Application and Maintenance of Molded Case Breakers…

...To Assure Safe and Reliable Operation

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Global Segment Manager, Mining
Eaton Corporation
Wilsonville, OR

Western Mining Electrical Association Conference
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There are a few concerning assertions out there

• Assertion 1: “Several studies have revealed that circuit breakers that were not maintained within a period of five years have a 50% probability of failure”
• Assertion 2: “If a breaker has not been operated within as little as 6 months, it should be removed from service and manually exercised”
• Assertion 3: “Maintenance of molded case circuit breakers is limited to proper mechanical mounting, electrical connections and periodic manual operation”
Why We Authored This Paper…

There are a few application myths out there

- Myth 1: It is necessary to derate the nameplate interrupting rating of Molded Case Circuit Breakers (MCCBs)
- Myth 2: MCCBs have a history of inherent nuisance tripping problems when applied in motor circuits
- Myth 3: Circuit breakers take longer to clear a fault than other types of overcurrent protective devices
- Myth 4: Only more sophisticated current limiting design breakers will limit let-through current during a fault interruption
- Myth 5: Single pole interrupting capabilities of MCCBs restrict applications where these devices can be safety applied
Why We Authored This Paper…

To de-mystify MCCBs and share best practices

- MCCBs are subjected to rigorous testing standards to assure long-term reliability
- Although typically in a factory sealed molded case, there are several ways to determine the condition of a MCCB
- Test standards exist that offer excellent step-by-step instructions on ways to field test MCCBs
- Field based infrared thermography has proved an excellent predictive tool in identifying potential problems with MCCBs that are installed and operational
Framing the Issues…

**MCCBs are comprised of five major components**

- Molded case or frame
- Operating mechanism
- Arc extinguishers
- Contacts
- Trip components
Framing the Issues…

Ceding the point: It is often difficult to determine when a MCCB should be considered as a candidate to be replaced

- Most MCCBs are in sealed cases – breaking the seal jeopardizes manufacturer’s warranty
- Internal damage that may occur during repeated high level fault current interruption could affect the breaker’s ability to interrupt a future fault
- Electrical safe workplace standards (NFPA70E) assume a MCCBs will function as intended, regardless of age, maintenance history, or condition
UL489: Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures.

Standard Tests – 225A
- **Endurance**: cycled 8,000 operations – 4,000 under load
- **Overload**: cycled 50 operations @ 600% rated current
- **“Limited” Fault Current**: 2 interruptions @ 10kA for 225A
- **“Maximum” Fault Current**: 2 interruptions @ rated
NEMA Standard AB4: Guidelines for Inspection and Preventive Maintenance of Molded Case Circuit Breakers Used in Commercial and Industrial Applications

- The first industry standard (1991) covering MCCB maintenance, written by manufacturers
- Focus on inspection, preventive maintenance, and test procedures for MCCBs that are in service
- Latest issue 2003, free download at http://www.nema.org/
IEEE Standard 1458: Recommended Practice for the Selection, Field Testing, and Life Expectancy of Molded Case Circuit Breakers for Industrial Applications

- PAR originally sponsored by the IEEE IAS Petroleum & Chemical Industry Committee
- Procedures for field testing and determining the remaining life of molded case circuit breakers
- First introduces thermography as a useful predictor of MCCB condition
- First issued 2005
A. Is it necessary to always derate the MCCB interrupting rating?

**NO!**

- MCCBs are subjected to UL489 tests to prove them safely capable of interrupting multiple fault currents.
- The UL489 test standard requires MCCBs to interrupt their maximum nameplate fault current twice.
- Exception: Consider derating of MCCB interrupting ratings when applied on corner grounded delta connected systems.
B. Do breakers have a history of inherent nuisance tripping problems in motor circuits?

They did… this was resolved with a NEC change

- National Electrical Code Article 430.51 (NEC) has historically recognized the application of magnetic-only MCCBs in motor circuits, but has limited the maximum magnetic setting to 13 times the motor rated full load current.
- 2005 edition of the NEC was the first to allow breaker magnetic trip setting to be as high as 17 times for Design B energy-efficient motors.
MCCB Application Myths versus Facts

C. Don’t circuit breakers take longer to clear a fault than other types of overcurrent protective devices?

**NO!**

- Most MCCBs clear sub-cycle, when operating in their instantaneous range

0.007 seconds
D. Only more sophisticated current limiting design breakers will limit let-through current during a fault interruption.

**NO!**
- Newer MCCBs employ a reverse-loop design
- Higher currents = higher forces
- Trip free
- Dynamic impedance

Arc Impedance
MCCB Application Myths versus Facts

E. Don’t single pole interrupting capabilities restrict applications where MCCBs can be safety applied?

An old topic that seems to never die..

- UL489 single pole test is 10kA
- But, a single pole of MCCBs are generally not called upon to clear phase voltages
- To be a concern, a second fault on a different phase and on the source side would need to occur simultaneously (HRG)
- Exception: corner grounded delta connected systems
**Application of Thermography**

**IR Surveys at NW Paper Mill**

- Thermal Imaging has been used at the mill site for the past 10 years.
- Company employees are deployed to do this work
- Many applications for IR, electrical and otherwise, have proven successful
Application of Thermography

IR Surveys at NW Paper Mill

Bill’s Horse!

• IR Scan proved more reliable than Doctor’s diagnosis!
Application of Thermography

IR Surveys at NW Paper Mill

- Thermal scans for electrical equipment conducted twice/year
- MCCBs in low-voltage MCC units are part of the survey
- Thermographer wears appropriate PPE while in the flash protection boundary
Application of Thermography

IR Surveys at NW Paper Mill

- 2002 experience sending MCCBs back to the manufacturer’s Product Integrity Center (PIC) yielded encouraging results!

<table>
<thead>
<tr>
<th>Table 1: Norpac Breaker Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date Code</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>As-Found</td>
</tr>
<tr>
<td>Test Results</td>
</tr>
</tbody>
</table>
Application of Thermography

Test Case #1: 150 ampere MCCB 4919-2

• January 2008 IR scan identified 149.4°F hot spot temperature
• Temperature above the IEEE 1458 Standard of 130°F.
• Removed from service and returned to PIC for further analysis
Application of Thermography

Test Case #1: 150 ampere MCCB 4919-2

PIC Photos – visible wear

PIC Test Data – confirmed hot spot

<table>
<thead>
<tr>
<th>TIME</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>a</th>
<th>b</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>2:25</td>
<td>61.15</td>
<td>54.37</td>
<td>42.70</td>
<td>57.44</td>
<td>51.99</td>
<td>46.64</td>
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<tr>
<td>2:30</td>
<td>61.27</td>
<td>54.44</td>
<td>42.76</td>
<td>57.65</td>
<td>52.07</td>
<td>46.66</td>
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<tr>
<td>2:35</td>
<td>61.38</td>
<td>54.44</td>
<td>42.78</td>
<td>57.57</td>
<td>51.99</td>
<td>46.63</td>
</tr>
</tbody>
</table>
**Application of Thermography**

**Test Case #2: 150 ampere MCCB 4919-4**

- January 2008 IR scan identified 130.8°F hot spot temperature
- Temperature above the IEEE 1458 Standard of 130°F.
- Removed from service and returned to PIC for further analysis

![ELECTRICAL INSPECTION Image]

**TABLE**

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>E-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMMENT</td>
<td></td>
</tr>
<tr>
<td>TIME OF IMAGE</td>
<td>11:07 AM</td>
</tr>
<tr>
<td>DATE OF IMAGE</td>
<td>12/2/2008</td>
</tr>
<tr>
<td>DATE OF REPORT</td>
<td>12/2/2008</td>
</tr>
<tr>
<td>THERMOGRAPHER</td>
<td>ROGERS LEAK</td>
</tr>
<tr>
<td>THERMAL IMAGE</td>
<td></td>
</tr>
<tr>
<td>VISUAL IMAGE</td>
<td></td>
</tr>
<tr>
<td>HOT SPOT</td>
<td>130.8°F</td>
</tr>
<tr>
<td>REFERENCE TEMP.</td>
<td>96.7°F</td>
</tr>
<tr>
<td>DELTA T</td>
<td>40</td>
</tr>
<tr>
<td>MAX RATED AMP LOAD</td>
<td></td>
</tr>
<tr>
<td>ACTUAL AMP LOAD</td>
<td></td>
</tr>
<tr>
<td>COMMENTS</td>
<td>CHECK CONNECTION TOP OF BREAKER, 0-C PHASE</td>
</tr>
<tr>
<td>REPAIR DATE</td>
<td></td>
</tr>
<tr>
<td>REPAIRED BY</td>
<td></td>
</tr>
<tr>
<td>COMMENTS</td>
<td></td>
</tr>
</tbody>
</table>
**Application of Thermography**

**Test Case #2: 150 ampere MCCB 4919-4**

PIC Photos – visible wear

PIC Test Data – confirmed hot spot

<table>
<thead>
<tr>
<th>Temperature Rise</th>
<th>Lines:</th>
<th>Loads:</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIME</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>3:00</td>
<td>34.91</td>
<td>55.26</td>
</tr>
<tr>
<td>3:05</td>
<td>34.48</td>
<td>56.45</td>
</tr>
<tr>
<td>3:10</td>
<td>34.69</td>
<td>56.60</td>
</tr>
</tbody>
</table>

163.1°F
Application of Thermography

Test Case #3: 150 ampere MCCB 4919-1

- January 2008 IR scan identified 171.8°F hot spot temperature
- Temperature above the IEEE 1458 Standard of 130°F.
- Removed from service and returned to PIC for further analysis
Application of Thermography

Test Case #3: 150 ampere MCCB 4919-1

PIC Photos – less visible wear

Temperature Rise

<table>
<thead>
<tr>
<th>TIME</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>a</th>
<th>b</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>4:25</td>
<td>38.50</td>
<td>43.37</td>
<td>42.47</td>
<td>44.52</td>
<td>46.24</td>
<td>45.04</td>
</tr>
<tr>
<td>4:30</td>
<td>38.50</td>
<td>43.37</td>
<td>42.49</td>
<td>44.45</td>
<td>46.13</td>
<td>45.75</td>
</tr>
<tr>
<td>4:35</td>
<td>38.40</td>
<td>42.85</td>
<td>41.99</td>
<td>44.33</td>
<td>45.57</td>
<td>45.40</td>
</tr>
</tbody>
</table>

PIC Test Data – no hot spot found!

142.3°F
Application of Thermography

**Test Case #4: 150 ampere MCCB 4919-9**

- June 2008 IR scan identified 105.9°F hot spot temperature
- Temperature below the IEEE 1458 Standard of 130°F.
- Removed from service and returned to PIC for further analysis
Application of Thermography

Test Case #4: 150 ampere MCCB 4919-9

PIC Photos – external pole A discolored

PIC Test Data – hot spot found!

Temperature Rise

<table>
<thead>
<tr>
<th>TIME</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>a</th>
<th>b</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:10</td>
<td>37</td>
<td>31</td>
<td>50</td>
<td>54</td>
<td>41</td>
<td>44</td>
</tr>
<tr>
<td>1:15</td>
<td>56</td>
<td>98</td>
<td>50</td>
<td>56</td>
<td>41</td>
<td>50</td>
</tr>
<tr>
<td>1:20</td>
<td>37</td>
<td>07</td>
<td>50</td>
<td>58</td>
<td>41</td>
<td>46</td>
</tr>
</tbody>
</table>

ELECTRICAL INSPECTION

LOCATION: MF-2
EQUIPMENT: ...
TIME OF IMAGE: 9:39:14 AM
DATE OF IMAGE: 6/20/2009
DATE OF REPORT: 6/20/2009
THERMOGRAPHER: ROGGER LEAK

HOT SPOT: 105.5°F
REFERENCE TEMP: 90.9°F
DELTA-T: ...
MAX RATED AMP LOAD: ...
ACTUAL AMP LOAD: ...
COMMENTS: CHECK FOR Loose CONNECTION & REPLACE...
Application of Thermography

Other overcurrent protective devices

- Paper Machine #1 area, built 1979
- MCCBs included current limiters
- IR scans also useful here - 249.6°F!
  - 3 of 4 elements melted!
- “Aged” limiter removed from service
Other Off-Line Breaker Testing Methods

**Rotational outages – 5 week intervals**

- Lockout and tagout procedure for equipment maintained during the period
- MCCBs in the respective operating area may be mechanically exercised and the trip system tested via the push-to-trip feature
- General condition of each circuit breaker is noted
- External condition of the outer case may warrant immediate replacement or subsequent spot thermographic inspection after the equipment is back in service.
Circuit Breaker Reliability Results

Using the UL489 50°C Rise Threshold

- 11 MCCBs removed from service in one-year period from a total population of 876 operating in PM # and Deink area
- Of the 11 MCCBs returned to the PIC, 5 demonstrated test temperature rise above the 50°C threshold
- Good overall reliability. 5 of 876 breakers = 0.57%!
**Circuit Breaker Reliability Results**

**Additional Observations**

- None of the 11 breakers returned to the PIC actually failed! Mechanical operation and trip system verified.
- Perhaps up to 7 of those field surveyed did not require immediate replacement - results recorded hot spot temperature below 130°F.
- Erring on the side of caution not uncommon in a continuous process environment!

**Ideas to Improve This Process**

- Better discipline in exercising breaker using push-to-trip feature.
- Record fault current magnitudes with substation meter waveform-capture.
An Arc Flash - An electrical arc due to either a phase to ground or phase to phase fault. Caused by many factors - dropped tools, improper work procedures, etc.

- 80 percent of all electrical injuries are burns that result from the electric arc flash
- Arc flashes cause electrical equipment to explode, resulting in an arc-plasma fireball
- Solid copper vaporizes, expands to 67,000 times its original volume
- Temperatures exceed 35,000 degrees F
- Detected sound levels of 141.5 decibels
- Pressure levels of 2,160 pounds per square foot
Addresses electrical safety-related work practices
Developed in cooperation with OSHA, to fulfill their needs.
Assumes an NEC compliant installation.
1979: First published,
1995: Added Flash Protection Boundary
2000: Focused on use of personal protective equipment (PPE).
2004: Emphasizes safe work practices.
2009: Energized work permits, Adopted in parts of APAC & LAM, Harmonized CSA Z462 introduced
2012: Newest edition released October 2011
“Standard for Electrical Safety in the Workplace”
First published in 1979 – Established at the bequest of OSHA.

- **130.3 Arc-Flash Hazard Analysis**
  “A flash hazard analysis shall be done…”

- **130.3 (B) Personal Protective Equipment (PPE)**
  “… Where it has been determined that work will be performed within the flash protection boundary by 130.3(A), the flash hazard analysis shall determine, and the employer shall document, the incident energy exposure of the worker (in calories per square centimeter)… and personal protective equipment (PPE) shall be used by the employee based upon the incident energy exposure”
<table>
<thead>
<tr>
<th>Hazard Risk Category</th>
<th>Clothing Description</th>
<th>Required Minimum Arc Rating of PPE cal/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Non-melting, flammable materials (i.e., untreated cotton, wool, rayon, or silk, or blends of these materials) with a fabric weight at least 4.5 oz/yd² (1)</td>
<td>N/A</td>
</tr>
<tr>
<td>1</td>
<td>FR shirt and FR pants or FR coverall (1)</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Cotton underwear – conventional short sleeve and brief/shorts, plus FR shirt and FR pants (1 or 2)</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>Cotton underwear plus FR Shirt and FR pants plus FR coverall, or cotton underwear plus two FR coveralls (2 or 3)</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>Cotton Underwear plus FR Shirt and FR Pants plus multilayer flash suit (3 or more)</td>
<td>40</td>
</tr>
</tbody>
</table>

Based upon maximum energy for a 2nd degree burn (1.2 cal/cm²)

**NFPA 70E-2012: Table 130.7 (C) (11)**

**Protective Clothing Characteristics**
The intent of NFPA 70E/CSA Z462 regarding arc flash is to provide guidelines which will limit injury to the onset of second degree burns (1.2 cal/cm²).

Note: The heat reaching the skin of the worker is dependent primarily upon:

- **Power of the arc at the arc location**
- **Distance of the worker to the arc**
- **Time duration of the arc exposure**
“Guide for Performing Arc Flash Calculations”

- Provides guidance for the calculation of incident energy and arc flash protection boundaries.
- It presents formulas for numerically quantifying these values.
- The IEEE 1584 Guide also includes an Excel Spreadsheet “Arc-Flash Hazard Calculator” which performs the actual calculations using the formulas stated in the Guide.
Unit Substation Applications

Safety: Unit Substation Design

Typical LV Substation with Fused Load-Break Switch

Arc Flash Study Results

Fault at 480V Switchgear Bus
- 31.8kA Symmetrical Fault current
- 1167” AF Boundary
- 702.4 cal/cm @ 18”

UNAPPROACHABLE:
NFPA70E-2009: Category 4 is highest category @ 40 cal/cm
**Unit Substation Applications**

**15kV Vacuum Circuit Breaker**
- 25”H X 20”W X 18” D, 330 lbs
- ANSI C37.20 Rated at 25 and 40kA
- 600, 1200, 2000 and 2500A ratings
- Integral trip unit with linear trip actuator
- 2-step stored energy mechanism

**15kV Vacuum Circuit Breaker**
- 31”H X 29.5W X 25”D, 460 lbs
- ANSI C37.20 Rated at 25, 40 and 50kA
- 1200, 2000, 3000 and 5000A ratings
- External relay required
- 2-step stored energy mechanism
Unit Substation Applications

Improved Unit Substation Design

LV Substation with Retrofit Vacuum Primary Breaker

Arc Flash Study Results

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sym. Fault at 480V Switchgear Bus</td>
<td>31.8kA</td>
<td>31.8kA</td>
</tr>
<tr>
<td>AF Boundary</td>
<td>1167&quot;</td>
<td>18&quot;</td>
</tr>
<tr>
<td>Cal/cm²</td>
<td>702.4</td>
<td>1.4</td>
</tr>
<tr>
<td>NFPA70E HRC</td>
<td>UNAPPROACHABLE</td>
<td>1</td>
</tr>
</tbody>
</table>
Design the Hazard Out (Safety by Design)

VCP-T Substation Vacuum Breaker

Safety: Non PPE Unit Substation Design

Typical LV Substation with Replacement VCP-T Vacuum Breaker in MSB Assembly

Industry Users: P&G, Weyerhaeuser, ADM
Design the Hazard Out (Safety by Design)
VCP-T Substation Vacuum Breaker

Substation One-Line
Alternate Primary Protection

LV SUBSTATION

MV VCB LSI 600AF 3500AT

FUSED LOAD-CIRCUIT BREAKER WITH VACUUM BREAKER

(3) 3150:1 CURRENT SENSORS
(3) 3200:5 CT

HIGH RESISTANCE GROUNDING

480V, 3PH, 3 WIRE, 3 GROUND, 30A, 60HZ, 100VAC

ZSI
LV PCB LSI 800AF 800AT

ZSI
LV PCB LSI 800AF 800AT

ZSI
LV PCB LSI 800AF 800AT

ZSI
LV PCB LSI 800AF 800AT

ZSI
LV PCB LSI 800AF 800AT

ZSI
LV PCB LSI 800AF 800AT

OC RELAY

300V/300V, 3PH, 480V/277V
250V/250V, 3PH, 480V/277V

LV Switchgears
**Above Ground Mining Electrical Systems**

**Above Ground E-House**

**North America**

LV Switchgear Assembly
Type Tested UL1558
Up to 600 Vac

Arc Resistant Assembly
ANSI C37.20.7

**ROW**

LV Controlgear Assembly
Type Tested IEC61439-1
Up to 690 Vac

Internal Arc Classified Assembly IEC 61439-1

**Arc Rated Testing**
**Underground Mining Electrical Systems**

North America
No Standards

ROW
Some Standards

Underground Power Center

Standards Application?

- UL489
  - 600V Max

- IEC60947.2
  - 1000V Max

LV Molded Case Mining Circuit Breaker
- 1000-1250Vac
Molded Case Circuit Breakers

415/480/600V Air Circuit Breaker
- Various Dimensions
- UL489: 18 to 50kA
- 150 thru 2000A ratings
- Manually Operated
- Arc interruption in air

1.2kV Air Circuit Breaker - Mining
- Various Dimensions
- IEC60947.2: 8 to 25kA (to 1200V)
- 150 thru 2000A ratings
- Manually Operated
- MSHA 30 CFR 75 (USA)
- Arc interruption in air
Underground Power Center Typical Schematic

- 15kV Switch & Fuse
- 2500kVA Transformer
- 1000V Molded Case Breakers

- Trend toward larger kVA ratings & higher voltages
Application of Molded Case Breakers

Fail-Safe Protection

- Ground Fault & Pilot Wire Protection
- UV Release Coil internal to Molded Case Circuit Breaker
- Operator Attempted breaker reset on power loss presents a problem
**Molded Case Breakers & Trip Free**

**Standard Close Operation**
- Contacts continue to full close position
- Momentum of mechanism is carried to stationary contacts

**Trip Free Operation**
- Action happens 10X faster than standard close operation.
- Mechanism forces that are stored in the springs to drive crossbar motion is released and completely absorbed by mechanism causing significant stresses in the mechanism.

- Main contact
- Stationary contact
- Main contact
- Stationary contact
- Undervoltage Release
- Latch activated during UV condition
Resolving the Application Issue

Adding UV Control Power Indicator

- Operator confirms UV trip control power is present
- Only then resets the circuit breaker
Application of MV Vacuum Breakers

Primary Protection
- Underground Power Center Primary Protection
- Vacuum Breaker with Integral Trip Unit
- Arc Flash Reduction Maintenance System
Third-Party Repair of Molded Case Breakers

MSHA Safety Alert – April 2011

MSHA has been made aware of a hazardous condition that may exist in 600 volt and 1000 volt circuit breakers. This includes all frame sizes. The circuit breakers may appear to be new or rebuilt, but they have been changed from the manufacturer’s original design. These mining circuit breakers may have been purchased either directly from the 3rd party or through a mining supply company. .... the frames used for both 600 volt and 1000 volt have been rebuilt and may contain parts, such as tips and springs, of unknown origin and specifications. Because of the potential for injury and/or death from the failure one of these circuit breakers can cause, they should be removed from service immediately.”
MSHA has been made aware of a hazardous condition that may exist in 600 volt and 1000 volt circuit breakers. This includes all frame sizes. The circuit breakers may appear to be new or rebuilt, but they have been changed from the manufacturer’s original design. These mining circuit breakers may have been purchased either directly from the 3rd party or through a mining supply company. ... the frames used for both 600 volt and 1000 volt have been rebuilt and may contain parts, such as tips and springs, of unknown origin and specifications. Because of the potential for injury and/or death from the failure one of these circuit breakers can cause, they should be removed from service immediately.”

Manufacturer’s Authorized Breaker Service Center

- Factory trained personnel
- Genuine parts designed to manufacturer’s specifications
- Fully tested the repaired circuit breaker
- New factory warranty for the serviced product.
Trends for Underground Power Centers

Bigger is better!

- Primary voltages up to 27kV (inspired by cable costs)
- Transformer ratings in excess of 4000kVA
- Protective device interrupting ratings up to 40kA
- Remote open/close capability for both primary and secondary circuit breakers
Application Opportunities for Higher Ratings

1.2kV Air Circuit Breaker
- 15”H X 15”W X 10” D, 118 lbs
- IEC60947.2: 8 to 25kA
- 150 thru 2000A ratings
- Manually Operated
- MSHA 30 CFR 75 (USA)
- Arc interruption in air

12/17kV Vacuum Circuit Breaker
- 25”H X 20”W X 19” D, 330 lbs
- IEC 62271-100: 25, 31.5 & 50kA
- 630 thru 3150A ratings
- Electrically Operated
- 2-step stored energy mechanism
- Arc interruption in vacuum - encapsulated pole

15kV Vacuum Circuit Breaker
- 31”H X 29.5W X 25”D, 460 lbs
- ANSI C37.20: 25, 40 & 50kA
- 1200 thru 5000A ratings
- Electrically Operated
- 2-step stored energy mechanism
- Arc interruption in vacuum - vacuum bottle
**Sulfur Hexafluoride (SF6)**

The Good, …
- An excellent dielectric
- Superior insulating properties

…The Bad,
- Colorless, odorless, 5 times heavier than air

… & The Ugly!
- Replaces oxygen, causing suffocation
- The world’s most potent greenhouse gas - 23,900 times greater than CO₂

<table>
<thead>
<tr>
<th>By Products</th>
<th>Toxicity (As defined by various agencies mentioned below)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HSDB</td>
</tr>
<tr>
<td>Sulfur-tetrafluoride (SF₄)</td>
<td>Extremely irritating to the eyes, nose, and throat</td>
</tr>
<tr>
<td>Sulfur-pentafluoride (SF₅)</td>
<td>-</td>
</tr>
<tr>
<td>Sulfur-dioxide (SO₂)</td>
<td>Extremely irritating to the eyes, nose, and throat</td>
</tr>
<tr>
<td>Hydrofluoric Acid (HF)</td>
<td>Extremely irritating to the eyes, nose, and throat</td>
</tr>
</tbody>
</table>
Conclusions

- Molded Case Circuit Breakers are successfully applied in countless industrial settings
- Common misconception regarding application of MCCBs prevail - proper application improves both safety and reliability
- Knowing when to remove a MCCB from service based on it’s service history can be difficult
- New maintenance standards including NEMA AB4 and IEEE1458 serve as useful guides in determining when to remove an MCCB from service
- Thermal imaging of MCCBs has been applied and verified as an excellent predictive maintenance tool
- Consider Substation Design alternatives to reduce arc-flash hazards
- Circuit breaker applications in underground mining warrant special considerations
Questions?

I encourage you to attend the
IEEE IAS Annual Meeting
Mining Industry Committee Technical Sessions
October 6-10, 2013 Orlando, Florida  www.ieee.org/ias2013

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