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PRODUCT VERIFICATION REPORT

TEST RESULTS AND TECHNICAL DATA FOR THE LITTELFUSE 242 SERIES, HAZARDOUS AREA BARRIER NETWORK FUSE

January 21, 2020 (Revised May 08, 2020)

ELECTRICAL TEST RESULTS AND TECHNICAL DATA FOR THE LITTELFUSE 242 SERIES, HAZARDOUS AREA BARRIER NETWORK FUSE

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1. INTRODUCTION

1.1 KEY OBJECTIVE

To confirm that Littelfuse 242 Series Hazardous Area Barrier Network Fuse meets or exceeds all performance specifications outlined in the datasheet after fuse body enhancement (Metallized Body). Note that the tested samples are from the 50mA fuse.

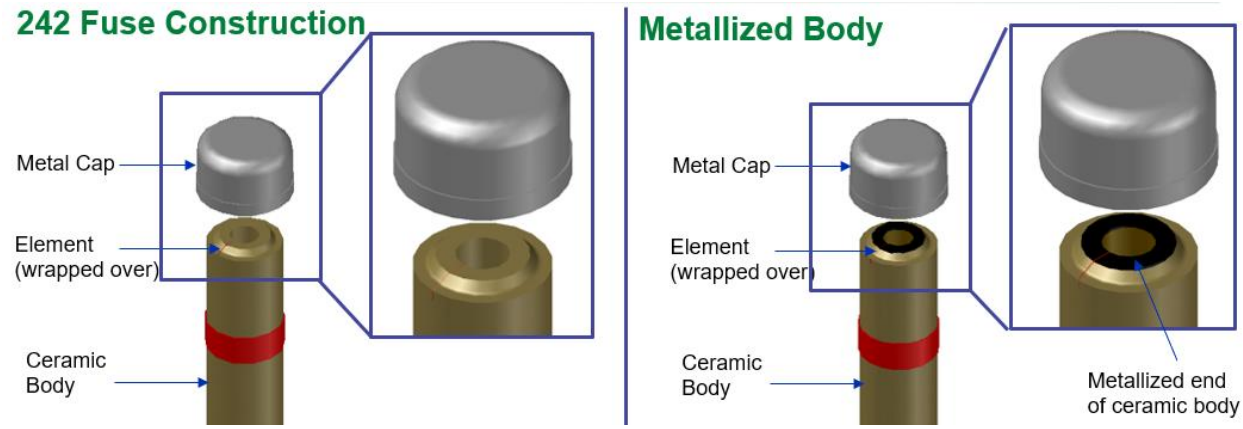


Figure 1: Metallized Body Concept

1.2 TEST PLAN

The test plan and methodology discussed in the following pages will verify the fuse performance as per Littelfuse internal specification and relevant MIL-STD. The tested part is 0242.050UR only.

Samples are soldered on 10 position test boards before electrical or environmental testing except for cap retention and bond analysis tests. Resistance is measured at each step (after soldering, and after environmental testing). Post electrical tests will be conducted for all fuses after the environmental test to check for electrical damage. 50% of the fuse quantity will undergo life test while the other 50% will undergo overload test.

Date code for control samples is 9L19 / November 19, 2019 with metallized samples being built on the same day.

Table I. Test Plan

Test	Test Condition	Target	Samples per Group
Bond Analysis	Remove cap on both sides.	New Criteria: Presence of wire found on both caps.	90pcs
Cap Retention	Pull the caps apart and measure peak force.	Minimum force of 6.75 lbf.	90pcs

Life Test	110%In for a minimum of 4 hours	All fuses survived the required 4 hours (no open fuse) and there was no visible damage to the external package or body printing.	90pcs
Overload	300%In	Fuse shall open within specified limit: 300%In - 10s, Max	90pcs
	300%In at Rated Voltage	Fuse shall open within specified limit: 300%In - 10s, Max	90pcs
	1000%In	Fuse shall open within specified limit: 1000%In - 2ms, Max	90pcs
Short Circuit	4000A @ 250VAC	Fuses shall be able to operate satisfactorily and safely without endangering the surroundings.	60pcs
	4000A @ 250VDC	Fuses shall be able to operate satisfactorily and safely without endangering the surroundings.	60pcs
Mechanical Shock	MIL-STD-202 Method 213 Test Condition I (100Gs peak, 6msec duration)	Fuses are required to complete the test with no evidence of electrical or mechanical damage. All fuses must pass the post electrical tests.	90pcs
Low Frequency Vibration	MIL-STD-202 Method 201 (10-55 Hz)	Fuses are required to complete the test with no evidence of electrical or mechanical damage. All fuses must pass the post electrical tests.	90pcs
High Frequency Vibration	MIL-STD-202 Method 204 Test Condition C (55-2000Hz)	Fuses are required to complete the test with no evidence of electrical or mechanical damage. All fuses must pass the post electrical tests.	90pcs
Thermal Shock	MIL-Std 202 Method 107 (-55 C to 125 C, 100 cycles)	Fuses are required to complete the test with no evidence of electrical or mechanical damage. All fuses must pass the post electrical tests.	90pcs

2. TEST PURPOSE, DESCRIPTION AND RESULT

2.1 BOND ANALYSIS (CUSTOMER BASED TEST)

1st cap was removed via cap retention test. 2nd cap was removed by peeling the cap using a side cutter. Based on customer request, wires on both caps should be present to be considered passed.

Table II. Bond Analysis Data

Bond Analysis	Results
Control	30/30 Passed
Metallized Body	90/90 Passed

All fuses successfully passed this test.

Several samples were analyzed through SEM to further verify the solder joint condition. Refer to Appendix 4.1 (SEM Photos of Solder Joint).

2.2 CAP RETENTION

Caps are pulled apart using appropriate fixture and the force required to remove at least one of the caps is measured. This test is performed to verify the structural bond between the fuse components e.g. ceramic body, cap, etc. Fuses must have a minimum of 6.75 lbf peak tensile force.

Table III. Cap Retention Data

Bond Analysis	Pull Force Data (lbf)			Results
	Min	Ave	Max	
Control	7.2	15.5	22.2	30/30 Passed
Metallized Body	9.1	19.1	30.7	90/90 Passed

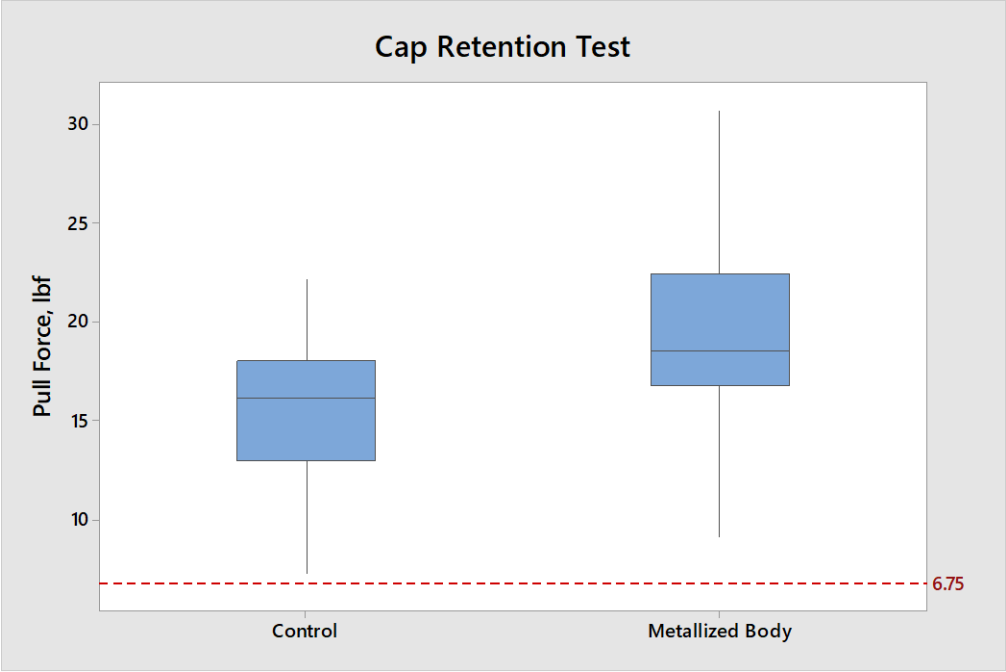


Figure 2. Boxplot of Cap Retention Data

2.3 CURRENT CARRYING CAPACITY (LIFE TEST)

Fuses were subjected to life test to validate the capability of the fuses to withstand 110% of its rated current for a minimum of 4 hours as specified in the datasheet.

Table IV. Life Test Result and Resistance Data

Life Test	Sample Size	On Board Resistance (Ω) Before Life Test			Resistance (Ω) After Life Test		
		Min	Ave	Max	Min	Ave	Max
Control	30	10.53	11.14	12.66	10.55	11.18	12.72
Metallized Body	90	10.30	11.04	12.35	10.31	11.05	12.35

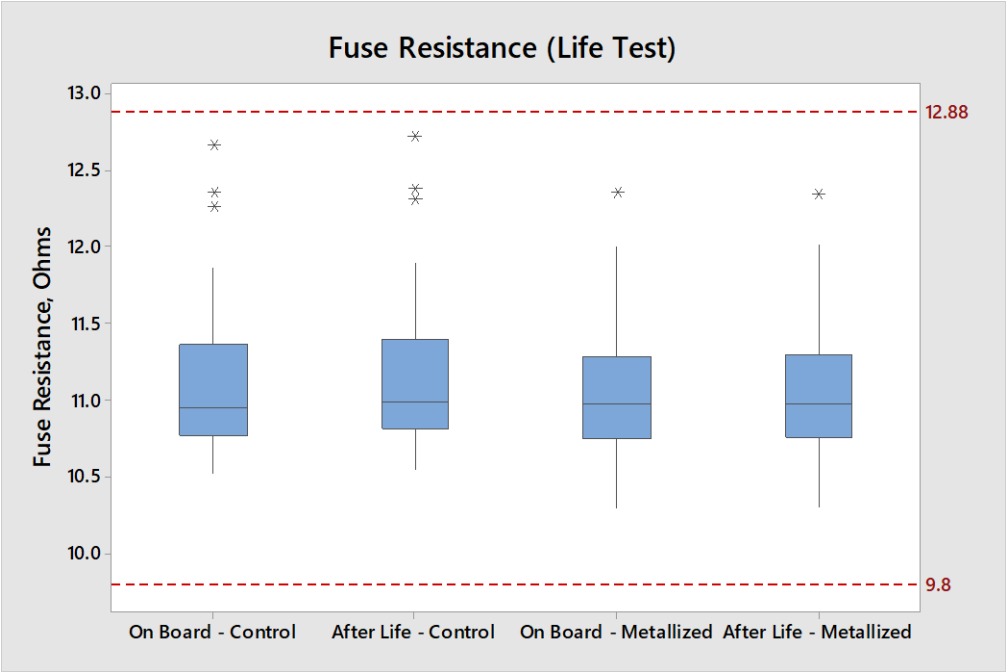


Figure 3. Boxplot of Fuse Resistance (Before & After Life Test)

All fuses successfully passed the test without visible damage to the external package or body printing. There were no open fuses.

2.4 TIME/CURRENT CHARACTERISCTIC (OVERLOAD TEST)

Fuses were subjected to specified overload currents to validate that the fuses will open within specified time limits before damage occurs in a circuit due to the sustained overload condition.

Fuses are required to operate within the following parameters for the overloads specified. 300% overload gate must open within 10 seconds. 1000% overload gate must open within 2 milliseconds.

Table V. Overload Test Results

Overload Test	Sample Size	300%In Overload			300%In Overload at Rated Voltage			1000%In Overload		
		10 seconds Max			10 seconds Max			2 milliseconds Max		
		Min	Ave	Max	Min	Ave	Max	Min	Ave	Max
Control Group	30	0.007	0.009	0.013	0.007	0.011	0.016	0.524	0.894	0.964
Metallized Body	90	0.006	0.008	0.014	0.008	0.018	0.143	0.726	0.885	0.984

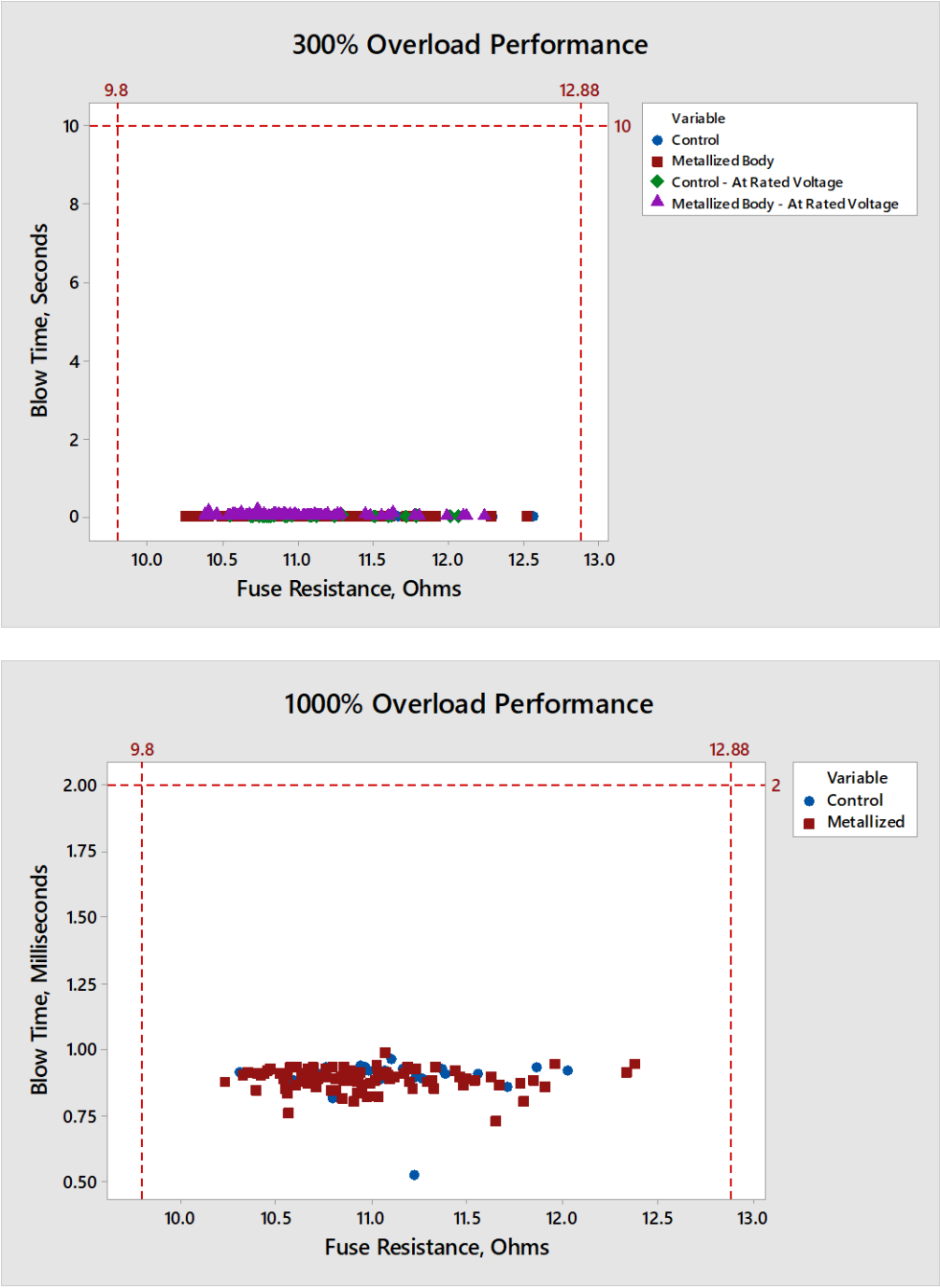


Figure 4. Scatterplot of Blow Time and Resistance (300% and 1000% Overload)

All fuses successfully passed the test without visible damage to the external package or body printing.

2.5 SHORT CIRCUIT TEST

Short circuit test is performed to validate that the fuses safely operate and protect the circuit when subjected to the maximum approved current at rated voltage.

Table VI. Short Circuit Test Result

242 250mA	**4000A @ 250V AC Circuit**	**4000A @ 250V DC Circuit**
Control Group	30/30 Passed (NVD - No Visible Disturbance)	30/30 Passed (NVD)
Metallized Body	60/60 Passed (NVD)	60/60 Passed (NVD)

All fuses were able to operate satisfactorily and safely without endangering the surroundings.

2.6 MECHANICAL SHOCK TEST

Fuses were subjected to mechanical shocks similar to what could be experienced during rough handling and transportation. Test performed as per MIL-STD-202, Method 213, Test condition I: 100G's peak value, 6ms duration, Sawtooth waveform. There are three shocks for each direction along 3 axes which leads to 18 total shocks.

Fuses are required to complete the test with no evidence of electrical or mechanical damage. 50% of the fuses (45pcs for the metallized body group) were subjected to life test while the other 50% were subjected to overload test after mechanical shock.

Table VII. Mechanical Shock Data

Mechanical Shock Data	**Sample Size**	**On Board Resistance (Before Mechanical Shock)**			**Fuse Resistance Before Post Test (After Mechanical Shock)**			**Post Life Test**	**Post Overload Test**
		Min	**Ave**	**Max**	**Min**	**Ave**	**Max**		
Control Group	30	10.33	11.21	12.53	10.29	11.14	12.51	Passed	Passed
Metallized Body	90	10.31	10.94	12.00	10.27	10.90	11.97	Passed	Passed

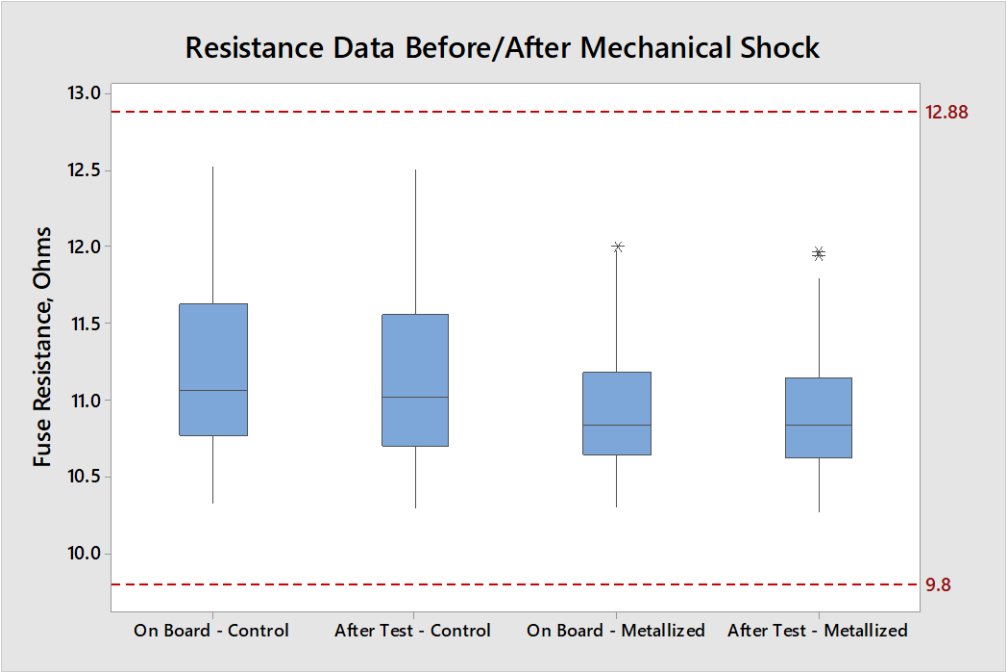


Figure 5. Boxplot of Fuse Resistance (Before & After Mechanical Shock)

There were no open fuses after post life test. All fuses on overload test opened within the specification limits. As noted above, resistance values (after mechanical shock) were within specifications.

2.7 LOW FREQUENCY VIBRATION TEST

Fuses were subjected to vibration in frequencies which would be usually encountered in field service. Test performed as per MIL-STD-202, Method 201. Frequency range used for the test is 10-55Hz, which is traversed back and forth in approximately 1 minute. Duration is 2 hours per axis which totals 6 hours of vibration. The test follows a simple harmonic motion with 0.03inch amplitude. The acceleration is not specified on the standard but is proportional to the specified amplitude and frequency. Max acceleration at 55hZ is less than 10G's (~9.3 G's).

Fuses are required to complete the test with no evidence of electrical or mechanical damage. 50% of the fuses (45pcs for the metallized body group) were subjected to life test while the other 50% were subjected to overload test after low frequency vibration.

Table VIII. Low Frequency Vibration Data

Low Frequency Vibration Data	Sample Size	On Board Resistance (Before Low Frequency Vibration)			Fuse Resistance Before Post Test (After Low Frequency Vibration)			Post Life Test	Post Overload Test
		Min	Ave	Max	Min	Ave	Max		
Control Group	30	10.57	11.23	12.24	10.58	11.21	12.24	Passed	Passed
Metallized Body	90	10.39	11.07	12.06	10.39	11.06	12.02	Passed	Passed

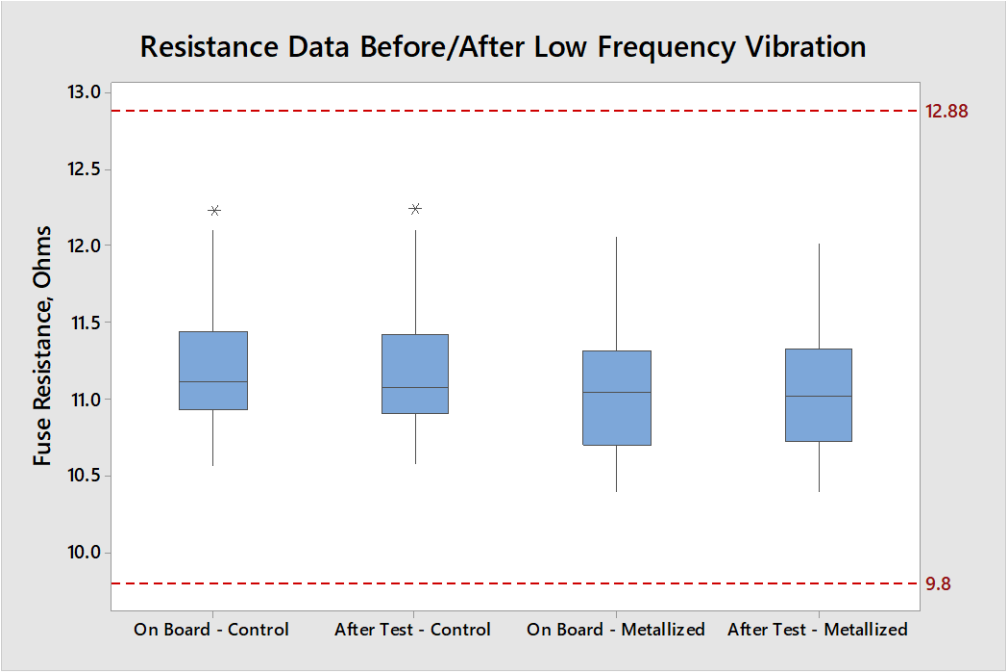


Figure 6. Boxplot of Fuse Resistance (Before & After Low Frequency Vibration)

There were no open fuses after post life test. All fuses on overload test opened within the specification limits. As noted above, resistance values (after low frequency vibration) were within specifications.

2.8 HIGH FREQUENCY VIBRATION TEST

Fuses were subjected to vibration in frequencies which may be encountered in military or aircraft applications. Test performed as per MIL-STD-202, Method 204, Test Condition C Part 2. Frequency range used for the test is 55-2000Hz. The entire range is traversed in approximately 35minutes and is conducted on the three perpendicular axes. This test follows a simple harmonic motion with varied amplitude to maintain a constant 10g peak acceleration.

Fuses are required to complete the test with no evidence of electrical or mechanical damage. 50% of the fuses (45pcs for the metallized body group) were subjected to life test while the other 50% were subjected to overload test after high frequency vibration.

Table IX. High Frequency Vibration Data

High Frequency Vibration Data	Sample Size	On Board Resistance (Before High Freq. Vibration)			Fuse Resistance Before Post Test (After High Freq. Vibration)			Post Life Test	Post Overload Test
		Min	Ave	Max	Min	Ave	Max		
Control Group	30	10.50	11.19	12.49	10.44	11.11	12.42	Passed	Passed
Metallized Body	90	10.37	11.00	12.69	10.33	10.96	12.63	Passed	Passed

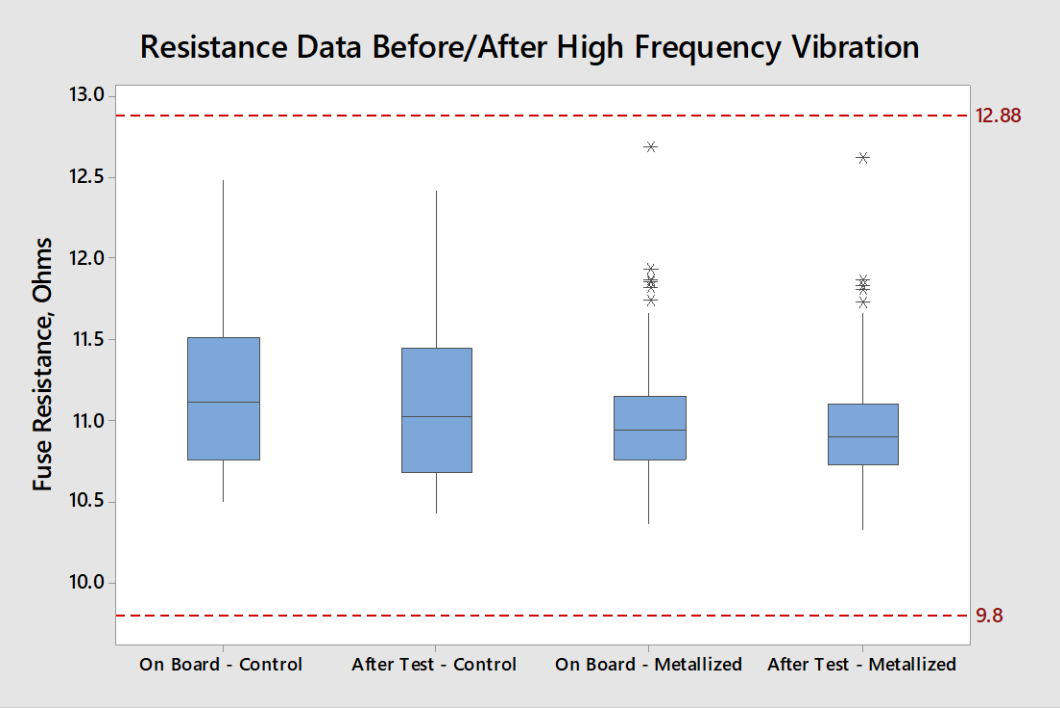


Figure 7. Boxplot of Fuse Resistance (Before & After High Frequency Vibration)

There were no open fuses after post life test. All fuses on overload test opened within the specification limits. As noted above, resistance values (after high frequency vibration) were within specifications.

2.9 THERMAL SHOCK TEST

Fuses were subjected to alternating extreme temperatures which could induce stresses as material components expand and contract at different rates. Test performed as per MIL-STD-202, Method 107. Maximum and minimum temperatures are 125C and -55C, respectively, which is in line with the LF datasheet thermal shock requirement. The number of cycles has been increased to 100 cycles as opposed to the 5 cycle datasheet requirement for additional confidence. As per standard, duration of exposure at extreme temperatures lasts for 15 minutes with transfer time of 5 minutes (max) when changing between the extreme temperatures.

Fuses are required to complete the test with no evidence of electrical or mechanical damage. 50% of the fuses (45pcs for the metallized body group) were subjected to life test while the other 50% were subjected to overload test after thermal shock.

Table X. Thermal Shock Data

Thermal Shock Data	Sample Size	On Board Resistance (Before Thermal Shock)			Fuse Resistance Before Post Test (After Thermal Shock)			Post Life Test	Post Overload Test
		Min	Ave	Max	Min	Ave	Max		
Control Group	30	10.59	11.10	12.01	10.54	11.14	11.98	Passed	Passed
Metallized Body	90	10.15	10.68	11.80	9.98	10.56	11.87	Passed	Passed

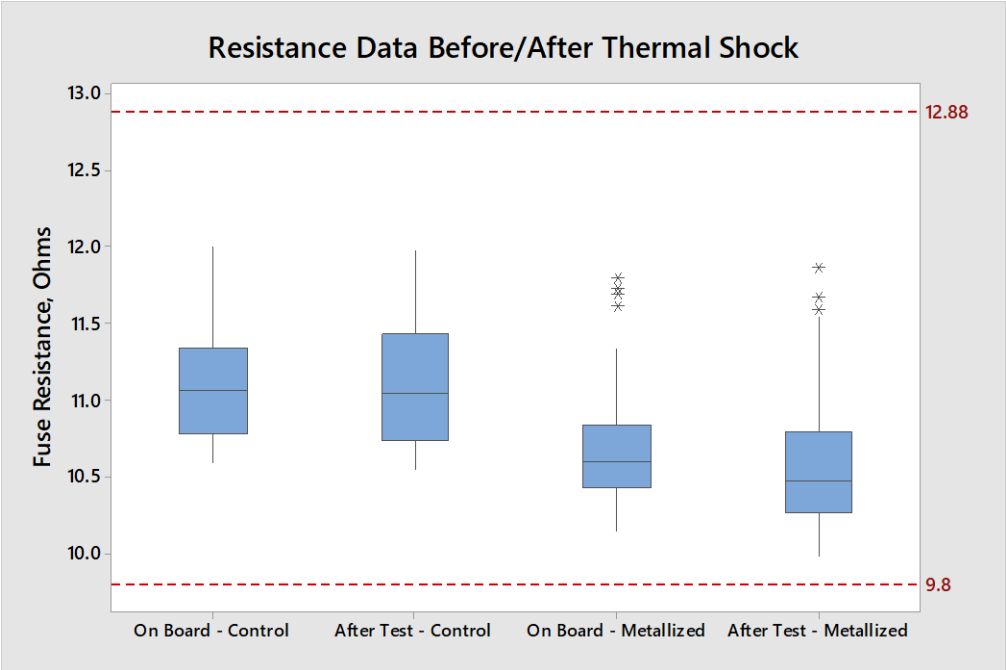


Figure 8. Boxplot of Fuse Resistance (Before & After Thermal Shock)

There were no open fuses after post life test. All fuses on overload test opened within the specification limits. As noted above, resistance values (after thermal shock) were within specifications.

3. SUMMARY OF TEST RESULTS

All metallized body fuses successfully passed the tests.

Table XI. Test Results

Test	Test Condition	Target	Sample Size (Control)	Sample Size (Metallized)	Control	Metallized Body
Bond Analysis	Remove cap on both sides.	New Criteria: Presence of wire found on both caps.	30pcs	90pcs	PASSED	PASSED
Cap Retention	Pull the caps apart and measure peak force.	Minimum force of 6.75 lbf.	30pcs	90pcs	PASSED	PASSED
Life Test	110%In for a minimum of 4 hours	All fuses survived the required 4 hours (no open fuse) and there was no visible damage to the external package or body printing.	30pcs	90pcs	PASSED	PASSED
Overload	300%In	Fuse shall open within specified limit: 300%In - 10s, Max	30pcs	90pcs	PASSED	PASSED
	300%In at Rated Voltage	Fuse shall open within specified limit: 300%In - 10s, Max	30pcs	90pcs	PASSED	PASSED
	1000%In	Fuse shall open within specified limit: 1000%In - 2ms, Max	30pcs	90pcs	PASSED	PASSED
Short Circuit	4000A @ 250VAC	Fuses shall be able to operate satisfactorily and safely without endangering the surroundings.	30pcs	60pcs	PASSED	PASSED
	4000A @ 250VDC	Fuses shall be able to operate satisfactorily and safely without endangering the surroundings.	30pcs	60pcs	PASSED	PASSED
Mechanical Shock	MIL-STD-202 Method 213Test Condition I (100Gs peak, 6msec duration)	Fuses are required to complete the test with no evidence of electrical or mechanical damage. All fuses must pass the post electrical tests.	30pcs	90pcs	PASSED	PASSED
Low Frequency Vibration	MIL-STD-202 Method 201 (10-55 Hz)	Fuses are required to complete the test with no evidence of electrical or mechanical damage. All fuses must pass the post electrical tests.	30pcs	90pcs	PASSED	PASSED
High Frequency Vibration	MIL-STD-202 Method 204 Test Condition C (55-2000Hz)	Fuses are required to complete the test with no evidence of electrical or mechanical damage. All fuses must pass the post electrical tests.	30pcs	90pcs	PASSED	PASSED
Thermal Shock	MIL-Std 202 Method 107 (-55 C to 125 C, 100 cycles)	Fuses are required to complete the test with no evidence of electrical or mechanical damage. All fuses must pass the post electrical tests.	30pcs	90pcs	PASSED	PASSED

4. APPENDIX

4.1 SEM PHOTOS OF SOLDER JOINT

Criteria: Poor Joint
The close-up photos (image c, d) below are samples of poor joint. Even if the wire is attached, there is very little contact between the wire and solder surface. In some cases, the wire will be easily removed during sample preparation and will show only shallow imprints as evidence of its original location.

For reference, both samples are non-metallized fuses. Location of close-up photos are noted on the low magnification photos.

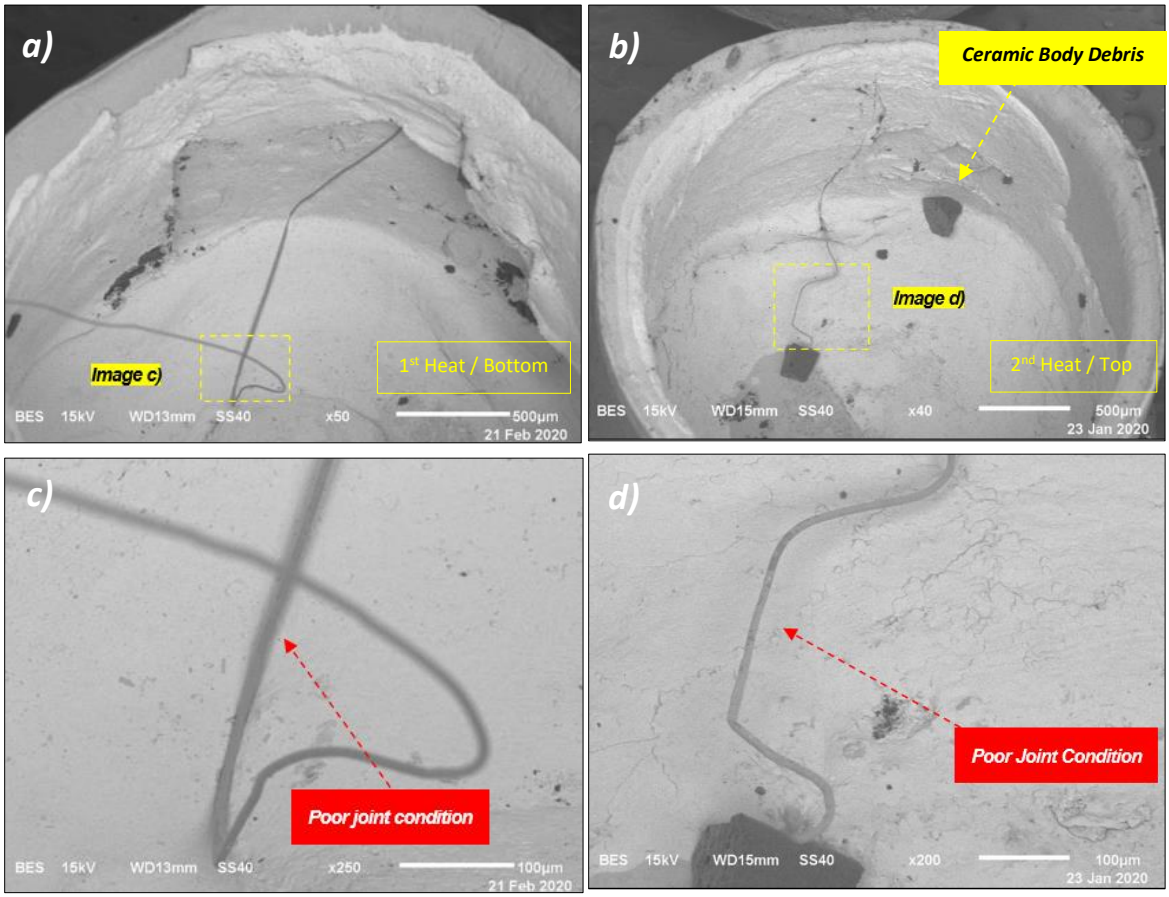


Figure 9. SEM Photos of Poor Joint Condition

Criteria: Embedded Wire

On these close-up photos (image c, d), either most of the circumference of the wire is embedded or the wire is fully embedded under solder (i.e. wire is not visible).

For reference, both samples are from non-metallized fuses. Location of close-up photos are noted on the low magnification photos.

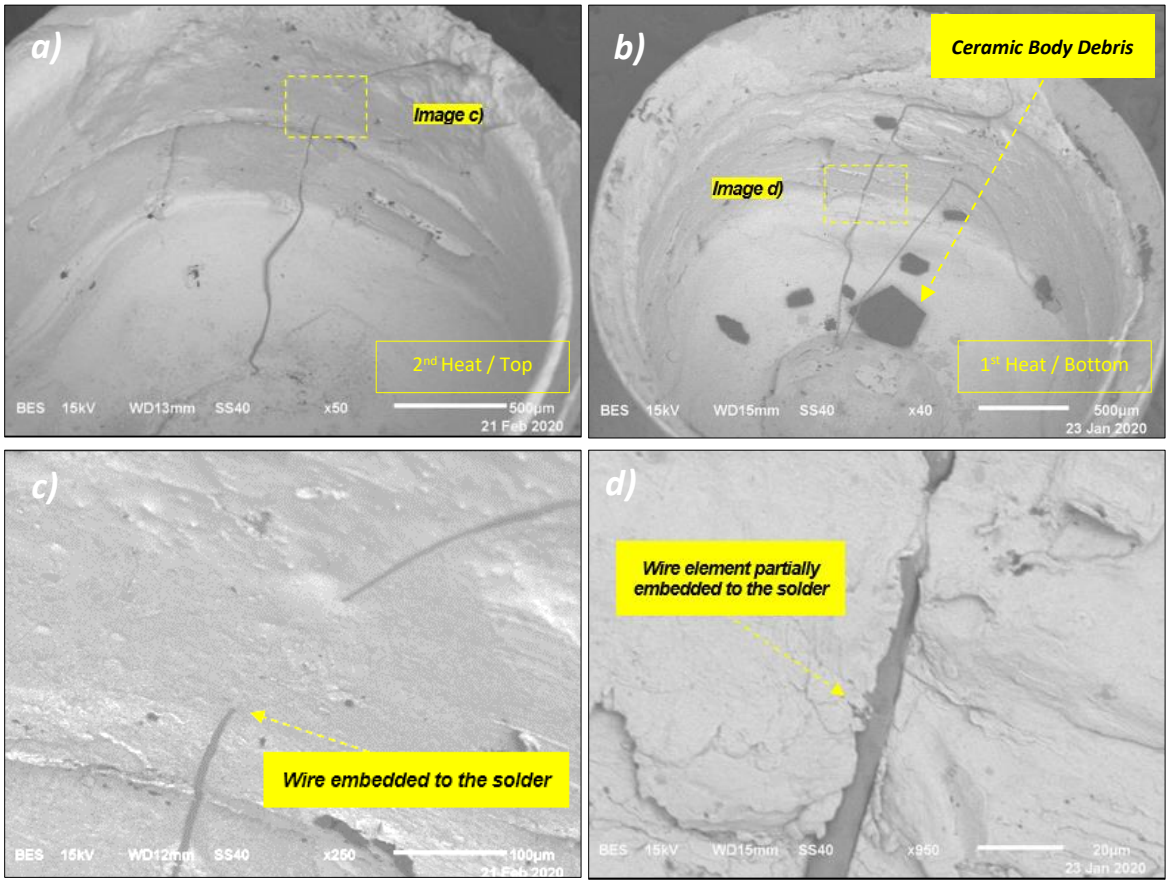
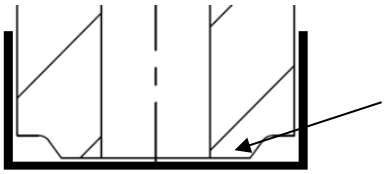
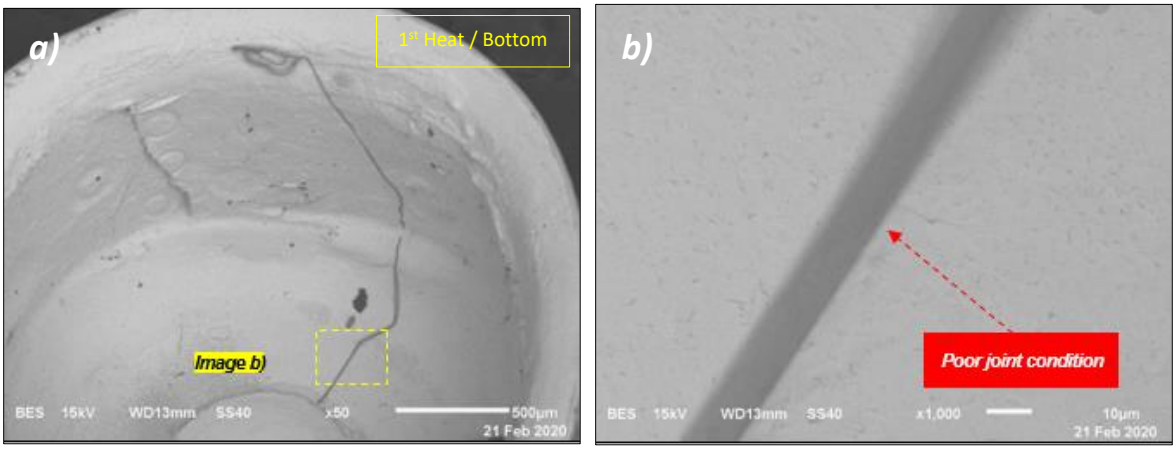


Figure 10. SEM Photos of Embedded Wire



Succeeding photos comparing metallized and non-metallized fuses will focus on this area where metallization layer will be added. Refer to above diagram.

Non-Metallized Sample 1



Non-Metallized Sample 2

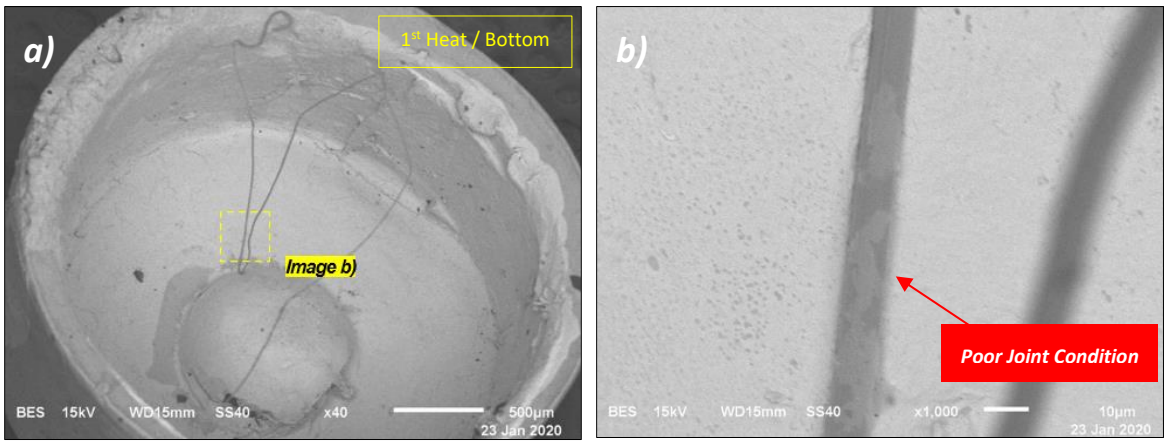
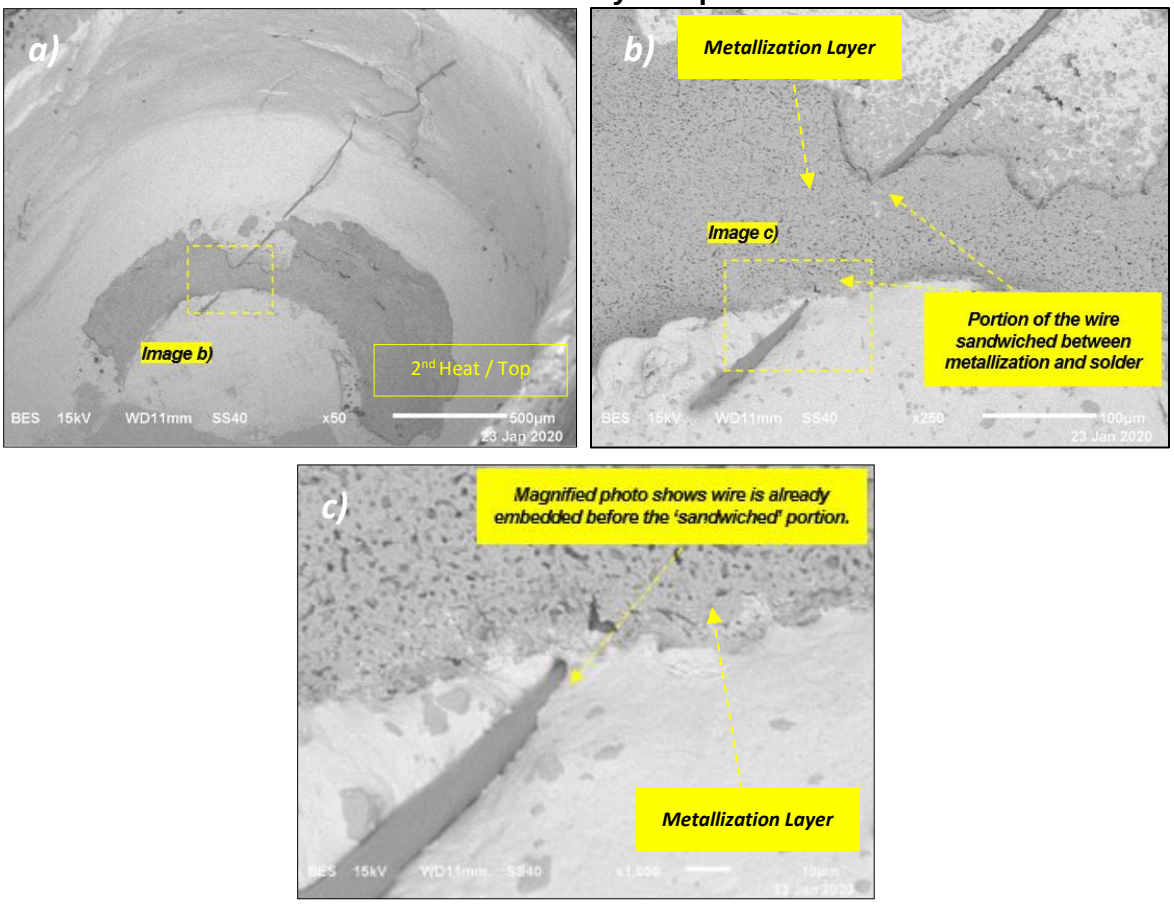
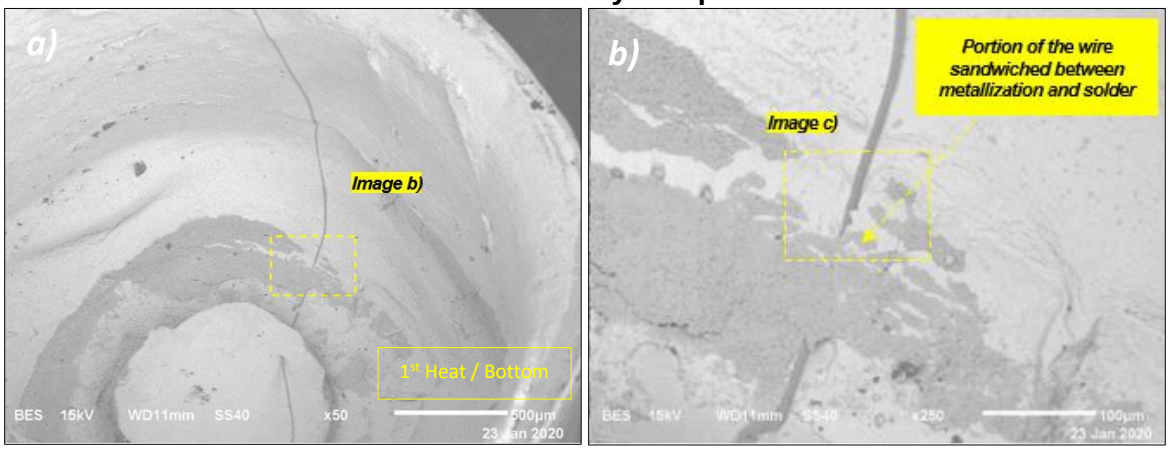


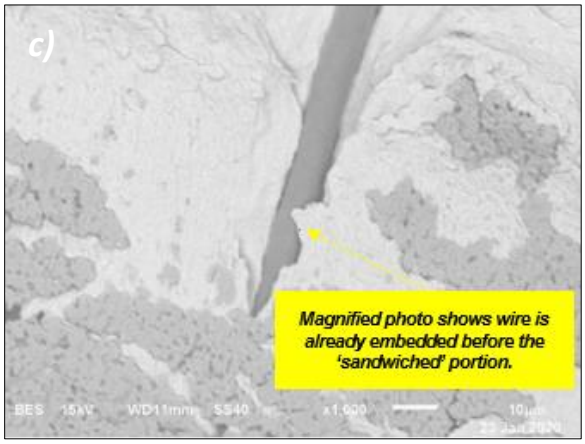
Figure 11. Solder Joint Condition of Non-metallized Body Fuses (SEM Photos)

Metallized Body Sample 1

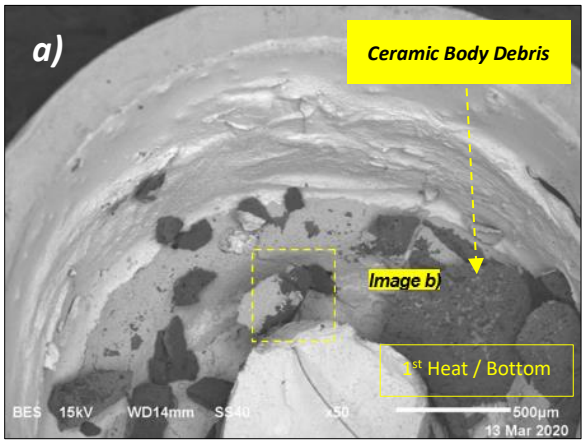


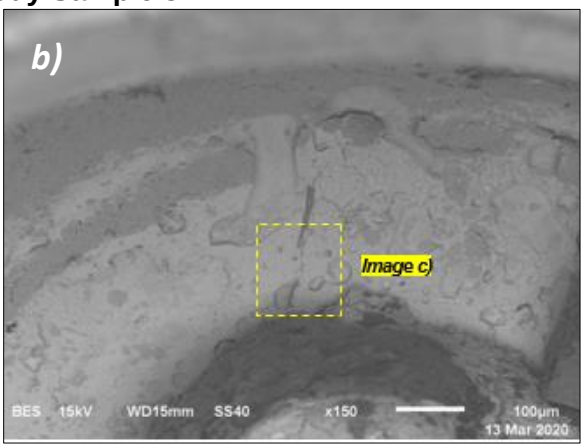
Metallized Body Sample 2

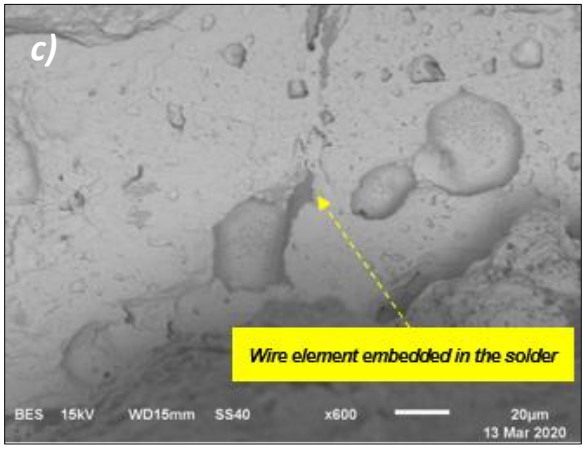




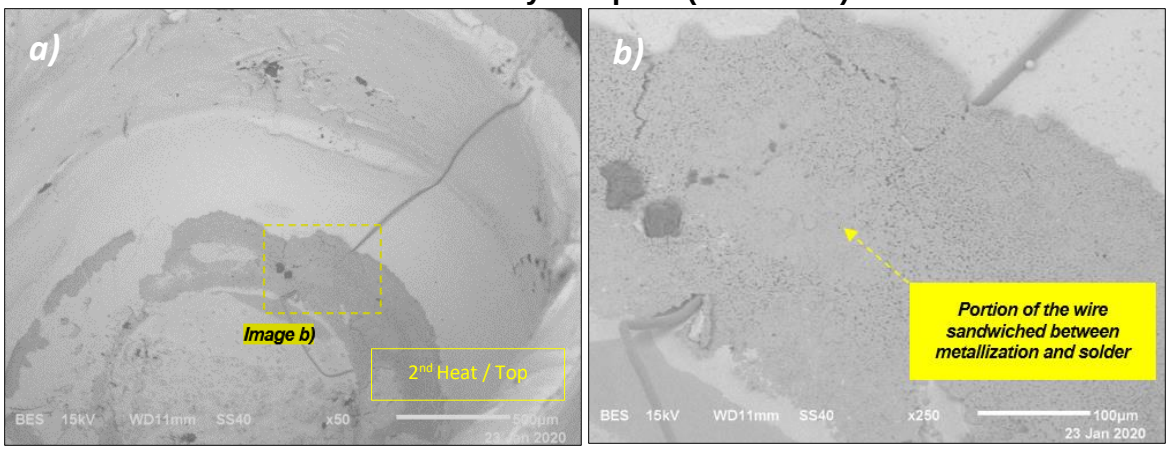
Metallized Body Sample 3



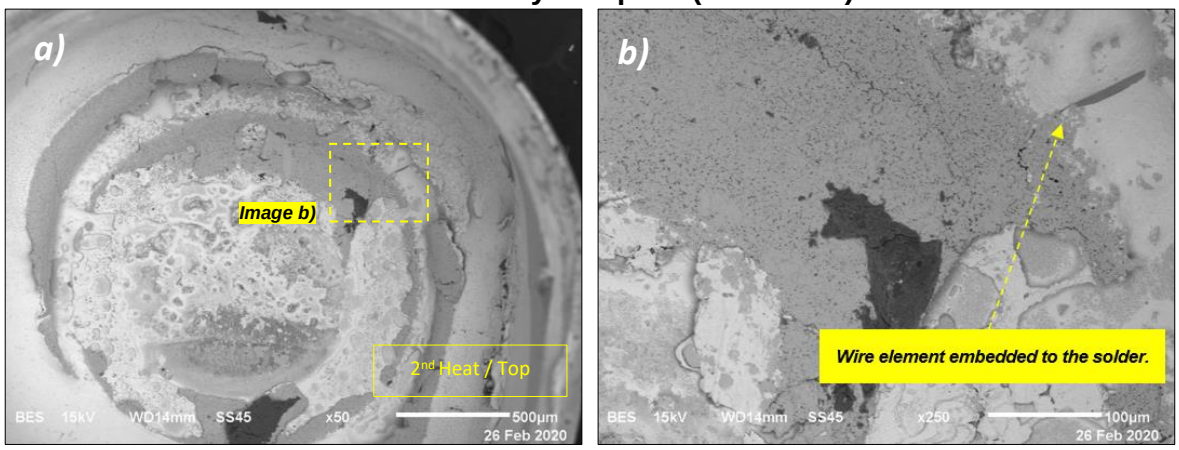




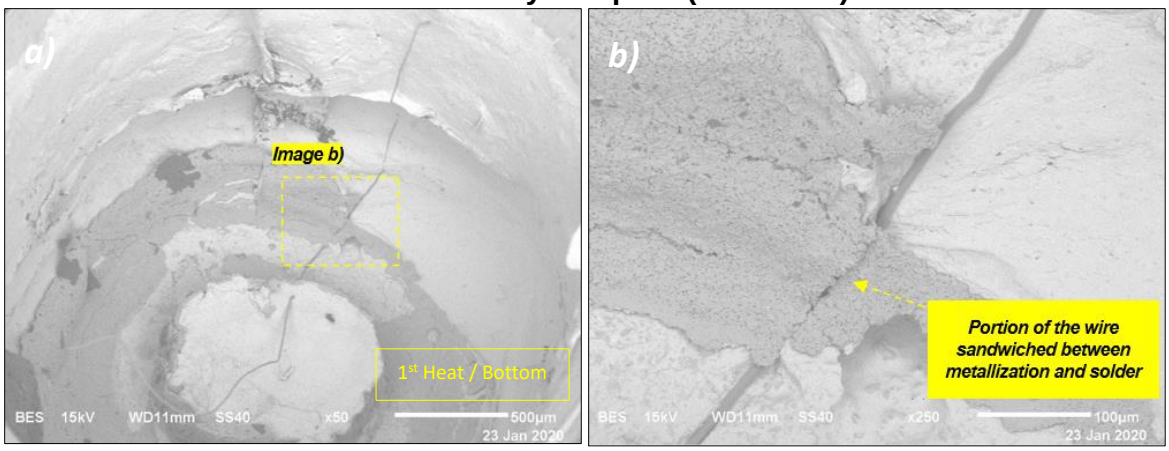
Metallized Body Sample 4 (Additional)



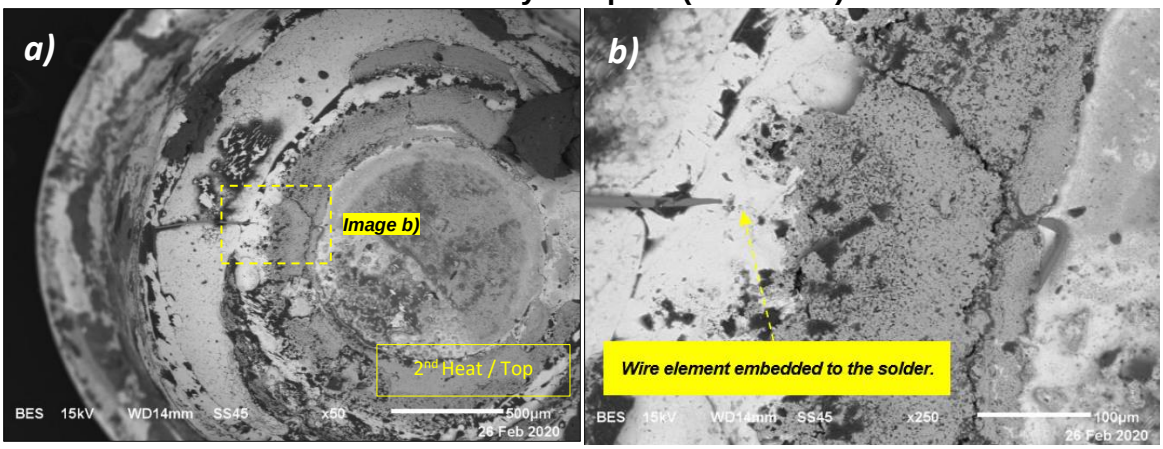
Metallized Body Sample 5 (Additional)



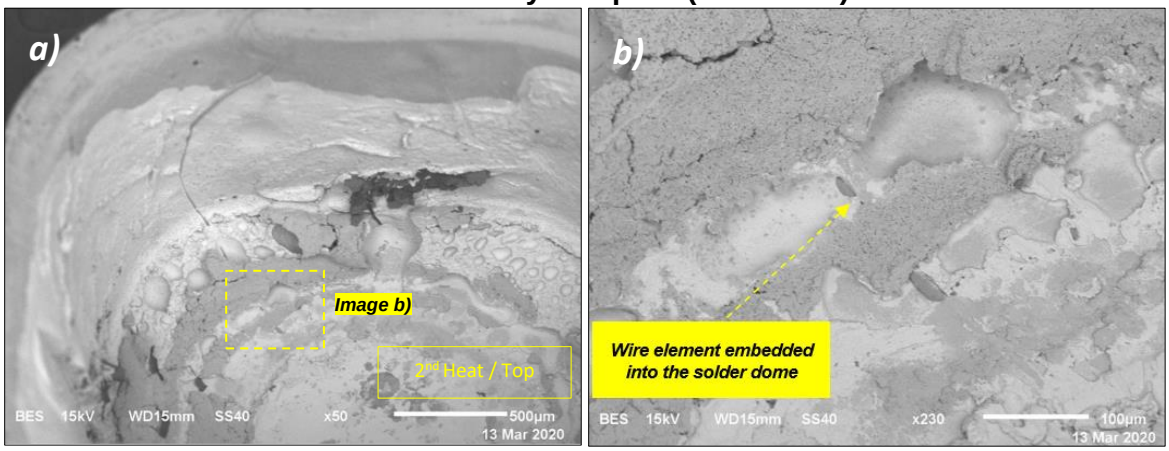
Metallized Body Sample 6 (Additional)



Metallized Body Sample 7 (Additional)



Metallized Body Sample 8 (Additional)



Metallized Body Sample 9 (Additional)

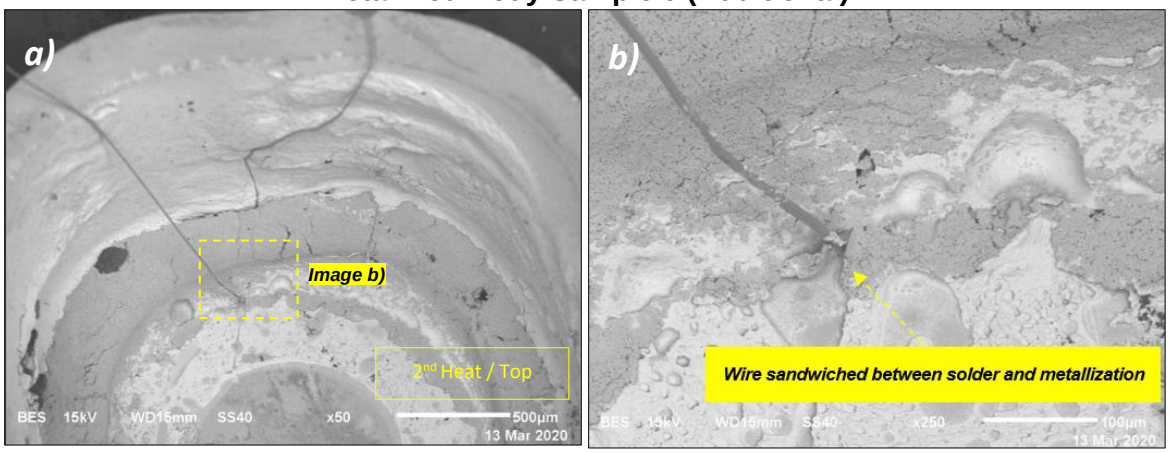


Figure 12. Solder Joint Condition of Metallized Body Fuses (SEM Photos)

Summary:

- If there is very little contact between the wire and solder, then it is considered a poor joint.
    - Sample photos have been provided for reference.
- SEM photos of non-metallized samples does not have embedded wires on the area where metallization will be added while metallized samples show that the wire is now embedded under the metallization layer.
- For reference, ‘sandwiched’ means that the wire is in between the silver metallization layer and the solder but it doesn’t imply the absence of solder-wire bond. Close up photos are usually checked before the wire is sandwiched to verify if the wire is indeed embedded. This is shown in image ‘c’ of the 1st three samples.

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Expertise Applied | Answers Delivered

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