

Some Observations On The Dilation Of Casecarburized Steel

and

The Transformation Point At 470°C In Ieta Brass

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Some Observations On The Dilation Of Casecarburized Steel

The Metallurgist of today has at his command many more tools to aid him in his search for a more thorough knowledge of the physical and chemical properties of metals than did his predecessors of a few years ago. Besides chemical analysis, the principal methods of metallography are photomicrography and thermal analysis. Photomicrography reveals the structure of the specimen at ordinary temperatures after it has been subject to chemical or physical changes. Being applicable only in the vicinity of room temperature, it cannot give us any information as to the reactions to which the metal is subject during heat treatment.

It is common knowledge that metals expand on heating and upon being cooled contract. Upon looking in our handbook at the table of the Coefficients Of Thermal Expansion, we find a great number of materials listed, but only for a small range of temperature. A great many substances expand at the same rate for several hundred degrees and then through a small temperature range expand at an entirely different rate. A thorough knowledge of the expansion characteristics of a metal throughout the whole range of temperature to which a metal may be subjected is of prime importance to the man who is endeavoring to use the metal to its best advantage.

We know that steel is composed of several elements. It would be rather surprising if all these elements had the same rate of expansion. These elements may all have a different rate of expansion so that the net expansion

would be the average of the algebraic sum of the coefficients of all of the constituents. There is a possibility that at certain temperatures new compounds or solid solutions may be formed. This would cause the steel to recrystallize and produce marked changes in the dilation of the metal. On the other hand, if the dilatometer reveals changes in the rate of expansion, even though it is impossible to detect any thermal change, there is evidence of a change of state.

When a solid material changes from one type of crystal to another, it is always accompanied by an energy change, which is generally manifested by an evolution or an absorption of heat. Steel in its various forms is a good example of such a material. Although heat must be conducted into the steel from an outside source in order to raise its temperature, yet at the instant of recrystallization some of the heat required will be drawn from the metal itself. This will produce a slight cooling of the metal and consequent contraction. Or, if the opposite reaction should occur and heat is evolved during the change, the metal would become warmer, thus causing an increase in the rate of expansion. This phenomenon of absorption and the evolution of heat at certain temperatures is known to every one who has had experience in the heat treatment of metals. The temperatures at which this occurs are commonly called Critical Temperatures.

Thermal analysis registers the peculiarities of a metal during its transformation under heat, such as intensity,

velocity hysteresis and the phenomena of fusion, vaporization and allotropic transformation in the solid state. The changes that occur in the dilation of a metal are sufficiently large so that an instrument can readily be built to detect and record them. There are several excellent instruments on the market. The instrument used in this experiment was a Chevenard Industrial Thermal Analyzer.

Some Observations On The Dilation Of Casecarburized Steel

The Chevenard Industrial Thermal Analyzer used in this investigation is a simple but delicate form of a dilatometer. A picture of this instrument is shown in Figure(1a). The sketch in Figure(1b) shows the instrument with part of the tube cut away to give a view of the specimen and the pyros rod. The specimen, a cylinder of metal 55 millimeters long and 16 millimeters in diameter having an axial hole drilled through it one-fourth inch in diameter, is placed in the silica tube. The specimen is placed firmly against the end of the silica tube which is flat and perpendicular to its axis. A pyros rod(nickle-chromium-tungsten alloy) is placed within the specimen. Two silica rods connect the specimen and the pyros rod through a system of levers to pen arms. Any movement of the specimen is magnified seventy times and is recorded on a revolving drum by the pen arm while the movement of the pyros rod is calibrated to read direct in degrees centigrade. Two curves are drawn on the chart at the same time, one the expansion of the specimen and the other the temperature.

Pure charcoal is powdered and placed in the silica tube to keep the specimen from oxidizing, which would introduce errors if the silica tube were eaten away by the iron oxide. The specimen is heated by a horizontal tube muffle electric furnace which slides over the silica tube. The current to the furnace is controlled by a finely graded rheostat so that the heating and cooling rates can be controlled easily. A small amount of heat may be used while

Figure 1a

Figure 1b

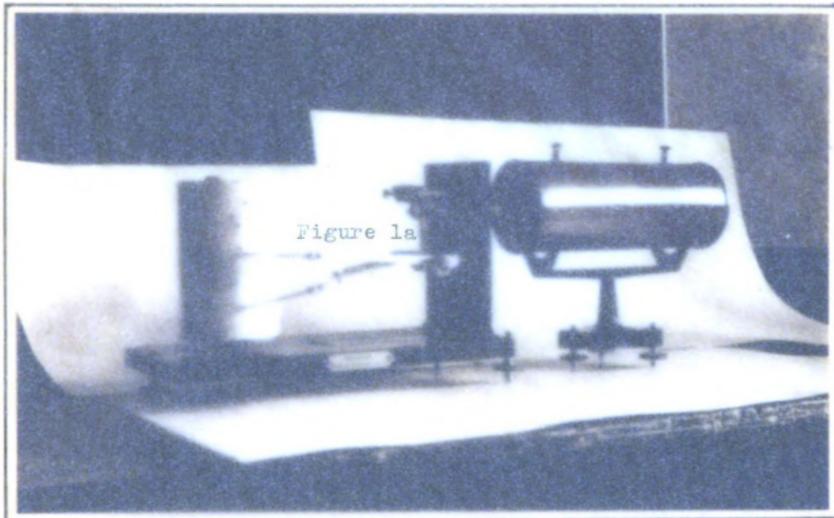


Figure 1a



Figure 1b

CHEVENARD DILATOMETER

cooling so that any cooling rate down to an air quench can be obtained. A very fast heating rate can be used by heating up the furnace before it is placed around the silica tube.

This instrument is very accurate and measurements made with it checked with those made on a recording interferometer. Careful manipulation is necessary in order to produce satisfactory results.

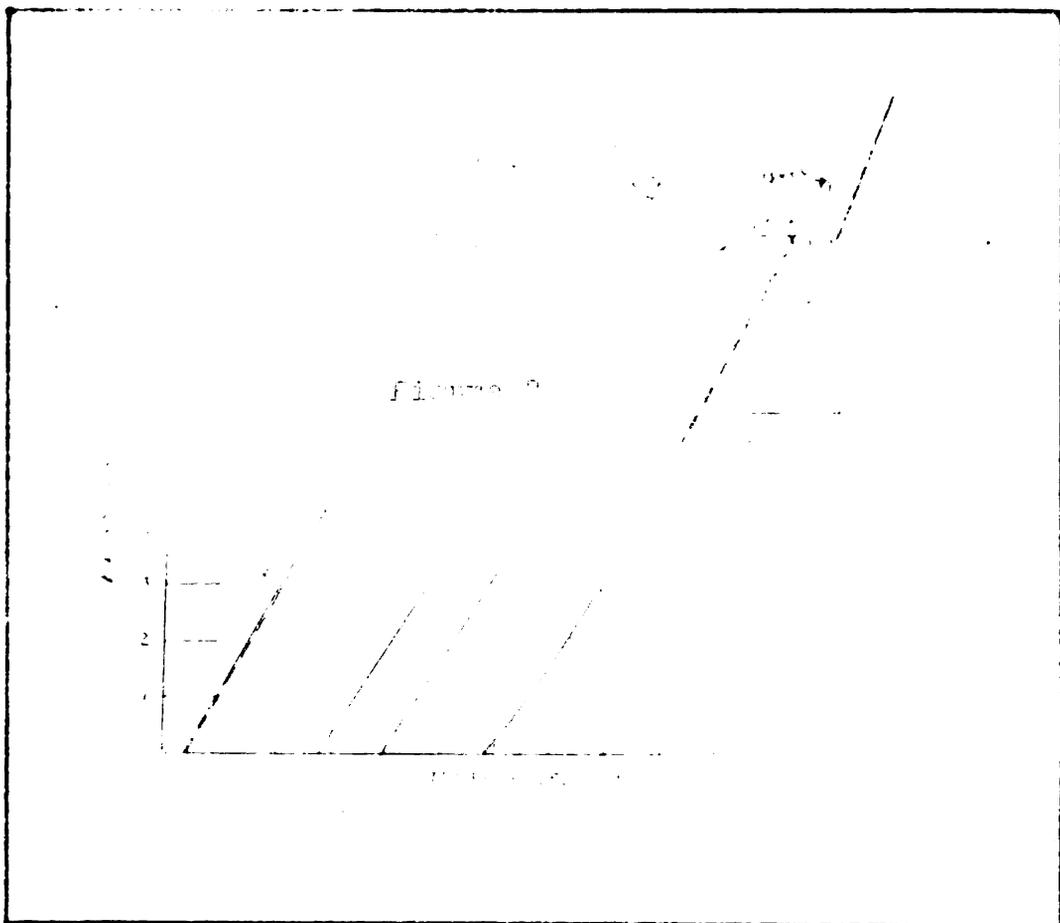
As stated before two curves are drawn on the drum. The upper curve is the temperature-time and is ruled off every 50°C. while the lower is the dilation-time curve of the specimen. Many interesting characteristics of metals are shown in the dilation curve which are not shown by any other means of analysis. By the use of the data obtained from the temperature-time and the dilation-time curves, another curve may be plotted using the change in length as one co-ordinate and temperature as the other co-ordinate. As the rate of heating and cooling has a marked effect upon the change in length of the metal, a study of both the dilation-time curves and the dilation-temperature curves should be made in any investigation.

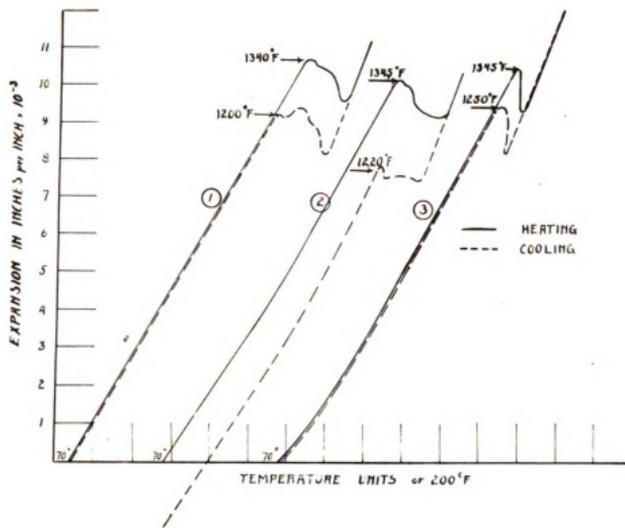
Observations On The Dilation Of Carburized 1020 Steel

It is common knowledge that case carburized steel tends to warp and shrink when heated above the critical temperature. The dilatation of S.A.E. 1020 carburized steel was investigated to find out how long a piece of it would continue to shrink, what depth of case produced the greatest shrinkage, the effect of temperature, and heating and cooling rates.

Before going into the discussion of this investigation let us see why a piece of carburized steel shrinks when heated through the critical range. Three dilatation curves are shown in Figure(2). Curve Number 1 shows the dilatation of a plain carbon steel, while Number 2 shows the same steel after being carburized. Number 3 shows the curve of a 0.90% carbon steel. All three steels were annealed before being placed in the dilatometer and were cooled at the same rate in the instrument. The curve of the plain low carbon steel has almost a constant rate of expansion until the lower critical is reached. After the recrystallization is complete, the coefficient of expansion again becomes constant, but the rate is different from that before the recrystallization took place.

When the metal is cooled, it undergoes the reverse reaction. The metal expands when passing through the critical instead of shrinking as it did when heated through the critical range. At the lower critical, as can be seen from the curve, the metal has expanded almost the same amount as





it contracted on heating. After the metal is cooled below the lower critical, the heating and cooling curves follow each other very closely and when room temperature is reached the metal is practically the same length as before heating. Curve Number 3 shows the dilatation of a steel that is almost of the eutectoid composition. The coefficient of expansion is different from that of plain low carbon steel but on cooling it returns to practically its original length.

As is evident from the curves Number 1 and Number 3, plain low carbon and 0.80% carbon steels do not shrink any on being heated through the critical range and that they have different coefficients of expansion. For purposes of analysis let us consider the case carburized specimen as a cylinder of plain low carbon steel surrounded by a ring of eutectoid steel. When the case carburized steel is heated up it continues to expand until the lower critical is reached. At this temperature the case tries to contract but the core is still expanding. Then as the temperature continues to rise the case wishes to expand but the core is still changing to gamma iron and prevents the case from expanding. After all of the core has changed to gamma iron the piece starts to expand again. The effect of the reactions working against each other is less contraction in the carburized than in the uncarburized steel.

Upon cooling the piece shrinks until the upper critical is reached. The core at this point begins to expand but at this temperature the case undergoes no reaction so continues to shrink. If the case is fairly thick, it will be strong

enough to keep the core from expanding the normal amount. At the lower critical point the case tries to expand but the core is holding back and this expansion is also suppressed. Thus it becomes a battle between the core and the case and the case seems to get the upper hand, the net effect being a considerable contraction. The contraction of carburized specimens is consistent. In fact several specimens have been heated up through the critical temperature and cooled a great number of times and the contraction of a single heat, if the heating and cooling rates and the maximum temperature were the same in all cases.

Since case-carburized steel, both plain carbon and alloy, show a contraction on being heated and cooled through the critical range, a series of tests were run to determine whether contraction would continue to occur on successive heat treatments. Before these tests were run, it was desirable to know the heating and cooling rate that would produce the maximum temperature and the greatest amount of shrinkage. The dilatation data from the different rates of heating and cooling showed that there was very little difference in the amount of shrinkage that any heating or cooling combination produced. It was therefore decided to use a rapid heat and a rapid cool to save time and also to prevent the specimen from oxidizing a great amount which would deteriorate the silica tube. A specimen was heated and cooled rapidly 55 times and showed only slight oxidation and no noticeable decarburization.

To determine the temperature that would produce the maximum shrinkage, a rapid heating and cooling rate were

used. Since the shrinkage takes place at or above the critical points, the desired temperature must be above the critical temperature. Temperatures at 50° intervals were tried, above the critical temperature, until 1000°C was reached which is the limit of the electric furnace. From the dilatation data it was found that 950°C and 1000°C produced the maximum and almost identically the same amount of shrinkage. Since 950°C would cause less oxidation, it was used as the maximum temperature to which any specimen was heated. If a slower rate of heating had been used, the maximum shrinkage might have been produced at a lower temperature.

Specimens that have been run in the Dilatometer previous to this had contracted different amounts and seemed to be dependent upon the depth of case. To determine the effect of the depth of case upon the shrinkage, specimens of S.A.E. 1020 steel were carburized for 45 minutes, 2.5 hrs., 5 hrs., 8 hrs., and 12 hours. Each piece was then run in the dilatometer several times so that the average shrink per heat could be obtained. From the dilatation data it was found that the shrinkage varies directly with the depth of case. The greater the depth of case, the greater the shrinkage per heat. There must be a certain depth of case such that the shrinkage will decrease, if a specimen was carburized all the way through, the shrinkage would stop or at least become very small. In production or commercial practice, it would follow that in order to get away from shrinkage and warpage it is best to have as thin a case as possible.

After the heating and cooling rates had been determined, a specimen of S.A.E. 1020 steel, carburized for 12 hours at 1700°F. and cooled in the box, was heated and cooled through the critical range 21 times. This specimen showed a contraction each time. The shrinkage per heat was not a constant but varied with the heating and cooling rate and also the maximum temperatures reached. The contraction per each heat is shown in Table 1. The greater amount of contraction shown in heat Number 11 was caused by the maximum temperature being 100° higher than in any other heat. On the last run the temperature was raised to same point as that at which the specimen had been carburized and then cooled slowly through the critical range. The structure of this specimen is shown in Figure 4. This structure may be compared with that of Figure 3 which has not been run in the dilatometer. The structure of the specimens will be discussed on another page. The Rockwell hardness was the same before and after running in the dilatometer. The overall length of the specimen before the test was 2.160 inches. After being shrunk 21 times the length was only 2.135 inches. This checks the shrinkage as measured by the dilatometer. A second specimen was carburized for 12 hours and heated and cooled through the critical range 55 times. This specimen, as the preceding one, showed a contraction each heat. The shrinkage per heat also varied as before. Table 2 gives the contraction for each heat and the total shrinkage. The cross-sectional area of these specimens changed very little, most of the contraction taking place lengthwise. This piece contracted

Table 1

Heat No.	Contraction per heat in inches	Total Shrinkage in inches
1	0.0004	0.0004
2	0.0004	0.0008
3	0.0004	0.0012
4	0.0004	0.0016
5	0.0007	0.0023
6	0.0005	0.0028
7	0.0006	0.0034
8	0.0006	0.0040
9	0.0006	0.0046
10	0.0007	0.0053
11	0.0010	0.0063
12	0.0006	0.0069
13	0.0007	0.0076
14	0.0006	0.0082
15	0.0007	0.0089
16	0.0006	0.0095
17	0.0005	0.0100
18	0.0007	0.0107
19	0.0006	0.0113
20	0.0006	0.0119
21	0.0006	0.0125

so much during the 55 heats that the axial hole, in which the pyros rod slides, had to be drilled out three times. Before this specimen was run in the dilatometer, it was weighed so that the contraction and the loss in weight could be compared. The loss in weight after the 55 runs was .090 grams while the total shrinkage was 0.125 inches. From the shrinkage the loss in volume was calculated and there was no relation between loss in weight and shrinkage.

Because of the fact that the contraction filled in the hole in which the pyros rod slides, a third specimen was made without a hole. After being carburized for 15 hours, it was weighed and run in the dilatometer 110 times. This specimen warped a large amount in comparison with the other two. The end of the piece bulged out, the corners rounded off, and it was bent a little lengthwise. The total contraction of this specimen is only approximately one-fourth greater than the specimen that was run 55 times. The loss in weight was only 0.07 grams which again has no relation to the contraction. The amount of contraction per heat does not decrease as the number of runs is increased. The amount of contraction of the last heat seems to be a little greater than that of the first, although this may be due to the variation in the rate of heating and cooling.

Finding that a case carburized specimen of S.A.E. 1020 steel continued to shrink independently of the number of times it was heated and cooled through the critical range and that after repeated runs the total shrinkage was a comparatively large amount, it would seem plausible that this shrinking must have some effect upon the structure

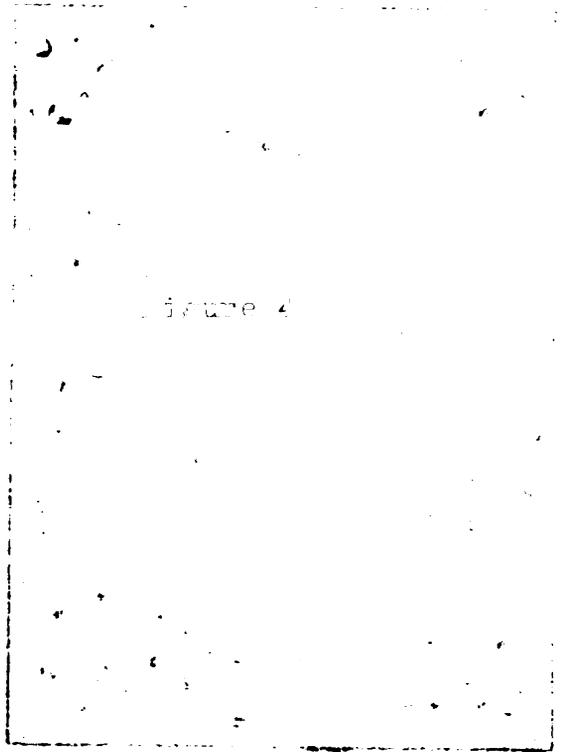
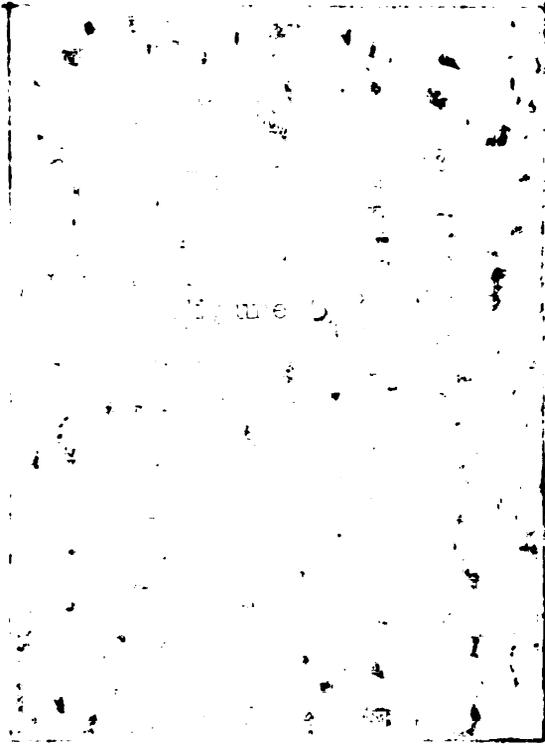
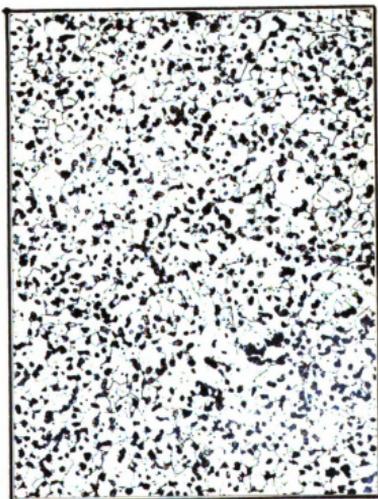
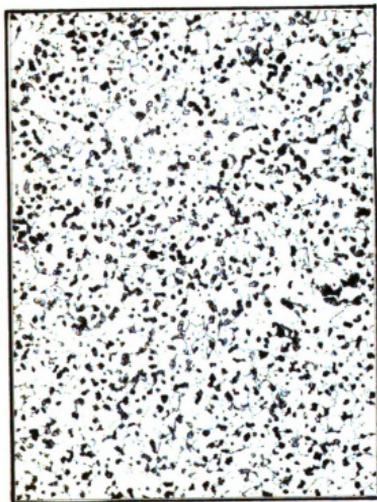
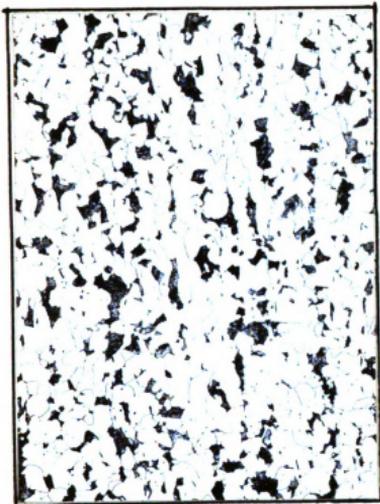


Figure 4

Figure 5

Figure 6

Figure 7

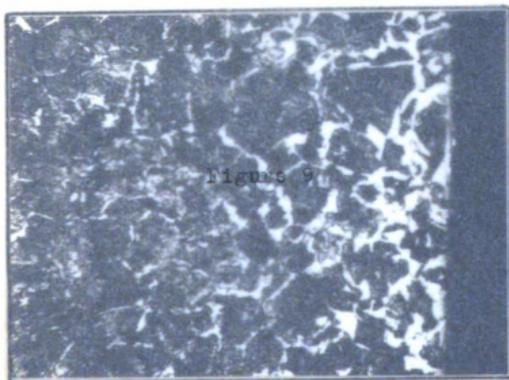
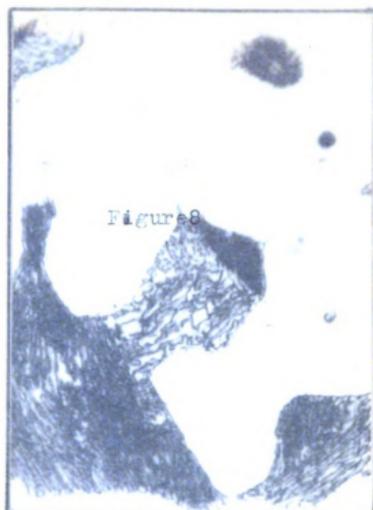
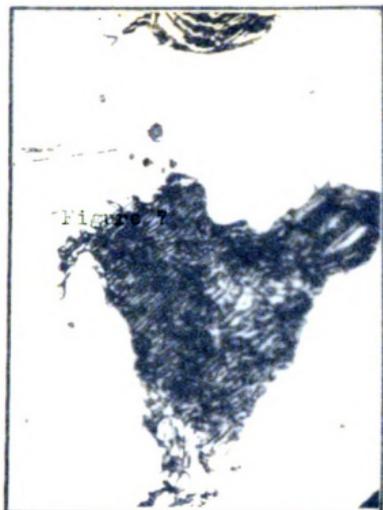


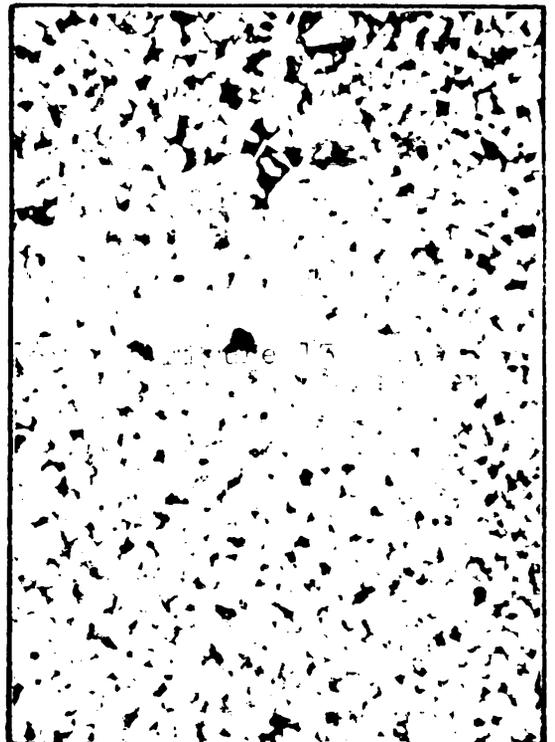
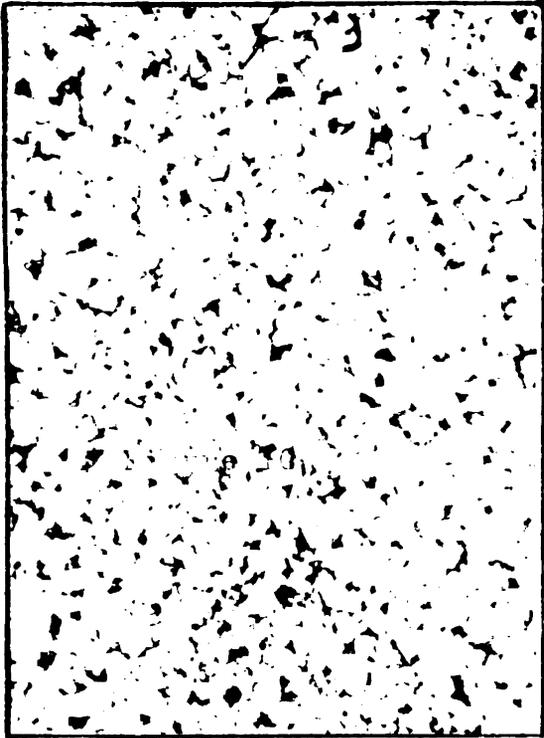
of the core. All specimens were heated to 1700°F. and cooled at the same rate after carburizing and after being run in the dilatometer. Theoretically at least, all of the specimens should now have the same structure as they were all taken from the same bar of steel. Figure 3 shows a specimen that was heated to 1700°F. held for 15 minutes and cooled at approximately the same rate as were the carburized specimens. The structure is that of normal pearlitic steel. The specimen shown in Figure 4 was carburized for 12 hours and heated and cooled through the critical range 22 times. Some of the grains of pearlite are about the same size as the original, but most of them are reduced about one-half and look as if they had started to "ball-up." A specimen that was case-carburized 12 hours and heated and cooled through the critical range 55 times is shown in Figure 5. Although all of the grains of pearlite are reduced in size and appear to have formed "balls", the original grain boundaries are still visible. Figure 6 is that of a specimen (without an axial hole drilled through it) which was case-carburized for 15 hours and heated and cooled through the critical range 110 times. This structure looks like that of Figure 5 except that the pearlite grains are slightly larger. Although the pearlite grains in Figure 3 and Figure 6 look entirely different, it can be seen from Figure 7 and Figure 8 (which were taken respectively from the same specimens as were Figure 3 and Figure 6) that the grains of pearlite appear very similar at 2000 diameters. The case of the specimen that was heated and

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Figure 2



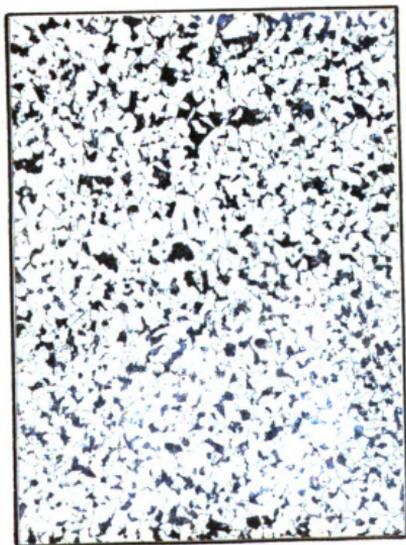
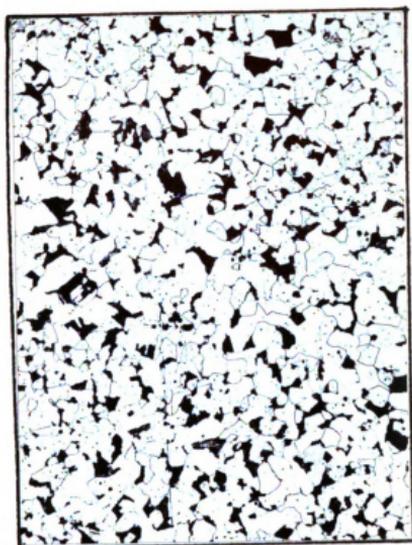
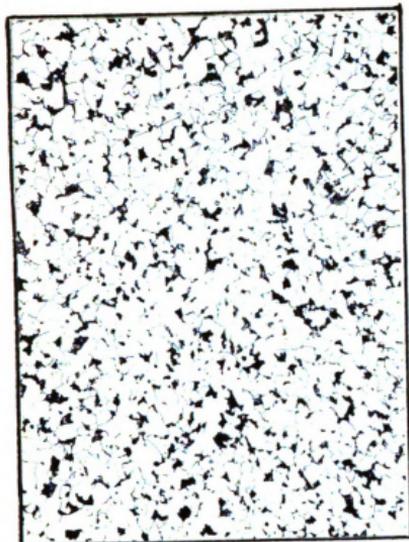


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cooled through the critical range 110 times is shown in Figure 9. It can be seen from this that although the piece was heated and cooled a great number of times, there was practically no decarburization and very little oxidation. Figures 10, 11, 12, and 13 are those of specimens that have been case-carburized 45 minutes, 2½ hours, 5 hours, and 8 hours respectively, showing that the grains of pearlite are reduced in size a small amount after being heated and cooled through the critical range only twice.

In order to determine if heating and cooling the specimen through the critical range 110 times had changed the dimensions of the crystal lattice, the following X-ray patterns were made by Dr. Wayne Siscoin of the University of Illinois.



1-ray Samples

Sample 1. :- As received. Not casecarburized

Sample 2. :- Annealed. Not casecarburized

Sample 3. :- Casecarburized at 1700° for 8 hours.
Not run in the dilatometer.

Sample 4. :- Casecarburized at 1700° for 15 hours.
Run in the dilatometer 110 times.

X-Ray Pictures

Sample No. 1.

1a - Beam normal to the flat disk sample.

1b - " parallel " " " " " but perpendicular to a radial section.

1c - Beam parallel to the disk and a radial section.

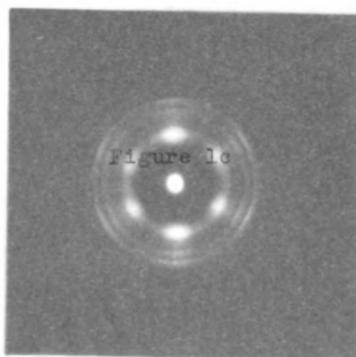
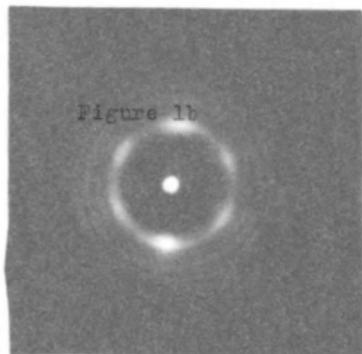
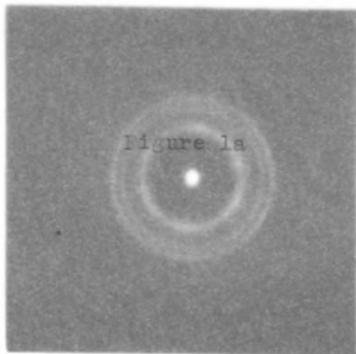
The continuous rings in the X-Ray patterns for the three sections show that slippage has taken place in all the grains(Fe crystals) due to the rolling process. The continuous rings of 1a show that the crystal fragments are arranged at random around an axis normal to the disk. 1b and 1c have 6 intensity maxima on the inside broad band and the 2 inner rings(due to Ka and Kb rays diffracted from the 110 planes). This shows that the crystal fragments have taken up a preferred direction with the 110 direction of the body centered lattice parallel to an axis normal to the disk, but the crystal fragments are rotated at random around this direction.

Sample No. 2.

2a - X-ray beam normal to the disk.

2b - X-ray beam parallel to the disk.

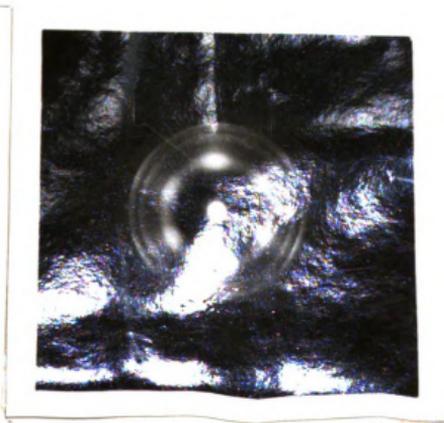
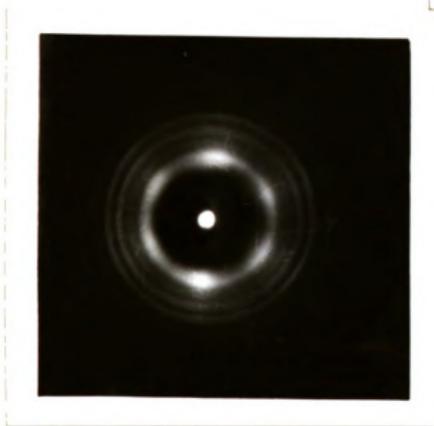
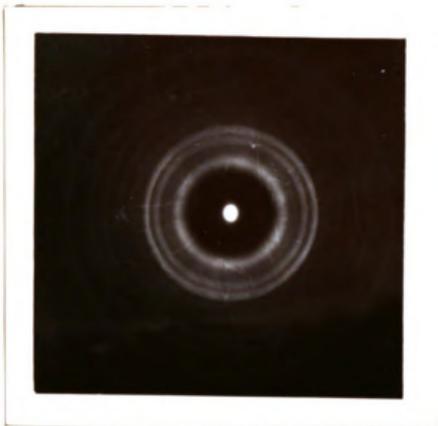
The X-ray patterns of this sample have changed from rings to spots due to the recrystallization of the steel. These patterns show that the crystals have grown and are now free from strain and are arranged at random in the 2 directions.



of a...

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of a...



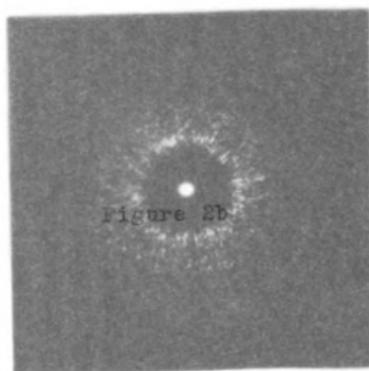
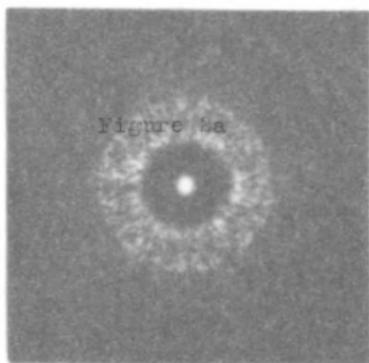
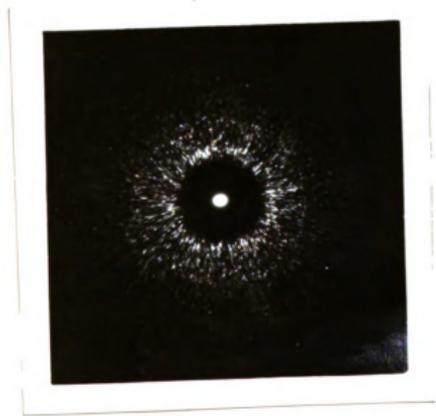


Figure 15

Figure 16



Sample 3 Noticing that there was considerable difference in the Rockwell hardness near the inside and the outside of the ring, specimen I took two exposures, one near the inside and one near the outside. In both cases the beam was normal to the disk.

3a - Inside.

3b - Outside.

You will notice that there is a difference between the inside and the outside patterns. There is also a difference between the patterns of sample 2 and 3. Both 3a and 3b show indications of internal strain while the difference between 3a and 3b is probably due to the carburized surface.

Sample 4 Specimens were taken from No. 4 in the same manner as 3.

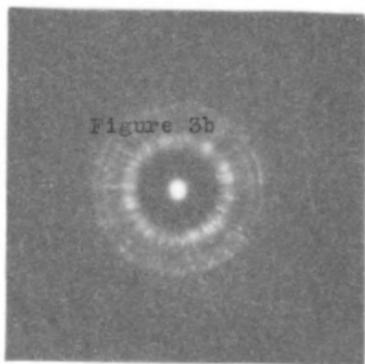
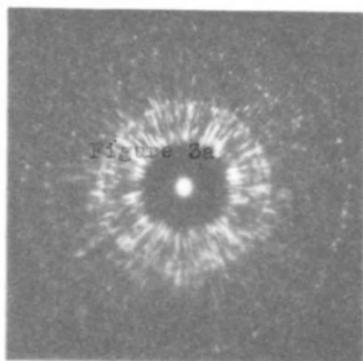
4a - Inside

4b - Outside.

There appears to be only a slight difference between the X-ray patterns of sample No. 3 and 4.

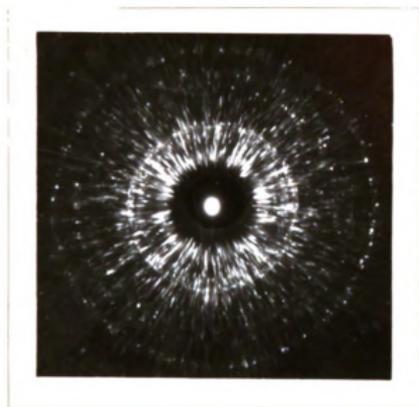
Note: The difference in diameter of the rings of 1b and 4b are due to the film being a greater distance from the specimen.

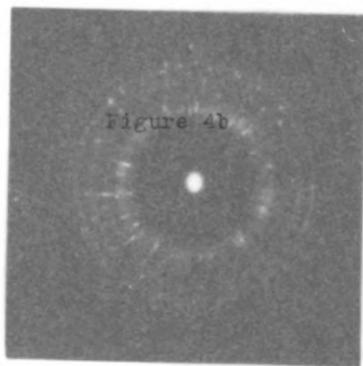
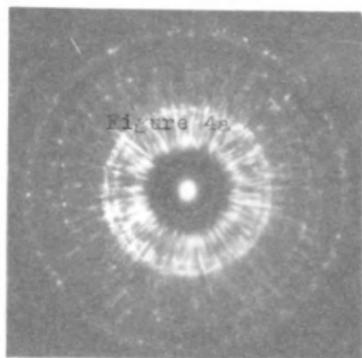
The above patterns were taken to show the nature of the grains within the sample. In order to determine if the treatment of passing through the critical range 100 times had changed the dimensions of the iron lattice, accurate determinations of the spacing of the crystal lattice were made. Sample No. 1 was compared with No. 4. The results are shown on the long films. By comparing the position of



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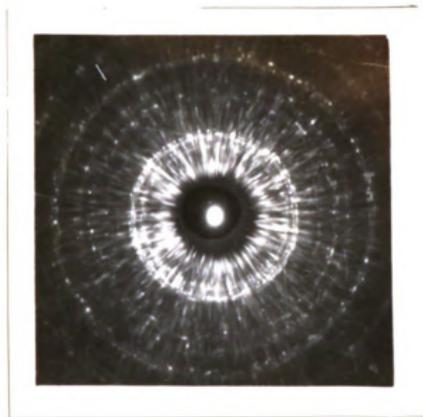
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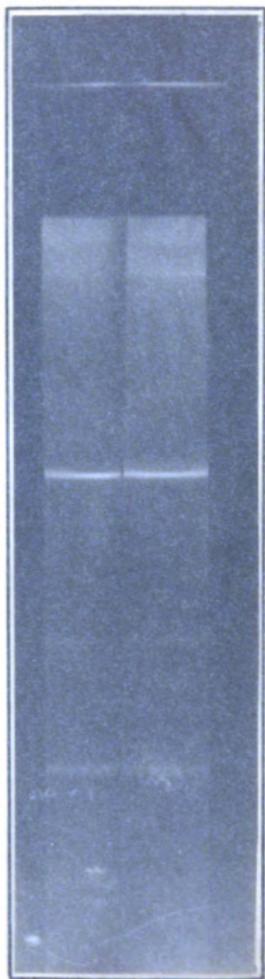
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the lines relative to the zero line, we see that the spacings are almost identical for the two samples, with the exception of a possible slight shift of the lines for No. 4 towards the zero line. You will notice that there are a few extra faint lines in No. 4. In order to determine if these extra lines were due to the effect of the carbon from the carburizing, photographs were made of the surface and the interior of sample No. 3. The pattern of the surface of No. 3 shows the same faint lines as No. 4, which indicates that they were due to the carbon. You will notice also that the iron lines from the surface of No. 3 have the same shift towards the zero line as was noticed in No. 4. This small shift is probably due to the iron holding a small amount of carbon or carbide in the form of a solid solution which would expand the lattice and account for the very small expansion noticed. I have not been able to identify the faint lines mentioned above. They may be similar to some of those discussed by Westgren in the July and August numbers of Metal Progress for 1951.

Note:

The X-ray patterns on the long films were obtained from a powder specimen - the pinhole patterns from a thin (0.01cm) solid specimen.



From the foregoing work there is a possibility that a few conclusions may be drawn.

First:- Casecarburized steel with a thin case will have less tendency to warp than steel with a thick case.

Second:- Casecarburized steel if slowly cooled from the carburizing heat and then hardened by quenching from just above the lower critical will have the least tendency to warp or shrink due to the fact that we get away from the tendency of the core and case to work against each other.

Third;- Casecarburized steel shrinks every time it is heated and cooled through the critical.

Fourth:- Repeated shrinks have very little if any effect upon the space lattice.

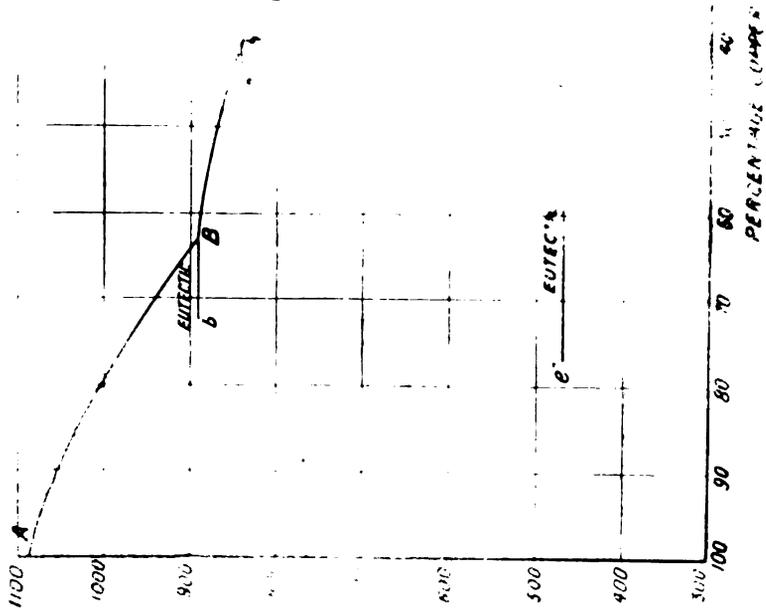
The Transformation Point At 470°C In Beta Brass

The late Sir Roberts-Austen in 1897 published the first complete freezing point curve of the copper-zinc alloys. In his diagram, which is shown in Figure 1, certain thermal changes represented by horizontal lines bE, cC, eE, and e'e' were included. As can be seen from his diagram, these horizontal lines were interpreted by him as evidence of the presence of eutectics at these temperatures. This diagram was the first attempt to construct what would in present day phraseology be called the equilibrium diagram of the copper-zinc system.

The horizontal line e'e' indicates a thermal change at about 470°C. occurring in alloys containing approximately 46 to 76% of copper. Although Roberts-Austen regarded e'e' as evidence of a eutectic change, he did not find any support for this view in his study of the structures of the alloys in this range and he does not appear to have thought of any other interpretation of this thermal change.

At a latter date E. S. Sheperd made a careful determination of the constitution of this series of alloys, and in 1904 published the first complete equilibrium diagram of the copper-zinc system. This diagram is reproduced in Figure 2. E. S. Sheperd made repeated records of the heating and cooling curves of alloys ranging in composition from 50 to 75% copper without finding any evidence of the line e'e'.

Figure 1



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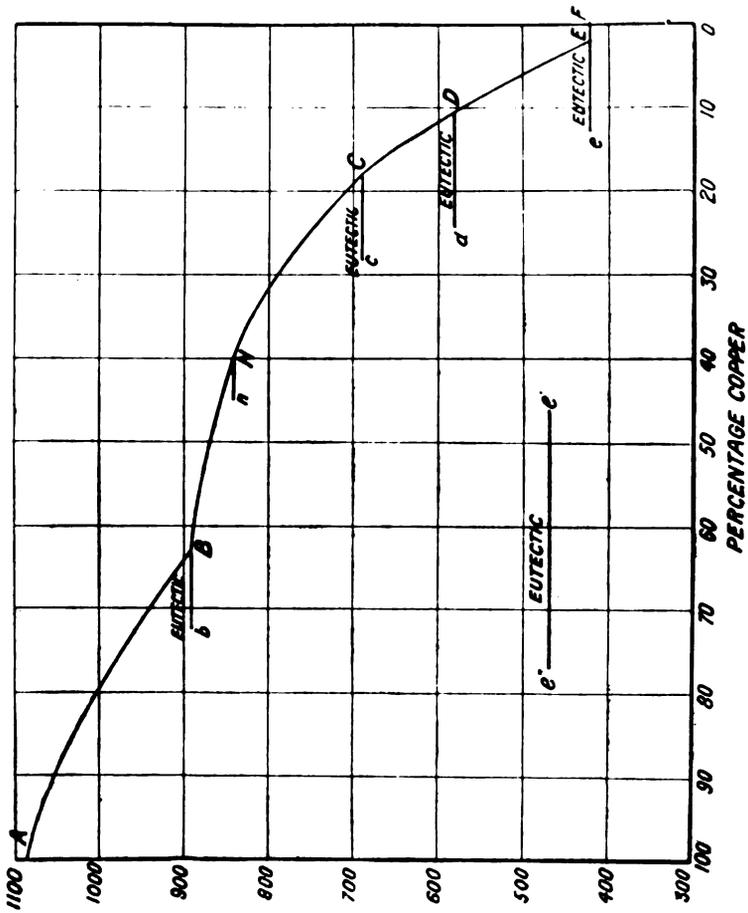


FIG. 1.

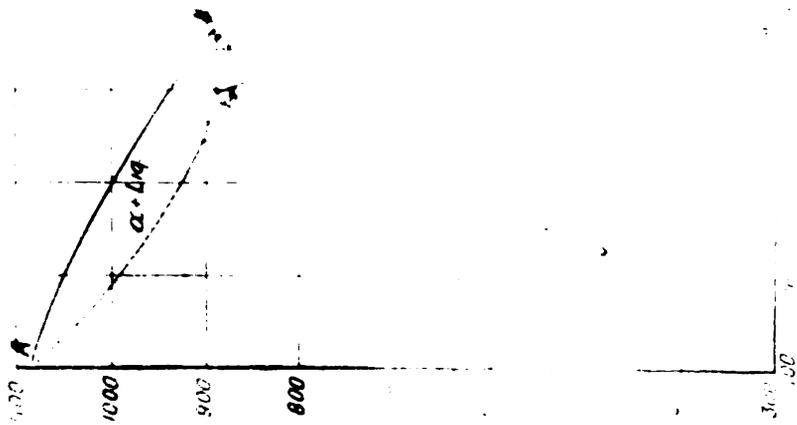
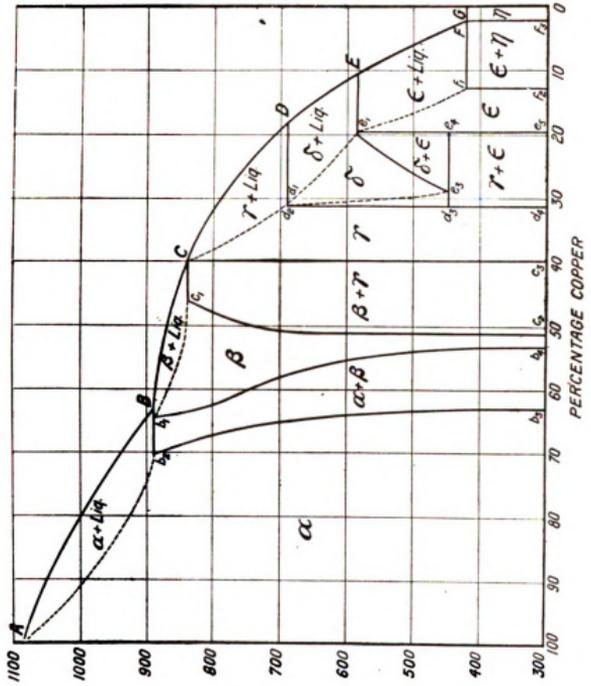


Figure 1

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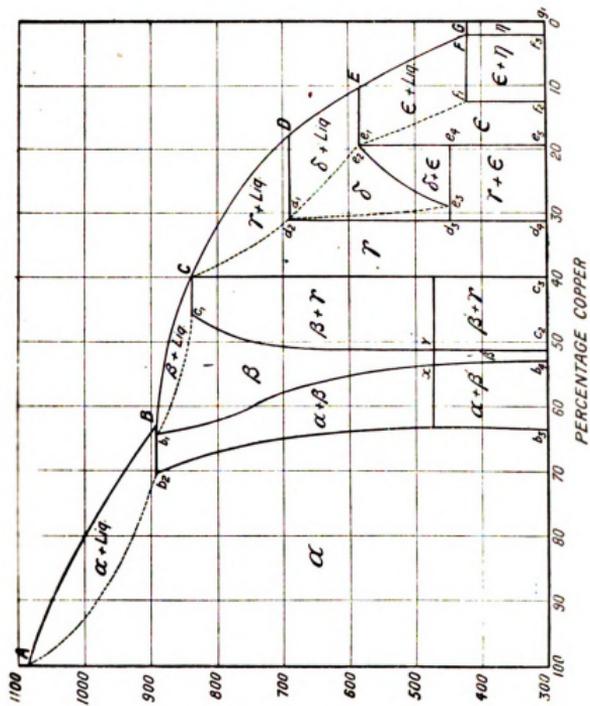


Tafel also made special tests to determine whether the line e''e' was real or not. He found no evidence for its existence, and concluded, though with more hesitation than Shepard, that it was based upon an experimental error. Later, Carpenter and Edwards, using a differential method were able to rediscover Roberts-Austen's horizontal line e''e' and prove its existence. Although the limits do not agree exactly with those given in Roberts-Austen's diagram, the temperature at which the inversion occurs is the same in both cases.

It has been shown by Shepard and others that no eutectics exist in the copper-zinc system. It is a matter of considerable theoretical interest to define the change that must of necessity occur in alloys at the temperature indicated by the critical point. Since the critical point occurs in alloys containing alpha plus beta, beta and beta plus gamma - since it occurs in the absence of both alpha and gamma - it must be due to the beta constituent. Therefore, whatever the physical interpretation of this point may be, it necessitates an alteration in Shepard's diagram.

If the two curves b_1b_2 and c_1c_2 (Figure 2) do not actually meet at 470°C., then the physical meaning of the critical point would be that there is an allotropic change in the beta constituent at this temperature, and it would be necessary to modify Shepard's diagram as shown in Figure 3. Above 470°C. there would be normal beta and below that temperature a polymorphic form of the same constituent described as B'.

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According to Figure 2, B is a homogeneous solid solution which may vary in composition at 470°C. from 53.5 to 51.0% copper. In this case the composition of the ought to influence the temperature of the critical for the following reasons. Alloys to the left of the point x Figure 3 on cooling from temperatures above the line b_1x deposit alpha at temperatures on that line. The separation of alpha proceeds with falling temperatures, and beta is consequently impoverished in copper until at 470°C. the composition is represented by the point x. Alloys to the right of y when cooled from above the line c_1y deposit gamma, which means that beta becomes relatively richer in copper until at 470°C. its composition corresponds to the point y. In these two classes of alloys, if the two lines b_1x and c_1y do not meet, the compositions of beta at 470°C would be quite different, and if the critical point were due to an allotropic change, the temperature at which it occurred should be different in the two classes, that is, alpha plus beta and beta plus gamma.

Since the critical point indicated on the diagram in Figure 3 occurs at the same temperature in both the alpha plus beta and the beta plus gamma alloys, Carpenter and Edwards discredited the foregoing diagram and tried to find evidence to support what appeared to them to be the only alternative explanation. Carpenter and Edwards' hypothesis is that the solubility lines b_1b_4 and c_1c_2 actually meet at a point at 470°C and at this temperature the following inversion occurs $B \rightarrow \alpha + \gamma$

Figure 4.

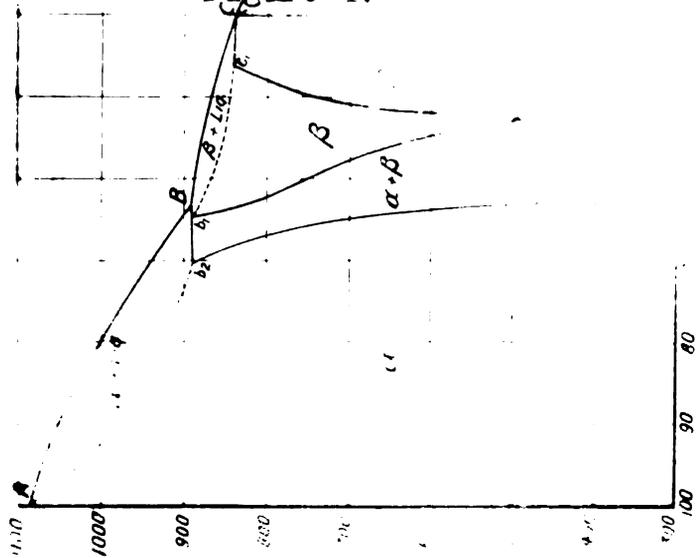
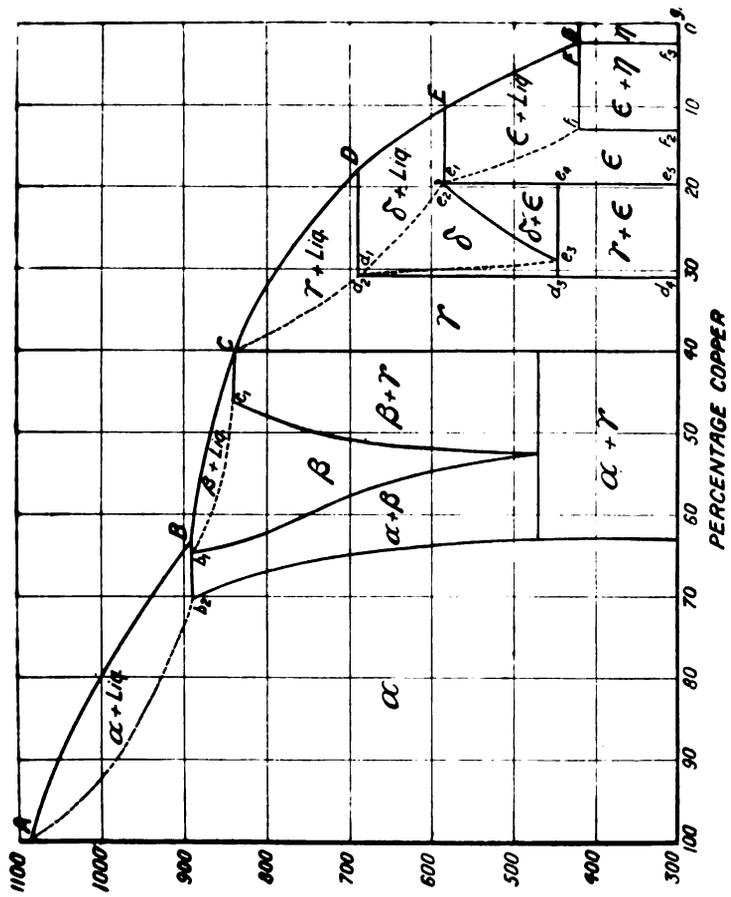
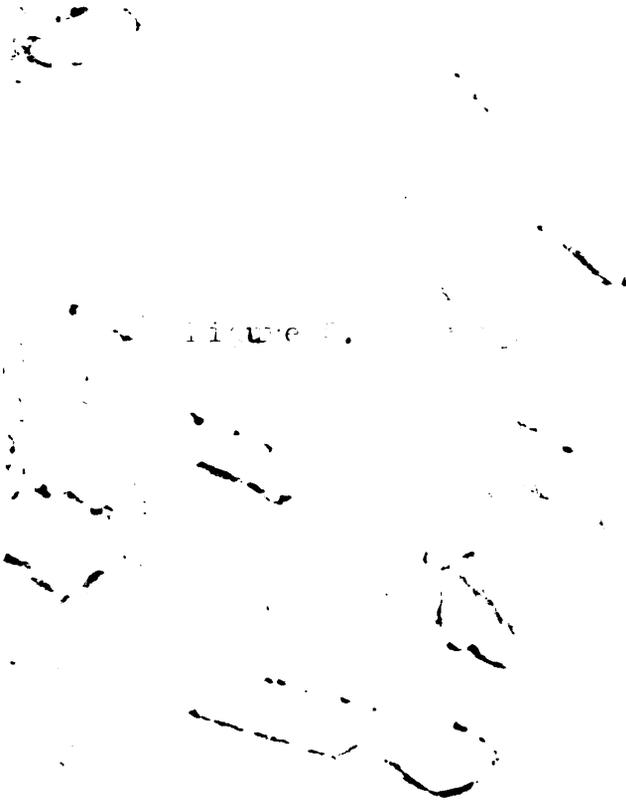


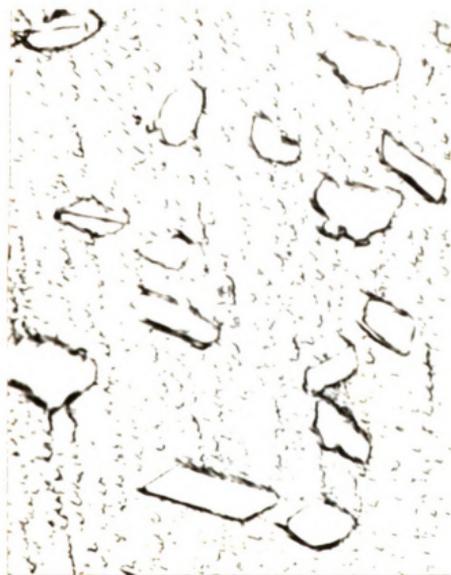
Figure 4.



This hypothesis would necessitate the equilibrium diagram shown in figure 4. If the lines b_1b_2 and c_1c_2 do meet at 470°C ., the beta phase would then disappear on cooling below this temperature with the formation of alpha plus gamma. A great number of experiments have shown that alpha and gamma are never present in the same ingot. Between 50 and 55% copper the ingots consist entirely of the red beta and the white gamma crystals. The 55% copper alloy is homogeneous when annealed at 750°C and quenched. It becomes heterogeneous when annealed at 450° showing both alpha and beta crystals. This is shown in Figure 5. The 57% copper alloy differs from this by being homogeneous at all temperatures above 470° and probably at lower temperatures. At least it has not been observed to break down after annealing at 450°C . for 72 hours as shown in Figure 6. From the above statement it is evident that the change of constitution required by the interpretation of the equilibrium diagram in Figure 4 must be very difficult to detect structurally by means of the microscope.

Carpenter and Edwards were unable to show in any logical manner that beta on annealing below 470°C inverted into alpha plus gamma. They ran heating and cooling curves on alpha plus beta, beta and beta plus gamma alloys. The first two alloys gave the critical temperatures at 445° and the third at 457°C . It can be seen from this that their rejection of E' on the ground of consistency of temperature was not fully established. Since the alpha plus beta and the beta plus





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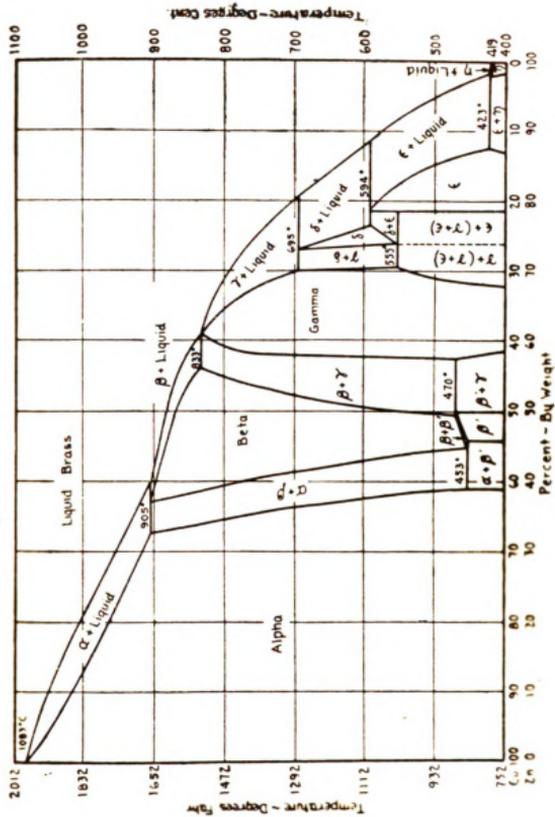


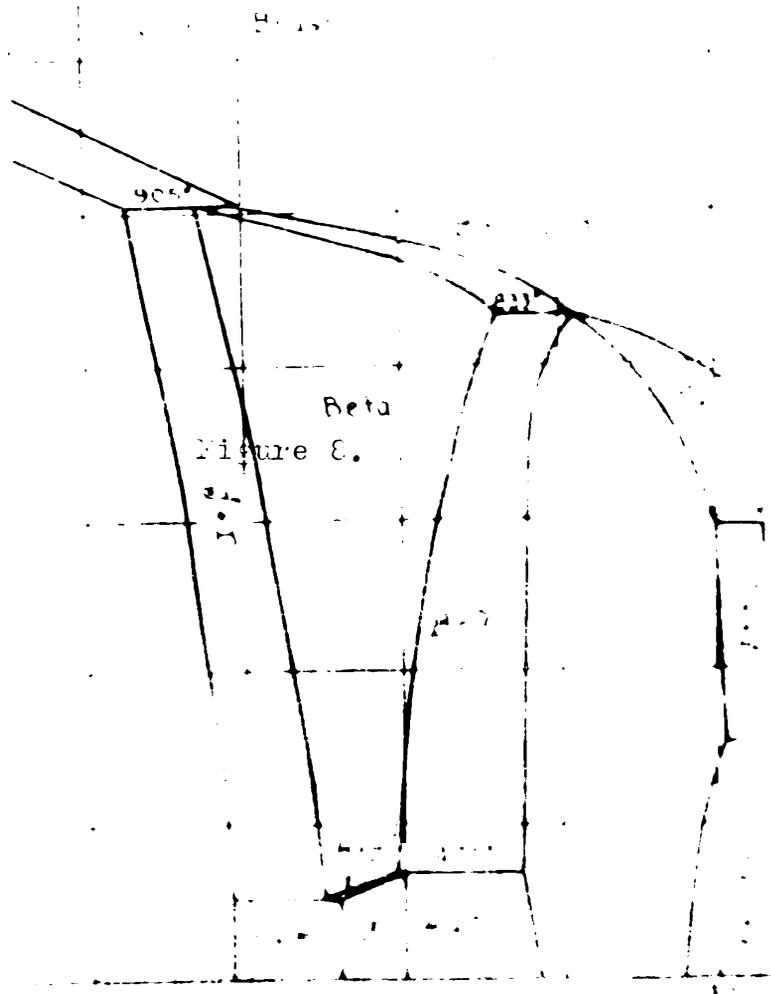
gamma do not transform at the same temperature, and since long anneals below the critical temperature do not separate out alpha plus gamma (that can be observed by the microscope) these facts would necessitate the diagram shown in Figure 7.

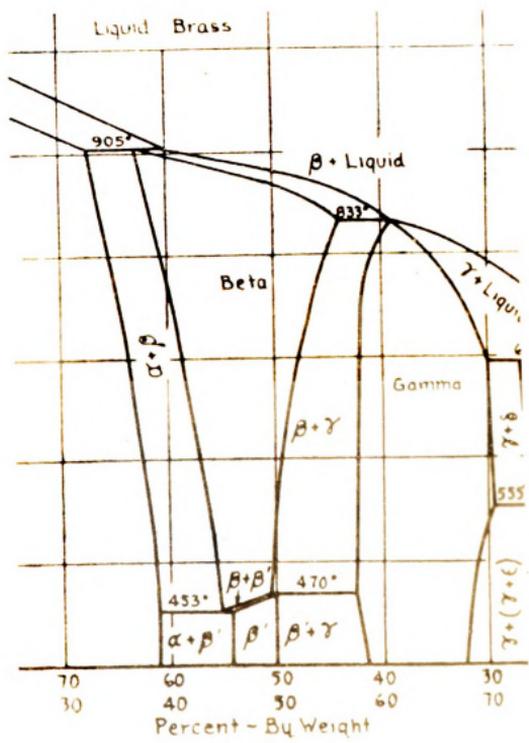
This diagram which is reproduced from the 1930 edition of the National Metals Handbook, has been assembled from data carefully selected from a great many sources. It is impossible here to make detailed and adequate acknowledgments of the many investigators contributing to this equilibrium diagram. It will be said here, however, that the course of the beta transformation, extending from 453°C to 470°C from the alpha to the gamma solubility curves, has been taken from the data of Laughton and Griffiths. A double line extending through the beta field represents a narrow B plus B' field. According to the phase rule this could not be a single line since two solid solutions cannot exist next to each other.

As has been stated before, long anneals below the critical temperature of beta brass failed to show signs of recrystallization except possibly a slight grain growth. Matsuda says that it is impossible to prevent the B to B' transformation by ordinary quenching. Repeated quenches from 750°C into ice cold brine of beta brass failed to reveal a different structure than that of annealed beta brass. The only noticeable difference was that the repeated quenches cracked the specimen at the grain boundaries. It has been found by X-ray analysis that there is no difference in

Figure 7.







the space lattice between annealed and quenched beta brass.

From the above data it is evident that at the present it is impossible to differentiate between B and B'. Huddner brought forward evidence to show that B could be formed synthetically at temperatures below at which the transformation took place. This strongly suggests that at least it was not an eutectic transformation and he considered that the evidence indicated the occurrence of a polymorphic change in B to B'. It may be similar to the Ag in iron, that is, a change takes place within the crystals but the grain boundaries remain the same, which makes it impossible to distinguish one from the other. Above the transformation B, brass is body centered. On the basis of X-ray evidence, it appears that the beta transformation is not associated with a eutectoid inversion nor a polymorphic transformation, if by polymorphic transformation a change of atomic arrangement is demanded, but is simply an energy change within the atom without any fundamental alteration of the crystalline lattice. The transformation shows a marked point on the differential pyrometer recorder but shows an exceedingly small, if any, point on the dilatometer. This is further proof of the above point that the B -- B' inversion is an energy change within the atom.

In considering a transformation point, one usually thinks of three things taking place when the metal is heated or cooled through a critical point. First, that there is an evolution or absorption of heat. Second, that there

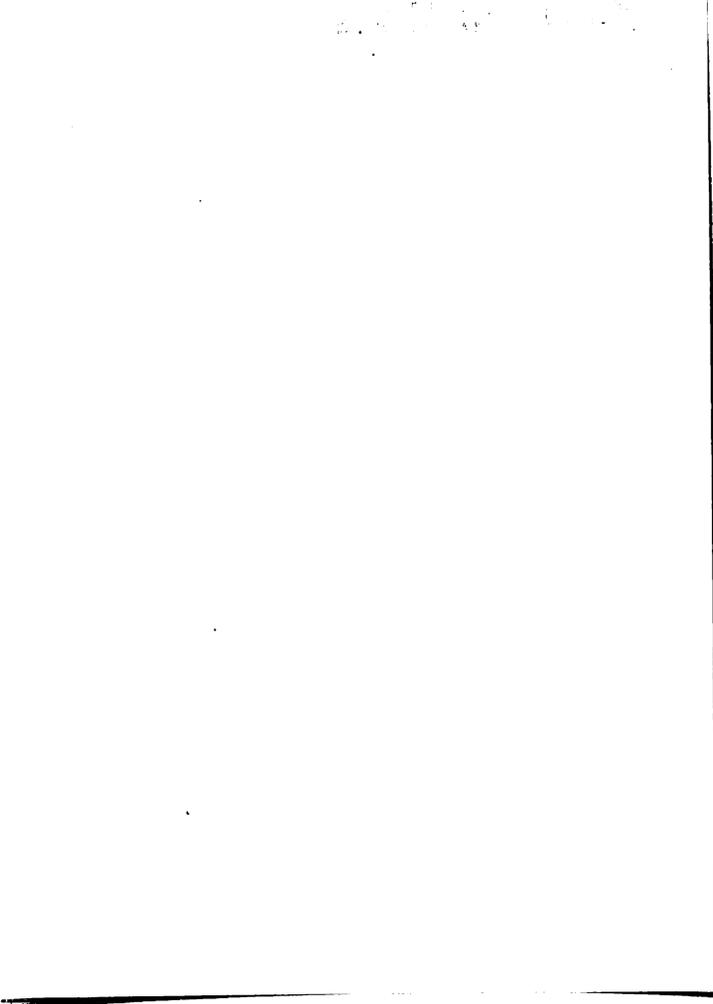
is a change in dilation and third, that accompanying the above two, re-grainulation takes place.

It was found in iron 99.995% pure, when heated through the critical absorbed heat and showed a marked dilation but there was no change in grain structure. When beta brass was heated through the critical, there was a marked absorption of heat, but no dilation or re-grainulation. From the above, it is seen that re-grainulation and dilation do not always accompany a thermal change. It is also evident that some of our equilibrium diagrams ought to be changed or that we should change our idea as to what takes place at a critical point.

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