AN INVESTIGATION OF THE NEEDLE LIKE STRUCTURE IN HIGH SPEED STEEL

Thesis for the Degree of Met. E.

Walter G. Hildorf

1927

Steel - Testing

AN INVESTIGATION OF THE NEEDLE LIKE STRUCTURE IN HIGH SPEED STEEL

A Report Submitted To The
Faculty Of The Michigan State College

by

Walter G. Hildorf

Candidate For The Degree Of
Metallurgical Engineer

June 1927

Approved - H.B. Dirks, 6/7/1927
Prof. Mech. Engg.

THESIS

AN INVESTIGATION OF THE NEEDLE LIKE STRUCTURE IN HIGH SPEED STEEL

CONTENTS

AN INVESTIGATION OF THE NEEDLE LIKE STRUCTURE IN HIGH SPEED STEEL.

INTRODUCTION

CHARACTERISTICS OF THIS STRUCTURE

The needle like structure, so called because of its similarity to a myriad of needle points has been under investigation at the laboratory of the Reo Motor Car Company for some time because it has been found in practically all high speed steel milling cutters, reamers and other tools which have failed due to breakage of the teeth or crumbling of the cutting edges. This structure seems to make the steel very brittle. In most cases it exists as a thin layer on the outside of the tool, often not over .005" deep which will soon crumble away and the tool will not cut smoothly nor to size. If this structure extends very deep - it has been found to extend completely through some milling cutters and reamers - the result is quite often that the edges will wear away quickly and then the additional load will cause the teeth to break, ruining the tool.

CAUSE OF THIS STRUCTURE IS UNKNOWN

The exact cause of this structure or a heat treating practice by which it may be avoided appears to be unknown, although its bad effects are often eliminated by allowing enough stock on the

tools so that this structure can be ground away.

A fairly accurate survey of the literature on metallurgical subjects revealed only three papers in which this structure was mentioned.*

Dr. C. A. Edwards states that "A new brittle constituent appears at about 1292°F. in tempering which caused the failure of high speed tools". In a later paper published jointly with Mr. H. Kikkawa he abandons this position.

Dr. J. A. Matthews refers to the "brittle constituent" mentioned in Dr. Edwards' paper and states "This constituent is due solely to overheating and is not produced when tempering at 1292°F. in properly hardened high speed steel".

THEORIES AS TO ITS CAUSE

Other theories have been advanced such as:

1. Uneven heating.
2. Insufficient tempering.
3. Hardening temperature too low and not allowing the tools to cool to a low enough temperature in the quench before they are tempered.
4. That the structure is martensite.

PURPOSE OF THE INVESTIGATION

Since this structure does not occur regularly and since no

*The Iron Age - July 3, 1919.

one has proven how it can be produced or avoided it was decided to make this investigation as simple and as free from complications and a large number of variables as possible and yet help to prove or disprove one or more of the above theories.

SAMPLES AND THEIR HEAT TREATMENT

SIZE OF SAMPLES

Two samples of high speed steel 1/2 in. x 1/2 in. x 18 in. long were chosen from a steel company who furnish about 85% of the high speed steel used by the Reo Motor Car Company. These bars were chosen because we have had more experience with this steel than with other steels and because it seems to be fairly free from this brittle structure. This, however, might be due to our method of heat treatment rather than to the steel itself.

HEAT TREATMENT AND METALLOGRAPHIC EXAMINATION

HARDENING

The samples were preheated at 1550°F. and then the bars were placed in the furnace so that about 12 in. was inside the door or in the furnace proper, while the balance of the bar was outside the door. The furnace was gas heated having a heating chamber 8 in. x 11 in. x 13 in. This furnace was maintained at a temperature of 2500°F. by means of a Brown pyrometer equipment. The samples were in the furnace approximately four minutes. The object of this method was to heat the end of the bars to as near 2500°F. as possible and have the balance of the bars grade in

temperature from 2500°F. to the cold ends which were outside of the furnace door. After heating, the bars were quenched in oil at 125°F. and allowed to cool to the temperature of the oil. The bars were then removed from the oil and allowed to cool to room temperature.

METALLOGRAPHIC INSPECTION OF HARDENED SAMPLES

Samples, 7/16 in. long were cut from the bar as shown in Fig. 1-A, starting at the end of the bar which had been heated to 2500°F. We removed and examined 29 samples. Only 21 samples are included in this report because it was found that the samples beyond the 21st. had not been heated to a hardening temperature and therefore were all alike. Each sample was polished, etched with 5% nitric acid in alcohol and examined under the microscope, for the needle like structure. The magnification was 1000 diameters.

In order to have a comparison of the various structures the center of each sample was photographed.

TEMPERING

The samples mentioned above were next tempered by heating in a Leeds and Northrup electric automatically controlled furnace. The temperature was 330°F. when the samples were placed in the furnace. It took one hour and 36 minutes for the temperature to reach 1100°F. The temperature was maintained between 1080 and

and 1100°F. for 14 hours. The samples were cooled in air.

METALLOGRAPHIC INSPECTION OF TEMPERED SAMPLES

The samples were repolished and examined under the microscope, using the same magnification and etching medium as for the hardened samples. The center of each sample was again photographed to provide a comparison of the structures.

DESCRIPTION OF MICROSTRUCTURES

TYPICAL NEEDLE LIKE STRUCTURE

A typical needle like structure is shown in Fig. 1. The reader should not confuse this structure with a martensitic structure which is also of a needle like type. Our observations lead us to believe that this structure is separate and distinct from a martensitic structure. A study of the following photomicrographs will aid in making this clear.

SERIES OF HARDENED STRUCTURES

The series of hardened structures are shown in Fig. 1-H to and including Fig. 21-H. The numbering begins at the end of the bar which was heated to 2500°F. (See Fig. 1-A)

A study of the hardened samples failed to reveal any needle like structure. However, there are several very interesting things brought out in this series of photographs which it might be well to mention. The overheating extended to about Fig. 11-H. This is

shown by the size of the austenite grains and also by the fact that the carbides have gone to the grain boundaries. In all samples up to Fig. 14-H the carbides were more or less in the shape of cubes, while in the balance of the samples they were more nearly spherical in shape. The first indication of incomplete austenite grains is shown in Fig. 19-H which indicates that the temperature at this point was not high enough for the formation of complete grains.

SERIES OF TEMPERED STRUCTURES

This series shows the tempered structures of the samples above mentioned. They are designated by Fig. 1-D to and including Fig. 21-D.

The tempered samples showed no needle like structure in the first sample, Fig. 1-D, but it was very evident from Fig. 2-D to and including Fig. 17-D. The depth of the needle like structure varied from .005 in. in Fig. 2-D to .0005 in. in Fig. 17-D. This series of photographs also shows several very interesting features, which probably have no bearing on the needle like structure, but are of general interest. The carbides exist in the form of cubes and also in narrow irregular shaped bands from Fig. 1-D to Fig. 11-D, beyond this they exist mainly as spheres.

The martensitic structure is present in a large number of the samples for example Fig. 2-D shows this structure. A large number of the samples show the outlines of the austenite grains.

This is rather remarkable, because the samples were drawn for 14 hours.

ROCKWELL HARDNESS

The Rockwell hardness was taken of both the hardened and the tempered samples. The hardness is shown under each of the structures.

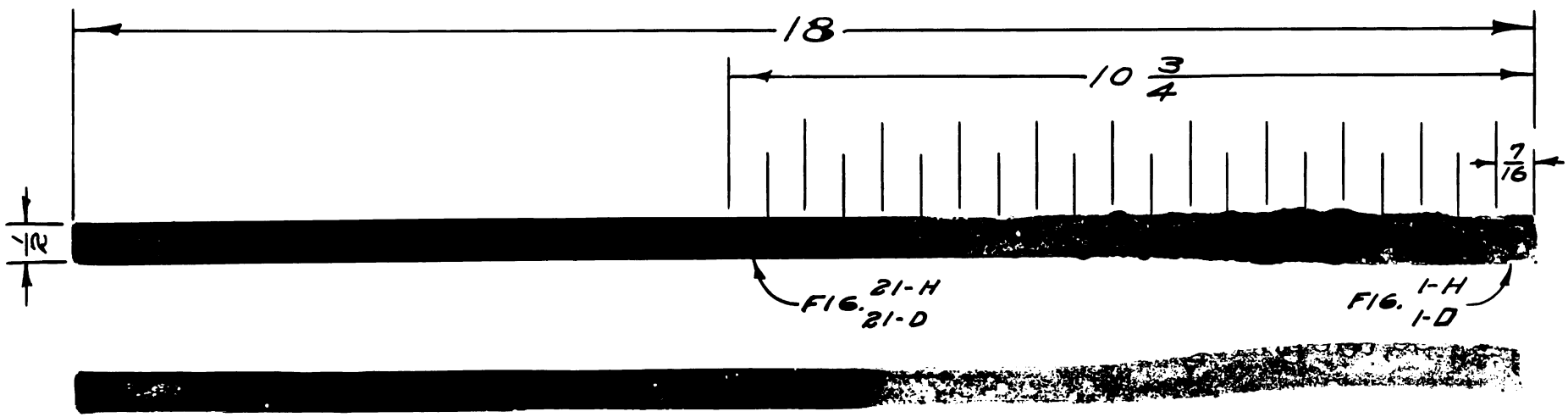

FIG. 1-A

HIGH SPEED STEEL SAMPLES USED IN THIS INVESTIGATION.

TYPE OF HIGH SPEED STEEL.

C-.55-.75
MN-.30
Si-.25
CR-3.50
V-.75-1.50
W-17-19
S-.025
P-.025

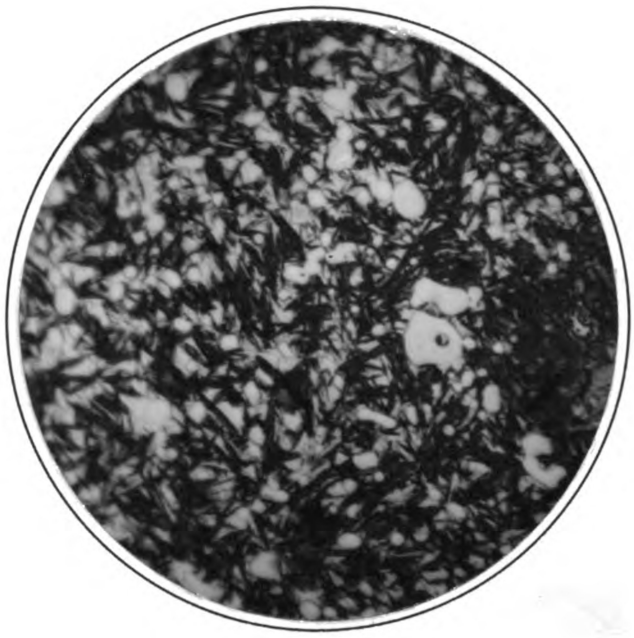

Fig. 1.

This shows a typical needle like structure. It is believed that this structure is not martensite. Compare it with Figs. 2-D and 3-D and also with martensitic structures as shown in The Metallography of Steel and Cast Iron by H. M. Howe and in The Metallography and Heat Treatment of Iron and Steel by Albert Sauveur.

Magnification ---------- 1000X

Etched with a 5% solution of nitric acid in alcohol.

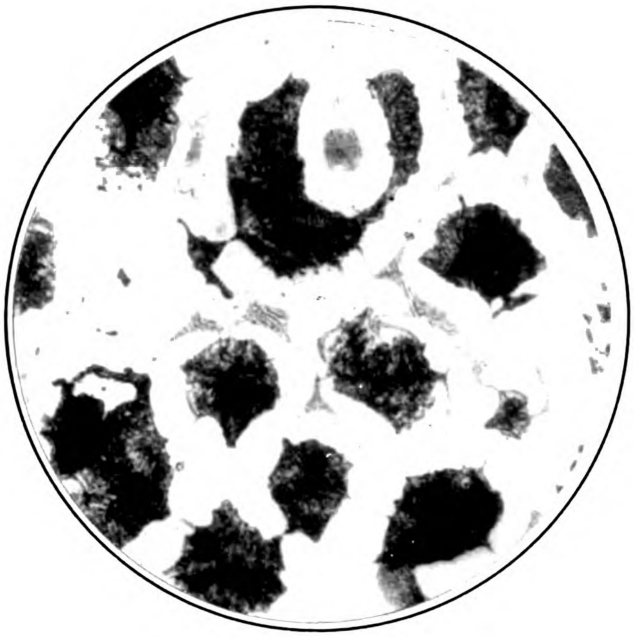

Fig. 1-H

Rockwell hardness ----- 62.6
Depth of needle like
structure ------------- None
Badly overheated

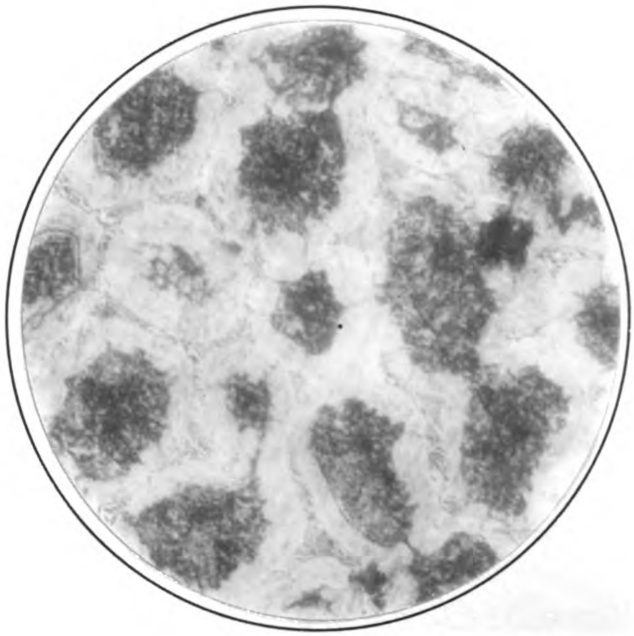

Fig. 1-D

Rockwell hardness ----- 62.6
Depth of needle like
structure ------------- None
Badly overheated

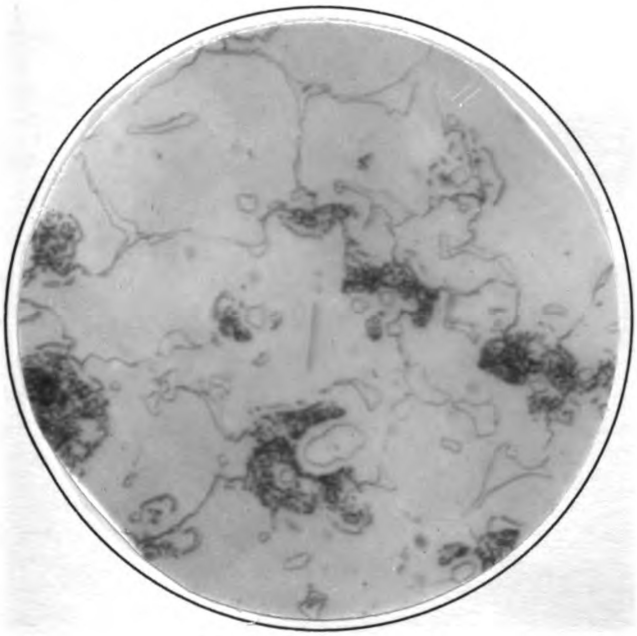

Fig. 2-H

Rockwell hardness ----- 64.8
Depth of needle like
structure ------------- None
Carbides are mainly in the
grain boundaries

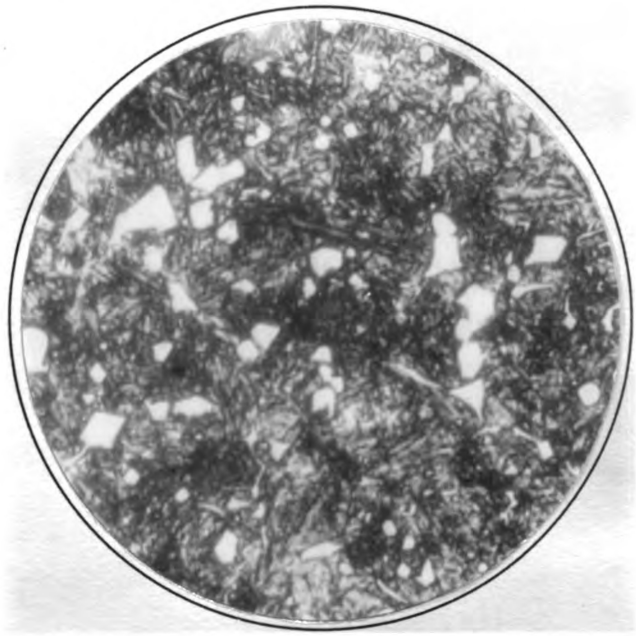

Fig. 2-D

Rockwell hardness ----- 62.6
Depth of needle like
structure ------------ .005"
Structure is martensitic

Magnification ----- 1000X
Etched with 5% nitric acid in alcohol

Fig. 3-H

Rockwell hardness ----- 64.5
Depth of needle like
structure ------------ None

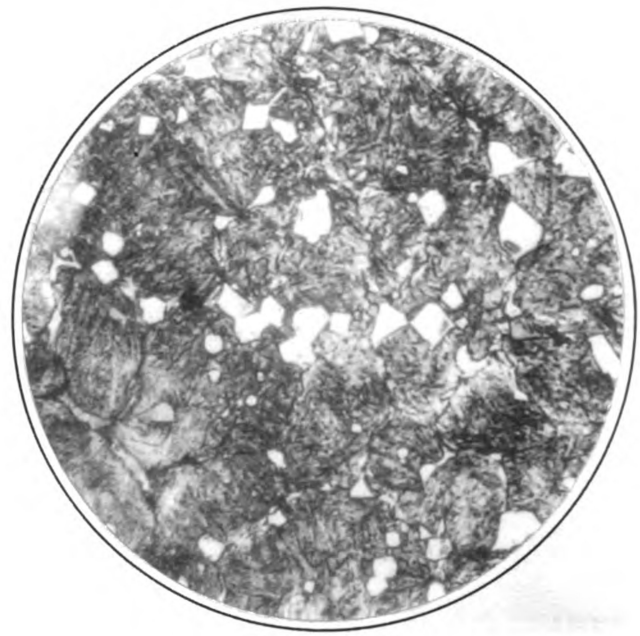

Fig. 3-D

Rockwell hardness ----- 62.8
Depth of needle like
structure ------------ .004"
Structure is martensitic

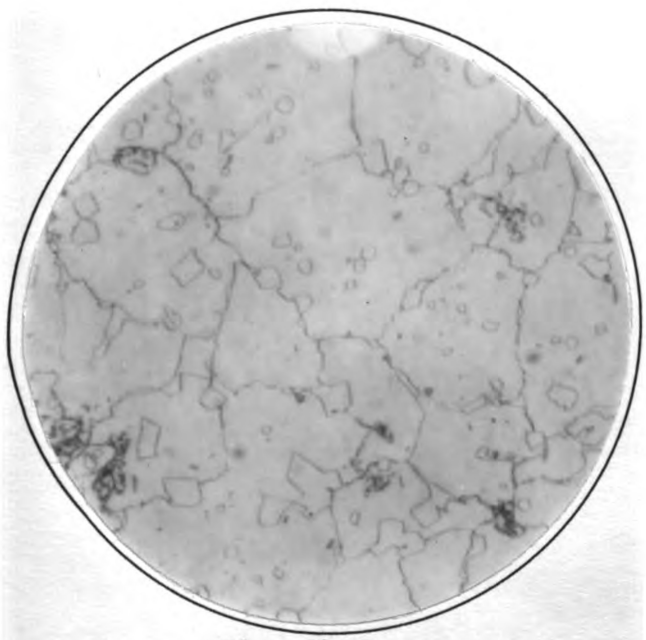

Fig. 4-H

Rockwell hardness ----- 63.8
Depth of needle like
structure ------------ None

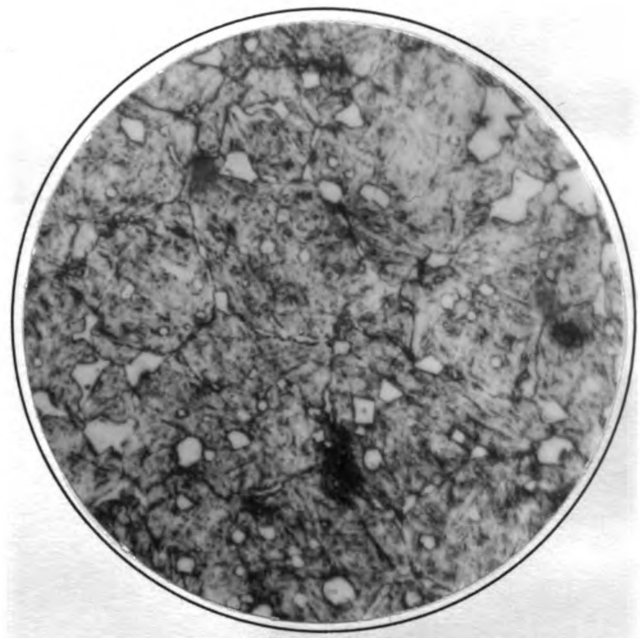

Fig. 4-D

Rockwell hardness ----- 61.5
Depth of needle like
structure ------------ .0025"
The outline of the austenite
grains is still present

Magnification ----- 1000X
Etched with 5% nitric acid in alcohol

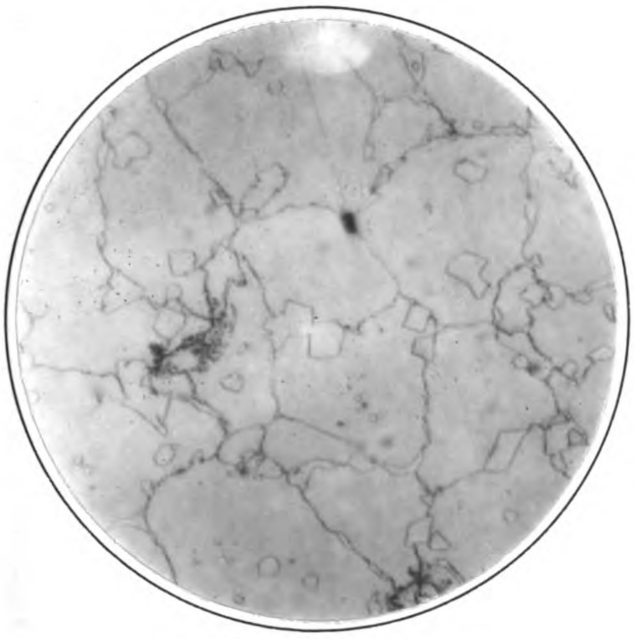

Fig. 5-H

Rockwell hardness ----- 64
Depth of needle like
structure ---------- None

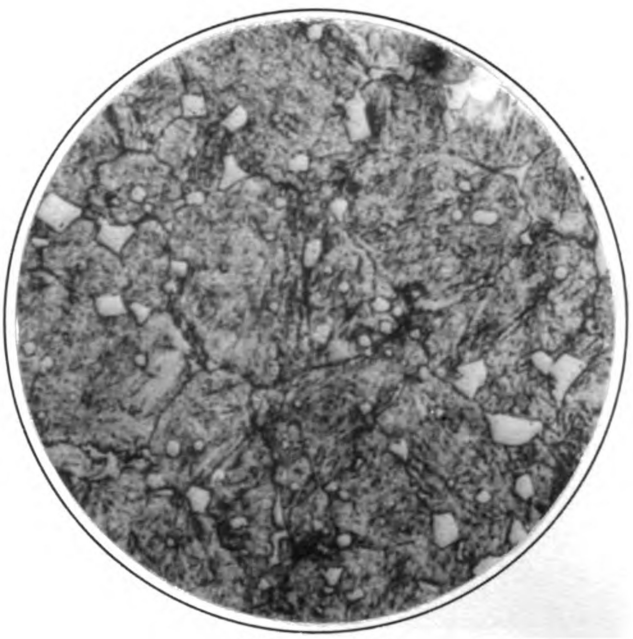

Fig. 5-D

Rockwell hardness ----- 62.8
Depth of needle like
structure ---------- .002"

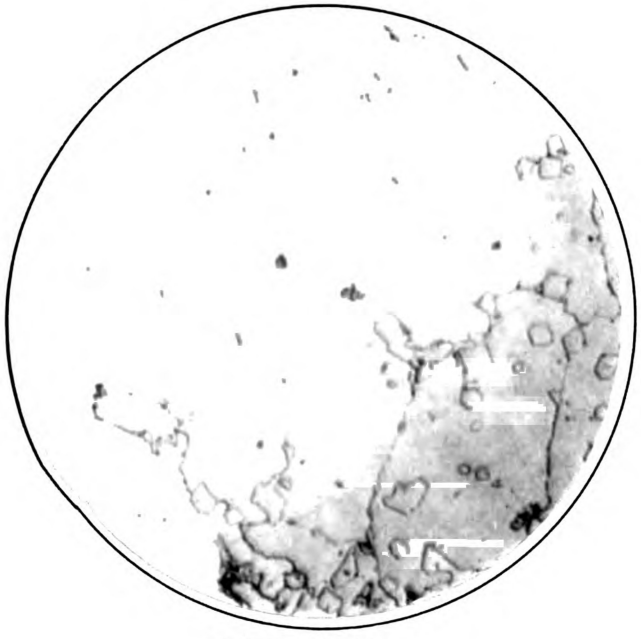

Fig. 6-H

Rockwell hardness ----- 64.6
Depth of needle like
structure ---------- none

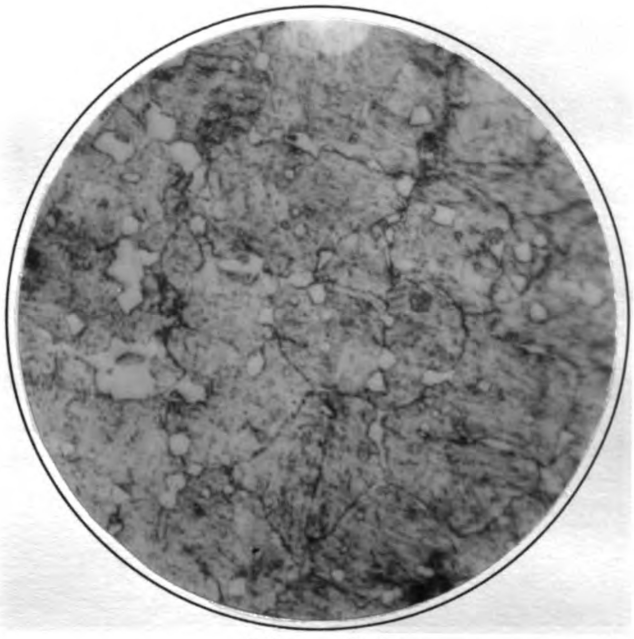

Fig. 6-D

Rockwell hardness ----- 62
Depth of needle like
structure ---------- .003"

Magnification ----- 1000X
Etched with 5% nitric acid in alcohol

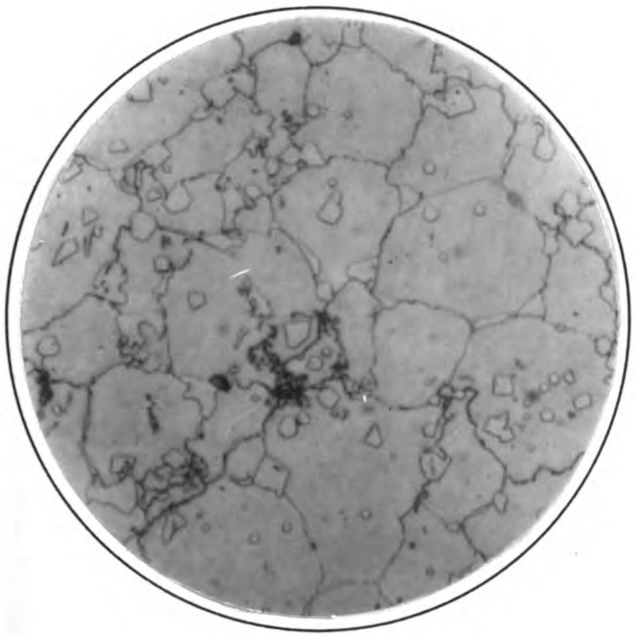

Fig. 7-H

Rockwell hardness ----- 64
Depth of needle like
structure ---------- None

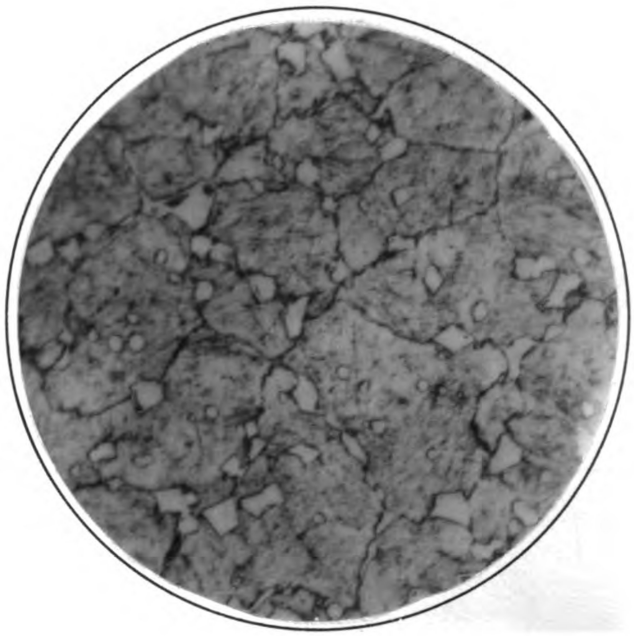

Fig. 7-D

Rockwell hardness ----- 62.8
Depth of needle like
structure ---------- .002"

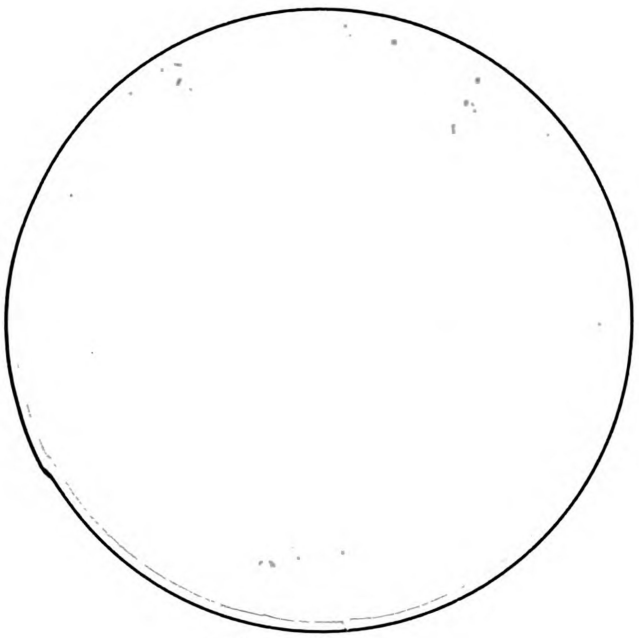

Fig. 8-H

Rockwell hardness ----- 65.5
Depth of needle like
structure ---------- None

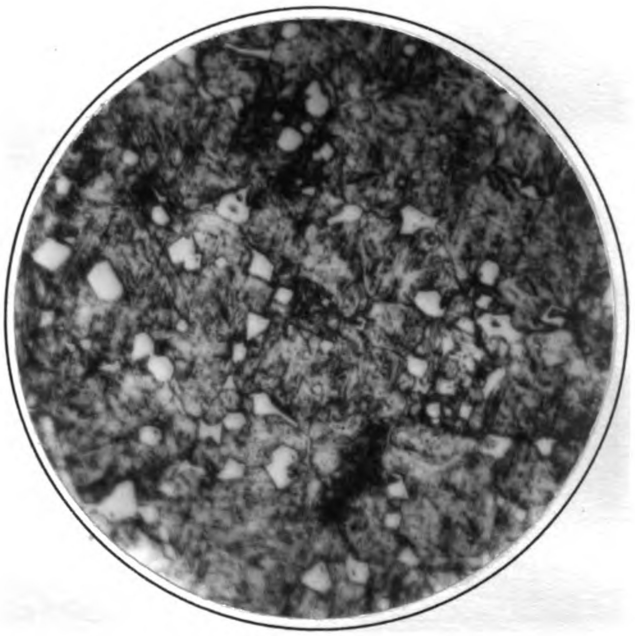

Fig. 8-D

Rockwell hardness ----- 61.8
Depth of needle like
structure ---------- .002"

Magnification ----- 1000X
Etched with 5% nitric acid in alcohol

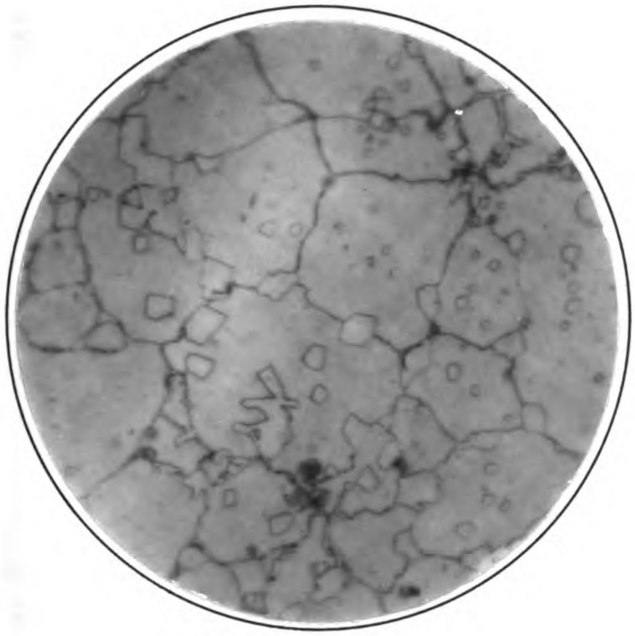

Fig. 9-H

Rockwell hardness ----- 64.2
Depth of needle like
structure ------------- None

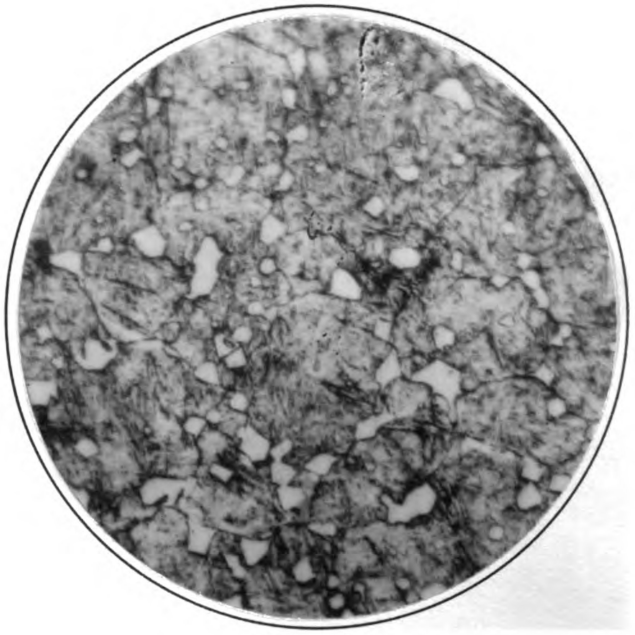

Fig. 9-D

Rockwell hardness ----- 63.1
Depth of needle like
structure ------------- .002"

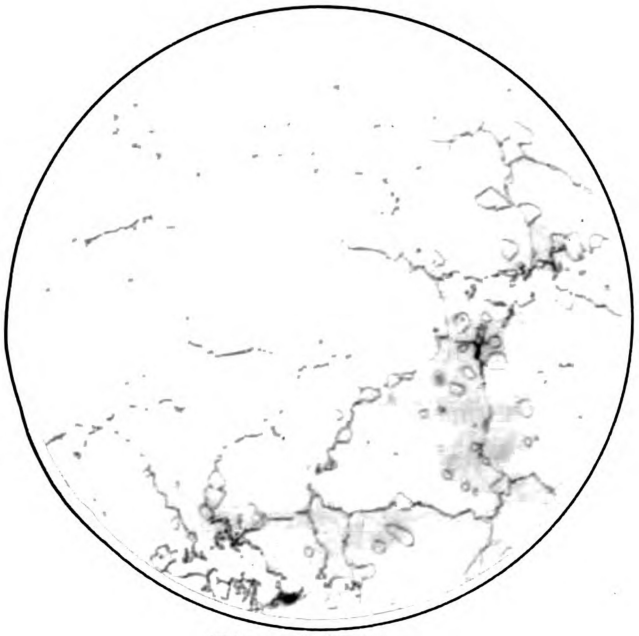

Fig. 10-H

Rockwell hardness ----- 64.6
Depth of needle like
structure ------------- None

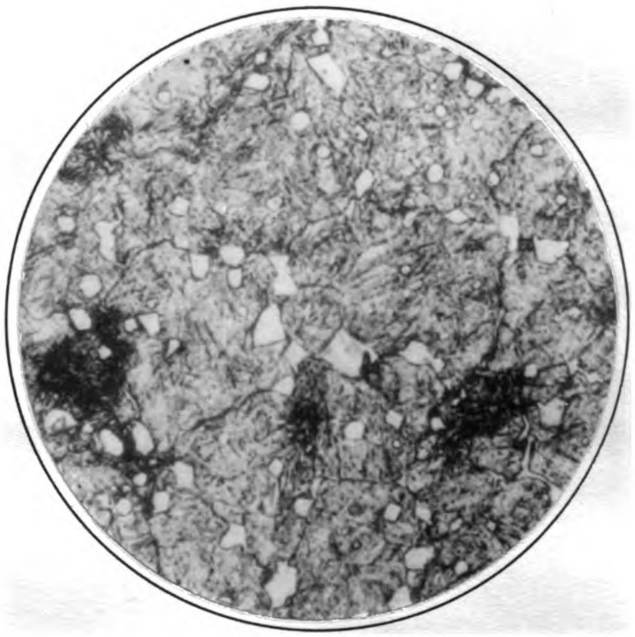

Fig. 10-D

Rockwell hardness ----- 63.5
Depth of needle like
structure ------------- .002"

Magnification ----- 1000X
Etched with 5% nitric acid in alcohol

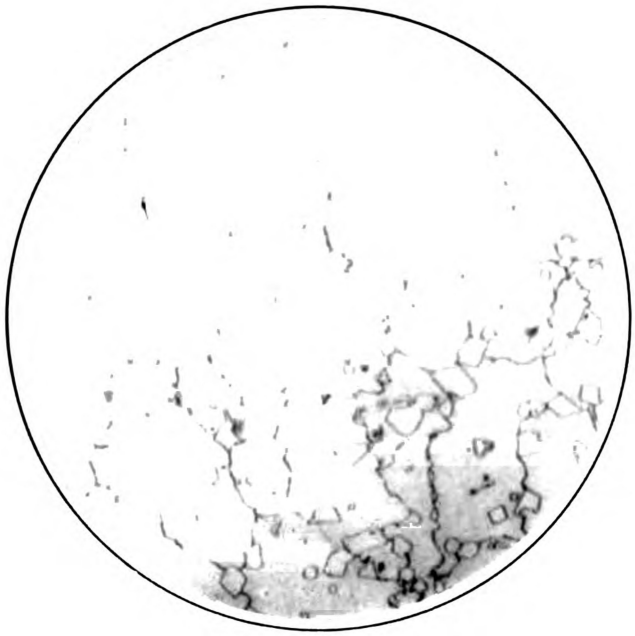

Fig. 11-H

Rockwell hardness ----- 65
Depth of needle like
structure ------------- None
Correct hardening temperature

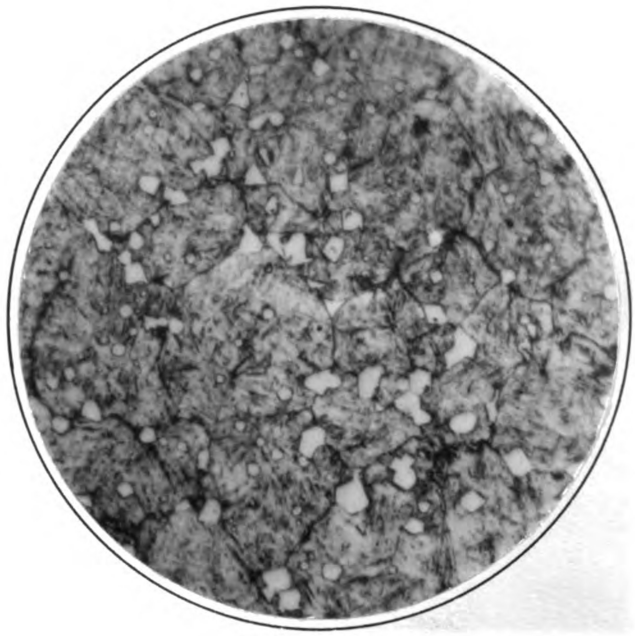

Fig. 11-D

Rockwell hardness ----- 62.3
Depth of needle like
structure ------------- .004"
Note the martensitic structure

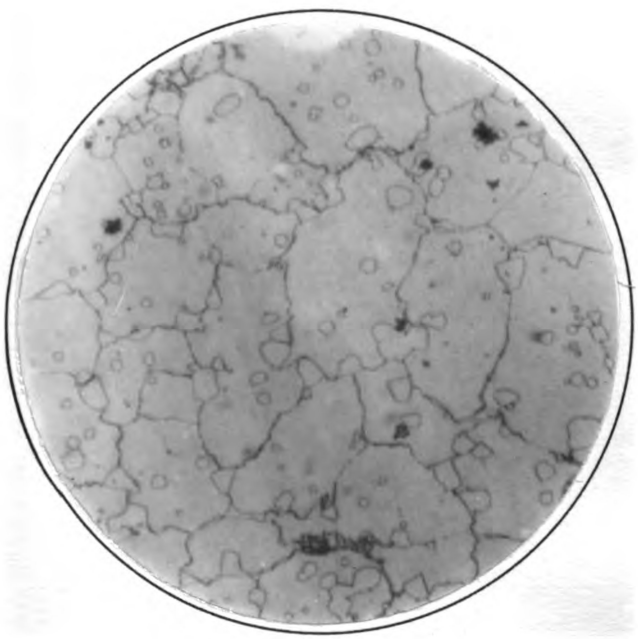

Fig. 12-H

Rockwell hardness ----- 65.1
Depth of needle like
structure ------------- None

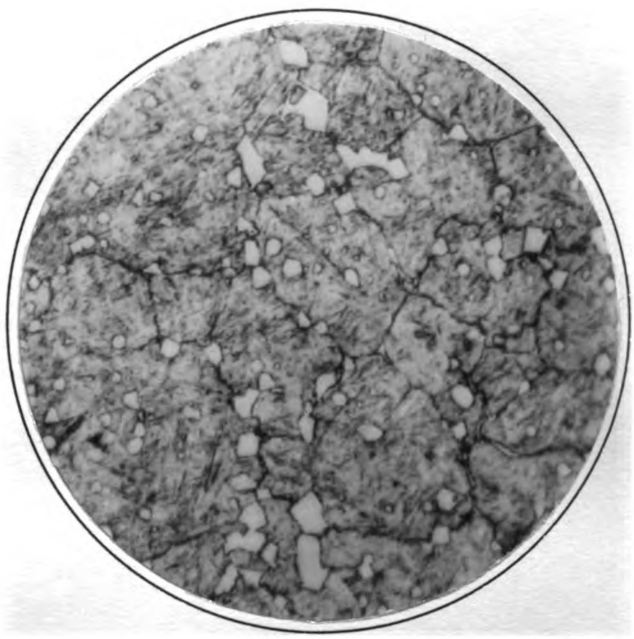

Fig. 12-D

Rockwell hardness ----- 63
Depth of needle like
structure ------------- .002"

Magnification ------ 1000X
Etched with 5% nitric acid in alcohol

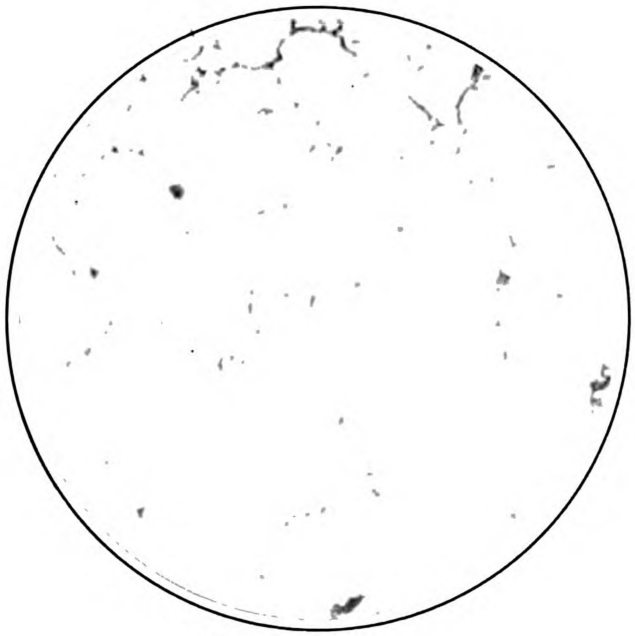

Fig. 13-H

Rockwell hardness ----- 64.5
Depth of needle like
structure ------------ None

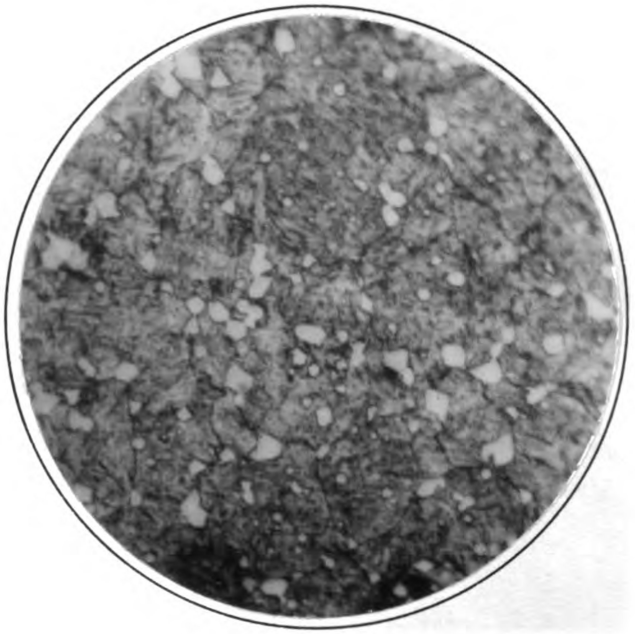

Fig. 13-D

Rockwell hardness ----- 62.5
Depth of needle like
structure ------------ .002"

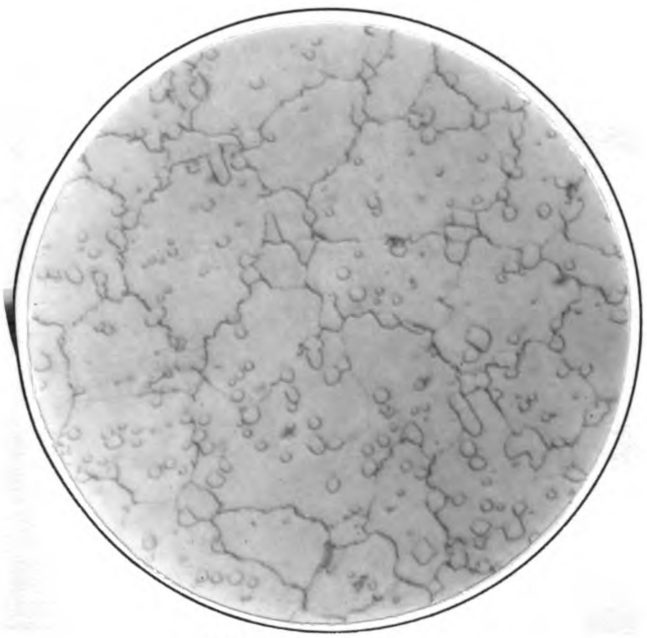

Fig. 14-H

Rockwell hardness ----- 65.1
Depth of needle like
structure ------------ None

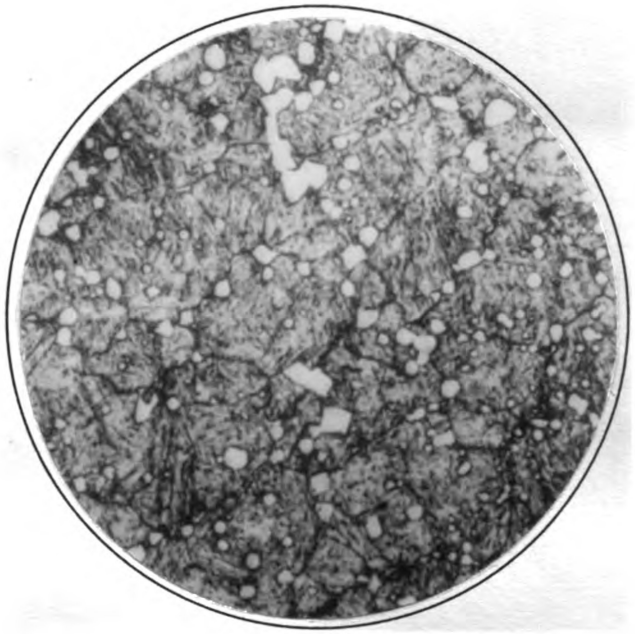

Fig. 14-D

Rockwell hardness ----- 62.1
Depth of needle like
structure ------------ .0005"

Magnification ----- 1000X
Etched with 5% nitric acid in alcohol

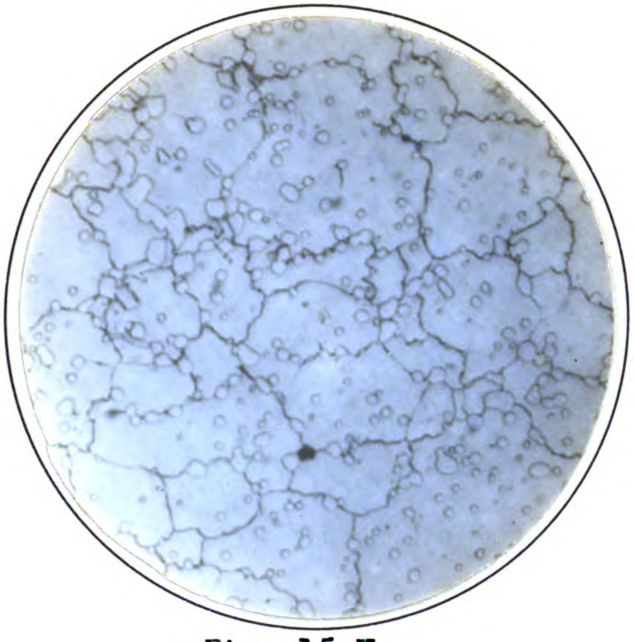

Fig. 15-H

Rockwell hardness ----- 63.8
Depth of needle like
structure ---------- None
Note large number of very
small carbides

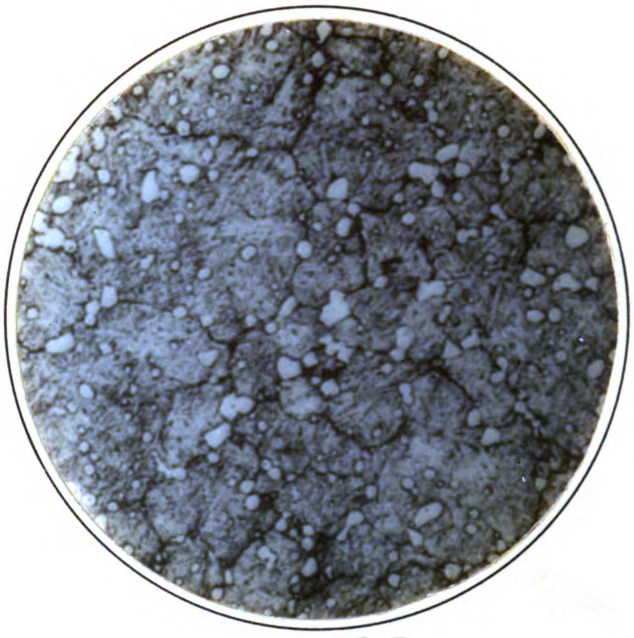

Fig. 15-D

Rockwell hardness ----- 61.3
Depth of needle like
structure ---------- .0005"

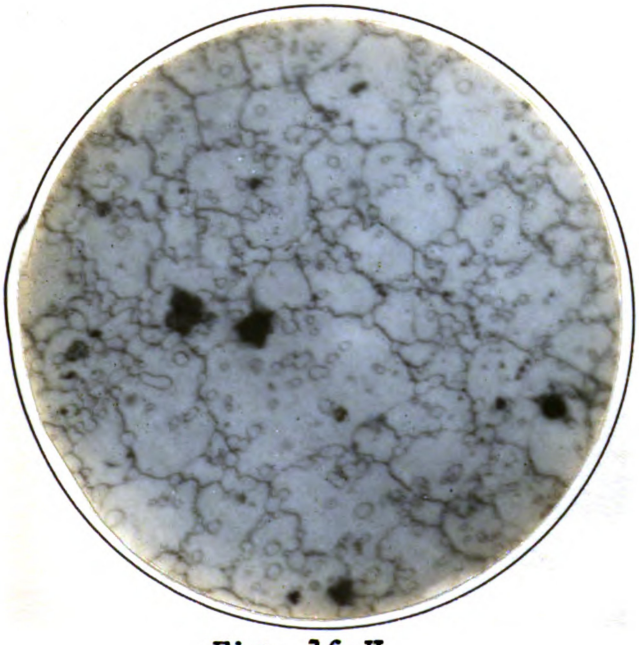

Fig. 16-H

Rockwell hardness ----- 65.1
Depth of needle like
structure ---------- None

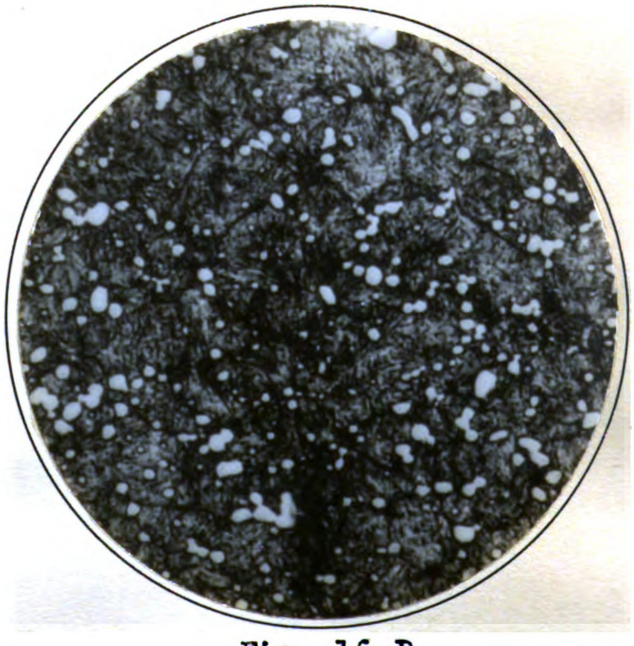

Fig. 16-D

Rockwell hardness ----- 61.5
Depth of needle like
structure ---------- .0005"

Magnification ----- 1000X
Etched with 5% nitric acid in alcohol

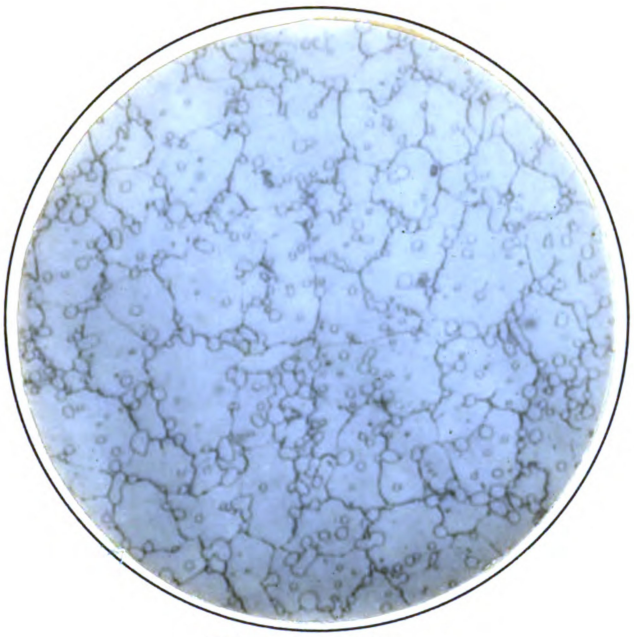

Fig. 17-H

Rockwell hardness ----- 64.3
Depth of needle like
structure ------------ None
Nearly all carbides are
spherical

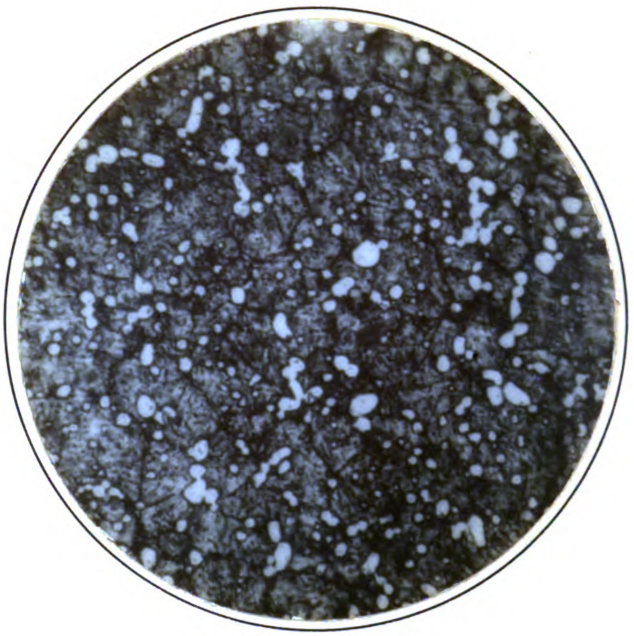

Fig. 17-D

Rockwell hardness ----- 60
Depth of needle like
structure ------------ .0005"

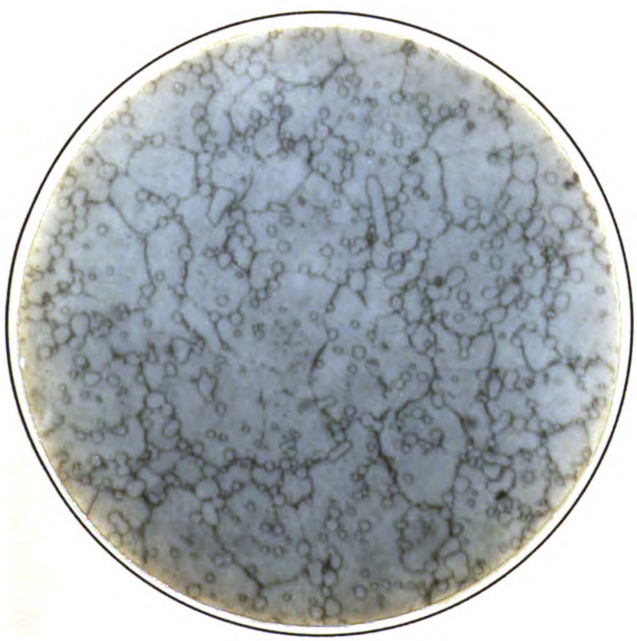

Fig. 18-H

Rockwell hardness ----- 64.1
Depth of needle like
structure ------------ None

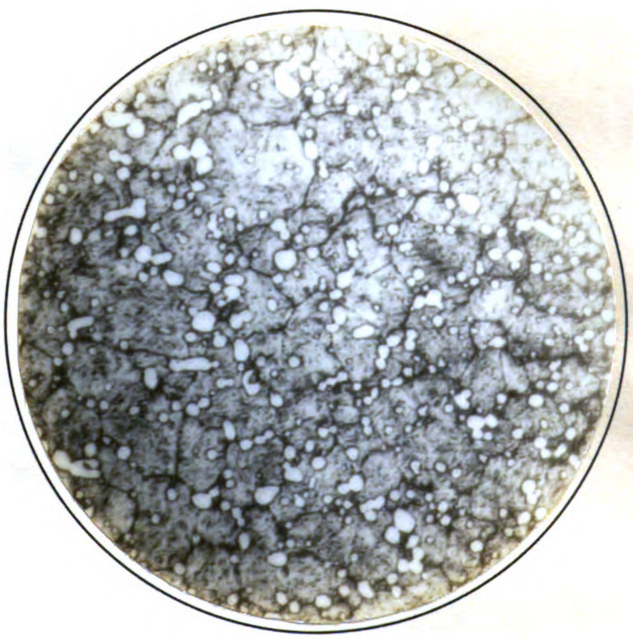

Fig. 18-D

Rockwell hardness ----- 59.6
Depth of needle like
structure ------------ None

Magnification ----- 1000X
Etched with 5% nitric acid in alcohol

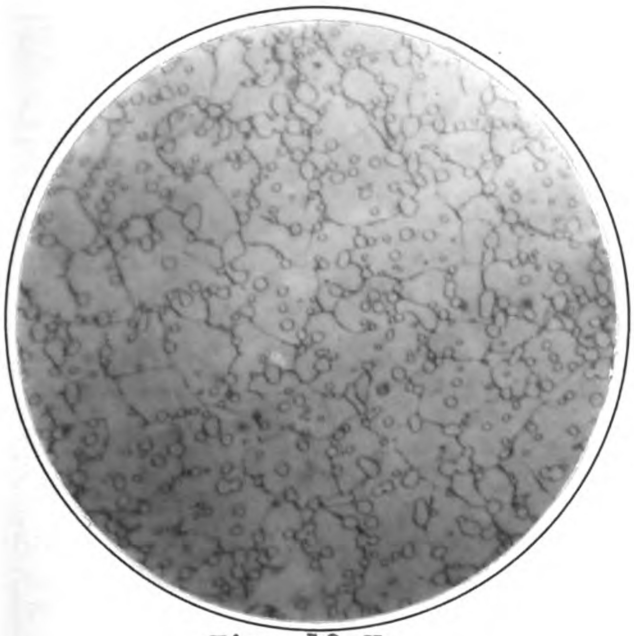

Fig. 19-H

Rockwell hardness ----- 63.3
Depth of needle like
structure ------------ None
Incomplete austenite grains

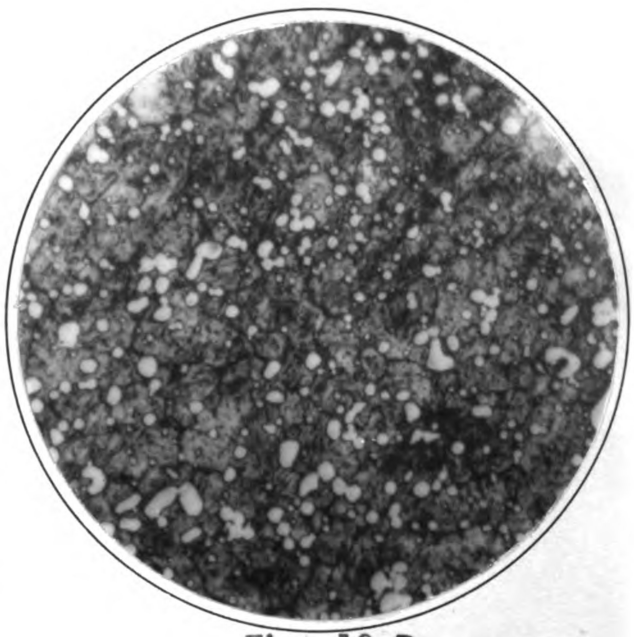

Fig. 19-D

Rockwell hardness ----- 58
Depth of needle like
structure ------------ None

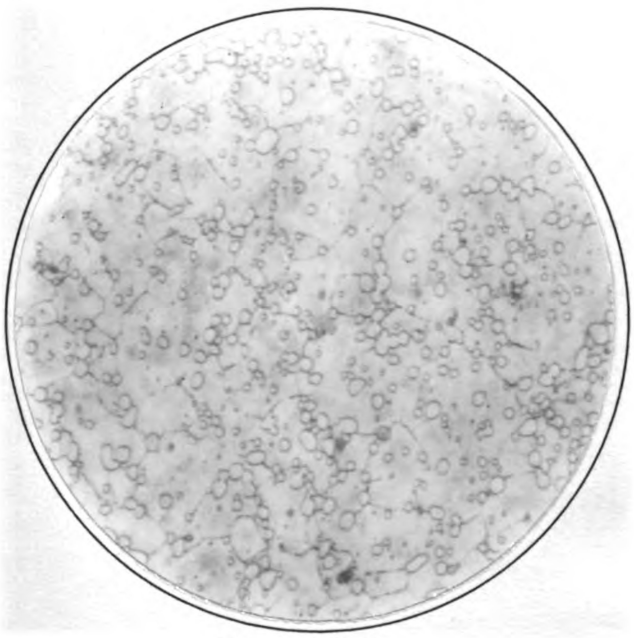

Fig. 20-H

Rockwell hardness ----- 62.8
Depth of needle like
structure ------------ None

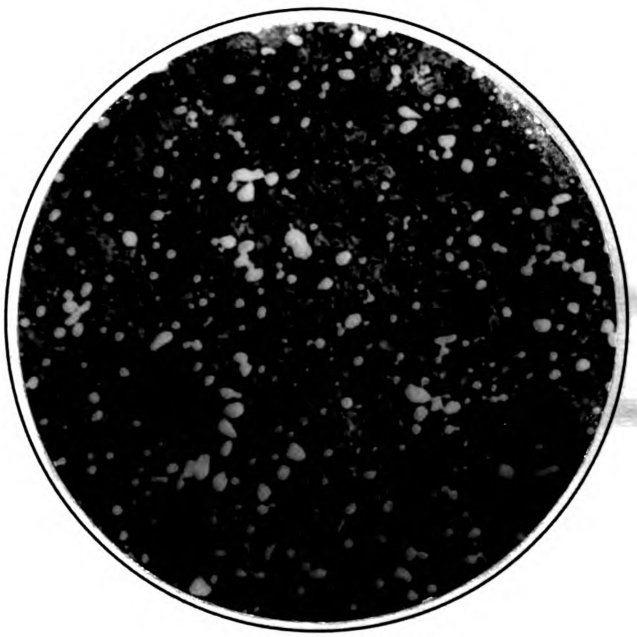

Fig. 20-D

Rockwell hardness ----- 56.3
Depth of needle like
structure ------------ None

Magnification ----- 1000X
Etched with 5% nitric acid in alcohol

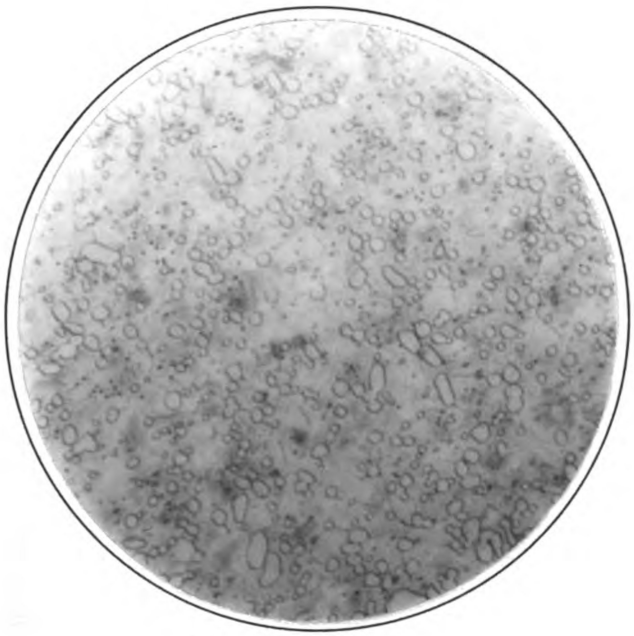

Fig. 21-H

Rockwell hardness ----- 58
Depth of needle like
structure ------------ None
No definite austenite grains.
Temperature too low for the
formation of austenite grains.

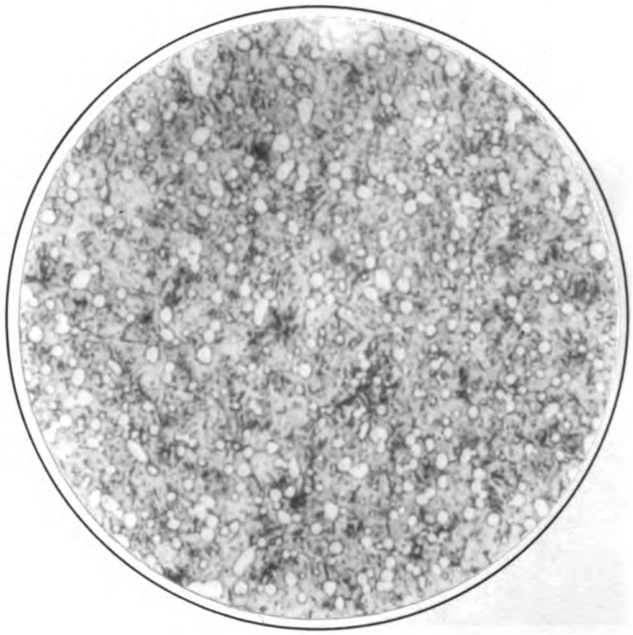

Fig. 21-D

Rockwell hardness ----- 52.5
Depth of needle like
structure ------------ None
Structure very similar to
the hardened structure.

RESULTS FROM OTHER INVESTIGATIONS OF THIS STRUCTURE

In a series of tests, to determine the effect of varying the length of the tempering time upon the structure and impact value of quenched high speed steel, each sample was quenched from as near 2300°F. as possible and then tempered at various times, varying from 15 minutes to 13 hours. The temperature was 1070 to 1080°F. Every tempered sample showed the needle like structure. It varied in depth from .010 in. in the sample tempered for 12 hours to .0007 in. in the sample drawn for 9 hours. There appeared to be no connection between the length of the tempering time and the depth of the needle like structure. For example it was .0025 in. deep in both the sample tempered for 15 min. and the sample tempered for 5 hours. Other investigations, including the present one, seem to indicate that a variation in the tempering time or temperature has no influence in causing this structure.

ONE METHOD OF OVERCOMING THIS STRUCTURE

Since this structure is usually not over .005 in. deep it can usually be removed by leaving enough stock on both sides of the cutting edges so that .005 in. may be ground away after hardening and tempering. However, this is difficult and expensive and in some cases even impossible without special grinding machines.

SUMMARY

In conclusion, the results of this and our other investigations would seem to warrant the following statements:

1. That overheating might not be entirely the answer because this structure was present as far as Fig. 17-D, while Fig. 11-D showed about the correct hardening temperature. In other investigations where the temperature was held as near 2300°F. as possible this structure was sometimes present. However, overheating or some one temperature not necessarily very high considering high speed steel temperatures probably has a decided influence, if it is not the entire cause, because in most cases this structure is on the outside of the samples, which becomes the hottest, also this structure is always very coarse which helps to prove the above statement.
2. That uneven heating is out of the question because it is often present in small samples which have been heated with laboratory accuracy.

3. Insufficient tempering is not the cause for the reason that the samples in this investigation were tempered for 14 hours, which is many times the usual length of time. In a previous investigation where the tempering time was varied, there seemed to be no effect so far as time was concerned.

4. Tempering before the tools were entirely cold, certainly was not the cause of the needle like structure in this case, for the reason that the samples were at room temperature for two days before they were tempered.

5. The structure does not appear to be a martensitic structure because they do not look alike, and because it seems to bear no relation to tempering time nor temperature. Martensite is a transitory structure which should vary with both time and temperature. Dr. Edwards and Dr. Matthews both refer to it as though it was a new structure. In fact Dr. Edwards calls it "a new brittle constituent".

6. The information obtained in this and in our other investigations, does not definitely prove the cause of this structure. It does, however, show one method of overcoming the difficulty where it exists as a thin layer on the outside of tools. It also shows that tempering time nor temperature seem to have no effect upon it and that it is very likely caused in some way during the hardening operation, therefore a practice of hardening should be used which would eliminate this structure as much as possible.

ROOM USE ONLY