

Life Cycle Analysis of a Ceramic Three-Way Catalytic Converter

Elizabeth Lynn Belcastro

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science
In
Materials Science and Engineering

David E. Clark, Chair
Sean P. McGinnis
Gary R. Pickrell
Michele M. Holbrook

04-23-12
Blacksburg, VA

Keywords: Catalytic converter, Life cycle analysis, Air emission,
Cordierite ceramic, and Passenger car

Copyright 2012, Elizabeth Belcastro

Source 2: Equations 1.1 and 1.2

Environmental Protection Agency, EPA National Vehicle and Fuel Emissions Laboratory. (n.d.). *Automobile emissions: An overview* (EPA 400-F-92-007). Retrieved from Office of Mobile Sources website: <http://www.epa.gov/otaq/consumer/05-autos.pdf>

WHEN U.S. WORKS PASS INTO THE PUBLIC DOMAIN

(3) the work is a work of the U.S. Government.

Source 8: Table 1.1

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Elizabeth Belcastro

Description of item under review for fair use: Degobert, P. (1995). Automobiles and pollution. (2 ed., pp. 124-129). Warrendale, PA: Society of Automotive Engineers, Inc.

Report generated on: 04-10-2012 at : 20:14:44

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use*

Source 11: Figure 1.1

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Elizabeth Belcastro

Description of item under review for fair use: Motor vehicle emission controls: Technologies. (n.d.). Retrieved from <http://www.air-quality.org.uk/25.php>

Report generated on: 04-10-2012 at : 20:20:04

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *against fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use*

Source 12: Figure 1.3 and Table 2.2

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Elizabeth Belcastro

Description of item under review for fair use: Lachman, I., Bagley, R., & Lewis, R. (1981). Thermal expansion of extruded cordierite ceramics. Ceramic Bulletin, 60(2), 202-205.

Report generated on: 04-10-2012 at : 20:30:40

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *against fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use*

Source 20 – Figure 1.4

Curran, M. A. U.S. Environmental Protection Agency, Office of Research and Development. (2006). *Life cycle assessment: Principles and practice* (EPA/600/R-06/060). Reston: Scientific Applications International Corporation (SAIC).

WHEN U.S. WORKS PASS INTO THE PUBLIC DOMAIN

(3) the work is a work of the U.S. Government.

Source 28 – Figure 2.2

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Elizabeth Belcastro

Description of item under review for fair use: Benito, J.M., Turrillas, X., Cuello, G.J., De Aza, A.H., De Aza, S., Rodriguez, M.A. (2012). Cordierite synthesis. A time-resolved neutron diffraction study. *Journal of the European Ceramic Society*, 32(2), 371-379, Retrieved from <http://www.sciencedirect.com/science/article/pii/S0955221911004766>.

Report generated on: 05-03-2012 at : 12:01:20

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use*

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Elizabeth Belcastro

Description of item under review for fair use: AEP's average fuel mix of electricity provided to Virginia customers. In (2010). 2010 Environmental Information.

Report generated on: 04-19-2012 at : 14:34:14

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use*

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Elizabeth Belcastro

Description of item under review for fair use: [19] Reference document on best available techniques in the ceramic manufacturing industry. (2007). Retrieved from http://eippcb.jrc.es/reference/BREF/cer_bref_0807.pdf

Report generated on: 04-10-2012 at : 20:37:07

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use*

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Elizabeth Belcastro

Description of item under review for fair use: Sheppard, L. (1988). Manufacturing ceramics with microwaves: the potential for economical production. Ceramic Bulletin, 67(10), 1656-1660.

Report generated on: 04-10-2012 at : 20:39:23

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use*

Source 35 – Table 2.9 and Table 2.10

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Elizabeth Belcastro

Description of item under review for fair use: Colls, J. (2002). Air pollution: measurement, modelling, and mitigation. (Second ed., pp. 127-137). New York, NY: Spon Press.

Report generated on: 05-03-2012 at : 12:03:16

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *against fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use*

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Elizabeth Belcastro

Description of item under review for fair use: [28] Stainless steel, ferritic, AISI 409, wrought, annealed. In (2011). CES EduPack 2011

Report generated on: 04-10-2012 at : 20:42:01

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use*

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Elizabeth Belcastro

Description of item under review for fair use: Platinum, commercial purity, P04995, annealed. In (2011). CES EduPack 2011

Report generated on: 04-10-2012 at : 20:47:17

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use*

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Elizabeth Belcastro

Description of item under review for fair use: Platinum-rhodium alloy, annealed. In (2011). CES EduPack 2011

Report generated on: 04-10-2012 at : 20:48:25

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use*

Source 47 – Figure 4.1

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Elizabeth Belcastro

Description of item under review for fair use: Kempler, S. NASA, (2011). Amateur guide for air quality testing . Retrieved from website: http://disc.sci.gsfc.nasa.gov/oceancolor/additional/science-focus/locus/amateur_guide_for_air_quality_000.shtml

Report generated on: 04-10-2012 at : 20:49:36

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use*

Source 48 – Figure 4.1

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Elizabeth Belcastro

Description of item under review for fair use: (n.d.). Los angeles. [Web Photo]. Retrieved from <http://www.stratosjets.com/featured-jet-charter/Jet-Charter-Flights-in-Los-Angeles>

Report generated on: 04-10-2012 at : 20:50:57

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *against fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use*