Motor Vehicle Fire Research Institute
Awarded Contracts

Title: Study of Arc Track Properties of Plastic Materials When Subjected to DC Voltages Ranging from 12 volt DC – 150 volt DC

Contractor: Underwriter's Laboratories

Duration: July 28, 2003 – July 27, 2004

Funding: Jointly Funded by USCAR (45%) and MVFRI (55%)

Purpose:

The automotive industry is evolving automobile designs using greater electrification of systems and components previously mechanically operated (e.g. air conditioning, water pumps, oil pumps, heating, and solenoid operated engine valves). The resulting demands on electrical systems require upgrading from the traditional 12 volt DC battery supply to a 36 volt DC battery supply with a nominal 42 volt DC charging circuit.

A potential fire hazard from failures of polymeric materials used for automotive switches, electrical connectors, etc. has been identified as a concern when operating at increased DC voltage levels. One specific concern is the DC arc ignition properties of polymeric materials. A DC electrical arc, once struck may be more readily sustained than an AC arc due to the inherent stability of its uni-polarity. In a DC arc, the arc voltage and arc current do not experience a zero crossover and once DC arcing is established the arc tends to be self-sustaining. This project has been developed to document the potential fire hazard associated with the increased DC voltages and to study ignition properties of polymeric materials when exposed to a DC high-current arc ignition source. An existing method for evaluating arc ignition performance of polymeric materials is the High Current Arc Ignition Test (HAI) using the apparatus described in UL 746A Polymeric Materials – Short Term Property Evaluations. Under certain normal or abnormal operation of electric equipment, insulating materials might be in proximity to electrical arcing. Depending upon the intensity and duration of the arcing, the insulating material may ignite. The HAI test is intended to simulate such a condition.

In order to develop a meaningful test to evaluate polymeric materials for automotive use, modifications to an AC tester will be necessary to operate at DC voltages. The Research will be conducted in three phases. Exploratory Research and Equipment Development will be conducted as part of Phase 1. Phase 2 will Conduct Testing on Automotive Specific Polymeric Materials. Phase 3 will complete the validation of the DC test procedure through a series of round robin tests. The work tasks associated with each phase are as follows:

Phase 1 - Exploratory Research

- **Task 1 – Situation Analysis**

  Literature, standards developed by others, and previous research work will be reviewed for relevant information concerning the proposed DC-CTI test.

- **Task 2 – Equipment Development**

  The equipment used for AC-HAI testing will be modified to permit DC-HAI testing. Testing with the following modifications will be explored:

  - Replacing AC voltage supply with a DC power supply.
  - Testing with the current that the power supply is capable of delivering.
  - Experimentation to determine the influence of electrode separation rate and dwell time.
  - Experimentation to optimize the withdrawal rate and dwell time at the maximum electrode separation.
  - The use of permanent magnets on either side of the polymeric material
  - Experimentation to verify the effects of electrode polarity on the movable and stationary electrodes.
  - Each test will be conducted at a rate of 40 arcs/minute for a maximum of 200 arcs or ignition of the test specimen, whichever occurs first.
  - A rationale for each modification will be developed and the relative influence considered.

- **Task 3 – Preliminary Materials Testing**

  A maximum of 10 polymeric materials will be subjected to preliminary testing to assure that the developed DC-HAI test protocol incorporates sufficient control and precision to produce repetitive test results that would allow the test to be used to establish a polymeric material performance hierarchy when automotive material are tested as part of Phase 2

- **Task 4 – Data Analysis**

  Following completion of the above testing, the data will be reviewed to determine if further areas of exploratory research testing may be required.

- **Tasks 5, 6, & 7 – Draft & Final Report and Presentation Review**

  From the information obtained in the above tasks, a summary report will be prepared for Phase 1. This includes draft and final reports along with a presentation reviewing the results.

Phase 2 – Automotive Testing

- **Task 8 – Automotive Materials Testing**

  A maximum of seventy-Five (75) polymeric materials will be identified by USCAR/MVFRI for testing by manufacturer and grade designation. These materials will be taken from 4 groups as follows:

  - Group A (25 Materials) – This group will consist of the identical thermoplastic materials being evaluated as part of the DC-CTI testing.
  - Group B (18 Materials) – This group will be the identical materials used in the Southwest Research Institute cone calorimeter test and will consist primarily of exterior body materials.
  - Group C (25 Materials) – This group of materials will consist largely of interior materials (e.g. dash material, seat cushion material, floor carpeting, etc.).
  - Group D Fluids (7 Fluids) – This group will consist of under hood fluids (e.g. power steering fluid, automatic transmission fluid, windshield washer fluid, motor oil, radiator anti-freeze, brake fluid and clutch fluid)

For each material, the DC HAI test will be performed for a maximum of 200 arcs or flaming ignition of the test specimen, whichever occurs first. For each test, the number of arcs and the elapsed time to cause ignition will be recorded. The voltage and current will be recorded at a sampling rate of 25 kHz for each test.

- **Task 9 – Data Analysis**

  Following completion of the above testing, the data will be analyzed and summarized. This analysis will include a determination of the minimum total arc energy to cause ignition (up to a maximum of 200 arcs) of each material tested. Where possible, the performance of the materials on the DC test will be compared to the performance of the same materials on the AC test, if previously tested.

- **Tasks 10, 11, & 12 – Draft & Final Report and Presentation Review**

  From the information obtained in the above tasks, a summary report will be prepared for Phase 2. This includes draft and final reports along with a presentation reviewing the results.

Phase 3 – Validation of Test Procedure

- **Task 13 – Testing Expanded Sample Base**

  A total of 40-50 polymeric materials will be solicited from 5-10 different suppliers giving specific attention to selecting polymeric materials typically used in automobiles.

- **Task 14 – DC-HAI Test Equipment**

  Three HAI testers (modified to test using DC voltages) will be obtained from an outside equipment supplier. These new testers will incorporate all necessary modifications and safety upgrades to permit DC-HAI testing of polymeric materials on a routine basis. One of these testers will be located at each of three different UL domestic test locations.

- **Task 15 – Round Robin Testing**

  A series of round robin tests will be performed to validate the DC-HAI test procedure. Identical materials will be tested at each of the selected test locations and the test results obtained compared.

- **Tasks 16 – Analysis of Data and Relationships**

  Following completion of the DC-HAI testing, the data will be analyzed. The test methodology and results will be subjected to scrutiny for repeatability, reproducibility, and the ability to represent likely operation or failure modes.

- **Tasks 17 – Final Report**

  Following completion of the activities associated with Phase 3, a final report will be prepared.