Electrical Equipment - Course 230.2

SWITCHGEAR: PART 3

AIR CIRCUIT BREAKERS

1. OBJECTIVE

The student must be able to:

1. *State the purpose of a circuit breaker.*
2. State the purpose of each of the operational components in an air circuit breaker.
3. Describe the operation of an air circuit breaker.
4. Explain the three basic ratings for a circuit breaker and explain the consequences of exceeding any of these ratings.
5. State the operator actions that must be taken in the event of abnormalities.

2. INTRODUCTION

For applications where infrequent operation is required, the voltages are 600 V (or less) and the currents are less than about 200 A, simple fused switches can be used. This arrangement is common in domestic and small plant applications. Where frequent operation is required, when voltages are greater than 600 V and when *currents greater than 200 A are involved*, circuit breakers are used in conjunction with some means for isolating the circuit breaker. Figure 1 shows the symbol for the air circuit breaker which is the type used at 15 kV and below. At voltages *above* 15 kV, different types of breaker are used. These types are discussed in the next lesson.

ARROWS INDICATE BREAKER CAN BE RACKED OUT

Figure 1: Symbol for Air Circuit Breaker Which can be "Racked Out" for Isolation or Maintenance.

2.1 Circuit Breakers: Purposes

All circuit breakers are designed for the following two purposes:

(a) to **control** *electrical loads by connecting and* disconnecting them from the electrical supply.

(b) to **interrupt** fault currents which are produced when short circuits and other abnormalities occur.

Circuit breakers, which can be racked, **can** be used for isolation purposes. The term **racking** is given to the action of physically removing (usually with a worm and crank mechanism) the circuit breaker from its busbar and circuit connections. Figure 2(a) shows a breaker racked into its "service position" and Figure 2(b) shows it in its "racked out" position. Note the clearance between the breaker "tulips" and the busbar "stabs".

The connection between the two busbars and the breaker consist of the fixed portion, (attached to *the busbars) called the "stabs" and the moving* portion (attached to the breaker) called the "tulips". When the breaker is racked in, the tulips fit over the stabs and connect the breaker to the supply and load busbars. *These connections* have no mechanism for making or breaking load (or fault current) and consequently the breaker must be in the open position before it is racked in or out. Mechanical interlocks are provided to ensure that a breaker is in the open position before racking in or out can commence. Before racking, it is good operator practice to check that the breaker is in its open position. If a breaker was racked out while it was closed, (assuming the interlock has failed), the stabs and tulips would try to break the load current. Violent arcing and an explosiion would follow. Damage to equipment would be severe. Any personnel close to the breaker would, in all probability, receive serious injuries.

Shutters are provided to cover the supply and load stabs. When the breaker is racked out, these shutters automatically lower and cover both sets of stabs. *The shutters can now be locked preventing:*

(i) the breaker being racked in,

(ii) persons or objects touching the stabs, which may be alive.

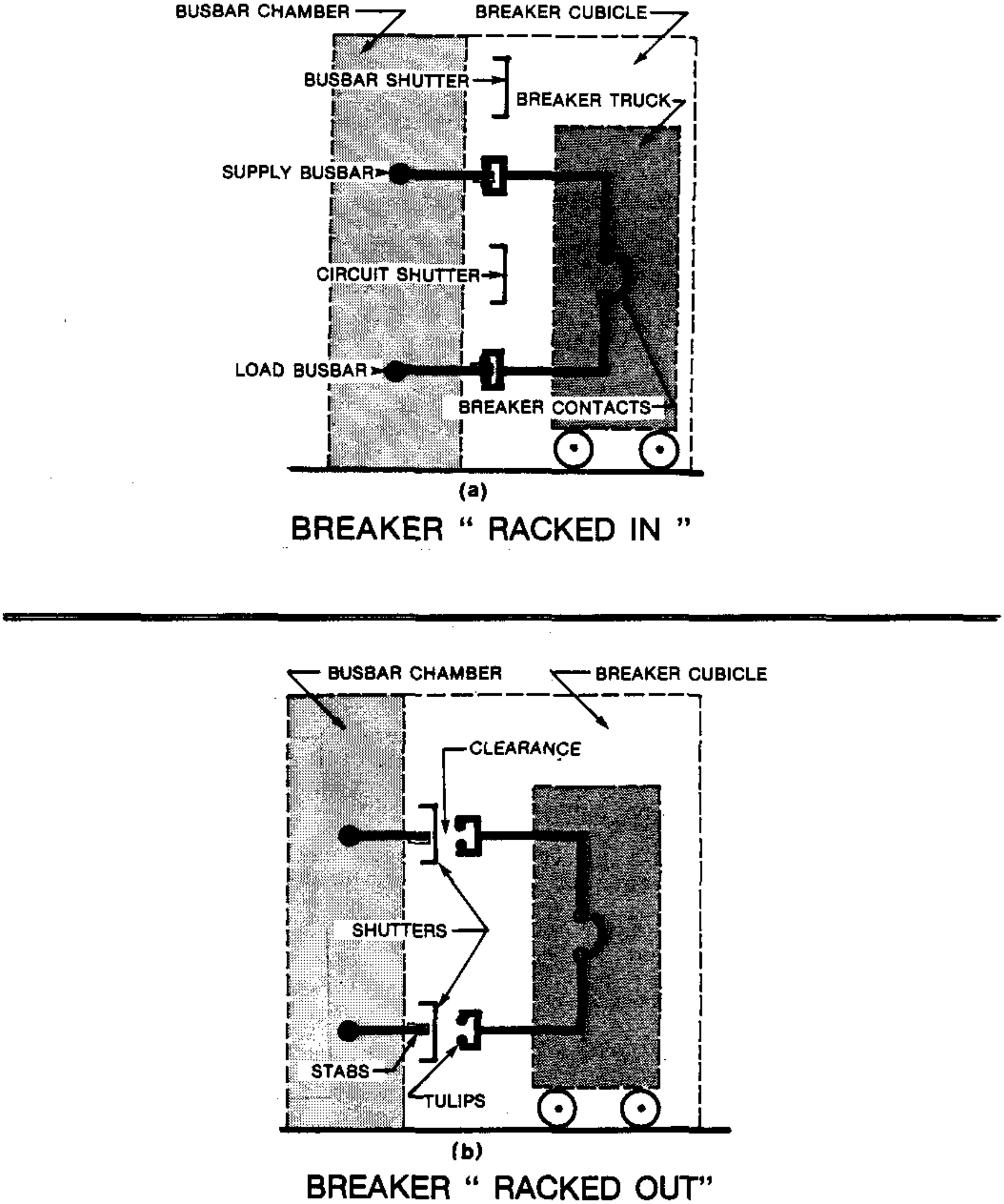

Figure 2: Breaker Showing Racking Action.

Before returning the breaker to service, the shutters must be unlocked. As the breaker is racked in, the shutters automatically open and expose the stabs.

2.2.1 Summarizing the Above

(a) When isolating a circuit,

(i) first the breaker must be opened,

(ii) then the breaker must next be racked out,

(iii) finally the busbar and circuit shutters must be locked in the closed position.

(d) Before returning a circuit to service:

(i) first the shutters must first be unlocked,

(ii) then the breaker must next be racked in,

(iii) the breaker can then be closed.

3. PRINCIPLE OF OPERATION AND CONSTRUCTION DETAILS

3.1 Construction Details

In an air circuit breaker, see Figure 3, there are three sets of contacts per phase,

(a) the main contacts which carry the load current.

(b) the arcing contacts.

(c) the arcing horns.

The main contacts are made from a good conducting metal, usually silver or copper. This is necessary because these contacts must not overheat in service. The arcing contacts are usually made from a harder material, for example tungsten, and this is because the contacts have to withstand the arc and any consequential burning. The arcing horns, to which the arc is transferred after the arcing contact has opened, are normally made from hard copper or similar material.

The arc chutes are made from a fire proof insulating material. Inserted in the arc chutes are cooling plates made from asbestos sheet or steel. These arc chutes convect the hot gases away from the contacts. The metal plates cool the gases and at the same time further stretch the arc.

3.2 Opening Cycle

The breaker **opening cycle** is:

(a) With the breaker closed, the load current passes through the low resistance main contacts. See Figure 3(a).

(b) As the breaker opens, the main contacts open **first,** transferring the current to the arcing contacts. The main contacts do not break any current. See Figure 3(b). When these arcing contacts open, arcing occurs across their faces, see Figure 3(c). As these faces are made from tungsten and because the arc only persists for 2-3 cycles, little or no damage occurs.

(c) As the breaker opens further, the arc rises. This is because hot gases rise due to the convection principle. At the same time the arc is being lengthened. When the arc enters the arc chute, see Figure 3(d), it is rapidly cooled by the cooling plates. Cooled gases cannot conduct electricity and consequently the arc is extinguished.

3.3 Closing Cycle

For the breaker **closing cycle,** the arcing contacts close **first** making the circuit. Only slight contact burning will occur during closing. This is because of the tough tungsten faces. The main contacts close about a cycle after the arcing contacts, complete the closing operation and carry the load current.

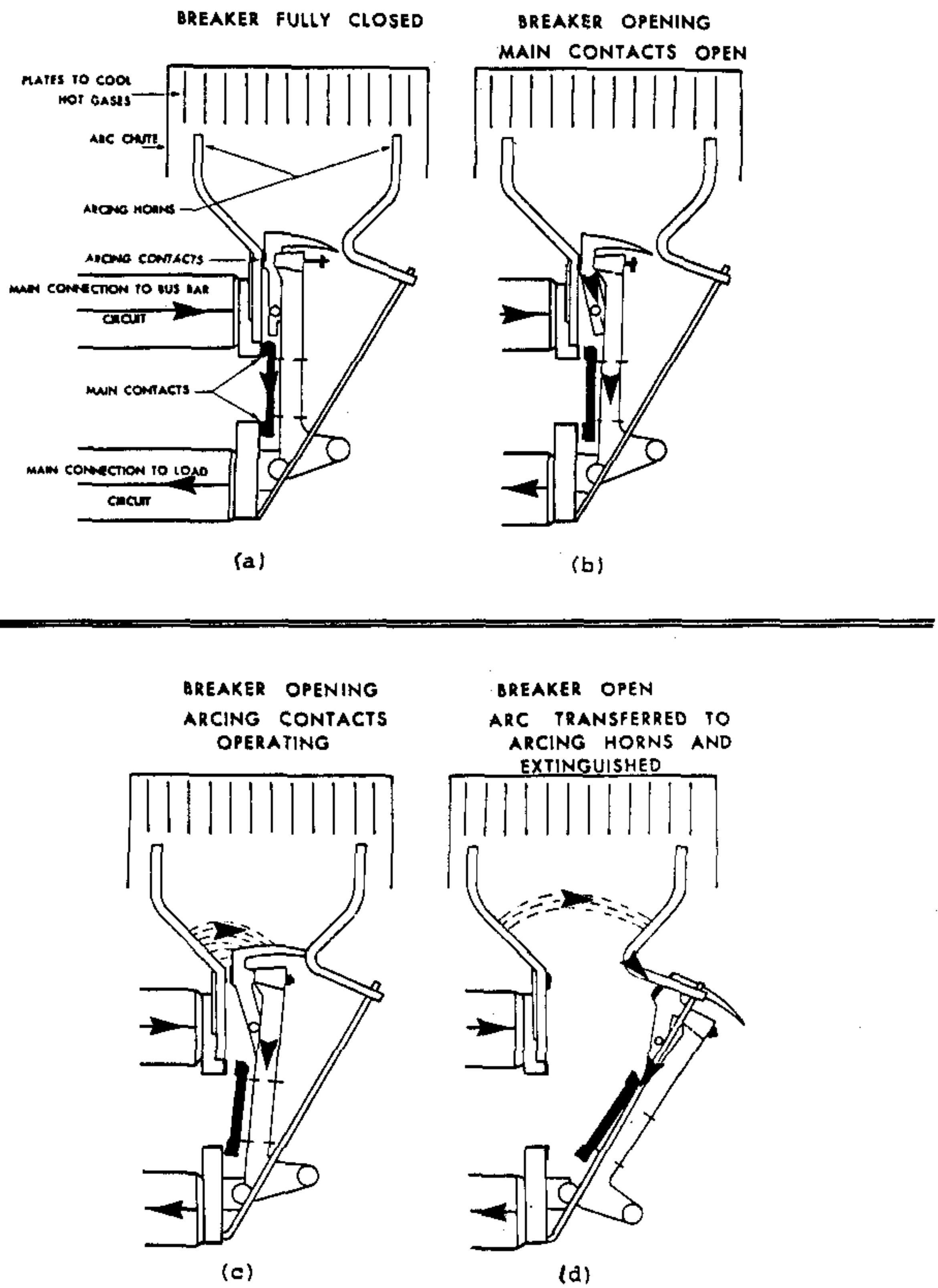

Figure 3: Air Circuit Breaker Operating Sequence. Arrows Show Current Flow.

3.2 The Latching Mechanism

When a **closing signal** is applied to the breaker closing coil, the arcing and main contacts close. The breaker mechanism then **latches** in the closed position. As soon as the breaker has latched fully, the current to the closing coil is "cut off". This is necessary to prevent the closing coil burning out, (it is rated to carry current for approximately 15 seconds) and to prevent undue drain on the Class I battery.

When a **tripping signal** is applied to the breaker trip coil, the breaker mechanism trips **(unlatches)** and the main and arcing contacts open. As soon as the breaker has opened fully, the current to the trip coil is "cut off". Again this is necessary to prevent the trip coil burning out and undue drain on the Class I battery.

4. BREAKER RATINGS

4.1 Voltage and Current Ratings

All circuit breakers have three esential ratings, they are:

(a) **Rated Voltage.** This is the design voltage rating for the circuit breaker and busbars and is determined by insulation thickness and quality.

(b) **Rated Current (Continuous).** This is the maximum design current that the breaker can carry continuously without overheating. The rating is determined by conductor size and in-service temperature rises of the contacts, connections and busbars.

(c) **Rated Current (Interrupting).** This is the maximum short time short-circuit or fault current that the breaker can interrupt (break) without sustaining damage. The rating is dependent upon the arc breaking capability of the arcing contacts, arcing horns and arc chute. It is also dependent upon the breakers ability to withstand the electromagnetic stresses associated with short circuit currents. Remember that when large currents flow, large attractive and repulsive forces are produced. These forces highly stress the breaker insulation and current carrying components.

The interrupting capacity rating of a breaker is often quoted in MVA. This rating is derived from

Interrupting Capacity = $\sqrt{3}$ x Rated Line Voltage x Rated Current (Interrupting $\div 10^6$ (MV.A)

For example, a 4160 V breaker whose interrupting capacity is 250 MVA will have a rated current (interrupting) of approximately 35,000 A.

$$U = \sqrt{3}.V_L.I_L \quad V.A.$$

$$250 \times 10^6 = \sqrt{3} \times 4160 \times \text{Rated Currents (Interrupting)} \quad (MV.A)$$

Rated Current (Interrupting) = 34,700 A

4.2 Consequences of Exceeding Ratings

Exceeding any of the ratings of a circuit breaker can cause it to EXPLODE. This is clearly very dangerous to both plant and personnel.

- If the voltage rating is exceeded by more than 10%, there is the danger of an arc occuring between phases and ground. This will release a large amount of energy and an explosion will result.

- If the current (continuous) rating is exceeded, there is the danger of current carrying components overheating, arcing and burning. Insulation will also be damaged.

- If the current (interrupting) rating is exceeded, there is the danger that the breaker will not be able to interrupt the arc. If the arc persists after the breaker has opened, an enormous amount of heat is produced and an explosion results. When this occurs, anyone standing in front of a breaker is liable to receive burns and other physical injury.

It is possible to exceed the current (interrupting) rating by having a short circuit at the same time as two or more power sources are incorrectly paralleled. Course 235 details how this can occur.

4.3 Operational Problems with Breakers

Breakers are carefully designed and maintained to high standards. However, in service problems do occur and when they happen, very great care must be taken to ensure that they are solved - safely. Three probable problems are:

4.3.1 Overheating may be suspected in a breaker. Because of the metalclad cubicles, the contacts and other current carrying components cannot be seen it must be assumed that the overheating is occurring in a dangerous part of the breaker. Consequently, it is inadvisable to attempt to open the breaker, (it could only open half way for instance). The only safe solution is to de-energize the complete busbar and all other sources of power infeed to the breaker. The source of the overheating can then be safely investigated.

4.3.2 A breaker may fail to close due to either:

(a) A defect on the closing control system. If this occurs, the breaker should first be racked out. The defect can then be safely investigated and cleared.

(b) The breaker closing mechanism releasing but the breaker jamming before it can complete its closing stroke. Clearly, this is a dangerous condition as the mechanism may free and close the breaker at any instant. The safe way to investigate this defect is to first de-energize the circuts as described in 4.3.1 above.

4.3.3 A breaker may fail to open (trip). This problem can be very dangerous as the breaker may be supplying energy to equipment that must be shut down. If a breaker fails to open, the circuits must first be de-energized as described in 4.3.1 above. The reason for the failure can then be investigated with safety.

ASSIGNMENT

1. State the two purposes of a circuit breaker. (Section 2.1)

2. State the purposes of the following breaker components:

   (a) Stabs
   (b) Tulips
   (c) Shutters
   (d) Supply Busbar
   (e) Load Busbar
   (f) Main Contacts
   (g) Arcing contacts
   (h) Arcing Horns
   (i) Arc Chute
   (j) Racking Mechanism
   (k) Latching Mechanism

   (Sections 2.1, 3.1)

3. Desribe the normal operation of a circuit breaker from

   (a) the circuit being on load right through to the circuit being fully isolated.

   (b) the circuit being fully isolated right through to the circuit being on load.

   Make sure you describe the action of all relevant components. (Section 2.1)

4. Explain the three essential ratings for a circuit breaker and explain the consequence of exceeding any of these ratings. (Sections 4.1 and 4.2)

5. State what action(s) an operator should take when:

   (a) a breaker shows signs of overheating.

   (b) a breaker jams in the open or closed positions.

   (Section 4.3)

6. (a) Describe the opening cycle of an air circuit breaker. (Section 3.2)

   (b) Describe the closing cycle of an air circuit breaker. (Section 3.3)

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