

Spring 5-28-1957

The Rating of a Power Type Transistor

Richard Lee Mann

Follow this and additional works at: https://digitalrepository.unm.edu/ece_etds

 Part of the [Electrical and Computer Engineering Commons](#)

Recommended Citation

Mann, Richard Lee. "The Rating of a Power Type Transistor." (1957). https://digitalrepository.unm.edu/ece_etds/339

This Thesis is brought to you for free and open access by the Engineering ETDs at UNM Digital Repository. It has been accepted for inclusion in Electrical and Computer Engineering ETDs by an authorized administrator of UNM Digital Repository. For more information, please contact disc@unm.edu.

378.789
Un3Oma
1957
cop. 2

DOWN THE FRONT OF THE MAIN

THE LIBRARY
UNIVERSITY OF NEW MEXICO




Call No.
378.789
Un30ma
1957
cop.2

Accession
Number
225594

A14407 597221

DATE DUE

MCT - 788			
SEP 27 1988			

DEMCO 38-297

COLLEGE CONTENT

EXERCISES

MILITARY HISTORY

UNIVERSITY OF NEW MEXICO LIBRARY

MANUSCRIPT THESES

Unpublished theses submitted for the Master's and Doctor's degrees and deposited in the University of New Mexico Library are open for inspection, but are to be used only with due regard to the rights of the authors. Bibliographical references may be noted, but passages may be copied only with the permission of the authors, and proper credit must be given in subsequent written or published work. Extensive copying or publication of the thesis in whole or in part requires also the consent of the Dean of the Graduate School of the University of New Mexico.

This thesis by Richard Lee Mann
has been used by the following persons, whose signatures attest their acceptance of the above restrictions.

A Library which borrows this thesis for use by its patrons is expected to secure the signature of each user.

NAME AND ADDRESS

DATE

MANUSCRIPT THESIS

Unpublished theses submitted for the degree of Master of Arts and Doctor of Philosophy are deposited in the University of New Mexico Library and are open for inspection, but are to be read only and are not to be loaned. The rights of the author, bibliographer, and other persons named in the preface may be copied only with the permission of the author, and proper credit must be given in any work containing the same. Extensive copying or reproduction of the thesis in whole or in part requires also the consent of the Dean of the Graduate School of the University of New Mexico.

This thesis by _____
has been read by the following persons whose signatures are attached in acceptance of the above statement:

A library which borrows this thesis for use in its service is expected to secure the signature of each user.

DATE

NAME AND ADDRESS

THE RATINGS OF A POWER TYPE TRANSISTOR

A Thesis

Presented to

the Faculty of the Department of Electrical Engineering
University of New Mexico

In Partial Fulfillment

of the Requirements for the Degree
Master of Science in Electrical Engineering

by

Richard Lee Mann

June 1957



THE UNITED STATES OF AMERICA

1957

Report No.

of the Department of Commerce

Department of the Interior

In Special Publication

of the Department of the Interior

Report of the Director of the Geological Survey

1957

1957

This thesis, directed and approved by the candidate's committee, has been accepted by the Graduate Committee of the University of New Mexico in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

E. Castetter
DEAN

DATE May 28, 1957

Thesis committee

Bob M. Jannin
CHAIRMAN

Charles S. Williams Jr.

R. Moore

This document is a copy of the original document and has been prepared for the use of the Commission of the European Communities. It is not to be used for any other purpose.

[Faint handwritten signature]

[Faint handwritten text]

[Faint handwritten text]

[Faint handwritten text]

[Faint handwritten text]

Transcription

[Faint handwritten signature]

[Faint handwritten signature]

[Faint handwritten signature]

378.789
Ucn30m2
1957
Cop. 2

THE RATINGS OF A POWER TYPE TRANSISTOR

by
Richard Lee Mann
Junior Engineer

Electrical Engineering Department
University of New Mexico
Engineering Experiment Station

TECHNICAL REPORT EE-2

Report No. 1 on Project 56-2EE

September, 1956

The work described in this report was performed under Sandia Corporation Purchase Order No. 53-4020.

*This paper is also being used as a thesis in partial fulfillment of the requirements for the Degree of Master of Science in Electrical Engineering at the University of New Mexico.

225594

27781
1957
10/2

THE RATING OF A POWER TYPE TRANSISTOR

by
Richard Lee Mann
Junior Engineer

Electrical Engineering Department
University of New Mexico
Engineering Experiment Station

TECHNICAL REPORT EE-1

Report No. 1 on Project EE-100

September, 1956

The work described in this report was performed under Sandoz Corporation Purchase Order No. 55-4030.

*This paper is also being used as a thesis in partial fulfillment of the requirements for the Degree of Master of Science in Electrical Engineering at the University of New Mexico.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION	1
II. THE METHOD OF TEST	4
Preparation for testing	4
Testing procedure	4
III. THE DESCRIPTION OF THE TEST EQUIPMENT	12
Temperature chamber	12
Equipment for obtaining transistor characteristics. .	14
Pulse Testing Equipment	20
IV. THE RESULTS	24
Pulse testing	24
Direct current testing	25
Heat sink characteristics	32
V. DISCUSSION OF RESULTS AND CONCLUSIONS	37
BIBLIOGRAPHY	40
APPENDIX A	43
APPENDIX B	47
APPENDIX C	50
APPENDIX D	58

TABLE OF CONTENTS

	CHAPTER
1	I. INTRODUCTION
4	II. THE METHOD OF TEST
10	Preparation of Test
15	Testing Procedure
18	III. THE RESULTS OF THE TEST
20	Temperature Changes
25	Requirements for the Test
30	Pulse Length and Rate
35	IV. THE RESULTS
40	Pulse Position
45	Direct Current Voltage
50	Heat and Characteristics
55	V. DISCUSSION OF RESULTS AND CONCLUSIONS
60	BIBLIOGRAPHY
65	APPENDIX A
70	APPENDIX B
75	APPENDIX C
80	APPENDIX D

LIST OF TABLES

TABLE

PAGE

I. Pulse Widths and Repetition Rates 5

215

THE STATE

1880

1880

1. Prince William and Fairfax Counties

LIST OF FIGURES

FIGURE	PAGE
1. Pulse Test Circuit	6
2. Amplifier & Back Bias Stage	7
3. Sixty Percent Duty Factor Circuit	9
4. Direct Current Test -- $I_b = 0$	10
5. Direct Current Test -- $I_b = 200$ ma	10
6. 165° F. Temperature Chamber (Interior)	13
7. 165° F. Temperature Chamber	15
8. Temperature Chamber and Curve Tracer Equipment	16
9. Circuit Description of the Transistor Characteristic Equipment	17
10. Transistor Characteristics	18
11. Curve Tracer Circuit	19
12. Waveform-Time Relationship	21
13. Pulse Test Set Up	22
14. Pulse Test Circuit (General)	23
15. Pulse Power Ratings -- 60 CPS	26
16. Pulse Power Ratings -- 200 CPS	27
17. Pulse Power Ratings -- 600 CPS	28
18. Pulse Power Ratings -- 2000 CPS	29
19. Effects of Duty Factor	30
20. Average Power - Temperature Relationship	31
21. Direct Current Ratings -- $I_b = 0$	33
22. Direct Current Ratings -- $I_b = 200$ ma	34

- 1. Pulse Test Results
- 2. Amplifier & Back Stop Test
- 3. Sixty Percent Duty Factor Results
- 4. Direct Current Test - 100%
- 5. Direct Current Test - 100%
- 6. 150° F. Temperature Test - 100%
- 7. 150° F. Temperature Test - 100%
- 8. Temperature Change - 100%
- 9. Circuit Description of the Inverter
- 10. Transformer Connections
- 11. Core Type Transformer
- 12. Waveform - 100%
- 13. Pulse Test Set Up
- 14. Pulse Test Circuit (General)
- 15. Pulse Power Rating - 100%
- 16. Pulse Power Rating - 100%
- 17. Pulse Power Rating - 100%
- 18. Pulse Power Rating - 100%
- 19. Effects of Duty Factor
- 20. Average Power - Temperature Relationship
- 21. Direct Current Test - 100%
- 22. Direct Current Test - 100%

FIGURE	PAGE
23. Heat Sink Characteristics - 165° F. Ambient	35
24. Heat Sink Characteristics - 85 and 165° F. Ambient . . .	36

5

- 23. Heat Sink Temperature - 200°C
- 24. Heat Sink Temperature - 250°C

CHAPTER I

INTRODUCTION

The transistor, first publicly announced in June 1948, is an offshoot of the germanium crystal rectifier which played an important role in World War II in radar receivers. The germanium crystal rectifier had high-inverse-voltage characteristics which were lacking in preceding type rectifiers, thus making it the center of attraction of electronic interest. By adding an electrode to the crystal rectifier in order to control the surface charges, a new semi-conducting device, the "transistor" (TRANSfer resISTOR) came into existence.

Transistors are replacing electronic vacuum tubes in many applications since they are much smaller in size and weight and the power requirements are much less. They are capable of being used in circuits to provide amplification, oscillation, pulse generation, gating, and many other functions. The miniaturization of electronic equipment has even furthered the importance of the transistor. Great efforts are being made to extend the useage of transistors by increasing their current carrying capacity and useful frequency range.

The large transistors, which are very small compared with an equivalent tube, are referred to as power type transistors. While all transistors, in a general sense, are power transistors, they have been referred to as being capable of carrying 0.5 amperes or greater¹.

¹LeRoy A. Griffith, Germanium Power Transistors (Minneapolis-Honeywell Regulator Company, Minneapolis 8, Minnesota, Transistor Division, paper dated February 9, 1955, TR73pl.)

The transmitter circuit is a simple LC circuit consisting of a coil and a capacitor. The coil is wound on a ferrite core and is connected to the antenna. The capacitor is a variable capacitor which is used to tune the circuit to the desired frequency. The transmitter is powered by a battery and a vibrator unit which provides the necessary high voltage for the vacuum tube. The transmitter is capable of transmitting signals over a distance of several miles.

The receiver circuit is also a simple LC circuit consisting of a coil and a capacitor. The coil is wound on a ferrite core and is connected to the antenna. The capacitor is a variable capacitor which is used to tune the circuit to the desired frequency. The receiver is powered by a battery and a vibrator unit which provides the necessary high voltage for the vacuum tube. The receiver is capable of receiving signals over a distance of several miles.

The transmitter and receiver are connected to the antenna by means of a matching network. This network consists of a series of inductors and capacitors which are used to match the impedance of the transmitter and receiver to the impedance of the antenna. This ensures that the maximum power is transferred to the antenna.

The transmitter and receiver are housed in a metal enclosure which is shielded against external electromagnetic interference. The enclosure is also equipped with a cooling fan to prevent the vacuum tube from overheating. The transmitter and receiver are operated by means of a control panel which is located on the front of the enclosure. The control panel includes a power switch, a tuning knob, and a volume knob.

Robert A. ...
 ...
 ...

Like most new devices, the standardization of terms and ratings is a slow process. Manufacturing skills and methods are continually changing in an attempt to perfect a device which can be mass-produced with reasonably similar characteristics so that they will be interchangeable. The problem of interchangeability of power type transistors has not been solved as yet which makes transistor circuit design more difficult than tube circuit design. As this paper will show, the characteristics of a type transistor may vary widely from one transistor to another.

Ratings for a type of transistor are furnished by the manufacturer. These ratings are direct current ratings only and the characteristic curves furnished are typical characteristics which may be quite useless as far as a specific circuit design is concerned.

Sandia Corporation personnel have witnessed failures of transistors in their circuitry design due to what was thought of as being large amplitude current pulses of short time duration. In an effort to establish definitely the causes of these failures and the permissible limits of these pulses, a contract was negotiated with the University of New Mexico to do the research described in this paper.

The purpose of this paper, then, is to describe the tests performed and present the results obtained in an attempt to establish the maximum permissible direct current and pulse ratings for the type CTP-1003 (Clevite Transistor Products) power transistors under typical operating conditions. The manufacturer's specifications for the type CTP-1003 power transistor are located in Appendix A.

...the first part of the ...
...the second part of the ...
...the third part of the ...
...the fourth part of the ...
...the fifth part of the ...
...the sixth part of the ...
...the seventh part of the ...
...the eighth part of the ...
...the ninth part of the ...
...the tenth part of the ...

...the eleventh part of the ...
...the twelfth part of the ...
...the thirteenth part of the ...
...the fourteenth part of the ...
...the fifteenth part of the ...
...the sixteenth part of the ...
...the seventeenth part of the ...
...the eighteenth part of the ...
...the nineteenth part of the ...
...the twentieth part of the ...

...the twenty-first part of the ...
...the twenty-second part of the ...
...the twenty-third part of the ...
...the twenty-fourth part of the ...
...the twenty-fifth part of the ...
...the twenty-sixth part of the ...
...the twenty-seventh part of the ...
...the twenty-eighth part of the ...
...the twenty-ninth part of the ...
...the thirtieth part of the ...

Tests were performed at 165°F. ambient temperatures to establish the maximum permissible ratings (i.e., current, voltage, and dissipation or combinations of these quantities applied to any terminals of the transistor) over the active operating region of the transistor characteristics. Maximum permissible ratings are defined as those values at which the transistor may operate with good stability, long life and no irreversible changes in characteristics.

The effects of duty cycle, heat sink characteristics, spread of transistor properties, ambient temperature, and transistor connection on the ratings were established for

1. Ambient temperature: +165°F.
2. Duty cycle range: Pulse widths between 10 microseconds and 10 milliseconds; pulse repetition frequencies between 60 CPS and 2000 CPS.

Tests were conducted to determine the maximum
the maximum distance between the
dissipation of energy in the system
terminal of the system, over the whole
the terminal of the system, over the whole
defined as those cases in which the
good stability, especially in the
cases.

The system is designed to be
of transfer function, which is
section on the right side of the

1. Maximum distance between the
 2. Duty cycle of the system
 - and to determine the system
- section on the right side of the

CHAPTER II
THE METHOD OF TEST

I. PREPARATION OF TESTING

Each transistor was numbered with red paint such as, C-1. "C" for Clevite to distinguish from other transistors being tested in the laboratory.

Prior to all testing, the transistor was securely fastened to a 6" x 6" heat sink by 3 - #6 x 3/8" machine screws and placed in the temperature chamber and allowed to reach ambient temperature. A thermocouple (iron-constantan) was placed in a small groove cut in the heat sink just under the base of the transistor to measure the transistor temperature. Care was taken so that no air gap existed between the transistor and the heat sink. A picture was then taken of the transistor characteristics as the thermocouple passed through a temperature, ten degrees above ambient temperature. This is necessary since the curve tracer, operating intermittently at two amperes or better (collector current), causes a heating of the transistor, thus changing the transistor characteristics.

II. TESTING PROCEDURE

Pulse testing at 165° F. This test was designed for the purpose of establishing the maximum permissible pulse ratings and the effects of duty cycle on the power transistor at 165° F. ambient temperature.

Pulse widths and repetition rates shown in Table I were used in establishing the maximum pulse ratings.

Each transmitter was connected to the circuit by means of a switch for choice of either the 100 or 200 cycle current in the laboratory.

Prior to this study, the transmitter was connected to a 60 x 60 watt lamp by means of a switch which allowed the temperature changes and allowed the transmitter to operate at a temperature (intermittent) was found to be a very important factor in the heat sink test under the form of the transmitter in testing the transmitter temperature. Data was taken at 100 and 200 cycles between the transmitter and the lamp and a graph of the results of the transmitter characteristics in the form of the power factor, a temperature, and degree above ambient temperature. This is shown in any since the curve shows the transmitter characteristics in any or better (collector output, constant loading of the transmitter) than changing the transmitter characteristics.

II. TESTING RESULTS

Power testing at 100 c. The test was made for the purpose of establishing the output characteristics of the transmitter and the degree of duty cycle on the power transformer at 100 c. and the results are shown in the table and graphs for the transmitter and receiver characteristics in testing the transmitter in establishing the various other factors.

TABLE I

PULSE WIDTHS AND REPETITION RATES

Repetition Rates, CPS	60	200	600	2000
Pulse Widths	10	10	10	10
in	100	100	100	100
Microseconds	1000	1000	1000	---
	10000	----	----	----

The pulse widths in Table I at a given repetition rate was applied to the base of the transistor connected common emitter. The pulse amplitude was then varied in steps from a minimum value to a value which destroyed the transistor. The size of the pulse steps was decreased as the temperature of the transistor increased. The amplitude of the collector pulse was held constant until a constant transistor temperature was maintained prior to advancing to the next step. Continuous observation of the input and output pulses, transistor and ambient temperatures was made throughout the pulsing test.

Where feasible, at least one transistor was made to fail at each of the above repetition rates and pulse widths by increasing the pulse amplitude. Where time allowed, not less than five transistors were pulsed at each repetition rate and pulse width and they were pulsed where possible beyond the point where failure existed on the preceding transistor. The transistor characteristics were checked against the original characteristics whenever there was any indication of an unusual change in output or sharp temperature change. Figure 1

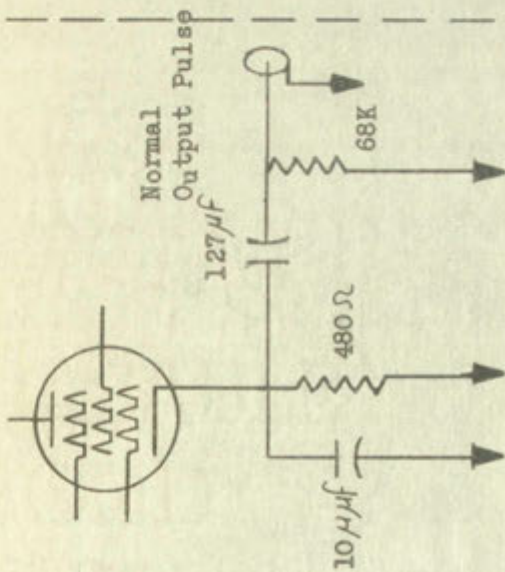
REPORT

[Faded Title]

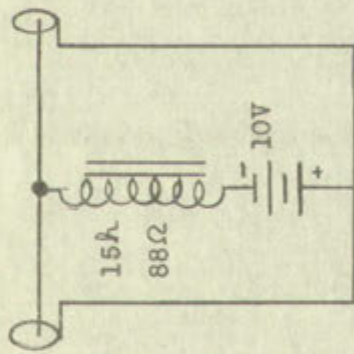
<i>[Faded Column Header 1]</i>	<i>[Faded Column Header 2]</i>	<i>[Faded Column Header 3]</i>	<i>[Faded Column Header 4]</i>	<i>[Faded Column Header 5]</i>
<i>[Faded Data]</i>	<i>[Faded Data]</i>	<i>[Faded Data]</i>	<i>[Faded Data]</i>	<i>[Faded Data]</i>
<i>[Faded Data]</i>	<i>[Faded Data]</i>	<i>[Faded Data]</i>	<i>[Faded Data]</i>	<i>[Faded Data]</i>
<i>[Faded Data]</i>	<i>[Faded Data]</i>	<i>[Faded Data]</i>	<i>[Faded Data]</i>	<i>[Faded Data]</i>
<i>[Faded Data]</i>	<i>[Faded Data]</i>	<i>[Faded Data]</i>	<i>[Faded Data]</i>	<i>[Faded Data]</i>
<i>[Faded Data]</i>	<i>[Faded Data]</i>	<i>[Faded Data]</i>	<i>[Faded Data]</i>	<i>[Faded Data]</i>

The first value in the column is the value of the variable at the start of the first interval. The value of the variable at the end of the interval is the value at the start plus the value of the increment multiplied by the number of intervals. The value of the variable at the end of the second interval is the value at the end of the first interval plus the value of the increment multiplied by the number of intervals. The value of the variable at the end of the third interval is the value at the end of the second interval plus the value of the increment multiplied by the number of intervals. The value of the variable at the end of the fourth interval is the value at the end of the third interval plus the value of the increment multiplied by the number of intervals. The value of the variable at the end of the fifth interval is the value at the end of the fourth interval plus the value of the increment multiplied by the number of intervals. The value of the variable at the end of the sixth interval is the value at the end of the fifth interval plus the value of the increment multiplied by the number of intervals. The value of the variable at the end of the seventh interval is the value at the end of the sixth interval plus the value of the increment multiplied by the number of intervals. The value of the variable at the end of the eighth interval is the value at the end of the seventh interval plus the value of the increment multiplied by the number of intervals. The value of the variable at the end of the ninth interval is the value at the end of the eighth interval plus the value of the increment multiplied by the number of intervals. The value of the variable at the end of the tenth interval is the value at the end of the ninth interval plus the value of the increment multiplied by the number of intervals.

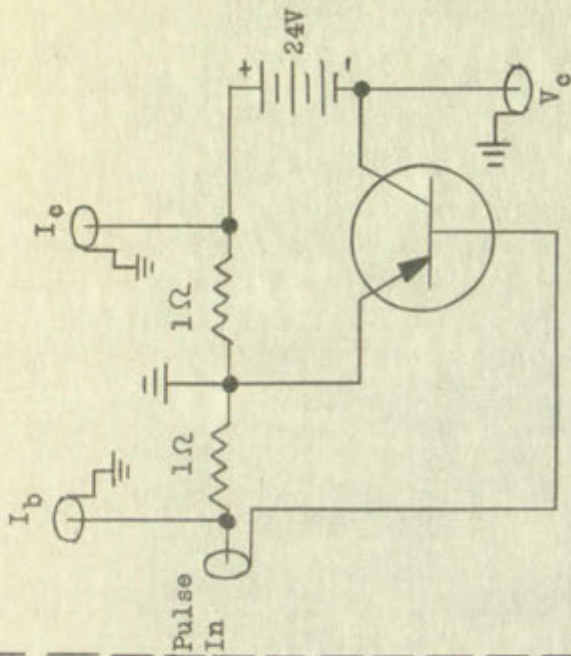
3E 29 TUBE



PULSE GENERATOR



BACK BIAS



TEST TRANSISTOR

PULSE TEST CIRCUIT

Figure 1

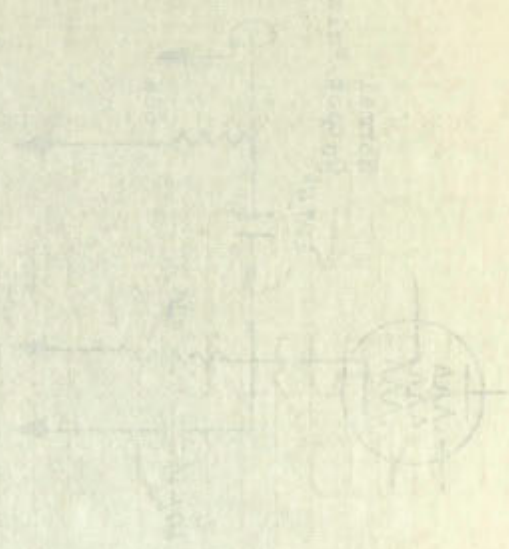
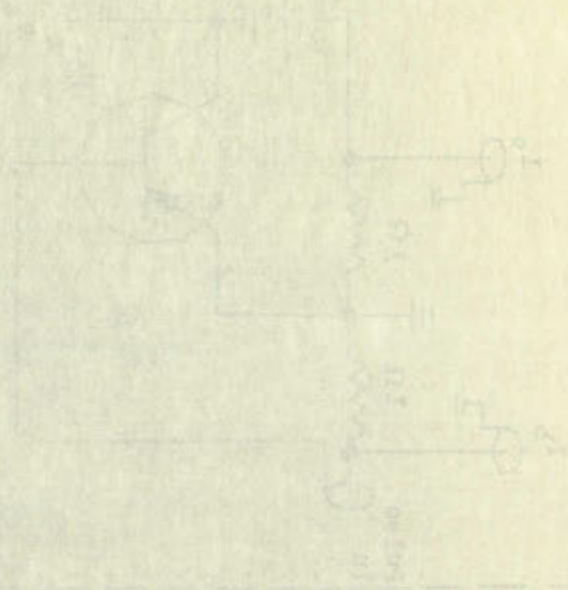
Figure 1

WINDING CONNECTION

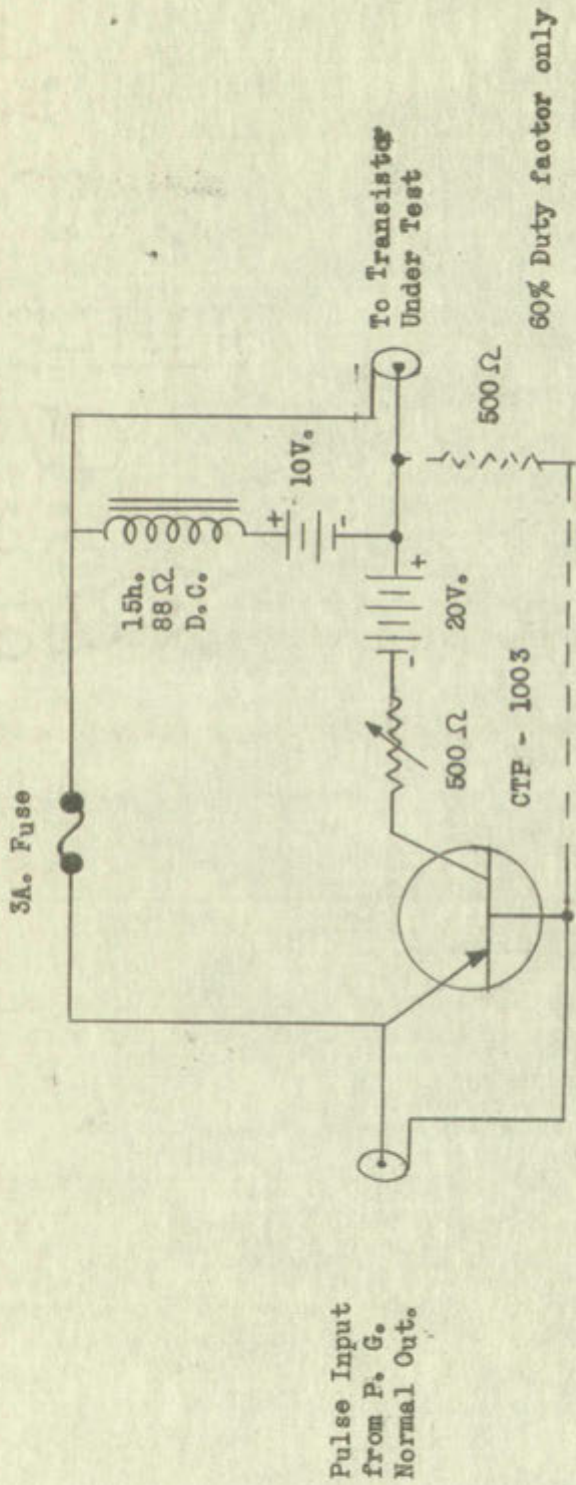
WINDING CONNECTION

Figure 2

WINDING CONNECTION



WINDING CONNECTION

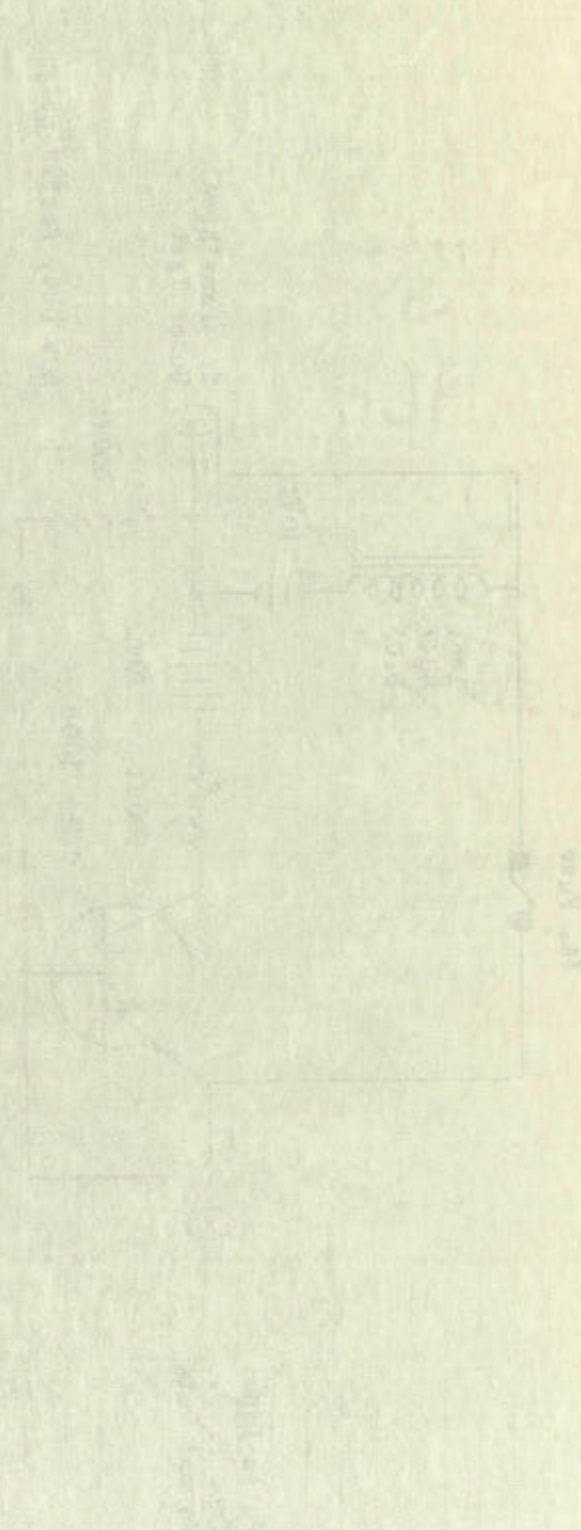


AMPLIFIER & BACK BIAS STAGE

FIGURE 2

1. 5000 2

FORWARD BIAS (VOLTAGE)



shows the pulse testing circuit. In order to obtain greater pulse amplitudes for the 100 microsecond pulses and larger, a transistor stage of amplification was used. This circuit is shown in Figure 2.

The pulse generator's normal output pulse is limited to twenty-five percent duty factor. Where the duty factor exceeded this rating, pulses were taken from the delay unit of the pulse generator. The dash line and 500 ohm in Figure 2 shows the positive feedback circuit required for the sixty percent duty factor pulses. This feedback circuit eliminates the deleterious signals between the 250 volt power supply ground and the oscilloscope ground which caused a distorted signal in the test circuit. Figure 3 shows an interstage of amplification required for the sixty percent duty factor pulses.

Direct current test at 165° F. This test is designed for the purpose of establishing the maximum D. C. power rating of the power transistor. In the circuit shown in Figure 4, the collector voltage and current was varied until the failure point was reached. In this case, the base circuit is open. Transistor and ambient temperatures were recorded at each step. Using the circuit in Figure 5, I_b (base current) was held at 200 milliamperes while V_c and I_c were varied until failure. Five randomly picked transistors were used for each of these tests. V_c was measured by a calibrated oscilloscope and I_b and I_c by laboratory instruments.

Heat sink characteristics at 165° F. This test was designed to establish the effects of the heat sink on the power ratings of the transistor.

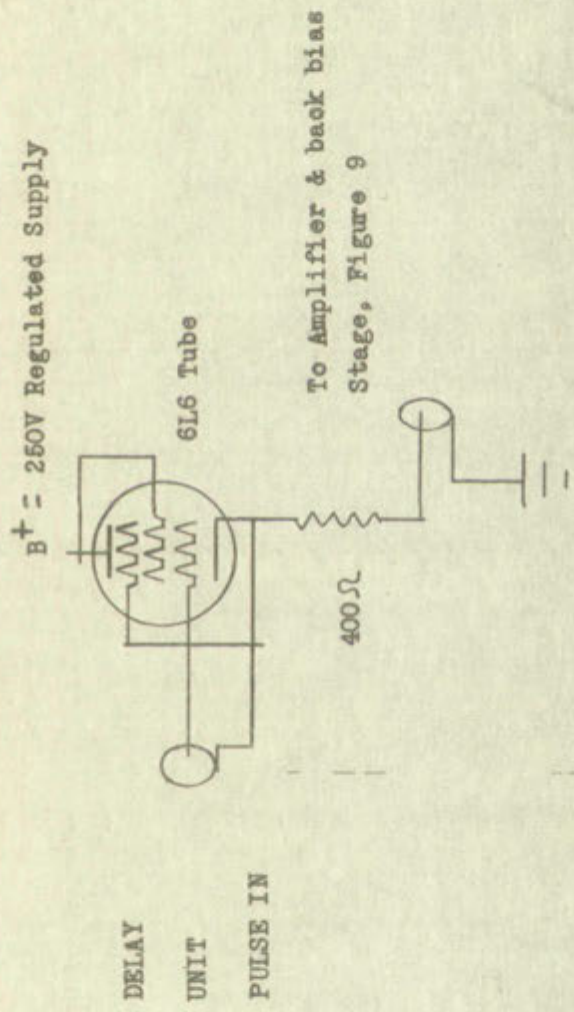
...the ... of ...

The ... of ...

Direct

That

1953
BUREAU



60% DUTY FACTOR CIRCUIT

FIGURE 3

ALIRAN AIR

TIPO

ALIRAN AIR

ALIRAN AIR
TIPO



Fig. 2. ALIRAN AIR TIPO

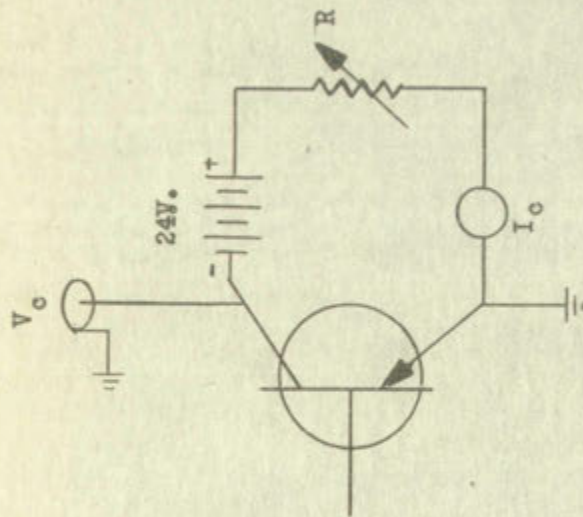


FIGURE 4

D. C. Test - $I_b = 0$

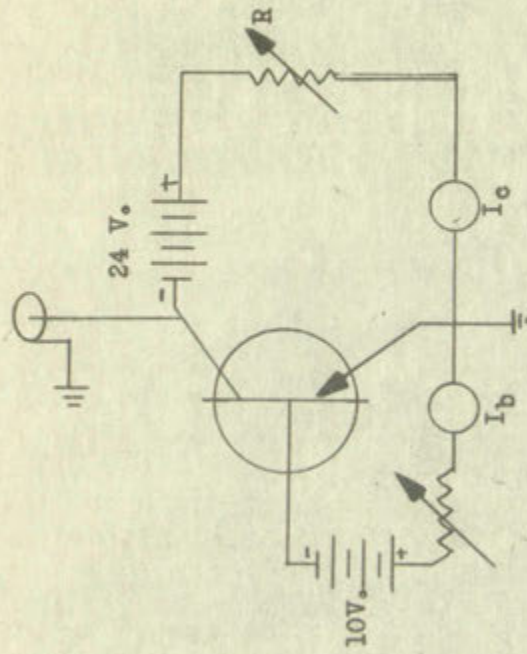


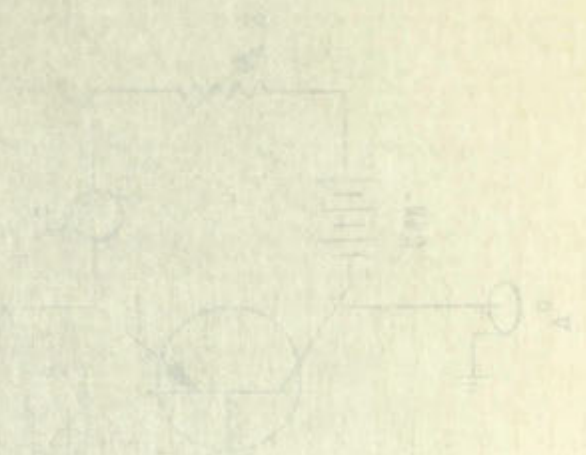
FIGURE 5

D. C. Test - $I_b = 200 \text{ ma.}$

Figure 1: A circuit diagram showing a battery, a switch, a lamp, and a voltmeter connected in a series circuit.



Figure 2: A circuit diagram showing a battery, a switch, a lamp, and an ammeter connected in a series circuit.



The heat sinks for this test were made from AN-4-13 Alclad, S-T 24 Alcoa Aluminum, .064" thick. Three sizes of heat sinks were used: (1) 3" x 3", (2) 4 1/4" x 4 1/4", and (3) 6" x 6". The circuit in Figure 4 was also used for this test. Three sets of data were taken for each heat sink using a different transistor for each set of data. Heat sink characteristics were also taken at room temperature.

The first of these is the fact that the
... of the ...
... of the ...
... of the ...
... of the ...
... of the ...
... of the ...
... of the ...

CHAPTER III

THE DESCRIPTION OF THE TEST EQUIPMENT

I. TEMPERATURE CHAMBER

An electric oven, 9 1/2" x 11 1/2" x 9 1/2", thermostatically controlled, manufactured by Schaar & Company was used for the temperature chamber. A few additions were made to the original oven: (1) an aluminum sheet, 0.40" thick, was placed above the heating elements to diffuse the heat, (2) a four-inch cage type fan was placed on the rear wall of the chamber to circulate the heat in effort to prevent hot spots, (3) two strands of asbestos covered wire spaced four inches apart were suspended 3 1/2" from the top of the chamber as supports for the heat sink containing the transistor under test, (4) coaxial receptacles and metering resistors were installed on the outside surface of the oven, and (5) the interior was wired with 50 ohm coax cable, all wiring being as short as possible and free from sharp bends.

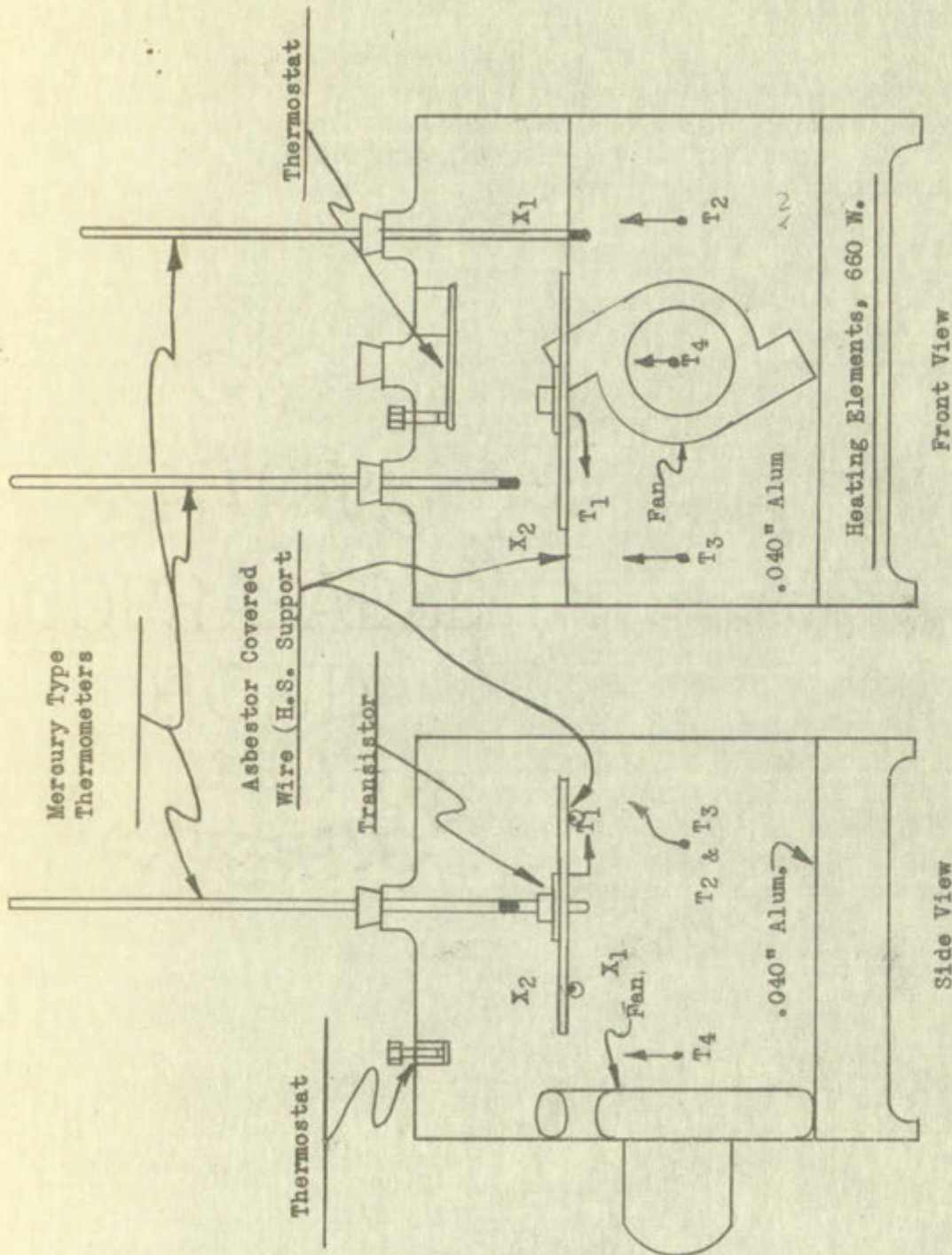
Two mercury type, 30 - 180° F. thermometers, designated by X_1 and X_2 , and three iron-constantan thermocouples, designated by T_2 , T_3 , and T_4 were used for measuring the ambient temperature. Figure 6 shows the location of these temperature measuring devices. A potentiometer calibrated for 0-400° F., was used in obtaining the thermocouple temperatures.

During a test, the thermostat was adjusted so that thermometer X_1 maintained a reading of 165° F. \pm 1° F. The thermocouple T_1 located in a groove cut in the heat sink just under the base of the transistor,

THE HISTORY OF THE CITY OF BOSTON

CHAPTER I

An attempt was made to ...
 controlled, management ...
 state of affairs ...
 an attempt was made ...
 to diffuse the ...
 rear wall of the ...
 space ...
 apart were ...
 for the best ...
 footings and ...
 face of the ...
 cable, all ...
 The ...
 and ...
 the location of ...
 calculated for ...
 during a ...
 of ...
 in a ...



Scale 1/4" = 1' - 0"
 1650 F. TEMPERATURE - (Figure 6)
 CHAMBER (Interior)

Diagram showing the
arrangement of the
main engine and
propeller shaft.

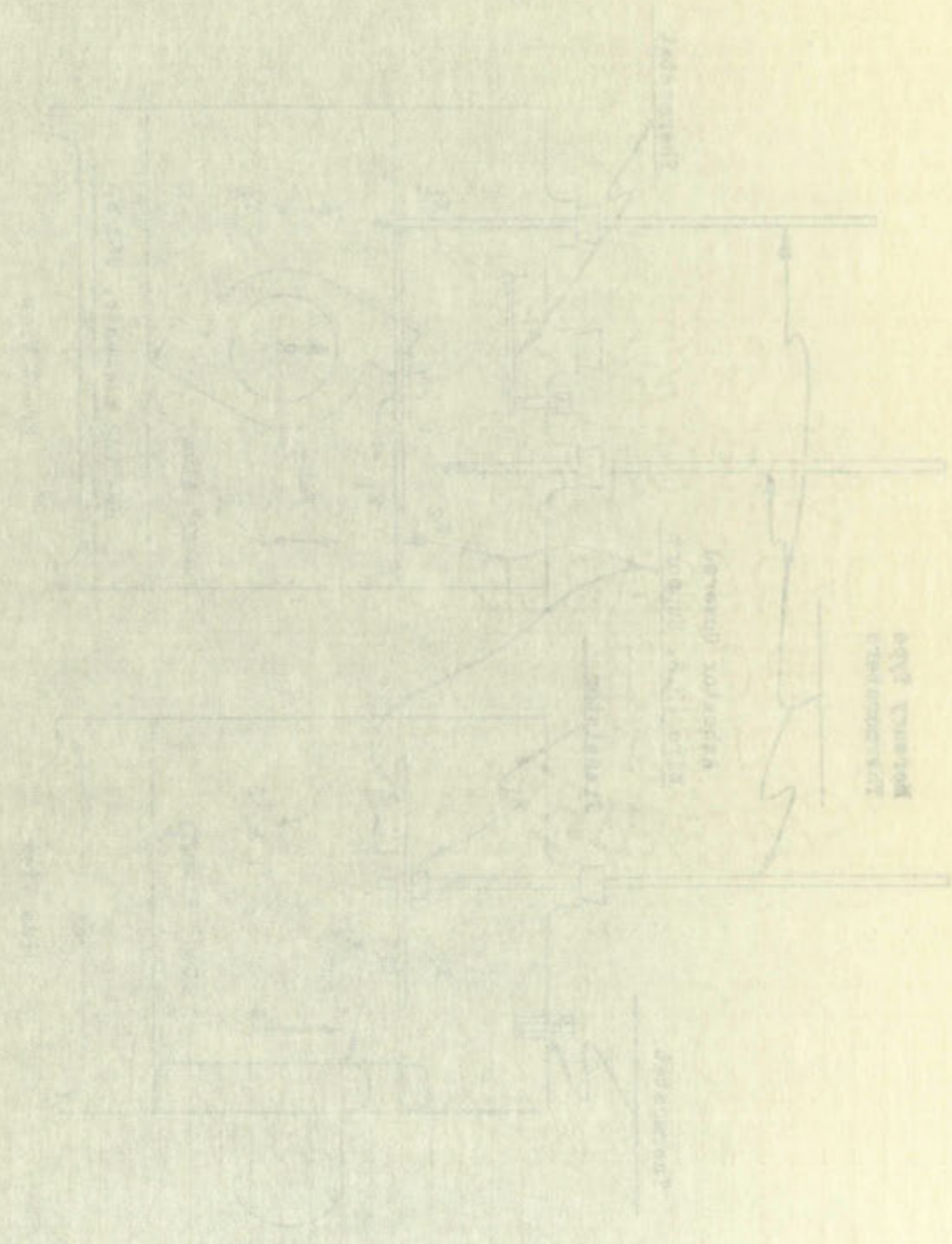


Fig. 1

Главный двигатель
Propeller shaft

was employed to read transistor temperature.

The following shows the temperatures at the various locations inside the temperature chamber in a typical case:

Prior to test

$X_1 = 165^\circ \text{ F.}$	$X_2 = 161^\circ \text{ F.}$	$T_1 = 169^\circ \text{ F.}$
$T_2 = 177^\circ \text{ F.}$	$T_3 = 171^\circ \text{ F.}$	$T_4 = 176^\circ \text{ F.}$

While the transistor is dissipating 135 watts peak power at a duty cycle of six percent

$X_1 = 165^\circ \text{ F.}$	$X_2 = 164^\circ \text{ F.}$	$T_1 = 206^\circ \text{ F.}$
$T_2 = 175^\circ \text{ F.}$	$T_3 = 176^\circ \text{ F.}$	$T_4 = 177^\circ \text{ F.}$

Figure 7 shows the temperature chamber in operation, except the door is open to display the interior. The metering resistors on the exterior of the chamber are the non-inductive type (Koolohm) used in measuring the collector current and base current by using a calibrated oscilloscope.

II. EQUIPMENT FOR OBTAINING TRANSISTOR CHARACTERISTICS

The equipment used in obtaining the characteristics of the transistor is shown in Figure 8. A block diagram, Figure 9, is a general circuit description of this equipment. Figure 10 shows three sets of curves describing the transistor characteristics with the transistor connected common emitter. These curves were displayed on the face of the cathode ray tube and photographed with a polaroid land camera. The circuitry used in building the transistor characteristics curve tracer is shown in Figure 11.

was applied to the test in the following manner:

The following about the test results were obtained:

Inside the separator, the test results were:

Index of refraction

$$n_D^{20} = 1.471$$

$$n_D^{25} = 1.468$$

While the test results are given in the following table:

any value of the parameter

$$n_D^{20} = 1.471$$

$$n_D^{25} = 1.468$$

Figure 7 shows the test results in the following manner:

the test is open to the atmosphere, the test results are:

the test results are given in the following table:

in securing the test results, the test results are:

tested results:

II. TEST RESULTS AND DISCUSSION

The test results are given in the following table:

separator in which the test results are given in the following table:

and direct measurement of the test results are given in the following table:

of curves describing the test results are given in the following table:

conducted under various test conditions are given in the following table:

the test results are given in the following table:

The test results are given in the following table:

test results are given in the following table:

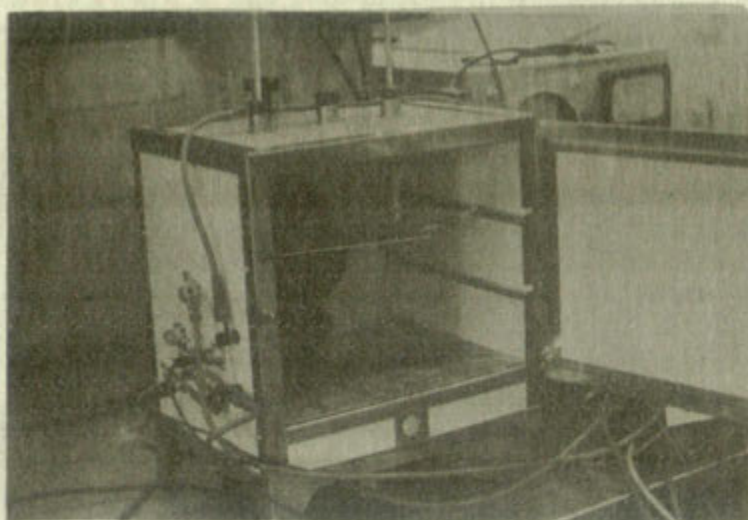
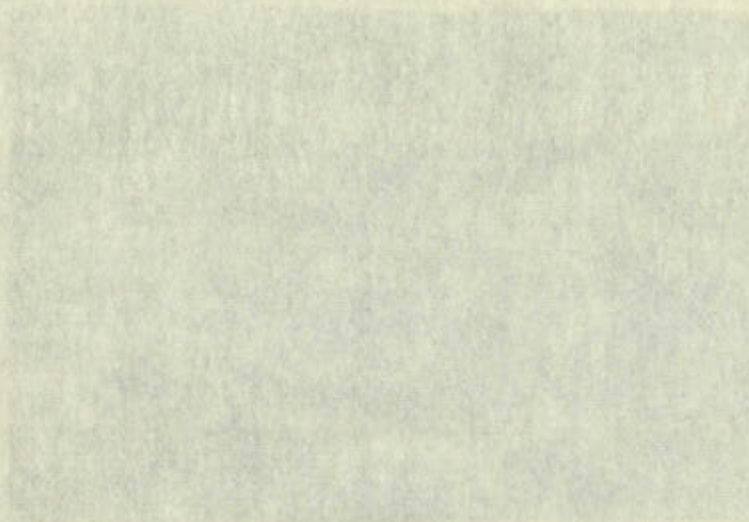


FIGURE 7
TEMPERATURE CHAMBER



100

101

102

103

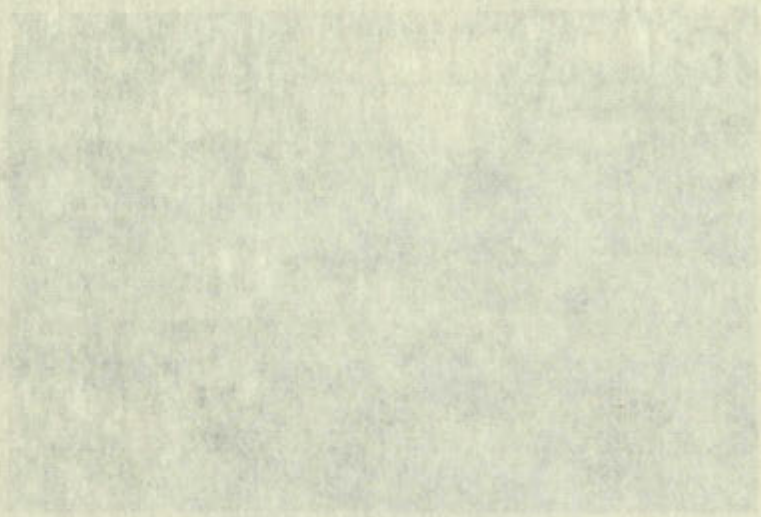
104



FIGURE 8

TEMPERATURE CHAMBER AND CURVE TRACER EQUIPMENT

1. Oven, electric.
2. Collector voltage supply (Battery Booster 6-12 volt).
3. Power Supply, D. C., 300 volt regulated, 250 milli-ampere capacity.
4. Step generator (Tektronix type 570 curve tracer).
5. Chassis, terminating including 6L6 cathode variable 500 ohm resistor and metering resistors for taking characteristics at room temperature.
6. Potentiometer, temperature measuring, direct reading 0-400° F.
7. Switch, 8 point multiple for use with the potentiometer.
8. Oscilloscope, (Tektronix type 545).



REPORT

ANNUAL REPORT OF THE BOARD OF DIRECTORS

The Board of Directors has the honor to acknowledge the cooperation and assistance of the various departments and divisions of the organization in the preparation of this report. The report is a summary of the activities of the organization during the year ending December 31, 1945. It is intended to provide a general overview of the organization's operations and to inform the public of the progress made during the year. The report is divided into several sections, each dealing with a different aspect of the organization's activities. The first section deals with the organization's financial operations, and the second section deals with its administrative operations. The third section deals with the organization's educational and research activities, and the fourth section deals with its public relations and community service activities. The report concludes with a statement of the Board's plans for the future.

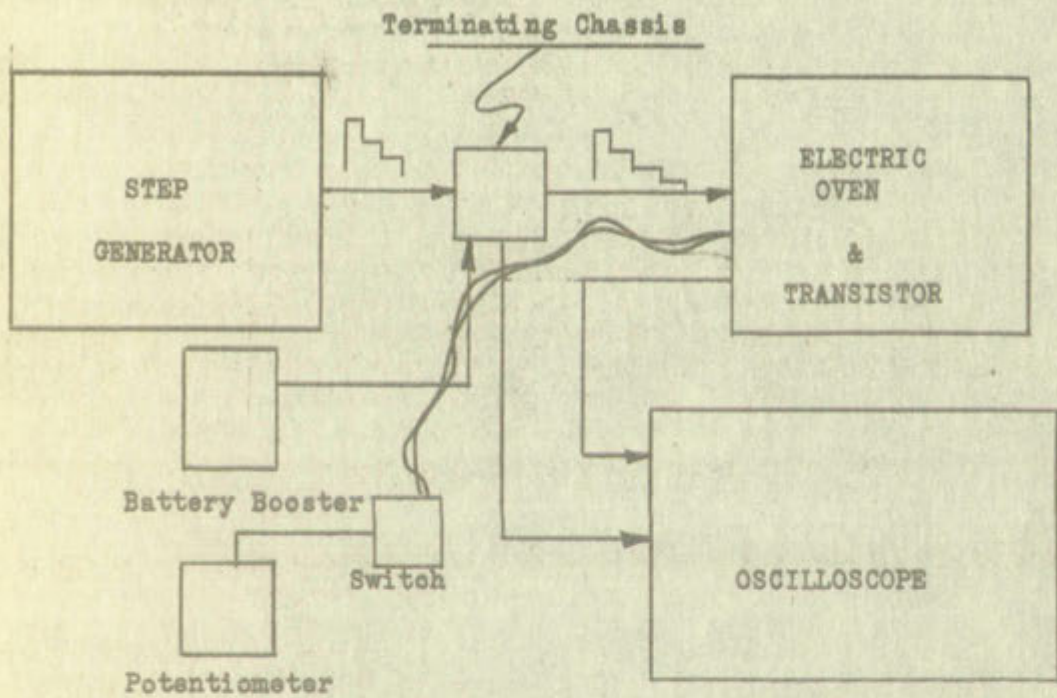
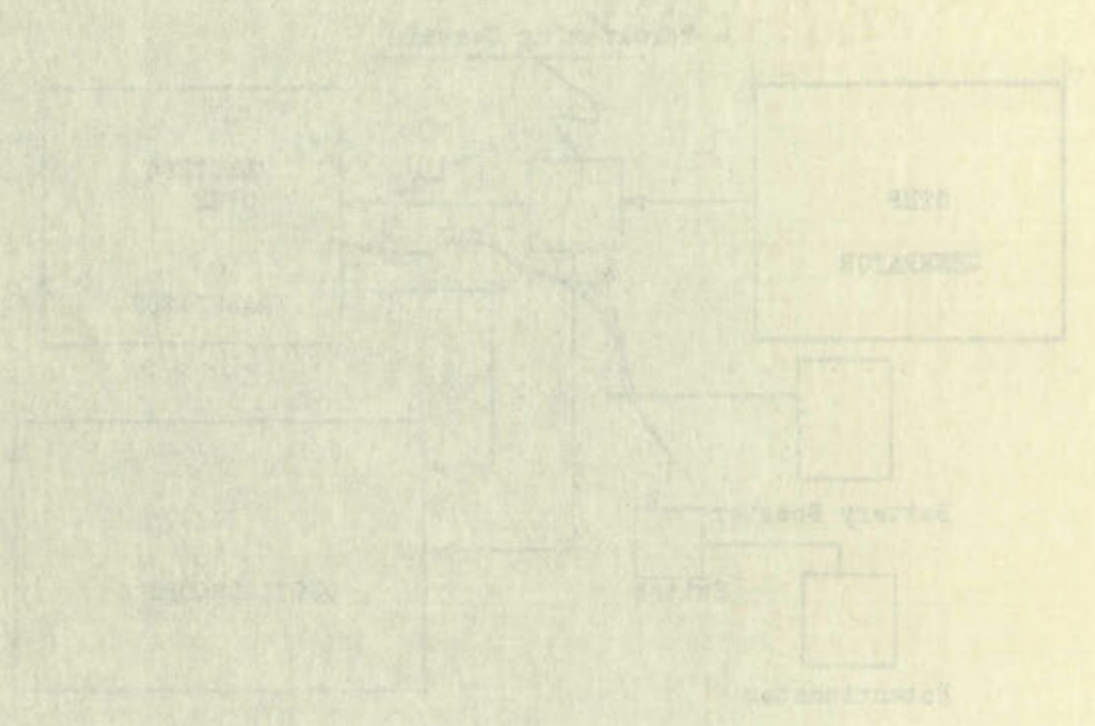


FIGURE 9
 CIRCUIT DESCRIPTION OF THE
 TRANSISTOR CHARACTERISTIC
 EQUIPMENT

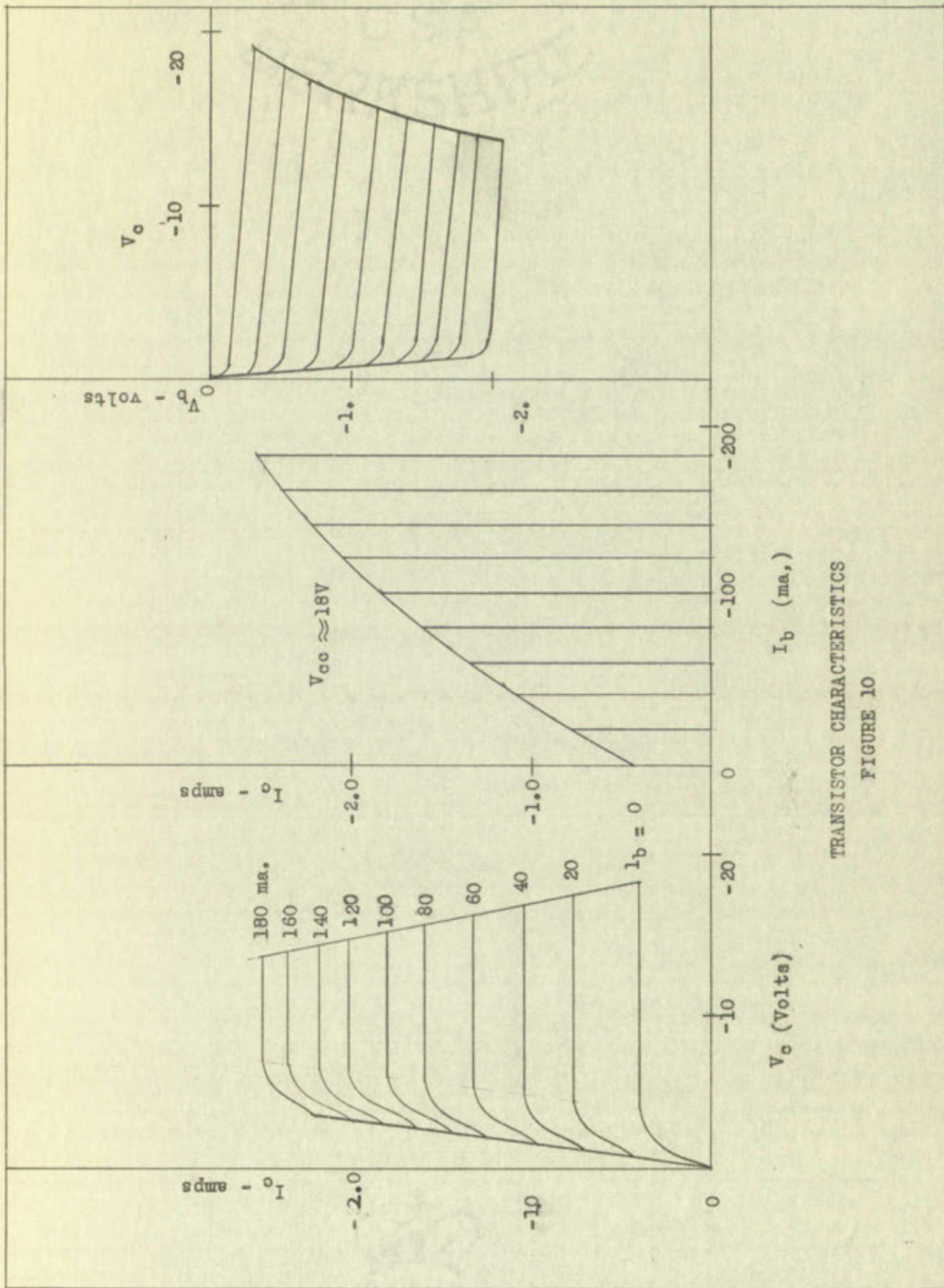
APPENDIX

FIG. 1

USA



THE UNIVERSITY OF
MICHIGAN LIBRARY
SERIALS ACQUISITION
DEPARTMENT



TRANSISTOR CHARACTERISTICS
FIGURE 10

COBBETT



200
100
50

Figure - 101



100
50

Figure - 102

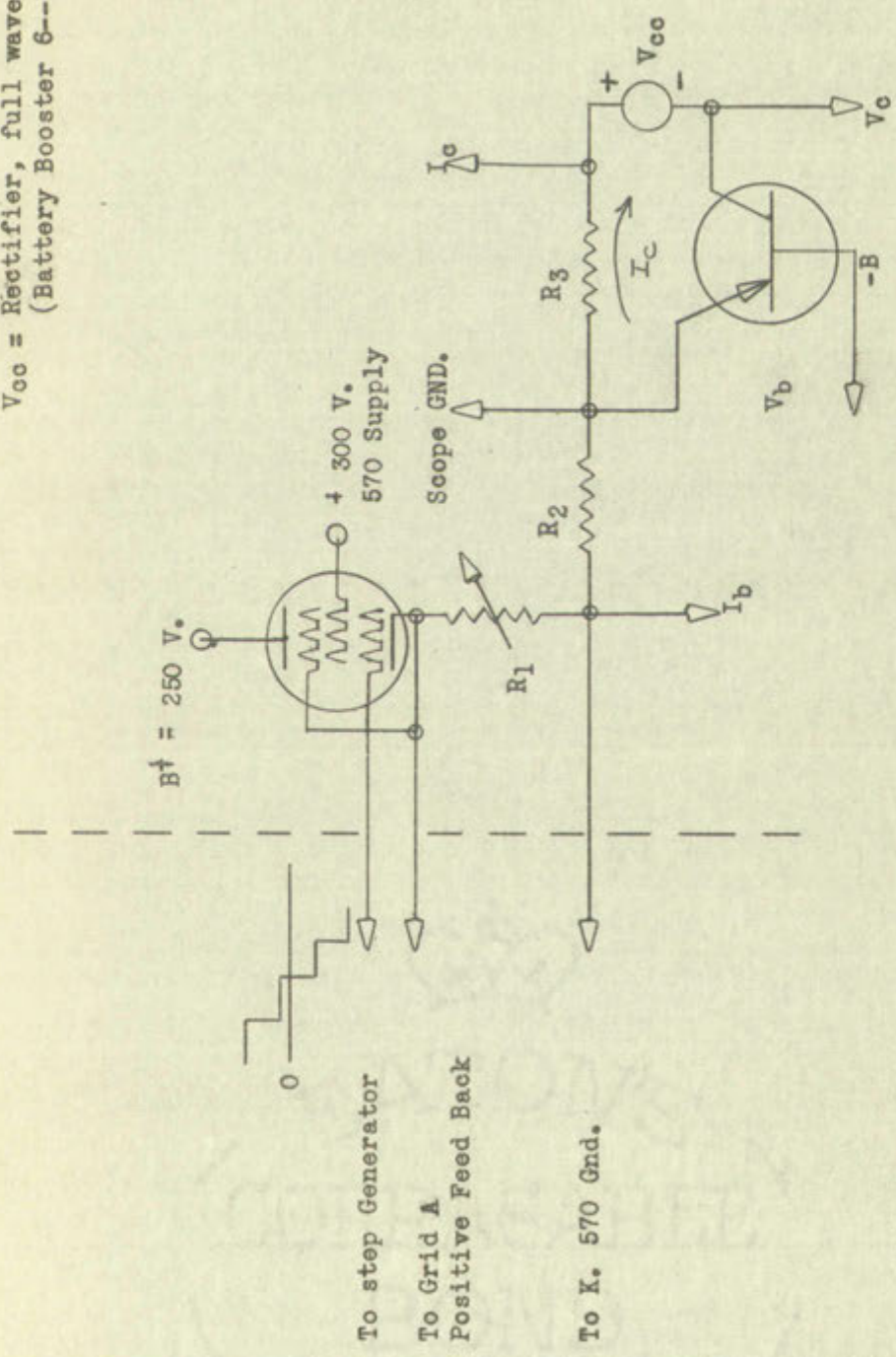


100
50

Figure - 103

COBBETT

- R1 = Resistor, 0-500 Ohm for Varying steps
- R2 = 5 Ohm, 5 Watt non-inductive for meter-bass current.
- R3 = 1 Ohm (4 ea. 4 Ohm, 5 Watts) noninductive metering Collector Current.
- Vcc = Rectifier, full wave 18 volt peak (Battery Booster 6--12 Volt,



TEKTRONIX 570
Curve Tracer

FIGURE 11
CURVE TRACER CIRCUIT

Handwritten text, possibly a title or reference number, located at the top left of the page.



Handwritten text, possibly a list of specifications or a description of the components shown in the diagrams. The text is written in a cursive or semi-cursive style.

Large, faint, mirrored text at the bottom of the page, likely bleed-through from the reverse side of the document. The text is difficult to read but appears to contain technical terms.

Theory of the Curve Tracer Circuit (General). Voltages of equal steps are impressed on the grid of the 616 tube, thus causing constant current steps in the base circuit of the transistor. A sweeping voltage of 18 volts, is impressed on the collector circuit. The base current steps are 1/120 second in duration but timed so that the step comes during the time that the collector voltage is a maximum or the change of collector voltage $\frac{dV_c}{dt}$ is a minimum and the fall time of the current steps are not so critical. Figure 12 shows this time relationship of the base current, collector voltage and the collector current.

III. PULSE TESTING EQUIPMENT

The overall pulse testing set up is shown in Figure 13 and a general description of the pulse testing circuit is shown in Figure 14.

equal and the pressure of the fluid is constant throughout the length of the vessel. The rate of flow is the same in all parts of the vessel. The rate of flow is the same in all parts of the vessel. The rate of flow is the same in all parts of the vessel.

THE RATE OF FLOW

The rate of flow is the same in all parts of the vessel. The rate of flow is the same in all parts of the vessel. The rate of flow is the same in all parts of the vessel.

COPIES
FOR
JOURNAL
L. J. BRYAN
1914

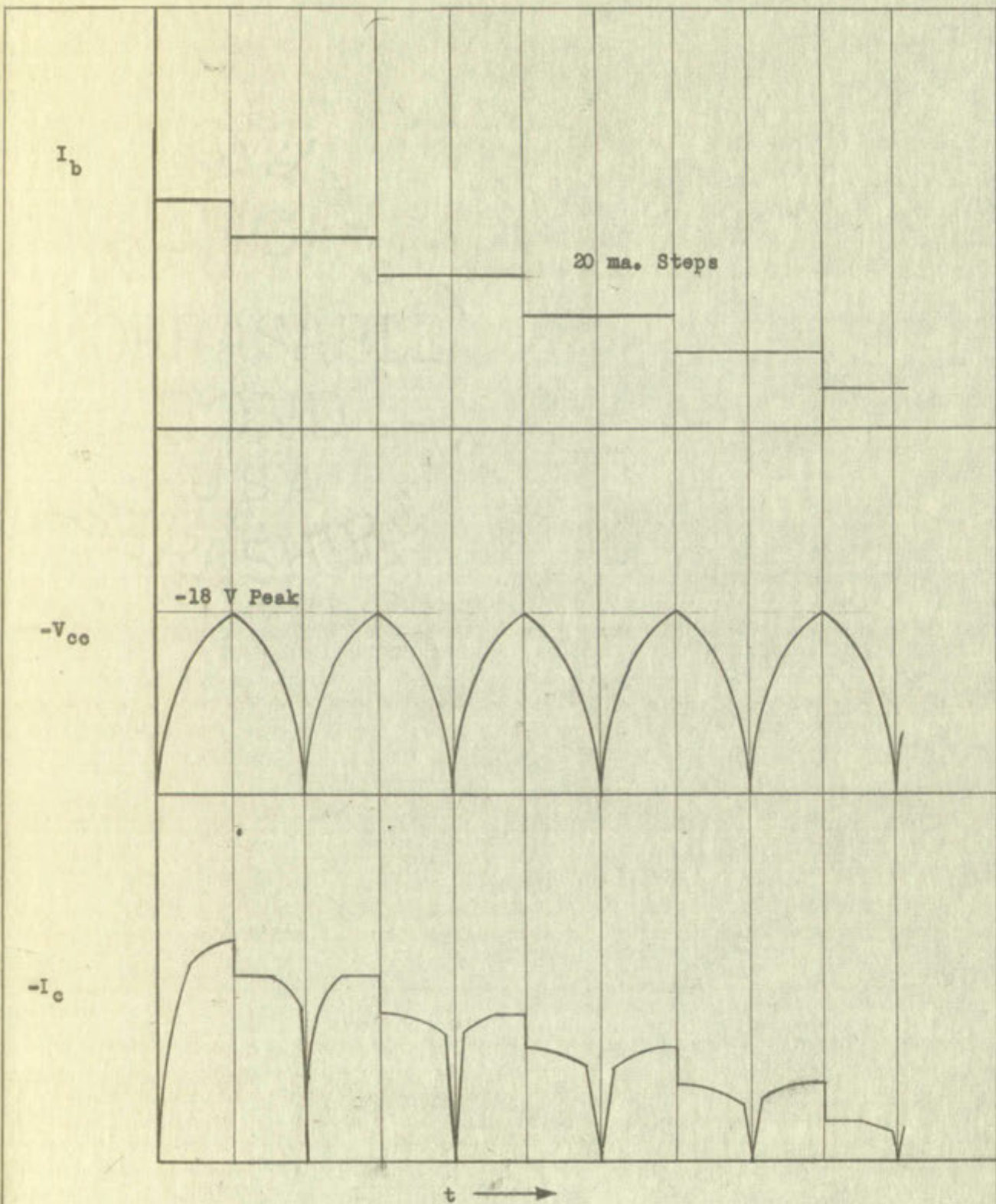


FIGURE 12

WAVEFORM-TIME RELATIONSHIP



1

2

3

REVERSE SIDE OF PHOTOGRAPH

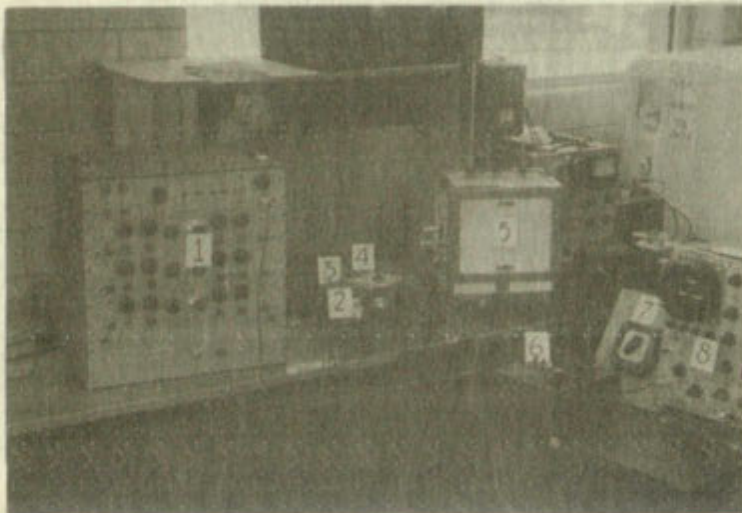


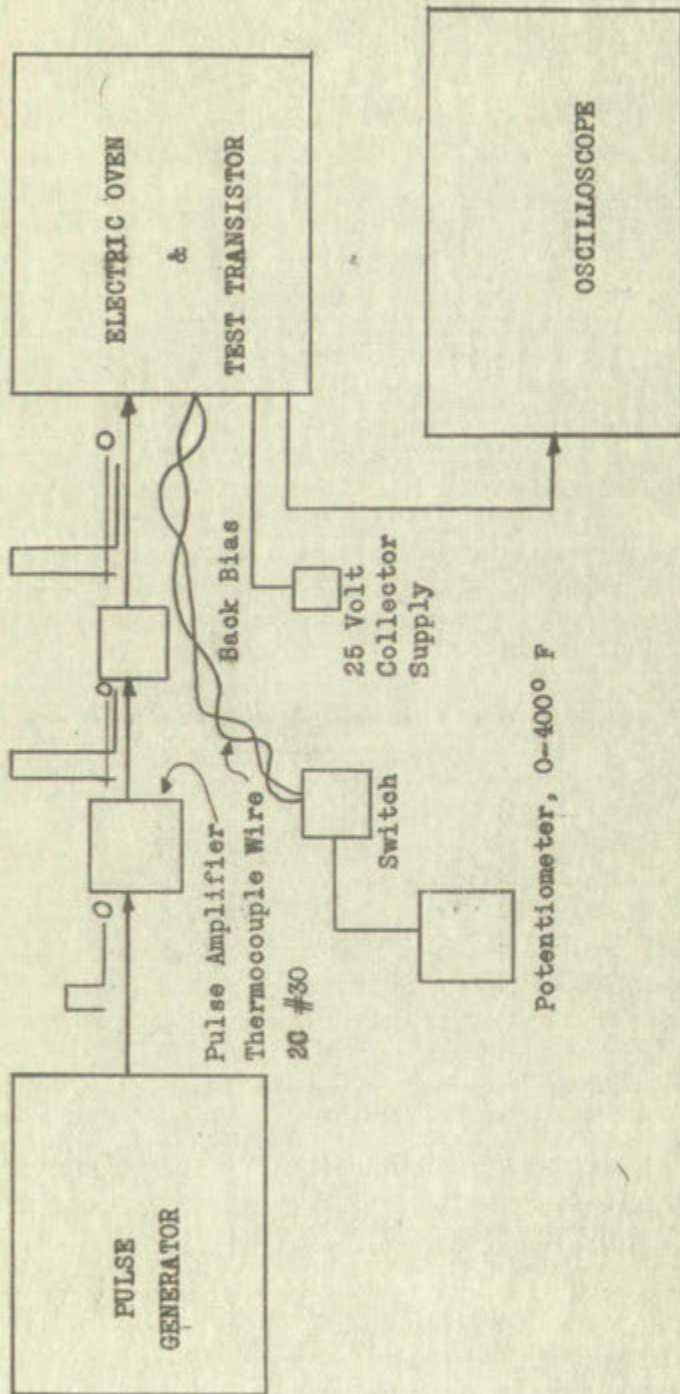
FIGURE 13

PULSE TEST SET UP

1. Pulse generator
2. Transistor (pulse) amplifier
3. Back bias battery and 15 henry inductor
4. Battery, 20 volt collector supply
5. Temperature chamber
6. Potentiometer
7. Switch, 8 point multiple
8. Oscilloscope



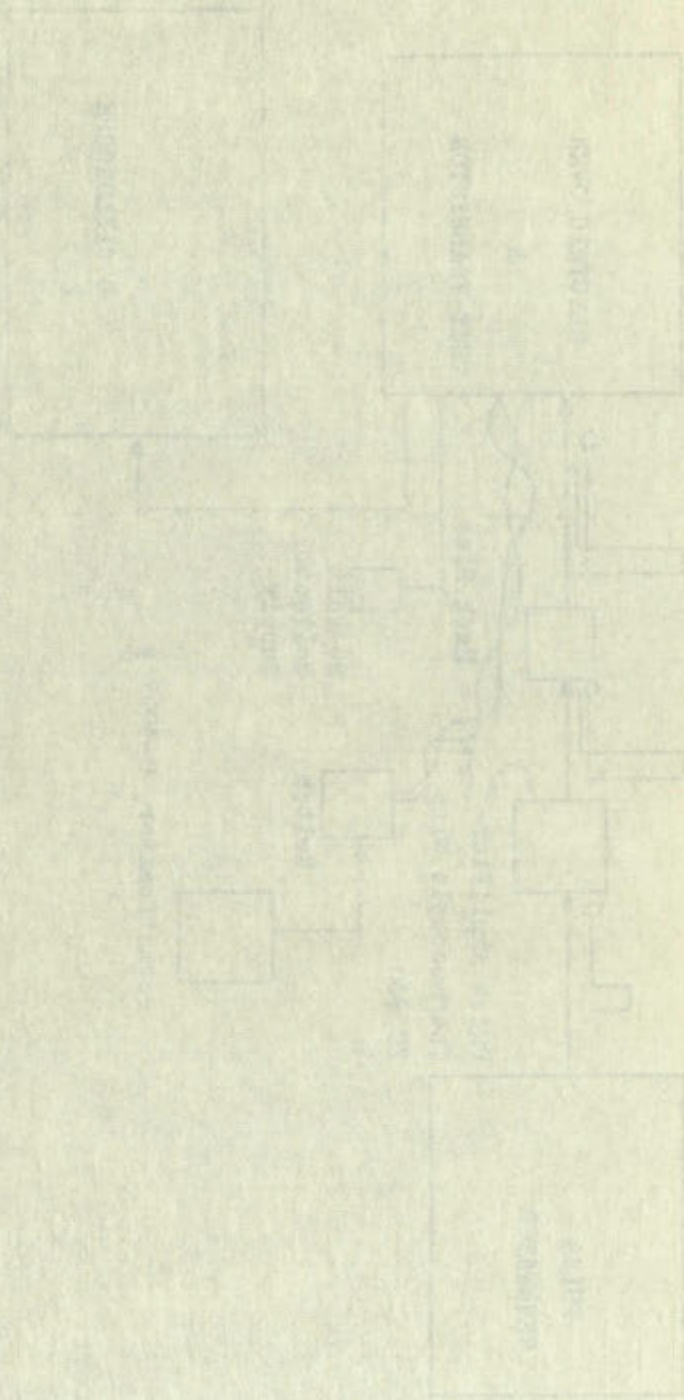
1. [Illegible]
2. [Illegible]
3. [Illegible]
4. [Illegible]
5. [Illegible]
6. [Illegible]
7. [Illegible]
8. [Illegible]
9. [Illegible]
10. [Illegible]



PULSE TEST CIRCUIT (GENERAL.)

FIGURE 14

Handwritten title: *Handwritten Title*



Handwritten text at the bottom right: *Handwritten text*

CHAPTER IV

THE RESULTS

I. PULSE TESTING

The transistors were placed in the temperature chamber and tested as described in Chapter II, The Method of Test. Where the available input pulse was too small in amplitude to cause an appreciable change in transistor temperature, the number of transistors pulsed at this duty factor was decreased expecting to devise a pulse generator at a later date which would extend these amplitudes.

The permissible peak power in the pulses at various repetition frequencies and pulse widths are presented in Figures 15, 16, 17, and 18. The solid flat-topped lines are the last peak power readings at which the transistor reproduced stable pulses and reached a constant temperature. The dash lines extending the flat-topped lines are the points where either the transistor failed completely or became unstable. The pulsing circuit, in many cases, would not provide pulses of large enough amplitude to destroy the transistor. These points are designated by a pointed line.

The maximum transistor temperature, average power of the permissible peak power reached, and the transistor used is also placed on the graphs.

The effects of duty factor or duty cycle are shown in Figure 19. Since failures occur in the temperature region of 200° F. and 216° F. transistor temperature, this information is plotted from curves in

SECTION 1

The following is a list of the names of the persons who

acted as described in the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

the subject of the report of the committee on

Appendix C at the 200° F. temperature point. Scarcely any failures occurred from pulsing below 200° F., the majority failed just after 200° F. For this reason then, in order to overcome the difference in transistor characteristics, the effects of duty cycle are taken at a safe operating temperature, 200° F., which is only slightly different from the maximum pulse ratings.

Since it was impossible to destroy the type CTP-1003 transistor in the small duty factor range with the existing pulsing equipment, peak power versus transistor temperature was plotted at these duty factors so that the curves could be extrapolated into the failure region. This set of curves is present in Appendix C. The six percent and smaller duty factor curves deviate from the expected power-temperature curves in that they have a tendency to droop or flatten out in the upper temperature region. Above six percent, the curves are straight lines as would be expected since dissipated energy is directly related to temperature and also to power. That is energy = power times time (Joule's law). Figure 20 is a typical curve showing this drooping effect in a manner to emphasize the reason for this deviation from the straight line relationship between dissipated power and temperature. This is to say that base current cannot be ignored in calculating the total power dissipated in a transistor at small duty factors in the upper temperature region.

II. DIRECT CURRENT TESTING

The two D. C. tests were performed as previously described in Chapter II, The Method of Test. With these tests, the transistors can

Appendix 6 to the 1977 Environmental Impact Statement for the
proposed project, dated 1977. The project is located in
2000 N. York Ave., West York, Pa. The project is a
transmission line, and the project is located in
the project area, 2000 N. York Ave., West York, Pa.
from the project area.

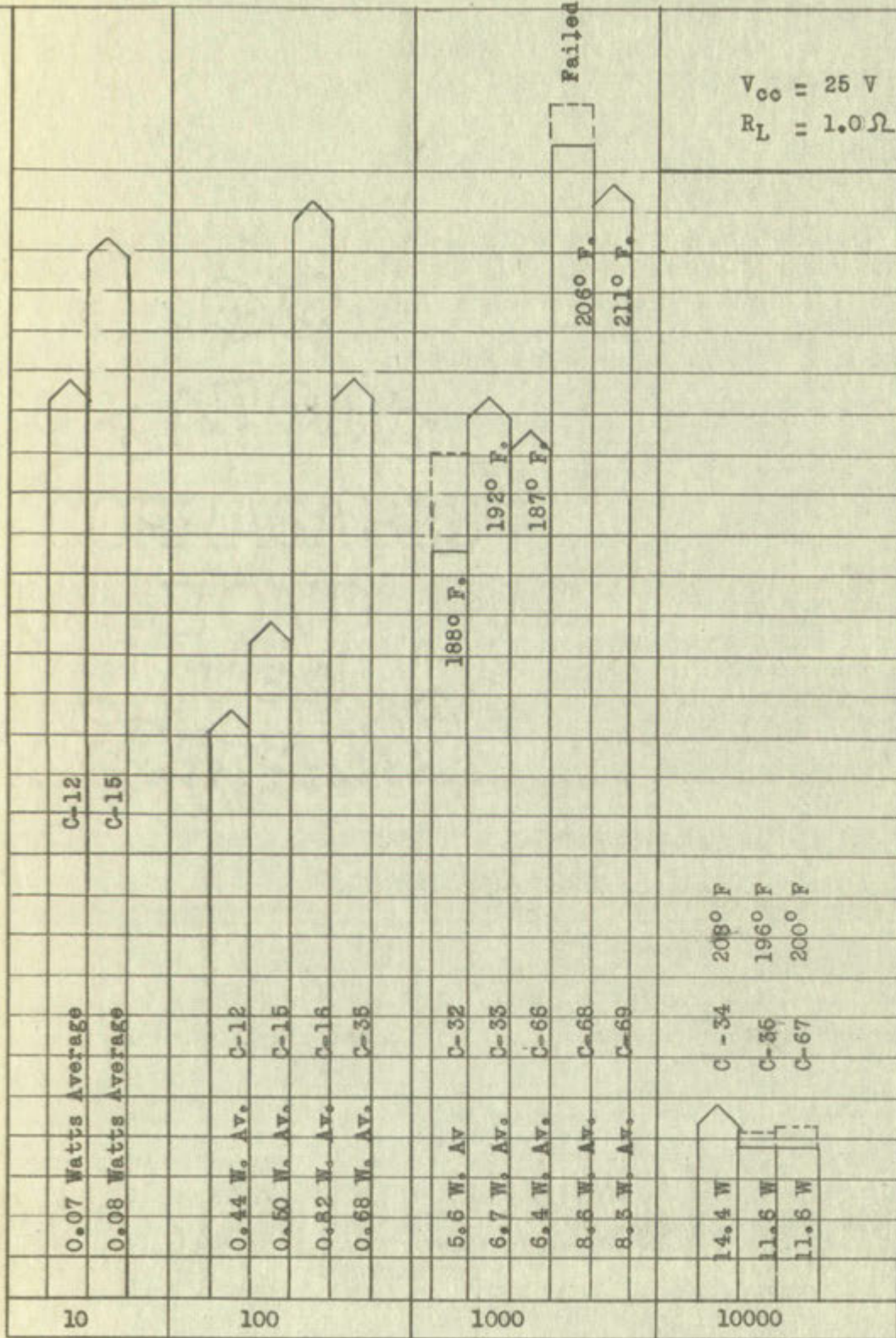
Since it is not possible to identify the project area
in the area of the project, the project area is
best power system from the project area, and the
factors in the project area are identified in the
report. This report is intended to identify the project
and identify the project area, and the project area
factors are identified in the report. The project area
out in the project area, and the project area
are identified in the report. The project area
directly related to the project area, and the project area
power lines are identified in the report. The project area
this project area, and the project area
the first two sections of the report, and the project area
temperature, and the project area
calculating the project area, and the project area
factors in the project area.

The two D. & E. project area, and the project area
Chapter II, The Project Area, and the project area

PEAK POWER -- WATTS

$V_{CC} = 25 \text{ V}$
 $R_L = 1.0 \Omega$

140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

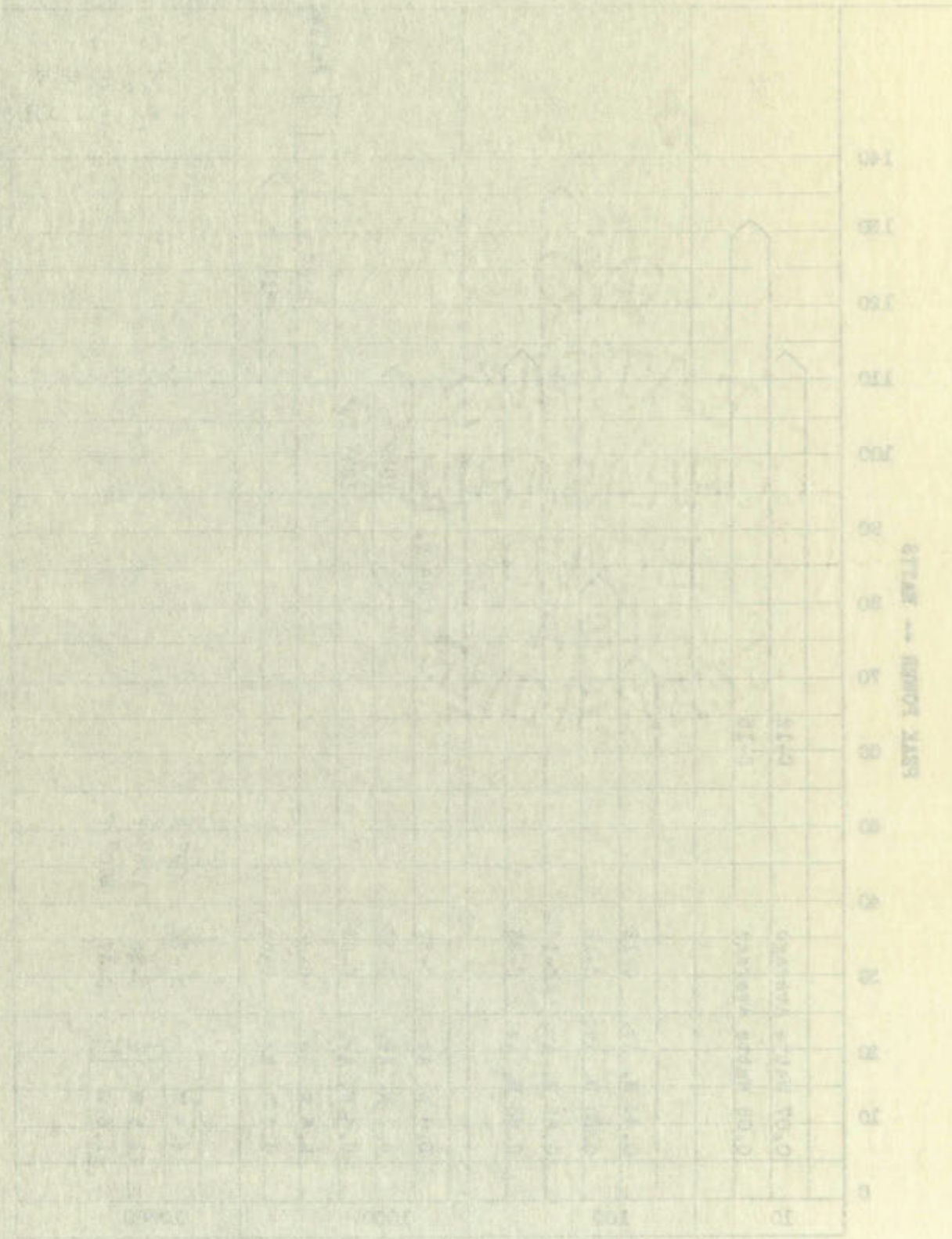


PULSE WIDTHS - MICROSECONDS

FIGURE 15

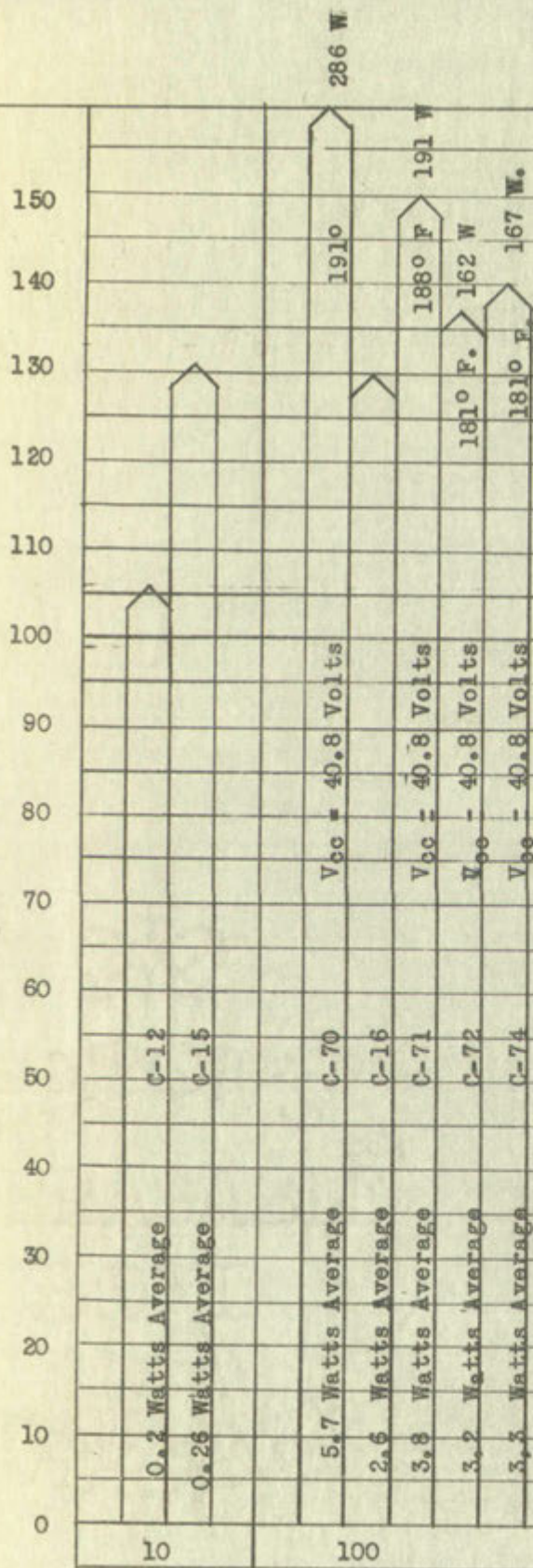
PULSE POWER RATINGS -- 60 CPS

POLYMERIZATION OF
 STYRENE IN
 AQUEOUS SOLUTION

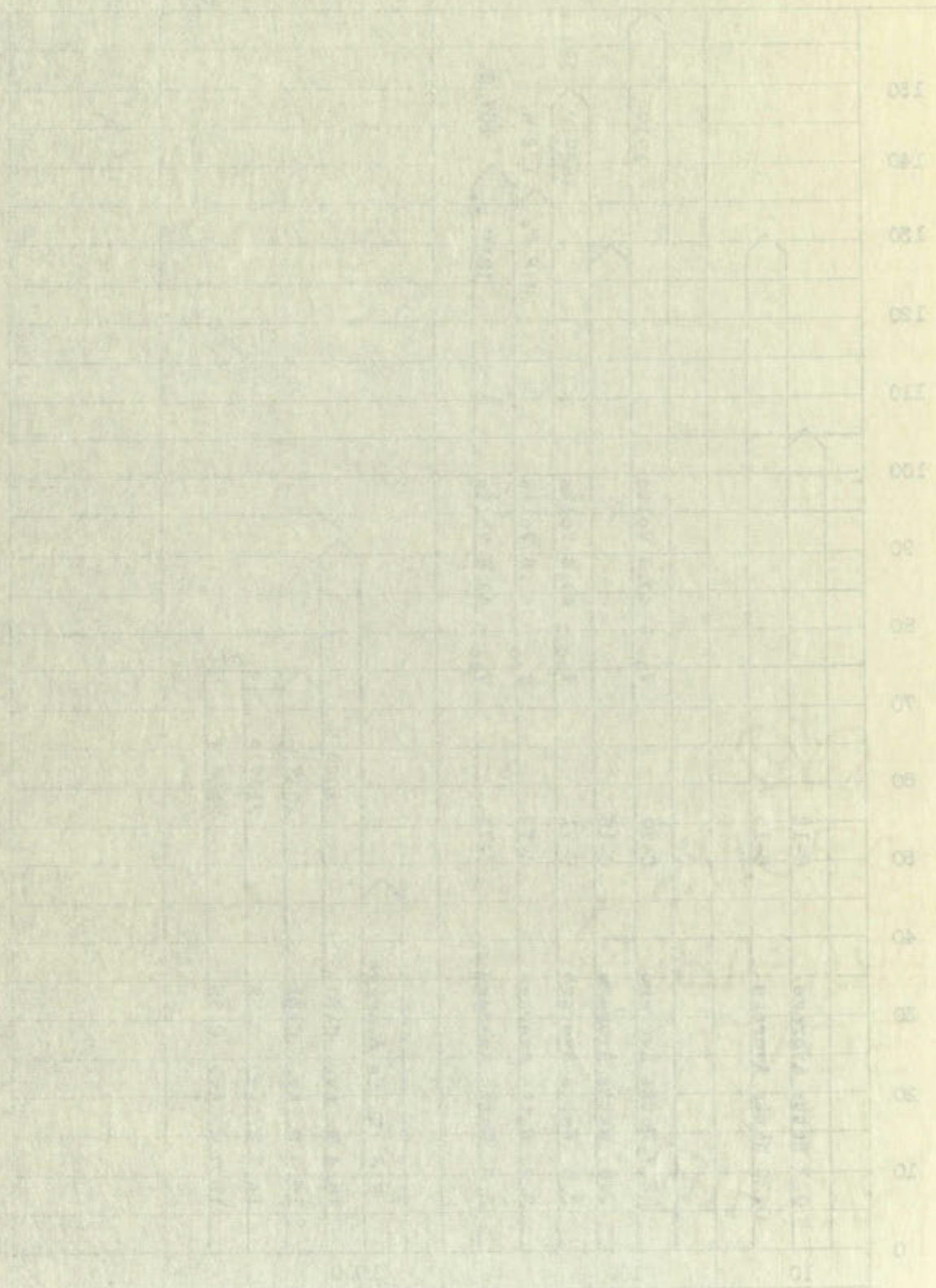


PEAK POWER -- WATTS

$V_{CC} = 25 \text{ V.}$
 $R_L = 1.0 \Omega$



Pulse Widths -- Microseconds
 Figure 16
 Pulse Power Ratings - 200 CPS
 165° F. Ambient



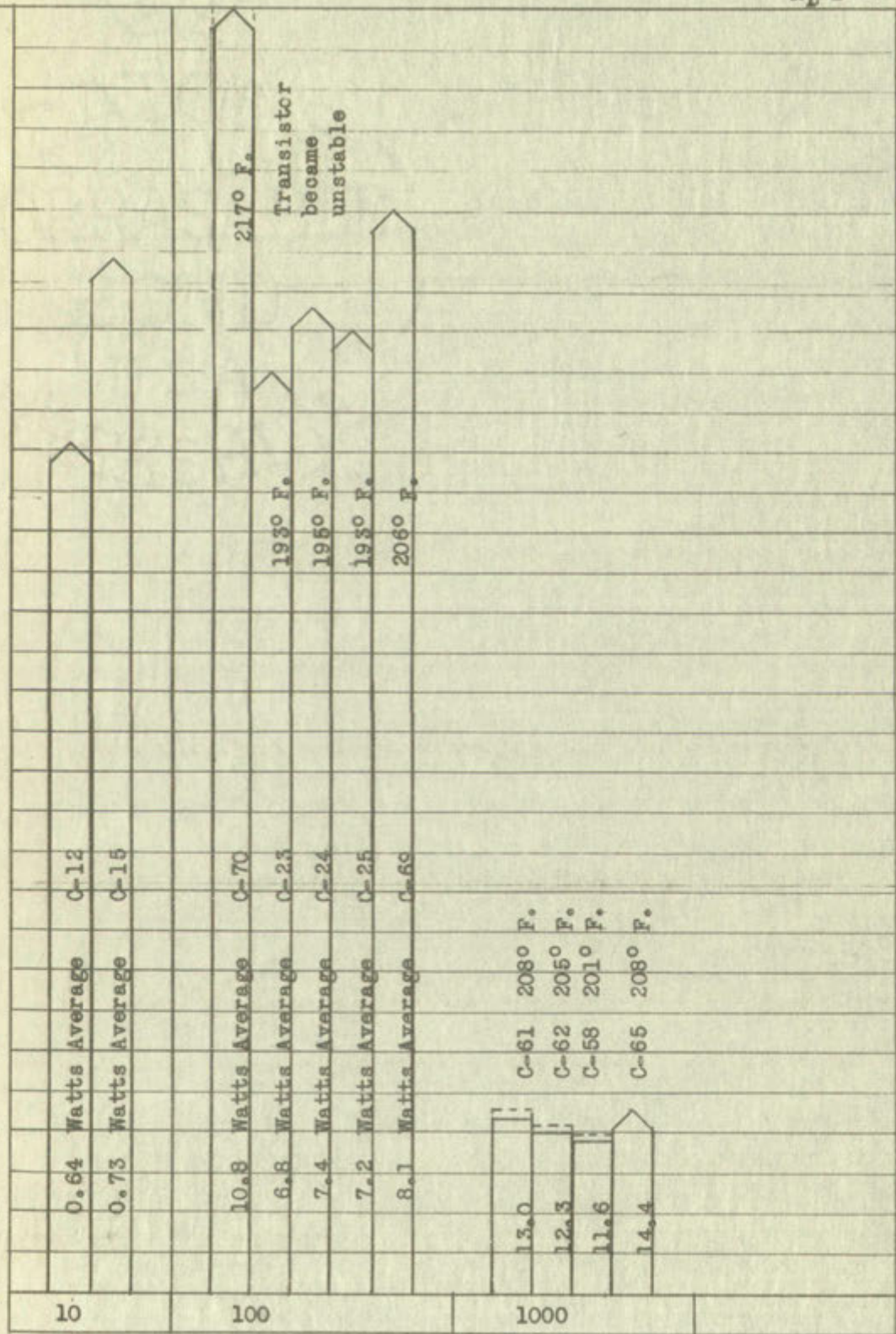
100
 90
 80
 70
 60
 50
 40
 30
 20
 10
 0

V_{cc} = 25V.

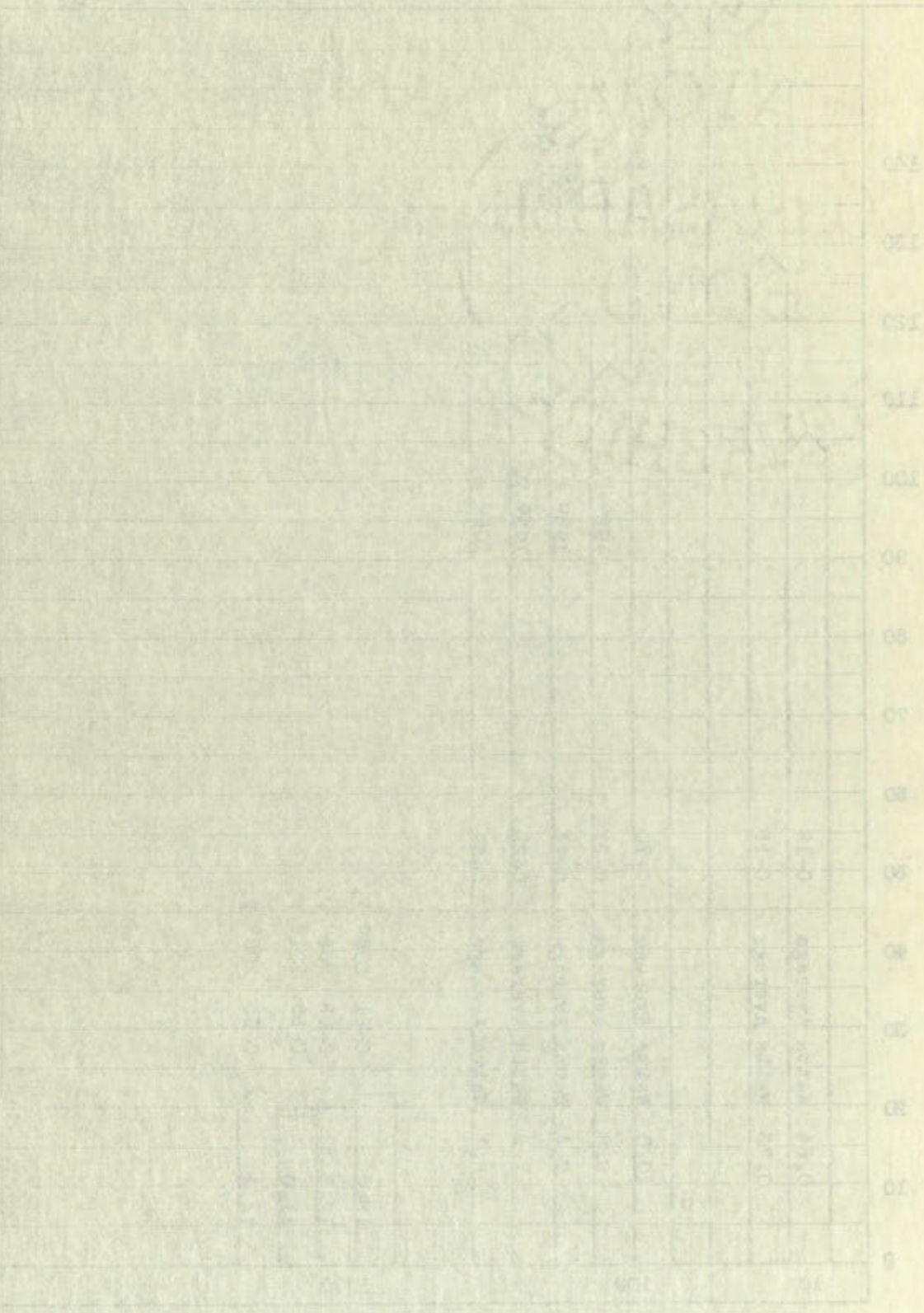
R_L = 1.0Ω

PEAK POWER -- WATTS

140
130
120
110
100
90
80
70
60
50
40
30
20
10
0



PULSE WIDTHS -- MICROSECONDS
FIGURE 17
PULSE POWER RATINGS -- 600 CPS
165° F. Ambient



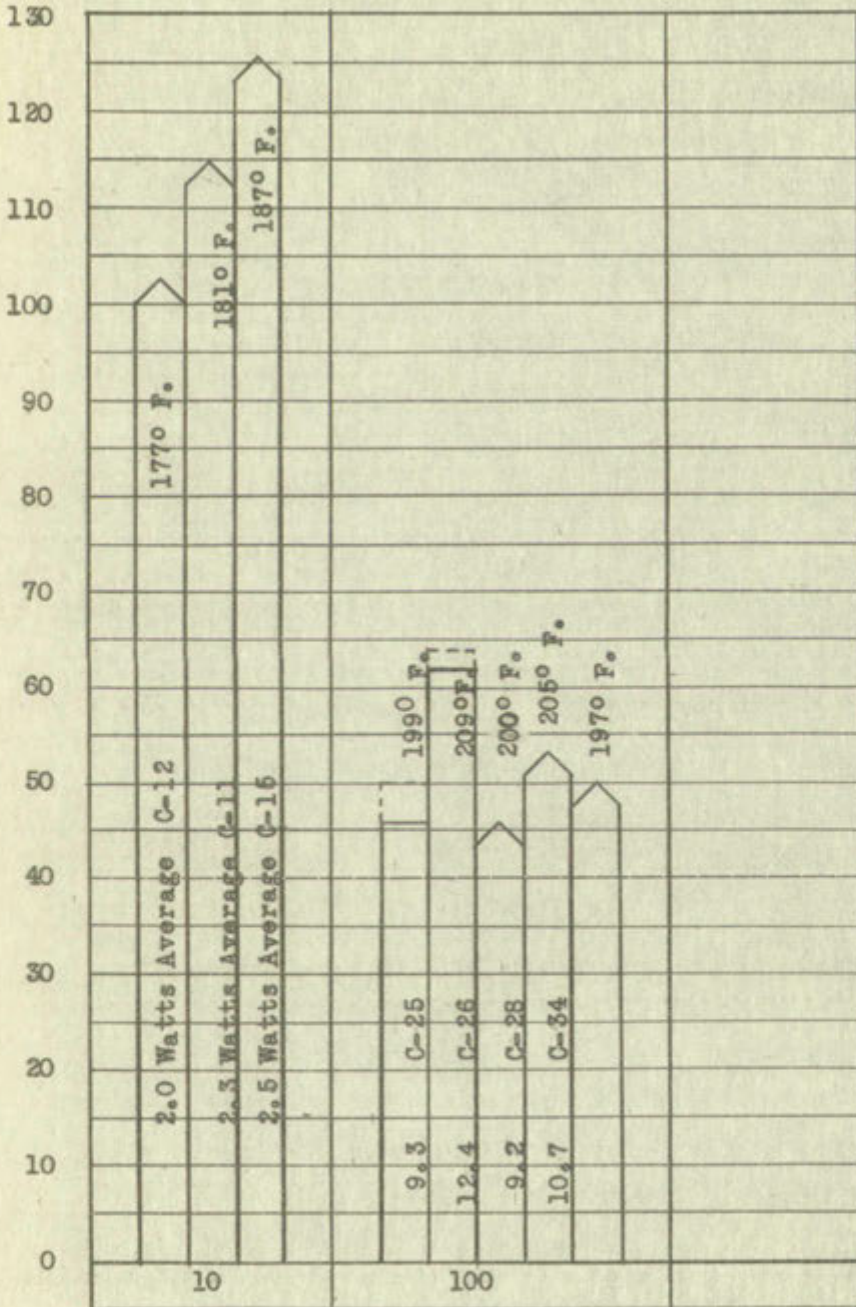
1877 1878

Section of the ...
 showing the ...
 of the ...
 in the ...

$V_{CC} = 25 \text{ V.}$

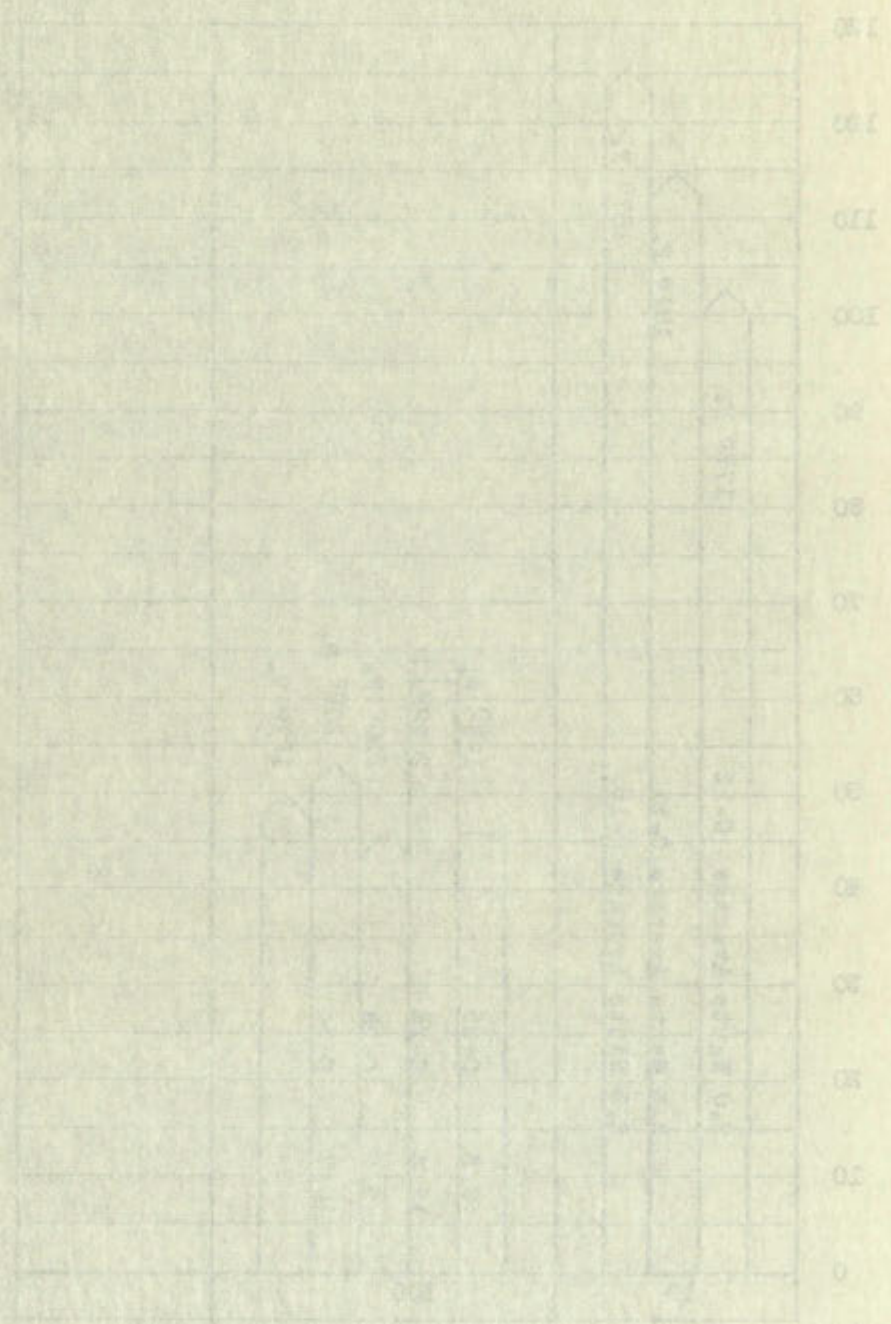
$R_C = 1.0 \Omega$

Pulse Power - Watts



Pulse Widths - Microseconds

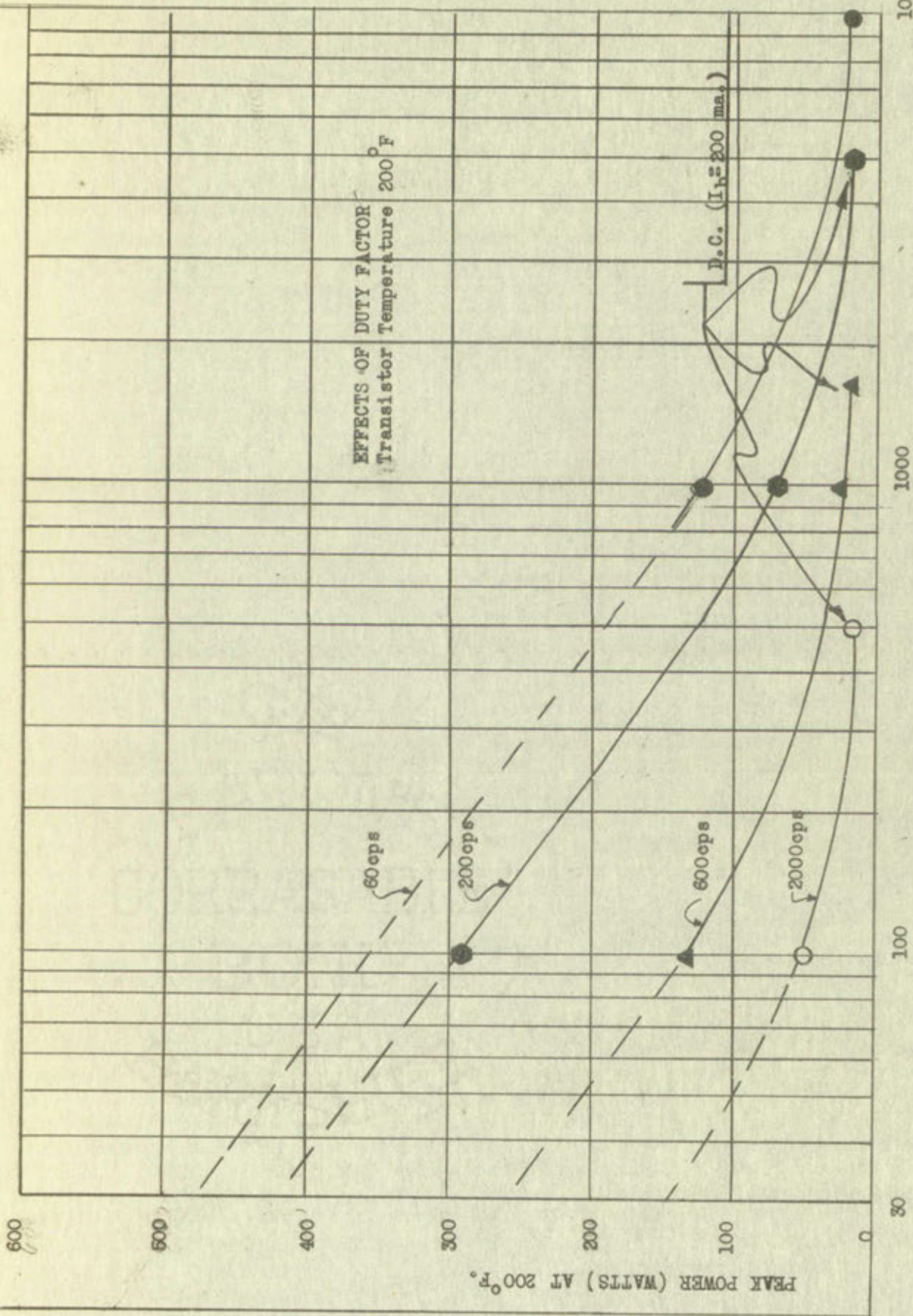
Figure 18
Pulse Power Ratings -- 2000 CPS
165° F. Ambient



SINUSOIDAL - 100

THE UNIVERSITY OF CHICAGO
 LIBRARY
 540 EAST 58TH STREET
 CHICAGO, ILL. 60637

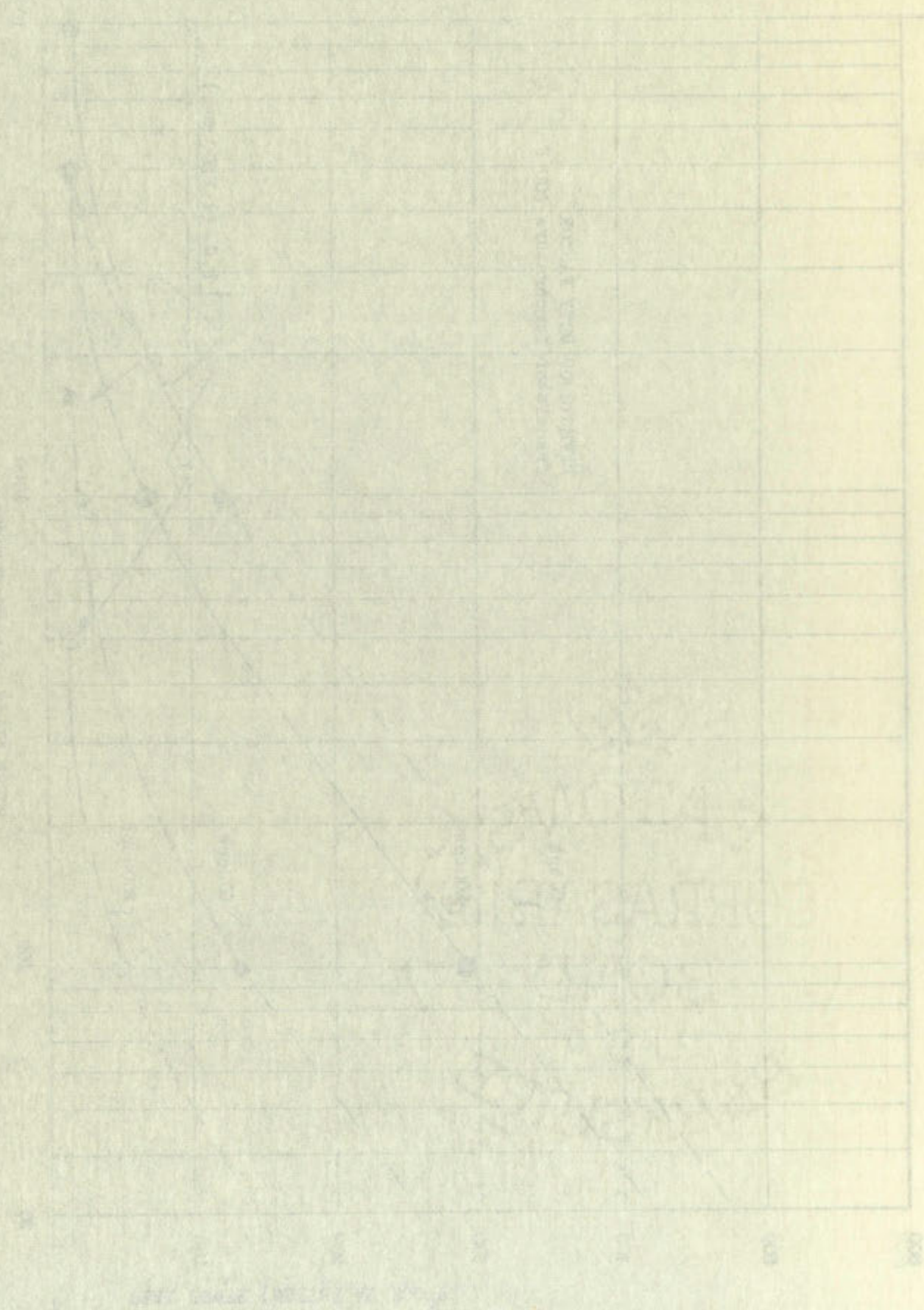
PULSE WIDTHS -- MICROSECONDS

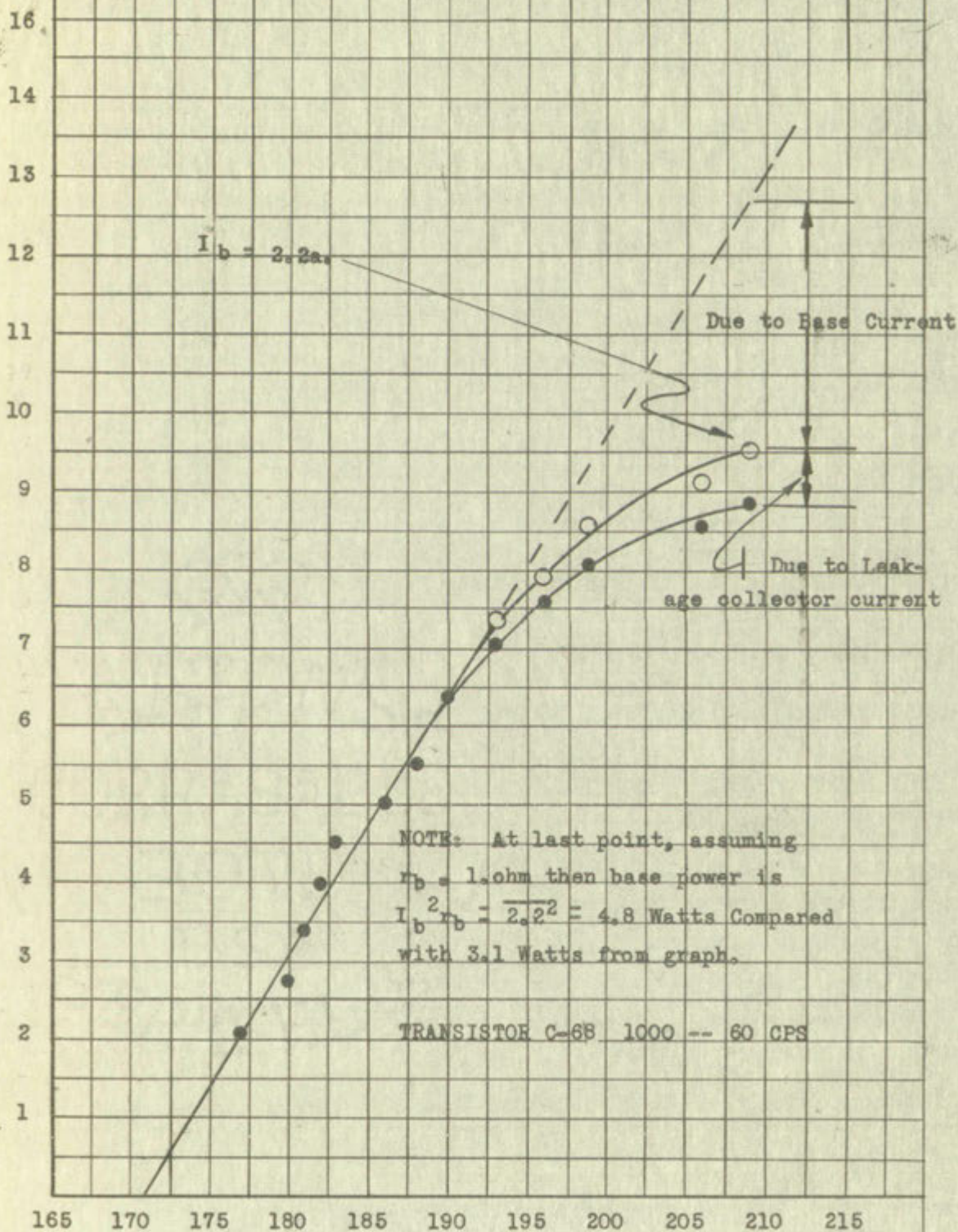


FULSE WIDTH -- MICROSECONDS

Figure 19

WATER MINERS -- MICROSECONDS

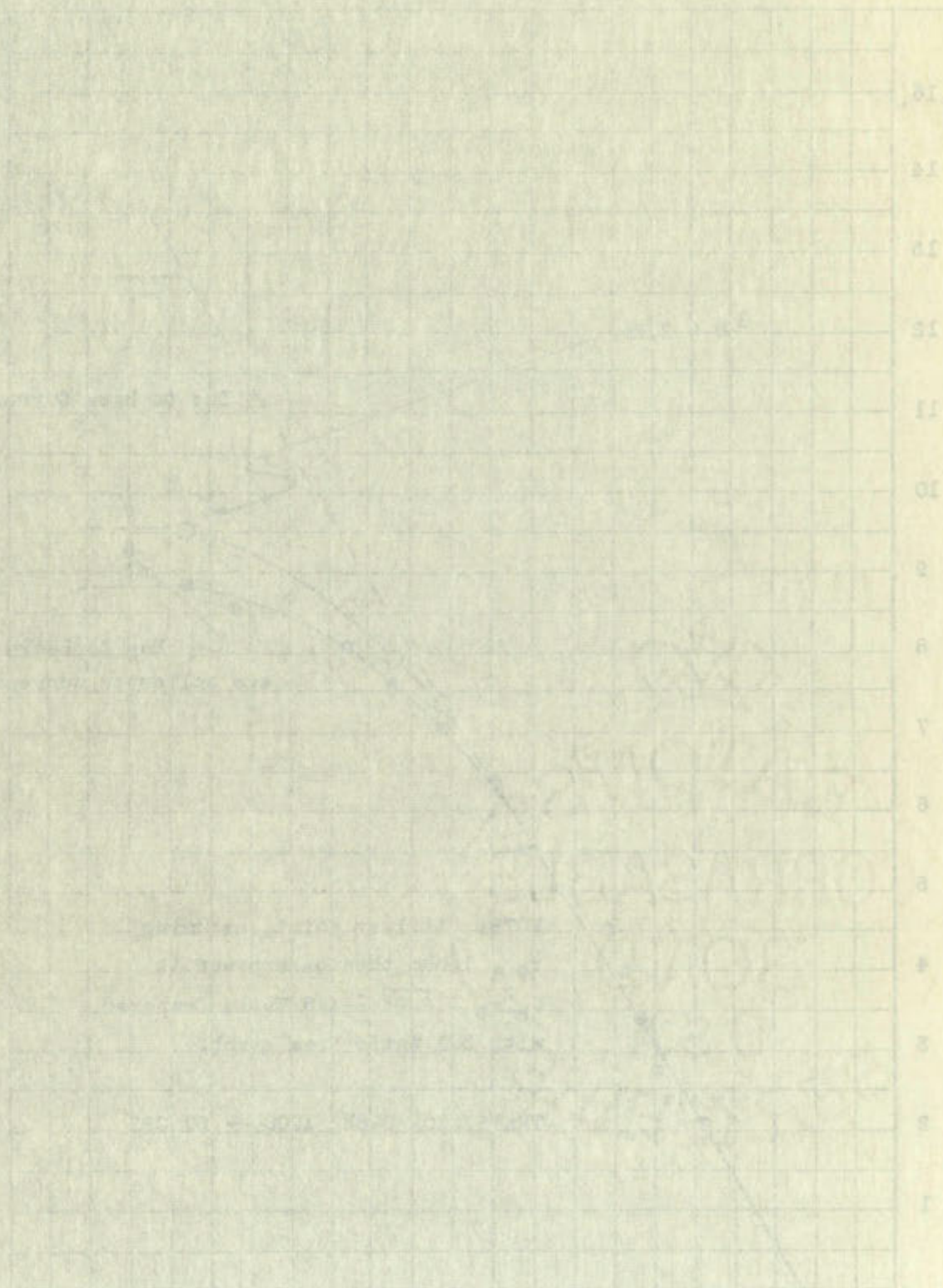




TRANSISTOR TEMPERATURE--DEGREES FAHRENHEIT

FIGURE 20

AVERAGE POWER - TEMPERATURE RELATIONSHIP



15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

IN THE PRESENCE OF THE COURT AT THE CITY OF NEW YORK
 I, JAMES H. HARRIS, Clerk of the Court, do hereby certify that the
 above is a true and correct copy of the original as filed in my
 office on this 15th day of June, 1915.

be controlled to prevent failure and yet the failure point can be determined. This makes it possible to use the same transistors for both tests.

The results of these tests are presented in Figures 21 and 22.

III. HEAT SINK CHARACTERISTICS

This test shows that approximately fifty percent more power can be dissipated in the transistor by doubling the area of the heat sink (in the heat sink range tested) and approximately three hundred percent more power can be dissipated in going from no heat sink to a three inch square sink. This information is contained in Figure 23. A comparison of heat sink characteristics of 85° F. and 165° F. ambient temperatures is made in Figure 24.

be controlled by means of a...
determined...
both...
The... of these... are...

THE... OF...

This... and...
can be...
also...
present...
There...
A...
which...

Average Collector Volts = 16.4
 " Collector Current = 660 ma.
 " Collector Power = 10.8 Watts
 6" sq. Heat Sink
 165° F. Ambient

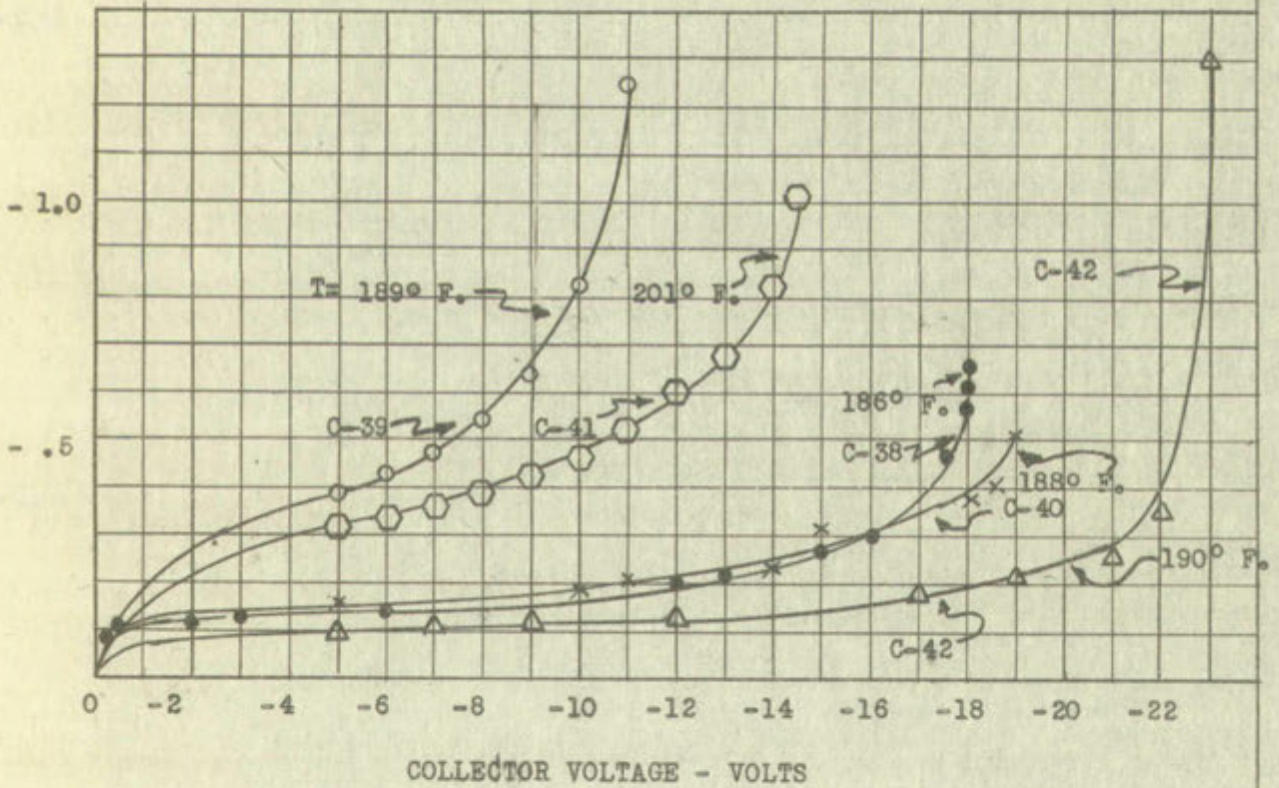


Figure 21

DIRECT CURRENT RATINGS -- $I_b = 0$

EXPERIMENTAL

RESULTS

Report No. 100
 Department of Physics
 University of California
 Berkeley, California
 1952

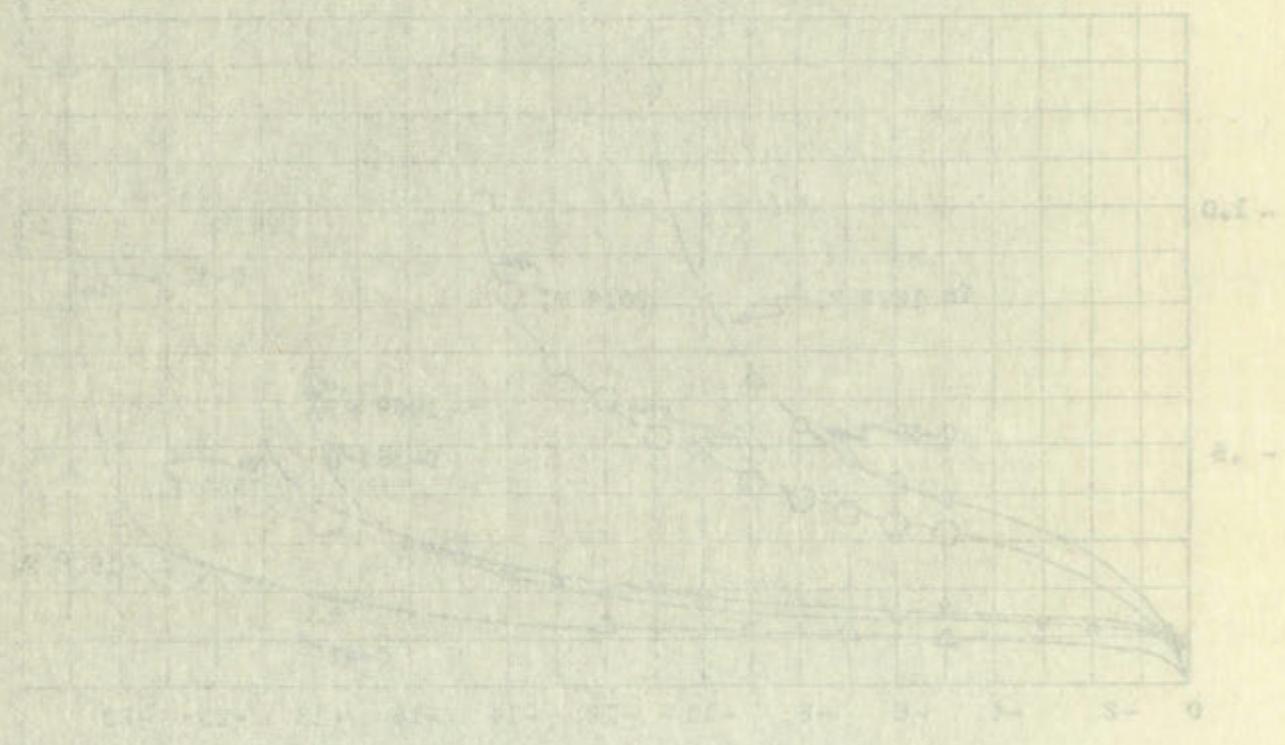


Figure 1
 Plot of G.I. versus X

100

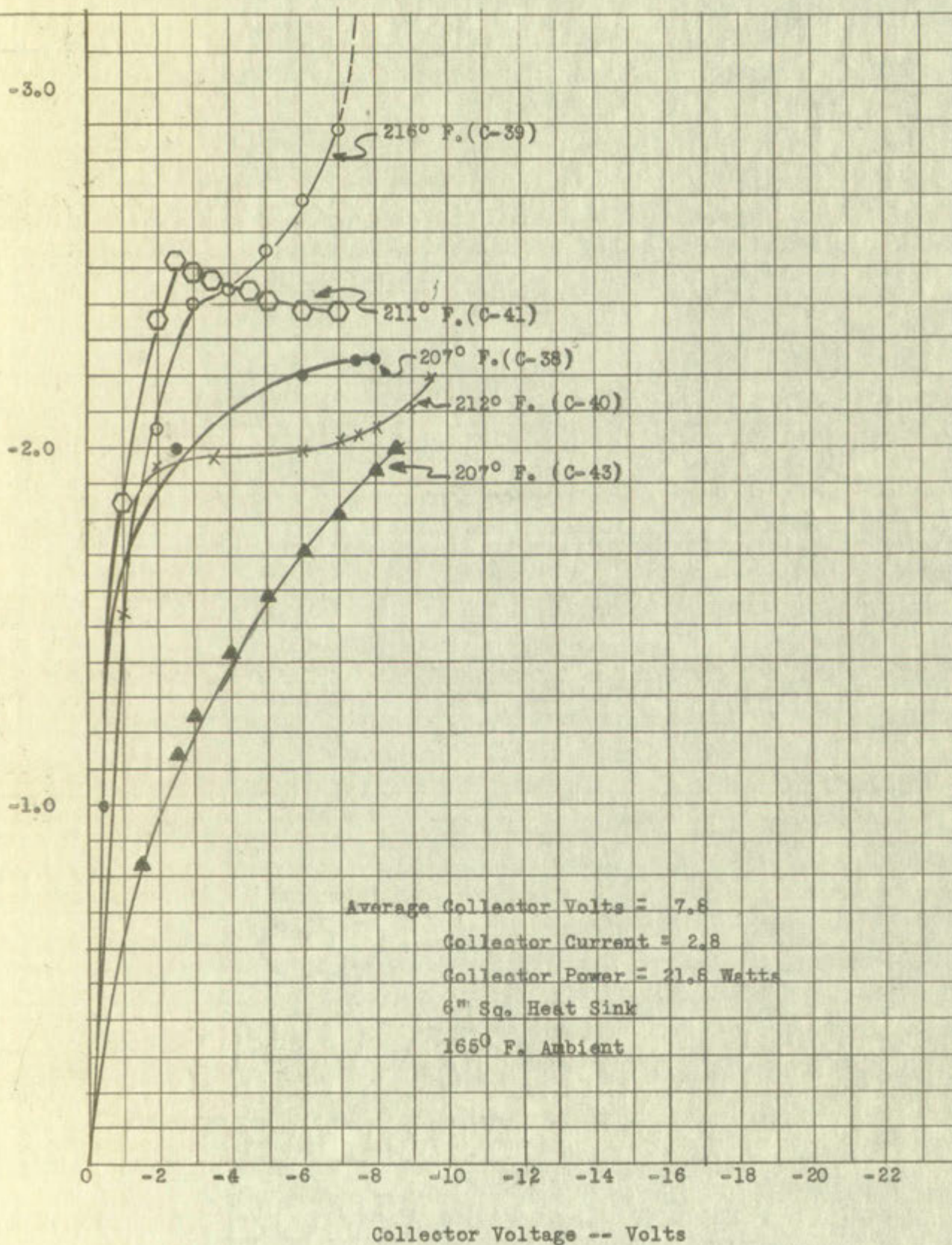
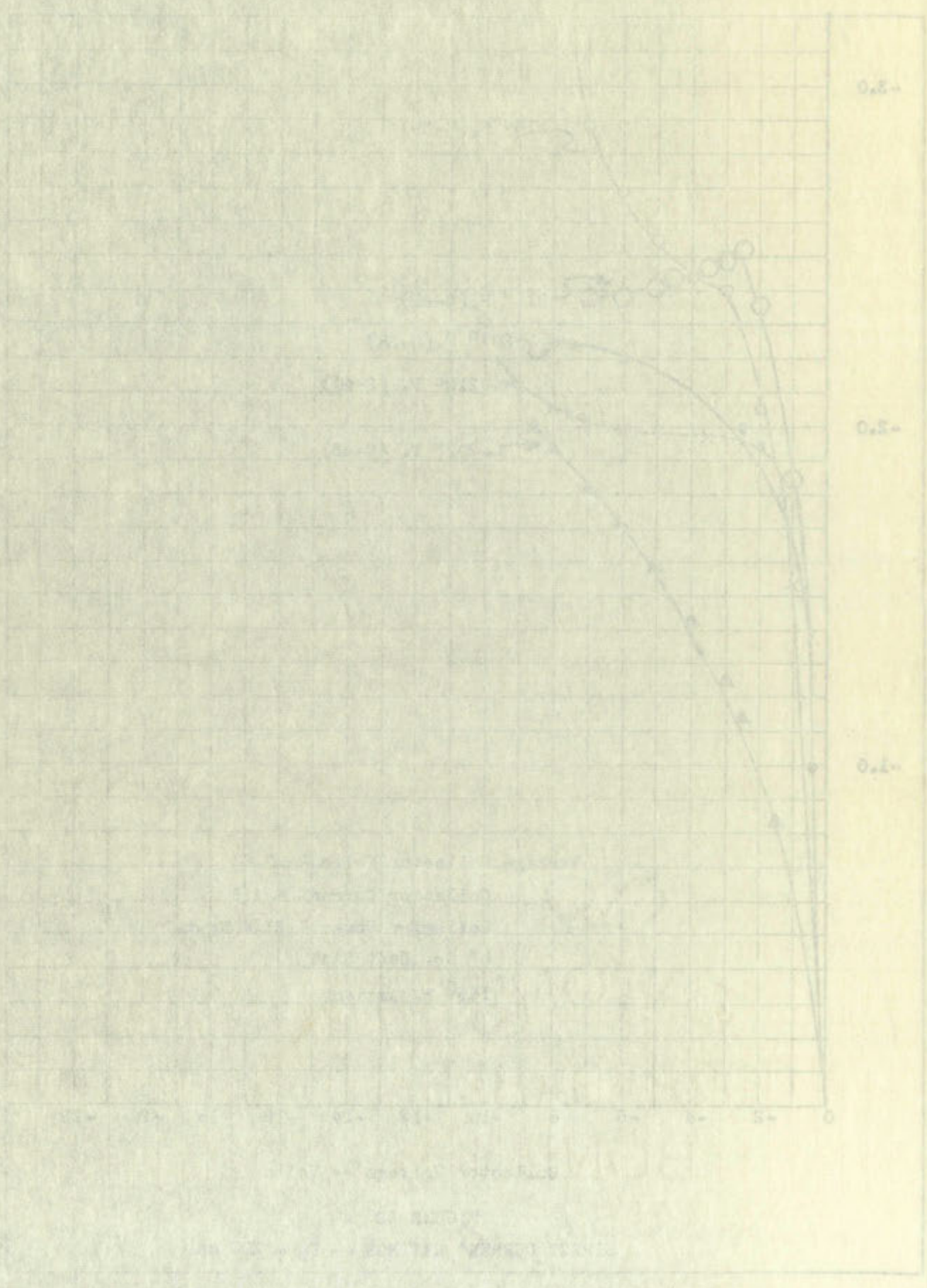


FIGURE 22
 DIRECT CURRENT RATINGS -- $I_b = 200$ ma.



14

12

10

8

6

4

2

0

6" square Heat sink
Slope = .36

4.25" square Heat Sink
Slope = .27

$$T_{op} = 165 + \frac{17P}{L}$$

3" square Heat Sink
Slope = .18

Without Heat Sink
Slope = .055

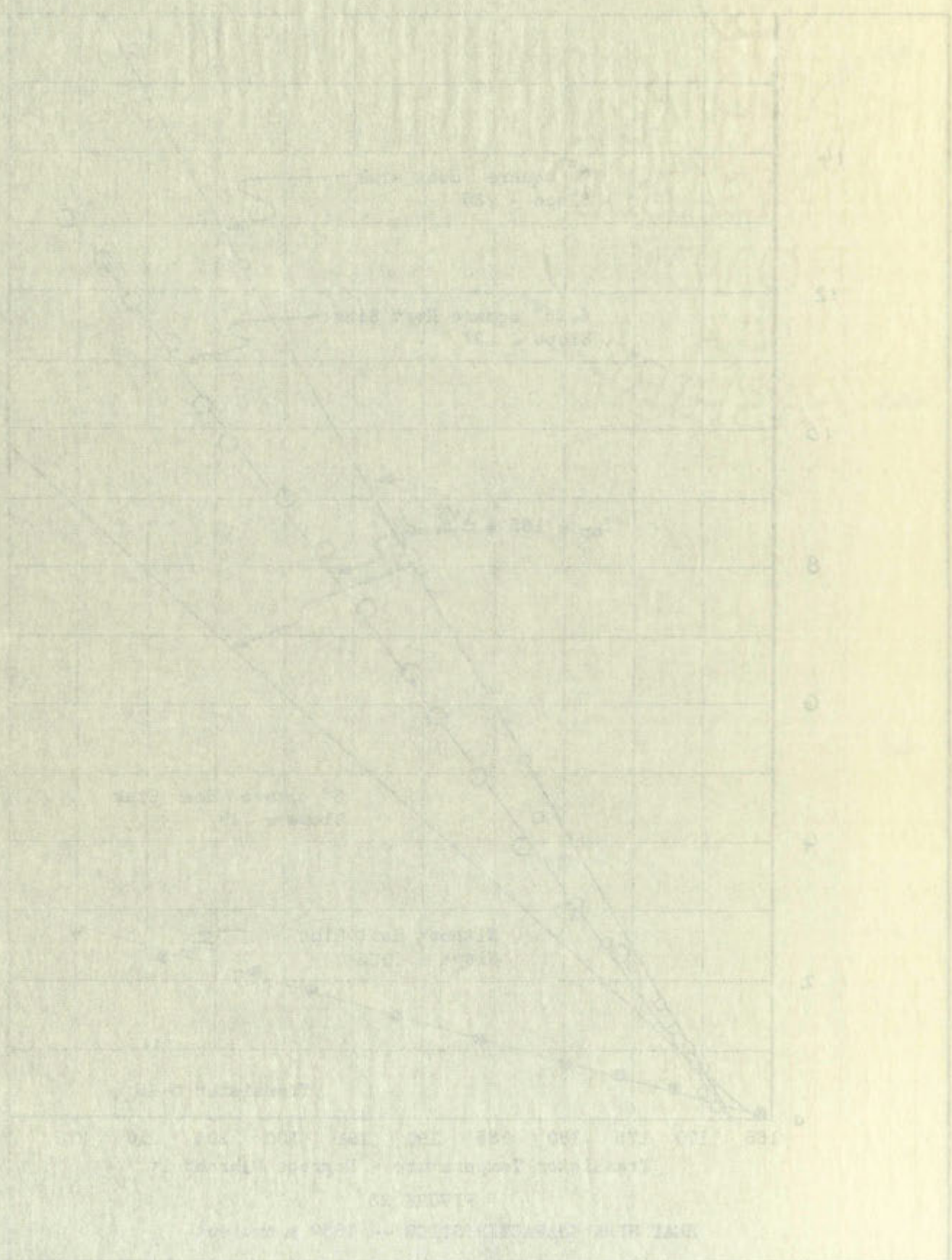
Transistor C-45

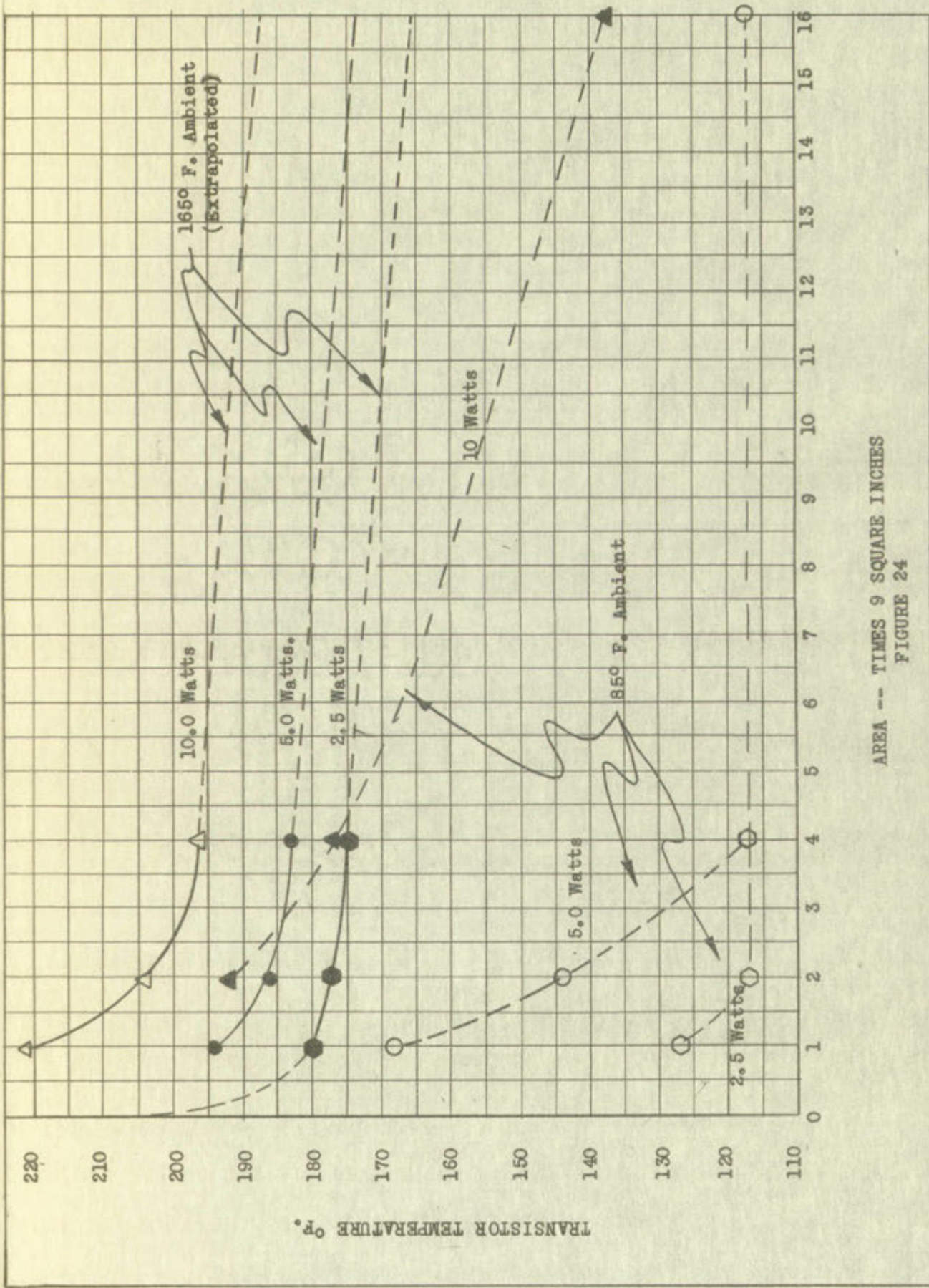
165 170 175 180 185 190 195 200 205 210 215

Transistor Temperature - Degrees Fahrenheit

FIGURE 23

HEAT SINK CHARACTERISTICS -- 165° F. Ambient

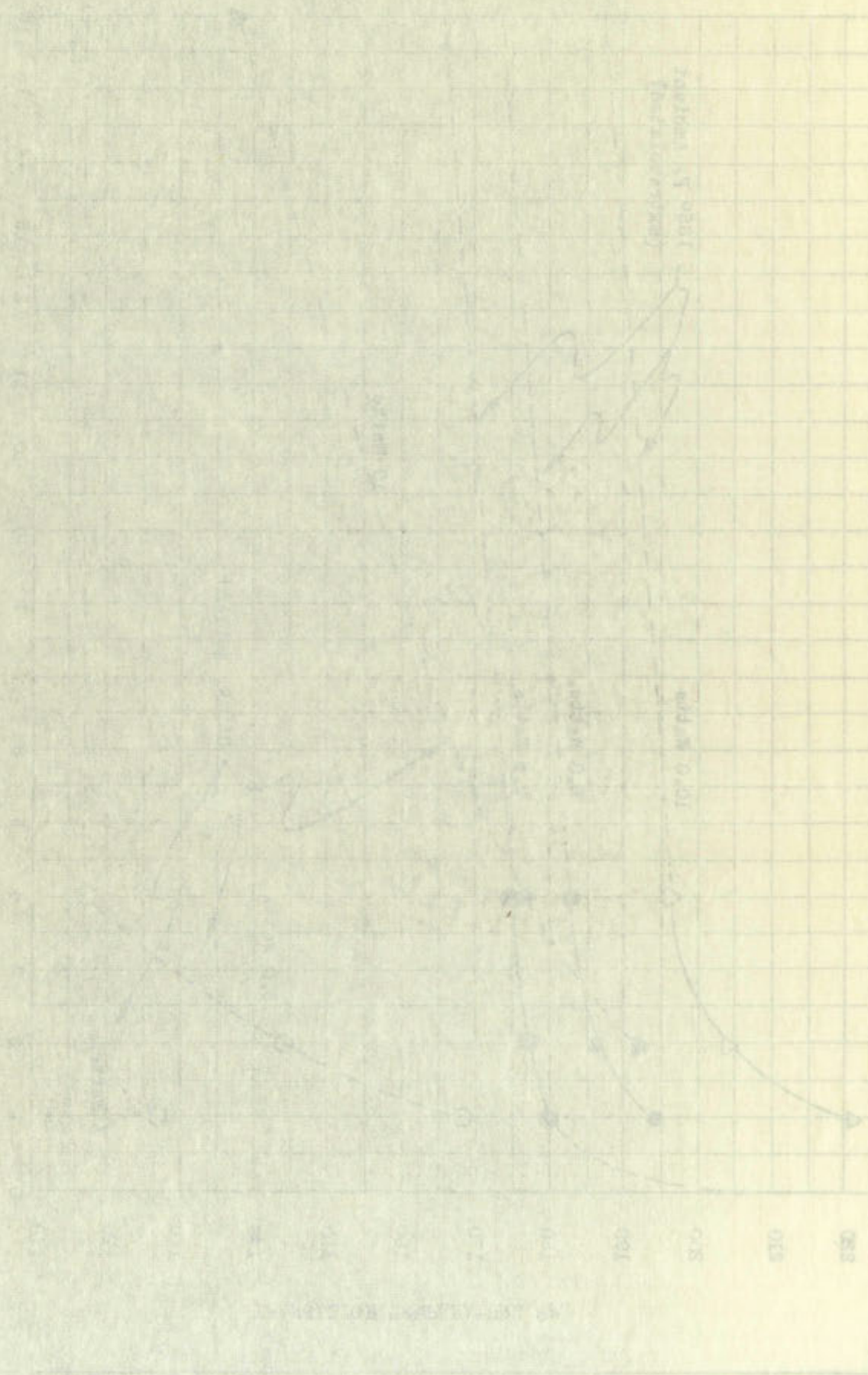




AREA -- TIMES 9 SQUARE INCHES
 FIGURE 24

HEAT SINK CHARACTERISTICS - 85 & 165° F. AMBIENT

1964 - 1965 - 1966 - 1967 - 1968 - 1969 - 1970 - 1971 - 1972 - 1973 - 1974 - 1975 - 1976 - 1977 - 1978 - 1979 - 1980 - 1981 - 1982 - 1983 - 1984 - 1985 - 1986 - 1987 - 1988 - 1989 - 1990 - 1991 - 1992 - 1993 - 1994 - 1995 - 1996 - 1997 - 1998 - 1999 - 2000 - 2001 - 2002 - 2003 - 2004 - 2005 - 2006 - 2007 - 2008 - 2009 - 2010 - 2011 - 2012 - 2013 - 2014 - 2015 - 2016 - 2017 - 2018 - 2019 - 2020 - 2021 - 2022 - 2023 - 2024 - 2025



1964 - 1965 - 1966 - 1967 - 1968 - 1969 - 1970 - 1971 - 1972 - 1973 - 1974 - 1975 - 1976 - 1977 - 1978 - 1979 - 1980 - 1981 - 1982 - 1983 - 1984 - 1985 - 1986 - 1987 - 1988 - 1989 - 1990 - 1991 - 1992 - 1993 - 1994 - 1995 - 1996 - 1997 - 1998 - 1999 - 2000 - 2001 - 2002 - 2003 - 2004 - 2005 - 2006 - 2007 - 2008 - 2009 - 2010 - 2011 - 2012 - 2013 - 2014 - 2015 - 2016 - 2017 - 2018 - 2019 - 2020 - 2021 - 2022 - 2023 - 2024 - 2025

CHAPTER V

DISCUSSION OF RESULTS AND CONCLUSIONS

The results of the pulse and D. C. tests point strongly in the direction that temperature destroys transistors. It could be stated further that average collector power destroys transistors except for the low duty cycle cases. If the collector power is assumed to be the only power increasing the temperature of the transistor, then less average power is required to raise the transistor temperature at the low duty factors than at the higher duty factors. This certainly can not be possible. That is to say that although the base resistance is quite small the base current becomes very large for the low duty factor pulses, thus increasing the total power input to the transistor and affecting the transistor temperature. The base power then, cannot be overlooked in the low gain region.

Efforts were made to pulse the transistor with 0.1 microsecond pulses but it was found that reproduction was very poor below 100 microsecond pulses. Ten microsecond pulses could be amplified but the rise time was equal to the pulse width while the fall time was usually about four times the pulse width.

The spread of transistor characteristics (taken from the characteristics of approximately seventy transistors) located in Appendix B, is so wide that a sample of five transistors does not give a very reliable picture of the maximum permissible ratings. Possibly a sample of twenty-five at each duty factor would be more reliable.

THE HISTORY OF THE UNITED STATES

The results of the war were...
discussed the...
further the...
the...
only...
average...
for...
not...
part...
factor...
and...
be...
effort...
person...
microscopic...
also...
about...

The...
characteristic...
Algebra...
give...
Boutby...
relatively...

The D. C. tests show clearly that in order for the transistor circuit to be stable at 165° F. ambient with the collector voltage of any size that the base circuit must be back biased. Back bias of ten volts was used for all tests except the D.C. tests which did not require back bias since a large resistor was used in the collector circuits to limit the collector current.

From the heat sink characteristics at 165° F. ambient an equation was developed which makes it possible to predetermine the operating temperature of a transistor at an average D. C. power dissipated in the transistor for an arbitrary heat sink. The equation

$$T_{op} = 165 + \frac{17 \bar{P}}{L}$$

is developed in Appendix D. T_{op} is the operating temperature of the transistor when dissipating an average power, \bar{P} using a square heat sink with L the length of a side.

Thus, if an average power of five watts were to be dissipated in a transistor using a square heat sink of a length of three inches.

then

$$T_{op} = 165 + \frac{17 (5)}{3} = 165 + \frac{80}{3} = 193^{\circ} \text{ F.}$$

as compared with 194° F. from Figure 23.

The failures witnessed by the Sandia Corporation as mentioned in Chapter I, Introduction, were most likely due to a large D. C. component of power which did not exceed the limits of the transistor until the large current spikes were induced.

The first part of the report is devoted to a description of the experimental apparatus and the method of measurement. It is shown that the results obtained are in good agreement with the theoretical predictions. The second part of the report is devoted to a discussion of the results and their significance. It is shown that the results are in good agreement with the theoretical predictions.

From the results of the experiment it is concluded that the results are in good agreement with the theoretical predictions. The third part of the report is devoted to a discussion of the results and their significance. It is shown that the results are in good agreement with the theoretical predictions.

It is concluded that the results are in good agreement with the theoretical predictions. The fourth part of the report is devoted to a discussion of the results and their significance. It is shown that the results are in good agreement with the theoretical predictions.

That is, a certain part of the results are in good agreement with the theoretical predictions. The fifth part of the report is devoted to a discussion of the results and their significance. It is shown that the results are in good agreement with the theoretical predictions.

The results are in good agreement with the theoretical predictions. The sixth part of the report is devoted to a discussion of the results and their significance. It is shown that the results are in good agreement with the theoretical predictions.

The results are in good agreement with the theoretical predictions. The seventh part of the report is devoted to a discussion of the results and their significance. It is shown that the results are in good agreement with the theoretical predictions.

Further testing could be done to prove this point by pulsing the collector circuit with large power pulses which were known not to contain a D. C. component.

Further reading would be in the form of a book
the subject being the same as that of the
to be read in the course of the year.

1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900

BIBLIOGRAPHY

REPRODUCTION

BIBLIOGRAPHY

Griffith, LeRoy A., Germanium Power Transistors, Minneapolis-
Honeywell Regulator Company, Minneapolis 8, Minnesota, Trans-
istor Division, paper dated February 9, 1955, TR73pl.

MEMORANDUM

Griffin, John A., General in Charge, Western
Engineering Company, Cincinnati, Ohio
Refer attached paper dated February 1, 1934.

APPENDICES

1850
THE
GREAT
REPUBLICAN
PARTY
OF
THE
UNITED STATES

APPENDIX A
MANUFACTURER'S SPECIFICATIONS OF
THE TYPE CTP-1003 TRANSISTORS

Description. The CTP-1003 transistor is a hermetically sealed PNP germanium power transistor designed for general use at nominal collector voltage up to 28 volts D.C. It is characterized by low collector saturation voltage, moderate current gain, and high current handling capacity. The collector is electrically connected to the metal housing. Where the collector must be insulated from the chassis, the large area of the mounting flange permits adequate heat flow through the insulating medium (e.g., mica).

Electrical Specifications.

Absolute maximum ratings

Instantaneous collector to base voltage	60 V.
Collector supply voltage	30 V.
Junction temperature	85° C.
Instantaneous total peak power	25 W.
Average total power with infinite heat sink at 25° C.	25 W.
Average total power (no heat sink) in free air at 25° C.	2.25 W.

ANNEX A

MANUFACTURER'S SPECIFICATIONS OF
THE TYPE CTR-1003 TRANSISTOR

Description. The CTR-1003 transistor is a silicon, junction
type germanium power transistor designed for general use as a signal
collector voltage up to 50 volts D.C. It is characterized by low
collector saturation voltage, moderate current gain, and high
current handling capacity. The collector is electrically connected
to the metal housing. Where the collector was not connected from
the chassis, the large area of the mounting flange serves to dissipate
heat flow through the insulating medium (air, oil, etc.).

Electrical Specifications

Absolute maximum ratings

Instantaneous collector base voltage	50 V.
Collector supply voltage	30 V.
Junction temperature	85°C
Instantaneous total peak power	25 W.
Average total power with pulsed heat sink at 50°C	35 W.
Average total power (no heat sink) in free air at 50°C	5.5 W.

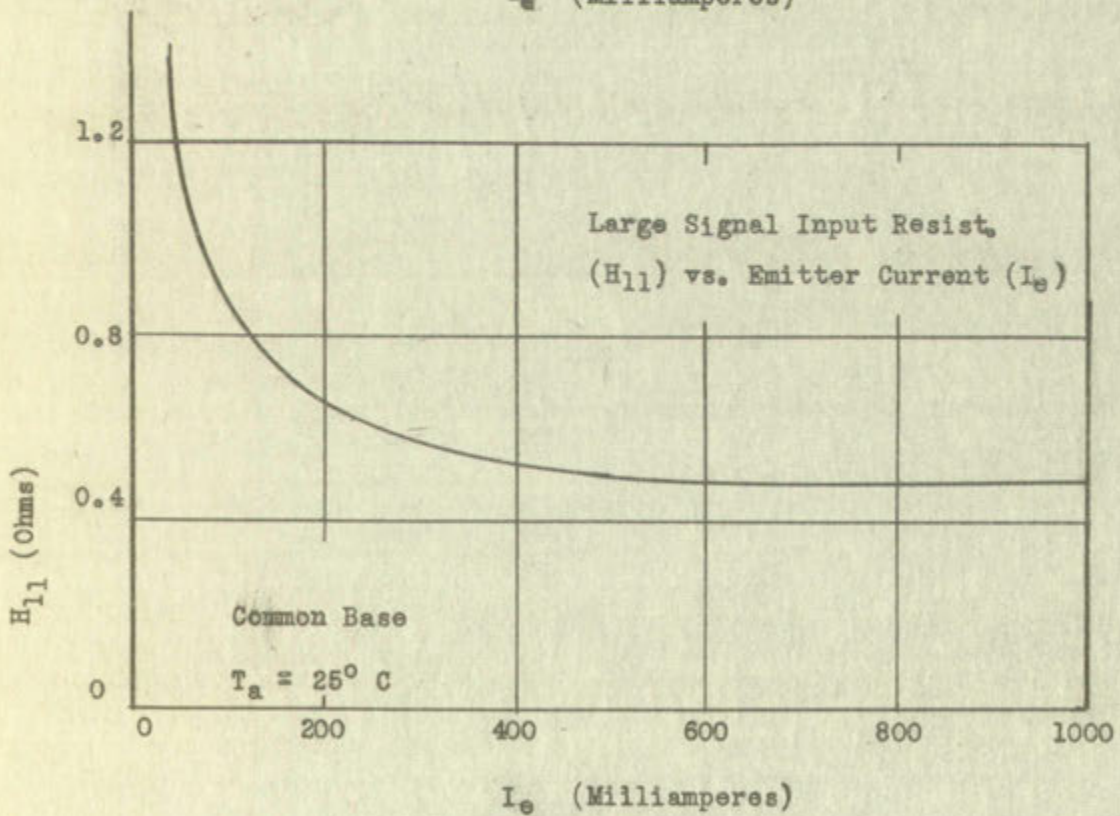
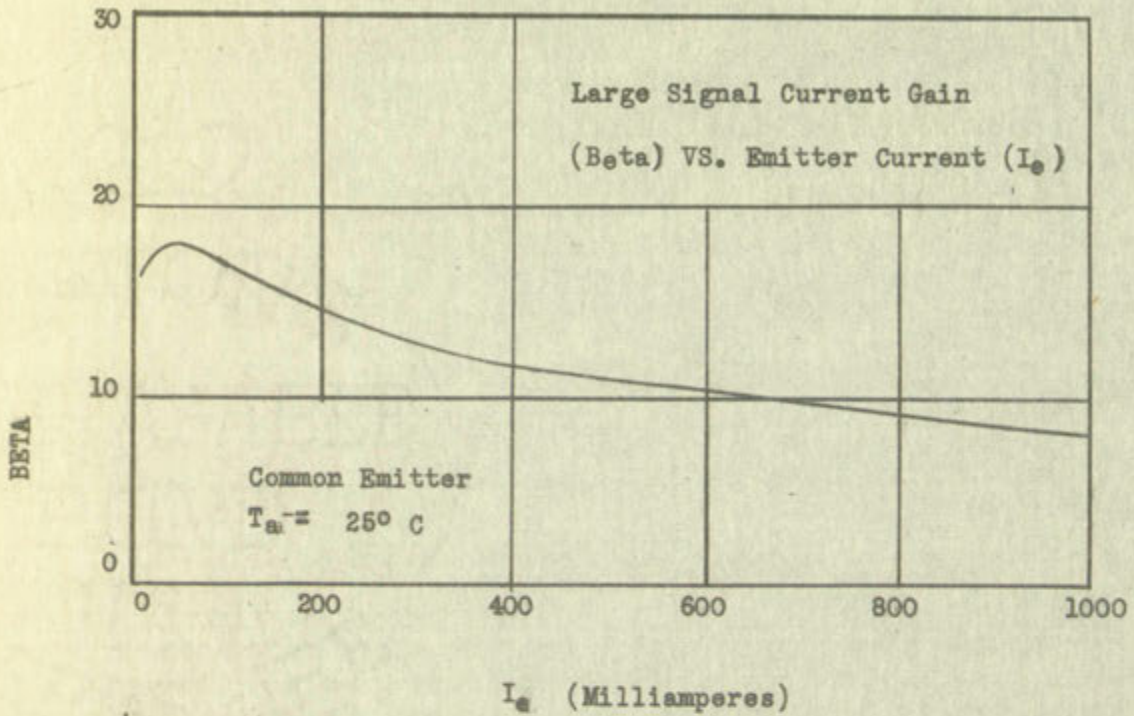
Characteristics at 25° C.*

Test	Conditions	Symbol	Min	Max	Unit
Collector cut-off current	$V_{cb} - -60V$ $I_e - 0$	I_{co}		2.0	ma
Emitter cut-off current	$V_{eb} - 6V$ $I_c - 0$	I_{eo}		.20	ma
Power gain, common emitter, transformer coupled	$V_{cc} - 14.2V$ $I_c - .37A$ $R_L - 30\text{ ohms}$ $R_g - 10\text{ ohms}$	P_g	23.0		db
Power gain cut-off frequency	Same as for Power gain	f_{pg}	4	K_c (250 M.S.)	

*Cooling must be provided equivalent to mounting the transistor in the center of a 3" x 3" piece of aluminum, 1/16" thick, suspended in free air.

Test	(Symbol)	Value
Collector cut-off current	I_{c0}	0.00
Emitter cut-off current	I_{e0}	0.00
Power gain, common emitter, transformer coupled	A_p	10
Power gain cut-off	A_{p0}	10
Frequency	f	1000

Cooling was provided equivalent to that of the transistor in the center of a 1" x 1" piece of aluminum. The transistor was in free air.



CLEVITE TRANSISTOR PRODUCTS

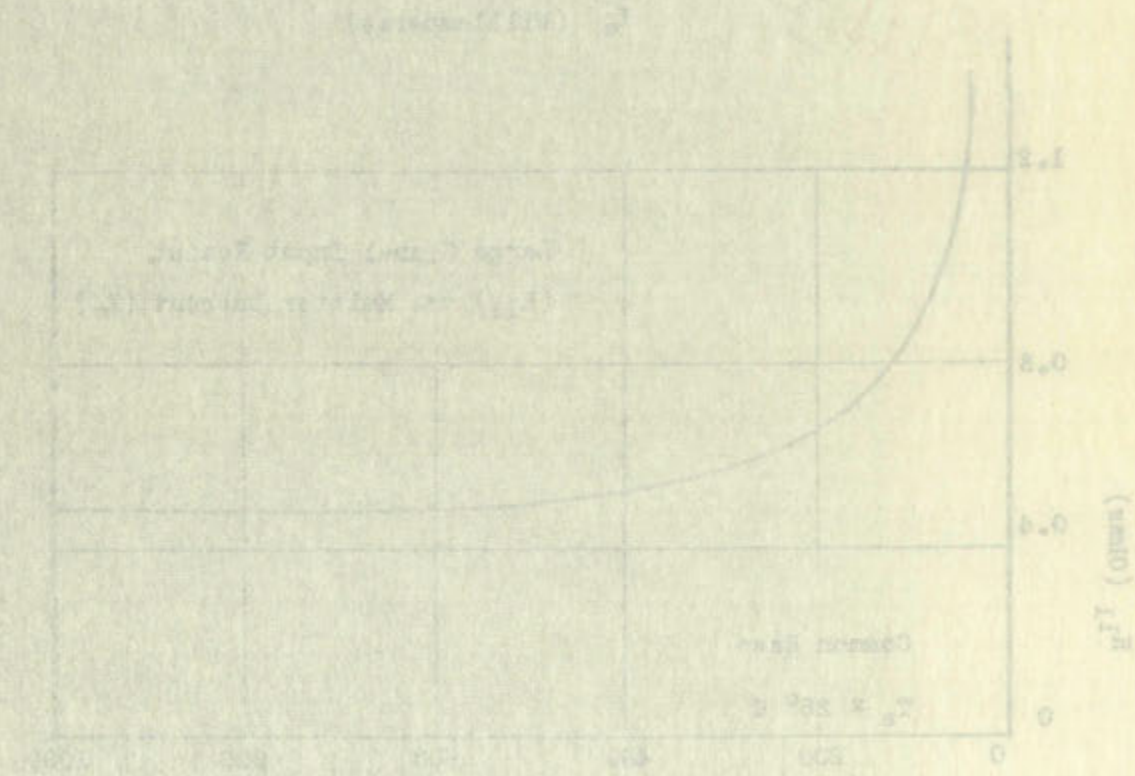
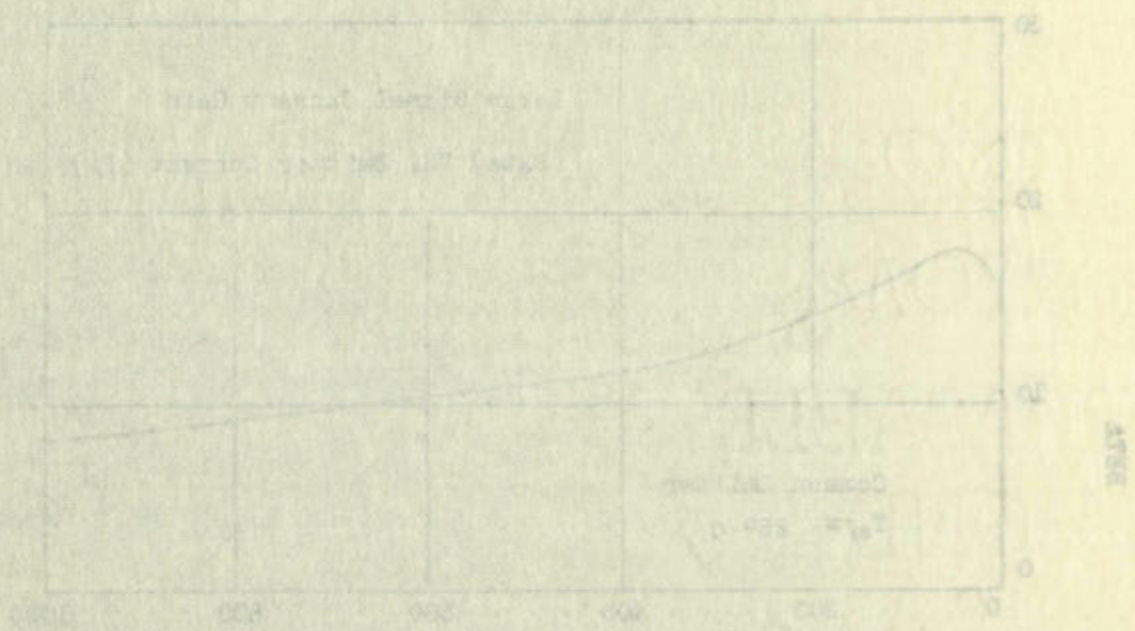
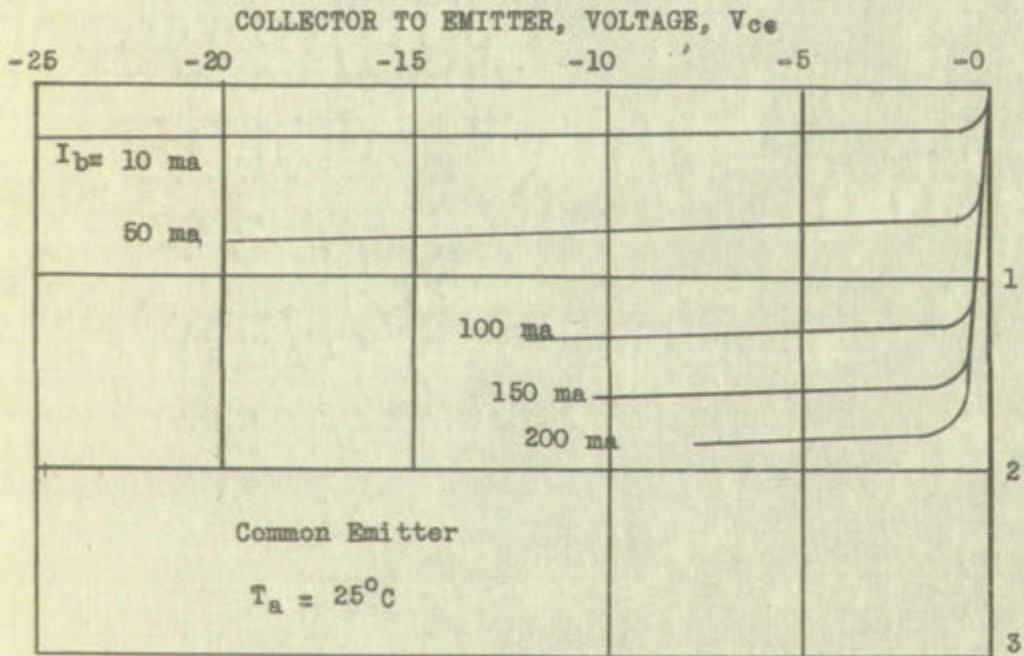


Figure 1. ATRFE vs. Wavelength (nm) and ATRFE (nm) vs. Wavelength (nm) for a common law.

CTP-1003

TYPICAL CHARACTERISTICS



CLEVITE TRANSISTOR PRODUCTS

FEDERAL BUREAU OF INVESTIGATION
 DEPARTMENT OF JUSTICE
 CONSENT TO RELEASE INFORMATION

			10
			20
		Signature of Agent Date	

FEDERAL BUREAU OF INVESTIGATION

APPENDIX B

THE SPREAD OF TRANSISTOR CHARACTERISTICS

Preceding all tests, a photograph of the input (base) and output (collector) characteristics of each transistor as taken with the transistor connected common emitter.

It is from these characteristics that the following spread of collector and base characteristics was taken.

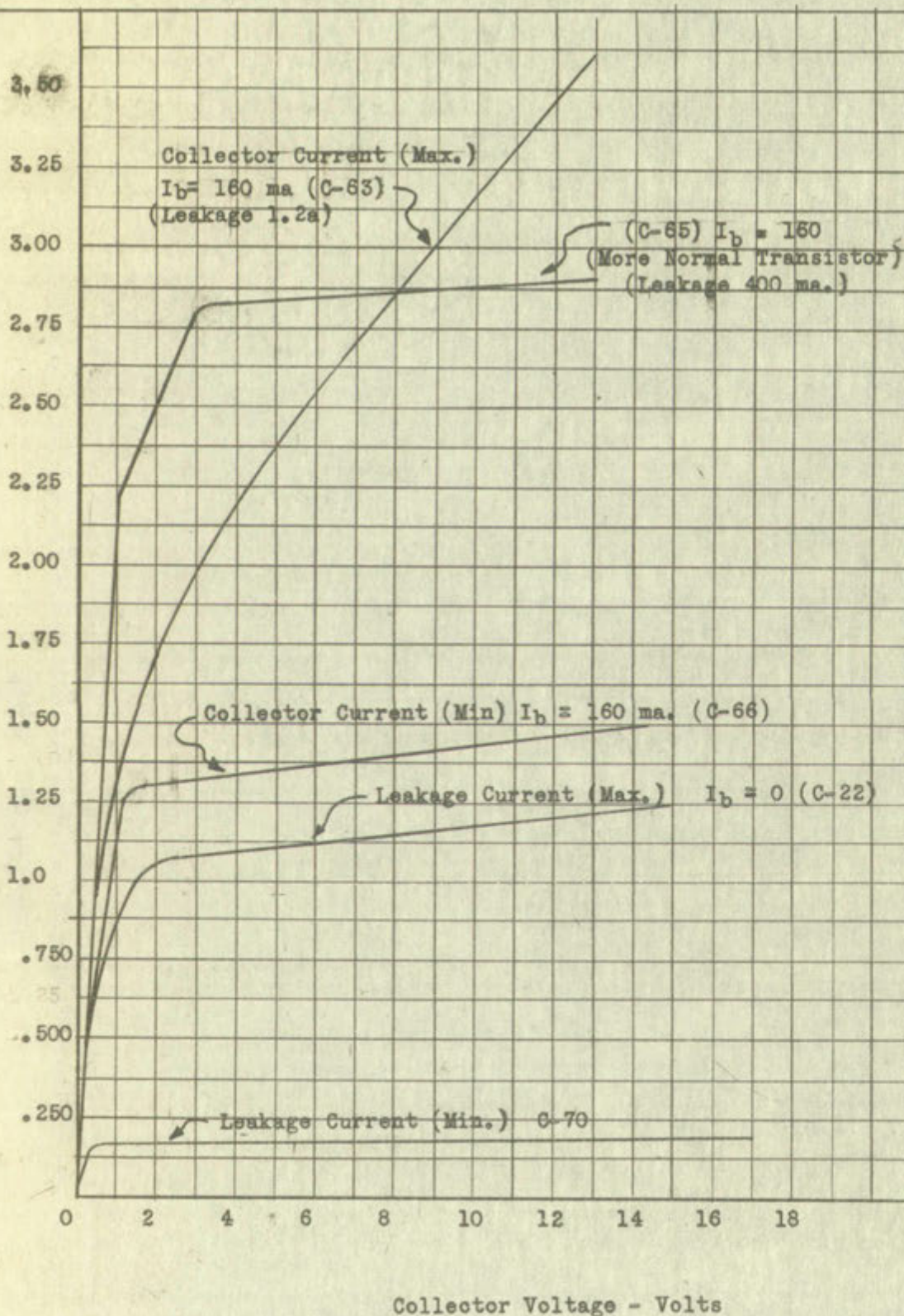
MEMORANDUM

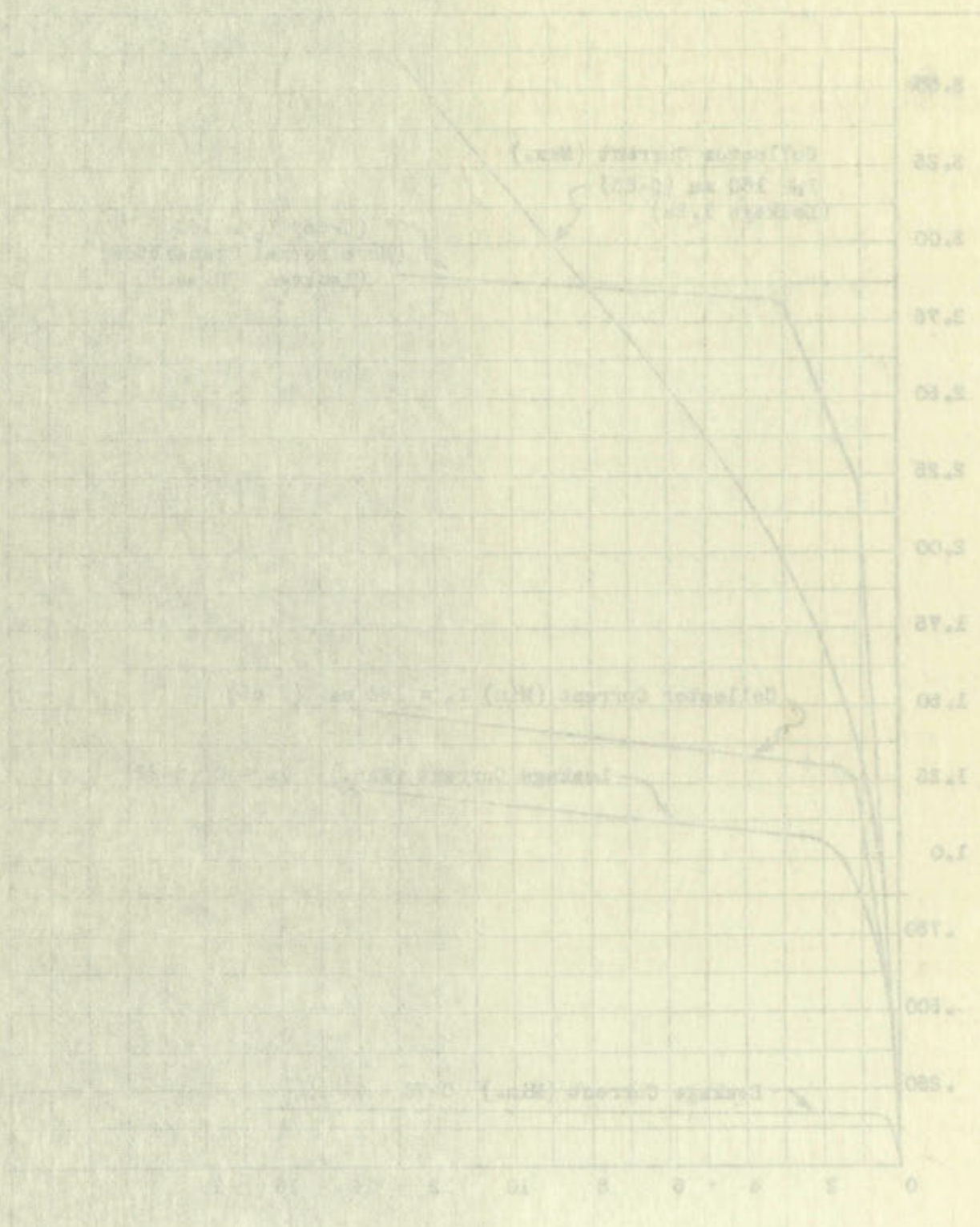
FOR THE CHIEF OF BUREAU OF REVENUE

Proposed to amend the provisions of the Internal Revenue Code relating to the collection of taxes on the sale of certain commodities, and to provide for the collection of such taxes in certain cases.

It is proposed that the following provisions be added to the Internal Revenue Code:

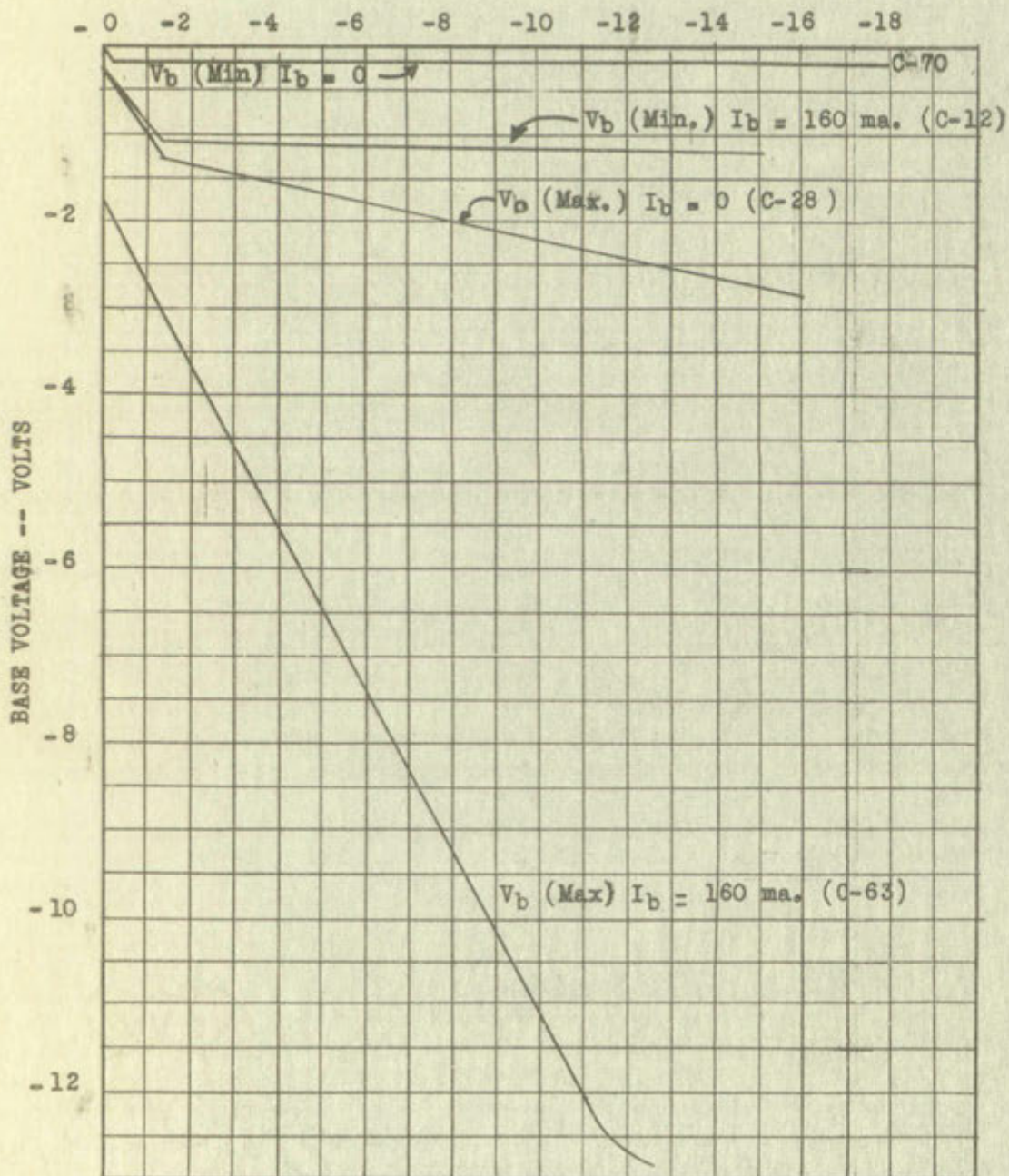
THE SPREAD OF COLLECTOR CHARACTERISTICS





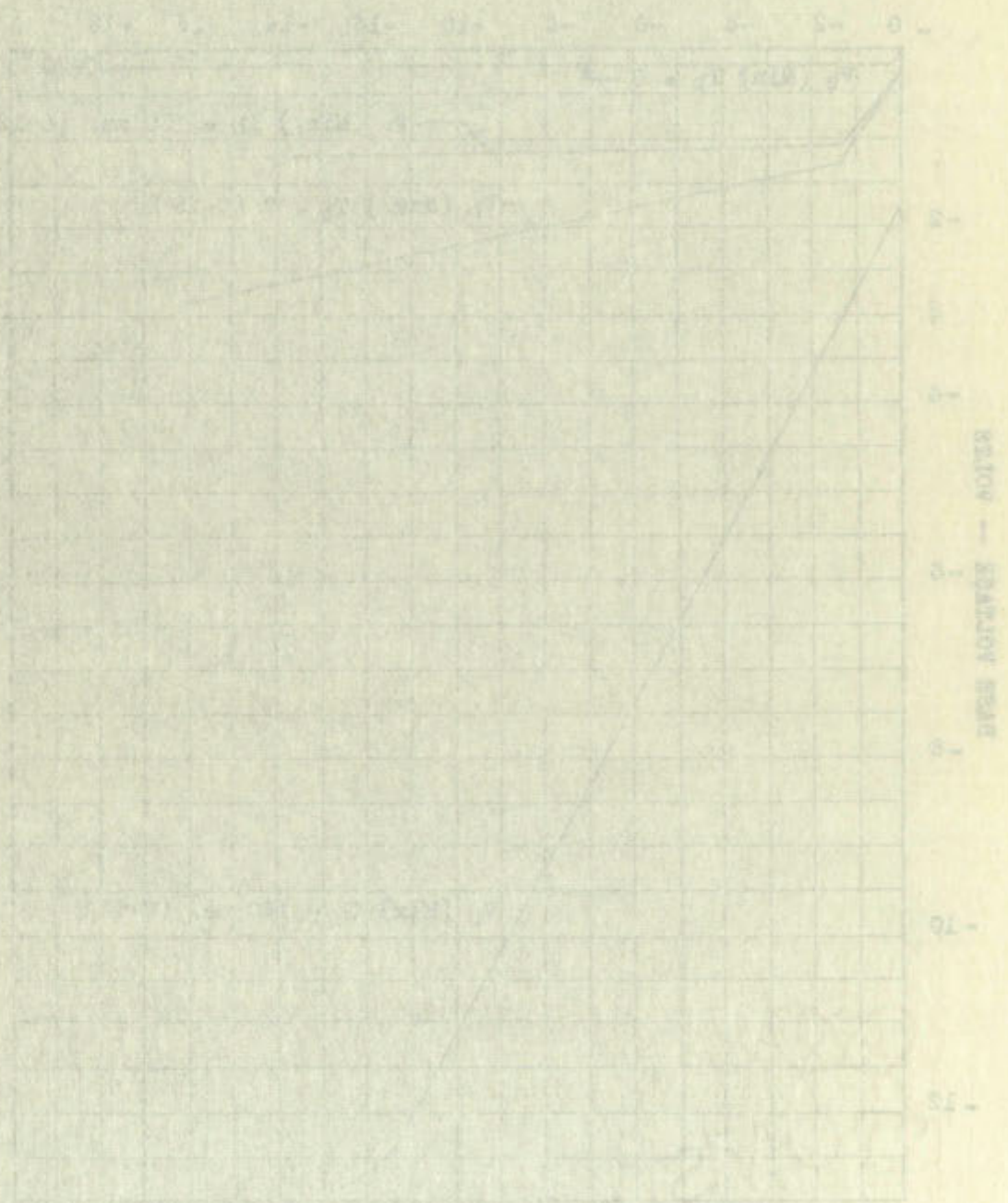
THE SPREAD OF BASE CHARACTERISTICS

Collector Voltage -- Volts



THE STATE OF TEXAS, COUNTY OF DALLAS

BEFORE ME, the undersigned authority, on this day personally appeared _____



WITNESSED my hand and seal of office this _____ day of _____, 19____.

Notary Public in and for the State of Texas

APPENDIX C

PERCENT DUTY FACTOR CURVES

The curves contained in this appendix are the plot of the various collector peak power points against transistor temperature taken directly from the experimental data. This set of curves was plotted for the purpose of extending the pulse power into the failure region which had not been done experimentally.

REPORT ON THE PROGRESS OF THE WORK DURING THE YEAR 1900

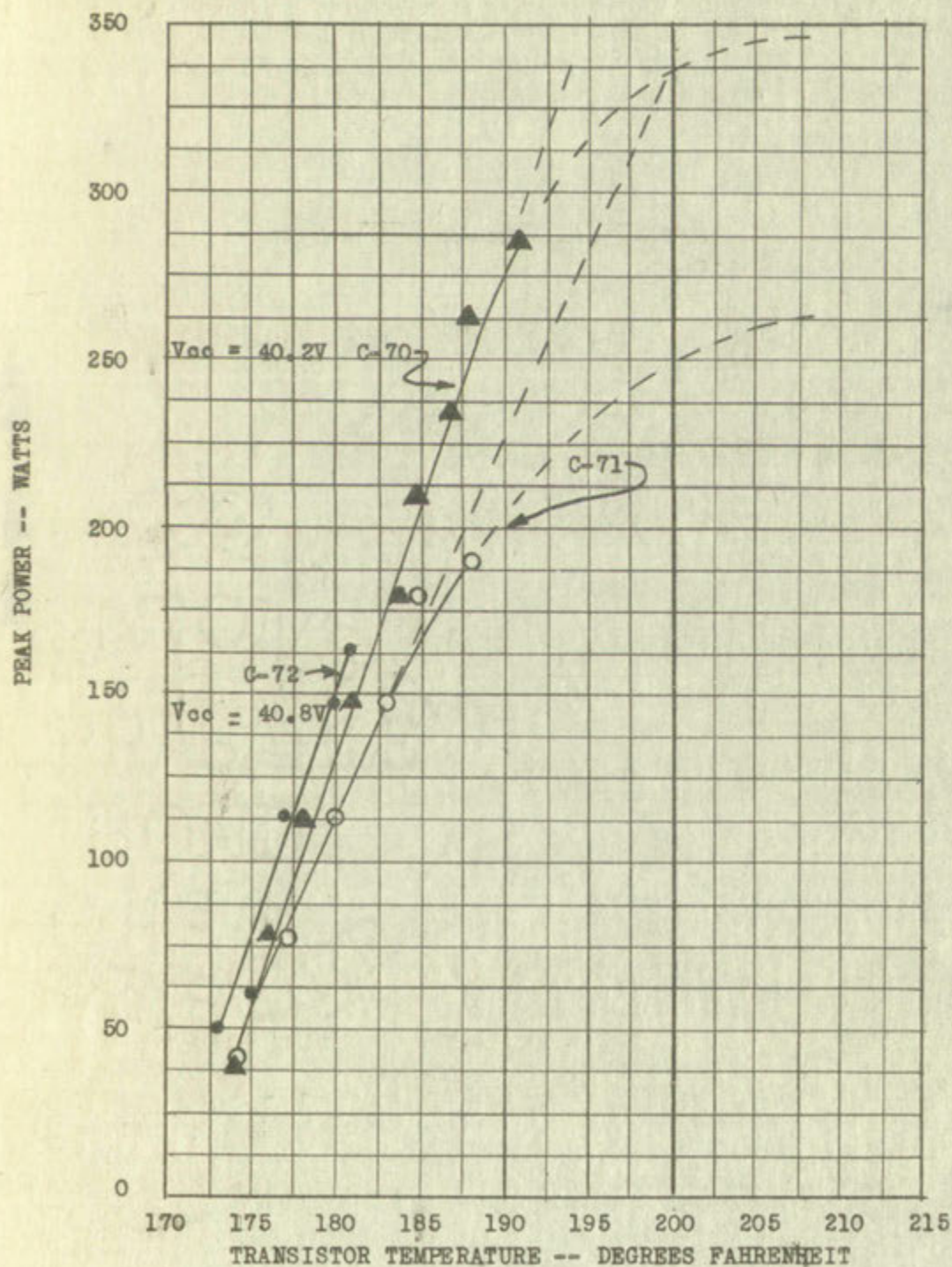
The work of the Bureau during the year 1900 has been devoted to the study of the various collections of the Bureau and to the preparation of reports on the progress of the work. The following are the reports published during the year:

1900

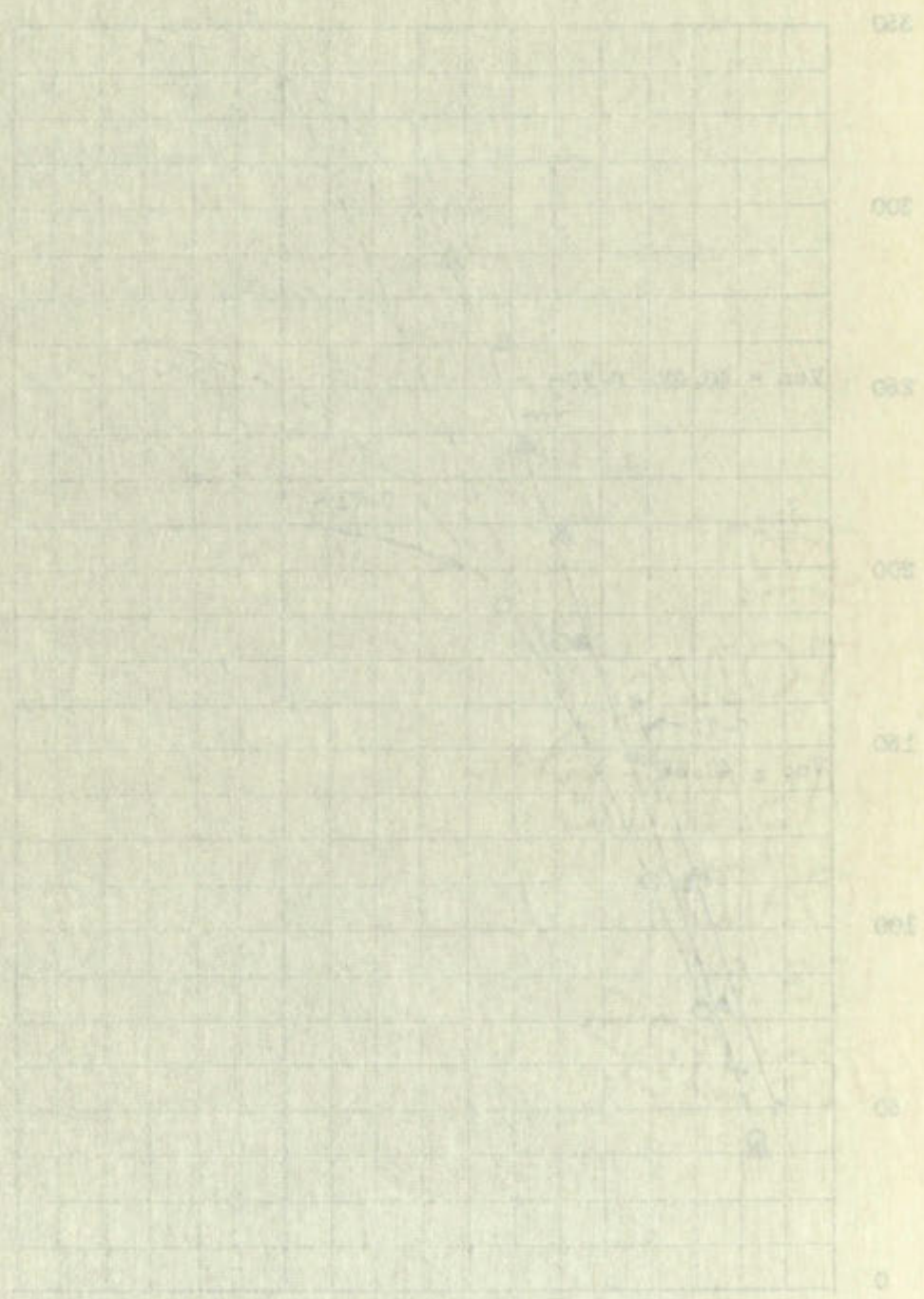
THE BUREAU OF GEOGRAPHICAL NAMES
WASHINGTON, D. C.

TWO PER CENT DUTY FACTOR

100 -- 200 CPS



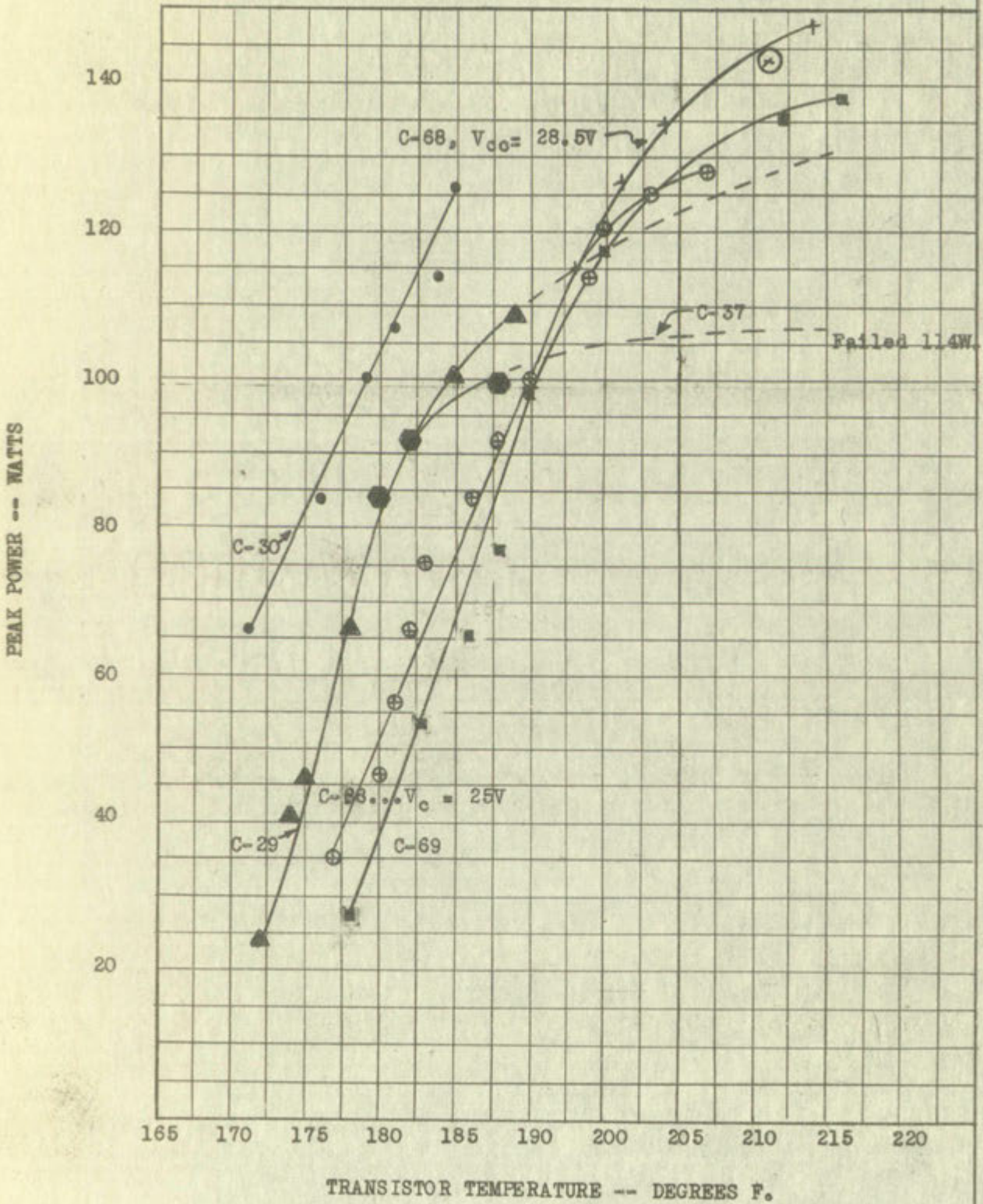
THE 1950-51 WINTER
1950-51

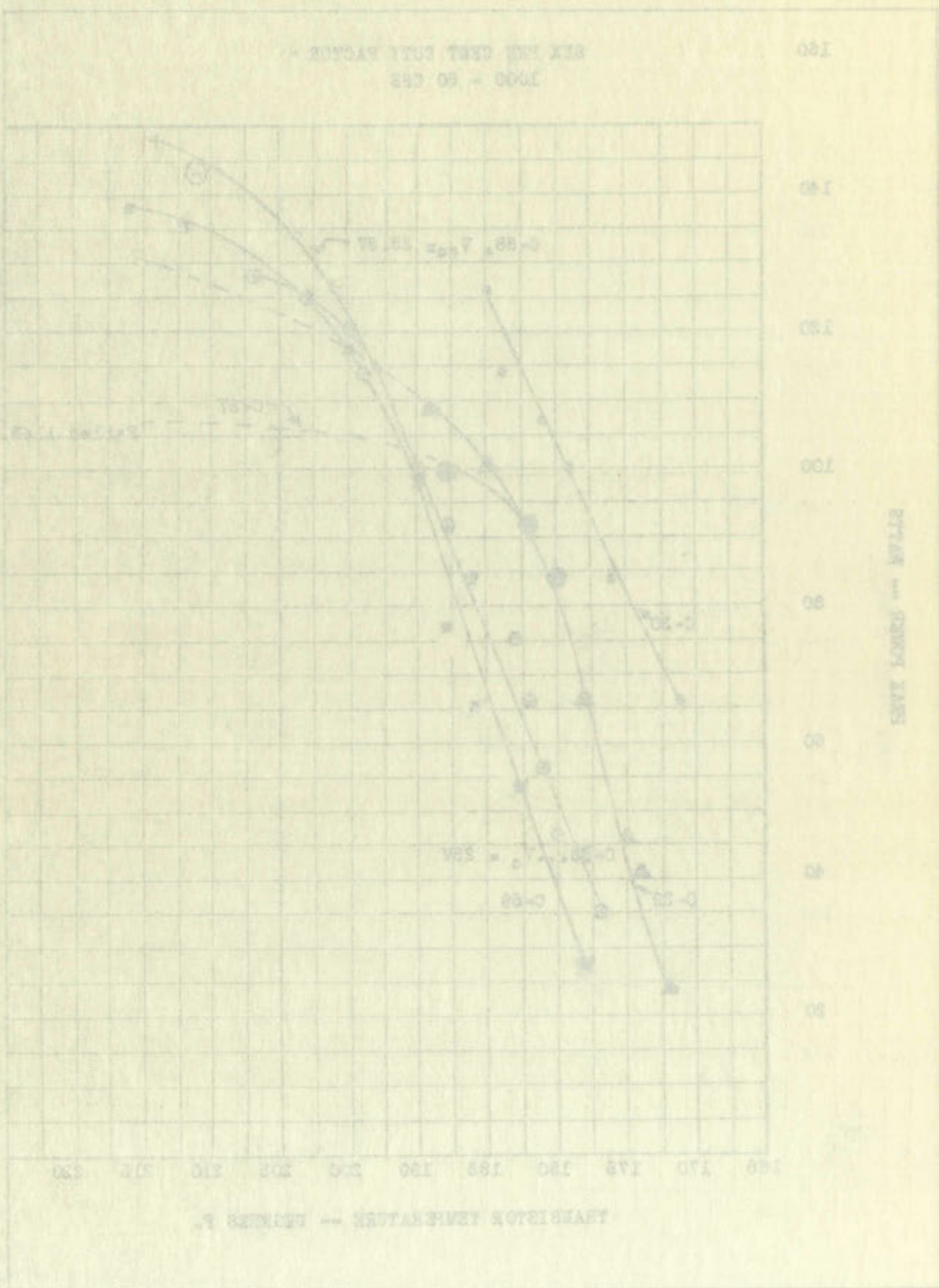


THE 1950-51 WINTER
1950-51

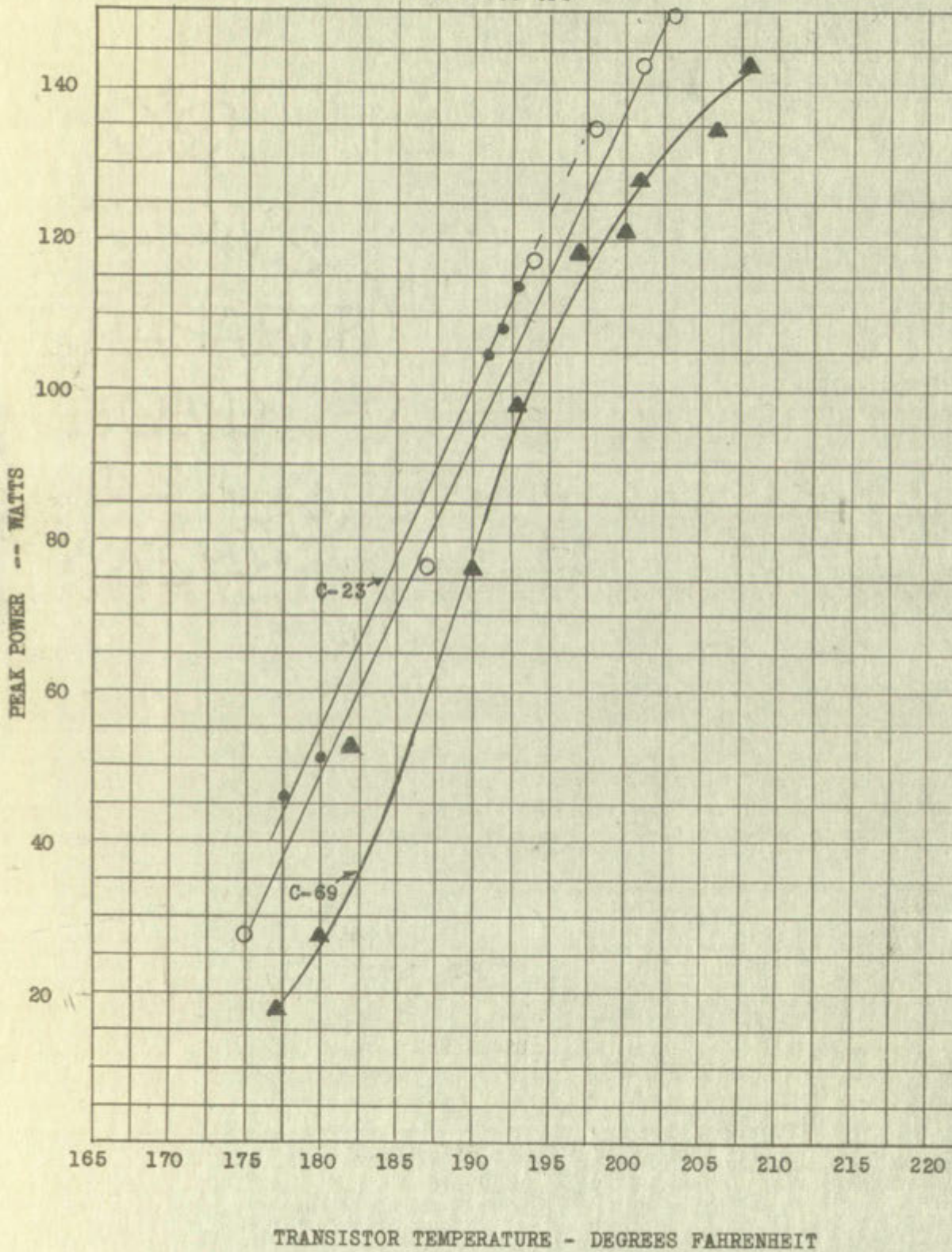
160

SIX PER CENT DUTY FACTOR
1000 - 60 CPS

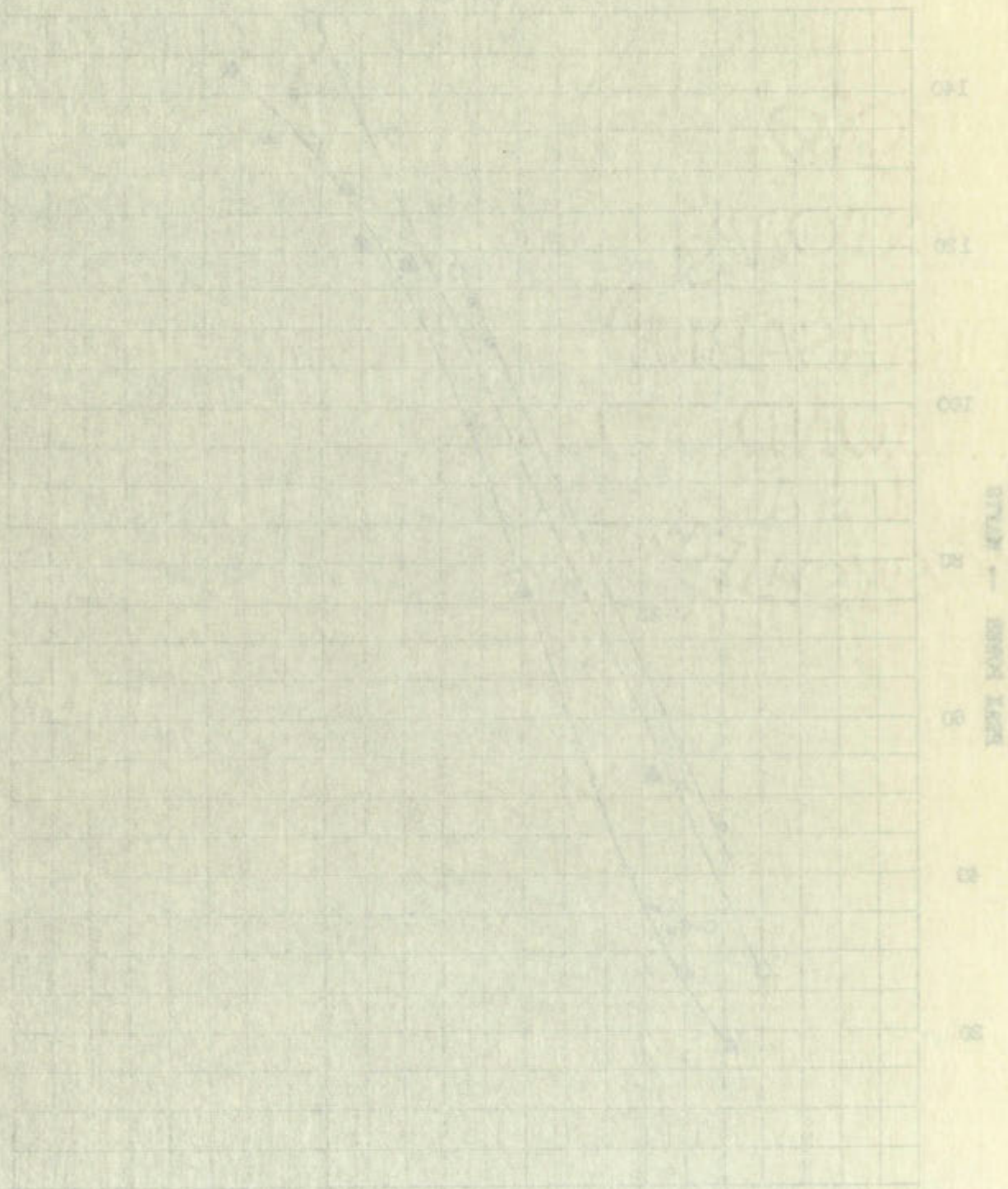




SIX PER CENT DUTY FACTOR
100 - 600 CPS



THE UNIVERSITY OF CHICAGO
LIBRARY

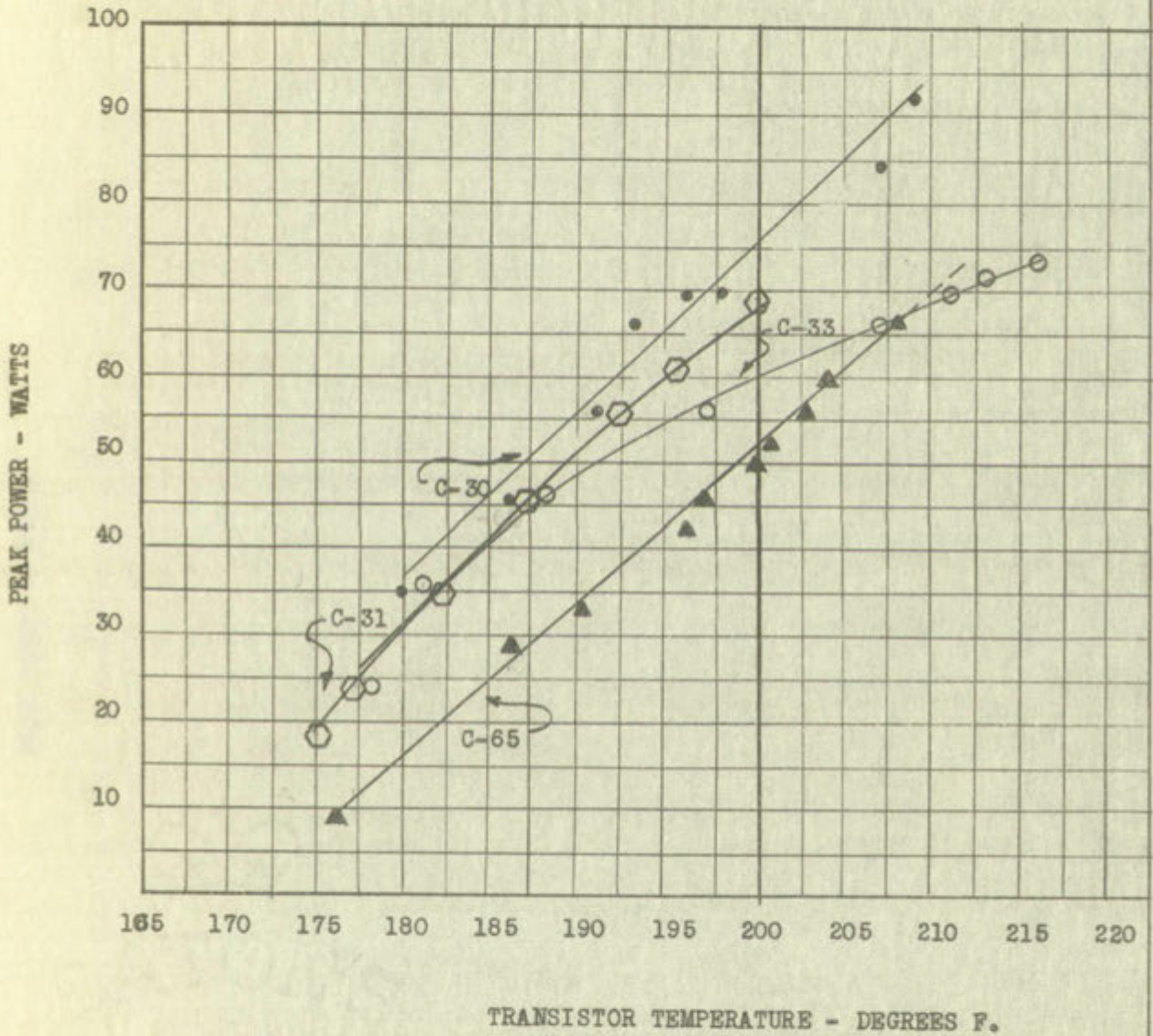


STUDY 100 110 120 130 140 150

STUDY 1 2 3 4 5 6 7 8 9 10

TWENTY PER CENT DUTY FACTOR

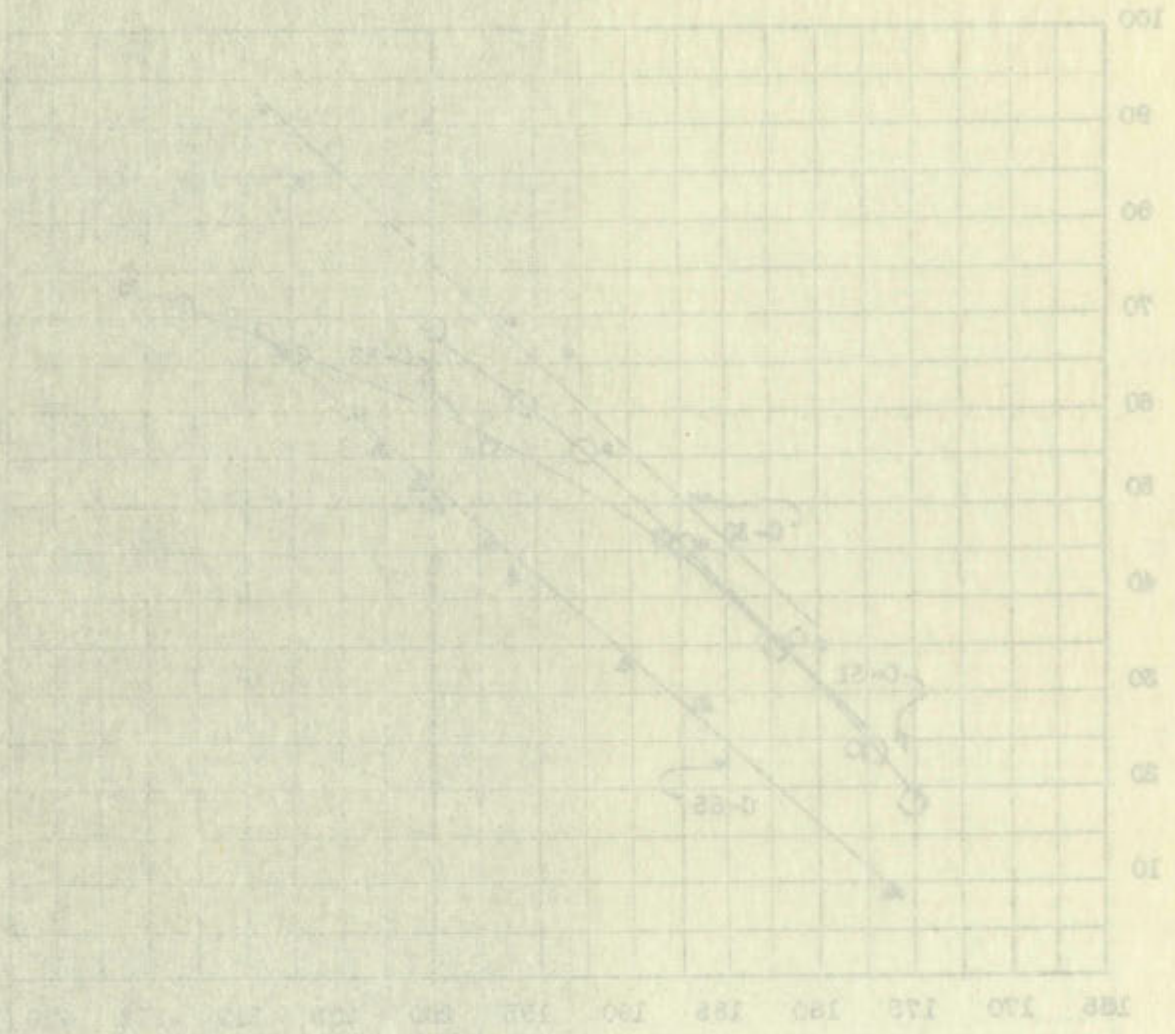
1000 - 200 CPS



TWENTY PER CENT OF WATER

1000 - 300 FTS

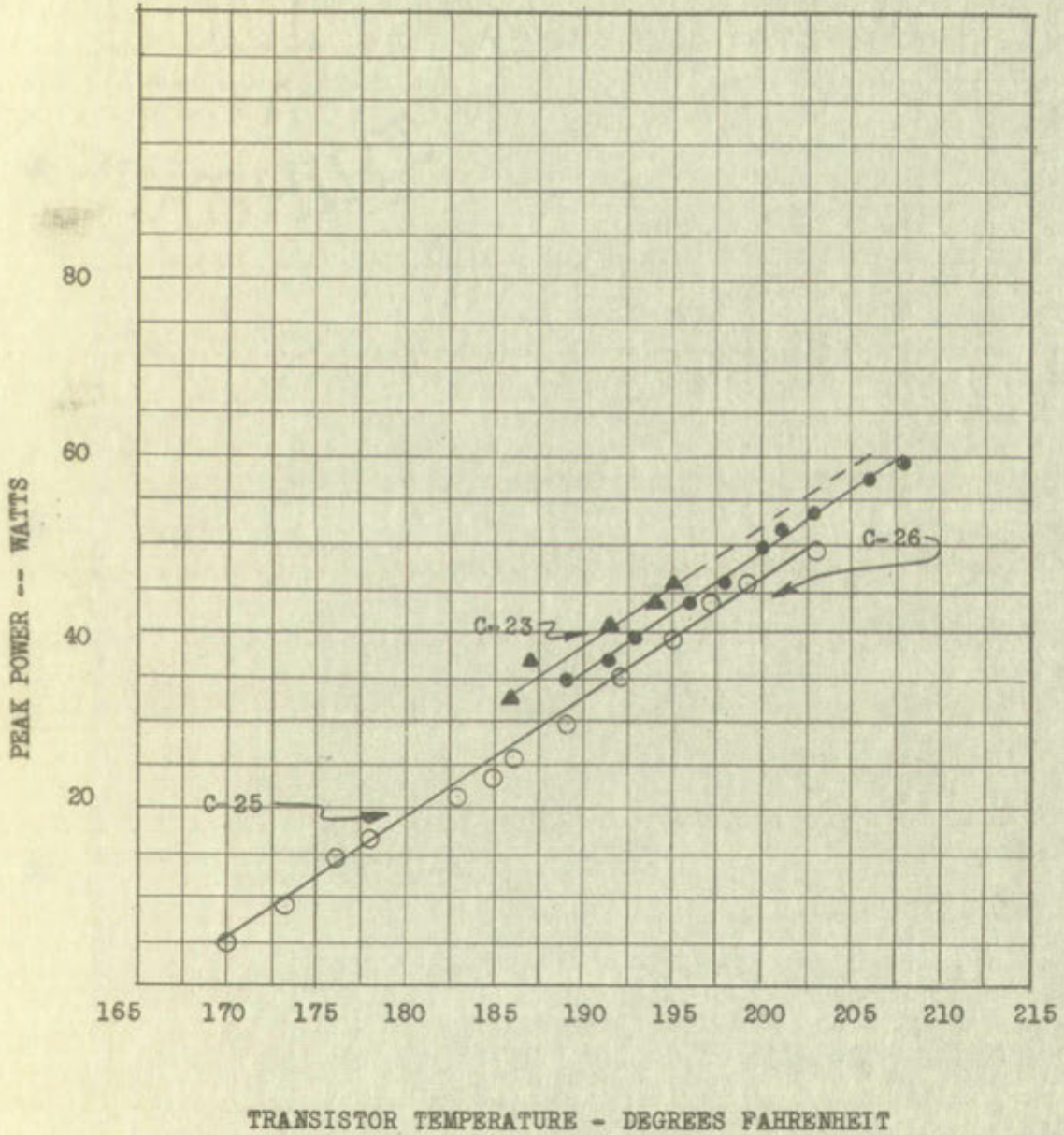
DEPTH - FEET



TRANSITION ZONE - 100 FT

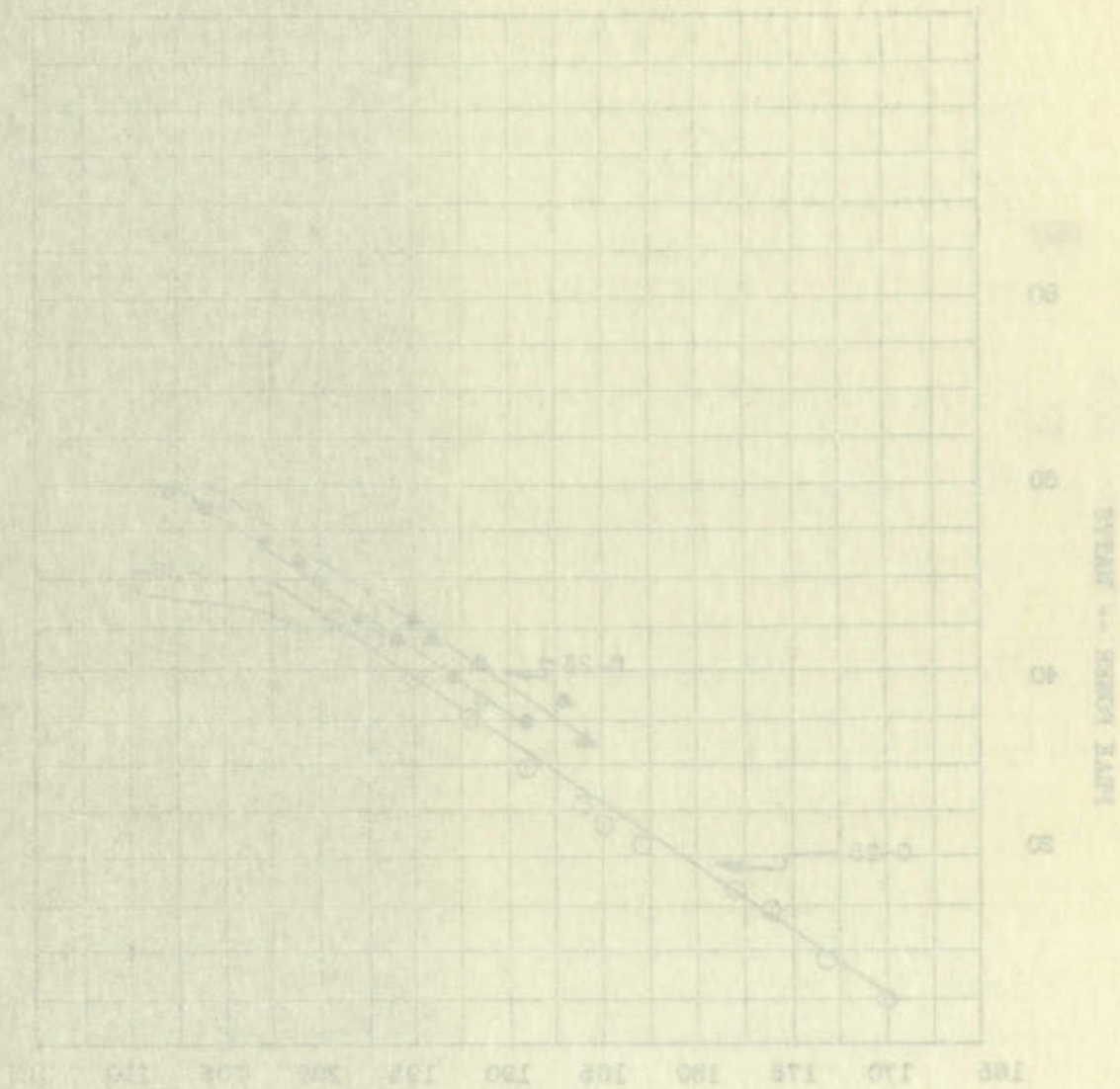
TWENTY PER CENT DUTY FACTOR

100 - 2000 CPS



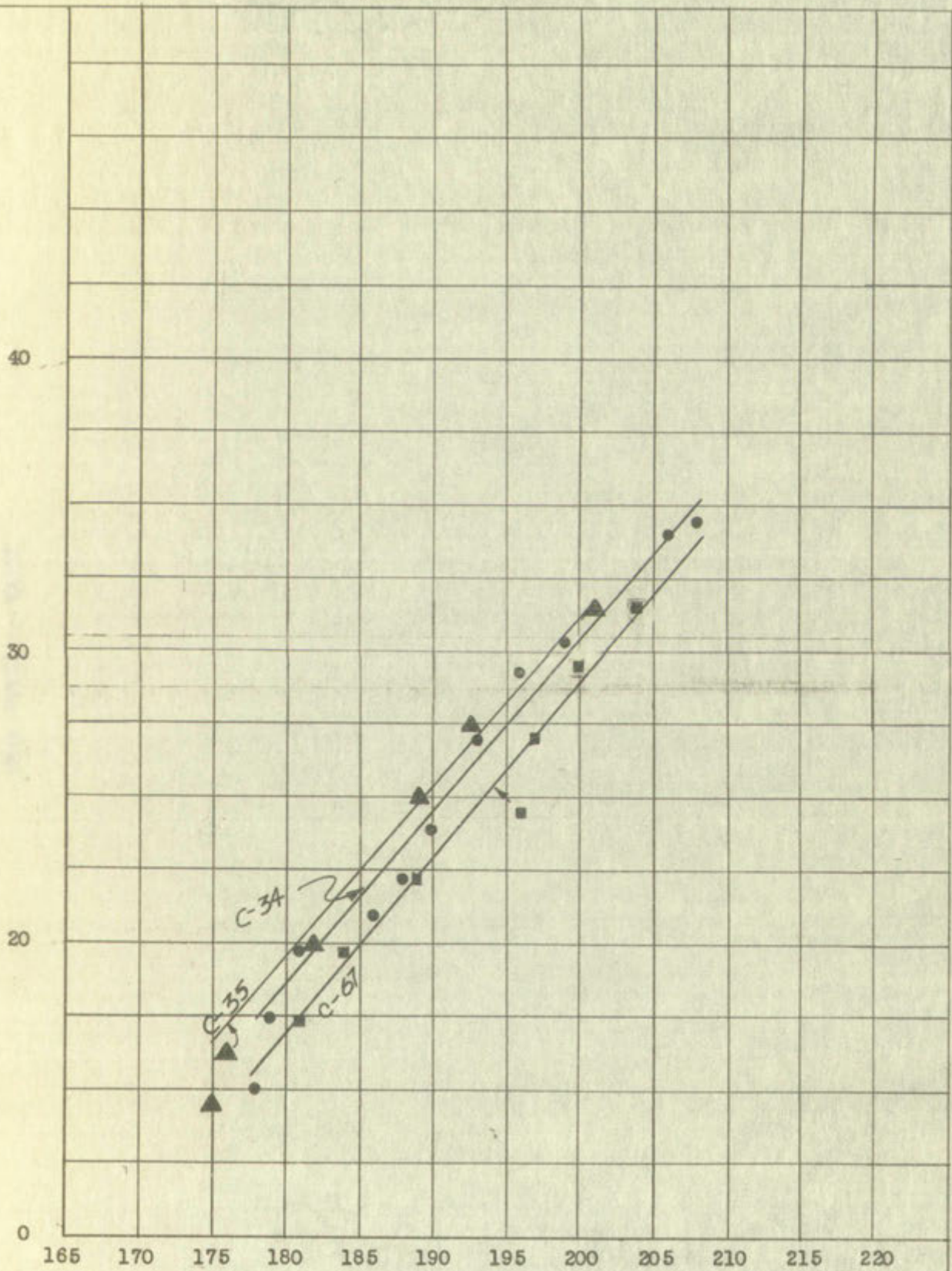
TWENTY PER CENT BUTYLACETATE

100 - 3000 GRS

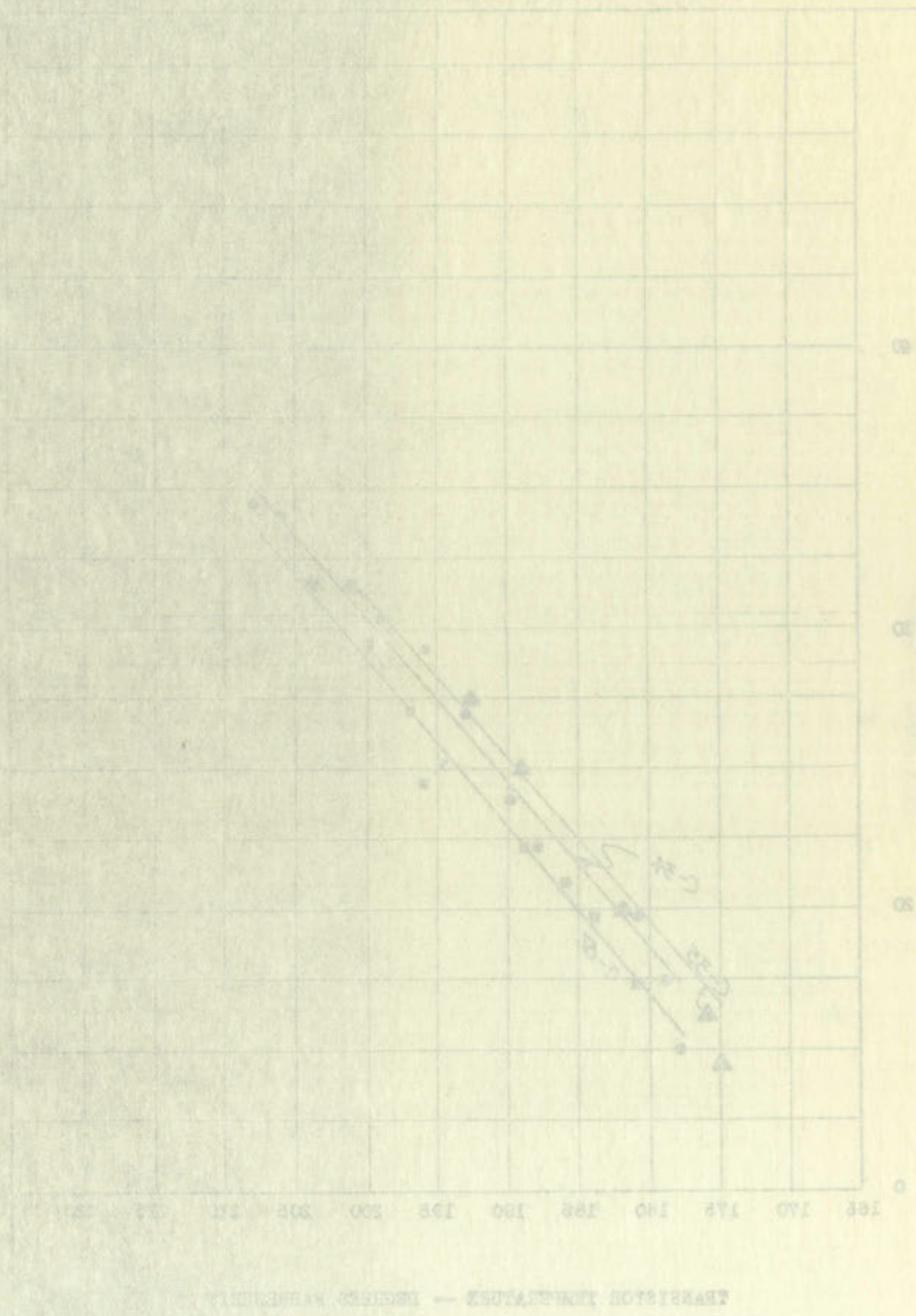


TRANSISTOR TEMPERATURE - INCREASING MEASUREMENT

SIXTY PER CENT DUTY FACTOR
10000 -- 60 CPS

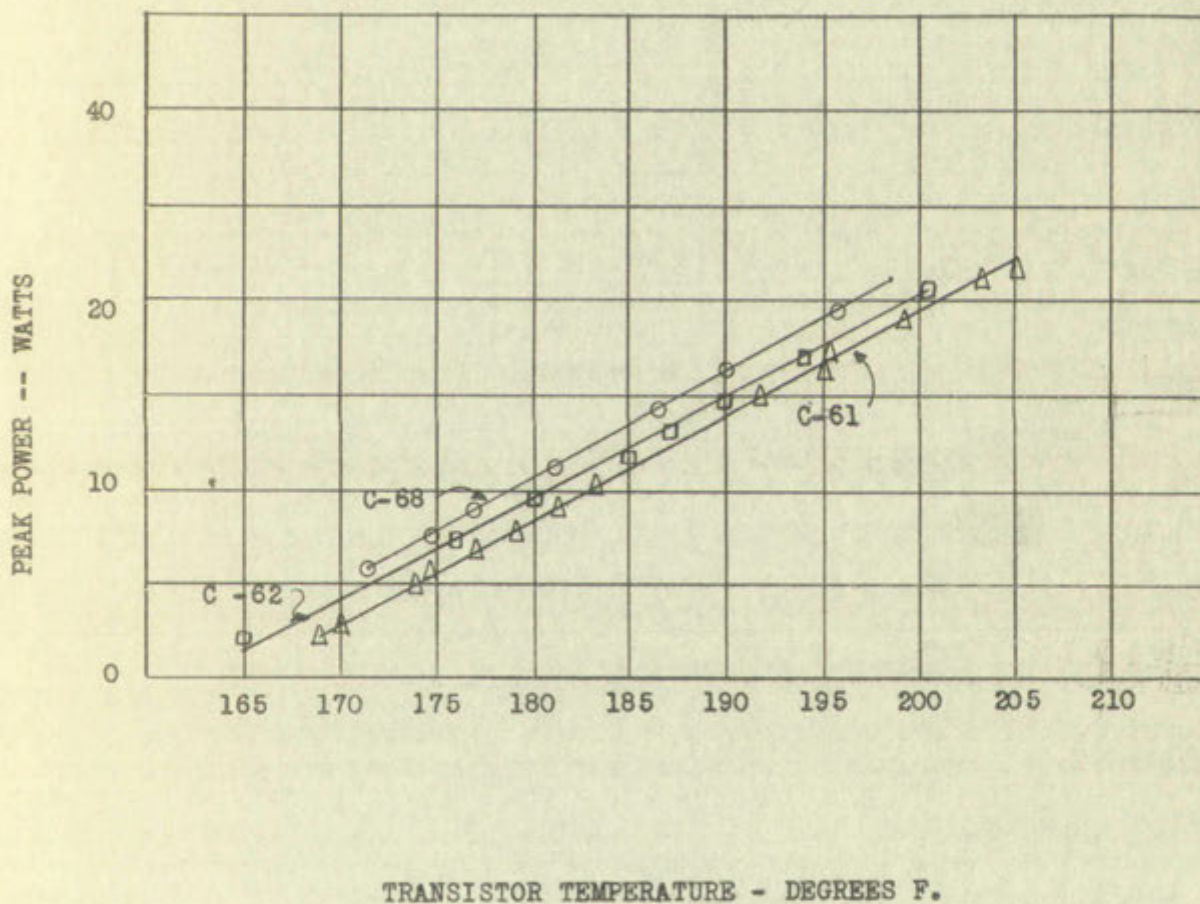


TRANSISTOR TEMPERATURE -- DEGREES FAHRENHEIT

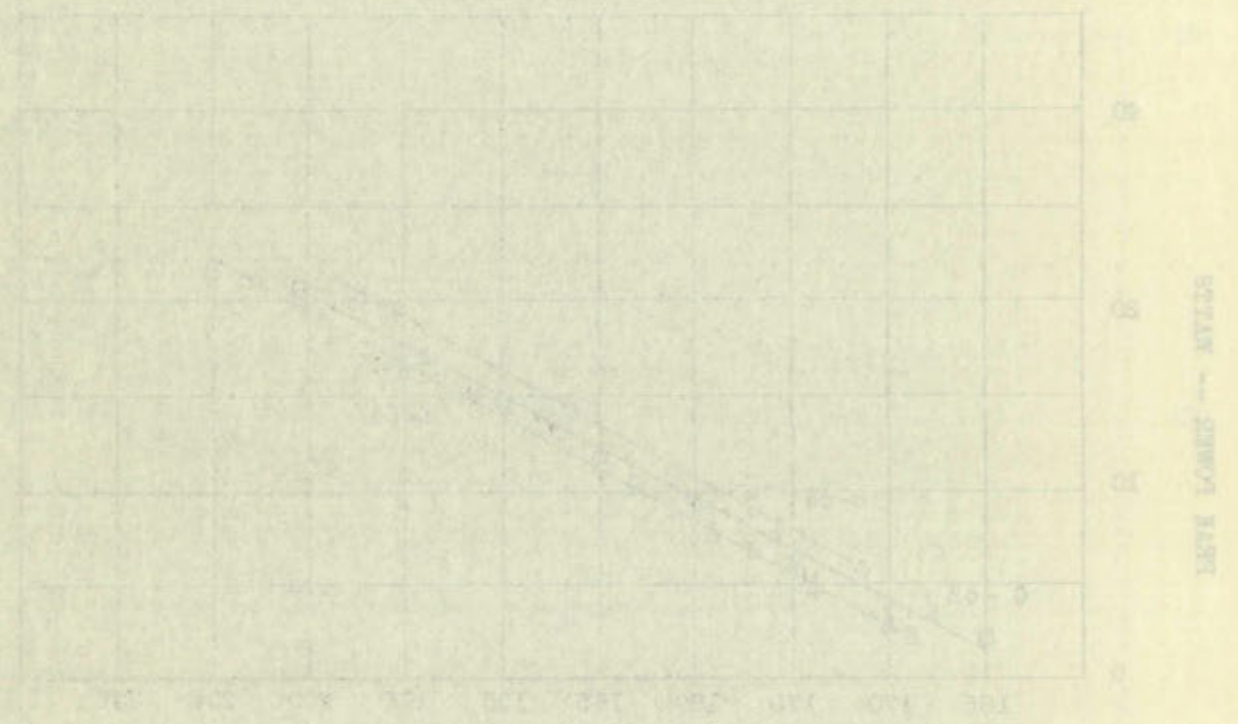


SIXTY PER CENT DUTY FACTOR

1000 - 600 CPS



FEDERAL BUREAU OF INVESTIGATION
 BOARD OF INVESTIGATION
 UNITED STATES DEPARTMENT OF JUSTICE
 WASHINGTON, D. C. 20535



LIFE LINES -- MILES

APPENDIX D

DEVELOPMENT OF THE OPERATING TEMPERATURE EQUATION

The equation for the power-temperature curves in terms of temperature is

$$T_{op} = 165 + \frac{\bar{P}}{\tan \theta} \quad (2)$$

where θ is the angle between the curve and the temperature axis. The transistor temperature rise per watt of average power is dependent on the thermal resistance of the transistor and the heat sink used. $\frac{1}{\tan \theta}$ is a measurement of this thermal resistance which is dependent on the area and material used in making the transistor and heat sink. Since only one type of transistor and heat sink is involved here, then $\frac{1}{\tan \theta}$ is directly proportional to K, a constant dependent on thermal resistance of the materials, and inversely proportional to the area of the heat sink.

Then an equation can be developed using the length of the side of the heat sink which should be helpful in circuit design.

First using a 6" square sink, the slope of the curve is $\frac{1}{.36}$.

Then using only the last part of the equation

$$\frac{\bar{P}}{\tan \theta} = \frac{\bar{P}}{.36}$$

let equal $\frac{K\bar{P}}{L^2}$ where $K = kL$, both k's are constants;

so for the 6" sink

$$\frac{k_1 L_1 \bar{P}}{(\text{area})_1} = \frac{k_1 L_1 \bar{P}}{L_1^2} = \frac{\bar{P}}{.36}$$

APPENDIX

DETERMINATION OF THE RELATIONSHIP BETWEEN TEMPERATURE AND

The equation for the heat conduction through a wall is

temperature is

$$Q = \frac{kA(T_1 - T_2)}{L}$$

where Q is the heat transfer, k the thermal conductivity, A the area, and L the thickness.

axis. The thermal conductivity of the wall is a function of the

temperature. The thermal conductivity of the wall is a function of the

temperature. The thermal conductivity of the wall is a function of the

temperature. The thermal conductivity of the wall is a function of the

temperature. The thermal conductivity of the wall is a function of the

temperature. The thermal conductivity of the wall is a function of the

temperature. The thermal conductivity of the wall is a function of the

temperature. The thermal conductivity of the wall is a function of the

Then an equation can be developed which relates the length of the wire

of the heat sink which should be selected in design conditions.

First using a 0.5 square inch, the slope of the curve is

Then using only the last part of the equation

$$\frac{Q}{A} = \frac{k(T_1 - T_2)}{L}$$

Let $T_1 = 100^\circ\text{F}$, $T_2 = 70^\circ\text{F}$, $L = 0.5$ inch, $Q = 100$ Btu/hr

so for the 0.5 inch

$$\frac{100}{A} = \frac{k(100 - 70)}{0.5}$$

then

$$k_1 = \frac{L_1}{\tan \theta} = \frac{6}{.36} = .167 \approx 17$$

for the 4.25" sink

$$\frac{k_2}{L_2} = \frac{1}{\tan \theta_2} = \frac{1}{.27}, \quad k_2 = \frac{L_2}{.27} = \frac{4.25}{.27} = 15.7 \approx 17$$

for the 3" square sink

$$\frac{k_3}{L_3} = \frac{1}{.18}, \quad k_3 = \frac{3}{.18} = 16.6 \approx 17$$

Since $k_1 \approx k_2 \approx k_3$, equation 2 can be expressed as follows:

$$T_{op} = 165 + \frac{17\bar{P}}{L}$$

where

T = temperature in degrees fahrenheit of a transistor with a square heat sink of side L inches long dissipating an average power \bar{P} . The heat sink material is described in Chapter II, THE METHOD OF TEST.

then

$$T_1 = \frac{1}{\frac{1}{T_2} + \frac{1}{T_3}} = \frac{T_2 T_3}{T_2 + T_3}$$

for the 1.5" disk

$$\frac{1}{T_1} = \frac{1}{T_2} + \frac{1}{T_3} = \frac{1}{10} + \frac{1}{10} = \frac{2}{10}$$

$$T_1 = \frac{10 \times 10}{2} = 50$$

for the 3" square disk

$$\frac{1}{T_1} = \frac{1}{T_2} + \frac{1}{T_3} = \frac{1}{10} + \frac{1}{10} = \frac{2}{10}$$

Since T_1 for the 3" square disk is expressed as follows

$$T_1 = \frac{1}{\frac{1}{T_2} + \frac{1}{T_3}}$$

where

T_2 = temperature difference between the two surfaces

with a square head disk of side 3 inches long distributed as a steady

power \dot{Q} . The heat sink material is described in Chapter 11, 11.1

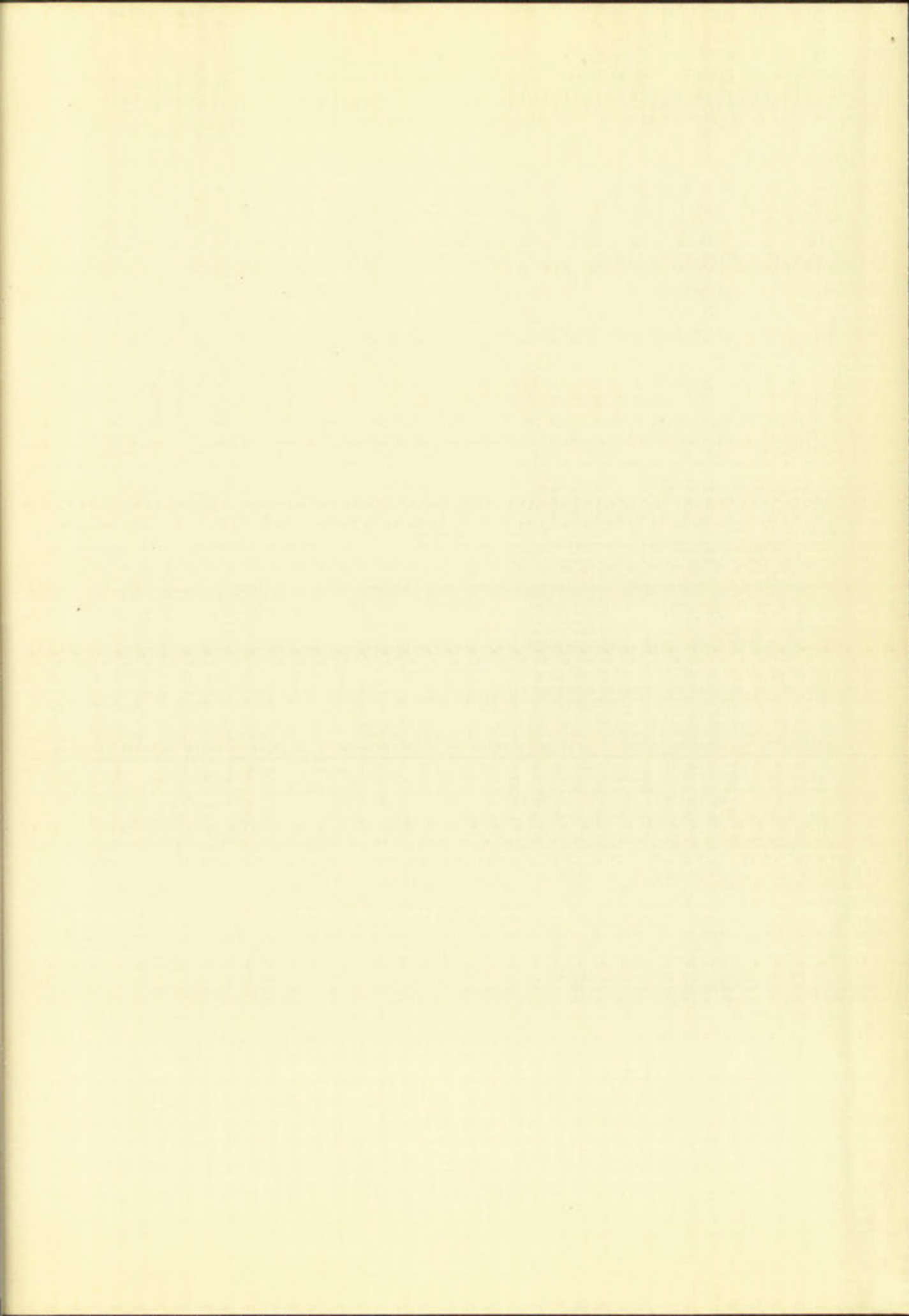
METHOD OF TEST.

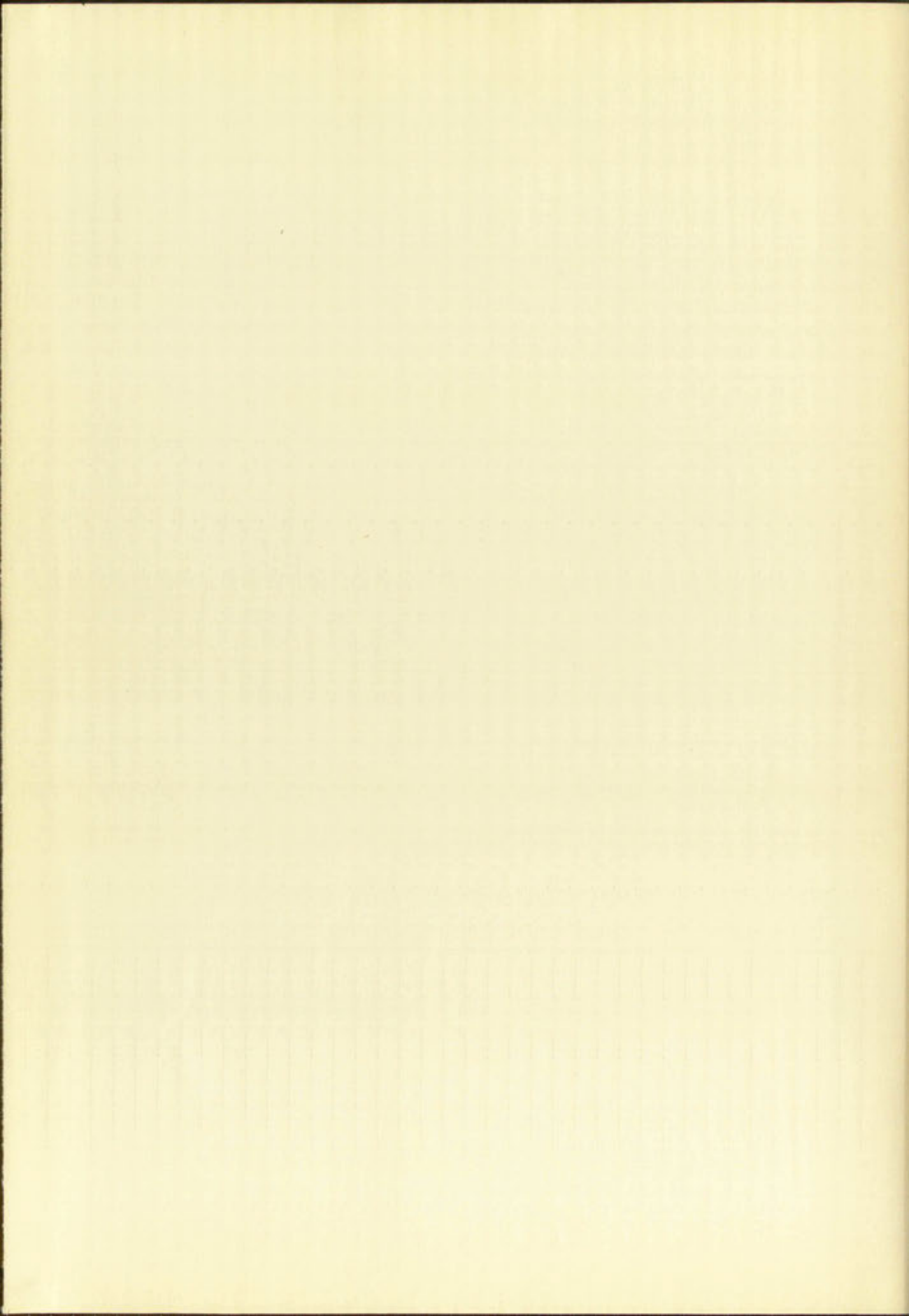
COMMON COUNCIL

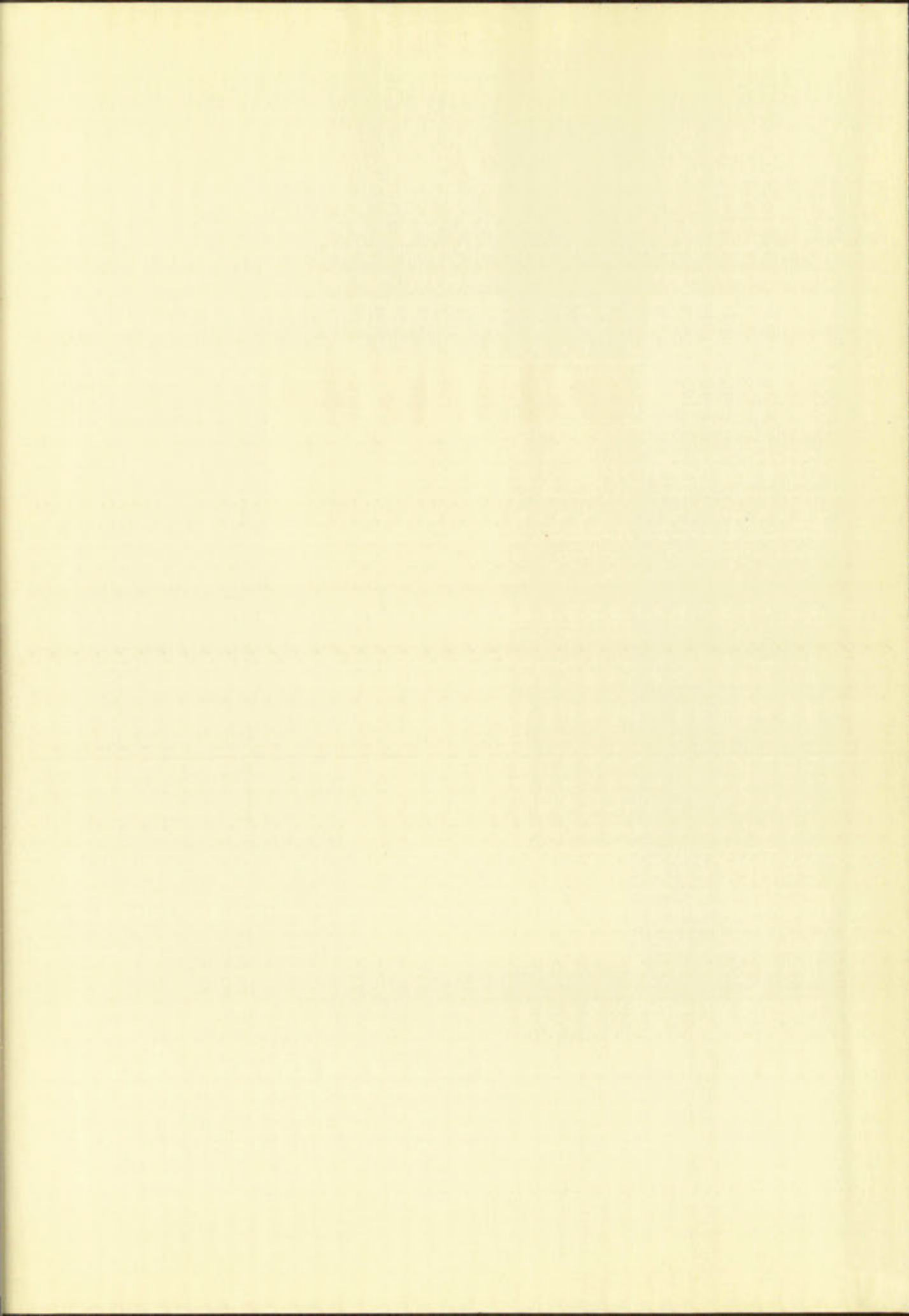
1875

RECORDS

COLLEGE OF THE SACS
SACRAMENTO, CALIF.








IMPORTANT!

Special care should be taken to prevent loss or damage of this volume. If lost or damaged, it must be paid for at the current rate of typing.

Date Due			
NOV 11	1957		
NOV 8	RECD		
MAY 12	1958		
APR 26	RECD		
JAN 30	1959		
JAN 26	RECD		
	PRINTED	IN U. S. A.	

