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Characterization of Bimetal Displacement of a 35 Ampere Circuit Breaker

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Abstract:

The calibration process of aircraft circuit breakers is an operation that requires high production costs due to its difficulty and the time needed to achieve an optimal calibration of the device to make it work within the predefined time window to protect the aircraft wiring once installed.This research is motivated by the need of reducing the calibration times of circuit breakers in the production line and hence improving the line capacity while reducing associated costs with the number of operators required to fulfill the process.An experimental analysis is performed using a digital microscope to process images to analyze the bimetal movement of a 35 amperes circuit breaker under a current range from 20 to 70 amperes with the propose of characterize it and find the relation between initial and final position to lay the groundwork to develop a method to simplify the calibration process in the production line.

Keywords **—Characterization, bimetal, circuit breaker, thermostatic element, calibration**

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I. INTRODUCTION

The method of calibration of aircraft circuit breakers consists of supplying 200% of nominal current to the circuit breaker while two calibration screws are inserted, so that these push the bimetal until it releases the button of the device pushing the component that releases the mechanism that opens the circuit. The thermostatic element should be set into an ideal position to guarantee the tripping of the device within a time window of 38 to 41 second. This process can be slow, needing several tries due to the dependence of the operator skill, which translates into high cycle times in the production line.

II. THEORETYCAL FOUNDATIONS

A. Definition of Circuit Breaker

A circuit breaker is a mechanical device connected to an electrical system, whose function is to provide a path for the flow of current andprovide protection and control of the electrical circuit either by initiating or stopping the flow of current. These devices will remain in closed position providing a constant flow of current, or in open position cutting off all electrical flow.

B. Applications

Currently, the uses for thermostatic metals range from industrial applications to the automotive and aerospace sector. Its main benefits are its low weight, small size and robustness, in addition to not requiring external energy or magnetic fields to function.

Thermostatic bimetals have a wide variety of applications, among which are:

- Temperature measurement
- Compensation (normally for room temperature)
- Control of any parameter vs. temperature

• Thermo-mechanical applications where heat is converted into mechanical energy.

C. *Classification*

The circuit breakers can be used for high and low voltage applications, for the present work will be treated the devices for low voltages known as miniature circuit breakers.Miniature circuit breakers are tested and classified according to UL 489-1991. All its mechanisms and components are completely contained in a moulded box of insulating material.Within the miniature circuit breakers there are many applications, including the aerospace sector, which are the devices covered in this study.

D. *Operating Principle*

Like most circuit breakers, the key element for its operation is the use of a bimetallic sensor or thermostatic bimetal that reacts directly to the current flow while heating. The factors that contribute to cable overheating are inherently perceived by the bimetal. A thermostatic bimetal is a composite material, usually in the form of a strip or sheet, and made of two or more metal layers with different coefficients of expansion. When these are permanently joined, the material will change its curvature when subjected to temperature changes. The bimetal when changing its curvature will be the actuator that will cause the button's interlocking mechanism to unlock, causing the internal contacts to separate and interrupting the electric current flow, protecting the wiring connected to it.

E. *Analysed Device Basic Schematics*

As already stated the thermal element is the key component of the circuit breaker, it provides the mechanical movement required to unlatch the pushbutton of the device. When latched the main contacts of the device will allow the flow of electricity. Fig (1a).

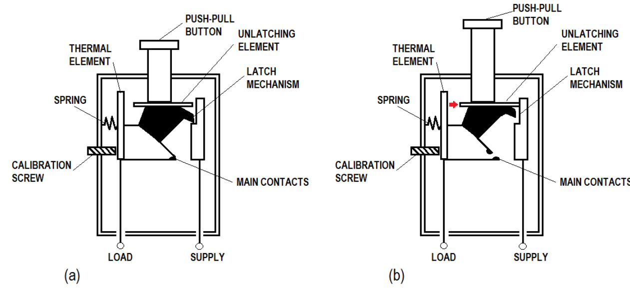

Fig 1. Working principle of circuit breaker; a)Closed; b)Open

Once under the effects of electric current the thermal element will heat and flex, pushing the unlatching element, causing the latch mechanism to separate and hence making the main contacts to stop the flow of electricity. Fig (1b).

F. *Thermostatic Element*

The thermostatic element that allows the devices to function consists of an alloy P35R consisting of 36.1% P alloy (72% Mn, 18% Cu, 10% Ni) for the high expansion side, 32% alloy 10 (36% Ni, 64% Fe) for the low expansion side, and 32% copper CDA 107 in its central layer.This alloy has a high flexivity and a low electrical resistance thanks to the central layer of copper.Its thermostatic and physical properties are the following:

TABLE I
P35R ALLOY PROPERTIES

ASTM Flexivity (50-200 °F)	200 x 10^{-7} (in/in)/°F
ASTM Flexivity (100-300 °F)	190 x 10^{-7} (in/in)/ °F
Specific Curvature (10-93°C)	36.0 X 10^{-6}(mm/mm)/°C
Specific Curvature (38-149°C)	34.2 X 10^{-6} (mm/mm)/°C
Maximum Sensitivity Temperature Range	-20 to 200 °C
Useful Deflection Temperature Range	-70 to 260 °C
Electrical Resistivity @ 75°F (24°C)	0.053 to 0.063 µohms-m
Density	8.05 g/cm^3
Modulus of Elasticity (E)	131 GPa

III. EXPERIMENTAL PROCEDURE

A. *Circuit Breaker Modification*

Ten 35 ampere circuit breakers where modified milling a window in the front case of them. This window (Fig. 2) allows to observe the thermostatic element displacement once the device is connected to electrical current.

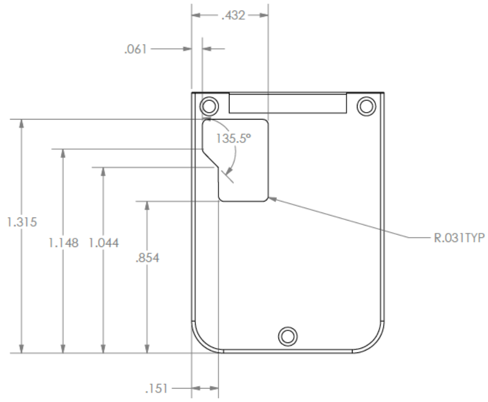

Fig.2. Modification performed to analysed devices.

B. *Electrical Current Supply*

For thistest, each of the 10 devices underwent a current of 20, 30, 40, 50, 60 and 70 amperes for 39.5 seconds in order to compare the bimetal displacement in each phase of the process. The device is connected using AWG number 10 22" long test leads according to specification MIL-C-5809.

The devices were connected into a custom made current supply equipment powered by an Agilent 6690A current source with working capacity of 0 to 15 volts and 0 to 440 amperes which has an accuracy of 0.04% v and 0.1% amp at 25 +/- 5 ℃ according to the manufacturer's specifications. This current supply equipment can be programmed to supply the desired amperage for the desire amount of time.

C. *Fixturing*

During the supply of electric current the device was placed on a specially designed fixture to assure a repeatable position of the circuit breaker and the image analysis device.

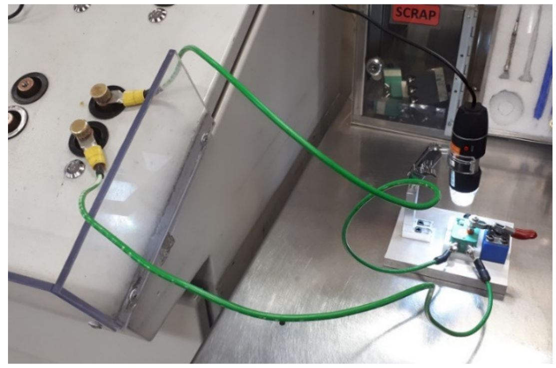

Fig. 3. Circuit breaker in holding fixture and connected to power source.

D. *Image Analysis*

To perform the bimetal movement analysis a picture at second 39.5 of the test was taken using a U500X digital microscope by CoolingTech.Its characteristics are:

CMOS image sensor
Speed control
Focus from 15mm to 40mm
Software for image processing
0.3M video resolution
Integrated lighting with manual adjustment
Resolution of images of 640 * 480
5X digital zoom

E. *Experiment*

Fig. 4 shows the procedure followed to perform the test.

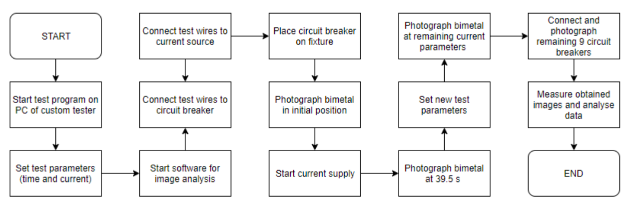

Fig. 4. Test diagram

IV. RESULTS

The displacement of the 10 circuit breakers was measured from 0 to 70 amperes at 39.5 seconds. The displacement was measured from the tip of the bimetalto the edge of the milled window. An example of the measurement is showed in Fig. 5.

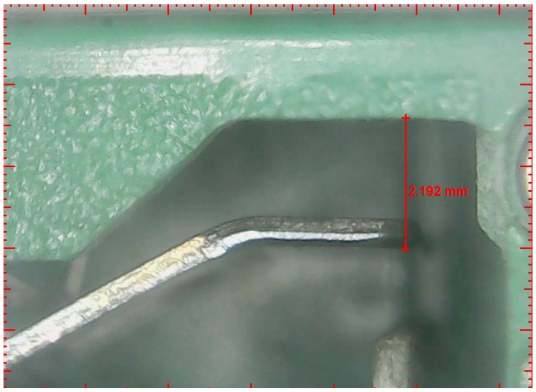

Fig 5. Measurement performed on initial position of bimetal

The initial point was subtracted from all other readings to obtain the final displacement in each phase of the test.

Table II and Fig. 6 show the displacement of the bimetal in each circuit breaker undergoing different currents after 39.5 seconds once the initial position was subtracted from al values.

TABLE III
DISPLACEMENTS OF BIMETALS (MM)

	0	20 A	30 A	40 A	50 A	60 A	70 A
1	0	0.151	0.274	0.561	0.959	1.356	1.539
2	0	0.096	0.288	0.534	0.932	1.411	1.568
3	0	0.096	0.274	0.575	1	1.411	1.619
4	0	0.082	0.288	0.562	1.014	1.410	1.71
5	0	0.137	0.343	0.576	1.028	1.288	1.301
6	0	0.082	0.279	0.53	1.014	1.425	1.529
7	0	0.11	0.315	0.589	1.041	1.439	1.79
8	0	0.096	0.261	0.548	0.918	1.37	1.552
9	0	0.151	0.315	0.548	1.068	1.52	1.624
10	0	0.123	0.342	0.616	1.013	1.342	1.537

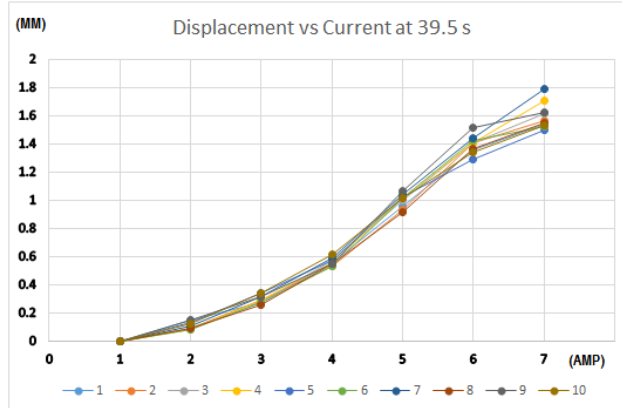

Fig. 6. Scatter Plot of bimetal displacements

V. CONCLUSIONS

The data obtained in this experiment is a good start point to implement a calibration reduction time project. Knowing the average flexion of the bimetal at a given temperature the displacement needed during the calibration process can be calculated and set by turning the calibration screws after calculating the travel that they can achieve. This will translate in shorter calibration times in the production line.

ACKNOWLEDGMENT

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