

THOMAS W. EAGAR, Sc.D., P.E.
ROOM 4-136
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MA 02139-4307
617-253-3229
FAX 617-252-1773

October 28, 2008

Fisher Kanaris
200 South Wacker Drive
33rd Floor
Chicago, Illinois 60606

Attention: Howard Lieber

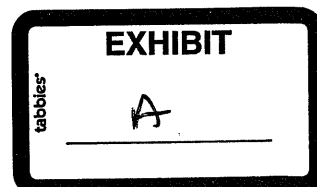
RE: Uponor Brass Fittings for PEX Tubing

Dear Mr. Lieber,

At your request, I have investigated a number of field failures of brass fittings distributed by Uponor. The list of samples which I inspected are given in Appendix A. It was reported that there have been over sixty failures of fittings over less than a year and that additional field failures were reported thereafter.

My investigation has included the following:

1. Visual inspection of both field failures and exemplar fittings using a stereomicroscope. Selected samples were also examined in the Scanning Electron Microscope.
2. Chemical analysis of 13 exemplar fittings as listed in Appendix B.
3. Review of ASTM F1807, B16 and B283.
4. Bend and fracture tests on selected exemplars.
5. Metallography and microhardness of both selected field failures and exemplar fittings.
6. Microfocus x-rays of exemplar fittings.



Howard Lieber
October 28, 2008
Page Two

7. Depositions of: William Marshall, July 8, 2008
William Marshall, July 9, 2008
Jugal Malani, July 9, 2008
8. Uponor – Summary of Abbreviated Investigation, July 13, 2006, RMA: 717447
9. Uponor – Summary of Investigation – Unique Brass Fittings
- Undated Bates Numbers UI08452 to 08472
10. NSF/ANSI Standard 14 – Bates UI08070 to 08079
11. Uponor Notice of Revision – UI02098 to UI02102
12. Emails: a) from Mark Dubanoski to Anders Tollsten
January 11, 2007
b) from Loc Hoang to John Liebelt, 12/01/2006
13. Documents: UI08062 to UI08069
UI08434 to UI08451
UI08474 to UI08495
UI00689 to 00693
UI00944
UI00714
UI00899-00900
UI01261 to 01263
Deposition Exhibits 45 – 51
Deposition Exhibits 30 – 36
UI01016 to 01018
14. Documents: Unique/Uponor 000095 to 000168

Based upon this investigation, I have made the following observations and I have formed the following opinions based upon a reasonable degree of engineering certainty.

1. Each of the field failures fractured due to stress corrosion cracking. These cracks were initiated by cracks on the inside wall of the fittings. This inside wall is a machined (drilled) surface; however, the machined surfaces of both fractured and new exemplar fittings showed severe smearing and surface cracking. Such smearing and surface cracking can be produced by a number of factors, including *inter alia* dull tools, excessive tool feeds and speeds, and improper alloy composition or microstructure.

2. The fittings made from wrought material were specified as C36000 brass alloy. The forged fittings (elbows, tees and the like) were specified as C37700 alloy. The chemical analyses (performed by Inductively Coupled Plasma Spectroscopy except for the oxygen content) show that the lead analysis of the C37700 alloy was consistently outside the ASTM B283 specification range. Some of the iron analyses were above the B283 maximum value. Some of the C36000 alloy samples also failed to meet the chemical requirements for iron content.
3. The bend tests showed significantly different behavior between the C36000 couplings and the C37700 forgings. The couplings, which were presumably machined from bar stock could sustain a 2T bend of 180°. The C37700 forgings fractured with low ductility at a considerably smaller angle and a larger bend radius. Observation of the fracture surface of the C36000 alloy in the Scanning Electron Microscope, revealed ductile dimples. The C37700 fractures exhibited little evidence of ductile dimpling.
4. Microhardness tests across the thickness of an exemplar sample LL-1 indicated a Vicker's hardness on both machined surfaces of 145 to 152 with a core hardness of 115. This higher surface hardness is consistent with the smearing and cracking observed on the machined surfaces. Such smearing and higher hardness will create surface residual stresses on the fitting.
5. Observation of the lead particle size distribution using both the microfocus x-ray and metallography, showed a 20 to 100 micron lead particle size in the C36000 alloy as expected for free machining brasses. The C37700 forgings had no larger lead particles; the entire lead distribution was a fine dispersion of 1 to 3 micron particles. Such a fine dispersion of second phase particles results in a substantial loss of ductility [see W.A. Backofen, *Deformation Processing*, Addison Wesley, 1972, p.247].
6. The fine dispersion of lead particles can be explained by reference to the copper-zinc-lead ternary phase diagram [see, Handbook of Ternary Alloy Phase Diagrams, Volume 8, ASM International, 1995, p.9937]. As these brasses are heated to temperatures above 700°C, the lead will dissolve in the brass. If the alloy cools too quickly, the lead will re-precipitate as a fine dispersion.

7. Mr. Marshall indicated that the brass fittings would fail the dimensional checks 1 to 2 percent of the time [Marshall deposition, 8 July 2008, p.44]. Uponor's internal testing also reflected failure of dimensional checks [see the email referred to in 12(b) above]. These dimensional discrepancies, plus the failure to meet the chemical specifications (see paragraph 2 above as well as testing performed by Stork Labs) indicates that a substantial number of these fittings did not meet the ASTM F1807 specifications.
8. Mr. Malani indicated that the Korean manufacturer used a lead leaching process to remove lead from the surface [Mulani deposition, p.22]. Such leaching of the lead would produce notches in the surface. These notches, combined with the surface residual stresses, will contribute significantly to the formation of stress corrosion cracking both prior to service and during service of these fittings.
9. Although Dr. Hays' report indicates that the failures occurred due to fatigue, I see no evidence of fatigue failure on the fracture surface of the brass fittings. In addition, estimation of the cyclic stresses due to "the pulsating flow of the water throughput," indicates levels of less than 100 psi. These cyclic stresses are too low to cause fatigue in brass alloys such as these fittings. Thus, failure due to fatigue is highly improbable.
10. Dr. Hays' report indicates that the neutral axis of the fitting is the mid-thickness of the tube wall. This is incorrect. For a tube, the neutral axis is at the axial center of the tube. Use of the neutral axis as selected by Dr. Hays will result in huge errors in the calculated bending stresses.
11. The failures of these fittings are related to manufacturing deficiencies (rough machining, compositional variations, dimensional deviations, aggressive leaching) and are not due to deficiencies in design of the fittings. Detection of such manufacturing defects is the responsibility of both the manufacturer and the distributor (Unique). The manufacturer is responsible for quality control continuously throughout the manufacturing process. The distributor or reseller (Unique) is responsible for quality assurance. Such quality assurance requires periodic quality audits of the manufacturing facility as well as random testing of samples of the received products to ensure that the specifications are being met. Unique acknowledges that such quality assurance procedures were not in place and incoming material was merely trans-shipped to Uponor.

Howard Lieber
October 28, 2008
Page Five

The distinction between design and manufacturing applies to the approval of NSF as well. NSF approves designs and materials, but NSF does not certify or audit the manufacturing process to ensure that a consistent product quality is being produced. Stated simply, NSF approval certifies the design but does not provide manufacturing quality control or even quality assurance. NSF approval indicates that the design meets a particular specification.

Based upon the foregoing, I have concluded to a reasonable degree of engineering certainty that these failures occurred due to stress corrosion cracking (SCC). The cause of the SCC was multi-dimensional including the high surface residual stresses and pre-cracking. These high residual stresses and pre-cracks were due to improper machining and lead leaching of the fittings. Many of the fittings did not conform to ASTM F1807, as required. The failure of the fittings to comply with F1807 also played a role in the process leading to SCC. Thus, these failures result from manufacturing defects in the fittings.

Based upon this investigation, it is my opinion that it was appropriate for Uponor to reject fittings which did not conform to the ASTM F1807 specification in terms of chemical composition and dimensions. Any seller of fittings represented to conform to the ASTM specification, which seller knew that the fittings did not conform, would be making a serious misrepresentation of the product. In addition, the smeared metal due to improper machining meant that these fittings were not of the standard of quality expected of parts manufactured from free cutting brass. Free cutting brass should produce one of the cleanest and smoothest and least deformed machined surfaces.

Sincerely yours,


Thomas W. Eagar

jh

APPENDIX A

1. New fittings rejected by Uponor for non-conforming chemistry (52 fittings total):
 - a. P4516375-P119 (2 fittings)
 - b. P4515050-T1 (2 fittings)
 - c. P4845050-T1 (2 fittings)
 - d. P4175050-T1 (2 nuts)
 - e. P4525050-T1 (2 fittings)
 - f. P4376375-P119 (2 fittings)
 - g. P4503850-P119 (2 fittings)
 - h. P4175050-P119 (2 fittings)
 - i. P4705050-P119 (2 fittings)
 - j. P4506375-T3 (2 fittings)
 - k. P4703838-T3 (2 fittings)
 - l. P4545050-P119 (2 fittings)
 - m. AA-1-Loose/P4707555 (2 fittings)
 - n. CC-1-Loose/P4710500 (2 fittings)
 - o. EE-Loose/P4710500 (5 fittings)
 - p. EE-1-P4710500 (5 fittings)
 - q. JJ-1/P4705050 (5 fittings)
 - r. KK-4/P4705050 (5 fittings)
 - s. MM-1/P4705050 (1 fitting)
 - t. NN-3-Loose/P4707555 (3 fittings)
2. Field-returned fitting that Uponor destructively evaluated:
 - a. MA00507
3. Field-returned fractured fittings in the as-received condition:
 - a. MA00492
 - b. MA00523
 - c. MA00539
4. New fittings (never installed) returned from distributors who have had fittings crack in the field:
 - a. LL-Loose (5 fittings)
 - b. LL-1 (5 fittings)
 - c. JJ-1 (5 fittings)

5. Field-returned fittings received March 16:
 - a. MA00506
 - b. MA00493
6. 25 – P4710500 elbows from Ryan Homes
7. Received March 22:
 - a. LL-1 (5 fittings)

APPENDIX B



A Subsidiary of THE MMR GROUP, INC.

Massachusetts Materials Research, Inc.

P.O. BOX 810 • 1500 CENTURY DRIVE • WEST BOYLSTON, MA 01583 • TEL. 508-835-6262 • FAX 508-835-9025

ANALYTICAL REPORT

Harold R. Larson, ScD
 Massachusetts Institute of Technology
 77 Mass Ave., Room 4-049
 Cambridge, MA 02139

DATE: February 28, 2007

P.O. NO.:

MMR NO.: 61061

MMR ID#: 1

PAGE #: 1 of 1

ATTENTION: Harold Larson

SAMPLE IDENTIFICATION

Brass Sample, JJ-1

CHEMISTRY

<u>Element</u>	<u>Composition (%)</u>
Copper	57.1
Zinc	40.9
Lead	1.39
Aluminum	<.01
Sulfur	<.001
Iron	.24
Tin	.19
Antimony	.01
Arsenic	.02
Silicon	.01
Oxygen	14 PPM

MASSACHUSETTS MATERIALS RESEARCH, INC.

Vernon K. Coutu

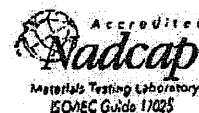
Chief Corporate Chemist

The recording of false, fictitious or fraudulent statements or entries on the certificate may be punishable as a felony under federal law.

Chemical analysis performed by Inductively Coupled Plasma/Optical Emission Spectrometer. Carbon, sulfur, nitrogen, hydrogen and oxygen performed by Leco Combustion. Mechanical and metallurgical testing performed per MMR Procedures.

The results reported above apply only to the test sample(s) provided.

In no event shall Massachusetts Materials Research, Inc. be liable for any special, consequential or other damages.





A Subsidiary of THE MMR GROUP, INC.

Massachusetts Materials Research, Inc.

P.O. BOX 810 • 1500 CENTURY DRIVE • WEST BOYLSTON, MA 01583 • TEL. 508-835-6262 • FAX 508-835-9025

ANALYTICAL REPORT

Harold R. Larson, ScD
 Massachusetts Institute of Technology
 77 Mass Ave., Room 4-049
 Cambridge, MA 02139

DATE: February 28, 2007

P.O. NO.:

MMR NO.: 61061

MMR ID#: 2

PAGE #: 1 of 1

ATTENTION: Harold Larson

SAMPLE IDENTIFICATION

Brass Sample, P4503850-P119

CHEMISTRY

<u>Element</u>	<u>Composition (%)</u>
Copper	59.5
Zinc	35.8
Lead	2.87
Aluminum	.12
Sulfur	<.001
Iron	.52
Tin	.74
Antimony	.04
Arsenic	.02
Silicon	.05
Nickel	.31
Oxygen	6 PPM

MASSACHUSETTS MATERIALS RESEARCH, INC.

Vernon K. Coutu
Chief Corporate Chemist

The recording of false, fictitious or fraudulent statements or entries on the certificate may be punishable as a felony under federal law.

Chemical analysis performed by Inductively Coupled Plasma/Optical Emission Spectrometer. Carbon, sulfur, nitrogen, hydrogen and oxygen performed by Leco Combustion. Mechanical and metallurgical testing performed per MMR Procedures.

The results reported above apply only to the test sample(s) provided.

In no event shall Massachusetts Materials Research, Inc. be liable for any special, consequential or other damages. This report shall be reproduced, except in full, without written approval of MMR.





A Subsidiary of THE MMR GROUP, INC.

Massachusetts Materials Research, Inc.

P.O. BOX 810 • 1500 CENTURY DRIVE • WEST BOYLSTON, MA 01583 • TEL. 508-835-9262 • FAX 508-835-9025

ANALYTICAL REPORT

Harold R. Larson, ScD
 Massachusetts Institute of Technology
 77 Mass Ave., Room 4-049
 Cambridge, MA 02139

DATE: February 28, 2007

P.O. NO.:

MMR NO.: 61061

MMR ID#: 3

PAGE #: 1 of 1

ATTENTION: Harold Larson

SAMPLE IDENTIFICATION

Brass Sample, JJ-1

CHEMISTRY

<u>Element</u>	<u>Composition (%)</u>
Copper	56.3
Zinc	41.8
Lead	1.34
Aluminum	<.01
Sulfur	<.001
Iron	.25
Tin	.19
Antimony	.02
Arsenic	.02
Silicon	.01
Nickel	.05
Oxygen	7 PPM

MASSACHUSETTS MATERIALS RESEARCH, INC.

Vernon X. Coutu

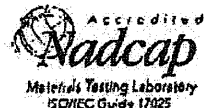
Chief Corporate Chemist

The recording of false, fictitious or fraudulent statements or entries on the certificate may be punishable as a felony under federal law.

Chemical analysis performed by Inductively Coupled Plasma/Optical Emission Spectrometer. Carbon, sulfur, nitrogen, hydrogen and oxygen performed by Leco Combustion. Mechanical and metallurgical testing performed per MMR Procedures.

The results reported above apply only to the test sample(s) provided.

In no event shall Massachusetts Materials Research, Inc. be liable for any special, consequential or other damages.





A Subsidiary of THE MMR GROUP, INC.

Massachusetts Materials Research, Inc.

P.O. BOX 810 • 1500 CENTURY DRIVE • WEST BOYLSTON, MA 01583 • TEL. 508-835-6282 • FAX 508-835-9025

ANALYTICAL REPORT

Harold R. Larson, ScD
 Massachusetts Institute of Technology
 77 Mass Ave., Room 4-049
 Cambridge, MA 02139

DATE: February 28, 2007

P.O. NO.:

MMR NO.: 61061

MMR ID#: 4

PAGE #: 1 of 1

ATTENTION: Harold Larson

SAMPLE IDENTIFICATION Brass Sample, EE-1

CHEMISTRY

<u>Element</u>	<u>Composition (%)</u>
Copper	57.1
Zinc	41.0
Lead	1.15
Aluminum	.02
Sulfur	<.001
Iron	.23
Tin	.32
Arsenic	.02
Silicon	.04
Nickel	.11
Oxygen	20 PPM

MASSACHUSETTS MATERIALS RESEARCH, INC.

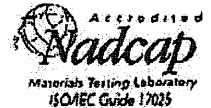
Vernon K. Coutu
 Vernon K. Coutu

Chief Corporate Chemist

The recording of false, fictitious or fraudulent statements or entries on the certificate may be punishable as a felony under federal law.

Chemical analysis performed by Inductively Coupled Plasma/Optical Emission Spectrometer. Carbon, sulfur, nitrogen, hydrogen and oxygen performed by Leco Combustion. Mechanical and metallurgical testing performed per MMR Procedures.

The results reported above apply only to the test sample(s) provided.
 In no event shall Massachusetts Materials Research, Inc. be liable for any special, consequential or other damages.





A Subsidiary of THE MMR GROUP, INC.

Massachusetts Materials Research, Inc.

P.O. BOX 810 • 1500 CENTURY DRIVE • WEST BOYLSTON, MA 01583 • TEL. 508-835-8262 • FAX 508-835-9025

ANALYTICAL REPORT

Harold R. Larson, ScD
 Massachusetts Institute of Technology
 77 Mass Ave., Room 4-049
 Cambridge, MA 02139

DATE: February 28, 2007

P.O. NO.:

MMR NO.: 61061

MMR ID#: 5

PAGE #: 1 of 1

ATTENTION: Harold Larson

SAMPLE IDENTIFICATION Brass Sample, EE-Loose

CHEMISTRY

<u>Element</u>	<u>Composition (%)</u>
Copper	57.2
Zinc	41.0
Lead	1.27
Aluminum	<.01
Sulfur	<.001
Iron	.27
Tin	.21
Antimony	.01
Arsenic	.03
Silicon	.03
Nickel	.06
Oxygen	4 PPM

MASSACHUSETTS MATERIALS RESEARCH, INC.

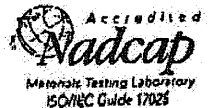
Vernon K. Coutu
 Vernon K. Coutu

Chief Corporate Chemist

The recording of false, fictitious or fraudulent statements or entries on the certificate may be punishable as a felony under federal law.

Chemical analysis performed by Inductively Coupled Plasma/Optical Emission Spectrometer. Carbon, sulfur, nitrogen, hydrogen and oxygen performed by Leco Combustion. Mechanical and metallurgical testing performed per MMR Procedures.

The results reported above apply only to the test sample(s) provided. In no event shall Massachusetts Materials Research, Inc. be liable for any special, consequential or other damages.





A Subsidiary of THE MMR GROUP, INC.

Massachusetts Materials Research, Inc.

P.O. BOX 810 • 1500 CENTURY DRIVE • WEST BOYLSTON, MA 01583 • TEL. 508-835-8262 • FAX 508-835-9025

ANALYTICAL REPORT

Harold R. Larson, ScD
 Massachusetts Institute of Technology
 77 Mass Ave., Room 4-049
 Cambridge, MA 02139

DATE: February 28, 2007

P.O. NO.:

MMR NO.: 61061

MMR ID#: 6

PAGE #: 1 of 1

ATTENTION: Harold Larson

SAMPLE IDENTIFICATION Brass Sample, AA-1

CHEMISTRY

<u>Element</u>	<u>Composition (%)</u>
Copper	55.4
Zinc	12.5
Lead	1.43
Aluminum	<.01
Sulfur	<.001
Iron	.35
Tin	.19
Arsenic	.02
Silicon	.03
Nickel	.05
Oxygen	7 PPM

MASSACHUSETTS MATERIALS RESEARCH, INC.

Vernon K. Coutu
Chief Corporate Chemist

The recording of false, fictitious or fraudulent statements or entries on this certificate may be punishable as a felony under federal law.

Chemical analysis performed by Inductively Coupled Plasma/Optical Emission Spectrometer. Carbon, sulfur, nitrogen, hydrogen and oxygen performed by Leco Combustion. Mechanical and metallurgical testing performed per MMR Procedures.

The results reported above apply only to the test sample(s) provided.

In no event shall Massachusetts Materials Research, Inc. be liable for any special, consequential or other damages.





A Subsidiary of THE MMR GROUP, INC.

Massachusetts Materials Research, Inc.

P.O. BOX 810 • 1500 CENTURY DRIVE • WEST BOYLSTON, MA 01583 • TEL. 508-835-6262 • FAX 508-835-9025

ANALYTICAL REPORT

Harold R. Larson, ScD
 Massachusetts Institute of Technology
 77 Mass Ave., Room 4-049
 Cambridge, MA 02139

DATE: February 28, 2007

P.O. NO.:

MMR NO.: 61061

MMR ID#: 7

PAGE #: 1 of 1

ATTENTION: Harold Larson

SAMPLE IDENTIFICATION

Brass Sample, P4545050-P119

CHEMISTRY

<u>Element</u>	<u>Composition (%)</u>
Copper	58.5
Zinc	36.5
Lead	2.71
Aluminum	.18
Sulfur	<.001
Iron	.68
Tin	.88
Antimony	.04
Arsenic	.01
Manganese	.02
Silicon	.06
Nickel	.39
Oxygen	9 PPM

MASSACHUSETTS MATERIALS RESEARCH, INC.

Vernon K. Coutu
 Vernon K. Coutu
 Chief Corporate Chemist

The recording of false, fictitious or fraudulent statements or entries on the certificate may be punishable as a felony under federal law.

Chemical analysis performed by Inductively Coupled Plasma/Optical Emission Spectrometer. Carbon, sulfur, nitrogen, hydrogen and oxygen performed by Leco Combustion. Mechanical and metallurgical testing performed per MMR Procedures.

The results reported above apply only to the test sample(s) provided.

In no event shall Massachusetts Materials Research, Inc. be liable for any special, consequential or other damages.





A Subsidiary of THE MMR GROUP, INC.

Massachusetts Materials Research, Inc.

P.O. BOX 810 • 1500 CENTURY DRIVE - WEST BOYLSTON, MA 01583 • TEL. 508-835-6282 • FAX 508-835-9025

ANALYTICAL REPORT

Harold R. Larson, ScD
 Massachusetts Institute of Technology
 77 Mass Ave., Room 4-049
 Cambridge, MA 02139

DATE: February 28, 2007

P.O. NO.:

MMR NO.: 61061

MMR ID#: 8

PAGE #: 1 of 1

ATTENTION: Harold Larson

SAMPLE IDENTIFICATION

Brass Sample, LL-1

CHEMISTRY

<u>Element</u>	<u>Composition (%)</u>
Copper	57.2
Zinc	40.9
Lead	1.31
Aluminum	< .01
Sulfur	< .001
Iron	.24
Tin	.18
Antimony	.01
Arsenic	.02
Silicon	.02
Nickel	.06
Oxygen	9 PPM

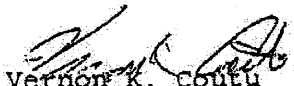
MASSACHUSETTS MATERIALS RESEARCH, INC.

The recording of false, fictitious or fraudulent statements or entries on the certificate may be punishable as a felony under federal law.

Chemical analysis performed by Inductively Coupled Plasma/Optical Emission Spectrometer. Carbon, sulfur, nitrogen, hydrogen and oxygen performed by Leco Combustion. Mechanical and metallurgical testing performed per MMR Procedures.

The results reported above apply only to the test sample(s) provided.

In no event shall Massachusetts Materials Research, Inc. be liable for any special, consequential or other damages.


 Vernon K. Coutu
 Chief Corporate Chemist





A Subsidiary of THE MMR GROUP, INC.

Massachusetts Materials Research, Inc.

P.O. BOX 810 • 1500 CENTURY DRIVE • WEST BOYLSTON, MA 01583 • TEL. 508-835-6262 • FAX 508-835-2025

ANALYTICAL REPORT

Harold R. Larson, ScD
 Massachusetts Institute of Technology
 77 Mass Ave., Room 4-049
 Cambridge, MA 02139

DATE: February 28, 2007

P.O. NO.:

MMR NO.: 61061

MMR ID#: 9

PAGE #: 1 of 1

ATTENTION: Harold Larson

SAMPLE IDENTIFICATION Brass Sample, LL-Loose

CHEMISTRY

<u>Element</u>	<u>Composition (%)</u>
Copper	56.1
Zinc	40.2
Lead	2.78
Aluminum	.04
Sulfur	<.001
Iron	.39
Tin	.31
Antimony	.03
Arsenic	.04
Silicon	.02
Nickel	.11
Oxygen	6 PPM

MASSACHUSETTS MATERIALS RESEARCH, INC.

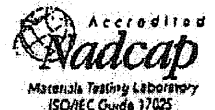
Vernon R. Coutu
Chief Corporate Chemist

The recording of false, fictitious or fraudulent statements or entries on the certificate may be punishable as a felony under federal law.

Chemical analysis performed by Inductively Coupled Plasma/Optical Emission Spectrometer. Carbon, sulfur, nitrogen, hydrogen and oxygen performed by Leco Combustion. Mechanical and metallurgical testing performed per MMR Procedures.

The results reported above apply only to the test sample(s) provided.

In no event shall Massachusetts Materials Research, Inc. be liable for any special, consequential or other damages, which shall not be reproduced, except in full, without written approval of MMR.





A Subsidiary of THE MMR GROUP, INC.

Massachusetts Materials Research, Inc.

P.O. BOX 810 • 1500 CENTURY DRIVE • WEST BOYLSTON, MA 01583 • TEL. 508-835-6262 • FAX 508-835-9025

ANALYTICAL REPORT

Harold R. Larson, ScD
Massachusetts Institute of Technology
77 Mass Ave., Room 4-049
Cambridge, MA 02139

DATE: February 28, 2007

P.O. NO.:

MMR NO.: 61061

MMR ID#: 10

PAGE #: 1 of 1

ATTENTION: Harold Larson

SAMPLE IDENTIFICATION Brass Sample, P4525050-T1

CHEMISTRY

<u>Element</u>	<u>Composition (%)</u>
Copper	59.0
Zinc	34.7
Lead	2.99
Aluminum	.61
Sulfur	<.001
Iron	1.10
Tin	.87
Antimony	.04
Arsenic	.02
Manganese	.06
Silicon	.08
Nickel	.52
Phosphorus	.01
Oxygen	7 PPM

MASSACHUSETTS MATERIALS RESEARCH, INC.

Vernon K. Coutu
Vernon K. Coutu

Chief Corporate Chemist

The recording of false, fictitious or fraudulent statements or entries on the certificate may be punishable as a felony under federal law.

Chemical analysis performed by Inductively Coupled Plasma/Optical Emission Spectrometer. Carbon, sulfur, nitrogen, hydrogen and oxygen performed by Leco Combustion, Mechanical and metallurgical testing performed per MMR Procedures.

The results reported above apply only to the test sample(s) provided. In no event shall Massachusetts Materials Research, Inc. be liable for any special, consequential or other damages.





A Subsidiary of THE MMR GROUP, INC.

Massachusetts Materials Research, Inc.

P.O. BOX 810 • 1500 CENTURY DRIVE • WEST BOYLSTON, MA 01583 • TEL. 508-835-6262 • FAX 508-835-9025

ANALYTICAL REPORT

Harold R. Larson, ScD
Massachusetts Institute of Technology
77 Mass Ave., Room 4-049
Cambridge, MA 02139

DATE: February 28, 2007

P.O. NO.:

MMR NO.: 61061

MMR ID#: 11

PAGE #: 1 of 1

ATTENTION: Harold Larson

SAMPLE IDENTIFICATION Brass Sample, P4175050-P119 Nut

CHEMISTRY

<u>Element</u>	<u>Composition (%)</u>
Copper	56.6
Zinc	39.0
Lead	3.65
Aluminum	<.01
Sulfur	<.001
Iron	.29
Tin	.34
Antimony	.01
Silicon	.02
Nickel	.10
Oxygen	12 PPM

MASSACHUSETTS MATERIALS RESEARCH, INC.

Vernon K. Cowtu
Vernon K. Cowtu
Chief Corporate Chemist

The recording of false, fictitious or fraudulent statements on this certificate may be punishable as perjury under federal law.

Chemical analysis performed by Inductively Coupled Plasma/Optical Emission Spectrometer. Carbon, sulfur, nitrogen, hydrogen and oxygen determined by Leco Combustion. Mechanical and metallurgical testing performed per MMR Procedures.

The results reported above apply only to the test sample(s) provided. In no event shall Massachusetts Materials Research, Inc. be liable for any special, consequential or other damages.





A Subsidiary of THE MMR GROUP, INC.

Massachusetts Materials Research, Inc.

P.O. BOX 810 • 1500 CENTURY DRIVE • WEST BOYLSTON, MA 01583 • TEL. 508-835-8262 • FAX 508-835-9025

ANALYTICAL REPORT

Harold R. Larson, ScD
Massachusetts Institute of Technology
77 Mass Ave., Room 4-049
Cambridge, MA 02139

DATE: February 28, 2007

P.O. NO.:

MMR NO.: 61061

MMR ID#: 12

PAGE #: 1 of 1

ATTENTION: Harold Larson

SAMPLE IDENTIFICATION Brass Sample, P4515050-T1

<u>CHEMISTRY</u>	<u>Element</u>	<u>Composition (%)</u>
Co	Cr	59.6
Zn		35.3
Le		2.90
Al	ium	.26
Se		<.001
Ir		.66
T		.89
Ar	ony	.04
Ma	nese	.03
S	on	.07
N	el	.34
C	n	9 PPM

MASSACHUSETTS MATERIALS RESEARCH, INC.

Vernor K. Coutu
Vernor K. Coutu
Chief Corporate Chemist

The records, statements and analyses on this certificate may be punishable if used for false, fictitious or fraudulent purposes under federal law.

Chemical analysis performed by Inductively Coupled Plasma/Optical Emission Spectrometer. Carbon, sulfur, nitrogen, hydrogen and oxygen determined by Leco Combustion. Mechanical and metallurgical testing performed per MMR Procedures.

The results and analyses above apply only to the test sample(s) provided. Massachusetts Materials Research, Inc. be liable for any special, consequential or other damages.





A Subsidiary of THE MMR GROUP, INC.

Massachusetts Materials Research, Inc.

810 • 1500 CENTURY DRIVE • WEST BOYLSTON, MA 01583 • TEL. 508-835-8262 • FAX 508-835-9025

ANALYTICAL REPORT

Requested by: R. Larson, ScD
 Massachusetts Institute of Technology
 77 Massachusetts Ave., Room 4-049
 Cambridge, MA 02139

DATE: February 28, 2007

P.O. NO.:

MMR NO.: 61061

MMR ID#: 13

PAGE #: 1 of 1

ATTENTION: Harold Larson

SAMPLE IDENTIFICATION Brass Sample, NN-3-Loose

ELEMENT	Composition (%)
Copper	57.0
Zinc	39.4
Lead	2.76
Antimony	<.01
Sulfur	<.001
Iron	.35
Tin	.29
Silicon	.02
Nickel	.08
Oxygen	10 PPM

MASSACHUSETTS MATERIALS RESEARCH, INC.

Vernon K. Coutu
 Vernon K. Coutu

Chief Corporate Chemist

The recording of statements is punishable if fictitious or fraudulent information on the certificate may be provided under federal law.

Chemical analysis performed by Inductively Coupled Plasma/Optical Emission Spectrometer. Carbon, sulfur, nitrogen, hydrogen and oxygen analyzed by Leco Combustion. Mechanical and metallurgical testing performed per MMR Procedures.

The results above apply only to the test sample(s) provided. Massachusetts Materials Research, Inc. be liable for any special, consequential or other damages. This report may be reproduced, except in full, without written approval of MMR.

