

# Benchmark tests of factory production and third-party reconditioned mining circuit breakers

## Abstract

This paper examines the quality, safety, and reliability of a random sample of 12 reconditioned circuit breakers resold and refurbished by third parties for mining applications ①. Improper modifications to circuit breakers could lead to application failure, unsafe conditions, unreliable operation, or personal injury. This paper contrasts test results of the 12 refurbished breakers with newly manufactured Eaton molded-case circuit breakers. When breakers fail to perform to specifications, there is an increased possibility of application failure and unsafe conditions for personnel.

① Genuine Eaton breakers are sold through Eaton and vetted, authorized channel partners.

## Introduction

Fundamentally, breakers are designed to provide circuit protection for power distribution systems. They safeguard connected wiring and equipment from overloads and short circuits. In other words, they are designed to protect equipment and people.

Eaton has been advancing circuit breaker technology for over 75 years. Every one of Eaton's circuit breakers sold through an authorized channel partner is tested to meet stated specifications and relevant standards. When required, Eaton recommends that the service of Eaton circuit breakers be performed by Eaton Breaker Service Centers, as they replicate Eaton original factory design, manufacturing, and test procedures, and use Eaton proprietary technology.

In the mining industry, it is common to refurbish circuit breakers to extend their useful life in the harsh environment and underground operating conditions. Refurbishment must be approached with care because, while modifications may not change the outward appearance of a circuit breaker, alterations within the circuit breaker that are improperly performed may present safety hazards.

The performance of a sample of 12 third-party ② reconditioned circuit breakers was evaluated alongside newly manufactured Eaton circuit breakers to demonstrate the reliability and quality of the refurbished circuit breakers.

② Third-party refers to an organization other than Eaton or its authorized channel partner.

## Testing protocol

The third-party breakers were tested alongside newly manufactured Eaton mining circuit breakers. Each breaker was subject to the following tests, which mirror the testing criteria Eaton uses:

- Calibration and dielectric analysis, including a prescribed number of overload switching operations followed by temperature rise measurements on the breaker. The tests analyze the breaker's ability to carry its rated current without tripping, and to open under overload
- Endurance testing, along with calibration and dielectric assessment. These tests examine the breaker's ability to open and close reliably under a determined number of load and non-load operations
- Low-level short-circuit test, including single-pole tests between two phases of a three-phase circuit, which validates the breaker's ability to interrupt short circuits
- High interruption test, which involves a sequence of two high-level fault interruptions. These tests confirm that the breaker can safely interrupt high fault currents and still be reset



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The sampling of third-party breakers tested included models that appeared similar to actual Eaton breakers, from the following Eaton models:

- HKA
- HKAM
- LAM
- HMA

Both the new Eaton mining breakers and the sample third-party refurbished breakers were tested to the breakers' stated capabilities<sup>③</sup>. So, for example, HKA breakers were tested in the high interruption test at 480V, 60 Hz with an available fault of 35,000A, as described on the breaker nameplate. Additionally, each of the breakers was subject to a thorough visual inspection. Examining both internal and external components, visual inspections looked at nameplate information for accuracy and completeness, the presence of lubrication, machine refurbishing, painting and sand blasting, and any observed modification from the original manufactured breakers.

<sup>③</sup> A breaker's performance characteristics and capabilities are stated on the breaker nameplate and in Eaton's published information.

### Test results

The test results reported are specified according to the indicated type of breaker, and the failures or successes are detailed below.

Visual inspection of the sampling of third-party reconditioned breakers indicated that both the external and internal components were modified. Specifically, in the sample of refurbished breakers:

- Eight of the nameplates had limited information, listing only the breaker type, style number, and rated voltage. Further, two of these nameplates appeared to be made with a home label maker, indicating a potential change from original manufacturer's specifications. The nameplates of the other four breakers did not appear authentic. Eaton recommends that a circuit breaker be marked with manufacturer name, ampere rating, voltage rating, interrupting rating, open and closed position indication, and termination details
- All of the breakers were cleaned using an abrasive process, likely shot-blasted, both internally and externally; this could result in lost conductor-plating surfaces, which can cause overheating
- There was a lack of lubrication in ten of the third-party supplied breakers
- Two of the breakers appeared to have machined or entirely different arc runners placed on the line conductors
- Covers and bases were also machined during refurbishing in three of the breakers, for access to undervoltage release levers and plungers

### HKA circuit breakers: calibration and high interruption test

An HKA labeled third-party breaker was tested and compared to a new Eaton circuit breaker. The third-party breaker failed to trip on time in pre-test calibration, and then received its first high-level fault-interrupting test, which resulted in the center pole cable pulling out of the breaker, and the cover separating from the base (see **Figure 1** and **Figure 2**). The test breaker failed to interrupt the fault in time, so the laboratory backup breaker had to clear the circuit. The refurbished breaker was unable to attempt a second interruption. Eaton's new breaker received both high-current faults and is in notably better condition post-interruption (**Figure 3**) than the sample third-party modified breaker, pictured in **Figure 1** and **Figure 2**.



**Figure 1. HKA Breaker Repaired by Third-Party Refurbisher, Following Testing**



**Figure 2. Breaker Cover Separated from Base During High Fault Test**



**Figure 3. Eaton Manufactured Mining Breaker with Proper Identification and Labeling; Successfully Passed Testing Sequence**

**HKA circuit breakers: high interruption test**

A similar looking breaker from a third party was tested. This breaker appeared like Eaton's HKA; however, it had no nameplate or catalog information to properly identify it or its ratings. The breaker's ratings were assumed to be those of the Eaton HKA design, and it was subjected to the high interruption test. When the breaker was first closed, there was no continuity in the center and right poles, which prevented it from being calibrated. It failed the first high fault interrupting test, with the cover separating from the base, and the laboratory backup breaker cleared the fault (see **Figure 4** and **Figure 5**). The sample third-party breaker is in worse condition than the comparable newly manufactured Eaton breaker after the same test (**Figure 3**).



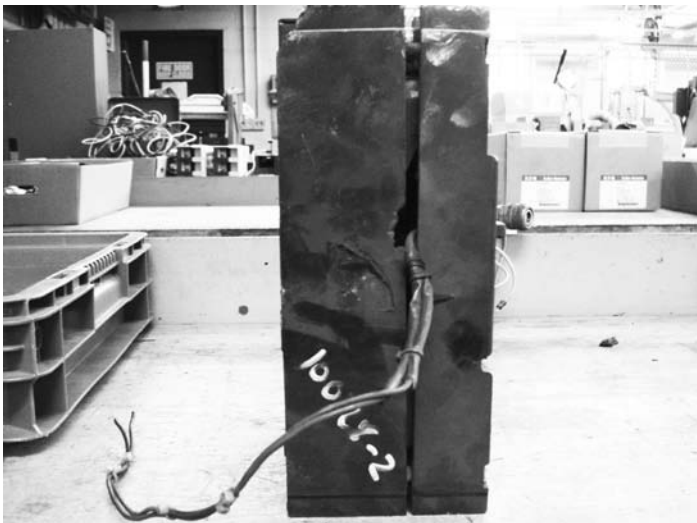
**Figure 4. Third-Party Refurbished Breaker Without Nameplate or Product Identification**

**HKA circuit breakers: high interruption test**

Another sample modified breaker, type HKA, was tested in the high interruption test at 480V, 60 Hz, with 35,000A available. The third-party sample failed the first high fault interruption test, with the base separating from the cover and the lab back-up breaker clearing the fault. The wires were pulled out of the left and center poles. The third-party sample is again in much worse condition than the new Eaton sample, even after the Eaton breaker endured a second fault interruption test. **Figure 6** shows the third-party unit after testing, and **Figure 7** shows that the A and C phase line conductors (on top) overheated and the material melted off.



**Figure 6. Third-Party Refurbished Breaker Shown Post-Testing; No Nameplate Provided**



**Figure 5. Post High Fault Test; Breaker with Cover Separate from Base**



**Figure 7. Breaker After High Fault Test; Conductor Material Overheated and Melted Away**

**HKA circuit breakers: low-level short-circuit test**

Another HKA third-party reworked breaker was subjected to a low-level short-circuit test. The third-party sample passed pre-test calibration, but it failed to interrupt in the first short-circuit test and allowed an arc to strike the test enclosure. The ground fuse connected to the enclosure was opened by the excess current of the arc to ground, and the wires welded to the terminals. In addition to failing to interrupt, the opening of the ground fuse is also a non-conformance. **Figure 8** and **Figure 9** show the unit after testing.

**HKA circuit breakers: endurance test**

The unit was believed to be an HKA; the sample was tested for endurance based on Eaton's published data for the HKA frame. The third-party sample passed initial calibration, but failed the endurance test when the ground fuse opened during the load operations at the rated current. After the ground fuse opened, the center pole of the breaker did not have continuity when closed. **Figure 10** and **Figure 11** depict the third-party breaker after testing.



**Figure 8. Third-Party Refurbished Breaker Failed to Interrupt on Short-Circuit Test**



**Figure 10. Third-Party Refurbished Breaker After Failing Load Endurance Test**



**Figure 9. Wires Welded to Terminals After Excess Current Traveled to the Ground**



**Figure 11. After Failure, Breaker Lost Continuity in the Center Pole**

**LAM circuit breakers: calibration test**

In this test, the third-party unit appeared similar to Eaton's LAM circuit breaker, but the nameplate had limited information. It was tested in accordance with the calibration test procedures. The third-party breaker tripped below the maximum time limits in 200% single-pole and 135% three-pole initial calibration tests and passed the overload portion, but it failed to remain closed during the temperature rise test at 100% of rated current. The breaker tripped before its temperature stabilized. The results indicated that the thermal release on the third-party sample was not properly calibrated; the error was likely to result in nuisance tripping. Eaton's production test procedures require trip units to be calibrated so that breakers will not trip before temperatures are stabilized at 100% of the rated current in their designated ambient temperature. **Figure 12** and **Figure 13** are photographs of the failed refurbished breaker after the test.



**Figure 12. Third-Party Refurbished Mining Breaker with Limited Nameplate Information**



**Figure 13. Breaker Did Not Stay Closed During Temperature Testing, Indicating Incorrect Calibration**

**HKAM circuit breakers: endurance test**

A sample third-party modified HKAM breaker was subject to the endurance testing and compared to an Eaton HKAM circuit breaker from current production. The third-party refurbished breaker had a malfunctioning undervoltage release (UVR) that would not stay engaged with the full rated 120V applied to it. Consequently, it would not remain latched and the breaker could not be closed; **Figure 14** and **Figure 15** are photographs of the third-party breaker after testing. In contrast, the Eaton newly manufactured breaker passed every portion of the testing procedure, which includes pre-calibration, endurance operations, a low-level interruption, post-calibration, and dielectric withstand. **Figure 16** is an image of the Eaton production breaker after testing. Eaton tests the pickup and dropout voltage of each UVR to ensure that the accessory functions properly when installed in the circuit breaker.



**Figure 14. HKAM Mining Breaker Modified by Third-Party Refurbisher**



**Figure 15. Undervoltage Release Accessory Malfunctioned; Breaker Could Not be Reclosed**



**Figure 16. Eaton Manufactured Breaker; Undervoltage Release is Tested for Proper Operation**

**HKA circuit breakers: low-level interruption test**

The third-party breaker had incomplete information on homemade labels. The sample was tested for low-level interruption and compared to a new Eaton HKAM circuit breaker from current production. The third-party breaker failed initial calibration, with one pole carrying 200% of rated current past the allowable trip time. The sample completed the short-circuit portion of the test and passed post-interruption dielectric withstand. Eaton's circuit breaker passed the sequence with no non-conformances.

**Figure 17** and **Figure 18** are of the third-party and Eaton production units, respectively.

**HMA circuit breakers: test calibration and interruption tests**

Four sample refurbished HMA units from third parties were marked as having 1000V ratings. Two 1000V samples were tested under conditions generally similar to the high interruption tests described previously (for ratings above 600V, testing procedures vary somewhat). Based on published specifications, it was assumed that these breakers were rated to interrupt 10,000A, so they were tested with this available fault current at 1000V, 60 Hz. While both units succeeded in interrupting the faults and passing post-calibrations and dielectric breakdown, one of them had a UVR that would not remain engaged with the full 120V applied to it; therefore, this breaker would not be functional in the field. The accessory was removed to perform the testing.

Calibration and dielectric analysis were performed on one of the third-party units. On the eighth overload operation (out of the 50 required operations), the circuit breaker failed to interrupt the current within the allotted time.

The fourth 1000V third-party sample was tested to the low-level interruption test. For the single-pole test, available current was 8660A, and each pole is required to interrupt twice. The sample circuit breaker failed when the first pole tested failed to interrupt.

Conversely, new Eaton HMA circuit breakers meet stated ratings and perform to published specifications.



**Figure 17. Third-Party Refurbished HKA Breaker with Poor Quality, Homemade Labels; the Breaker Failed to Trip on Overload Test**



**Figure 18. Eaton Production Breaker Shown After Testing; it Passed the Entire Test Sequence with No Issues**

## **Test results summary**

The new Eaton circuit breakers out-performed the 12 sample third-party units they were compared against during the testing conducted by Eaton. All of the third-party breakers tested experienced non-conformances, ranging from failing pre-test calibration to the cover separating from the base and the breaker not clearing the fault.

Improper refurbishing techniques can compromise the internal and external components of the circuit breaker. The third-party refurbished circuit breakers evaluated for this report had several defects in common, both in appearance and in performance. The sampling of third-party circuit breakers exhibited the following:

- Typically, they were shot-blasted internally and externally, which removed plating in critical areas such as line/load conductors, arc runners, and contacts. The shot-blasting may also leave debris in the mechanism, and may affect the structural and dielectric integrity of the molded case
- Little, if any, lubrication was left in the mechanisms of ten of these units, which would limit the life of the breaker and could cause malfunction
- The labels on the sample circuit breakers were not original nameplates, and in some cases there was no information on them at all. This could result in improper application of the breaker, if performance is assumed to be equal to original manufacturer's published data
- Some units had modified or alternate materials inside, such as barriers, arc runners, contacts, and covers and bases, which could affect the breaker's performance
- Many parts were clearly in poor condition

Failures recorded in these tests where the refurbished breaker's base separated from the cover and the laboratory backup breaker was forced to clear the fault are severe; these improperly refurbished breakers may not be able to perform in the field and could lead to application failure, unsafe conditions, unreliable operation, or personal injury.

A number of calibration and undervoltage release issues were also recorded, in which the third-party refurbished breakers would not operate correctly upon installation. The ground fuse opening during the rated-current endurance test is a highly unusual failure mode, which emphasizes the low quality and poor performance of many of the refurbished breakers Eaton tested.

Of the 12 third-party units tested, 11 exhibited some type of non-conformance. From the 11 failures, four of them could be considered severe, with covers being separated from bases and ground fuses opening.

## **Conclusion**

In these tests, the sample breakers purchased from third parties did not conform to specifications, whereas new breakers from Eaton's production performed to specified ratings. Put simply, the refurbished breakers tested in this sample were unable to pass Eaton's criteria for dependable circuit protection. A breaker failure means the loss of production, possible equipment damage, and the increased risk of worker injury at the time of failure or during maintenance.

As the original equipment manufacturer, Eaton provides both new circuit breakers and breaker service to customers through a network of authorized channel partners. Eaton's Breaker Service Centers use factory parts and processes to restore breakers to original design specifications. Eaton recommends purchasing new circuit breakers or circuit breaker service exclusively through Eaton authorized channel partners.

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