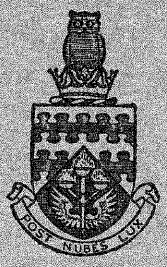

THE COLLEGE OF AERONAUTICS
CRANFIELD

CHARACTERISTICS OF THE HIGH TEMPERATURE MECHANISMS OF CREEP AND RECOVERY IN GRAPHITE

Contract No. DA-91-591-E.U.C.2629
Quarterly Technical Status Report No. 3
February 1st - April 30th 1963

CoA Note 151

Part 3

THE COLLEGE OF AERONAUTICS

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Cranfield, Bletchley,
Buckinghamshire, England.

1. Statement of work carried out

Progress has been made in establishing the creep and recovery characteristics, over the temperature range 2000-2750°C, of the commercial graphite Morgan's EY9 and its ungraphitised form CY9. The results are presented in graphical form and salient points described below. These results will form the basis of a paper to be presented at the forthcoming 6th Biennial Carbon Conference. A full discussion of these and later results will be given in the paper.

The specimen used for this work is of the type quoted in our previous report. Three minor modifications have been introduced to reduce the stress in the material around the top pin. These are:-

a) The outer tube diameter of the upper part of the specimen has been increased from 1.000 to 1.100 ins., giving an increased wall thickness.

b) The top $\frac{1}{2}$ in. is impregnated under vacuum by phenol formaldehyde.

c) A plug 1.5 inch long is inserted into the tube and bonded by phenol formaldehyde. A small air vent hole is provided below this plug. The hole for the loading pin is bored when the plug has been bonded into place.

a) Torsional stress - torsional strain results

The torsional stress strain results, over a range of temperatures for EY9 and CY9, are given in Figures 1 and 2 respectively.

For both materials, the stress to produce a given strain decreases with increasing temperatures, except for EY9 above 2600°C. Whilst the curves for CY9 and EY9 are markedly different at 2000°C, they become similar at 2250°C and 2400°C. As this may be due to graphitisation during the heating period, a microstructural investigation of the effect of the heating cycle is in progress. Details of the heating cycles used for these specimens are given in Appendix 1.

b) Creep results

The creep curves for EY9 are shown in Figure 3. The creep rate increases with increasing temperature and stress. The effect of an increase in temperature from 2000 to 2100 more than trebles the creep produced in 100 mins., even by a smaller load. At 2250°C the increase in creep rate appears to be proportional to an increase in load, but at 2600°C this is no longer true.

The creep curves for CY9 (Figure 4) show increasing creep rates with increasing temperature for a constant stress, though the

temperature effect is less marked than in EY9. The creep rate is about 10 times faster than in EY9 at 2000°C, reducing to 3 times faster at 2400°C.

c) Recovery on unloading at the test temperature. Figures 5 and 6.

E.Y.9. Two trends can be noted. Firstly, as the creep temperature is increased, so the proportion of strain recoverable in a given time decreases. Secondly, as the amount of strain is increased, the proportion of strain recoverable in a given time decreases.

C.Y.9. As the creep temperature increases, the proportion of strain recoverable in a given time decreases. The proportion recoverable appears to be less in CY9 than EY9, although this may be due to the greater strain.

d) Recovery during cooling

Similar readings to those reported in our previous report have been made, but have not yet been analysed.

e) Microstructure

All specimens are being examined for changes in microstructure after creep. Some changes have been observed, particularly in CY9, and further work is in progress.

Back-reflection X-ray diffraction techniques revealed no observable differences after creep up to a maximum strain of 4.4°/ins at 2600°C in EY9.

2. Research plans

These broadly remain as originally proposed. The special graphites referred to in our previous report are in course of manufacture and should shortly be available.

3. Personnel, administrative actions, etc.

The full-time personnel engaged on this work remain the same. About 150 man-hours were contributed by the College Workshop.

4. Utilisation of funds

These have been fully utilised.

5. Important property acquired

None.

6. Miscellaneous

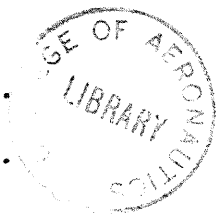
Arrangements have been made for Dr. Younger to attend the 6th Biennial Carbon Conference and for him to visit a number of laboratories working on graphite in the U.S.A.

Appendix 1

Heating cycles employed on CY9 specimens

Heating to 2000°C

$1\frac{1}{2}$ hours soak at 1500°C.
Almost instantaneous rise to 1750°C.
5 mins. at 1750°C.
Almost instantaneous rise to 2000°C.
Soak 5 mins at 2000°C, then test.



Heating to 2250°C

Heat to 1500°C.
Slow heating over 10 mins from 1500 to 1900°C.
Rapid rise to 2000°C.
Slow heating over 10 minutes from 2000 to 2250°C.
Soak 5 minutes at 2250°C, then test.

Heating to 2400°C

Heat in 5 mins to 1500°C.
Rapidly heat to 1750°C and soak for 5 mins.
Rapidly heat to 1900°C and soak for 5 mins.
Rapidly heat to 2150°C and soak for 5 mins.
Rapidly heat to 2250°C and soak for 5 mins.
Rapidly heat to 2400°C and soak for 5 mins., then test.

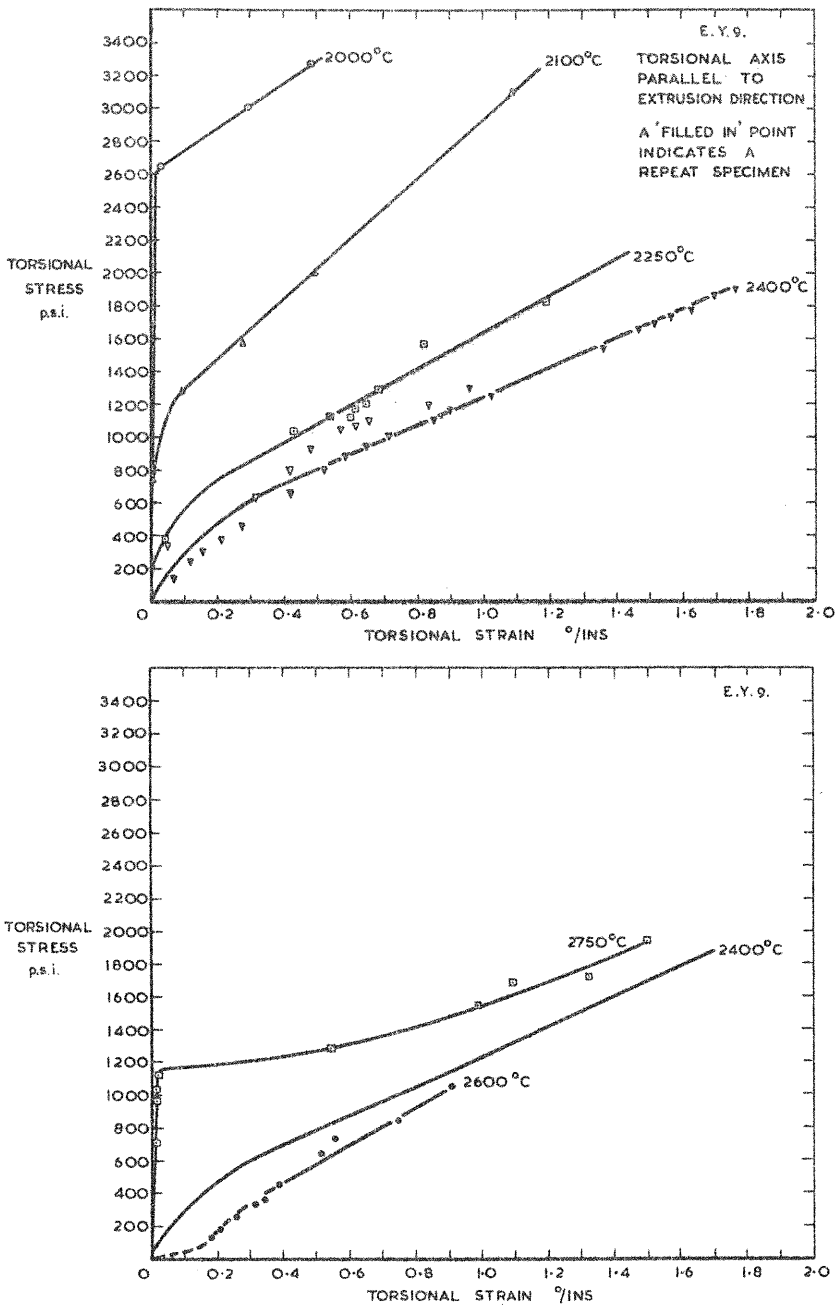


FIG. 1 TORSIONAL STRESS-TORSIONAL STRAIN CURVES FOR EY9

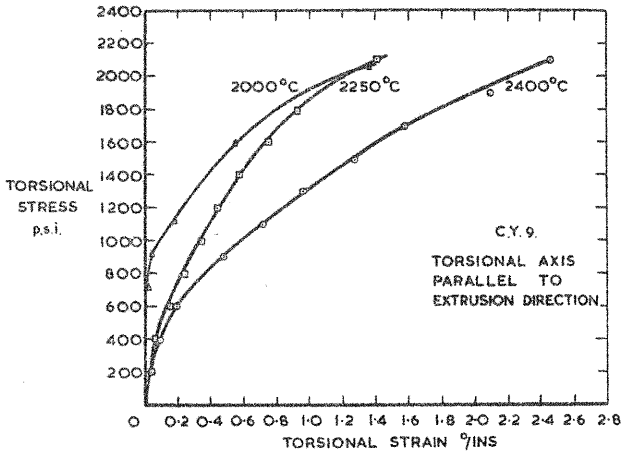


FIG. 2 TORSIONAL STRESS-TORSIONAL STRAIN CURVES FOR CY9

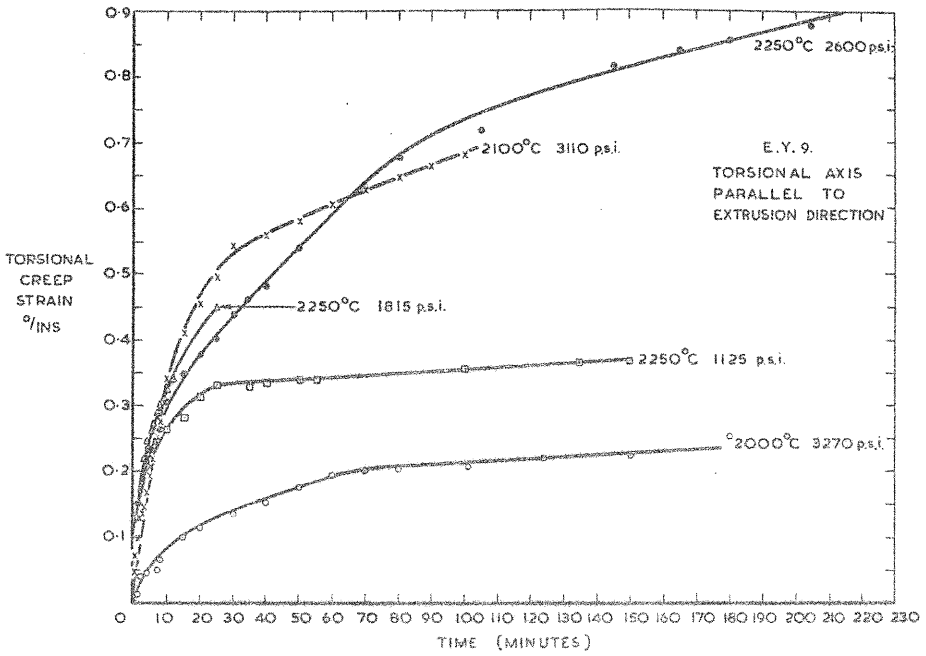


FIG. 3 TORSIONAL CREEP CURVES FOR EY9

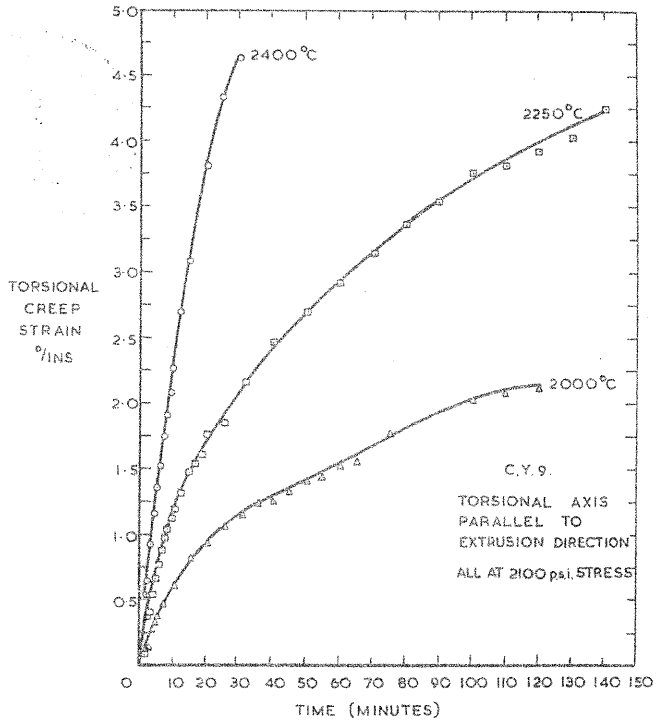
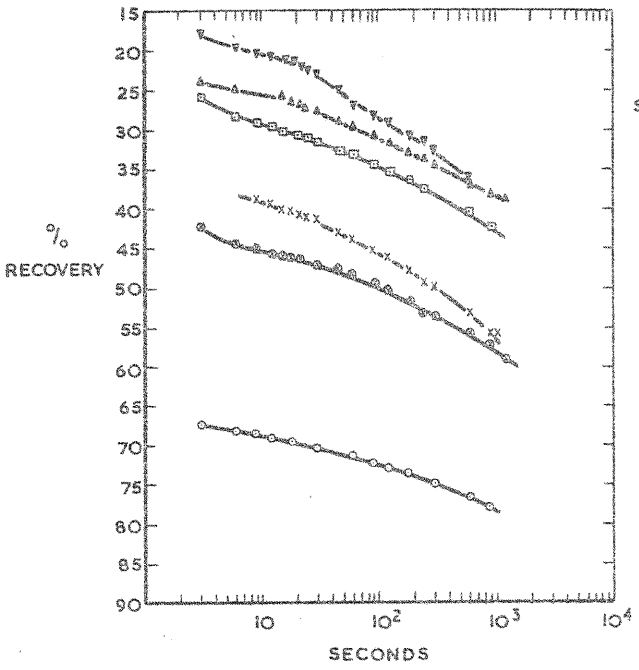


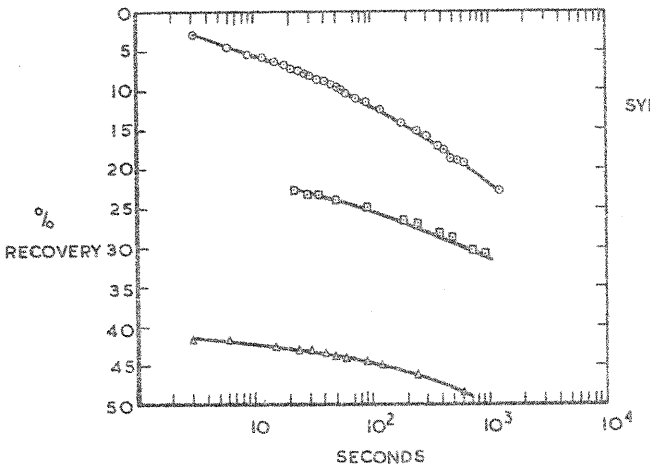
FIG. 4 TORSIONAL CREEP CURVES FOR CY9



E.Y.9 RECOVERY

SYMBOL	TEMP°C	INITIAL STRAIN °/INS
⊙	2000	0·739
x	2250	1·767
⊛	2400	3·813
▲	2400	5·41
⊡	2600	2·50
▽	2600	6·07

FIG. 5 RECOVERY OF EY9 AT THE TESTING TEMPERATURE ON UNLOADING



C.Y.9 RECOVERY

SYMBOL	TEMP°C	INITIAL STRAIN °/INS
△	2000	7·08
⊡	2250	5·8
⊙	2400	3·46

FIG. 6 RECOVERY OF CY9 AT THE TESTING TEMPERATURE ON UNLOADING