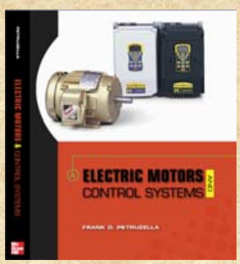
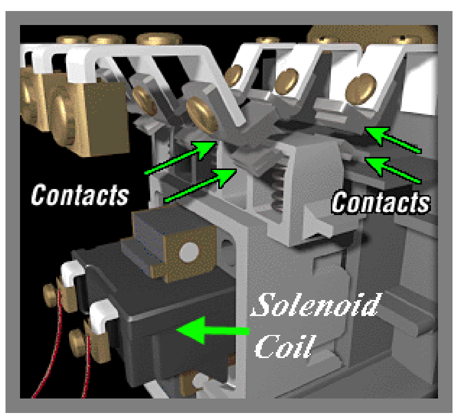


Chapter 6

Electric Motors

PART 1 Magnetic Contactor

NEMA defines a *magnetic contactor* as a magnetically actuated device for repeatedly establishing or interrupting an electric power circuit.



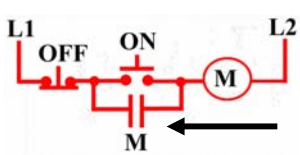
The magnetic contactor is similar in operation to the electromechanical relay.

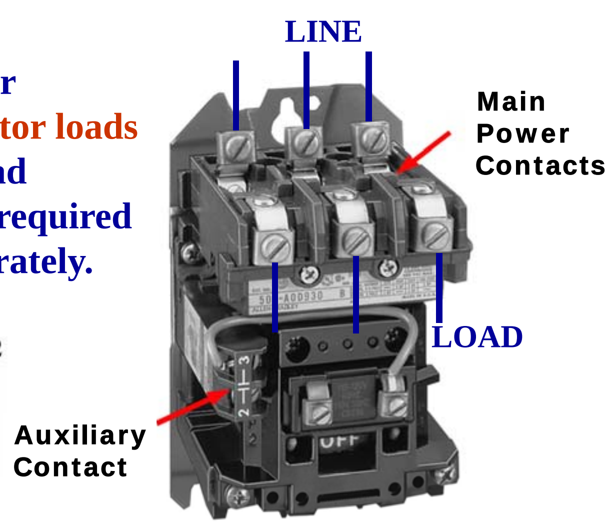
RELAY

CONTACTOR

Both have one important feature in common: contacts operate when the coil is energized. Generally, unlike relays, contactors are designed to make and break electric power circuit loads in excess of 15-amperes without being damaged.

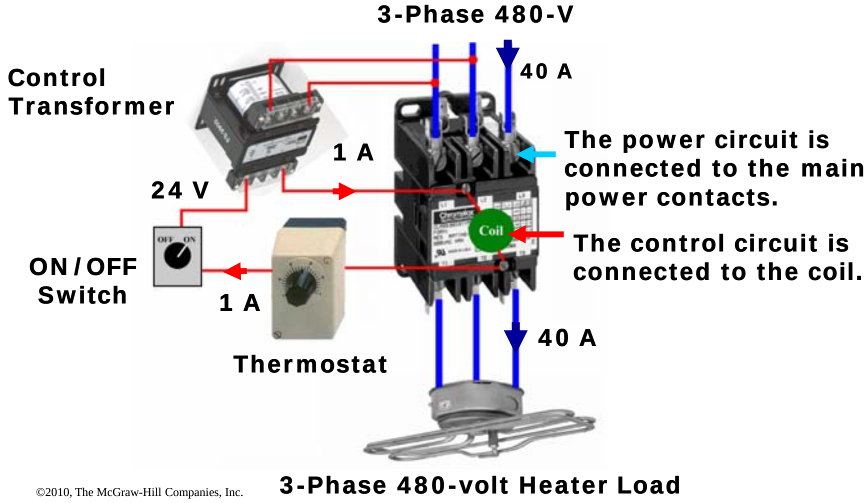
NEMA magnetic contactor used for switching AC motor loads for which overload protection is not required or provided separately.

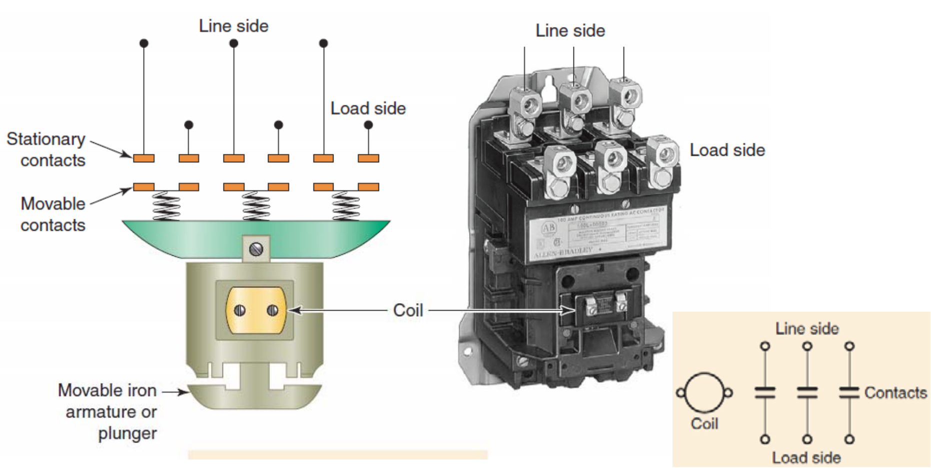




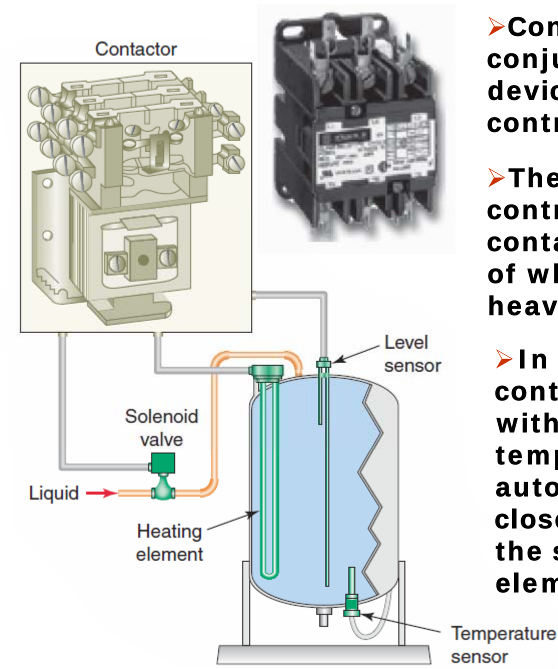
In addition to the three power contacts, one normally open auxiliary hold-in contact is provided to accommodate 3-wire push button control.

There are two circuits involved with the operation of a magnetic contactor, the *control* circuit and the *power* circuit.





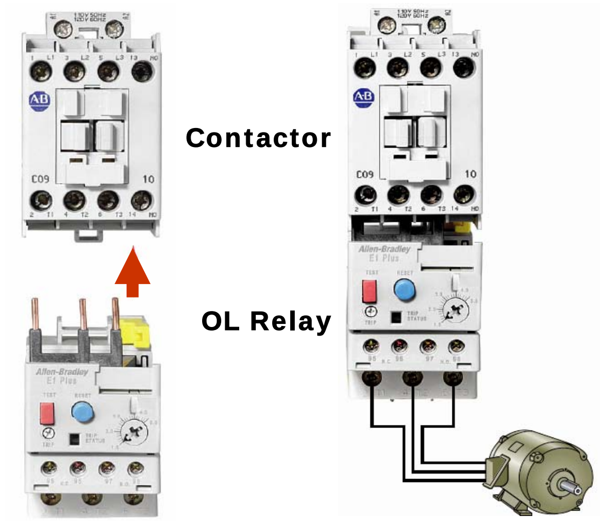
When voltage is applied to the coil it creates a magnetic field which magnetizes the stationary iron frame turning it into an electromagnet. The electromagnet draws the armature towards it pulling the movable and stationary contacts together. Power then flows through the contactor from the line side to the load side.

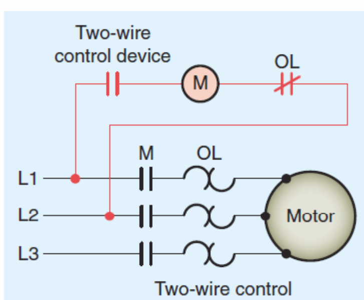


- Contactors are used in conjunction with pilot devices to automatically control high current loads.
- The pilot device is use to control current to the contactor coil, the contacts of which are used to switch heavier load currents.
- In this application the contactor coil connects with the level and temperature sensors to automatically open and close the power contacts to the solenoid and heating element loads.

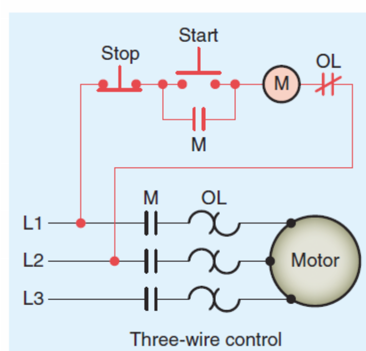
SWITCHING LOADS

Contactors may be used for switching motor loads when separate overload protection is provided.



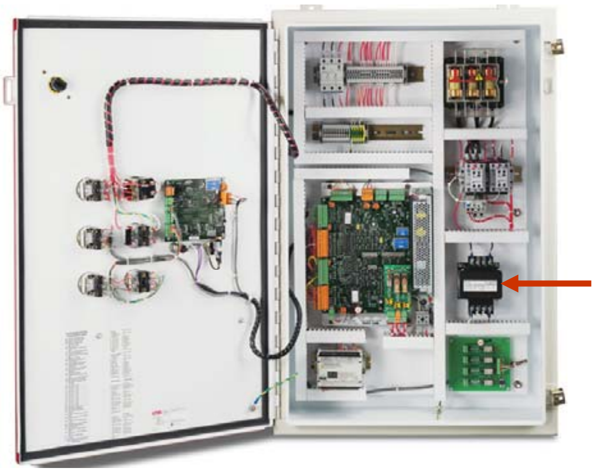


The two-wire control circuit is used in applications where the operation of a circuit is automatic. This may include such applications as pumps, electric heating, and air compressors where the pilot device starts the motor automatically as needed.



Three-wire control uses an extra set of contacts to seal it in the circuit. The most common application is a motor controlled by momentary start/stop push buttons.

High voltage may be handled by the contactor and kept entirely away from the operator, thus increasing the safety of an installation.

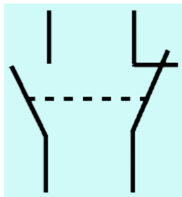


When this is the case a **step-down control transformer** is used to lower the AC voltage level required for the control circuit.

The *auxiliary contacts* of a contactor have a much lower current rating than the main contacts and are used in control circuits for interlocking, holding, and status indication.

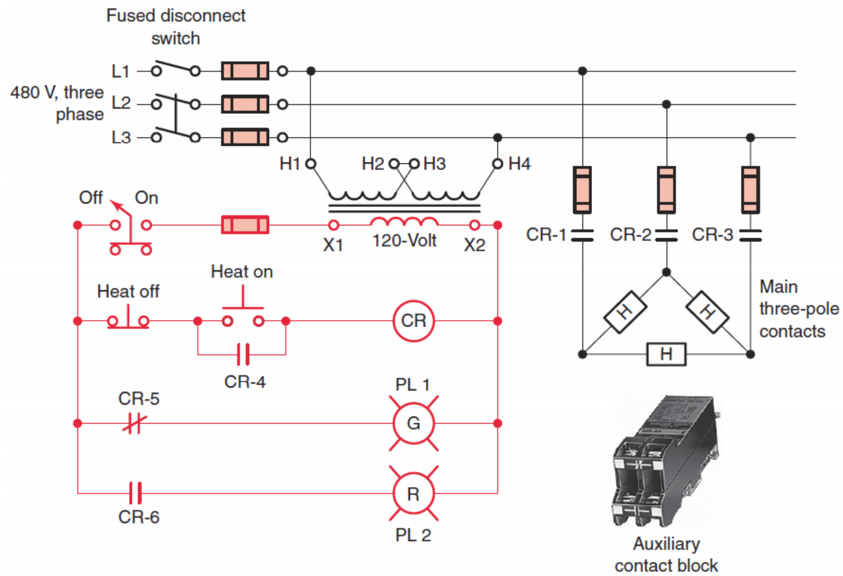
IEC Contactor

Auxiliary Contact Block

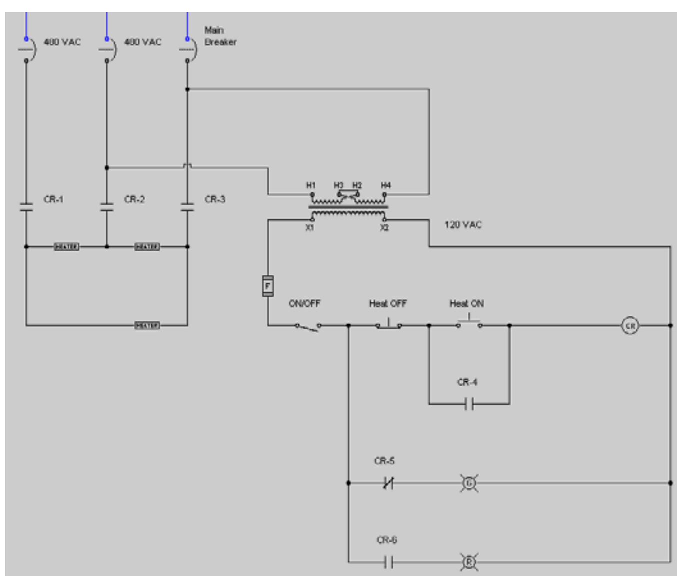


IEC Auxiliary Contact Symbol

Heater Circuit Controlled By A Magnetic Contactor



Simulated Heater Circuit



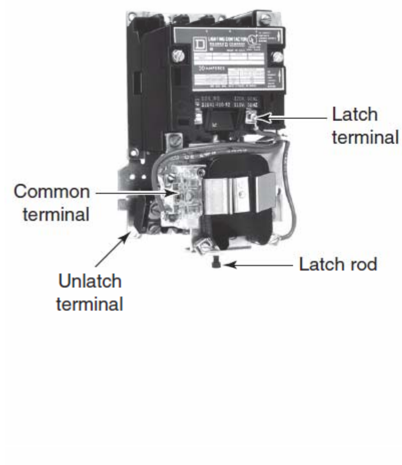
Definite purpose contactors are specifically designed for applications such as lighting.

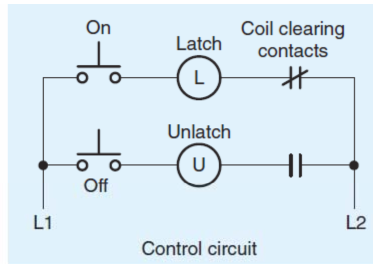
Contactors may be electrically held or mechanically held.

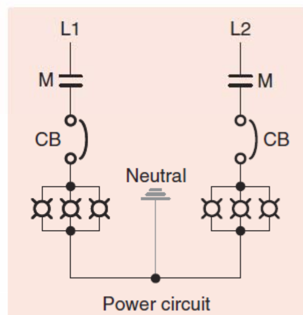
With an electrically held contactor the coil needs to be energized continuously all the time the main contacts are closed.

Mechanically held **contactors require only a pulse of coil current to change state. Once changed a mechanical latch holds the main contacts in place so the control power can be removed.**

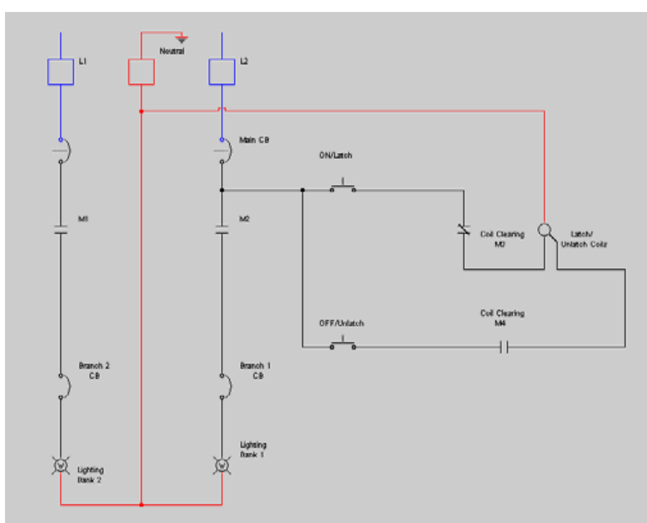
Dual Coil Mechanically Held Lighting Contactor Circuit



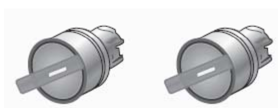


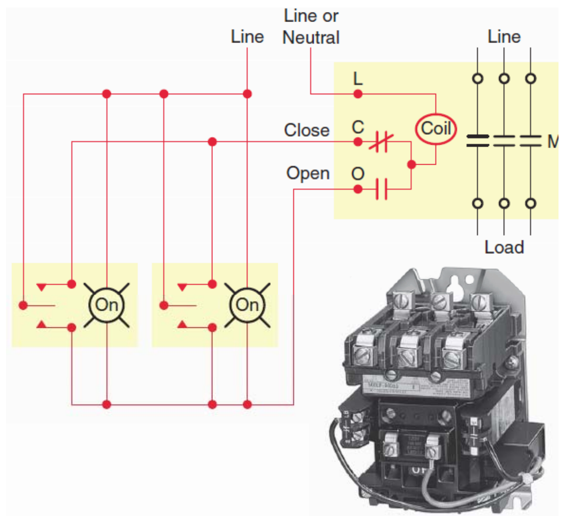


Simulated Dual Coil Mechanically Held Lighting Contactor Circuit



Mechanically held lighting contactor that has a *single operating coil* that is momentarily energized to either close or open the contactor.



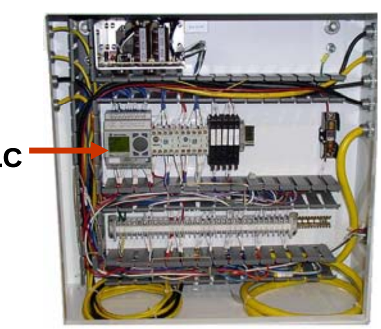


A wide variety of automatic control devices can interface with the contactor as well.

LIGHT SENSOR

MOTIO
N
SENSOR

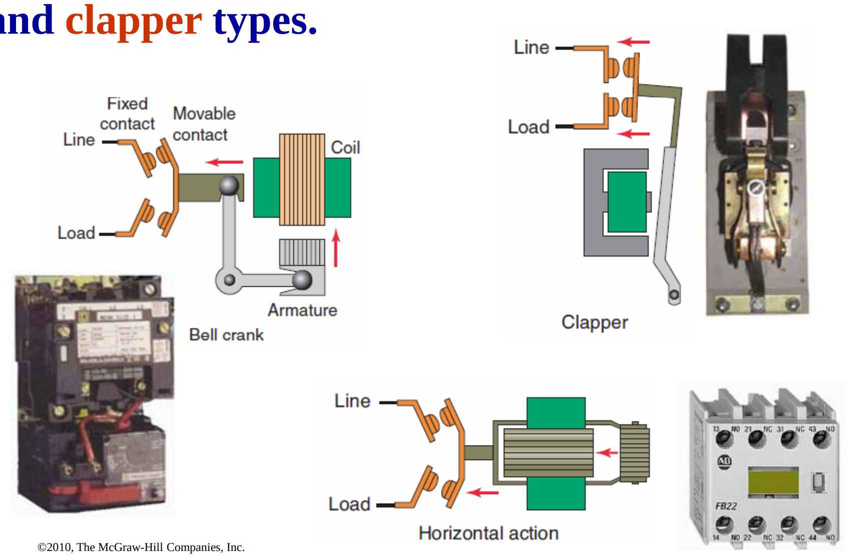
PLC



ENERGY MANAGEMENT CONTROLLER

CONTACTOR ASSEMBLIES

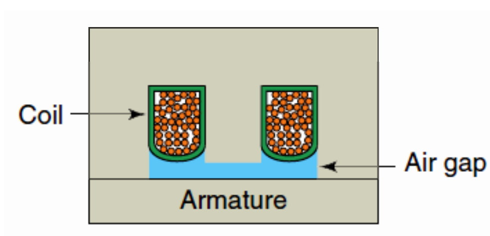
Typical operating mechanisms for magnetic contactors include bell-crank, horizontal-action, and clapper types.



The contactor coil is molded into an epoxy resin to increase moisture resistance and coil life.

Encapsulated Coil

Shape varies as a function of the type of contactor.



A permanent air gap between in the magnetic circuit in the closed state prevents the armature from being held in by residual magnetism.

To measure the coil resistance disconnect one of the coil leads and measure the resistance. A defective coil will read zero or infinity, indicating a short or opened coil respectively.

AC Operating Coils	
Voltage (V)	Frequency (Hz)
24	50
	60
115...120	60
110	50
110...115	50
200...208	60
208	60
220	50

As contactors are used to control different line voltages, when selecting coils you must choose one that matches the available control voltage.

Magnetic Coil Specifications

Rated voltage **refers to the coil supply voltage and must match that of the control circuit power source.**

Pick-up voltage **is the amount of voltage required to overcome the mechanical forces, like gravity and spring tension, trying to keep the contacts from closing.**

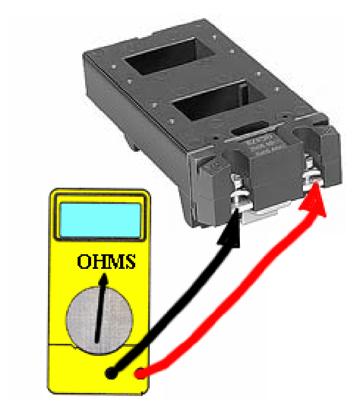
Hold-in voltage **is the amount of voltage needed to maintain the contacts in their closed position after pick-up voltage is reached (hold-in voltage is normally less than pick-up voltage).**

Drop-out voltage **is the amount of voltage below which the magnetic field becomes too weak to maintain the contacts in their closed position.**

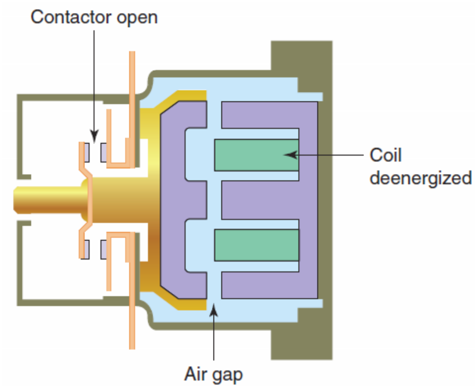
AC and DC contactor coils with the same voltage ratings are not interchangeable.

With a DC coil only the wire ohmic resistance limits the current flow, whereas with AC coils both resistance and reactance (impedance) limits the current flow.

Direct current contactor coils have a large number of turns and a high ohmic resistance compare to their AC counterpart.

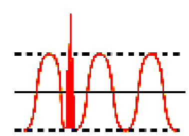


For a DC operated coil, since current is limited by resistance only, the current flow through the coil upon closing is the same as the normal energized current flow. However, this is not the case when the coil is AC operated.



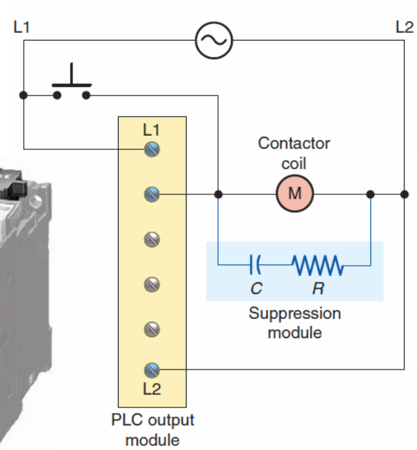
- With a de-energized AC coil, part of the magnetic path has an air gap because the armature is not pulled in.
- When the contactor closes, the armature closes the magnetic path causing the inductive reactance of the coil to increase and the current to decrease.
- This results in a high current to close the contactor and low current to hold it. The in-rush current for an AC coil may range from 5 to 20 times that of the sealed current.

When current in an inductive load, such as a contactor coil, is turned off, a very high voltage spike is generated.



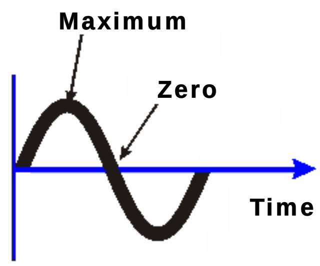
If not suppressed, these voltage spikes can reach several thousand volts and produce surges of damaging currents. This is especially true for applications requiring interface with solid-state components such as PLC modules.

Suppression Module

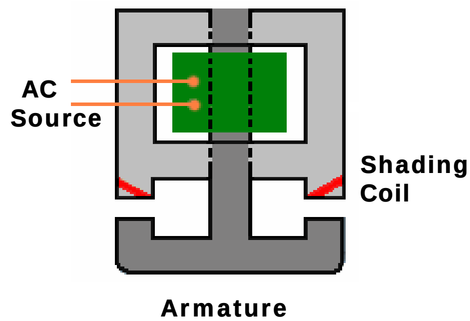


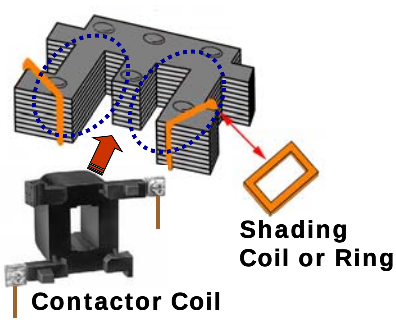
Contactor

AC operated contactor coils experience changes in the magnetic field surrounding them. As the current goes through zero, the magnetic force decreases, and tends to drop the armature out.



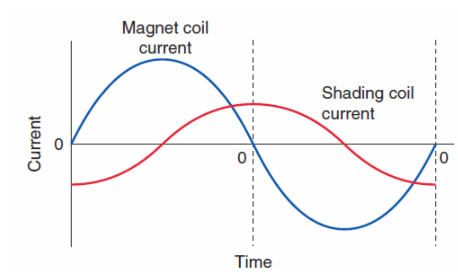
When the current increases the armature is pulled back in. This motion of the armature, in and out, makes the contactor **buzz or chatter** creating a humming noise and wear on the contactor's moving parts. This noise and wear can be prevented by the use of **shading coils or rings.**

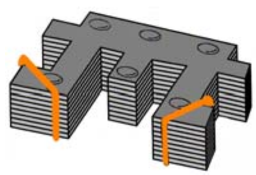




Shading coils are not electrically connected to the power source, but mounted to inductively couple with the contactor coil.

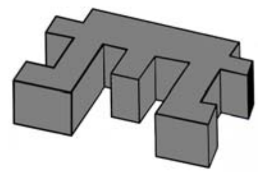
The shading coil sets up an **auxiliary magnetic attraction** that is **out of phase** with the main field and of sufficient strength to hold the armature tight to the core even though the main magnetic field has reached zero on the sine wave.



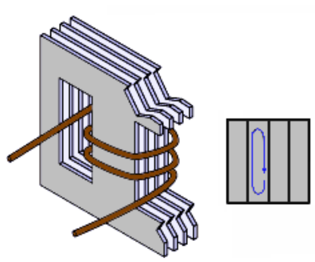


AC Assembly

The core and armature of AC contactor assemblies are made of laminated steel, whereas DC assemblies are solid.

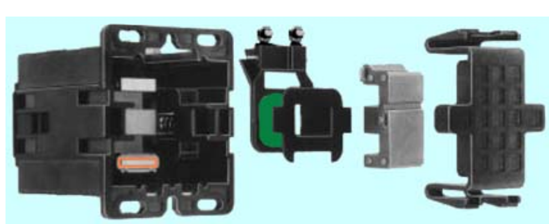


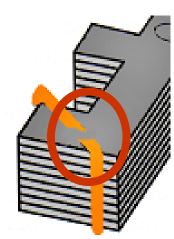
DC Assembly



DC assemblies are solid due to the lack of induced eddy currents. Using a solid iron core for AC assemblies would result in a large induced circulating current flow. So, instead, with AC coils the core is made up of a stack of thin insulated laminations designed to contain and reduce the amount of eddy curent flow.

Misalignment or obstruction of the armature's ability to properly seat when energized causes increased current flow and hum in an AC coil.

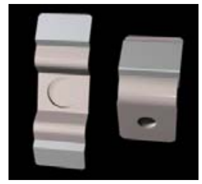




Depending on the amount of increased current, the coil may merely run hot, or it may burn out if the current increase is large enough and remains for a sufficient length of time.

A louder hum will occur if the shading coil is broken because the electromagnet will cause the contactor to chatter.

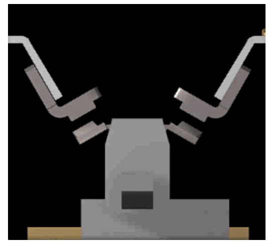
Most contacts are made of a low-resistance silver alloy. Silver contacts are used because they ensure a lower contact resistance than other less expensive material.

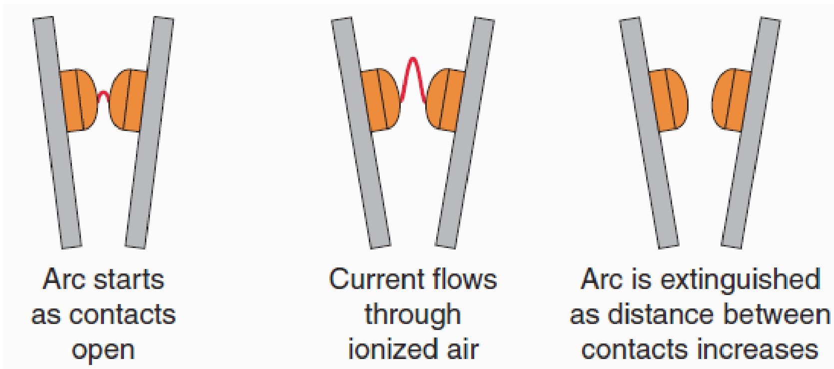


Often silver inserts are welded on copper contacts so silver carries the current and copper carries the arc on interruption. Most manufacturers recommend that silver contacts ***never* be filed** as the black discoloration that appears is silver oxide, which is a relatively good conductor.

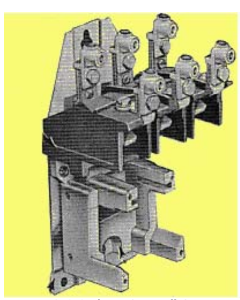
ARC SUPPRESSION

One of the main reasons contacts wear is the electric arc that occurs when contacts are opened under load.

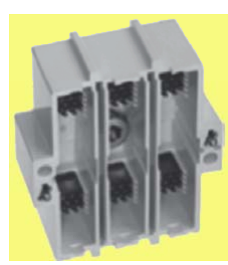




Arc current can create a substantial temperature rise on the surface of the contacts causing them to become molten and emit vaporized metal into the gap between the contacts.



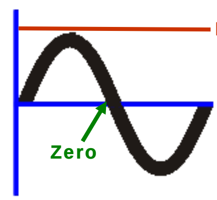
The sooner the arc is extinguished the better as that if allowed to continue the hot arc will melt the contact surface. Most contactors contain some type of arc chamber to help extinguish the arc.



Factors That Contribute To Contact Arcing

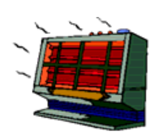
Level of voltage and current being switched. **As circuit voltage and current increases the gap between the opening contacts ionizes more rapidly into a conductive path.**

***Whether the voltage being switched is AC or DC*. DC arcs are considerably more difficult to extinguish than AC arcs. An AC arc is self-extinguishing, as the arc will normally extinguish as the AC cycle passes through zero.**



The type of load (resistive versus inductive). **With resistive loads the duration of the arc is primarily determined by the speed at which the contacts separate. With inductive loads the release of stored energy built up in the magnetic field serves to maintain the current and cause voltage spikes. Inductive loads in AC circuits are less of a problem than in DC circuits.**

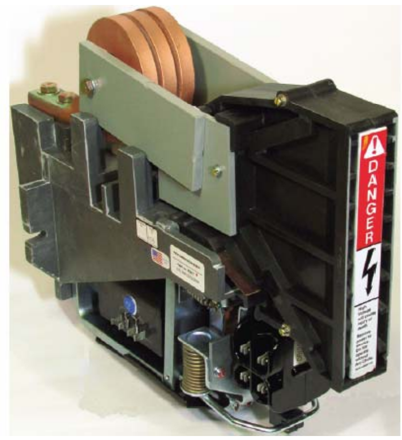
Inductive



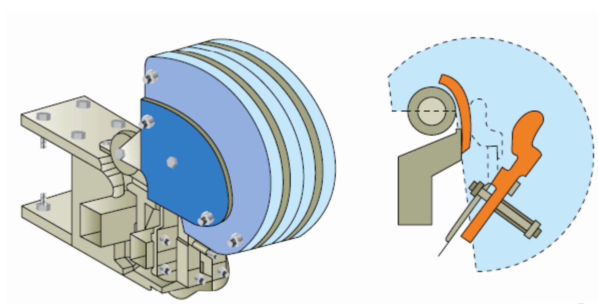
Resistive

***How quickly the contactor operates*. The faster the speed of contact separation the quicker the arc will be extinguished**

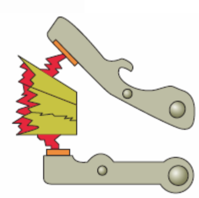
DC contactor switching mechanisms are constructed so that the contacts will separate rapidly and with enough air gap to extinguish the arc as soon as possible on opening. DC contactors are larger than equivalently rated AC types to allow for the additional air gap



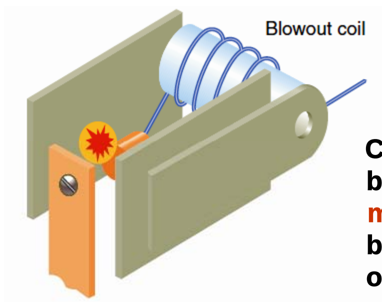
An arc chute or shield is a device designed to help confine, divide, and cool an arc, resulting in the arc being unable to sustain itself.



Arc chutes split the arc established at contactor tips while breaking the current to quench the arc. In addition, they also provide phase barriers between phases.



In addition to an arc chutes, most DC contactors use a magnetic blowout coil to assist with arc suppression. Blowout coils consist of heavy copper coils mounted above the contacts and connected in series with them.



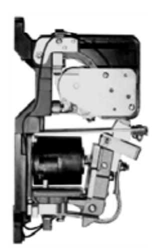
Current flow through the blowout coil sets up a magnetic field between the breaking contacts that blows out the arc.

Contactor Maintenance

Blowout coils seldom wear out or give trouble when operated within their voltage and current ratings.

Arc chutes are constantly subjected to the intense heat of arcing and may eventually burn away, allowing the arc to short-circuit to the metal blowout pole pieces. They should be inspected regularly and replaced before they burn through.

Large contactors should be checked periodically for contact wear, contact wipe, shunt terminal connections, free movement of the armature, blowout structure, blowout coil connections, coil structure, correct contact spring tension, and correct air gap.



Normally the **slight rubbing action** and burning that occur during normal operation keep the contact surfaces clean for proper operation. Copper contacts, still used on some contactors, should be cleaned to reduce contact resistance.

Worn contacts should always be replaced in pairs to ensure that complete and proper surface contact is maintained. High contact resistance produces causes overheating of contacts as well as a significant voltage drop across the contacts resulting in less voltage being delivered to the load.

A vacuum contactor switches power contacts inside a sealed vacuum bottle.

The vacuum provides a better environment than free air for breaking the arc because without air to ionize, the arc extinguishes more quickly. Housed in vacuum bottles, the arc is isolated and the contacts are protected from dust and corrosion.

Vacuum contactors offer a significantly higher electrical endurance and are the preferred switching devices in applications with a high switching frequency, for heavy-duty starting and for line voltages above 600-volts.