

Series Combination Rating Requirements

by Tim Crnko



CHECK LIST



Series combination ratings are utilized to attempt to save money on some jobs. This article presents a simple checklist that can be completed by the contractor and/or designer when series rated combinations are proposed. The checklist is designed to be a single sheet that is double sided [checklist can be found on pages fifteen and sixteen]. The front side requires information for a specific series rated application. The backside provides an easy reference of general application information and provides the specific *National Electrical Code* requirements. In the plan review stage, the checklist provides the AHJ the necessary information to review series combinations in their specific application. During the inspection phase of the installation, the AHJ can use this checklist as a guide to confirm compliance with the design and proper installation requirements.

Why the Checklist?

There is confusion in the industry on the requirements of properly applying and installing series combination ratings. What combinations are suitable?

In the specific building installation, is the series combination rating greater than the available short-circuit current? Is the motor contribution within allowable limits? Is the panelboard or switchboard properly marked by the manufacturer for the series combination rated devices that are to be used? Has the installer properly affixed the required field markings? Are there selective coordination requirements that would not permit using series rated combinations? If these questions are not investigated and found to be acceptable for a specific application, then the series rated combination cannot be used. After a job is designed with fully rated fuses or circuit breakers, sometimes the job is value engineered and series rated combinations are proposed for portions of the system. It is important to insure that the design still meets the *NEC*. This checklist can help that process.

Fully Rated System

A fully rated system is one in which all of the overcurrent protective devices have an individual interrupting rating equal to or greater than the available short-circuit current at their line terminals. This is a requirement in 110.9. Fully rated systems can consist of all fuses, all circuit breakers, or a combination of fuses and circuit breakers (see figures 1 and 2).

Series Rated

Series rated is a combination of circuit breakers or fuses and circuit breakers that can be applied at available short-circuit levels above the interrupting rating of the load side (protected) circuit breaker, but not above the interrupting rating of the main or line-side device. A series rated combination can consist of fuses protecting circuit breakers, or circuit breakers protecting circuit breakers. It is very important to note that with a series rated combination there is an allowance per 240.86 to permit application of a load side (protected) circuit breaker beyond its individual interrupting rating. Figure 3 illustrates a fuse/circuit breaker series rated combination. Figure 4 illustrates a circuit breaker/circuit breaker series rated combination.

Which Is Best: Fully Rated or Series Rated?

From an inspection perspective, the first priority is

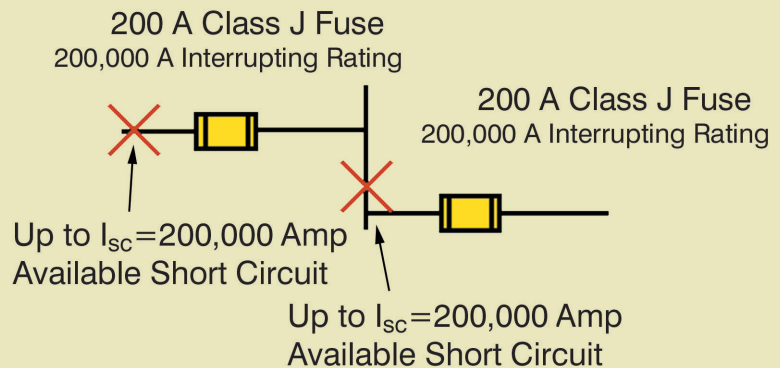


Figure 1. Fully Rated Fuse System

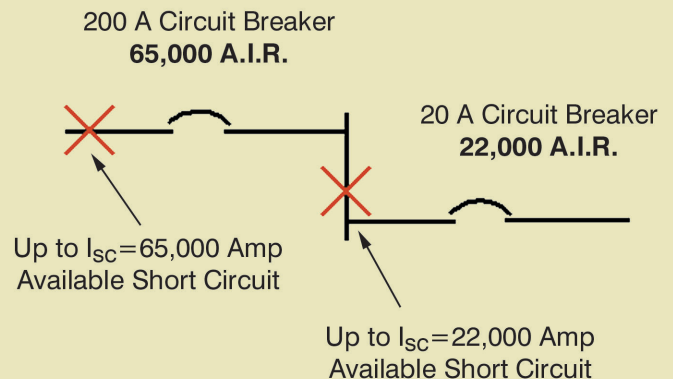


Figure 2. Fully Rated CB System

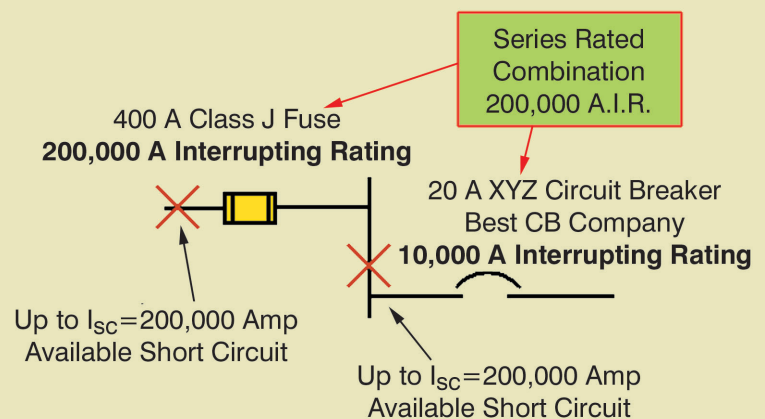


Figure 3. Series Rated System Fuse/CB

to focus on compliance to 110.9. The most suitable application for series rated combinations is for branch circuit, lighting panel circuit breakers. With a series rated combination, the load side circuit breaker is applied beyond its individual interrupting rating. Because of this, if a series rated combination is to be used, the designer and contractor should select the tested, listed and marked line-side protection that will assure reliable performance over the lifetime of the electrical system. If the line-side protecting overcurrent protec-

How Is A Series Rated Combination Listed?

A nationally recognized testing laboratory (NRTL) does not list a fuse/circuit breaker or circuit breaker/circuit breaker series combination by itself. The listing for a series combination has to be evaluated and found suitable for a specific manufacturer's panelboard, loadcenter or switchboard line.

Basically, it works like this. A specific type circuit breaker (XYZ) by Best CB Company is tested as the load-side (protected) circuit breaker with a specific line-side (protecting) overcurrent protective device, which can be either a circuit breaker or fuse. For instance in figure 3, the 20-amp XYZ circuit breaker by Best CB Company is tested with a 400-amp Class J fuse (a special umbrella fuse is used to insure the let-through represents the 400 A Class J fuses as made by all manufacturers). The short-circuit test is at 200,000 amperes even though the XYZ circuit breaker has an interrupting rating of 10,000 amperes. Based on UL 489, Standard for Molded-Case Circuit Breakers, if the circuit breaker passes the evaluation criteria, the combination of a 400-amp Class J fuse and the 20-amp XYZ circuit breaker manufactured by Best CB Company is filed by the NRTL as only a recognized series rated combination (see figure 5). However, this is not a listing, further evaluation is necessary.

To be useful, the panelboard or switchboard manufacturer (XYZ Panelboard Manufacturing Company) must have their equipment tested, evaluated and listed by a NRTL using the recognized combination in their panelboard or switchboard (see figure 6).

If this recognized series combination passes the NRTL's evaluation, then this series combination of load-side 20-amp XYZ circuit breaker by Best CB Company and line-side 400-amp Class J fuses is marked on that specific manufacturer's style panelboard or switchboard (referred to as tested, listed and marked). The load-side (protected) circuit breaker would be installed in that panelboard or switchboard. The line-side (protecting) Class J fuses, up to 400 A, could be in that panelboard or switchboard or in another upstream panelboard or switchboard. And now the XYZ circuit breaker manufactured by Best CB Company, which has a 10,000 A interrupting rating, installed in XYZ Panelboard with the series rated combination mark, can be applied on a system with 200,000 amperes available short-circuit current (see figure 7). That is, if other *NEC*® requirements are met! These other requirements are extremely important to make sure a series rated combination is, in fact, applied per its testing, listing and marking [110.3(B)].

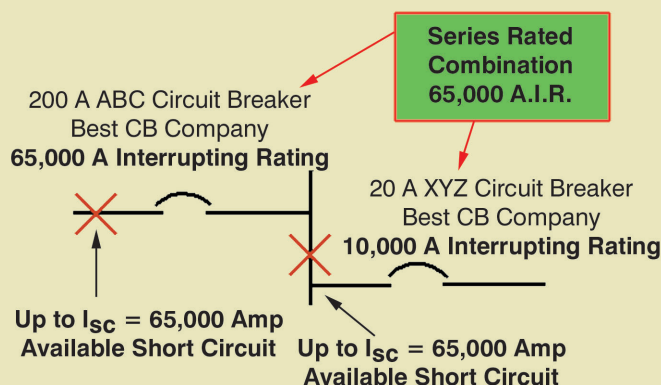


Figure 4. Series Rated System CB/CB

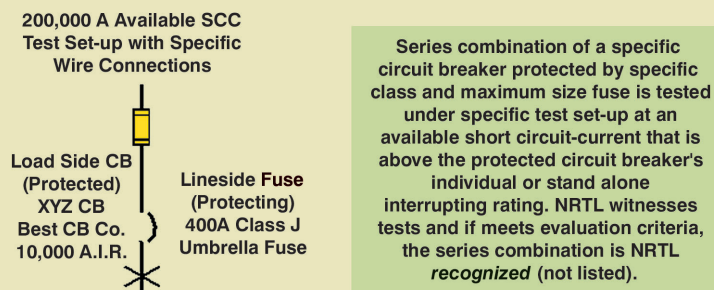


Figure 5. Series Combination Recognition Testing

tive device does not react as intended due to lack of maintenance or loss of calibration, the load-side circuit breaker may be on its own to interrupt. Although series rated combinations save a small percentage of the initial equipment costs, there are many issues about designing and utilizing series rated combinations. However, that is another article topic targeted at the designers and contractors. This article is focused on the *NEC* compliance requirements for series rated combinations.

What Other Requirements Must Be Met?

240.86(A) Factory Labeling Requirement. The process of testing, listing and marking a series rated combination was just covered. Section 240.86(A) requires that, when a series rated combination is used, the switchboard or panelboard be listed and *factory marked* for use with the series rated combinations to be utilized. Often there is not enough room in the equipment to show all of the legitimate series rated combinations. So UL 67, Panelboards, allows for a booklet to be referenced and supplied with the panelboard. The booklet is to be affixed to the panelboard. These booklets typically provide all of the acceptable combinations for the panelboard. This provides evidence that a switchboard or panelboard is listed up to a specified available short-circuit current for a specific series combination in that specific panelboard or switchboard. For a specific job, the AHJ must be provided data to demonstrate that the series rated combination has an adequate series (interrupting) rating for the available short-circuit current at the installation point of the load side (protected) circuit breaker. See figure “110.22 & 240.86(A) Labeling” on the second page of the checklist at the end of this article.

110.22 Field Labeling Requirement

This section places responsibility on the *installer* (electrical contractor) to *affix labels* on the equipment enclosures, which note the interrupting rating of the series rated combination and call out the specific replacement overcurrent protective devices to be utilized. If the upstream overcurrent protective device protecting the downstream circuit breaker is in a different enclosure, then both enclosures need to have field-installed labels affixed and call out the other location on the labels. See figure labeled “110.22 & 240.86(A) Labeling” on the second page of the checklist at the end of this article.

This field marking is critical for ensuring that proper devices are installed as initially intended and properly replaced years later. It becomes absolutely necessary when replacement of fuses or circuit breakers is needed; this field marking helps ensure that the original system design integrity is maintained. If the wrong replacement circuit breaker is used on the load side or line side or the wrong fuse is used on the line side, the series rating is no longer valid. This could result in a serious fire and safety hazard.

These labeling requirements are also very important for evaluating the suitability of this equipment, if at a future date the electrical system is changed or upgraded. Proper labeling per 240.86(A) and 110.22

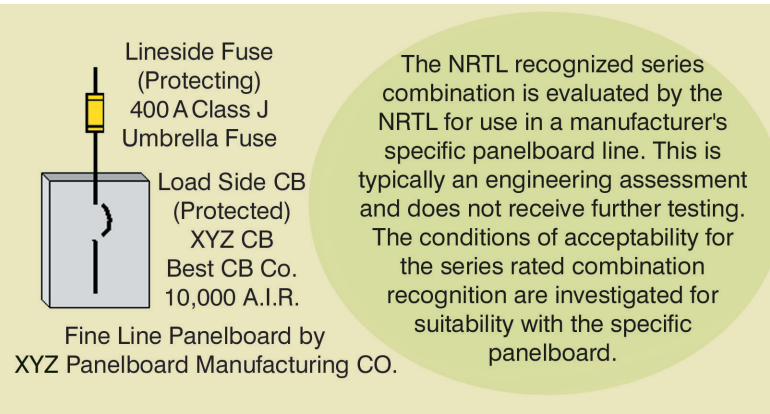


Figure 6. Series Combination Evaluated for Panelboard

provides a means to assess the suitability of the series rated combination when the electrical system parameters later change due to a refurbishment or other system change. The owners or maintenance contractors should maintain these labels throughout the life of the equipment. When electrical system upgrades occur, without this labeling affixed to the equipment, the owner most often must needlessly throw out the existing equipment and buy new equipment.

240.86(B) Motor Contribution Limitations

Where motors are connected between the line-side (protecting) device and the load-side (protected) circuit breaker, 240.86(B) has a critical limitation on the use of series rated combinations. This section requires that a series rated combination shall not be used where “the sum of *motor full-load currents exceeds 1 percent of the* *load side (protected) circuit breaker’s individual “interrupting rating”* [italics added.] The rea-

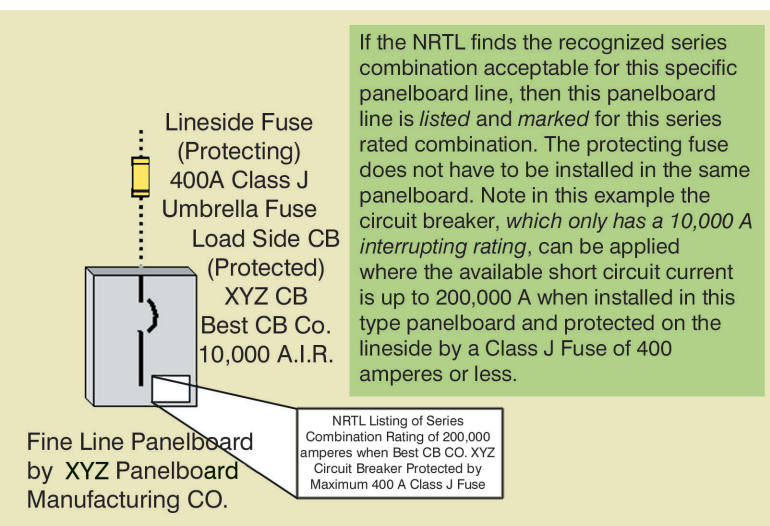


Figure 7. Series Rated Combination NRTL Listed with Panelboard

If a series rated combination is to be used, what must be the standalone or individual interrupting rating of the feeder circuit breaker?

- A. 10,000 A.
- B. 22,000 A.
- C. 42,000 A.
- D. at least 50,000 A.

Answer: D

The series combination interrupting rating may be much higher, but the protected CB, which is the feeder, shall have an individual interrupting rating of at least 50,000 A, per 240.86(B)

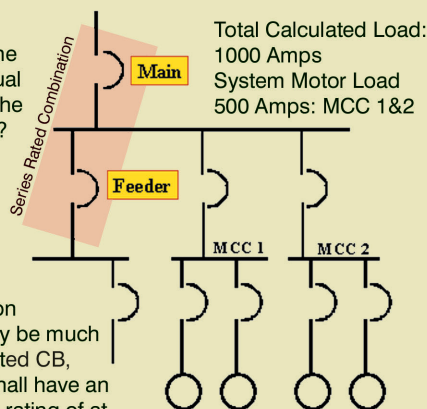


Figure 8. Motor Contribution Limitations of Series Combinations

son is that when a fault occurs, running motors momentarily contribute current to the short-circuit (usually about four to six times their rating). This added motor contribution could result in a short-circuit current in excess of what the load-side (protected) circuit breaker was tested to handle per the series rated combination testing, listing and marking. See the figure on motor contribution on the second page of the checklist at the end of this article.

This is one of the major reasons that series rated combinations are generally recommended only for lighting panel applications. Lighting panels generally do not have significant motor loads so the motor contribution is typically not an issue. However, series rated combinations used for power panel or main/feeder applications can pose a problem upon initial installation or if the loads change in the fu-

ture. On a new installation with a 1000-A service load containing 50 percent motor load (which is motor full load amperes of 500), the motor contribution could be an issue in selecting a series rated combination. If a main/feeder series rating were to be considered, the feeder could require at least a 50,000-A individual or stand-alone interrupting rating (1 percent of 50,000 = 500). See figure 8 to illustrate this example.

Then consider the uncertain future of building spaces. For instance, many building spaces by their nature inherently incur future changes, such as strip malls, enclosed malls, business park buildings, manufacturing facilities, many institutional buildings, and many commercial spaces. A properly designed and initially installed series rating could be negated if the building loads change to significantly higher motor loads.

Selective Coordination Requirement Limitations

Inherently, series rated combinations cannot be selectively coordinated. The line-side (protecting) device must open at the same time and in conjunction with the load-side (protected) circuit breaker. This means that the entire panel loses power because the device feeding the panel must open under medium- to high-level short-circuit and ground-fault conditions.

Therefore, in health care facilities where selective coordination of ground-fault protection is required between the main and feeders, series rated combinations do not meet the 517.17 requirements. Also, series rated combinations do not meet the selective coordination requirement for elevator circuits per 620.62 where there are two or more elevators. Series rated combinations reduce emergency circuit overall system reliability as presented in the 700.25 FPN because of their limitation of fault current coordination (see figure 9).

In summary, there are specific *NEC* requirements that shall be met by the designer and installer if series rated combinations are to be used. At the end of this article is a two-page checklist that can be copied onto one double-sided sheet. The AHJ may require the designer and/or contractor to complete this checklist if a series rated combination is to be used. An electronic copy of this checklist can be downloaded from www.bussmann.com under "Application Info / NEC®/IAEI Information." ✍

Tim Crnko, training & technical services manager for Cooper Bussmann, has MSEE and is a member of IAEI, IEEE and NFPA. tcrnko@buss.com

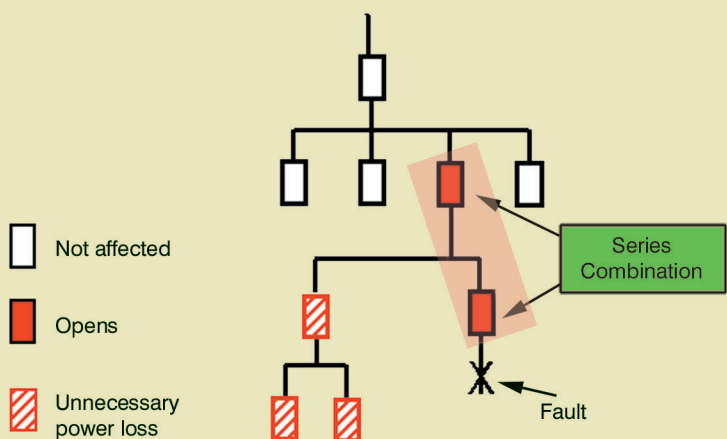


Figure 9. Selective Coordination Limitations of Series Combinations

INSPECTION FORM: Series Rated Combination

ISSUED BY: _____

This form provides documentation to assure compliance with the following National Electrical Code®, NFPA 70, sections on the use of Series Rated Combinations: **110.9, 110.22 & 240.86**

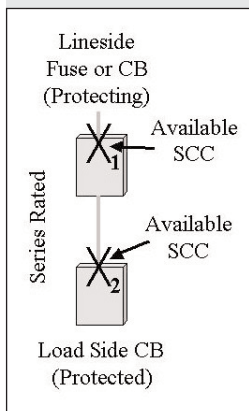
JOB # _____

NAME: _____

LOCATION: _____

CONTRACTOR: _____

ESSENTIAL INFORMATION:



Line Side Panel Designation (If applicable) _____

Line Side Overcurrent Protective Device Part Number _____

Line Side Overcurrent Protective Device Interrupting Rating _____

X₁ Available Short Circuit Current at Line side OCP Device _____

Load Side Panel Designation _____

Load Side Circuit Breaker Part Number _____

Load Side Circuit Breaker Individual Interrupting Rating _____

Series Combination Interrupting Rating _____

X₂ Available Short Circuit Current at Load side Circuit Breaker _____

Compliance Checklist

(For further information see discussion on reverse side for each item)

1. Short-Circuit Currents

Is the interrupting rating of the line side fuse or circuit breaker greater than the available short-circuit current (X₁) at its lineside (110.9) ☐ YES ☐ NO

Is the series combination interrupting rating greater than the available short-circuit current (X₂) at the load side circuit breaker (permitted per 240.86)? ☐ YES ☐ NO

2. Manufacturer's Label

Are both devices in use for the series rated combination marked on the end use equipment in which the load side circuit breaker is installed (or contained in a booklet affixed to the equipment) as required in 240.86(A)? ☐ YES ☐ NO

3. Field Installed Label

Are field labels, as required by 110.22, that indicate "CAUTION – Series Rated Combination", along with the required replacement parts, panel designations, and series combination interrupting rating, installed on all end use equipment that contain the series combination rating devices? ☐ YES ☐ NO

4. Motor Contribution

If motors are connected between the series rated devices, is the combined full load current from these motors less than 1% of the downstream circuit breakers' interrupting rating (individual or stand alone interrupting rating) per 240.86(B)? ☐ YES ☐ NO

5. Selective Coordination

Is this series rated combination being installed in something other than a health care facility (see NEC® 517.17)? ☐ YES ☐ NO

Elevator circuits only: Is this series rated combination being installed on an elevator circuit with only one elevator in the building (see NEC® 620.62)? ☐ YES ☐ NO

AN ANSWER OF "NO" TO ANY OF THESE QUESTIONS MAY INDICATE A LACK OF COMPLIANCE. LACK OF SUBMITTAL IS CONSIDERED AS EVIDENCE OF LACK OF COMPLIANCE.

Series Rated Combination

What is a Series Rated Combination?

A combination of two devices, that have been tested under specific test conditions that work together to clear a fault. The allowed combinations are limited to those that have been selected by the circuit breaker manufacturer for testing. Only tested combinations can be used.

CAUTION: A series rated combination allows a load side circuit breaker to be applied where the available short circuit current exceeds the interrupting rating marked on that circuit breaker.

BACKGROUND TO CHECKLIST ITEM

1) Short-Circuit Currents

The series combination interrupting rating must be greater than the available short-circuit current at the load side circuit breaker (240.86) and the interrupting rating of the line side fuse or circuit breaker must be greater than the available short-circuit current at its line terminals (110.9).

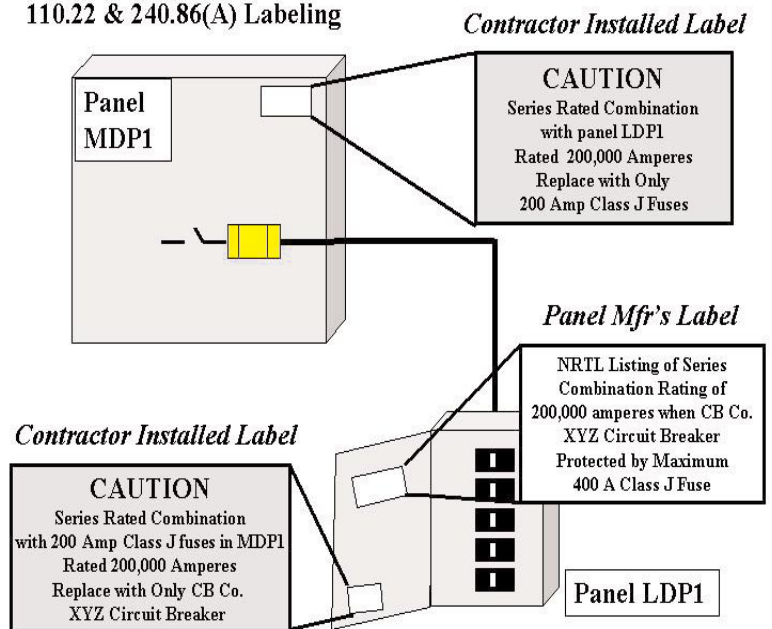
2) Manufacturer's Label

Since the use of series rated combinations are limited to specific combinations that have been tested, the end use equipment is required to be marked, by the **manufacturer**, per 240.86(A) of the 2002 NEC®. Since there are hundreds of combinations, this marking may be in a book that is affixed to the end use equipment, as allowed in UL67. The manufacturer's marking is used to verify that both devices are part of a recognized series rated combination, the panelboard is listed for use with the combination, and that the series combination interrupting rating is sufficient for the available short circuit current. This label also provides guidance for future upgrades as to the specific replacement devices that are allowed.

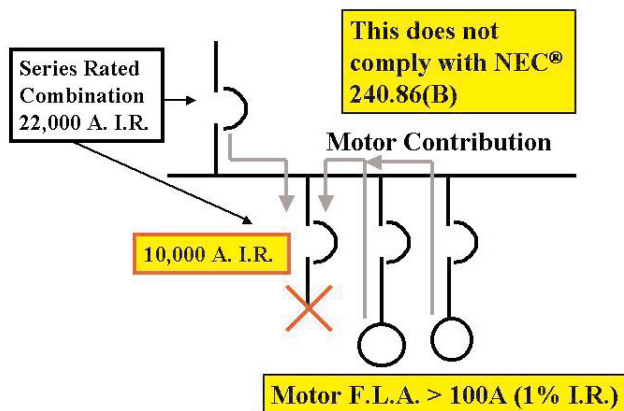
3) Field Installed Label

110.22 of the 2002 NEC® requires the **installer** to apply a field caution label warning that a series rated combination is being used. This label must be applied on the panel containing the series rated combination or on both pieces of electrical equipment if the line side device is located separate from the load side circuit breaker to assure that the proper devices have been installed and that proper future replacements are made. The inspector can check the devices noted on the field label required by 110.22 against the tested and listed series rated combinations marked on the panelboard or switchboard by the manufacturer per 240.86.

110.22 & 240.86(A) Labeling



Series Rated Systems



4) Motor Contribution

A series rated combination is evaluated under specific testing conditions of which motor contribution is not a part of the criteria. If a motor(s) were connected in the middle of the combination, it would supply extra fault current that did not exist when the combination was tested. 240.86(B) of the 2002 NEC® addresses this by prohibiting the use of series rated combinations when the sum of the full load current of the motors exceeds 1% of the interrupting rating marked on the **LOAD SIDE** circuit breaker. For example, if the load side circuit breaker is rated 10,000 A.I.R., with motor loads exceeding 100 amps, then a series rated combination could not be used. For other than lighting panels, it is necessary to investigate the protected circuit breaker of a series combination to insure that the protected circuit breaker's individual interrupting rating complies with 240.86(B). For other than lighting panels, it is advisable not to utilize series rated combinations for building spaces where the loads may change during the life of the electrical system. If more motor loads are added, the series combination rating for that application could be negated.

5) Selective Coordination

A disadvantage of a series rated combination is that, by definition, for fault conditions the line side (protecting) device must open at the same time, and in conjunction with, the load side (protected) circuit breaker. This means that the entire panel loses power because the device feeding the panel must open under medium to high level short-circuit conditions. For life and safety reasons, the NEC® requires selective coordination in some applications. Main to feeder series rated combinations do not meet the requirements of 517.17 in health care facilities. Series rated combinations do not meet 620.62 for elevator circuits that contain more than one elevator. Series rated combinations would reduce the overall system reliability of emergency circuits as presented in 700.25 FPN because of their inherent lack of fault current coordination.