A. V. ROE CANADA LIMITED

MALTON ONTARIO

TECHNICAL DEPARTMENT (Aircraft)

ANALYZED

AIRCRAFT: CF-105

EXTRACT 2

REPORT NO. - A47/A.C. Man./2

FILE NO.

~~SECRET~~

NO. OF SHEETS

TITLE:

Classification cancelled / Changed to UNCLASS

By authority of AVRS

Date 27 Sept 56

Signature DBOL

Unit / Rank / Appointment AVRS 5

PLANE MANOEUVRES AT MAXIMUM 'g' FOR THE CF-105

PREPARED BY T. F. Potts T.F.P. DATE April 1957

CHECKED BY R. R. Carley AVR DATE April 1957

SUPERVISED BY DATE

APPROVED BY DATE

ISSUE No.	REVISION No.	REVISED BY	APPROVED BY	DATE	REMARKS

FORM 1316A

AVRO AIRCRAFT LIMITED
MALTON - ONTARIO
TECHNICAL DEPARTMENT

AIRCRAFT: CF-105

SECRET

PREPARED BY	DATE
T. F. Potts	April 1957
CHECKED BY	DATE
R. R. Carley	April 1957

PLANE MANOEUVRES AT MAXIMUM 'g' FOR THE CF-105

INDEX

AVRO AIRCRAFT LIMITED
MALTON · ONTARIO
TECHNICAL DEPARTMENT

AIRCRAFT:		PREPARED BY	DATE
CF-105	SECRET	T. F. Potts	April 1957
		CHECKED BY	DATE
		R. R. Carley	April 1957

INDEX (Continued)

FORM 1319A

AVRO AIRCRAFT LIMITED
MALTON - ONTARIO
TECHNICAL DEPARTMENT

AIRCRAFT:		PREPARED BY	DATE
CF-105	SECRET	T. F. Potts	April 1957
		CHECKED BY	DATE
		R. R. Carley	April 1957

INDEX (Continued)

Extract

AVRO AIRCRAFT LIMITED
MALTON · ONTARIO
TECHNICAL DEPARTMENT

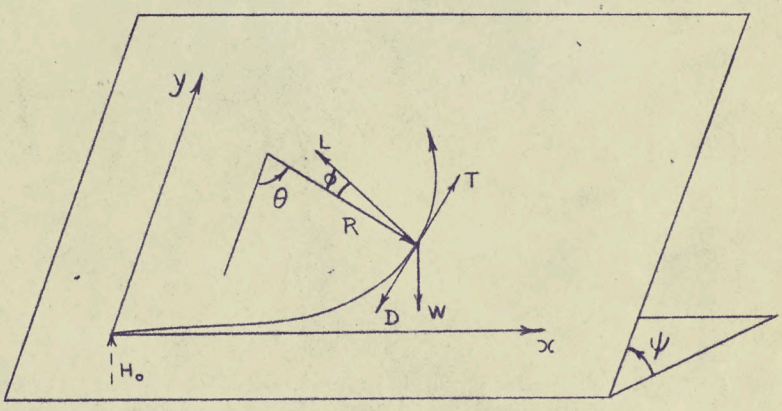
REPORT No 2 - A47/A.C. Man./2
SHEET No 1

AIRCRAFT:	PREPARED BY	DATE
CF-105	T. F. Potts	April 1957
	CHECKED BY	DATE
	R. R. Carley	April 1957

PLANE MANOEUVRES AT MAXIMUM 'G' FOR THE CF-105

This report is the first of a series to be prepared on Dynamic Manoeuvres for the CF-105, and its purpose is to investigate manoeuvring capabilities of the aircraft in maximum 'g' turns confined to a plane, for various altitudes and speeds.

GEOMETRY AND EQUATIONS OF MOTION:-



$$(1)\quad \frac{dM}{dt} = \frac{g}{aW}\left\{2F_N^* \cdot \frac{F_N}{F_N^*} - p\left[K_1\left(\frac{n}{p} \cdot W \times 10^{-4} - 2.11\right)^2 + \frac{D_{MIN}}{p}\right]\right\} - \frac{g}{a}\,\text{SIN}\,\psi\,\text{SIN}\,\theta$$

$$(2)\quad \frac{d\theta}{dt} = \frac{57.3g}{aM}\left(p \cdot \frac{n}{p}\,\text{COS}\,\phi - \text{SIN}\,\psi\,\text{COS}\,\theta\right)$$

$$(3)\quad p \cdot \frac{n}{p}\,\text{SIN}\,\phi = \text{COS}\,\psi$$

$$(4)\quad \frac{dx}{dt} = aM\,\text{COS}\,\theta$$

$$(5)\quad \frac{dy}{dt} = aM\,\text{SIN}\,\theta$$

$$(6)\quad H = H_0 + y\,\text{SIN}\,\psi$$

$$(7)\quad V = aM$$

SYMBOLS USED:-

D	- Total aircraft drag	(lb.)
D_{MIN}	- Fictitious minimum drag, used in the mechanization of the drag function	
F_N	- Net thrust of one engine with maximum afterburner.	(lb.)
F_N^*, F_N, $\frac{F_N}{F_N^*}$	- Functions of Mach number and altitude used in thruet mechanization	
H	- altitude	(ft.)
K_1	- Function of Mach number, used in drag mechanization	
L	- Total aircraft lift	(lb.)
M	- Mach number	
V	- Aircraft speed	(ft./eec.)
W	- Aircraft weight	(lb.)
a	- Speed of sound	(ft./sec.)
g	- Acceleration due to gravity	(ft./sec.^{2})
n	- Total normal acceleration	('g' unite)
p	- Ambient static pressure	(lb./in.^{2}abs.)
t	- Time	(eec.)
x, y	- Rectangular Cartesian coordinates in the plane of the manoeuvre	(ft.)
θ	- Angle turned	(deg.)
ϕ	- Angle of bank relative to manoeuvre plane	(deg.)
ψ	- Angle of inclination of manoeuvre plane	(deg.)

Subscript 0 - Initial conditione.

MECHANIZATION OF THRUST, DRAG AND NORMAL ACCELERATION:-

In the expreseion $2F_N^* \cdot \frac{F_N^*}{F_N^*}$, $2F_N^*$ and $\frac{F_N}{F_N^*}$ are functions of Mach number and altitude respectively, whose product yielde maximum thruet for two PS - 13 engines with afterburnere. The valuee of $2F_N$ given by thie mechanization are everywhere within 2½% of the values given by the carpet, and over moet of the range the error is considerably lees than thie value.

The expreesion $p\left(K_1\left(\frac{n}{p} \cdot W \times 10^{-4} - 2.11\right)^2 + \frac{D_{MIN}}{p}\right)$ is the mechanization for the carpet of total trimmed drag with 4° up ailsron deflection. The values of drag given by this mechanization are everywhere within 2% of the values given by the carpet, and over most of the range the error ie conaiderably less than this value. Although the ailerons will only be deflected above 45,000', and the carpet for undeflected ailerons ehould be ueed below this altitude, lack of computing equipment makee thie impoesible at the moment. The one eet of data was therefore used throughout.

Normal acceleration 'n' is obtained from the product $p \cdot \left(\frac{n}{p}\right)_{MAX,}$ where $\left(\frac{n}{p}\right)_{MAX,}$ is a function of Mach number. Maximum 'n' ie limited by buffet for M 1.08 and by available trim for M 1.08. Hinge

moment limitation is not considered serious at these altitudes and Mach numbers, and its effects have been ignored. In the simulation, the velue of n_{MAX} has been limited to 5.5 'g', corresponding to the damper command limit. A lag of $\frac{1}{1 + .5S}$ has been introduced in $\frac{n}{p}$ in the simulation, to allow for the response of the aircraft in pitch.

The data for these mechanizetions was obtained from Messrs. J. Cohen and T. Roberts of Performance Group.

CASES STUDIED:-

Initial altitudes and Mach numbers, and angles of plane inclination studied are as follows;

H_o = 36,000'; M_o = 2.0, 1.75, 1.50; ψ = 90°, 0
H_o = 40,000'; M_o = 2.0, 1.75, 1.50; ψ = 90°, 0
H_o = 50,000'; M_o = 2.0, 1.75, 1.50; ψ = 90°, 0, -90°
H_o = 60,000'; M_o = 2.0, 1.75, 1.50; ψ = 90°, 0, -90°
H_o = 70,000'; M_o = 2.0, 1.75, 1.50; ψ = 0, -90°

The solutions are valid for $H \geq 36{,}000'$, $M \geq 1.0$ and $\theta \leq 180°$.

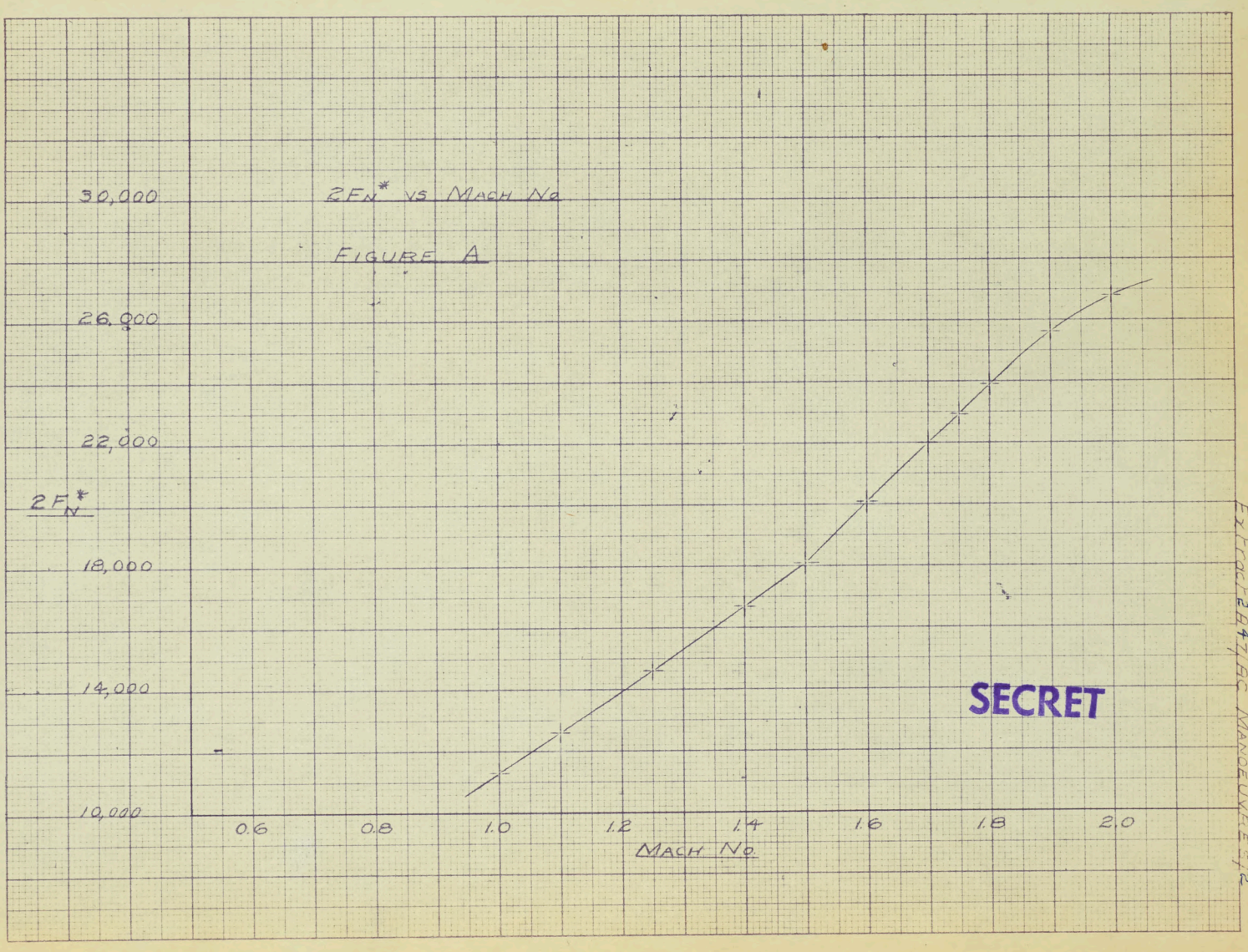
The weight of the aircraft was taken as 51,000 lbs. and the speed of sound was taken to be constant at 968.5 ft./sec.

Solutions are presented as curves of M, θ, and n vs. t, and y vs. x. In addition, composite curves of y vs. x for the different plane inclinations are given, with time intervals and Mach number noted along the curves.

Hand calculated check solutions for the cases
H_o = 40,000', M_o = 2.0, ψ = 0 and
H_o = 60,000', M_o = 2.0, ψ = 0
are given for comparison.

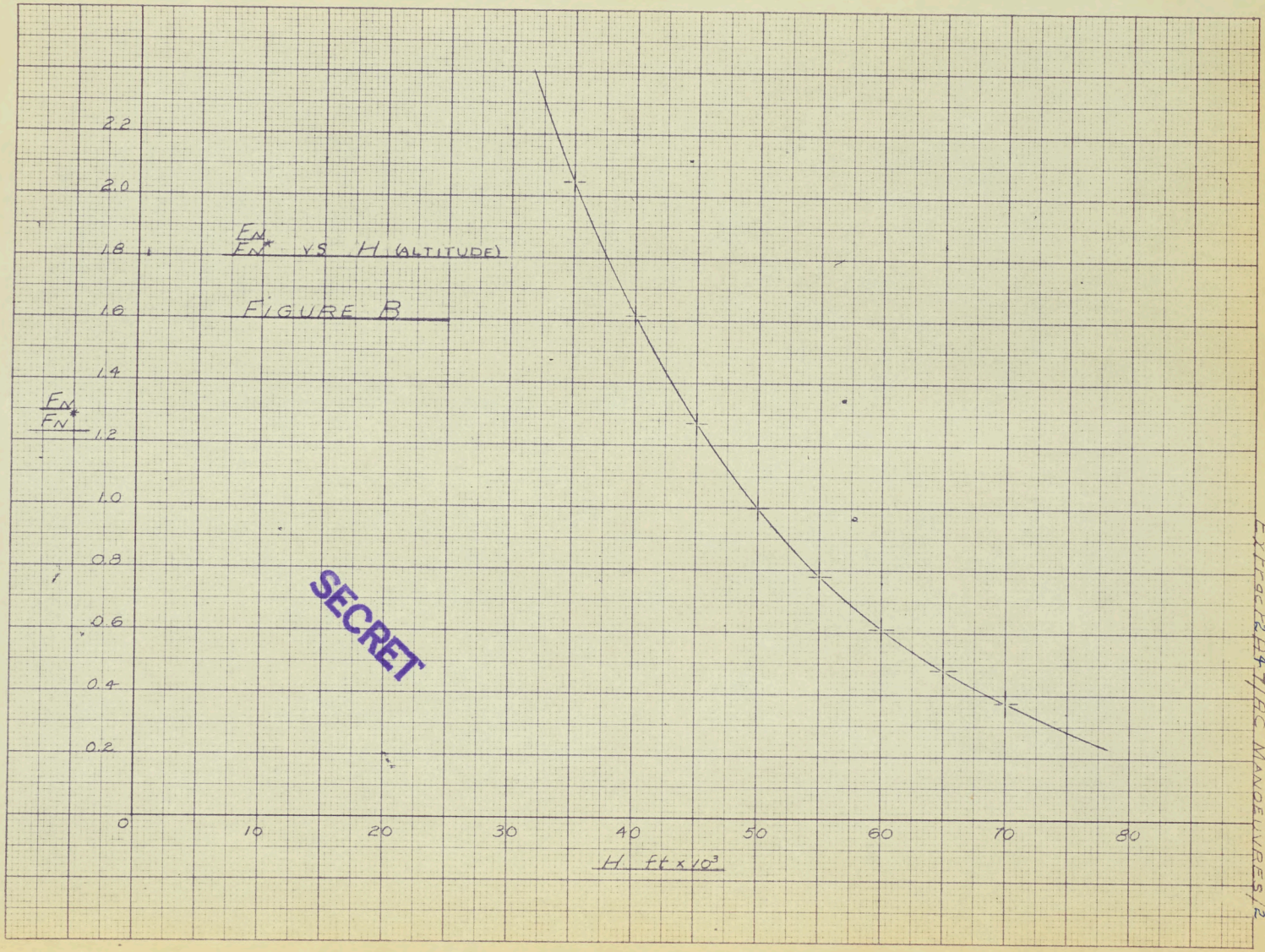
$2F_N^*$ vs Mach No

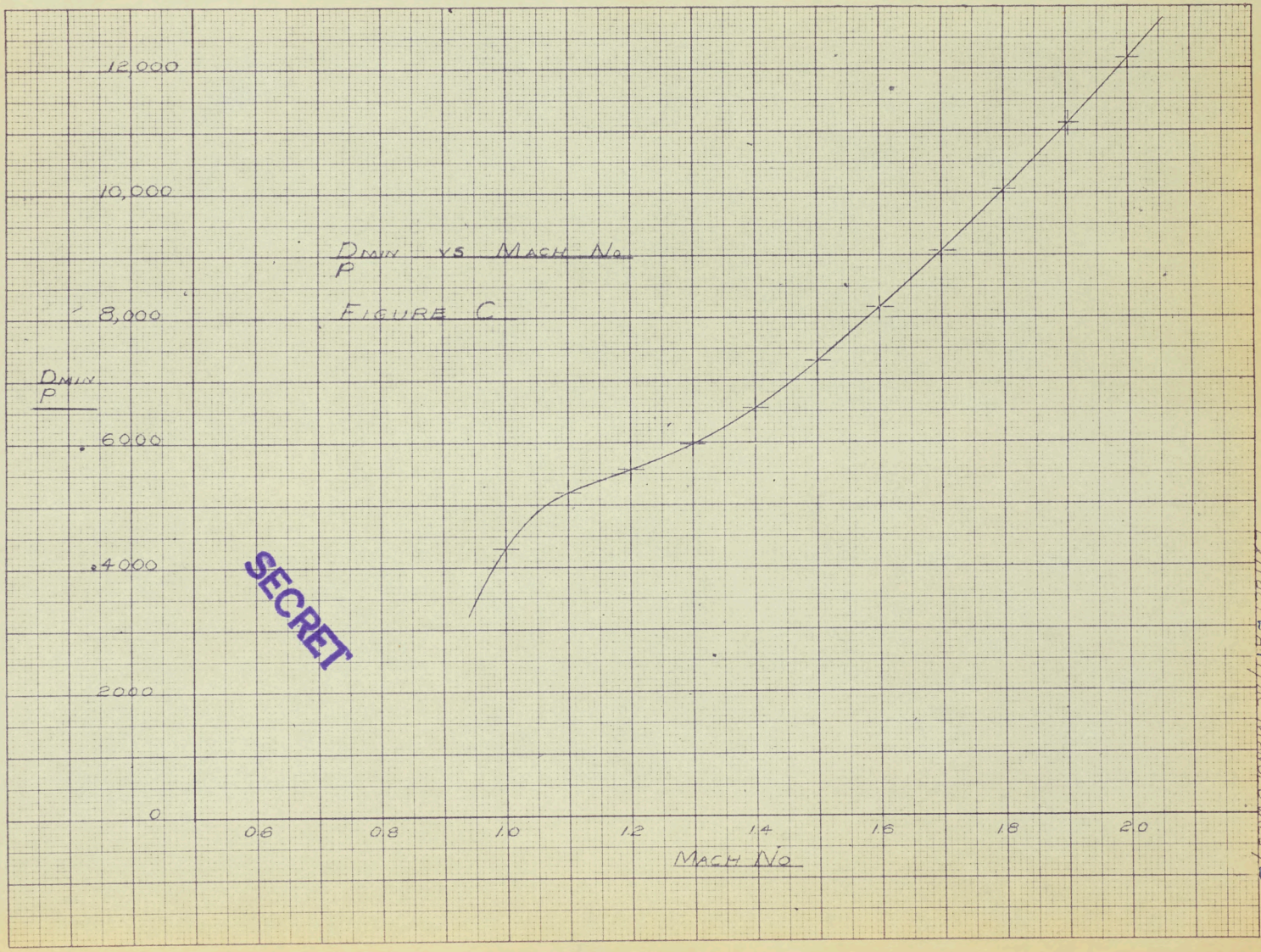
FIGURE A



$\frac{F_M}{F_N^*}$ VS H (ALTITUDE)

FIGURE B



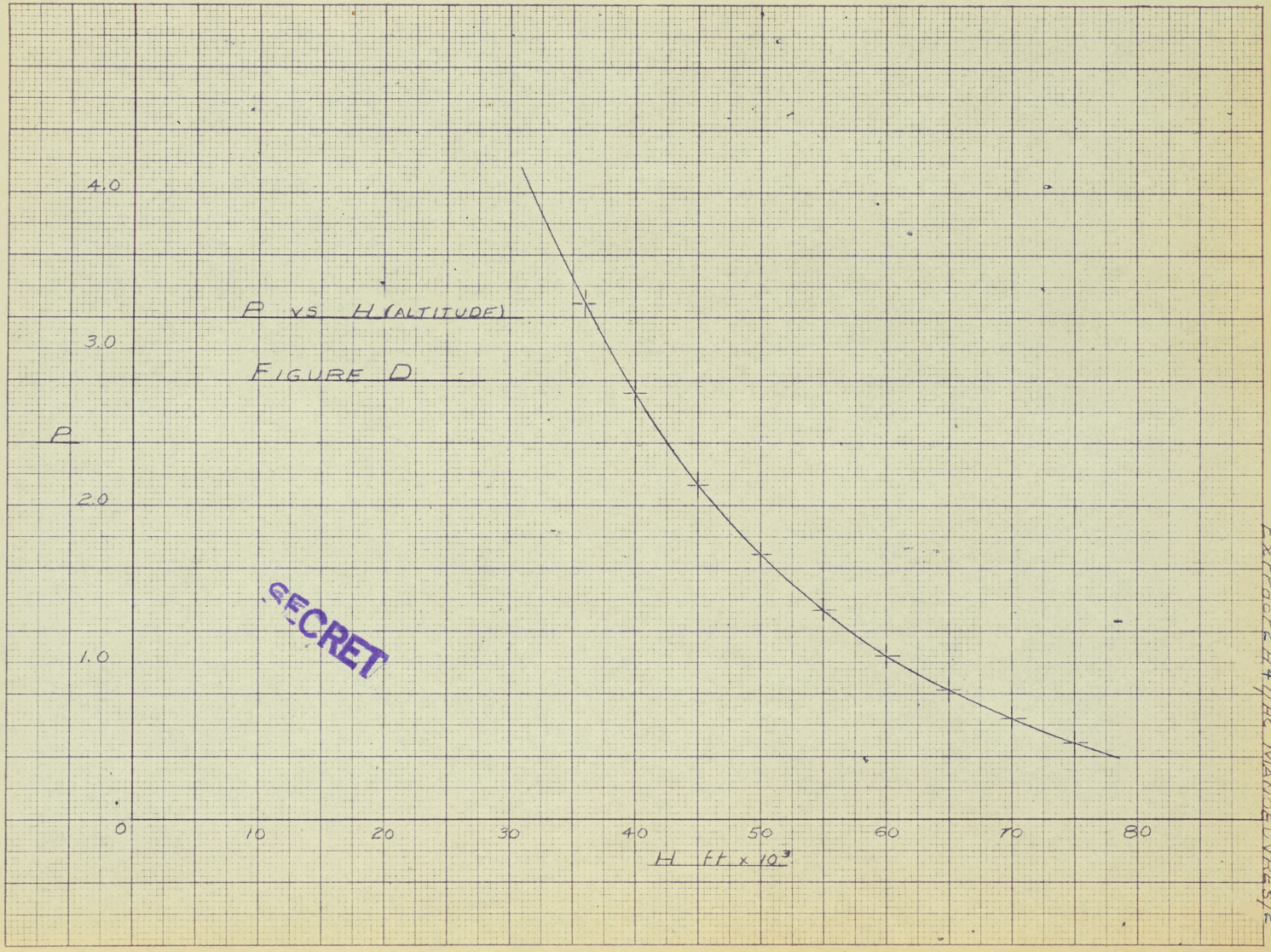


$\frac{D_{MIN}}{P}$ VS MACH No.

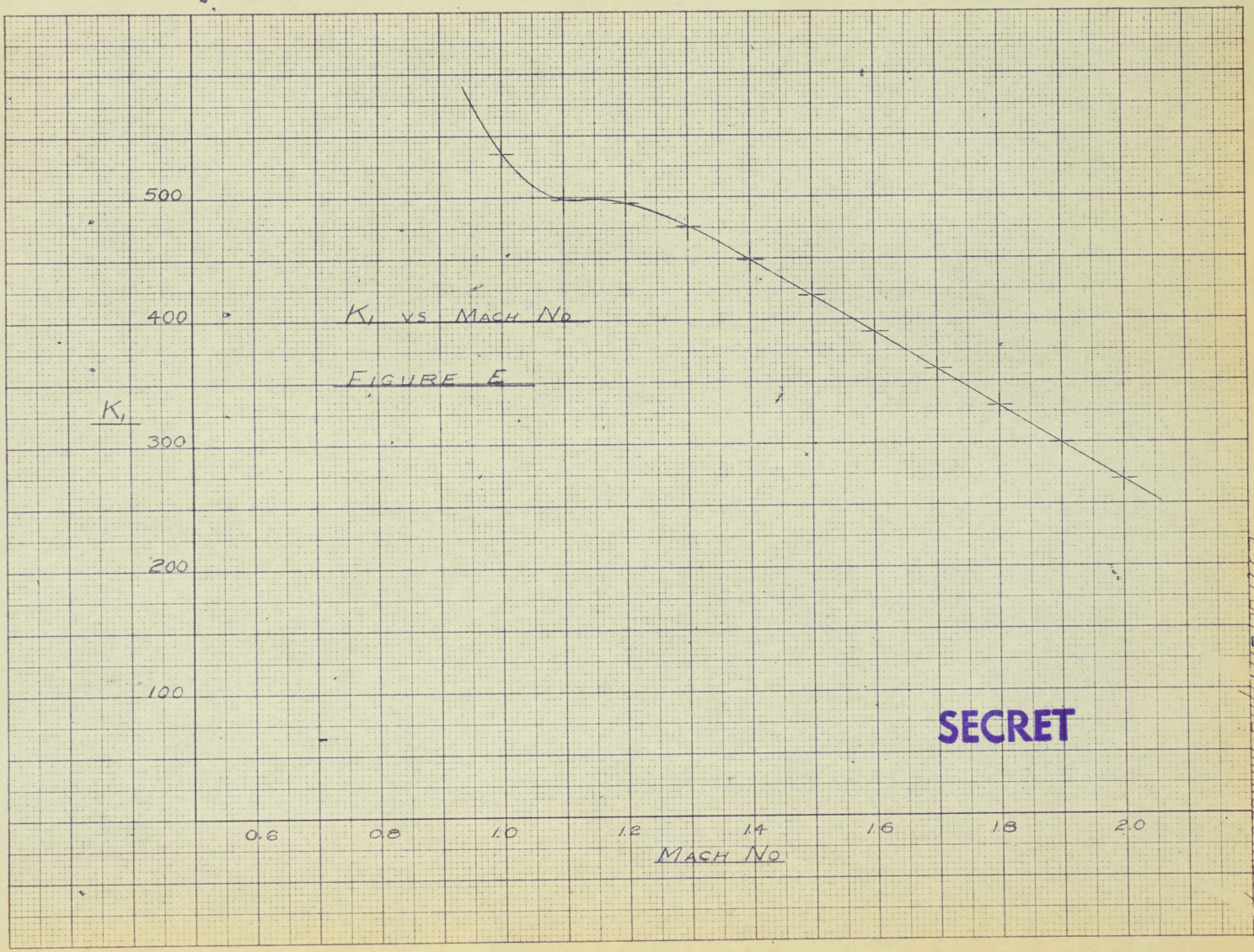
FIGURE C

P VS H (ALTITUDE)

FIGURE D

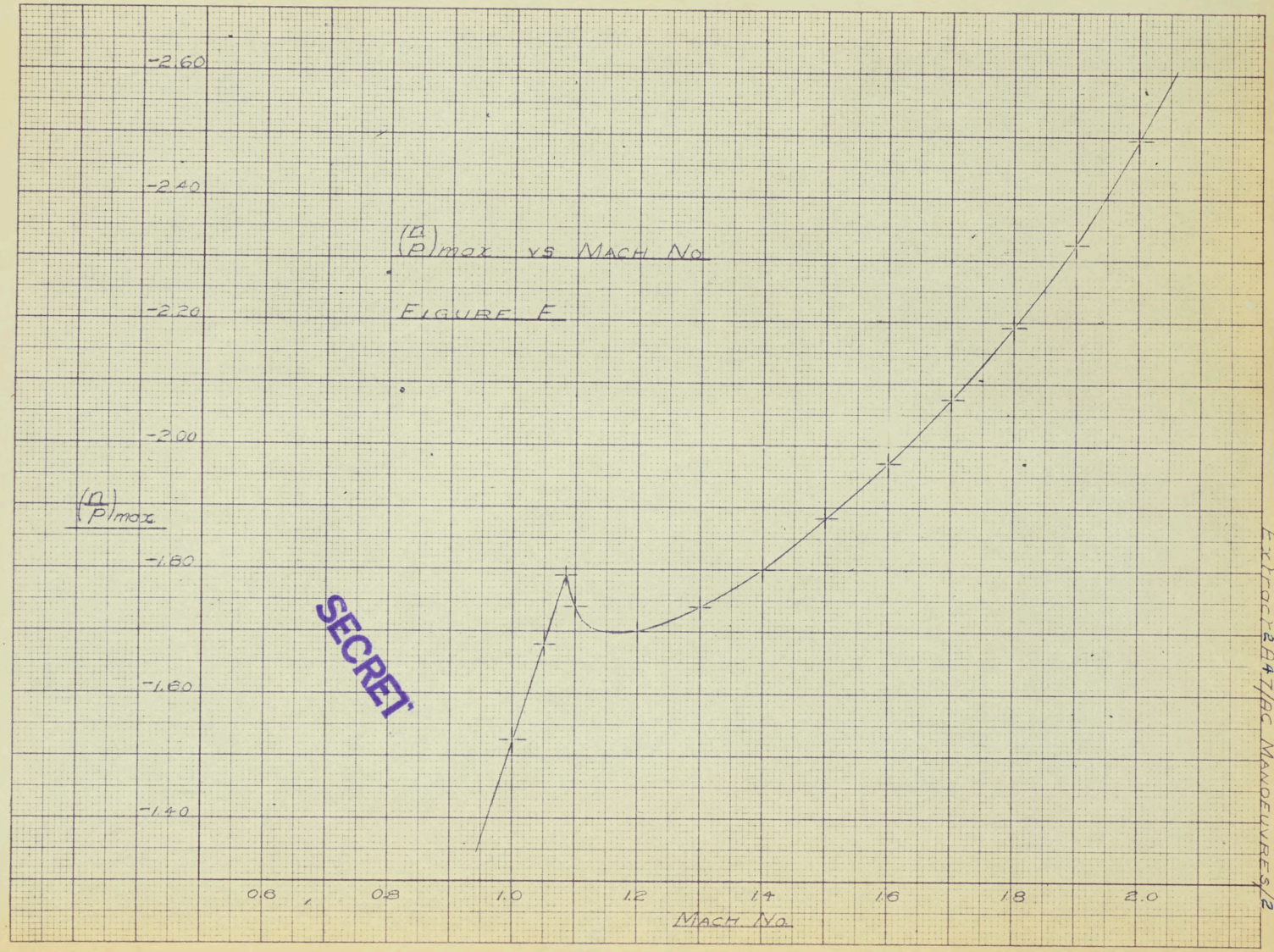


Extract 2447/RC MANOEUVRES/2



K_1 VS MACH NO

FIGURE E



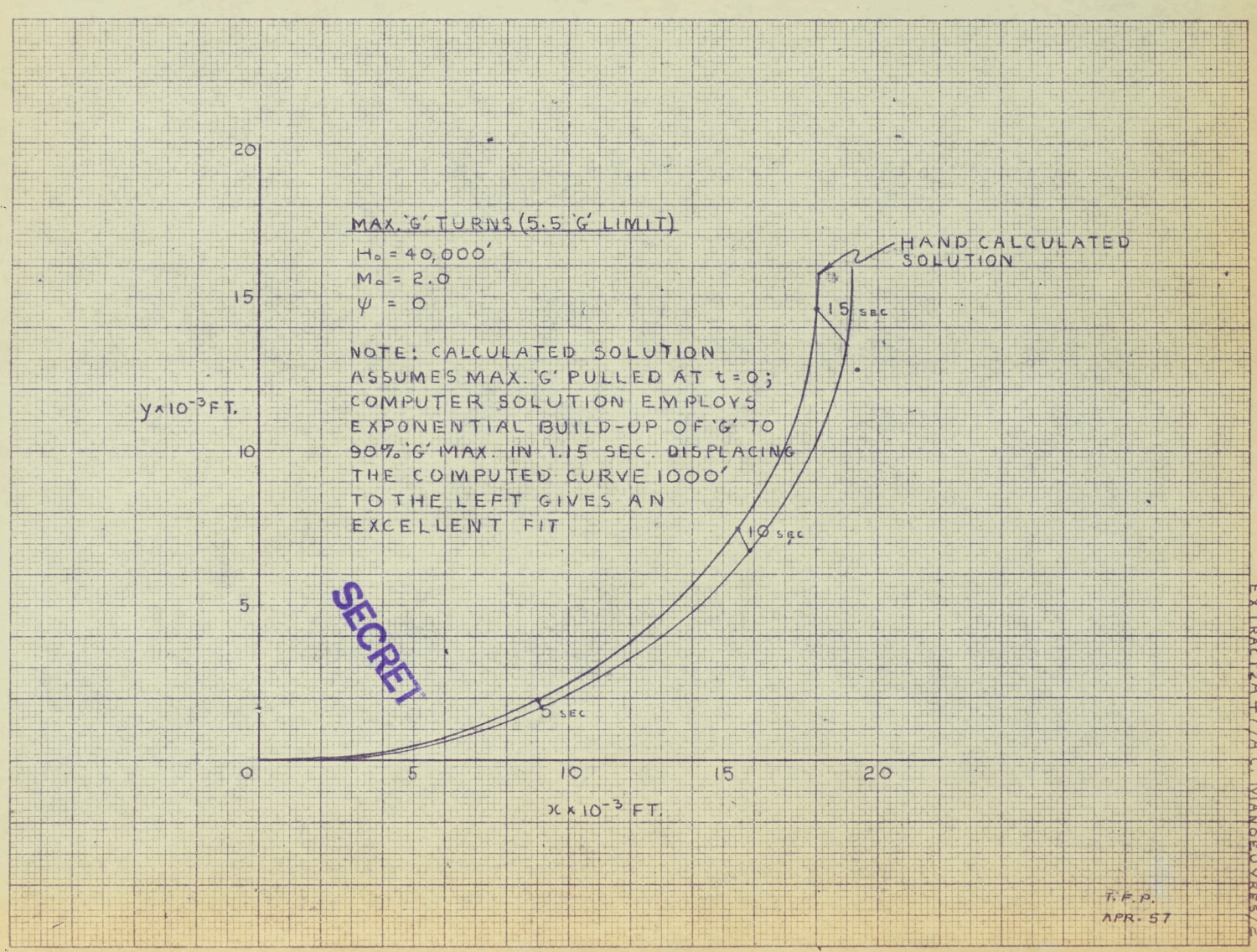
$(n/p)_{max}$ VS MACH No.

FIGURE E

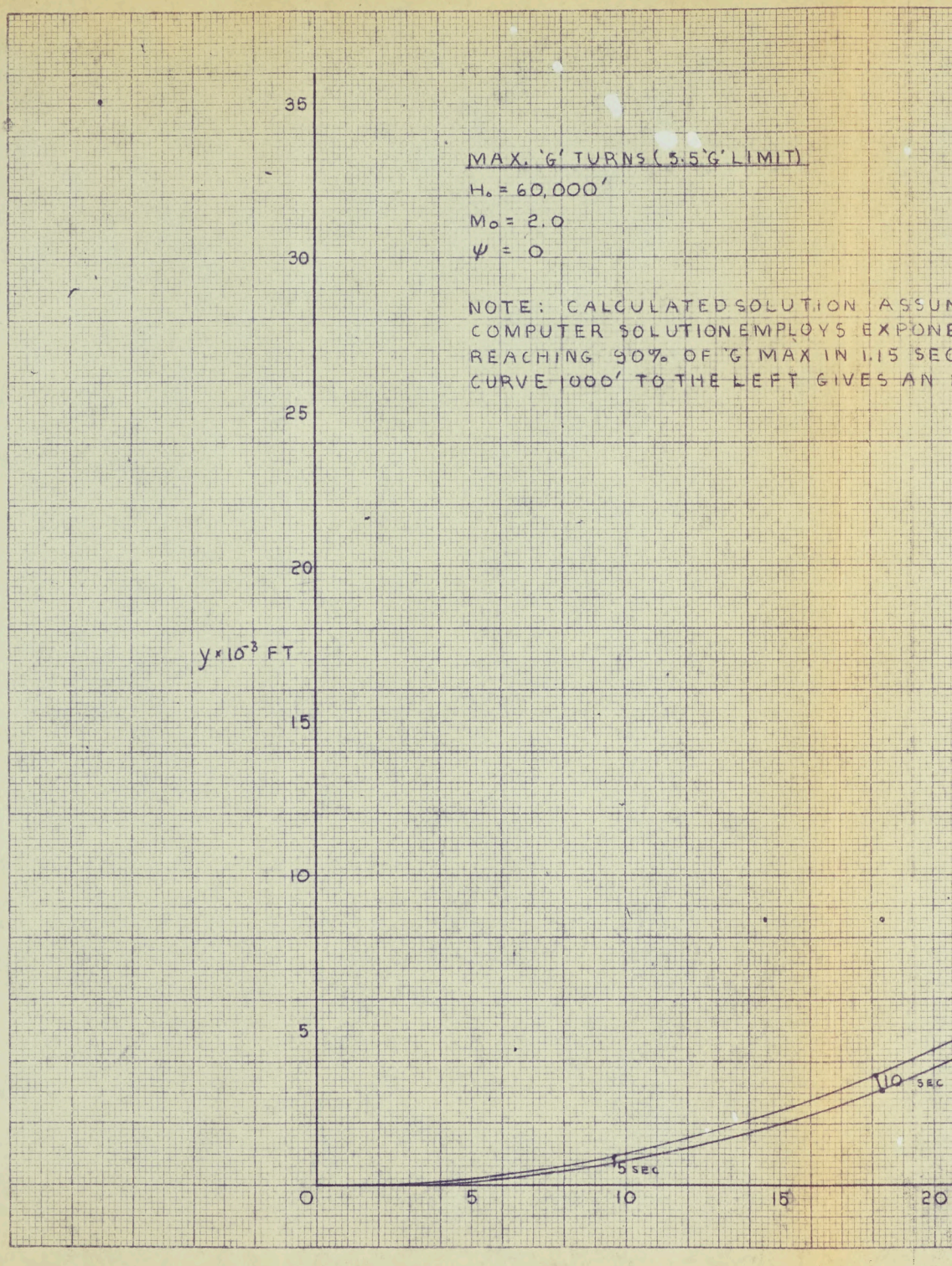
SECRET

Extract 2047/RC MANOEUVRES 1/2

11

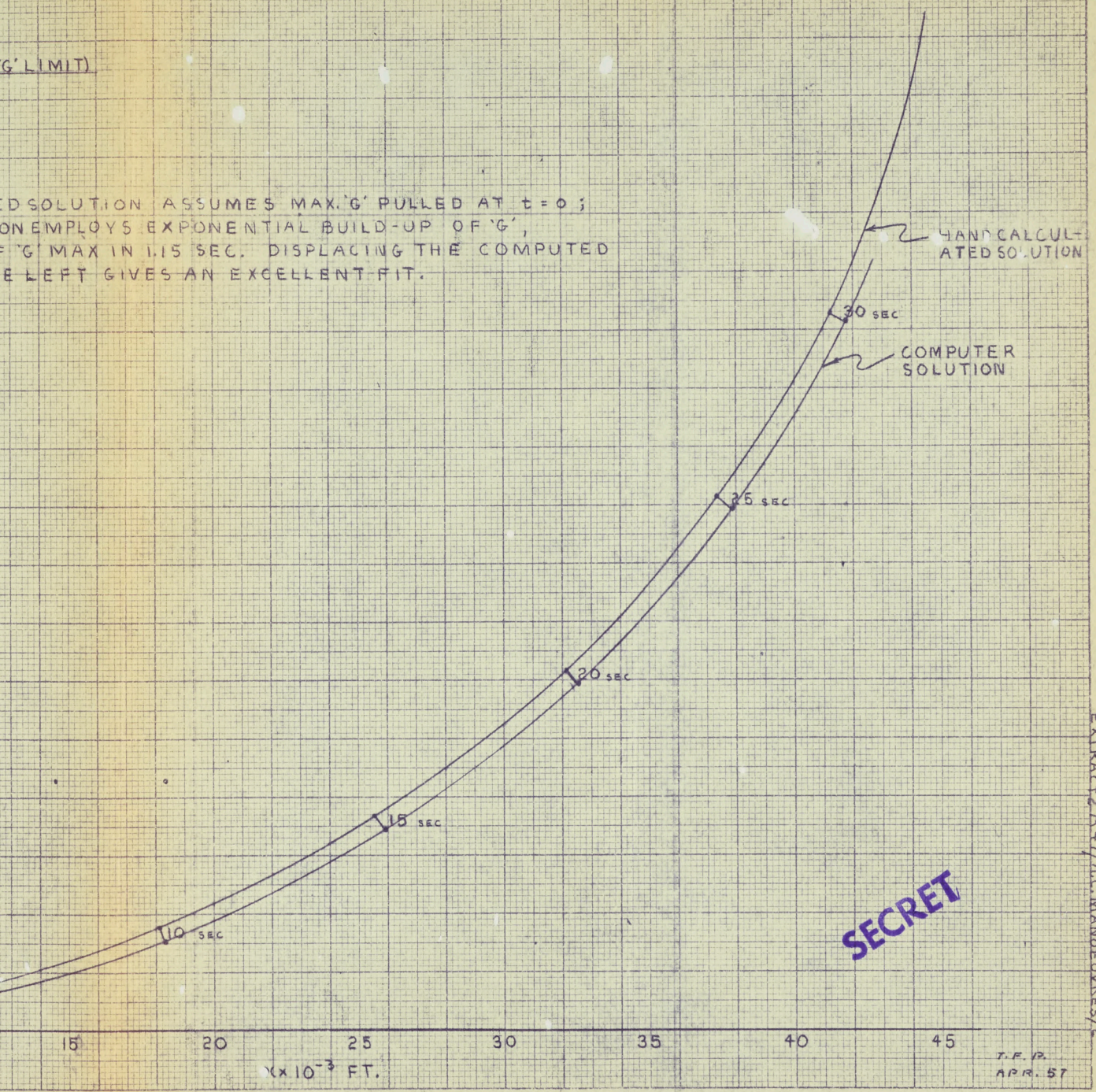


T. F. P.
APR. 57



'G' LIMIT)

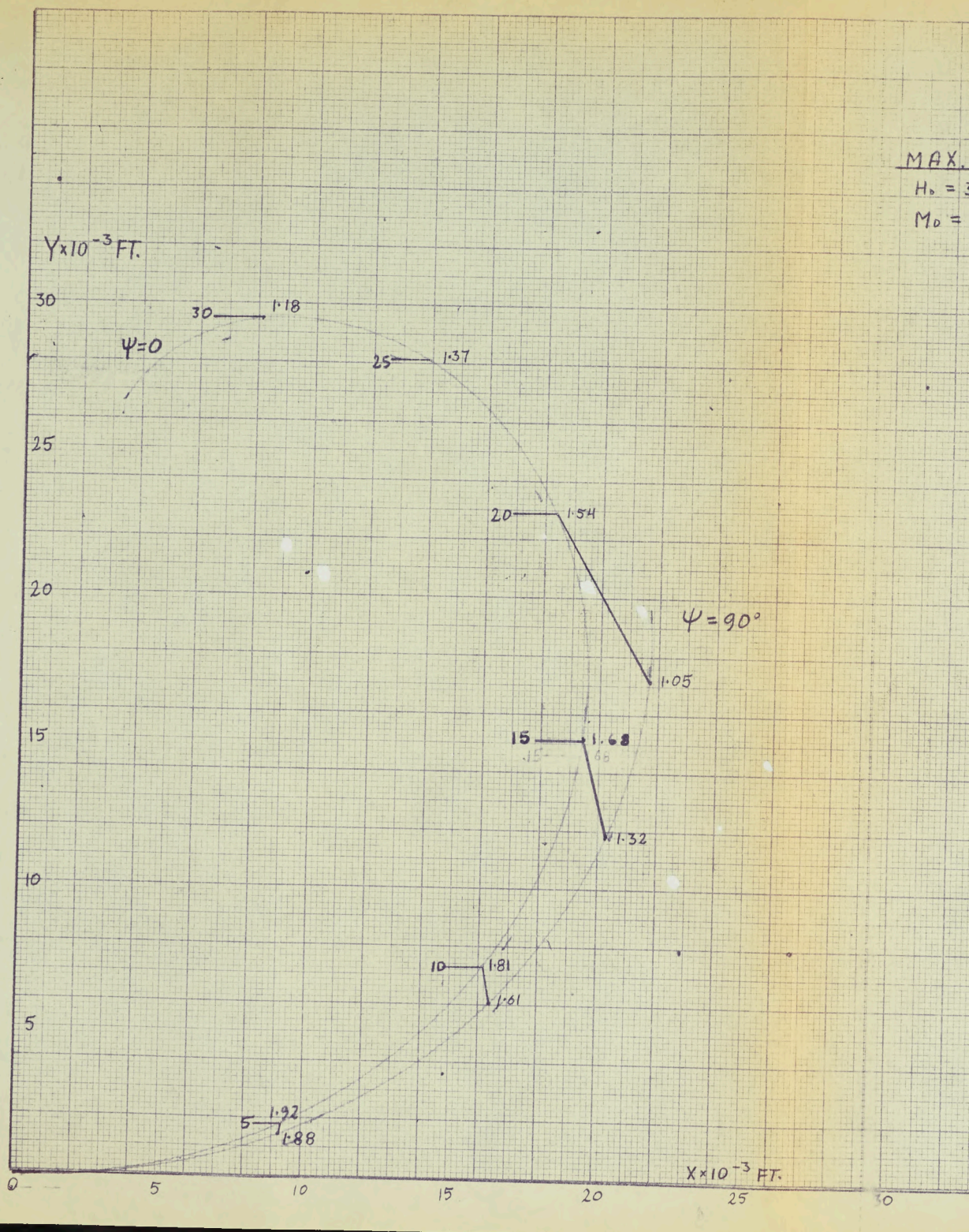
ED SOLUTION ASSUMES MAX. 'G' PULLED AT t = 0 ;
ON EMPLOYS EXPONENTIAL BUILD-UP OF 'G',
= 'G' MAX IN 1.15 SEC. DISPLACING THE COMPUTED
E LEFT GIVES AN EXCELLENT FIT.



SECRET

EXTRACTS A47/A.C. MANOEUVRES/2

T. F. P.
APR. 57



MAX. G TURNS (5·5 G LIMIT)

$H_0 = 36000'$

$M_0 = 2{\cdot}0$

$\Psi = 90°$

·05

$X \times 10^{-3}$ FT.

25

0

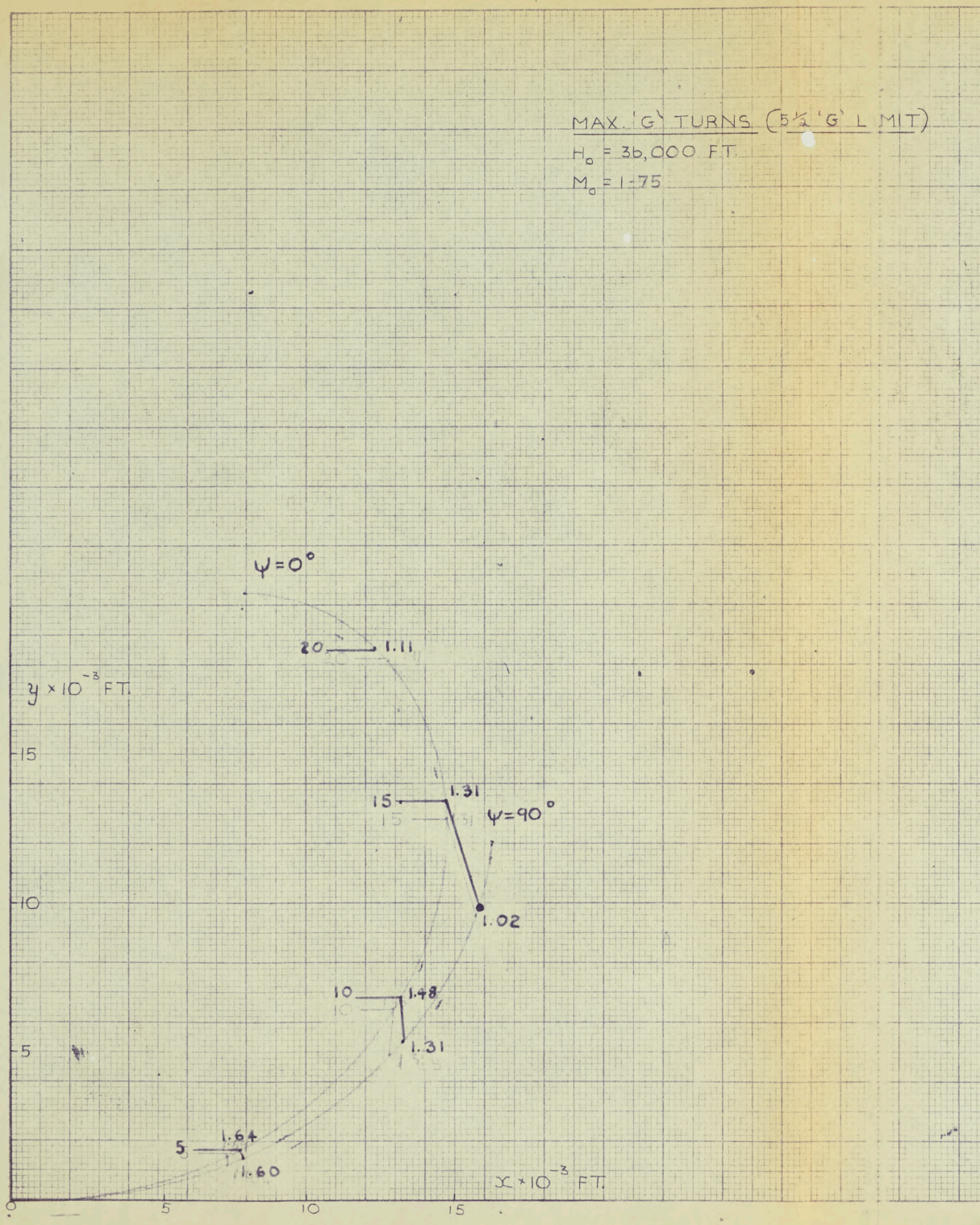
EXTRACT 2 A47/A·C. MANOEUVRES/2

SECRET

MAX. 'G' TURNS (5½ 'G' LIMIT)

H_o = 36,000 F.T.

M_o = 1.75



TURNS (5½ 'G' LIMIT)
O F.T.

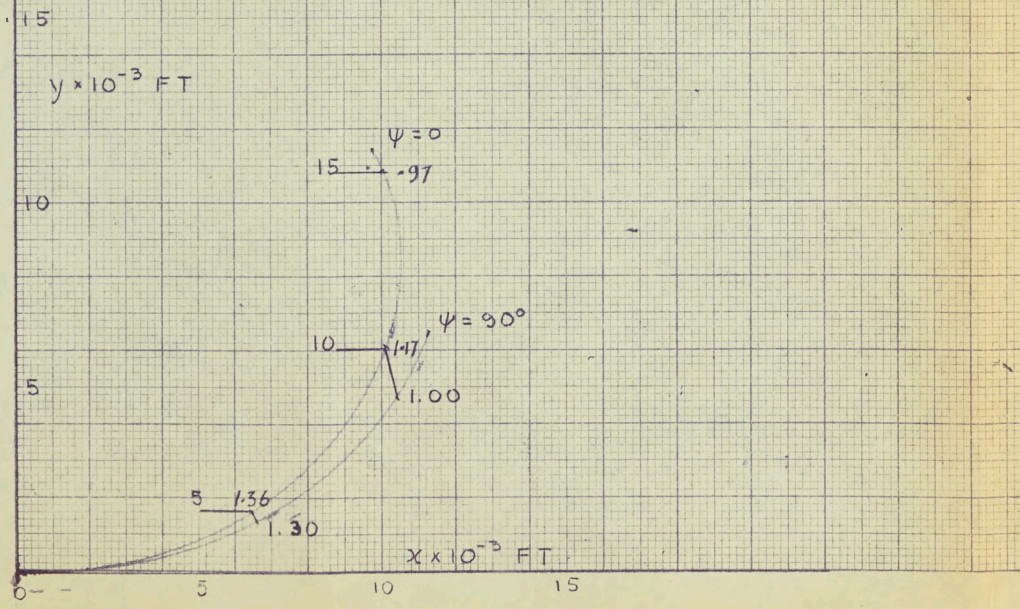
SECRET

EXTRACT A47/A.C. MANOEUVRES/2

MAX 'G' TURNS ($5\frac{1}{2}$ 'G' LIMIT)

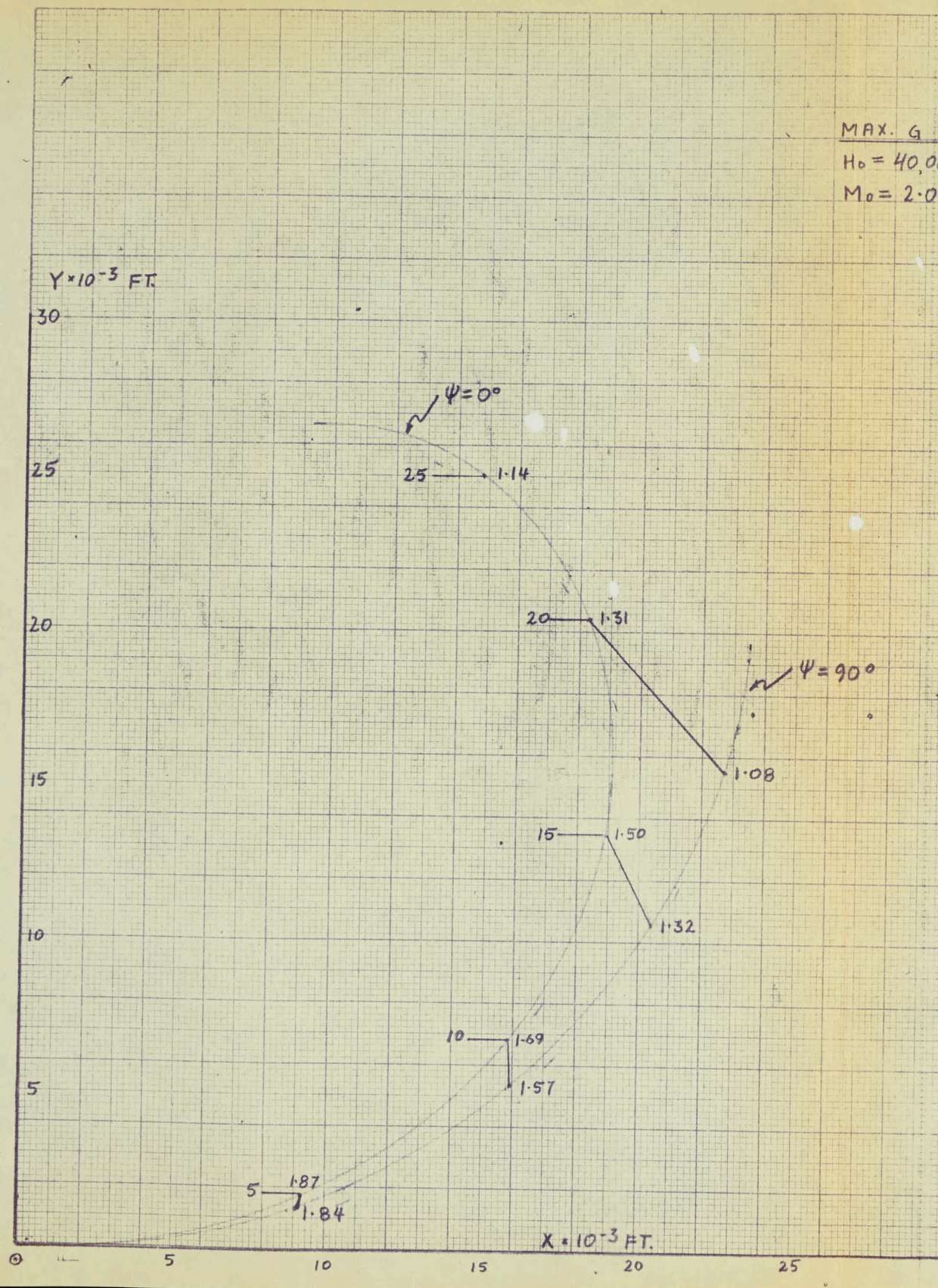
$H_o = 36,000'$

$M_o = 1.50$



'G' LIMIT)

SECRET



MAX. G TURNS (5·5 G LIMIT)

$H_0 = 40{,}000'$

$M_0 = 2{\cdot}00$

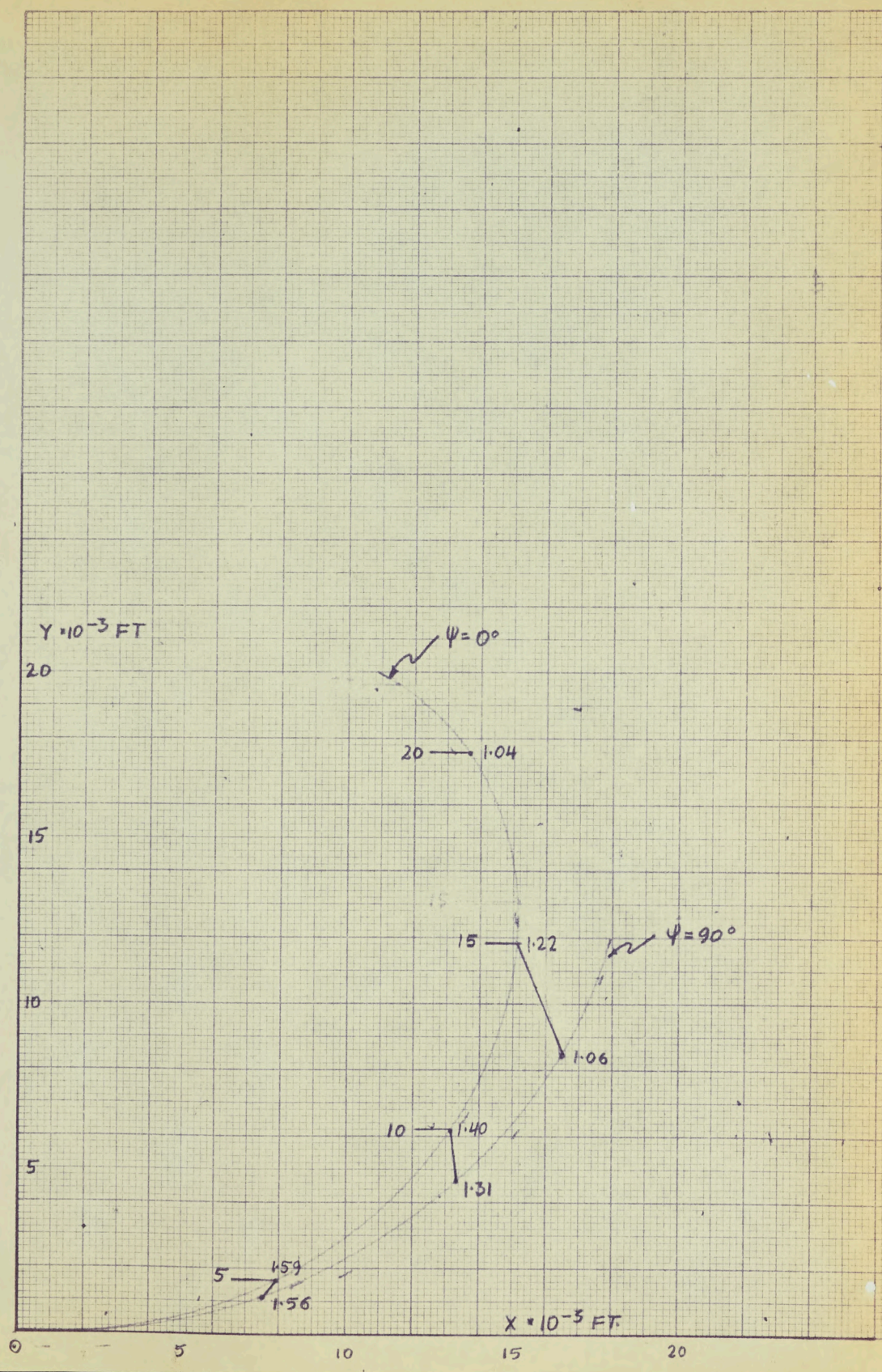
90°

SECRET

MAX. G

$H_o = 40.$

$M_o = 1.75$



MAX. G TURNS (5·5 G LIMIT)

$H_o = 40.000'$

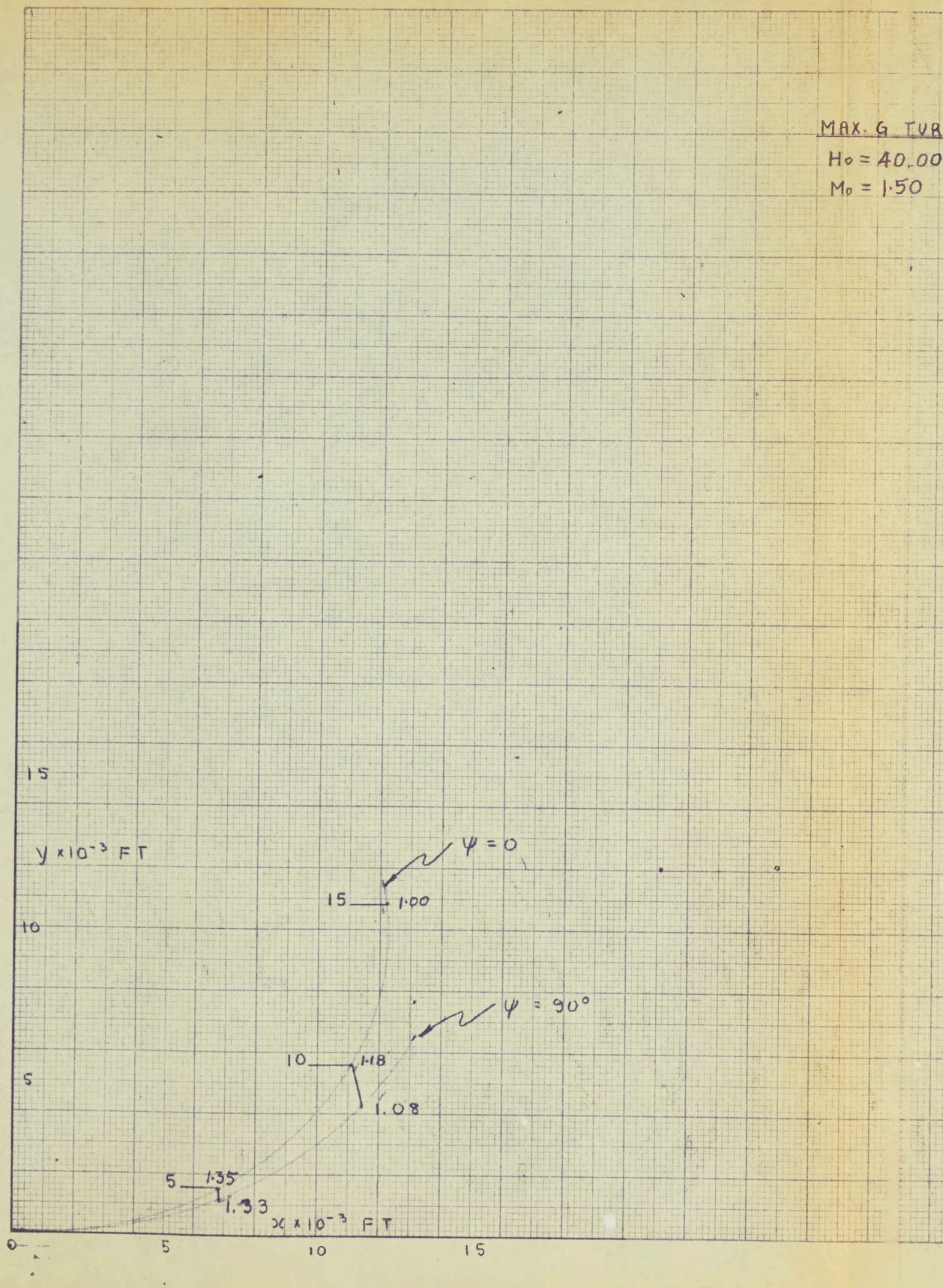
$M_o = 1.75$

SECRET

MAX. G TUR

$H_o = 40.00$

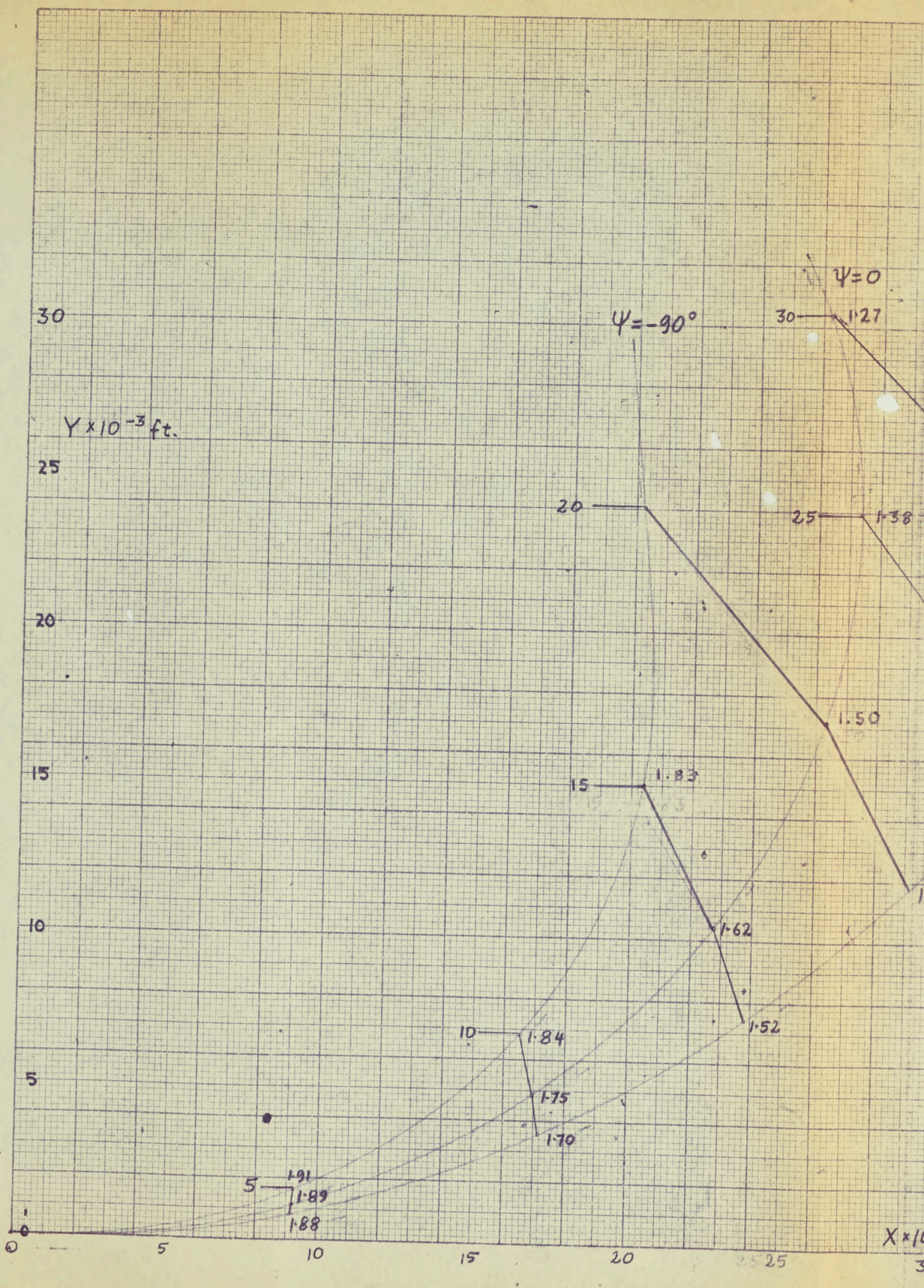
$M_o = 1.50$



MAX. G TURNS (5·5 G LIMIT)

$H_0 = 40{,}000'$

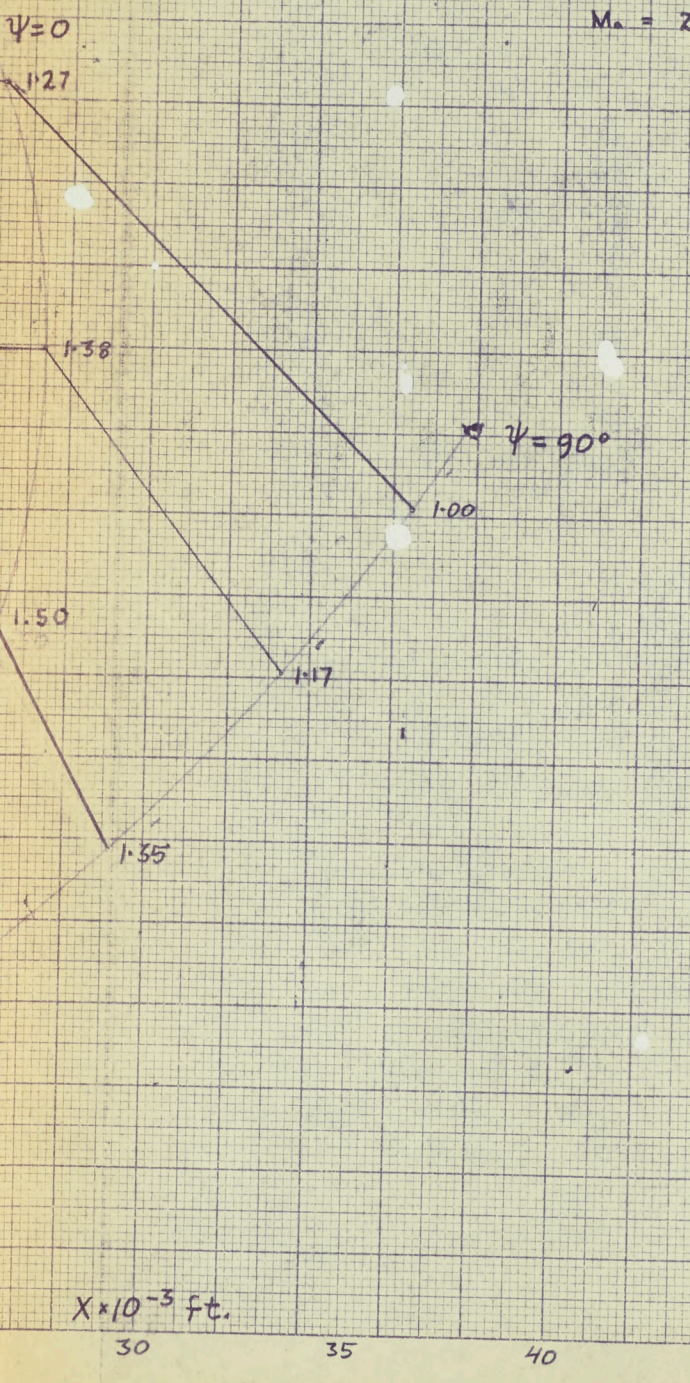
$M_0 = 1{\cdot}50$



MAXIMUM "G" TURNS (5.5G LIMIT)

H_0 = 50000'

M_0 = 2.0



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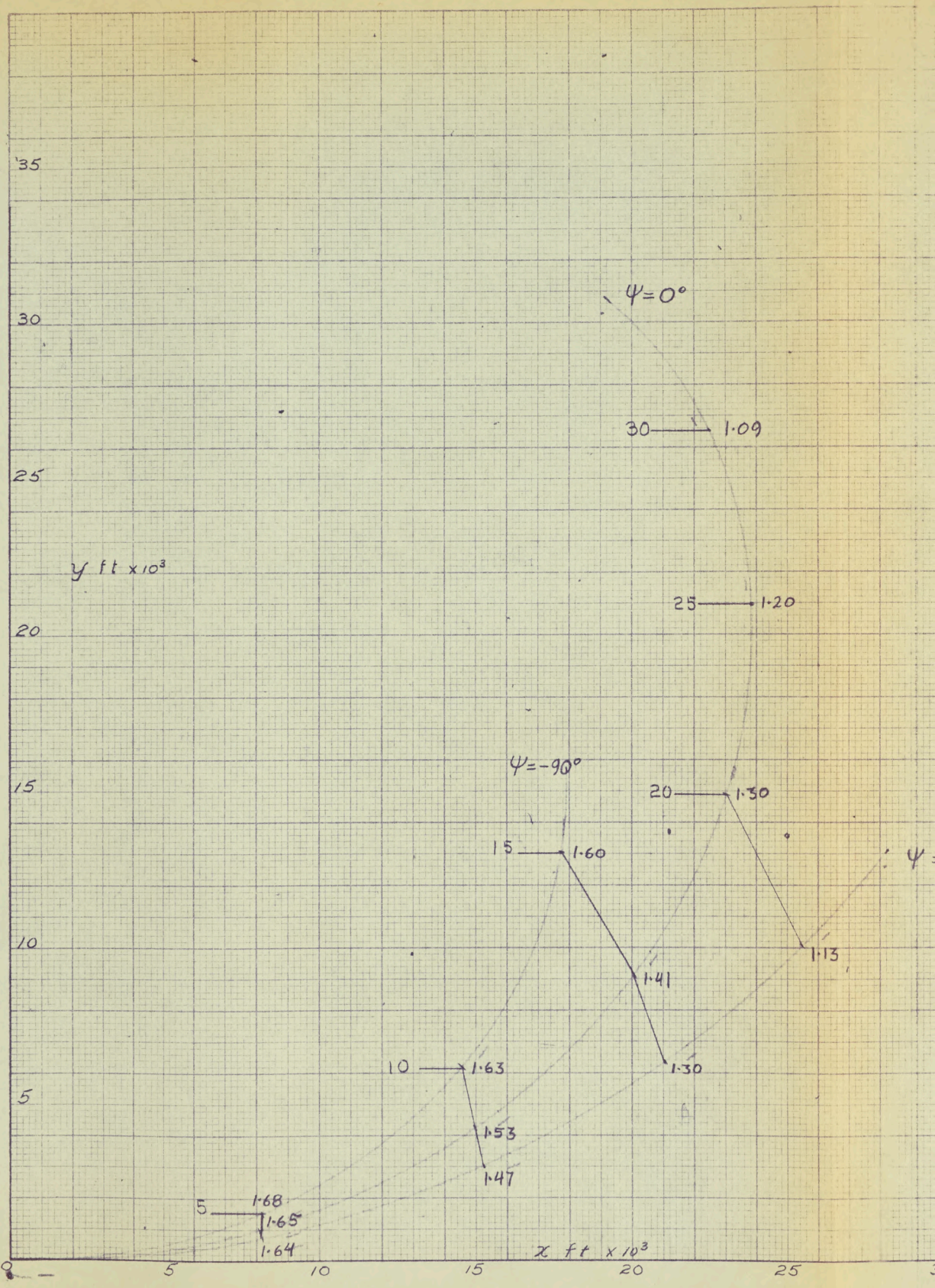


MAXIMUM 'G' TURNS (5.5 'G' LIMIT)

$H_o = 50,000'$

$M_o = 1.75$

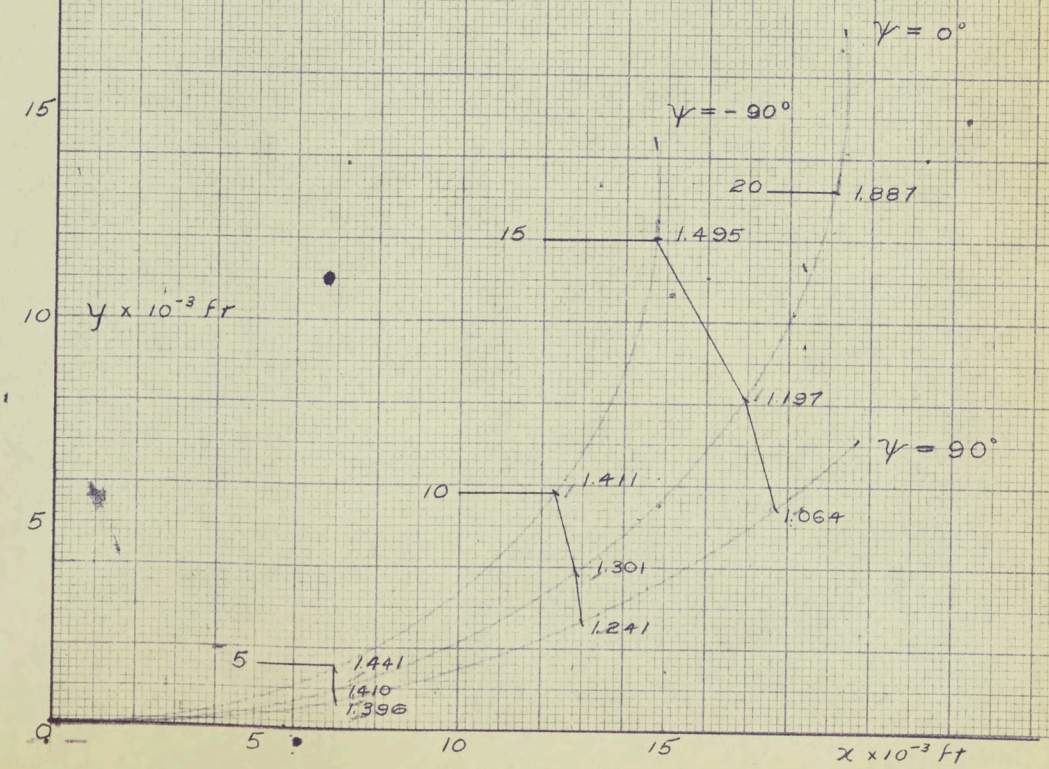
$\therefore \Psi = 90°$

1-13

MAXIMUM 'G' TURNS (55

$H_o = 50{,}000'$

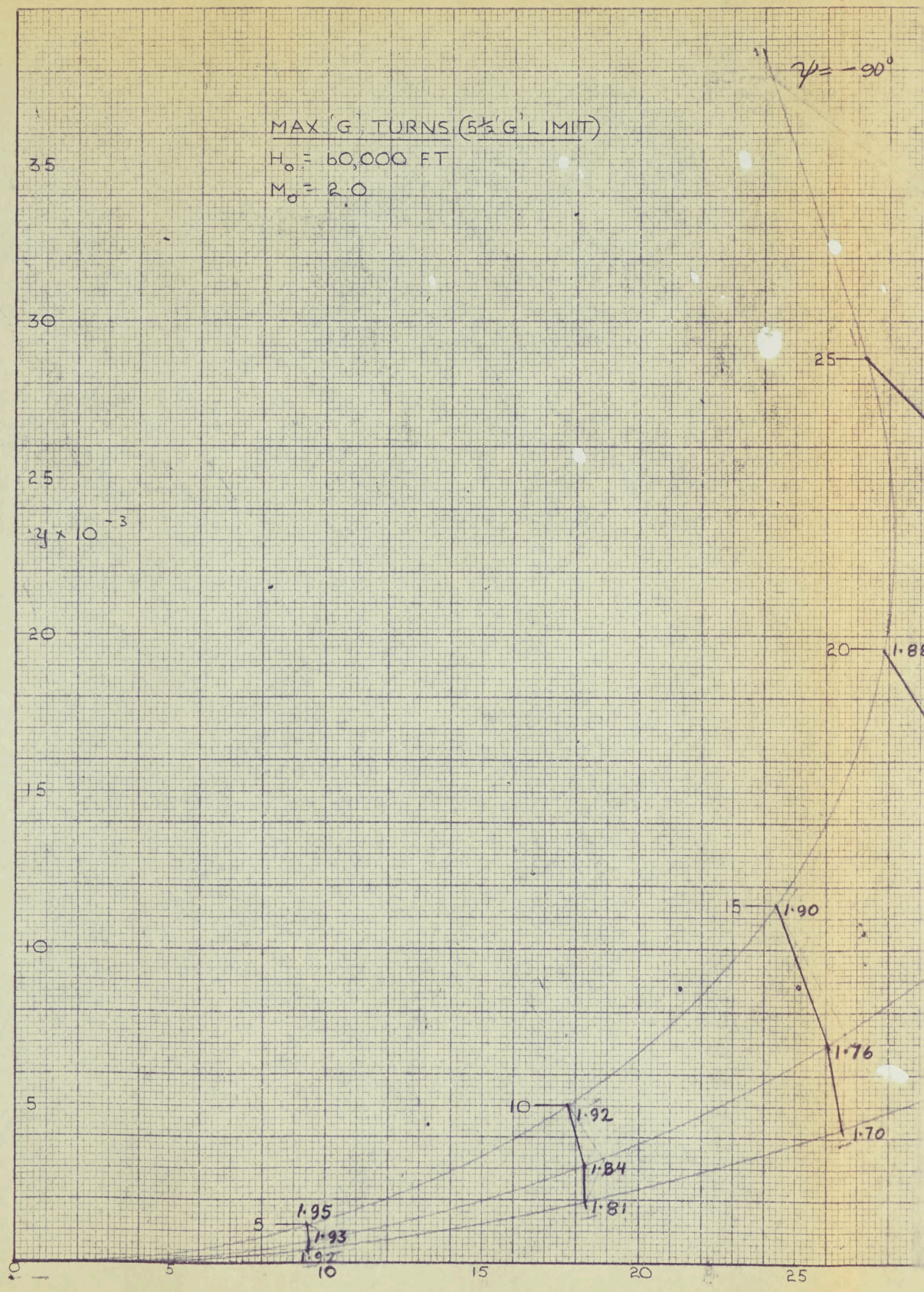
$M_o = 1.50$

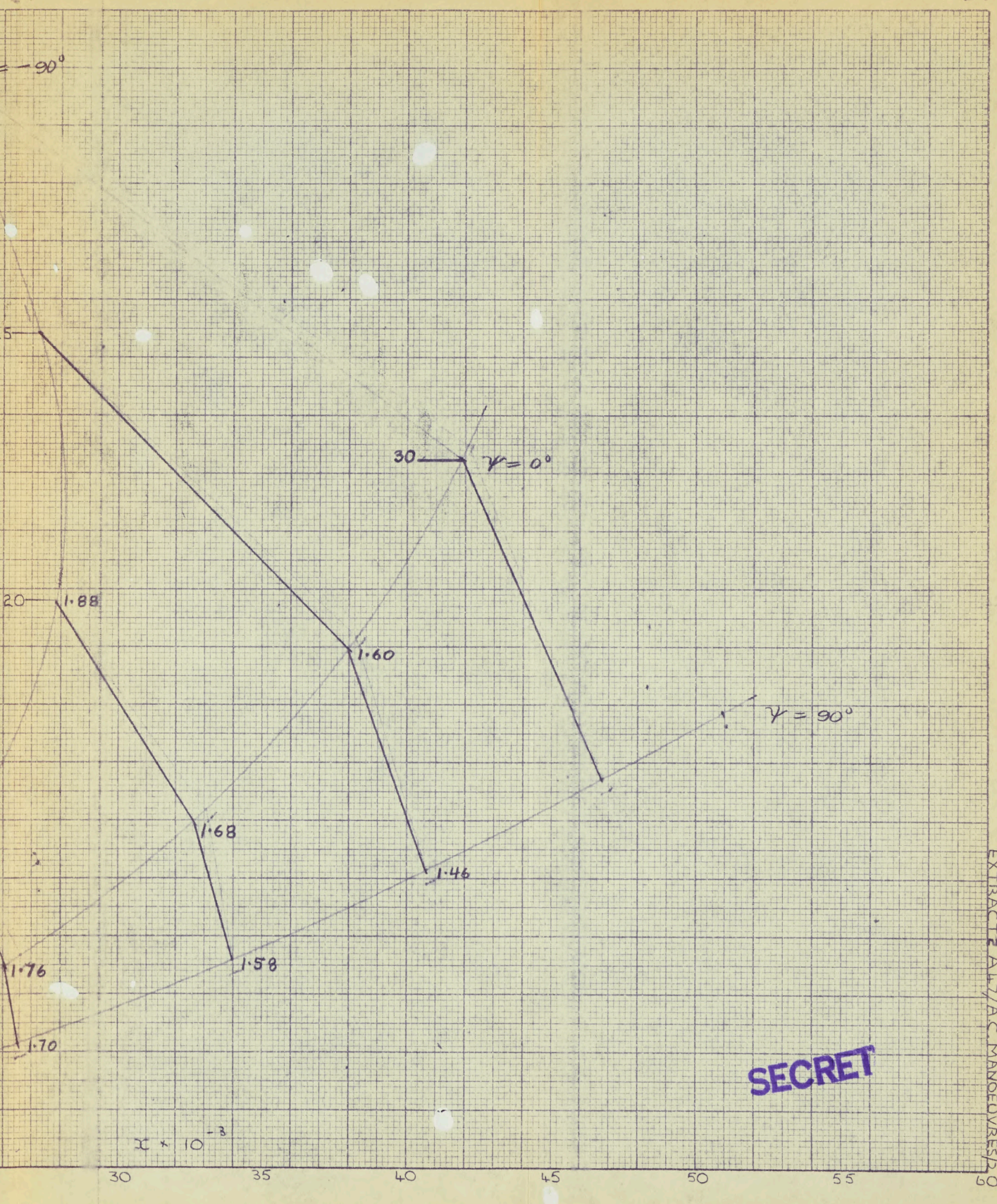


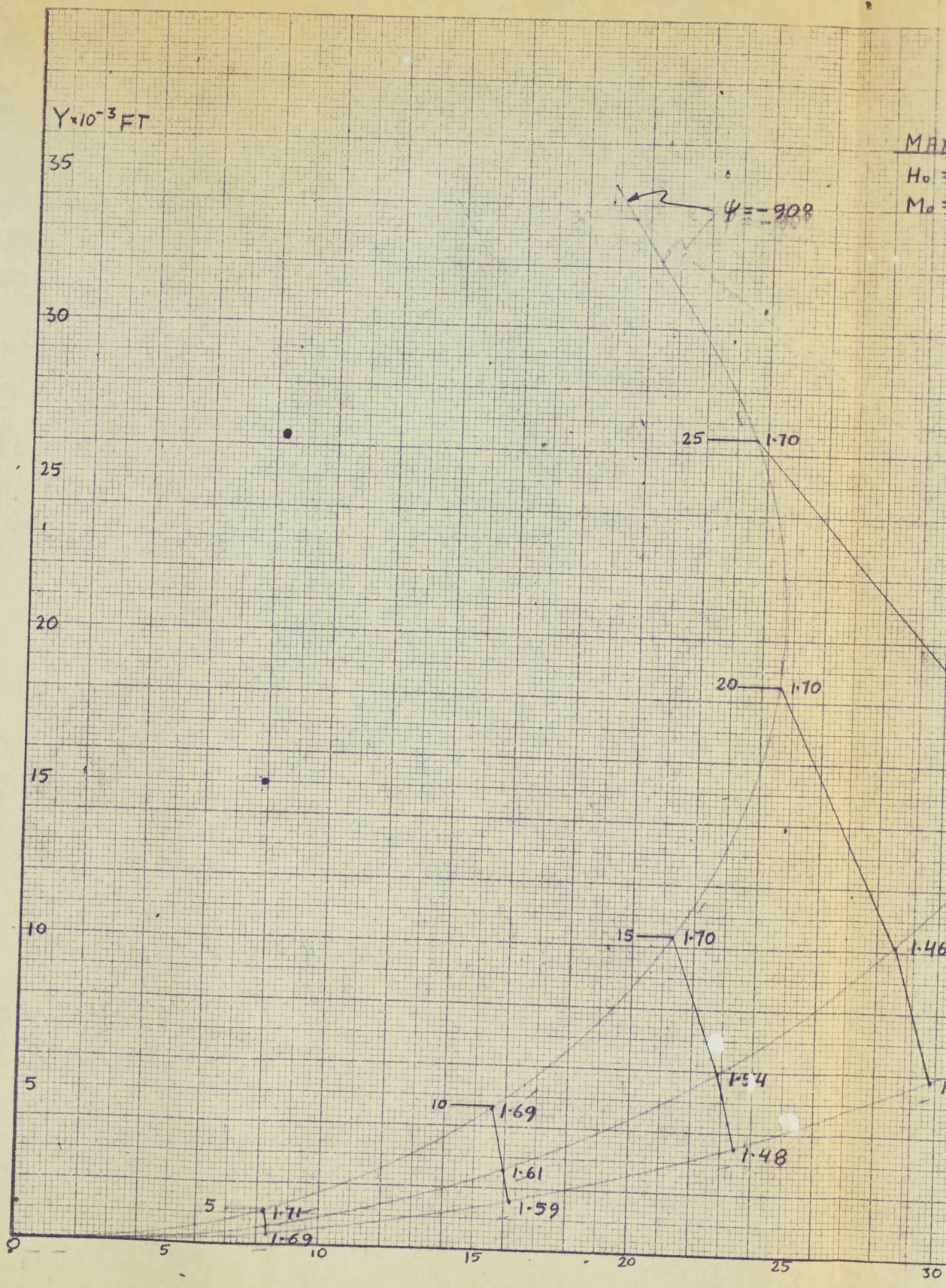
(55 'G' LIMIT)

EXTRACT A47/A.C. MANOEUVRES/2

SECRET



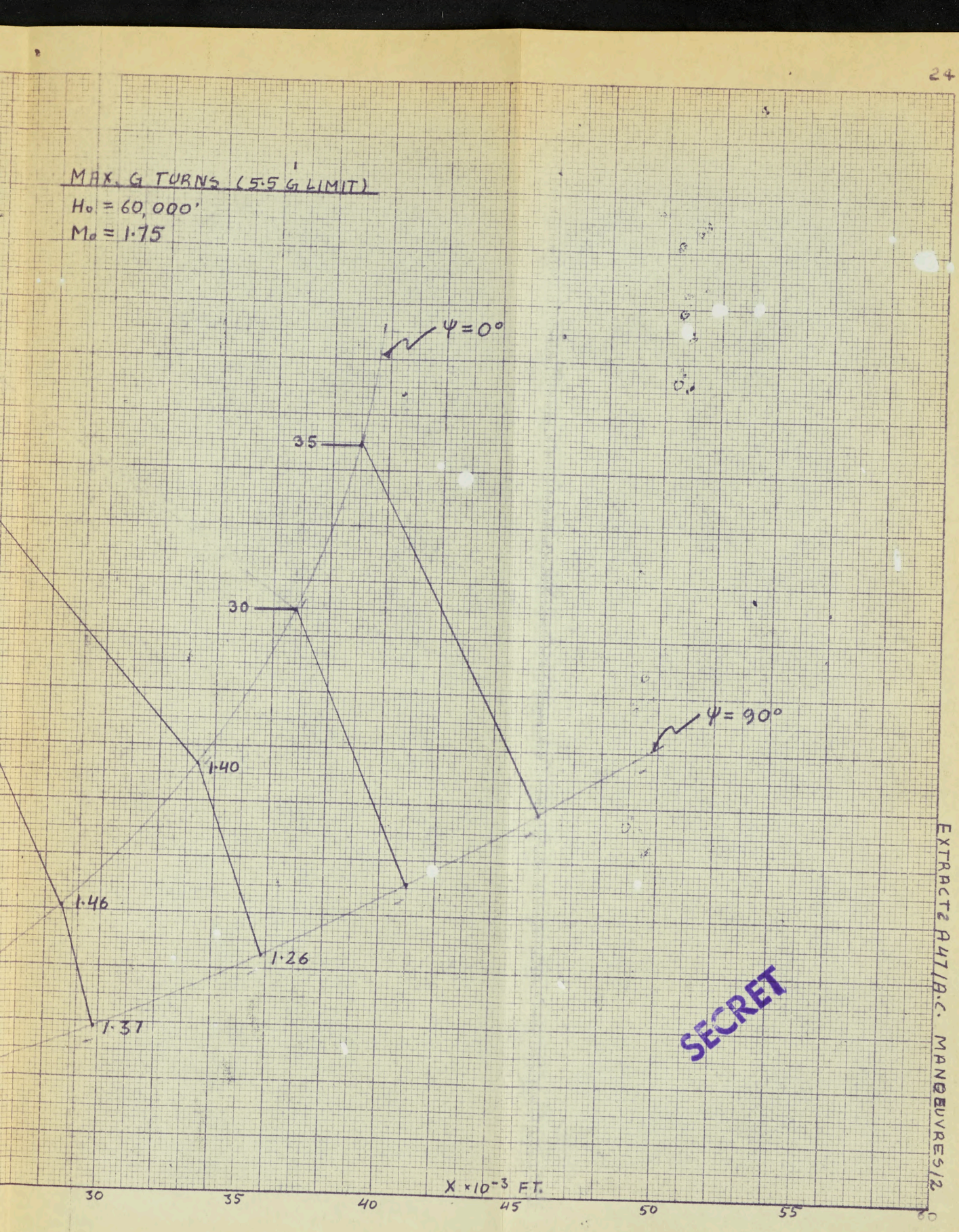




MAX. G TURNS (5·5 G LIMIT)

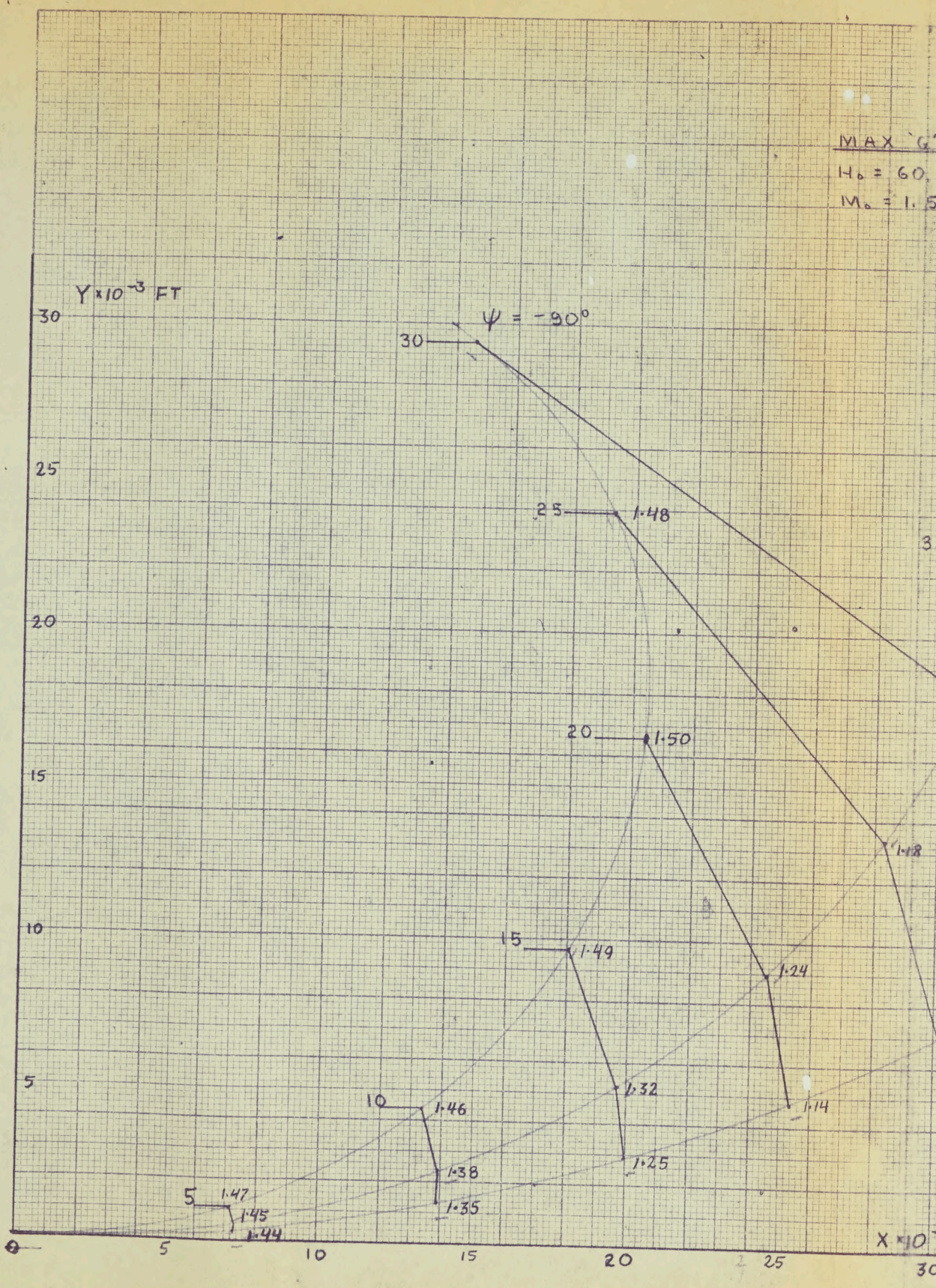
$H_o = 60,000'$

$M_o = 1·75$



SECRET

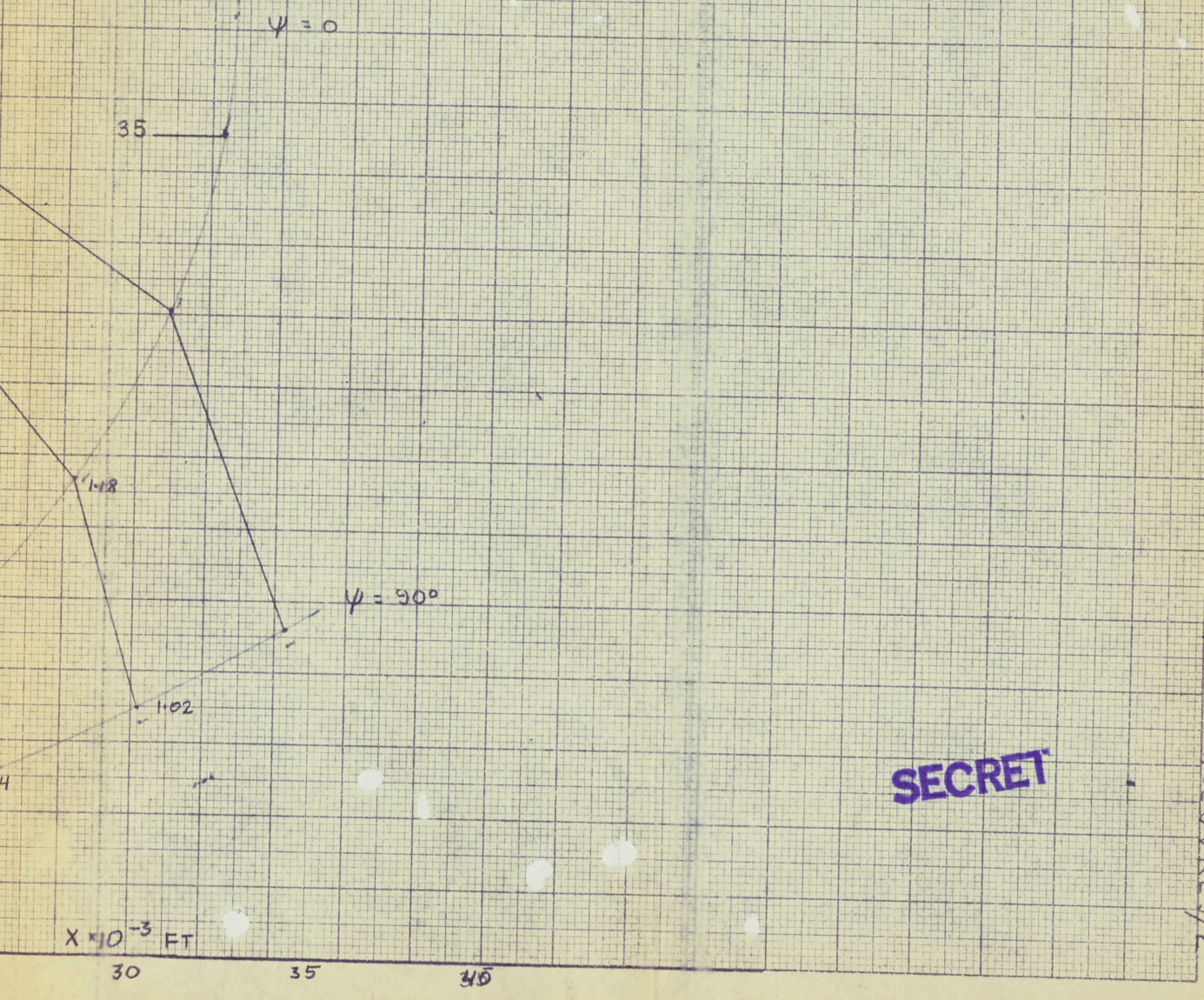
EXTRACTED A47/A.C. MANOEUVRES 1/2

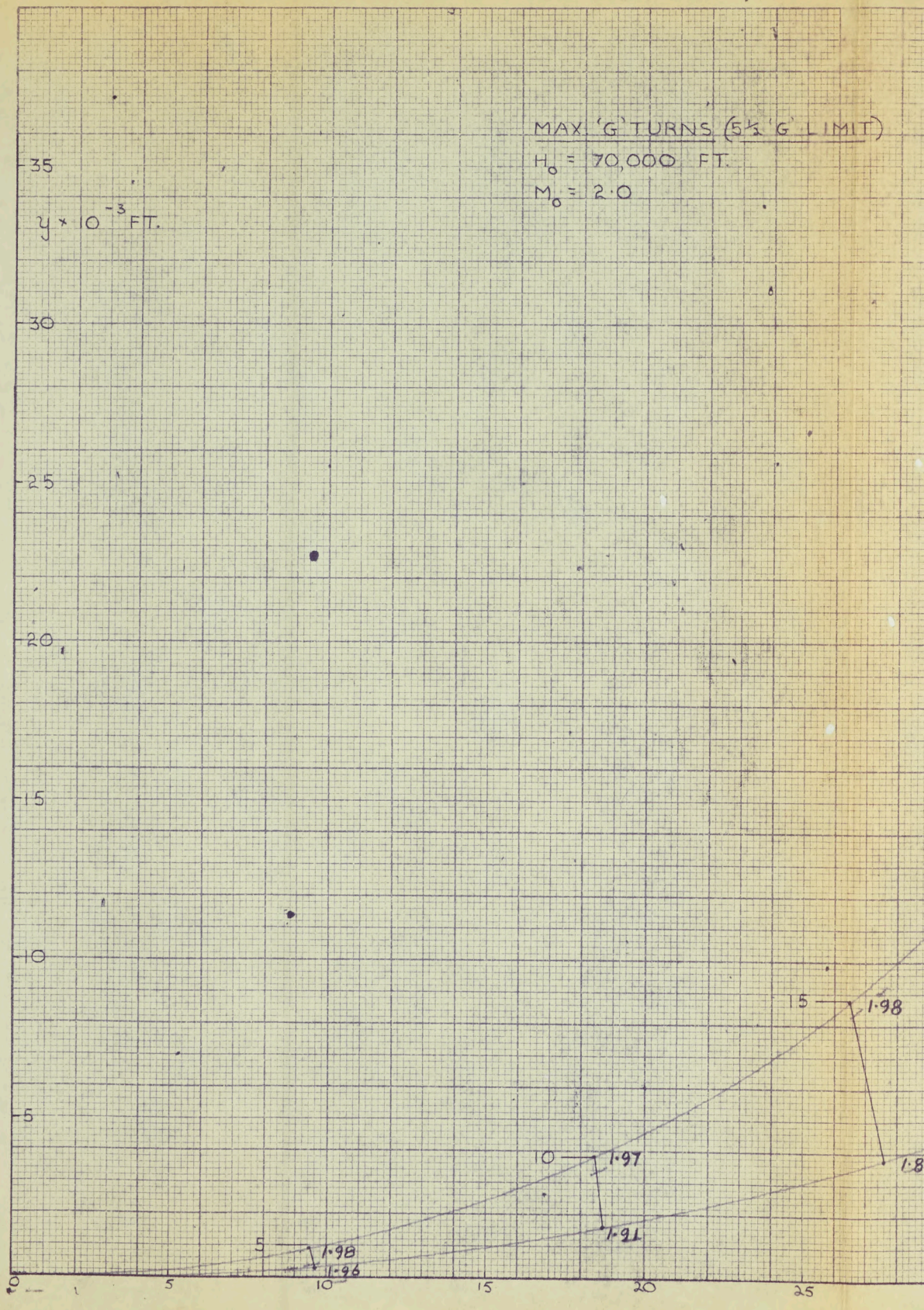


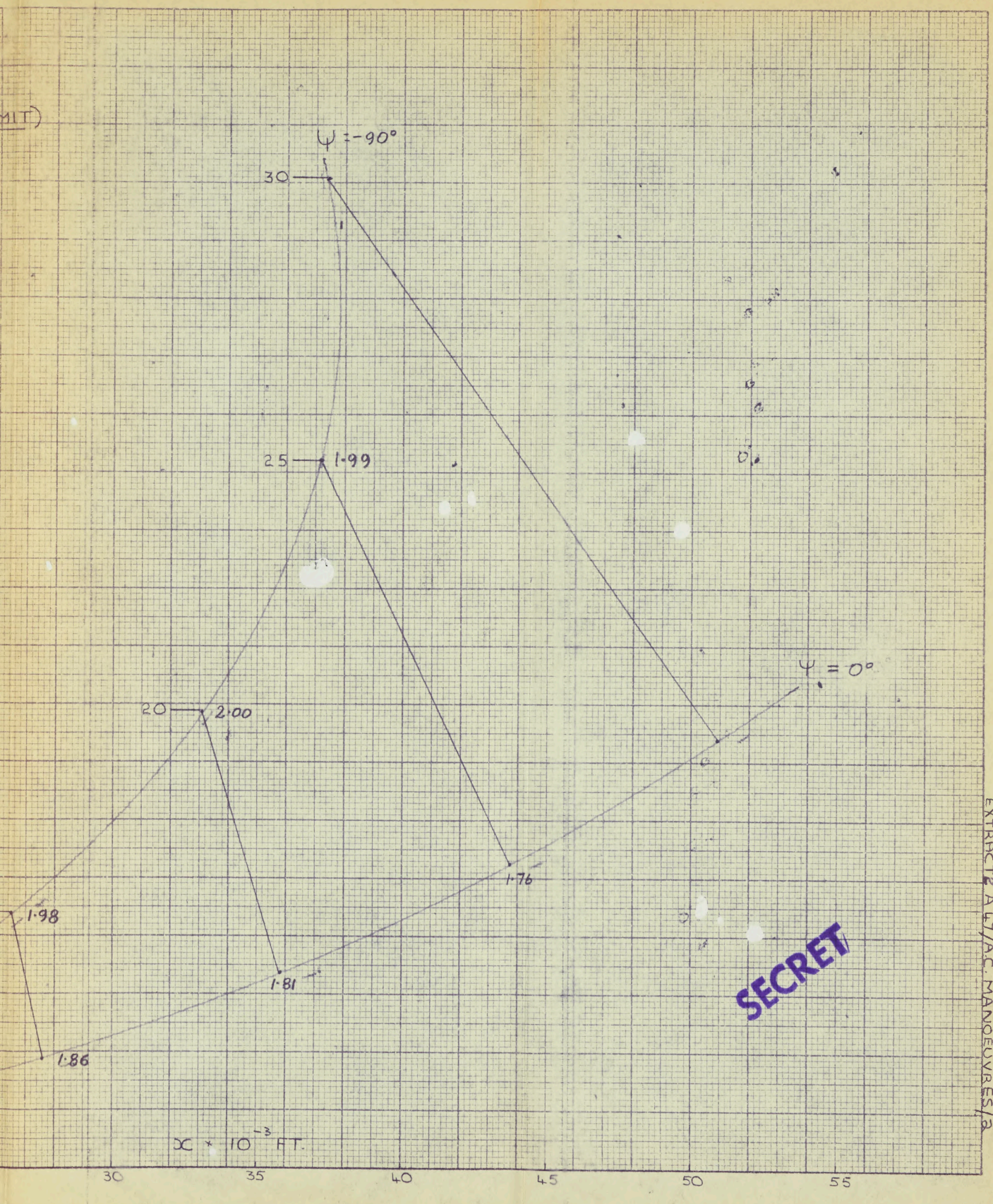
MAX 'G' TURNS (5.5 'G' LIMIT)

$H_0 = 60,000'$

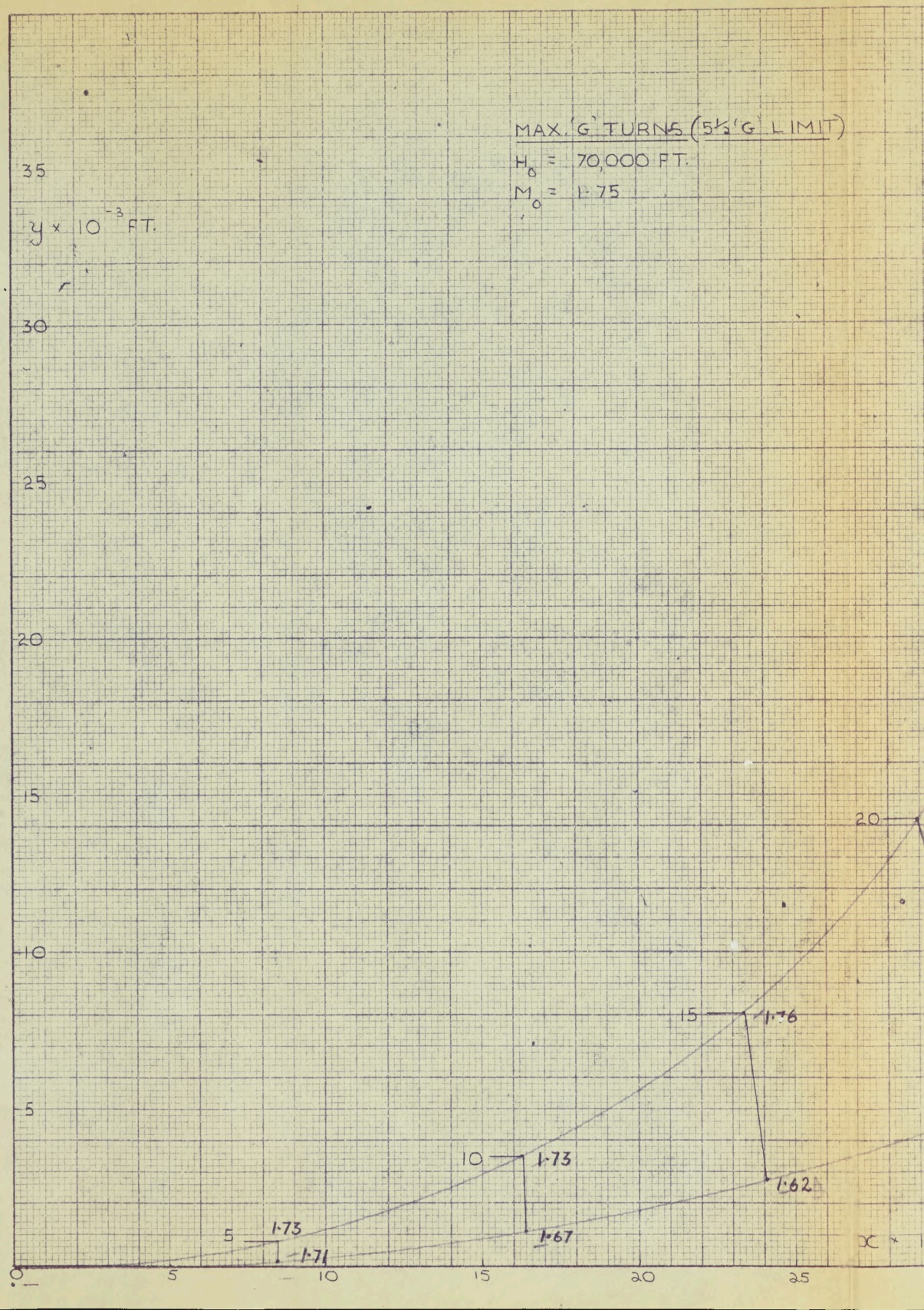
$M_0 = 1.50$

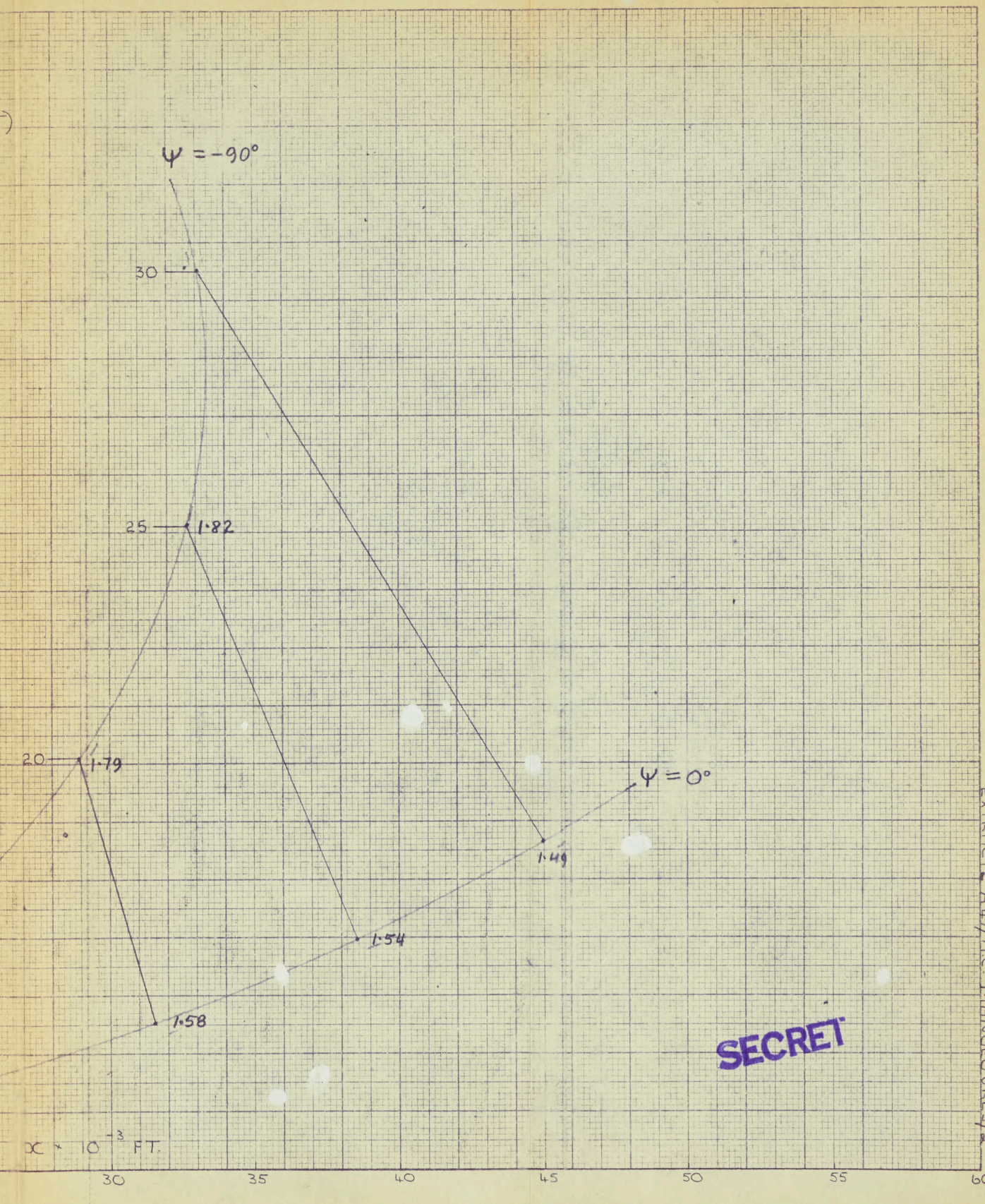


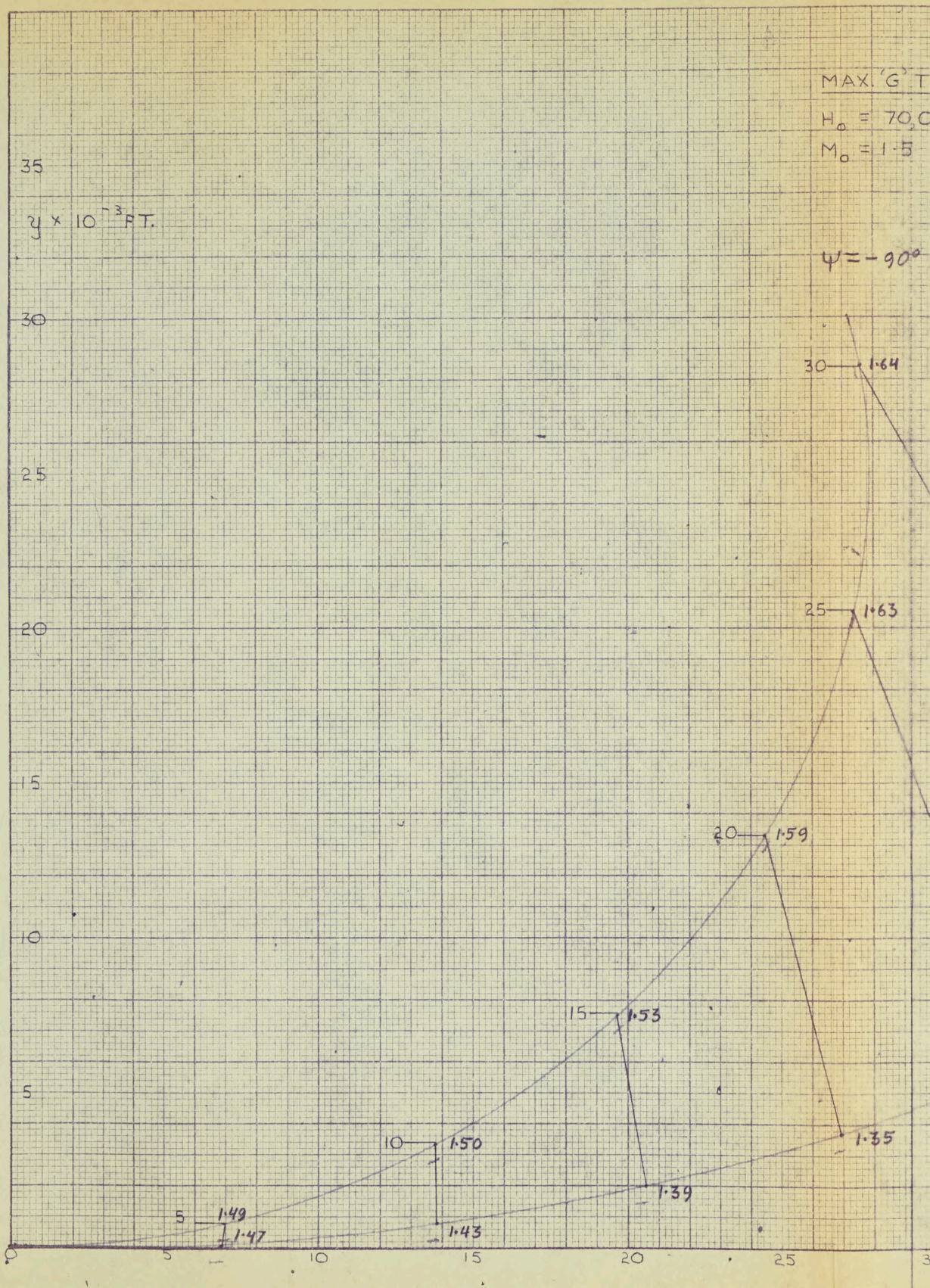




EXTRACTED A 47/A.C. MANOEUVRES/a



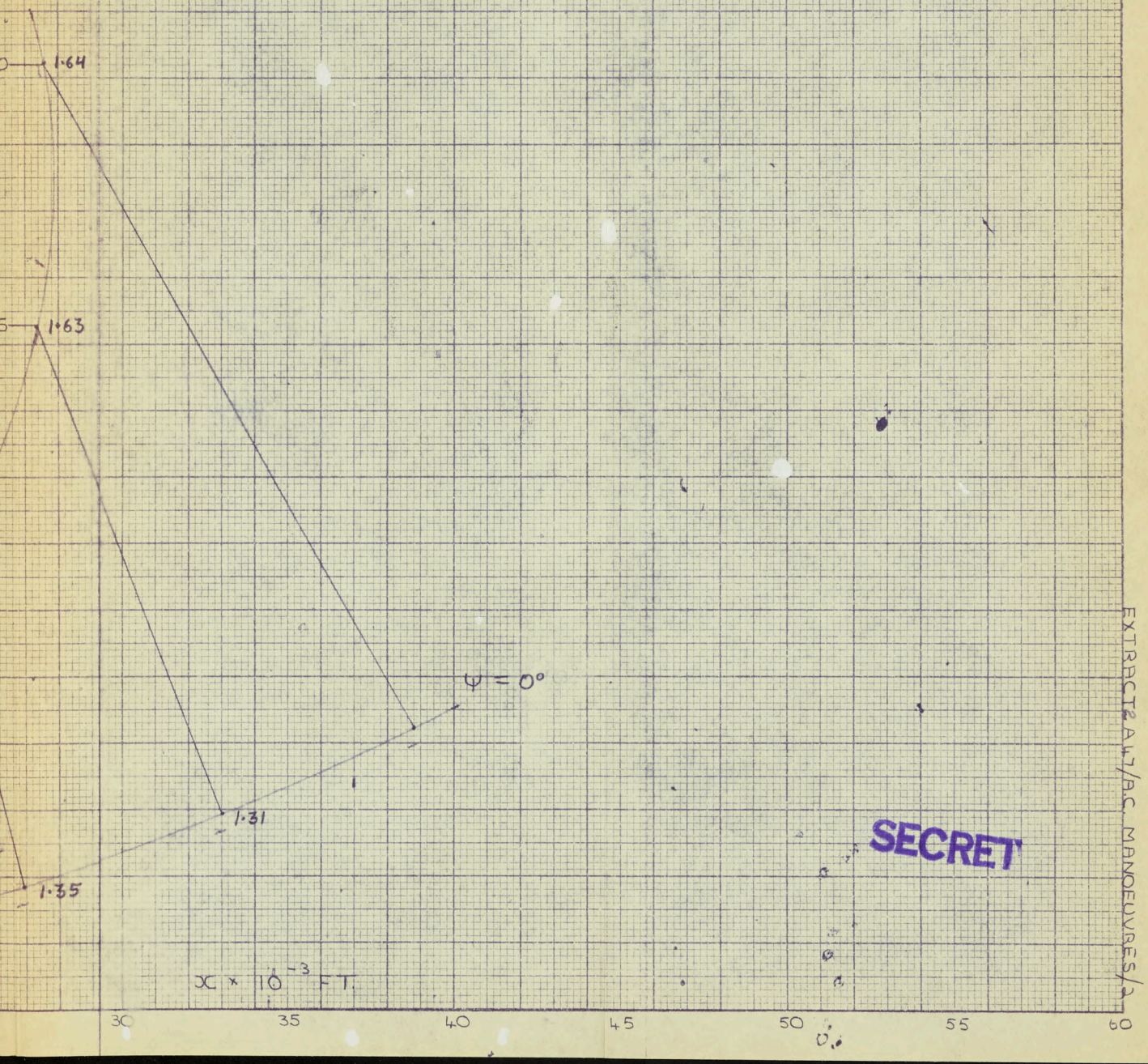




MAX. 'G' TURNS (5½ 'G' LIMIT)

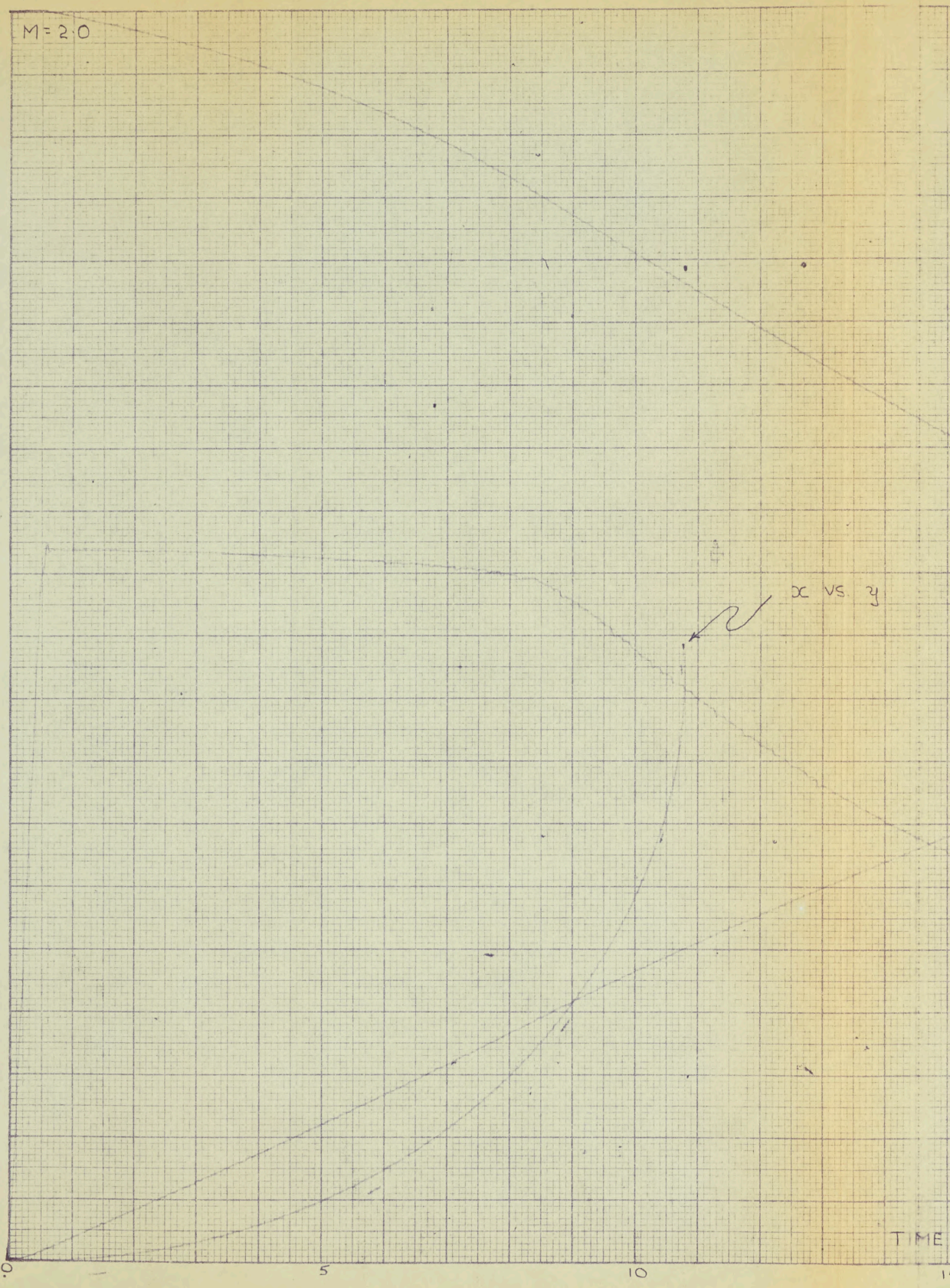
H_o = 70,000 FT.

M_o = 1·5



SECRET

EXTRACT FROM A47/A.C. MANOEUVRES/2



MAX. 'G' TURNS (5½ 'G' LIMIT)

H_0 = 36,000 FT

M_0 = 2·0

ψ = 90°

M = 0·1

n = 0·5 'G'

θ = 10°

VS ψ

M

θ

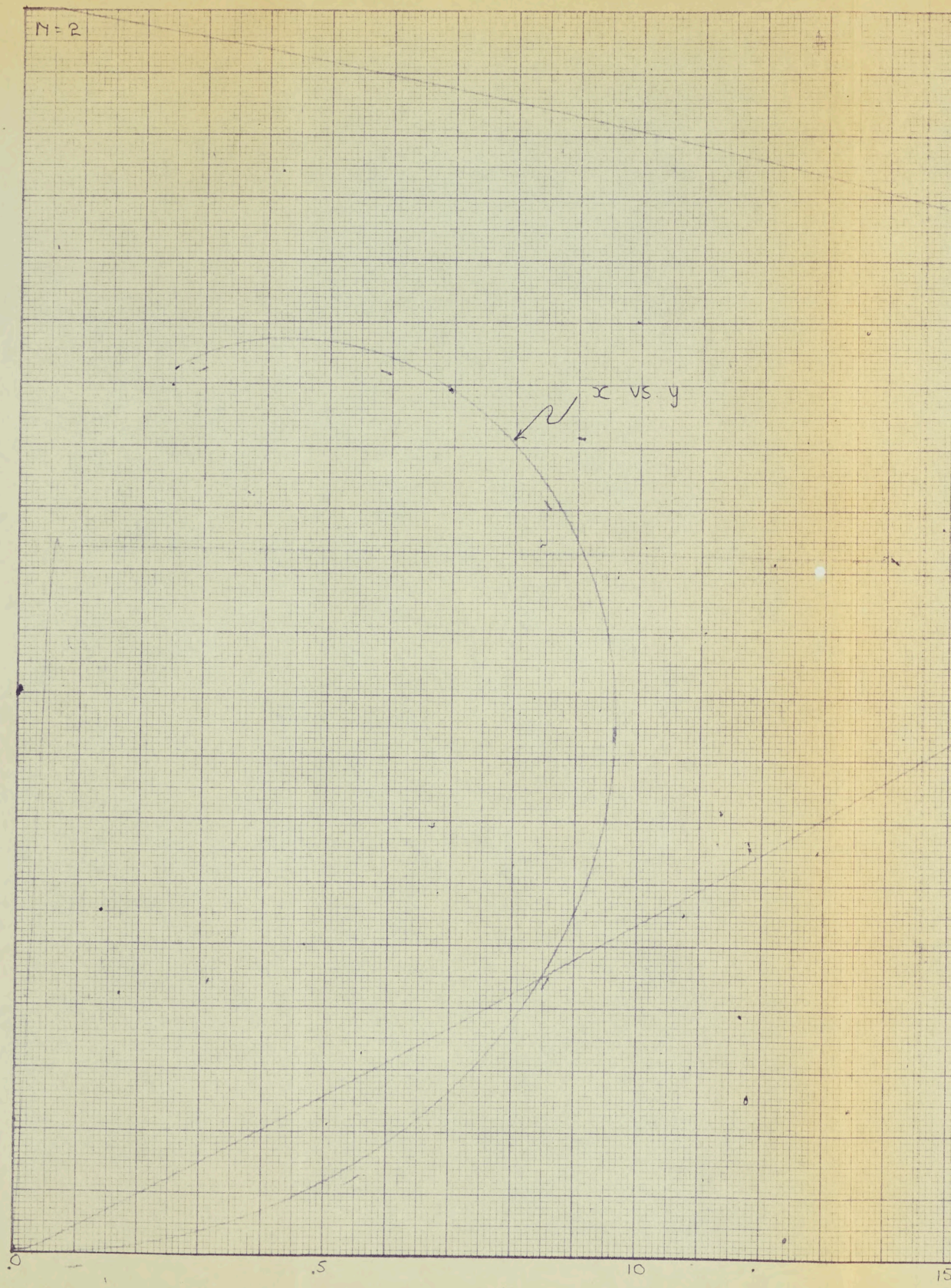
n

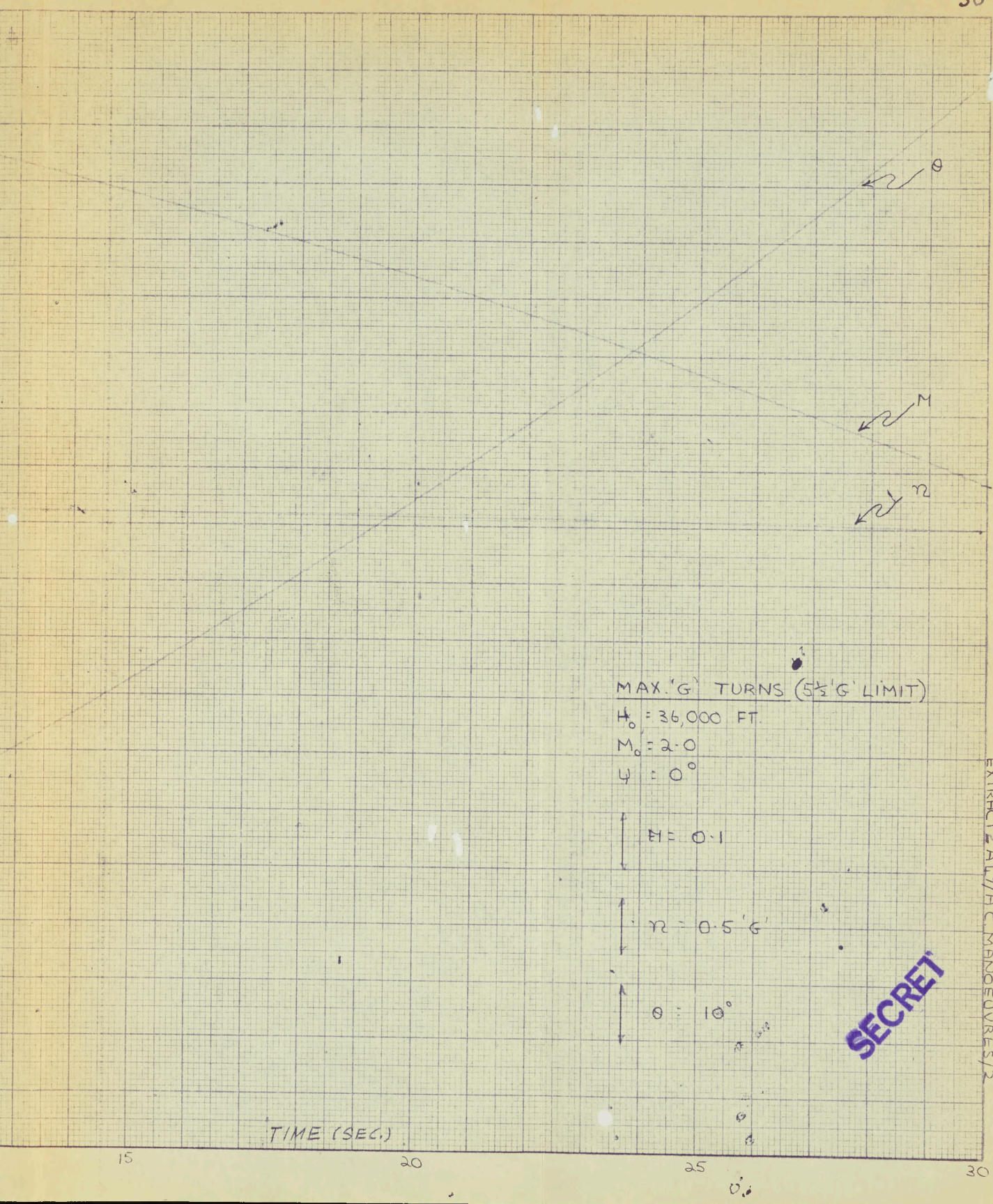
SECRET

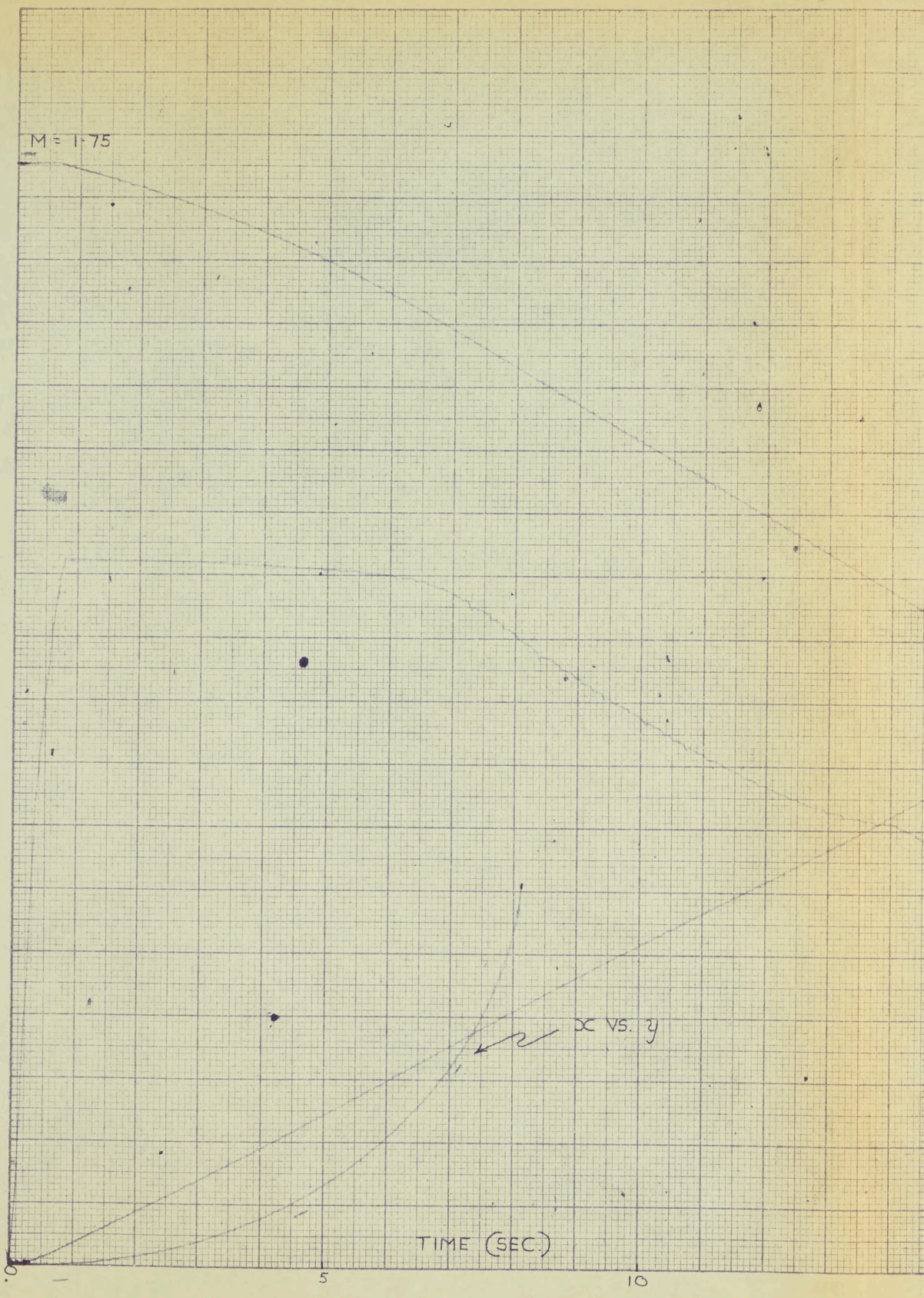
TIME (SEC.)

15 20 25 30

EXTRACT FROM A47/A.C. MANOEUVRES /2




θ
M
n
MAX. 'G' TURNS (5½ 'G' LIMIT)
H_o = 36,000 FT
M_o = 2·0
ψ = 0°
H = 0·1
n = 0·5 'G'
θ = 10°
TIME (SEC.)
15
20
25
30

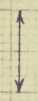


MAX. 'G' TURNS (5½ 'G' LIMIT)

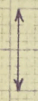
H_o = 36,000 FT.

M_o = 1·75

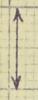
ψ = +90°



M = 0·1



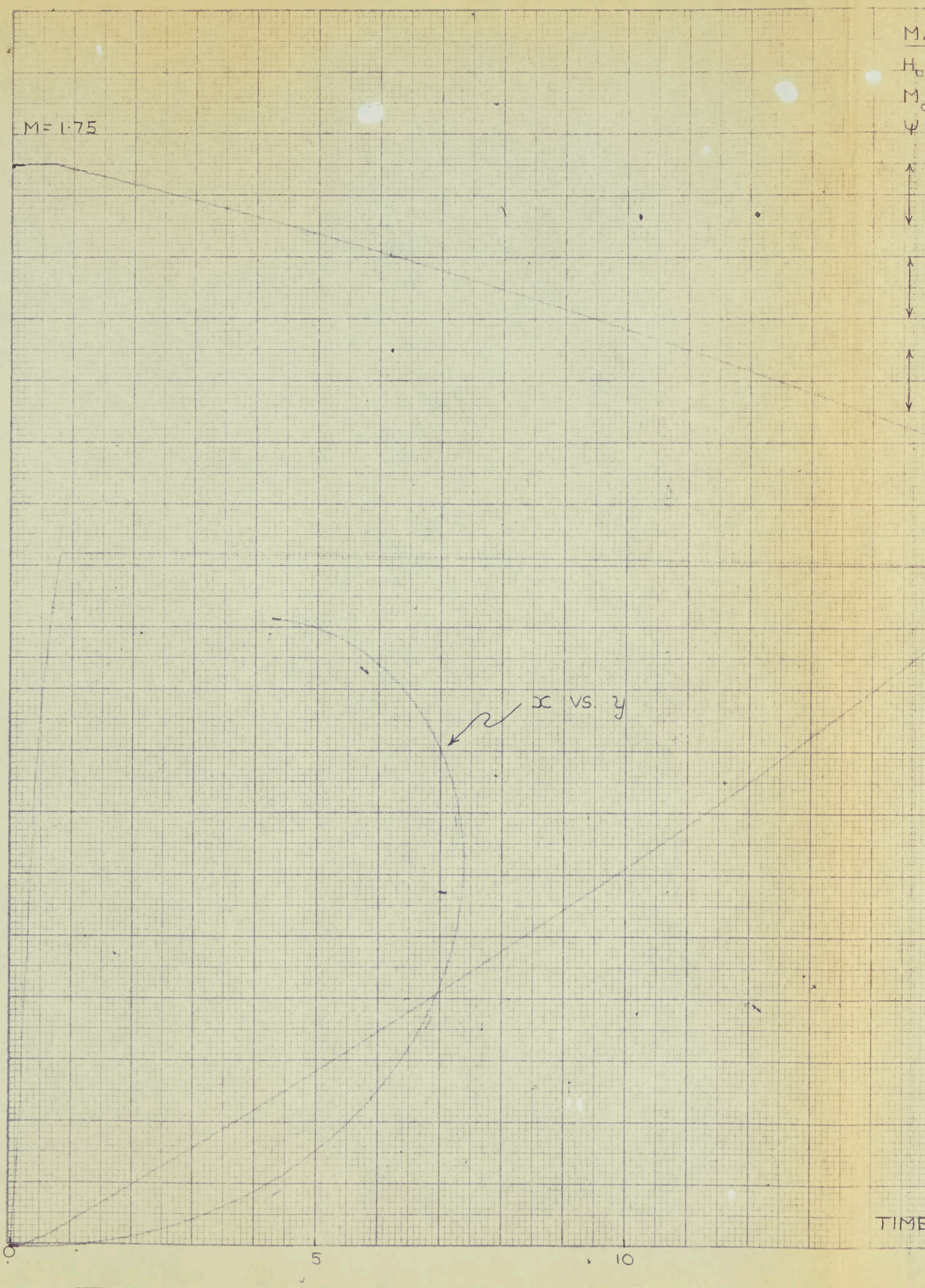
n = 0·5 'G'



θ = 10°

SECRET

EXTRACT 2 A47/R.C. MANOEUVRES/2



MAX. 'G' TURNS (5½ 'G' LIMIT)

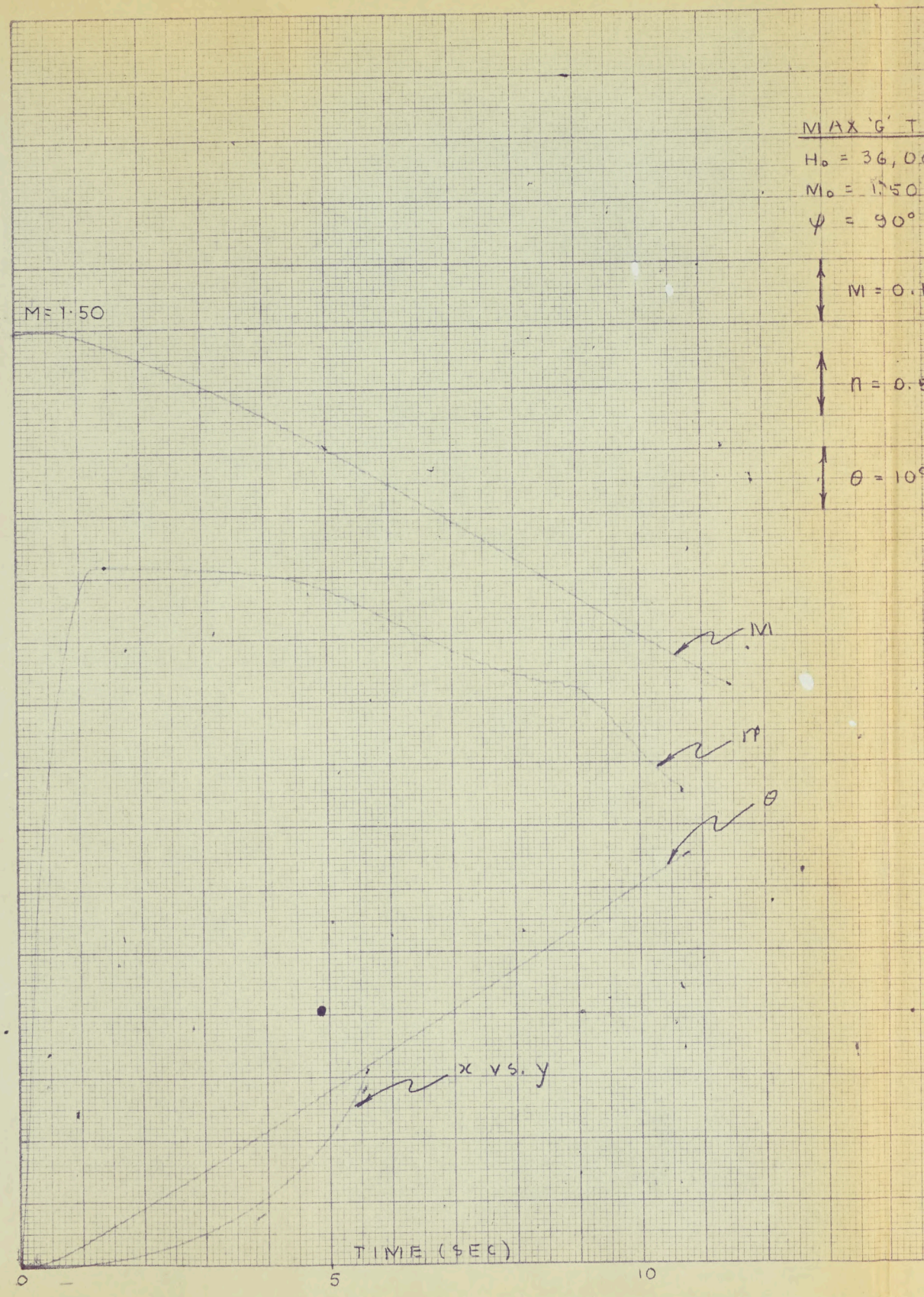
H_o = 36,000 FT.

M_o = 1·75

Ψ = 0°

SECRET

EXTRACT FROM A47/A.C. MANOEVRES/2



X 'G' TURNS (5½ 'G' LIMIT)

= 36,000 FT

= 1.50

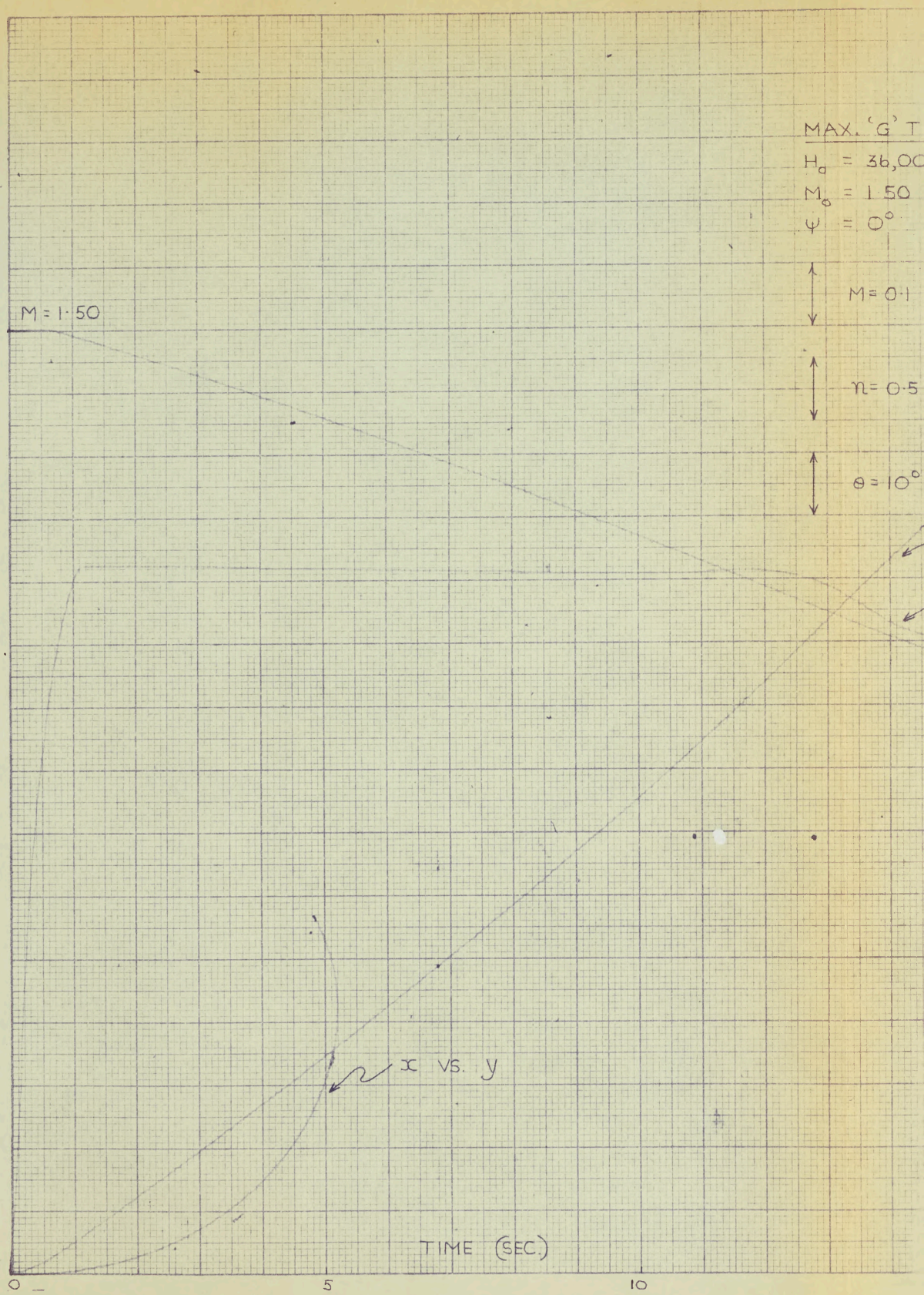
= 90°

M = 0.1

n = 0.5'G'

θ = 10°

SECRET



. 'G' TURNS (5½ 'G' LIMIT)

= 36,000 FT

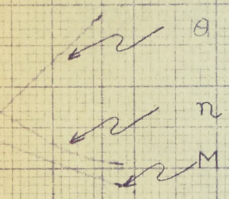
= 1·50

= 0°

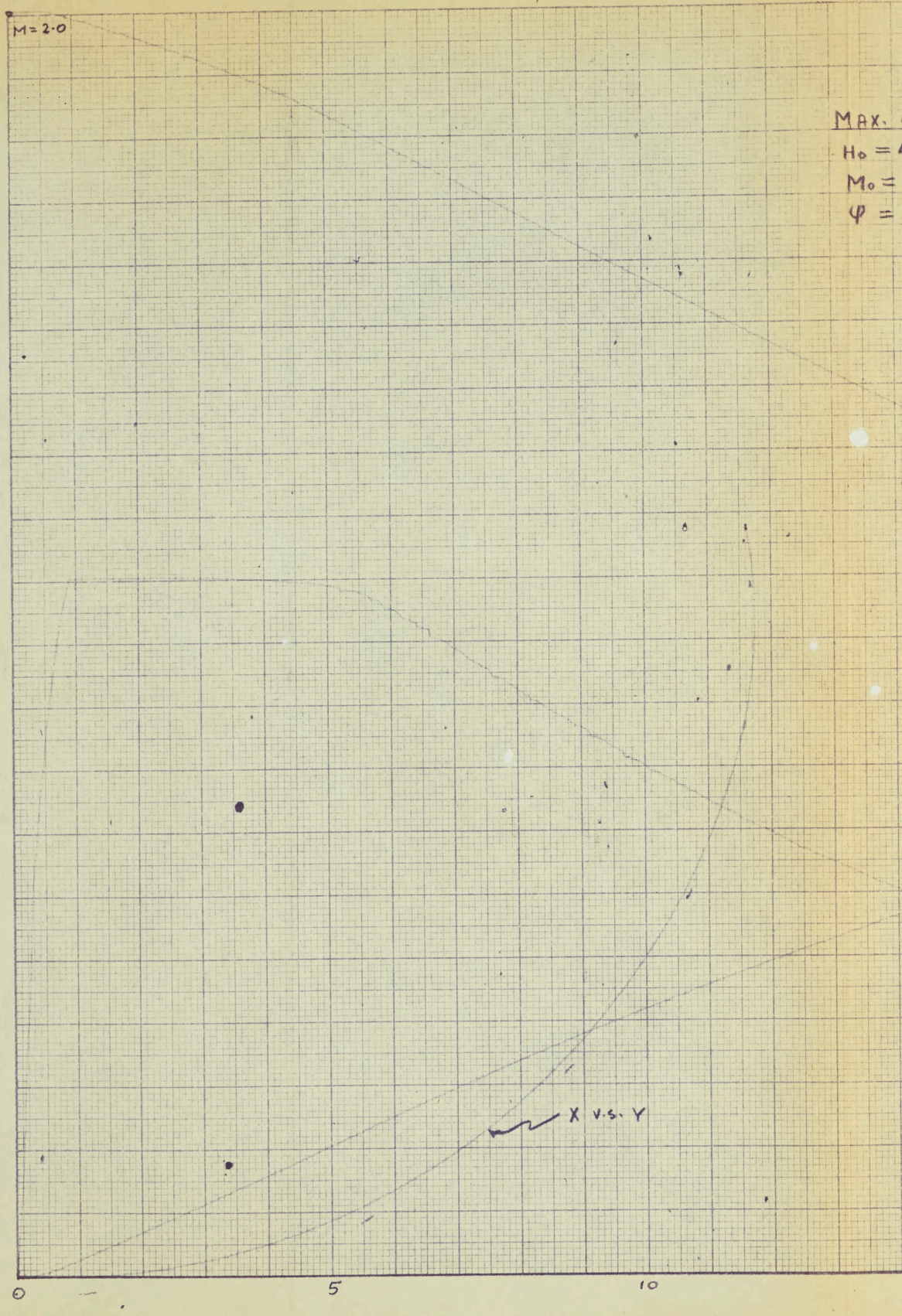
M = 0·1

n = 0·5 'G'

θ = 10°



SECRET

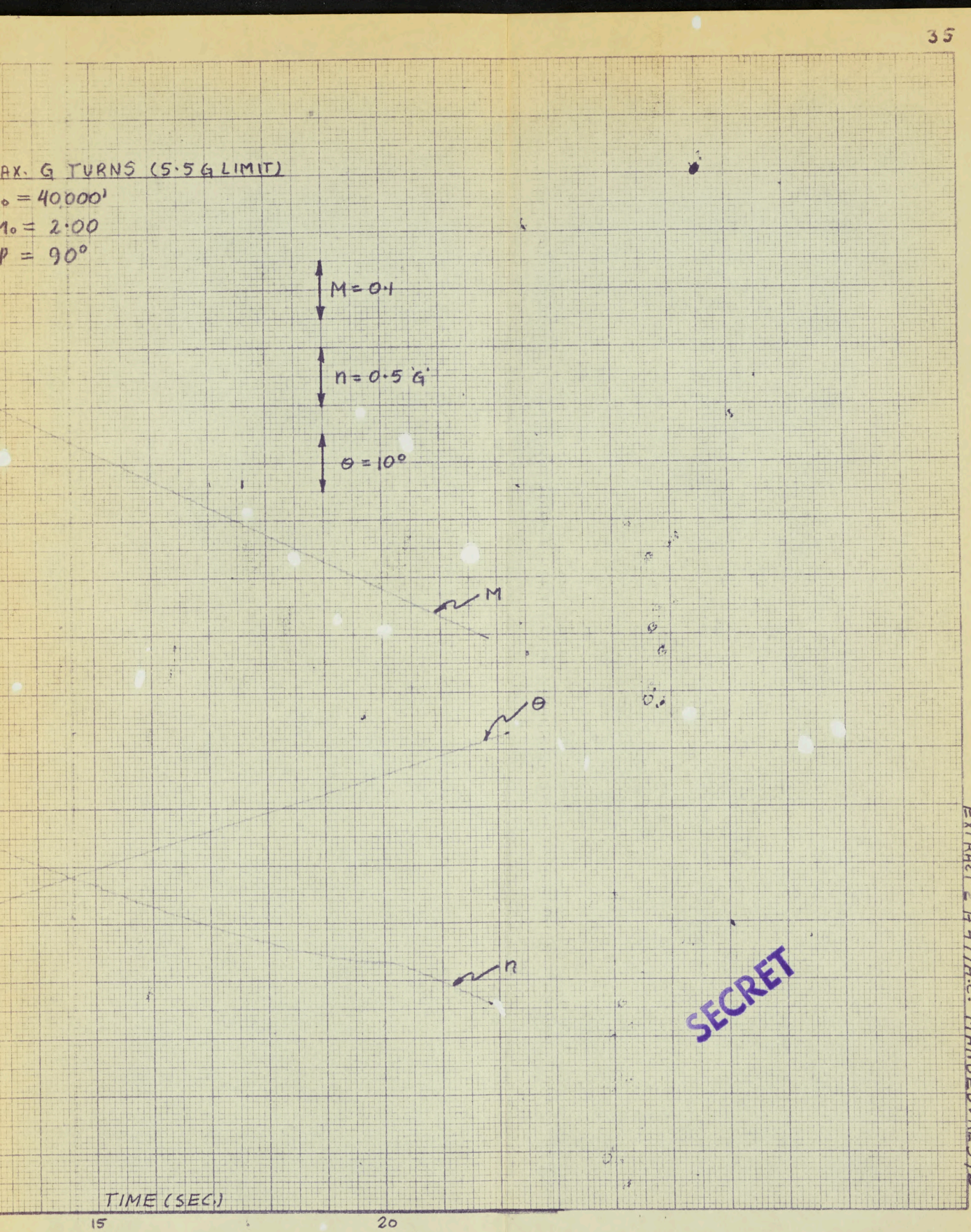


AX. G TURNS (5·5 G LIMIT)

$_0$ = 40,000'

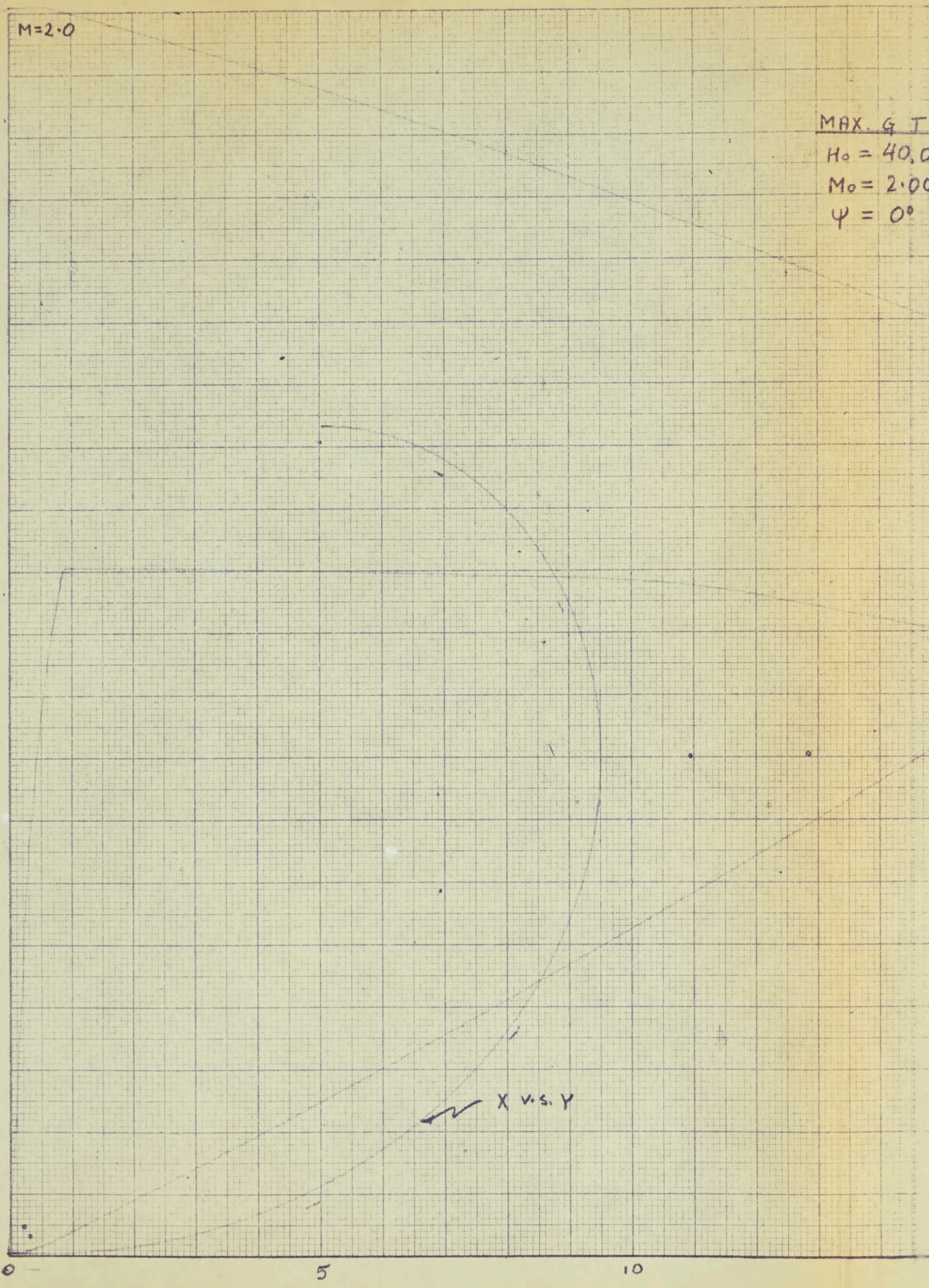
M_0 = 2·00

β = 90°



SECRET

EXTRACT FROM A 47/A.C. MANOEUVRES /2

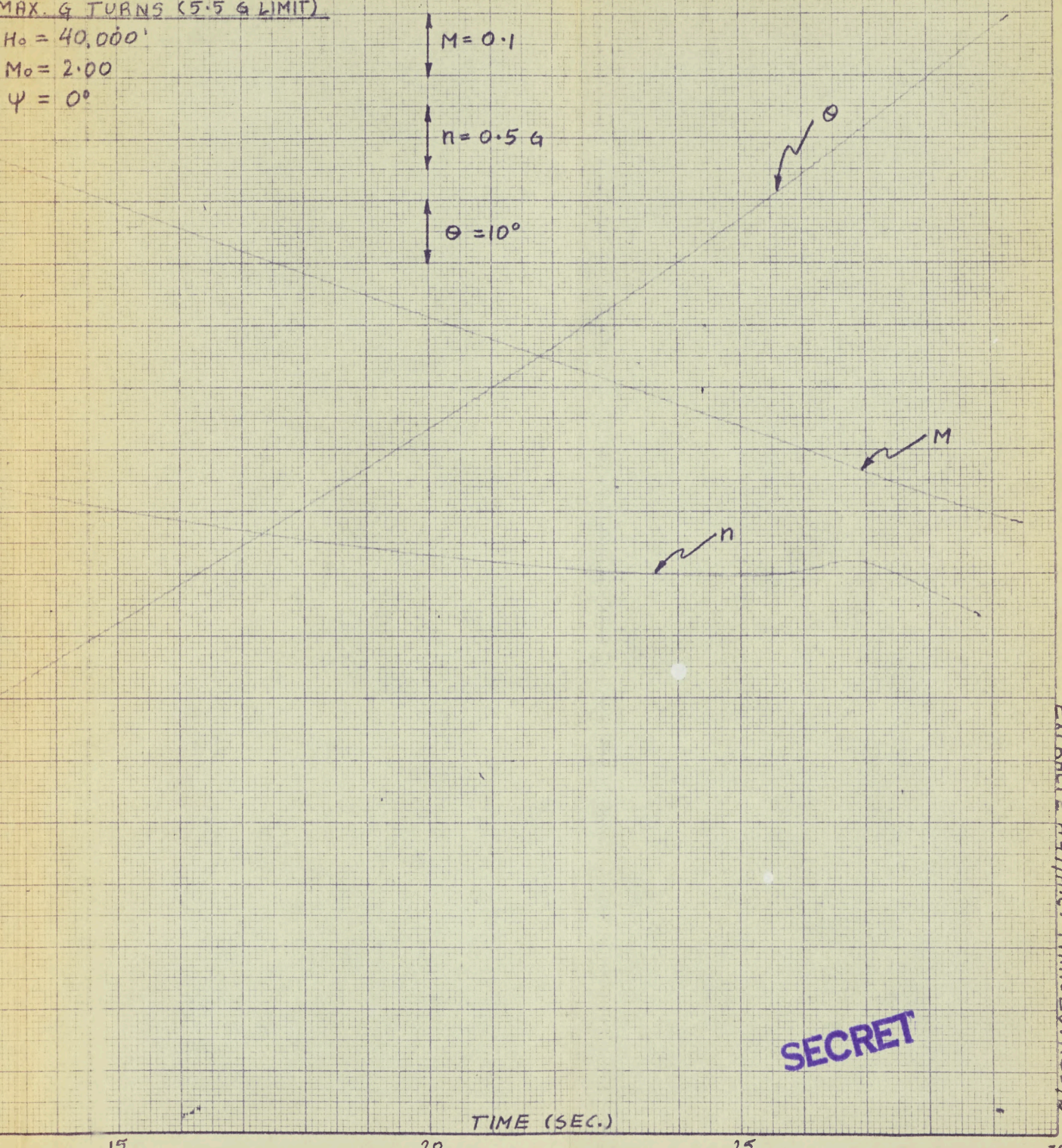


MAX. G TURNS (5·5 G LIMIT)

H_o = 40,000'

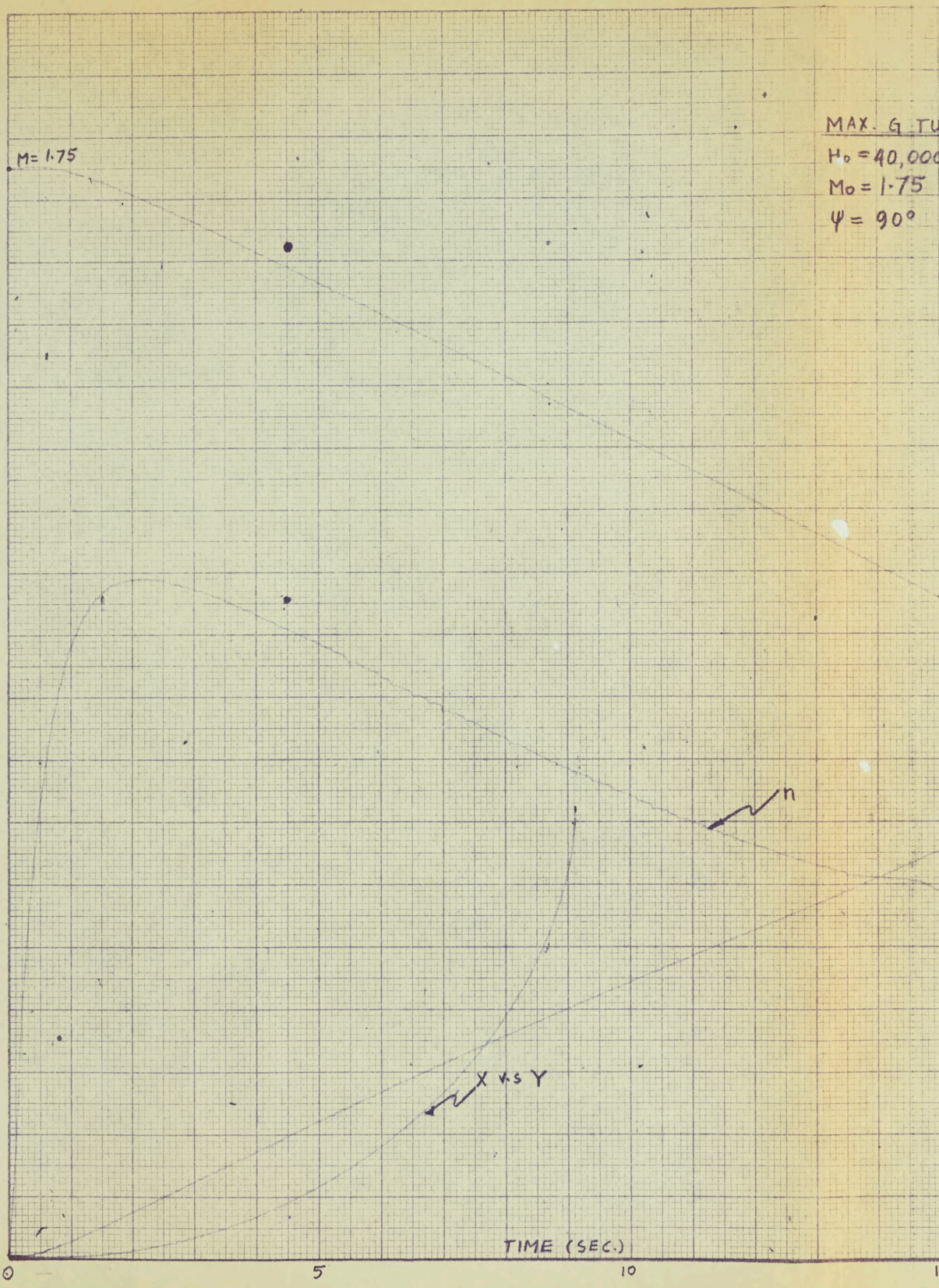
M_o = 2·00

Ψ = 0°



SECRET

EXTRACT A47/A.C. MANOEUVRES/2

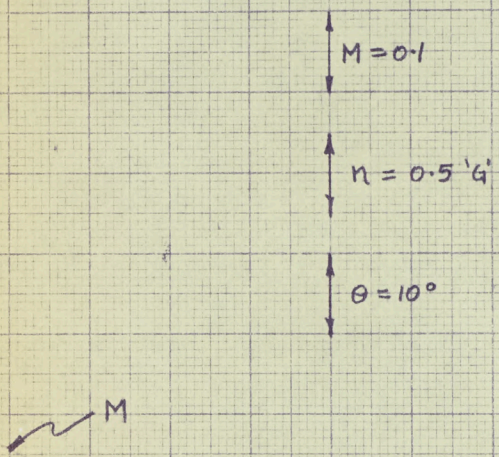


MAX. G TURNS (5·5 G LIMIT)

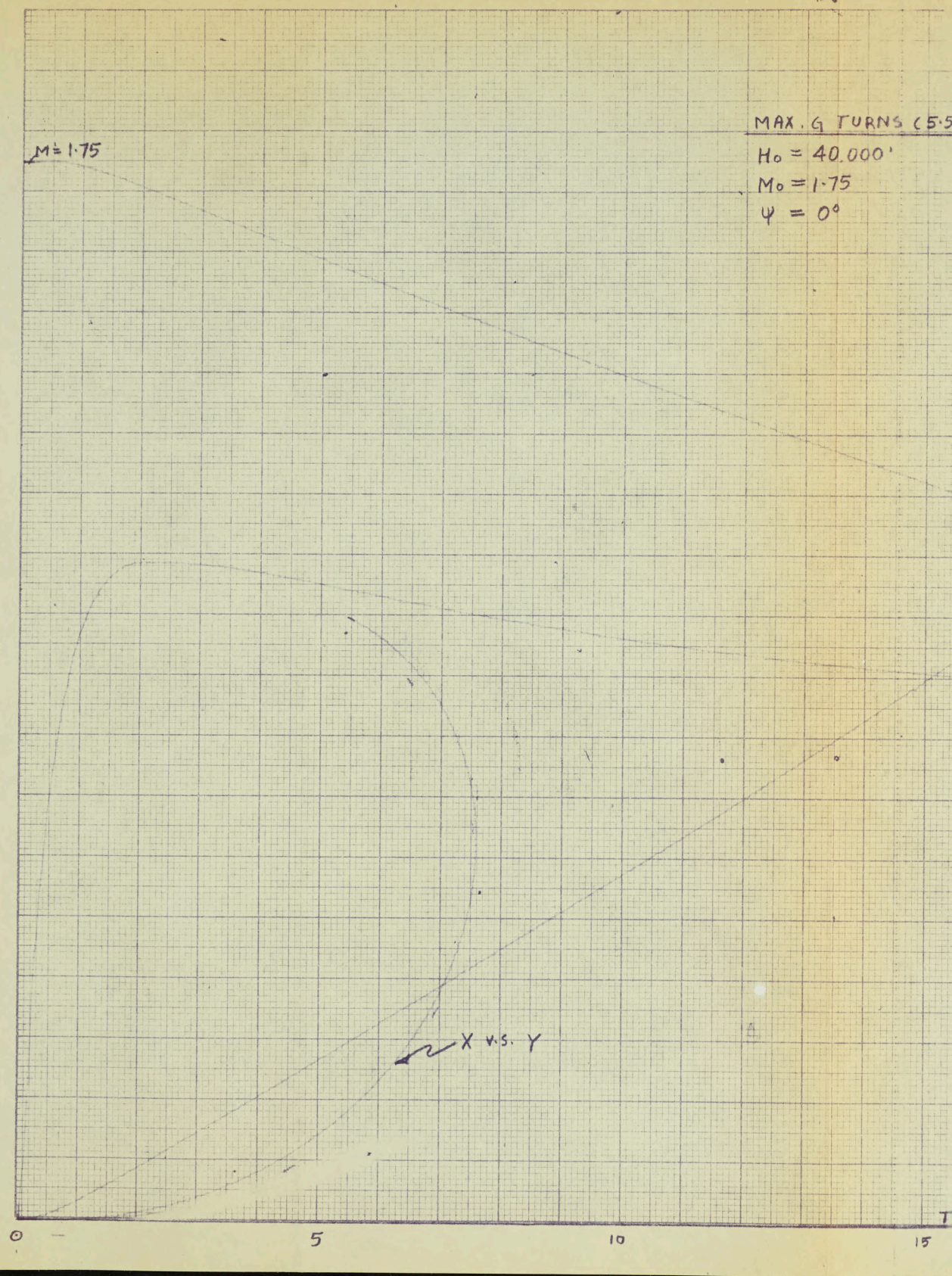
$H_o = 40,000'$

$M_o = 1·75$

$\Psi = 90°$



15 20

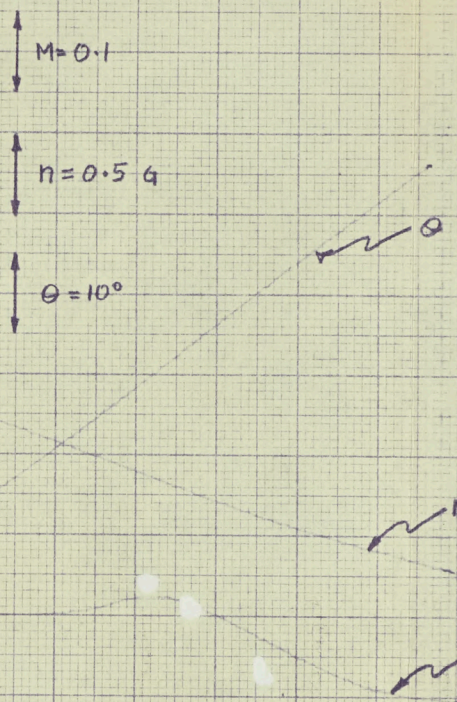


G TURNS (5·5 G LIMIT)

40.000'

1·75

0°

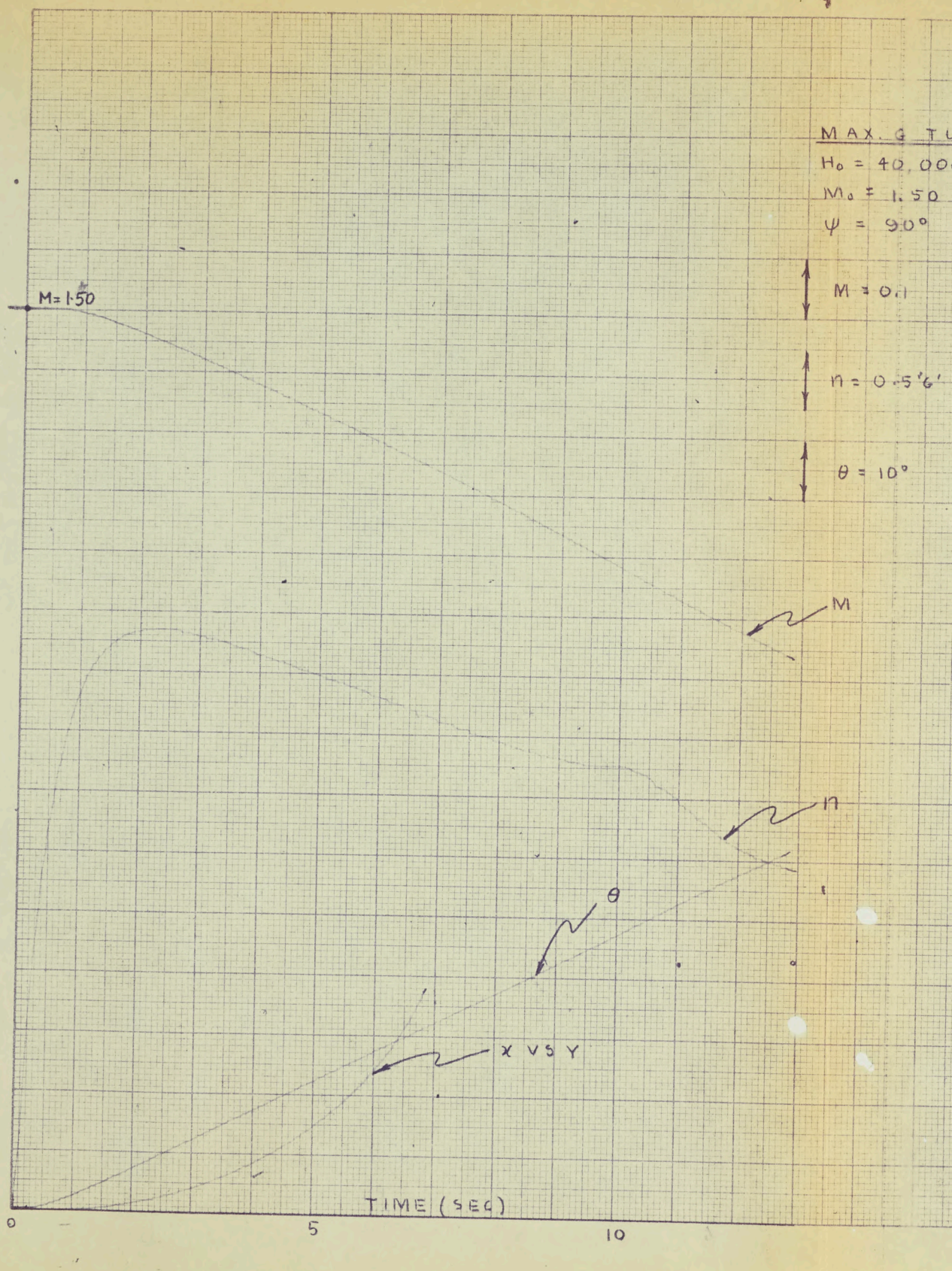


TIME (SEC.)

15 20

SECRET

EXTRACT A47/A.C. MANOEUVRES/2



MAX. G TURNS (5.5 G LIMIT)

$H_0 = 40,000'$

$M_0 = 1.50$

$\psi = 90°$

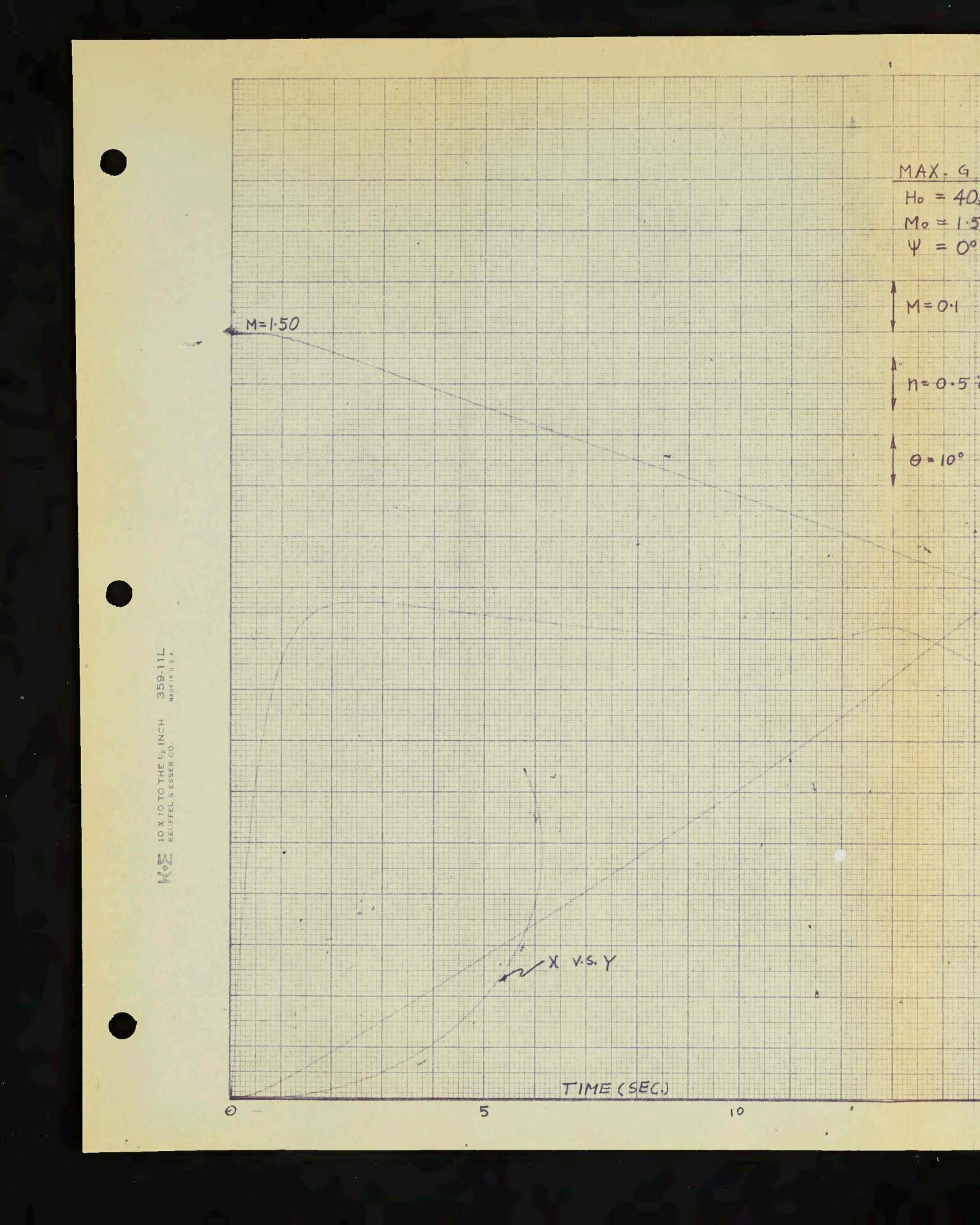
$M = 0.1$

$n = 0.5'6'$

$\theta = 10°$

M

n


MAX. G
Ho = 40
Mo = 1.5
Ψ = 0°
M = 0.1
n = 0.5
θ = 10°
M=1.50
X V.S. Y
TIME (SEC.)
0
5
10
10 X 10 TO THE ½ INCH
KEUFFEL & ESSER CO.
359-11L
MADE IN U.S.A.

MAX. G TURNS (5·5 G LIMIT)

H_o = 40,000'

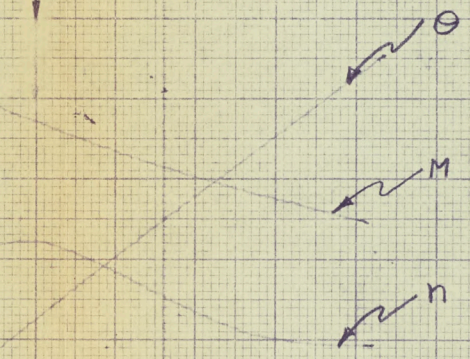
M_o = 1·50

Ψ = 0°

M = 0·1

n = 0·5 'g'

θ = 10°



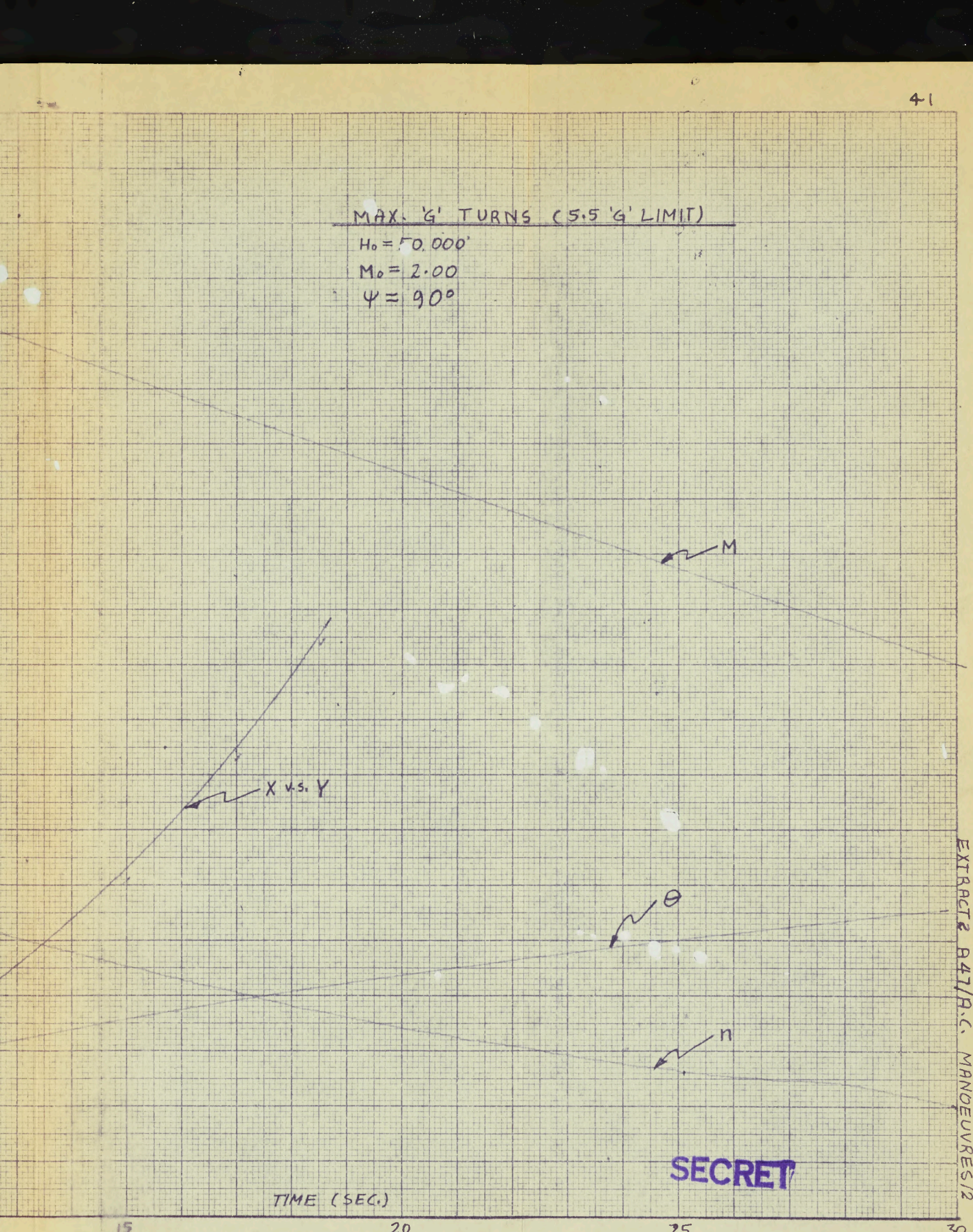
15

MAX. 'G' TURNS (5.5 'G' LIMIT)

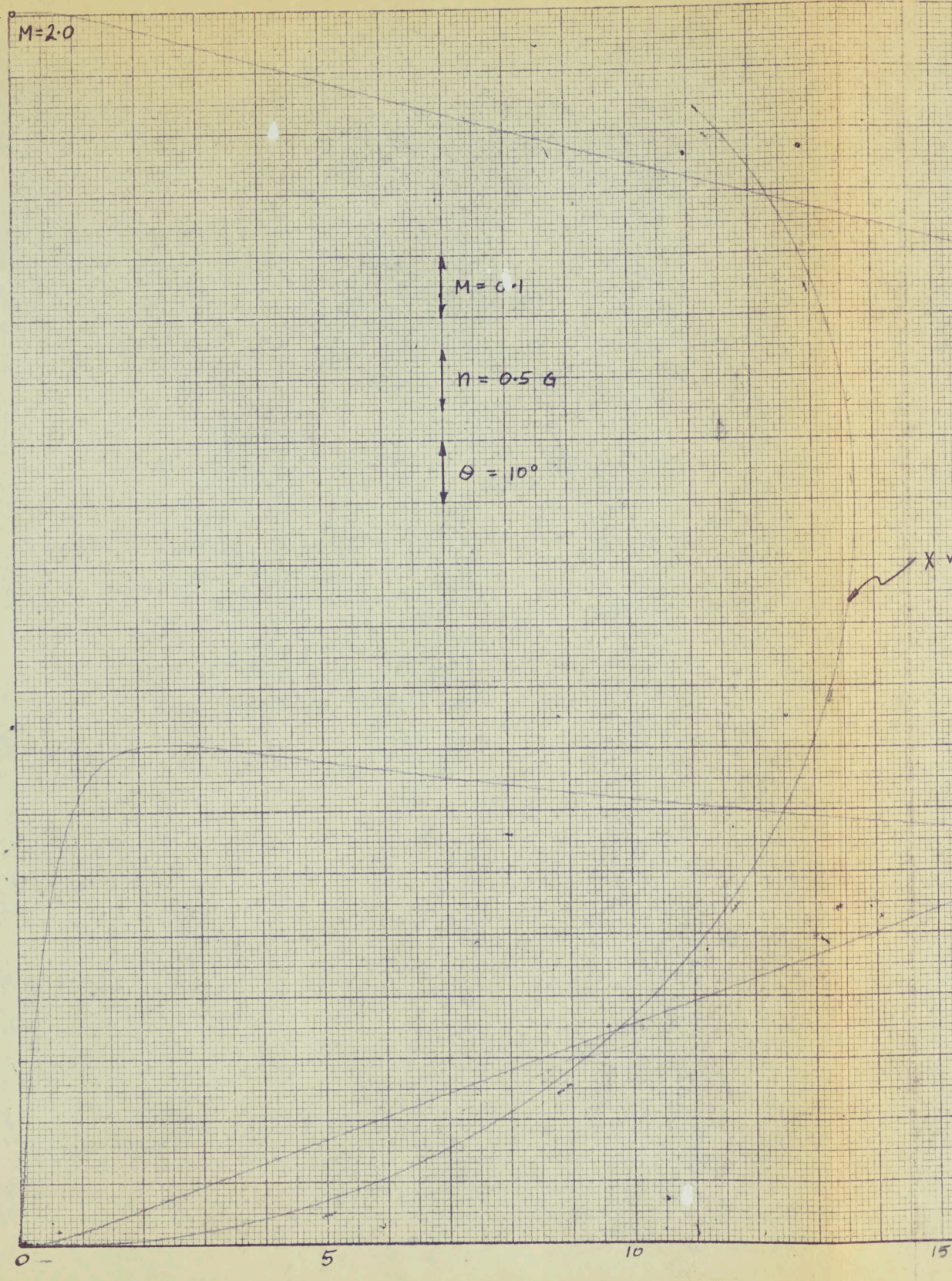
$H_0 = 10,000'$

$M_0 = 2.00$

$\psi = 90°$



SECRET

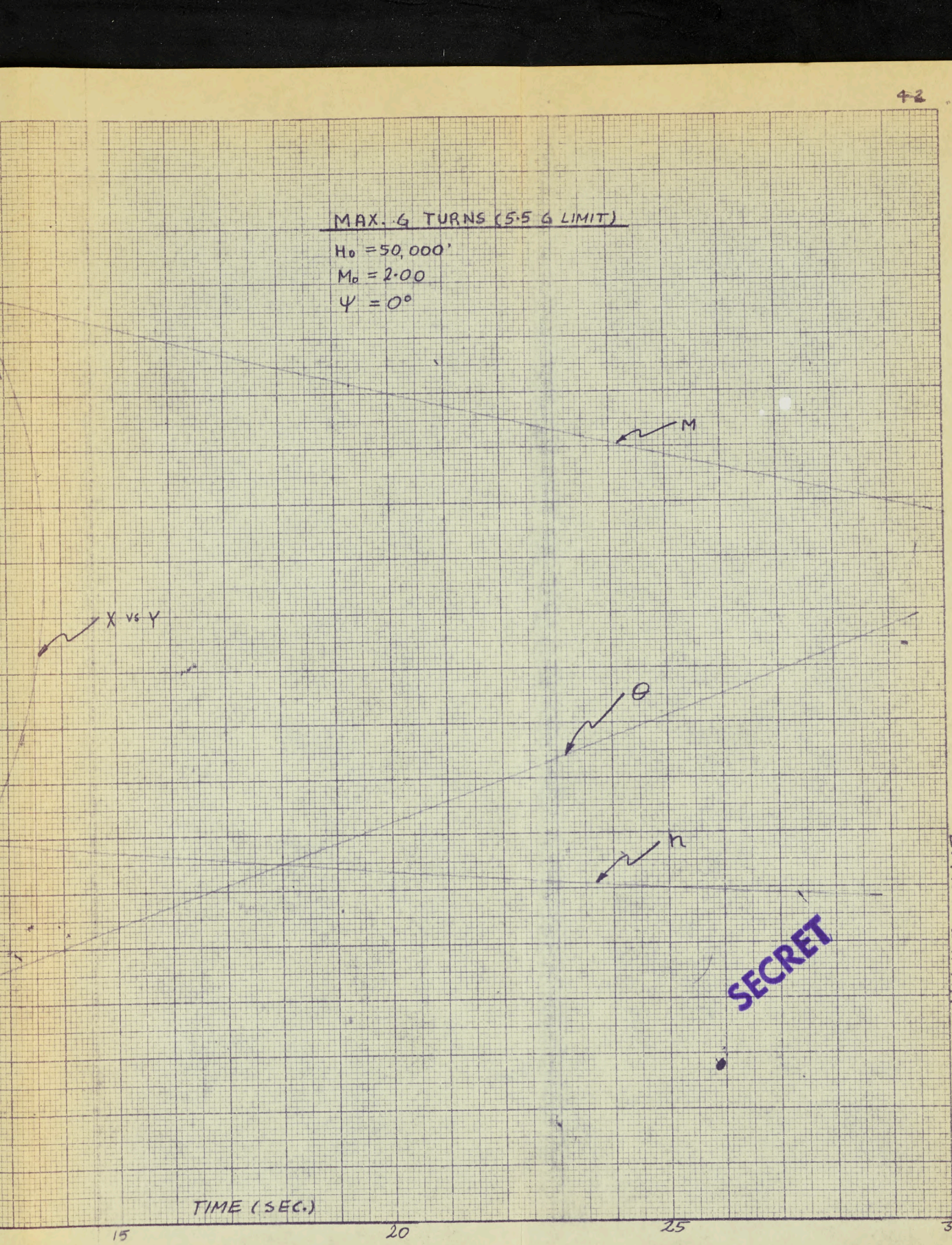


MAX. G TURNS (5.5 G LIMIT)

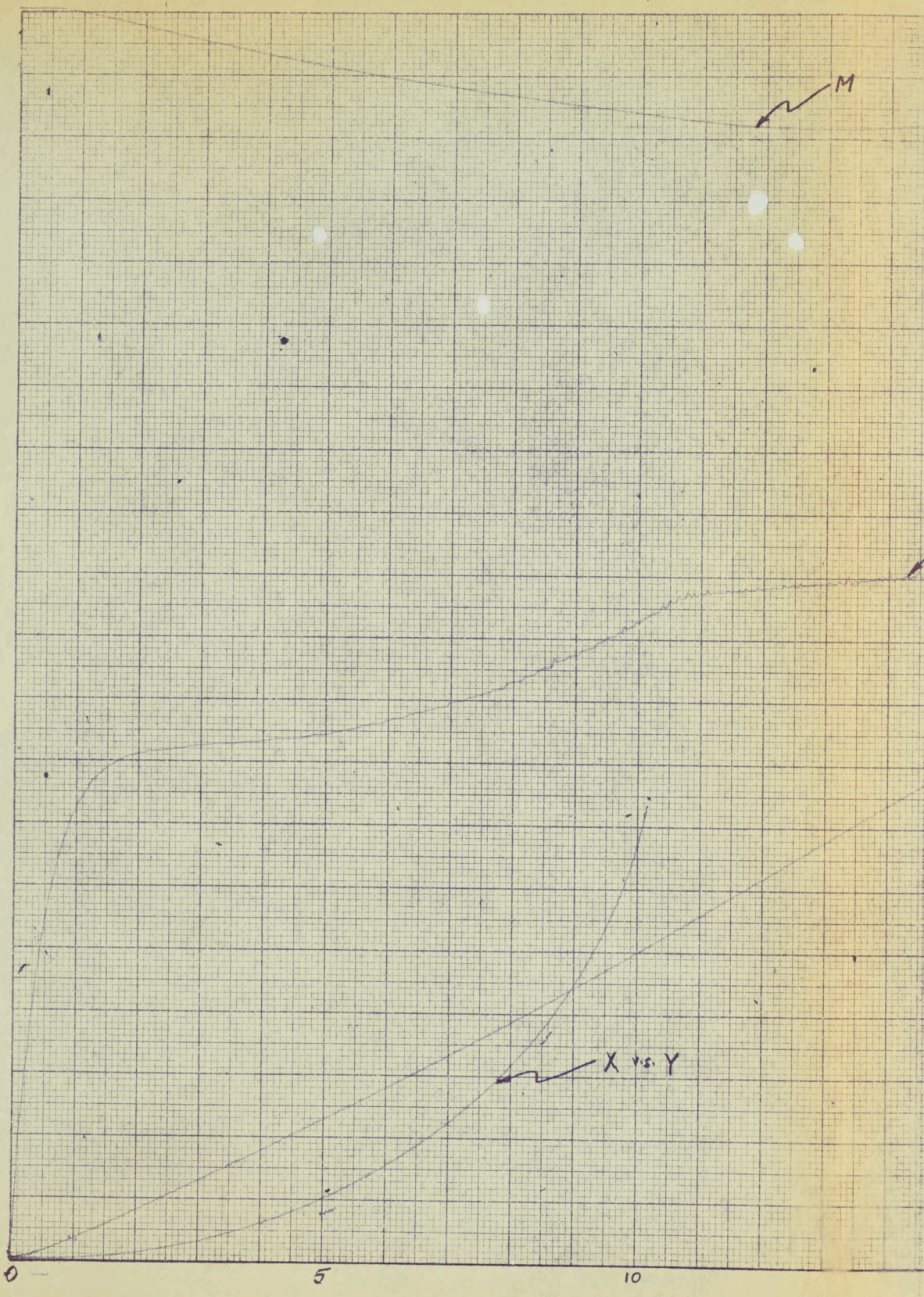
$H_0 = 50,000'$

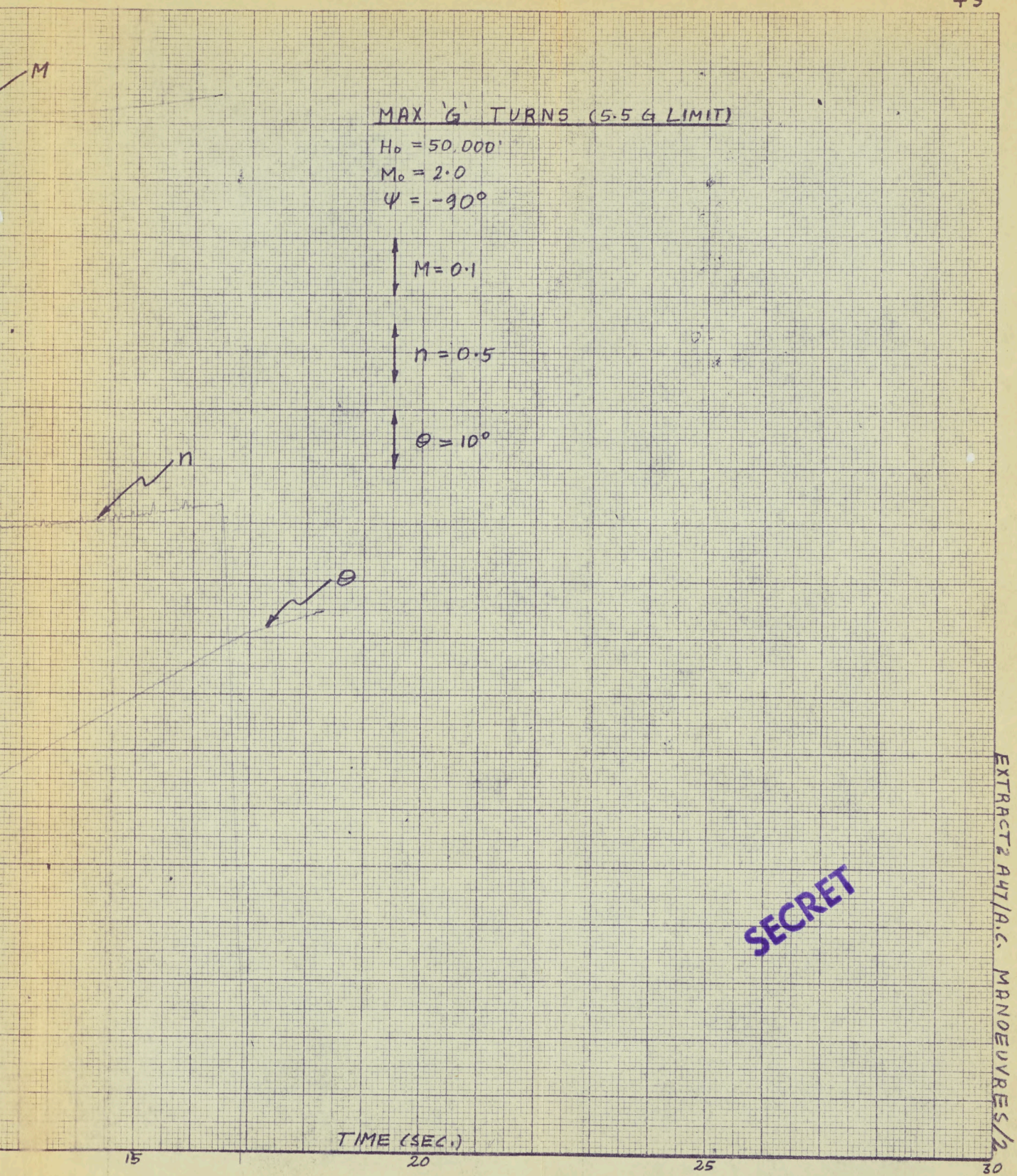
$M_0 = 2.00$

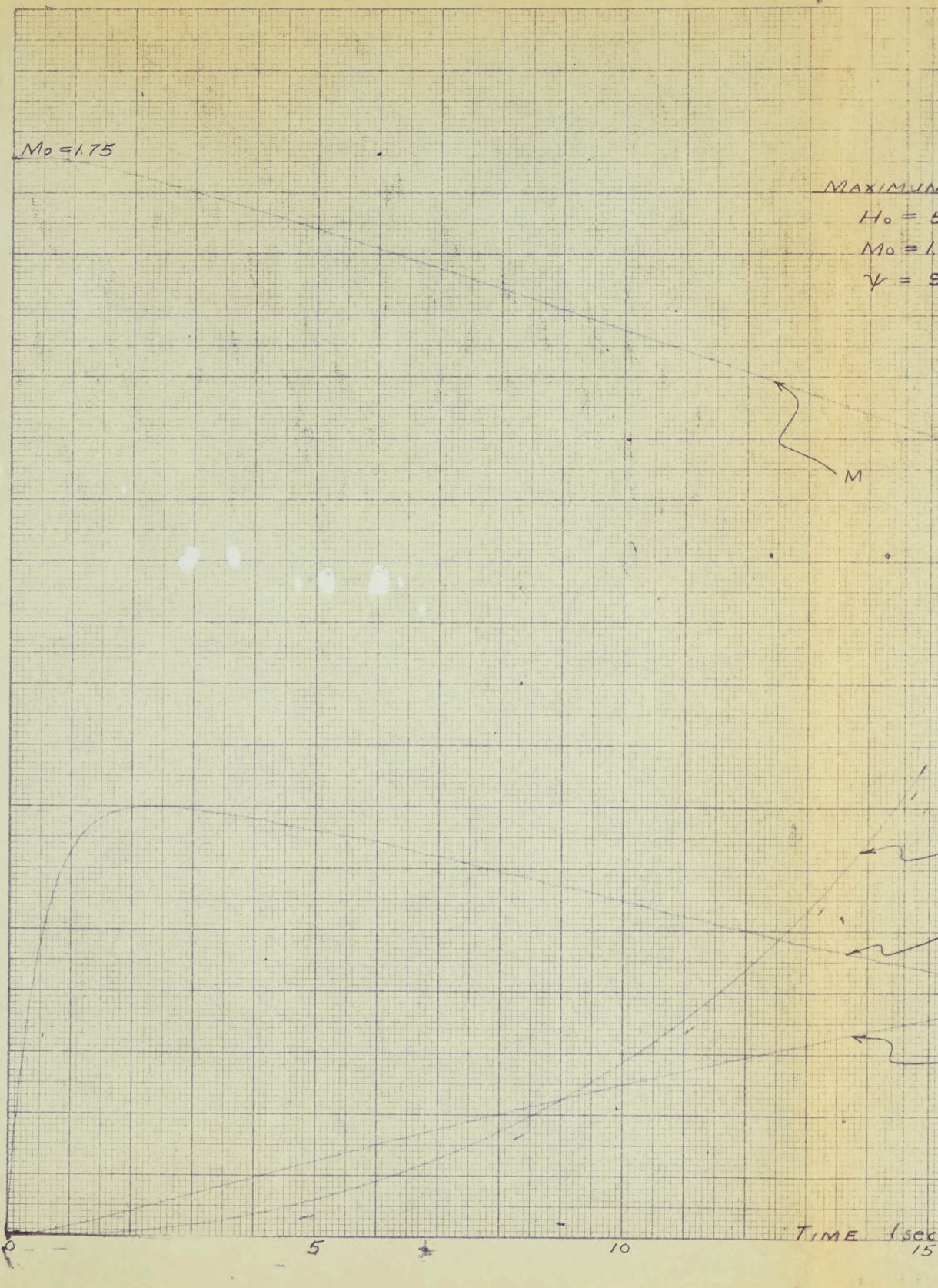
$\psi = 0°$



EXTRACT 2 A47/A.C. MANOEUVRES 12




MAX 'G' TURNS (5.5 G LIMIT)
H₀ = 50,000'
M₀ = 2·0
Ψ = -90°
M = 0·1
n = 0·5
θ = 10°
M
n
θ
TIME (SEC.)
15
20
25
30

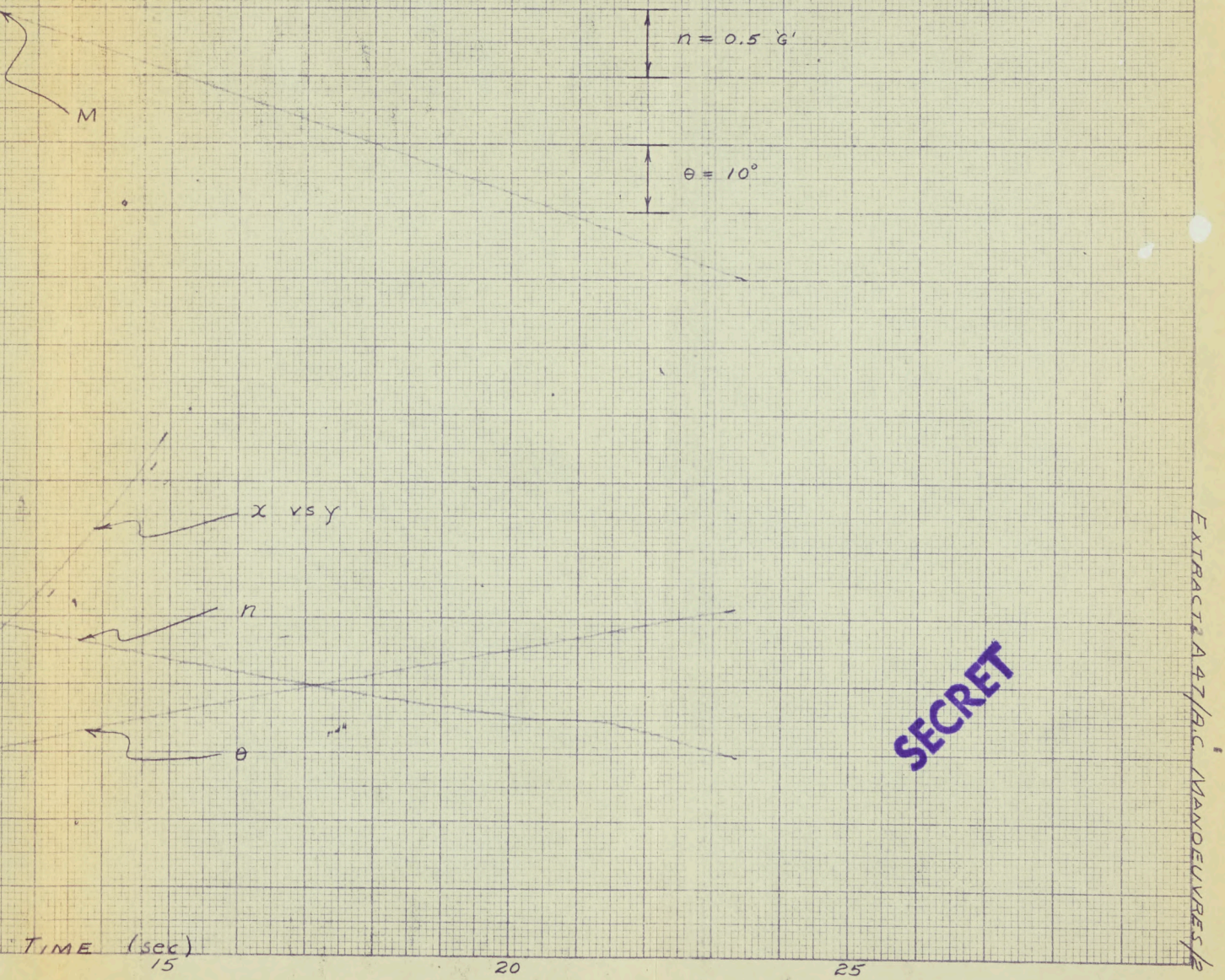


MAXIMUM 'G' TURNS (5.5 'G' LIMIT)

H_o = 50,000 ft.

M_o = 1.75

ψ = 90°



SECRET

EXTRACT A47/R.C. MANOEUVRES/2

MAXIMUM 'G' TURNS (5.5 'G' LIMIT)

$H_o = 50{,}000'$

$M_o = 1.75$

$\psi = 0°$

$M = 0.1$

$n = 0.5$ 'G'

$\theta = 10°$

M

x vs y

n

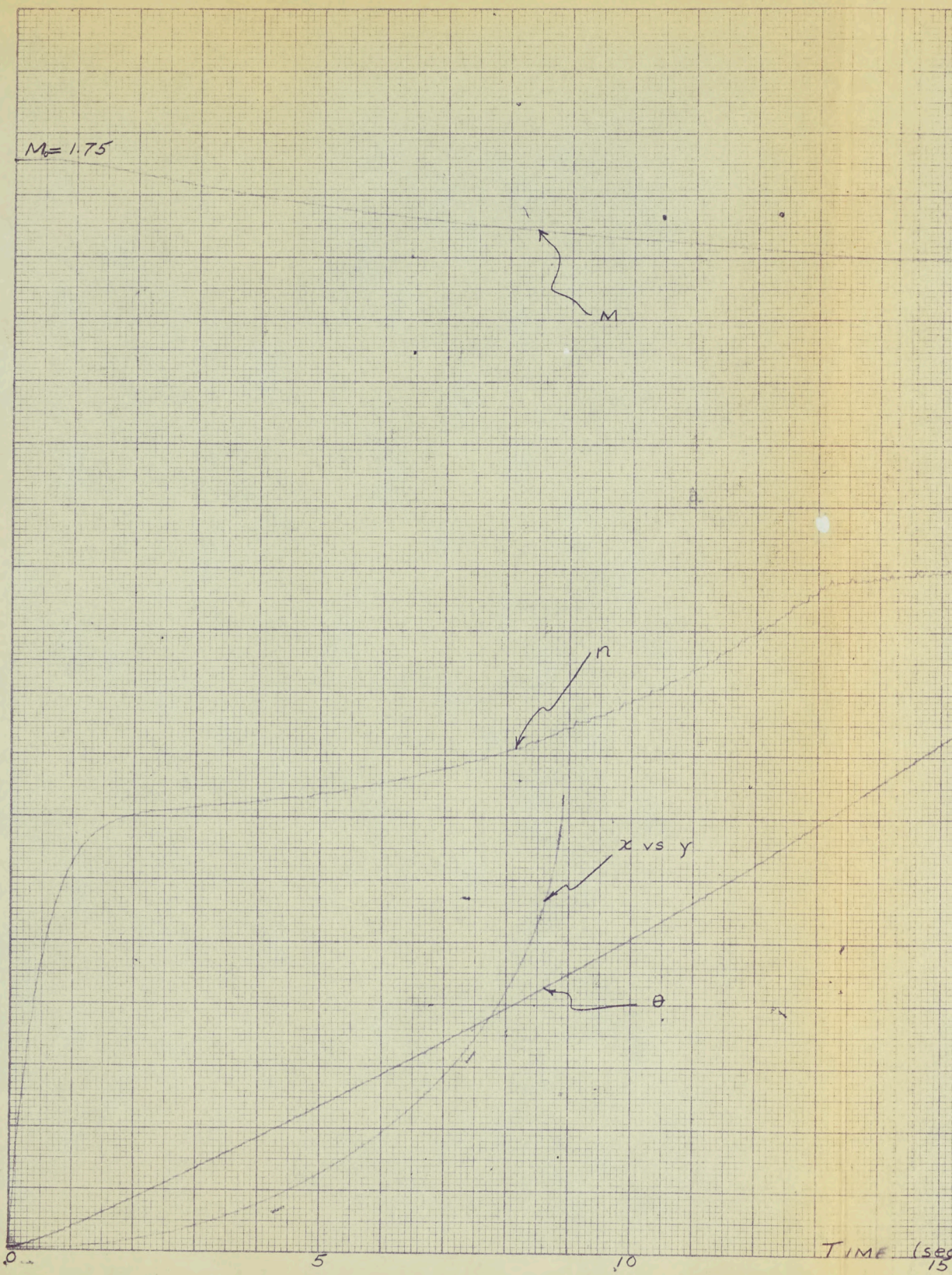
θ

TIME (sec)

15 20 25 30

SECRET

EXTRACT Q47/B.C. MANOEUVRES/2

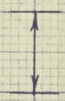


MAXIMUM 'G' TURNS (5.5 'G' LIMIT)

H_o = 50,000 ft

M_o = 1.75

ψ = -90°



M = 0.1

n = 0.5 'G'

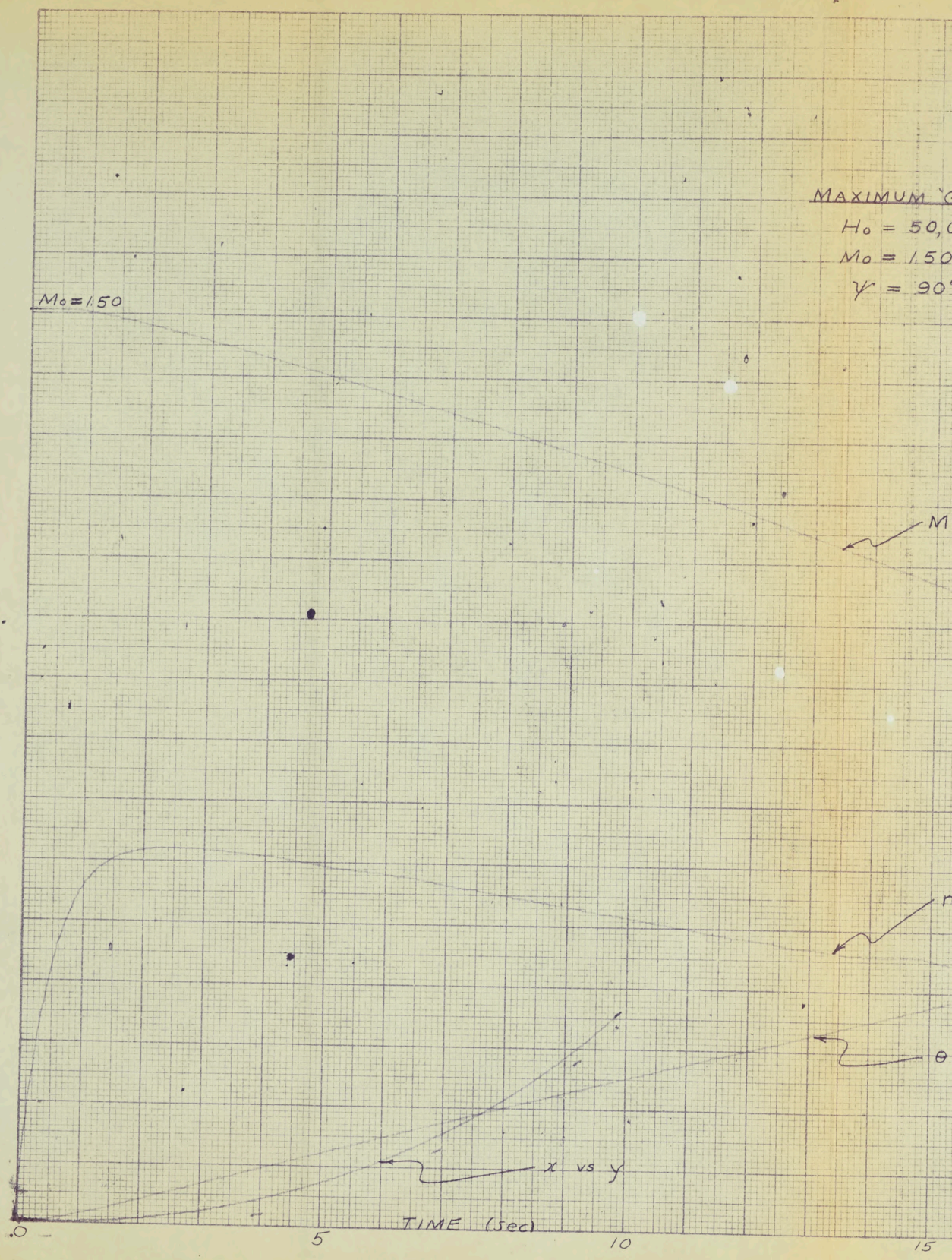
θ = 10°

SECRET

EXTRACT FROM R.C. MANOEUVRES 1/2

TIME (SEC)

15 20 25

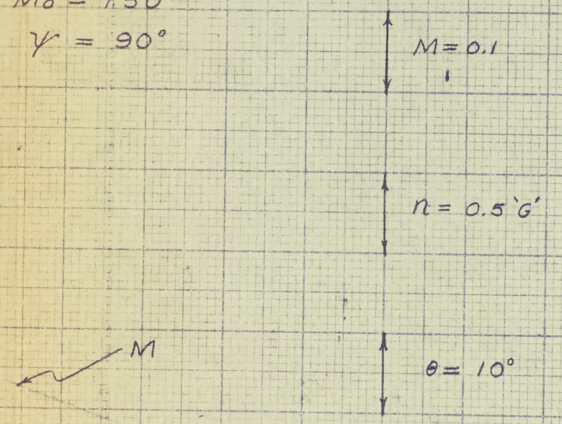


MAXIMUM 'G' TURNS (5.5 'G' LIMIT)

H_o = 50,000 ft

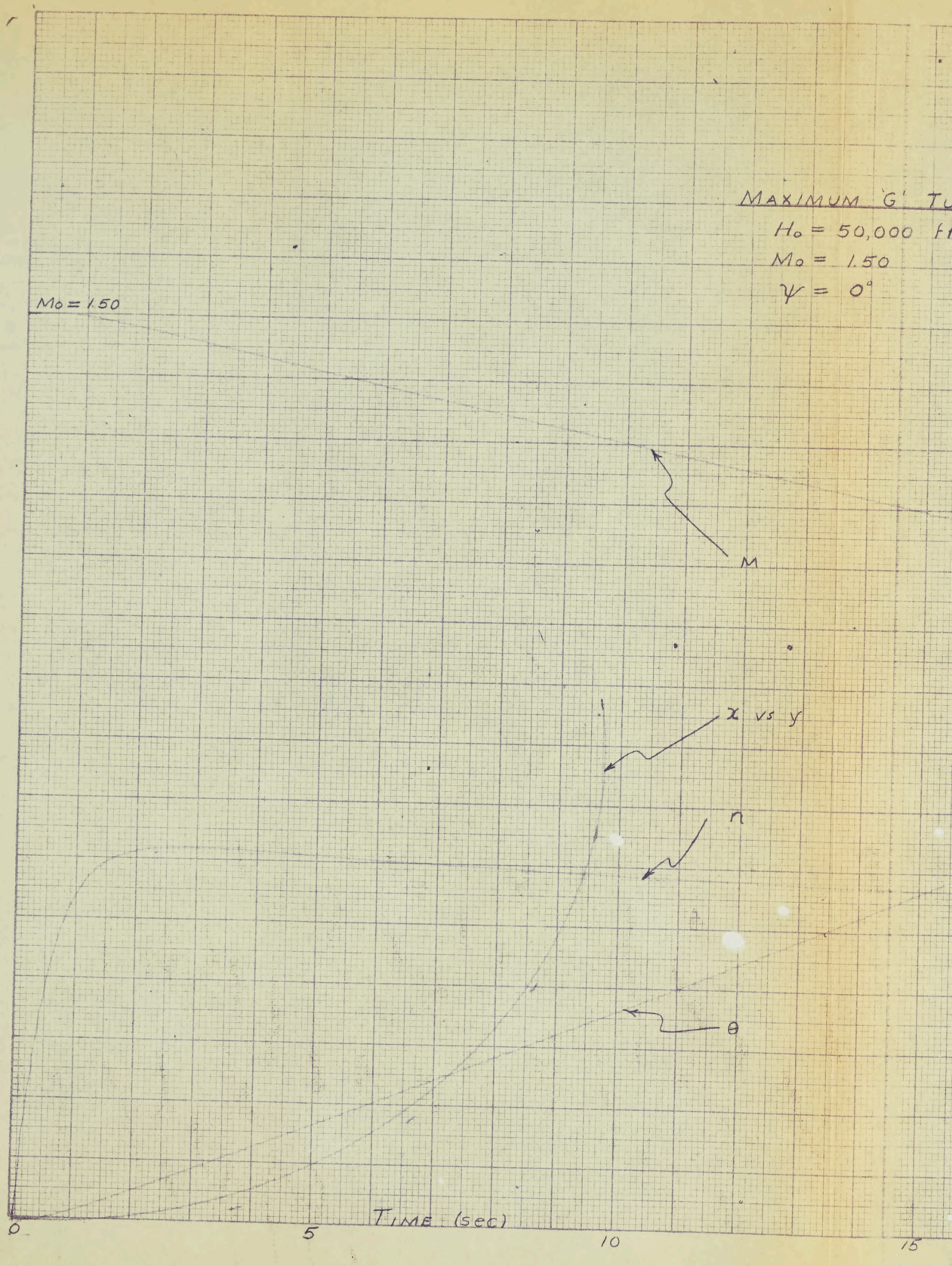
M_o = 1.50

γ = 90°



SECRET

EXTRACT A47/A.C. MANOEUVRES 1/2

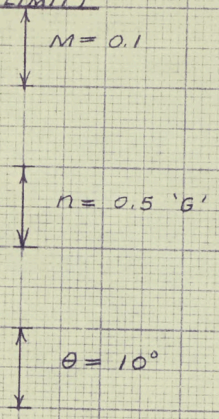


KIMUM 'G' TURNS 5.5 'G' LIMIT)

H_o = 50,000 ft

M_o = 1.50

γ = 0°

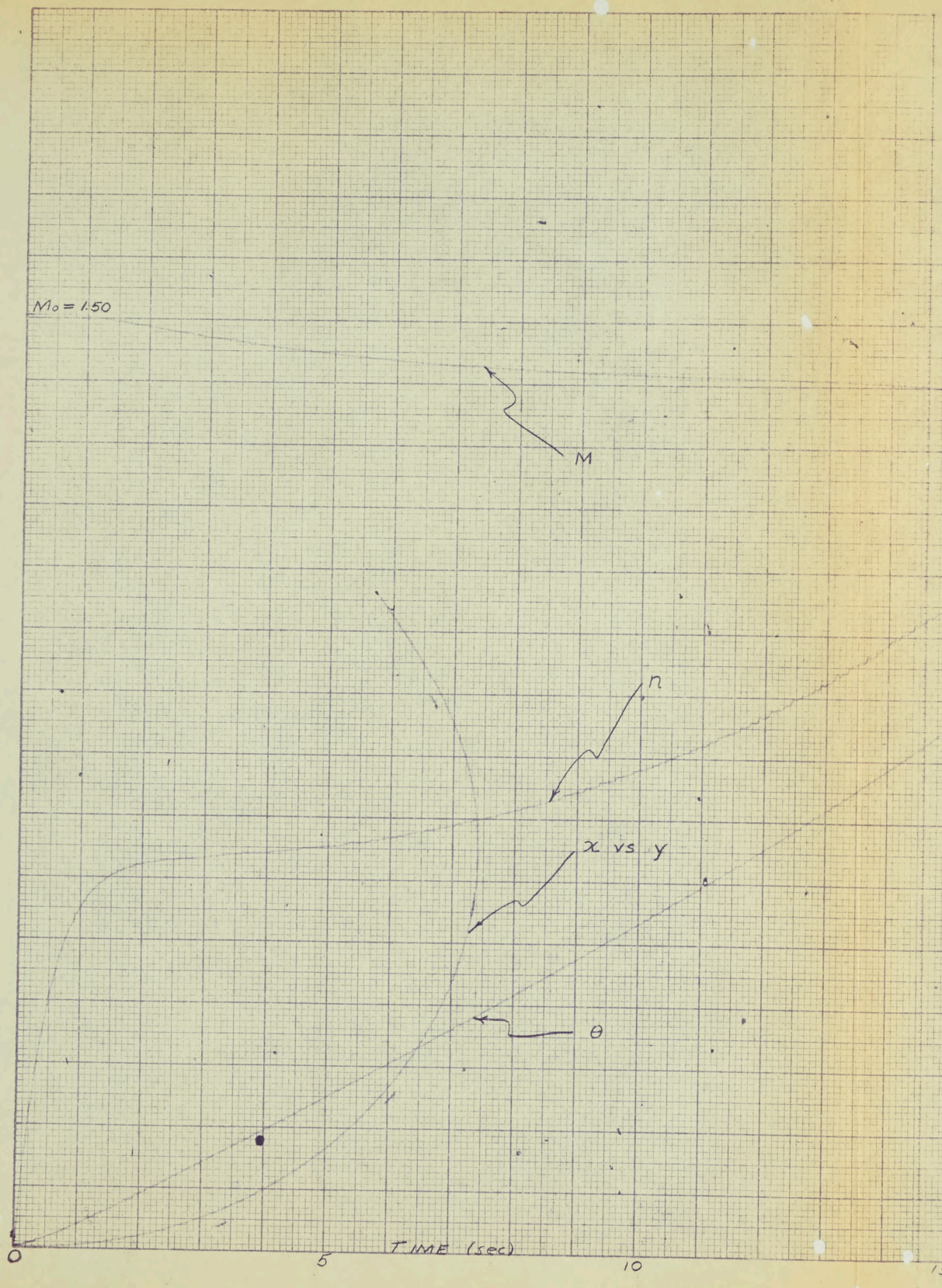


y

15 20 25

SECRET

EXTRACT A47/AS. MANOEUVRES/2

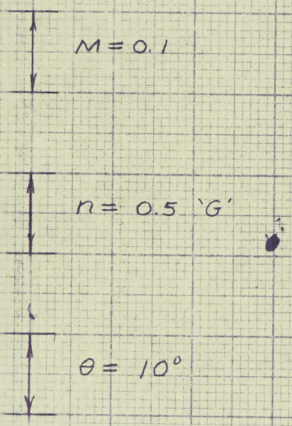


MAXIMUM 'G' TURNS (5.5 'G' LIMIT)

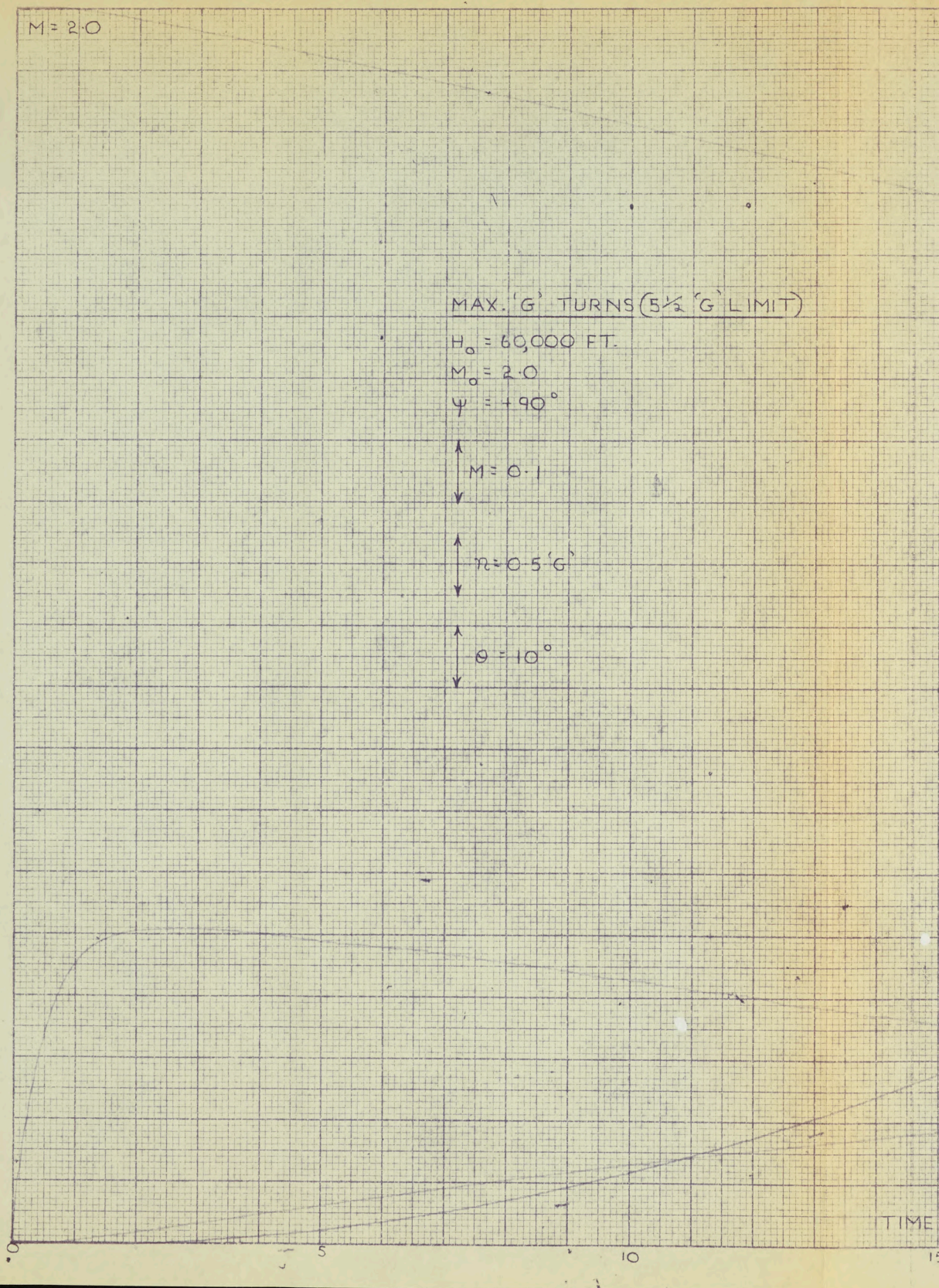
H_o = 50,000 ft

M_o = 1.50

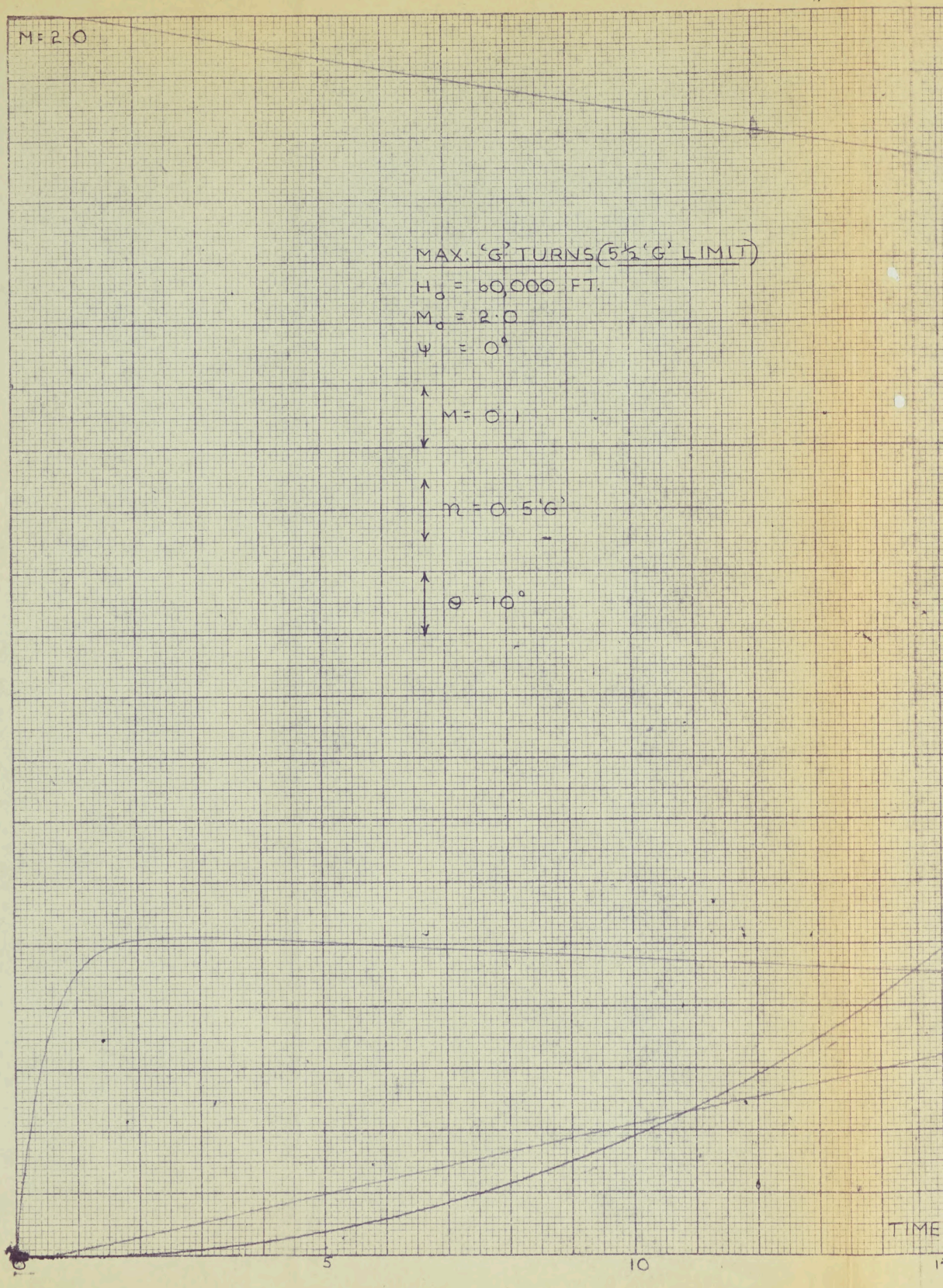
ψ = -90°

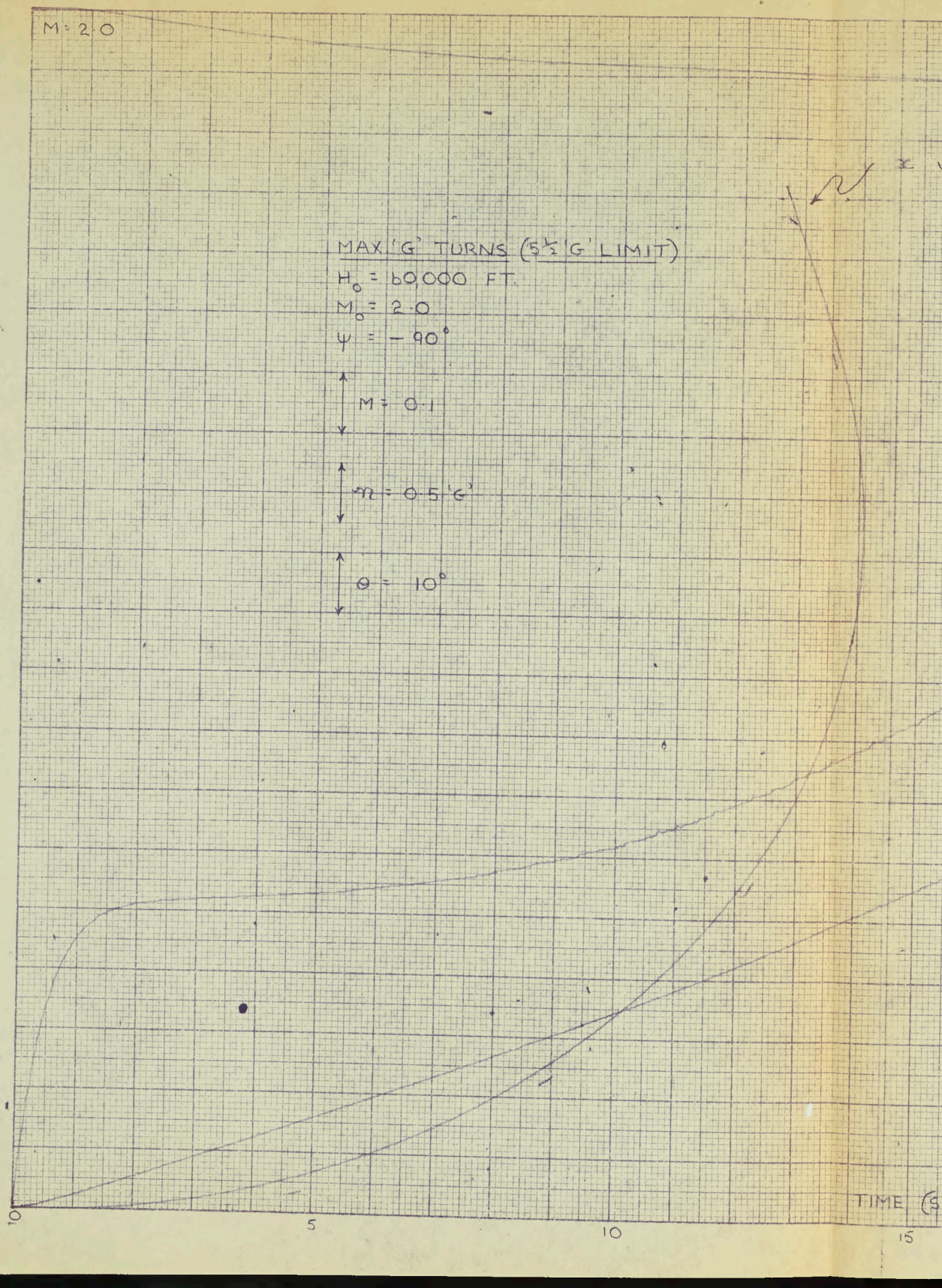


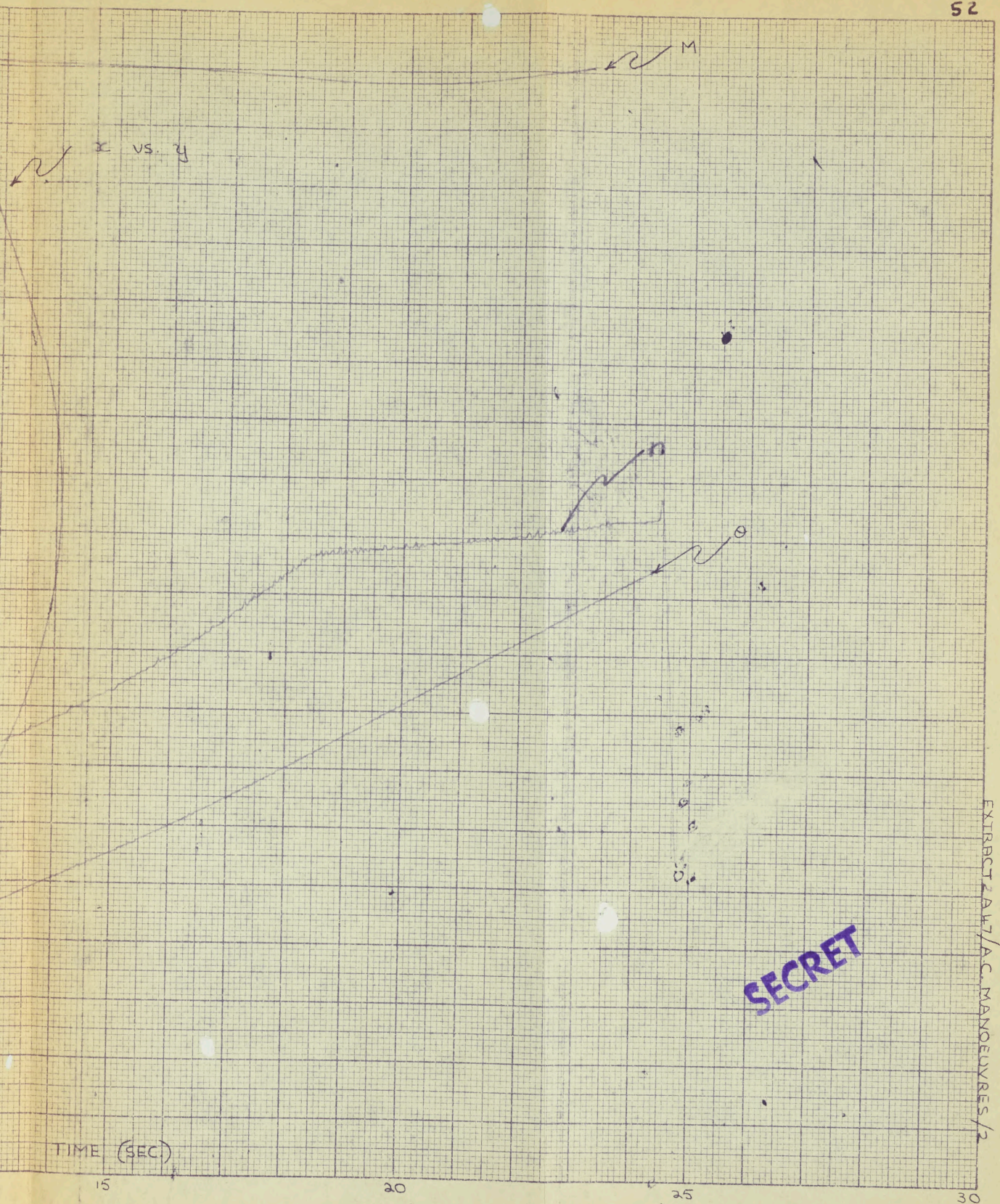
SECRET



EXTRACT FROM A.47/A.C. MANOEUVRES/2





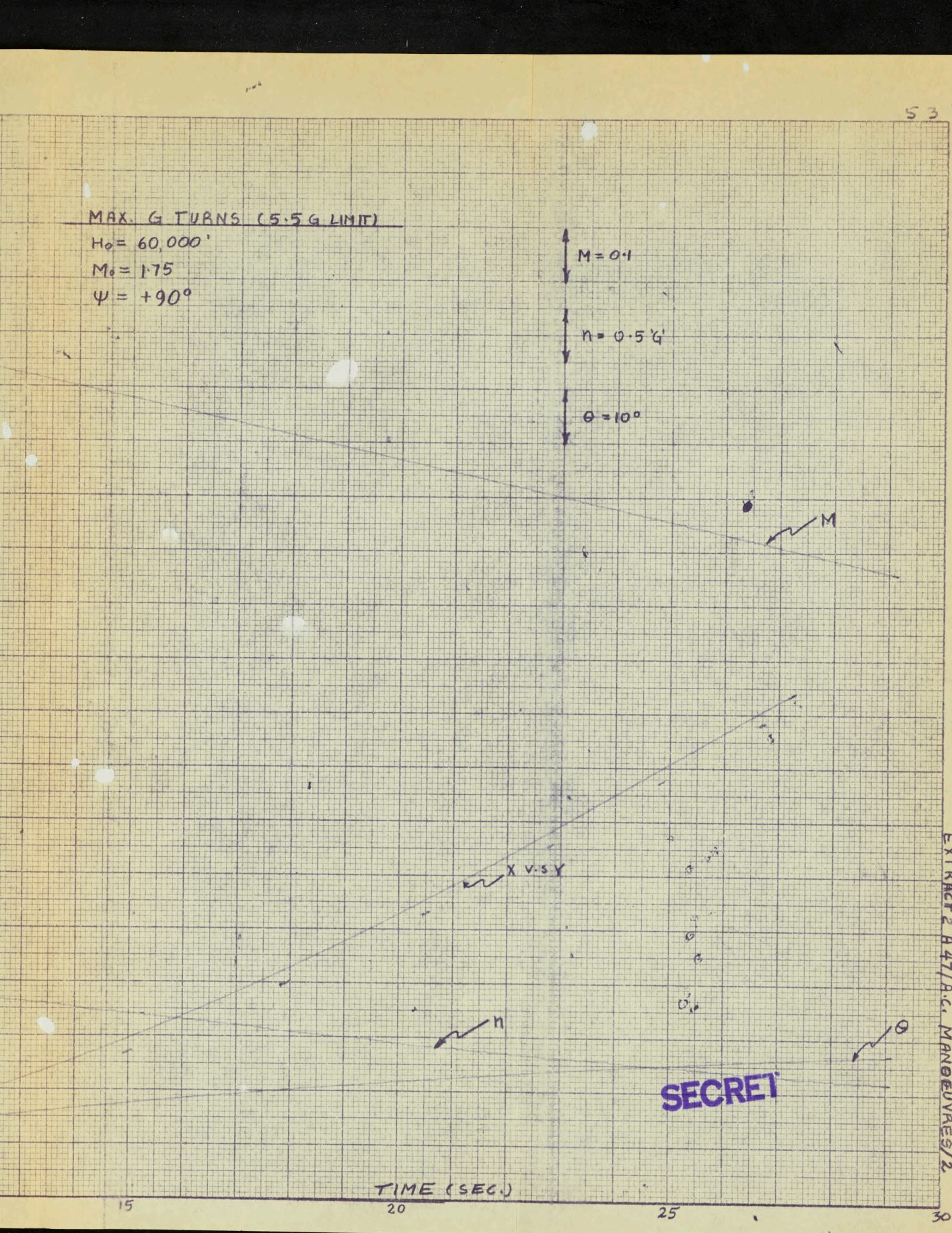


MAX. G TURNS (5·5 G LIMIT)

$H_0 = 60,000'$

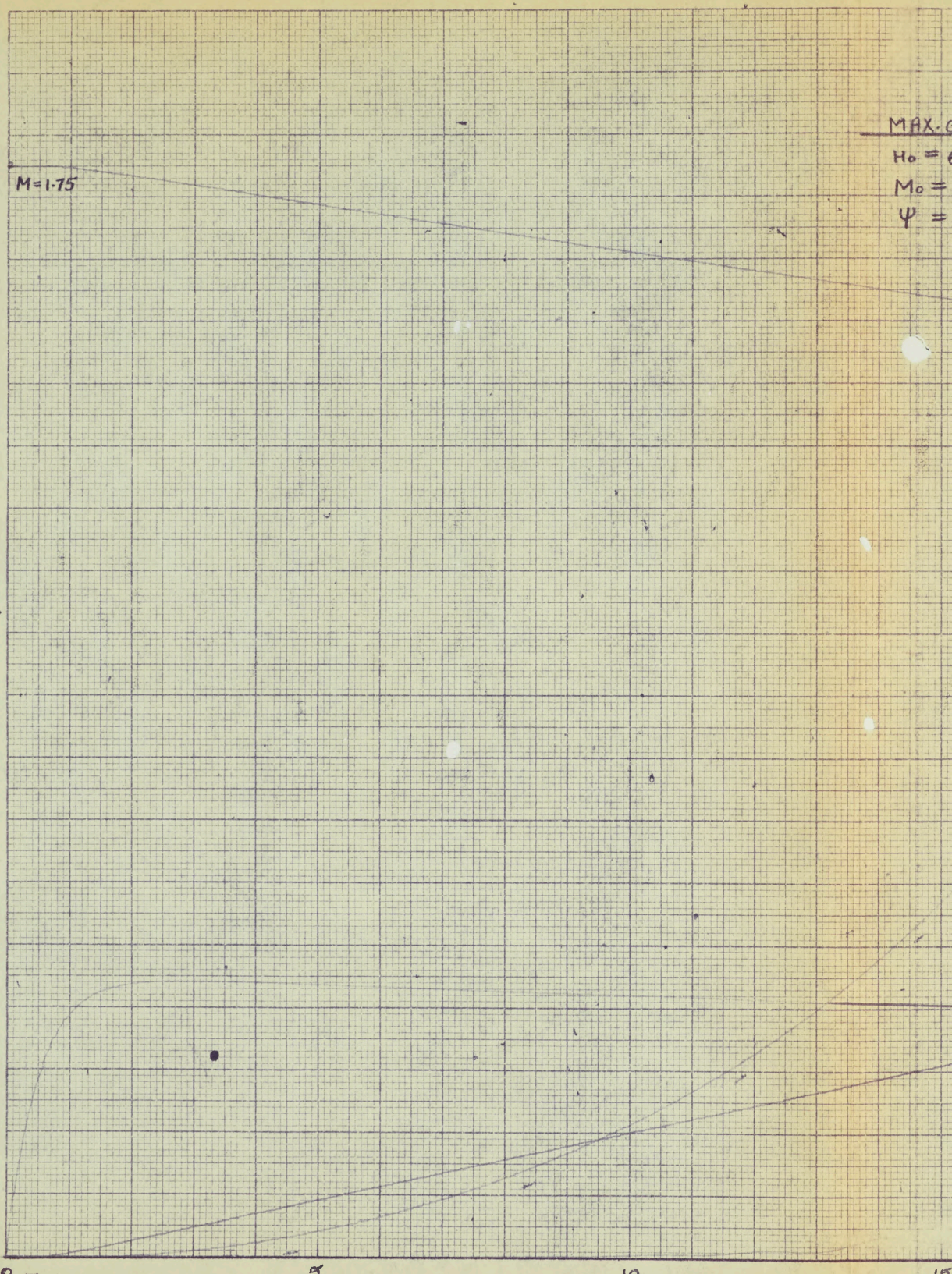
$M_0 = 1·75$

$\psi = +90°$



SECRET

EXTRACT 2 A47/A.C. MANOEUVRES/2

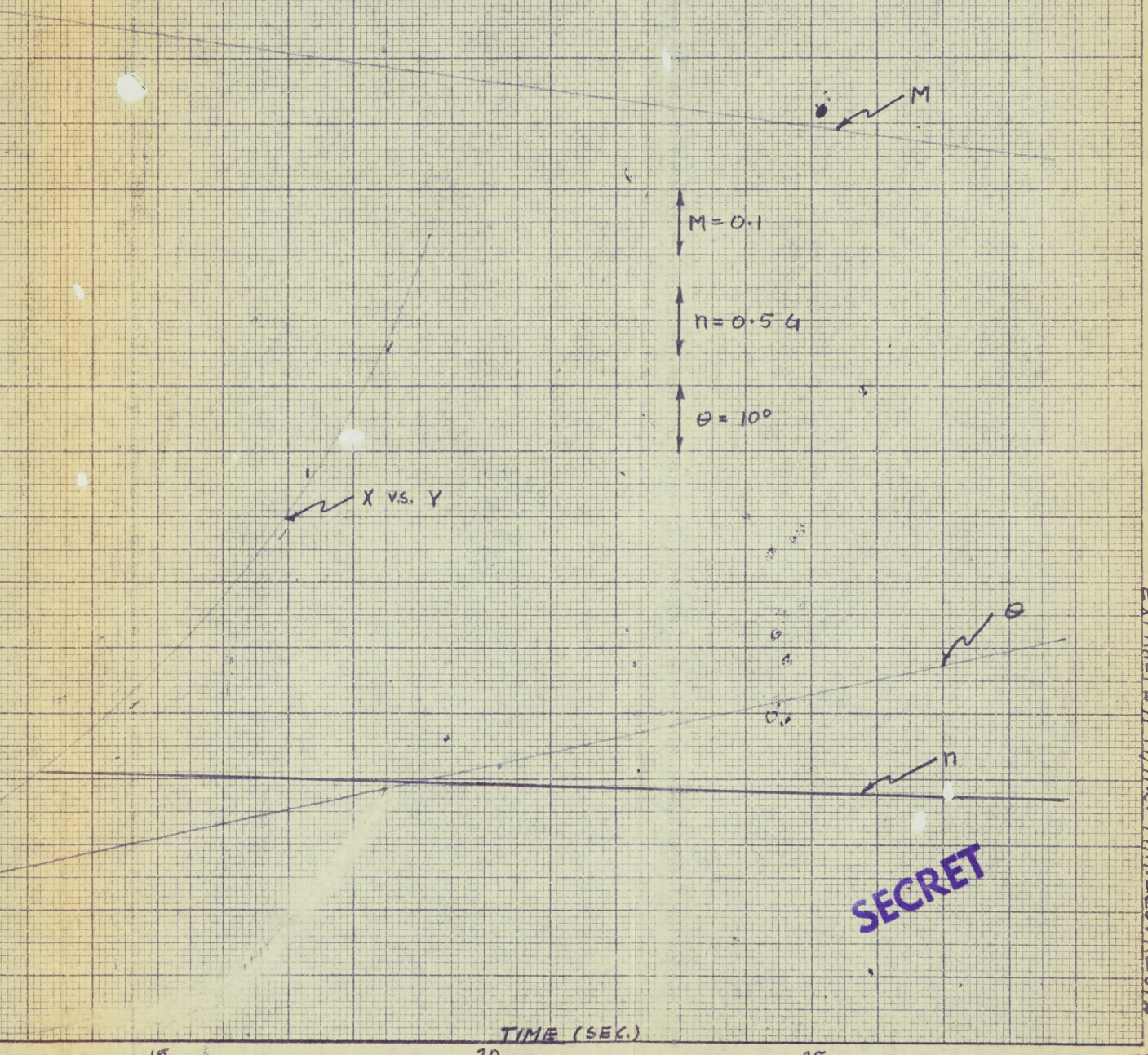


MAX·G TURNS (5·5 G LIMIT)

$H_0 = 60{,}000'$

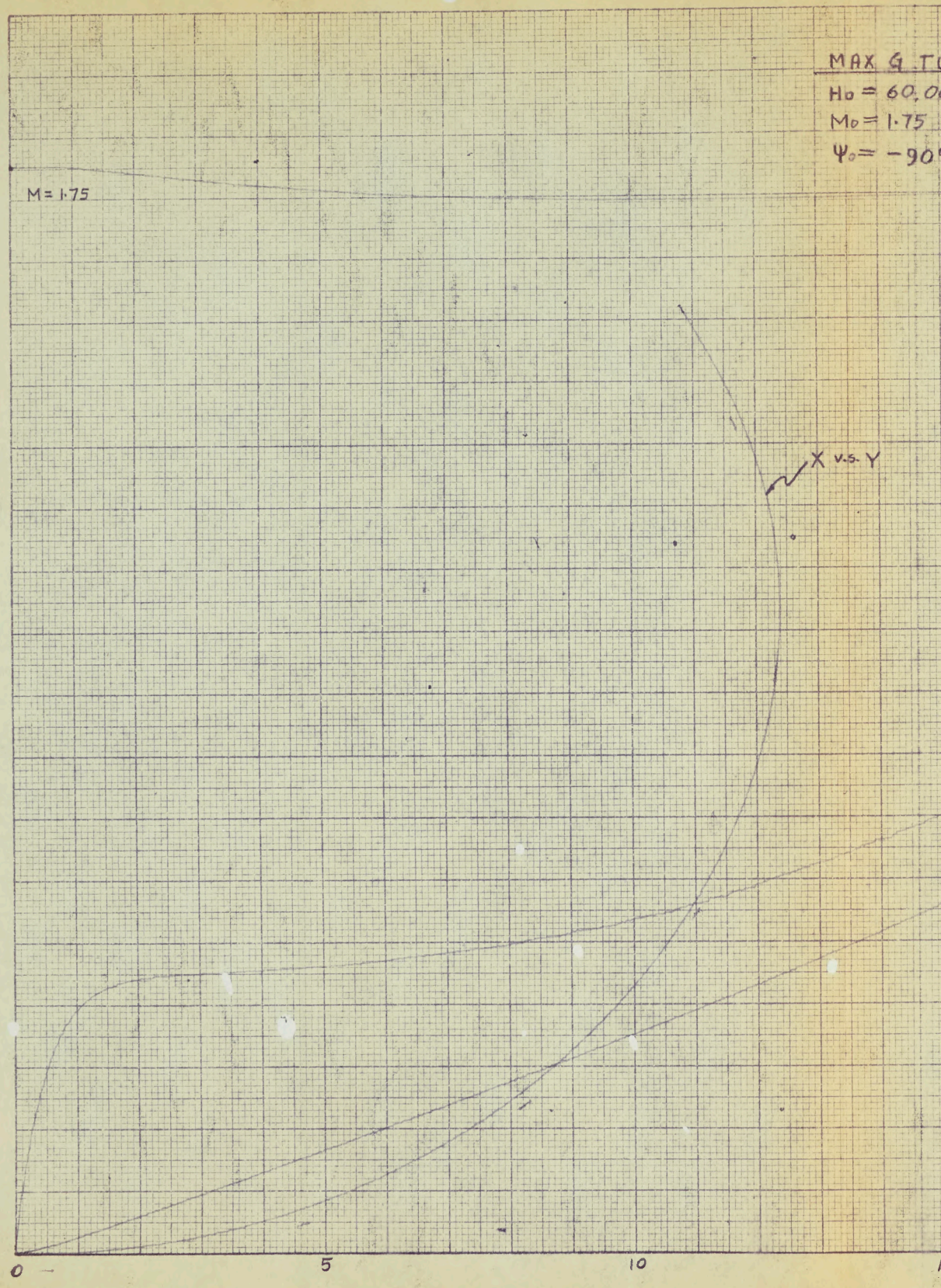
$M_0 = 1{\cdot}75$

$\psi = 0°$



SECRET

EXTRACT 2A 47/A.C. MANOEUVRES/2

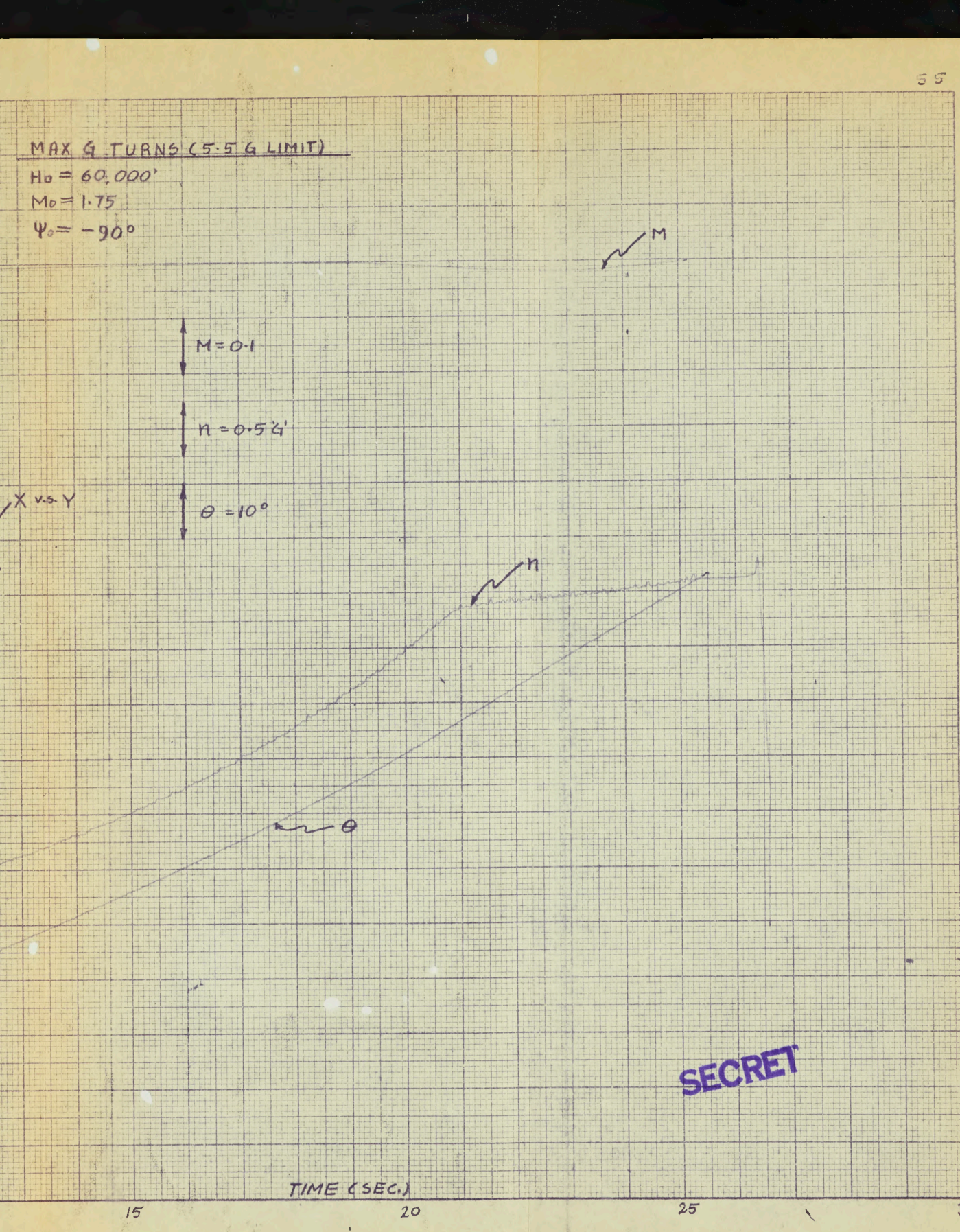


MAX G TURNS (5·5 G LIMIT)

$H_0 = 60,000'$

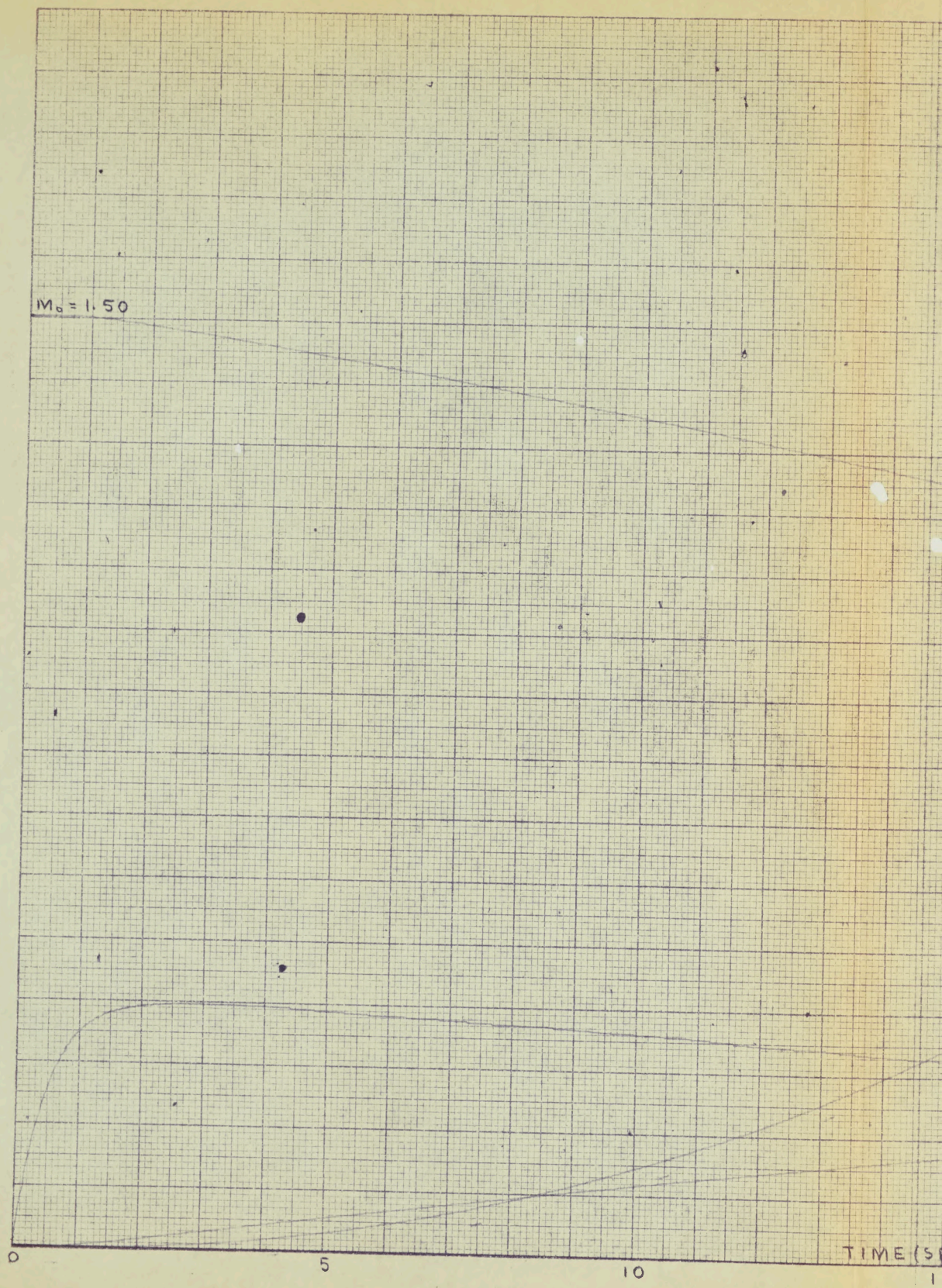
$M_0 = 1.75$

$\psi_0 = -90°$



SECRET

EXTRACT A47/A.C. MANOEUVRES/2



MAX 'G' TURNS (5.5 'G' LIMIT)

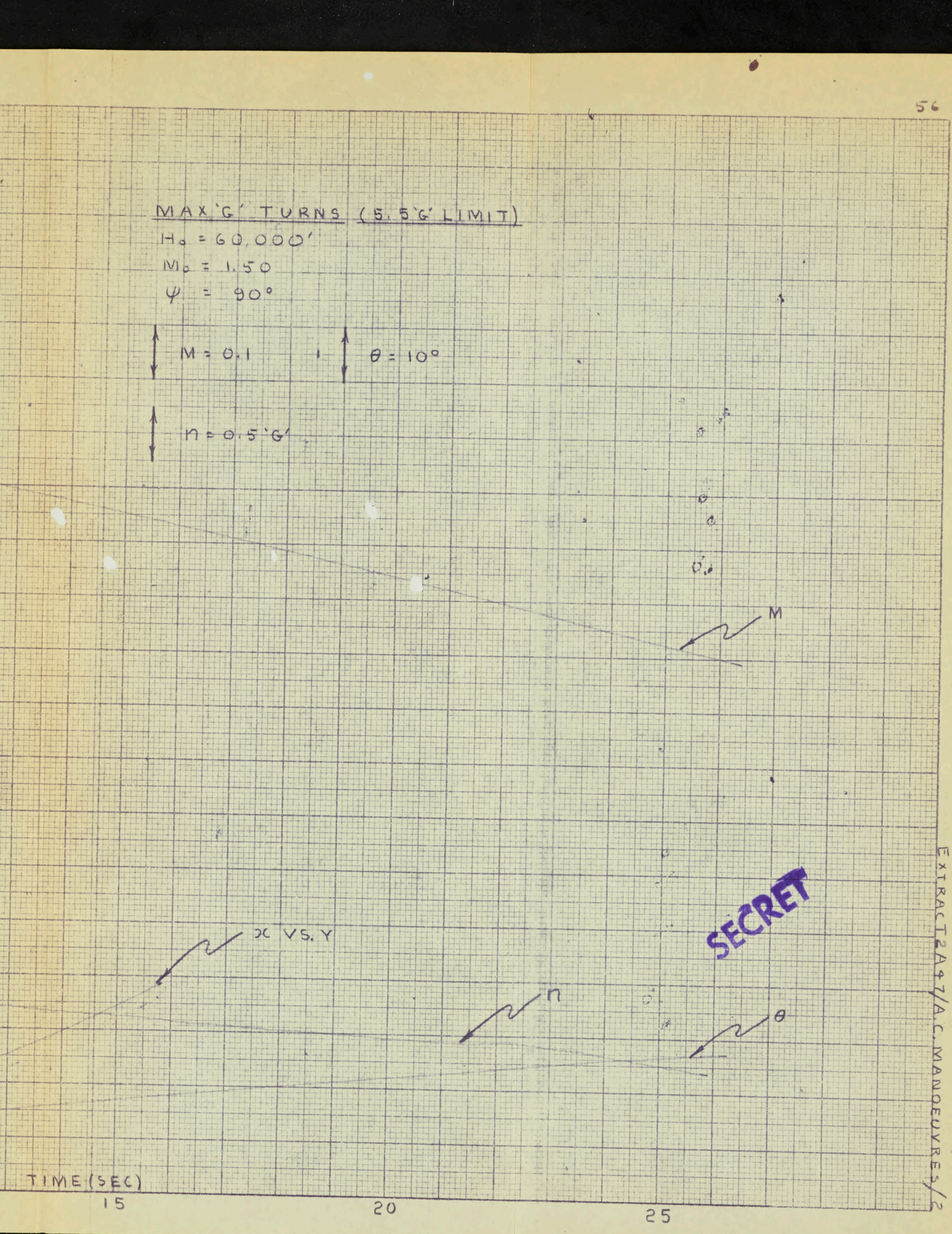
H_o = 60,000'

M_o = 1.50

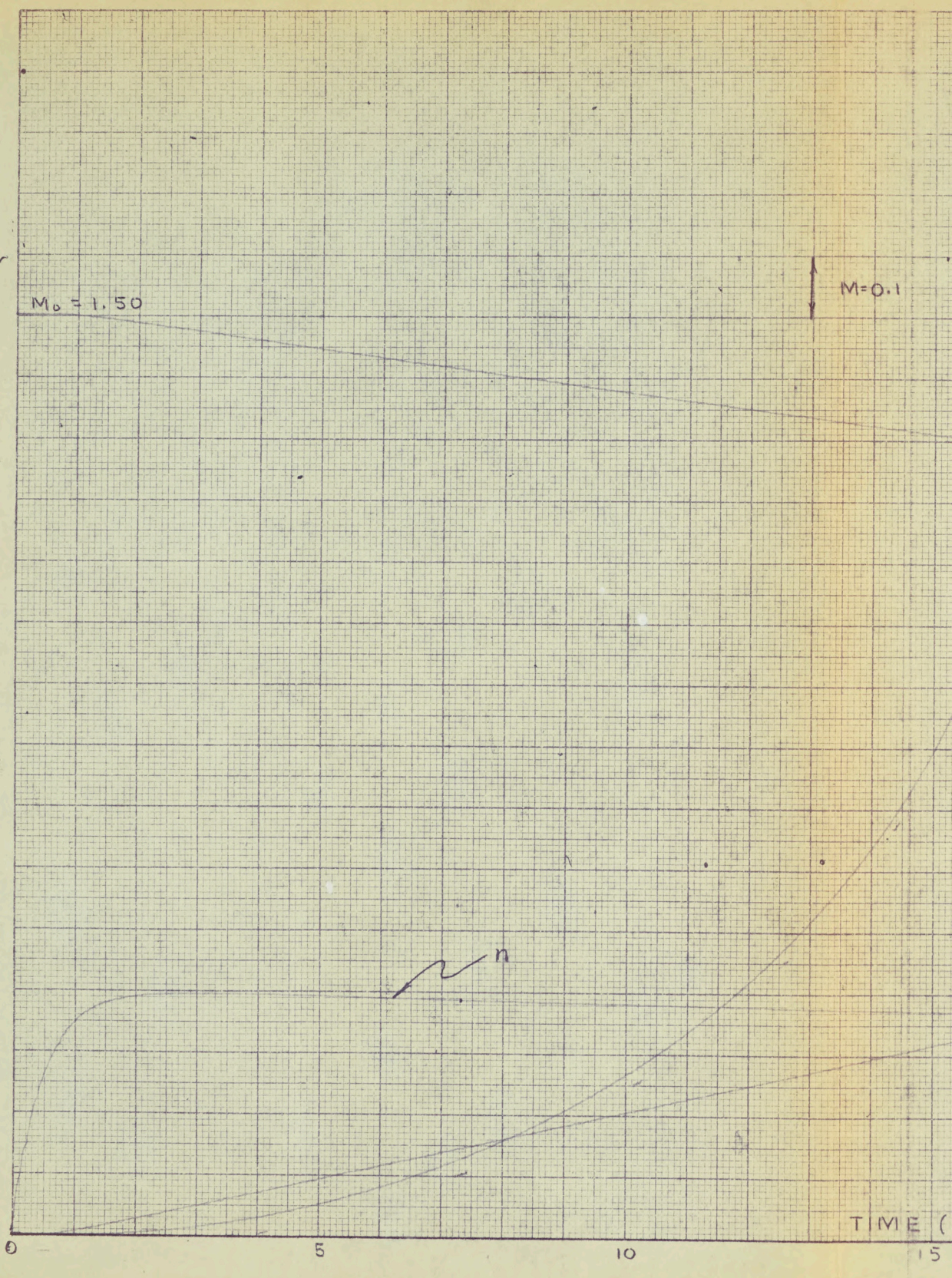
ψ = 90°

M = 0.1 | θ = 10°

n = 0.5 'G'



SECRET



MAX. 'G' TURNS (5.5 'G' LIMIT)

$H_0 = 60,000'$

$M_0 = 1.50$

$\psi = 0°$

M=0.1 | n=0.5 'G' | θ=10°

M = 1.50

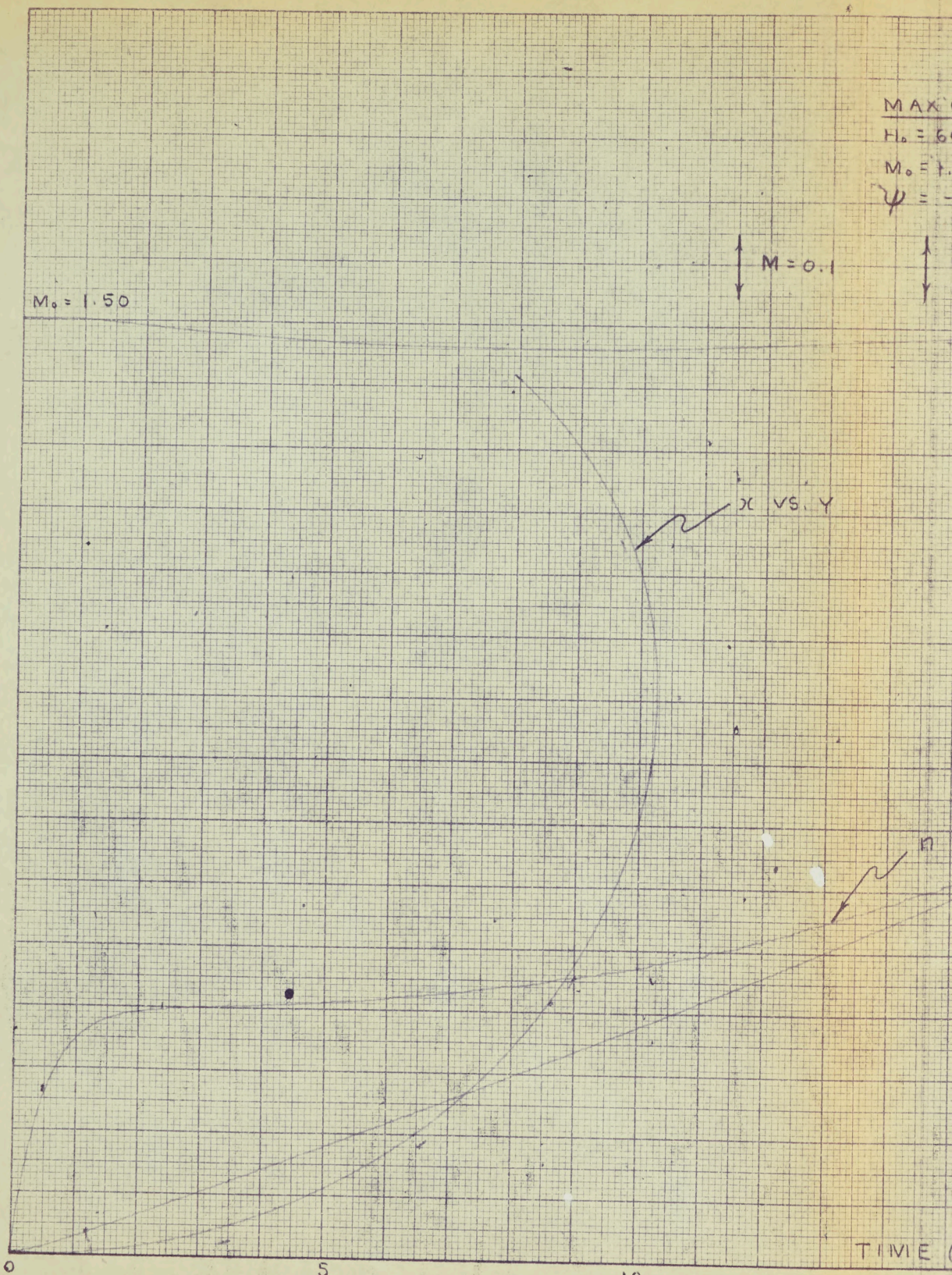
x vs. Y

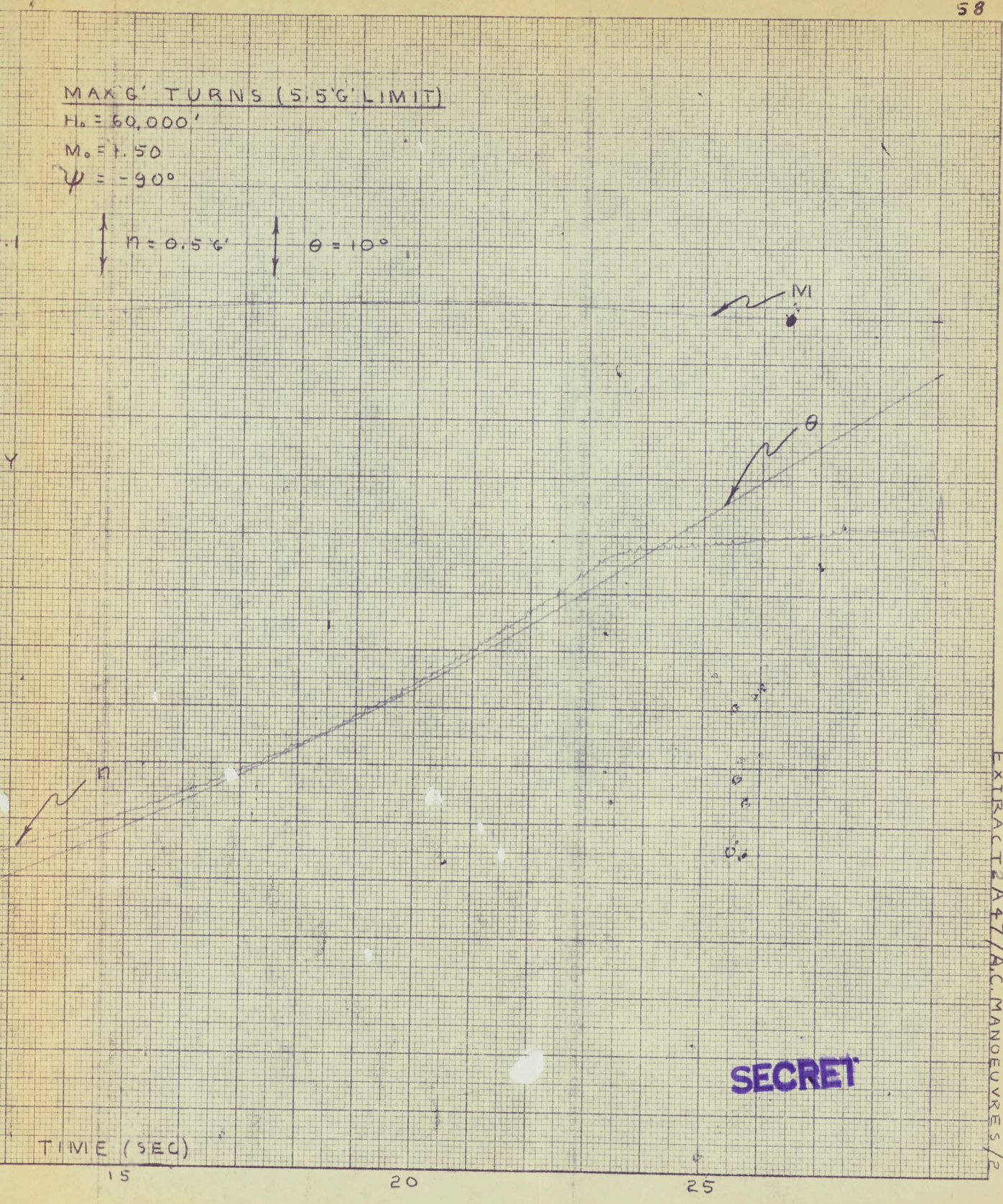
θ

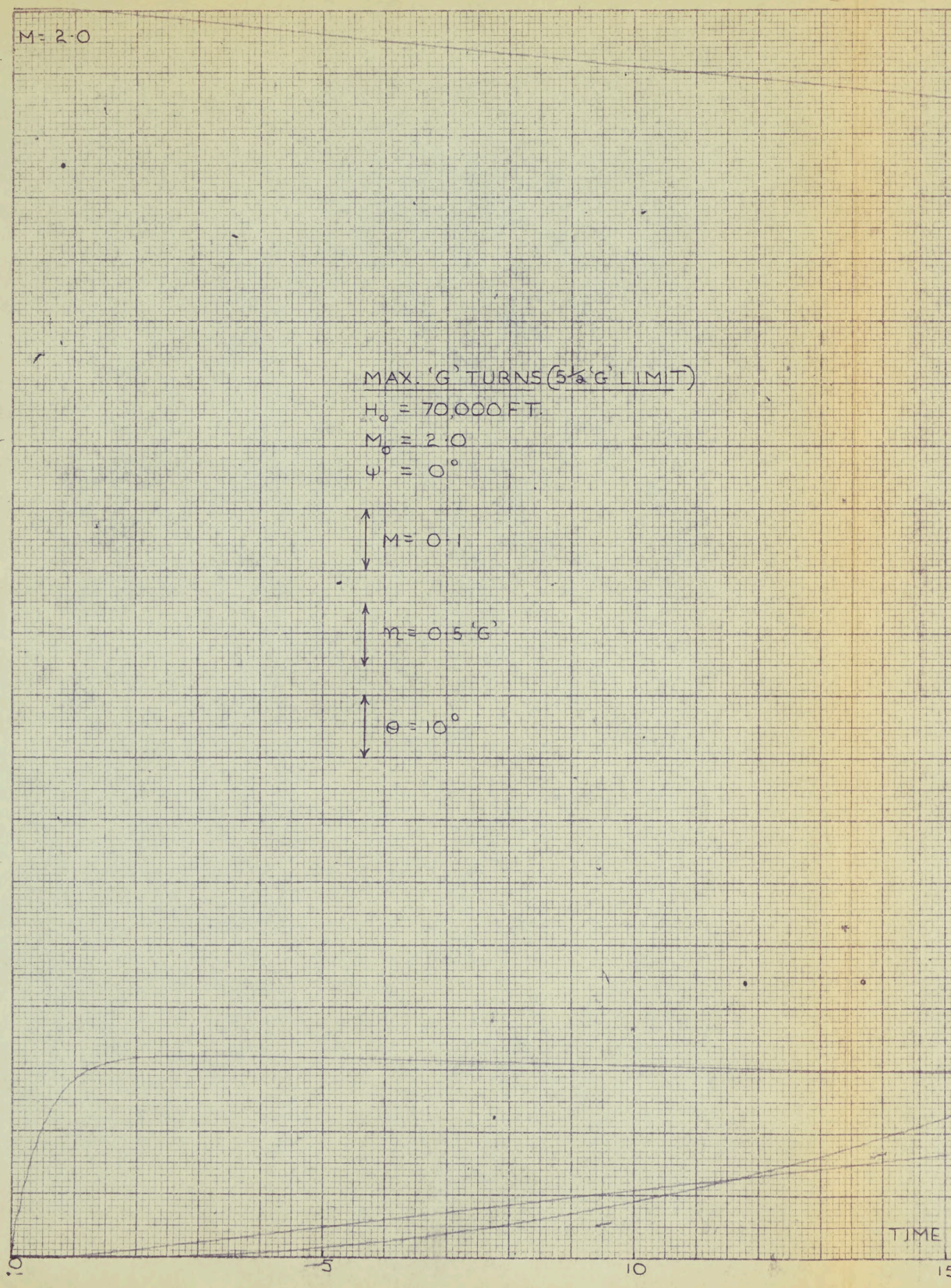
SECRET

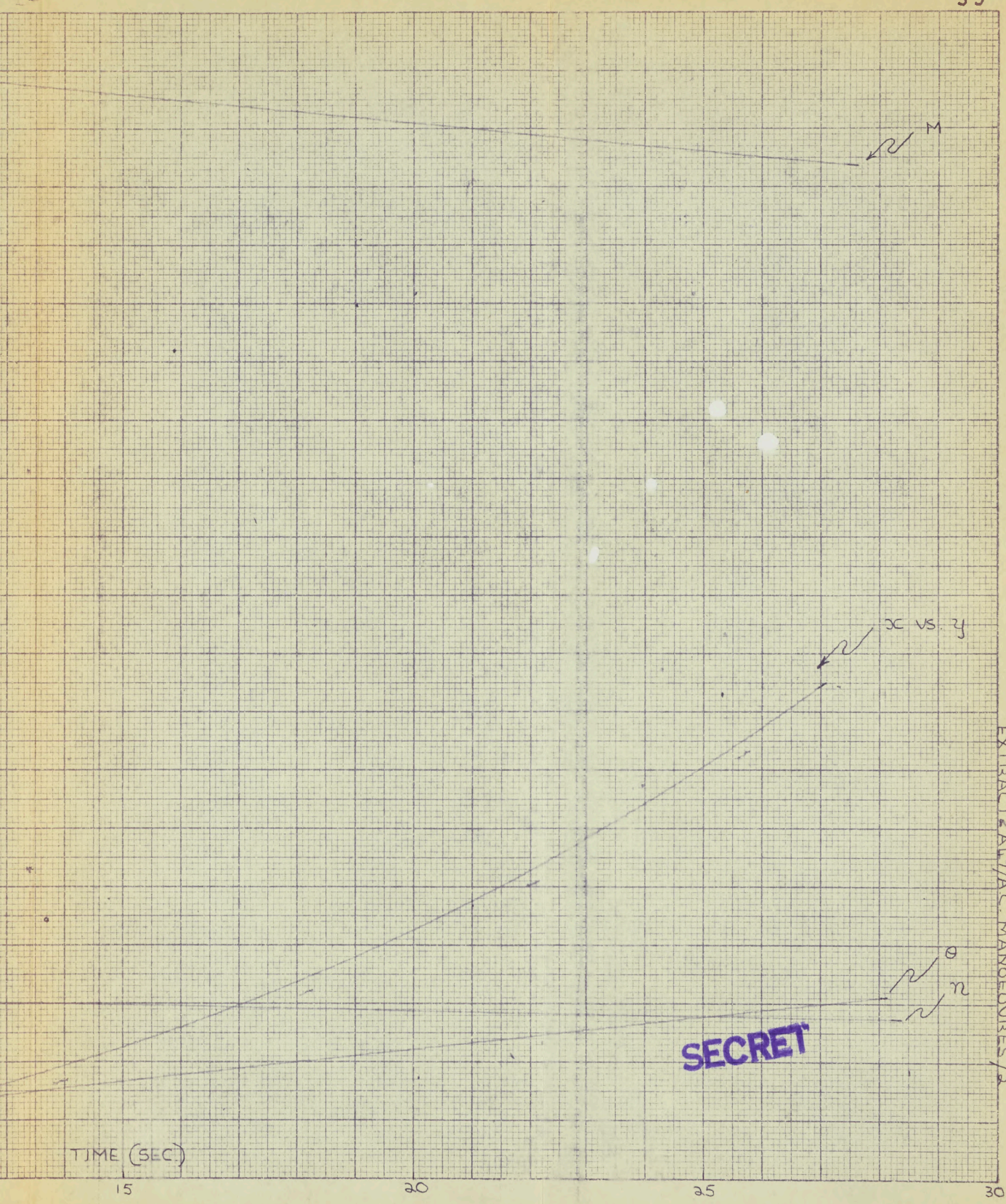
TIME (SEC)

15 20 25

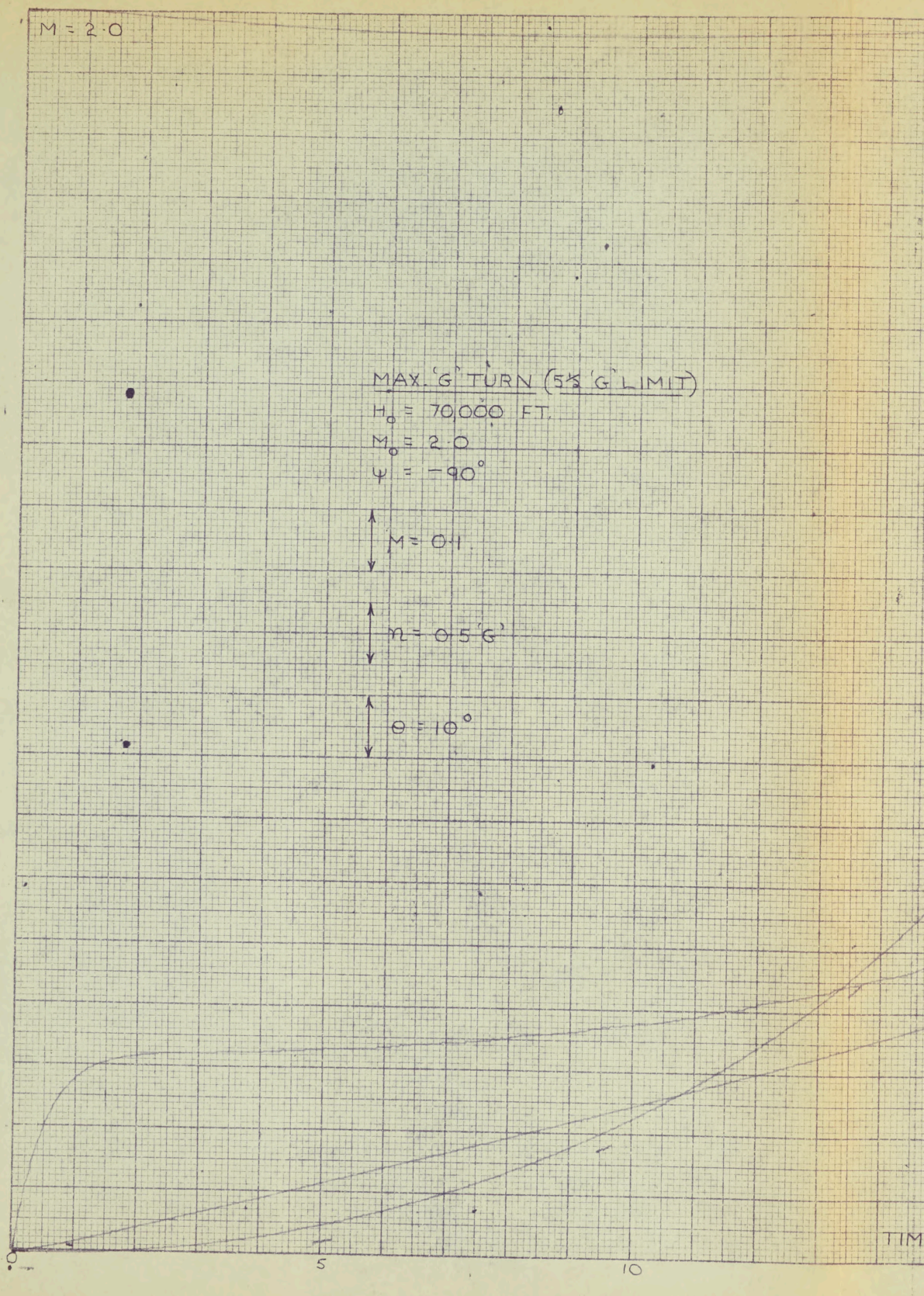


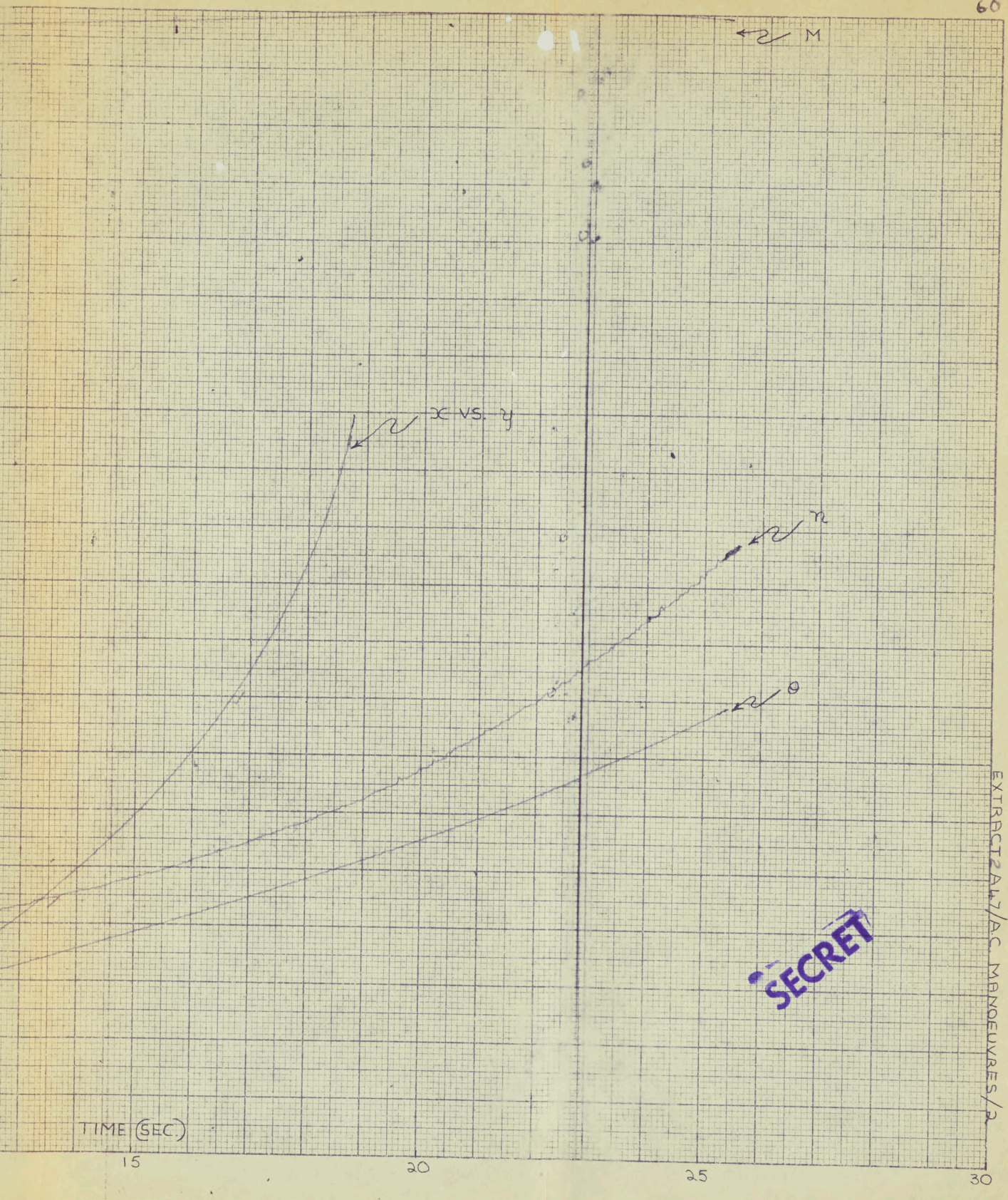


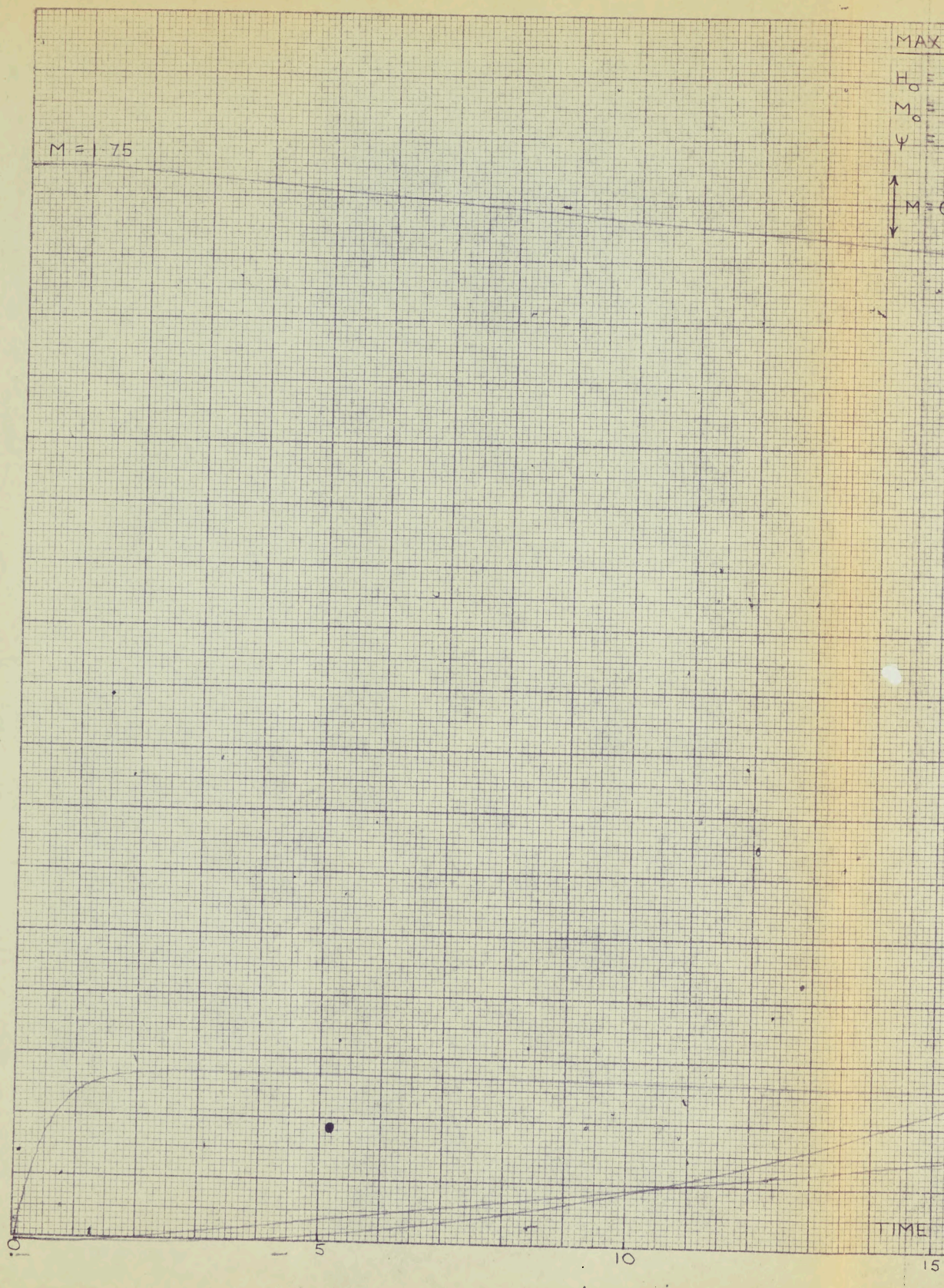




EXTRACT FROM A.C. MANOEUVRES /2





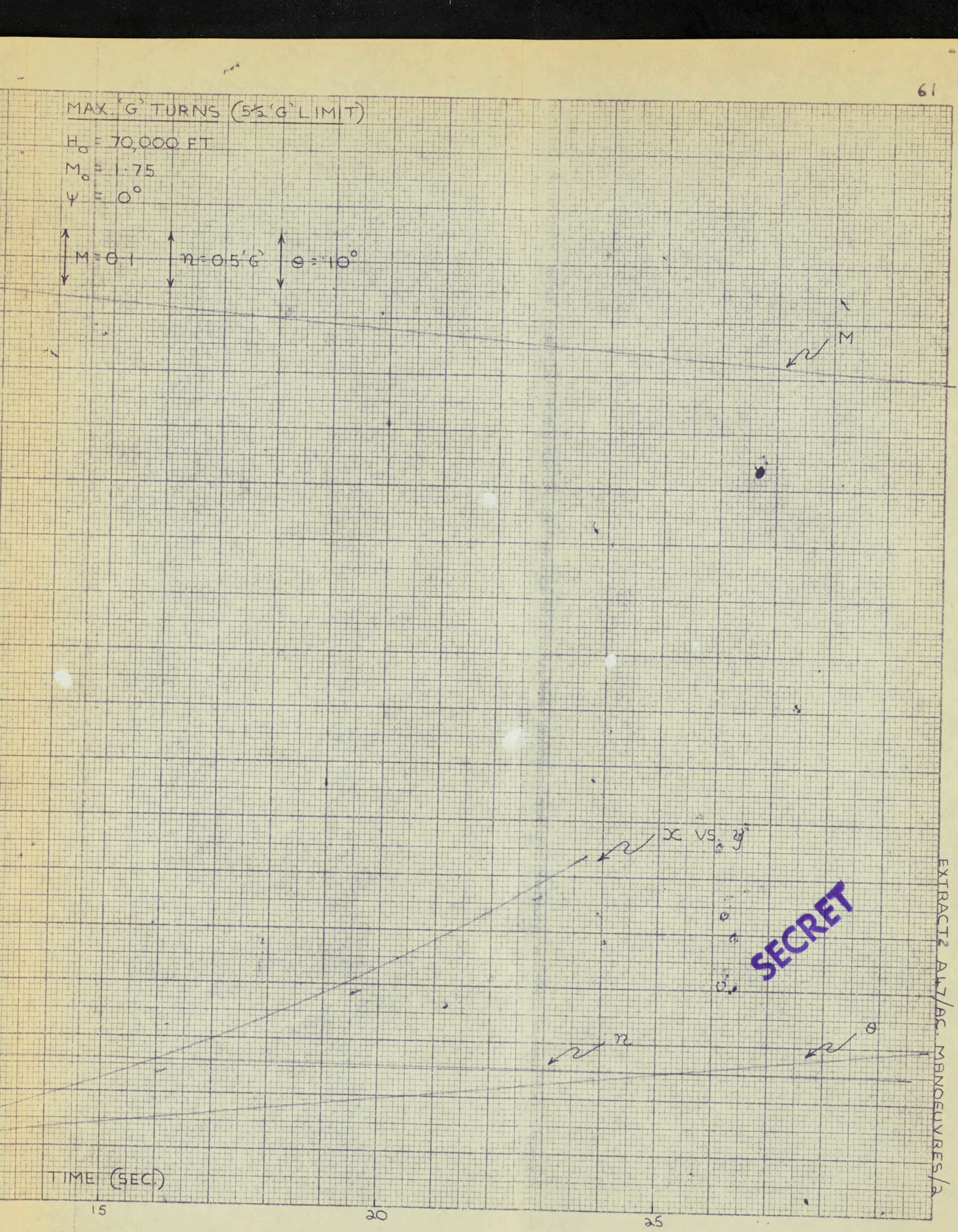


MAX. 'G' TURNS (5½ 'G' LIMIT)

H_o = 70,000 FT

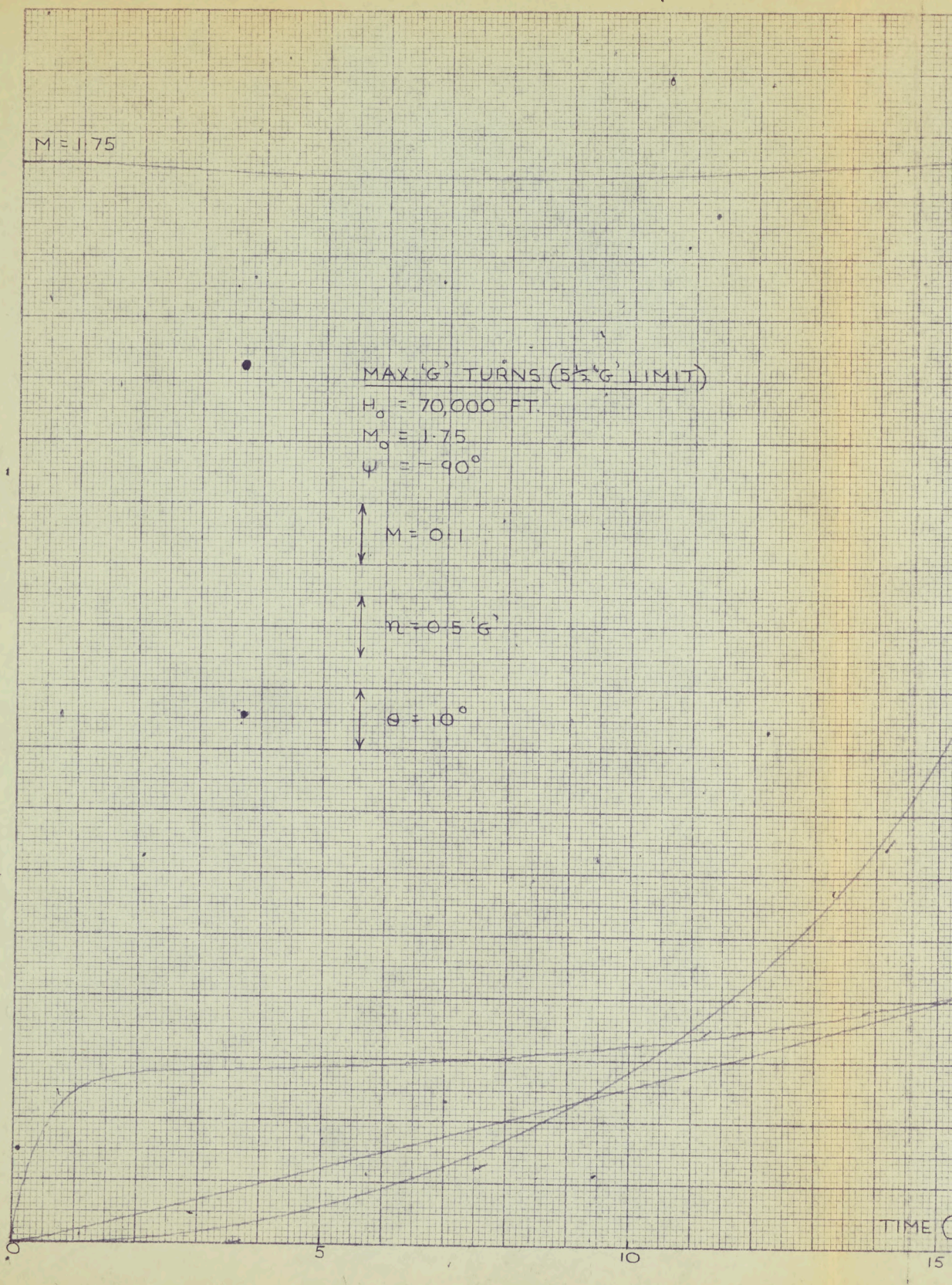
M_o = 1·75

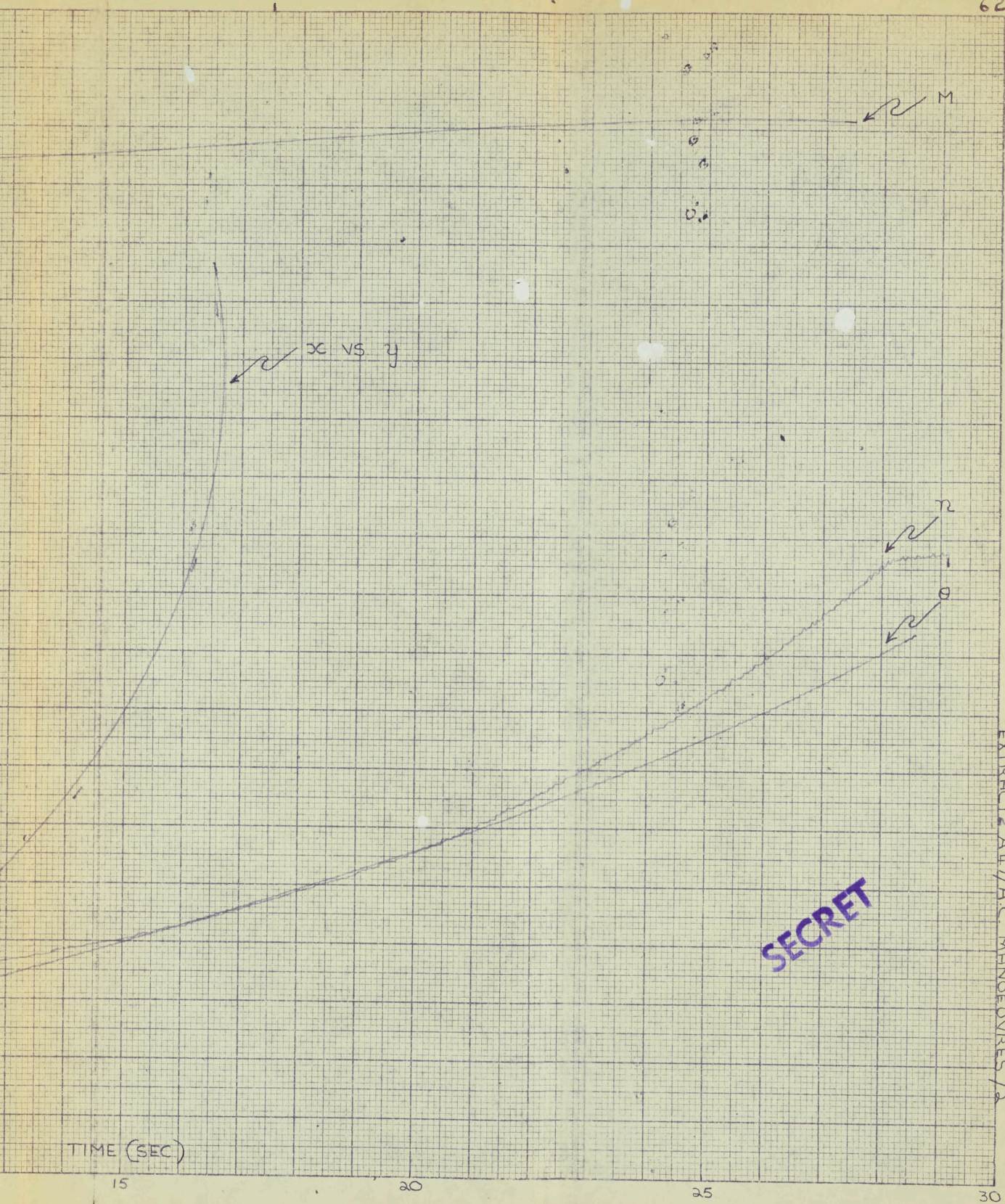
ψ = 0°



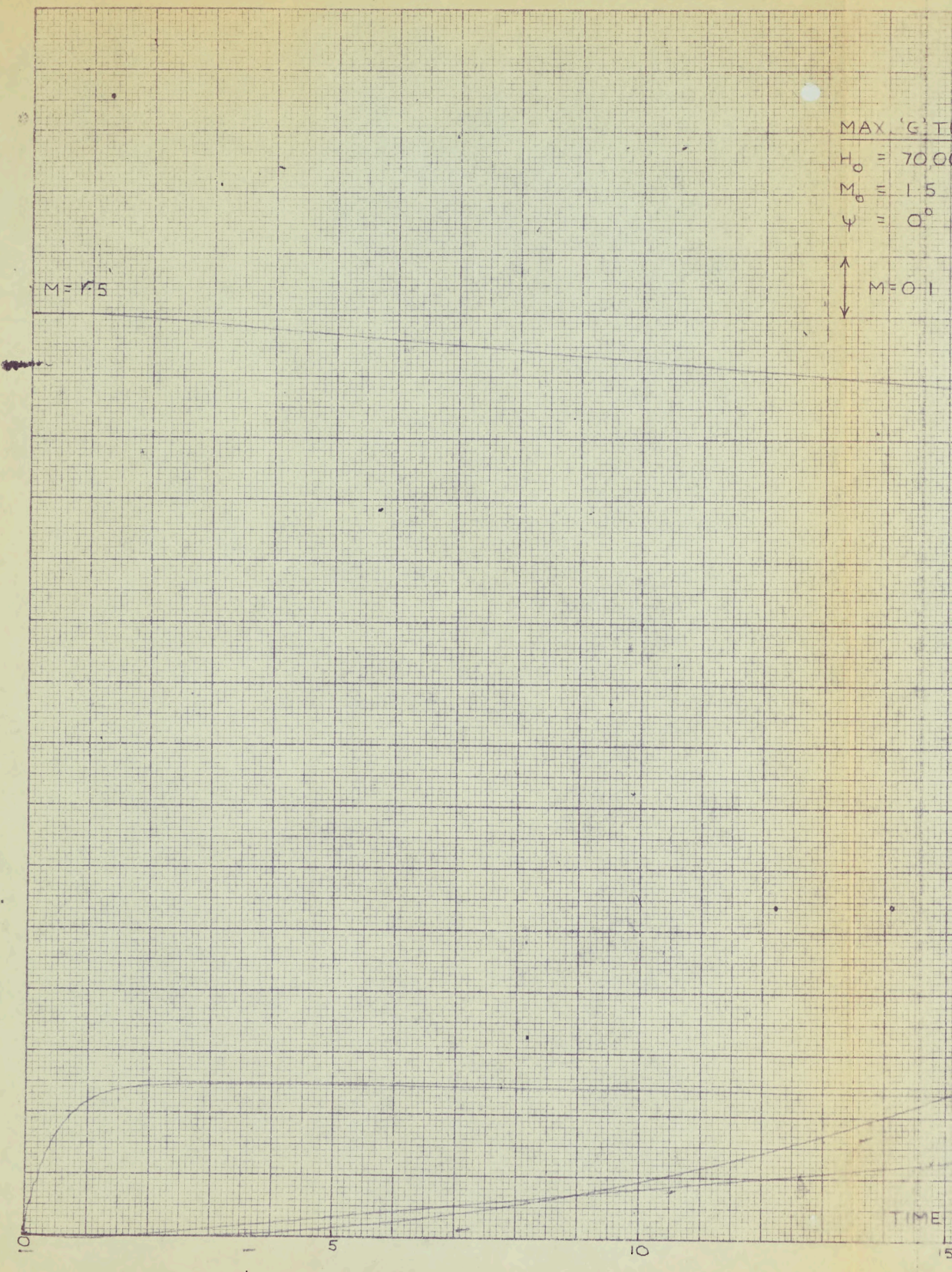
SECRET

EXTRACTS A4/AC. MANOEUVRES/2





SECRET



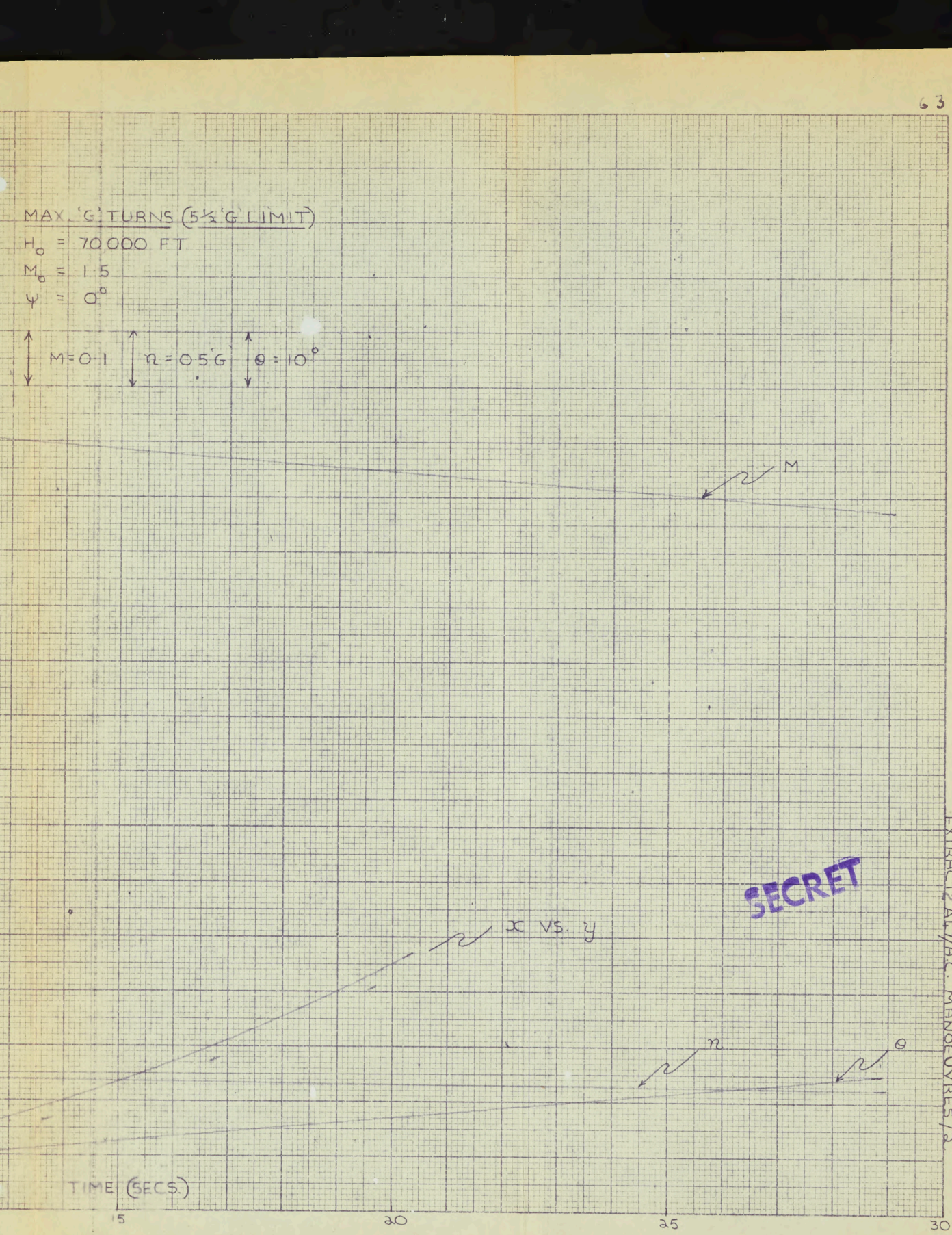
MAX. 'G' TURNS (5½ 'G' LIMIT)

H_o = 70,000 FT

M_o = 1.5

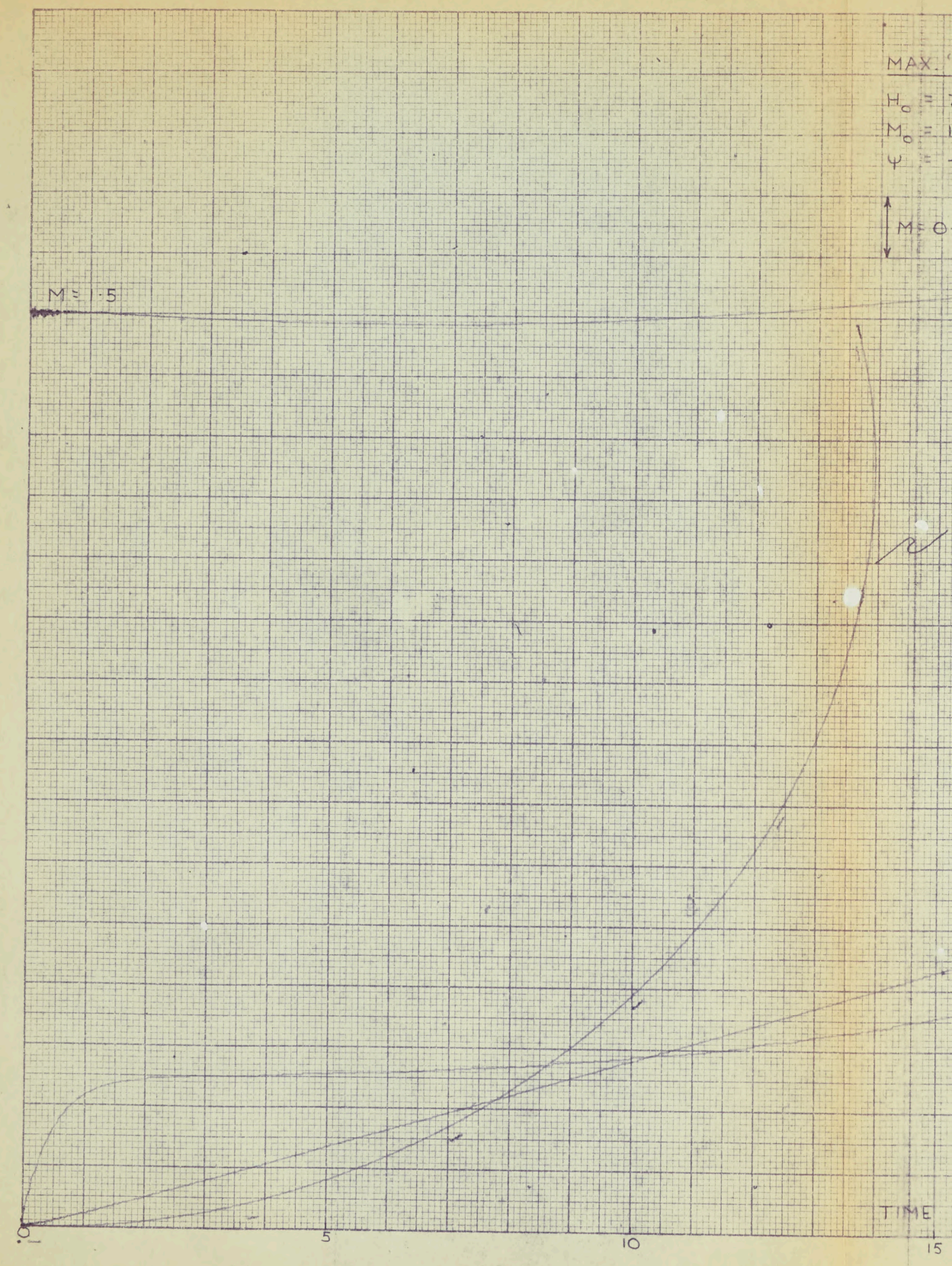
ψ = 0°

M=0·1 | n=0·5'G' | θ=10°



SECRET

EXTRACT 2 A4/A.C. MANOEUVRES/2



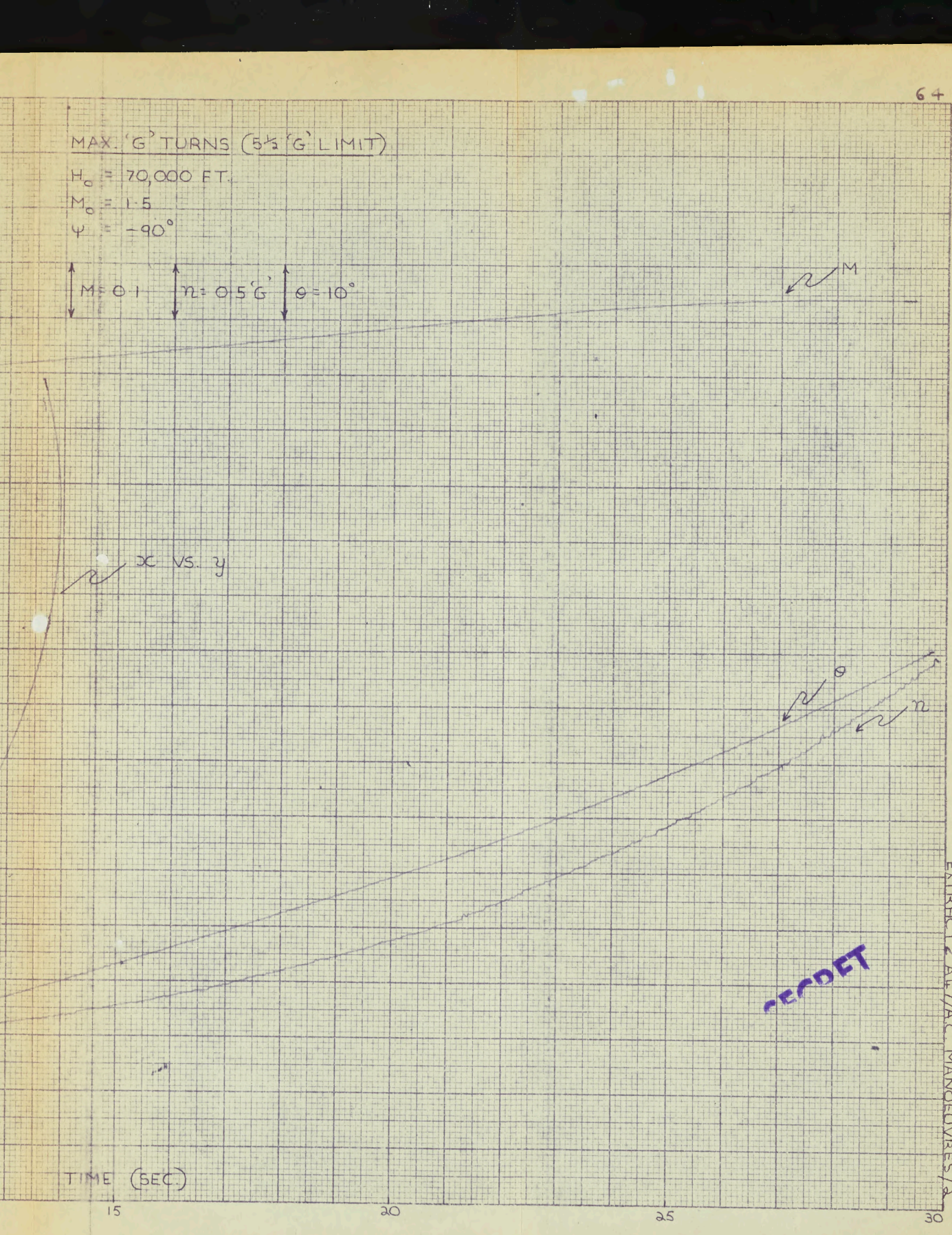
MAX. 'G' TURNS (5½ 'G' LIMIT)

H_o = 70,000 FT.

M_o = 1·5

ψ = −90°

M = 0·1 | n = 0·5 'G' | θ = 10°



EXTRACT 2 A47/A.C. MANOEUVRES/2