# Arc Damage Modeling Tool (ADMT) Simplifying EWIS Failure Severity Assessments

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## Background

Electrical arcing occurs when a power wire makes intermittent contact with an object or wire of a different voltage potential.  Often arcing is a brief event, but can cause significant damage to the wire, surrounding wires and nearby objects. This damage can have a significant impact on aircraft airworthiness.  To address this concern, the FAA requires that aircraft wire design and installation be reviewed for the functional and physical impact of wire failure.

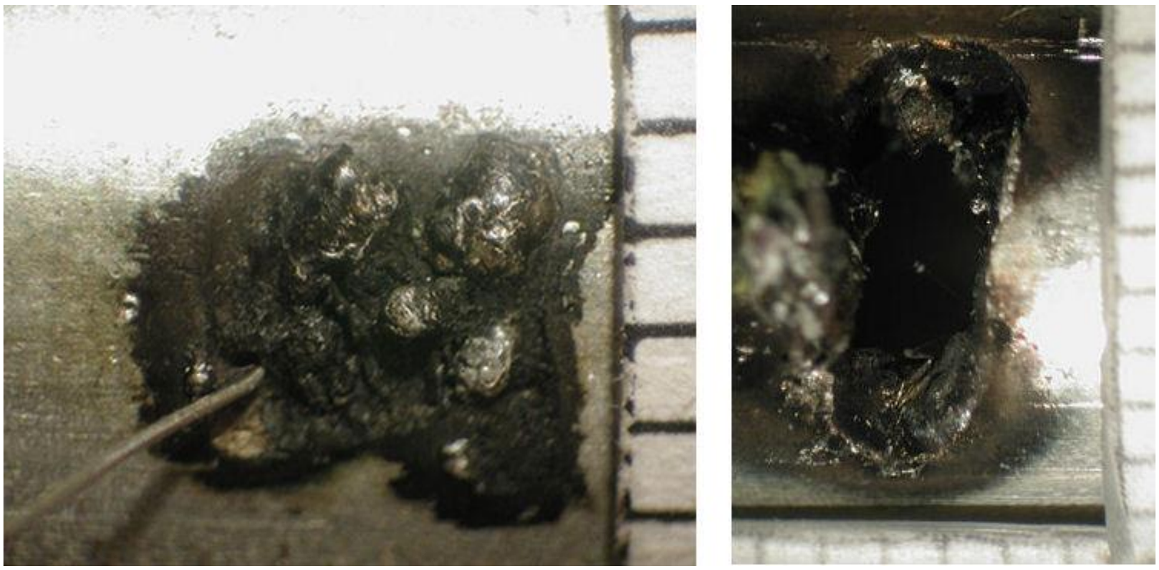

**Figure 1: These are posttest photos of arcing damage to aluminum hydraulic lines. Although the damage to the tube on the right is more severe, results were generated under the same test configuration.**

### What is ADMT?

The Arc Damage Modeling Tool (ADMT) was developed by Lectromec in coordination with the Federal Aviation Administration (FAA) to predict electrical arcing damage. The ADMT successfully models the energy dissipated in an arcing event.

### Goals

ADMT seeks to:

1) Provide a fundamental understanding of arc damage by quantifying the energy in the arc,
2) Supplement and extend test data throughout the range of test parameters,
3) Provide insight to how variation in test parameters will affect arc damage, and
4) Demonstrate the impact of mitigation techniques.

ADMT has been validated through thousands of arc damage tests.  The ADMT can model the damage based on analytical and empirical data through energy quantification, arc damage envelopes, heat dissipation, heat transfer, and damage distribution.

## Types of Simulations

Lectromec regularly updates the ADMT to meet the clients' needs. The following is a partial list of simulations that the ADMT can perform:

- Direct arcing to structure
- Damage to Wire/Harness
- Indirect arcing (arcing damage to nearby equipment)
- AC arcing
- DC arcing
- Single Phase arcing events
- Multiple Phase arcing events
- Pressurized Tubes
- Harness Protection Schemes
- Impact of molten materials

### Simulation Foundation

Examination of test data sought to determine the factors impacting the system's arc energy, energy distribution, and the impact of energy involved in and near the arcing event.

## Analytical Models

The analytical models were developed using the laboratory test data.


Figure 2: The three main components of modeling electrical arcing.

## Model Arc

The arc model determines the arc power and duration for a set of input parameters. An arc event duration is determined by two factors: the activation of circuit protection or by increasing the separation distance. Different circuit protection type, ratings, and initial temperatures can be modeled to determine the arc duration. The arc power is affected by several factors (i.e. fault current, source impedance etc...). If the circuit protection trips or damage occurs, there is potential damage that can impact the circuit.

## Partition of Arc Energy

The arc energy partitioning determines the energy division to various sources (target, melting source wires, heating the air and radiation) from an arcing event. Both system configurations and separation distance affect the arc energy distribution. Lectromec has assessed thousands of laboratory tests and has an established models identifying how the arc energy distribution changes with varying parameters.

The ADMT provides multiple mechanisms for application of the arc energy and arc model selection. The different arc models are necessary to address different configurations. Some models address the case in which the wire is striking the tube, and others consider wire damage or "burn back".

An example of the ADMT system complexity is the single point arc damage model. In the single point model, the arc energy is represented as coming from a single point at a set distance from the simulated target. The separation distance is fully dependent on the particular configuration.

An example of how the energy is distributed is shown in the following figures.

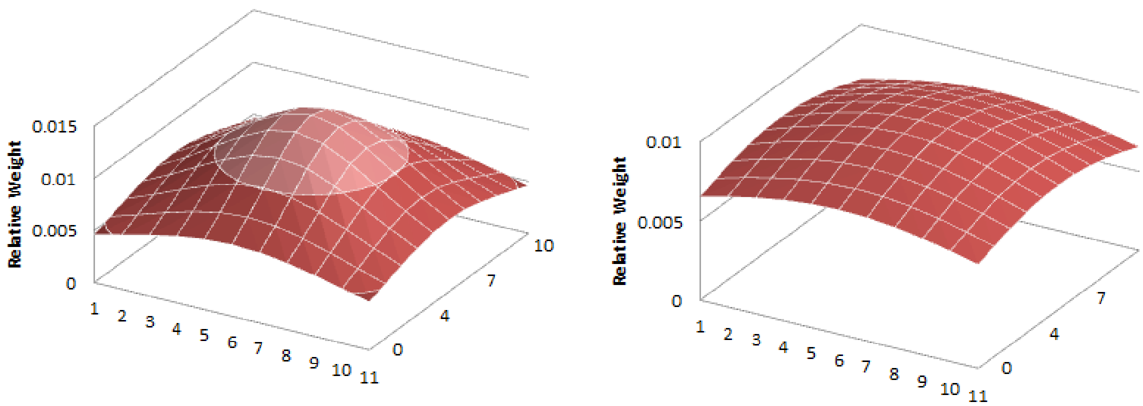


**Figure 3: Comparison of the relative arc energy weight for different arc locations. The figure on the left shows an arc spot 50% closer than the arc spot relative weight of the figure to the right.**

The damage area shape and dimensions are dependent on the target geometry and its interaction with the arcing source. Most energy is expended at the cathode and anode (the high voltage and ground electrical potentials), with some energy going to the arc plume.

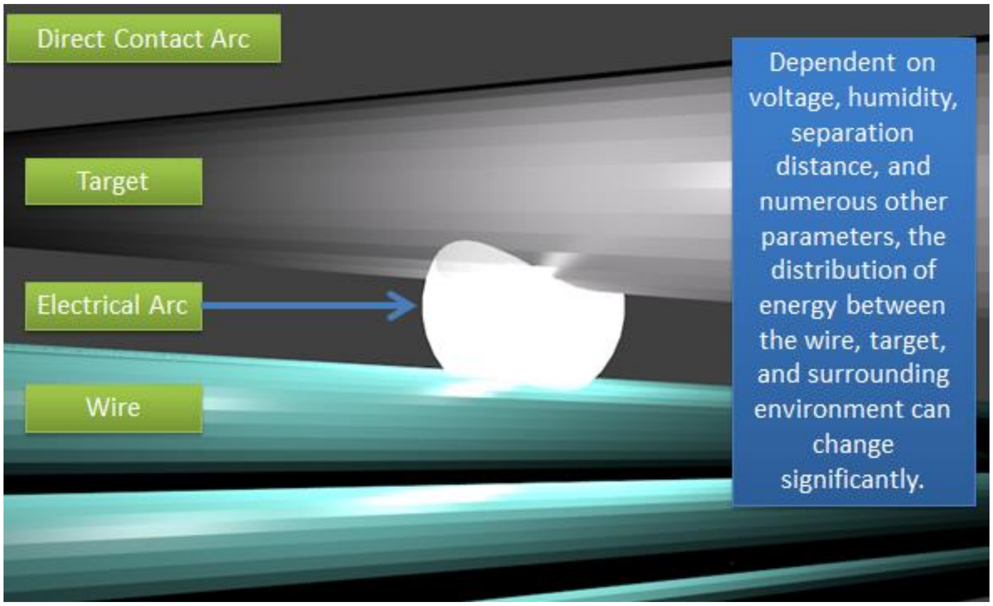


**Figure 4: Representation of a single powered wire making direct contact with a grounded pressurized tube.**

A scenario where the target is physically separated from arcing wires is called indirect arc damage. In the case of indirect arc damage, the arcing event is initiated between two or more wires in the wire bundle; this increases the arc energy in the wire bundle and lowers the amount of energy incident the target. A pictorial description of this can be seen in Figure 5.

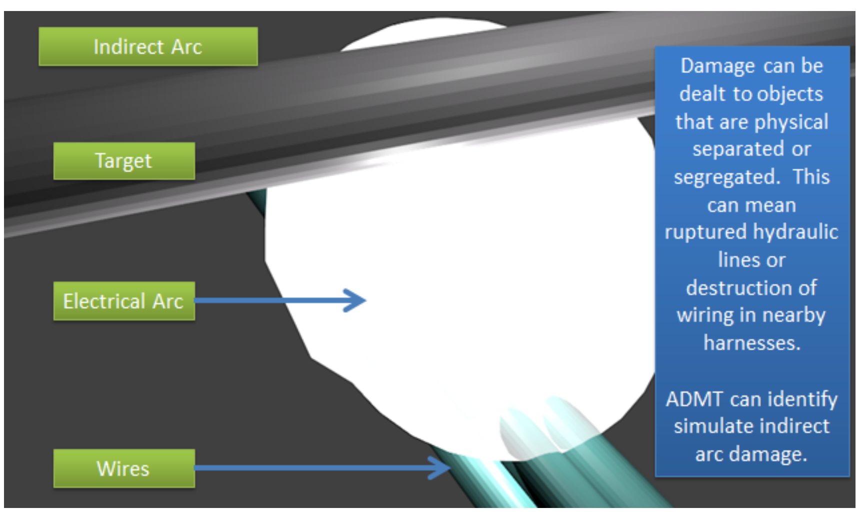


**Figure 5: Representation of arc energy in the case of a wire to wire arcing event with the target separated from the event.**

### Model Damage to Targets

The targets model damage evaluates the influx of thermal and electrical energy from the arcing event. If the target observes a phase change at a specific temperature or, it has reached a threshold temperature (such as in the case of pressurized fuel/hydraulic/oxygen lines), then target damage has occurred and this result is highlighted as a configuration of concern.

The arc energy influx causes damage to different targets at different rates. A target's thermal and chemical properties affect the damage. Properly modeling these temperature dependent properties is critical to accurately forecasting the damage. To achieve this, ADMT uses a finite difference method to calculate the heat and electrical energy flow . Figure 4 is a flow chart that illustrates the process for the simulation.

## Benefits of the ADMT

The ADMT can facilitate the determination of system reliability. The following are a few benefits the ADMT can provide.

1) Verify safety of a design
   The process of verifying safety of a design is time consuming through the set up and performance of various physical tests at many configurations. The tool accurately represents the damage caused by an arcing even based on analytical and empirical data.

2) Provide simulations that are difficult/dangerous to perform
   Simulations that are difficult to perform would include tests performed at high temperatures, low altitudes and high pressure. These test configurations are difficult to simulate and would return inaccurate results. The ADMT allows users to input the parameters (i.e. temperature, pressure, altitude) that may be difficult to imitate through physical tests in order to determine accurate data of the electrical arcing damage.

3) Reduce the need for physical tests
   The ADMT can provide comprehensive data on the potential damage and reliability of systems without the necessity of performing the physical tests.

4) Provide data for certification
   The ADMT can provide the results needed for certification.

5) Quick turnaround results
   The process of performing simulations is more efficient than running physical tests. This can be beneficial especially if the parameters need to be modified several times before the final

input parameters are determined. Running simulations in lieu of physical tests will greatly reduce costs, making it a cheaper option for customers.

6) User friendly software
The ADMT was developed in a manner that allows the user to easily interact with the program without having in-depth knowledge on electrical arcing. The ADMT allows the user to quickly adapt to the functions of the program and utilize all functions of the program.

## Features

Specific features on the ADMT can provide beneficial information catered to the customer's needs. The program has three user modes: laboratory, parameter and damage investigation modes that can be used depending on the data and goals of the customer.

Figure 8 shows an example of a general damage chart using penetration into a titanium tube as a measure of damage. Damage is calculated as a function of distance from the electrical bus which limits the fault current at three different cases shown below. The three cases include:

- (Blue) 20AWG polyimide wire harness with 7.5A thermal circuit breaker
- (Red) 20AWG polyimide wire harness with 7.5A arc fault circuit breaker
- (Green) 20AWG composite wire harness with 7.5A thermal circuit breaker

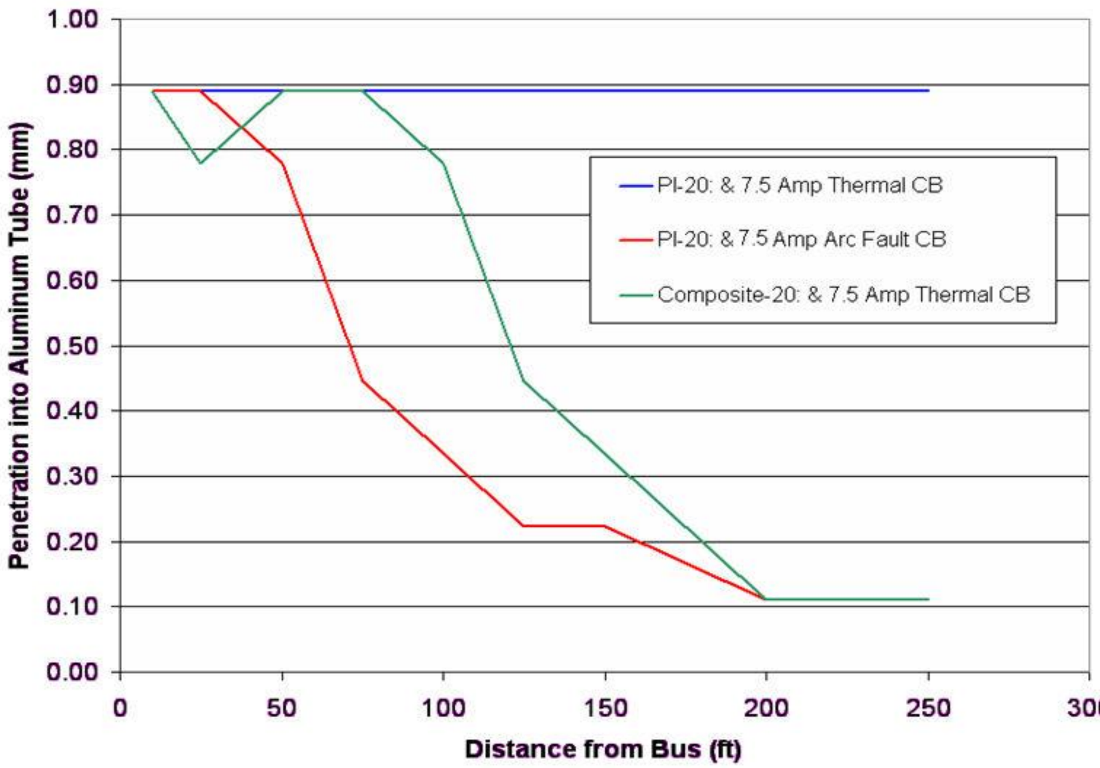


Figure 6: Example of a General Damage Chart created in Parameter mode

The implications and impact of the results shown in figure 7 are significant for aircraft design: the potential damage for a given configuration is not constant even within the same circuit. Circuit protection response time, circuit heating, and resistance can change a configuration from one with no safety impact to one that could potentially cause a catastrophic event.

## Other Features

The following are some unique features of the ADMT:

- The program provides a visual representation of the arcing event damage.
- The arc waveform can be imported or it can be generated through input parameters.
- New materials can be easily added and modeled.

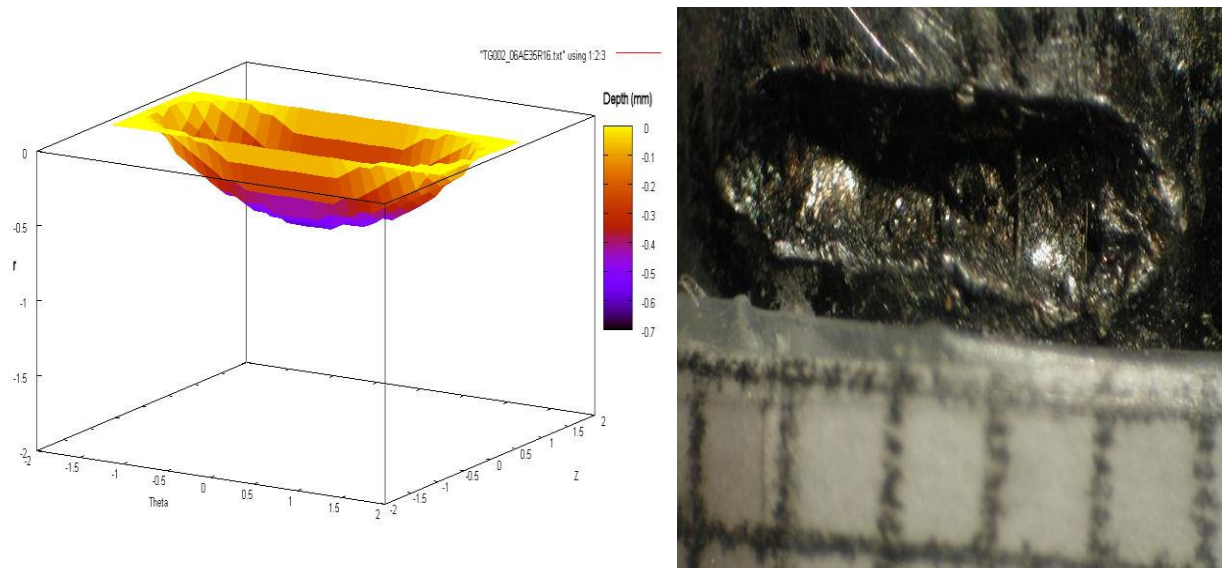


**Figure 7: On the left is a simulation damage 3-D contour plot, where damage from the actual test is shown on the right. ADMT was loaded with the system configuration and predicted the damage level before the test was executed.**

**Evaluating the Extremes**

The min-max analysis was developed to set boundaries on the expected damage level from any given electrical arcing event. This analysis provides greater confidence level in a given design and extends simulations beyond the physical test. The min-max analysis examines possible scenarios for arcing events given similar initial conditions.

| | | Spot Size | | |
|---|---|---|---|---|
| | | + 25% total size | Best Result Spot Size | - 25% total size |
| Arc Efficiency | - 25% AE | Least Severe (Severity Level 1) | (Severity Level 2) | (Severity Level 3) |
| | Best Result AE | (Severity Level 4) | Actual Test Results | (Severity Level 6) |
| | + 25% AE | (Severity Level 7) | (Severity Level 8) | Most Severe (Severity Level 9) |

More Energy

Smaller Spot Size

**Figure 8: Representation of min-max analysis results.**

The figure above shows a potential configuration for a min-max analysis and is driven by the customer's need. The min-max boundaries are based on data and analysis of more than 30,000 individual arcing half cycles under different electrical and environmental conditions.

## Process

In order to provide test results tailored to your company's needs, Lectromec will deploy an engineer on-site to review or assist in development of a test plan and perform a review of a physical test setup. The physical baseline tests will then be performed by Lectromec to validate ADMT results and provide data needed for certification.

Based on the test plan, Lectromec will run simulations with the ADMT software to determine estimated damage to target, maximum temperature of target and profile, performance of ADMT min-max analysis to determine safety margin and safe separation distance for all input parameters. If the results do not match desired results, modifications to the requirements will be made prior to running new simulations. This process will be repeated until desired results are achieved.

Once the desire results are achieved, a report and data of tests performed by Lectromec will be provided detailing safe separation distances, description of test configurations and expected safety margins. If requested, Lectromec can participate in discussions with certification authorities.

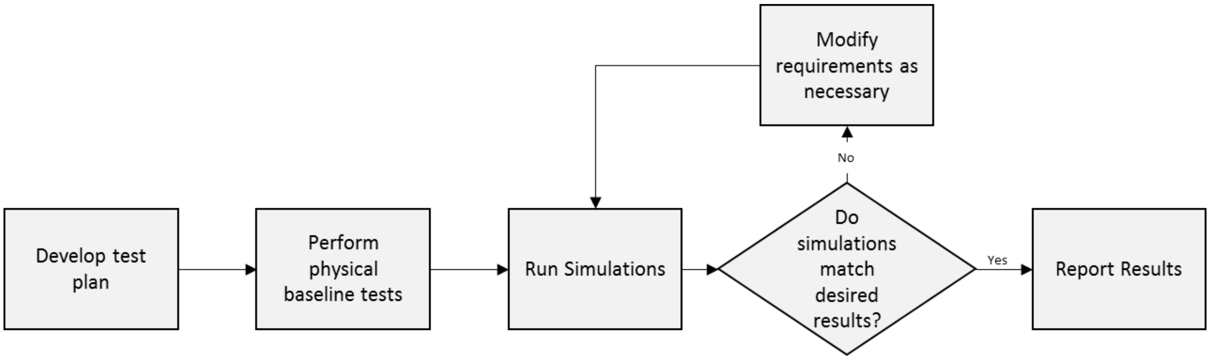


**Figure 9: Process flowchart.**

## Protecting Your System

If you are interested in finding out more about how Lectromec can help with arc damage testing, contact us today. We will begin with a brief 30 minute discussion to review your needs and how they can be addressed through Lectromec's process.

Lectromec has the knowledge and experience to deliver the results you need to make well-informed decisions for your aircraft wire maintenance.

Start to quantify the risk today.

## About Lectromec

Lectromec is a Chantilly, Virginia based technology and engineering firm specializing in aircraft wiring testing, wire management services and design. Lectromec has worked with a large number of customers from government, defense, and private industries designing customer specific, results driven, and effective programs. Lectromec has tested and evaluated large arcing damage since 1984 developing an unmatched expertise in this field.

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