



LPI, Inc. Consulting Engineers

*Advanced Analysis & Fitness for Service
Failure & Materials Evaluation
Nondestructive Engineering*

REPORT NO. F16108-R-01

EVALUATION OF FUEL PUMP BOLTS - CARNIVAL LIBERTY

FOWLER RODRIGUEZ

OCTOBER 12, 2016

Lucius Pitkin – established 1885

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October 12, 2016

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Fowler Rodriguez
400 Poydras Street, 30th Floor
New Orleans, LA 70130

Attention: [REDACTED]

Subject: **EVALUATION OF FUEL PUMP BOLTS - CARNIVAL LIBERTY**

1.0 INTRODUCTION

LPI, Inc. was requested by Fowler Rodriguez to provide engineering services in the evaluation of four fuel injection pump bolts. The bolts reportedly attached a fuel injection pump to diesel generator 4 onboard the Carnival Liberty. LPI was advised that the bolts were found loose, after a fuel leakage at the flange caused a fire in the engine room.

LPI initially received two of the four bolts for evaluation. At a later date LPI also received the two remaining bolts, which were initially in NTSB/USCG custody after the incident, together with five plastic Petri dishes, containing various swaps and debris. No information regarding the origin of the samples in the Petri dishes was provided to LPI.

2.0 WORK SCOPE

The purpose of this evaluation was to determine the bolt material properties, the composition of the debris in the bolt threads, and if the subject bolts exhibited any signs of cracking or over-torqueing.

3.0 PROCEDURES AND OBSERVATIONS

3.1 Visual Examination

The submitted bolts are shown in Figs. 1 and 2 in the as-received condition. The two bolts initially submitted, shown in Fig. 1, were arbitrarily marked 1 and 2 by LPI. The two bolts provided by NTSB/USCG, shown in Fig. 2 had been marked "Separated" and "Attached" and were identified by LPI as bolt



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3 (“Seperated”) and bolt 4 (“Attached”). The submitted Petri dishes are shown in Fig. 3 in the as-received condition.

All four bolts exhibited identical bolt head markings (SBE 8.8) identifying them as ISO 898-1 Grade 8.8 metric bolts, as shown in Fig. 4. The bolts measured approximately 2.67 in. overall length x 0.46 in. (11.7mm) outer thread diameter. The thread pitch was determined, utilizing a thread pitch gage, to be 1.75 mm, thus the subject bolts were nominal M12 coarse thread bolts.

The bolts were covered with black oxide and exhibited debris in the bolt threads. The debris was collected for further analysis, shown in Fig. 5, and all four bolts were cleaned. Magnified visual examination of the bolt threads did not reveal any signs of cracking or spalling of the black surface oxide layer due to excessive bolt torquing. In addition, thread pitch measurements and utilization of a thread gage did not reveal any permanent stretch of the bolt shank. Liquid fluorescent magnet particle inspection and dye penetrant inspection performed did not reveal any cracks in the thread roots or at the bolt head radii.

The threaded bolt area was visually examined for any bending utilizing a straight edge. No noticeable bending was observed on any of the four bolts.

3.2 Composition

Bolt 3 and bolt 4 material compositions were determined utilizing Direct Reading Atomic Emission Spectroscopy. Results of the analyses given in Table 1 below indicated that the material of bolt 3 and bolt 4 conformed to the requirements of ISO 898-1 for Grade 8.8 bolts.

TABLE 1
BOLT MATERIAL COMPOSITION (WT.%)

Element	ISO 898-1, Grade 8.8	Bolt 3	Bolt4
Carbon		0.19	0.20
Phosphorous	0.025 max.	0.015	0.015
Sulfur	0.025 max.	0.008	0.008
Boron	0.003 max.		



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3.3 Hardness

Rockwell C hardness (HRC) measurements were performed on sections cut and ground parallel from bolt 3 and bolt 4. Hardness testing was performed in accordance with the requirements of ISO 898-1. The hardness test results, given in Table 2, revealed an average material hardness of 29 HRC for both bolts, indicating that the material hardness conformed to the hardness requirements of ISO 898-1 of 22 HRC to 32 HRC.

**TABLE 2
BOLT HARDNESS**

Indentation	Bolt 3	Bolt 4
1	30	29
2	29	30
3	29	29
Avg.	29	29

3.4 Debris Analysis

Debris removed from bolt 3 was analyzed to determine the presence of any Loctite type adhesives or anti-seize products. LPI was informed prior to the analysis that Carnival could have potentially utilized a copper based anti-seize product called Loctite LB 8008 C5-A.

Examination of the bolt thread debris for the presence of any thread locking adhesives was performed by Analyze, Inc. The Analyze report, given in the attachment, revealed that no cyanoacrylate was present in the examined debris. The cyanoacrylate family is a sub-class of adhesives typically associated with Loctite thread locking products.

In addition, Energy Dispersive X-Ray Spectroscopy (EDS) was performed on the debris collected from the bolt 3. The acquired spectrum, shown in Fig. 6, revealed that no copper was present in the collected debris, indicating that anti-seize product Loctite LB 8008 C5-A had not been used during bolt installation.



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4.0 CONCLUSIONS AND RECOMMENDATIONS

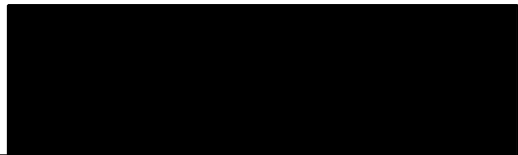
Results of the evaluation revealed that the bolts examined conformed to the applicable hardness and compositional requirements of ISO 898-1, for Grade 8.8 bolts.

Visual examination and dimensional evaluation of the bolt shanks and head radii, did not reveal any signs of excessive or insufficient bolt preload such as thread root cracking or plastic deformation of the threaded bolt shank. Insufficiently preloaded bolts can develop fatigue cracks in the thread roots due to separation of the bolted members causing increased cyclic loading in the bolts during service. Excessively preloaded bolts can exhibit local stretching (yielding) and/or cracking in the protective black surface oxide layer.

Examination of debris removed from the threaded shank of bolt 3 revealed the absence of cyanoacrylate containing thread locking adhesives. Further, from the absence of copper in the debris it was apparent that an anti-seize product known as Loctite LB 8008 C5-A had not been present on the bolt.

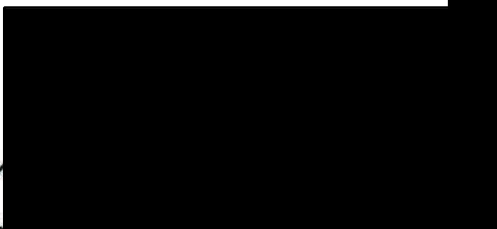
Respectfully submitted,

LPI INC.



Principal Engineer

Appro



JPC: BK/P:Projects/2016/F16108 – Fowler Rodriguez – Evaluation of Fuel Pump Bolts-Carnival Liberty

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Fig. 1 Initially submitted bolts 1 and 2 as-received.

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Fig. 2 Bolt 3(left) and bolt 4 (right) as-received.



Fig. 3 Submitted Petri dishes as-received.

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Fig. 4 Bolt head markings.



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Fig. 5 Debris collected from the thread shank of bolt 3.

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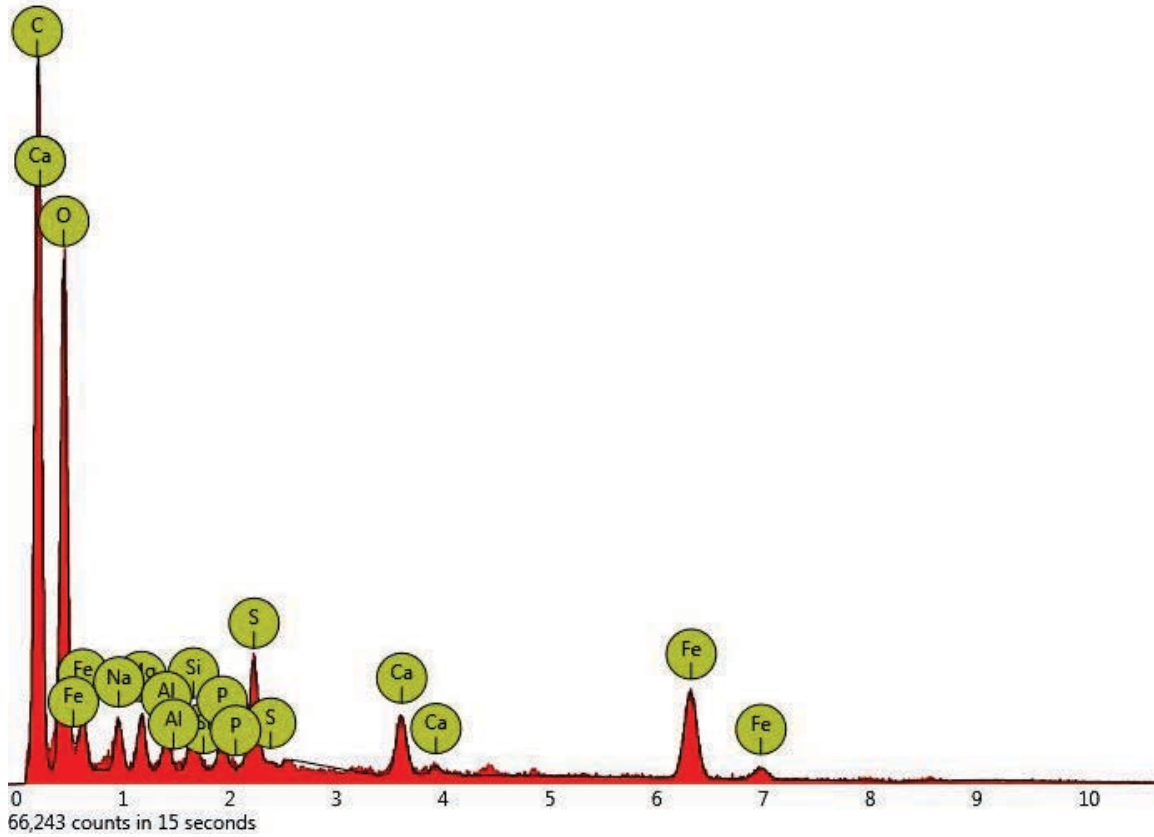


Fig. 6 EDS spectrum of debris removed from bolt 3.