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THE MMR GROUP, INC.
an ESOP Company

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For: **Report of Findings**
LTL Job #: **R-48-20**

Overview

A comparison of the aluminum alloy chemistry of Artifact 2-2-V-1, presumed possibly to be a starboard window patch from the Lockheed Electra 10 piloted by Mrs. Amelia Earhart Putnam during her second around the world attempt, with various other aluminum aircraft alloys from the 1930's and the 1940's. The *objective* is to see if there are any suitable markers that help to establish a time line for 2-2-V-1.

Samples

1. Artifact 2-2-V-1 Earhart Artifact
2. Lockheed Electra 12 (1936 – 1941?)
3. Artifact 2-9-A-9 Gillam Electra 10 (1935)
4. Artifact 2-9-A-9 Gillam Electra 10 (1935) Sample #2
5. Artifact 2-8-I-1 Idaho Accident Electra (1936)
6. Unknown WW2 Aircraft (B-24?)
7. B-17 Shoo-Shoo Baby (1942-1943)
8. Artifact 2-18 Heat Shield
9. National Bureau of Standards (NBS) 859 Aluminum alloy (7075) was used as an analytical control*

Summary and Discussion of Results

The results of our analysis were that, with the exception of the heat shield, which must be treated as a separate issue, all of the base alloys were copper, magnesium, manganese, aluminum alloys similar to UNS (United Numbering System) A92024 (2024) wrought aluminum alloy, heat treatable. That being established a careful examination of the data reveals at least two markers that appear to potentially be time dependent. It will be noted that chromium and zinc are significantly more concentrated in the later aircraft, B-17 Shoo-Shoo Baby from 1942-1943 and the WW2 Bomber suspected B-24 (Chromium 134 – 185 PPM, Zinc 207-243 PPM) than in any of the 1930's Electra's (Chromium 10-28 PPM, Zinc 57-78 PPM). Comparatively, artifact 2-2-V-1 has a chromium concentration of 151 PPM and a zinc concentration of 130 PPM. While the zinc difference may be a toss-up, the chromium content appears to be a strong marker and would thus appear to show 2-2-V-1 to resemble the alloys from the later dates.

Nickel may also be a potentially important marker as it would appear to follow this same trend. Of course this very limited data base is by no means conclusive, but neither is it supportive of the patch being from the earlier era as the trend appears to be consistent and predictable. However, one also realizes that 2-2-V-1 was not apparently part of the original aircraft, but a "patch". Thus, the question is could this "recipe" for 24ST (2024) with higher chromium especially and higher zinc (and nickel) been available at the time (1937) in question?

The artifact 2-18 Heat Shield could not be matched to a specific UNS type aluminum alloy and does not resemble the other 24ST (2024) type aircraft alloys presented here. Whether or not its composition has altered from corrosion, age or otherwise we did not determine.

Mechanical Testing results are attached for information.

Results Detail

Element	Artifact 2-2-V-1 Earhart Artifact	Lockheed Electra 12 (1936 – 1941?)	Artifact 2-9-A-9 Gillam Electra 10 (1935)	Artifact 2-9-A-9 Gillam Electra 10 (1935) Sample #2	Artifact 2-8-I-1 Idaho Accident Electra (1936)	Unknown WW2 Aircraft (B-24?)	B-17 Shoo-Shoo Baby (1942-1943)
Aluminum	**balance**	**balance**	**balance**	**balance**	**balance**	**balance**	**balance**
Beryllium	**<0.0001 %**	**<0.0001 %**	**<0.0001 %**	**<0.0001%**	**<0.0001 %**	**<0.0001 %**	**<0.0001 %**
Boron	**0.0009 %**	**0.0006 %**	**0.0005 %**	**0.0006 %**	**0.0007 %**	**0.0008 %**	**0.001 %**
Silicon	**0.15 %**	**0.17 %**	**0.17 %**	**0.13 %**	**0.15 %**	**0.14 %**	**0.17 %**
Titanium	**0.01 %**	**0.008 %**	**0.009 %**	**0.007 %**	**0.007 %**	**0.008 %**	**0.008 %**
Vanadium	**0.003 %**	**0.002 %**	**0.0009%**	**0.001 %**	**0.002 %**	**0.003 %**	**0.003 %**
Chromium	**0.015 %**	**0.003 %**	**0.001 %**	**0.001 %**	**0.001 %**	**0.013 %**	**0.018 %**
Manganese	**0.62 %**	**0.59 %**	**0.43 %**	**0.48 %**	**0.45 %**	**0.51 %**	**0.45 %**
Iron	**0.23 %**	**0.17 %**	**0.20 %**	**0.19 %**	**0.13 %**	**0.21 %**	**0.24 %**
Nickel	**0.002 %**	**<0.0006 %**	**<0.0006 %**	**<0.0007%**	**0.0008 %**	**0.003 %**	**0.004 %**
Zinc	**0.013 %**	**0.007 %**	**0.008 %**	**0.007 %**	**0.006 %**	**0.021 %**	**0.024 %**
Zirconium	**0.003 %**	**0.004 %**	**0.005 %**	**0.004 %**	**0.005 %**	**0.003 %**	**0.003 %**
Tin	**0.004 %**	**0.005 %**	**0.004 %**	**<0.001 %**	**<0.001 %**	**<0.001 %**	**0.002 %**
Sodium	**< 0.002 %**	**<0.002 %**	**<0.002 %**	**<0.002 %**	**0.004 %**	**<0.002 %**	**0.003 %**
Calcium	**<0.0004 %**	**<0.0004 %**	**<0.0004 %**	**<0.0004%**	**<0.0004 %**	**<0.0004 %**	**<0.0004 %**
Gallium	**0.01 %**	**0.02 %**	**0.01 %**	**0.02 %**	**0.02 %**	**0.02 %**	**0.02 %**
Strontium	**<0.0001 %**	**0.0001 %**	**<0.0001 %**	**0.0001 %**	**0.0001 %**	**<0.0001 %**	**0.0001 %**
Lead	**0.02 %**	**0.03 %**	**0.02 %**	**0.02 %**	**0.03 %**	**0.03 %**	**0.03 %**
Magnesium	**1.48 %**	**1.49 %**	**1.49 %**	**1.46 %**	**1.46 %**	**1.42 %**	**1.31 %**
Lithium	**<0.0004 %**	**0.0004 %**	**<0.0004 %**	**<0.0004%**	**0.0006 %**	**0.0004 %**	**0.0006 %**
Scandium	**0.0001 %**	**0.0002 %**	**0.0001 %**	**0.0001 %**	**0.0003 %**	**0.0002 %**	**0.0002 %**
Bismuth	**<0.005 %**	**<0.005 %**	**<0.005 %**	**<0.005 %**	**<0.005 %**	**<0.005 %**	**<0.005 %**
Copper	**4.49 %**	**4.48 %**	**4.29 %**	**4.06 %**	**3.55 %**	**4.14 %**	**4.30 %**

Element	Artifact 2-18 Heat Shield
Aluminum	balance
Beryllium	<0.0001%
Boron	0.001%
Silicon	0.41 %
Titanium	0.01 %
Vanadium	0.003 %
Chromium	0.033 %
Manganese	0.56 %
Iron	0.50 %
Nickel	0.02 %
Zinc	0.32 %
Zirconium	0.003 %
Tin	0.01 %
Sodium	<0.002 %
Calcium	<0.0004 %
Gallium	<0.005 %
Strontium	<0.0001 %
Lead	0.03 %
Magnesium	0.32 %
Lithium	<0.0004 %
Scandium	0.0002 %
Bismuth	<0.005 %
Copper	3.55 %

Controls

***National Bureau of Standards**
NBS 859 7075 Aluminum Alloy

Element	NBS 859 (After Calibration)	NBS 859 (Post Analysis)	NBS 859 Certified Values
Aluminum	balance	balance	
Beryllium	0.0025 %	0.0025 %	0.0026 %
Boron	0.0005 %	0.0008 %	
Silicon	0.1718 %	0.1689 %	0.17 %
Titanium	0.0415 %	0.0410 %	0.041 %
Vanadium	0.0093 %	0.0096 %	0.0082 %
Chromium	0.1760 %	0.1730 %	0.176 %
Manganese	0.0776 %	0.0770 %	0.078 %
Iron	0.1952 %	0.1917 %	0.202 %
Nickel	0.0650 %	0.0639 %	0.063 %
Zinc	5.55 %	5.47 %	5.46 %
Zirconium	0.0037 %	0.0039 %	
Tin	<0.0013 %	<0.0013 %	
Sodium	<0.0021 %	0.0048 %	
Calcium	<0.0004 %	<0.0004 %	
Gallium	0.0253 %	0.0284 %	
Strontium	0.0001 %	0.0001 %	
Lead	0.0371 %	0.0418 %	
Magnesium	2.450 %	2.413 %	2.45 %
Lithium	<0.0004 %	0.0007 %	
Scandium	0.0002 %	0.0003 %	
Bismuth	<0.005 %	< 0.005 %	
Copper	1.578 %	1.561 %	1.59 %

Results are reported based upon the instrument detection limits at the time of calibration. No attempt was made to determine uncertainties.

Chemistry

The samples were ground on a belt grinder using 60 grit abrasive papers to remove the ALCLAD coating and reveal the base material for preparation (the ALCLAD coatings will be analyzed by SEM / EDS in a cross-sectional mount / polish in separate samples). The samples were then cut and weighed to 0.1 mg and digested in mineral acids using classical methods. Once digested the samples were volumetrically diluted for analysis by inductively coupled plasma atomic emission spectroscopy (ICP-AES). A Spectro CIROS ICP spectrometer with HF resistant torch and nebulizer was used.

Procedure For Mechanical Testing of Samples

A sample of each artifact tested was cut into a small strip approximately ½" wide. The sample was then machined down to a sub size ¼" specimen strip.

After all machining was completed on the specimens they were brought in for testing on a Sintech 30 Material Testing Instrument. Each sample was loaded into wedge grips. Dimensions were recorded for width and thickness. A one inch extensometer was then attached to the specimen. The test was then started and ran until failure. All numerical data was recorded. The width, thickness, yield strength (0.2% offset), tensile strength, elongation and reduction of area were recorded and included in the final report.

Thank you for giving us this opportunity to assist you with these analyses. Should you have any questions regarding the information provided, please contact us.

Sincerely,

Peter M. Engelgau

Peter M. Engelgau
Principal Chemist

Deborah A. Hotra, Senior Technician
Kevin Sexton, Mechanical Testing Technician

Attachments
Mechanical testing scans and data

Lehigh Testing
Tension Testing Report

1/5/2015

Sample ID: R-48-20.mss
Method: 1 Inch Flat LTL.msm

Test Date: 12/17/2014
Operator: KEVIN

Sample Information:

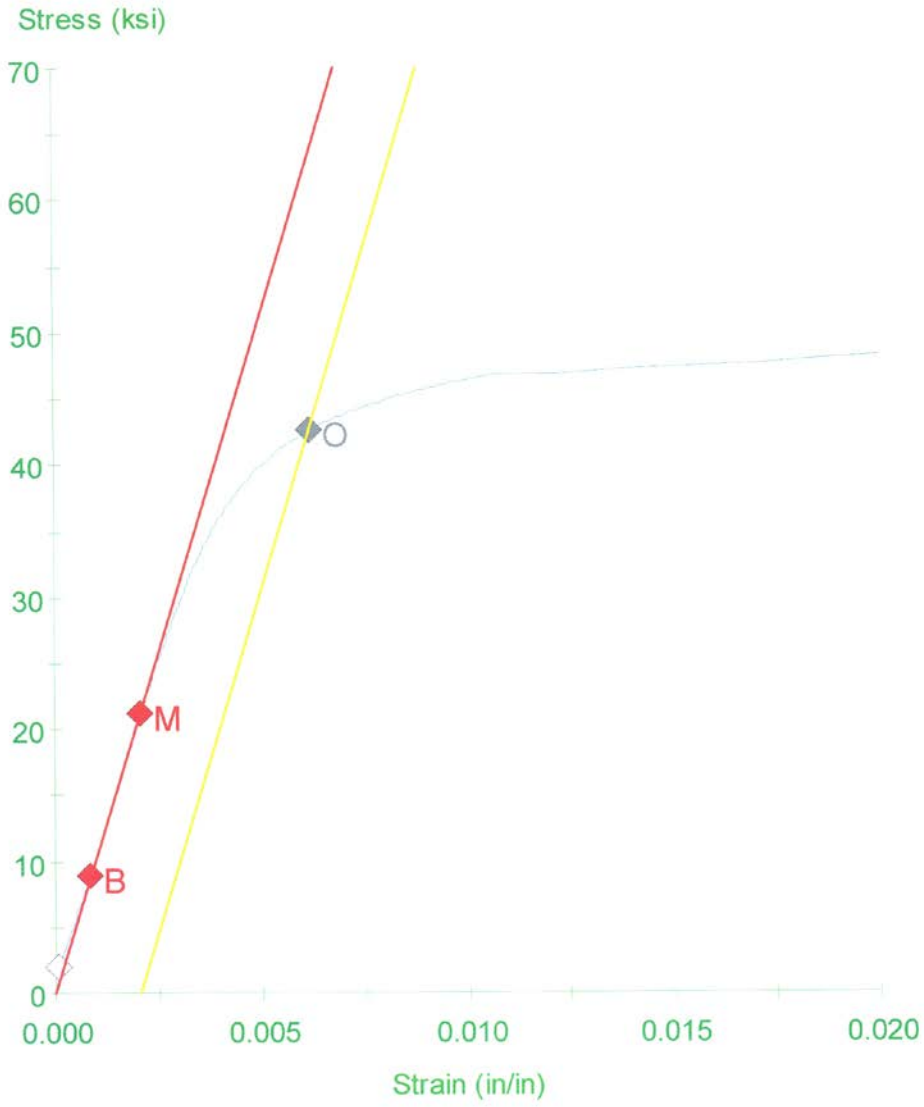
Name	Value
Customer	TIGHAR
LTL#	R-48-20

Specimen Results:

Specimen #	Sub #	Measured Elongation in	Post Thickness in	Post Width in	Thickness in	Width in	Yield psi	Tensile psi	Elongation %
1	28I1 1935 ELECTRA 2B	1.20	0.036	0.223	0.039	0.246	42536.1	61801.3	20.00
2	29A9 1935 ELECTRA GILLIAM	1.08	0.022	0.240	0.025	0.246	38871.4	52472.8	8.00
3	B17..1942/43 CONTRACT AC SHOO SHOO BABY	1.03	0.018	0.000	0.019	0.245	45107.2	50964.6	3.00
4	22V1 ARTIFACT	1.26	0.027	0.228	0.030	0.248	41611.3	52712.5	26.00
5	ELECTRA 12 1936/41	1.14	0.025	0.231	0.031	0.247	47594.4	63656.2	14.00
Mean		1.14	0.026	0.184	0.029	0.246	43144.1	56321.5	14.20
Std. Dev.		0.09	0.007	0.103	0.007	0.001	3340.4	5923.7	9.18

Specimen #	Area in^2	Peak Load lbf	Modulus psi	StrainRate (in/in)/min	Stress At 5% psi	% Area Reduction %	Post Area in^2		
1	0.0096	592.9	10311321.1	0.011	51288.655	16.323	0.0080		
2	0.0061	322.7	9021923.3	0.027	47551.784	14.146	0.0053		
3	0.0047	237.2	17483968.2	0.021	****	100.000	0.0000		

4	0.0074	392.2	8905675.0	0.060	****	17.258	0.0062		
5	0.0077	487.4	10098890.9	0.051	56015.341	24.579	0.0058		
Mean	0.0071	406.5	11164355.7	0.034	51618.593	34.461	0.0050		
Std. Dev.	0.0018	138.9	3587897.7	0.021	4241.414	36.846	0.0030		


Stress (ksi)
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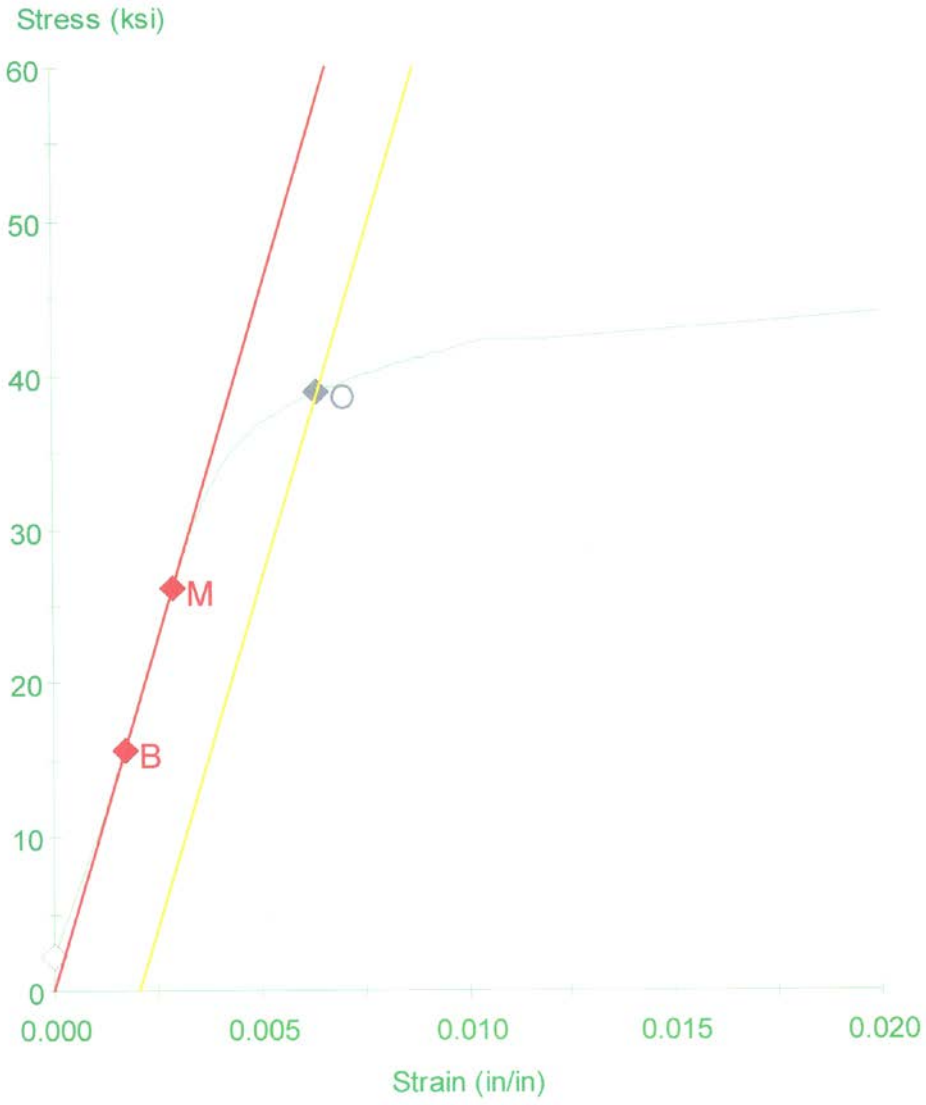
60
50
40
30
20
10
0
M
B
O
0.000
0.005
0.010
0.015
0.020
Strain (in/in)

[1]


Stress (ksi)
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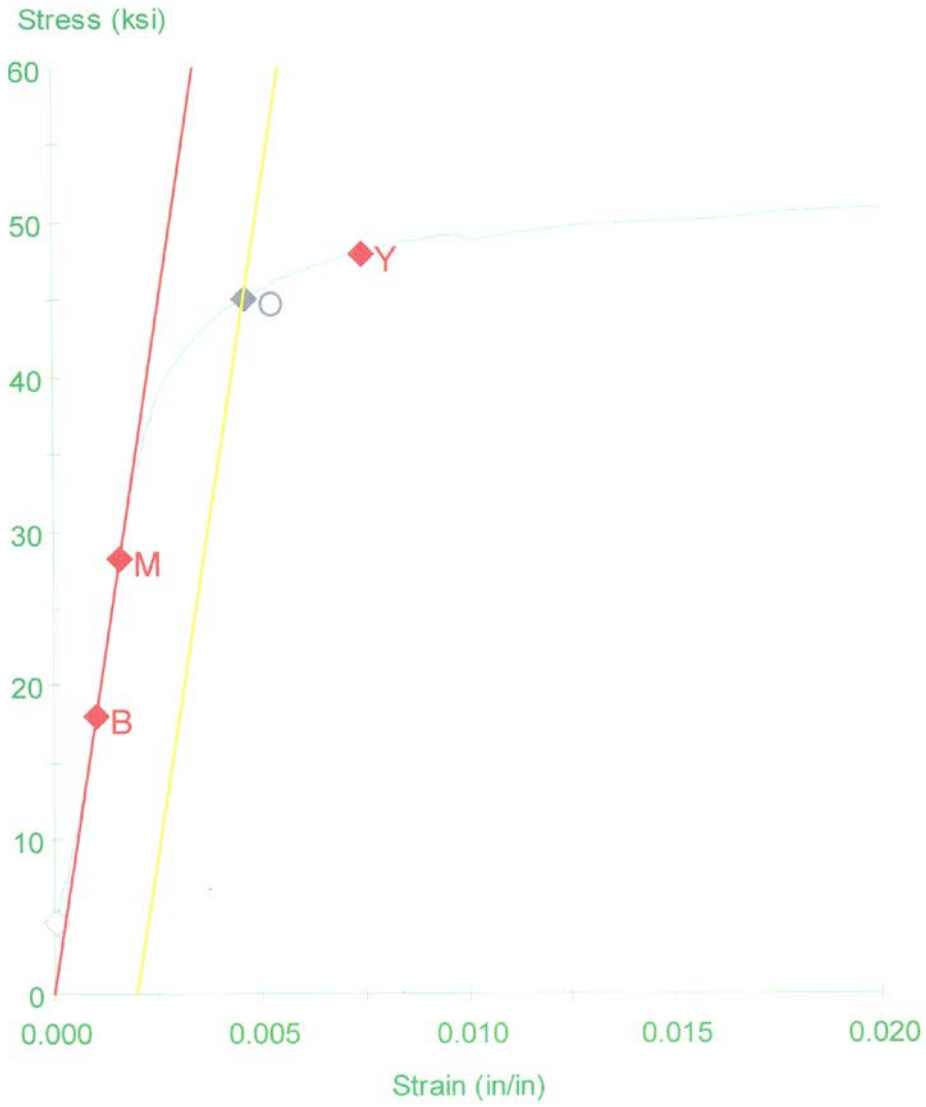
0.000
0.005
0.010
0.015
0.020
Strain (in/in)

[2]


Stress (ksi)
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Y
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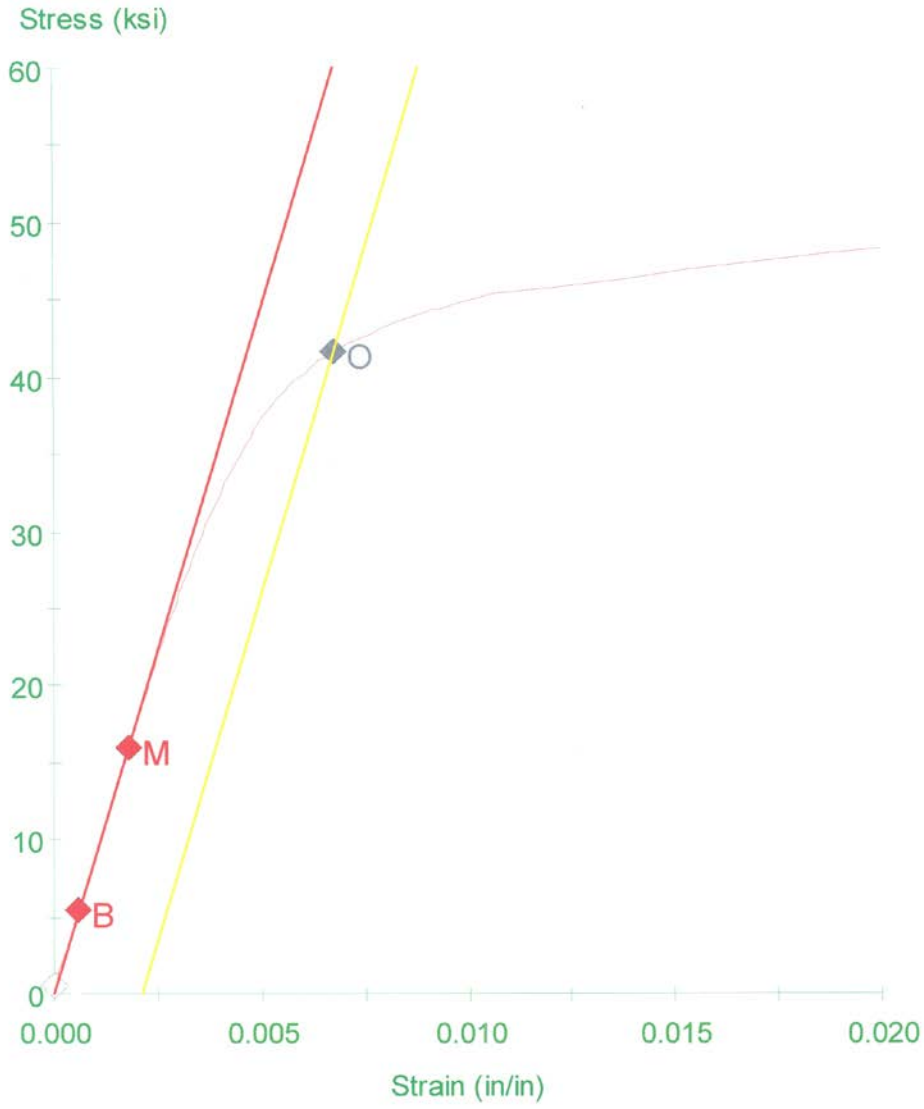
0.000
0.005
0.010
0.015
0.020
Strain (in/in)

[3]


Stress (ksi)
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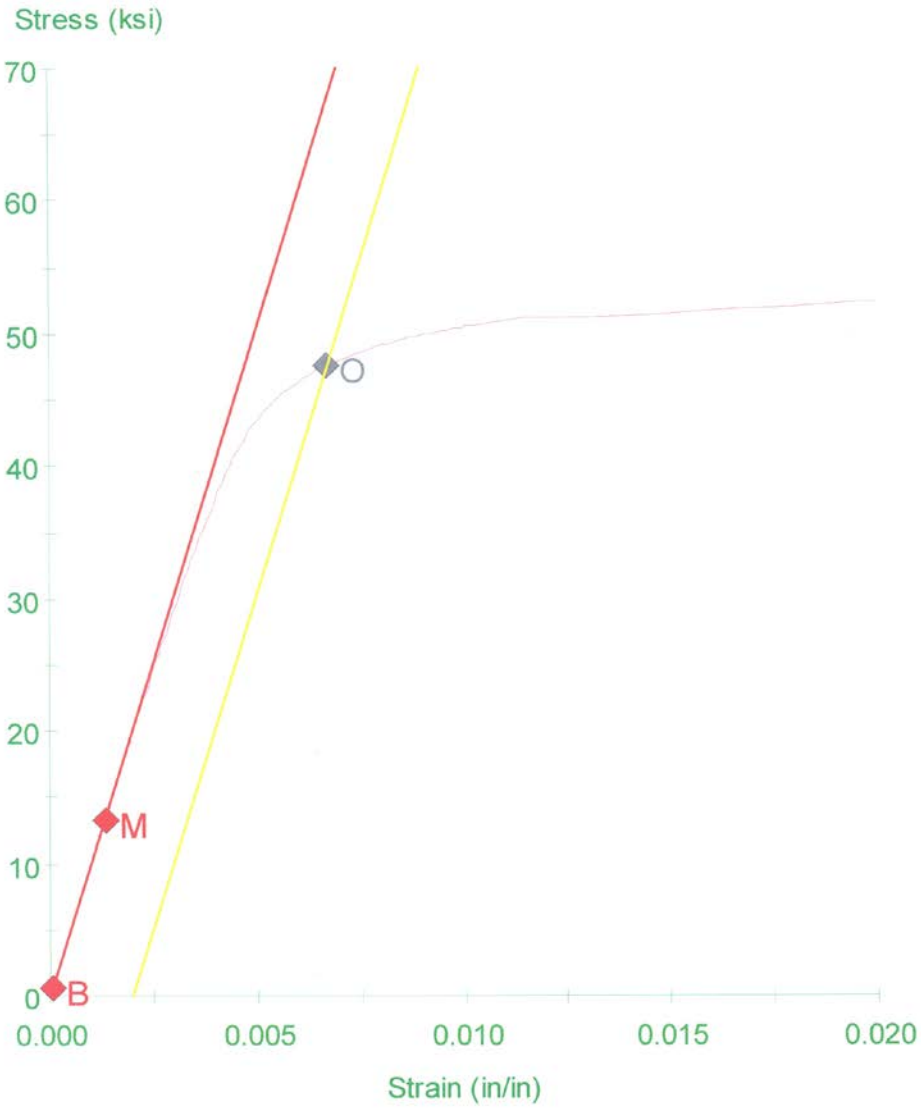
Strain (in/in)
[4]


Stress (ksi)
70
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0.005
0.010
0.015
0.020
Strain (in/in)

[5]