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INVESTIGATION OF STRUCTURAL PROPERTIES OF FIBER GLASS FILAMENT-WOUND PRESSURE VESSELS AT CRYOGENIC TEMPERATURES

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Cleveland, Ohio

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1 DOUGLAS AIRCRAFT COMPANY, INC.
2 SANTA MONICA, CALIFORNIA

2687002

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GENERAL

All of the coupon testing, except for evaluation of glass flake material, has been completed. Biaxial testing has been held up due to hook-up and check-out problems with the vacuum system. Some ambient temperature biaxial testing has been done and preparations are in the final stages for initial liquid hydrogen work.

The newly submitted revised Master Schedule (9/30/63) reflects more accurately the status of the project over the original schedule.

A detailed description of work accomplished to date and work to be performed during November 1963 in each Task Area is given in the pages to follow.

PHASE I

1. Liner Material Investigation

All of the materials have been tested as coupons except the glass flake material. As reported upon in Reference 1, the material did not appear too satisfactory and an attempt has been made to secure a better quality laminate. An experimental technique for producing glass flake sheets is being developed by Douglas on another project and some material has been made available for evaluation in this project.

Recent work on another Douglas project has disclosed that the salt used for fabrication of the 18 inch diameter pressure vessels has had an adverse effect on metallic parts in contact with the hypereutectic material. Therefore, corrosion tests are being performed with the metallics contemplated for use in this program. Samples of nickel, silver, and copper have been immersed in a solution of water and Blue Temp 275 salt. A portion of each specimen remains above the solution in the atmosphere of the laboratory. Visual examinations recently revealed that the exposed and immersed sections of nickel and silver showed no change; the immersed copper showed a slight discoloration and the exposed copper was quite corroded.

1.1 Mechanical Properties Tests

All work in this area has been completed and reported upon in Reference 1.

1.2 Coefficient of Thermal Contraction

All work in this area has been completed and reported upon in Reference 1.

1.3 Permeability and Cyclic Tests

1.3.1 Permeability at Ambient Temperature - Unstressed

All work in this area has been completed and reported upon in Reference 1.

1.3.2 Permeability at Ambient Temperature - Biaxially Stressed

The first ambient temperature test was started early in the month. The residual gas analyzer (RGA) was calibrated for use in the vacuum system. A Mylar "A" specimen (SPV2-1') was initially pressurized with helium gas to 100 psi; a high permeability rate negated the use of the RGA. It was decided to utilize a sensitive pressure transducer for the permeability measurements. Another attempt with the same cylinder was made with an anticipated working pressure of 660 psi based on 60% of the 1100 psi burst test of specimen SPV2-10 (reference 1). The specimen was pressurized to 350 psi with helium, at

which time the leakage was so high as to prevent reaching the desired 660 psi. A high pressure air supply was then used in an attempt to burst the specimen and gain mechanical properties data; maximum pressure obtained was 580 psi at which time the specimen leaked excessively. No permeability data was generated. Mechanical properties for this specimen information is reported upon in Section 2.2. Upon disassembly of the test set-up, no liner damage was discernible. It may be possible to repair the specimen at probable leak locations and re-run the test.

A successful test was accomplished with a Kevlar specimen (SPV1-5) using helium gas. The vessel was pressurized to 660 psi (60% of ultimate) and held for 30 minutes during which time the permeability data was recorded. Then the specimen was cycled from 100 to 660 psi an additional 14 times. The loading was then increased to 65% of ultimate and the specimen failed at the peak of the fourth such cycle. The permeability data is being reduced; mechanical properties data is reported upon in Section 2.3.

A test with a nickel specimen (SPV3-4) using helium gas was unsuccessful. The vessel leaked excessively at approximately 450 psi and prevented further pressurization. Recorded data for this test was unfortunately lost in the photo lab developing process.

Subsequent recording will be made with an instantaneous read-out and final "photo fix" at a later date in order to preserve the much sought-after data.

Improvements have been made to the vacuum chamber in order to increase its effectiveness; a new burst diaphragm system has been designed and fabricated in order to decrease the possible leakage through the previous necessarily thin diaphragm; better electrical connections have been installed.

For November -
All ambient temperature permeability and cyclic tests will be completed.

1.3.2 Permeability at -320°F and -423°F

Design and fabrication of the mobile cryogenic pump cart has been completed. All of the electrical installation has been completed.

A 15 mil nickel specimen has been fabricated for use as the "battleship" liner. The structural shell remains the same as before. This specimen will be used for the initial burst with liquid hydrogen.

For November -
Most of the test specimens will have been fabricated and tested for the liquid hydrogen work.

Some of the liquid nitrogen specimens will be fabricated. No liquid nitrogen testing is contemplated.

2. Resin / Fiber Glass Composite Investigation

2.1 Uniaxial Cyclic Tests at Cryogenic Temperatures

All work in this area has been completed and reported upon in Reference 1.

2.2 Mechanical Properties

2.2.1 Ambient Temperature - Biaxially Stressed

Stress-strain data is shown in Figures 1 and 2 for the Tedlar specimen (SPV1-5). The properties obtained coincide closely with those of the initial burst specimen (Reference 1). Subsequent cycles are shown in Figures 3 through 6; it can be seen that the curves are quite consistent. Figures 7 and 8 are the data for the burst cycle; there was a permanent set of approximately .0057 in/in. Moduli for the initial and burst cycle are equal.

Stress-strain data for the Mylar specimen (SPV2-1') is shown in Figures 9 through 12. Cycle No. 1 was denoted as the initial test pressurization to 100 psi.

An effort will be made to measure more accurately the strain in the longitudinal glass. At present, the gage length has been taken as the total length of the specimen. Clips will be bonded to the specimen near the test

section. Measurements will be made with that gage length and correlated with the data measured on an over-all length basis.

For November -
All ambient temperature testing will be completed.

Most of the liquid hydrogen specimens will have been fabricated and tested.

Some of the liquid nitrogen specimens will be fabricated. No testing is contemplated.

2.3 Coefficient of Thermal Contraction

All work in this area has been completed and reported upon in Reference 1.

3. 10 Inch Diameter by 24 Inch Long Pressure Vessel Design and Fabrication

Nothing new to report. Work in this area has been curtailed due to the slippage in biaxial testing.

For November -
Analysis and design review will be completed. Preliminary design will be submitted for approval. Tooling and manufacturing planning tasks will be started.

PHASE II

At this point of the project, work in this phase is that reported under Section 3, Phase I.

PHASE III

At this point of the project, work in this phase is that reported under pertinent testing and instrumentation discussions in Section 1.3.2, Phase I.

PHASE IV

At this point of the project, work in this phase is that reported under pertinent testing and instrumentation discussions in Section 1.3.2, Phase I.

QUALITY ASSURANCE

Material review is being coordinated between materials Research and Inspection Receiving for the unacceptable materials.

More stringent requirements have been placed upon the supplier of the electrodeposited metallic liners. This was due to the low elongation data obtained for the metallics. Flat specimens have been made at the time of liner deposition, in the same bath, and these materials have been and will be tested before acceptance of the part.

Further quality control effort will be accomplished and reported upon pending release of technical information.

Quality control data is being compiled for the work to date and upon the completion of all work in each task area or major portion therof, the data will be reported.

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Approved By: C M McClelland (asst)

for H. F. Dixon, Chief
Structures Branch
Advanced Space Technology

REFERENCES

1. Toth, Jr., J. M. Quarterly Progress Report Number One - Investigation of Structural Properties of Fiber Glass Filament-Wound Pressure Vessels at Cryogenic Temperatures.

2. Douglas Aircraft Company, Inc., Materials Research and Production Methods Laboratory Report MP 1731. Lap Shear or Various Organic Fibers Using EC-2[illegible] and Harmon [illegible] Adhesives. October 27, 19[illegible]. (Internal Report)

STRESS - STRAIN DIAGRAMS (SPECIMEN 1-5)
AMBIENT TEMPERATURE

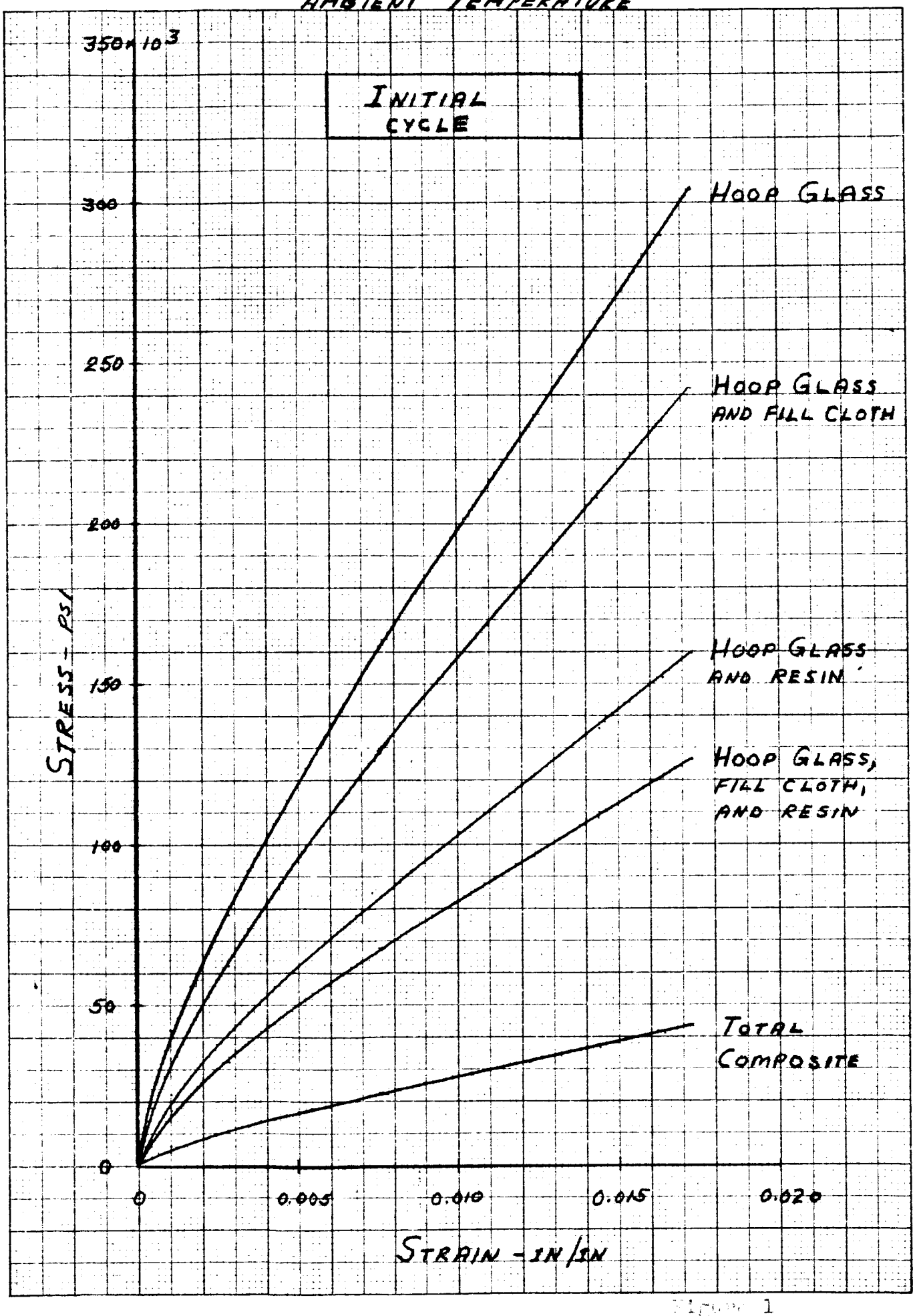
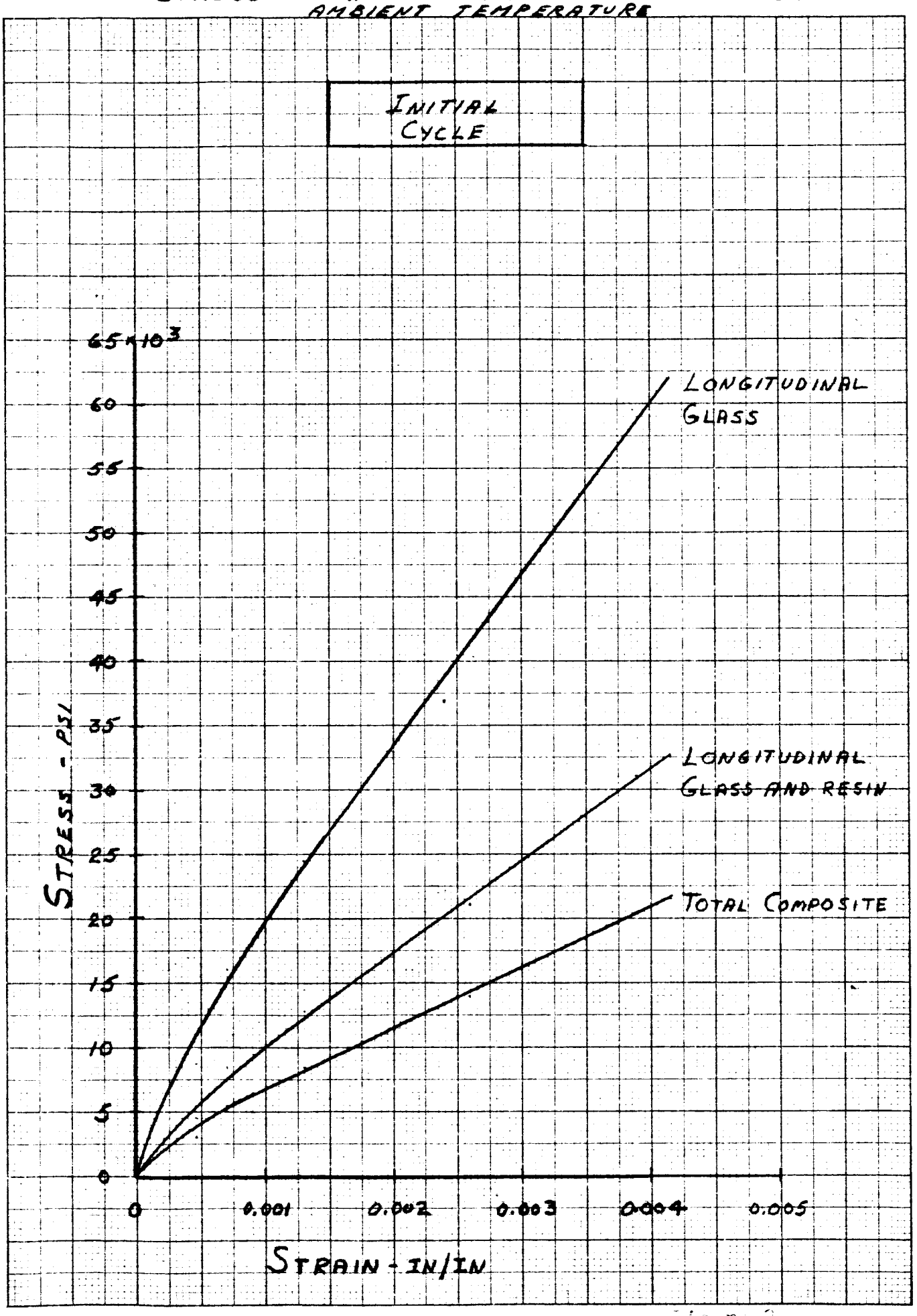


Figure 1

STRESS - STRAIN DIAGRAMS (SPECIMEN 1-5)
AMBIENT TEMPERATURE



STRESS- STRAIN DIAGRAMS (SPECIMEN 2-5)

AMBIENT TEMPERATURE

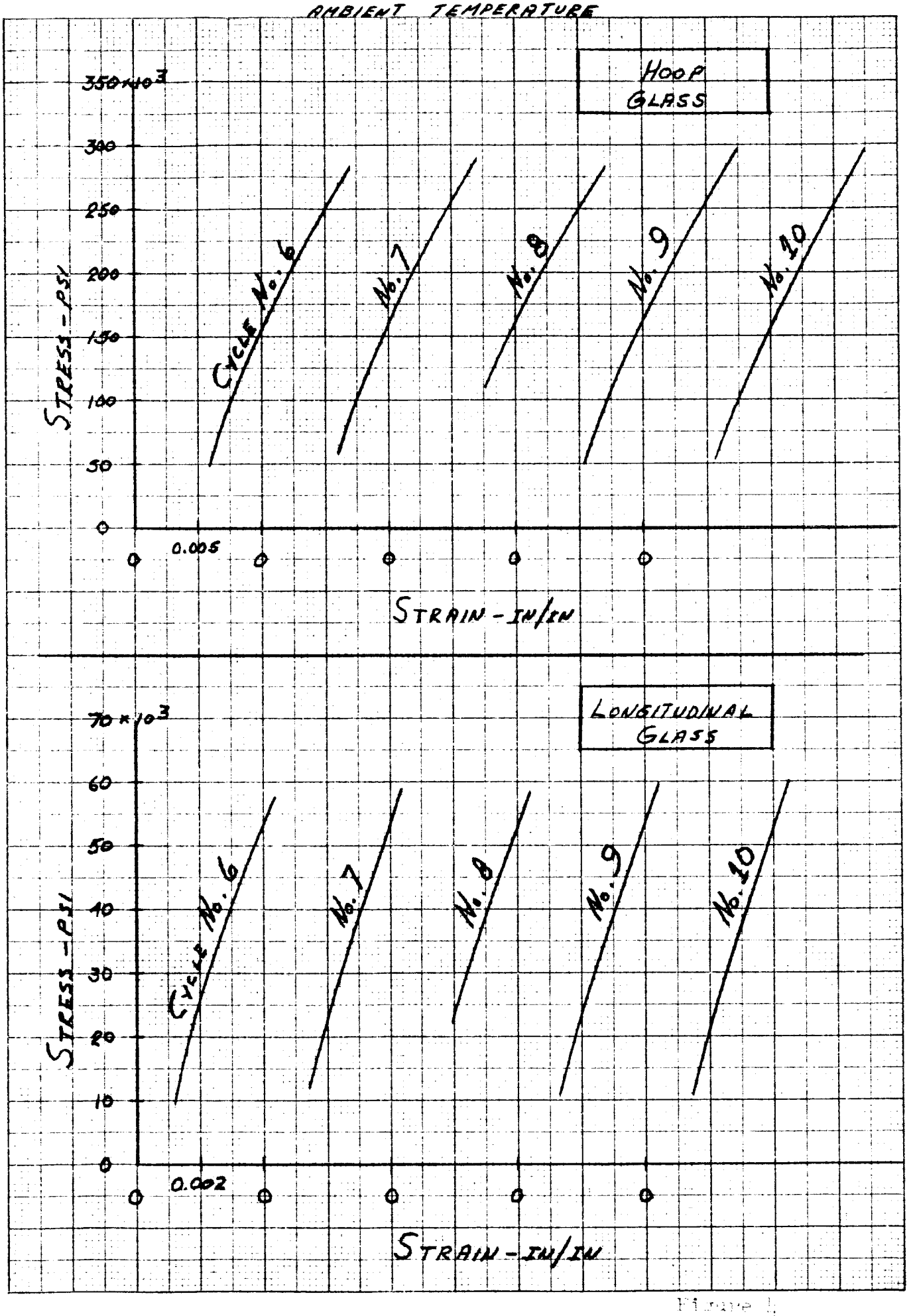
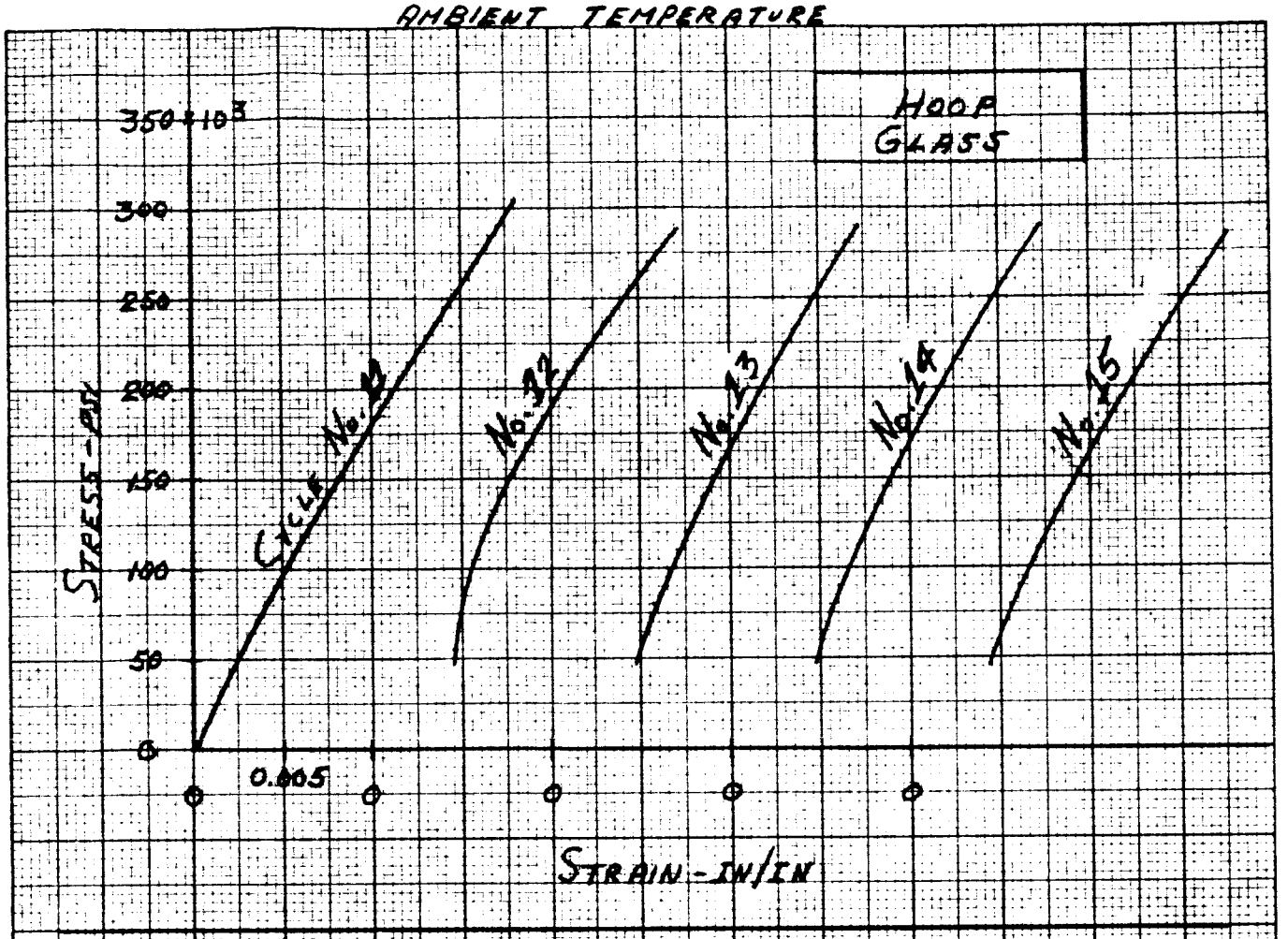
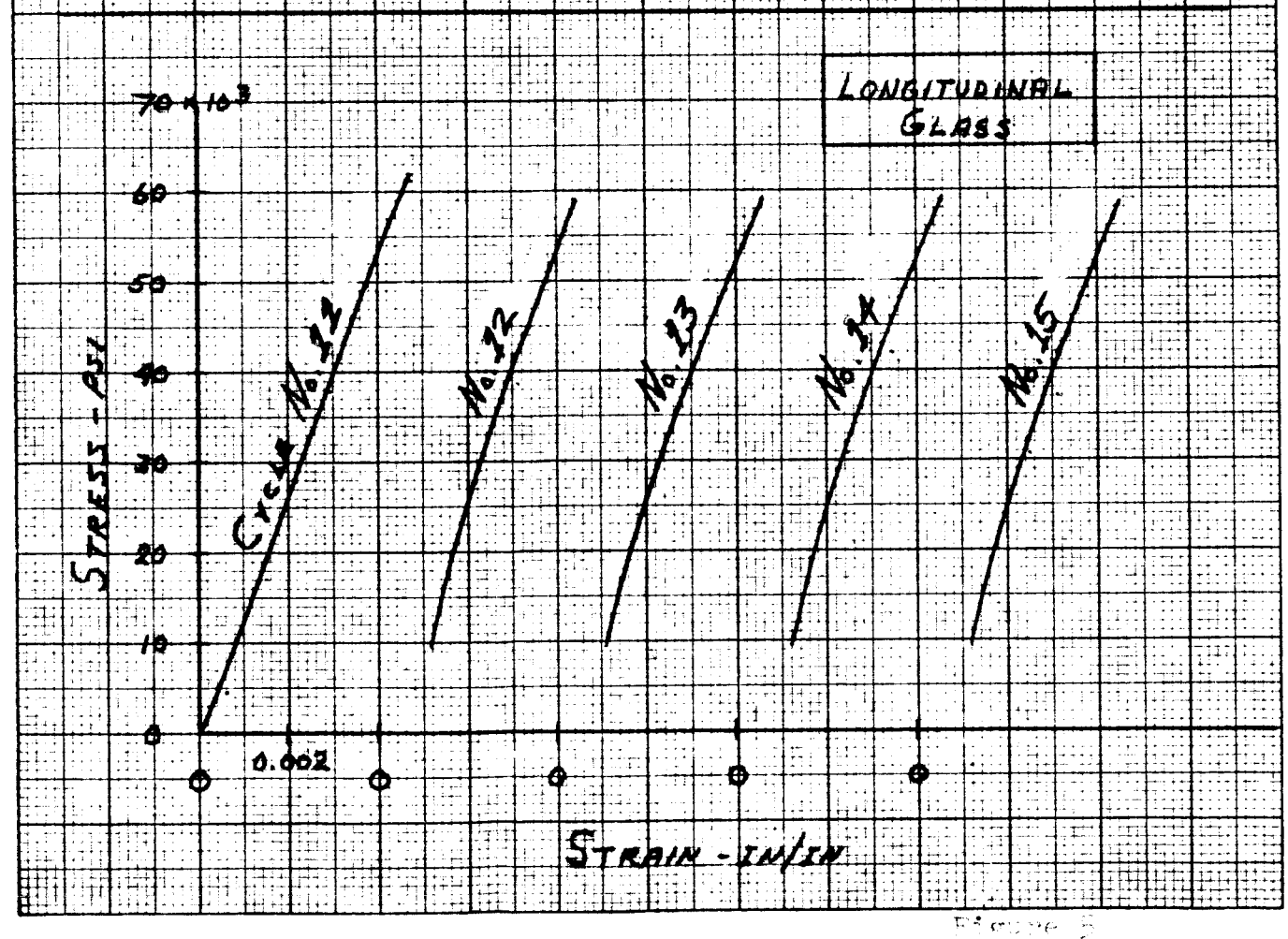


Figure 4

STRESS - STRAIN DIAGRAMS (SPECIMEN 1-5)

AMBIENT TEMPERATURE





10 X 10 TO THE 1/2 INCH 359T-11
KEUFFEL & ESSER CO.
ALBANY, N.Y.

STRESS - STRAIN DIAGRAMS (SPECIMEN 1-5)
AMBIENT TEMPERATURE

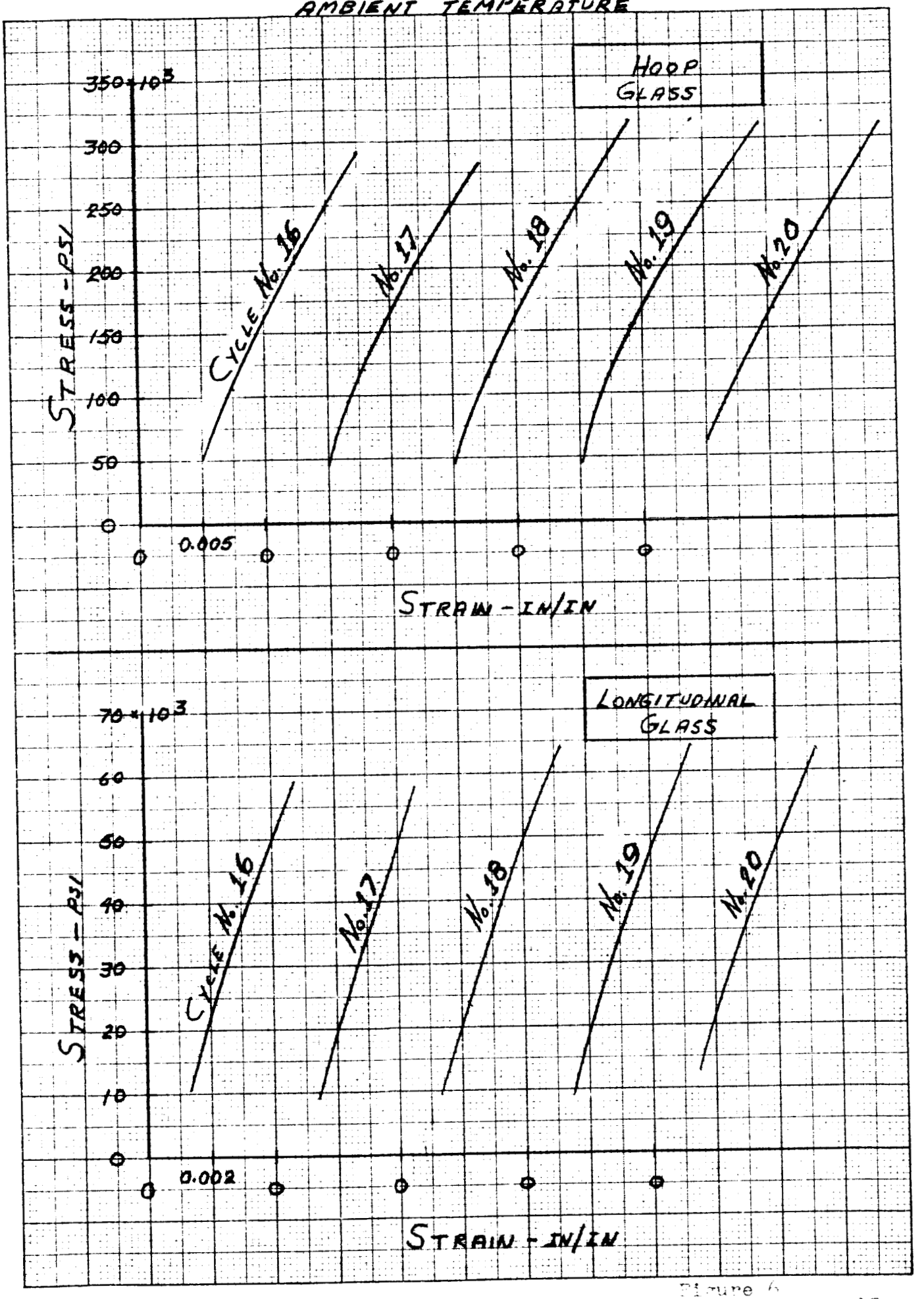


Figure 6

STRESS - STRAIN DIAGRAMS (SPECIMEN 1-5)

AMBIENT TEMPERATURE

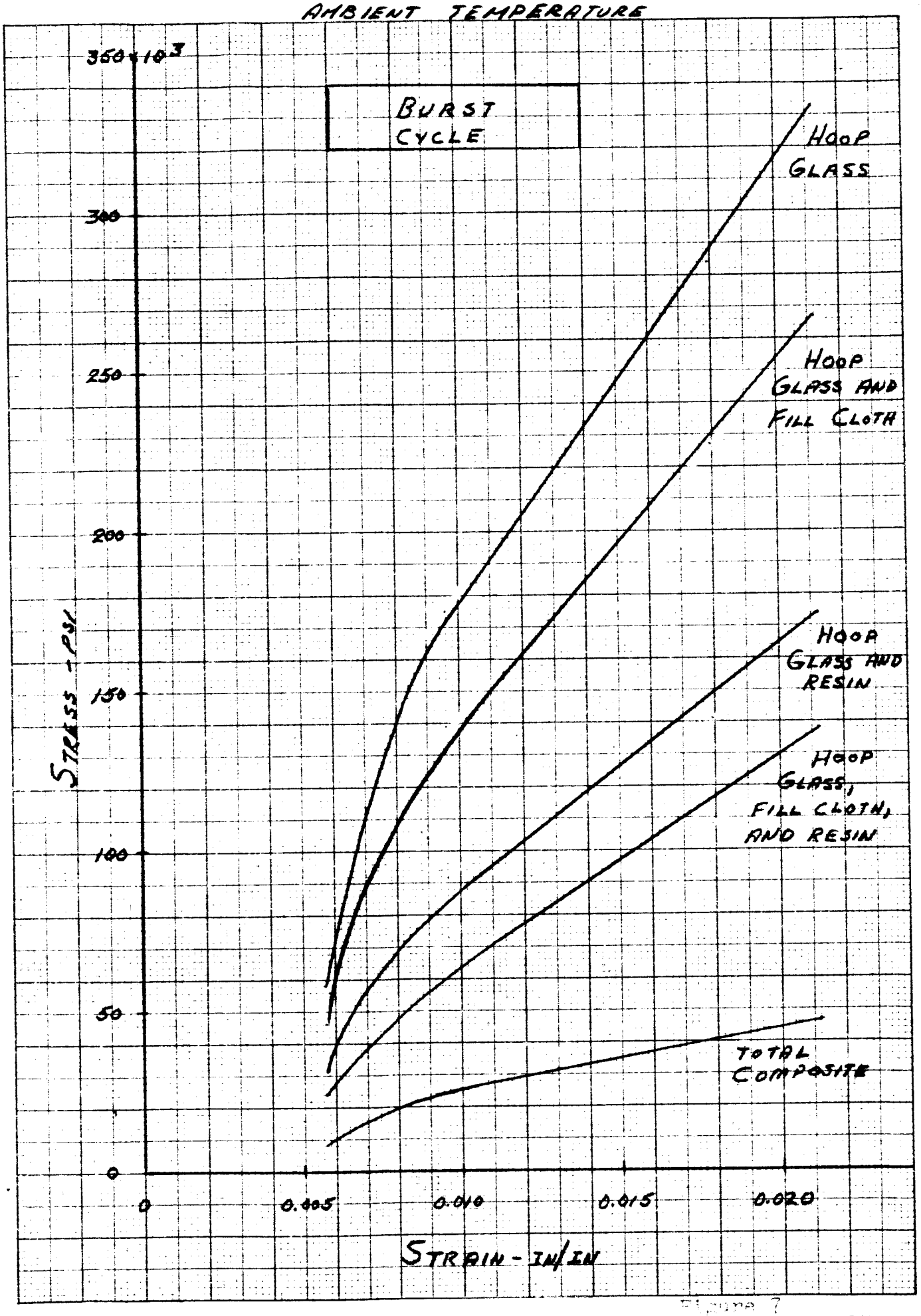


Figure 7

STRESS-STRAIN DIAGRAMS (SPECIMEN 1-5)

AMBIENT TEMPERATURE

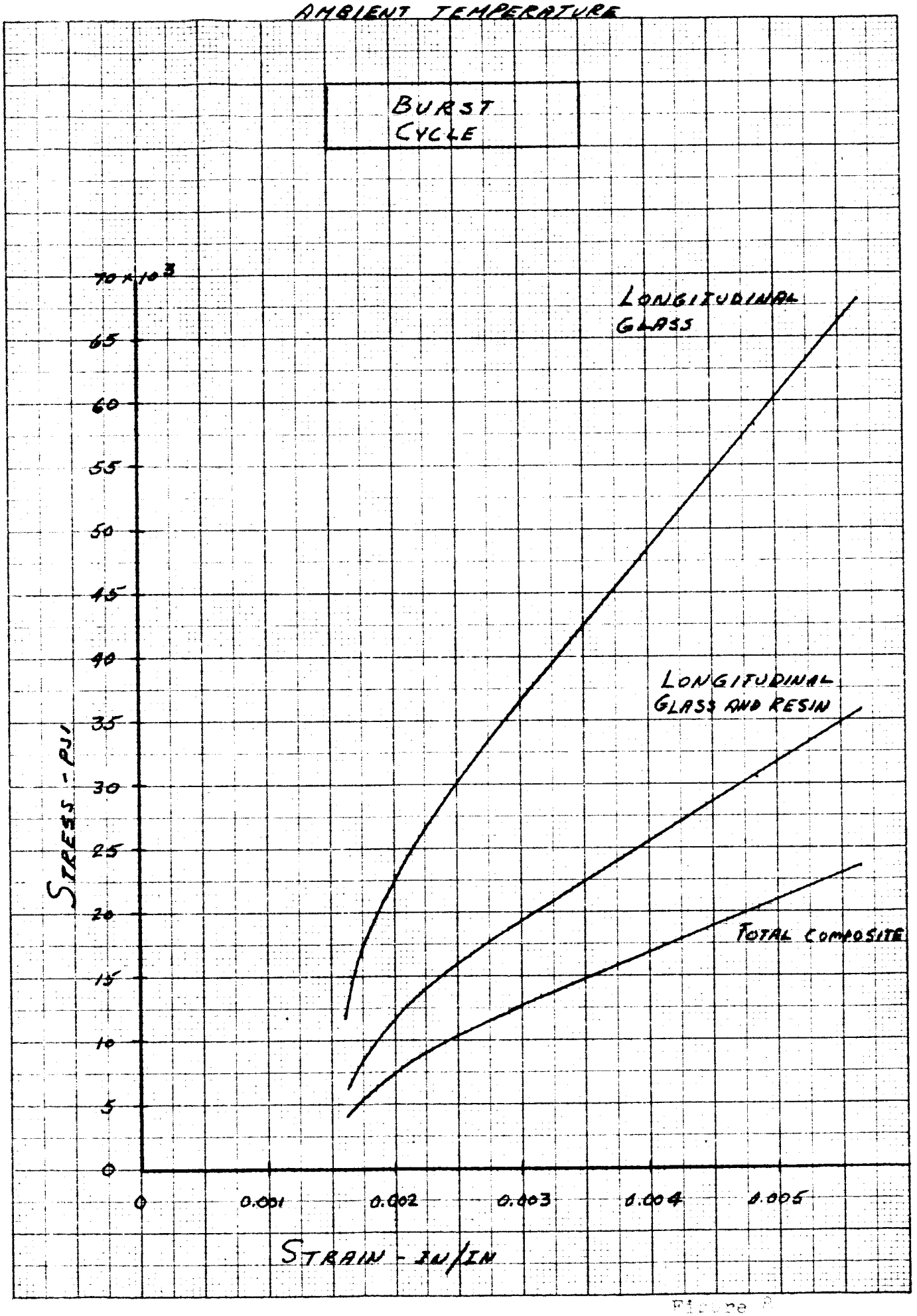


Figure 8

STRESS - STRAIN DIAGRAMS (SPECIMEN SPV 2-1')
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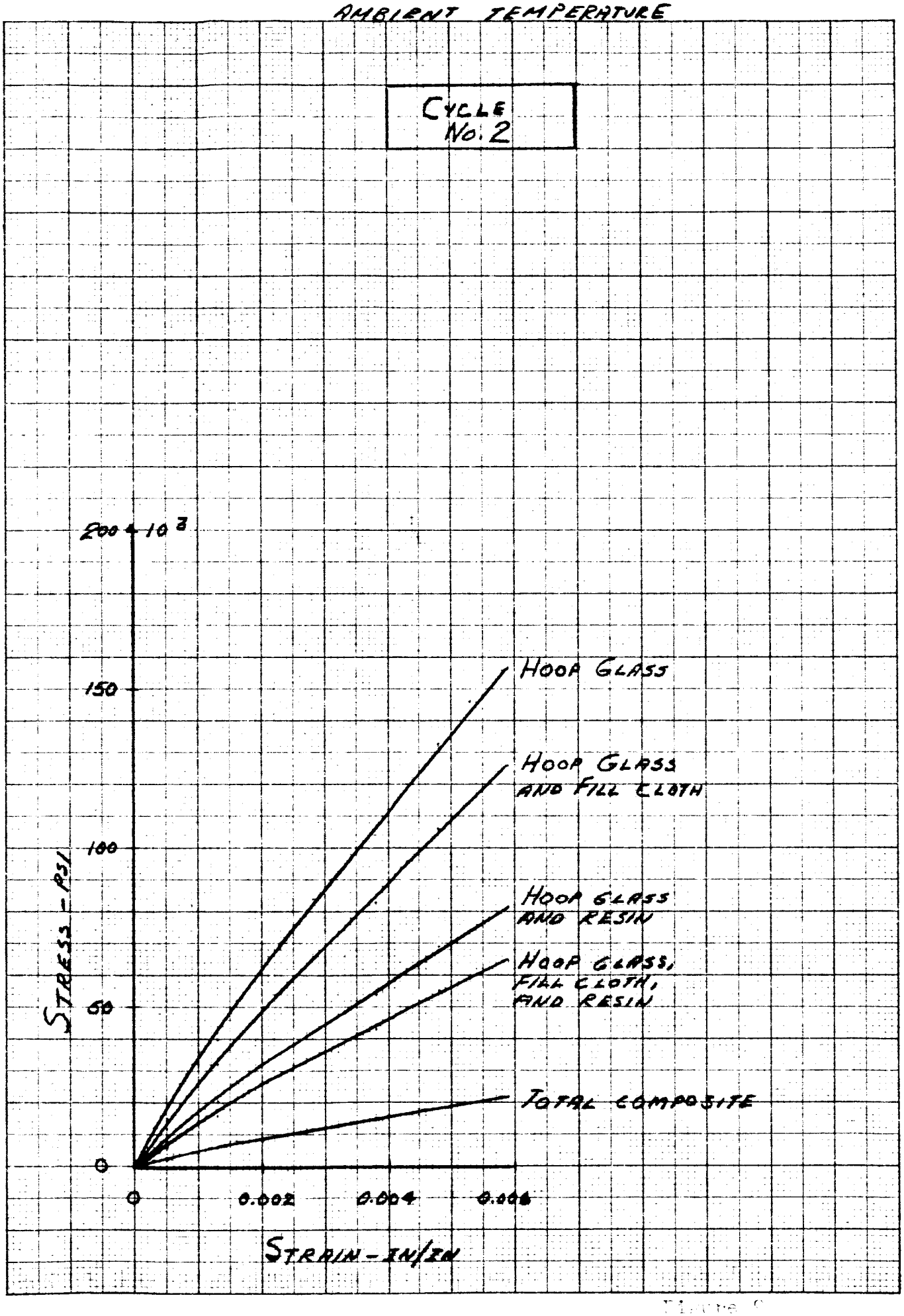


STRESS - STRAIN DIAGRAMS (SPECIMEN SPV 2-1)

AMBIENT TEMPERATURE

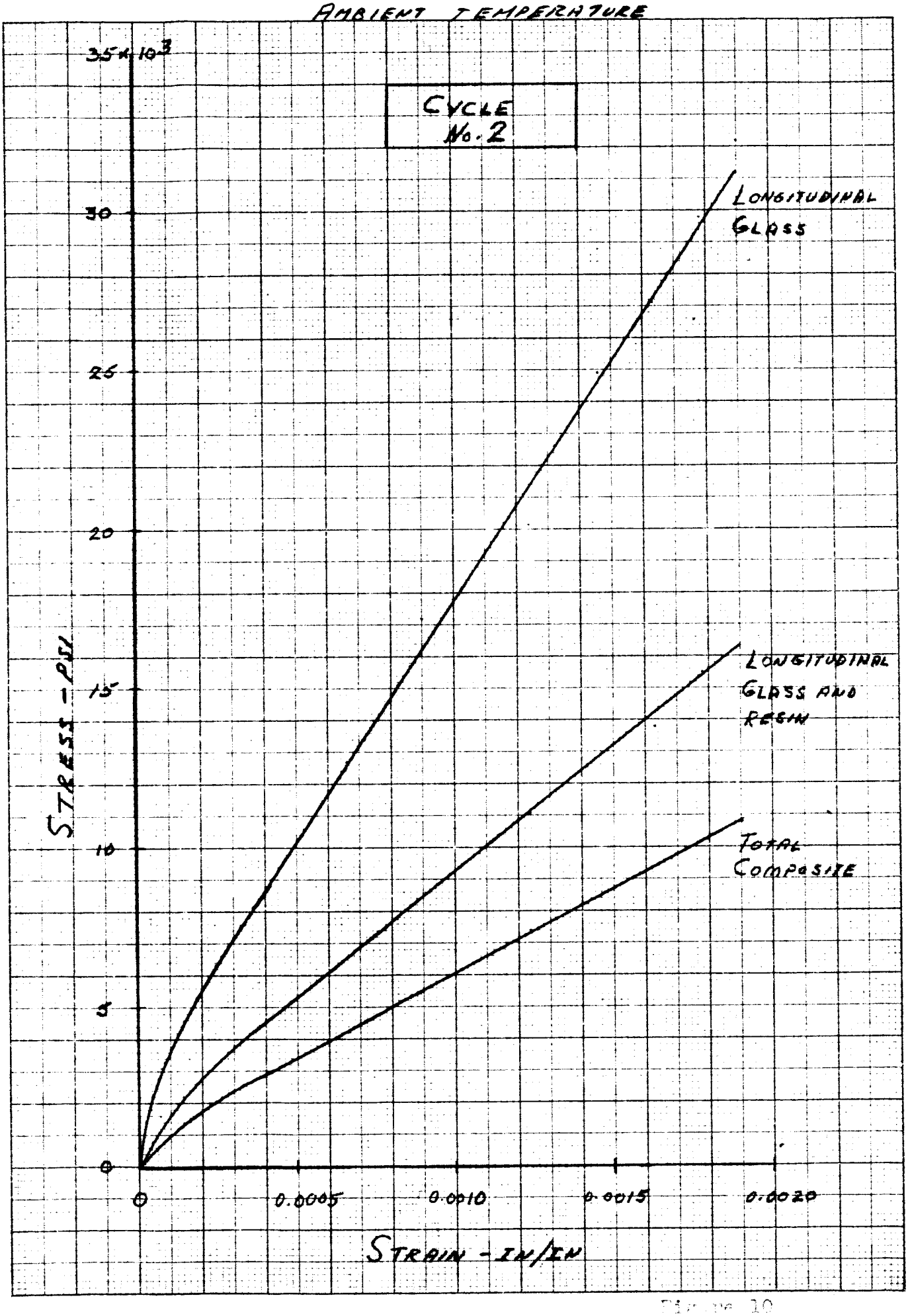
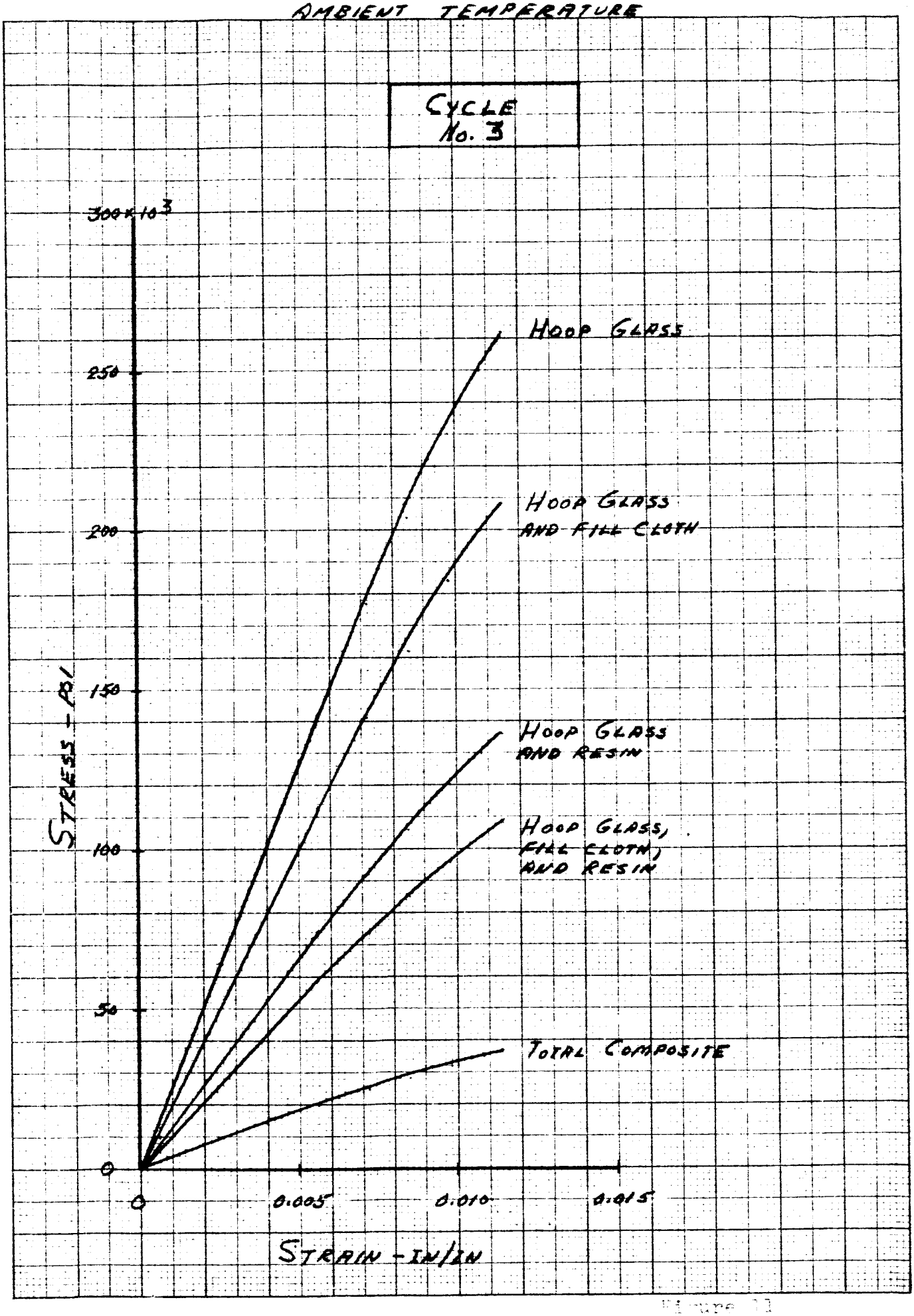


Figure 10

STRESS - STRAIN DIAGRAMS - (SPECIMEN SPI 2-1')

AMBIENT TEMPERATURE



STRESS - STRAIN DIAGRAMS (SPECIMEN SPV 2-1)

AMBIENT TEMPERATURE

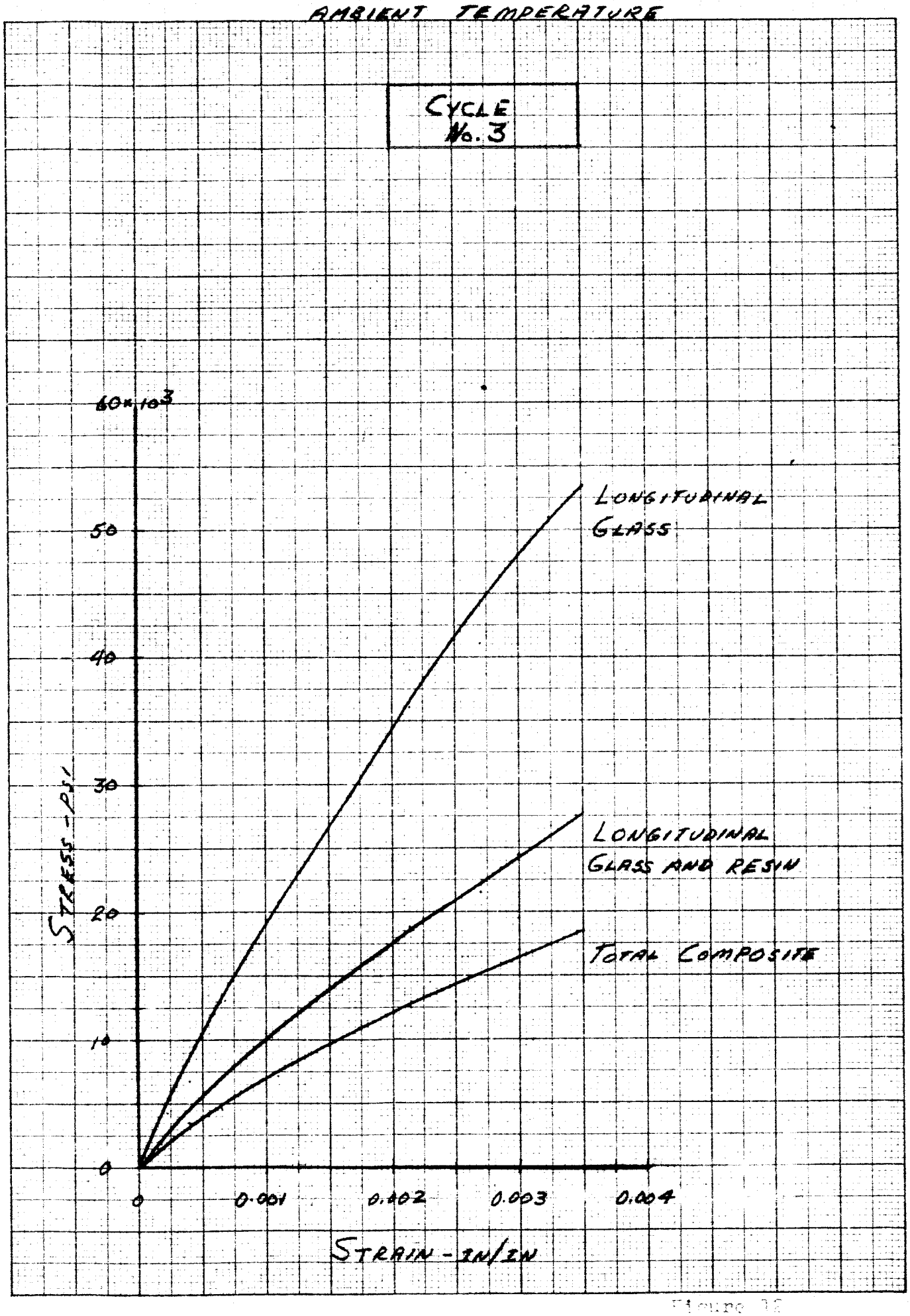
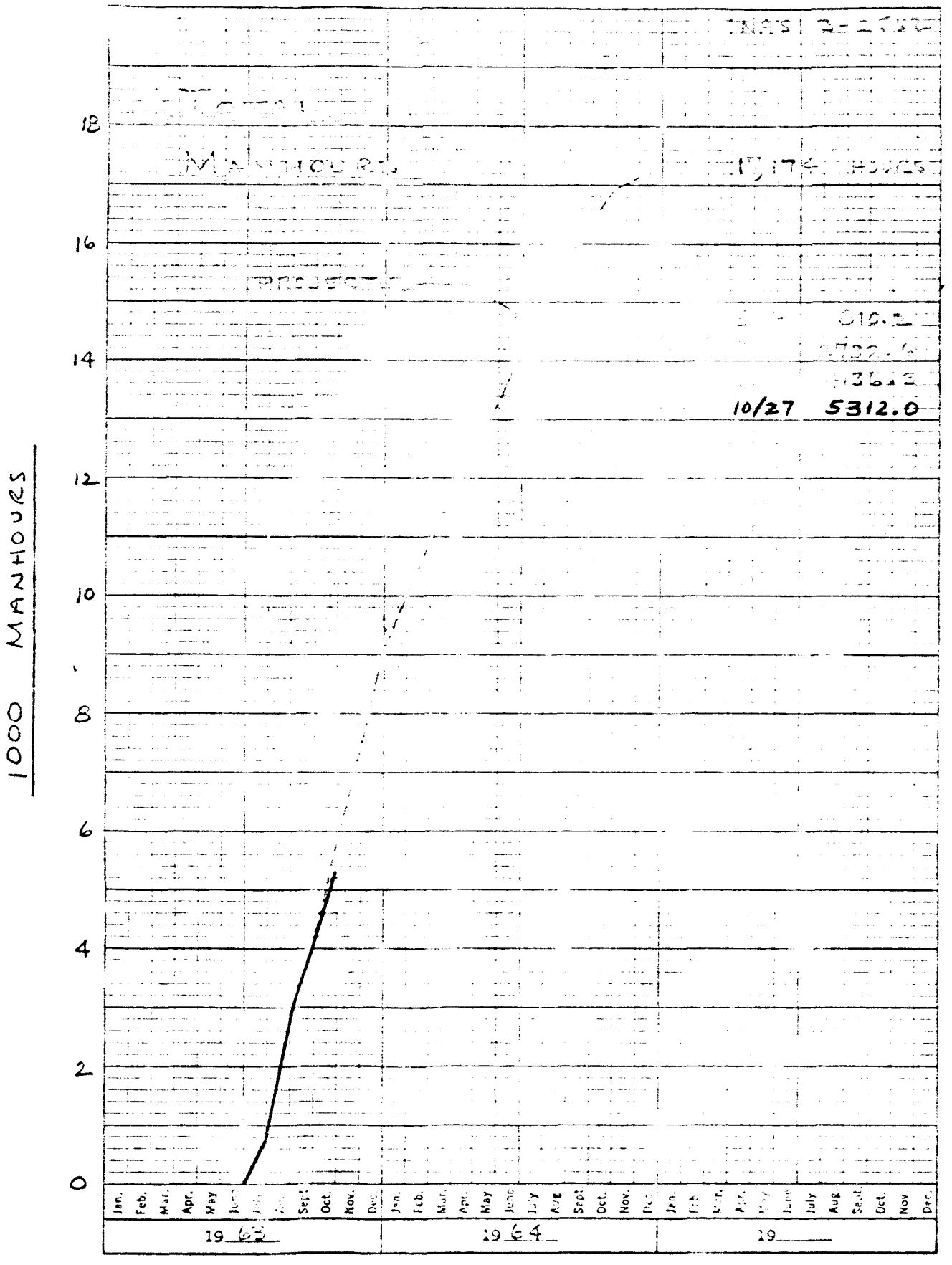


Figure 32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18
16
14
12
10
8
6
4
2
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Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
19 63
19 64
19

Chart 1

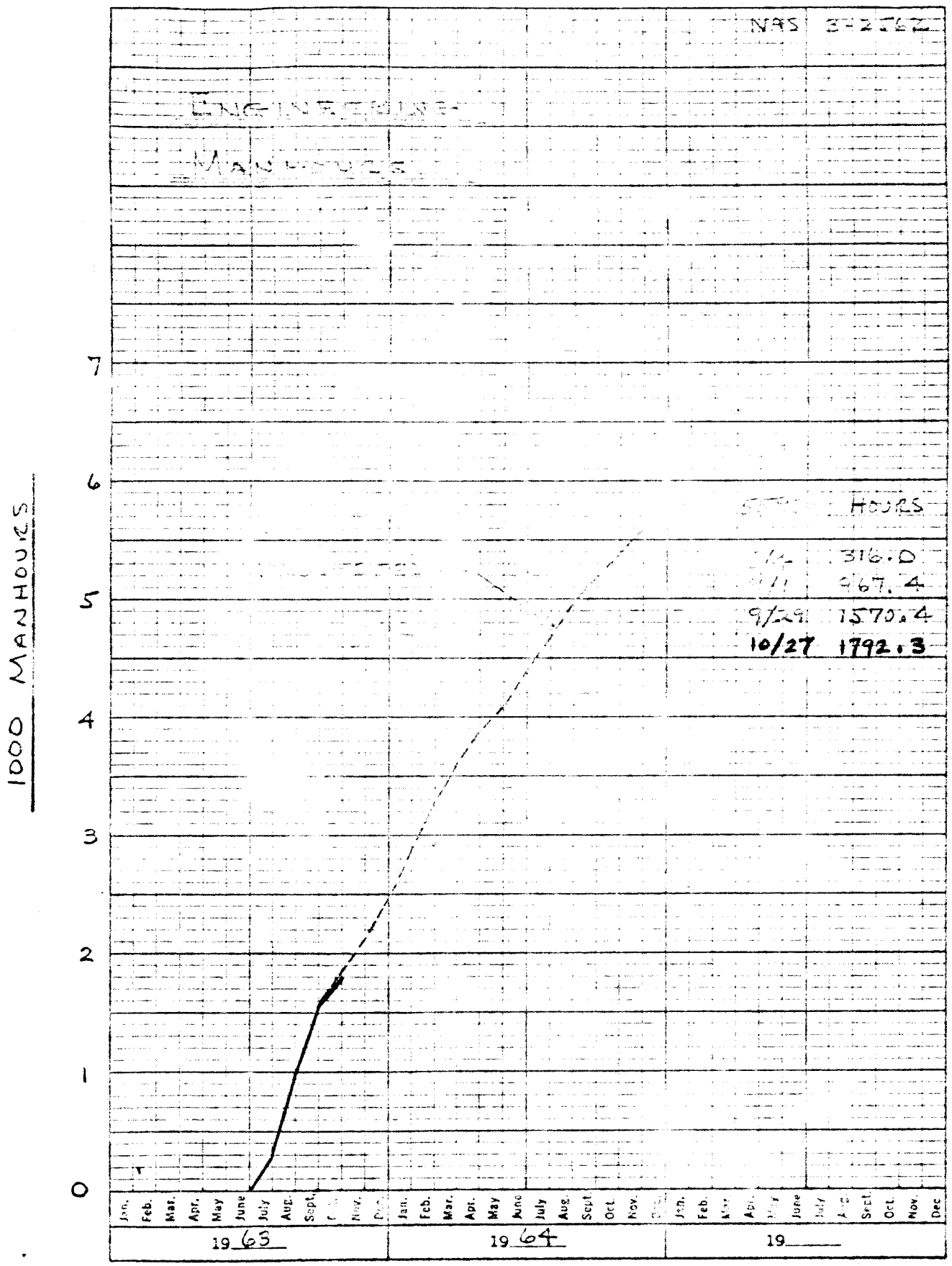
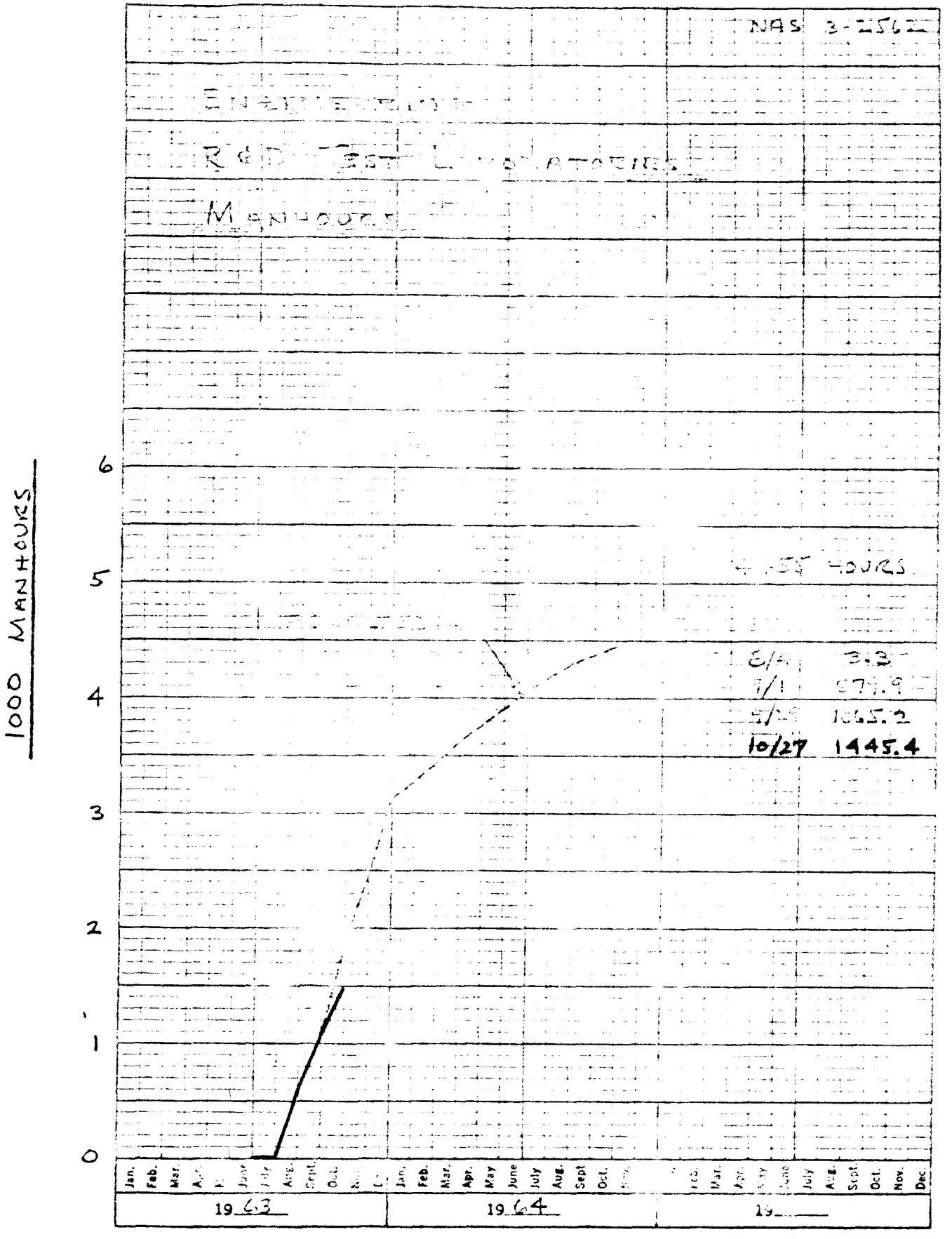

NAS 3-2762
ENGINEERING
MANHOURS
HOURS
316.0
967.4
9/29 1570.4
10/27 1792.3
1000 MANHOURS
0
1
2
3
4
5
6
7
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1963
1964
19

Chart 2


NAS 3-2562
1000 MANHOURS
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5
4
3
2
1
0
10/27 1445.4
Jan.
Feb.
Mar.
Apr.
May
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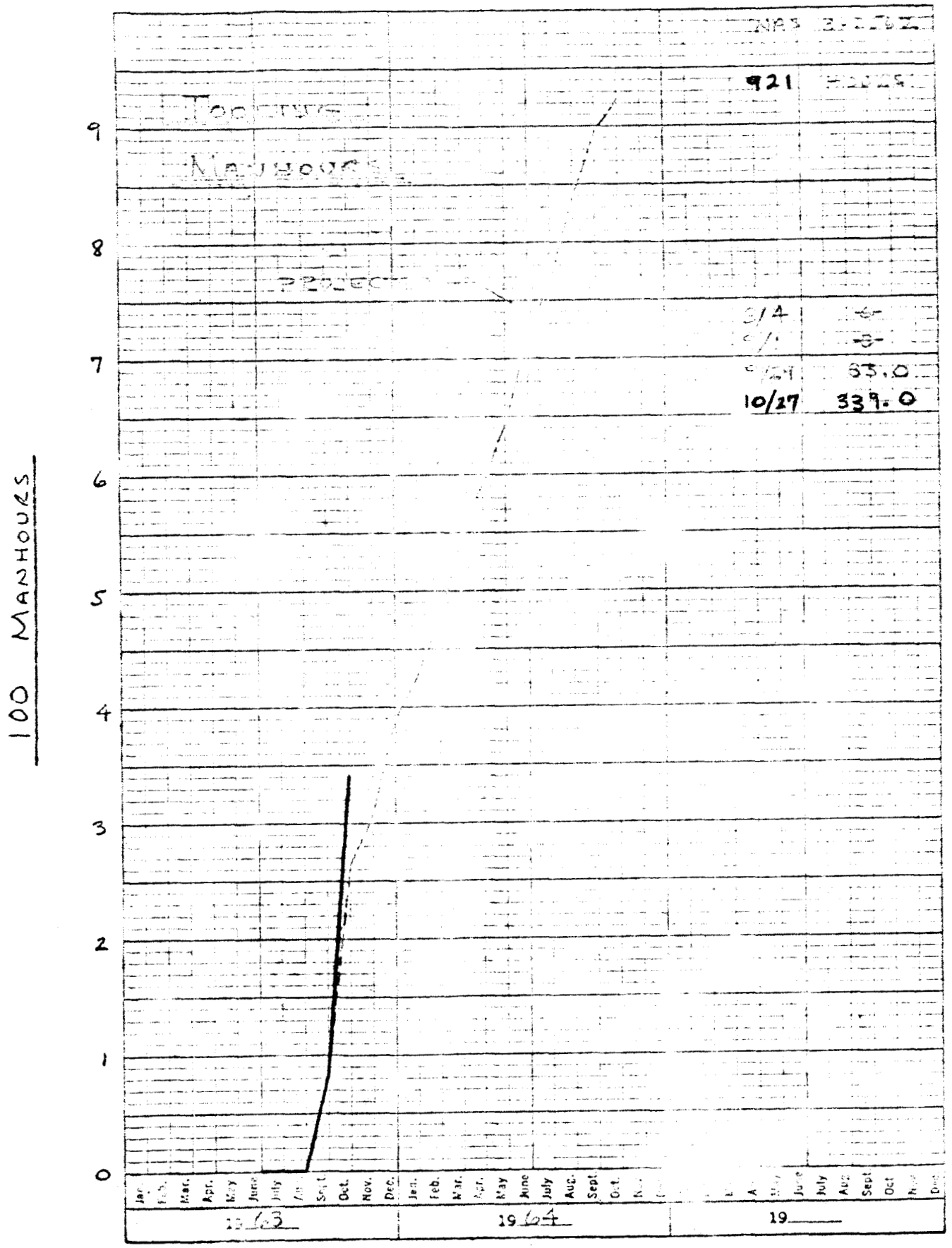
July
Aug.
Sept.
Oct.
Nov.
Dec.
19 63
19 64
19

Chart 3


100 MANHOURS
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3
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5
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7
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9
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May
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July
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Sept.
Oct.
Nov.
Dec.
1963
1964
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921
10/27
339.0

Chart 4

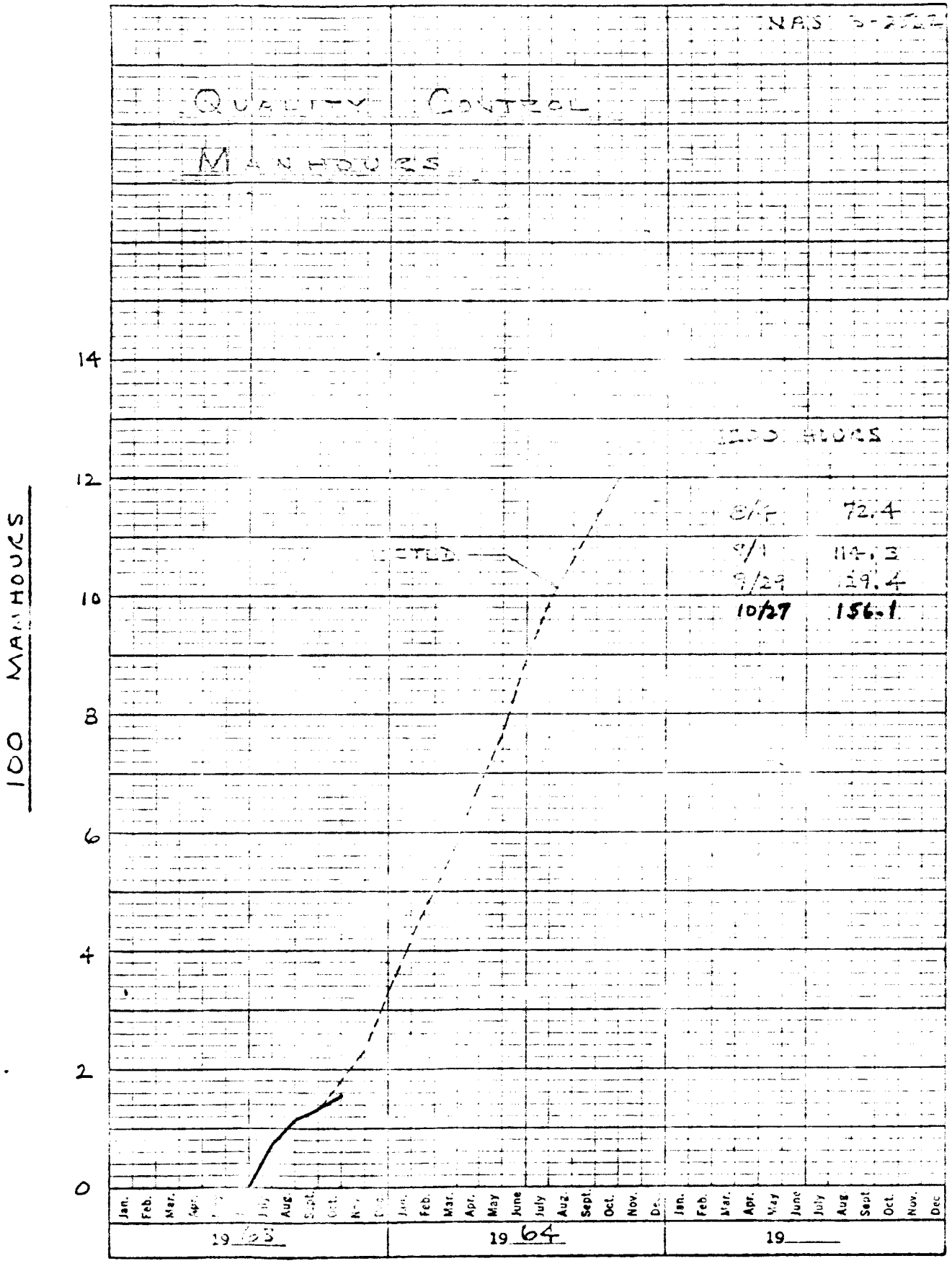
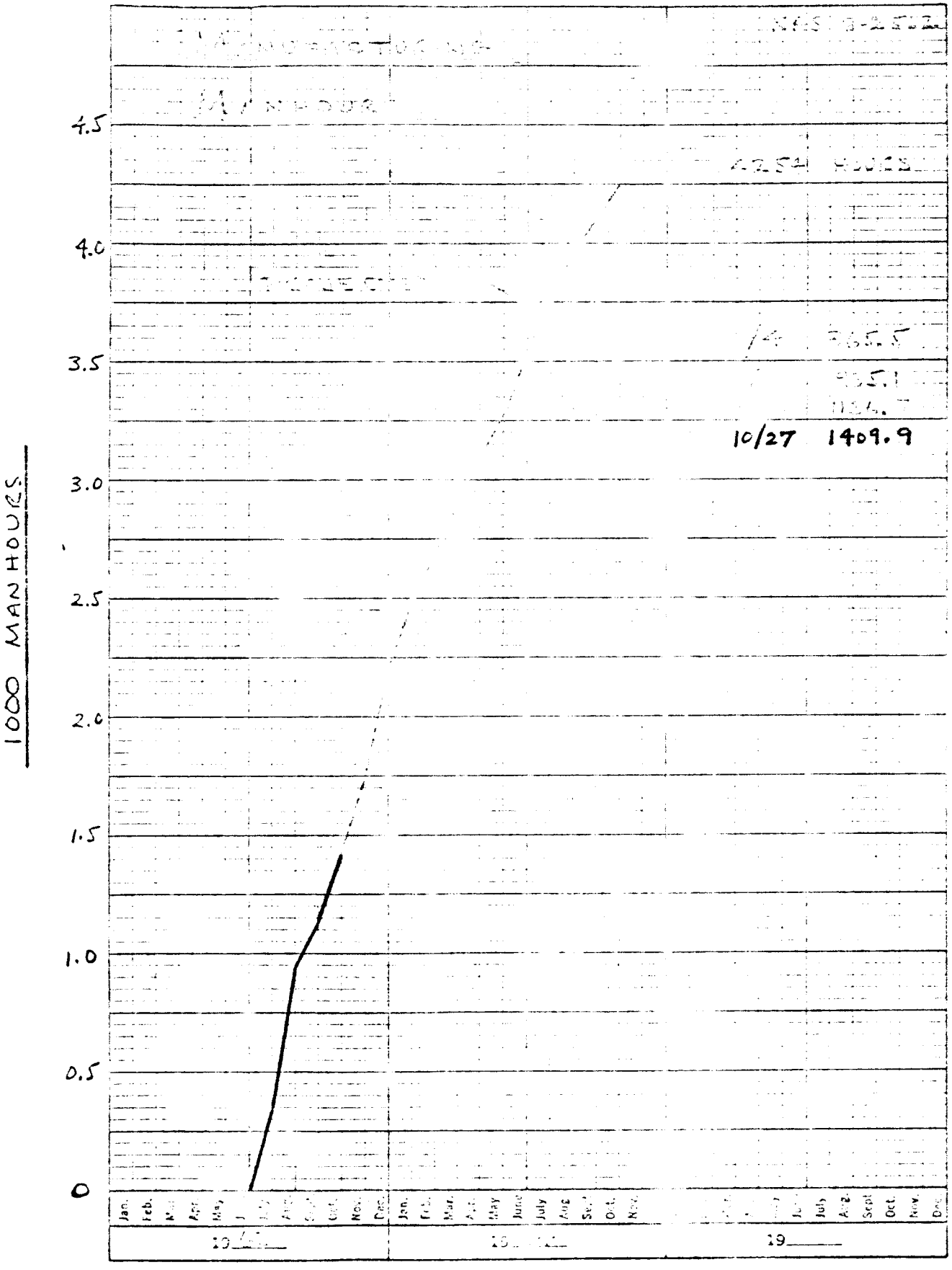

QUALITY CONTROL
MANHOURS
100 MANHOURS
14
12
10
8
6
4
2
0
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
19 63
19 64
19
9/1 114.3
9/29 129.4
10/27 156.1
72.4

Chart 5


1000 MANHOURS
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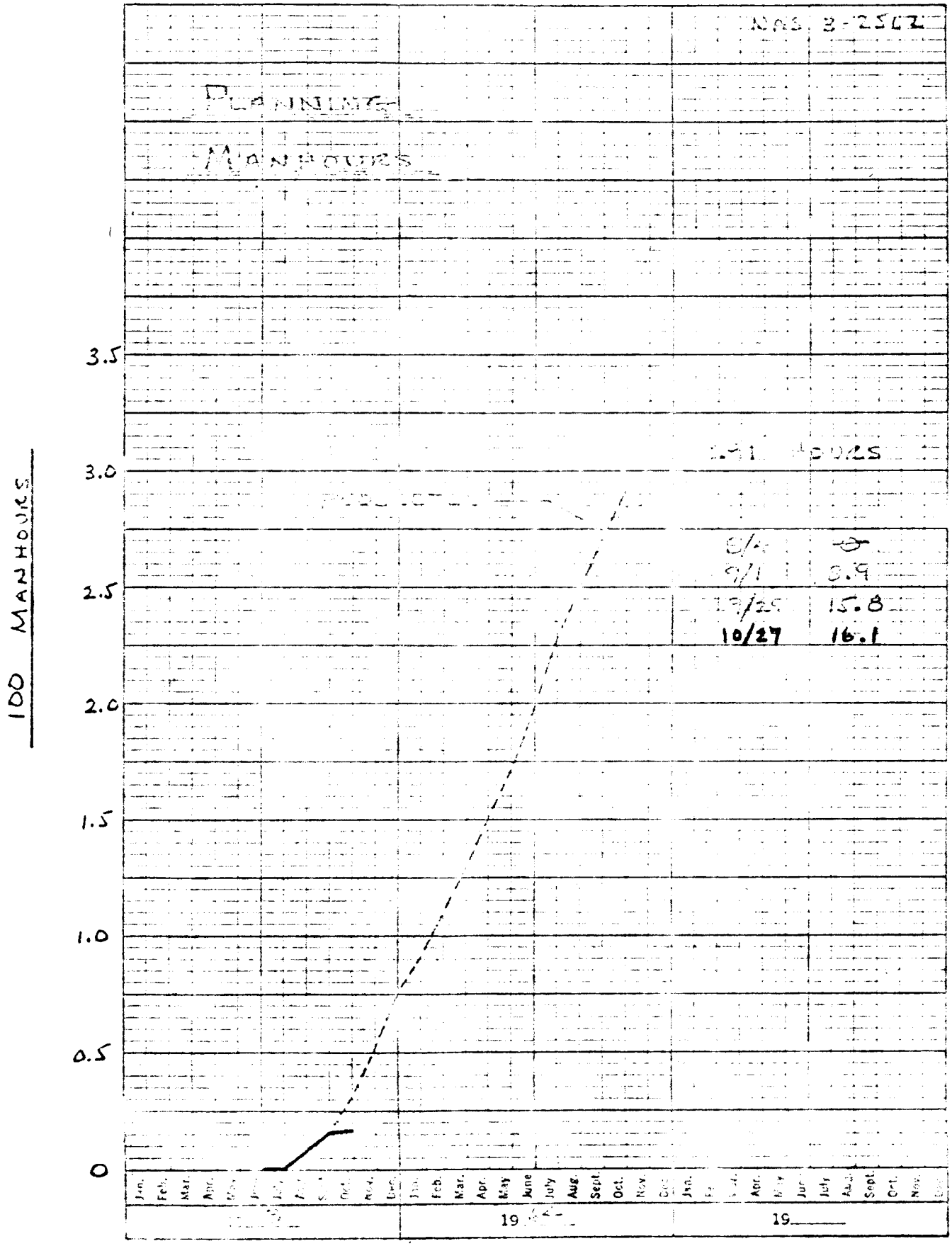
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
10/27 1409.9
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug
Sept
Oct.
Nov.
Dec.
19

Chart 6


NAS 3-2562
PLANNING
MANHOURS
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
100 MANHOURS
9/1
3.9
12/29
15.8
10/27
16.1
Jan.
Feb.
Mar.
Apr.
May
June
July
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Sept.
Oct.
19
19

Chart 7

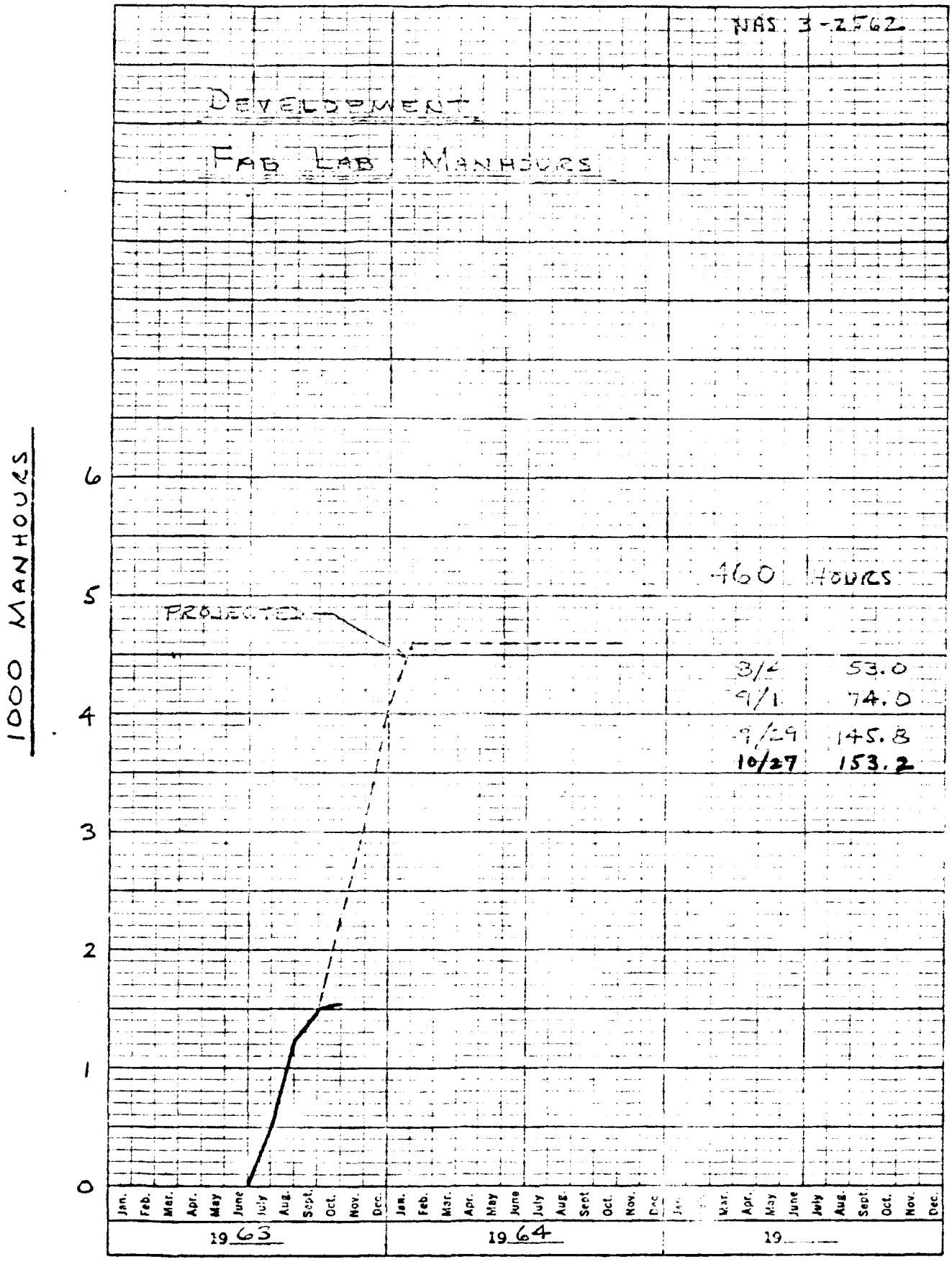
NAS 3-2562
DEVELOPMENT
FAB LAB MANHOURS
1000 MANHOURS
6
5
4
3
2
1
0
PROJECTED
460 HOURS
3/4 53.0
9/1 74.0
9/29 145.8
10/27 153.2
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1963
1964
19

Chart 8

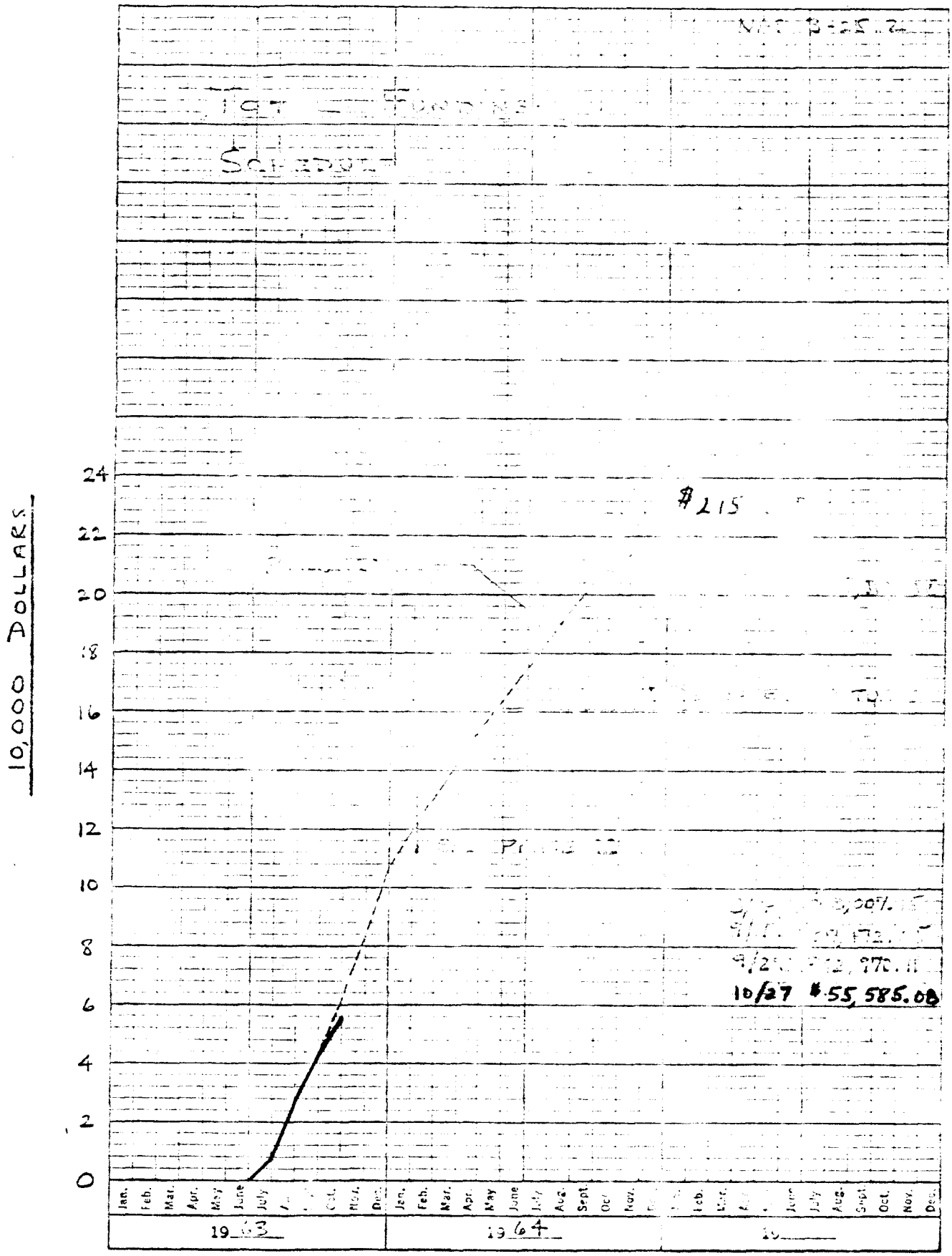
10,000 DOLLARS
24
22
20
18
16
14
12
10
8
6
4
2
0
$215
10/27 $55,585.00
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1963
1964

Chart 9