# 100 Cycle Testing Summary

# Elisha Reference – LR 1481

# Wheel Stud Scoping
# GM9540P Protocol

# December 5, 2005

## Background

Representatives of aluminum wheel manufacturer inquired about high performance coatings to be used on wheel studs for heavy trucks and trailers at the 2005 Annual Meeting of the Truck Maintenance Council (TMC). Discussions between Aluminum wheel manufacturer, Orscheln, and Elisha resulted in an agreement to test various Elisha-based fasteners coatings to benchmark performance on the Aluminum wheel manufacturer parts.

## Test Configuration & Test Initiation

Test wheel bolts and matching nuts were supplied for testing by Aluminum wheel manufacturer. Elisha coated the parts with test coating systems.

The bolts were installed into hubs that were cut along diameter at an angle appropriate for ASTM recommended accelerated corrosion orientation (15° in recline position). Each coating system was used on four fasteners and installed into the four full fastener holes across the top of the hub so as to minimize and eliminate drip and shielding.

Fasteners were installed with an aluminum spacer to simulate an aluminum wheel. The aluminum alloy used in wheels is 6061-T6. The assembly as used in the field sometimes includes a cast iron brake drum. A cast iron insert was not included in the test so that the results are not overwhelmed by the iron rust bleed from the cast iron. A spacer made from 6061-T6 was included to insure an engagement of the threads in the fastener joint.

Wheel bolts were pressed into place using a hydraulic press. A support fixture for bracing was used. The fastener joint was completed by installing the nut using a 1" air impact gun at approximately 75psi. Typical field data would indicate this tool at this pressure would impart the specified 450-500 ft-lbs torque. The approximate tension in the wheel stud after bolt-up was estimated to be 42,000 lbs.

## Test Coatings

Coated bolts with nuts coated in the same test coating system will be installed into aluminum hubs also supplied by the aluminum wheel manufacturer.

Elisha tested several high-performance coating systems which will be compared to the currently specified “phos & oil” coatings. The following coatings will be tested:

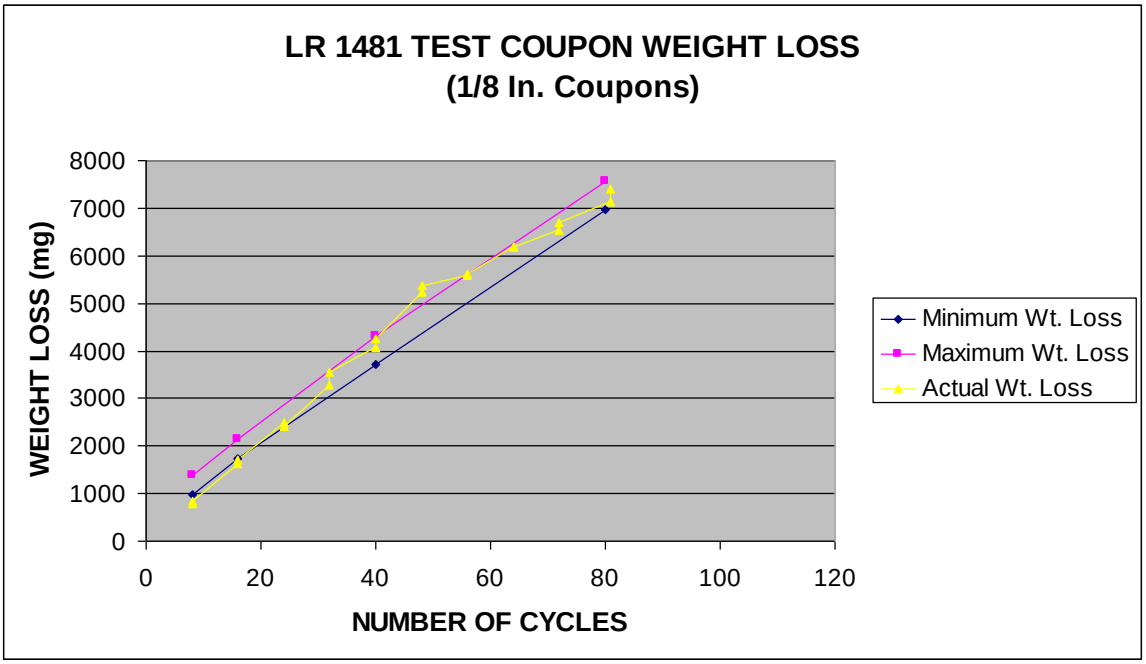
- **Elisha 0250 (Group 1)** further described as zinc plate with Elisha EMC coating and sealer. Currently approved to General Motors GM3044 8k120/240.
- **Elisha 0251 (Group 2**) further described as zinc plate with Elisha EMC coating and heat cured epoxy topcoat. Currently approved to Ford S440 applications, General Motors GM7113 (no-chrome), and under review by Department of Defense Truck Armament Command (DoD TACOM).
- **Elisha 7201 (Group 3)** further described as Sharperized zinc-nickel blackened alloy plate with EMC coating and black UV resistant sealer. Currently approved to Ford WSS

M21P25 B1/B2, Ford WSS M21P189-A10/A17, and General Motors GMW4205 specifications

- **Elisha 7203 (Group 4)** further described as Sharperized zinc-nickel silver alloy plate with EMC coating and clear sealer. Currently approved to Ford WSS M21P25 B1/B2, Ford WSS M21P189-A10/A17, and General Motors GMW4205 specifications. Do to scheduling conflicts, nuts using Elisha 7201 were used in this Group.
- **Aluminum wheel manufacturer Current Technology (Group 5)** further described as iron or zinc phosphate with oil immersion. No surface treatment of these parts will be done. The parts were tested "as received".

## Testing Protocol

Accelerated corrosion testing is being performed using GM9540P cyclic corrosion test protocol. As required by protocol, weight loss coupons will be used and tracked to determine the corrosion rate experienced during the testing cycle. The weight loss data through 80 cycles is illustrated in the following graph, and is within acceptable limits.




Break-away of the fasteners will be performed on two of the four fasteners at two or three intervals in the test. The suggested time period is 40, 80 and 120 cycles. The first break away tests were performed on two of the four samples at 40 cycles. The remaining two samples will be left in accelerated corrosion until the termination of the test to be used as comparison of those samples which were broken and retorqued intermittently in the test. It is not possible to directly measure the breakaway torque, but the nuts were removed using the same impact wrench. It was noted what air pressure is required to remove the nuts. The resulting torque to remove the nuts will be implied by the pressure required to remove relative to the installation pressure.

## Results and Reporting

Visual observations will be recorded every cycle for the first 5 cycles, then 10 cycles, and then every 20 cycles until test termination. Photographs will be taken at 5, 10, 20 cycles, and

then every 20 cycles until test termination. Groups will be terminated when all parts show 5% red corrosion.

Break-away data will be recorded at all break away intervals.

Interim reporting will be completed when at least two groups have failed from the testing.

Final report will be completed after all groups fail. Final report will include summary observations (first white, first red, 5% red), photographs and summary conclusions.

GM 9540P testing started on LR 1481 on July 20, 2005. Samples reached 40 cycles on August 29, 2005. Data for 40 cycles is included in this report. Additional reporting and overall conclusions will be made after further testing and at the termination of the test.

## Group ID & Pictorial Results

**Group 1 – Elisha 0250**
**Group 2 – Elisha 0251**
**Group 3 – Elisha 7201**
**Group 4 – Elisha 7203 studs (Elisha 7201 nuts)**
**Group 5 – Aluminum Wheel Manufacturer Current Technology**

The following photos were taken prior to and during corrosion testing. The pre-testing photos serve to document the level of damage that was inflicted by assembly.

## GROUP 1 – Elisha 0250


**Pre-Testing – Group 1 – Elisha 0250**
Note dark areas on edge of nuts indicating damage by installation.

**Pre Testing – Group 1 – Elisha 0250**
Individual studs prior to corrosion testing.


**40 Cycles – Group 1 – Elisha 0250**
Red rust was first observed at 15 cycles on heads/threads/nut, and 42 cycles on retained washer.


**80 Cycles – Group 1 – Elisha 0250**
Red rust was first observed at 15 cycles on heads/threads/nut, and 42 cycles on retained washer.
At 80 cycles, threads and nut fully involved in rust. Significant rust on heads.


**100 Cycles – Group 1 – Elisha 0250**
Red rust continued to engage until threads and nuts were fully involved.

## GROUP 2 – Elisha 0251


**Pre-Testing – Group 2 – Elisha 0251**

**Pre-Testing – Group 2 – Elisha 0251**
Individual studs prior to corrosion testing.


**40 Cycles – Group 2 – Elisha 0251**
General zinc corrosion (white rust) on threads and damaged areas of nut.


**80 Cycles – Group 2 – Elisha 0251**
General zinc corrosion (white rust) on threads. Nuts that were broken away at 40 cycles developed significant red corrosion on threads by 80 cycles.


**100 Cycles – Group 2 – Elisha 0251**
Significant corrosion on threads, especially on bolts that saw multiple breakaway sequences. Heads were clean of red rust at test termination.

## GROUP 3 – Elisha 7201


**Pre-testing – Group 3 – Elisha 7201**
No apparent damage to nuts after installation.

**Pre-testing – Group 3 – Elisha 7201**
Individual studs prior to corrosion testing.


**40 Cycles – Group 3 – Elisha 7201**
No white corrosion on heads or nut. Red corrosion first observed on heads at 8 cycles, threads at 2 cycles (but note nonprogressional), and 33 cycles on nut. No red on retained washer at 40 cycles.


**80 Cycles – Group 3 – Elisha 7201**
No white corrosion on heads or nut. Red corrosion first observed on heads at 8 cycles, threads at 2 cycles, with progression to significant amounts by 80 cycles. No red on retained washer at 80 cycles.


**100 Cycles – Group 3 – Elisha 7201**

No white corrosion on heads or nut. Red corrosion first observed on heads at 8 cycles, threads at 2 cycles, with progression to significant amounts by 80 cycles. No red on retained washer at 100 cycles.

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## GROUP 4 – Elisha 7203 (Elisha 7201 nuts)


**Pre-testing – Group 4 – Elisha 7203 Studs (Elisha 7201 nuts)**

**Pre-testing – Group 4 – Elisha 7203 Studs (Elisha 7201 nuts)**

Individual studs prior to corrosion testing.

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**40 Cycles – Group 4 – Elisha 7203 Studs (Elisha 7201 nuts)**
No red rust on heads or threads at 40 cycles. Nut first observed red rust at 14 cycles, no red on retained washer.


**80 Cycles – Group 4 – Elisha 7203 Studs (Elisha 7201 nuts)**
No red rust on heads at 80 cycles. First red on threads at 51 cycles on one piece, but not progressing at 80 cycle observation.


**100 Cycles – Group 4 – Elisha 7203 Studs (Elisha 7201 nuts)**
No red rust on heads at 80 cycles. No continuation of first red at 100 cycle observation.

## GROUP 5 – Current Technology


**Pre-testing – Group 5 – Current Aluminum Wheel Manufacturer Coating**

**Pre-testing – Group 5 – Current Aluminum Wheel Manufacturer Coating**
Individual studs prior to corrosion testing.


**40 Cycles – Group 5 – Current Aluminum Wheel Manufacturer Technology**
Threads totally involved in red rust. Extensive base metal (red rust) corrosion in damage areas on nuts.


**80 Cycles – Group 5 – Current Aluminum Wheel Manufacturer Technology**
Entire fastener fully involved in red rust with generation of voluminous corrosion products. According to accelerated corrosion observation data, first base metal corrosion (red rust) on threads was observed at 1 cycle with 5% red rust failure at 4 cycles.


**100 Cycles – Group 5 – Current Aluminum Wheel Manufacturer Technology**
Entire fastener fully involved in red rust with generation of voluminous corrosion products.

## BREAK AWAY RESULTS

### 40 Cycle Break-Away Results

Breakaway and retorquing of 2 wheel stud/lug nut assemblies from each sample group was conducted at 40 cycles of exposure to GM9540. The same impact wrench and regulator as were used for pre test assembly was used for breakaway to allow for comparisons and inference of the breakaway torque value. The breakaway and re-torque comparison is intended to be a qualitative evaluation due to the condition that a torque wrench with over 500 ft/# capacity was not available. Throughout the breakaway test, the following evaluation results were recorded:

1. Can the Stud/Lug nut assembly be disassembled using the same pressure regulator settings used for assembly or does the pressure need to be increased to overcome friction resulting from corrosion on the threads?
2. Approximate time required to breakaway the lug nut.
3. Once broken away is the lug nut free running?
4. Any additional observations?

Results from breakaway conditions observed are as follows.

| Breakaway conditions after 40 cycles GM 9540P Exposure | | | | |
|---|---|---|---|---|
| Group No. | Initial regulator pressure setting | Regulator pressure required to breakaway assembly | Approximate time required to breakaway Assembly | Free running after breakaway |
| 1 | 80 | 80 | <15 sec | Yes |
| 2 | 80 | 80 | <15 Se. | Yes |
| 3 | 80 | 80 | <15 sec. | Yes |
| 4 | 80 | 80 | <15 sec. | Yes |
| 5 | 80 | 80 | >20 sec. | No |

Additional Observations on Failed bolt:

While retorquing bolt #2 of group #1 a noise was observed. While inspecting the samples prior to restarting cyclic corrosion testing it was determined that the head of the second stud was loose on the hub. The fracture surface appears to consist of flat planes with little typical cup/cone which might indicate an ultimate tensile type of failure. The failure occurred along the plane where the shank of the stud transitions to the head of the stud in the transition fillet. An unusual feature on the surface is that the fracture plane splits into two layers approximately one third of the way across the surface. In order to accomplish a more detailed inspection, metallurgical analysis, micro-hardness, and SEM microscopy would be required.

These components were processed as part of a conventional production barrel load. For processing these samples were mixed with typical production parts. These samples had to be sorted out of the bulk process for secondary hydrogen relief baking. These parts are a different alloy and substantially different geometry that our typical components. A potential failure mode of this part is that it did not initiate baking for embrittlement relief within the appropriate time window to be effective. Typically part specific process parameters and controls are developed as part of the quality plan for production implementation. This indicates that particular attention should be attributed to process controls and development for this type of component.

**80 Cycle Break-away Results**

Breakaway procedure at 80 cycles was identical to procedure at 40 cycles with the same evaluation criterion.

The following table summarizes breakaway conditions observed after 80 cycles of GM 9540P cyclic corrosion exposure.

| Breakaway conditions after 80 cycles GM 9540P Exposure | | | | |
|---|---|---|---|---|
| Group No. | Initial regulator pressure setting | Regulator pressure required to breakaway assembly | Approximate time required to breakaway Assembly | Free running after breakaway |
| 1 | 80 | 80 | <15 sec | No |
| 2 | 80 | 80 | <15 Sec. | Yes |
| 3 | 80 | 80 | <15 sec. | Yes |
| 4 | 80 | 80 | <15 sec. | Yes |
| 5 | 80 | 80 | >20 sec. | No |

Notes and observations:

1. The head of the stud on bolt #1 of group #1 appeared to be dislocated prior to breakaway evaluation. While re-torquing the stud, the head became completely disconnected. The fracture

surface on this stud was completely corroded. The presence of corrosion on this surface indicates that this stud was probably also cracked during the 40 cycle breakaway evaluation allowing for corrosion material and corrosion activity to occur during the 40 cycles since the last breakaway procedure.

In discussion, it was noted that the head of this type of stud can be broken due to improper alignment while installing the stud in the hub. While assembling these hubs, it was necessary to change the stand-off block construction due to deformation. Deformation of the standoff block could change the alignment of the stud as it was being pressed in to the hub, and be a cause of failure previously not investigated. We will evaluate alternative causes for this condition.

2. The exposed threads on bolt 1 and 2 of Group #2 are experiencing more surface corrosion than the samples which were not subjected to Breakaway and re-torquing evaluation at 40 cycles.

3. Group #5 is experiencing material loss and thread deterioration on stud 1 and 2. Material loss and spalling of corrosion products was noted after the breakaway sequence at 80 cycles.

**100 Cycle Break-away Results**

. Based upon differentiation in corrosion performance of the tested coating systems it was decided to suspend 9540-P exposure after 100 cycles/100days. The following information was collected during breakaway testing after 100 cycles of corrosion exposure. Final breakaway evaluation procedure was modified to evaluate the breakaway characteristics of all four wheel stud/nut assemblies in each group. In addition the bolts were not retorqued after disassembly.

To accomplish this task the same impact wrench and regulator as were used for pre test assembly was used. The breakaway comparison is intended to be a qualitative evaluation. The evaluation criterion were the same as used at other break-away intervals.

Comparison of breakaway conditions observed after 100 cycles of GM 9540p cyclic corrosion exposure.

| Breakaway conditions after 100 cycles of GM 9540P Exposure | | | | |
|---|---|---|---|---|
| Group No. | Initial regulator pressure setting | Regulator pressure required to breakaway assembly | Approximate time required to breakaway Assembly | Free running after breakaway |
| 1 | 80 | Breakaway was accomplished but nut stalled after moving approx ¼". Pressure had to be increased to 120PSI to spin the nut approx. ½" removed regulator to operate Impact wrench at normal line pressure 175PSI to finish removal of nut. | >30 sec | No |
| 2 | 80 | 80 | <15 Se. | Yes |
| 3 | 80 | 80 | <15 sec. | Yes |
| 4 | 80 | 80 | <15 sec. | Yes |
| 5 | 80 | Breakaway was accomplished but nut stalled after moving approx 1/16" . Pressure had to be increased to 120PSI to finish removal of nut. | >40 sec. | No |

**100 Cycle Summary Results and Discussion**

Accelerated corrosion in cyclic chamber according to GM 9540P protocol was terminated at 100 cycles on Aluminum wheel manufacturer studs. Groups performing the in rank anticipated. First base metal corrosion was seen on Current Aluminum wheel manufacturer Technology, believed to be phosphate and oil. Typically, these phos/oil coatings are viewed as temporary coatings, and not adequate for corrosion durability. The initial results reinforced this assumption of temporary performance with first base metal corrosion observed at 1 cycle of the test protocol.

At the 40 cycle interval, and repeated at both 80 and 100 cycles, the best overall corrosion performance was observed on Group 4 (Elisha 7203). It is recommended that production feasibility analysis be initiated for coating the subject group of parts with Elisha 7203.