Characterization and Detection of the Deterioration of Electrical Connectors in a Flash-Lamp System

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Background

Summary

A process to analyze flash-lamp connector deterioration was developed and tested

- Repeated flash-lamp use causes connector degradation with a risk of failed shot operations
- The connector degradations can be diagnosed because metal displacement, caused by arcing, leads to a reduction in the resistance of the cooling water
- A test setup was built that successfully measures these changes in resistance
- The resistance change was found to increase as the connectors near the end of their life
- Implementation on OMEGA and OMEGA EP would provide more-precise estimates of when connectors need replacement, saving maintenance costs

TC14214

Flash-lamp system connectors show increasing deterioration over their lifetime

New connector | Used connector | Failed connector

TC14215

Abstract

In OMEGA and OMEGA EP, high-intensity flash lamps are used to excite the laser-glass amplifier medium. The amplification system includes a continuous flow of high-resistivity de-ionized water around the flash lamp. This keeps the lamps cool to decrease required laser-glass cooldown time and maximize the frequency of shot operations. When an electrical current travels through the flash-lamp connections, a small amount of metal is displaced into the cooling water, causing the resistance of the cooling water to decrease. The metal components in the flash-lamp connector system undergo degradation over time as a result of repeated displacement of metal debris. Replacing the damaged connectors after a failure occurs is a costly process. Failures also interrupt laser shot operations.

To remedy this problem, the concept of a non-invasive process to detect the levels of flash-lamp connector deterioration was developed and tested. This involves analyzing changes in the resistance of the water flowing through the flash-lamp cooling system. Flash-lamp systems at different stages of degradation were tested. It was found that the transient change in water resistance is correlated with the level of deterioration in the flash-lamp connectors. The minimum current needed to detect a resistance change was determined. Results from this research will allow for the non-invasive detection of deteriorated flash-lamp connectors in the amplification system before failure. Implementation of this technique will decrease the risk of failed laser amplifier operation during a laser shot, thereby increasing the reliability of the amplifier system.

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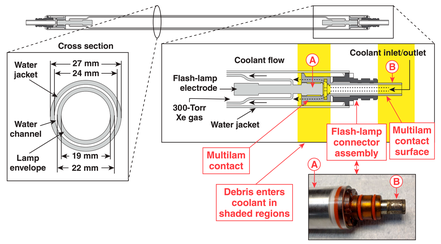
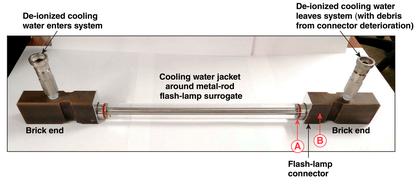
Setup to Test Flash-Lamp Connectors

OMEGA flash-lamp connectors were tested using a modified flash-lamp system

- OMEGA flash lamp



- Modified flash-lamp system



- the flash lamp is replaced by a metal rod
- the cooling system is the same
- the electrical current is the same
- a much smaller voltage is required to reach this current

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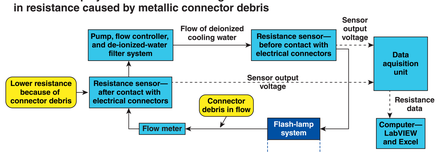
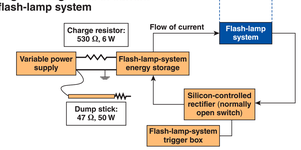
The test setup comprises a de-ionized water system and a power-conditioning unit

- De-ionized water system: controls flow through the flash-lamp system and detects changes in resistance caused by metallic connector debris



- Power-conditioning unit: controls the timing and magnitude of current to the flash-lamp system



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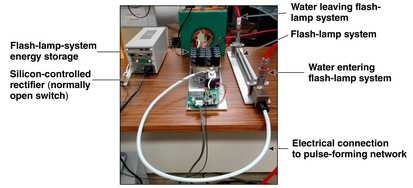
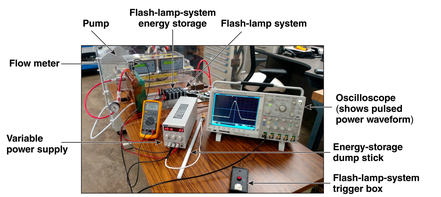
Equipment

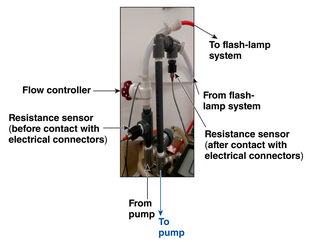
- Flash-lamp system



- Auxilary instruments of the pulse-forming network



- Water pump and resistance sensors



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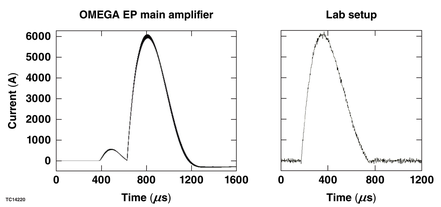
The power-conditioning waveform produced by the lab setup is very similar to a typical waveform from an OMEGA EP main amplifier



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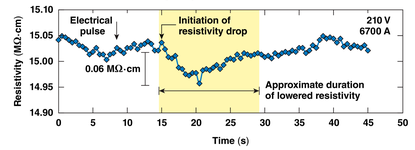
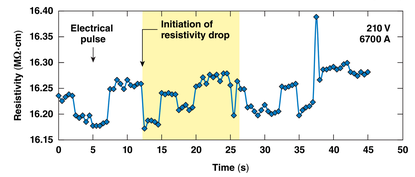
Results

Results for new, slightly used, and used connectors are compared at the same voltage

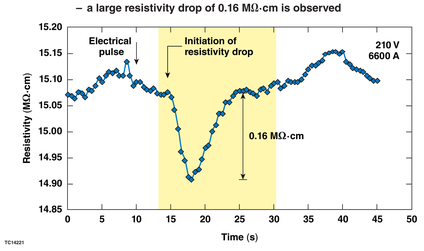
- New connector
  - a small resistivity drop of 0.06 MΩ·cm is observed



- Slightly used connector
  - sometimes noise makes it hard to detect a small resistivity drop



- Used connector
  - a large resistivity drop of 0.16 MΩ·cm is observed



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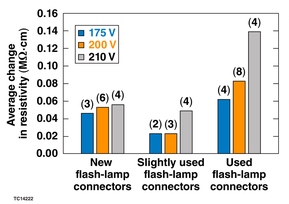
Average resistivity changes were obtained from multiple tests



- The resistivity change increased with voltage
  - a voltage ≳200 V is needed to detect deterioration in a used connector
- The slightly used connectors showed the smallest changes in resistivity, indicating that the connection initially becomes stronger with time

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Future Work

- Some irreproducible features of the data need to be explored (see plots below)
- A practical system for implementing this concept needs to be designed

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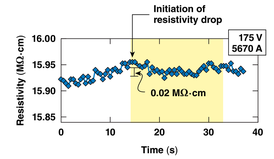
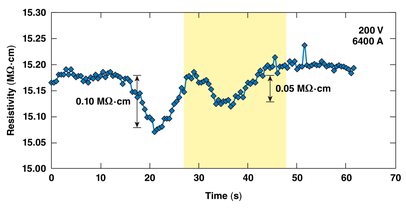
- Slightly used connector at lower voltage



  - the small resistivity change of ~0.02 MΩ·cm is around the detection threshold
  - the erratic behavior at 210 V is not observed

- Used connector at a comparable voltage, showing a second drop of resistance



  - the second drop probably originates from the second (more-distant) connector
  - this drop is only seen on some shots and may depend on particulate size and fluid-flow characteristics

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