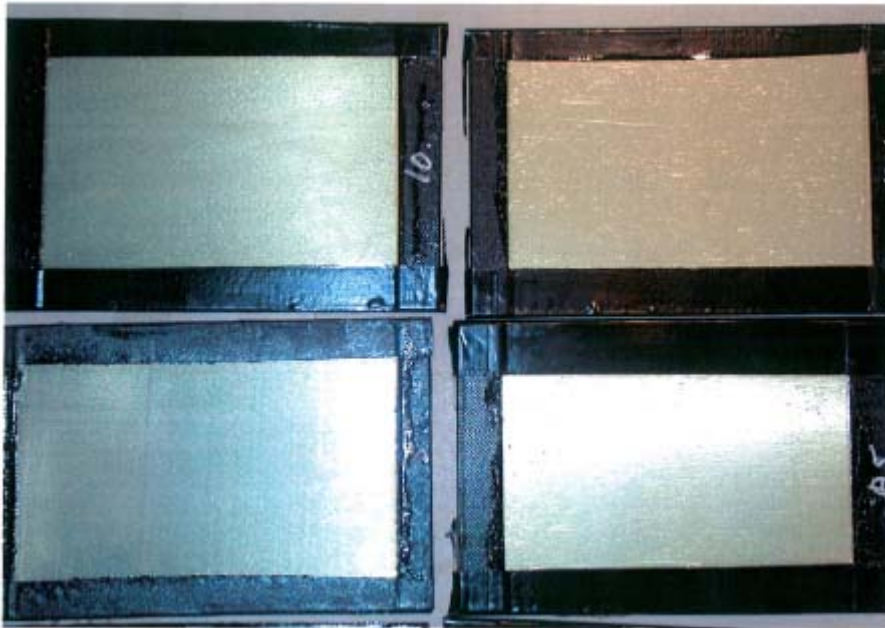
Picture 2. Plates 2, 7, A2, A7 before exposure



Picture 3. Plates 3, 8, A3, A8 before exposure



Picture 4. Plates 4, 9, A4, A9 before exposure



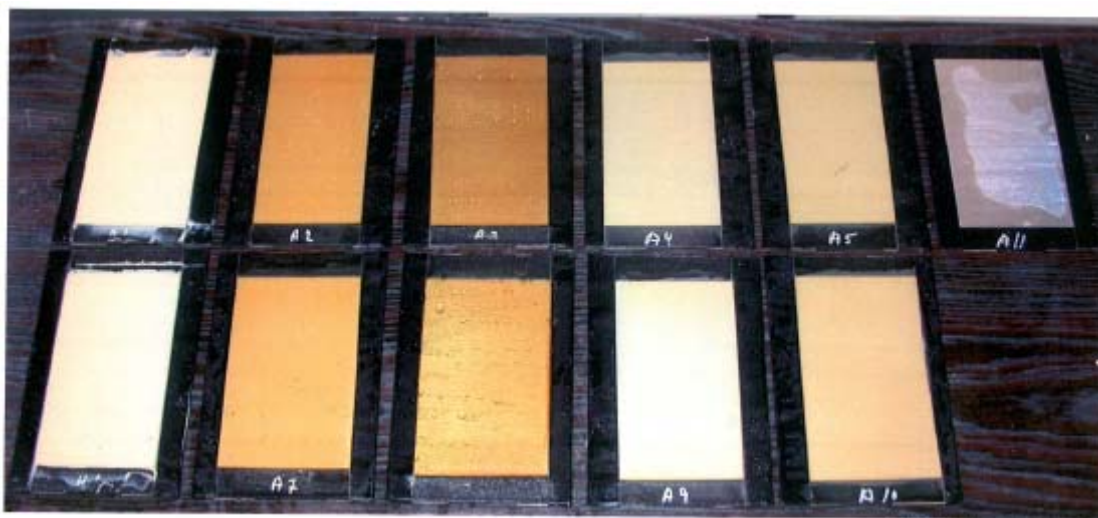
Picture 5. Plates 5, 10, A5, A10 before exposure



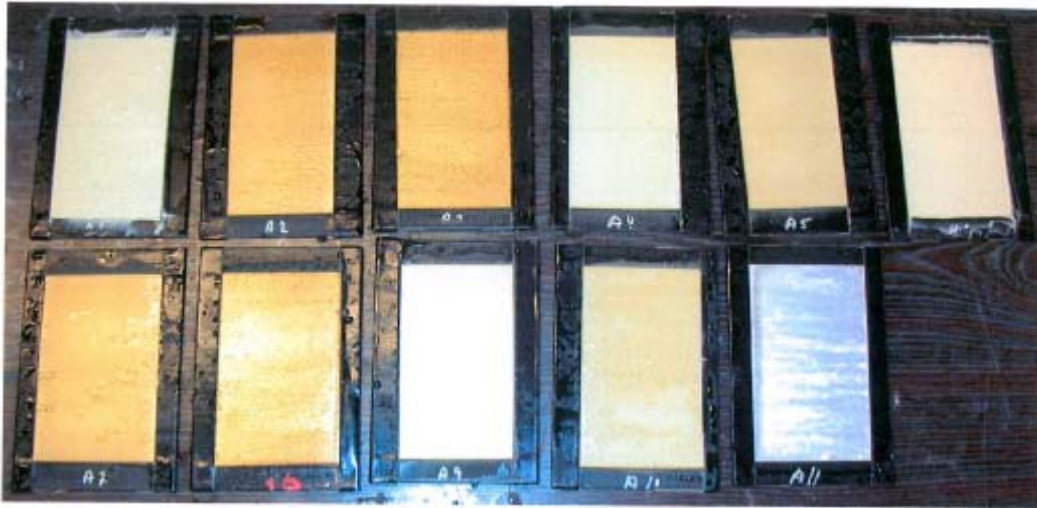
Picture 6. Reference plates before exposure



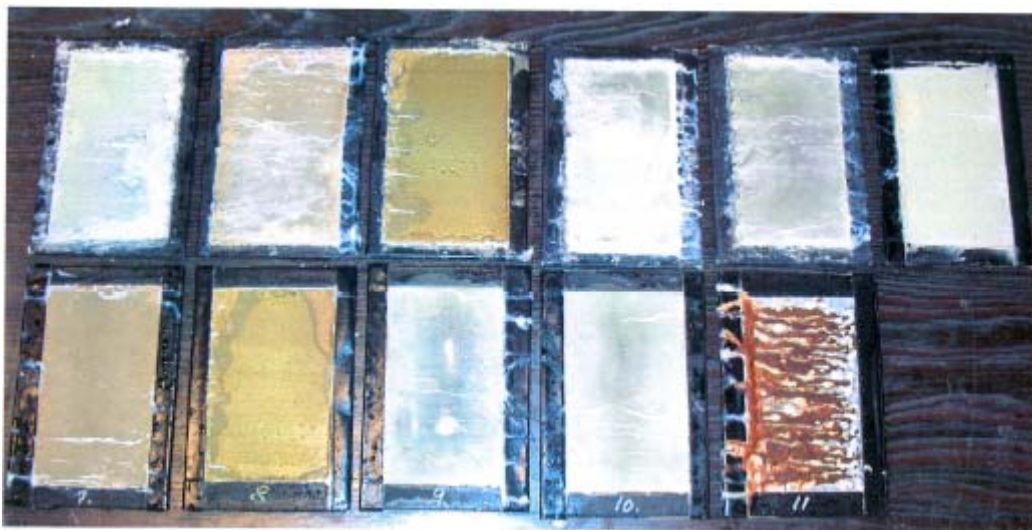
Picture 7. Overview over zinc coated steel plates after 511 hours exposure



Picture 8. Overview over aluminum plates after 511 hours exposure.



Picture 9. Overview over all aluminum plates after 1039 hours exposure



Picture 10. Overview over all zinc coated steel plates after 1039 hours exposure



Picture 11. Overview of all aluminum plates after 1467 hours exposure



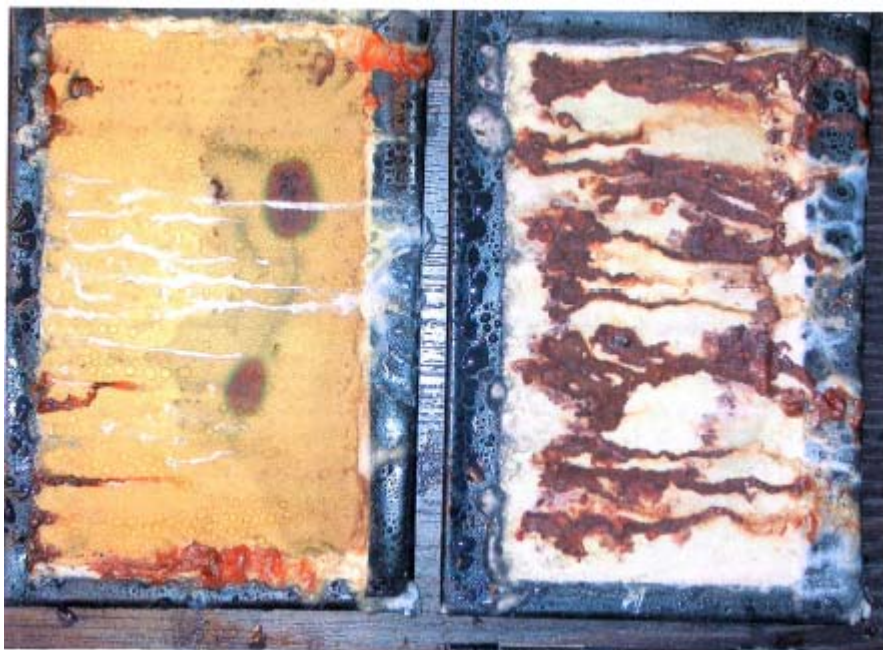
Picture 12. Overview of all zinc coated steel plates after 1467 hours exposure



Picture 13. Overview of all aluminum plates after 2212 hours exposure



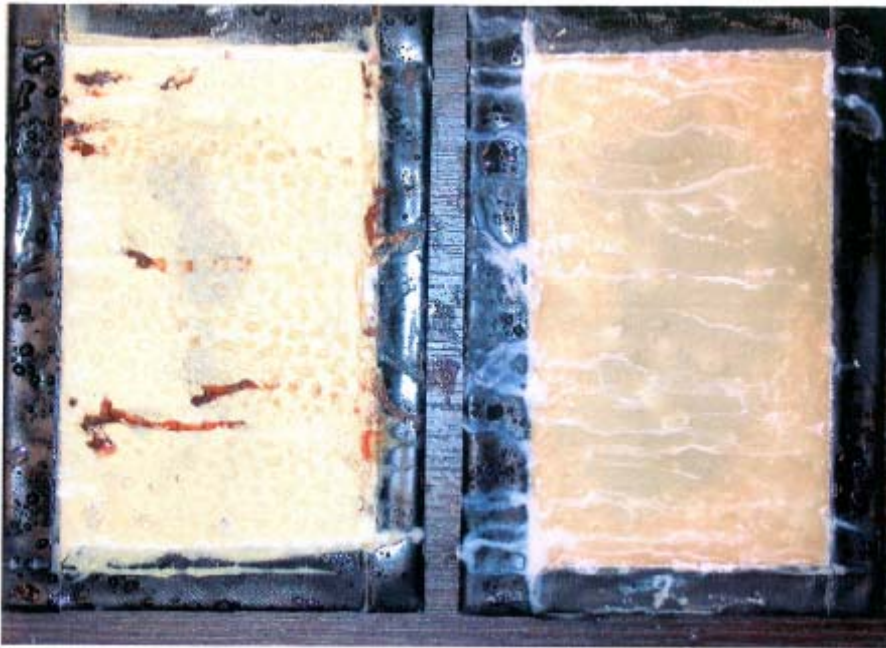
Picture 14. Plate 1, 2 after 2212 hours exposure



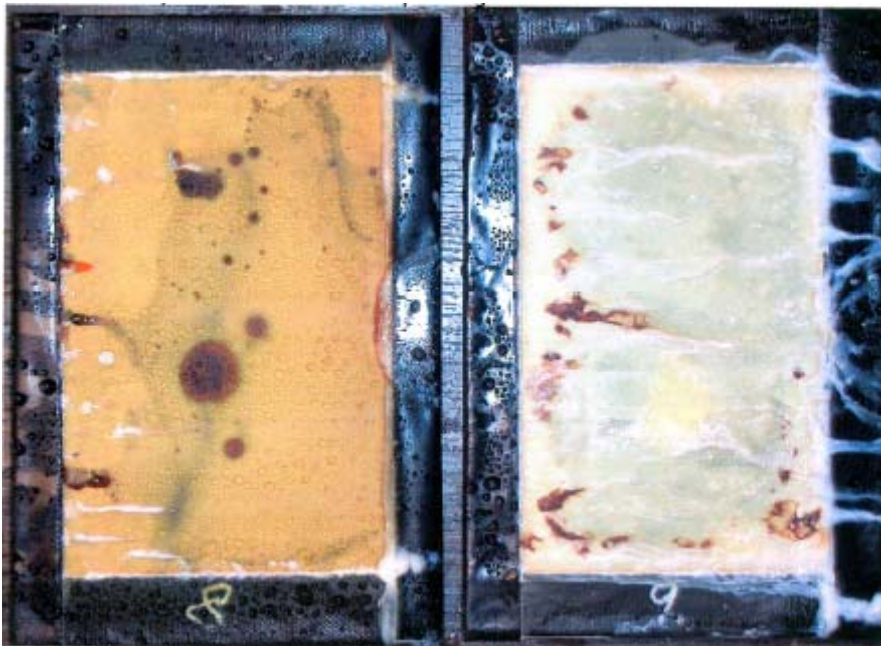
Picture 15. Plates 3,4 after 2212 hours exposure



Picture 16. Plate 5 after 2212 hours exposure



Picture 17. Plates 6, 7 after 2212 hours exposure



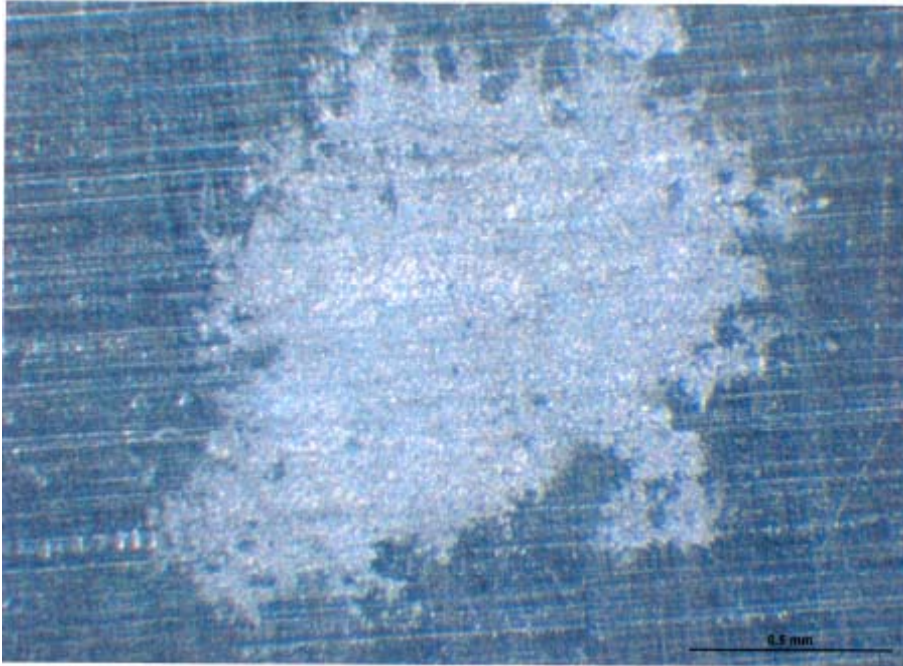
Picture 18. Plates 8, 9 after 2212 hours exposure



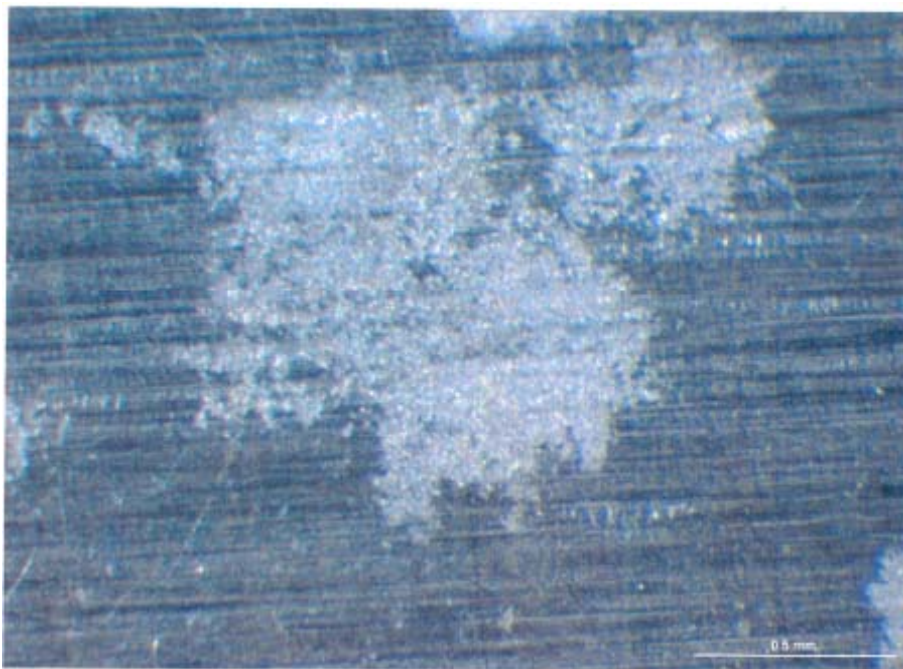
Picture 19. Plates 10, 11 after 2212 hours exposure



Picture 20. Stereo microscope. Plate A1 after 2212 hours exposure
In the middle of the picture, a small superficial corrosion attack is visible after removing the grease film. Note that the magnification is specified in right bottom corner



Picture 21. Stereo microscope. Plate A3 after 2212 hours exposure
Photo from stereo microscope showing superficial corrosion attack at aluminum surface



Picture 22. Stereo microscope. Plate A8 after 2212 hours exposure
Photo from stereo microscope showing superficial corrosion attack at aluminum surface

Appendix 1. Graphical overview over the results from visual examination of the plate surfaces.

The percentages of White rust (blue) and Red rust (brow) at plate surfaces by inspection 1-5.

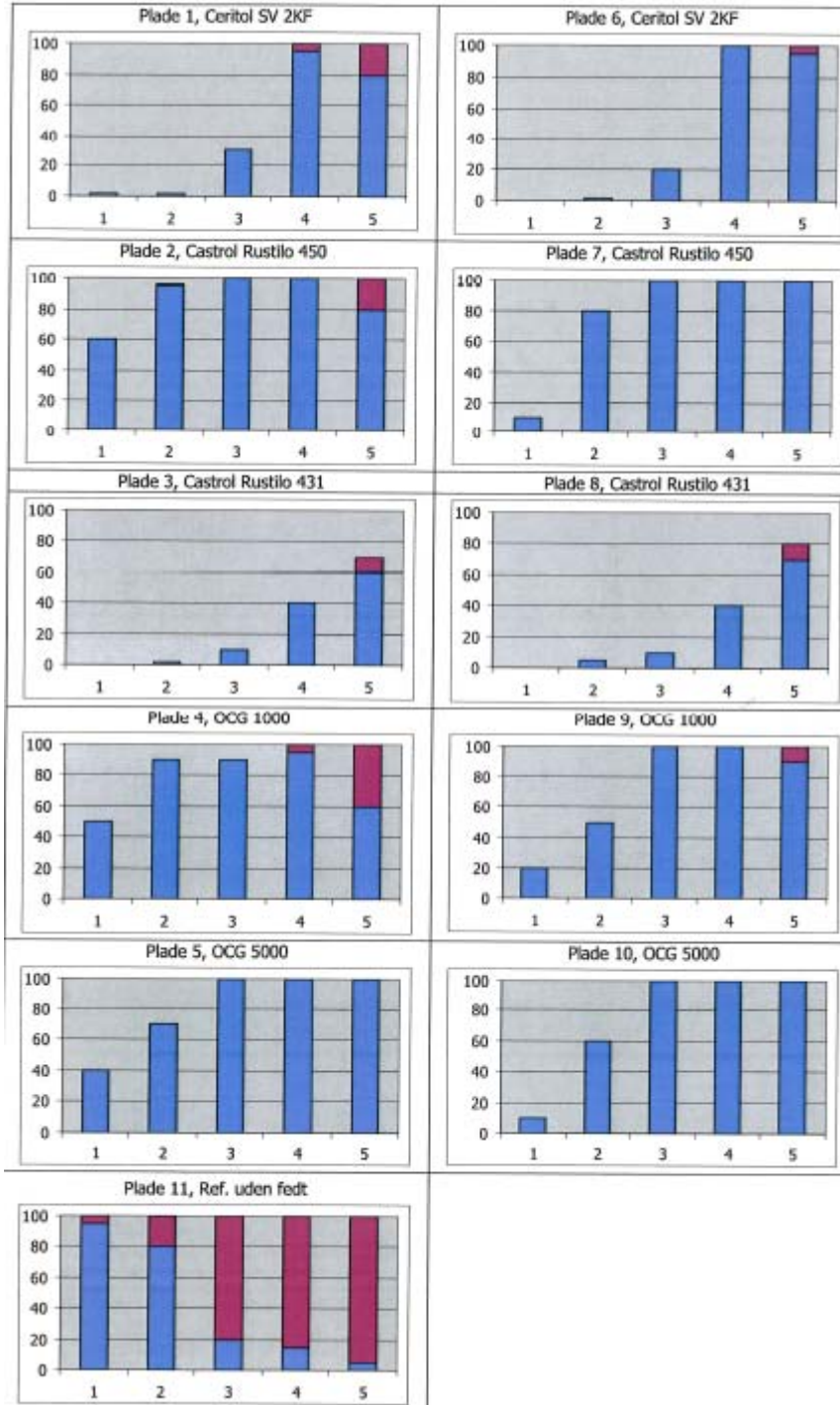




Plate 3 – 2212 hours

The zinc covering is mostly wasted away at the whole plate surface except upper right corner, where a remaining zinc layer at 6 µm is measured.

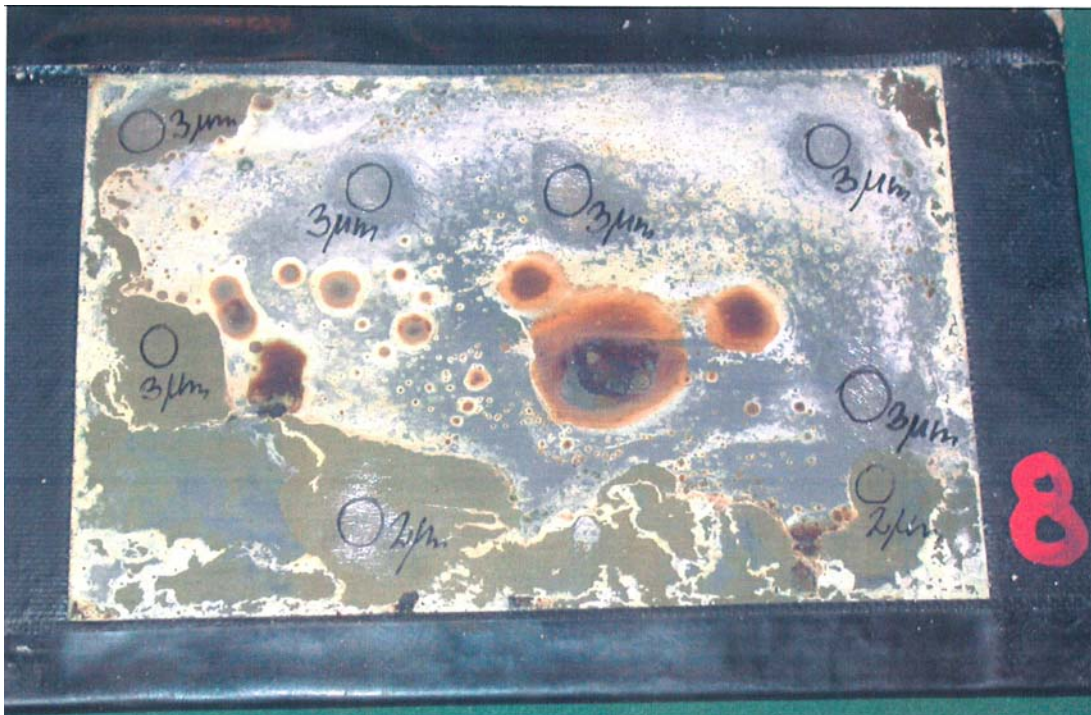


Plate 8 – 2212 hours

The zinc covering is mostly wasted away at the whole plate surface, as the remaining zinc layer is negligible.



Plate 5 – 2212 hours

The zinc covering is mostly wasted away at most of the plate surface along the tape edges. At the middle of the plate, in an area of app. 20 % of the surface, a zinc layer at 24 μm , corresponding to the layer before exposure, is measured. The grease has thus given a firm protection in this area.

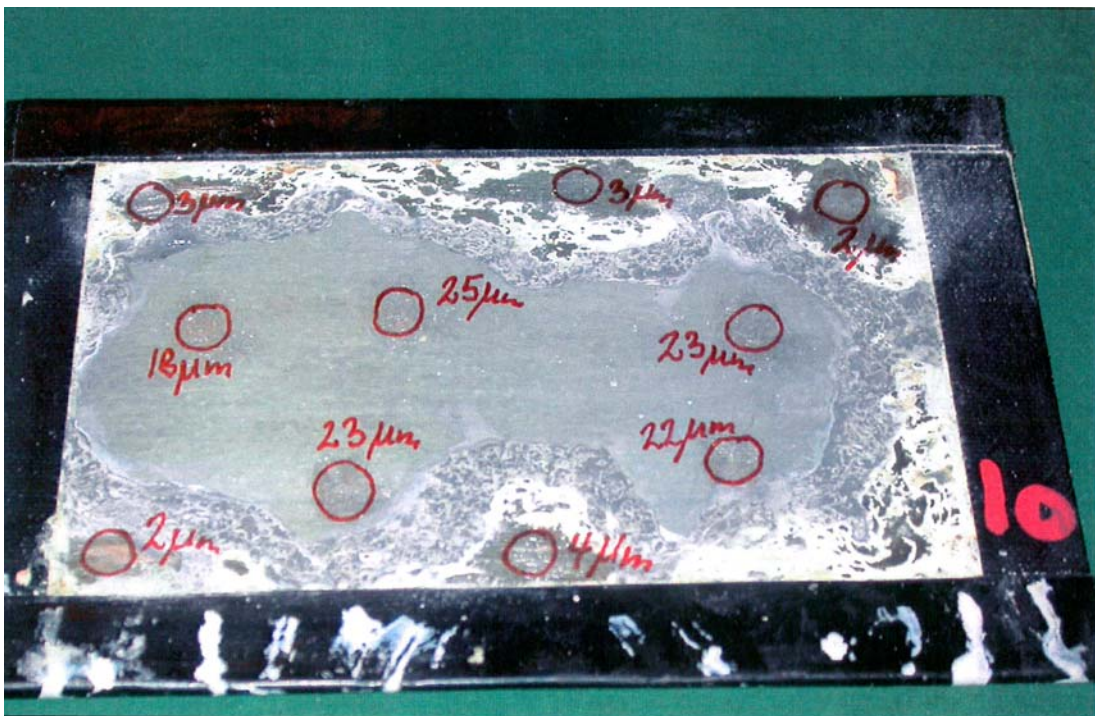


Plate 10 – 2212 hours

The zinc covering is shown to be mostly wasted away along the tape edges, where 2-4 μm remaining zinc layer is measured. The zinc covering is mostly intact at the rest of the plate surface (app. 60 % of the surface), where zinc layer thicknesses corresponding to the original is measured.