Electrical Equipment - Course 230.2

SWITCHGEAR: PART 6

OIL AND AIR BLAST CIRCUIT BREAKERS

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1. OBJECTIVE

The student must be able to:

1. For both oil and air blast circuit breakers:

   (a) State the purpose of each operational component,

   (b) Describe the closing and tripping,

   (c) Explain the consequences of exceeding any of the ratings,

   (d) State the operator actions that must be taken in the event of abnormalities.

2. INTRODUCTION

In Ontario Hydro, Nuclear Generation Division, oil and air blast circuit breakers are used at 230 kV. Air blast breakers are used at 500 kV. The table on page 2 gives some of the advantages and disadvantages of these types of breakers.

Breaker Type	Advantages	Disadvantages
Oil	(a) Quiet in operation. (b) High interrupting capacity can be achieved by series connecting several 'pots' which interrupt the current.	(a) Contains flammable oil. (b) Requires an oil treatment plant. Oil must be kept at a very high standard.
Air Blast	(a) High interrupting capacity can be achieved by series connecting several interrupters.	(a) Requires a supply of dry compressed air which is at a high pressure. (b) Noisy operation (silencers help). (c) Maintenance is difficult.

TABLE 1: Advantages and Disadvantages of Oil and Air Blast Circuit Breakers.

3. OIL CIRCUIT BREAKERS

Because of the noise problem associated with air blast circuit breakers, oil circuit breakers tend to be installed near built up areas and air blast breakers tend to be installed in rural areas.

3.1 Principle of Operation and Construction Details

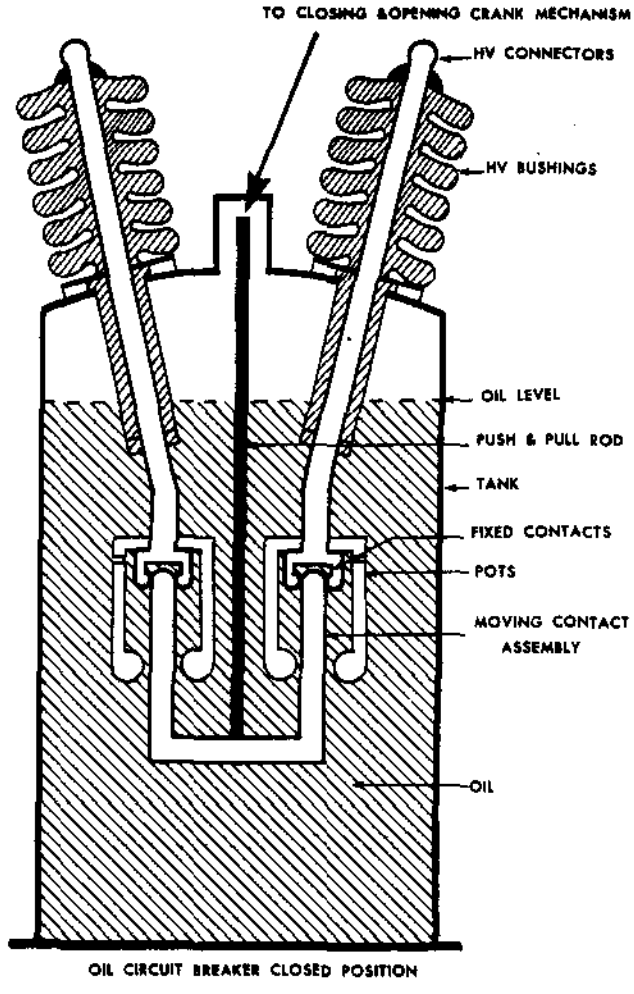


Figure 1: Diagram Showing a Section of an HV Oil Circuit Breaker in the Closed Position.

Figure 1 shows a section of one phase of an oil circuit breaker. The circuit breaking components are submerged in oil which is used for insulation and current interrupting purposes. At the top of each circuit breaker tank are two bushings which provide:

- insulation between the circuit and tank,
- support for the two 'pots'.

Each contact of the breaker is inside a pot whose function is to contain the arc and in conjunction with the oil, provide the extinguishing action for the arc which forms when the contacts open.

3.1.1 Tripping and Closing. Figure 2(a) shows a cross section of a breaker pot with the contacts closed. The pot is full of oil.

(a) Tripping. When the trip coil is energized, the latch is released and due to spring action, the contacts rapidly move downward. Figure (b) shows the contacts having just opened. As the contacts part, an arc is drawn between the fixed and moving contacts. This arc raises the oil temperature to a high value. The oil breaks down forming a large volume of gas which causes the pot to be pressurized. Oil is now forced past the opening contacts, cooling and extinguishing the arc.

(b) Closing. As soon as the arcs have extinguished, the gases escape through the vents and the pots re-fill with oil. The breaker is then ready for re-closing. With oil breakers, it is important to allow a few seconds between a trip and re-closure. This ensures that the gases have had time to vent and the pots have re-filled with oil.

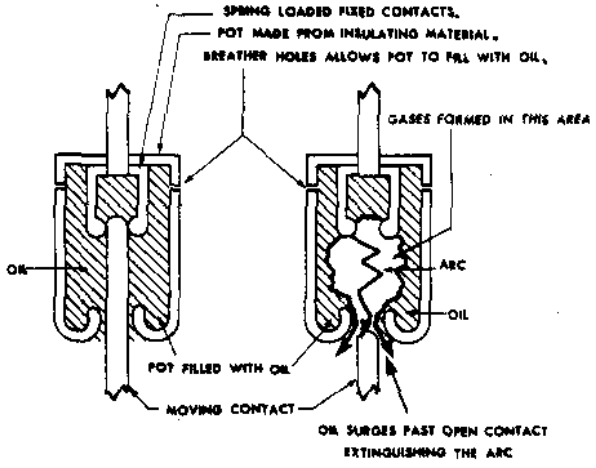


Figure 2(a):

Diagram Showing a Breaker Pot With Contacts in the Closed Position.

Figure 2(b):

Diagram Showing How the Arc is Extinguished In An Oil Circuit Breaker.

3.2 Problems with Oil Circuit Breakers

3.2.1 Oil Problems

(a) When oil is used for extinguishing arcs:

- **gases** are produced and must be vented from the breaker.

- **carbon particles** are also produced. These particles mix with the oil and after a time excessively contaminate the oil. Because carbon particles are conductive, for the oil to remain in good condition, it must be purified or changed at intervals dictated by the number of breaker operations. The breaker internal components will require periodic cleaning to remove the carbon particles which collect on insulating and other surfaces.

(b) Because of the **fire hazard** associated with oil, oil circuit breakers are installed outdoors.

(c) Care must also be taken to ensure that leaks are minimized and spills are immediately cleared up. Failure to do this will create an **environmental pollution** problem.

(d) The oil levels, in the main tanks of this type of breaker, require checking regularly. If the oil level is allowed to fall excessively, there is the danger that the breaker will have insufficient oil for current interruption and insulation purposes.

3.2.2 Compressed Air and Electrical Control Problems

Oil breakers operating at 230 kV are closed by energizing the closing coil which actuates an air valve. Compressed air is then applied to a piston which then closes the contacts and latches the breaker in the closed position. Tripping is done by energizing the trip coil which releases the latching mechanism causing the contacts to part rapidly.

If the pressure of the compressed air supply falls below a pre-determined pressure, the breaker closing will "lock out" and the breaker cannot be closed. An alarm will operate before the lock-out pressure is reached.

If the dc closing supply fails, the breaker cannot be closed. Similarly, if the tripping supply fails, the breaker cannot be tripped. The failure of the closing supply can lead to operational difficulties. The failure of the tripping supply can lead to a situation where plant that must be shut down cannot be shut down. Clearly this can cause or lead to a dangerous situation. Any defect on closing or tripping supplies requires immediate attention.

3.2.3 HV Bushings. The bushings (HV insulators) of an oil circuit breaker are filled with high purity insulating oil. The bushing oil levels are checked by observing the levels on the "goldfish bowls" at the top of each bushing. Note, this oil is separate from the oil in the breaker tank. Low oil levels indicate leakage. The breaker should not be energized if there is insufficient oil in the bushings. Failure to observe this precaution can lead to a short-circuit occurring within the bushing.

3.3 Electrical Ratings

Oil breakers, like other types of breakers have three main electrical ratings:

- voltage
- current (continuous)
- current (interrupting)

Again, like other types of breaker, exceeding the voltage rating may cause an electrical flash-over. Exceeding the continuous current rating will cause overheating which can lead to contact failure. If the interrupting current rating is exceeded, the breaker may not be able to interrupt the current and an explosion and an oil fire will follow.

4. AIR BLAST CIRCUIT BREAKERS

There are several manufactures of air blast circuit breakers. Each manufacturer produces a breaker (or breakers) which differ slightly from other types. However, there is one common factor, ie, a blast of dry compressed air is used to interrupt the current and blow out the arc.

Figure 3 shows the outlines of air blast circuit breaker. Mounted on the compressed air reservoir (pressure tank) are the hollow support insulators which carry the interruption heads and isolating chambers. The interrupting contacts in the interrupting heads interrupt the current. The isolating contacts in the isolating heads provide circuit isolation after the current has been interrupted. In this design, isolating contacts are necessary because the interrupting contacts re-close after they have interrupted the arc.

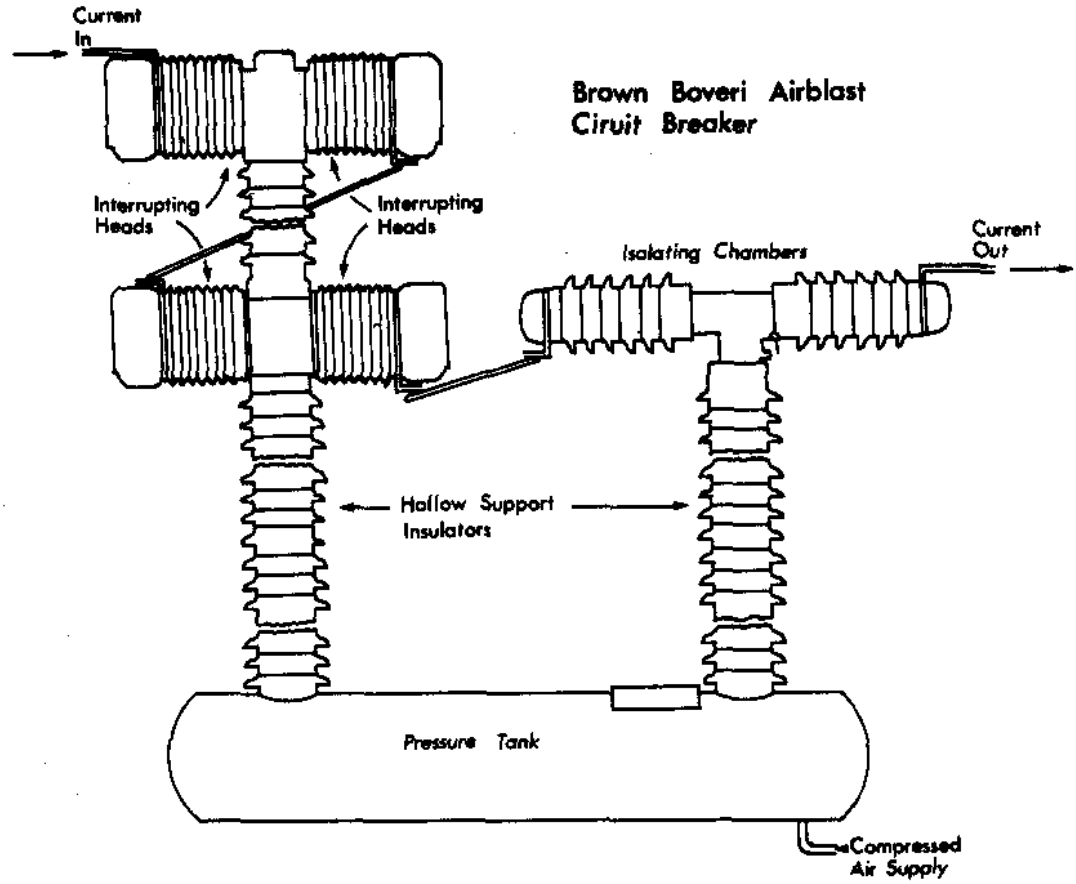


Figure 3: An Air Blast Circuit Breaker.

4.1 Principle of Operation

4.1.1 Opening Cycle. When a trip (open) signal is given to the breaker, the trip coil is energized which opens the blast valve allowing compressed air from the air pressure tank to enter the interrupting heads. The air pressure acts on the piston and forces the interrupting contacts apart and at the same time allows a blast of air to escape past the opening contacts, thus extinguishing the arc. See Figure 4(a), (b), and (c). Sometimes auxiliary tungsten tipped arcing contacts are fitted which prevent burning of the main contacts and, as with the air circuit breaker, concentrate any burning on a tungsten tip or tips which are resistant to arc damage.

After the arc has been interrupted (1-2 cycles), the blast valve closes and the air pressure in the interrupter falls to atmospheric. Due to spring action, the interrupting contacts re-close. To prevent the circuit from being re-energized, series isolating contacts, which are situated in the isolating heads, open just after the interrupting contacts have interrupted the current. These isolating contacts then, due to toggle and spring action, remain in the open position.

The clearances between the open isolating contacts are adequate to prevent a flashover at rated line voltages. However, it is possible that a high voltage surge (due to lightning for example) may cause a flashover between the isolating contacts. To guard against this happening, one of the series disconnect switches is automatically opened a few seconds after the breaker has been opened.

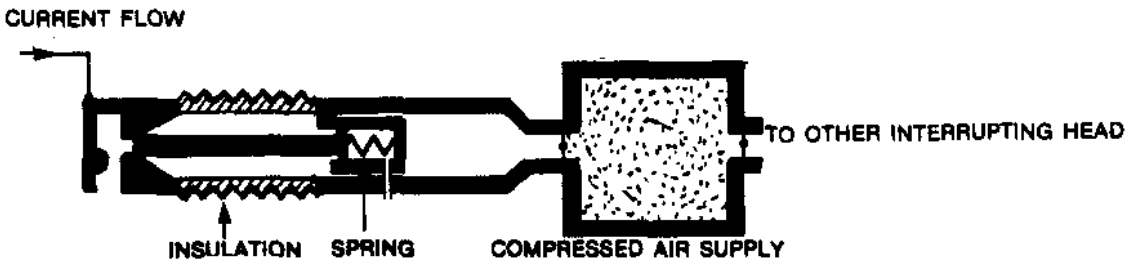


Figure 4(a): Air Blast Circuit Breaker Interrupting Head with the Contacts in the Closed Position.

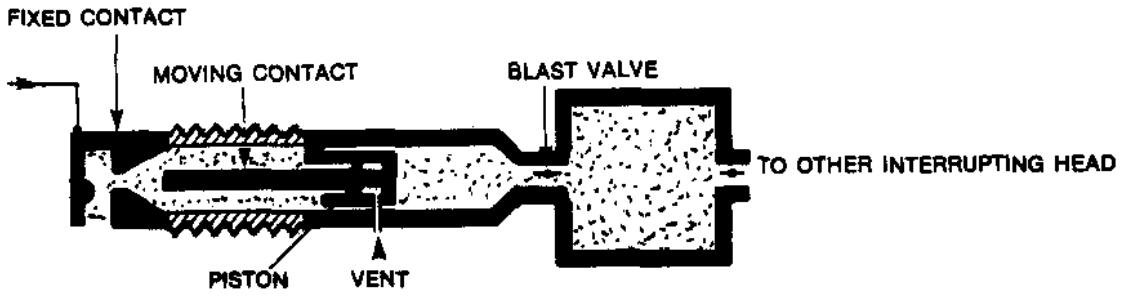


Figure 4(b): Air Blast Circuit Breaker Interrupting Head with the Contacts in the Open Position.

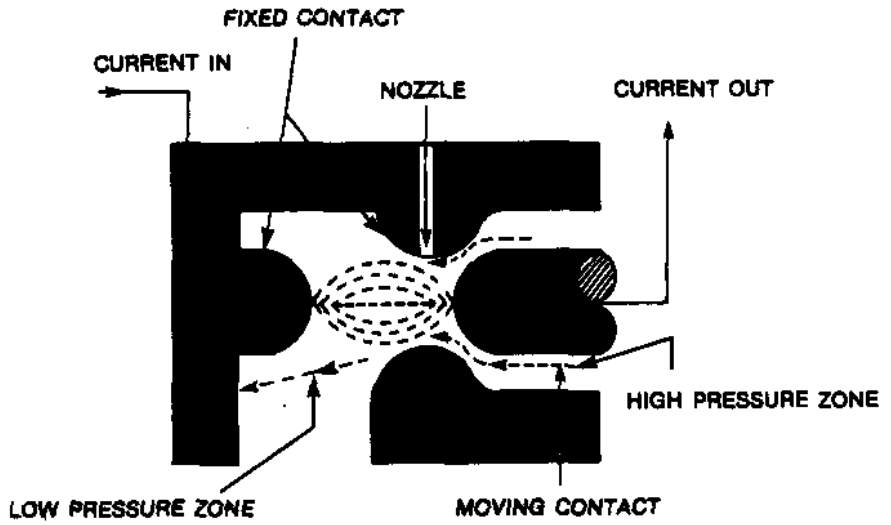


Figure 4(c): Diagram Showing How Air Blast Extinguishes the Arc.

4.1.2 Closing Cycle. Before closing the breaker, the operator must close the series disconnect switch which has previously been opened. The breaker is then closed by closing the isolating contacts.

4.2 Operating Sequence

The operating sequence of the interrupting and isolating contacts has to be exactly timed. Figures 5(a) to 5(f) detail this operating sequence. Note that there are resistors connected across each of the interrupting contacts. They are provided to ensure, while the interrupting contacts are open, equal voltage distribution occurs across each of the interrupting contacts. They also help to damp out transient voltages which are produced when inductive load currents are broken.

Breakers Closed

- In Figure 5(a), the breaker is shown closed. Both the interrupting and isolating contacts are closed.

Opening Cycle

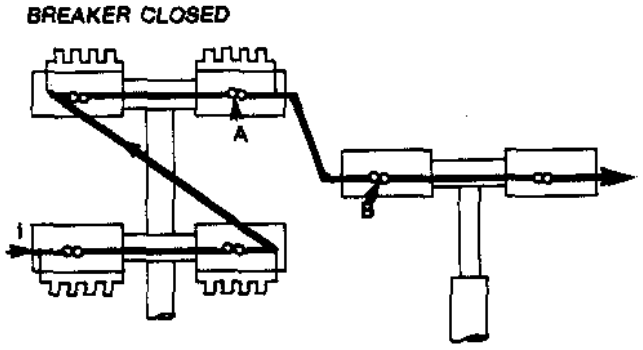
- In Figure 5(b), the load current has been interrupted by the interrupting contacts 'A'. The resistors are now in series with the isolating contacts. The value of the resistors is specified to limit the flow of the current to a small value, typically a few amperes.

- In Figure 5(c), the isolating contacts have interrupted the small value of current flowing through the resistors.

- In Figure 5(d), all the currents have been interrupted and all the contacts are open.

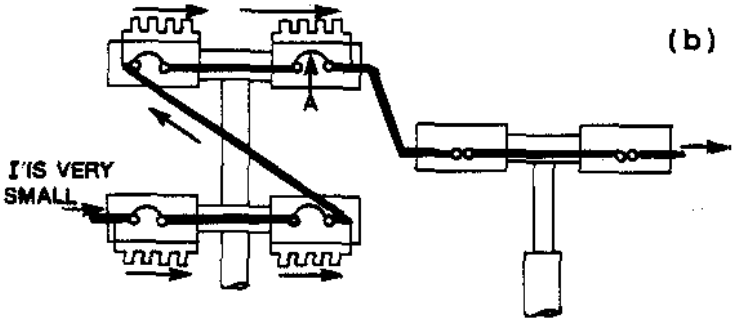
- In Figure 5(e), the interrupting contacts have re-closed. The circuit isolation is provided by the isolating contacts remaining open. (The series disconnect switch opens automatically.)

Breaker Closed

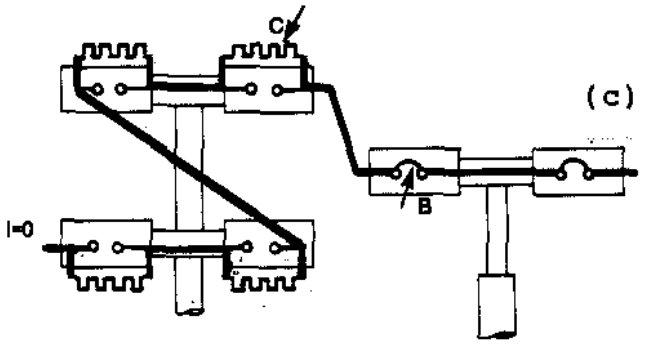


(a) Breaker Closed. Interrupting contacts 'A' and isolating contacts 'B' closed.

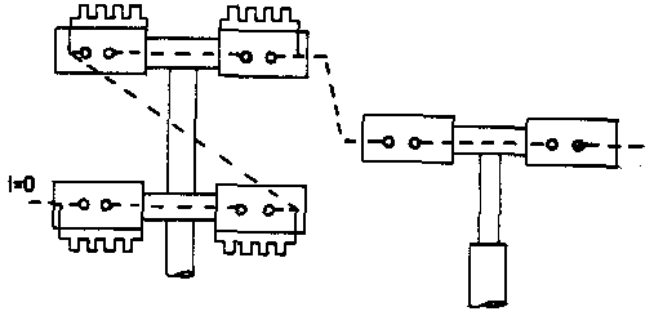
Opening Sequence



(b) Breaker opening: Stage 1. current interrupted by interrupting contacts 'A'. Resistors are now in series with the isolating contacts.

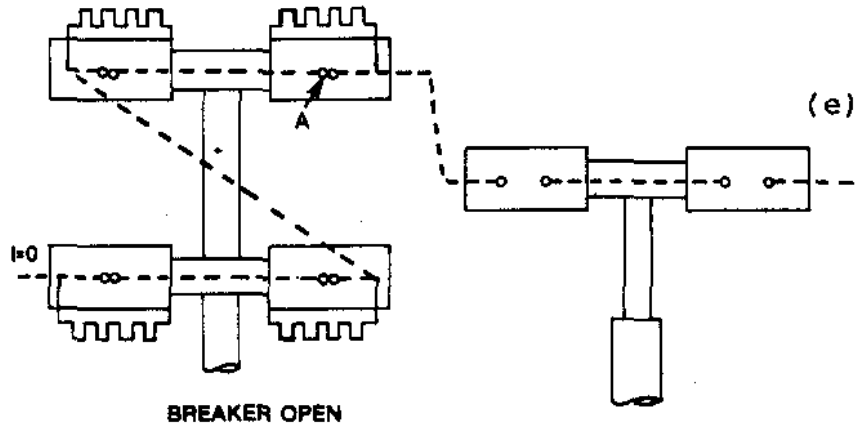


(c) Breaker opening: Stage 2. Isolating contacts interrupt the small value of current flowing through the resistors.



(d) Breaker opening: Stage 3. All currents have been interrupted. Note all contacts open.

Figure 5: Air Blast Circuit Breaker Operating Sequences.



(e) Breaker open. Interrupting contacts 'A' re-close, circuit isolation provided by isolating contacts remaining open.

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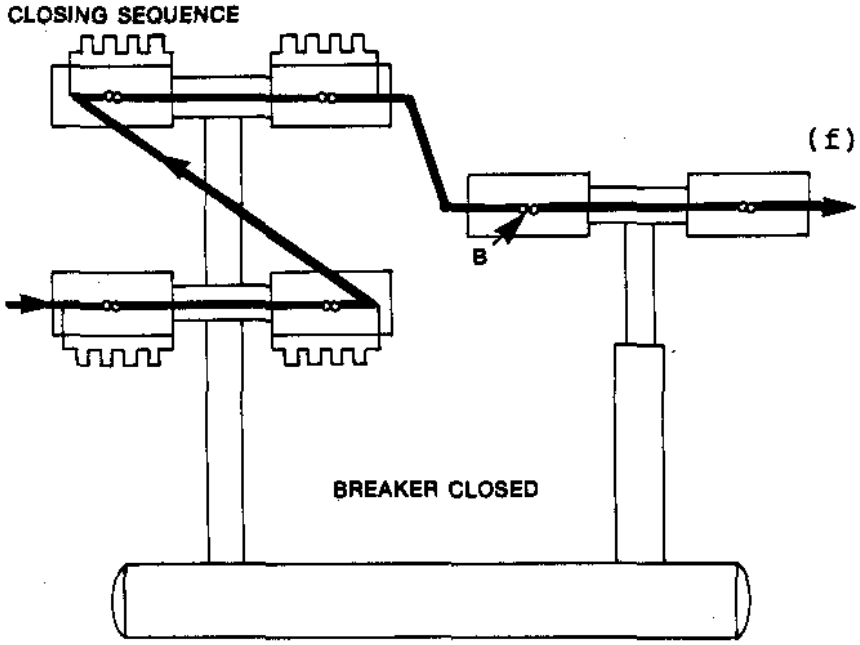
Closing Sequence



(f) Breaker re-closed. Closing is achieved by closing isolating contacts 'B'.

Figure 5 (Continued): Air Blast Circuit Breaker Operating Sequences.

4.3 Air Blast Circuit Breakers: Problems

4.3.1 Compressed Air Supplies. An air blast circuit breaker requires compressed air for operating the following:

(a) on the closing cycle: rapidly closing the isolating contacts.

(b) on the tripping cycle:

(i) rapidly opening the interrupting contacts, interrupting the current and extinguishing the arc.

(ii) opening the isolating contacts.

Clearly, the compressed air system must be highly reliable for the breaker to have a similar reliability. The compressed air must also be very dry. If the moisture content is higher than specified, due to the cooling which is produced when the air expands, ice would form and may jam the contacts and other mechanisms. Therefore, at all times, the compressed air system must be maintained at its specified pressure. It must also be kept at or below the specified moisture content by ensuring the dryers are working correctly.

If the air pressure, in the reservoir of an air blast circuit breaker, falls below the recommended working pressure and continues to fall (due to a leak for instance), then, in this order, the following will occur:

- the low air pressure alarm will be initiated.
- the closing lockout will be initiated. This will prevent breaker closing. (At this point the breaker can still be safely tripped.)
- the trip lockout alarm will be initiated.
- the trip lockout will be initiated. This will prevent breaker tripping.

4.3.2 DC Supplies. The dc closing and tripping supplies must be available at all times. If they fail, the breaker will remain in the open or closed position.

4.4 Electrical Ratings

Air blast circuit breakers have the same three main electrical ratings as oil and other circuit breakers, ie:

(a) Voltage,
(b) Current (continuous),
(c) Current (interrupting).

Exceeding any of these ratings will produce the same hazards as experienced with air circuit breakers. In addition, an explosion associated with an air blast circuit breaker is particularly dangerous. This is because of the large quantity of stored energy in the compressed air. This energy is rapidly released if the pressurized support insulators shatter.

ASSIGNMENT

1. For an oil circuit breaker,

   (a) State the purpse of the:

   (i) HV bushings (2 purposes),
   (ii) the oil (2 purposes),
   (iii) the pots (2 purposes).

   (Section 3.1)

   (b) State four problems associated with the oil. (Section 3.2.1)

   (c) Describe the normal operation of the breaker for:

   (i) the opening (tripping) cycle,
   (ii) the closing cycle.

   (Section 3.1.1)

   State why it is necessary to wait a few seconds between a trip and a re-closure. (Section 3.1.1)

   (d) State the problems which can occur with the closing and tripping circuits and mechanisms. (Section 3.2.2)

   (e) State:

   (i) the three electrical ratings,
   (ii) the consequences of exceeding these ratings.

   (Section 3.3)

2. For an air blast circuit breaker,

(a) State the purpose of:

(i) the compressed air tank, (Section 4)
(ii) the blast valve, (Section 4.1.1)
(iii) the interrupting heads, (Section 4.1.1 & 4.2)
(iv) the resistors connected across the interrupting heads,(Section 4.2)
(v) the isolating contacts. (Section 4.2)

(b) State the two problems associated with the compressed air supply and briefly explain how these problems are detected and corrected. (Section 4.3.1)

(c) Describe the normal operation of the breaker for:

(i) the opening (tripping) cycle, (Section 4.1.1 and 4.2)
(ii) the closing cycle. (Section 4.1.2)

(d) State the problems which can occur with the closing and tripping circuits. (Section 4.3.2)

(e) State:

(i) the three electrical ratings,
(ii) the consequences of exceeding these ratings.

(Section 4.4)

(f) State why, with air blast circuit breakers, a series disconnect switch is opened after the breaker has been tripped (opened). (Section 4.1.1)

J.R.C. Cowling