Defence Research and Development Canada
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Polaris Big Boss noise reduction

Report 1, Baseline measurements and aftermarket muffler tests

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Defence R&D Canada
Contract Report
DRDC Suffield CR 2012-192
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Report 1: Baseline measurements and aftermarket muffler tests

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HGC ENGINEERING
noise · vibration · acoustics

ATV NOISE REDUCTION FOR A POLARIS BIG BOSS 800 6X6

Project Reference: EDM-1-34494

REPORT #1

BASELINE MEASUREMENTS AND AFTERMARKET MUFFLER TESTS

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Abstract

Defence R&D Canada – Suffield is investigating methods of reducing the acoustical signatures of a variety of small all-terrain vehicles (ATVs). Before vehicle modifications are conducted on a test ATV platform, a set of baseline measurements are required to establish the noise level of the unmodified platform. It is also important to define the noise reduction achievable with commercially available mufflers as a benchmark for the custom solutions developed under this project. As such, HGC Engineering analysed the sound levels produced by a Polaris Big Boss 6x6 ATV with its factory exhaust system, and also with several "silent" muffler systems. The study found that the most effective approach existing approach for reducing noise without reducing vehicle power is using two Polaris factory mufflers in series.

Résumé

R et D pour la défense Canada – Suffield mène une étude sur les méthodes de réduction des signatures acoustiques d'une vaste gamme de petits véhicules tout terrain (VTT). Avant de procéder à des modifications de ce véhicule sur une plateforme d'essais de VTT, on a besoin d'un ensemble de mesures de base pour établir le niveau de bruit de la plateforme non modifiée. Il est également important de définir la réduction de bruit que l'on peut obtenir au moyen de silencieux disponibles commercialement comme références pour les solutions personnalisées élaborées dans le cadre de ce projet. Ainsi, HGC Engineering a analysé les niveaux de bruit générés par un VTT Polaris Big Boss 6x6 équipé de son système d'échappement installé en usine ainsi que de plusieurs systèmes de silencieux dits « silencieux ». Cette analyse a permis d'établir que la technique la plus efficace qui existe pour réduire le bruit sans réduire la puissance du véhicule consiste à utiliser deux silencieux Polaris installés en série en usine.

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Executive summary

Polaris Big Boss Noise Reduction: Report 1: Baseline measurements and aftermarket muffler tests

Antelmi, C.; DRDC Suffield CR 2012-192; Defence R&D Canada – Suffield; November 2012.

Introduction or background: Defence R&D Canada – Suffield is investigating potential avenues of reducing the acoustical signatures of a variety of small all-terrain vehicles (ATVs). The project will develop a set of custom modifications that can be applied to ATVs. However, no data on the factory performance of the ATVs was available. There are also several aftermarket muffler systems that promise significant noise reductions to ATV noise emissions, for which no data was available.

A Polaris Big Boss 6x6 vehicle was tested according to the SAE J1287, J1161, and J192 test standards in various configurations to get sound emission data. The vehicles were also tested on a chassis dynamometer to determine the power loss caused by the different muffler configurations.

Results: The factory vehicle and 4 additional exhaust configurations were tested. The configuration that produced the most effective combination of sound reduction and minimal power loss was to use two Polaris OEM mufflers, the second attached to the output of the first. This configuration produced a 6.7 dBA reduction in sound pressure for a J1161 pass-by test, and resulted in a 4% power loss.

Significance: These tests accomplished two goals: they provide a practical and effective muffler configuration for reducing ATV noise, and provide a benchmark to evaluate ATV modifications for further noise reduction

Future plans: The project will progress to the next phase: designing, constructing, and testing custom modifications to the ATV system. Once completed, results with the modified vehicle will be compared with those from this report. This will allow a decision to be made regarding the most practical and efficient methods for ATV noise reduction.

Sommaire

Polaris Big Boss Noise Reduction: Report 1: Baseline measurements and aftermarket muffler testsmesures de base et essais de silencieux du marché secondaire

Antelmi, C.; DRDC Suffield CR 2012-192; R & D pour la défense Canada – Suffield; novembre 2012.

Introduction ou contexte : R et D pour la défense Canada – Suffield mène une étude sur les pistes de solutions éventuelles en matière de réduction des signatures acoustiques d'une vaste gamme de petits véhicules tout terrain (VTT). Ce projet permettra l'élaboration d'un ensemble de modifications personnalisées pouvant s'appliquer aux VTT. On ne disposait cependant d'aucune donnée sur les performances en usine des VTT. Il existe également plusieurs systèmes de silencieux du marché secondaire promettant des réductions de bruit importantes relativement aux émissions de bruit des VTT et pour lesquels on ne disposait d'aucune donnée.

On a procédé à des essais sur un véhicule Polaris Big Boss 6x6 conformément aux étalons d'essais J1287, J1161 et J192 de la SAE dans diverses configurations, afin d'obtenir des données sur les émissions de bruit. On a également procédé à des essais sur des véhicules sur un dynamomètre à châssis, afin de déterminer la perte de puissance causée par les différentes configurations des silencieux.

Résultats : On a procédé à des essais sur la configuration d'échappement installée en usine sur le véhicule ainsi que sur 4 autres configurations d'échappement. La configuration qui a permis la combinaison la plus efficace de réduction du bruit et de perte de puissance minimale utilisait deux silencieux Polaris du FEO, le second fixé à la sortie du premier. Cette configuration produisait une réduction de 6,7 dBA de la pression acoustique, pour un essai de passage J1161, et elle a produit une perte de puissance de 4 %.

Importance : Ces essais ont permis l'atteinte de deux objectifs : ils ont permis l'obtention d'une configuration de silencieux pratique et efficace visant la réduction du bruit des VTT, et ils ont fourni une référence pour l'évaluation des modifications apportées aux VTT afin de réduire davantage le bruit.

Perspectives : Le projet passera à l'étape suivante : conception, construction et essais des modifications personnalisées apportées au système du VTT. Une fois cette étape terminée, on comparera les résultats obtenus au moyen du véhicule modifié à ceux figurant dans ce rapport, ce qui permettra de prendre une décision concernant les méthodes les plus pratiques et les plus efficaces de réduction du bruit des VTT.

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1 Introduction

HGC Engineering was awarded a contract by Public Works and Government Services Canada to develop a solution to reduce the operating noise level of the 2012 Polaris Big Boss 6X6 all-terrain vehicle (Project Reference: EDM-1-34494). This is the first interim report issued to summarize initial testing, results and observations. Some of the results in this report will serve as a baseline for the unmodified vehicle and subsequently used for comparison to measurements resulting from future alterations.

2 Sound evaluation methods

This report summarizes sound level measurements and other observations during baseline testing of a new, unmodified Polaris Big Boss 6x6 vehicle. In addition, testing was performed with various exhaust silencer configurations in order to evaluate add-on mufflers that have been available in the commercial aftermarket. This is the initial phase towards the goal of designing a noise reduction solution for this vehicle.

The following test procedures for sound level measurements of vehicles were used as a guideline for conducting measurements for this phase of the project:

SAE J1161 - for overall sound level produced during constant speed pass-by

SAE J192 - for maximum sound level produced during full throttle acceleration pass-by

SAE J1287 - for exhaust sound level, near tailpipe outlet, during stationary conditions

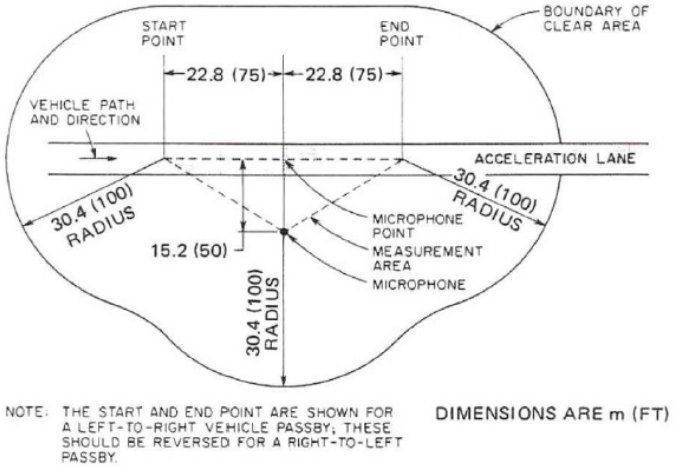

Figure 1: Basic uni-directional test layout used for pass-by tests.

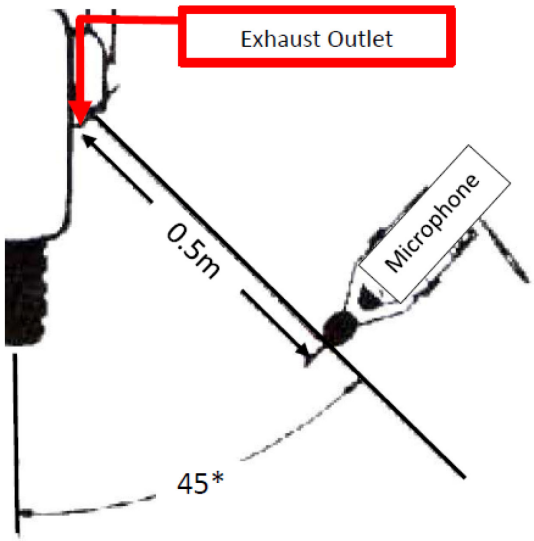

Figure 2: Stationary sound measurement test configuration.

3 Commercially available exhaust silencers tested

The following commercially available silencers were tested during this phase of the project:

1. Polaris OEM Muffler for the Big Boss 6X6 Part Number 126123-489
2. Flowmaster Hushpower ATV Silencer Part Number HP-7000
3. Koplin Industries Part Number 53570
4. Silent Rider (previously Benz) Part Number BT-47

All mufflers were retail priced at less than $250 CDN each.

4 Exhaust silencer test summary

4.1 Stationary sound level measurement (SAE J1287)

The Stationary Test results were performed under no load conditions, at 3150 rpm with the microphone located 0.5 meters from the tailpipe at a 45 degree angle from the exit direction. The results showed that all secondary muffler configurations resulted in a sound level reduction of at least 5 dBA relative to the single

stock muffler and they were all within 3 dBA of each other (see Figure 4.1a). The Silent Rider was the best performer at 82 dBA and the Kolpin was the worst at 85dBA. These measurements were obtained in the near field at 0.5 meters and the variation between the different mufflers is not expected to be significant in the far field.

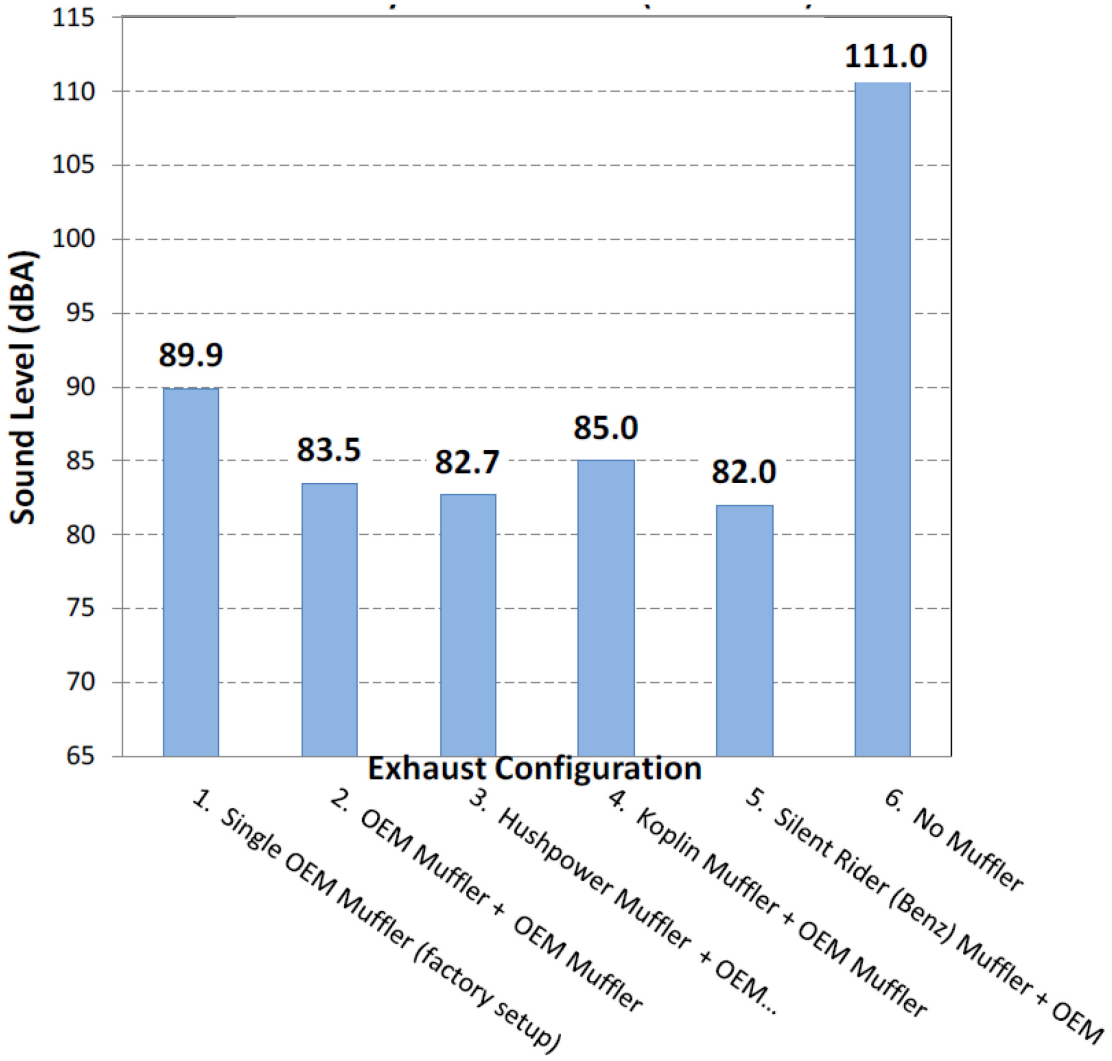

Figure 3: Exhaust sound level for various muffler configurations stationary measurement (SAE J1287).

Compared to the other mufflers tested, the Silent Rider provided up to 8 dB better attenuation in the lower audible frequency bands (see Figure 4.1b). It also provided marginally better performance in most other mid to high frequencies. The acoustic performances of the other mufflers were generally grouped closely together in most of the frequency bands.

The design of the Silent Rider, utilizing a significant blockage of exhaust flow and notably high back pressure, may result in better acoustic performance, but has negative effects on engine performance, consistency and reliability.

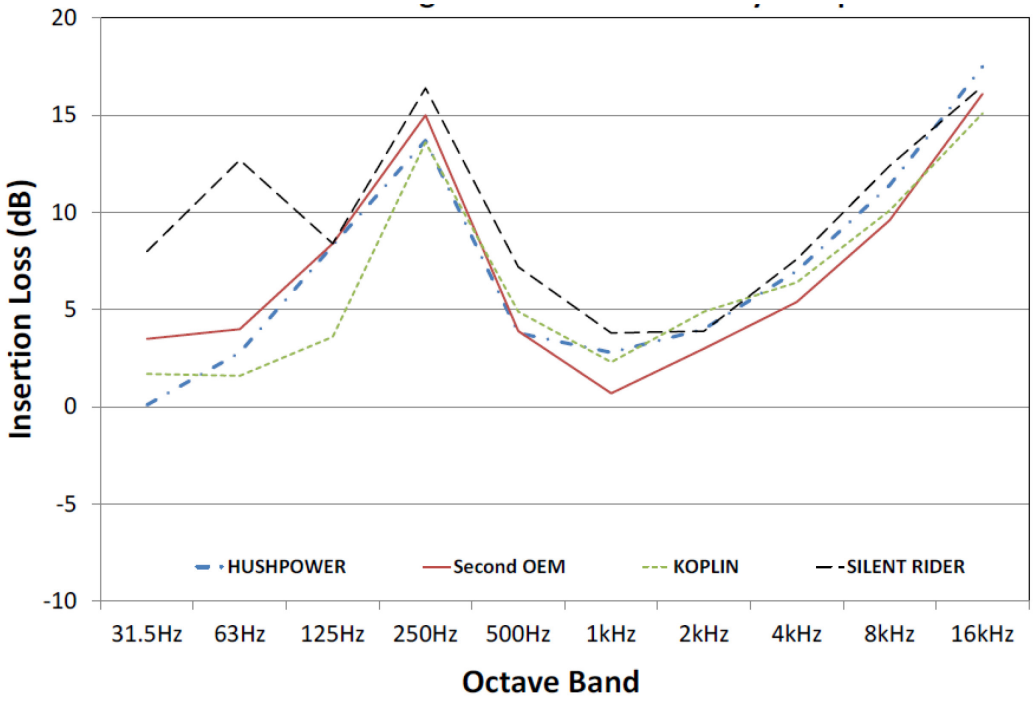

Figure 4: Acoustic insertion loss with secondary add-on muffler in series with OEM muffler relative to single OEM muffler factory setup.

4.2 Constant speed pass-by (SAE J1161)

The Constant Speed Pass-By was performed under minimal load conditions and measured at a distance of 15.2 meters from the centerline of travel. The resulting engine speed was 3900 rpm +/- 150. All dual muffler configurations resulted in a sound level reduction of at least 4.5 dBA and the reductions of each of the configurations were within 1 dBA of each other. These results indicate that the addition of any of the tested mufflers significantly reduced the sound level during this test and that there was no significant acoustic performance difference between the mufflers.

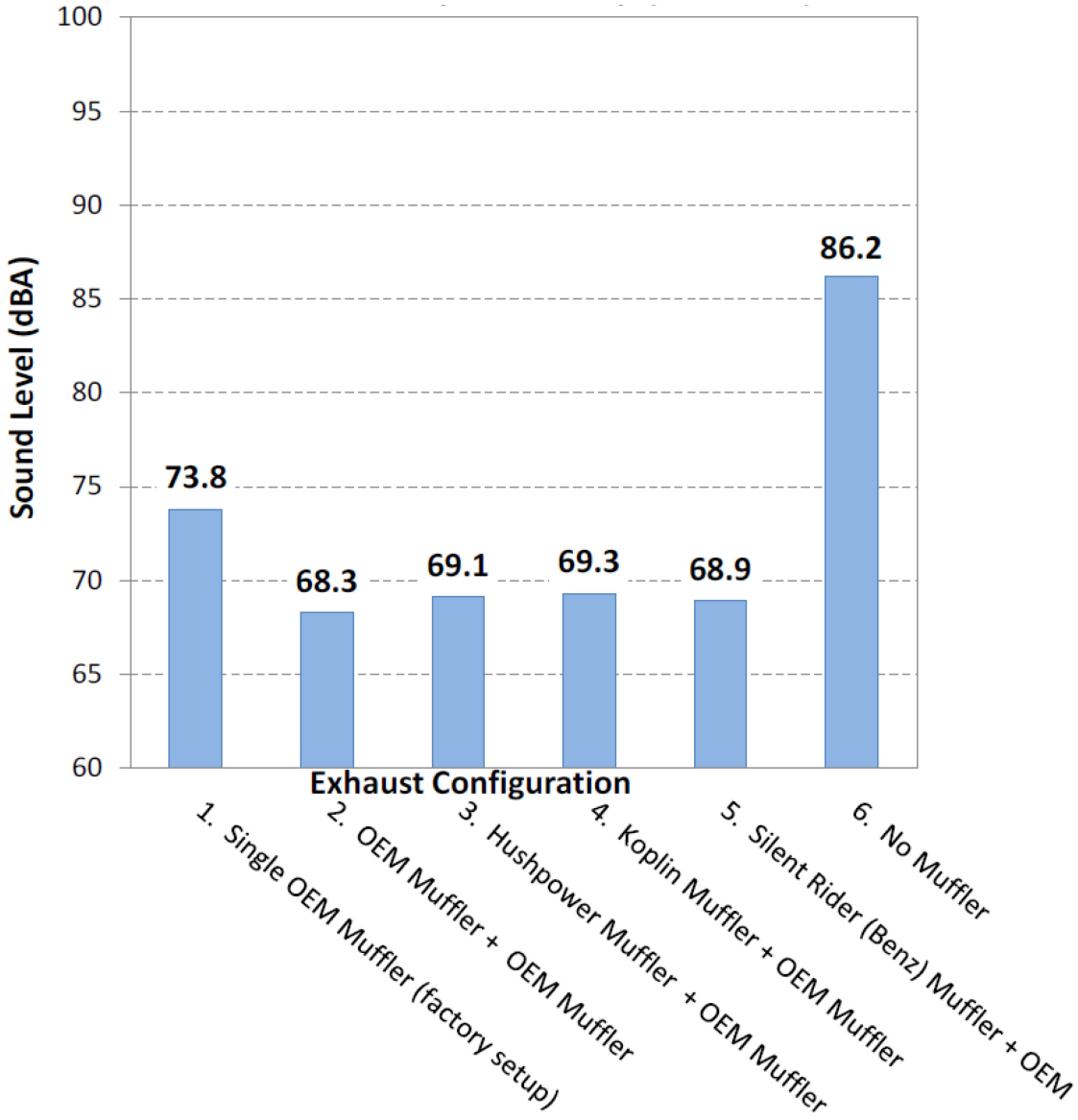

Figure 5: Sound level for various exhaust configurations 24km/h constant speed pass-by (SAE J1161).

4.3 Full throttle pass-by (SAE J192)

The vehicle entered the test zone at 24 km/h and full throttle was applied at the designated start point pylon. The vehicle accelerated for 45.6 meters until the end point pylon was passed at approximately 57 km/h. Engine speed ranged from approximately 3900 to 5900 rpm between the start and end points. Vehicle and engine speeds varied somewhat because of expected driving error and variations in power with the different muffler configurations.

All muffled sound level measurements, including for the baseline factory setup, were less than 1 dBA apart. This indicates that there was no significant improvement in sound reduction with any of the various muffler configurations under the maximum acceleration conditions of this test procedure. This could be due to vehicle sound sources, other than exhaust noise, having a significant effect during full throttle conditions. Other sound sources such as combustion air intake and engine/transmission radiated sound will be investigated during the next phase of this project.

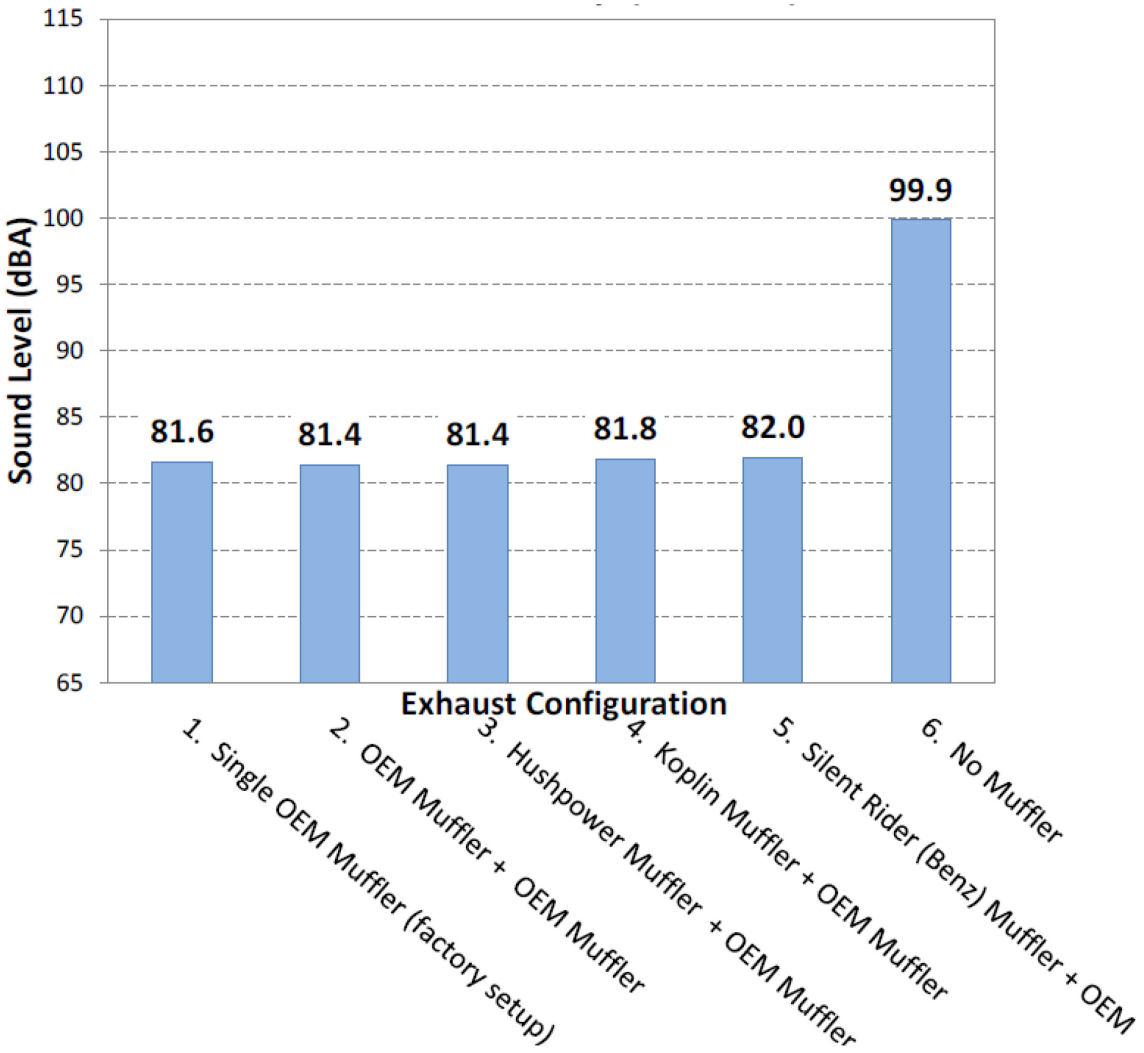

Figure 6: Sound level for various exhaust configurations full throttle Pass-by (SAE J192).

4.4 Power loss

For all test configurations shown, horsepower was measured on a Mustang brand chassis dynamometer, within a three hour period.

Both the OEM and Hushpower secondary muffler configurations performed similarly. They both added less than 0.5 psi of back pressure over the factory setup and resulted in a power loss of less than 5%.

The Silent Rider muffler configuration resulted in a substantial 6 psi increase in back pressure. This significantly affected the performance of the engine and resulted in a power loss of 14%.

The Koplin muffler configuration was not tested for power but, based on significantly higher back pressure measurements, is it expected result in more power loss than the OEM and Hushpower secondary muffler configurations but less than the Silent Rider setup.

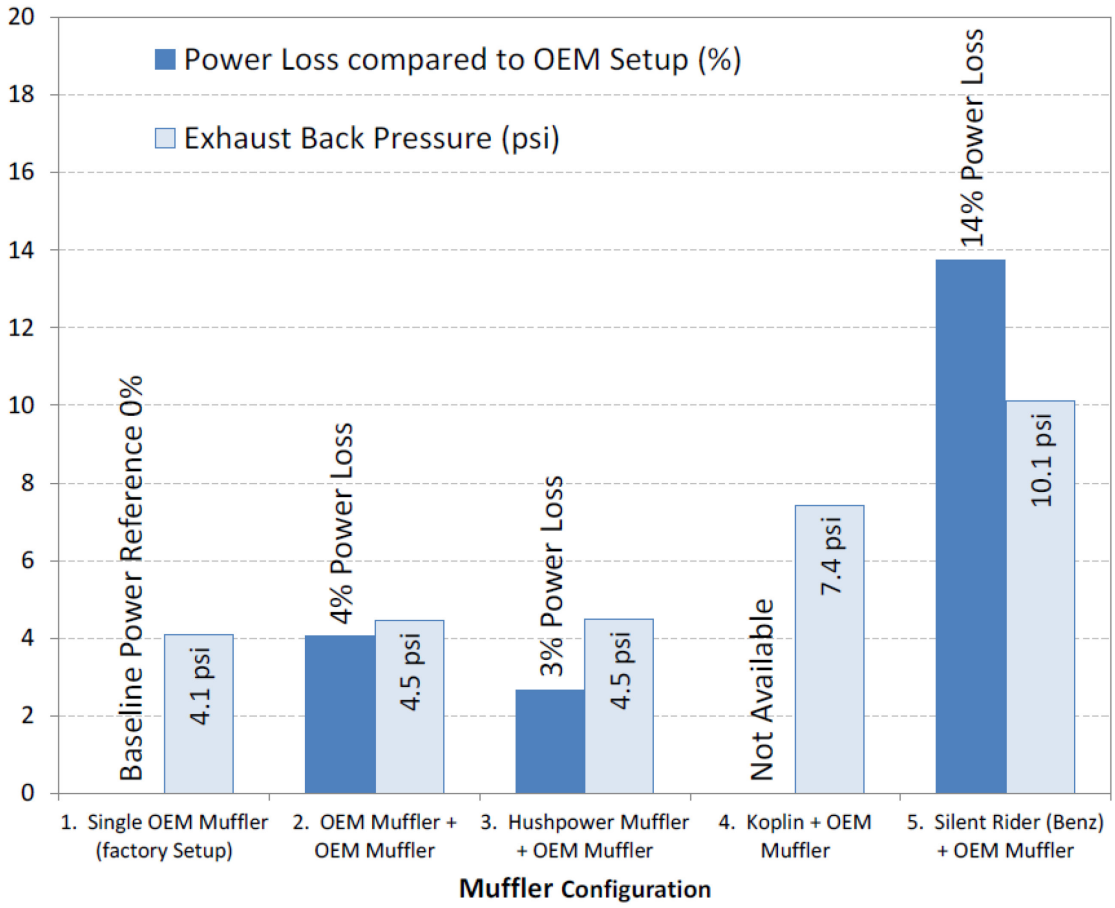

Figure 7: Loss of power and exhaust back-pressure for various exhaust configurations compared to OEM muffler configuration.

5 Summary of muffler performance

5.1 Polaris OEM muffler and Flowmaster Hushpower muffler

Both of these mufflers performed similarly in all tests and should be considered the best of the tested secondary muffler configurations. The Polaris muffler performed marginally better during the constant speed test by almost 1 dBA and could be given a slight acoustic performance advantage because of this. They both seem to be robustly built designs compared to the others, however some paint had burned off the Hushpower muffler by the end of the test. The Polaris silencer has a thicker casing and has likely gone through more rigorous durability testing because of its OEM intentions and higher production volumes.

Although some aftermarket suppliers seem to have some stock of the Hushpower muffler, it is no longer in production at the time of this report and the manufacturer does not have any stock. It does not seem likely that the quantity of mufflers required for this retrofit project would be available.

5.2 Koplin stealth muffler

This muffler did not excel in any categories. Its performance, design and build quality were unremarkable, but it did not have any obvious deficiencies. It was one of the lighter, more compact designs, but these characteristics were not a significant factor for this application.

This muffler would not be the best suited for this application.

5.3 Silent Rider (Benz) muffler

This muffler routes the exhaust flow through acoustic absorption packing. This design causes considerable exhaust back pressure that resulted in a significant reduction in engine performance. The power loss was 14%, which is more than the 10% that is allowed as part of this sound reduction project. The absorptive packing in this muffler shifted within the short time period of this test. The back pressure was 13 psi at full throttle at the beginning of testing. After several tests, the back pressure had changed to approximately 10 psi. Over time, this design is likely to result in degraded acoustic performance and reliability.

This muffler is not likely to perform adequately for this application.

6 Summary of OEM baseline test measurements

The following table summarizes baseline sound level measurements. Testing was performed with the factory setup, as delivered from the manufacturer, with the exception of the tires. The original equipment "knobby" tires were replaced with smooth tread tires in order to more easily help identify valid sound sources for this project.

The sound levels were obtained from a single ATV that was accessible at the time of initial testing. This project involves two vehicles and other baseline measurements may be obtained from the second ATV, if appropriate.

Table 1: Baseline sound level measurements.

Polaris Big Boss 800 6X6 (Factory setup, as delivered from the manufacturer*)

Stationary Conditions, Exhaust Sound Level Near Tailpipe Outlet (SAE J1287)	**90**
Constant Speed Pass-By Sound Level (SAE J1161)	**74**
Full Throttle Pass-By, Maximum Sound Level (SAE J192)	**82**

OEM "knobby" tires were replaced with smooth tread tires

7 Conclusions

Four exhaust configurations using different commercially available add-on mufflers were tested as part of this initial evaluation towards reducing the operational sound level of a Polaris Big Boss 800 vehicle. The use of a Polaris OEM muffler as a secondary silencer was considered the best choice for a commercially available add-on solution. This conclusion is based on the simple scope of this initial testing for acoustic and power performance, reliability and availability. This muffler, as with all the others, would require custom fitment in order to mount to this application. There are currently no aftermarket secondary muffler systems that will mount onto this 6x6 vehicle without custom fitting.

To further the goal of maximizing sound reduction, there are several opportunities that will be investigated as this project progresses. A specifically designed muffler system will be explored and is expected to be more effective in silencing exhaust noise. Other sources include induction air noise and mechanically radiated noise from the engine and transmission systems, which will also need to be treated, if overall reductions of greater than 1 to 4 dBA are to be achieved.

The next report will include items that were investigated to further reduce operational sound levels for the Polaris Big Boss 800 6X6.

Annex A Muffler configurations

A.1 General Notes

The original factory mounted muffler was left installed, in its original location, for all test configurations with the exception of the open exhaust tests, when there was no muffler installed in the system.

For all configurations involving a secondary muffler, the additional muffler was installed in series silencer and downstream of the existing OEM muffler. This is the suggested arrangement by all the aftermarket silencer manufacturers.

The exhaust pipe outlets for all the secondary mufflers were located in the same area and pointed in a similar direction towards the rear of the vehicle.

All secondary mufflers were bolted to the OEM existing muffler using a square flange connection with an exhaust gasket to seal the connection.

The originally mounted muffler outlet pipe diameter was 1-3/8" and all secondary muffler tailpipes were adapted to exhaust at this same outlet diameter.

Secondary mufflers generally experienced between 20-25 full throttle test runs, 10-15 constant speed pass-by runs, stationary noise measurements and other minor miscellaneous testing runs. In addition to the aforementioned testing runs, the Hushpower + OEM installed muffler configuration was used for sound power measurement on the chassis dynamometer and experienced the equivalent of approximately 30 additional full throttle extended runs plus 30 mid-throttle extended runs.

The various secondary mufflers were adapted for testing using a universal mount system. The location may not have been the most suitable for field operation, but it allowed for the most consistent configuration to compare the sound characteristics of the various mufflers.

The prices of the commercially available mufflers tested were in the $150 - 250 range. Cost was not considered a significant factor for this evaluation of these aftermarket mufflers.

A.2 Secondary muffler design details

A.2.1 Polaris OEM factory installed muffler only (Part Number 1261223-489)

The exhaust is directed through five different volume chambers. All of the chambers are surrounded by 5 mm of absorptive acoustic packing held in place by perforated metal. Three of the chambers direct the exhaust through perforated areas to swirl or break up the exhaust flow.

This muffler is stamped with “USFS QUALIFIED” that suggests it is qualified for its spark arresting capability under the United States Forest Safety guidelines.

Figure A 1: Polaris factory exhaust set up.

A.2.2 OEM muffler + OEM factory installed muffler (Part Number 1261223-489)

This configuration utilizes two OEM mufflers in series and added minimal pack pressure and resulted in a minor power loss of less than 5%.

The condition of internal metal components and acoustic packing appeared to be in very good after this testing phase.

This muffler is readily available from any Polaris dealer.

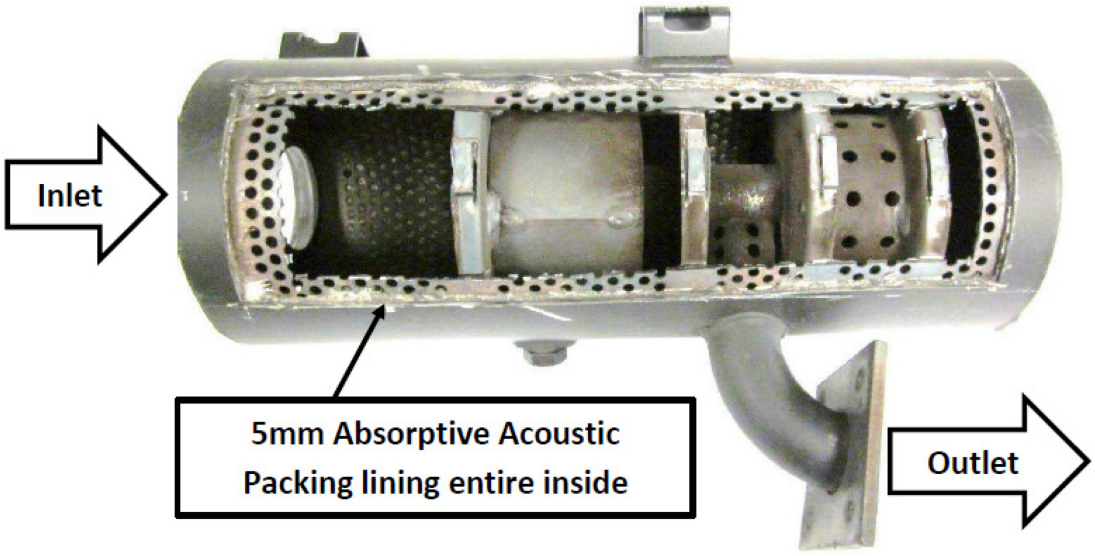

Figure A 2a: Polaris OEM muffler cutaway.

Figure A 2b: Polaris OEM muffler adapted for use as a second muffler.

Figure A 2c: Polaris OEM muffler mounted in series with factory installed muffler.

A.2.3 Flowmaster Hushpower muffler + OEM installed muffler

This design includes an open chamber at each of the inlet and outlet sides of the muffler. The core section diffuses the exhaust through a perforated venturi shape, then through a perforated tube, and then out a perforated reverse venturi. The large volume outside of the perforated tube is thickly packed with 30 mm of acoustic absorption material.

This configuration added minimal back pressure and resulted in a minor power loss of less than 5%.

The internal condition of the metal components and the acoustic packing appeared to be in very good condition after the testing process.

This ATV muffler was produced by Flowmaster Inc and has recently been discontinued. At the time of this report, there is almost no stock at dealers.

Figure A 3a: Hushpower muffler cutaway.

Figure A 3b: Hushpower muffler adapted for use as a secondary muffler.

Figure A 3c: Hushpower muffler mounted in series with factory installed muffler.

A.2.4 Koplin muffler + OEM installed muffler

This design utilizes three different volume chambers that are separated across the length of the muffler by two metal plates. Each separator plate has a similar small area with perforations. The exhaust is directed into the smallest volume chamber first. It then flows through the perforations into the intermediate chamber and then through the second perforated plate into the third and largest chamber. The exhaust then exits the muffler from the outlet.

This design does not utilize any acoustic packing for absorption.

The internal condition of the metal components appeared to be in very good condition after the testing phase.

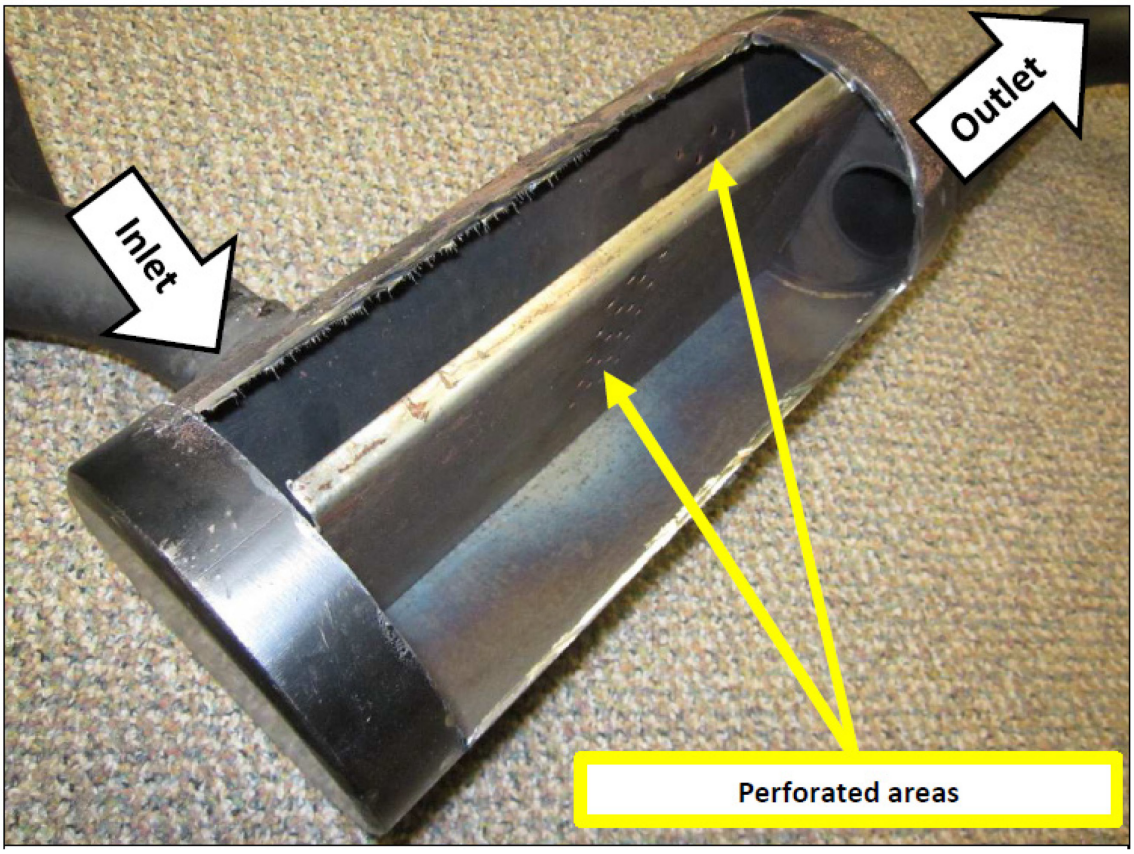

Figure A 4a: Koplin muffler cutaway.

Figure A 4b: Hushpower muffler adapted for use as a secondary muffler.

Figure A 4c: Hushpower muffler mounted in series with factory muffler.

A.2.5 Silent Rider (Benz) + OEM installed muffler

This design utilizes a perforated tube surrounded by acoustic packing in the surrounding chamber. There is a solid plug in the centre of the perforated tube which directs the flow into the surrounding chamber with 15 mm of acoustic packing. The exhaust must flow directly through the packing towards the other side of the chamber and then through the perforations on the opposite side of the plugged center tube.

With this new muffler installed, the back pressure under full throttle conditions was 13 psi for pass-by tests. By the time the various tests were concluded on the dynamometer, the back pressure had dropped to 10.1 psi. The reason for this inconsistency was obvious when the muffler was cut open for inspection at the end of testing. The acoustic packing had been blown to one side as the exhaust attempted to find the path of least resistance through the material.

Due to the design of this muffler, it is likely to produce inconsistent results for sound attenuation, power and reliability. Although it produced respectable sound attenuation when new and under low power conditions, its performance is expected to degrade significantly with use. The back pressure was very high when new, and although it was reduced after some use, it was still significantly higher than any other muffler tested.

Because of excessive back pressure, the use of this muffler resulted in a large maximum power drop of almost 5 horsepower. This calculates to a 14% power loss and significantly more than any other muffler configuration tested.

This silencer was previously known as a “Benz Muffler”.

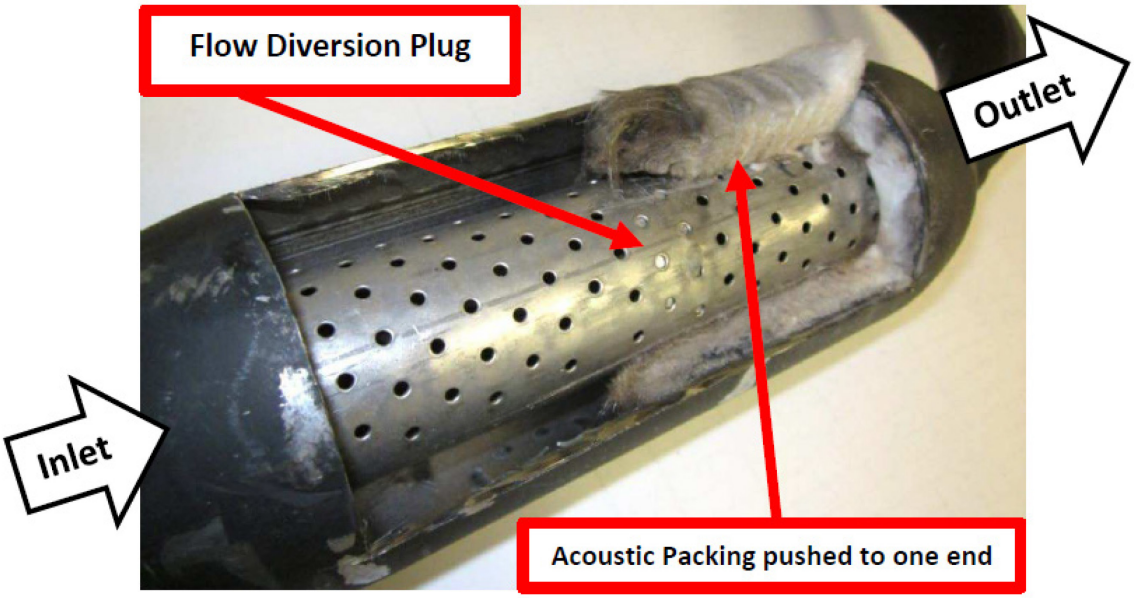

Figure A 5a: Silent Rider muffler cutaway after testing.

Figure A 5b: Hushpower muffler mounted in series with factory muffler.

Figure A 5c: Hushpower muffler mounted in series with factory muffler.

Annex B TEST and MEASUREMENT NOTES

Measurement area ground surface consisted of paved asphalt. There were no major obstructions within 60 meters of the measurement point. Sound measurement equipment was set to dBA, fast dynamic response.

Pass-by and stationary sound level measurements were conducted at the Hershey Centre in Mississauga, Ontario.

A high speed, 10 Hz satellite GPS digital data system was used to determine pass-by testing speeds (AIM Sports model Solo). This system helped insure better accuracy and consistency due to less calibration and reading errors.

Sound power measurements were primarily conducted in the chassis dynamometer chamber at the University of Oshawa Institute of Technology in Oshawa, Ontario. Some initial testing was performed on the chassis dynamometer at D'Sousa Performance in Milton, Ontario. Both chassis dynamometers utilized were manufactured by Mustang Dynamometers.

A pressure tap was installed upstream of the OEM muffler in order to measure exhaust back pressure for the various test configurations.

Initial testing was performed to compare sound levels of OEM "knobby" tires to smooth tread tires. The smooth tread tires produced approximately 1 dBA less noise during a 24 km/r constant speed evaluation. In the interest of better identifying sound sources, measurement consistency and tire reliability on the chassis dynamometer, Dura Top-Fighter tires were used for drive-by and dynamometer evaluations. This tire is a grooved, smooth tread design. (see figures B1 and B2)

Figure B 1: OEM knobby tires (Kenda K590).

Figure B 2: Smooth tread tires used during testing (Duro Top-Fighter).

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Defence R&D Canada – Suffield is investigating methods of reducing the acoustical signatures of a variety of small all-terrain vehicles (ATVs). Before vehicle modifications are conducted on a test ATV platform, a set of baseline measurements are required to establish the noise level of the unmodified platform. It is also important to define the noise reduction achievable with commercially available mufflers as a benchmark for the custom solutions developed under this project. As such, HGC Engineering analysed the sound levels produced by a Polaris Big Boss 6x6 ATV with its factory exhaust system, and also with several "silent" muffler systems. The study found that the most effective approach existing approach for reducing noise without reducing vehicle power is using two Polaris factory mufflers in series.

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Vehicle mobility; Sound testing; Mufflers; All-Terrain Vehicles

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