Electrical Equipment - Course PI 30.2

FUSES

OBJECTIVES

On completion of this module the student will be able to:

1. List, in writing, three ratings of a fuse and briefly explain each rating in a few sentences.

2. Given a fuse's characteristic curves, interpret curves and explain in writing, why these curves are referred to as inverse-time characteristic curves?

3. State, in writing, the difference between a fast-acting and a time delay fuse and give one application for each fuse type.

4. In two or three sentences, state two main advantages of HRC fuses.

5. Illustrate, with a simple sketch, the construction of an HRC fuse.

6. In three or four sentences, explain the term "co-ordination" as referred to in electrical circuit protection; using a simple sketch explain why co-ordination is necessary.

7. Select the appropriate fuse current rating, when given a motor specification and characteristic curves for a fuse.

1. Introduction

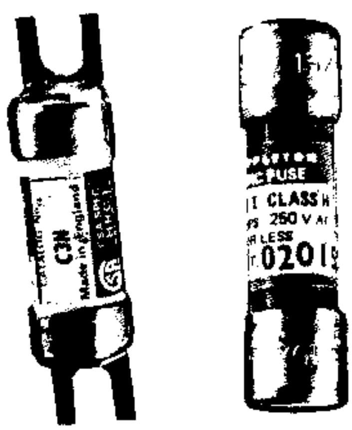
This lesson deals with:

(a) A fuse and its application.
(b) Fuse construction and specifications.
(c) Co-ordination and selection of fuse.

2. What is a Fuse

A fuse is a current sensitive device made of a conductor called an "element", surrounded by an arc quenching/heat conducting medium and is enclosed in a body fitted with endcaps. See Figure 1, below.

(a) High Rupture Capacity Fuse



(b) Cartridge Fuses

(c) Miniature, Glass Tube Fuse

(d) Plug Fuse

Figure 1: Commonly Available Fuse Types

3. Purpose of a Fuse

A fuse is a safety device. It provides safety to people and protection for equipment. A fuse is used to interrupt fault current, while allowing normal load current to pass.

The term "operation" of a fuse refers to the melting of the fuse element, or fuse blowing. When the current through the fuse reaches a point, where the heat produced by I^2R_F is sufficient to raise the element temperature to its melting point, the element melts and the fuse operates, or "blows". (R_F is the resistance of the fuse element and I is the current flowing through the fuse). At normal current, heat produced by I^2R_F is not sufficient to melt the element.

4. Fuse Ratings

Since the purpose of a fuse is to allow a normal load current to pass through and interrupt high fault currents, it has two current ratings:

(a) Continuous current rating: This means that the fuse element will not blow, age, deteriorate or overheat, if a current of up to 125% of rated capacity flows through the fuse.

(b) Interrupting current rating: This rating specifies the maximum fault current that the fuse can safely interrupt. Fuses normally "operate" from a minimum of 125% of continuous current rating, to the maximum specified interrupting current rating. This interrupting current rating can be as high as 200,000 amperes; depending on fuse type.

In addition to these two current ratings, there is also a voltage rating for the fuse.

(c) Voltage rating: After a fuse has "operated", or blown, arcing will not occur, internally or across the fuse terminals, if the fuse voltage rating is not exceeded. If the voltage rating of the fuse is lower than the voltage it is exposed to, arcing between the two ends may occur, the high fault current could continue to flow and the fuse could explode.

Fuse voltage ratings should always be equal to or greater than the circuit line voltage.

5. Fuse Construction

The basic parts of a fuse are:

(a) Fuse Element

It can be made of zinc, copper, aluminum, silver or silver alloy.

The cross sectional area of the element determines the current it is capable of handling. Element thickness, as well as, the type of material used, determine the melting point of the element.

(b) Fuse Body

It can be made of transparent glass, ceramics or fibreglass. The body should be able to withstand the mechanical forces and the heat produced during fuse "operation". As well, it must be able to provide proper electrical insulation between the two ends of the fuse, after the fuse element has blown.

(c) Endcaps and Terminals

Endcaps hold the element between the two ends of the fuse. Terminals are provided, in some high current fuses, for ease of installation.

End caps and terminals are made from copper to provide low resistance.

Screw-in type fuses are for 120V and currents of 30 amps or less. Applications of this type of fuse are normally found in the household. Screw type fuses have glass bodies with copper elements and screwends.

5. Fuse Construction (continued)

(a) Arc Quenching and Cooling

It is important to quench the arc as quickly as possible, when the fuse "operates". This is done in two ways:

(i) Create a vacuum in the fuse body. This also results in the elimination of element oxidation, thus improving fuse life.
(ii) Fill the fuse body with quartz sand which acts as a cooling agent, removes the air from the fuse, eliminates element oxidation and helps in arc quenching (by creating high resistance glass that is formed under high heat when the fuse element melts). This method is used in High Rupture Capacity (HRC) fuses.

6. Fuse Characteristics

A fuse operates when its element melts, due to the heat produced by I^2R_F. This heat produced increases as the current through the fuse increases. Hence, the fuse element melts faster for large fault currents, than for small fault currents. This time and current relationship of a fuse is referred to as the fuse characteristic. Figure 2 illustrates a typical set of characteristic curves for a fuse. These curves are very useful for:

(a) Selecting the degree of overload on a circuit.
(b) Co-ordination of other protective devices in the system.

How to interpret these curves will be discussed in the pages that follow.

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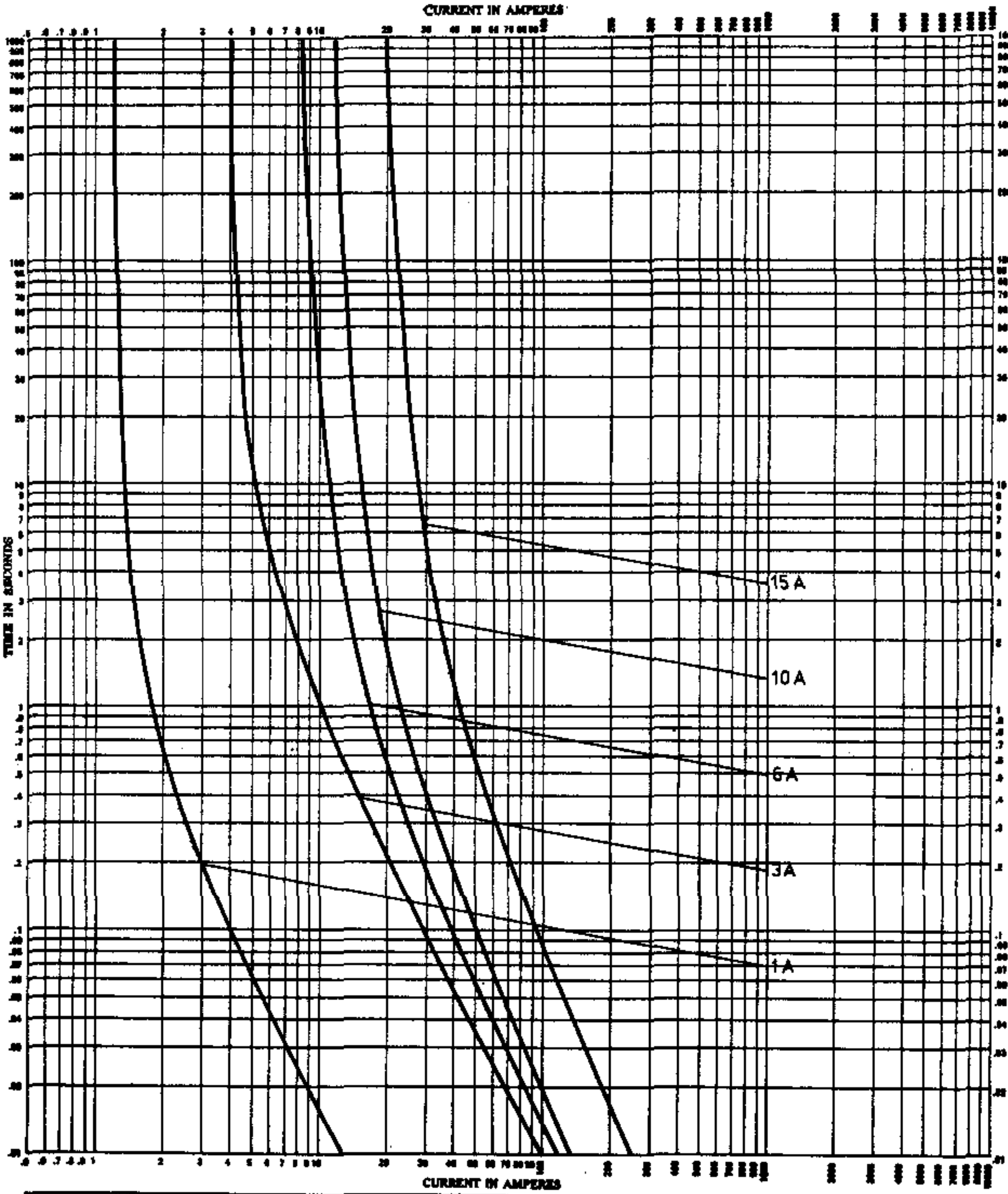

AVERAGE MELTING TIME-CURRENT CHARACTERISTIC CURVES

For TYPE HS-R 1-15A 600V Fuse Links, In OPEN

BASIS FOR DATA Standards CSA C22.2 No.106 Dated APRIL 1953

1. Tests made at ... Volts a.c. at ... p.f., Starting at 25C with no initial load

2. Curves are plotted to AVERAGE Test points so variations should be ±5% IN CURRENT

No. TC-574

Date FEB. 1979

Cefco® Shawmut®
Gould Electric Fuse Division
Toronto, Canada

GOULD

Figure 2: Characteristic Curves for a Fuse

6.1 How to Interpret Fuse Characteristic Curves

Figure 3 shows the curves for 1-ampere, 3-ampere, 6-ampere, 10-ampere and 15-ampere fuses. Consider the 10-ampere fuse curve.

If 10-amperes of current is flowing through the fuse, it will never "operate", or blow.

If 30-amperes of current is flowing through this 10-ampere fuse, it will blow in approximately 0.4 seconds.

If 100 amprezres of current is flowing through this fuse, it will blow in approximately 0.02 seconds.

Hence, as the fault current increases, the time taken for the fuse to blow, decreases. This is why fuse characteristic curves are referred to, as inverse time characteristic curves.

7. Fast Acting and Time Delay Fuses

A fast acting fuse is one which operates "instantaneously", when the current rating is exceeded. This type of fuse is used on resistive loads or semiconductor circuits which can not tolerate excess current for any length of time.

However, it should be noted that "instantaneous" *or fast acting fuses follow their time-current* relationship shown in the characteristic curves, at the right. The term "fast acting" or "instantaneous" is misleading.

Time delay fuses are designed to carry 500% of the rated continuous current, for ten seconds, without blowing. They are used in motor circuits to allow for motor in-rush currents, which are typically about 6 times the normal full load motor running current.

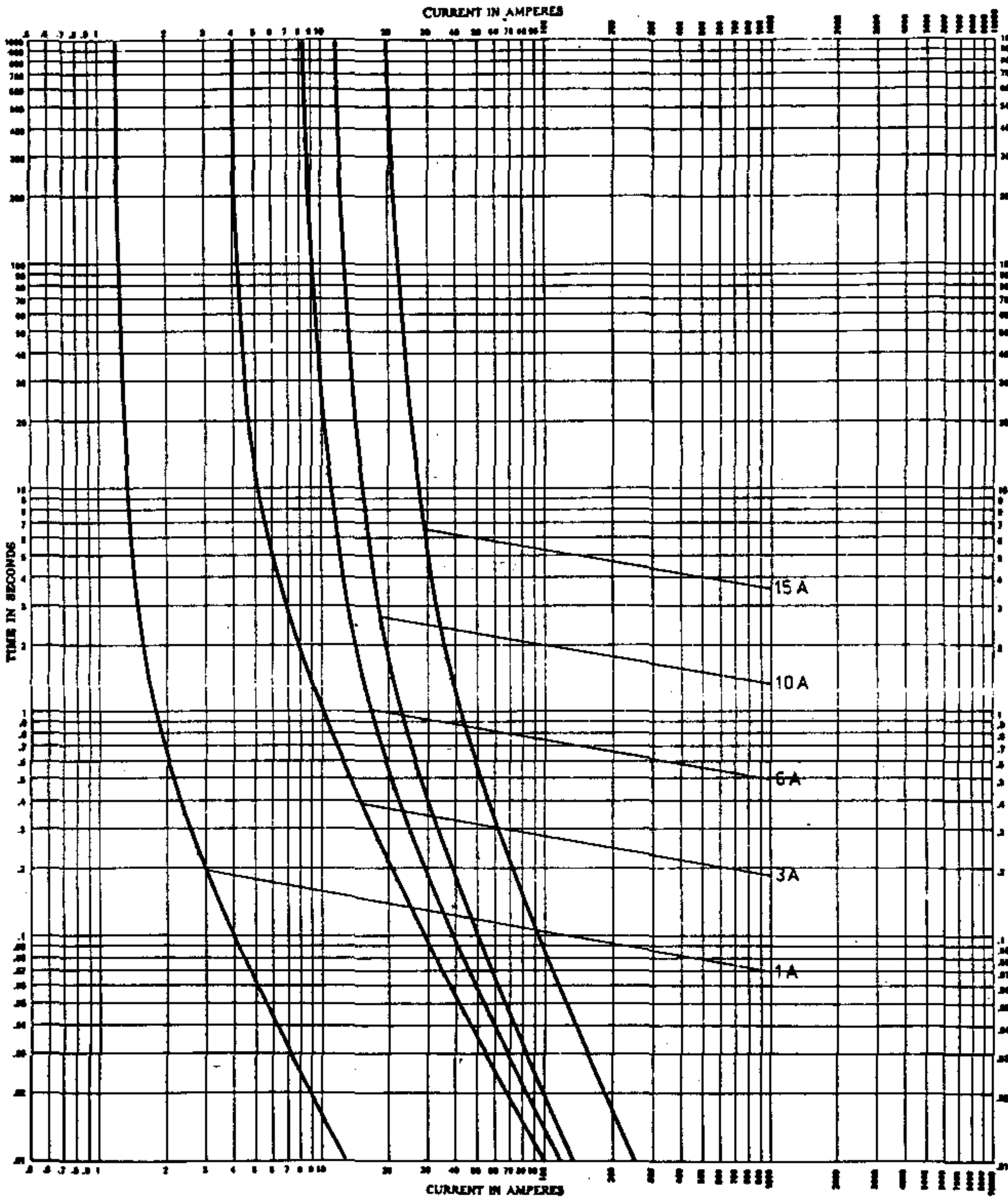

Figure 3: Characteristic Curve Example

8. High Rupture Capacity Fuses (HRC Fuses)

An HRC fuse is a type of fuse which can interrupt a high magnitude of fault current.

In power plants, HRC fuses are used extensively to protect buses, feeders and loads. The main advantages of HRC fuses are:

(a) It is a precision fuse whose operating characteristics are accurately known.

(b) It can interrupt a large magnitude of fault current.

8.1 HRC Fuse Construction

An HRC fuse is shown in Figure 4. Its construction consists of:

(a) The fuse element is made from silver or silver alloy, to improve fuse life and reduce the element resistance. Silver oxide is a good conductor of electricity. Hence, the fuse characteristics do not change appreciably over the installed life of the fuse. Also, the use of silver keeps element corrosion to a minimum.

(b) To improve reliability, the fuse element is notched. This ensures that the element will melt through at least one notch (possibly more), to quickly and cleanly, open the current path.

(c) The body of the fuse is made from ceramic or fibreglass. This provides good mechanical strength, high temperature stability and good electrical isolation between the two endcaps.

(d) The space, between the fuse element and the fuse body, is completely filled with silica sand, for the following reasons:

(i) It removes the air from inside. Hence, reduces oxidation of the element and improves the element life.

(ii) Provides cooling to the element, during the normal functioning of the fuse.

(iii) Acts as an arc quencher, by forming high resistance glass, when high heat is produced, during melting of the fuse element.

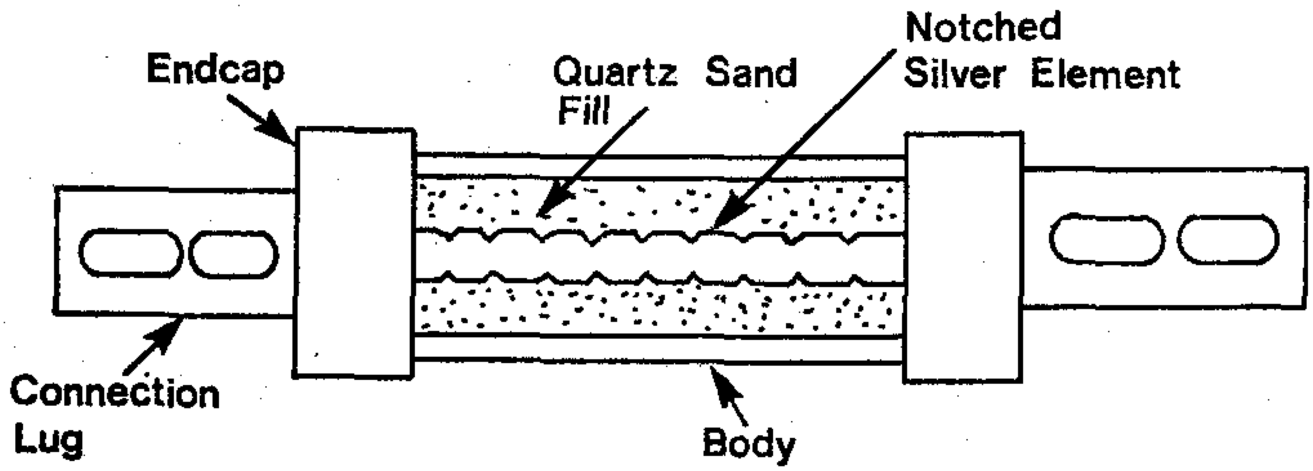

Figure 4: Internal Construction of an HRC Fuse

Note: If this fuse is only partially filled with silica sand, air could be inside the fuse. If the fuse "operates", this air will expand and may cause the fuse to explode. A partially filled fuse can be detected by shaking and listening for loose sand.

9. Co-ordination and Selection

9.1 Co-ordination

In an electrical distribution system, as shown in Figure 5, it is important that only the "load-side" fuse operates, when the fault is in the loadside. If a fault at the load causes the main supply fuse, or even a bus fuse, to operate, then it will result in unnecessary blackout and expensive down time for other loads, which are not at fault. To ensure that this does not happen, co-ordination between all the fuses, in the distribution tree, is necessary. This is done by calculating the fault current, at each step, and selecting a proper fuse accordingly.

Refer to Figure 5. From the transformer to the aluminum bus duct, there are impedances of the cables and the buses themselves. These impedances will progressively reduce the short circuit current. If a fault occurs at bus A, then it is desirable that only fuse F_1 blow. This prevents power interruption to any load connected to bus B. If a fault occurs on bus B, then only F_2 should blow, but not F_3.

In order to achieve the above co-ordination, it is required that the interruption current and "operate" time of F_2 be higher than the interruption current and time of F_1. The interruption current and time of F_3 should be higher than the interruption current and time of F_2.

Calculations involved in this process are beyond the scope of these notes. Detailed information can be found in the IEEE Buff Book, "Recommended Practice for Protection and Co-ordination of Industrial and Commerical Power Systems".

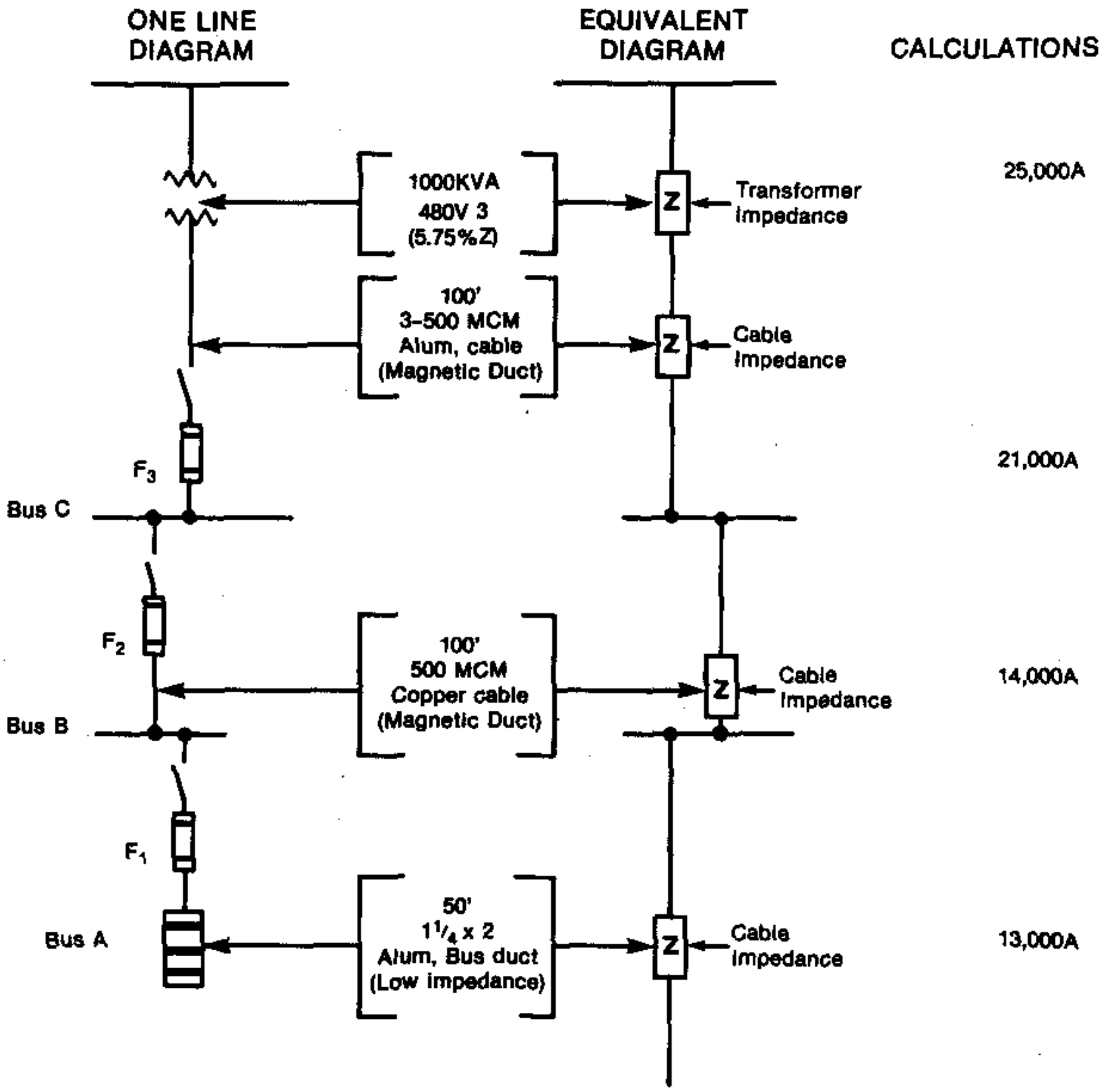

Figure 5: Distribution Tree Co-ordination

9.2 Fuse Selection For a Motor

A motor draws about six times the normal full load current, when it is started under load. The fuse, which is there to protect the motor under short circuit conditions, **must allow this high in-rush current, of the motor, to pass** .

Consider a motor whose full load current is 6 amperes and the motor takes one second to accelerate to its normal running speed.

Motor starting current = 6 x I_{FL} = 6 x 6 = 36-amperes

Motor acceleration time = 1 second.

Assume that a 6-ampere fuse is selected from Figure 6. For a 6-ampere fuse at a 36-ampere fault current, it will take 0.15 seconds to blow.

Since the motor takes one second to accelerate, the fuse will blow before the motor has fully accelerated.

However, if a 15-ampere fuse is selected, at a fault current of 36-amperes, the 15-ampere fuse would take about 2 seconds to blow. Therefore, the motor would have sufficient time to accelerate to its rated speed. Using this 15-ampere fuse, the motor can accelerate to its operational speed without blowing the fuse.

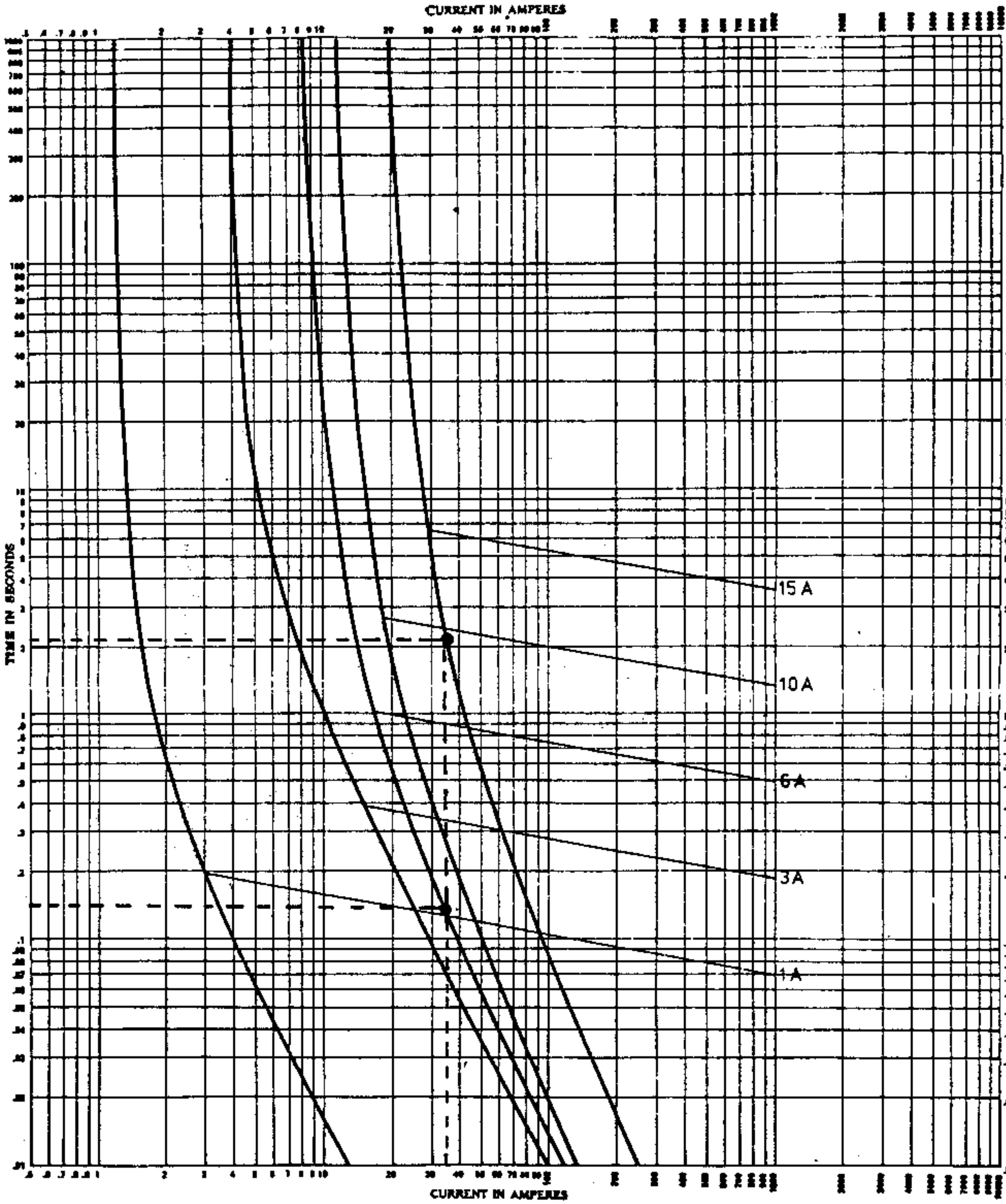

Figure 6: Fuse Selection for Motor Example

ASSIGNMENT

1. Explain what a fuse is and what purpose it serves. (Sections 2 and 3)

2. List the three ratings of a fuse and briefly explain each rating. (Section 4)

3. Explain what is meant by inverse time characteristics of a fuse. (Sections 6 and 6.1)

4. Explain what is meant by "fast acting" and "time delay" fuses. Give one application of each. (Section 7)

5. In an HRC fuse: (Section 8 and 8.1)

   (a) State two main advantages of an HRC fuse.

   (b) Give three functions for the quartz sand.

   (c) Why is the element made of silver or copper?

   (d) What is the consequence of installing an HRC fuse which has partial filling of quartz sand?

6. Why is it important to have fuse co-ordination in a distribution tree? Briefly explain how it is achieved. (Section 9.1)

7. Full load current of a motor is 50A and it takes three seconds to accelerate. For this motor, use Figure 7 and:

(a) Locate the in-rush current on the graph.
(b) How long it will take for the 70A fuse to blow at this in-rush current?

(c) Can this fuse be used for the motor protection? If not, why? Recommend a proper fuse from the various fuses shown in Figure 7. (Section 9.2)

Answers: (a) 300
(b) .7 seconds
(c) 100 Amp Fuse

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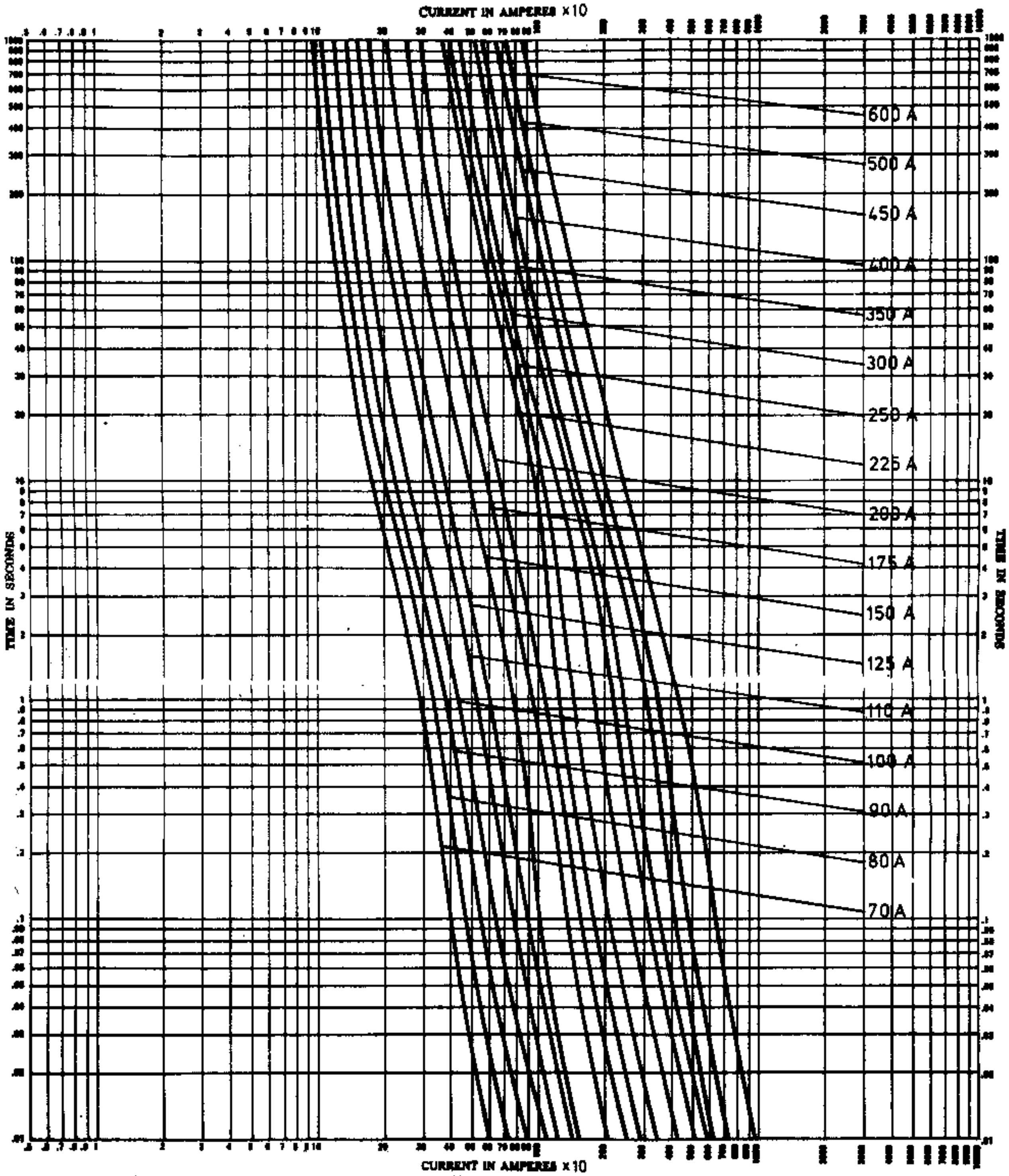

AVERAGE MELTING TIME-CURRENT CHARACTERISTIC CURVES
For TYPE CJ 70-600A 600V HRC1 Fuse Links, to OPEN
BASIS FOR DATA Standards CSA C22.2 No. 106 Dated APRIL 1953
1. Tests made at .... Volts a-c at .... p.f., Starting at 25C with no initial load
2. Curves are plotted to AVERAGE Test points so variations should be ±5% IN CURRENT

No. TC-570
Date FEB. 1979

Figure 7: Fuse Characteristic Curves