National Transportation Safety Board
Office of Railroad, Pipeline and Hazardous Materials Investigations
Washington, DC 20594

Mechanical Group Factual Report

Railroad Contractor Fatality
Norfolk Southern Railway Buffalo Line near
Reed, PA on
December 8, 2021

RRD22LR003

A. CONTENTS

B. ACCIDENT

Accident Number: RRD22LR003

Accident Type: Roadway Worker (Contractor) Fatality

Location: Reed, Pennsylvania

Date of Accident: December 8, 2021

Carrier: Norfolk Southern Railway Company (NS)

Work Group: R12 Curve Rail Replacement Gang

Contractor: National Salvage Corporation

Fatalities: 1

C. MECHANICAL INVESTIGATIVE GROUP

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D. Accident Summary

For a summary of the accident, refer to the IIC Factual Report within this docket

E. RAILROAD EQUIPMENT INVOLVED IN THE ACCIDENT

NS Curve Rail Replacement Gang R12

NS Curve Rail Replacement Gang R12 consisted of 15 Roadway Maintenance Machines (RMM) and approximately 28 employees. Two employees and one piece of equipment, a grapple truck, were contracted from National Salvage Corporation. One National Salvage employee operated the grapple truck and one worked on-foot performing tasks associated with marking and inventorying old rail with paint for disposition. The employee on-foot was fatally injured in this accident.

In the area of the accident there are three similar RMMs known as Spikers.
The gang was working southward. In the order they were working the spikers were:

- Spiker 1, GS 16043, s/n 550028, Built 12/16, Model SE
- Spiker 2, GS 15022, s/n 550027, Built 12/15, Model SE
- Spiker 3, GS 15021, s/n 550026, Built 12/15, Model SE

At the time there were two employees on Spiker 2 and Spiker 3, an Auto Spiker Machine Operator and Track Laborer on each. Spiker 1 had one employee an Auto Spiker Machine Operator.

Spiker 2, GS 15022, was involved in the incident.

Spiker No. GS 15022

Spiker No. GS 15022 was the second spiker in Gang R12. It was built in December 2015 by Nordco, Inc. The Machine is known as a "SE Hammer, Production Spike Driver". The spiker is a rail-bound machine designed to drive spikes into place through the use of opposing hydraulically driven, high impact spiking hammers. The spikes are fed from a bin on the rear of the machine into a loading mechanism by the operator or a track laborer in the cab. The enclosed climate-controlled cab is designed with seating for two spike hammer (gun) operators (one on each side) and one feed tray operator (laborer). The machine is powered by a 140 horsepower, 140 Amp alternator, Tier III diesel engine. Travel along the rail is accomplished with a variable hydrostatic pump and motors through a four-wheel, dual-axle, chain-driven propulsion system. The friction brake system includes spring-applied, hydraulically released brake shoes on each of the four wheels. The machine includes a 90-gallon diesel fuel tank and a 110-gallon hydraulic fluid tank. The operator controls the system with electronic joysticks positioned and foot pedals at both operator seats.

Figure 1. Photograph of NS Spiker GS 15022 near its post-accident resting position (NSTB Photo)

F. ACCIDENT SEQUENCE

- Approximately 5-7 minutes before the accident the National Salvage employee crossed in front of spiker 1 from the east side of the track to the west side of the track.
- He then crossed behind spiker 1 from the west side to the east side of the track
- He passed spiker 2 in a north direction between the main track and siding track.
- Spiker 2 had worked up to Spiker 1.
- The Spiker 2 operator changed his spiking pattern from rail spike pattern to anchor spike pattern and spiked the tie he was on.
- He stated he blew his horn three times, looked in the left rear view mirror, and moved the machine in reverse in a north direction to help Spiker 3.
- The operator stated he did not see anyone behind the Spiker. During the reverse movement he said it felt like the machine ran over a weld in the rail.
- He looked down through a space in the machine's floor toward the rail and saw someone underneath the machine and immediately stopped the machine and called for emergency assistance.
- As a result of the accident, the National Salvage Laborer was fatally injured.

G. POST-ACCIDENT EQUIPMENT DESCRIPTION

There was no damage sustained to the equipment involved as a result of the accident.

H. POST-ACCIDENT INSPECTIONS AND TESTING

Spiker GS 15022 – Horn

Investigators conducted several tests of the horns on all three Spikers in the R12 Gang.

First, investigators conducted a test for the roof-mounted electric horn on Spiker 2. Spiker 3 and Spiker 2 were started and the engines were brought to normal running rpm levels. An Officer from the Occupational Safety and Health Administration (OSHA) was positioned with his Type 1 Sound Level Measuring Device at the approximate point of impact, while the Spikers were positioned at their approximate location just prior to the backup movement. The background noise level was approximately 71.5 "A" Weighted Slow Response decibels (dBA).

The additional noise level from the horn was unreadable when the operator sounded 3 short blasts. This is due to the dosimeter measuring equipment, which is "slow weighted". Slow weighted dosimeter settings take about one sample per second. The noise level when the horn sounded continuously was 72.5 dBA. Investigators also recorded the sound readings for the horn on Spiker 3. Approximately 29 feet in front of the spiker the reading was 79 dBA when sounded continuously. Approximately 29 feet behind the spiker the reading was 76.2 dBA. During subsequent investigative activities on following days, investigators noted the horn on Spiker GS 16043 was perceived by them to be noticeably louder than Spiker 2 or 3.

Investigators were able to secure Spiker 2 in a secure NS facility in Enola, PA on December 13. At this location an investigator positioned himself on the roof of the

Spiker. The horn system consists of four trumpets, two facing forward and two facing backwards. Investigators cycled through each button in the cab for horn activation. It was determined that only one trumpet produced sound, a front facing trumpet. The other front facing trumpet, and both rear facing trumpets, did not produce any audible sound.

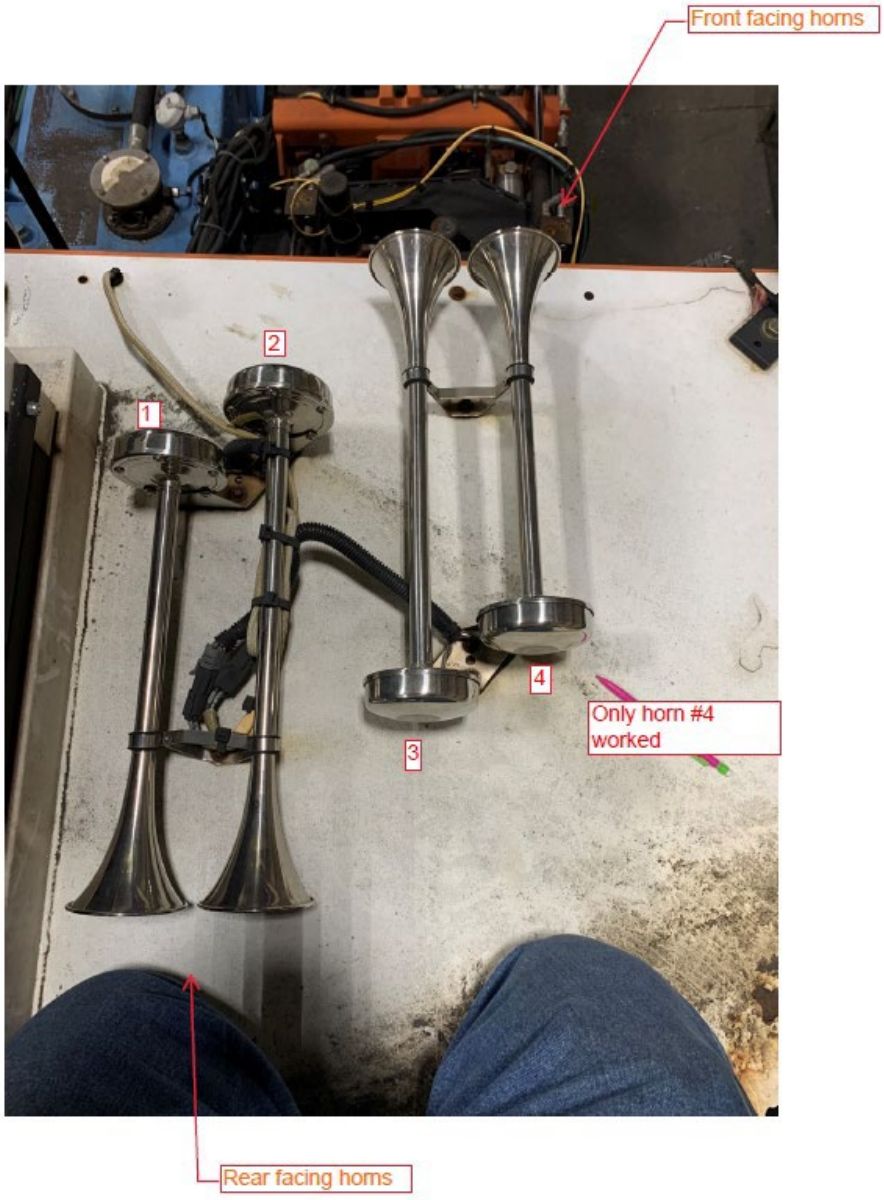

Figure 2 Spiker GS 15022 Horn System (FRA photograph and annotations)

Investigators also noted that a sticker covered a screw on the front facing trumpets.

The rear facing trumpets did not have a sticker over the screw.

Figure 3 Spiker GS 15022 Front facing trumpets with screw covered (FRA Photograph and annotations)

Figure 4 Spiker GS 15022 Rear facing trumpets with screws accessible (FRA Photograph and annotations)

Investigators returned to the Spiker on January 25, 2022. The rear cover of the leftmost, rear facing horn was removed. The interior of the horn motor coil, contacts,

and plate were photographed. All these internal parts were heavily corroded and rusted. The horn was then reassembled. Both the forward facing and the rear facing banks of horns were unplugged from the roof mounted connectors.

A new, known working set of horns was temporarily connected to each horn connector (one for forward facing bank, one for rearward facing bank). The horn circuit was tested from a horn button in the cab; the new horns functioned correctly while plugged into each of the connectors.

Figure 5. The interior condition of a horn trumpet.

Spiker GS 15022 – Change of Direction Alarm

Spiker GS 15022 is equipped with an automatic change-of-direction alarm which is designed to activate based on the position of a "Forward/Reverse Travel Switch" and the direction of travel pedal used by the operator. The "Forward/Reverse Switch" is a three-position toggle switch (Forward/Center/Reverse) located on the Main Control Cabinet (MCC).

Figure 6. GS 15022 MCC with Forward/Reverse Travel Switch located in the center of the photograph. Icons indicate the intended function of lights/alarms. (NTSB Photograph)

The change-of-direction alarm system has two exterior speakers, one mounted on upper front left corner of the operating cab and one mounted on the upper rear right corner of the cab.

Figure 7. Spiker with arrow pointing to front facing change-of-direction alarm speaker (NTSB Photograph and annotations)

Figure 8. Spiker GS 16043 with an arrow pointing to the rear facing change-of-direction alarm speaker. The disconnected speaker plug can be seen below the speaker. (NTSB Photograph and annotations)

Field Testing

Investigators devised a 6-point inspection to verify the operation of the change-of-direction alarm system. In a sequential manner, each combination of the toggle switch and the direction of travel was tested. The expected, or as-designed, response for each combination of switch positions and travel directions was confirmed by Nordco, Inc. On the first day of testing, an Officer from OSHA took noise level readings at a position representing the suspected approximate position of the National Salvage employee when the Spiker began a reverse movement. Each test below was conducted from the right and the left operator's seat, the results were the same from each position. Prior to testing, the electrical plug for the rear speaker on GS 15022 was found to be disconnected. Therefore, the tests for Spiker 2 were

conducted twice. Once with the speaker unplugged, "as found", and once with the speaker plugged back in.

For Spiker 2, while the OSHA Compliance Officer was available for noise monitoring, the background noise was between 69.5 and 71.5 dBA. The sound level at the Officer's position was recorded for each test after the signal was given to engage travel. Where "No Alarm" was recorded, the level recorded is simply the background noise level.

Test No.	Toggle Switch Position	Direction of Movement	Expected Result (As Designed)	Spiker No. 1 - GS 16043	Spiker No. 2 - GS 15022 *As found, rear speaker unplugged	Spiker No. 2 - GS 15022 *After plugging in rear speaker	Spiker No. 3 - GS 15021
1.	**Forward**	**Forward**	No Alarm	No Alarm	No Alarm (70.2 dBA)	Alarm – Rear Speaker Only (85.4 dBA)	No Alarm
2.	**Forward**	**Reverse**	Alarm – Rear Speaker Only	No Alarm	No Alarm (70.2 dBA)	No Alarm (70.2 dBA)	Alarm – Rear Speaker Only
3.	**Center**	**Forward**	Alarm – Both Speakers	Alarm – Front Speaker Only	Alarm – Front Speaker Only (71.6 dBA)	Alarm – Both Speakers (85.5 dBA)	Alarm – Rear Speaker Only
4.	**Center**	**Reverse**	Alarm – Both Speakers	Alarm – Front Speaker Only	Alarm – Front Speaker Only (70.9 dBA)	Alarm – Both Speakers (85.6 dBA)	Alarm – Rear Speaker Only
5.	**Reverse**	**Forward**	Alarm - Front Speaker Only	Alarm – Front Speaker Only	No Alarm (70.2 dBA)	No Alarm (70.2 dBA)	No Alarm
6.	**Reverse**	**Reverse**	No Alarm	No Alarm	Alarm – Front Speaker Only (71.6 dBA)	Alarm – Front Speaker Only (71.5 dBA)	No Alarm

The background noise level was nearly consistent at ~70.2dBA.

When only the front speaker produced sound (pointing away from the OSHA Officer), there was only a ~1.3dBA increase in sound.

When only the rear speaker produced sound (pointing directly at the OSHA Officer, there was a ~15.3dBA increase in sound.

Based on the testing, it can be factually stated that none of the spikers behaved as investigators expected based on Nordco's description of the design.

- Spiker 1, GS 16043, behaved in a manner consistent with a non-functioning rear speaker. The speaker appeared to be plugged in and there was no obvious damage.
- Spiker 2, GS 15022
    - First, it behaved in a manner consistent with a non-functioning rear speaker. The rear speaker was found unplugged, and investigators plugged it back in.
    - Second, after plugging in the rear speaker, the change-of-direction alarm system further behaved in an unexpected manner. The alarm sounded in the *working* direction, and did not sound for *a change-of-direction*. In other words, when traveling in the working direction, the alarm sounded. Finally, when the alarm did sound, it used the speaker opposite the direction of travel, meaning the sound was quieter than intended in the direction of travel.
- Spiker 3, GS 15021, behaved in a manner consistent with a non-functioning front speaker. The speaker appeared to be plugged in and there was no obvious damage.

Shop Testing – December 13th, 2021

Investigators conducted additional testing regarding the Change-of-Direction Alarm on Spiker GS 15022. Investigators studied the wiring diagram for the machine and

determined that any future testing plans would be easier to write if the results of a simple test were known.

To begin the testing, investigators first repeated the test above "Spiker 2 After plugging in rear speaker" and the same results were obtained.

Next, investigators swapped the two wires leading to the three position "Forward/Reverse Travel" rocker switch on the MCC. The change was recorded on video. The results of the test are below.

Test No.	Toggle Switch Position	Direction of Movement	Expected Result (As Designed)	Spiker No. 2 – GS 15022 *After plugging in rear speaker. Repeat of field test, before swapping any wires.	Spiker No. 2 – GS 15022 *After swapping wires on toggle switch.
1.	Forward	Forward	No Alarm	Alarm – Rear Speaker Only	No Alarm
2.	Forward	Reverse	Alarm – Rear Speaker Only	No Alarm	Alarm – Front Speaker Only
3.	Center	Forward	Alarm – Both Speakers	Alarm – Both Speakers	Alarm – Both Speakers
4.	Center	Reverse	Alarm – Both Speakers	Alarm – Both Speakers	Alarm – Both Speakers
5.	Reverse	Forward	Alarm - Front Speaker Only	No Alarm	Alarm – Rear Speaker Only
6.	Reverse	Reverse	No Alarm	Alarm – Front Speaker Only	No Alarm

For this new test, it can be said that the results were different than the field testing. And it can also be said that unexpected results were obtained as compared to the expected "as-designed" results.

Nordco, Inc used this additional data to draft a comprehensive test plan (Attachment 1).

Shop Testing – January 25, 2022

On January 25, 2022 the Mechanical Working Group convened in Enola Yard to execute a written test plan designed to determine the cause(s) for the unexpected results observed on the automatic change of direction alarm (ACDA) system and horns during previous inspections of Spiker GS 15022. (Attachment 1)

The “6-point test” was conducted to confirm that the ACDA behaved the same as it did at the end of the last inspection.

The written test plan (attached) Phase I tests 1 through 17 were completed with no exceptions found. In other words, the wires were confirmed to be installed in the correct locations and labeled correctly. Additionally, wires supplying voltage to the rear facing speaker were confirmed to be installed in the correct locations and labeled correctly. The team concluded that the master control cabinet (MCC) and all associated wiring controlling the ACDA system was wired correctly.

A new computer module was supplied by Nordco and installed (plugged in). The “6-point test” was performed again. There was no change in machine behavior. The original computer was reinstalled. The new computer was removed and returned to Nordco.

The team discovered that a diagnostic screen was available in the machine. The diagnostic screen allowed investigators to observe the inputs that the control computer was receiving. A test was performed in which each of the 6 travel pedals in the machine were pressed, one at a time, while the diagnostic screen was observed. It was discovered that when the reverse travel pedals were pressed, the computer received inputs to command forward travel. When the forward travel pedal was

pressed, the computer received inputs to command reverse travel. The team had already conducted dynamic tests with the machine, and knew the machine traveled forward with the forward pedal and reverse with the reverse pedal. In summary, a forward pedal press told the computer to travel in reverse, but the machine actually traveled forward. A reverse pedal press told the computer to travel forward, but the machine actually traveled in reverse.

Based on this new information, the team inspected the connections at the plugs for the pedals, and the electrical connections for the hydrostatic pump solenoids.

The conditions described here were for the left side of the cab pedals. The pedals at the center and right positions had the same condition. It was determined that the reverse pedal (PED 2206 on the schematic) was plugged into the plug for the forward pedal (PED 2202). The forward pedal was plugged into the plug for the reverse pedal.

The pedal plugs were swapped on the left side and the inputs were checked on the diagnostic screen. The computer now showed that the forward pedal sent a forward travel input to the computer. The reverse pedal now sent a reverse travel input to the computer.

The hydrostatic pump was inspected. The pump has two solenoids. Electrical input to one for forward travel (SOL 2813) and one for reverse travel (SOL2816). It was determined that the plug intended for the forward travel solenoid was plugged into the reverse solenoid. The plug intended for the reverse travel solenoid was plugged into the forward solenoid.

The solenoid plugs were swapped by the investigative team.

The machine was then started and a functional dynamic check was performed from the left set of pedals. The machine operated as intended. The forward pedal made the machine travel forward. The reverse pedal made the machine travel in reverse.

With the wires in their intended positions as described above, the automatic change of direction alarm system was tested using the "6-point test". The ACDA system functioned as intended. (Table 1)

MCC Switch Position	Pedal Press	Expected Result	First Morning Test (As Found Condition)	After swapping Pedal Plugs and Hydrostatic Pump Plugs
Forward	Forward	No Alarm	Rear Speaker Only	No Alarm
Forward	Reverse	Rear Speaker Only	No Alarm	Rear Speaker Only
Center	Forward	Both Speakers	Both Speakers	Both Speakers
Center	Reverse	Both Speakers	Both Speakers	Both Speakers
Reverse	Forward	Front Speaker Only	No Alarm	Front Speaker Only
Reverse	Reverse	No Alarm	Front Speaker Only	No Alarm

Table 1. Results of the "6-point test" conducted on January 25, 2022

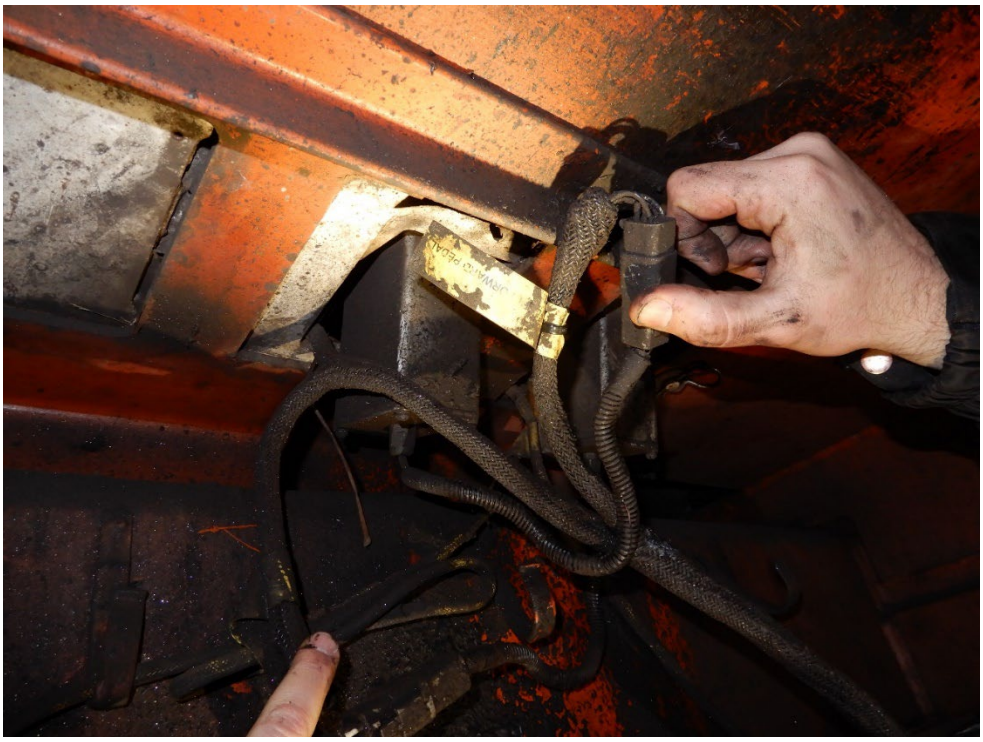

Figure 9. Under the cab, looking at the plugs for the left side pedals. They are reversed (as found) in this photo.

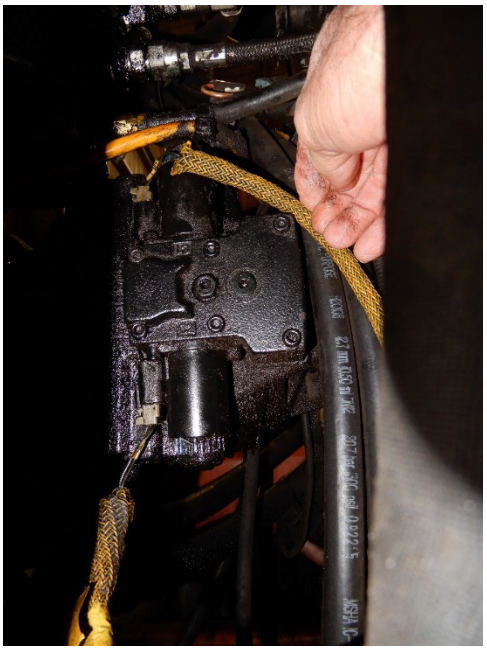

Figure 10. The electrical cables plugged into the hydrostatic pump solenoids, labeled C1 and C2.

Spiker GS 15022 – Braking System

The braking system of the Spiker consists of brake shoes that contact the tread of each wheel. The brake system does not have an adjustment feature, as the brake shoes wear down, the space between the shoe and the wheel increases. The brakes apply automatically when the operator releases the travel pedal.

Investigators observed the brake shoes and noted that all shoes were full not worn. Investigators observed dynamic brake applications and noted the machine appeared to stop normally.

I. INTERVIEWS CONDUCTED

On December 13, 2021 investigators interviewed the two Repairmen assigned to the R12 Gang. Transcripts of the interviews will be available in the docket.

J. EVIDENCE COLLECTED

The Mechanical Working Group placed an investigative hold on Spiker No. GS 15022 and NS held the machine in a secure facility at Enola Yard. On January 25, 2022 investigators returned to perform additional inspections and tests as outlined above. On February 1st, NTSB investigators released the investigative hold of Spiker No. GS 15022 to NS with the concurrence of all parties.

K. POST-ACCIDENT ACTIONS

The following post-accident actions have been taken

- Norfolk Southern instructed all Maintenance Equipment Supervisors to inspect the change of direction alarms on all RMMs, specifically Nordco Spikers. A written procedure was included in the instruction. (Attachment 2)
- Nordco, Inc. sent a Product Service Bulliten (PSB) to NS. The PSB provided instructions on testing change of direction alarms with a step-by-step procedure. Nordco requested written confirmation of the testing and offered a Nordco Service Tech if any discrepancies were found. Additionally, the PSB provided instructions for testing the pedal configurations of Spikers. (Attachment 3)
- Nordco, Inc. added information to the operator's manual of SE Spikers to correct information and provide additional details regarding the expected operation of change of direction alarms. (Attachment 4)
- Nordco, Inc. expanded the test track procedure for SE Spikers leaving the manufacturing facility. The new tests are designed to ensure the change of direction alarm is functioning properly and that all pedals are wired properly. (Attachment 5)

L. ACKNOWLEDGMENT SIGNATURES

Group Member to the Investigation - Acknowledgment Signatures

The undersigned designated Group Member to the Investigation representatives attest that the information contained in this report is a factually accurate representation of the information collected during the on scene phase of this investigation, to the extent of their best knowledge and contribution in this investigation.

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