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Better Brakes Enforcement Study 2017

by

Christina Wiseman

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Overview

There are over 6.8 million vehicles registered in the state of Washington. Each time a driver steps on the brakes, small amounts of metal and other material deposit onto roadways from brake pads. Brake pad friction material washes from roadways into our streams and rivers. Metals in these brake pads can include cadmium, copper, and lead which are toxic to fish. Over time, these small amounts of metals from millions of vehicles impact the water quality of our streams, rivers, lakes, and Puget Sound.

An estimated 250,000 pounds of copper enter Washington waters each year from vehicle brake pads with an estimated 130,000 pounds ending up in Puget Sound (Ecology and King County, 2011). Copper has been found to be highly toxic to fish and other aquatic species.

In 2010, the Better Brakes law was enacted (Chapter 70.285 Revised Code of Washington) requiring manufacturers of vehicle brakes to limit the amount of asbestos, hexavalent chromium, lead, mercury, and cadmium to less than 0.01 percent by weight. The law requires that brake manufacturers reduce the amount of copper in brake pads to less than 5 percent SAE J2975 by 2021 and 0.5 percent by 2025.

The law also requires brake manufacturers have their friction material (brake pads and shoes) analyzed in order to verify their brakes comply with these restrictions. Manufacturers must then provide Ecology with these results and list of materials used in their products.

The Washington State Department of Ecology (Ecology) conducted a product testing study of brake pad friction materials to determine concentrations of total cadmium, copper, and lead in brakes sold in Washington State in 2017. Purchased brake pads were compared to the list of certified brake products to identify manufacturers not in compliance with the certification requirement. The study also gathered information on uncertified brake products.

A total of 163 brake pads were purchased that represent a wide range of vehicle types and weights. Samples of the friction material on the brake pads were obtained by a contract laboratory (by drilling into the pad/friction material), the samples were then sent to Ecology's Manchester Environmental Laboratory (MEL) for metals analysis.

The data obtained during this study met the measurement quality objectives (MQO's) established in the [Better Brakes Enforcement Study 2017 - Addendum to Quality Assurance Project Plan: Product Testing Program, Version 1.0](#) (Wiseman 2017). The metals results were used by the Better Brakes Enforcement Officer for compliance enforcement. The snapshot of data collected from this study documented that the majority of manufacturers had certified their products and were in compliance with the law. A follow-up brake study will be conducted in either 2020 or 2024 anticipating the copper phase-out schedule that requires copper concentrations in brakes to be less than 0.5 percent by weight by 2025. If warranted, Ecology may conduct ongoing compliance and enforcement activities as part of our Better Brakes program implementation. Download complete laboratory results for this study from [Ecology's Product Testing Database](#).¹

¹ <https://fortress.wa.gov/ecy/ptdbpublicreporting/>

Click “study” under Download Data. Choose the Better Brakes Enforcement 2017 study from the dropdown menu.

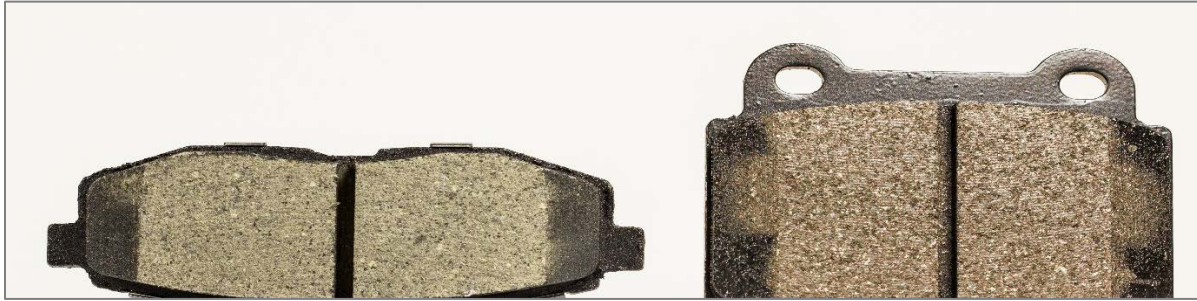


Figure 1: Brake pad on the left demonstrates the lowest copper value from the 2017 Better Brakes Enforcement Study while the brake pad on the right contained the highest copper result

Methods

To demonstrate compliance with Washington’s Better Brakes Law, we used the Society of Automotive Engineers (SAE) method J2975:2013 (SAE J2975). This method uses a specific pre-treatment drilling procedure with options for digestion and analysis methods based on the chemicals being analyzed. Due to the complex and heterogeneous nature of brake friction materials, SAE J2975 recommends that digestion and analysis for each pad be performed in triplicate (at a minimum) and an average value be reported.

We followed the SAE J2975 methods in order to meet the Data Quality Objectives of the *Better Brakes Enforcement Study 2017 Quality Assurance Project Plan* (Wiseman, 2017).

Product Collection

We targeted manufacturers that had not certified their products with Ecology. We bought brake friction materials (brakes) from 55 brake retailers, including online and Western Washington automotive parts stores. A local municipality donated two bus brakes to this study.

The brakes purchased represent the types of brakes sold in Washington State for a wide variety of vehicle types: different weights of passenger vehicles, heavy-duty vehicles, and special use vehicles (bus, ambulance, police car, garbage truck, and high-end sports cars).

All brake products collected were maintained by chain of custody procedure in accordance with the *Better Brakes Enforcement Study 2017 Quality Assurance Project Plan* (Wiseman, 2017).

Pre-treatment and Laboratory Sample Selection

An International Organization of Standardization (ISO) accredited brake drilling contractor prepared 163 brake friction material samples (brake samples) in 27 batches. To obtain a representative sample, the SAE J2975 pre-treatment procedure requires all brake friction material be drilled to a 5 mm depth. For small brake friction material, 35 - 40 drill holes were bored (see Figure 2). For brakes with thicker or longer friction material (like on buses, ambulances and trucks) a minimum of 1 hole per 2 cm² were bored.

Blanks (3 storage and 27 processing) were collected in accordance with procedures described in the *Better Brakes Enforcement Study 2017 QAPP* (Wiseman, 2017). All blanks and drilled brake

friction material samples were sent to Ecology's Manchester Environmental Laboratory (MEL) for chemical analysis.

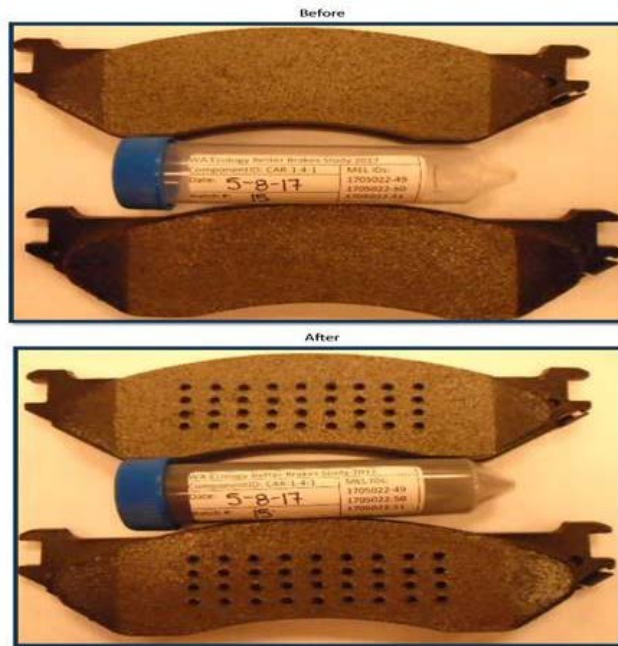


Figure 2: Example of a brake friction material sample before and after

Laboratory Procedures

MEL received 163 drilled brake samples, 3 storage blanks, and 27 processing blanks from the drilling contractor in good condition.

MEL performed digestion by the Environmental Protection Agency (EPA) 3050B and analysis by EPA 6010C, as allowable under SAE J2975A for 163 drilled brake samples. As specified in the *Better Brakes Enforcement QAPP*, the digestion and the cadmium, copper, and lead analyses were performed in triplicate. Results were reported by MEL as individual results.

One storage blank and two randomly selected drill processing blank samples were prepared and analyzed by MEL for cadmium, copper, and lead (Table 1) in accordance with EPA methods 200.2 and EPA 200.8 respectively. These methods were added to this study to effectively evaluate the storage and drill processing blank samples that were collected in deionized water and suspected to have results at or near the reporting limit (RL).

Table 1. The 2017 Better Brakes Study Laboratory Procedures

Analyte	Number of Samples	Expected Range of Results	Matrix	Reporting Limit (ppm)	Preparation Method	Analysis Method	Analysis Instrument
Metals (Cd,Cu,Pb)	163 results averaged in triplicate	< 5.0 – 400,000 ppm	Drilled brake friction material	5.0 ppm	EPA 3050B	EPA 6010D	ICP-OES
Metals ² (Cd,Cu,Pb)	3	< .10 – 400,000 ppm	Drilled brake friction material	0.10 µg/L	EPA 200.2	EPA 200.8	ICP-MS

One hundred and sixty three drilled brake sample were prepared in triplicate by EPA 3050B (SW3050B) and then analyzed in triplicate by EPA 6010D (SW6010D) (Table 1).

Data Quality

EPA 6010D

All 163 brake samples met the Measurement Quality Objectives (MQO) detailed in the *Better Brakes Enforcement QAPP* (Wiseman, 2017) for cadmium, copper, and lead analysis. The quality of the analytical data were assessed in terms of accuracy, representativeness, completeness, and precision in relation to the MQO. One hundred and sixty three samples were run in nine batches by method EPA 6010D. Every sample of cadmium, copper, and lead were prepared and analyzed in triplicate (i.e. 3 subsamples per sample for a total of 9 individual results per sample). Two samples were run as duplicates creating 18 results for those samples. MEL analyzed a total of 1,485 samples.

The Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) instrument was calibrated in accordance with method EPA 6010D. The instrument was calibrated with two NIST traceable standards. All the initial and continuing calibration verification checks and blanks were within the acceptable limit. None of the analytes of concern were detected in method blanks. All Laboratory Control Samples (LCS's) and Laboratory Control Duplicate Samples (LCS Dup's) recoveries met the precision MQO and were within the < 20% relative percent difference (RPD) method acceptance criteria.

The Better Brakes Study's reporting limit (RL) for cadmium, copper, and lead was set at five parts per million (ppm). However, some samples were diluted prior to analysis due to matrix interferences which resulted in elevated reporting limits. The samples that had elevated RL values were lower than one-third the compliance levels for the metals of concern in brake friction materials

The U qualifier indicates that the chemical was not found in the sample above the reporting limit. The RL values are used for the Analyses Value in cases where the result has been U-qualified. The U-qualified data is included in the component/sample averaging which requires at least a minimum of three analytical results per sample.

² This method only applies to blanks

One storage blank and two randomly selected drill processing blank samples were prepared and analyzed by EPA 200.2 and EPA 200.8 for cadmium, copper, and lead (Table 1.) Cadmium and lead were not detected in the storage or drill processing blanks above the 0.10 µg/L RL. The copper storage blank was reported at the 0.10 µg/L RL and the drill processing blanks were both just over the 0.10 µg/L reporting limit at 0.22 µg/L and 0.16 µg/L.

All analyses for both EPA 6010D and EPA 200.8 methods were evaluated by MEL and met the methods quality assurance guidelines. Case narratives are available upon request.

Because of the complex and heterogeneous nature of brake friction materials the SAE J2975 method recommends that each pad is digested and analyzed in triplicate (at a minimum) and the average value reported. Percent Relative Standard Deviation (RSD) (standard deviation /measurement average *100) should be < 20% for the triplicate measurements. Six percent of the triplicate subsamples groups exceeded the 20% RSD. No data were qualified because of RSD guideline exceedances. The samples that exceeded the 20% RSD guideline had results that were 10 times below the compliance limits and those results will not be used for enforcement.

Results

Individual Sample Results

One hundred and sixty three brake samples were analyzed in triplicate for cadmium, copper, and lead generating 1,467 individual test results. In addition, 2 samples were run as duplicates creating 18 results for those brake samples for a total of 1,485 cadmium, copper, and lead test results (Table 2). The duplicate results are included in both the total brake sample averaging results as well as the RDS calculations.

Table 2. Summary Statistics of Metals Detected in Brake Samples Individual Test Results

Analyte	Cadmium	Copper	Lead
Number (n)	1,485	1,485	1,485
n> RL ³	9	1,484	231
% > RL	0.6%	99.9%	15%
Minimum (ppm) ⁴	5.37	9.47	5.13
Maximum (ppm) ⁴	52	378,000	2,500

The individual cadmium results ranged from 5.37 to 52 ppm. Nine out of the 1,485 (0.6%) of the brake samples were detected above the reporting limit. The individual copper results ranged from 9.47 to 378,000 ppm. One thousand four hundred and eighty four (99.9%) out of 1,485 brake samples had results above the reporting limit. The individual lead results ranged from 5.13 to

³ RL = reporting (quantitation) limit. The RL values range due to the high metal concentrations and dilution factor. Cadmium RL range = 5. to 20.4 ppm. Copper RL range = 5. to 121 ppm. Lead RL range = <4.46 to 50.6 ppm.

⁴ Statistics include only detected results.

2,500 ppm. Two hundred and thirty one brake samples (15%) were detected above the reporting limit.

SAE J2975 Averaged Results

Cadmium

All 163 brake samples analyzed met the Better Brakes cadmium 0.01% compliance criteria. The cadmium values detected in the brake samples ranged from 5 to 50 ppm (Table 3). Three percent, (5 out of 163), brake samples had a cadmium result above the 5.0 ppm reporting limit.

Table 3. Better Brakes 2017 Compliance Criteria Summary Utilizing SAE J2975 (Averaged Results)

	Cadmium	Copper	Lead
Regulatory Limit	100 ppm	Current: No limit 2021: 50000 ppm 2025: 5000 ppm	1000 ppm
Number (n)	163	163	163
N > Compliance Criteria	0	N/A	4
% Compliance Criteria	0%	N/A	2.5%
Minimum (ppm) ⁵	5	14	5
Maximum (ppm) ⁵	50	347000	2433

⁵ Statistics include the averaging of non-detected and detected results.

Copper

- Forty-three % (71 out of 163) of the brake samples had copper at greater 5% (Compliance level A) (Figure 3).
- Seventeen % (24 out of 163) of the brake samples had between 0.5 to 5% copper (Compliance level B).
- Forty-one% (68 out of 163) brake samples had results that met 2025 copper criteria and contained less than 0.5% copper (Compliance Level N).

The reported copper values ranged from 14 to 347,000 ppm. All of the 163 brake sample results contained copper above the 5.0 ppm reporting limit (Table 3).

For copper, the legislation provided a phase out strategy for manufacturers to make reductions over the next 10 years. By 2021 all brake friction materials manufactured are to contain less than 5% copper (Level B) and by 2025 all friction materials must contain less than 0.5 percent copper (Level N).

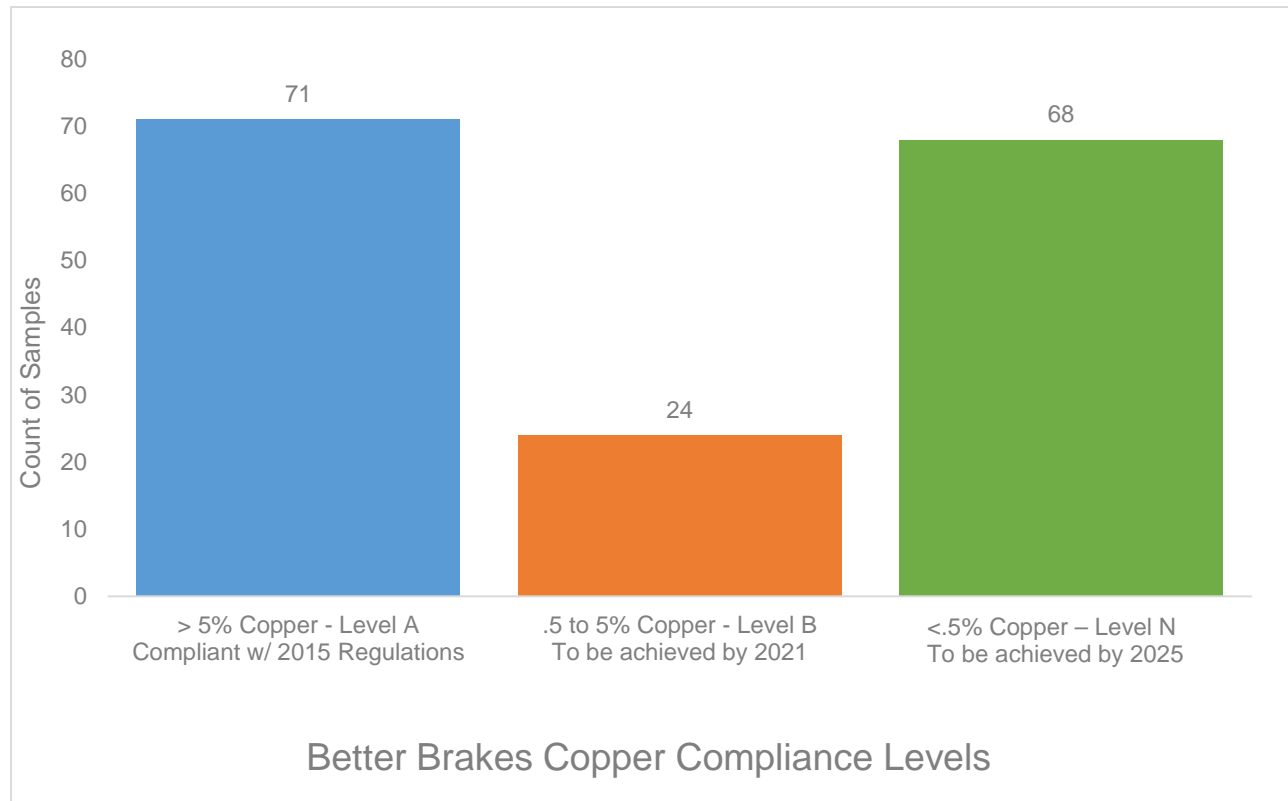


Figure 3. Better Brakes Copper Compliance Summary of 163 Brake Samples Utilizing SAE J2975

Lead

The lead regulatory compliance criteria for 2015, 2021 and 2026 for is 0.1% (1000 ppm).

- Four out of 163 brake samples (2.5%) had values above the 0.1% (1000 ppm) exceeding the Better Brakes compliance criteria for lead (Figure 4).
- Lead was detected in brake samples in a range of 5 to 2,433 ppm.
- Eighty-two out of 163 brake samples (50.5%) had lead results above the 5.0 ppm (RL) reporting limit (Table 3).

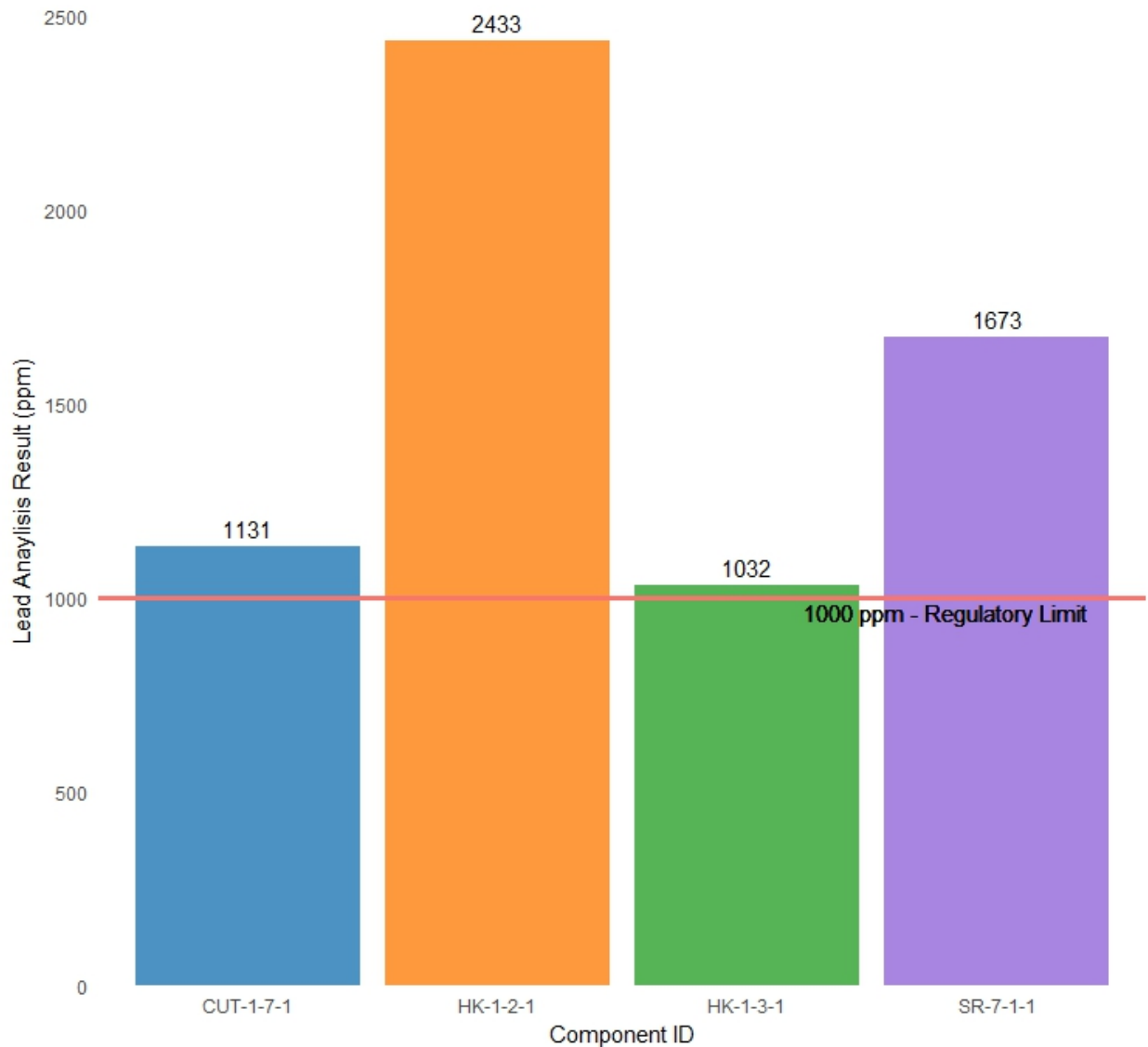


Figure 4. Better Brakes Lead Compliance Summary of 163 Brake Samples utilizing SAE J2975 (Averaged results)

The Better Brakes MEL data and the brake sample manufacturer information is stored in Ecology's Product Testing Database.

Conclusions

Cadmium results for all 163 met the Better Brakes Compliance criteria. Copper was present in all of the brake samples in level A, B and N. Four out of 163 brake samples were above the Better Brakes Compliance criteria for lead.

Data results from this study will be used enforce the Better Brakes Law by identifying uncertified and inaccurately certified brake products. Ecology will conduct brake enforcement studies in the future to assess compliance with the Better Brakes Law copper phase out, according to the following schedule:

- Brake pads and shoes manufactured after January 1, 2015 must not contain asbestos, hexavalent chromium, mercury, cadmium or lead. Auto shops and other distributors of brakes will be able to sell any existing inventory for 10 years.
- Brake pads manufactured after January 1, 2021 must contain less than 5% copper by weight.
- Brake pads manufactured after January 1, 2025 must contain less than 0.5% percent copper by weight.

Ecology will continue to conduct brake studies to assess compliance with the Better Brakes Law phase out schedule for cadmium, copper, and lead.

Compliance and Enforcement

The laboratory data for this project were submitted to the Better Brakes enforcement coordinator for assessment for compliance with Washington law. Ecology will conduct compliance and enforcement efforts on manufacturers whose products did not meet the Better Brakes legal requirements.

Additional Resources

The Quality Assurance Project Plan for this study is available at:

<https://fortress.wa.gov/ecy/publications/SummaryPages/1704005.html>

Data for this project is available at Ecology's Product Testing Database:

<https://fortress.wa.gov/ecy/ptdbpublicreporting>. Select Study, *Better Brakes Enforcement Study 2017*.

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[Better Brake Rule, Chapter 173-901 WAC](#)

[Brake Friction Material Law](#) Chapter 70.285 RCW

Appendix A

Better Brakes Enforcement 2017 – SAE J2975 Averaged Results Summary & RSD Values

Better Brakes Enforcement Study 2017 SAE J2975 Averaged Results Summary and RSD Values				
Bold results indicate RSD exceedances.				
All exceedances of the RSD criteria were at levels well below the regulatory thresholds and therefore were not used for enforcement.				
Component Id Code	Chemical Name	mean(Analysis Quantity Computed)	mean(Reporting Limit Quantity)	(RSD) Percent Relative Standard Deviation (standard deviation / measurement average * 100)
AA-1-1-1	Cadmium	5.00	5.00	0
AA-1-1-1	Copper	32.10	10.33	6
AA-1-1-1	Lead	10.33	10.33	1
AA-1-2-1	Cadmium	5.00	5.00	0
AA-1-2-1	Copper	128.87	5.19	110
AA-1-2-1	Lead	5.19	5.19	1
AA-1-3-1	Cadmium	5.00	5.00	0
AA-1-3-1	Copper	38500.00	10.60	3
AA-1-3-1	Lead	745.00	10.60	2
AA-1-4-1	Cadmium	5.00	5.00	0
AA-1-4-1	Copper	5150.00	30.63	3
AA-1-4-1	Lead	30.63	30.63	2
AA-1-6-1	Cadmium	5.00	5.00	0
AA-1-6-1	Copper	71766.67	10.19	0
AA-1-6-1	Lead	584.33	10.19	3
AA-1-7-1	Cadmium	5.00	5.00	0
AA-1-7-1	Copper	13833.33	34.07	11
AA-1-7-1	Lead	34.07	34.07	2
AAP-1-1-1	Cadmium	5.00	5.00	0
AAP-1-1-1	Copper	495.33	30.80	13
AAP-1-1-1	Lead	30.80	30.80	2
AAP-1-2-1	Cadmium	5.00	5.00	0
AAP-1-2-1	Copper	138666.67	20.33	13
AAP-1-2-1	Lead	211.00	20.33	2
AAP-2-1-1	Cadmium	5.00	5.00	0
AAP-2-1-1	Copper	76933.33	24.20	4
AAP-2-1-1	Lead	26.80	24.20	2

Better Brakes Enforcement Study 2017 SAE J2975 Averaged Results Summary and RSD Values
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Component Id Code	Chemical Name	mean(Analysis Quantity Computed)	mean(Reporting Limit Quantity)	(RSD) Percent Relative Standard Deviation (standard deviation / measurement average * 100)
AAP-2-2-1	Cadmium	5.00	5.00	0
AAP-2-2-1	Copper	1530.00	35.80	6
AAP-2-2-1	Lead	35.80	35.80	2
AM-13-1-1	Cadmium	5.00	5.00	0
AM-13-1-1	Copper	97700.00	20.23	4
AM-13-1-1	Lead	28.30	20.23	1
AM-13-10-1	Cadmium	5.00	5.00	0
AM-13-10-1	Copper	125666.67	20.43	3
AM-13-10-1	Lead	20.43	20.43	2
AM-13-11-1	Cadmium	5.12	5.00	4
AM-13-11-1	Copper	339000.00	31.57	1
AM-13-11-1	Lead	107.00	31.57	3
AM-13-2-1	Cadmium	5.00	5.00	0
AM-13-2-1	Copper	64.10	15.93	22
AM-13-2-1	Lead	15.93	15.93	2
AM-13-3-1	Cadmium	5.00	5.00	0
AM-13-3-1	Copper	17633.33	10.67	6
AM-13-3-1	Lead	66.40	10.67	1
AM-13-4-1	Cadmium	49.60	5.00	4
AM-13-4-1	Copper	56733.33	31.73	1
AM-13-4-1	Lead	538.67	31.73	1
AM-13-5-1	Cadmium	5.00	5.00	1
AM-13-5-1	Copper	47800.00	5.41	6
AM-13-5-1	Lead	138.67	5.41	2
AM-13-6-1	Cadmium	5.00	5.00	0
AM-13-6-1	Copper	18.59	15.90	82
AM-13-6-1	Lead	25.13	5.87	11
AM-13-7-1	Cadmium	5.00	5.00	0
AM-13-7-1	Copper	69700.00	5.09	7
AM-13-7-1	Lead	630.67	5.06	3

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Component Id Code	Chemical Name	mean(Analysis Quantity Computed)	mean(Reporting Limit Quantity)	(RSD) Percent Relative Standard Deviation (standard deviation / measurement average * 100)
AM-13-8-1	Cadmium	5.00	5.00	0
AM-13-8-1	Copper	2193.33	10.47	6
AM-13-8-1	Lead	22.40	10.47	11
AM-13-9-1	Cadmium	5.00	5.00	0
AM-13-9-1	Copper	241.33	32.43	3
AM-13-9-1	Lead	32.43	32.43	4
AP-1-1-1	Cadmium	5.00	5.00	0
AP-1-1-1	Copper	60133.33	26.10	1
AP-1-1-1	Lead	28.80	26.10	18
APAP-1-1-1	Cadmium	5.00	5.00	0
APAP-1-1-1	Copper	108666.67	10.57	4
APAP-1-1-1	Lead	78.90	10.57	4
APAP-1-2-1	Cadmium	5.00	5.00	0
APAP-1-2-1	Copper	245.67	35.97	5
APAP-1-2-1	Lead	35.97	35.97	4
APAP-1-3-1	Cadmium	5.00	5.00	0
APAP-1-3-1	Copper	26100.00	5.34	1
APAP-1-3-1	Lead	8.24	5.34	7
APAP-1-4-1	Cadmium	5.00	5.00	0
APAP-1-4-1	Copper	120000.00	11.17	0
APAP-1-4-1	Lead	11.17	11.17	1
APAP-1-5-1	Cadmium	5.00	5.00	0
APAP-1-5-1	Copper	345.00	31.53	1
APAP-1-5-1	Lead	31.53	31.53	7
APW-1-1-1	Cadmium	5.00	5.00	0
APW-1-1-1	Copper	193.33	17.13	54
APW-1-1-1	Lead	19.77	17.13	5
APW-1-2-1	Cadmium	5.00	5.00	0
APW-1-2-1	Copper	60433.33	5.71	4
APW-1-2-1	Lead	77.73	5.71	4
APW-1-3-1	Cadmium	5.00	5.00	0

Better Brakes Enforcement Study 2017 SAE J2975 Averaged Results Summary and RSD Values
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Component Id Code	Chemical Name	mean(Analysis Quantity Computed)	mean(Reporting Limit Quantity)	(RSD) Percent Relative Standard Deviation (standard deviation / measurement average * 100)
APW-1-3-1	Copper	143333.33	10.87	14
APW-1-3-1	Lead	56.93	10.87	5
APW-1-4-1	Cadmium	5.00	5.00	0
APW-1-4-1	Copper	11400.00	17.73	4
APW-1-4-1	Lead	29.37	17.73	7
APW-1-5-1	Cadmium	5.00	5.00	0
APW-1-5-1	Copper	176333.33	11.40	1
APW-1-5-1	Lead	11.40	11.40	3
APW-1-6-1	Cadmium	5.00	5.00	0
APW-1-6-1	Copper	565.67	34.90	14
APW-1-6-1	Lead	34.90	34.90	3
AT-1-1-1	Cadmium	5.00	5.00	0
AT-1-1-1	Copper	343.67	33.80	13
AT-1-1-1	Lead	33.80	33.80	1
AT-1-2-1	Cadmium	5.00	5.00	0
AT-1-2-1	Copper	13.97	5.45	20
AT-1-2-1	Lead	14.33	5.45	5
AZ-1-1-1	Cadmium	5.00	5.00	0
AZ-1-1-1	Copper	101700.00	10.97	9
AZ-1-1-1	Lead	19.70	5.50	12
AZ-1-2-1	Cadmium	5.00	5.00	0
AZ-1-2-1	Copper	107000.00	11.00	2
AZ-1-2-1	Lead	523.00	11.00	2
AZ-2-1-1	Cadmium	5.00	5.00	0
AZ-2-1-1	Copper	265.33	34.23	1
AZ-2-1-1	Lead	34.23	34.23	5
AZ-2-2-1	Cadmium	5.00	5.00	0
AZ-2-2-1	Copper	232.33	40.00	9
AZ-2-2-1	Lead	40.00	40.00	4
AZ-2-3-1	Cadmium	5.00	5.00	0
AZ-2-3-1	Copper	154000.00	10.93	2

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Component Id Code	Chemical Name	mean(Analysis Quantity Computed)	mean(Reporting Limit Quantity)	(RSD) Percent Relative Standard Deviation (standard deviation / measurement average * 100)
AZ-2-3-1	Lead	344.33	9.12	5
AZ-2-4-1	Cadmium	5.00	5.00	0
AZ-2-4-1	Copper	145333.33	11.40	8
AZ-2-4-1	Lead	9.43	9.43	33
AZ-2-5-1	Cadmium	5.00	5.00	0
AZ-2-5-1	Copper	193666.67	13.40	5
AZ-2-5-1	Lead	11.50	11.11	27
BFP-1-1-1	Cadmium	5.00	5.00	0
BFP-1-1-1	Copper	110666.67	11.27	4
BFP-1-1-1	Lead	10.03	9.36	20
BFP-1-2-1	Cadmium	5.00	5.00	0
BFP-1-2-1	Copper	712.00	32.00	6
BFP-1-2-1	Lead	32.00	32.00	1
BFP-1-3-1	Cadmium	5.00	5.00	0
BFP-1-3-1	Copper	33.83	5.28	34
BFP-1-3-1	Lead	12.02	5.28	26
BKW-1-1-1	Cadmium	5.00	5.00	0
BKW-1-1-1	Copper	149666.67	117.00	3
BKW-1-1-1	Lead	227.67	11.70	3
CAR-1-1-1	Cadmium	5.00	5.00	0
CAR-1-1-1	Copper	332.67	10.97	106
CAR-1-1-1	Lead	371.33	10.97	2
CAR-1-2-1	Cadmium	5.00	5.00	0
CAR-1-2-1	Copper	3853.33	5.75	4
CAR-1-2-1	Lead	283.67	5.75	3
CAR-1-3-1	Cadmium	5.00	5.00	0
CAR-1-3-1	Copper	85866.67	17.50	3
CAR-1-3-1	Lead	20.40	17.50	11
CAR-1-4-1	Cadmium	5.00	5.00	0
CAR-1-4-1	Copper	905.00	30.40	21
CAR-1-4-1	Lead	30.40	30.40	1

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Component Id Code	Chemical Name	mean(Analysis Quantity Computed)	mean(Reporting Limit Quantity)	(RSD) Percent Relative Standard Deviation (standard deviation / measurement average * 100)
CAR-1-5-1	Cadmium	5.00	5.00	0
CAR-1-5-1	Copper	62966.67	10.57	2
CAR-1-5-1	Lead	24.30	10.57	11
CAR-1-6-1	Cadmium	5.00	5.00	0
CAR-1-6-1	Copper	98800.00	20.80	4
CAR-1-6-1	Lead	20.80	20.80	3
CAR-1-7-1	Cadmium	5.00	5.00	0
CAR-1-7-1	Copper	98866.67	21.13	3
CAR-1-7-1	Lead	21.77	21.13	4
CHM-1-1-1	Cadmium	5.00	5.00	0
CHM-1-1-1	Copper	123000.00	13.73	9
CHM-1-1-1	Lead	13.73	13.73	14
CHP-1-1-1	Cadmium	5.00	5.00	0
CHP-1-1-1	Copper	98366.67	16.50	3
CHP-1-1-1	Lead	23.97	16.50	7
CPD-1-1-1	Cadmium	5.00	5.00	0
CPD-1-1-1	Copper	164666.67	14.83	1
CPD-1-1-1	Lead	14.83	14.83	4
CPD-1-2-1	Cadmium	5.00	5.00	0
CPD-1-2-1	Copper	146666.67	18.90	4
CPD-1-2-1	Lead	30.27	18.90	10
CPD-1-3-1	Cadmium	5.00	5.00	0
CPD-1-3-1	Copper	12233.33	5.28	10
CPD-1-3-1	Lead	5.28	5.28	4
CPD-1-4-1	Cadmium	5.00	5.00	0
CPD-1-4-1	Copper	176.67	32.97	26
CPD-1-4-1	Lead	32.97	32.97	3
CPD-1-5-1	Cadmium	5.00	5.00	0
CPD-1-5-1	Copper	214.67	31.03	1
CPD-1-5-1	Lead	31.03	31.03	6
CPD-1-6-1	Cadmium	5.00	5.00	0

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CPD-1-6-1	Copper	37600.00	5.14	3
CPD-1-6-1	Lead	84.37	5.14	6
CPD-1-7-1	Cadmium	5.00	5.00	0
CPD-1-7-1	Copper	490.33	20.13	6
CPD-1-7-1	Lead	249.00	20.13	1
CTP-1-1-1	Cadmium	5.00	5.00	0
CTP-1-1-1	Copper	85.30	15.13	8
CTP-1-1-1	Lead	11.30	11.30	2
CUT-1-1-1	Cadmium	5.00	5.00	0
CUT-1-1-1	Copper	121666.67	14.60	8
CUT-1-1-1	Lead	63.83	11.03	2
CUT-1-2-1	Cadmium	5.00	5.00	0
CUT-1-2-1	Copper	372.33	33.80	10
CUT-1-2-1	Lead	58.07	33.80	4
CUT-1-3-1	Cadmium	5.00	5.00	0
CUT-1-3-1	Copper	252.00	32.33	4
CUT-1-3-1	Lead	32.33	32.33	1
CUT-1-4-1	Cadmium	5.00	5.00	0
CUT-1-4-1	Copper	211333.33	32.27	1
CUT-1-4-1	Lead	16.33	16.10	3
CUT-1-5-1	Cadmium	5.00	5.00	0
CUT-1-5-1	Copper	34800.00	22.20	10
CUT-1-5-1	Lead	15.60	10.88	32
CUT-1-6-1	Cadmium	5.00	5.00	0
CUT-1-6-1	Copper	207.67	11.53	4
CUT-1-6-1	Lead	11.53	11.53	4
CUT-1-7-1	Cadmium	5.00	5.00	0
CUT-1-7-1	Copper	35866.67	22.10	16
CUT-1-7-1	Lead	1130.67	5.52	16
CUT-1-8-1	Cadmium	5.00	5.00	0
CUT-1-8-1	Copper	201666.67	23.03	6

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CUT-1-8-1	Lead	16.77	11.50	8
CVW-1-1-1	Cadmium	5.00	5.00	0
CVW-1-1-1	Copper	111666.67	19.87	6
CVW-1-1-1	Lead	19.87	19.87	5
DIB-1-1-1	Cadmium	5.00	5.00	0
DIB-1-1-1	Copper	153333.33	22.60	3
DIB-1-1-1	Lead	22.60	22.60	4
DIB-1-2-1	Cadmium	5.00	5.00	0
DIB-1-2-1	Copper	153333.33	114.67	8
DIB-1-2-1	Lead	112.33	17.20	5
DIB-1-3-1	Cadmium	5.00	5.00	0
DIB-1-3-1	Copper	441.33	33.80	80
DIB-1-3-1	Lead	33.80	33.80	6
DNL-1-1-1	Cadmium	5.00	5.00	0
DNL-1-1-1	Copper	249.67	11.40	82
DNL-1-1-1	Lead	55.20	11.40	2
DNL-1-2-1	Cadmium	5.00	5.00	0
DNL-1-2-1	Copper	463.33	33.63	1
DNL-1-2-1	Lead	33.63	33.63	2
DNL-1-3-1	Cadmium	5.00	5.00	0
DNL-1-3-1	Copper	98.47	11.27	7
DNL-1-3-1	Lead	11.27	11.27	3
DNL-1-4-1	Cadmium	5.00	5.00	0
DNL-1-4-1	Copper	50.67	36.67	7
DNL-1-4-1	Lead	36.67	36.67	12
DNL-1-5-1	Cadmium	5.00	5.00	0
DNL-1-5-1	Copper	116.33	34.73	7
DNL-1-5-1	Lead	34.73	34.73	6
DNL-1-6-1	Cadmium	5.00	5.00	0
DNL-1-6-1	Copper	1510.00	33.33	1
DNL-1-6-1	Lead	33.33	33.33	3

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Component Id Code	Chemical Name	mean(Analysis Quantity Computed)	mean(Reporting Limit Quantity)	(RSD) Percent Relative Standard Deviation (standard deviation / measurement average * 100)
EVF-1-1-1	Cadmium	5.00	5.00	
EVF-1-1-1	Copper	147.33	34.80	26
EVF-1-1-1	Lead	34.80	34.80	4
EVF-1-2-1	Cadmium	5.00	5.00	0
EVF-1-2-1	Copper	6346.67	32.50	2
EVF-1-2-1	Lead	32.50	32.50	2
FCP-1-1-1	Cadmium	5.00	5.00	0
FCP-1-1-1	Copper	128.00	32.97	2
FCP-1-1-1	Lead	32.97	32.97	2
FCP-1-2-1	Cadmium	7.70	5.00	61
FCP-1-2-1	Copper	48100.00	11.47	1
FCP-1-2-1	Lead	95.67	11.47	3
FT-1-1-1	Cadmium	5.00	5.00	0
FT-1-1-1	Copper	235333.33	16.33	2
FT-1-1-1	Lead	31.97	16.33	83
GE-1-1-1	Cadmium	5.00	5.00	0
GE-1-1-1	Copper	234000.00	20.23	7
GE-1-1-1	Lead	20.23	20.23	8
GIL-1-1-1	Cadmium	5.00	5.00	0
GIL-1-1-1	Copper	54233.33	5.52	3
GIL-1-1-1	Lead	5.52	5.52	4
GMP-1-1-1	Cadmium	5.00	5.00	0
GMP-1-1-1	Copper	99866.67	18.37	3
GMP-1-1-1	Lead	18.37	18.37	2
GMP-1-2-1	Cadmium	12.22	12.22	0
GMP-1-2-1	Copper	54666.67	19.43	9
GMP-1-2-1	Lead	19.43	19.43	4
HK-1-1-1	Cadmium	5.00	5.00	0
HK-1-1-1	Copper	165666.67	11.37	9
HK-1-1-1	Lead	11.47	9.48	1
HK-1-2-1	Cadmium	5.00	5.00	0

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HK-1-2-1	Copper	53966.67	22.40	4
HK-1-2-1	Lead	2433.33	22.40	4
HK-1-3-1	Cadmium	5.00	5.00	0
HK-1-3-1	Copper	19366.67	20.27	5
HK-1-3-1	Lead	1031.67	20.27	5
HS-1-1-1	Cadmium	5.00	5.00	0
HS-1-1-1	Copper	34233.33	10.97	4
HS-1-1-1	Lead	10.97	10.97	2
HYP-1-1-1	Cadmium	5.02	5.02	1
HYP-1-1-1	Copper	111000.00	48.40	8
HYP-1-1-1	Lead	48.40	48.40	5
JAA-1-1-1	Cadmium	5.00	5.00	0
JAA-1-1-1	Copper	108666.67	10.15	6
JAA-1-1-1	Lead	10.15	10.15	7
JCW-1-1-1	Cadmium	5.00	5.00	0
JCW-1-1-1	Copper	801.33	33.47	16
JCW-1-1-1	Lead	33.47	33.47	1
JCW-1-2-1	Cadmium	5.00	5.00	0
JCW-1-2-1	Copper	51533.33	5.34	2
JCW-1-2-1	Lead	262.67	5.34	6
LS-1-1-1	Cadmium	5.00	5.00	0
LS-1-1-1	Copper	4970.00	16.43	4
LS-1-1-1	Lead	16.43	16.43	5
LS-1-2-1	Cadmium	5.00	5.00	0
LS-1-2-1	Copper	45366.67	11.10	4
LS-1-2-1	Lead	11.10	11.10	5
NAP-1-1-1	Cadmium	5.00	5.00	0
NAP-1-1-1	Copper	98666.67	11.00	3
NAP-1-1-1	Lead	11.00	11.00	4
NAP-1-2-1	Cadmium	5.00	5.00	0
NAP-1-2-1	Copper	5890.00	5.11	9

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Component Id Code	Chemical Name	mean(Analysis Quantity Computed)	mean(Reporting Limit Quantity)	(RSD) Percent Relative Standard Deviation (standard deviation / measurement average * 100)
NAP-1-2-1	Lead	5.14	5.11	2
NAP-1-3-1	Cadmium	5.00	5.00	0
NAP-1-3-1	Copper	33100.00	5.24	2
NAP-1-3-1	Lead	107.33	5.24	2
NAP-1-4-1	Cadmium	5.00	5.00	0
NAP-1-4-1	Copper	100633.33	10.77	20
NAP-1-4-1	Lead	10.77	10.77	3
NAP-1-5-1	Cadmium	5.00	5.00	0
NAP-1-5-1	Copper	106133.33	15.77	8
NAP-1-5-1	Lead	15.77	15.77	3
NAP-1-6-1	Cadmium	5.00	5.00	0
NAP-1-6-1	Copper	255.00	10.93	21
NAP-1-6-1	Lead	213.00	10.93	4
NAP-1-7-1	Cadmium	5.00	5.00	0
NAP-1-7-1	Copper	126666.67	11.53	10
NAP-1-7-1	Lead	68.17	11.53	3
NEG-1-1-1	Cadmium	5.00	5.00	0
NEG-1-1-1	Copper	277.00	5.61	54
NEG-1-1-1	Lead	5.61	5.61	1
NEG-1-2-1	Cadmium	8.03	8.03	0
NEG-1-2-1	Copper	58133.33	8.30	4
NEG-1-2-1	Lead	93.65	8.30	3
NEG-1-3-1	Cadmium	5.00	5.00	0
NEG-1-3-1	Copper	23.33	5.26	7
NEG-1-3-1	Lead	5.26	5.26	5
NKR-1-1-1	Cadmium	5.00	5.00	0
NKR-1-1-1	Copper	100.10	30.30	6
NKR-1-1-1	Lead	28.33	28.33	5
NP-1-1-1	Cadmium	5.00	5.00	0
NP-1-1-1	Copper	347000.00	74.50	9
NP-1-1-1	Lead	20.83	16.10	11

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OAP-1-1-1	Cadmium	5.00	5.00	0
OAP-1-1-1	Copper	91.70	11.61	57
OAP-1-1-1	Lead	115.33	5.79	2
OAP-1-2-1	Cadmium	5.00	5.00	0
OAP-1-2-1	Copper	101533.33	5.46	6
OAP-1-2-1	Lead	35.80	5.46	2
OAP-1-3-1	Cadmium	5.00	5.00	0
OAP-1-3-1	Copper	181000.00	11.03	3
OAP-1-3-1	Lead	11.03	11.03	5
OAP-1-4-1	Cadmium	5.00	5.00	0
OAP-1-4-1	Copper	23.67	15.40	37
OAP-1-4-1	Lead	5.13	5.13	2
OAP-1-5-1	Cadmium	5.00	5.00	0
OAP-1-5-1	Copper	151666.67	11.27	4
OAP-1-5-1	Lead	11.27	11.27	3
OAP-1-6-1	Cadmium	5.00	5.00	0
OAP-1-6-1	Copper	38500.00	5.23	7
OAP-1-6-1	Lead	22.17	5.23	3
OEL-1-1-1	Cadmium	5.00	5.00	0
OEL-1-1-1	Copper	132000.00	21.80	3
OEL-1-1-1	Lead	32.73	21.80	13
PG-1-1-1	Cadmium	5.00	5.00	0
PG-1-1-1	Copper	539.00	16.40	10
PG-1-1-1	Lead	16.40	16.40	5
PG-1-2-1	Cadmium	5.00	5.00	0
PG-1-2-1	Copper	2540.00	10.73	12
PG-1-2-1	Lead	43.57	10.73	3
PG-1-3-1	Cadmium	5.00	5.00	0
PG-1-3-1	Copper	35.07	8.45	36
PG-1-3-1	Lead	8.45	8.45	4
RCA-1-1-1	Cadmium	22.73	5.00	1

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RCA-1-1-1	Copper	166666.67	10.87	8
RCA-1-1-1	Lead	78.13	10.87	6
RCA-1-2-1	Cadmium	5.00	5.00	0
RCA-1-2-1	Copper	313.00	28.87	11
RCA-1-2-1	Lead	26.97	26.97	5
RD-1-1-1	Cadmium	5.00	5.00	0
RD-1-1-1	Copper	130.00	10.50	15
RD-1-1-1	Lead	12.63	10.50	8
RD-1-2-1	Cadmium	5.00	5.00	0
RD-1-2-1	Copper	23.37	5.20	5
RD-1-2-1	Lead	17.67	5.02	5
RD-1-3-1	Cadmium	5.00	5.00	0
RD-1-3-1	Copper	63.07	31.57	20
RD-1-3-1	Lead	31.57	31.57	6
RD-1-4-1	Cadmium	5.00	5.00	0
RD-1-4-1	Copper	207.83	14.11	139
RD-1-4-1	Lead	14.11	14.11	107
RLAP-1-1-1	Cadmium	5.00	5.00	0
RLAP-1-1-1	Copper	106666.67	15.67	2
RLAP-1-1-1	Lead	15.67	15.67	4
SMR-1-1-1	Cadmium	5.00	5.00	0
SMR-1-1-1	Copper	100033.33	15.83	7
SMR-1-1-1	Lead	16.07	15.83	3
SMR-1-2-1	Cadmium	5.00	5.00	0
SMR-1-2-1	Copper	363.00	27.53	29
SMR-1-2-1	Lead	27.53	27.53	6
SR-7-1-1	Cadmium	5.59	5.00	18
SR-7-1-1	Copper	49933.33	12.67	4
SR-7-1-1	Lead	1673.33	12.67	7
SR-7-2-1	Cadmium	5.00	5.00	0
SR-7-2-1	Copper	1983.33	31.60	10

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SR-7-2-1	Lead	31.60	31.60	2
SR-7-3-1	Cadmium	5.00	5.00	0
SR-7-3-1	Copper	61900.00	5.79	6
SR-7-3-1	Lead	105.00	5.79	1
SR-7-4-1	Cadmium	5.00	5.00	0
SR-7-4-1	Copper	236.67	28.93	26
SR-7-4-1	Lead	60.20	28.93	15
SR-7-5-1	Cadmium	5.00	5.00	0
SR-7-5-1	Copper	368.67	33.63	2
SR-7-5-1	Lead	33.63	33.63	3
SR-7-6-1	Cadmium	5.00	5.00	0
SR-7-6-1	Copper	326.00	33.50	2
SR-7-6-1	Lead	33.50	33.50	7
SRI-1-1-1	Cadmium	5.00	5.00	0
SRI-1-1-1	Copper	348.33	32.47	0
SRI-1-1-1	Lead	32.47	32.47	3
SRI-1-2-1	Cadmium	5.00	5.00	0
SRI-1-2-1	Copper	18.47	5.37	52
SRI-1-2-1	Lead	29.87	5.37	1
SRI-1-3-1	Cadmium	5.00	5.00	0
SRI-1-3-1	Copper	16033.33	5.28	4
SRI-1-3-1	Lead	576.00	5.28	5
SRI-1-4-1	Cadmium	5.00	5.00	0
SRI-1-4-1	Copper	17400.00	5.40	6
SRI-1-4-1	Lead	577.33	5.40	0
SRI-1-5-1	Cadmium	5.00	5.00	0
SRI-1-5-1	Copper	13733.33	5.67	12
SRI-1-5-1	Lead	886.00	5.67	8
SRI-1-6-1	Cadmium	5.00	5.00	0
SRI-1-6-1	Copper	270.00	6.02	36
SRI-1-6-1	Lead	18.30	6.02	14

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Component Id Code	Chemical Name	mean(Analysis Quantity Computed)	mean(Reporting Limit Quantity)	(RSD) Percent Relative Standard Deviation (standard deviation / measurement average * 100)
SST-1-1-1	Cadmium	5.00	5.00	0
SST-1-1-1	Copper	129000.00	20.40	3
SST-1-1-1	Lead	20.40	20.40	2
SST-1-2-1	Cadmium	5.00	5.00	0
SST-1-2-1	Copper	126666.67	21.27	0
SST-1-2-1	Lead	21.27	21.27	4
SV-1-1-1	Cadmium	5.00	5.00	0
SV-1-1-1	Copper	84933.33	16.50	9
SV-1-1-1	Lead	16.50	16.50	7
SWA-1-1-1	Cadmium	5.00	5.00	0
SWA-1-1-1	Copper	627.00	16.67	51
SWA-1-1-1	Lead	16.67	16.67	4
SWA-1-2-1	Cadmium	5.00	5.00	0
SWA-1-2-1	Copper	91133.33	10.63	3
SWA-1-2-1	Lead	10.63	10.63	3
SWA-1-3-1	Cadmium	5.00	5.00	0
SWA-1-3-1	Copper	213333.33	15.73	2
SWA-1-3-1	Lead	203.67	15.73	1
SWA-1-4-1	Cadmium	5.00	5.00	0
SWA-1-4-1	Copper	811.00	16.03	80
SWA-1-4-1	Lead	18.77	16.03	15
SWA-1-5-1	Cadmium	5.00	5.00	0
SWA-1-5-1	Copper	424.00	32.47	4
SWA-1-5-1	Lead	32.47	32.47	2
SWA-1-6-1	Cadmium	5.00	5.00	0
SWA-1-6-1	Copper	206.33	29.63	22
SWA-1-6-1	Lead	29.63	29.63	1
TC-1-1-1	Cadmium	5.00	5.00	0
TC-1-1-1	Copper	1310.00	5.06	3
TC-1-1-1	Lead	109.67	5.04	5
TC-1-2-1	Cadmium	5.00	5.00	0

Better Brakes Enforcement Study 2017 SAE J2975 Averaged Results Summary and RSD Values
Bold results indicate RSD exceedances.

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Component Id Code	Chemical Name	mean(Analysis Quantity Computed)	mean(Reporting Limit Quantity)	(RSD) Percent Relative Standard Deviation (standard deviation / measurement average * 100)
TC-1-2-1	Copper	255.33	30.50	17
TC-1-2-1	Lead	30.50	30.50	8
TCN-1-1-1	Cadmium	5.00	5.00	0
TCN-1-1-1	Copper	108500.00	15.33	12
TCN-1-1-1	Lead	15.33	15.33	2
TPO-1-1-1	Cadmium	5.00	5.00	0
TPO-1-1-1	Copper	89200.00	10.57	4
TPO-1-1-1	Lead	28.90	10.57	3
TPO-1-2-1	Cadmium	5.00	5.00	0
TPO-1-2-1	Copper	131666.67	10.37	3
TPO-1-2-1	Lead	10.37	10.37	1
TRC-1-1-1	Cadmium	5.00	5.00	0
TRC-1-1-1	Copper	95533.33	10.53	4
TRC-1-1-1	Lead	51.60	10.53	4
TRC-1-2-1	Cadmium	5.00	5.00	0
TRC-1-2-1	Copper	90266.67	10.47	1
TRC-1-2-1	Lead	39.77	10.47	5
TRC-1-3-1	Cadmium	5.00	5.00	0
TRC-1-3-1	Copper	46233.33	10.60	2
TRC-1-3-1	Lead	78.40	10.60	2
TW-1-1-1	Cadmium	5.00	5.00	0
TW-1-1-1	Copper	75933.33	5.13	2
TW-1-1-1	Lead	5.97	5.13	6
WM-31-1-1	Cadmium	5.00	5.00	0
WM-31-1-1	Copper	371.00	31.40	1
WM-31-1-1	Lead	31.40	31.40	2
WRM-1-1-1	Cadmium	5.00	5.00	0
WRM-1-1-1	Copper	99200.00	10.53	2
WRM-1-1-1	Lead	29.57	10.53	11