

ELECTRIC MOTOR CONTROLS

Once the proper motor is selected, understanding the many various control devices available and their uses and limitations becomes an important part related to reliable operation and protection of the motor and the personnel using the motor.

Motor Control Topics

There are four major motor control topics or categories to consider. Each of these has several subcategories and sometimes the subcategories overlap to some extent. Certain pieces of motor control equipment can accomplish multiple functions from each of the topics or categories.

C The four categories include:

1) Starting the Motor

Disconnecting Means
Across the Line Starting
Reduced Voltage Starting

2) Motor Protection

Overcurrent Protection
Overload Protection
Other Protection (voltage, phase, etc)
Environment

3) Stopping the Motor

Coasting
Electrical Braking
Mechanical Braking

4) Motor Operational Control

Speed Control
Reversing
Jogging
Sequence Control

- An understanding of each of these areas is necessary to effectively apply motor control principles and equipment to effectively operate and protect a motor.

MOTOR STARTING

All motors must have a control device to start and stop the motor called a “motor controller”.

Motor Controller

A motor controller is the actual device that energizes and de-energizes the circuit to the motor so that it can start and stop.

- Motor controllers may include some or all of the following motor control functions:
 - starting, stopping, over-current protection, overload protection, reversing, speed changing, jogging, plugging, sequence control, and pilot light indication.
 - Controllers range from simple to complex and can provide control for one motor, groups of motors, or auxiliary equipment such as brakes, clutches, solenoids, heaters, or other signals.

Motor Starter

The starting mechanism that energizes the circuit to an induction motor is called the “starter” and must supply the motor with sufficient current to provide adequate starting torque under worst case line voltage and load conditions when the motor is energized.

- There are several different types of equipment suitable for use as “motor starters” but only two types of starting methods for induction motors:
 1. Across the Line Starting
 2. Reduced Voltage Starting

Across the Line Starting of Motors

Across the Line starting connects the motor windings/terminals directly to the circuit voltage “across the line” for a “full voltage start”.

- This is the simplest method of starting a motor. (And usually the least expensive).
- Motors connected across the line are capable of drawing full in-rush current and developing maximum starting torque to accelerate the load to speed in the shortest possible time.
- All NEMA induction motors up to 200 horsepower, and many larger ones, can withstand full voltage starts. (The electric distribution system or processing operation may not though, even if the motor will).



Across the Line Starters

There are two different types of common “across the line” starters including

1. Manual Motor Starters
2. Magnetic Motor Starters

Manual Motor Starters

A manual motor starter is package consisting of a horsepower rated switch with one set of contacts for each phase and corresponding thermal overload devices to provide motor overload protection.

- The main advantage of a manual motor starter is lower cost than a magnetic motor starter with equivalent motor protection but less motor control capability.
- Manual motor starters are often used for smaller motors - typically fractional horsepower motors but the National Electrical Code allows their use up to 10 Horsepower.
- Since the switch contacts remain closed if power is removed from the circuit without operating the switch, the motor restarts when power is reapplied which can be a safety concern.
- They do not allow the use of remote control or auxiliary control equipment like a magnetic starter does.

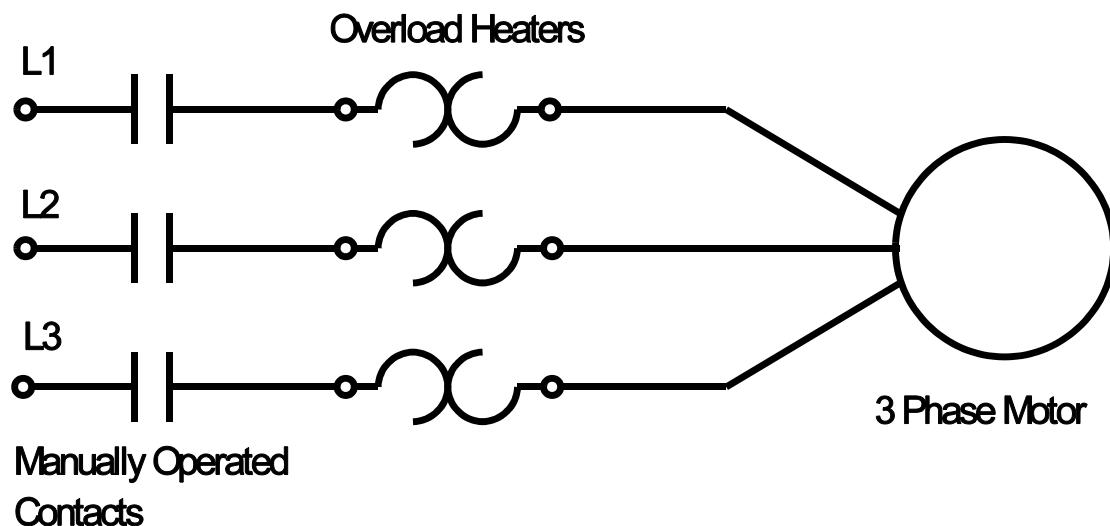


Figure 26. Manual Starter

Magnetic Motor Starters

A magnetic motor starter is a package consisting of a contactor capable of opening and closing a set

of contacts that energize and de-energize the circuit to the motor along with additional motor overload protection equipment.

- C Magnetic starters are used with larger motors (required above 10 horsepower) or where greater motor control is desired.
- The main element of the magnetic motor starter is the contactor, a set of contacts operated by an electromagnetic coil.
 - Energizing the coil causes the contacts (A) to close allowing large currents to be initiated and interrupted by a smaller voltage control signal.
 - The control voltage need not be the same as the motor supply voltage and is often low voltage allowing start/stop controls to be located remotely from the power circuit.

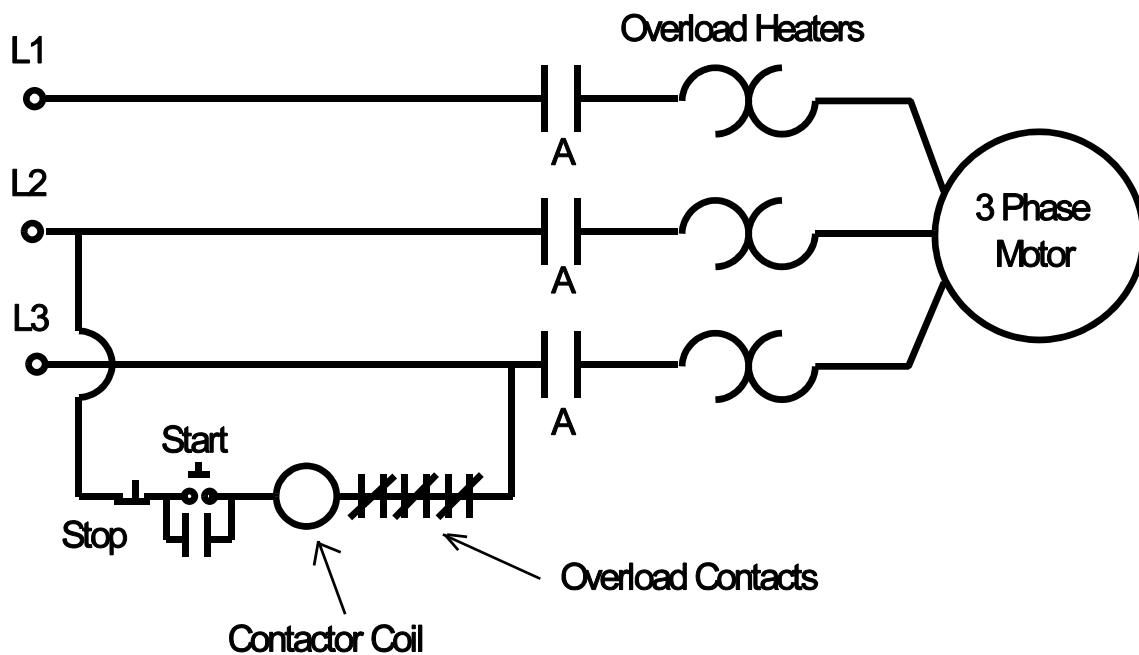


Figure 27. Magnetic Starter

- Closing the Start button contact energizes the contactor coil. An auxiliary contact on the contactor is wired to seal in the coil circuit. The contactor de-energizes if the control circuit is interrupted, the Stop button is operated, or if power is lost.
- The overload contacts are arranged so an overload trip on any phase will cause the contactor to open and de-energize all phases.

Reduced Voltage Starting of Motors

Reduced Voltage Starting connects the motor windings/terminals at lower than normal line voltage during the initial starting period to reduce the inrush current when the motor starts.

- Reduced voltage starting may be required when:
 - The current in-rush from the motor starting adversely affects the voltage drop on the electrical system.
 - needed to reduce the mechanical “starting shock” on drive-lines and equipment when the motor starts.
- Reducing the voltage reduces the current in-rush to the motor and also reduces the starting torque available when the motor starts.
- All NEMA induction motors can will accept reduced voltage starting however it may not provide enough starting torque in some situations to drive certain specific loads.

If the driven load or the power distribution system cannot accept a full voltage start, some type of reduced voltage or "soft" starting scheme must be used.

- Typical reduced voltage starter types include:
 1. Solid State (Electronic) Starters
 2. Primary Resistance Starters
 3. Autotransformer Starters
 4. Part Winding Starters
 5. Wye-Delta Starters

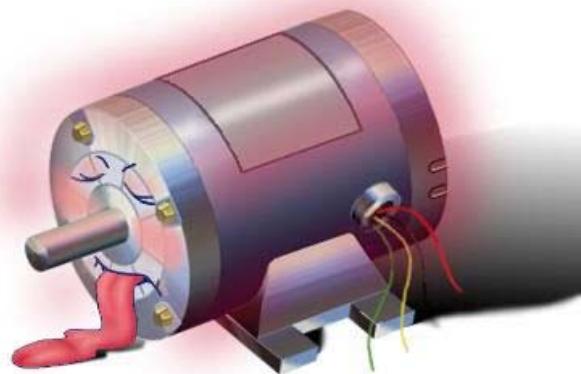
Reduced voltage starters can only be used where low starting torque is acceptable or a means exists to remove the load from the motor or application before it is stopped.

MOTOR PROTECTION

Motor protection safeguards the motor, the supply system and personnel from various operating conditions of the driven load, the supply system or the motor itself.

C Motor protection categories include

- Overcurrent Protection
 - Overload Protection
 - Other Types of Protection.
- The National Electrical Code requires that motors and their conductors be protected from both overcurrent and overload conditions.



Overcurrent Protection

Overcurrent protection interrupts the electrical circuit to the motor upon excessive current demand on the supply system from either short circuits or ground faults.

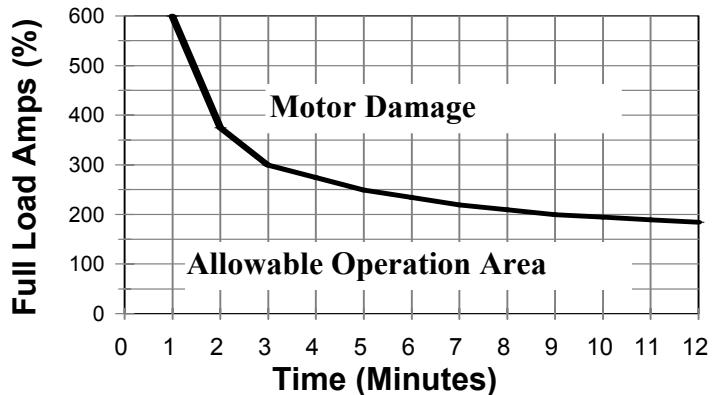
- Overcurrent protection is required to protect personnel, the motor branch circuit conductors, control equipment, and motor from these high currents.
- Overcurrent protection is usually provided in the form of fuses or circuit breakers. These devices operate when a short circuit, ground fault or an extremely heavy overload occurs.
- Most overcurrent sources produce extremely large currents very quickly.

Overload Protection

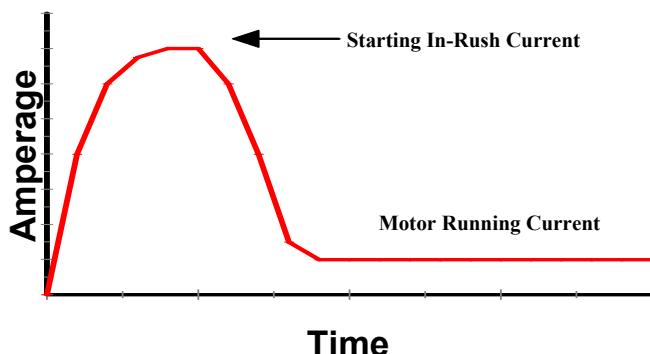
Overload protection is installed in the motor circuit and/or motor to protect the motor from damage from mechanical overload conditions when it is operating/running.

- The effect of an overload is an excessive rise in temperature in the motor windings due to current higher than full load current.
 - C Properly sized overload protection disconnects the motor from the power supply when the heat generated in the motor circuit or windings approaches a damaging level for any reason.
 - The larger the overload, the more quickly the temperature will increase to a point that is damaging to the insulation and lubrication of the motor.
 - C Unlike common instantaneous type fuses and breakers, overload devices are designed to allow high currents to flow briefly in the motor to allow for:
 - C Typical motor starting currents of 6 to 8 times normal running current when starting.
 - C Short duration overloads such as a slug of product going through a system.
 - If the motor inlets and outlets are covered by a blanket of lint or if a bearing should begin to lock, excessive heating of the motor windings will “overload” the motors insulation which could damage the motor.
5. The overcurrent device will not react to this low level overload. The motor overload device prevents this type of problem from severely damaging the motor and also provide protection for the circuit conductors since it is rated for the same or less current as the conductors.
- Overload protection trips when an overload exists for more than a short time. The time it takes for an overload to trip depends on the type of overload device, length of time the overload exists, and the ambient temperature in which the overloads are located.

Motor Heating Curve



Motor Current Draw



Other Motor Protection Devices

Low Voltage Protection

Low Voltage Disconnects - Protection device operates to disconnect the motor when the supply voltage drops below a preset value. The motor must be manually restarted upon resumption of normal supply voltage.

Low Voltage Release - Protection device interrupts the circuit when the supply voltage drops below a preset value and re-establishes the circuit when the supply voltage returns to normal.

Phase Failure Protection

Interrupts the power in all phases of a three-phase circuit upon failure of any one phase.

- C Normal fusing and overload protection may not adequately protect a polyphase motor from damaging single phase operation. Without this protection, the motor will continue to operate if one phase is lost.
- C Large currents can be developed in the remaining stator circuits which eventually burn out.
- C Phase failure protection is the only effective way to protect a motor properly from single phasing.

Phase Reversal Protection

Used where running a motor backwards (opposite direction from normal) would cause operational or safety problems.

- C Most three phase motors will run the opposite direction by switching the connections of any two of the three phases.
- C The device interrupts the power to the motor upon detection of a phase reversal in the three-phase supply circuit.
- C This type of protection is used in applications like elevators where it would be damaging or dangerous for the motor to inadvertently run in reverse.

Ground Fault Protection

- C Operates when one phase of a motor shorts to ground preventing high currents from damaging the stator windings and the iron core.

Other Motor Protection Devices

Bearing Temperature Monitors & Protection
Winding Temperature Monitors & Protection Devices
Current Differential Relays (Phase Unbalance)
Vibration Monitors & Protection

Sizing Motor Overcurrent Protection

Circuit overcurrent protection devices must be sized to protect the branch-circuit conductors and also allow the motor to start without the circuit opening due to the in-rush current of the motor.

National Electrical Code Procedures

Use the NEC motor current tables to find the design Full Load Current or FLA (adjusted for Service Factor) unless it is not available.

- C For Single Phase Motors: Use NEC Table 430-148
- C For Three Phase Motors: Use NEC Table 430-150

- These values are about 10% higher than what a typical motor would draw at full load to allow for bearing wear in the motor and load, etc.
- C The values in the NEC tables will allow for replacement of the motor in the future without having to replace the circuit conductors or overcurrent devices.

Types of Overcurrent Devices - NEC TABLE 430-152

Selection of the size of the overcurrent protection device is made using NEC Table 430-152 which lists information for four types of devices:

- 1) Standard (non-time delay) Fuses
 - 2) Time-Delay (dual element) Fuses
 - 3) Instantaneous Trip Circuit Breaker
 - 4) Inverse Time Circuit Breaker
- The table is used to size the device above normal starting current levels of most motors allowing them to start and run without tripping the overcurrent protection device.

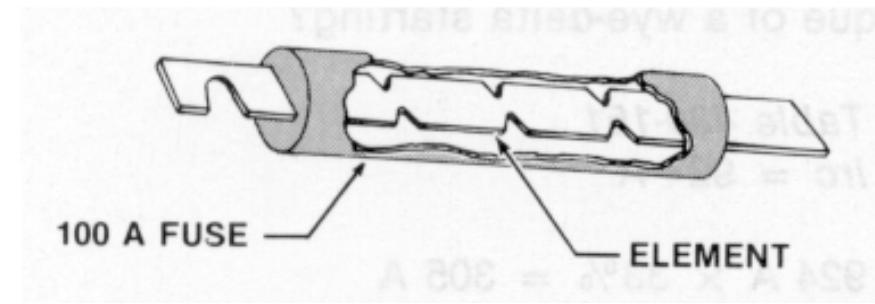
NEC TABLE 430-152: Maximum Rating of Motor Short-Circuit Protective Devices

% of Motor FLA				
Type of Motor	Non-Time Delay Fuse	Time Delay Fuse	Instantaneous Trip Breaker	Inverse Time Circuit Breaker
Single Phase	300	175	800	250
3 Phase Induction	300	175	800	250
Synchronous	300	175	800	250
Wound Rotor	150	150	800	150
Direct Current	150	150	200	150

- C Exceptions allow use of the next larger size until the motor will start if in-rush current is a problem.

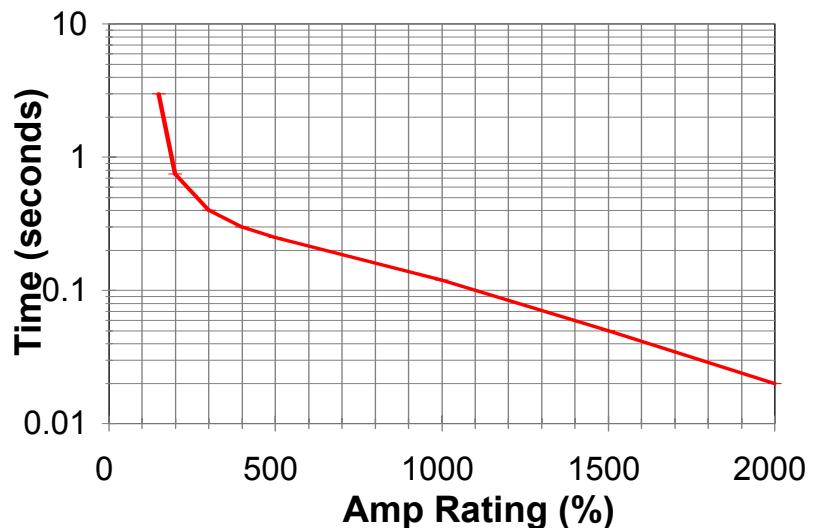
Standard (Non-Time Delay, Single Element) Fuses

Standard fuses protect against short circuits and ground faults using thermal features to sense a heat buildup in the circuit. Once blown standard fuses are no longer usable and must be replaced..



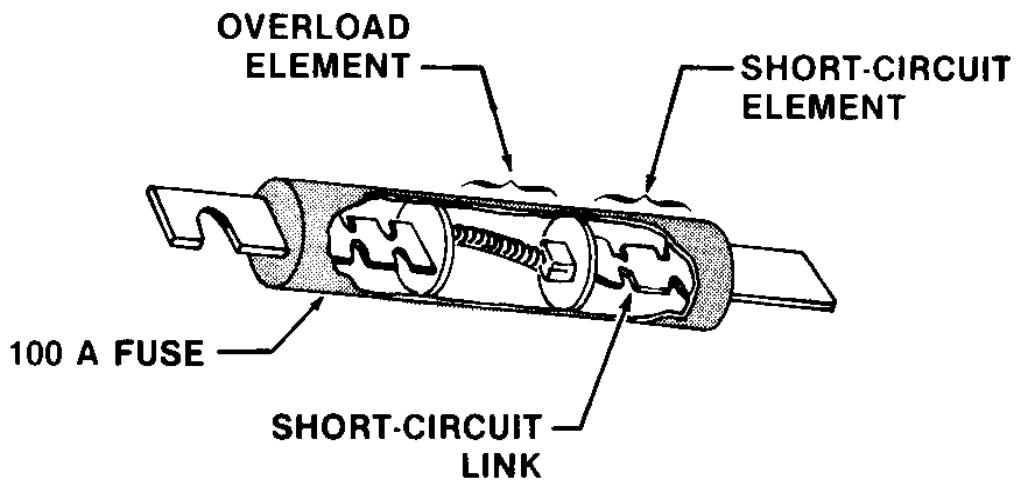
- The NEC allows standard fuses as overcurrent protection devices sized up to a maximum of 300% of the motor's FLA to allow the motor to start.
 - An exception allows the use of the next higher size fuse when the table value does not correspond to a standard size device.
- C An additional exception allows the use of the next size larger device until an adequate size is found if the motor will not start without operating the device.
- Standard fuses will hold 500% of their current rating for approximately one-fourth of a second.
- C **NOTE:** Some special standard fuses will hold 500% of their current rating for up to two seconds.
- In order for a standard fuse to be used as motor overload protection, the motor would have to start and reach its running speed in one-fourth of a second or less.
 - Standard fuses will not generally provide any overload protection for hard starting installations because they must be sized well above 125% of a motor's FLA to allow the motor to start.

Standard Fuse Response



Time-Delay (Dual Element) Fuses

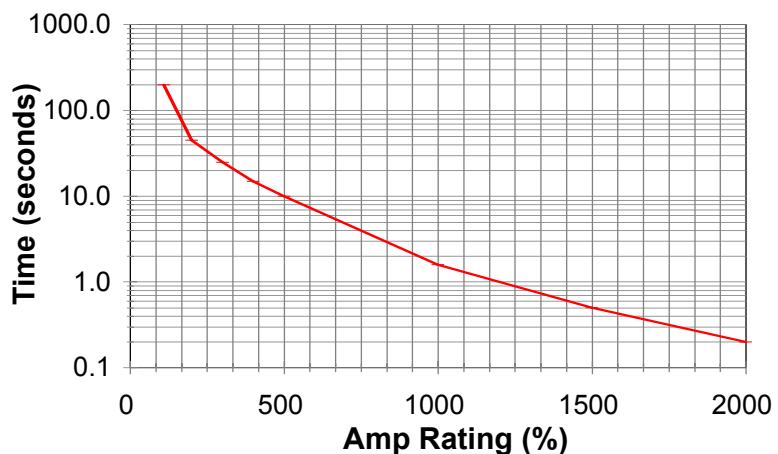
These are generally dual element fuses with both thermal and instantaneous trip features that allow the motor starting current to flow for a short time without blowing the fuse.



- Time delay fuses can also be used to provide some degree of overload protection which standard fuses cannot.
- The NEC allows time delay fuses to be sized up to a maximum of 175% of a motor's FLA for overcurrent protection.

Time Delay Fuse Response

- C Time-delay fuses will hold 500% of their amp rating for 10 seconds which will allow most motors to start without opening the circuit.

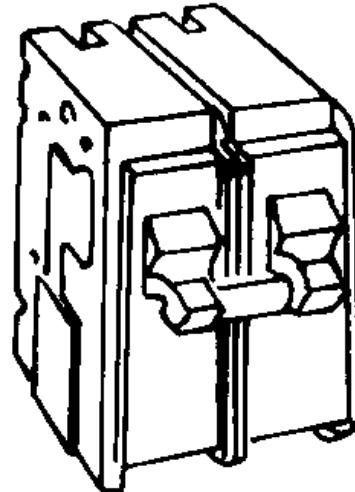


- C Under normal conditions, a 100-amp time-delay fuse will start any motor with a locked-rotor current rating of 500 amps or less.

Inverse Time Circuit Breakers

Inverse time circuit breakers have both thermal and instantaneous trip features and are preset to trip at standardized levels. This is the most common type of circuit breaker used in the building trades for residential, commercial, and heavy construction.

- C The thermal action of this circuit breaker responds to heat.
- C If a motor's ventilation inlets and outlets are not adequate to dissipate heat from the windings of the motor, the heat will be detected by the thermal action of the circuit breaker.
- If a short should occur, the magnetic action of the circuit breaker will detect the instantaneous values of current and trip the circuit breaker.
- The National Electrical Code requires inverse time circuit breakers to be sized to a maximum of 250% of the motor FLA.



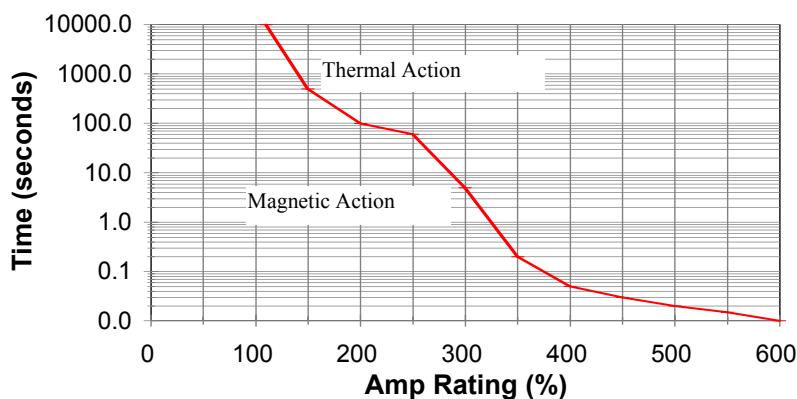
Inverse Time Circuit Breaker Trip Settings

Size (Amps)	Voltage	Percent of Load Held	Time (seconds)
100 or less	240	300%	4
100 or less	480	300%	9
110-225	240/480	300%	35
400-500	240/480	300%	50
600 or more	240/480	300%	40

The rating of an inverse time circuit breaker can be multiplied by 3 and this total amperage will start any motor with less locked-rotor amperage.

The time it takes to reach the 300% level varies with the amperage and voltage ratings of the breaker as shown in the table.

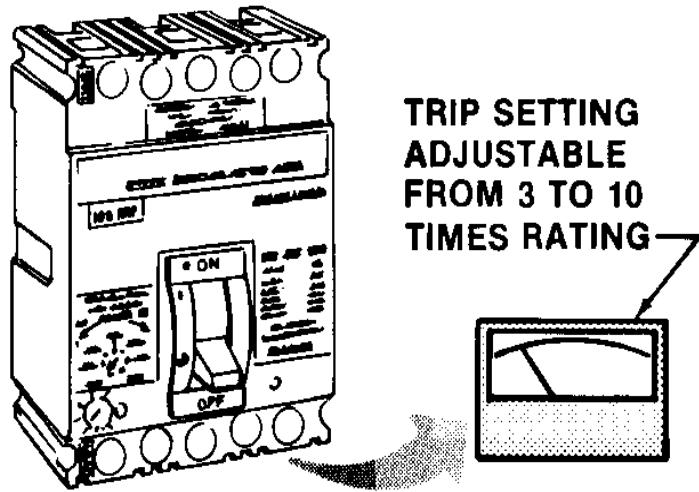
Inverse CB Trip Curve



Instantaneous Trip Circuit Breakers

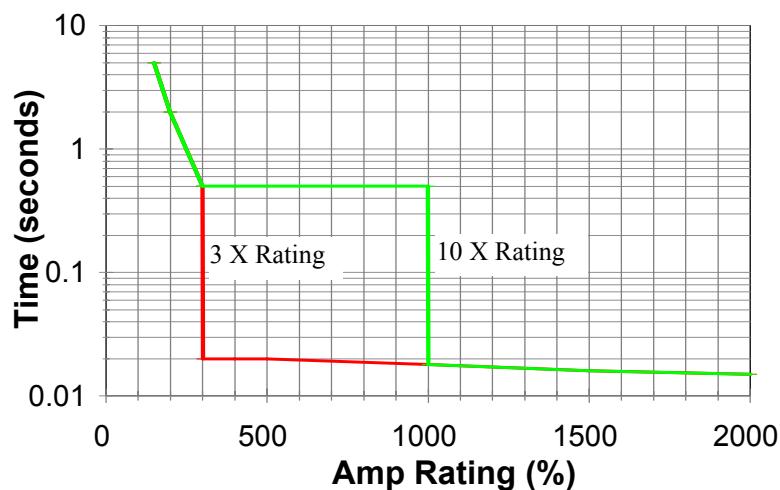
Instantaneous trip circuit breakers respond to immediate (almost instantaneous) values of current from a short circuit, ground fault, or locked rotor current.

- C This type of circuit breaker will never trip from a slow heat buildup due to motor windings overheating.
- A stuck bearing or a blanket of lint covering the inlets and outlets of the motor's enclosure will cause the motor to overheat and damage the windings.
- The National Electrical Code allows instantaneous trip circuit breakers to be sized to a maximum of 800% of a motor's FLA value.
- They are used where time-delay fuses set at five times their ratings or circuit breakers at three times their rating will not hold the starting current of a motor.



Some instantaneous trip circuit breakers have adjustable trip settings. The instantaneous trip ratings of an instantaneous trip circuit breaker can be adjusted above the locked-rotor current of a motor to allow the motor to start and come up to its running speed.

Instantaneous Trip CB



Example: an instantaneous trip circuit breaker can be set at 700 amps to permit a motor with a locked-rotor current of 650 amps to start.

- Care must be exercised not to adjust the trip setting above 800% unless specifically required. The NEC

prohibits settings above 800% if the motor will start and run up to speed at or below a setting of 800%.

Motor Overload Protection

Motors larger than 1 horsepower must be provided separate motor overload protection devices.

C The most common devices typically used include:

- 1) magnetic or thermal overload devices
- 2) electronic overload relays
- 3) fuses

Magnetic & Thermal Overloads

Overload devices are usually located in the motor's starter and connected in series with the motors electrical supply circuit and can be operated by either magnetic or thermal action.

C The same amount of current passes through the overload relay and the motor.

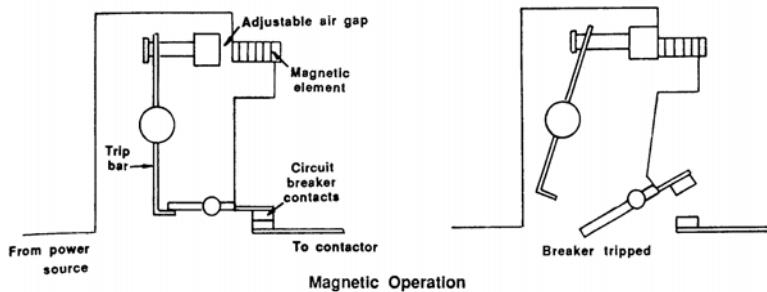
C If the current or heat through the overload device is higher than the device's rating, it trips and shuts down the electric power to the motor.

Magnetic Overload Relays

A magnetic overload relay is an electro-mechanical relay operated by the current flow in a circuit.

C When the level of current in the circuit reaches a preset value, the increased magnetic field opens a set of contacts.

- Electromagnetic overload relays operate on the magnetic action of the load current flowing through a coil.



C When the load current becomes too high, a plunger is pulled up into the coil interrupting the circuit.

C The tripping current is adjusted by altering the initial position of the plunger with respect to the coil.

Thermal Overload Relays

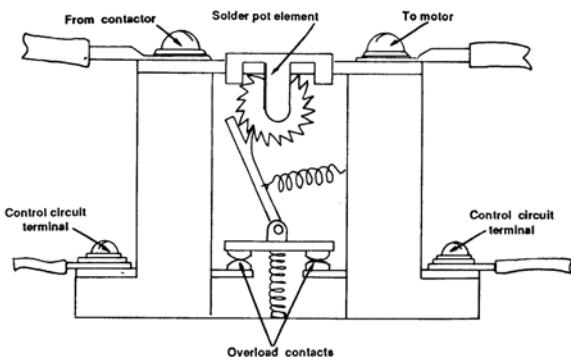
A thermal overload relay is an electro-mechanical relay that is operated by heat developed in the relay.

- C When the level of current in a circuit reaches a preset value, the increased temperature opens a set of contacts.
- C The increased temperature opens the contacts through a bimetallic strip or by melting an alloy that activates a mechanism that opens the contacts.
- C Two types include melting alloy and the bi-metallic strip.

Melting-Alloy Thermal Overload Relays:

These are probably the most popular type of overload protection.

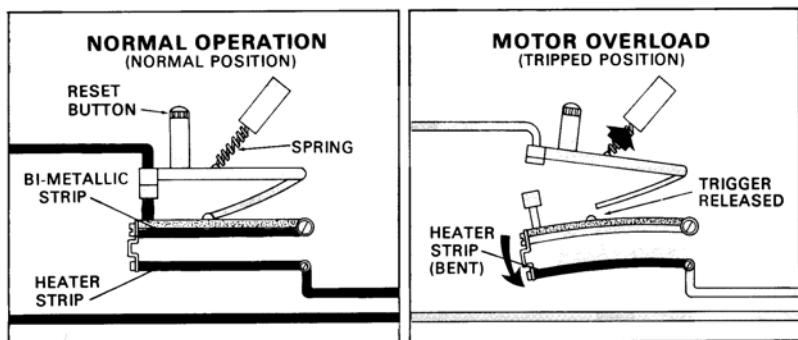
- C The motor current passes through a small heater winding and under overload conditions, the heat causes a special solder to melt allowing a ratchet wheel to spin thus opening the control circuit contacts.
- C Must be reset by hand operation
- C Heater coil and solder pot in one unit — non-tamperable



Bimetallic Thermal Overload Relays:

This design uses a bimetal strip associated with a current-carrying heater coil.

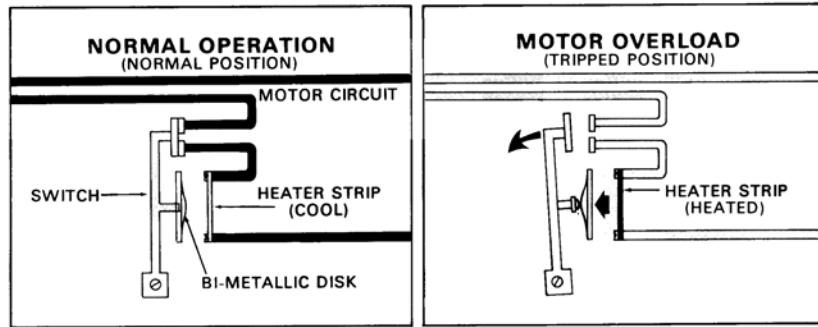
- C When an overload occurs, the heat causes the bimetal to deflect and actuate a tripping mechanism which opens a set of contacts in the control circuit interrupting power to the coil and opening the power contacts.
- C Most relays are adjustable over a range from 85% to 115% of their value.
- C They are available with ambient compensation. An ambient compensated devices' trip point is not affected by ambient temperature and performs consistently at the same value of current.



Automatic Reset Devices

Automatic reset is an advantage where the starter is inaccessible and the motor is provided three wire control from a magnetic starter.

- C This control doesn't allow the motor to restart until the start push button is manually pushed.
- C This permits the overload condition to be removed before the motor restarts.



Electronic Overloads

Electronic overloads sense the load current and the heating effect on the motor is computed. If an overload condition exists, the sensing circuit interrupts the power circuit.

- C The tripping current can be adjusted to suit the particular application.
- C Electronic overloads often perform additional protective functions such as ground fault and phase loss protection.

Fuses

Fuses have limited application as the primary means of overload protection for motors but can be effectively used to provide back up overload protection.

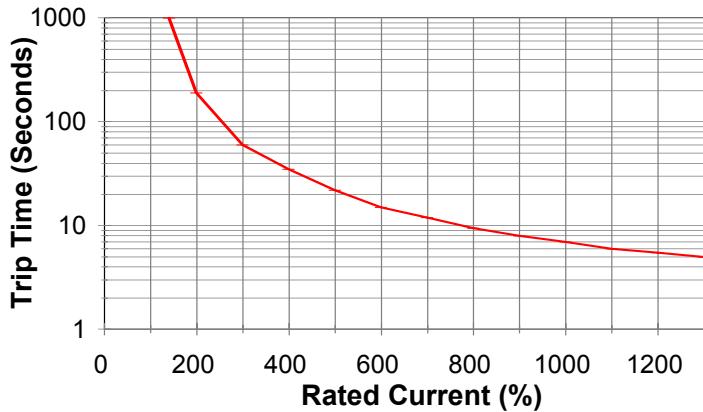
- Single-element fuses are not designed to provide overload protection.
- C Their basic function is to protect against short circuits and ground faults.
- C If sized to provide overload protection, they would blow when the motor starts due to high motor inrush current.
- Dual-element fuses can provide motor overload protection, but they have to be replaced when they blow which can be a disadvantage.
- There is a risk of single-phasing damage to the motor when only one fuse blows unless single-phase protection is provided.

Overload Trip Time

The time it takes an overload to trip depends on the length of time the overload current exists.

- A Heater Trip
Characteristics chart shows the relationship between the time an overload takes to trip and the current flowing in the circuit based on the standard 40EC ambient temperature installation.
- The larger the overload (horizontal axis), the shorter the time required to trip the overload (vertical axis).
- Any change from ambient temperature affects the tripping time of an overload.
 - For temperatures higher than 40EC, the overloads trip at a current rating less than the value of the overload.
- **Example:** At 50EC the overloads trip at 90% of their rated value. For temperatures lower than 40EC, the overloads trip at a current rating greater than the rated value of the overload.

Heater Trip Characteristics



Sizing Motor Overload Protection

There are several types of devices that can be used to provide overload protection and the sizing procedure can vary depending on the type of device used.

- C It is important to keep differences in the procedures separate and understood well so as not to install overloads that do not provide adequate protection to the motor.
- The simplest and most straightforward sizing procedures for motor overload protection are applied when sizing overload relays using the cover of the motor starter, control center, or manufacturer's catalog.
- The National Electrical Code specifies methods to calculate the maximum size motor overload protection for specific motors if a manufacturers chart is not available. Installations relying on fuses and circuit breakers as back-up overload protection must be calculated using the NEC method.

NEC Calculations

The NEC in general requires the maximum size overload device be set to open at 115% or 125% of the motor's full-load current rating, depending upon the service factor and/or temperature rise of the motor. There are however, exceptions.

- For motors rated 40EC with a Service Factor of 1.15 or greater, 125% of the motors FLA is used to calculate the maximum size device for overload protection.
- For motors rated greater than 40EC or unmarked, 115% of the motors FLA is used to calculate the maximum size device regardless of the motor's Service Factor.
- If use of the previous size rules results in the motor tripping off line during starting, the device can be increased to a maximum of 140% of the motors FLA.

Example:

Find the maximum size overload device to provide overload protection to a 3 phase, 230 Volt, 10 horsepower motor with FLA of 28 amps if:

Ambient Temp = 40EC, S.F.=1.15:	28 amps X 125% = 35 amps
Ambient Temp = 40EC, S.F.=1.00:	28 amps X 115% = 32.2 amps
Ambient Temp = 50EC, S.F.=1.15	28 amps X 115% = 32.2 amps
Ambient Temp = 50EC, S.F.=1.00	28 amps X 115% = 32.2 amps

If use of the size calculated results in the motor tripping off line when started, the overload device may be increased to a maximum of:

Maximum size allowable: 28 amps X 140% = 39.2 amps

Selecting Overloads From Starter Covers or Charts

The size overloads required to protect the windings of a motor can be determined by taking the motor's full-load current rating and selecting the size overloads from the cover of a magnetic starter, a motor control center, or the manufacturer's catalog.

- C The following things should be kept in mind when using manufacturer's charts.
 - When the overload size is selected from the cover of a magnetic starter or controller, the nameplate full-load running current of the motor is used. The full-load running current is NOT increased by 125% when the overloads are selected in this manner.
 - The charts are usually based on only the specific manufacturer's equipment.
 - Sizes from the charts may be different from those of calculated values from the National Electrical Code.

- C Manufacturers charts often provide smaller rated devices than the NEC would allow as a measure of extra protection.
 - Manufacturers' typically list the most common sizes in their charts. Certain sizes may require calculations if the chart is not available from the manufacturer.
 - If the motor will operate at/near service factor, the appropriate FLA of the motor at its Service Factor should be used to select the overload size from the manufacturer's chart.

OVERLOAD CHART

AMPERAGE	OVERLOAD UNIT
20.6-23.3	H1042
23.4-26.0	H1043
26.1-30.5	H1044
30.6-33.6	H1045
33.7-37.9	H1046
38.0-42.9	H1047
43.0-48.2	H1048
48.3-54.6	H1049
54.7-61.2	H1050
61.3-67.6	H1051
67.7-75.9	H1052
76.0-87.1	H1054
87.2-97.5	H1055
97.6-109.0	H1056
110.0-112.0	H1057
123.0-135.0	H1058

rating of 39 amps and a Service Factor of 1.00 requires three overload units with catalog number H1047.

Overload units number H1047 are selected because the 39-amp full-load current rating of the motor is between 38.0 and 42.9 amps.

What if the previous motor had a 1.15 Service Factor?

$$39 \text{ amps} \times 1.15 = 44.85 \text{ amps}$$

The motor requires three overload units with catalog number H1048 because the 44.85 amps of the motor at Service Factor is between 43.0 and 48.2 amps.

Example:

A three-phase motor with a full-load current

Ambient Temperature Compensation

The ambient temperature in which a starter and motor is located must be considered when selecting overloads because a high ambient temperature reduces overload trip time.

- C Reduced overload trip time can lead to nuisance tripping if a motor is located in a cooler ambient temperature than the starter and lead to motor burnout when the motor is located in a hotter ambient temperature than the starter.
- Most thermal overload devices are rated for use at a maximum temperature of 40 degrees C which is about 104 degrees F.
 - The overload device trips at less than 100 percent rated current when the ambient temperature exceeds 104 degrees F which can result in “nuisance tripping”.

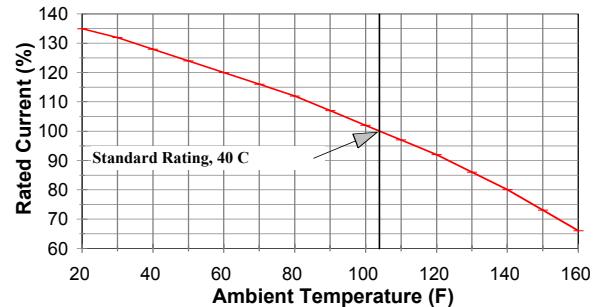
If the temperature is significantly below 104 degrees F, the overload device allows significantly more current through than it is rated for resulting in potential motor overload and failure without the overload tripping the motor off.

- A higher overload heater can be selected when the ambient temperature at the starter is higher than the temperature at the motor and a lower value selected when the ambient temperature at the starter is lower than the temperature at the motor.
- If the temperature varies widely during the year, the motor may not be protected when the temperature swings dramatically the other way unless the original overloads are switched back.

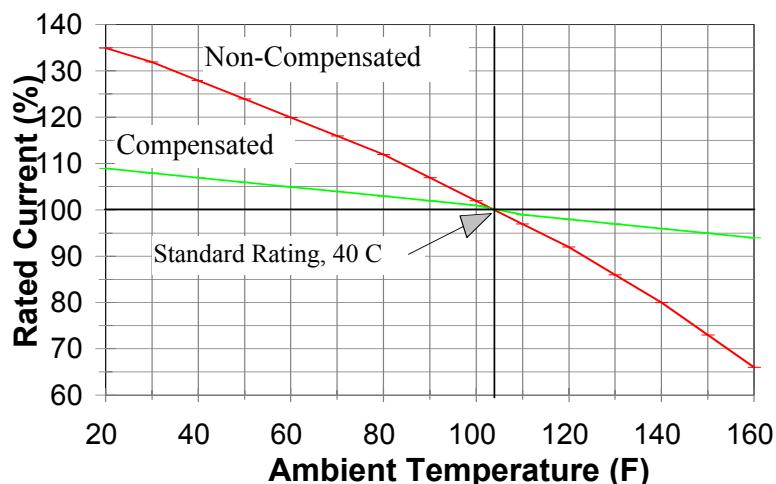
Ambient Compensated Heaters

For this reason, special **Ambient Compensated Heaters** which have a much “flatter” temperature response should be used in most outdoor applications and where ambient operating temperatures are significantly different.

Heater Ambient Temperature Correction



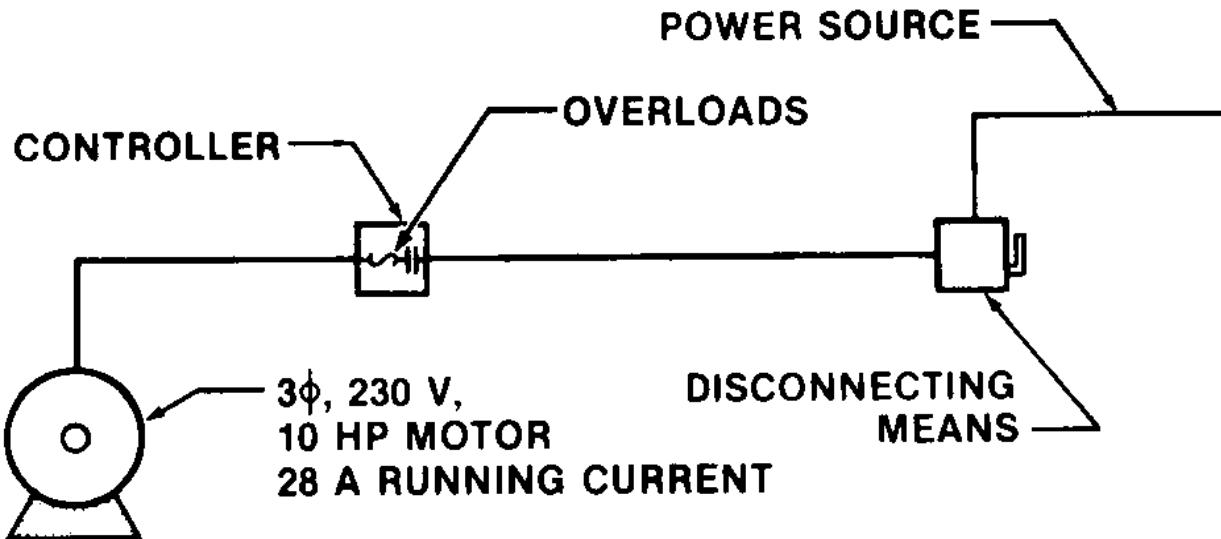
Ambient Temperature Correction



Sizing Motor Protection Systems

Given the following motor, size the conductors, motor overcurrent and motor overloads to adequately protect the motor and conductors.

Nameplate Info: FLA = 22 Service Factor = 1.00 Ambient = 40 C



STEP 1: Determine the motor's FLA (full load amps)

- C Go to the appropriate NEC Table to find the design FLA
 - NEC Table 430-150 for 3 phase: For 10 Hp, 230 Volt Motor = 28 amps

STEP 2: Determine the size of branch circuit conductor required.

- C NEC 430-22 says the conductor ampacity equals the FLA x 125%
 - Conductors supplying a single motor used for a continuous duty load must have a current carrying capacity of not less than 125% of the motor's full load current (FLA) rating as given in NEC tables 430-148 or 430-150.
 - Conductor Ampacity = 28 amps X 1.25 = 35 amps
- C Use NEC Table 310-16 to select the conductor with the required ampacity
 - From NEC Table 310-16: #8 AWG Copper
- C The NEC procedure requires use of the #8 AWG conductor so it will be large enough for any motor of the same size in the future.

STEP 3: Determine the branch circuit overcurrent device size.

The maximum branch circuit overcurrent device size is calculated based on the type of protective device selected (standard fuse, time-delay fuse, instantaneous breaker, inverse time breaker) and percentage multiplier from NEC Table 430-152.

C Multiply the motors design FLA by the appropriate percentage in NEC Table 430-152.

1. When the value found does not match a standard fuse/breaker size the NEC permits the next higher STANDARD size for a branch circuit overcurrent device.

Standard Fuse	28 X 300% = 84 amps Next Highest: 90 amps
Time-Delay Fuse	28 X 175% = 49 amps Next Highest: 50 amps
Instantaneous Breaker	28 X 800% = 224 amps Next Highest: 225 amps
Inverse Time Delay Breaker	28 X 250% = 70 amps Next Highest: 80 amps

STEP 4: Determine the required size for the motor running overload protection.

1. Use the nameplate FLA directly to find the appropriate overload device heater on the motor starter cover or from manufacturers tables.
 2. Use the nameplate FLA and NEC Section 430-32 to calculate the maximum size for the motor overload protection in amps.
- C NEC Section 430-32 specifies the maximum overload protection size for most installations if nameplate amps aren't available. (FLA X 115% or FLA X 125% depending on criteria).
- Since the motor's ambient rating was 40 deg C and the S.F. was 1.0, use 115%.
- For Ambient of 40 deg C and S.F. = 1.0: $22 \text{ amps} \times 115\% = 25.3 \text{ amps}$
- C NEC Section 430-34 specifies the maximum size if the calculated value in Section 430-32 will not allow the motor to start consistently. (Motor FLA X 140%).
- $22 \text{ amps} \times 140\% = 30.8 \text{ amps MAXIMUM}$