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Rethinking Contact Current Arcing

New insights on an old, chronic problem

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Contact Current Arcing

Contacts within relays, contactors, and other automated switches are a well known source of unintentional but predictable contact current arcing (with power sources operating above 15V and/or 1Amp). The destructive power of contact arcing significantly shortens contact life, often to a level that is only a fraction of the relay's or contactor's mechanical life (i.e., not operating under power). The example shown in Fig. I is a contact with a mechanical life rating of 10 million cycles that failed after just 100,000 cycles under power.

To date, we've found that contact current arcing has not been well understood. In fact, until now, only few have known that there are actually five (5!) different arcs that can occur as a contact cycles from OPEN to CLOSED and back again.

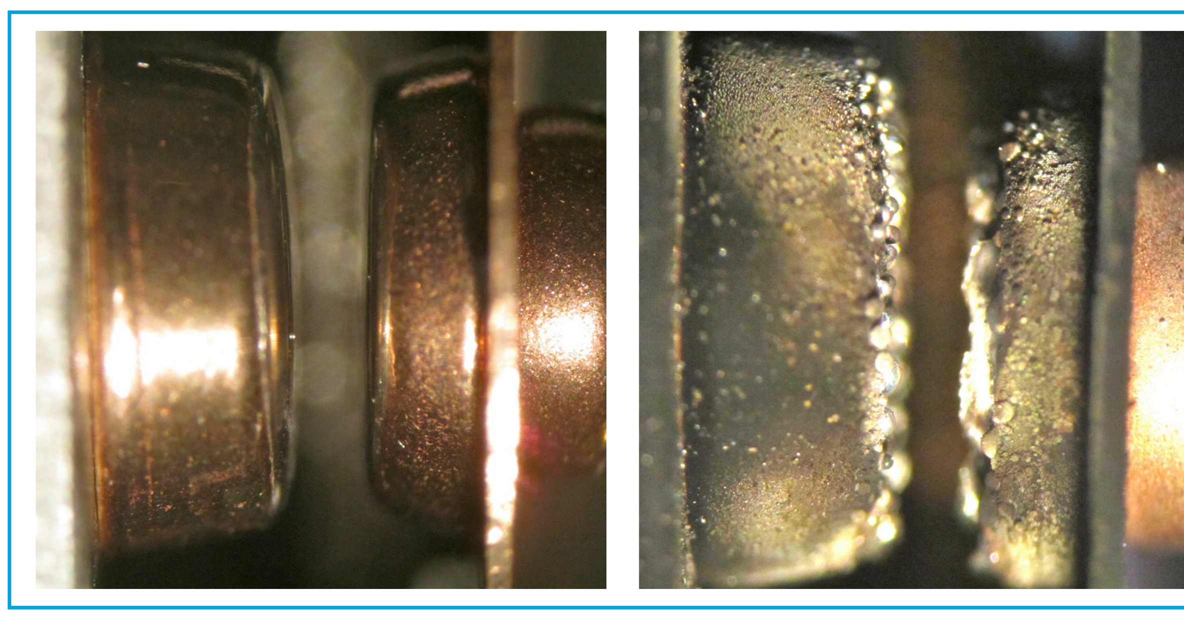


***Figure I** (above): New contact (left) and a contact that failed after 100,000 cycles (right)*

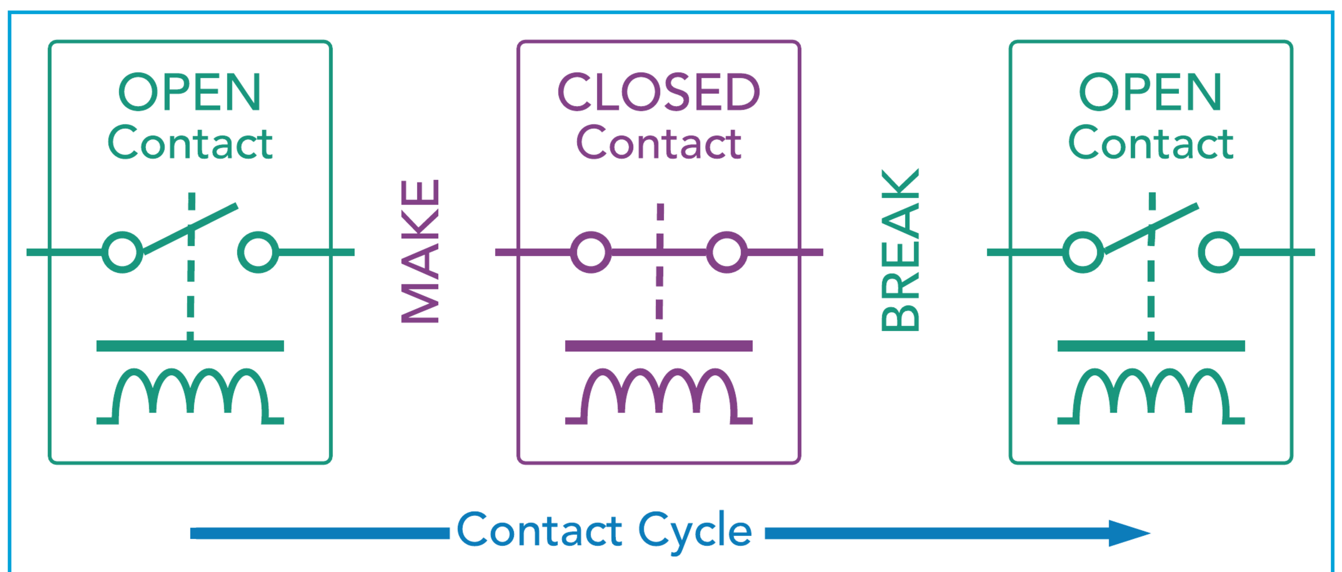


***Figure II** (above): Contact states transitions: OPEN, MAKE (contact closing), CLOSED, and BREAK (contact opening)*

Contact States and Contact Cycle Sequence

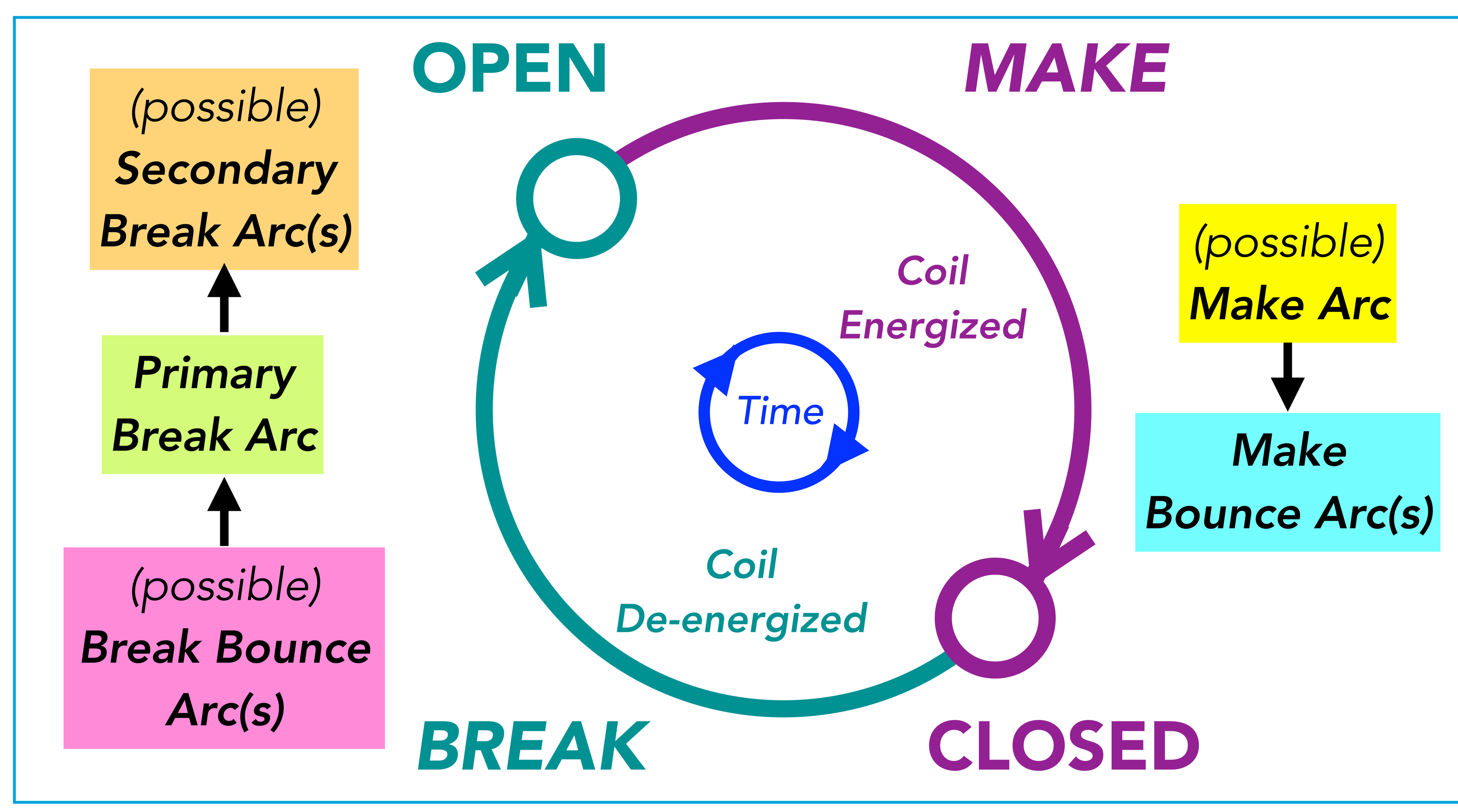
A contact cycles through four (4) distinct states: OPEN, MAKE, CLOSED and BREAK, as shown in Figs. II and III. The make and break states are generally transitional and are of generally short duration. The open and closed states are generally non-transitional and are of generally longer duration.

A general switch cycle may start with the OPEN state. As part of the MAKE state, the contact may bounce multiple times until it achieves the CLOSED state. A general switch cycle may remain a certain amount of time in the CLOSED state. As part of the BREAK state, the contact may "bounce" until it re-enters the OPEN state.

Each state generally has specific phases associated with them that the contact has to travel through as shown in Fig. III and Table I.

Note that the "Primary Break Arc" and "Secondary Break Arc(s)" are the direct cause of the noted deleterious effects seen in fig. I, including contact surface deterioration, metal sputtering, particle deposition, material migration, and surface destruction. A more detailed description of the contact cycle sequence is shown in Table II, below.

***Figure III** (right): A general switch cycle, starting and ending with the OPEN state*



<table>
<tr><th colspan="11">Contact Cycle Sequence   Time (not to scale) →</th></tr>
<tr><td>OPEN State</td><td colspan="3">MAKE Transition</td><td>CLOSED State</td><td colspan="5">BREAK Transition</td><td>OPEN State</td></tr>
<tr><td>Gap Widest</td><td colspan="3">Gap Narrowing</td><td colspan="2">No Gap</td><td colspan="4">Gap Widening</td><td>Gap Widest</td></tr>
<tr><td colspan="2">Voltage Across Contact</td><td colspan="7">Current Through Contact</td><td colspan="2">Voltage Across Contact</td></tr>
<tr><td colspan="2">No Arcing</td><td>(possible) Make Arc</td><td>Make Bounce Arc(s)</td><td colspan="2">No Arcing</td><td>(possible) Break Bounce Arc(s)</td><td>Primary Break Arc</td><td>(possible) Secondary Break Arc(s)</td><td colspan="2">No Arcing</td></tr>
<tr><td colspan="3">Broken Microwelds</td><td>Make New Microweld</td><td>New Microweld</td><td>Break Microweld</td><td colspan="5">Broken Microwelds</td></tr>
<tr><td colspan="2">Metal Cooling or Cold</td><td colspan="2">Metal Softening, Melting, and Boiling</td><td colspan="2">Metal Cooling or Cold</td><td colspan="3">Metal Softening, Melting, and Boiling</td><td colspan="2">Metal Cooling or Cold</td></tr>
</table>

***Table I** (above): Detailed contact cycle sequence; assumes that the contact of a switch, relay, or contactor is working within specified operating limits.*

2nd row: Contact States of OPEN, MAKE, CLOSED, and BREAK
3rd row: Contact Air Gap condition during cycle
4th row: Contact voltage or current condition
5th row: Arcing condition and type of arc
6th row: Micro weld condition
7th row: Contact metal condition

References:

1. M. Atalla, Mechanisms of the initiation of the short Arc, 1954
2. R. Holm, Electric Contacts Handbook, Springer Verlag, 1958

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