# The Growth of Grey Cast Iron.
## (Second Report.)

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(Received January, 10, 1937.)

*Synopsis.*

*The influence of ammonia, methane and water vapour mixed with nitrogen or hydrogen upon the growth of grey cast iron was confirmed by the same method as adopted in the previous investigation. The graphitization of the pearlite-cementite in grey cast iron was also measured by dilatometer in various atmospheric conditions. Examining the results, it was confirmed that the abnormal expansion at Ar transformation of grey cast iron is due to the graphitization of the pearlite-cementite as presumed by Benedicks and Löfquist.*

### Introduction.

The author has continued to investigate the same problem as treated in the first report[1] to supplement the former work. In the present report, the influence of ammonia, methane and water vapour mixed with nitrogen or hydrogen upon the growth of grey cast iron will be described. The graphitization of the pearlite-cementite in grey cast iron in various atmospheric conditions has been also studied.

### Materials used.

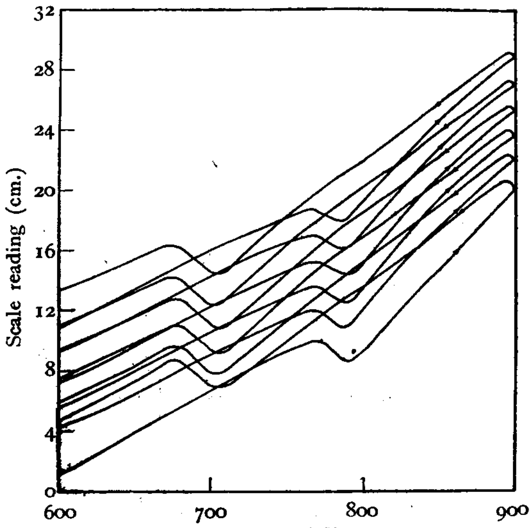
The specimens were prepared in the same manner as in the previous investigation. Their composition is given in Table I.

**Table I.**

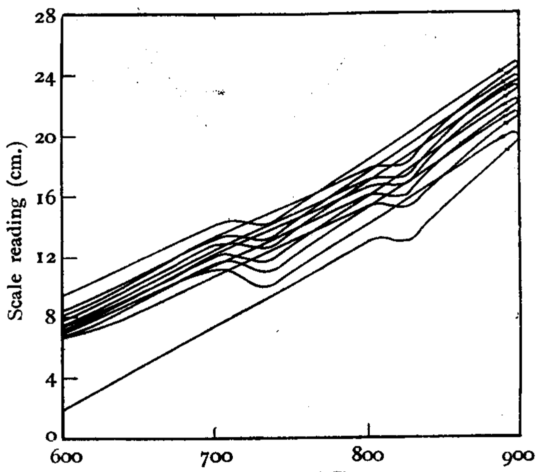
| Specimen No. | Composition % | | | | | |
|---|---|---|---|---|---|---|
| | Total C | Combined C | Si | P | Mn | S |
| A | 3.17 | 0.78 | 1.03 | 0.20 | 0.81 | 0.05 |
| B | 3.21 | 0.75 | 1.46 | 0.24 | 0.80 | 0.07 |
| C | 3.38 | 0.71 | 2.11 | 0.35 | 0.68 | 0.07 |
| D | 3.49 | 0.80 | 1.77 | 0.20 | 0.62 | 0.07 |

### Description of the experiments.

(*1*) *Influence of various gases upon the growth.*—Specimens A, B and C were used in the present experiments. The pure ammonia and methane were obtained by the same method as in the former investigation.[2] In order to find the influence of water vapour, nitrogen or hydrogen was adopted as vehicle which was saturated with water vapour at 25°C. The apparatus for this purpose was the same as used in the experiments on the cementation of steel by liquid hydrocarbons.[3] The description of dilatometer experiments will be here omitted, as it is given in detail in the first report.



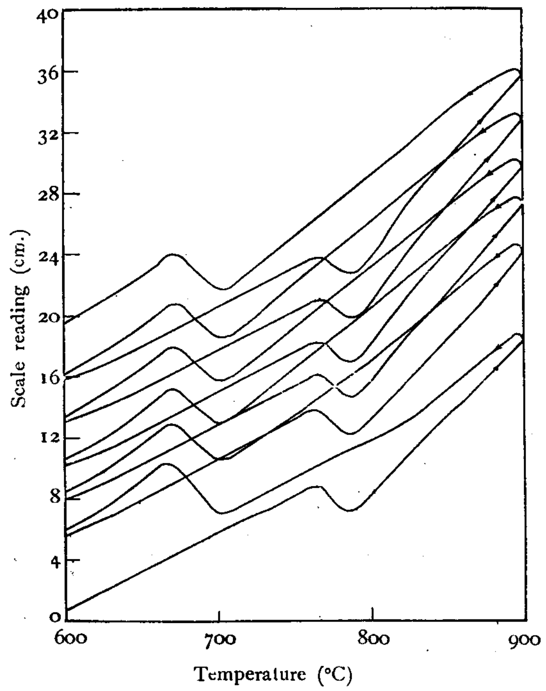

Specimen A in $NH_3$.
Fig. 1.




Specimen C in $NH_3$.
Fig. 2.

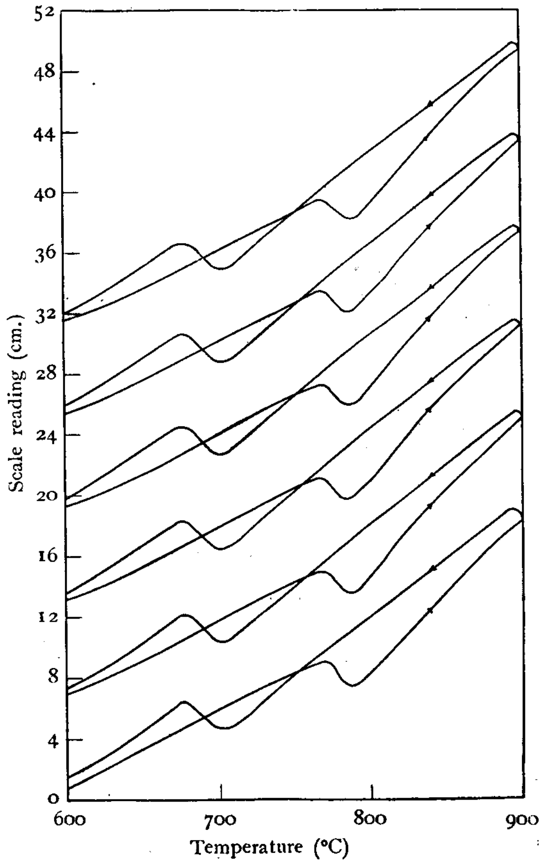
1) Prof. K. Honda's Annivers. Vol. (Sci. Rept., Tohoku Imp. Univ.), (1936) 896.
2) Mem. Coll. Engg., Kyoto Imp. Univ. 5 (1930) 249.
3) Ditto. 9 1936) 129—Fig. 2.

The results of experiments are graphically shown in Figs. 1—8. The results on Specimen B are omitted, as they are similar to those on the other kinds of specimen.



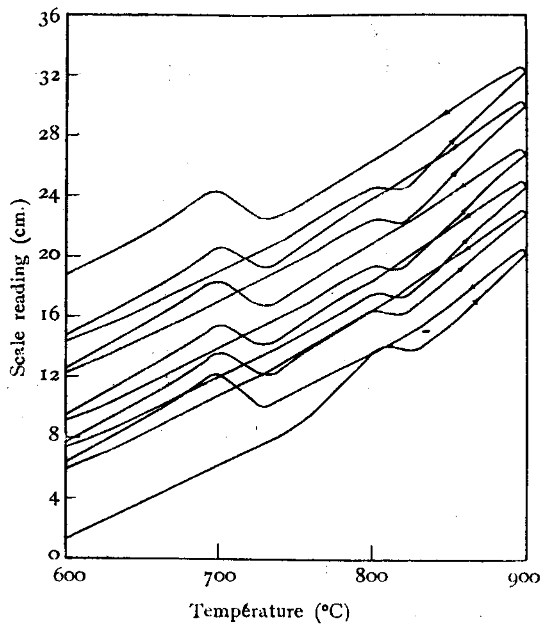

Specimen A in $CH_4$.

Fig. 3.



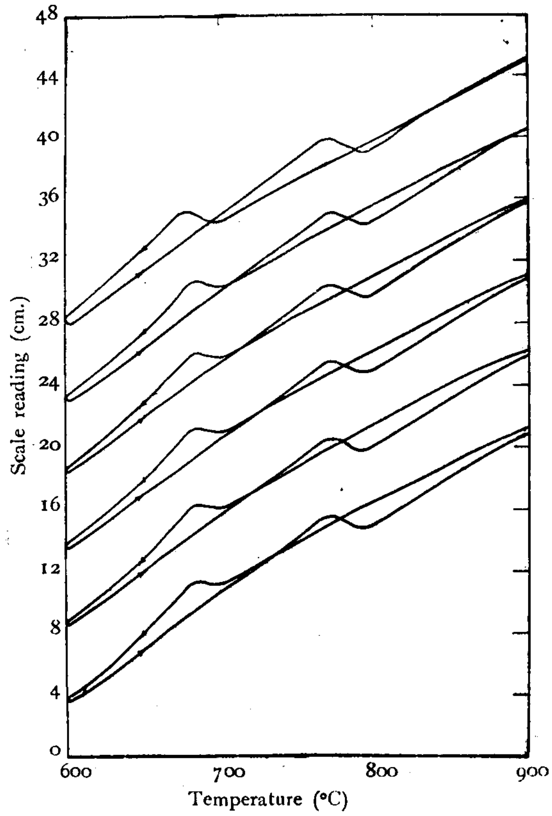

Specimen A in $H_2$ with water vapour.

Fig. 5.



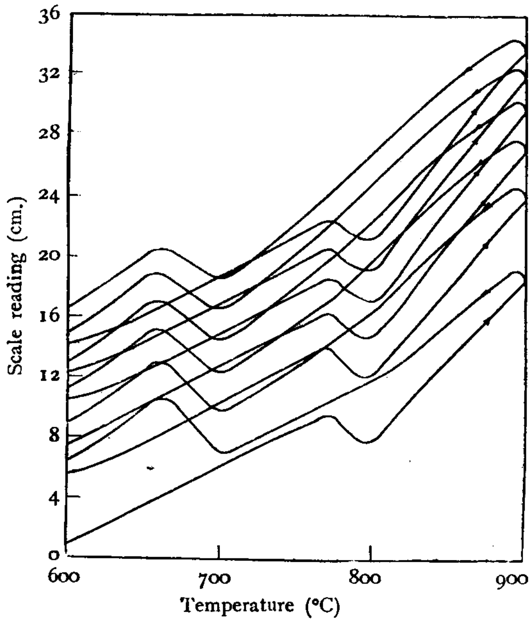

Specimen C in $CH_4$.

Fig. 4.

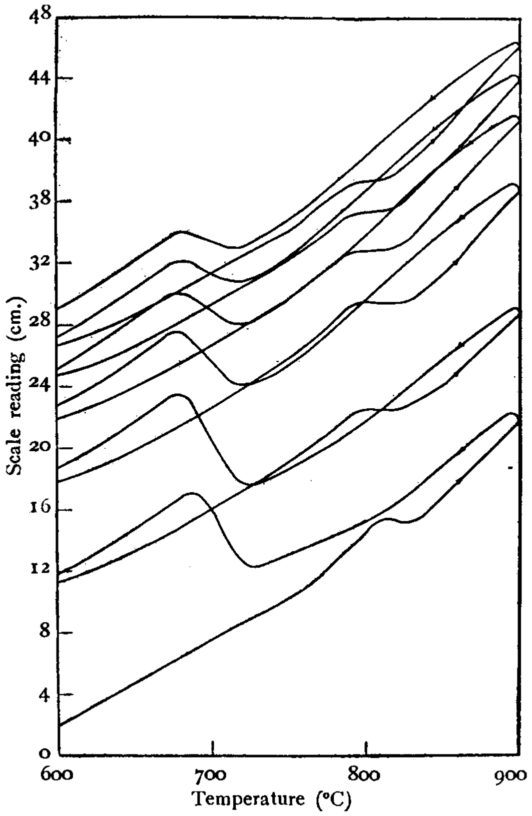



Specimen C in $H_2$ with water vapour.

Fig. 6.




Specimen A in $N_2$ with water vapour.
Fig. 7.




Specimen C in $N_2$ with water vapour.
Fig. 8.

The increase in length and the decrease in specific gravity after the sixth cooling is given in Table II, and the expansion at Ar transformation on the first cooling is measured on scale as given in Table III.

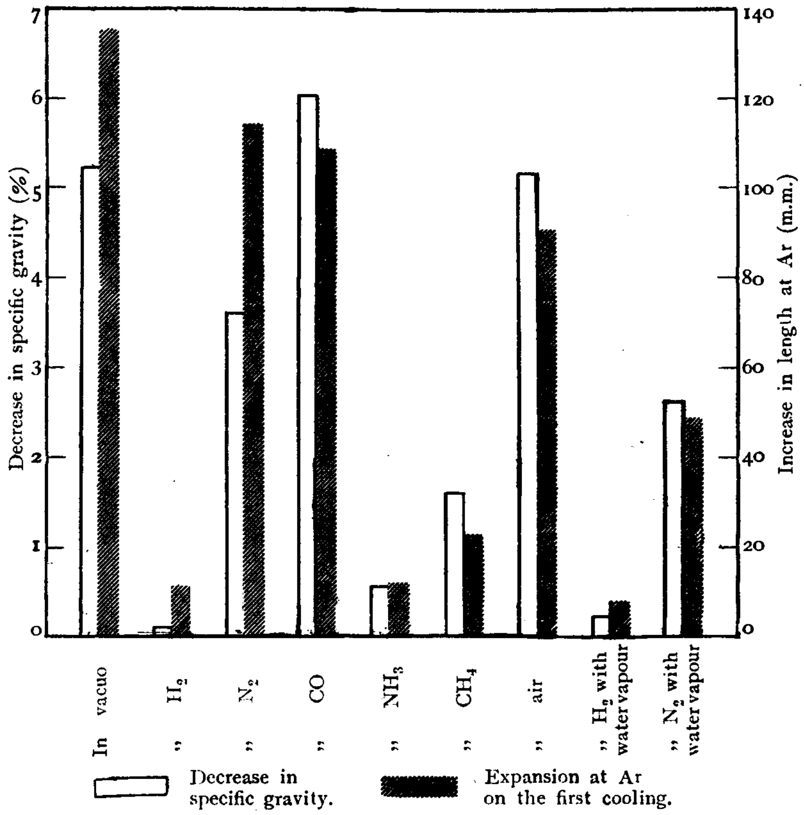
## Table II.

| Specimen No. | Atmospheric condition | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $NH_3$ | | $CH_4$ | | $H_2$ with water vapour (25°C) | | $N_2$ with water vapour (25°C) | |
| | Specific gravity % | Length % | Specific gravity % | Length % | Specific gravity % | Length % | Specific gravity % | Length % |
| A | 0.724 | 0.552 | 1.580 | 0.578 | 0.383 | 0.0580 | 1.504 | 0.412 |
| B | 0.674 | 0.464 | 2.027 | 0.716 | 0.359 | 0.0518 | 1.556 | 0.490 |
| C | 0.558 | 0.428 | 1.598 | 0.595 | 0.237 | 0.0270 | 2.640 | 0.672 |

## Table III.

| Specimen No. | Atmospheric condition | | | |
|---|---|---|---|---|
| | $NH_3$ | $CH_4$ | $H_2$ with water vapour | $N_2$ with water vapour |
| | m.m. | m.m. | m.m. | m.m. |
| A | 18 | 32 | 16 | 36 |
| B | 18 | 29 | 13 | 42 |
| C | 12 | 22 | 8 | 48 |

Summarizing the results on Specimen C, Fig. 9 was obtained which graphically shows the influence of various atmospheric conditions upon the change in specific gravity after the sixth cooling and the expansion at Ar transformation on the first cooling. The data published in the first report are also included in the same figure.




Specimen C (Si=2.11%).
Fig. 9.

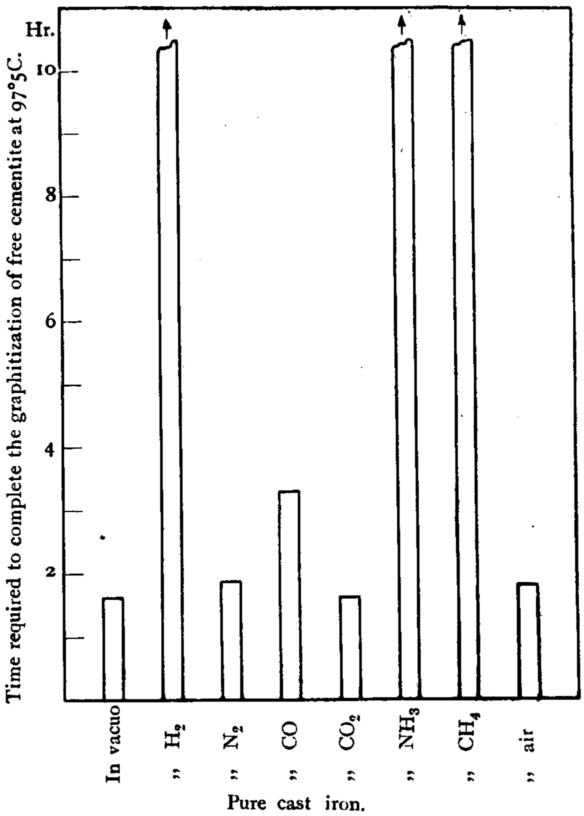



Fig. 10.

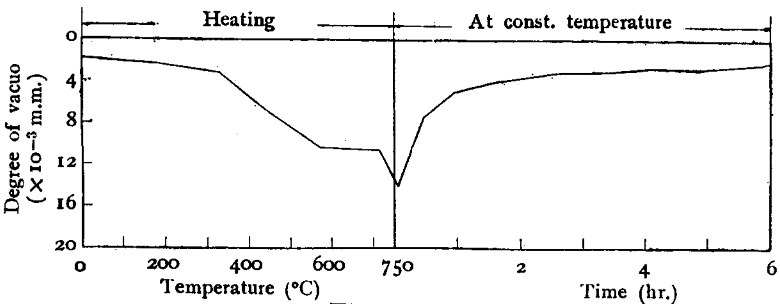



Fig. 11.

As shown in the above figures, grey cast iron grows little in ammonia and methane, and more greatly in pure nitrogen than in nitrogen with water vapour. The expansion at Ar transformation on the first cooling in ammonia or methane is so small as not be considered as abnormal.

(2) *Influence of various gases upon the graphitization of pearlite-cementite.*—Specimen D was adopted throughout this experiment. It was heated in the dilatometer at the rate of 10°C/min. up to 750°C which was then kept constant for 6 hours or more. The rate of flow of gas in the dilatometer was the same as in the experiments described in (1). The scale reading was taken every 5 minutes. The heating of the specimen in the vacuum dilatometer was begun after the degree of vacuum had become 2/1,000 m.m. Hg. Its variation during this experiment is shown in Fig. 11. Evacuation was not so satisfactory as in other vacuum experiments.

The results are graphically shown in Fig. 12 in which the ordinate represents the expansion of the specimen at 750°C. The microstructure of the treated specimens is in Photo. 1.

Though it is impossible to determine exactly the end of the graphitization of the pearlite-cementite, we can recognize that the graphitization takes place with great difficulty in hydrogen and ammonia and very easily in vacuo, nitrogen, carbon monoxide and air. The specimen expands also in methane moderately but not so greatly as in air. It is difficult to find the difference in the behaviour in question of the pearlite-cementite in

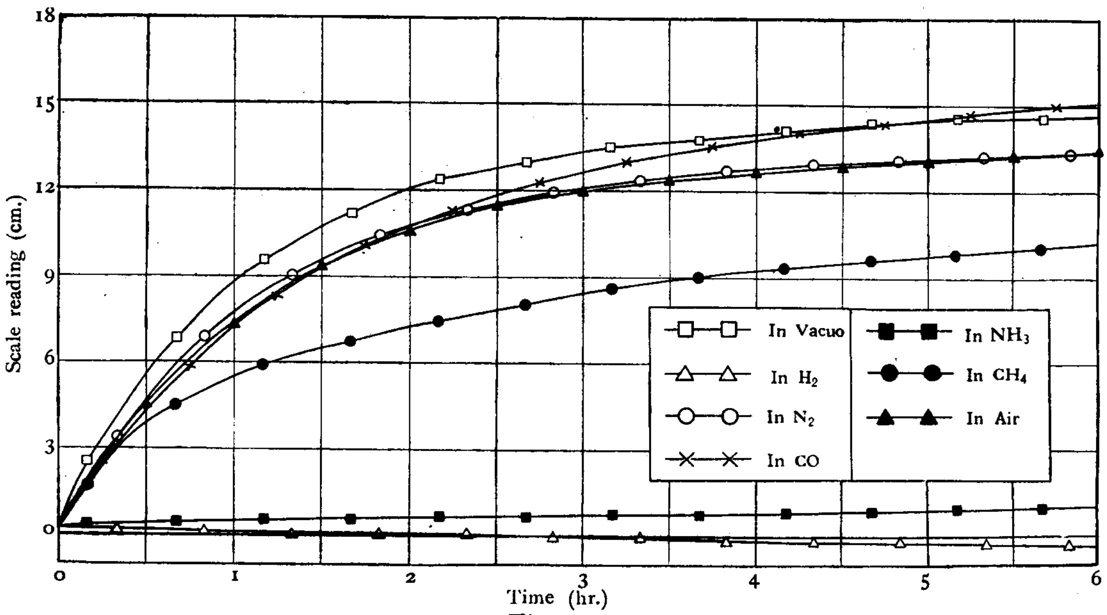
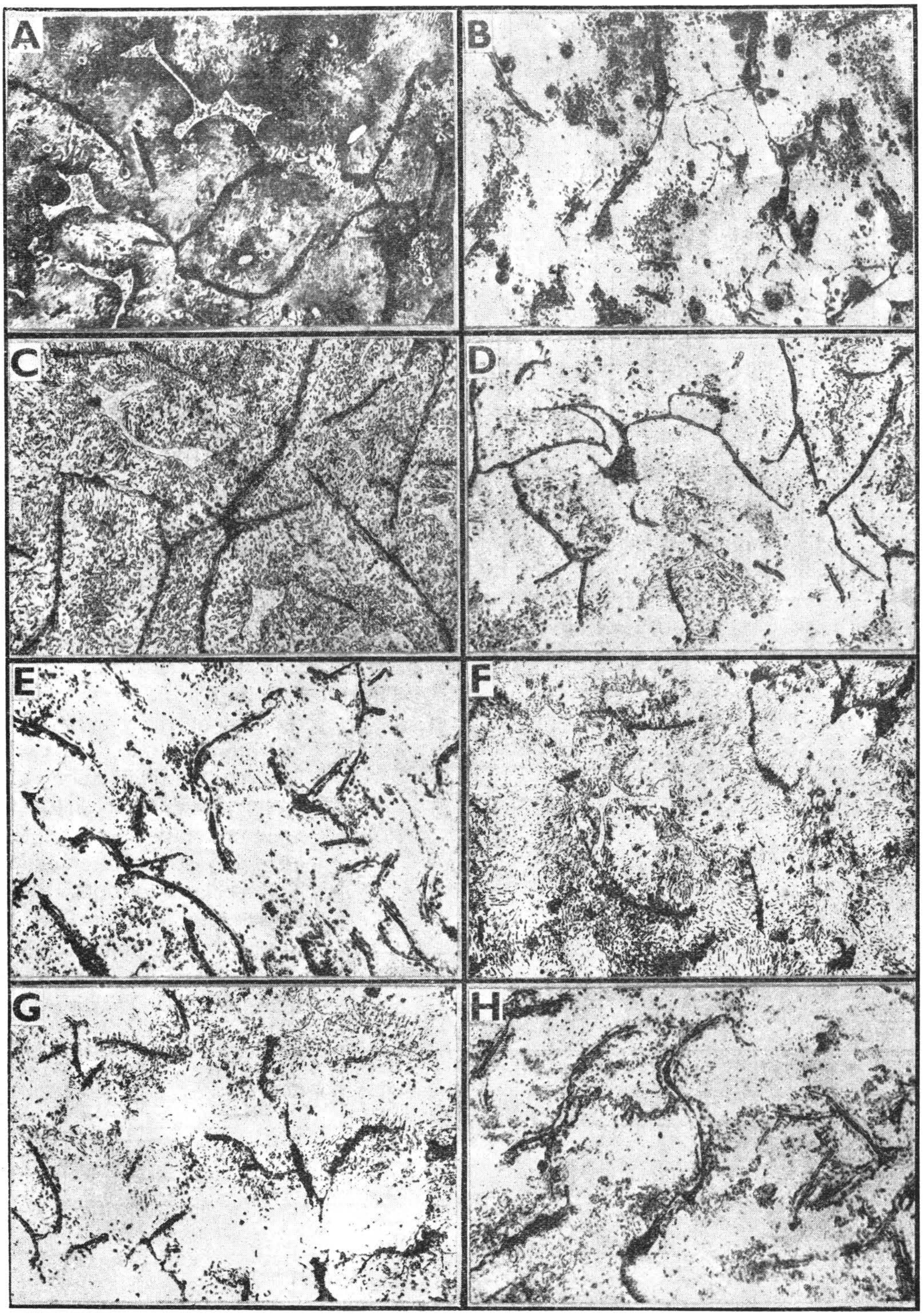



Fig. 12.

×250




A = Original　B = In vacuo　C = In $H_2$　D = In $N_2$
E = In CO　F = In $NH_3$　G = In $CH_4$　H = In air

Specimen D (Si = 1.77%).

Photo. 1.

nitrogen, carbon monoxide and air. The results, however, show that the peatlite-cementite graphitizes more easily in vacuo than in the other atmospheres.

## Consideration of results of experiments.

Comparing the expansion at Ar transformation on the first cooling with the graphitization of the pearlite-cementite in various atmospheric conditions, we can find a definite relation ; i.e., the former is very small in hydrogen and in ammonia in which the latter is retarded considerably, and the former is greatest in vacuo in which the latter occurs most easily as above mentioned. Fig. 10, reproduced from the author's former paper[1], shows the influence of various atmospheric conditions on the graphitization of the free cementite in white cast iron. The relation shown in this figure is almost the same as found in the pearlite-cementite in grey cast iron in the present-experiments.

Consequently, we can conclude that the abnormal expansion taking place during Ar transformation of grey cast iron must be due to the graphitization of the pearlite-cementite.

## Summary.

The results of the present investigation may be summarized as follows:

(1) The influence of ammonia, methane and water vapour contained in hydrogen or nitrogen upon the growth of grey cast iron when it is repeatedly heated and cooled during the temperature range 600°C to 900°C was studied.

(2) The expansion at Ar transformation on the first cooling was measured in the above mentioned experiments.

(3) The influence of various atmospheric conditions upon the graphitization of the pearlite-cementite in grey cast iron was investigated.

(4) Treating on the relation between the results obtained in (3) and (2) including the data published in the first report, it was confirmed that the abnormal expansion at Ar transformation of grey cast iron must be due to the graphitization of the pearlite-cementite as presumed by Benedicks and Löfquist.

In conclusion, the author desires to express his cordial thanks to Toyoda Jidoshokki Seisakusho, Kariya near Nagoya, for financial support and also to Mr. J. Yamamoto for his kind assistance.

1) Mem. Coll. Engg., Kyoto Imp. Univ., 5 (1930) 274—Fig. 12.