MSC Guidelines for Review of Coordination Study

Procedure Number: E2-4 Revision Date: 04/20/00

References

a. Title 46 CFR Parts 111 and 112

b. Navigation and Inspection Circular (NVIC) 2-89, "Guide for Electrical Installations on Merchant Vessels and Mobile Offshore Drilling Units"

c. American Bureau of Shipping (ABS), "Rules for Building and Classing Vessels under 90 Meters in Length", 1996

d. Safety Of Life at Sea (SOLAS), Consolidated Editions, 1997, Chapter II-1, Part D

e. ANSI/IEEE Std 242, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems

f. IEEE Std 141, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants

g. Square D Power Systems Engineering Date, Volume 1, Number 1, "Procedure for an Overcurrent Protective Device Time-Current Coordination Study", January 1979, by Ermal Curd and Larry E. Curtis

h. 0093-9994/86/0700-0623, 1986 IEEE, Standardization of Benchmarks for Protective Device Time-Current Curves, by Conrad R. St. Pierre and Tracey E. Wolny

i. MSC Guidelines Procedure numbers E2-6, E2-7, and E2-19

Disclaimer

Contact Information

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General Review Guidance

- Check subject vessel files for the following plan submittals:

    1. Electrical One-Line Diagram

    2. Computations of Short Circuit Currents

- Ensure technical plan review of the above plans have been satisfactorily completed as the calculations of short circuit currents are the basis of the coordination analysis.

- Review of a coordination analysis requires the availability of the following information from the previous submittals:

    1. From the short circuit analysis submittal, locate the marked-up one-line diagram that identifies the short circuit faults considered in the short circuit study. If not, locate the electrical one-line diagram submittal and plot all the fault points calculated in the short circuit study.

    2. From the short circuit analysis submittal, locate the short circuit summary that lists the maximum fault currents available (considering a zero-impedance (bolted) three-phase fault), when operating all generators that can simultaneously operate in parallel, and the largest possible motor loads. Then transfer the calculated fault currents at the corresponding fault-points in the electrical one-line. This information will provide you the necessary information to properly conduct the coordination analysis.

- The coordination of overcurrent protective devices should be demonstrated for all potential plant configurations.

- A coordination study should be presented on a log-log graph. The ordinate represents <u>time</u> and generally consists of a 5 decade logarithmic scale ranging from 0.01 to 1000 s, and the abscissa represents the <u>current level</u> and consists of four-and-a-half-decade logarithmic scale. The graph should contain or reference the following information, as needed in the particular segment of the electrical system under study:

    1. Cable heating limit curve (or cable damage curve), as needed when cable is small and the fault current level is high.

2. Transformer magnetizing inrush current (for 500-2500kVA, approximately 8 to 12 times the transformer full-load current for a maximum period of 0.1 sec., and for above 2500kVA, approximately 10 to 12 times the transformer full-load current for a maximum period of 0.1 sec)
3. ANSI transformer protection curve (Z-curve)
4. Generator decrement curve.
5. Motor characteristic curve (includes the inrush current, locked rotor current, acceleration time, allowable stall time, and full-load current). See Dwg. No. 1.

   Motor in-rush current calculations

   I (in-rush) = I (locked rotor) x 1.6 x 1.1

   where: 1.6 = offset multiplier

   1.1 = safety multiplier

   Notes: (a) transition between in-rush and locked rotor is approximately at 0.1 sec

   (b) transition between locked rotor and full-load current ends on the acceleration time, usually plotted between 5-10 seconds.
6. Time-current characteristic curves of all protective devices (such as, circuit breakers, relays, and fuses) must be shown and identified, if required by the particular coordination study.
7. Interrupting ratings of each overcurrent protection.
8. Maximum available short circuit current of the particular fault point under study.
9. The range of the current scale selected to match the voltage and current range of the devices being shown.

- Take one fault point at a time in the distribution system and analyze coordination or selectivity of overcurrent protective devices for that particular fault in the coordination study submittal.

- <u>Selectivity or coordination is achieved when:</u> (46 CFR 111.51-3)

1. A short circuit on a circuit that is not vital to propulsion, control or safety of the vessel does not trip equipment that is vital.

2. A short circuit on a circuit that is vital to the propulsion, control, or safety of the vessel, is cleared only by the protective device that is closest to the point of the short circuit. For example:

    a. Overcurrent protective devices are rated, selected and adjusted so only the fault current carrying device nearest the fault opens to isolate the faulted circuit from the system while permitting the rest of the system to remain in operation, providing maximum service continuity.
    b. Except for relays and certain fuse applications, coordination usually will be obtained in low-voltage systems when the log-log plot of time-current characteristics displays a **clear space** between the characteristics of the protective devices operating in series. Their time-current characteristic curves do not overlap or cross one another.
    c. Circuit breakers with magnetic or instantaneous trips can only be coordinated with each other if there is sufficient impedance between them so that the maximum available short circuit current at the downstream circuit breaker is less than the instantaneous trip setting of the upstream breaker. (Selectivity by impedance in the circuit) See example on Dwg. No. 2.
    d. On the other hand, time-current coordination is usually possible, regardless of the impedance between the breakers, if the upstream breakers are supplied with short time trips only. (Selectivity by time delay in the breaker) See example on Dwg. No. 3.

3. Protective devices are set or adjusted so that pickup currents and operating times are short but sufficient to override system transient overloads such as inrush currents experienced when energizing transformers or starting motors.

- Coordination Margins:

    1. For induction discs overcurrent relays, see Dwg. Nos. 4A and 4B
    2. Transformer protection, see Dwg. No. 5
    3. Induction motors, see Dwg. No. 6
    4. Recommended allowable time margins, see Dwg. No. 7
    5. Instantaneous trip of a generator circuit breaker must be set above, but as close as practicable to, the maximum asymmetrical short circuit available from any one of the generators that can be paralleled. See 46 CFR 111.12-11(e).

- Compromises in Setting:

1. Coordination plotting is directed towards obtaining settings for devices which will provide the best protection for equipment (usually meaning the lowest practical setting) over the whole range of current levels without conflict (overlap) of characteristics. To the degree that this is accomplished, the occurrence of any fault will be met with a response, in which the least portion of the circuit is disconnected, and the fault damage is limited to the maximum extent. There will be, however, cases where the settings obtained will be less than completely satisfactory. There are a number of instances which will require the selection of less than ideal settings. A few of these are mentioned below.

   a. Characteristic Mismatch. Characteristic curves for various devices will vary between manufacturers. Some curves have a wide sweep from pickup current to the instantaneous trip setting. To avoid overlap, the next curve upstream may have to be set undesirably high. Perhaps, too high to provide long-time protection to cables or circuit breakers. The choice may be to accept some overlap, or recommend changing to another device with a different characteristic.
   b. One Large Load on a Feeder. Some systems require one large motor and a number of small motors to serve a load area. The large motor obviously will determine the coordination, and its protective device settings will be almost as high as the ones on the next upstream device. This is, in several ways, similar to the situation in the paragraph above, and accepting an overlap is usually the logical solution.
   c. Oversized Devices. Overgenerous estimation of loads can result in protective equipment with current ratings much higher than the actual load currents. The selected equipment is under utilized, and affords a poorer level of protection to the loads with pickup settings higher than would be desirable. A fault will produce more damage than would otherwise be sustained because of these higher settings. Breaker trip settings should be changed to more nearly match the load currents. Sometimes, instantaneous trips may have to be added. Other times, a protective device may have to be replaced with a more suitable one. The alternative is to accept less protection.

2. Compromises are continually made between protection and service continuity. Knowledge of the process plays a large part of making many decisions about device settings. If applied with good judgment, it should result in improved system protection.

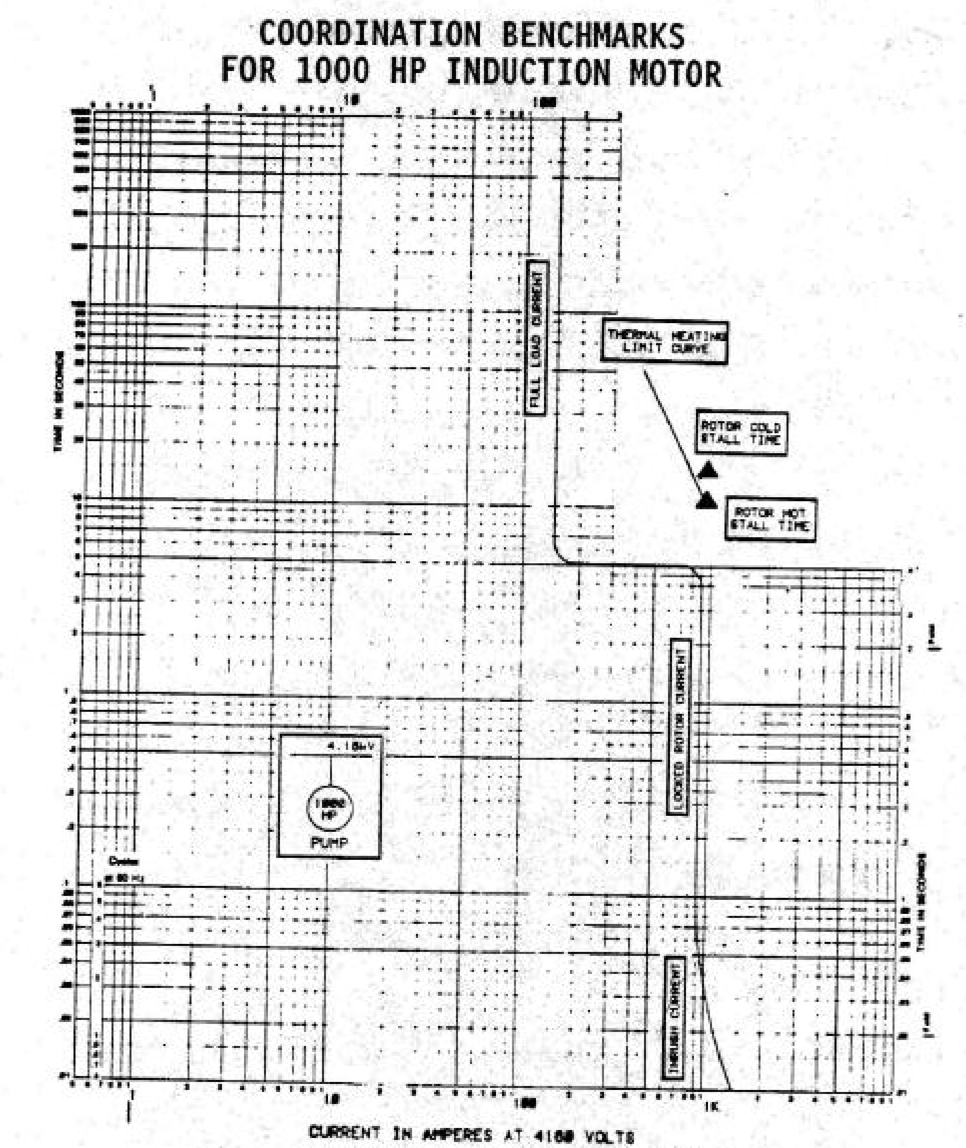
- Identification of Time-Current Curve Elements

1. A title block should be used to identify the time-current curve plot.
2. A legend can be included to identify the various elements of the particular coordination study.
3. Each protective device listed in the legend should be referred to by the manufacturer, model/type, and specified settings.
4. To identify the individual elements of a coordination study, a segment of the electrical one-line that is under study should be drawn on the coordination graph.

- Check coordination of other overcurrent protection devices not already covered or other downstream non-vital or smaller loads.

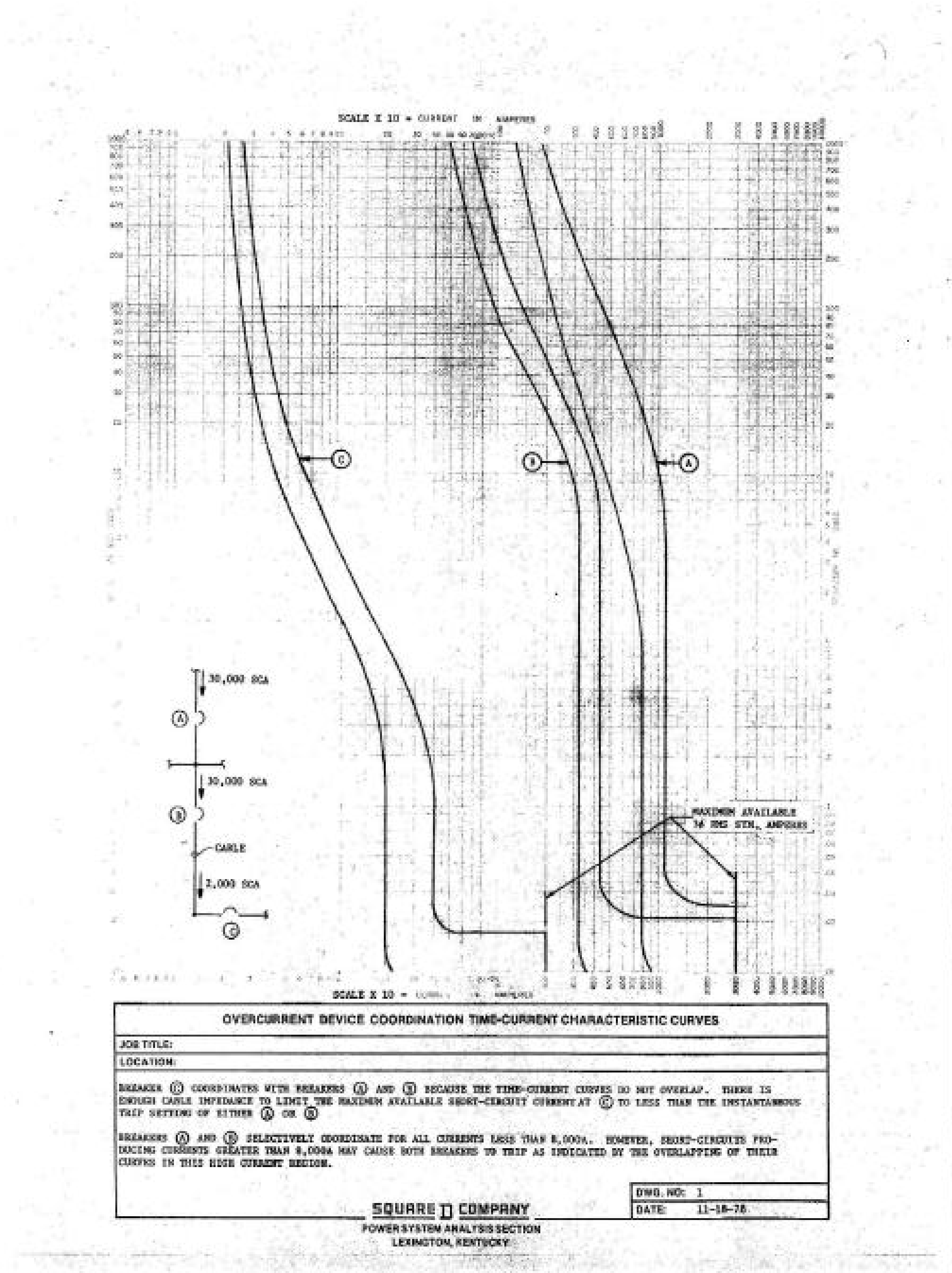
Attachments

1. Dwg. No. 1, Motor Benchmarks
2. Dwg. No. 2, Selectivity by Impedance in the Circuit
3. Dwg. No. 3, Selectivity by Time Delay in the Circuit Breaker
4. Dwg.No. 4A, OC Relay Margins
5. Dwg.No. 4B, OC Relay Margins
6. Dwg. No. 5, Transformer Protection
7. Dwg. No. 6, Induction Motors
8. Dwg. No. 7, Recommended Margins

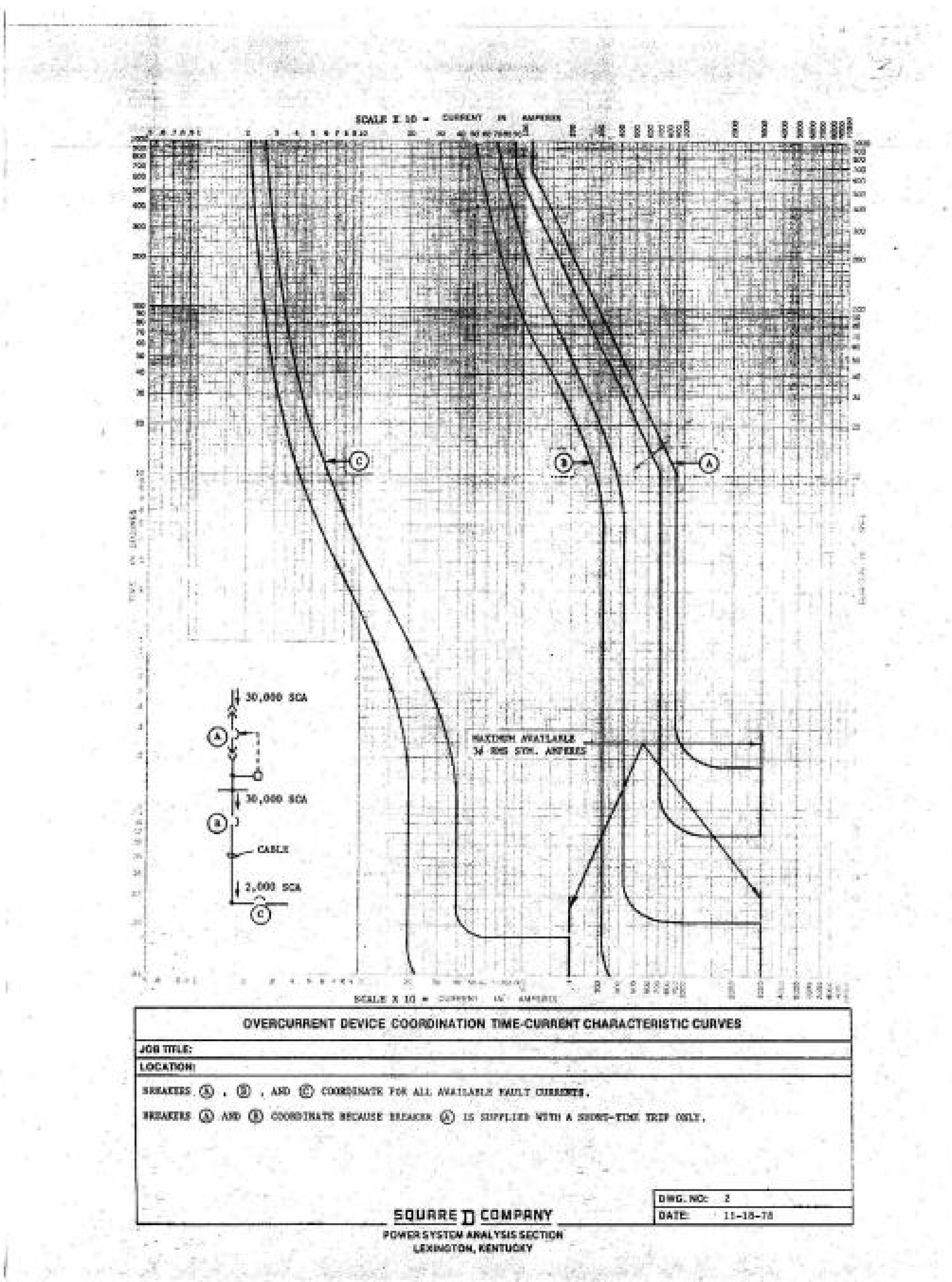


Coordination benchmarks for 1000-hp induction motor.

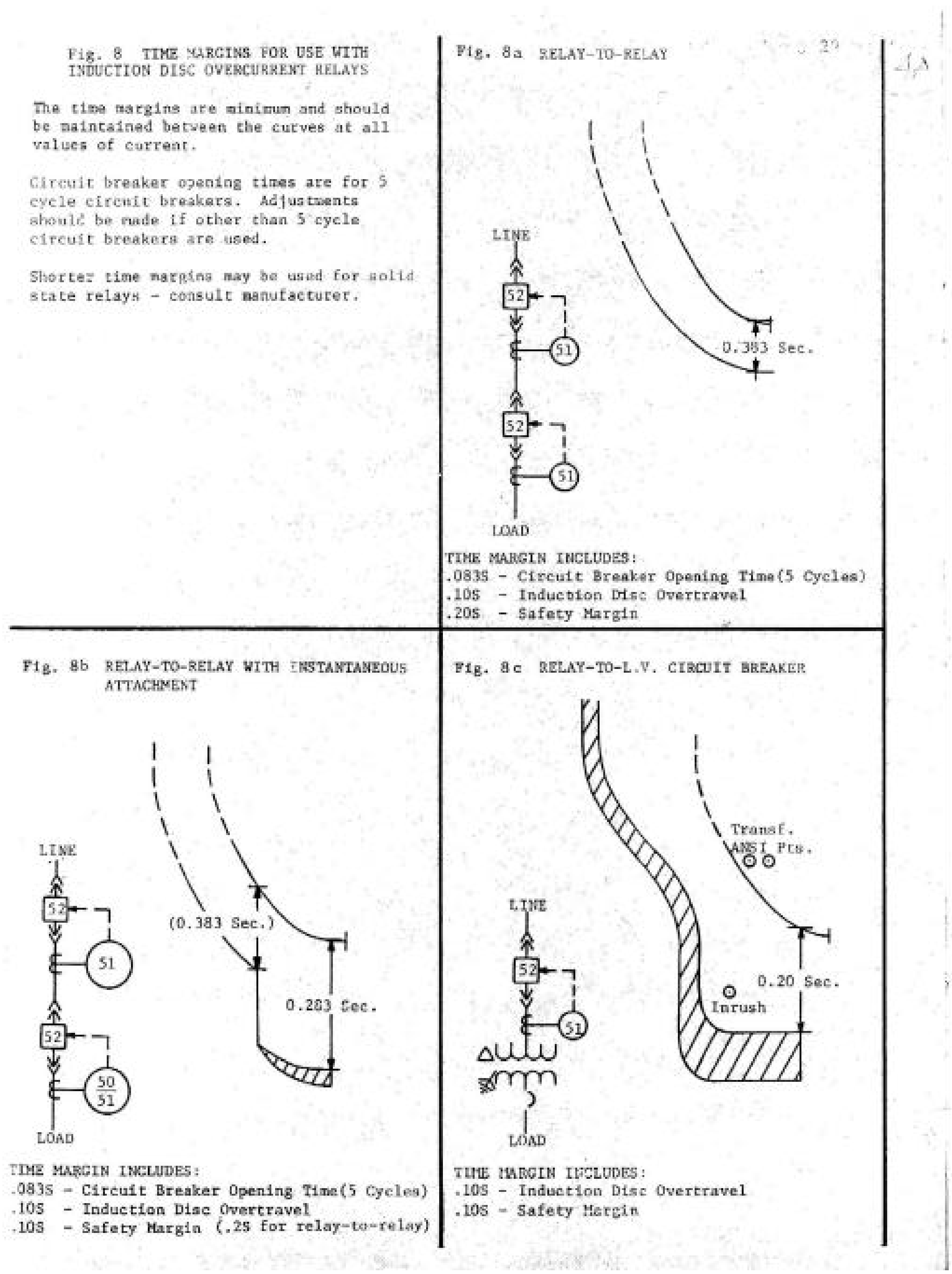
<u>Dwg. No. 1, Motor Benchmarks</u>



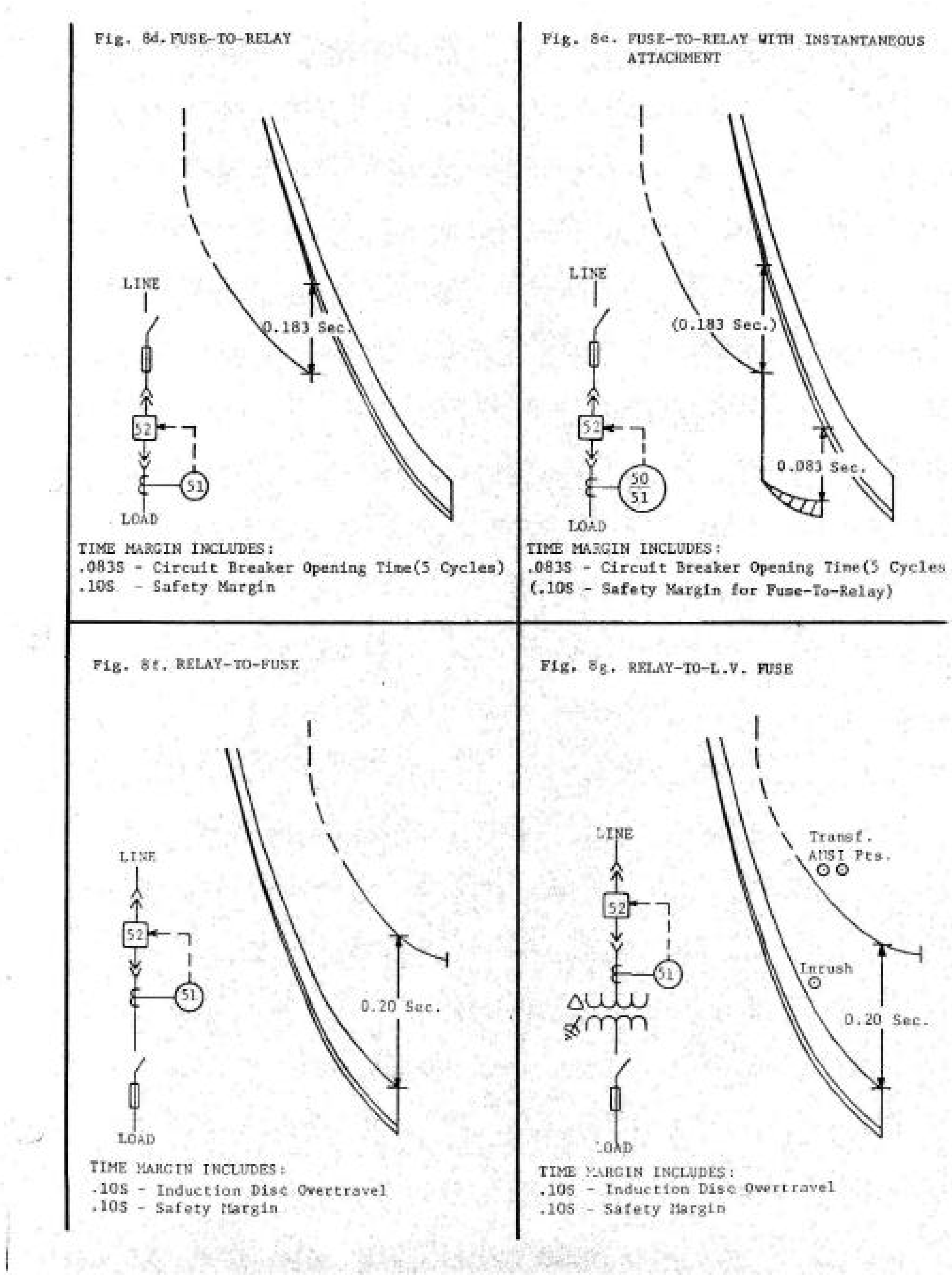
Dwg. No. 2, Selectivity by Impedance in the Circuit



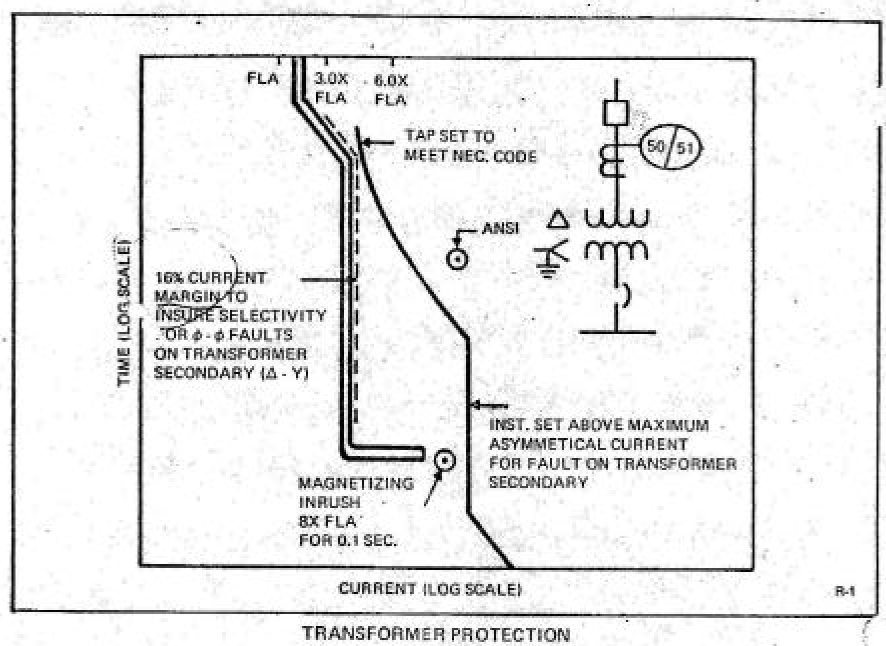
Dwg. No. 3, Selectivity by Time Delay in the Circuit Breaker



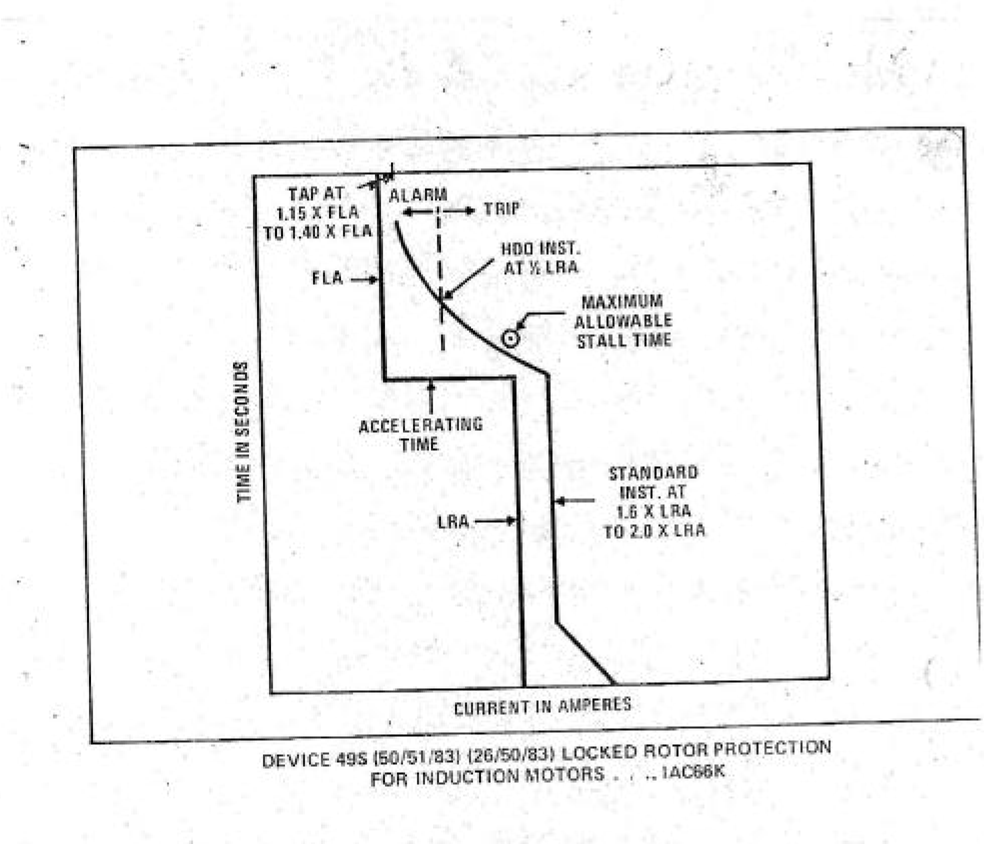
Dwg.No. 4A, OC Relay Margins



Dwg.No. 4B, OC Relay Margins



Dwg. No. 5, Transformer Protection



Dwg. No. 6, Induction Motors

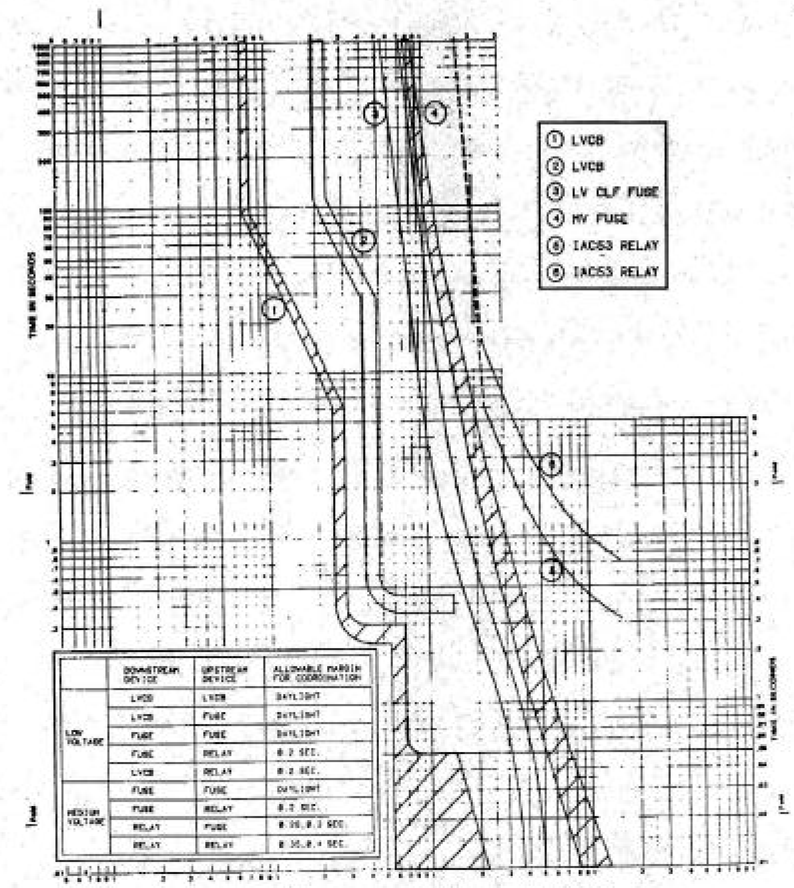


Fig. 6. Typical time-current curve title block and element identification.

Dwg. No. 7, Recommended Margins