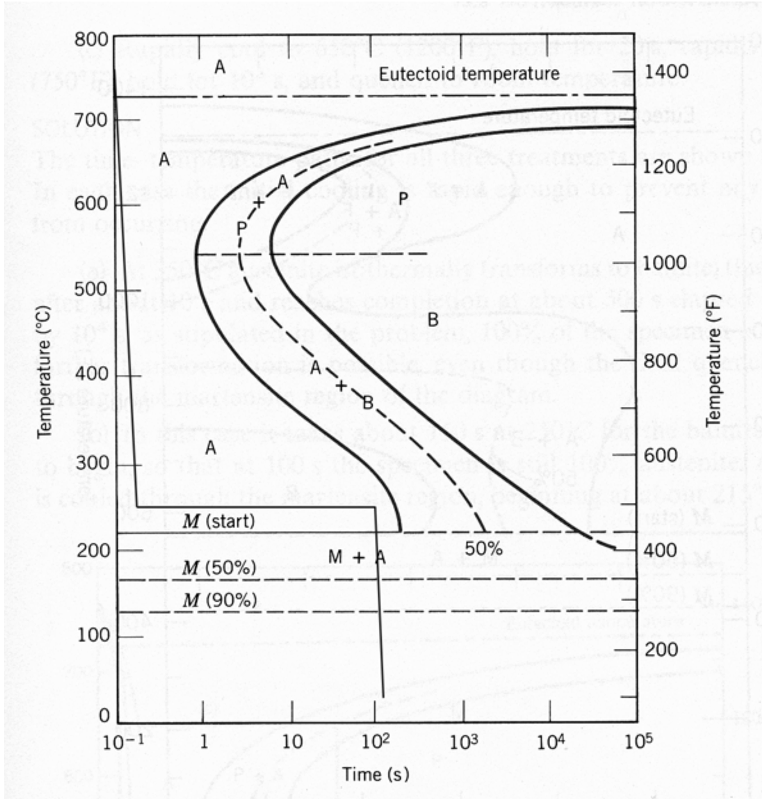


After cooling and holding at 250°C for 100 s, no transformations will have occurred—at this point, the entire specimen is still austenite. Upon rapidly cooling to room temperature in water, the specimen will completely transform to martensite. The second heat treatment (at 315°C for 1 h)—not shown on the above plot—will transform the material to tempered martensite. Hence, the final microstructure is 100% tempered martensite.

10.19 *Make a copy of the isothermal transformation diagram for an iron–carbon alloy of eutectoid composition (Figure 10.22) and then sketch and label time–temperature paths on this diagram to produce the following microstructures:*

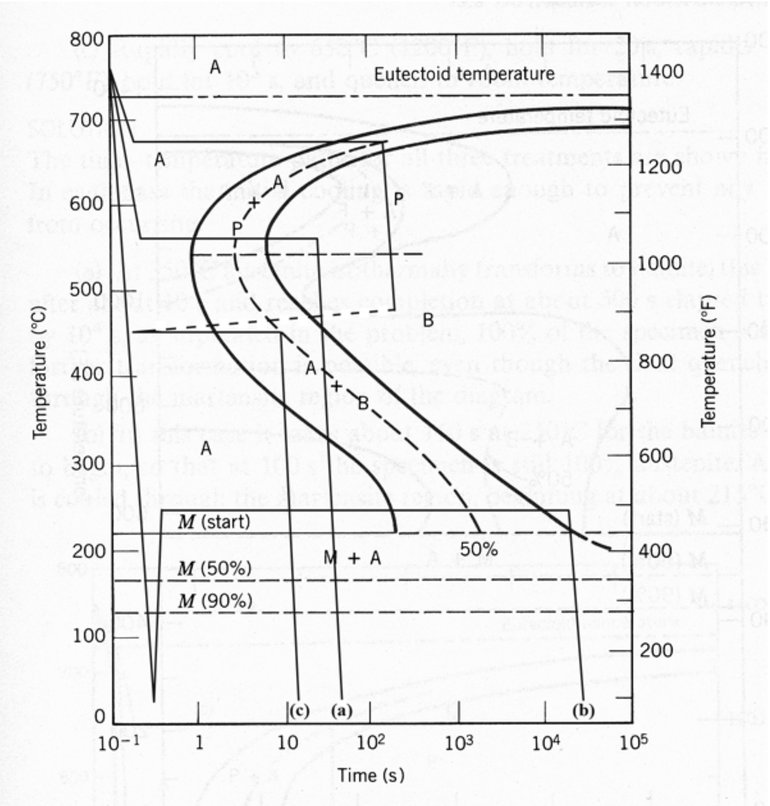
(a) 100% fine pearlite

(b) 100% tempered martensite

(c) 50% coarse pearlite, 25% bainite, and 25% martensite

<u>Solution</u>

Below is shown the isothermal transformation diagram for a eutectoid iron-carbon alloy, with time-temperature paths that will yield (a) 100% fine pearlite; (b) 100% tempered martensite; and (c) 50% coarse pearlite, 25% bainite, and 25% martensite.

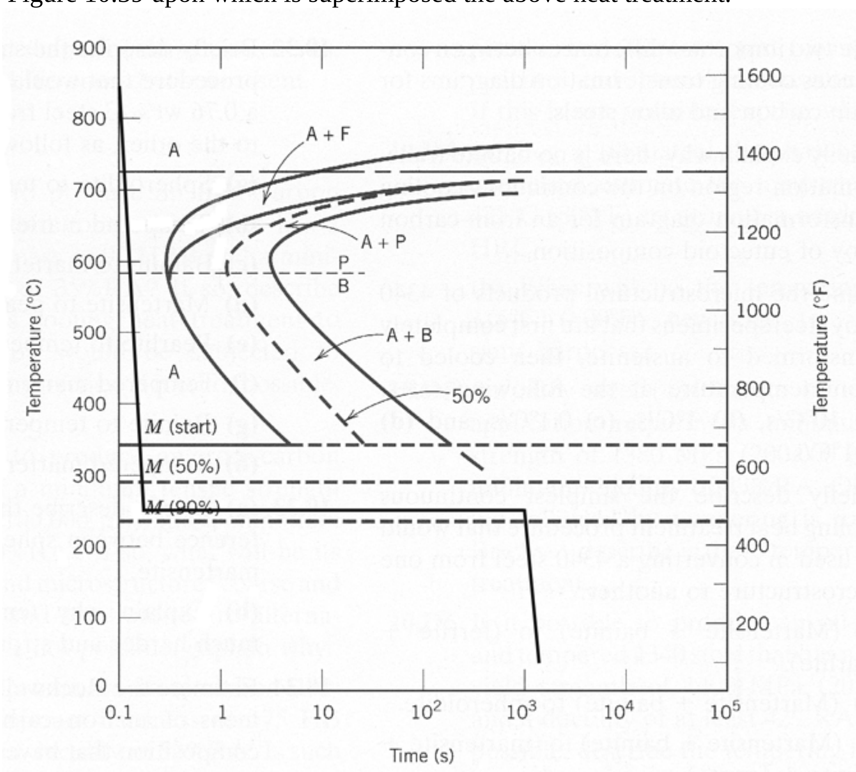


10.20 *Using the isothermal transformation diagram for a 0.45 wt% C steel alloy (Figure 10.39), determine the final microstructure (in terms of just the microconstituents present) of a small specimen that has been subjected to the following time-temperature treatments. In each case assume that the specimen begins at 845°C (1550°F), and that it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic structure.*

(a) Rapidly cool to 250°C (480°F), hold for 10^3 s, then quench to room temperature.

Solution

Below is Figure 10.39 upon which is superimposed the above heat treatment.

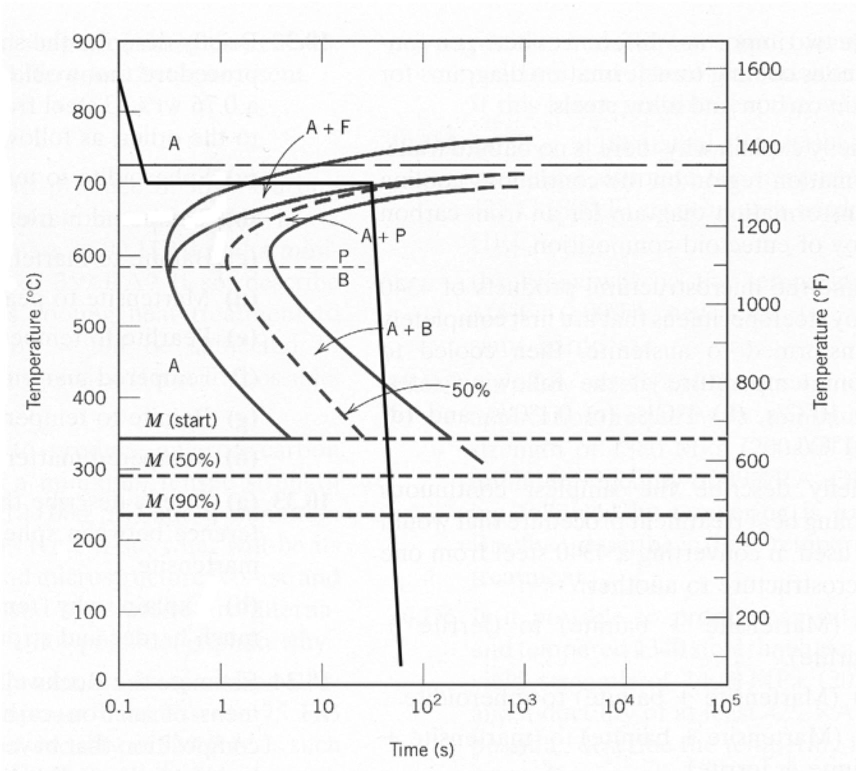


While rapidly cooling to 250°C about 80% of the specimen transforms to martensite; during the 1000 s isothermal treatment at 250°C no additional transformations occur. During the final cooling to room temperature, the untransformed austenite also transforms to martensite. Hence, the final microstructure consists of 100% martensite.

(b) Rapidly cool to 700°C (1290°F), hold for 30 s, then quench to room temperature.

Solution

Below is Figure 10.39 upon which is superimposed the above heat treatment.

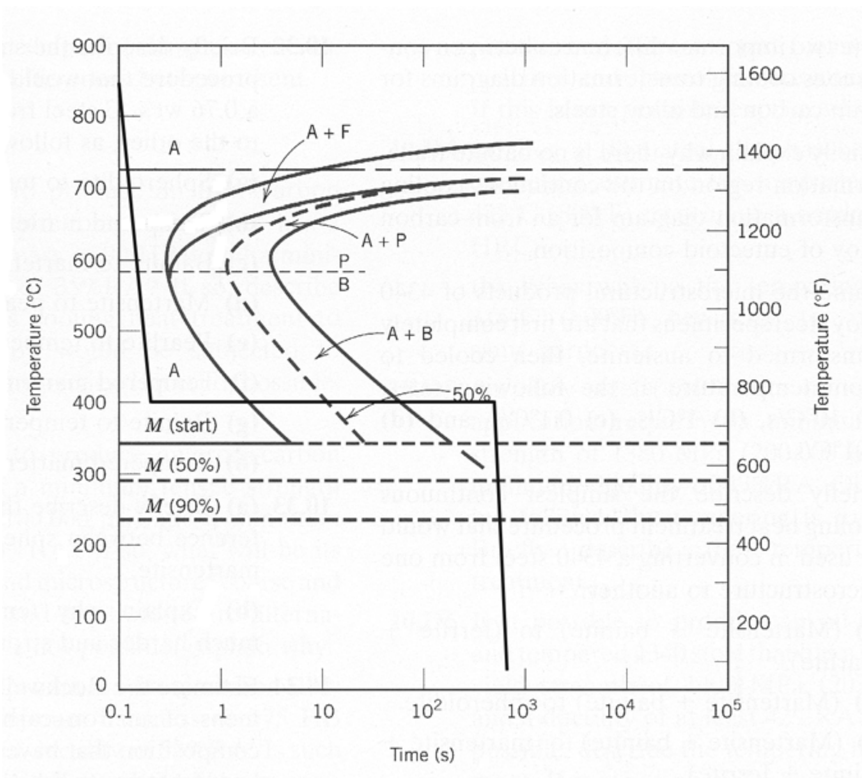


After cooling to and holding at 700°C for 30 s, a portion of specimen has transformed to proeutectoid ferrite. While cooling to room temperature, the remainder of the specimen transforms to martensite. Hence, the final microstructure consists proeutectoid ferrite and martensite.

(c) Rapidly cool to 400°C (750°F), hold for 500 s, then quench to room temperature.

Solution

Below is Figure 10.39 upon which is superimposed the above heat treatment.

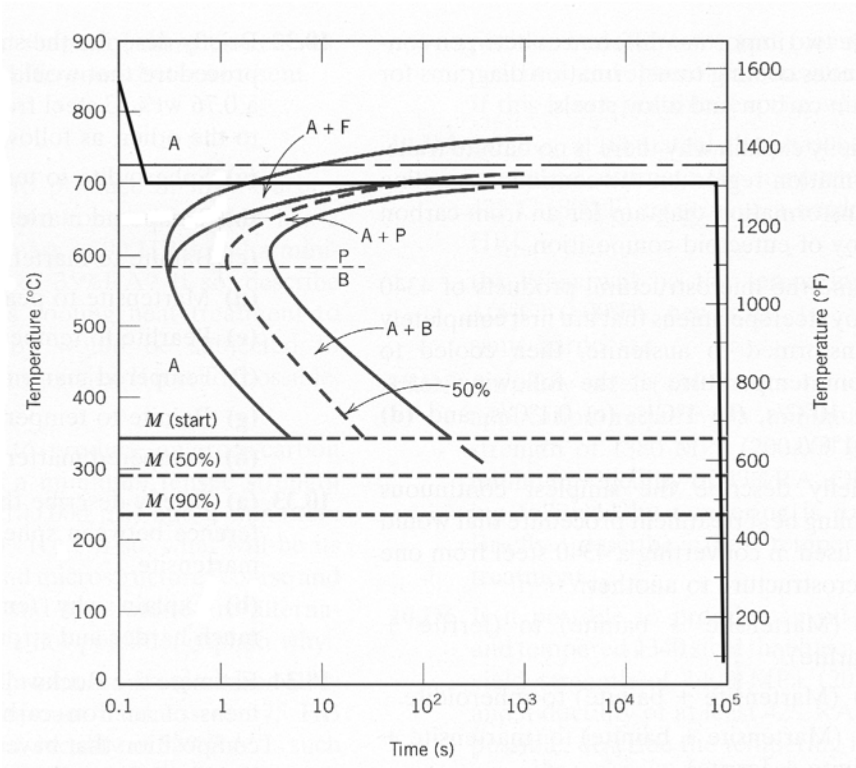


After cooling to and holding at 400°C for 500 s, all of the specimen has transformed to bainite. Hence, the final microstructure consists of 100% bainite.

(d) Rapidly cool to 700°C (1290°F), hold at this temperature for 10^5 s, then quench to room temperature.

<u>Solution</u>

Below is Figure 10.39 upon which is superimposed the above heat treatment.

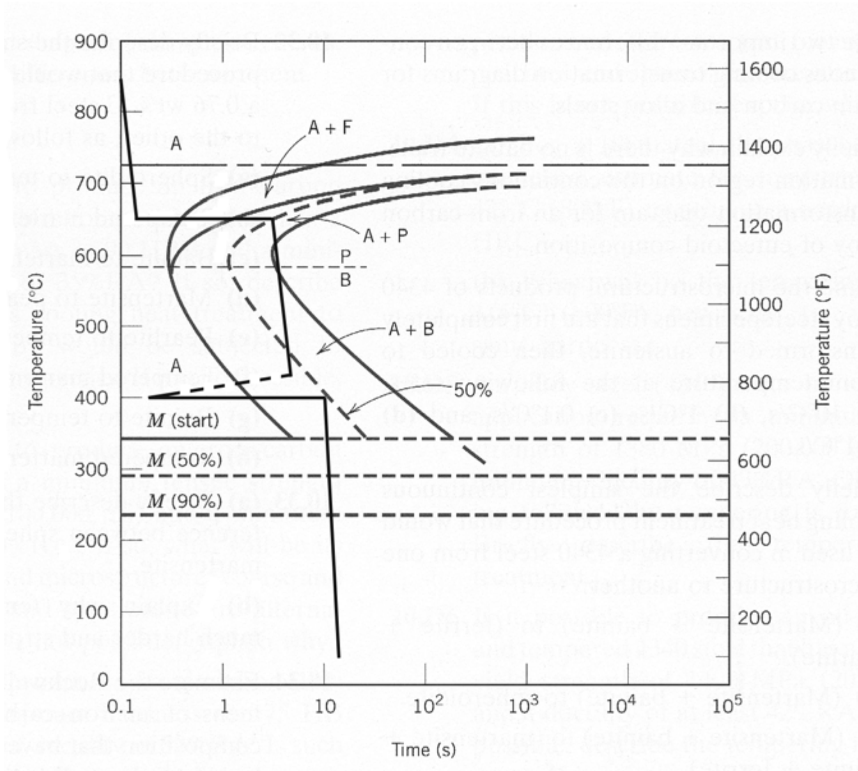


After cooling to and while holding at 700°C the specimen first transforms to proeutectoid ferrite and coarse pearlite. Continued heat treating at 700°C for 10^5 s results in a further transformation into spheroidite. Hence, the final microstructure consists of 100% spheroidite.

(e) Rapidly cool to 650°C (1200°F), hold at this temperature for 3 s, rapidly cool to 400°C (750°F), hold for 10 s, then quench to room temperature.

Solution

Below is Figure 10.39 upon which is superimposed the above heat treatment.

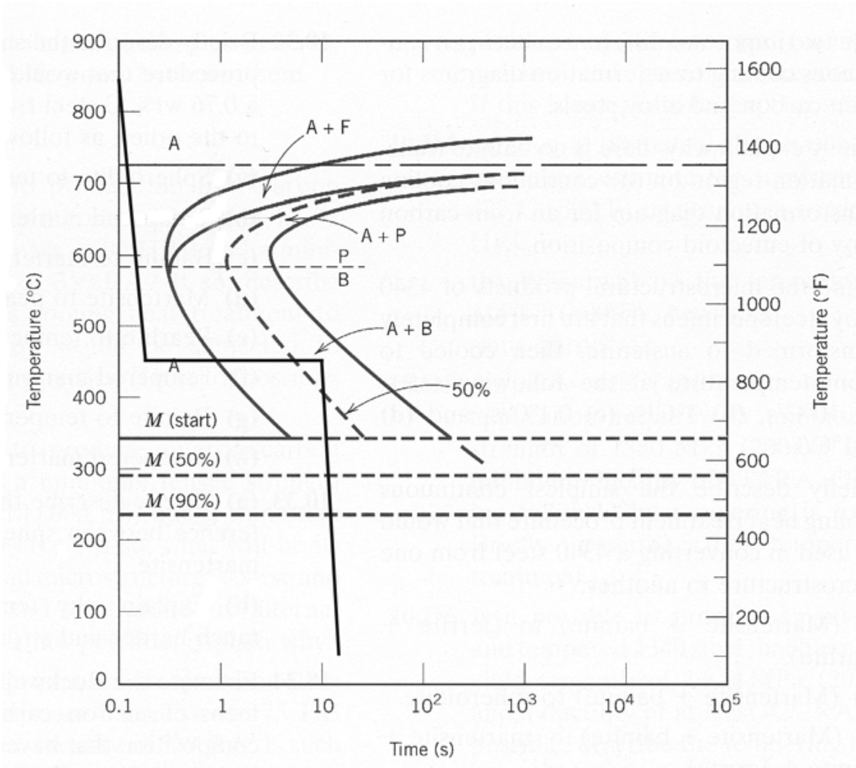


After cooling to and holding at 650°C for 3 s, some of the specimen first transformers to proeutectoid ferrite and then to pearlite (medium). During the second stage of the heat treatment at 400°C, some (but not all) of the remaining unreacted austenite transforms to bainite. As a result of the final quenching, all of the remaining austenite transforms to martensite. Hence, the final microstructure consists of ferrite, pearlite (medium), bainite, and martensite.

(f) Rapidly cool to 450°C (840°F), hold for 10 s, then quench to room temperature.

Solution

Below is Figure 10.39 upon which is superimposed the above heat treatment.

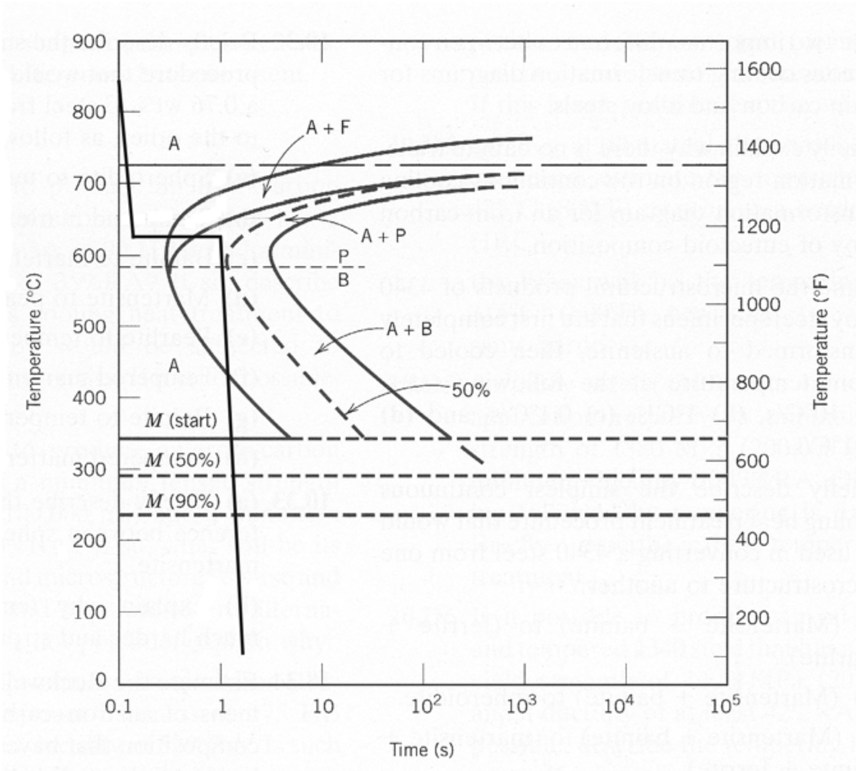


After cooling to and holding at 450°C for 10 s, a portion of the specimen first transformers to bainite. During the quenching to room temperature, the remainder of the specimen transforms to martensite. Hence, the final microstructure consists of bainite and martensite.

(g) Rapidly cool to 625°C (1155°F), hold for 1 s, then quench to room temperature.

<u>Solution</u>

Below is Figure 10.39 upon which is superimposed the above heat treatment.

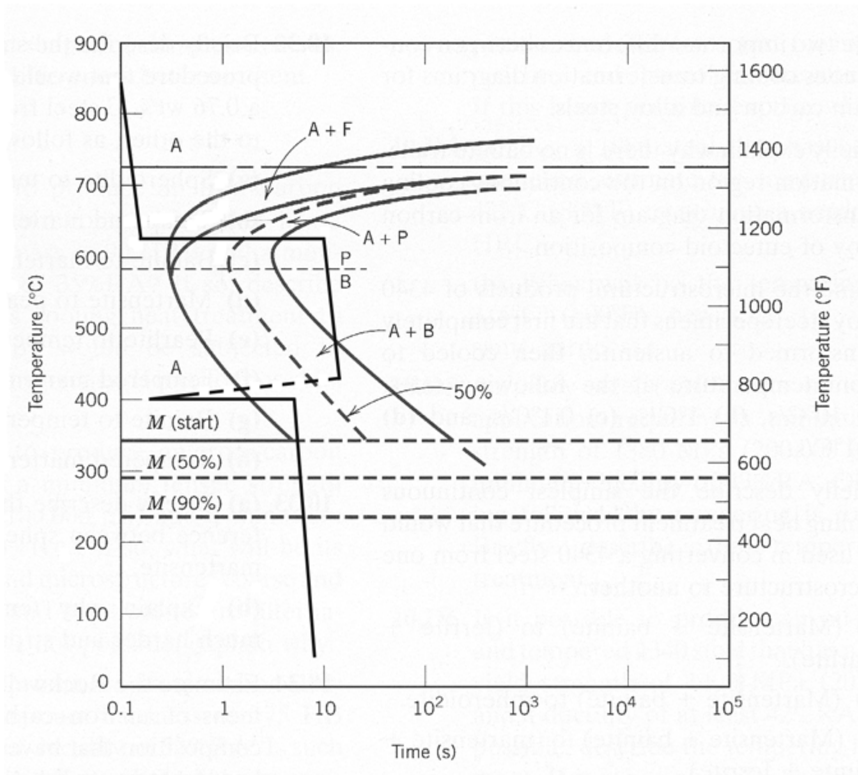


After cooling to and holding at 625°C for 1 s, a portion of the specimen first transformers to proeutectoid ferrite and pearlite. During the quenching to room temperature, the remainder of the specimen transforms to martensite. Hence, the final microstructure consists of ferrite, pearlite, and martensite.

(h) Rapidly cool to 625°C (1155°F), hold at this temperature for 10 s, rapidly cool to 400°C (750°F), hold at this temperature for 5 s, then quench to room temperature.

Solution

Below is Figure 10.39 upon which is superimposed the above heat treatment.



After cooling to and holding at 625°C for 10 s, all of the specimen transformers to proeutectoid ferrite and pearlite. During the second part of the heat treatment at 400°C no additional transformation will occur. Hence, the final microstructure consists of ferrite and pearlite.

10.21 *For parts (a), (c), (d), (f), and (h) of Problem 10.20, determine the approximate percentages of the microconstituents that form.*

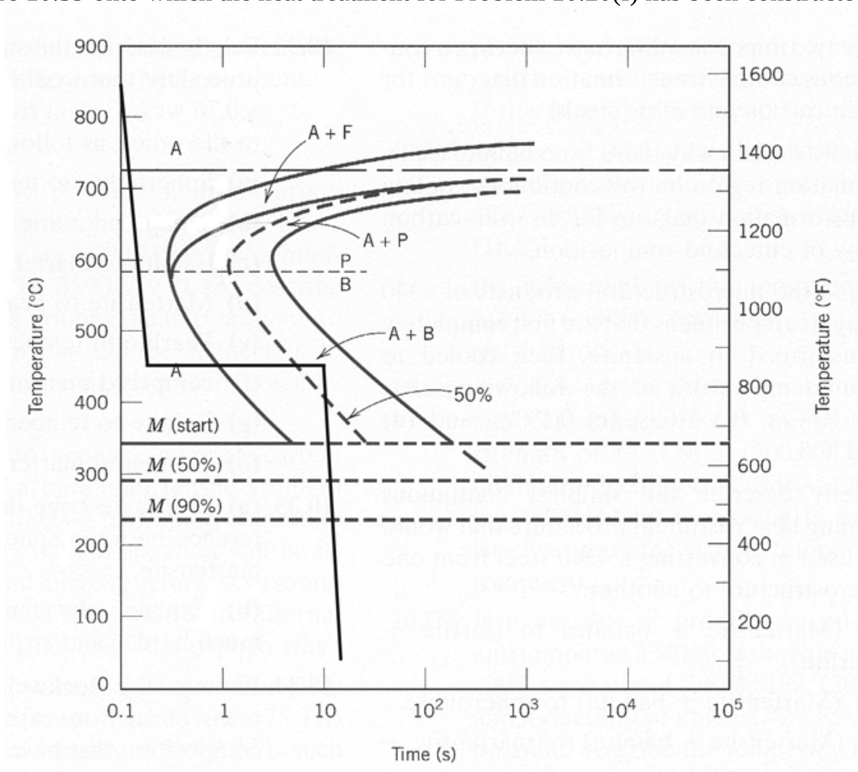
<u>Solution</u>

(a) From Problem 10.20(a) the microstructure consists of 100% martensite.

(c) From Problem 10.20(c) the microstructure consists of 100% bainite.

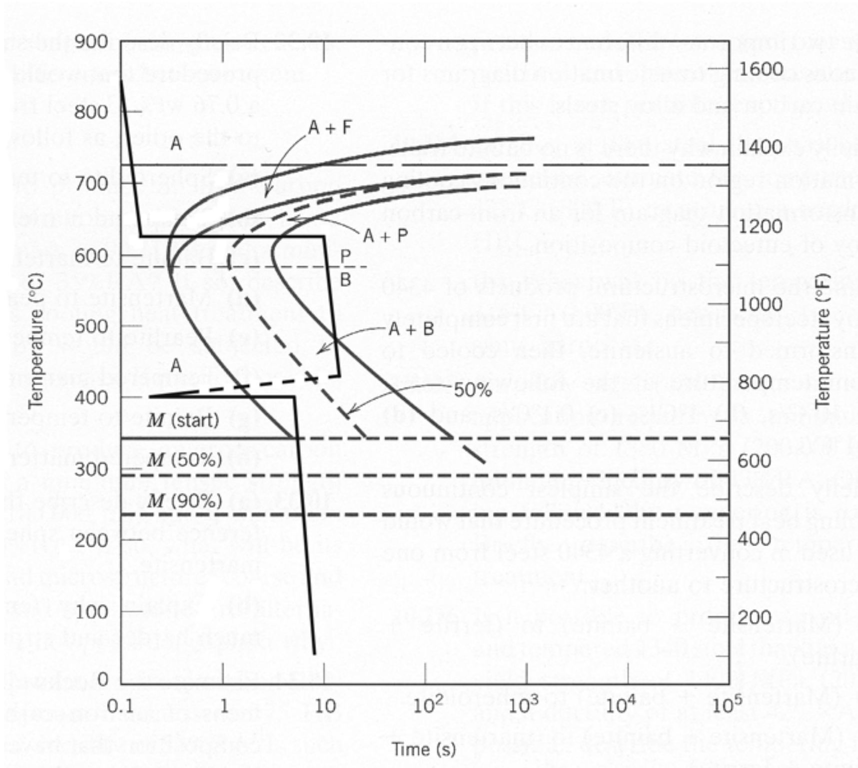
(d) From Problem 10.20(d) the microstructure consists of 100% spheroidite.

(f) Figure 10.39 onto which the heat treatment for Problem 10.20(f) has been constructed is shown below.



From this diagram, for the isothermal heat treatment at 450°C, the horizontal line constructed at this temperature and that ends at the 10 s point spans approximately 70% of the distance between the bainite reaction start and reaction completion curves. Therefore, the final microstructure consists of about 70% bainite and 30% martensite (the martensite forms while cooling to room temperature after 10 s at 450°C).

(h) Figure 10.39 onto which the heat treatment for Problem 10.20(h) has been constructed is shown below.



After holding for 10 s at 625°C, the specimen has completely transformed to proeutectoid ferrite and fine pearlite; no further reaction will occur at 400°C. Therefore, we can calculate the mass fractions using the appropriate lever rule expressions, Equations 9.20 and 9.21, as follows:

$$W_p = \frac{C_0' - 0.022}{0.74} = \frac{0.45 - 0.022}{0.74} = 0.58 \text{ or } 58\%$$

$$W_{\alpha'} = \frac{0.76 - C_0'}{0.74} = \frac{0.76 - 0.45}{0.74} = 0.42 \text{ or } 42\%$$

10.22 *Make a copy of the isothermal transformation diagram for a 0.45 wt% C iron-carbon alloy (Figure 10.39), and then sketch and label on this diagram the time-temperature paths to produce the following microstructures:*

(a) 42% proeutectoid ferrite and 58% coarse pearlite

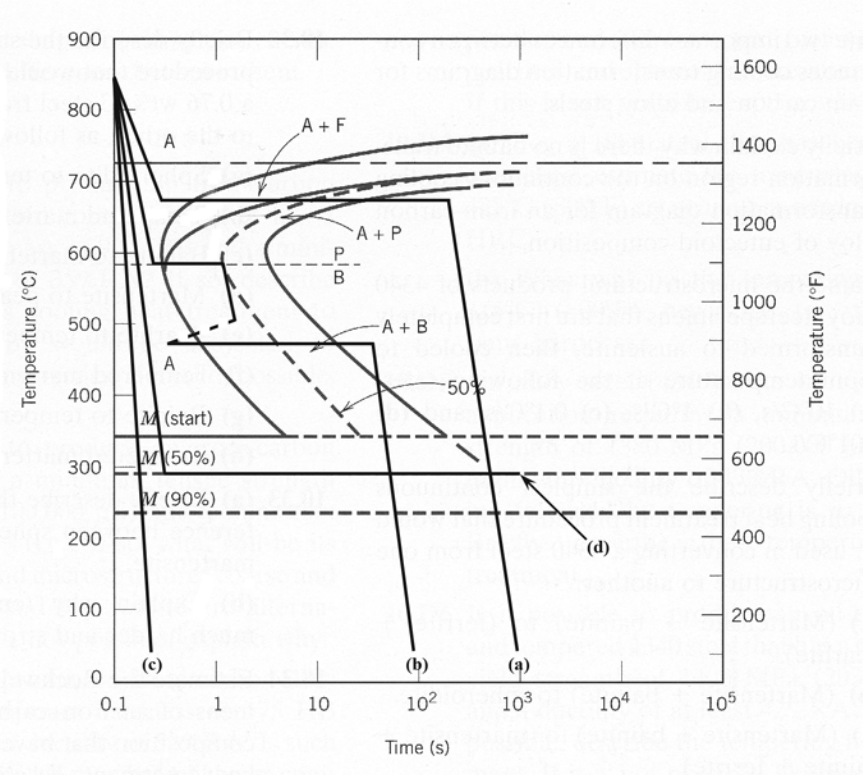
(b) 50% fine pearlite and 50% bainite

(c) 100% martensite

(d) 50% martensite and 50% austenite

Solution

Below is shown an isothermal transformation diagram for a 0.45 wt% C iron-carbon alloy, with time-temperature paths that will produce (a) 42% proeutectoid ferrite and 58% coarse pearlite; (b) 50% fine pearlite and 50% bainite; (c) 100% martensite; and (d) 50% martensite and 50% austenite.



Continuous Cooling Transformation Diagrams

10.23 *Name the microstructural products of eutectoid iron–carbon alloy (0.76 wt% C) specimens that are first completely transformed to austenite, then cooled to room temperature at the following rates:*

(a) 200°C/s,

(b) 100°C/s, and

(c) 20°C/s.

Solution

We are called upon to name the microstructural products that form for specimens of an iron-carbon alloy of eutectoid composition that are continuously cooled to room temperature at a variety of rates. Figure 10.27 is used in these determinations.

(a) At a rate of 200°C/s, only martensite forms.

(b) At a rate of 100°C/s, both martensite and pearlite form.

(c) At a rate of 20°C/s, only fine pearlite forms.