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CONFIDENTIAL

PROGRESS REPORT ON
HIGH ALTITUDE PLASTIC BALLOONS
CONTRACT NONR-710 (01)
December 22, 1952 to December 3, 1953
VOLUME II
CONFIDENTIAL INFORMATION

Copy No. 1 8

Confidential Information

PROGRESS REPORT ON RESEARCH AND DEVELOPMENT IN THE FIELD OF HIGH ALTITUDE PLASTIC BALLOONS

This material contains information affecting the national defense of the United States within the meaning of the Espionage Laws, Title 18, U.S.C., Sections 793 and 794, the transmission or revelation of which in any manner to an unauthorized person is prohibited by law.

CONDUCTED UNDER
CONTRACT NONR-710(01), NR 211 002
FOR PERIOD DECEMBER 22, 1952 to DECEMBER 3, 1953
WITH THE
OFFICE OF NAVAL RESEARCH

AND SPONSORED JOINTLY
BY THE ARMY, NAVY, AND AIR FORCE

PREPARED BY THE
DEPARTMENT OF PHYSICS
UNIVERSITY OF MINNESOTA
MINNEAPOLIS 14, MINNESOTA

This document has been reviewed in accordance with OPNAVINST 5510.17, paragraph 5. The security classification assigned herein is correct.

Date 25 March 1955 C. J. Latimer for
By direction of
Chief of Naval Research (Code 461)

Confidential Information

APR 20 1955
55 AA 17187

Confidential

PROGRESS REPORT ON CONTRACT 710(01)

From December 22, 1952, to December 3, 1953

VOLUME XI

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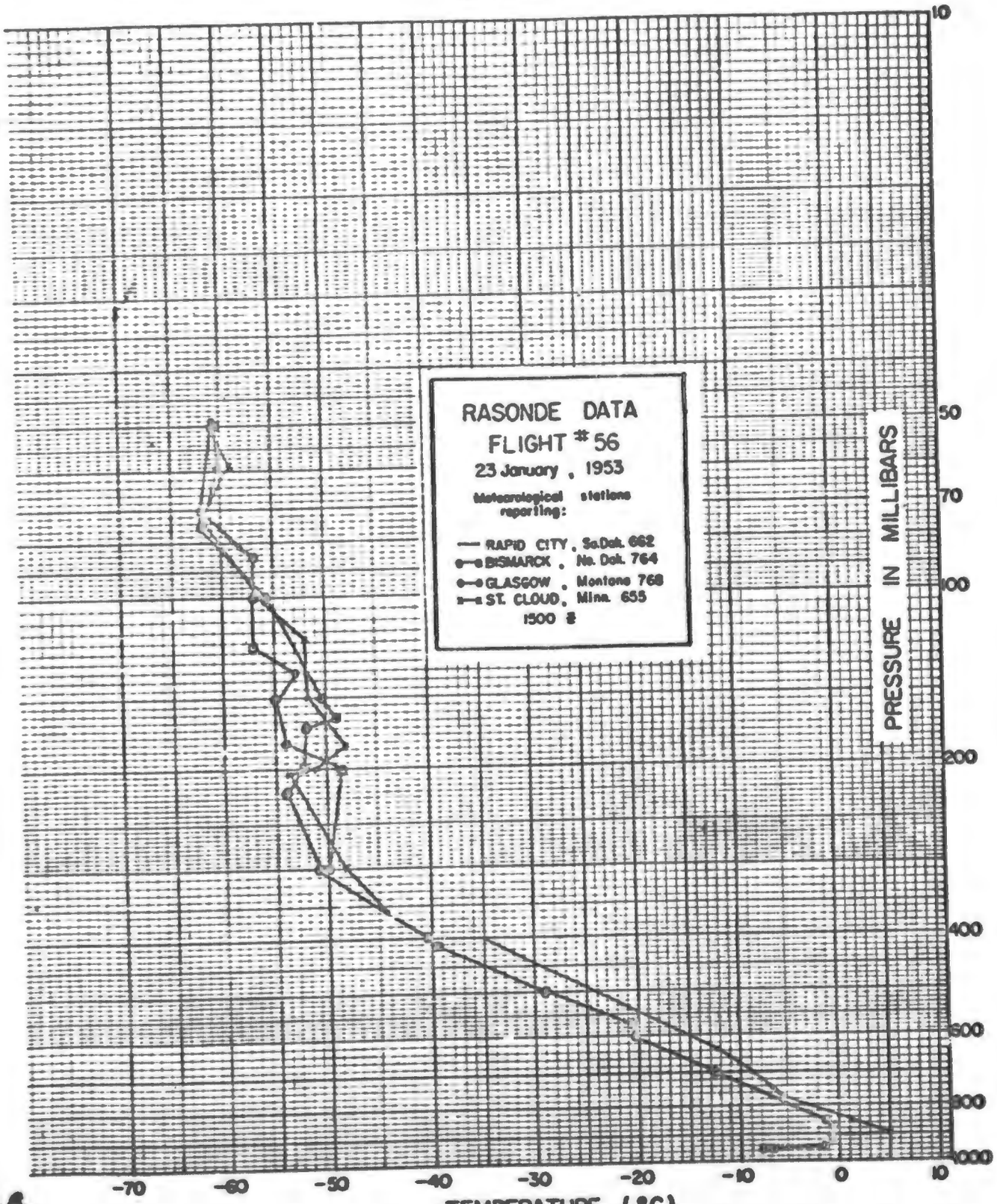
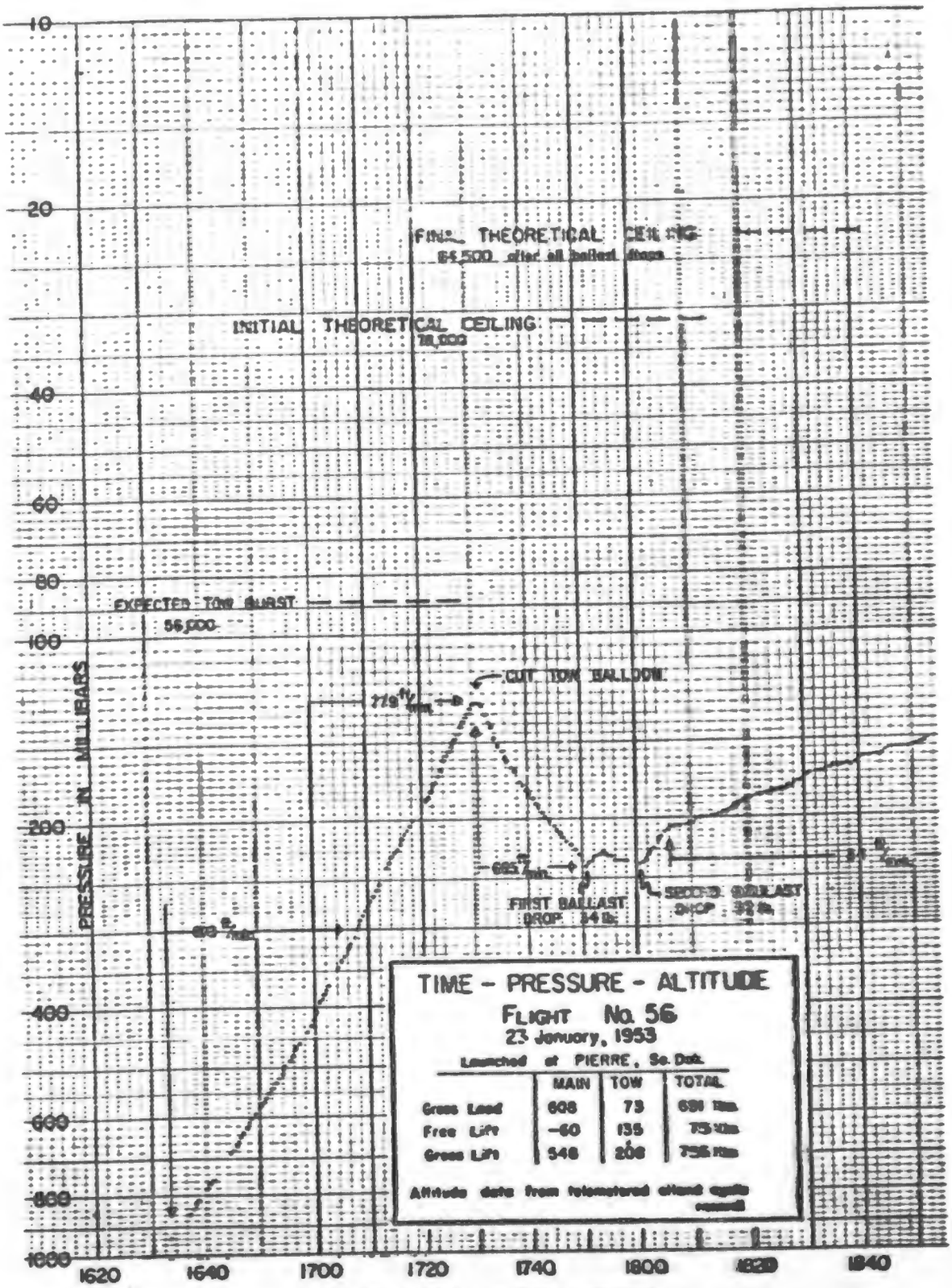
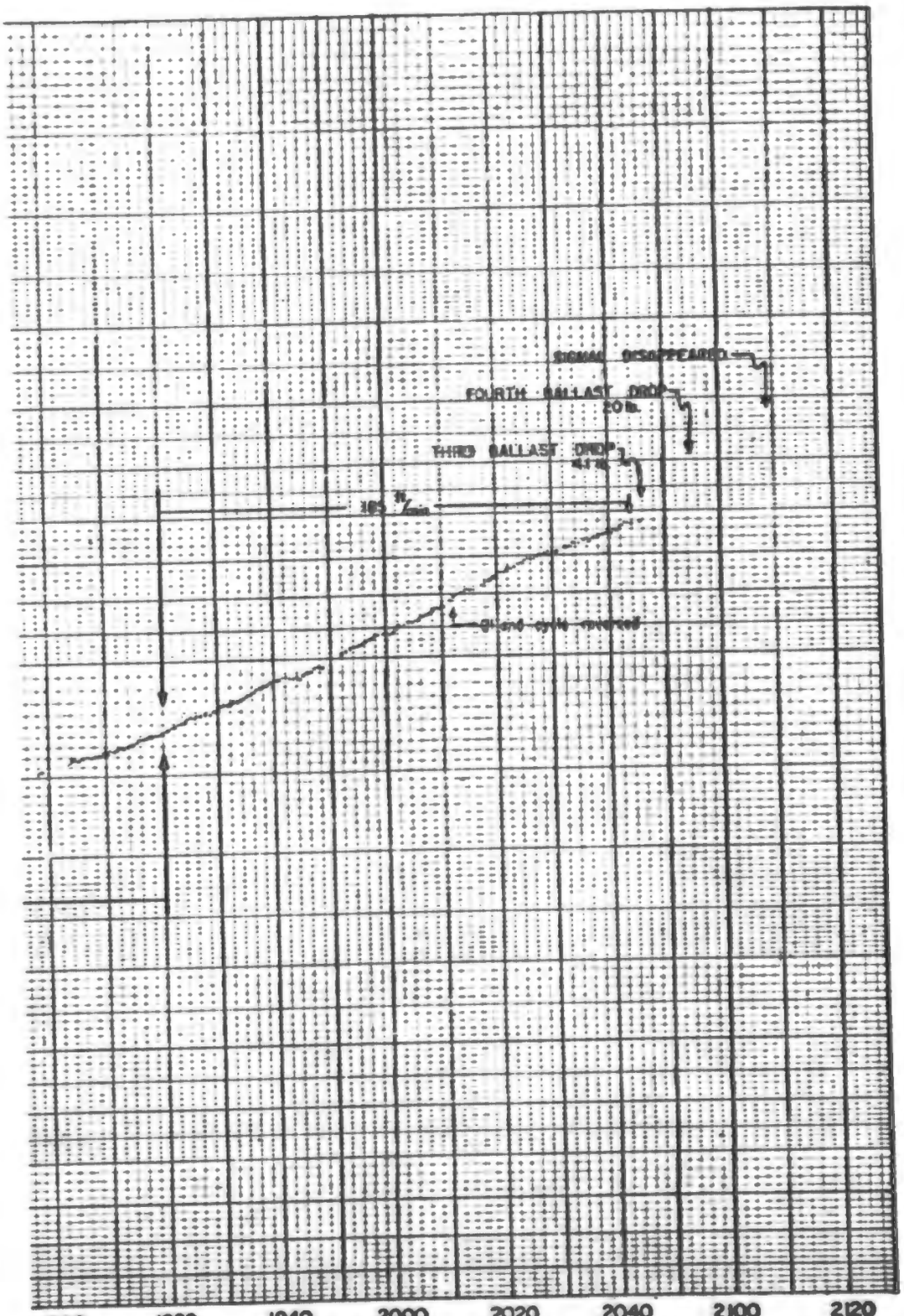
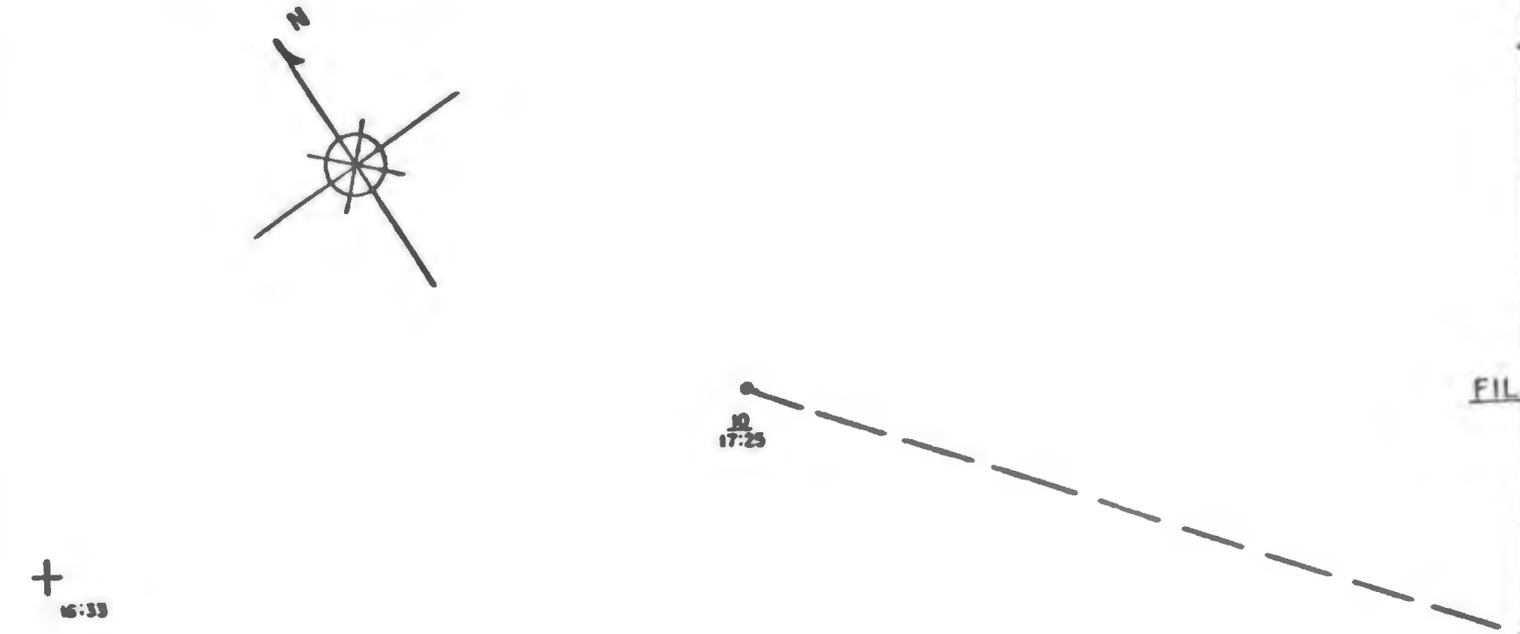
75 AA 17187


RASONDE DATA
FLIGHT # 56
23 January , 1953
Meteorological stations reporting:
RAPID CITY , So.Dak. 662
BISMARCK , No. Dak. 764
GLASGOW , Montana 768
ST. CLOUD, Minn. 655
1500 Z
PRESSURE IN MILLIBARS
10
50
70
100
200
400
600
800
1000
-70
-60
-50
-40
-30
-20
-10
0
10
TEMPERATURE (°C.)


FINAL THEORETICAL CEILING
64,500 after all ballast drops
INITIAL THEORETICAL CEILING
58,000
EXPECTED TOW BURST
56,000
CUT TOW BALLOON
719 ft/min
685 ft/min
FIRST BALLAST DROP 34 lb.
SECOND BALLAST DROP
PRESSURE IN MILLIBARS
10
20
40
60
80
100
200
400
600
800
1000
1620
1640
1700
1720
1740
1800
1820
1840
GREENWICH MEAN TIME
TIME - PRESSURE - ALTITUDE
FLIGHT No. 56
23 January, 1953
Launched at PIERRE, So. Dak.
MAIN
TOW
TOTAL
Gross Load
608
73
681 lbs
Free Lift
-60
135
75 lbs
Gross Lift
548
208
756 lbs
Altitude data from telemetered altitude rate record


SIGNAL DISAPPEARED
FOURTH BALLAST DROP
20 lb.
THIRD BALLAST DROP
1900
1920
1940
2000
2020
2040
2100
2120



LAUNCHED AT
PIERRE, SO.DAK.

+ LAUNCH SITE LAT. 44° 23' LONG 100° 17'

FLIGHT 56

LAUNCHED 16:33 G.M.T.
23 JANUARY, 1953

TRAJECTORY FROM FILM DATA

FILM FRAME NUMBERS

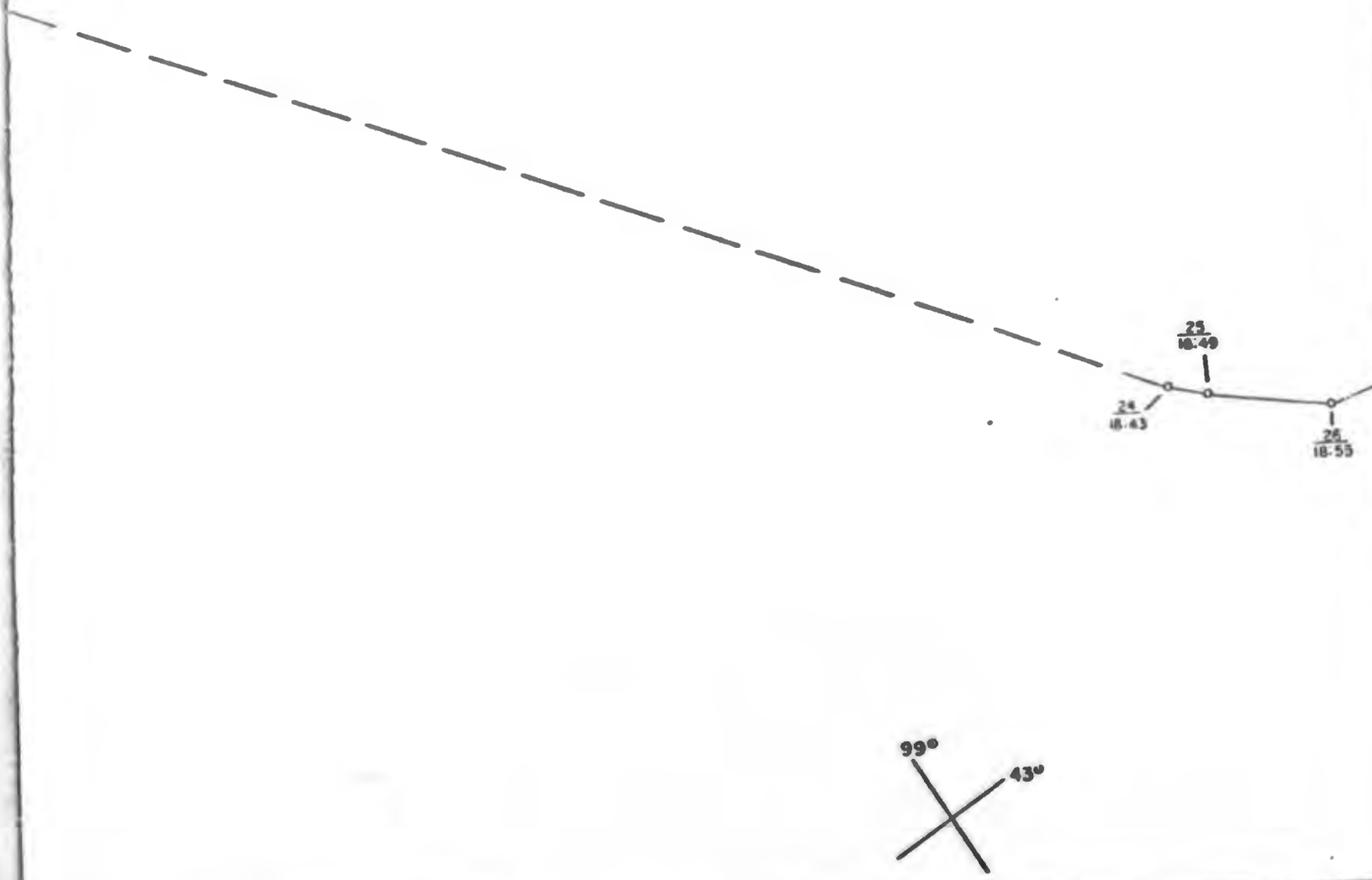
24
10:43

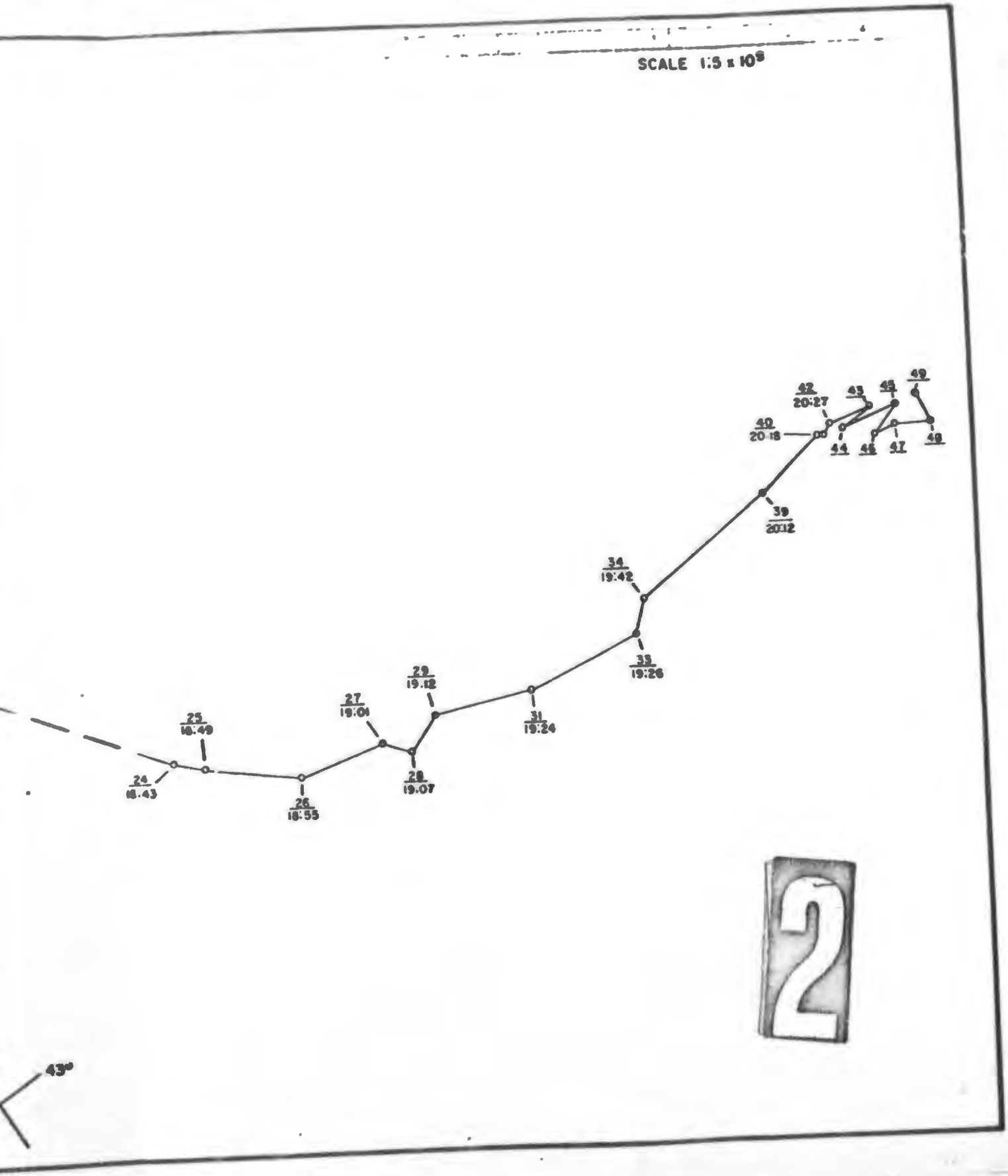
99°

43°

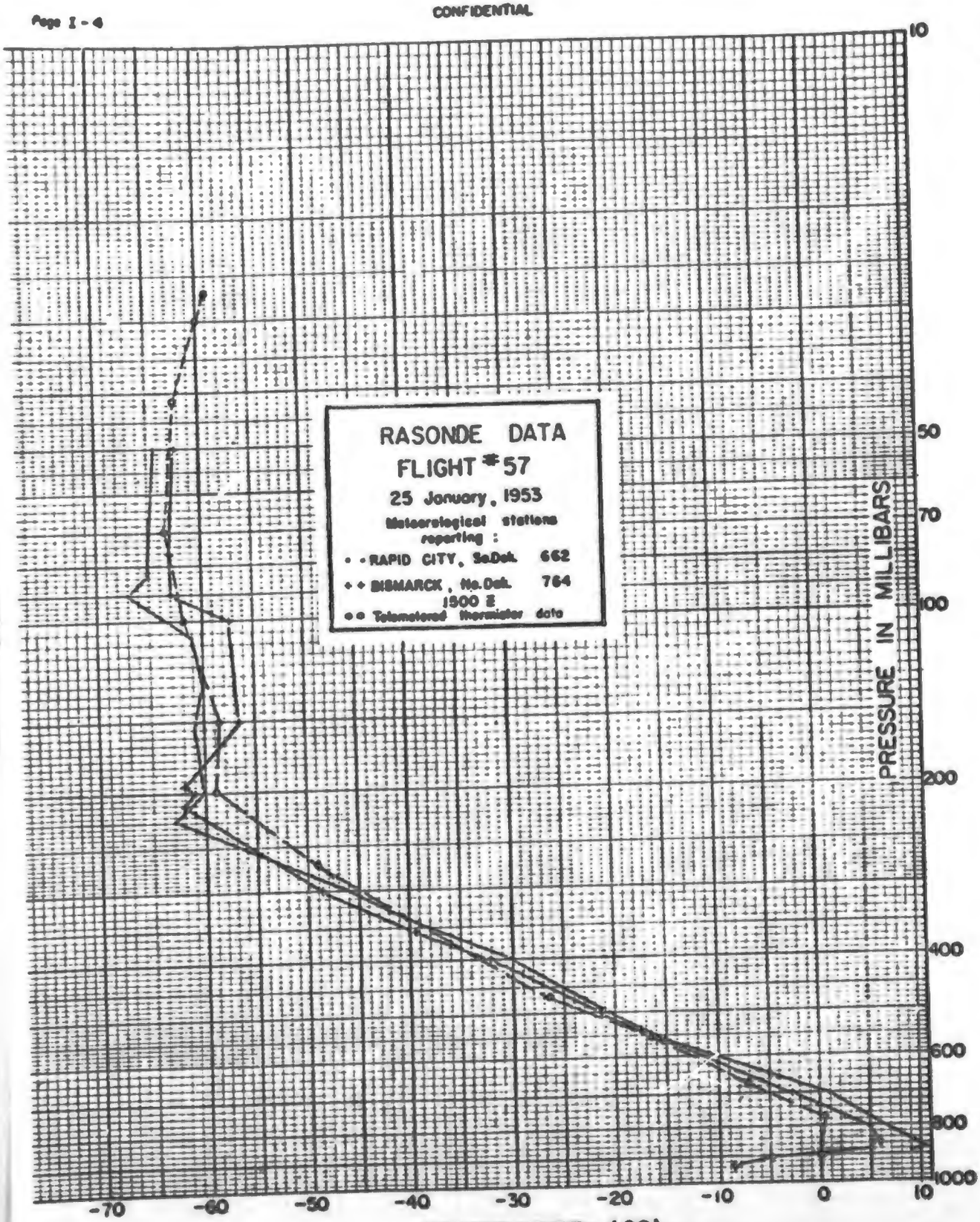
1. 2

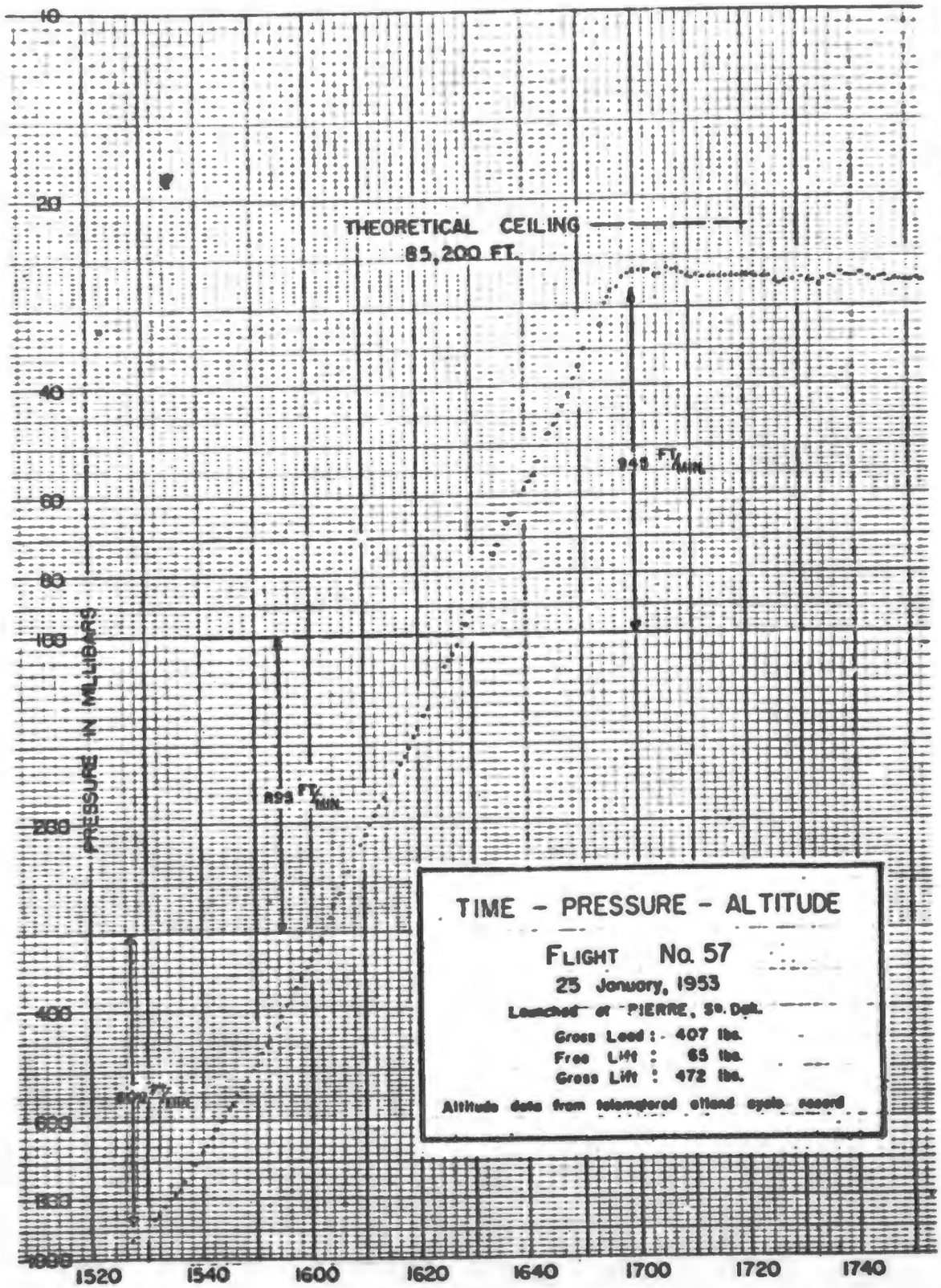
FILM FRAME NUMBERS

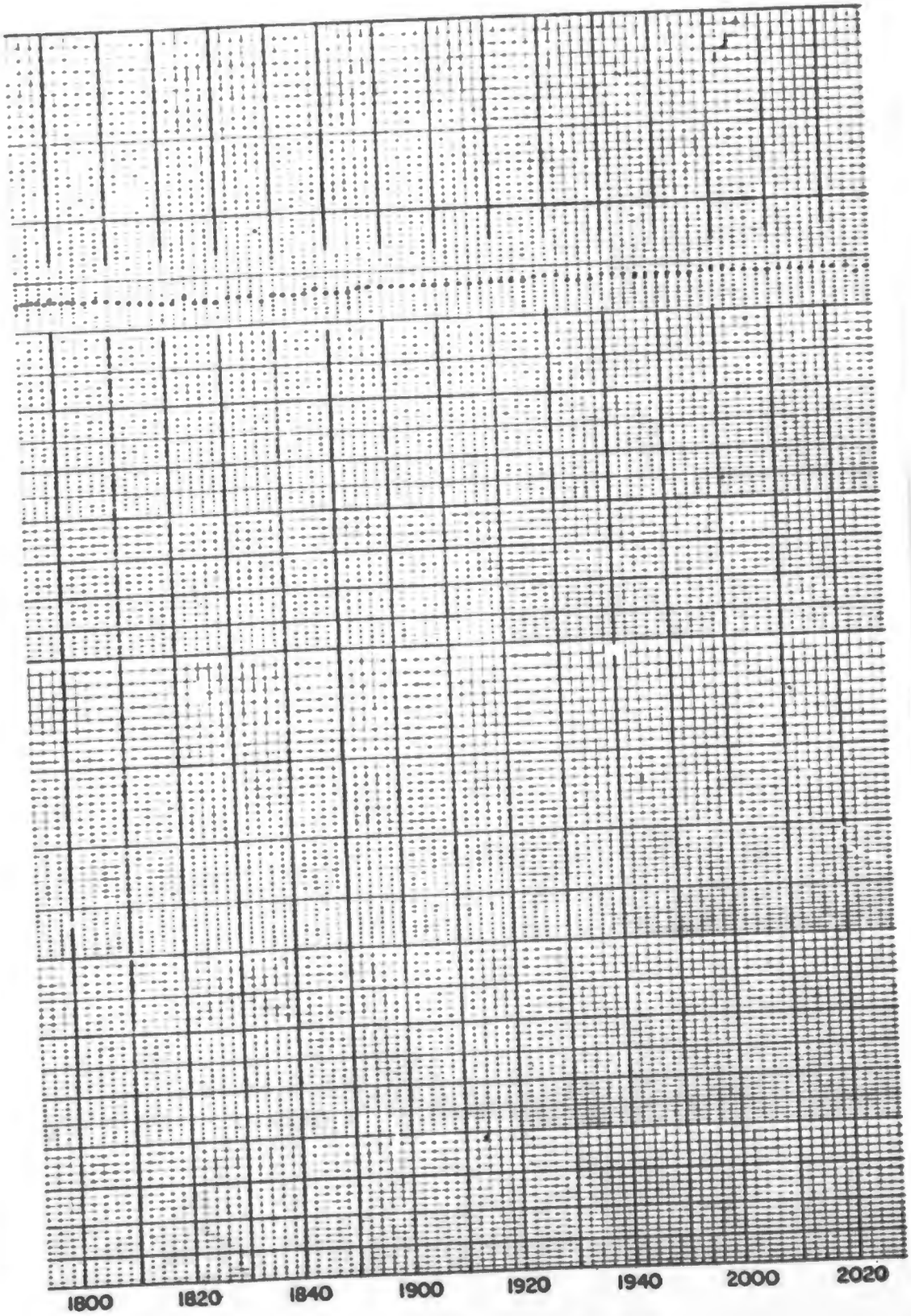


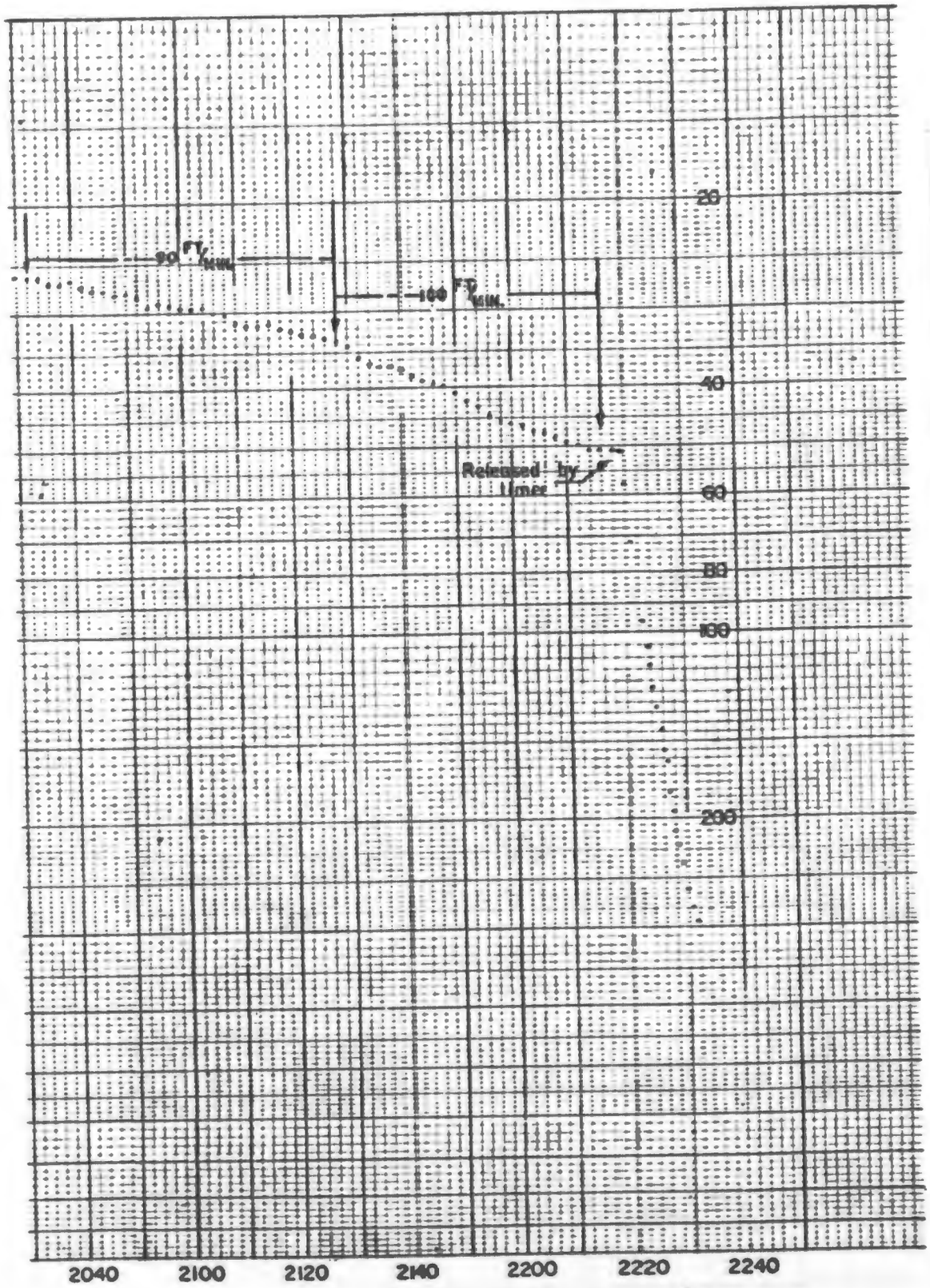

SCALE 1:5 x 10^8
24
18:43
25
18:49
26
18:55
27
19:01
28
19:07
29
19:12
31
19:24
33
19:26
34
19:42
39
20:12
40
20:18
42
20:27
43
44
45
46
47
48
49
43°

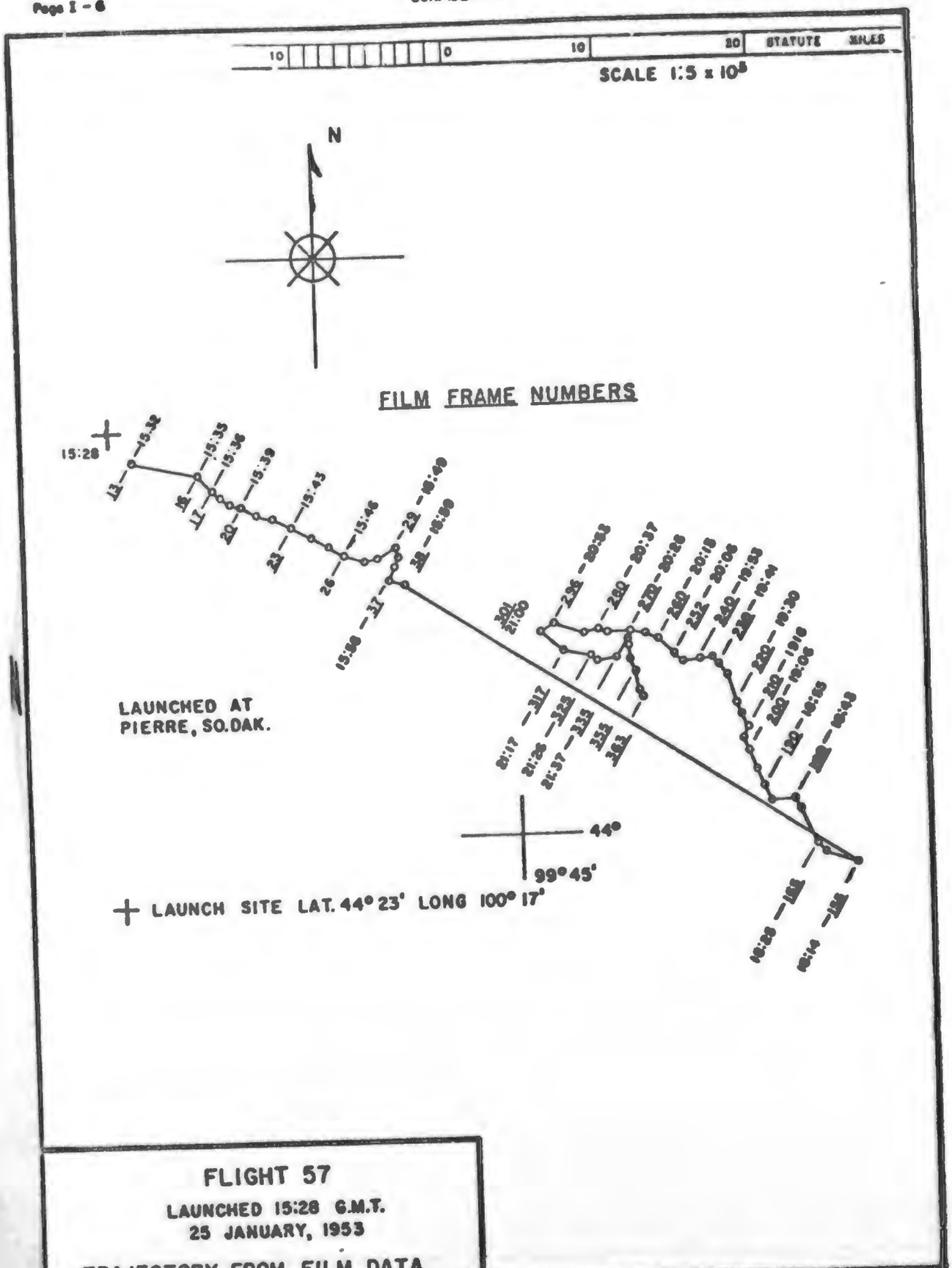
2


RASONDE DATA
FLIGHT #57
25 January, 1953
Meteorological stations reporting :
• • RAPID CITY, So.Dak. 662
+ + BISMARCK, No.Dak. 764
1500 Z
•• Telemetered thermistor data
PRESSURE IN MILLIBARS
10
50
70
100
200
400
600
800
1000
-70
-60
-50
-40
-30
-20
-10
0
10
TEMPERATURE (°C.)


THEORETICAL CEILING
85,200 FT.
PRESSURE IN MILLIBARS
10
20
40
60
80
100
200
400
600
800
1000
1520
1540
1600
1620
1640
1700
1720
1740
GREENWICH MEAN TIME
TIME - PRESSURE - ALTITUDE
FLIGHT No. 57
25 January, 1953
Launched at PIERRE, So. Dak.
Gross Load : 407 lbs.
Free Lift : 65 lbs.
Gross Lift : 472 lbs.
Altitude data from telemetered altitude cycle record


1800
1820
1840
1900
1920
1940
2000
2020

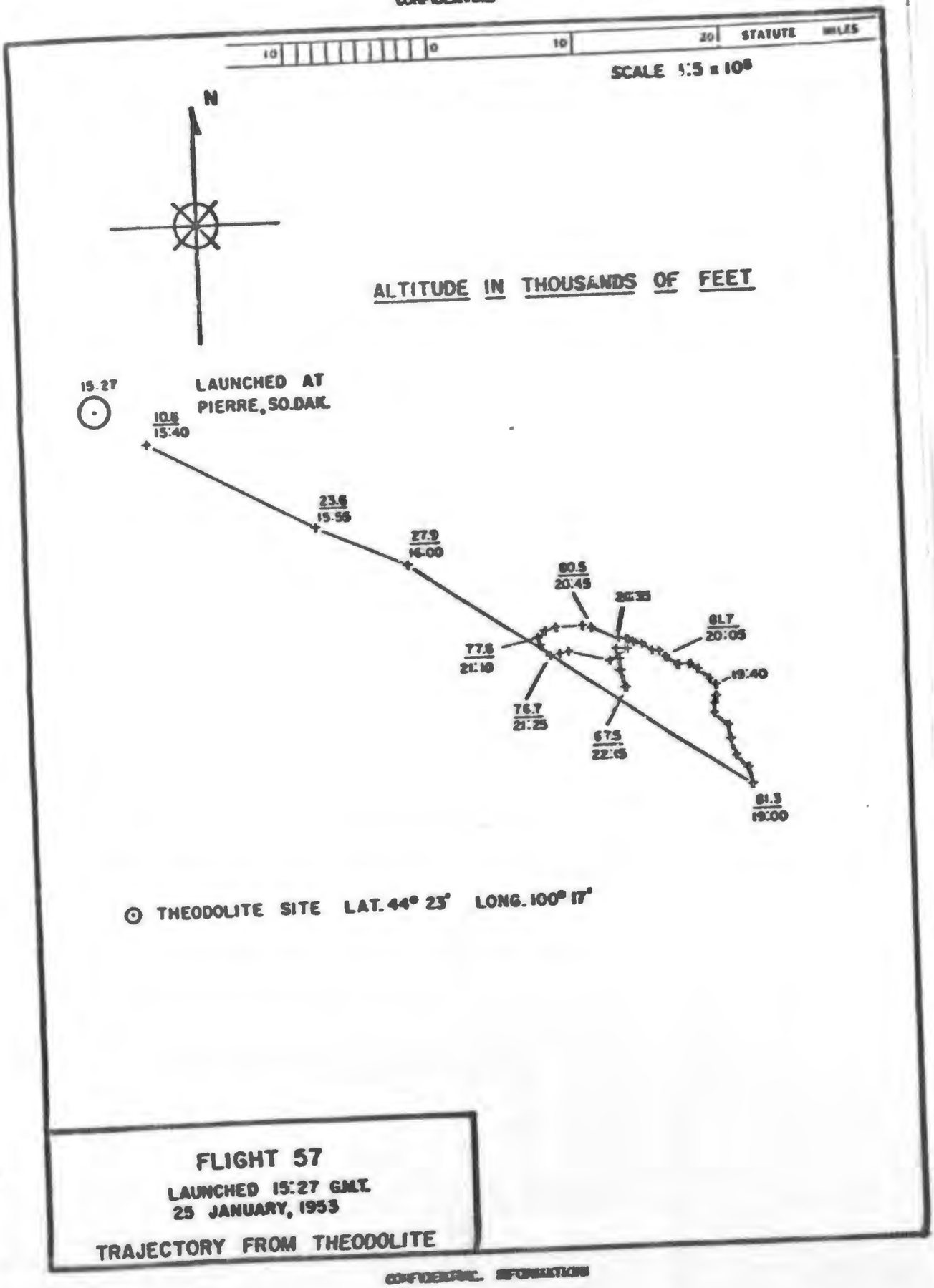

90 FT/MIN.
100 FT/MIN.
Released by timer
20
40
60
80
100
200
2040
2100
2120
2140
2200
2220
2240



FLIGHT 57

LAUNCHED 15:28 G.M.T.
25 JANUARY, 1953

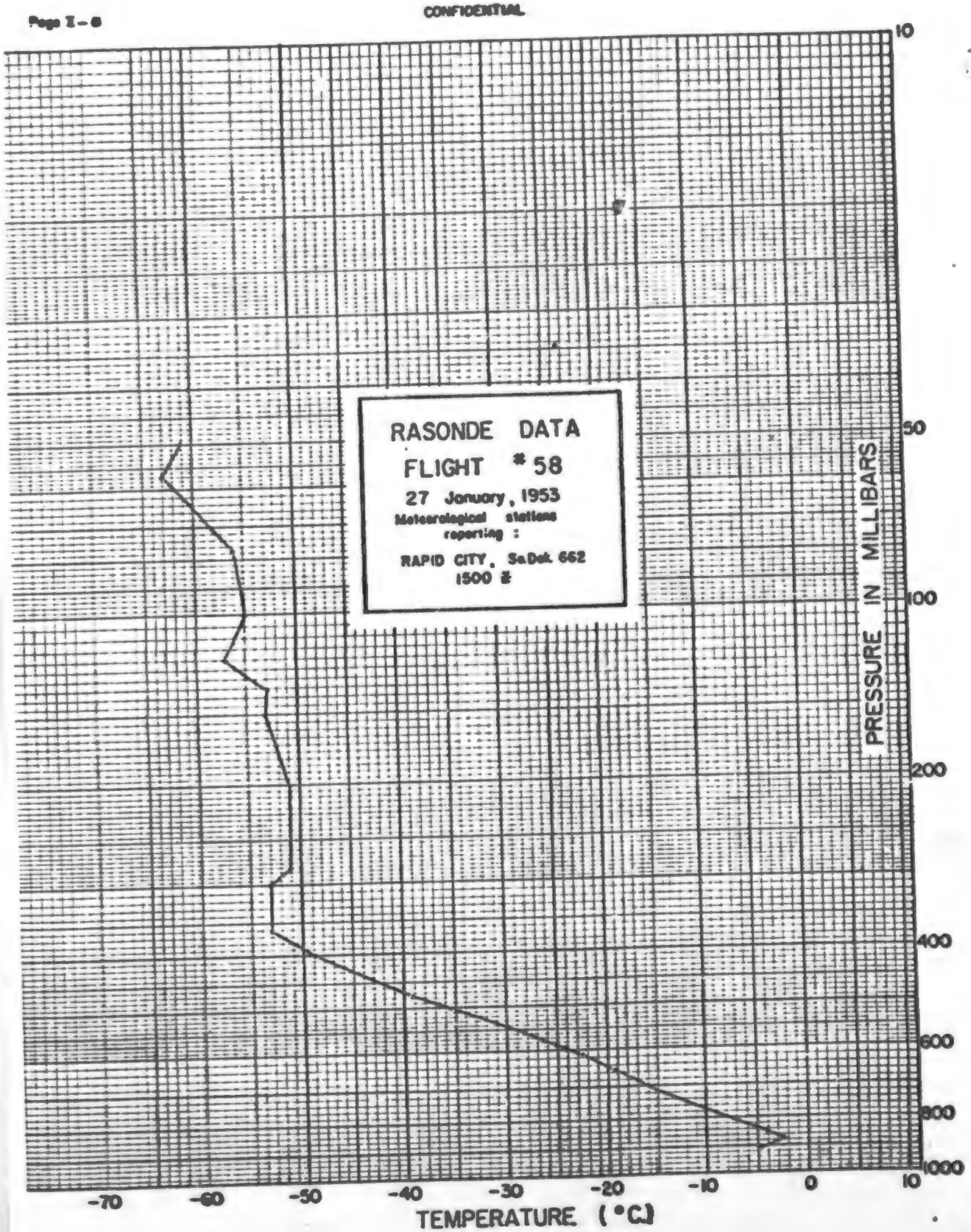
TRAJECTORY FROM FILM DATA

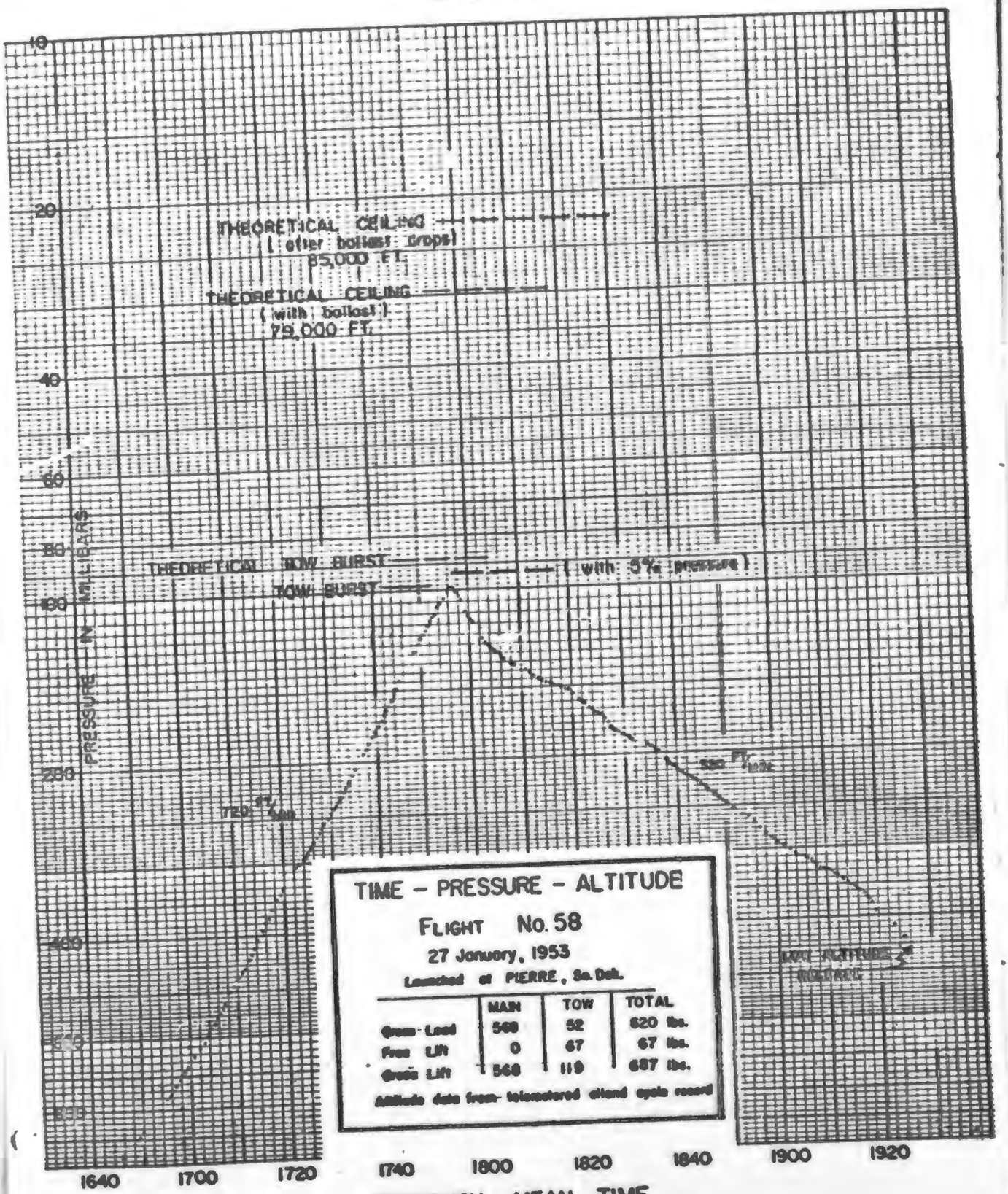


FLIGHT 57

LAUNCHED 15:27 G.M.T.
25 JANUARY, 1953

TRAJECTORY FROM THEODOLITE


RASONDE DATA
FLIGHT # 58
27 January, 1953
Meteorological stations reporting :
RAPID CITY, S.Dak. 662
1500 Z
PRESSURE IN MILLIBARS
10
50
100
200
400
600
800
1000
-70
-60
-50
-40
-30
-20
-10
0
10
TEMPERATURE (°C.)


THEORETICAL CEILING
(after ballast drops)
85,000 FT.
THEORETICAL CEILING
(with ballast)
79,000 FT.
THEORETICAL BOW BURST
(with 5% pressure)
TOW BURST
PRESSURE IN MILLIBARS
10
20
40
60
80
100
200
400
1640
1700
1720
1740
1800
1820
1840
1900
1920
GREENWICH MEAN TIME
TIME – PRESSURE – ALTITUDE
FLIGHT No. 58
27 January, 1953
Launched at PIERRE, So. Dak.
MAIN
TOW
TOTAL
Gross Load 568 52 620 lbs.
Free Lift 0 67 67 lbs.
Gross Lift 568 119 687 lbs.
Altitude data from telemetered aland cycle record

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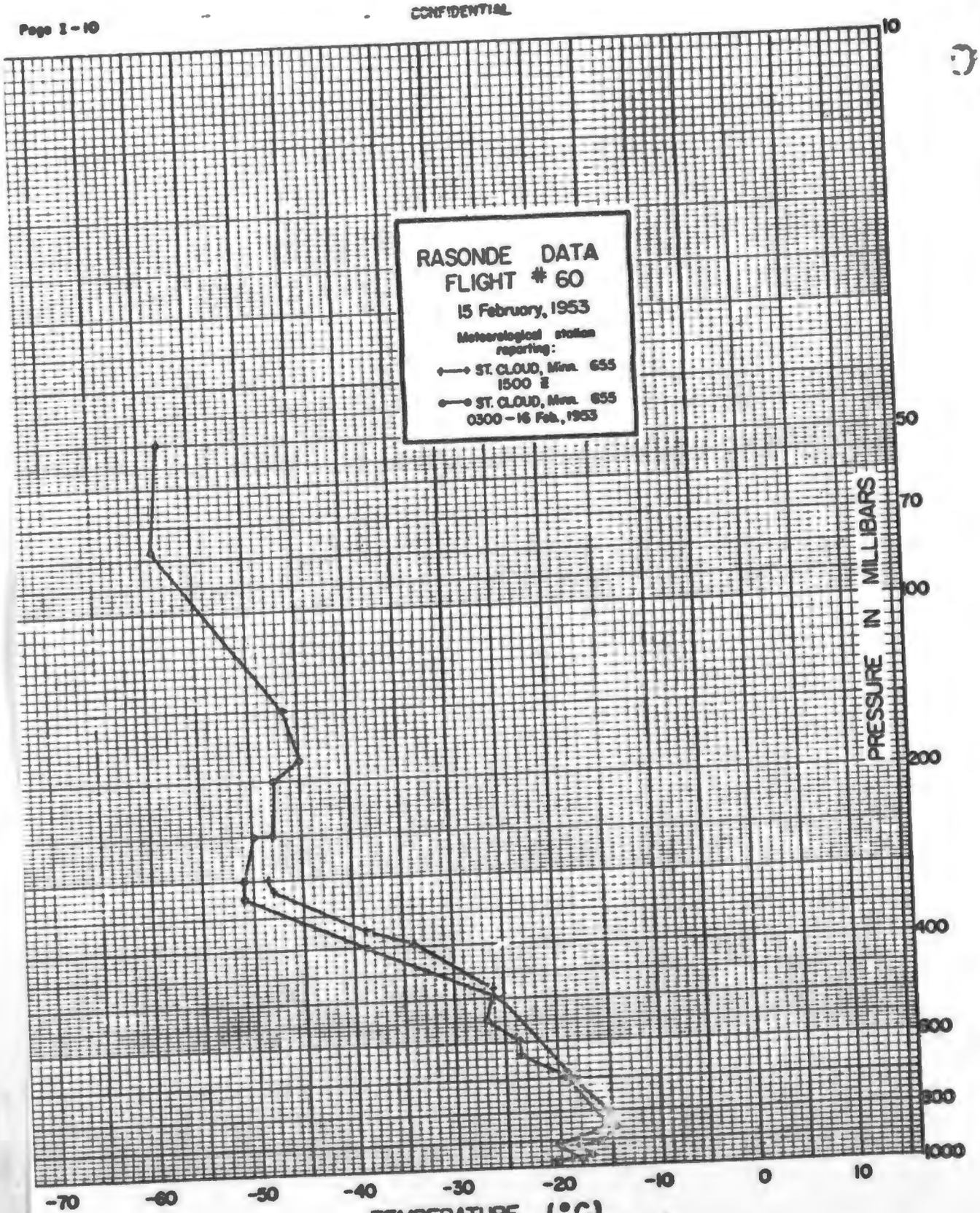
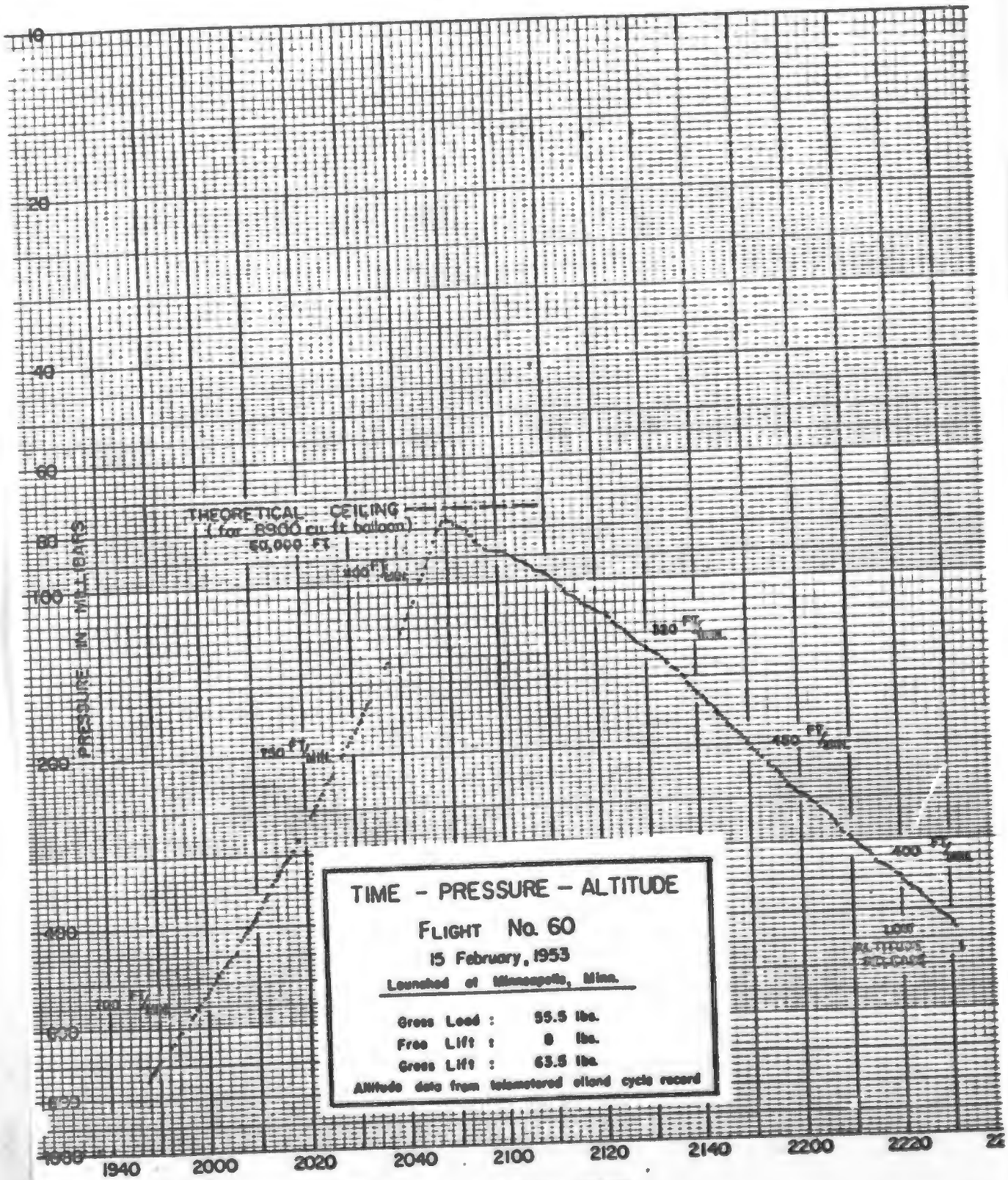
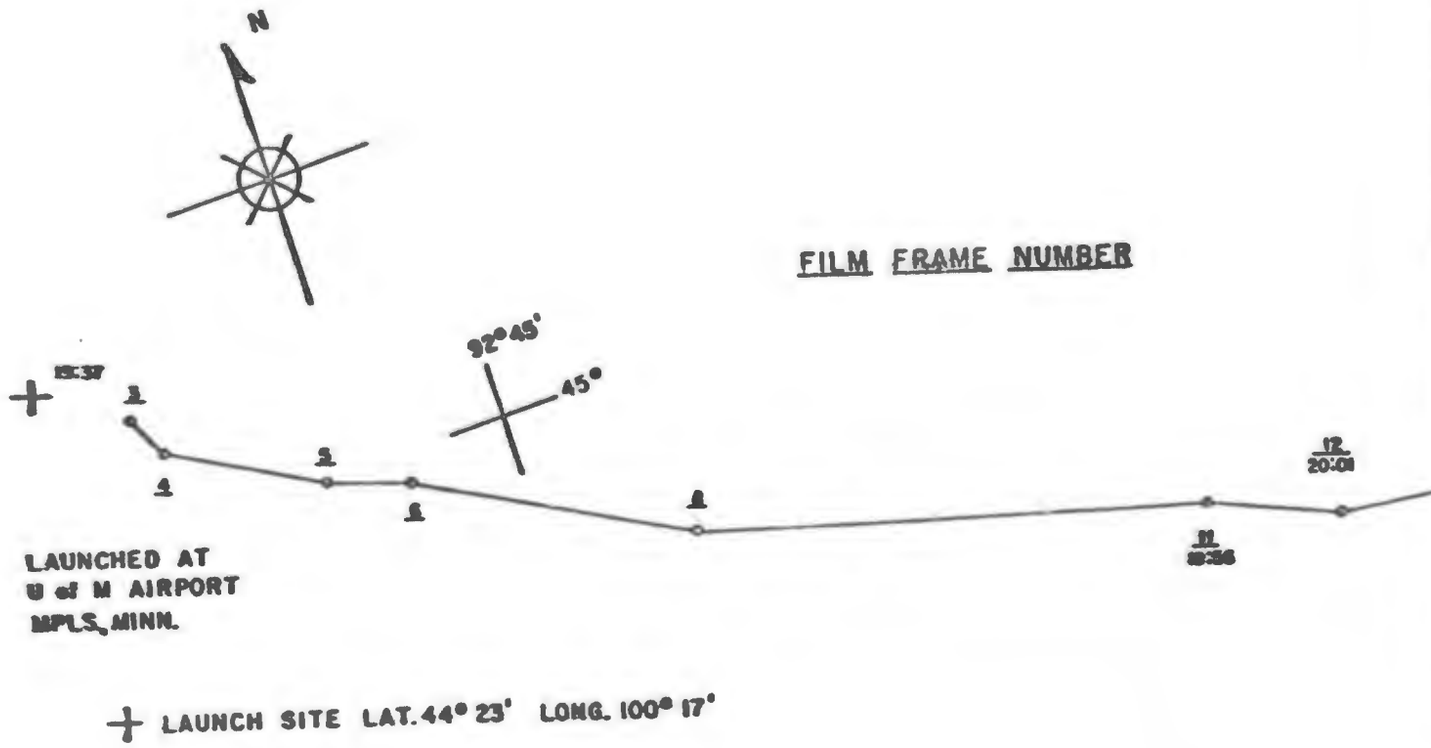


CONFIDENTIAL INFORMATION


TIME - PRESSURE - ALTITUDE
FLIGHT No. 60
15 February, 1953
Launched at Minneapolis, Minn.
Gross Load : 55.5 lbs.
Free Lift : 8 lbs.
Gross Lift : 63.5 lbs.
Altitude data from telemetered aland cycle record
THEORETICAL CEILING
(for 8900 cu. ft. balloon)
60,000 FT.
440 FT/MIN.
350 FT/MIN.
450 FT/MIN.
400 FT/MIN.
750 FT/MIN.
400 FT/MIN.
LOW ALTITUDE SIDE-CASE
PRESSURE IN MILLIBARS
10
20
40
60
80
100
200
400
600
800
1000
1940
2000
2020
2040
2100
2120
2140
2200
2220
GREENWICH MEAN TIME

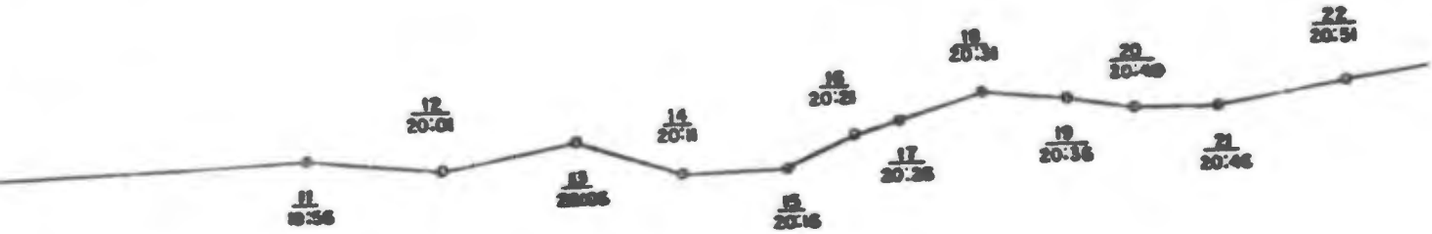


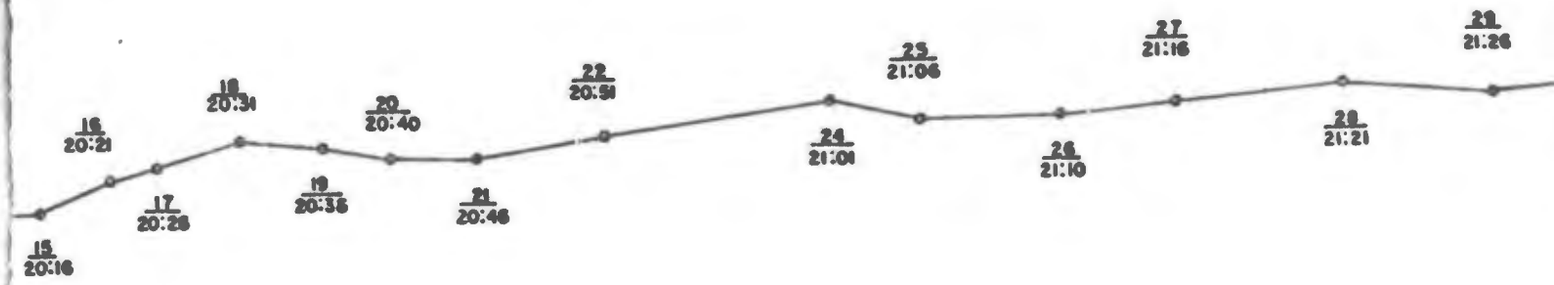
FLIGHT 60

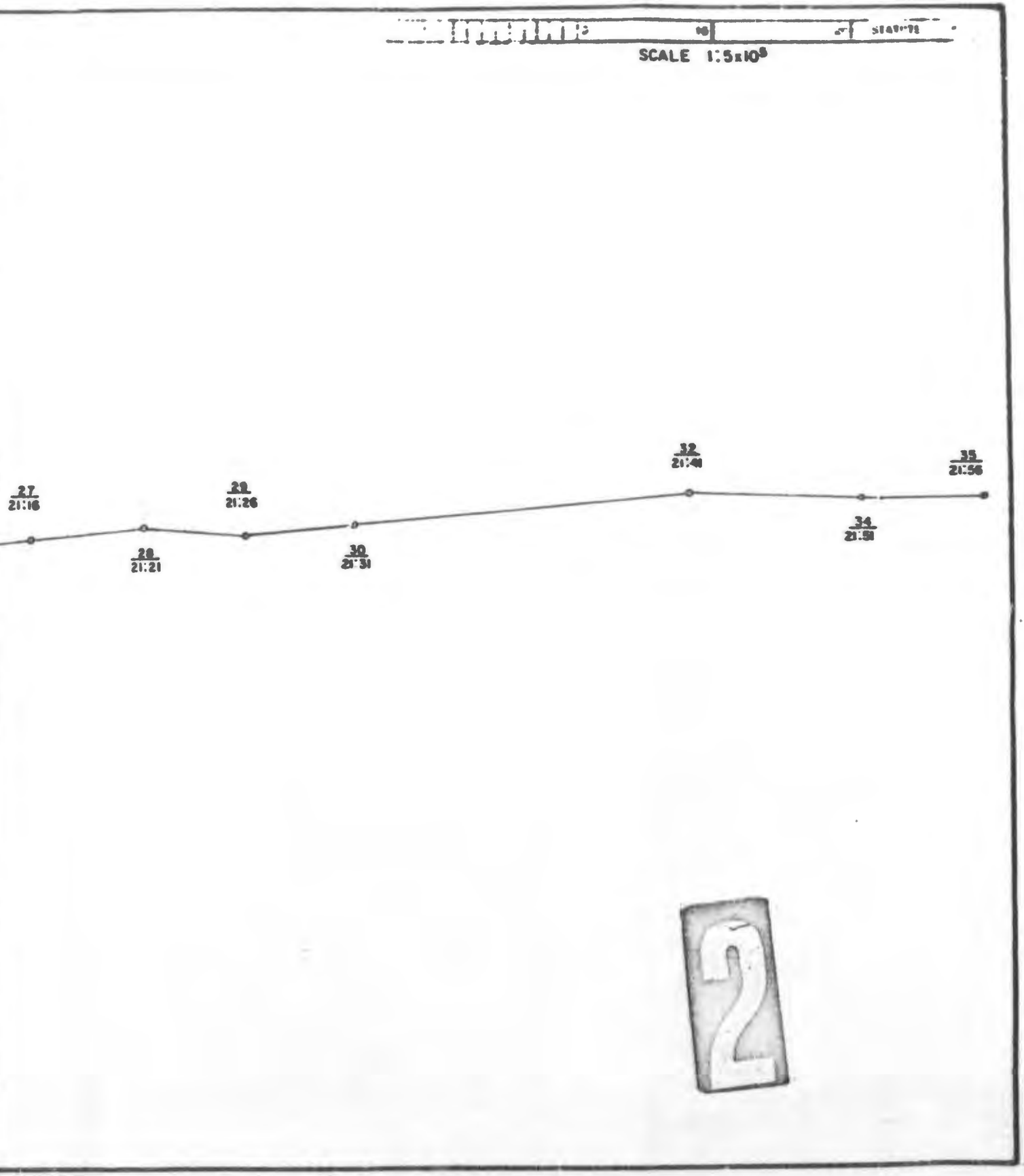
LAUNCHED 19:37 GMT
15 FEBRUARY, 1953

TRAJECTORY FROM FILM DATA

FRAME NUMBER




15
20:16
16
20:21
17
20:28
18
20:34
19
20:38
20
20:40
21
20:46
22
20:51
24
21:01
25
21:06
26
21:10
27
21:16
28
21:21
29
21:26


SCALE 1:5x10^5
27
21:16
28
21:21
29
21:26
30
21:31
32
21:46
34
21:51
35
21:56

2

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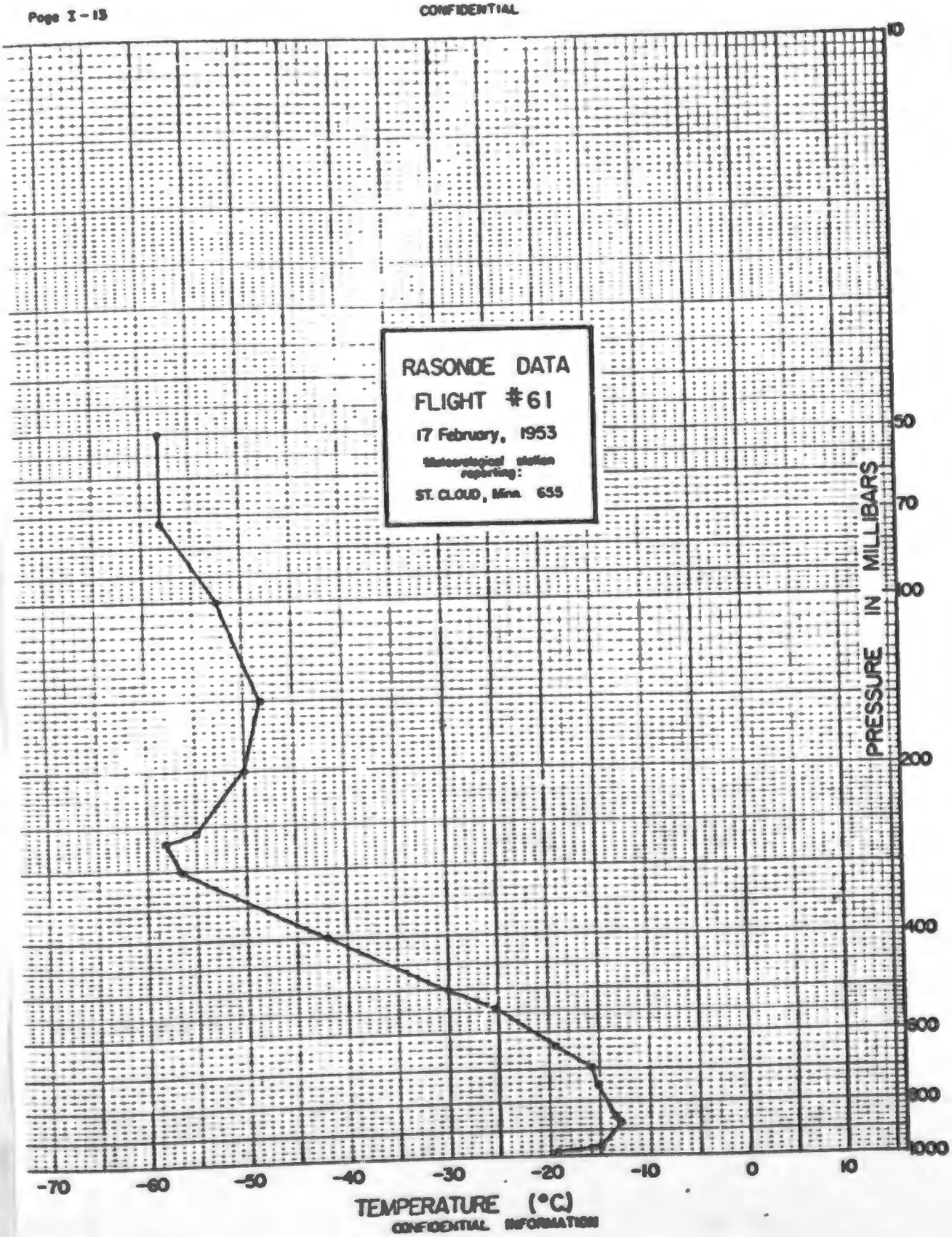

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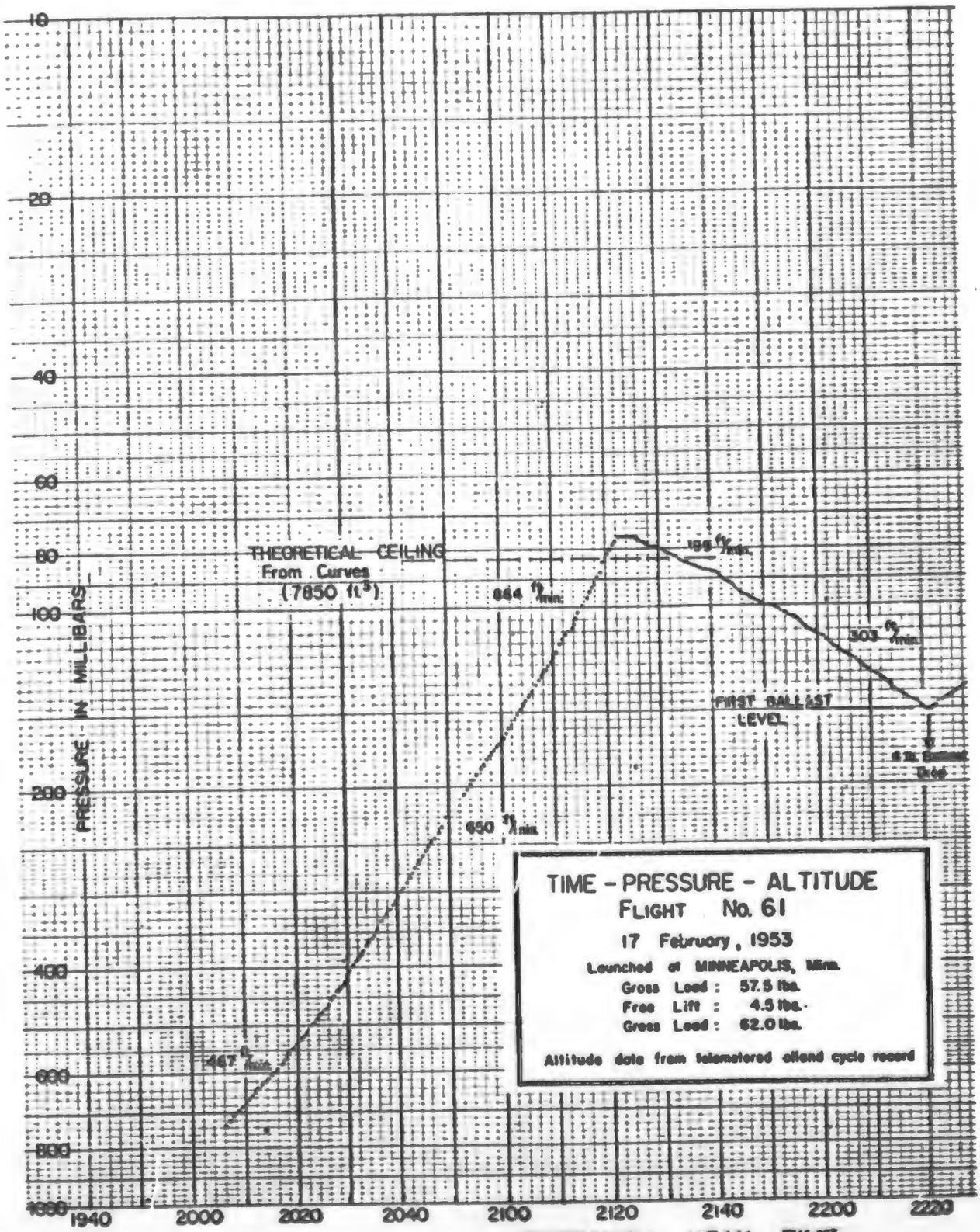
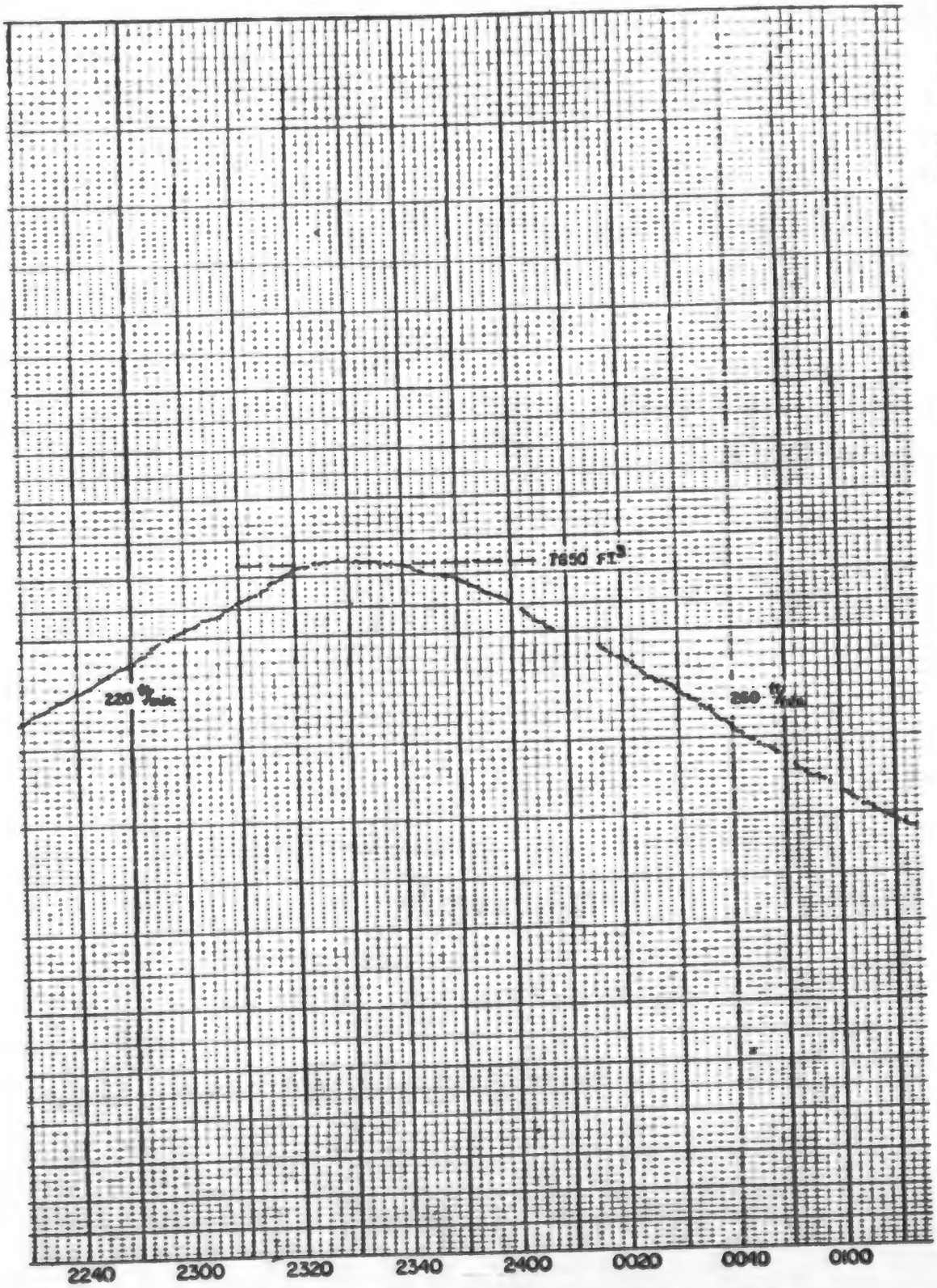
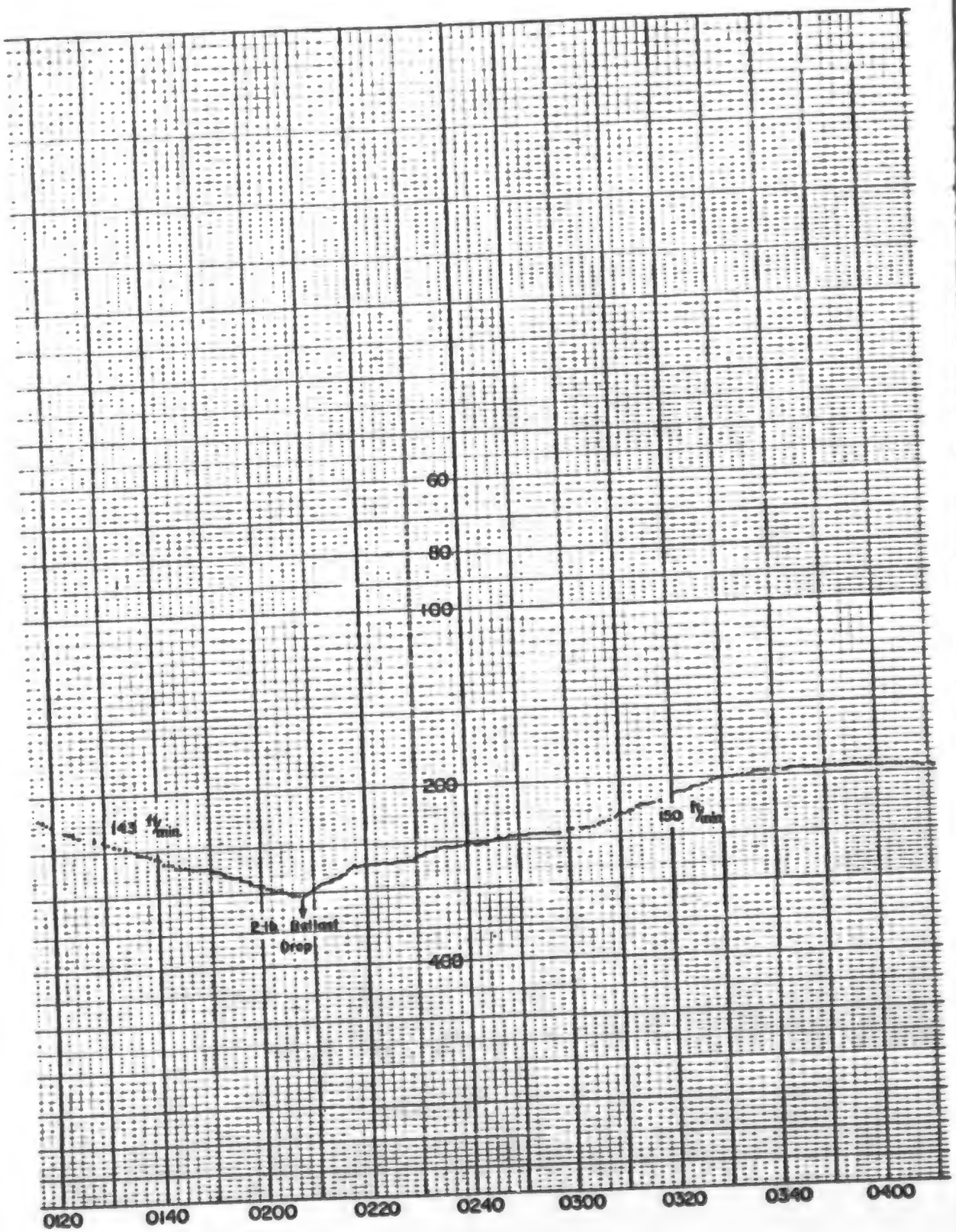
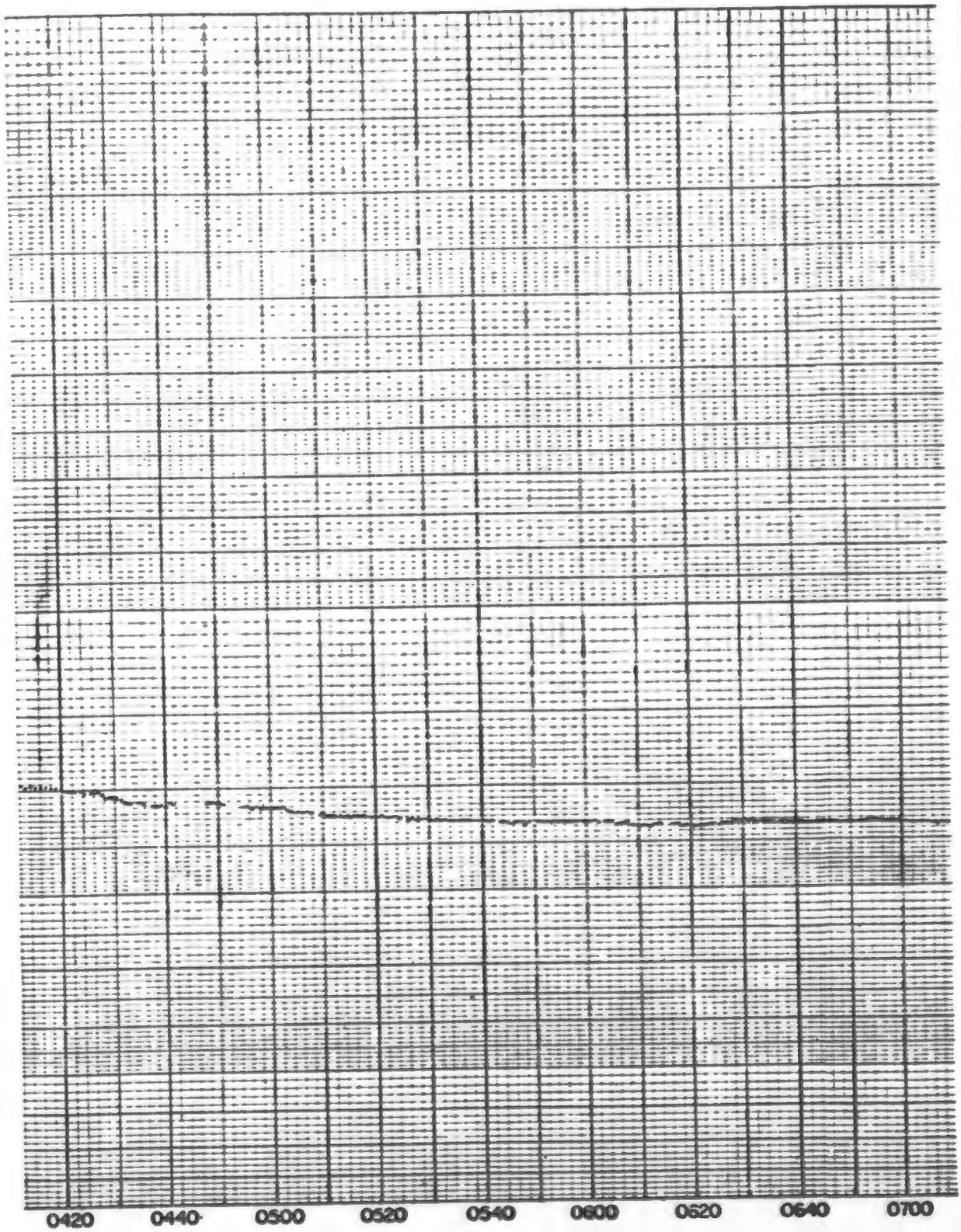
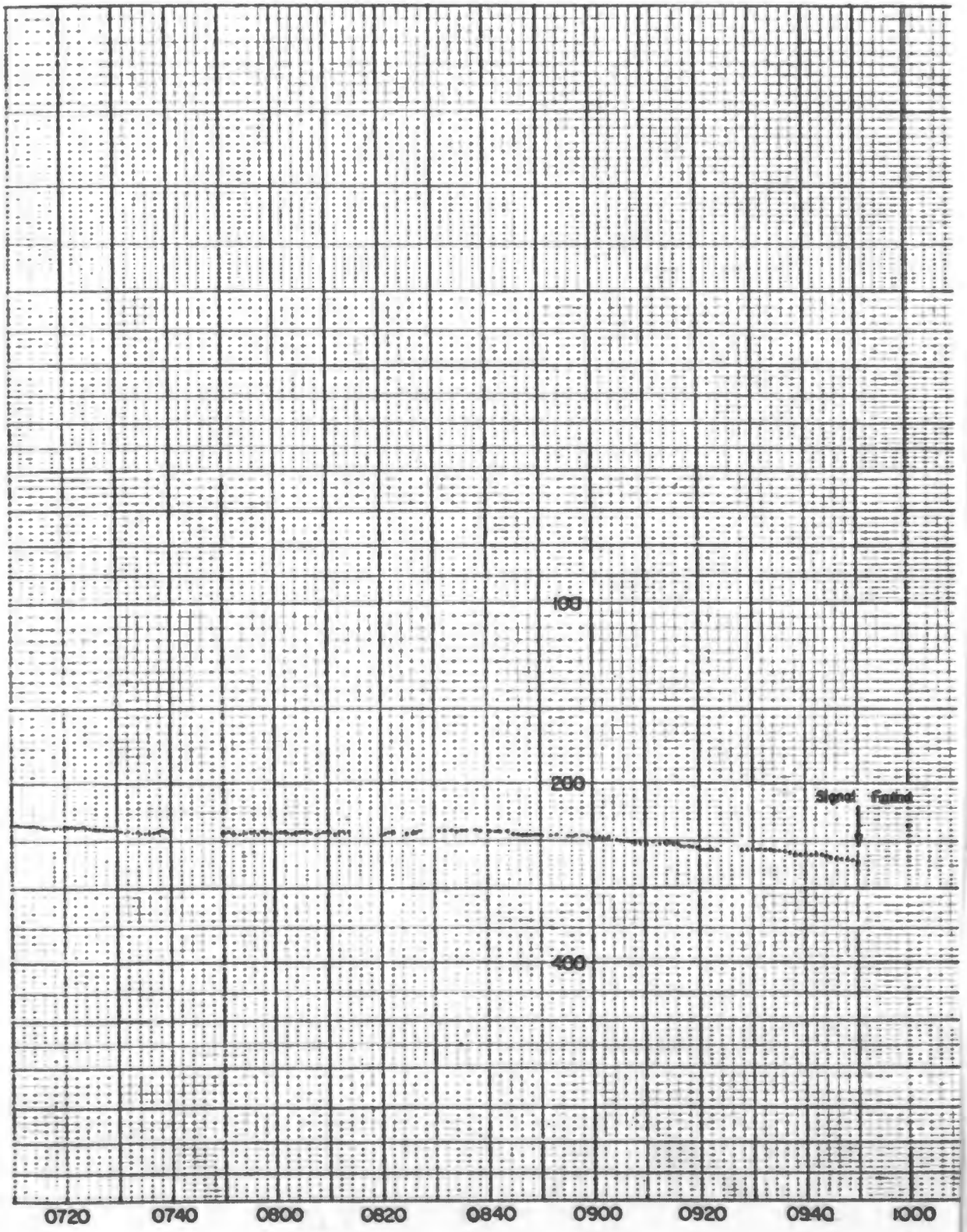
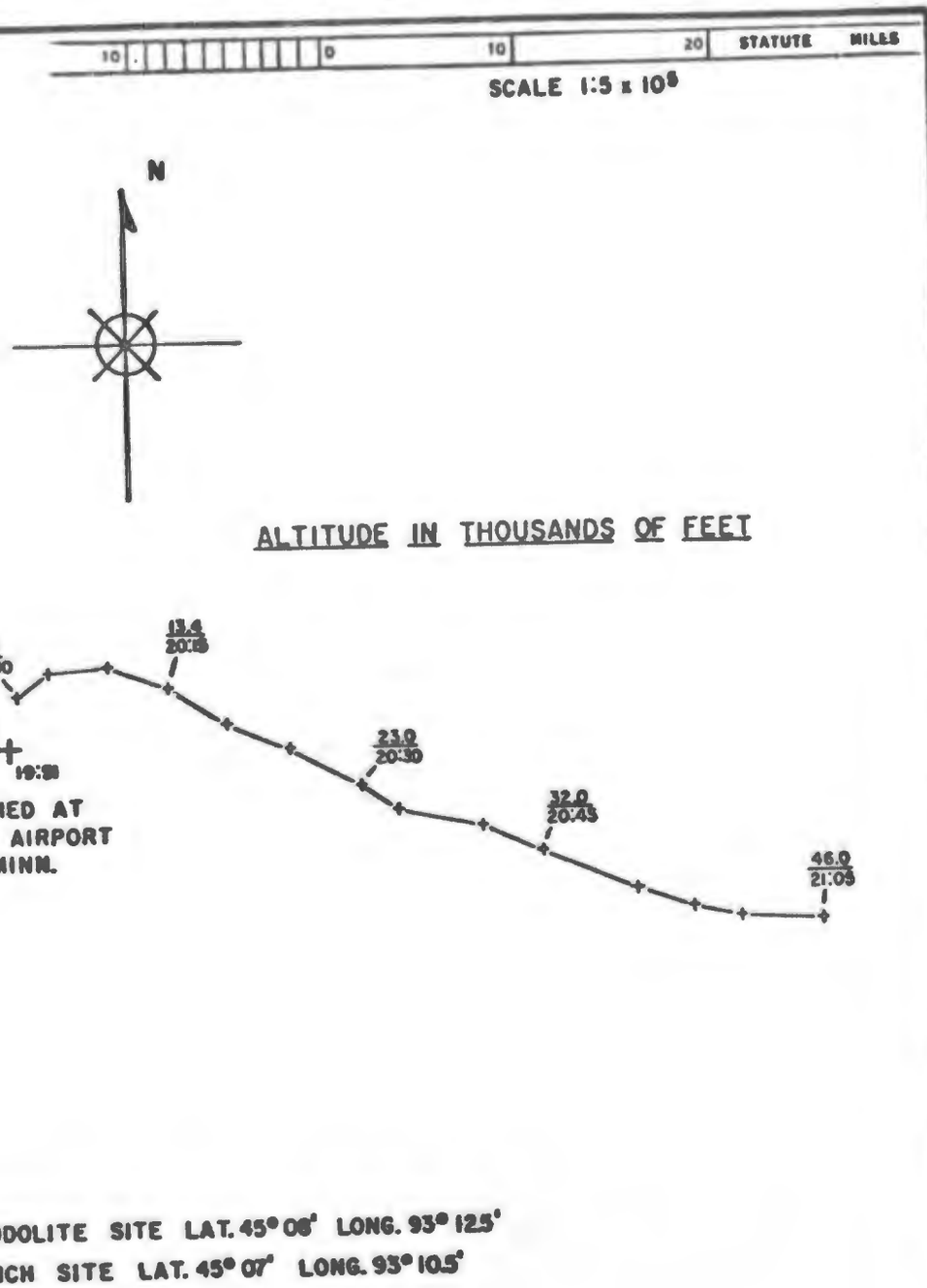

TIME - PRESSURE - ALTITUDE
FLIGHT No. 61
17 February, 1953
Launched at MINNEAPOLIS, Minn.
Gross Load : 57.5 lbs.
Free Lift : 4.5 lbs.
Gross Load : 62.0 lbs.
Altitude data from telemetered attend cycle record
THEORETICAL CEILING
From Curves
(7850 ft³)
664 ft/min.
650 ft/min.
467 ft/min.
195 ft/min.
303 ft/min.
FIRST BALLAST
LEVEL
PRESSURE IN MILLIBARS
10
20
40
60
80
100
200
400
600
800
1000
1940
2000
2020
2040
2100
2120
2140
2200
2220
GREENWICH MEAN TIME


7850 FT³
220 ft/min
260 ft/min
2240
2300
2320
2340
2400
0020
0040
0100


60
80
100
200
400
143 ft/min
150 ft/min
2 lb. Ballast Drop
0120
0140
0200
0220
0240
0300
0320
0340
0400


0420
0440
0500
0520
0540
0600
0620
0640
0700


100
200
Signal Faded
400
0720
0740
0800
0820
0840
0900
0920
0940
1000



⊙ THEODOLITE SITE LAT. 45° 08' LONG. 93° 12.5'

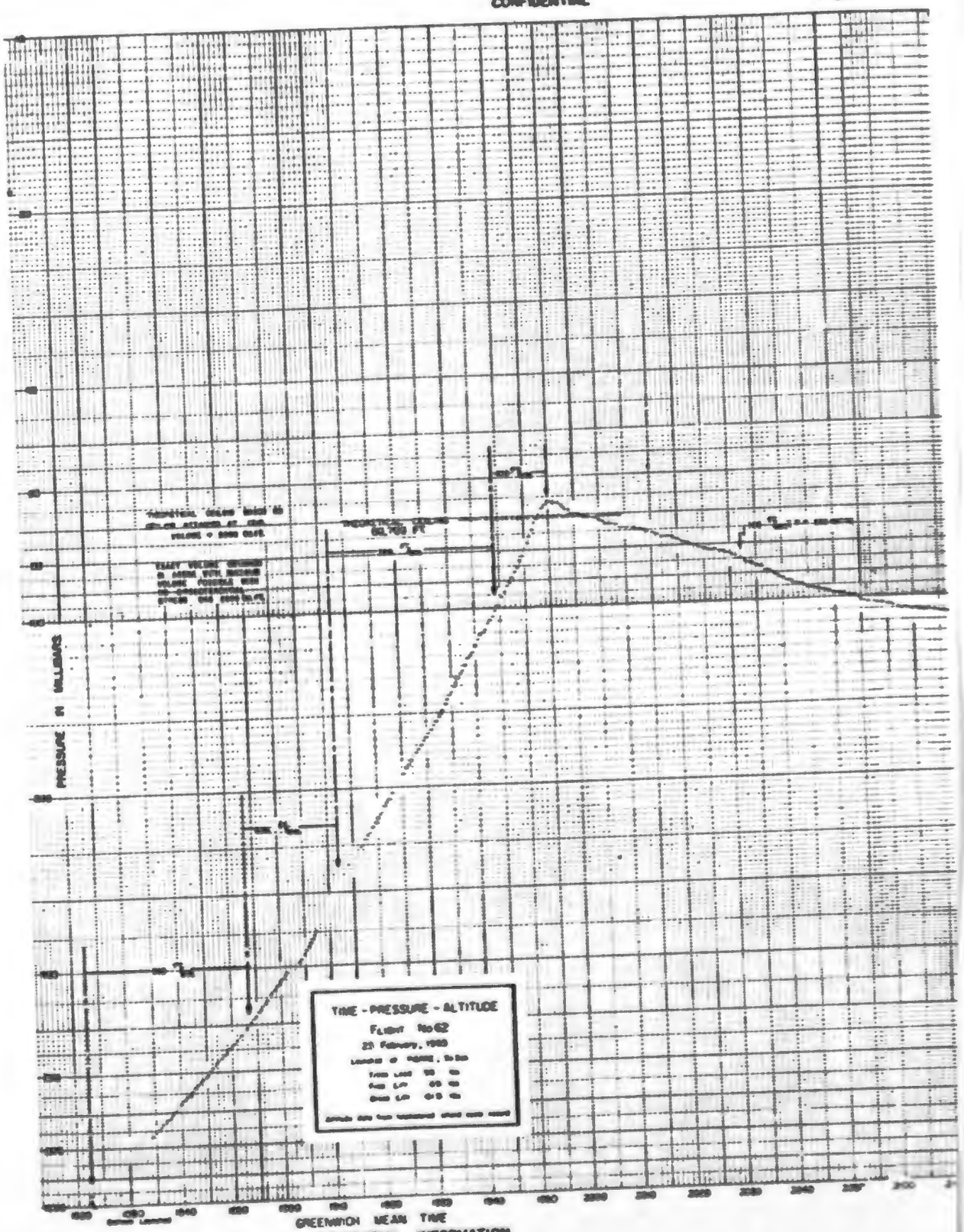
+ LAUNCH SITE LAT. 45° 07' LONG. 93° 10.5'

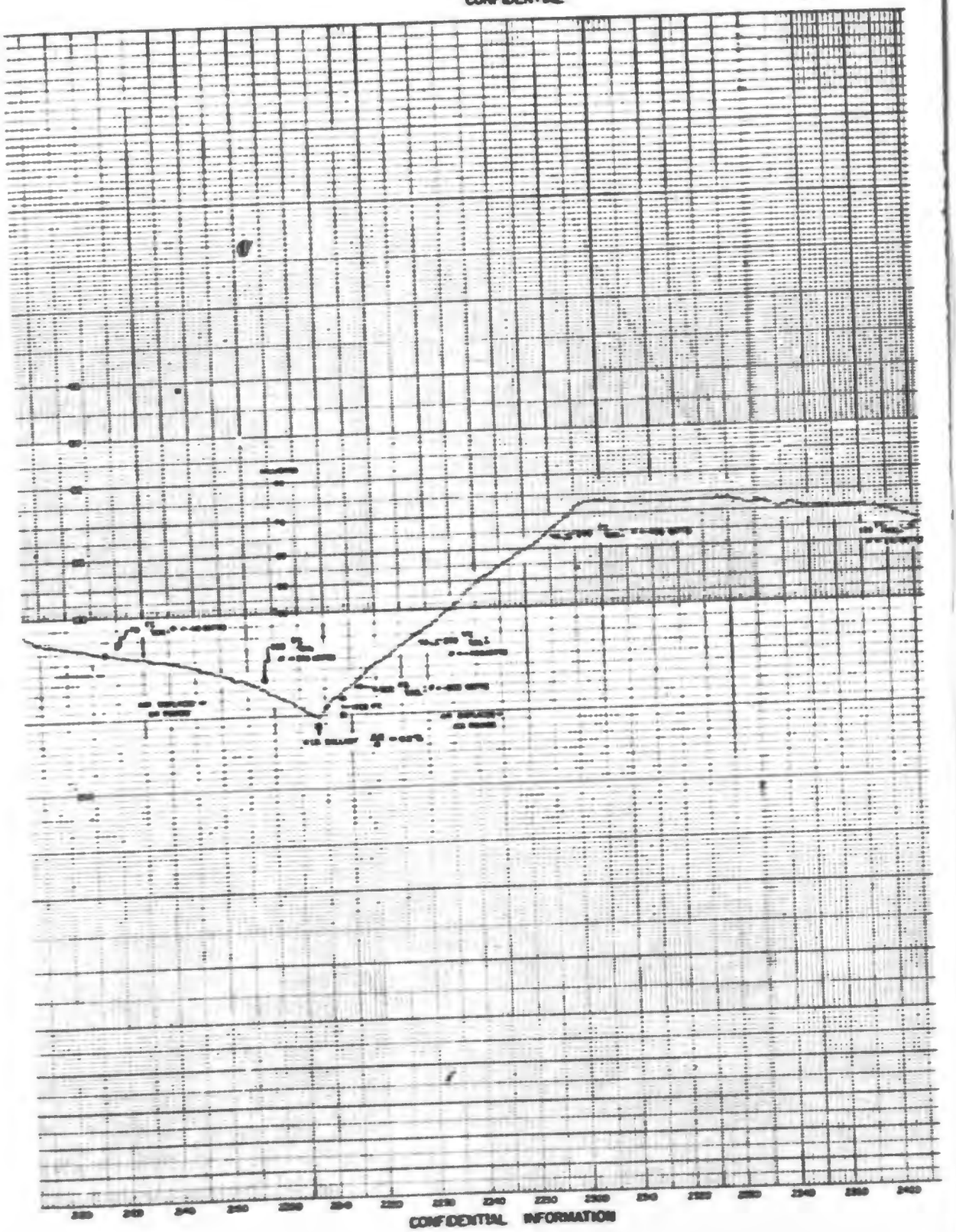
FLIGHT 61

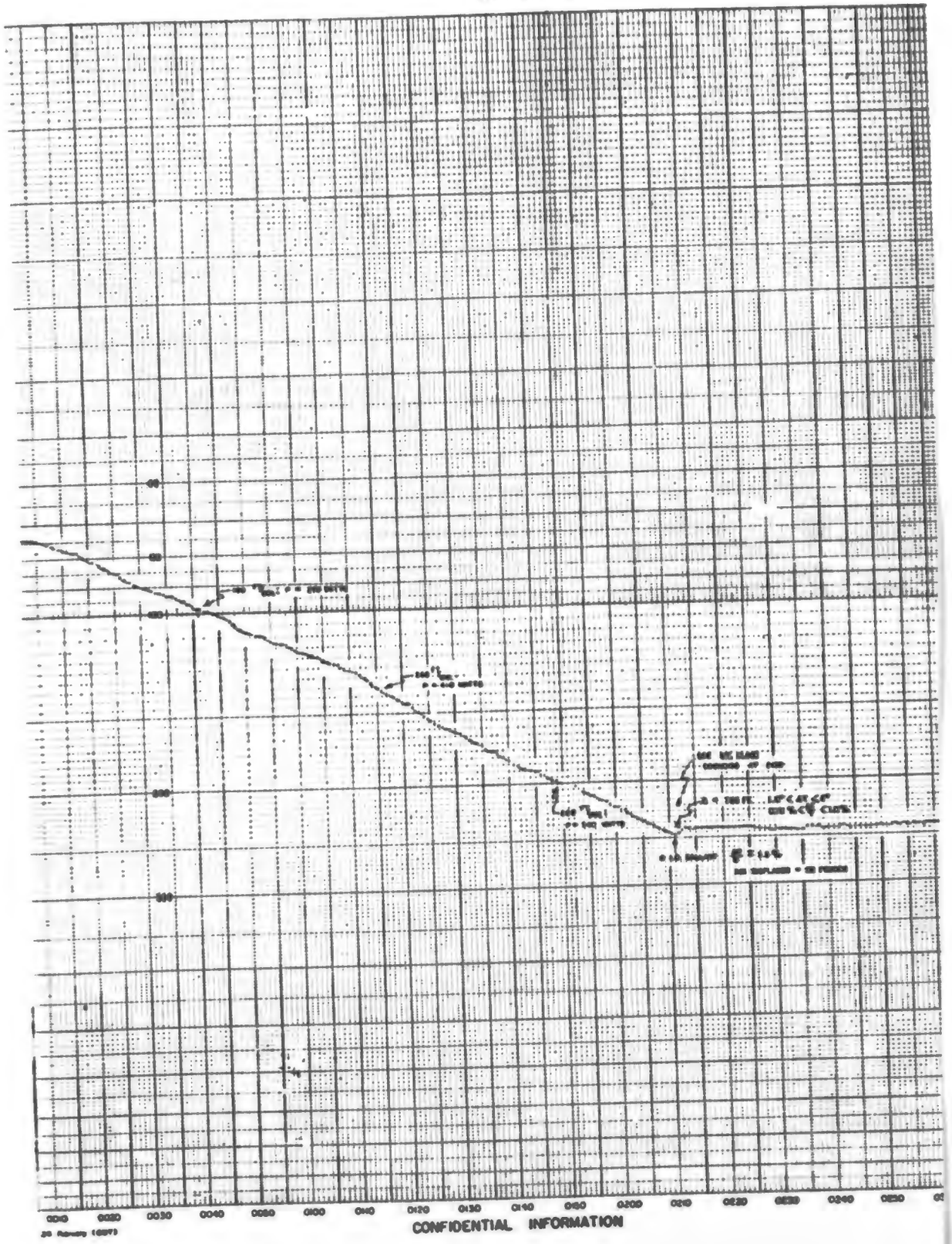
LAUNCHED 19:51 GMT

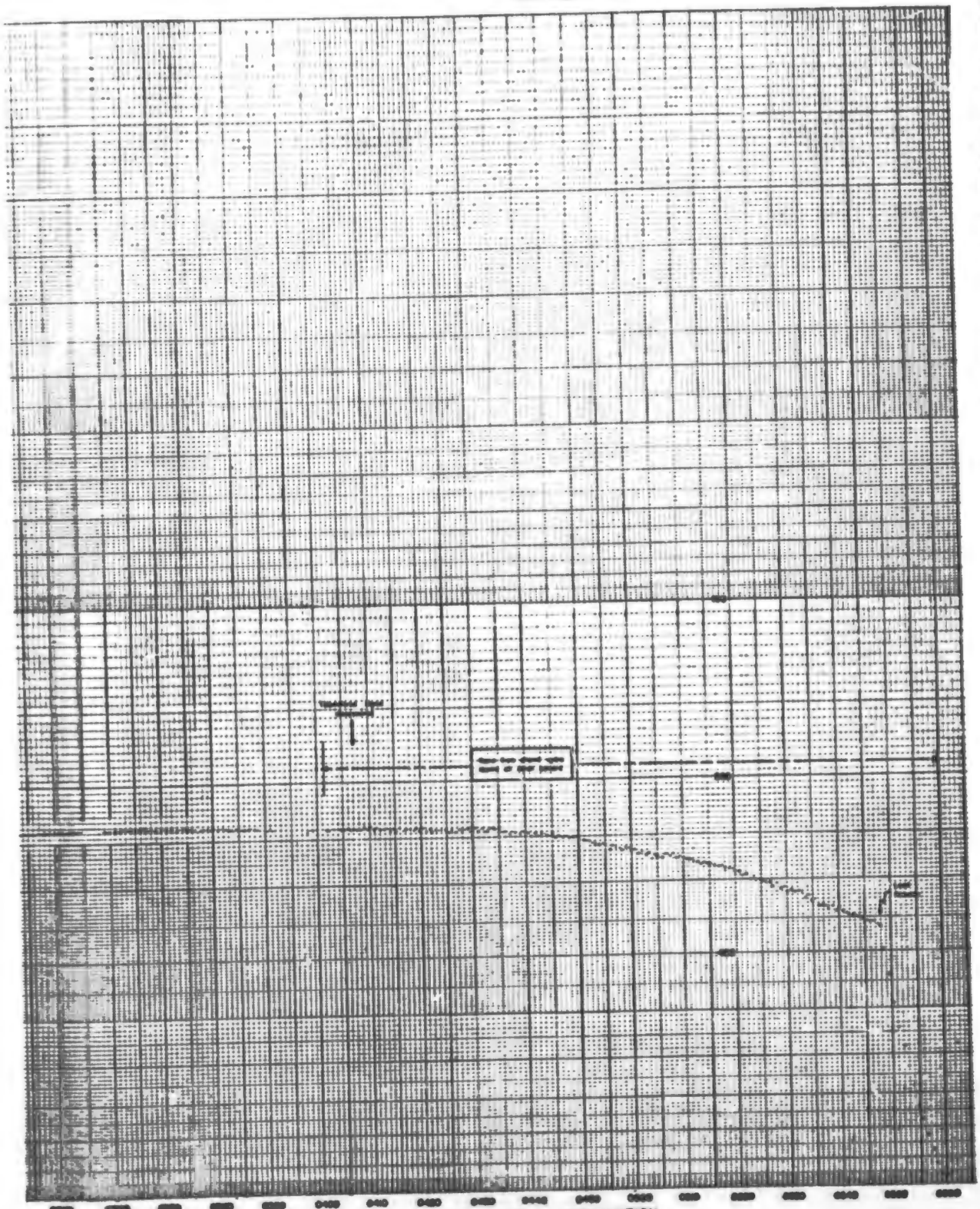
17 FEBRUARY, 1953

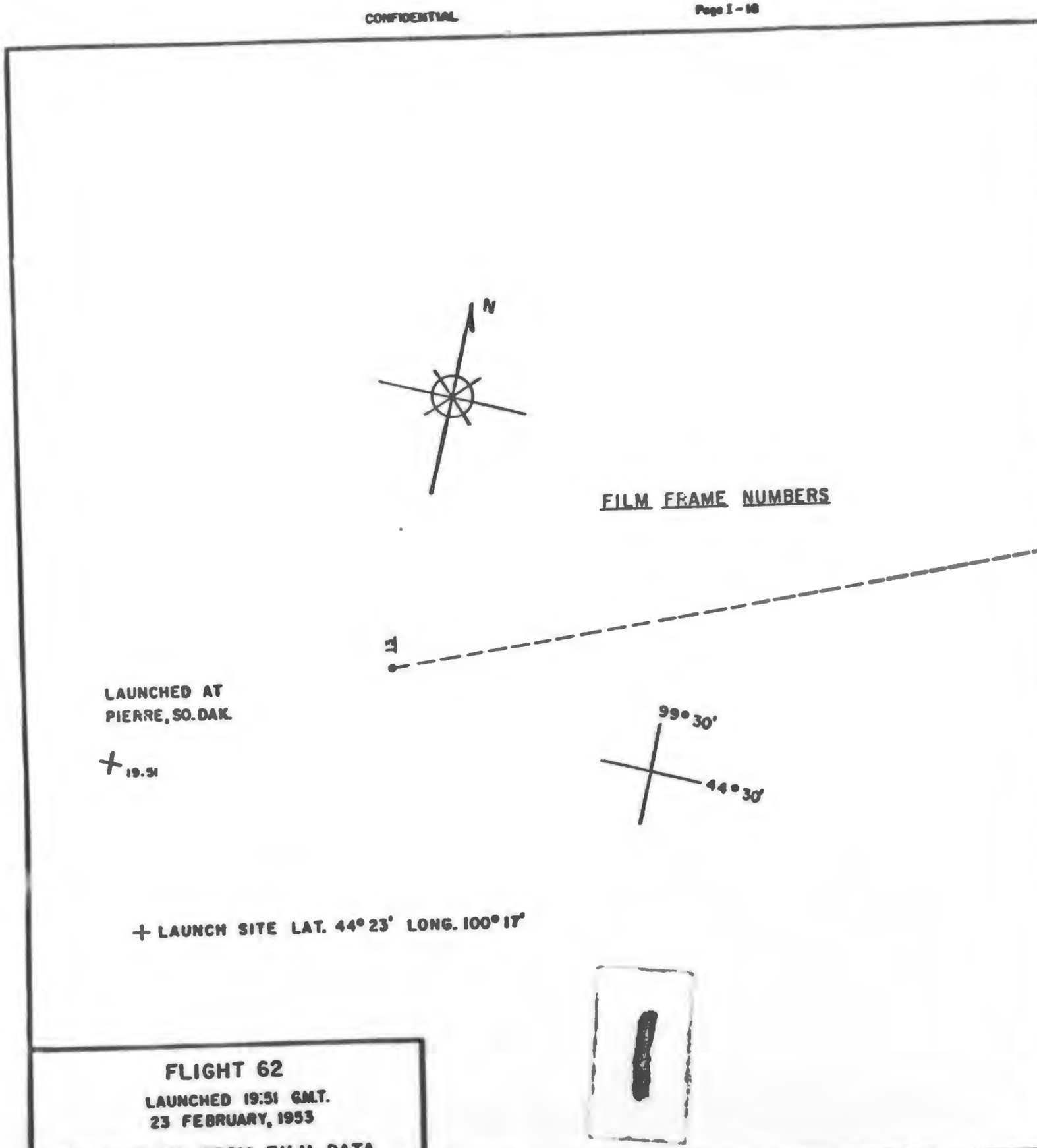
TRAJECTORY FROM THEODOLITE

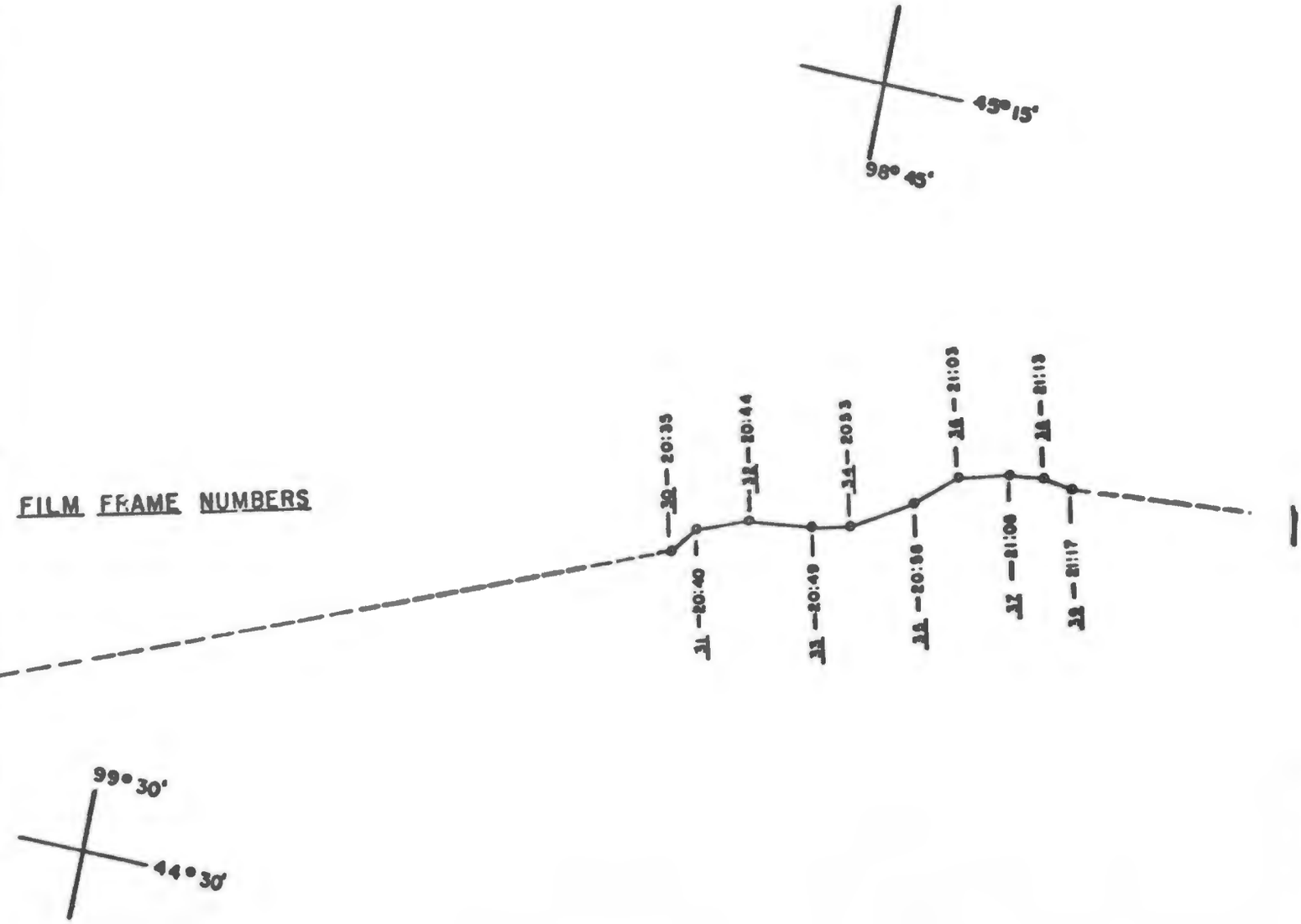

PRESSURE IN MILLIBARS
TIME - PRESSURE - ALTITUDE
Flight No 62
GREENWICH MEAN TIME







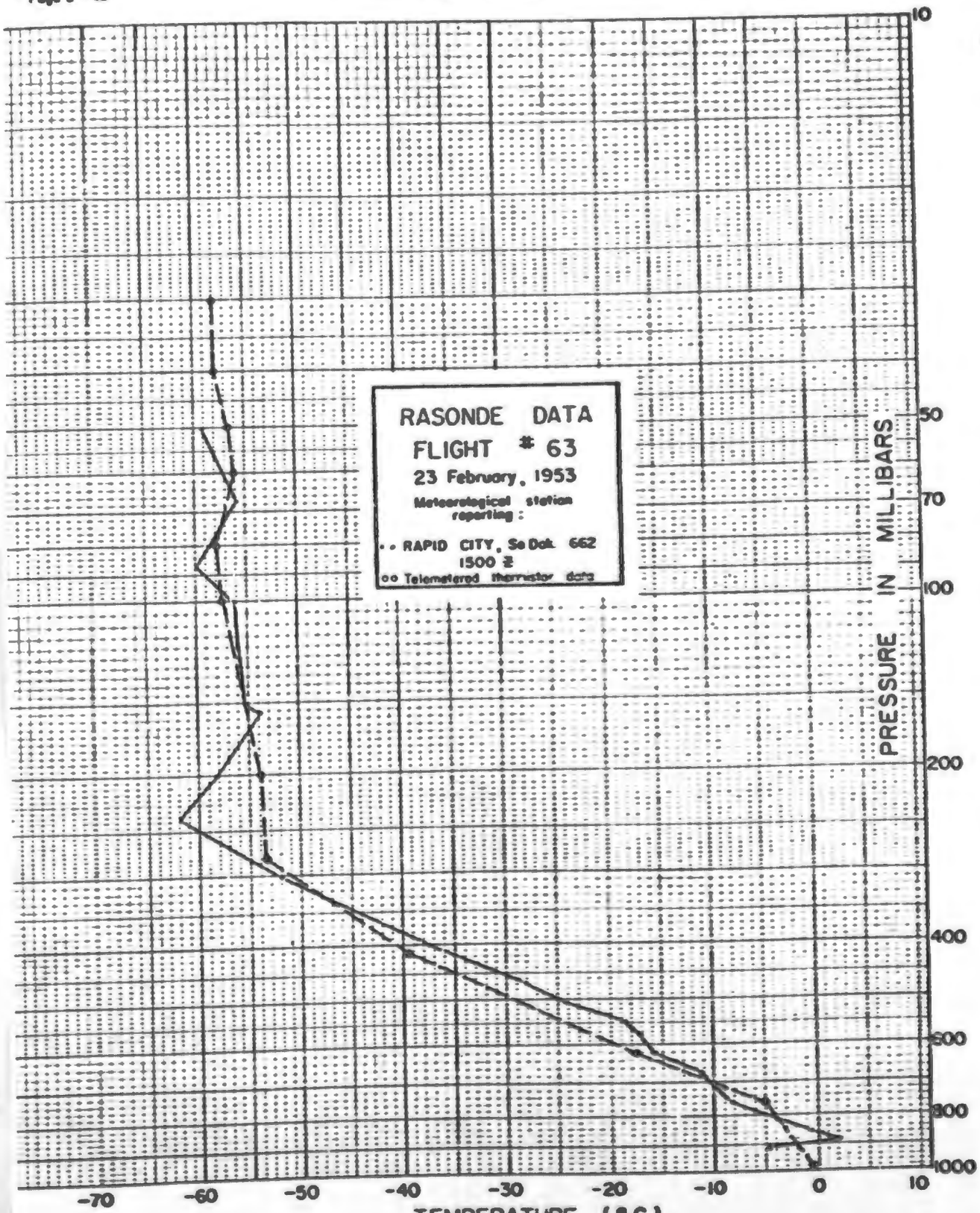

N
FILM FRAME NUMBERS
LAUNCHED AT
PIERRE, SO. DAK.
19.51
99° 30'
44° 30'
+ LAUNCH SITE LAT. 44° 23' LONG. 100° 17'
FLIGHT 62
LAUNCHED 19:51 G.M.T.
23 FEBRUARY, 1953
TRAJECTORY FROM FILM DATA

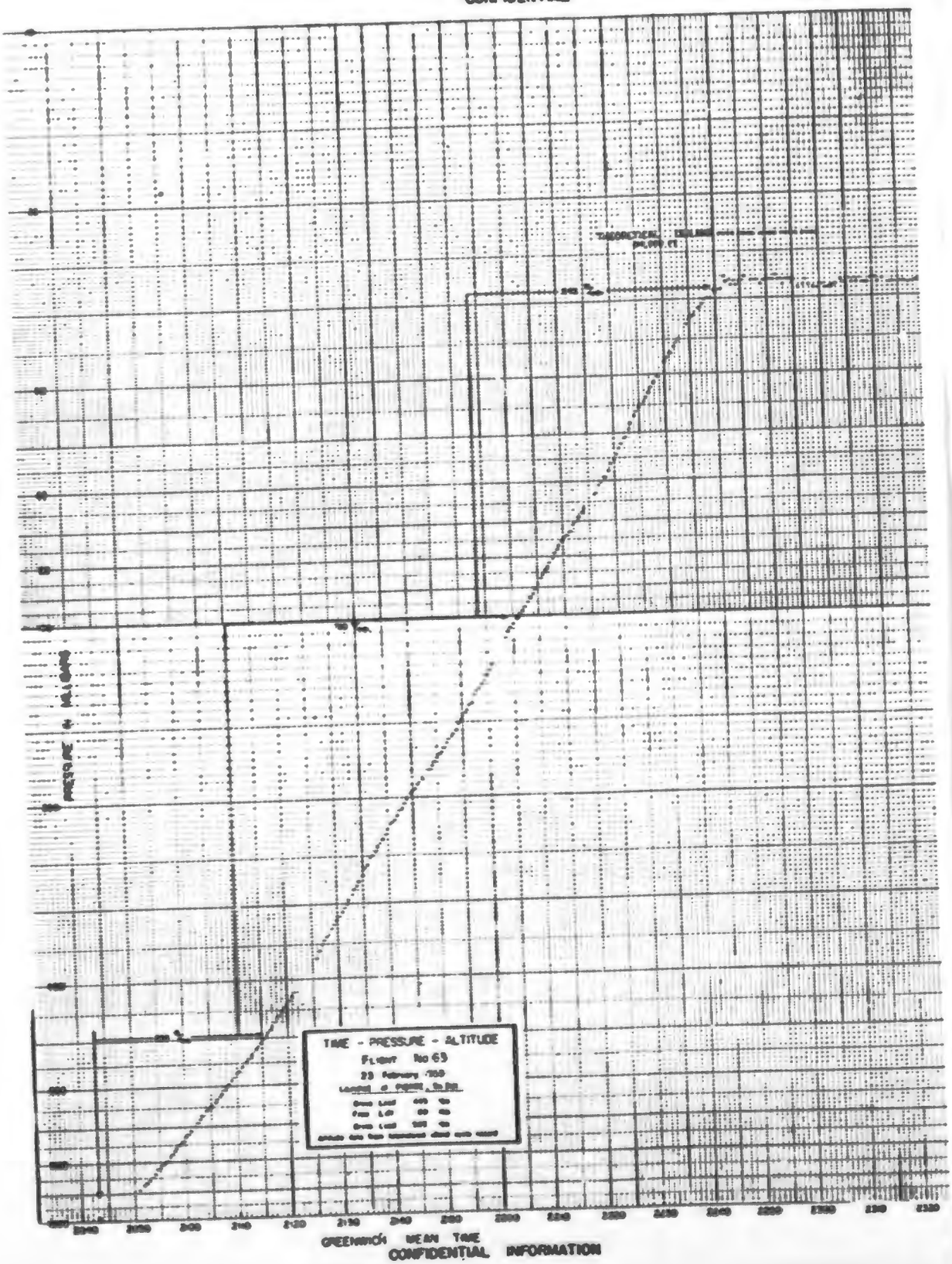

45° 15'
98° 45'
FILM FRAME NUMBERS
TF — 20:40 — 20:35
TF — 20:49 — 20:44
TF — 20:58 — 20:53
TF — 21:08 — 21:03
TF — 21:17 — 21:13
99° 30'
44° 30'

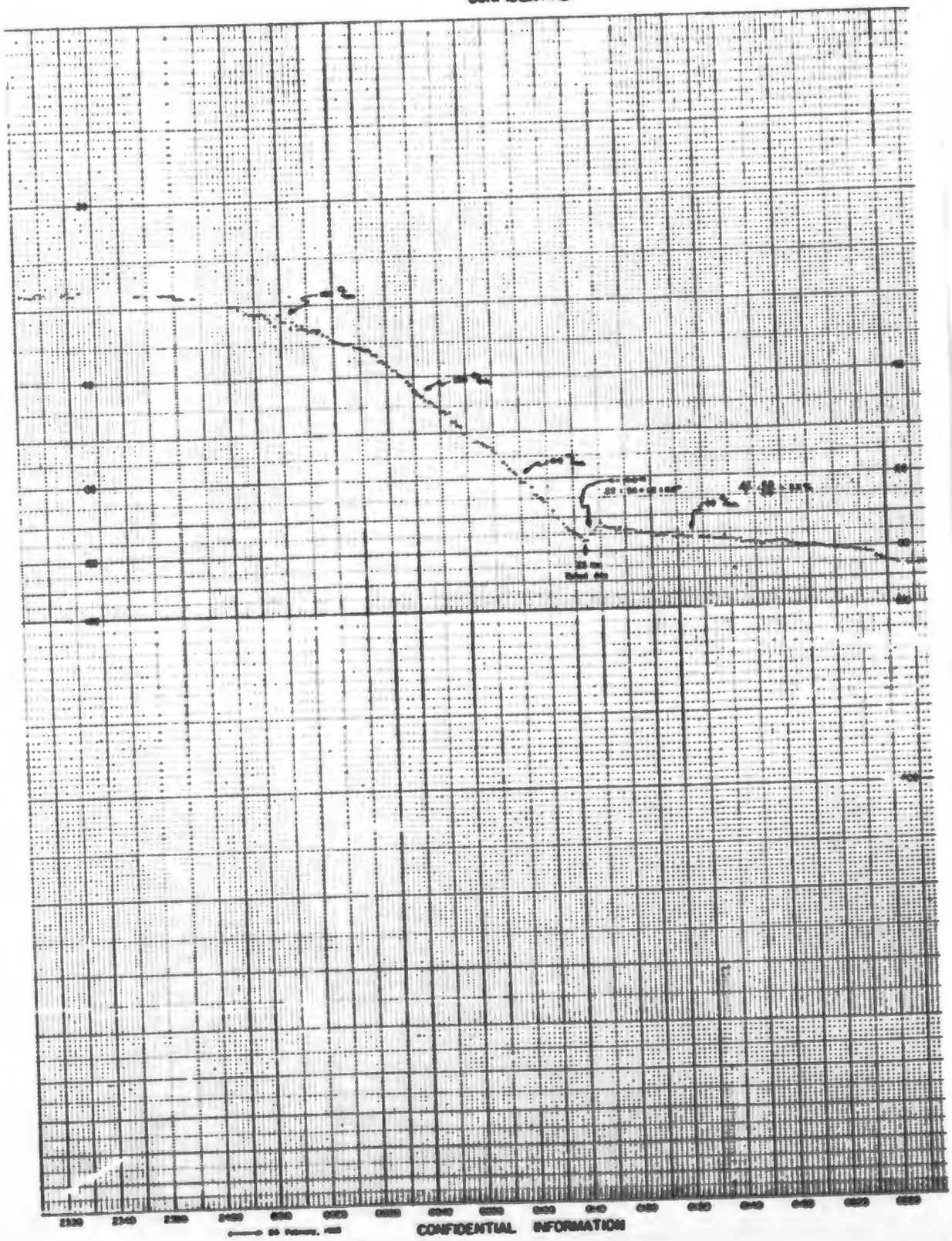
49° 15'
98° 45'
20:40
20:44
20:49
20:53
20:58
21:03
21:08
21:13
21:17

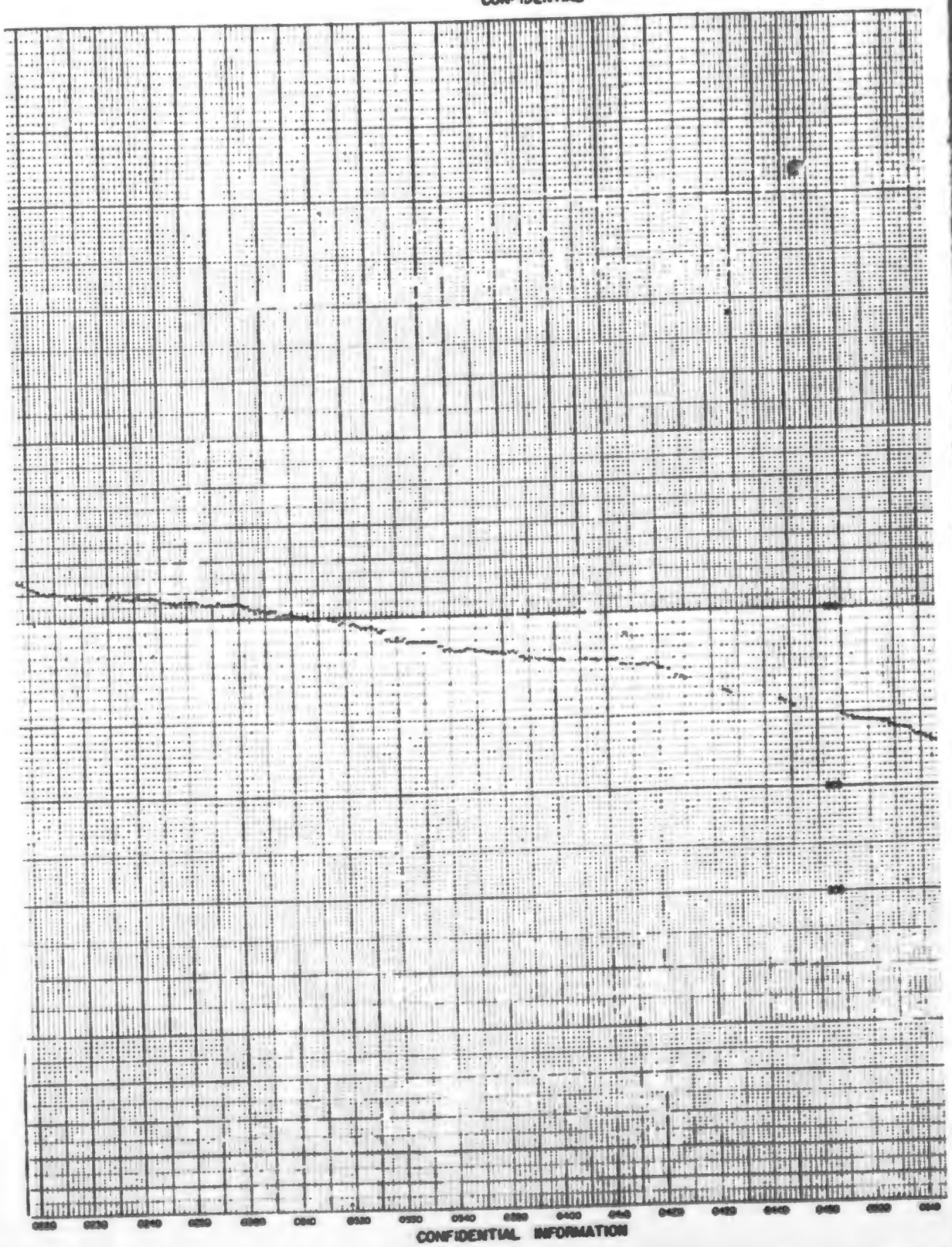
SCALE 1:5 x 10⁹

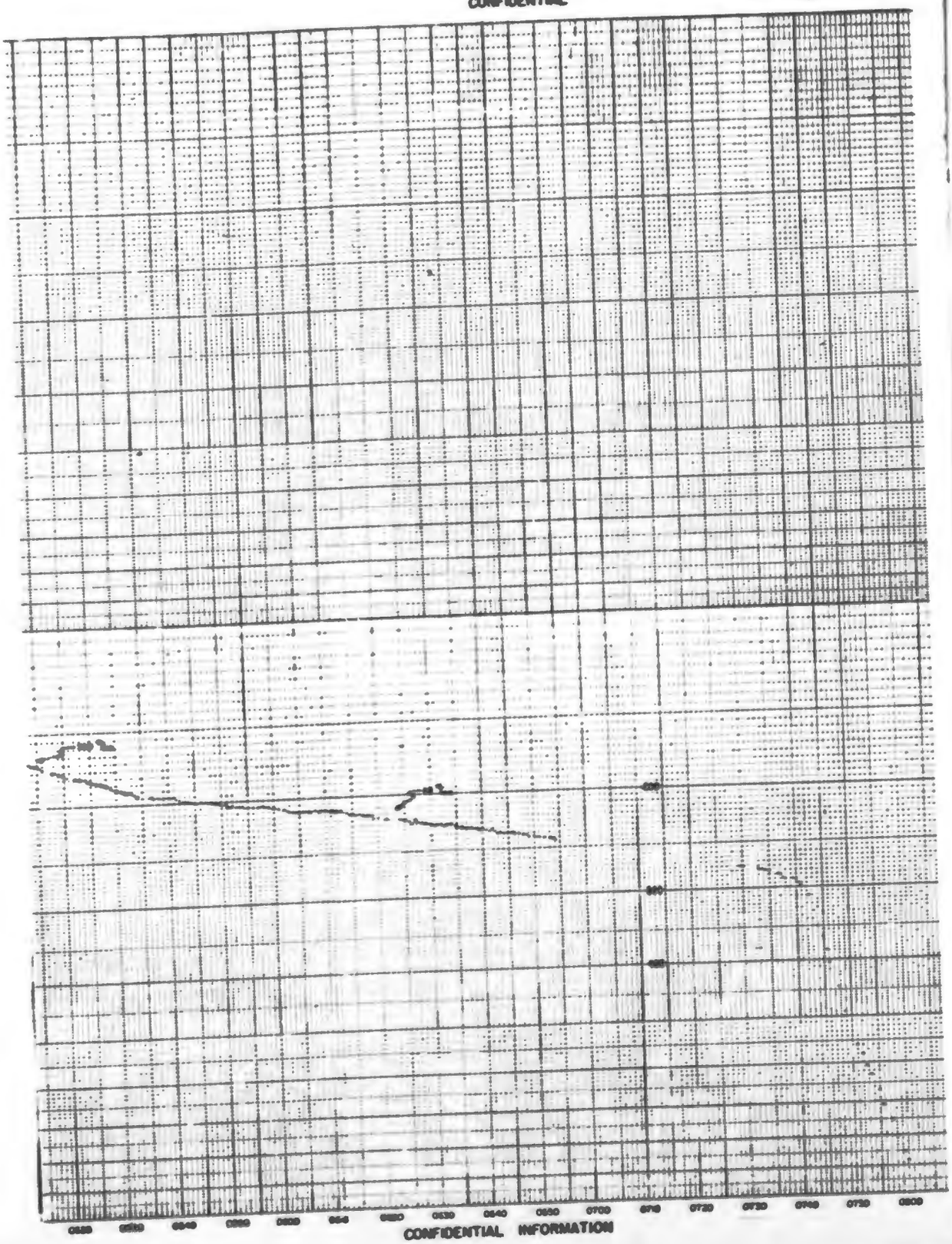
2


RASONDE DATA
FLIGHT # 63
23 February, 1953
Meteorological station reporting :
• • RAPID CITY, So Dak 662
1500 Z
o o Telemetered thermistor data
PRESSURE IN MILLIBARS
10
50
70
100
200
400
500
800
1000
-70
-60
-50
-40
-30
-20
-10
0
10
TEMPERATURE (°C.)

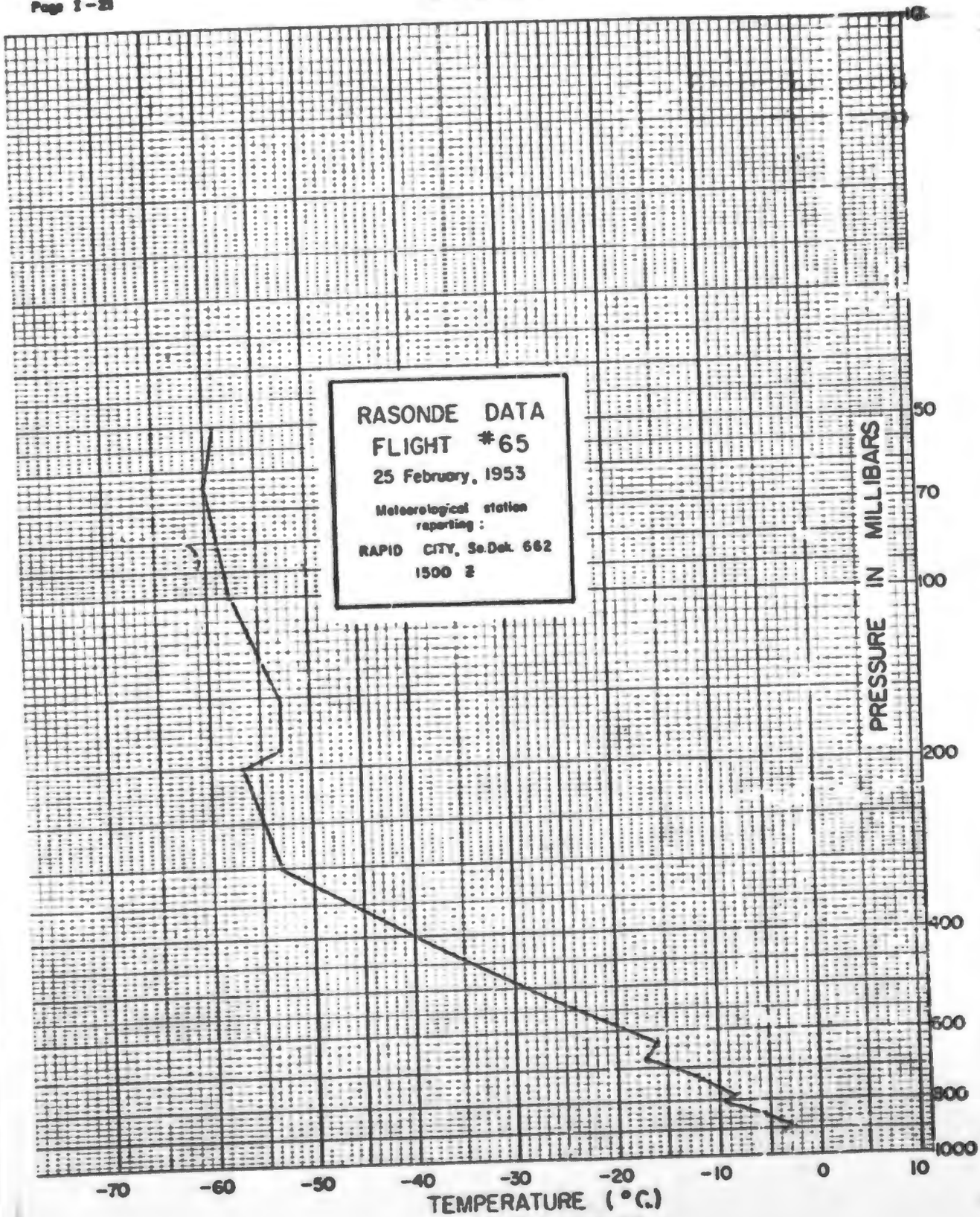

TIME - PRESSURE - ALTITUDE
Flight No 63
23 February 1960
PRESSURE - MILLIBARS
GREENWICH MEAN TIME



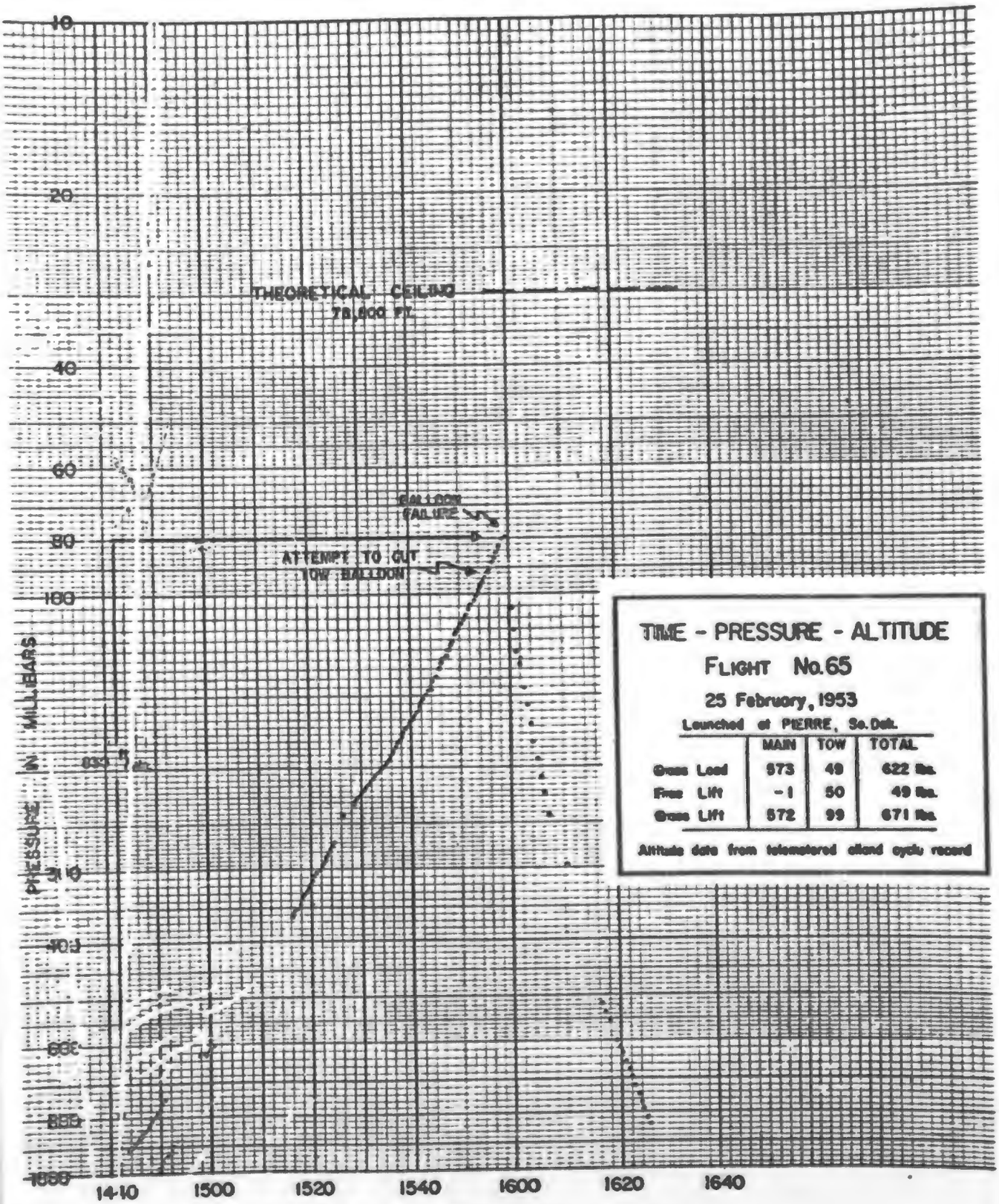



0630
0640
0650
0700
0710
0720
0730
0740
0750
0800

CONFIDENTIAL



CONFIDENTIAL INFORMATION



TIME - PRESSURE - ALTITUDE

FLIGHT No. 65

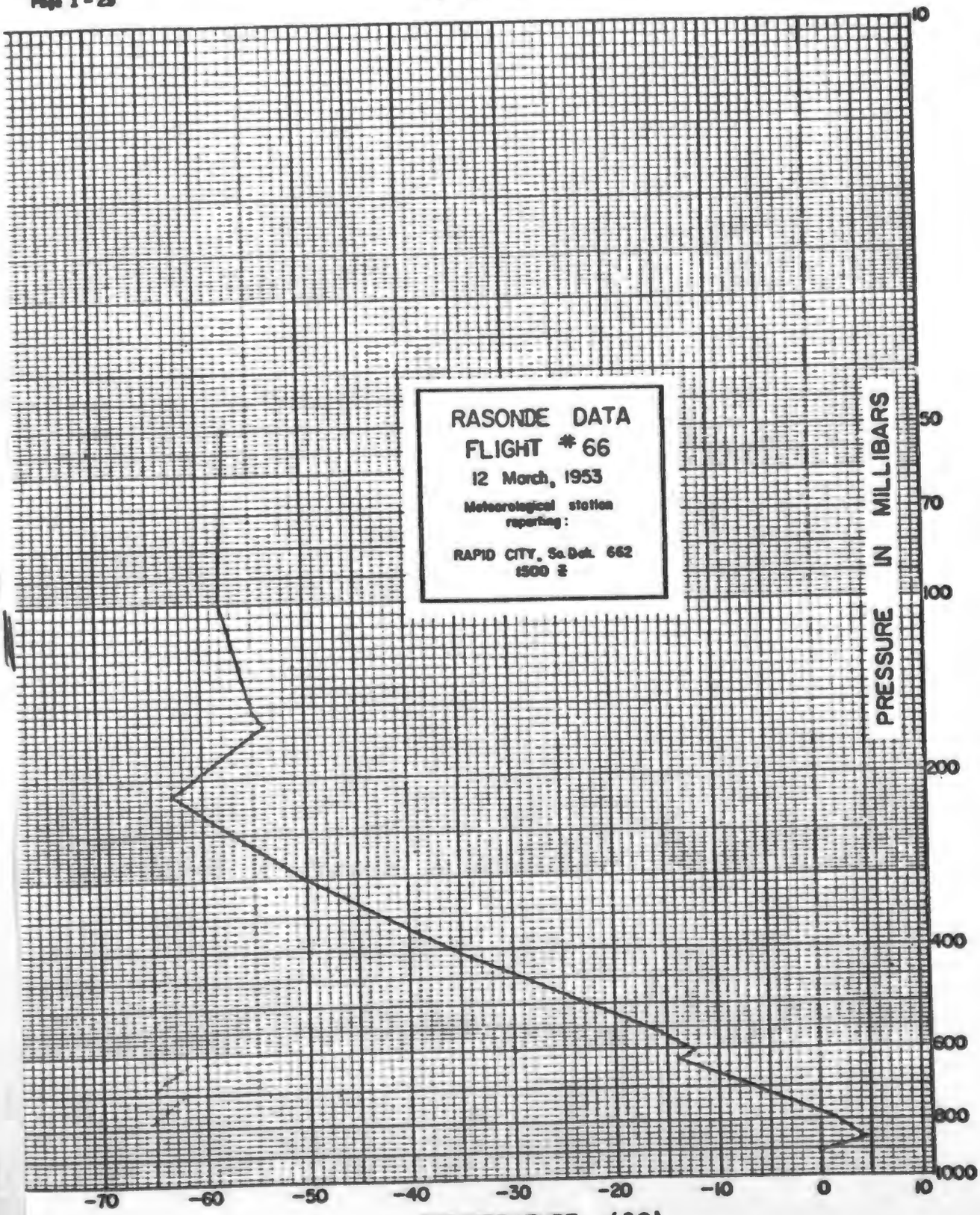
25 February, 1953

Launched at PIERRE, So. Dak.

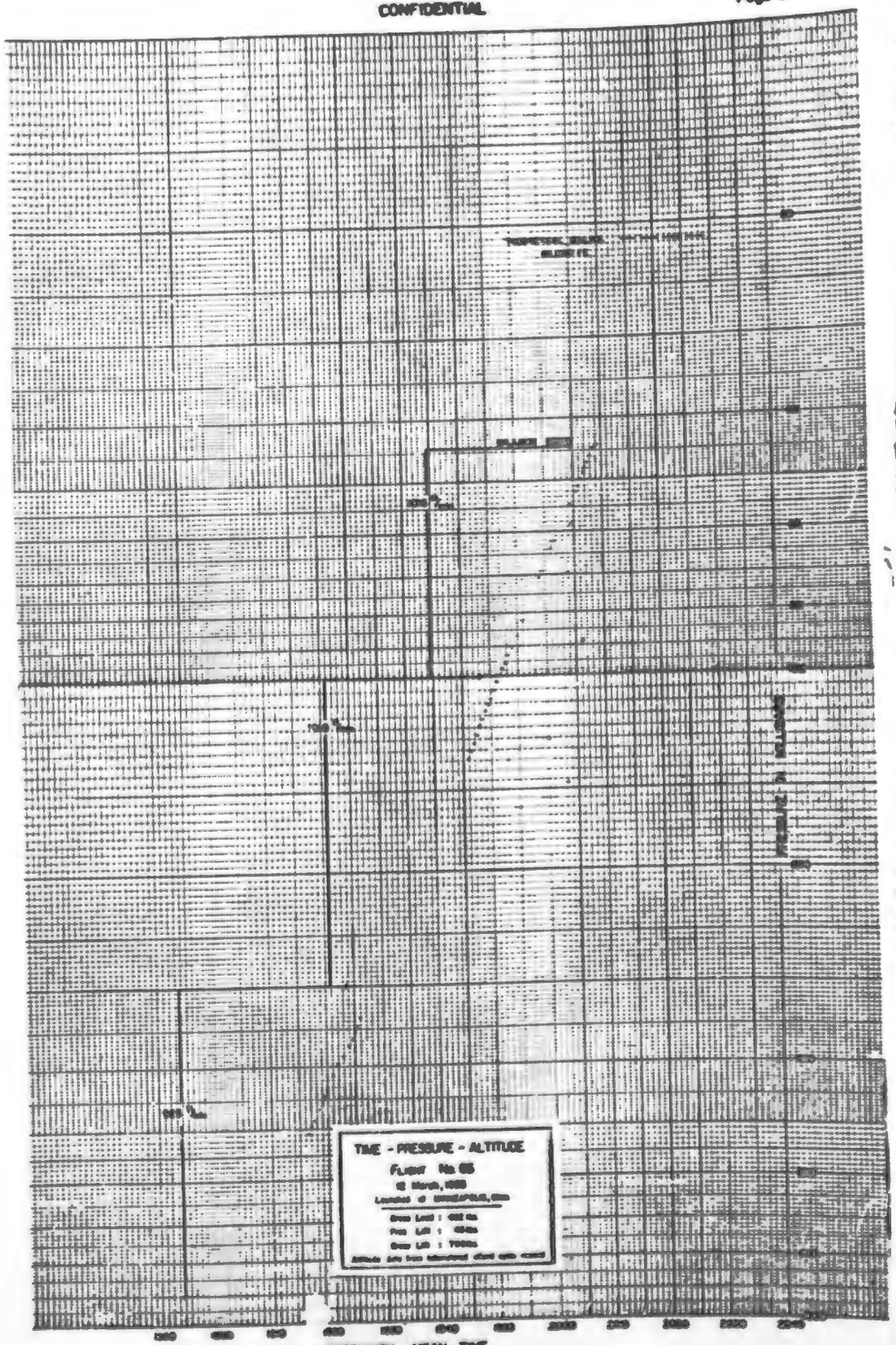
	MAIN	TOW	TOTAL
Gross Load	573	49	622 lbs.
Free Lift	-1	50	49 lbs.
Gross Lift	572	99	671 lbs.

Altitude data from telemetered aneroid cycle record

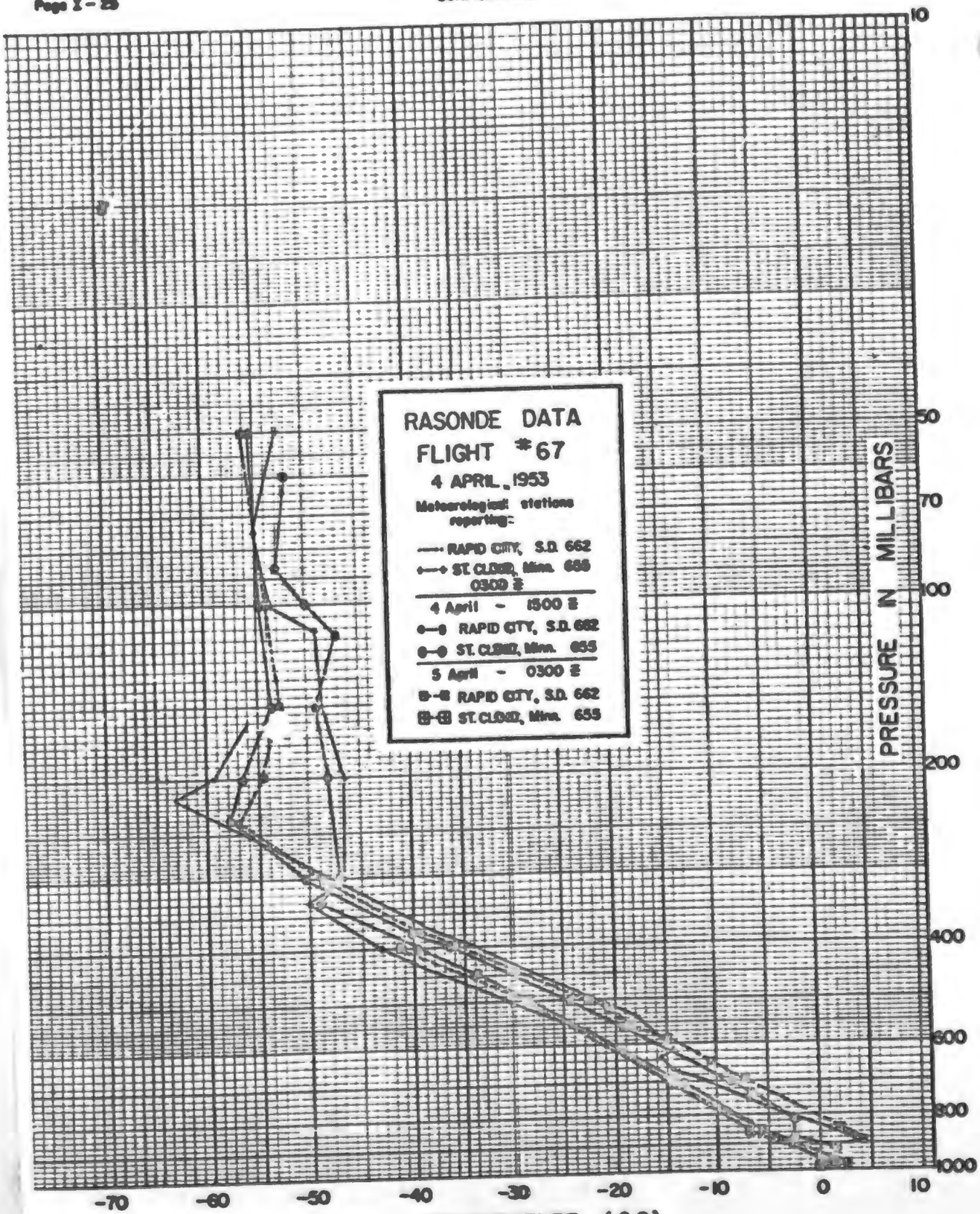
CONFIDENTIAL



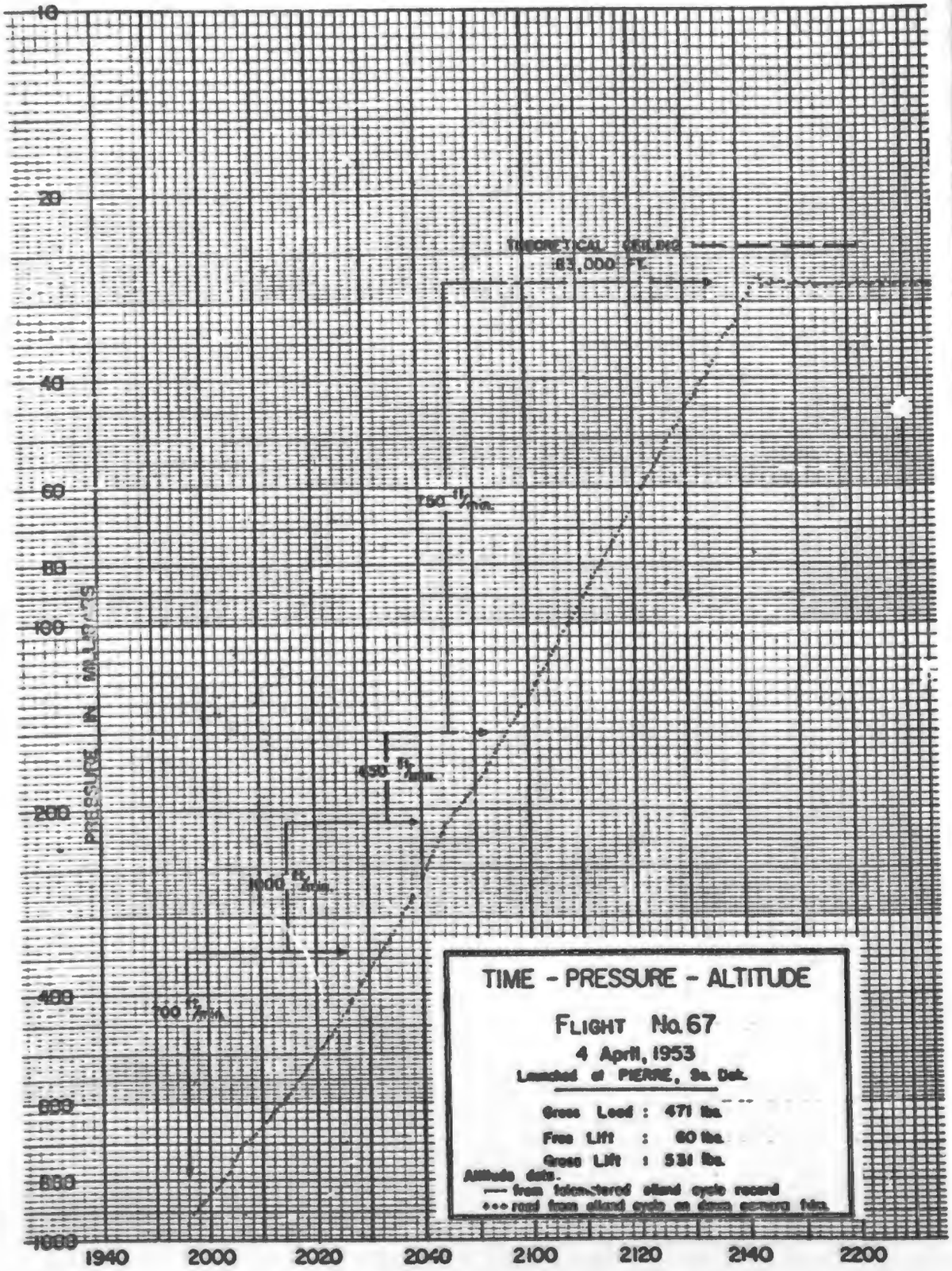
CONFIDENTIAL INFORMATION

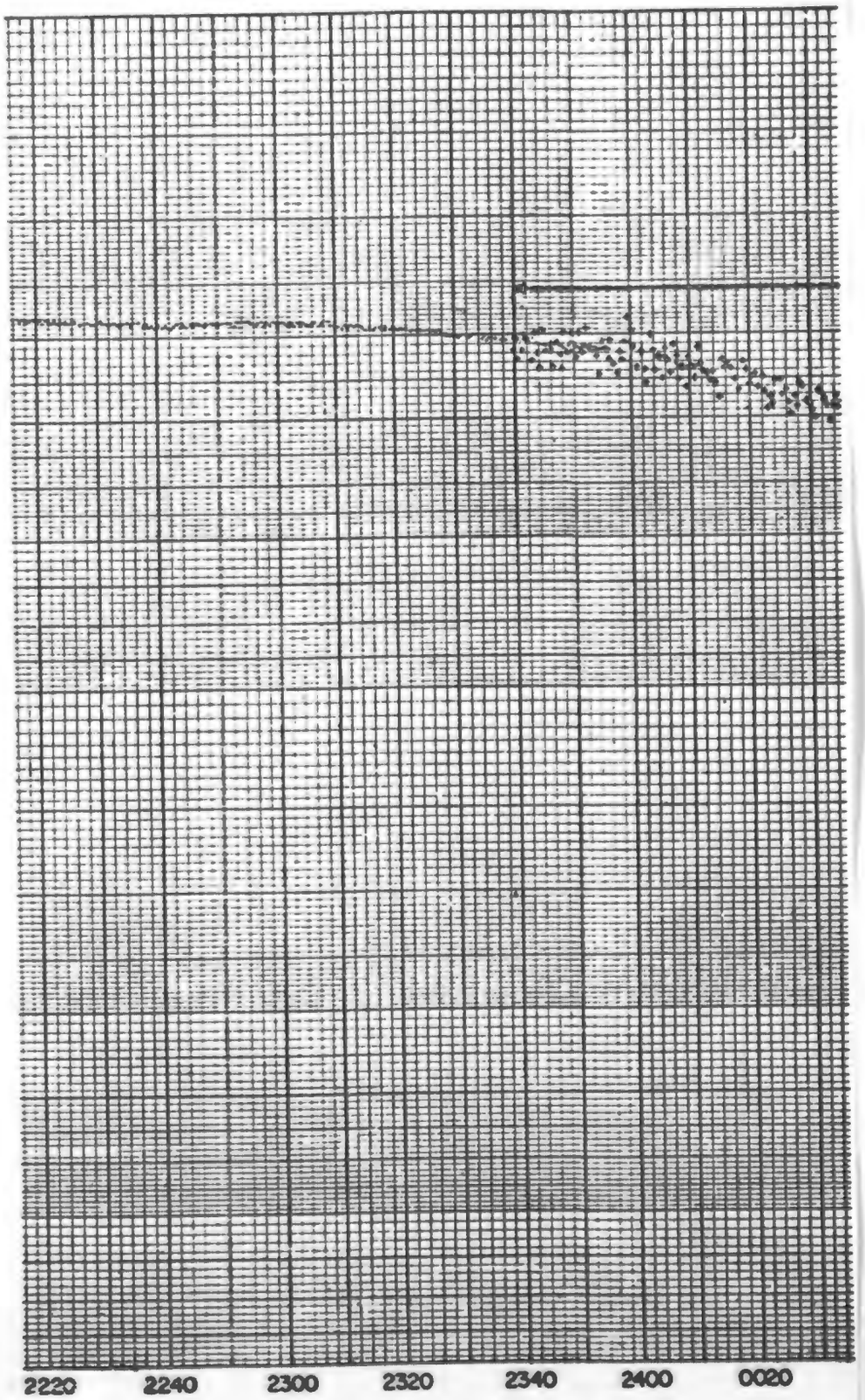

TIME - PRESSURE - ALTITUDE
FLIGHT No 65
GREENWICH MEAN TIME

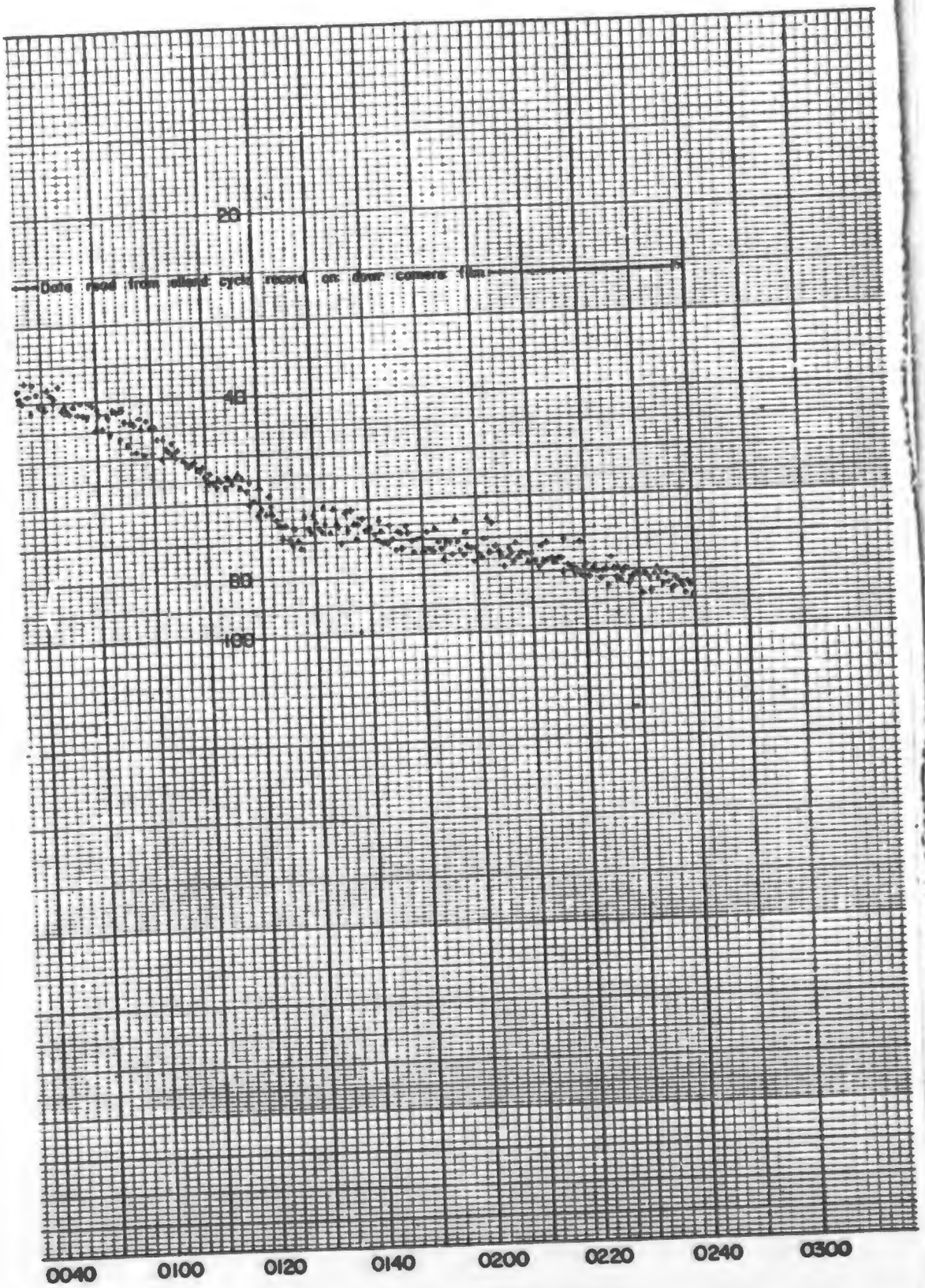
CONFIDENTIAL

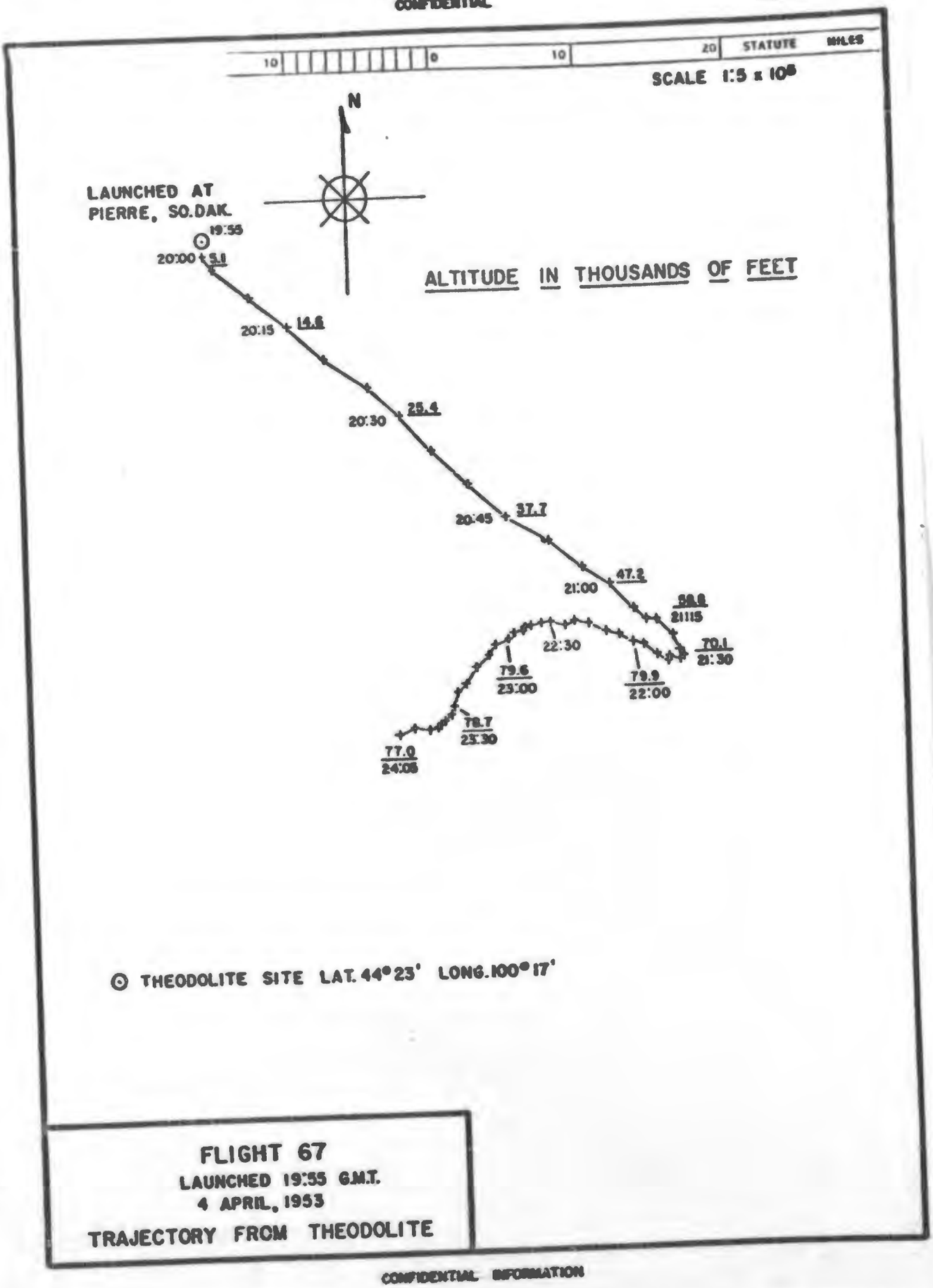


CONFIDENTIAL INFORMATION


THEORETICAL CEILING
83,000 FT.
750 ft/min.
450 ft/min.
1000 ft/min.
100 ft/min.
PRESSURE IN MILLIBARS
10
20
40
60
80
100
200
400
600
850
1000
1940
2000
2020
2040
2100
2120
2140
2200
GREENWICH MEAN TIME
TIME - PRESSURE - ALTITUDE
FLIGHT No. 67
4 April, 1953
Launched at PIERRE, So. Dak.
Gross Load : 471 lbs.
Free Lift : 60 lbs.
Gross Lift : 531 lbs.
Altitude data.
—— from telemetered aneroid cycle record
+++ read from aneroid cycle on down scanning film.

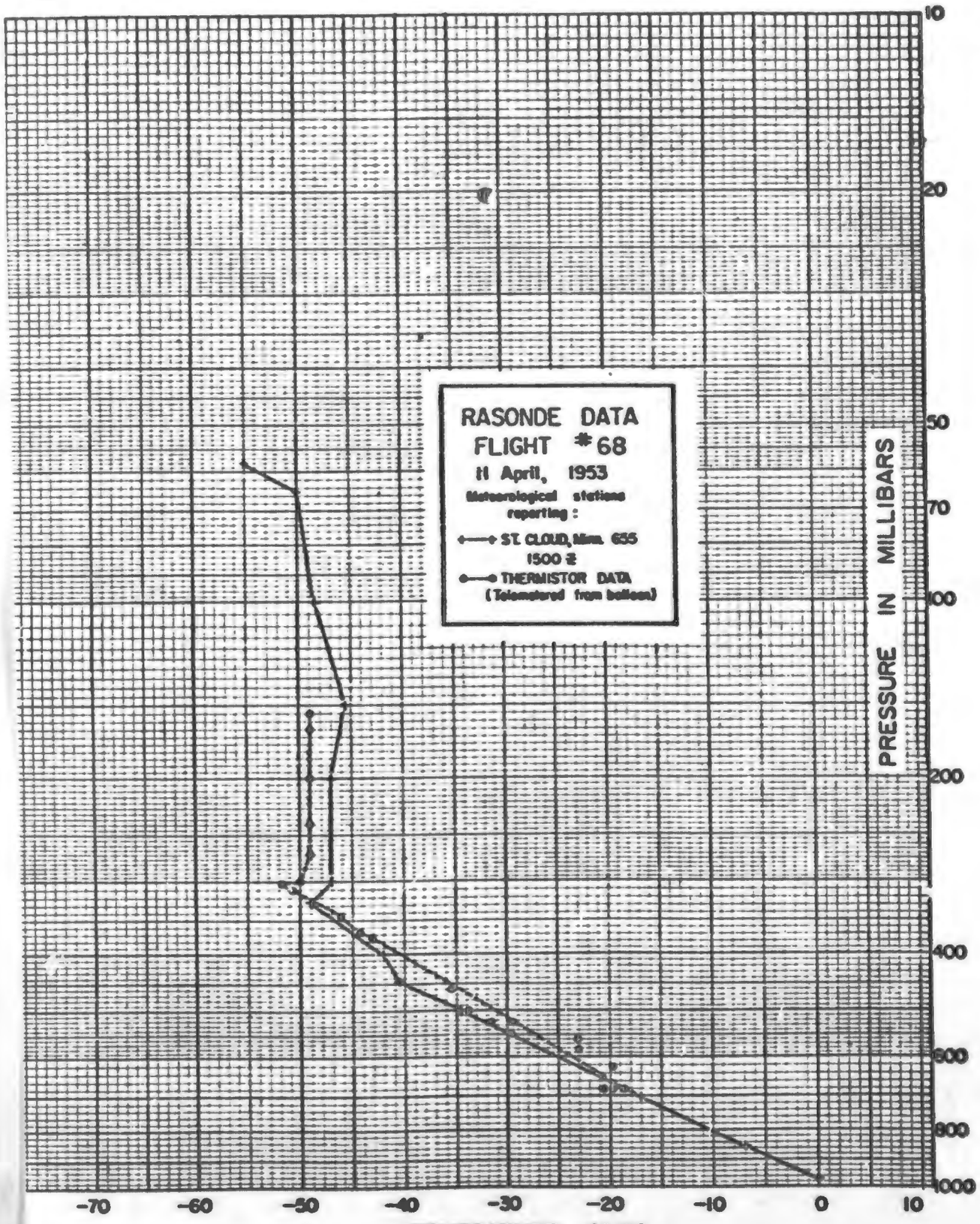

2220
2240
2300
2320
2340
2400
0020


20
Data read from attend cycle record on dour camera film
40
60
80
100
0040
0100
0120
0140
0200
0220
0240
0300

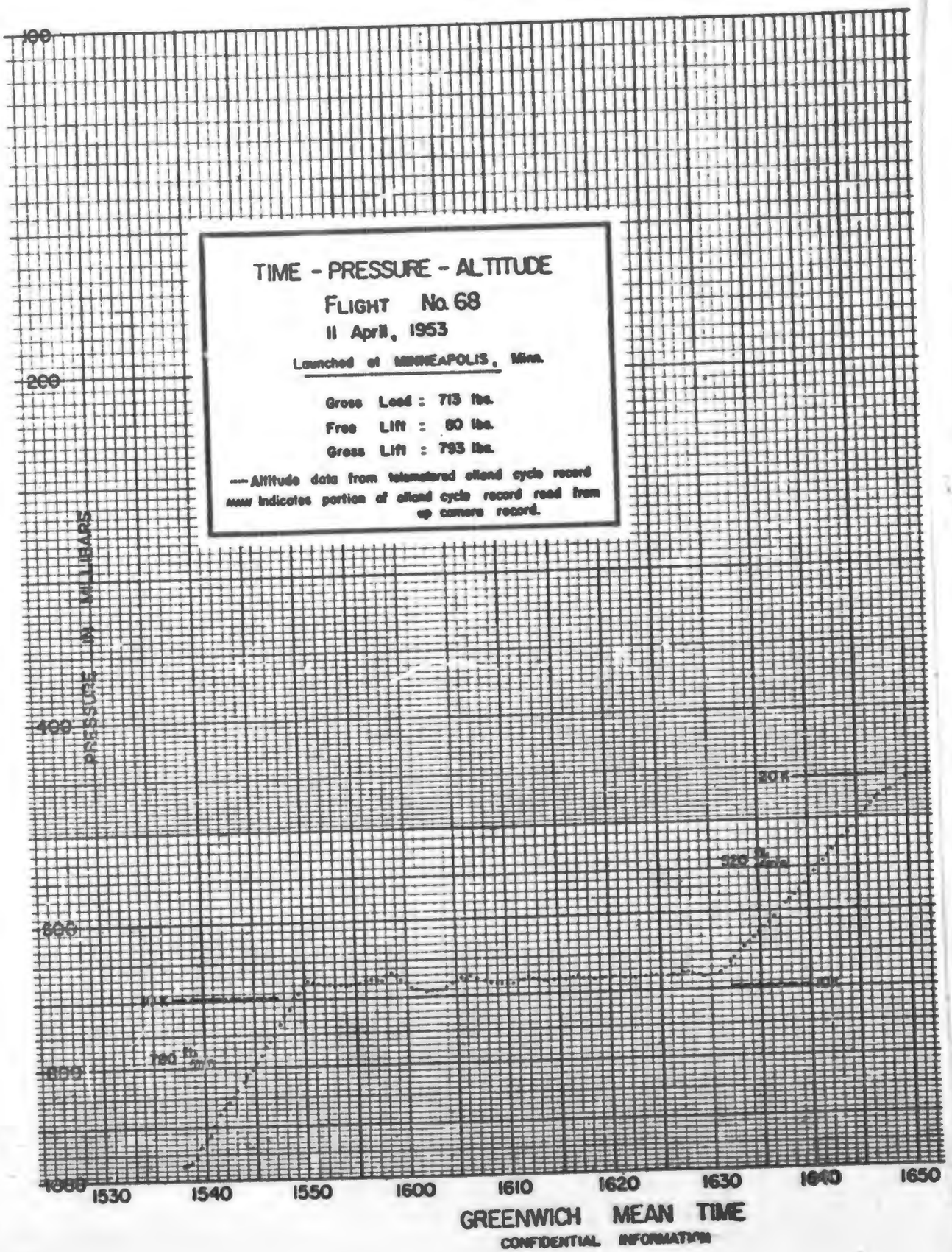


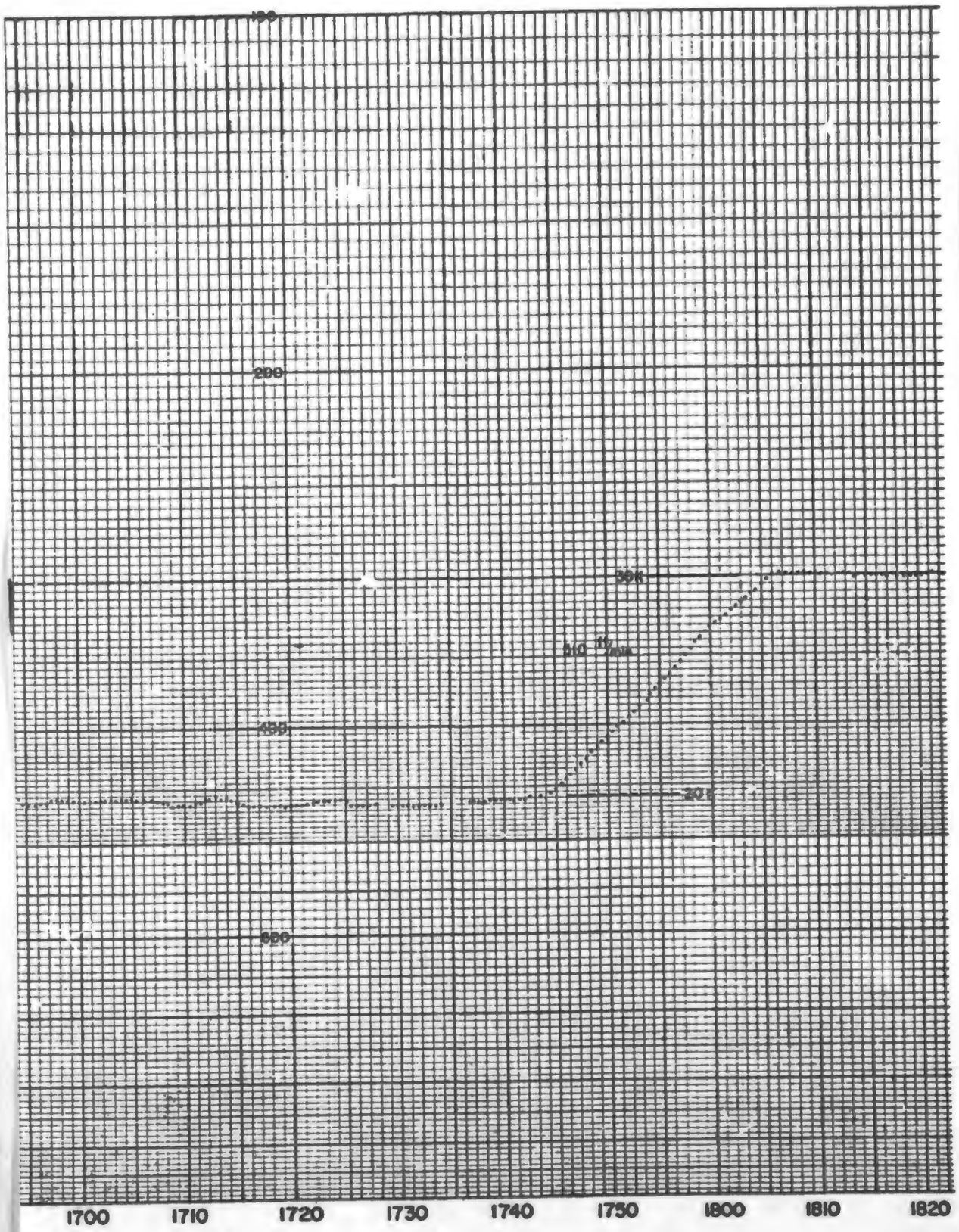
FLIGHT 67
LAUNCHED 19:55 G.M.T.
4 APRIL, 1953
TRAJECTORY FROM THEODOLITE

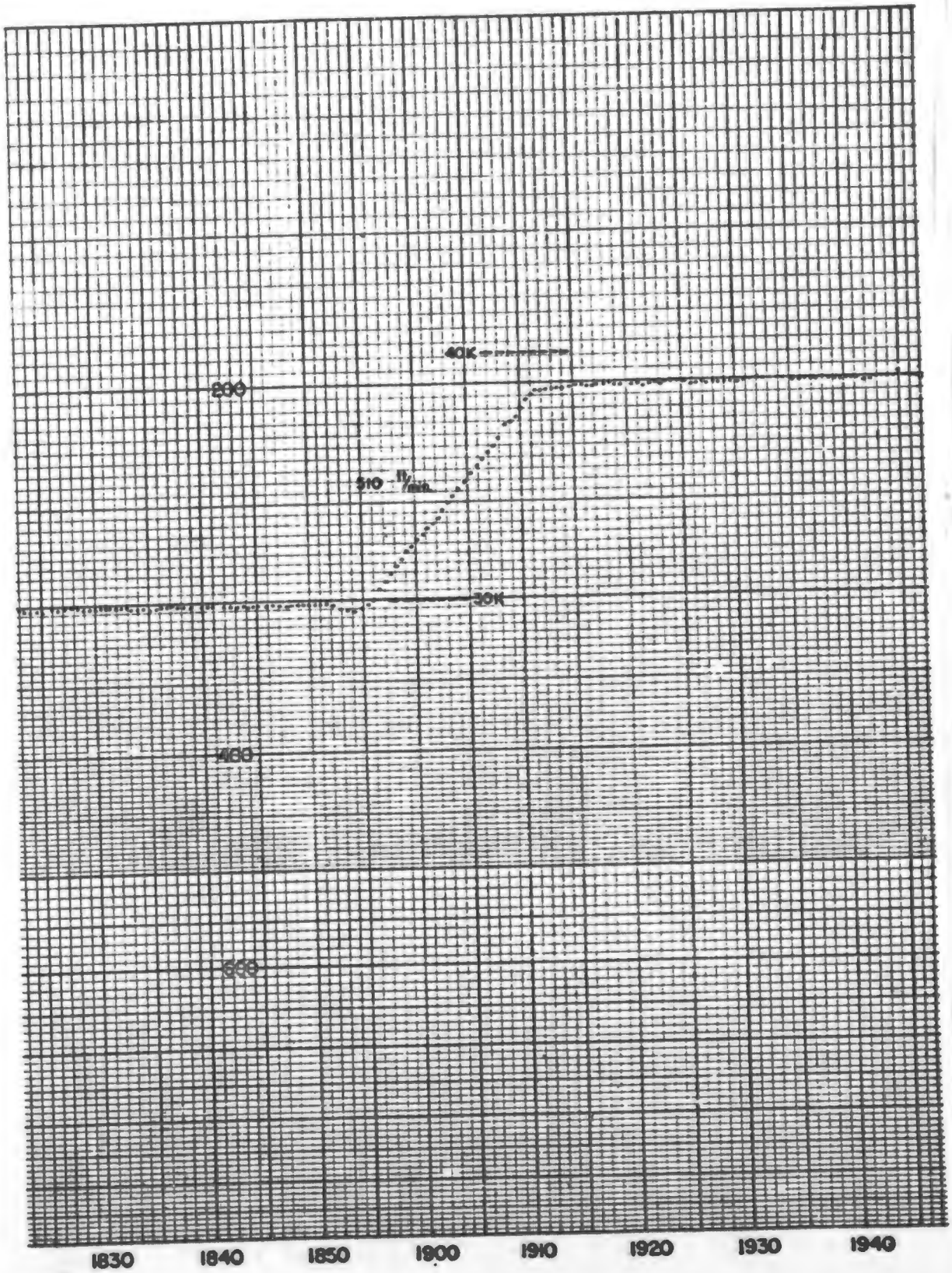
CONFIDENTIAL

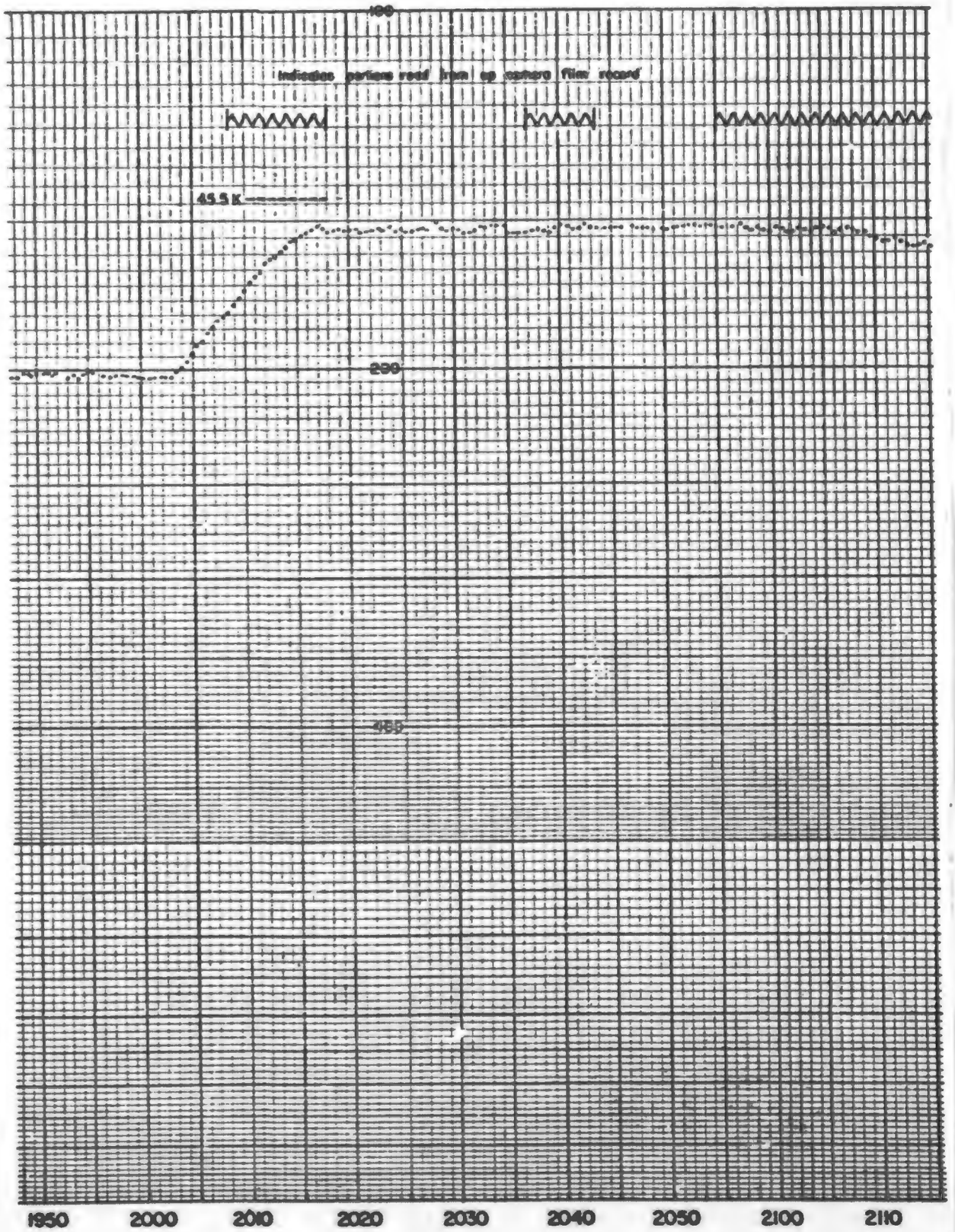


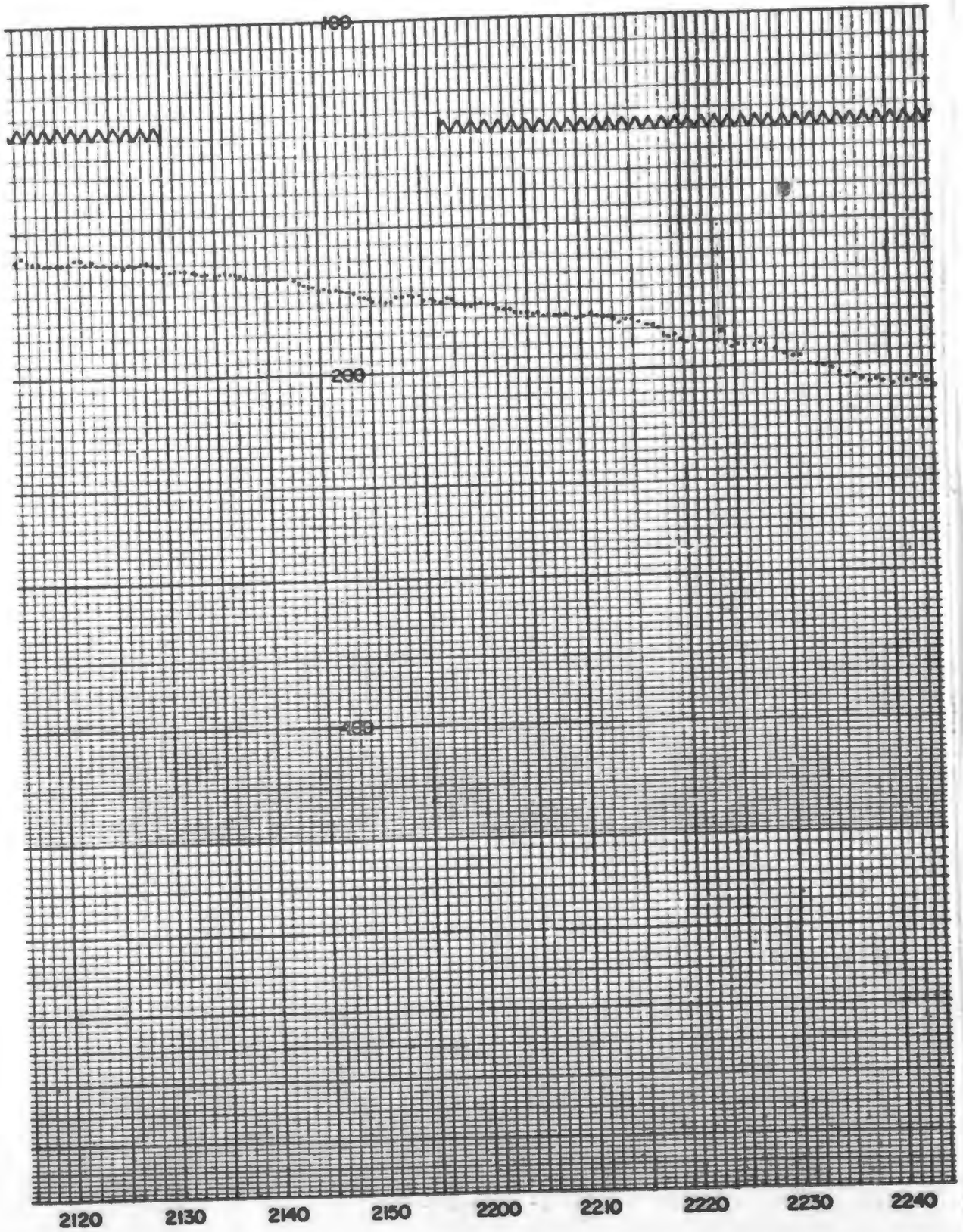
CONFIDENTIAL INFORMATION

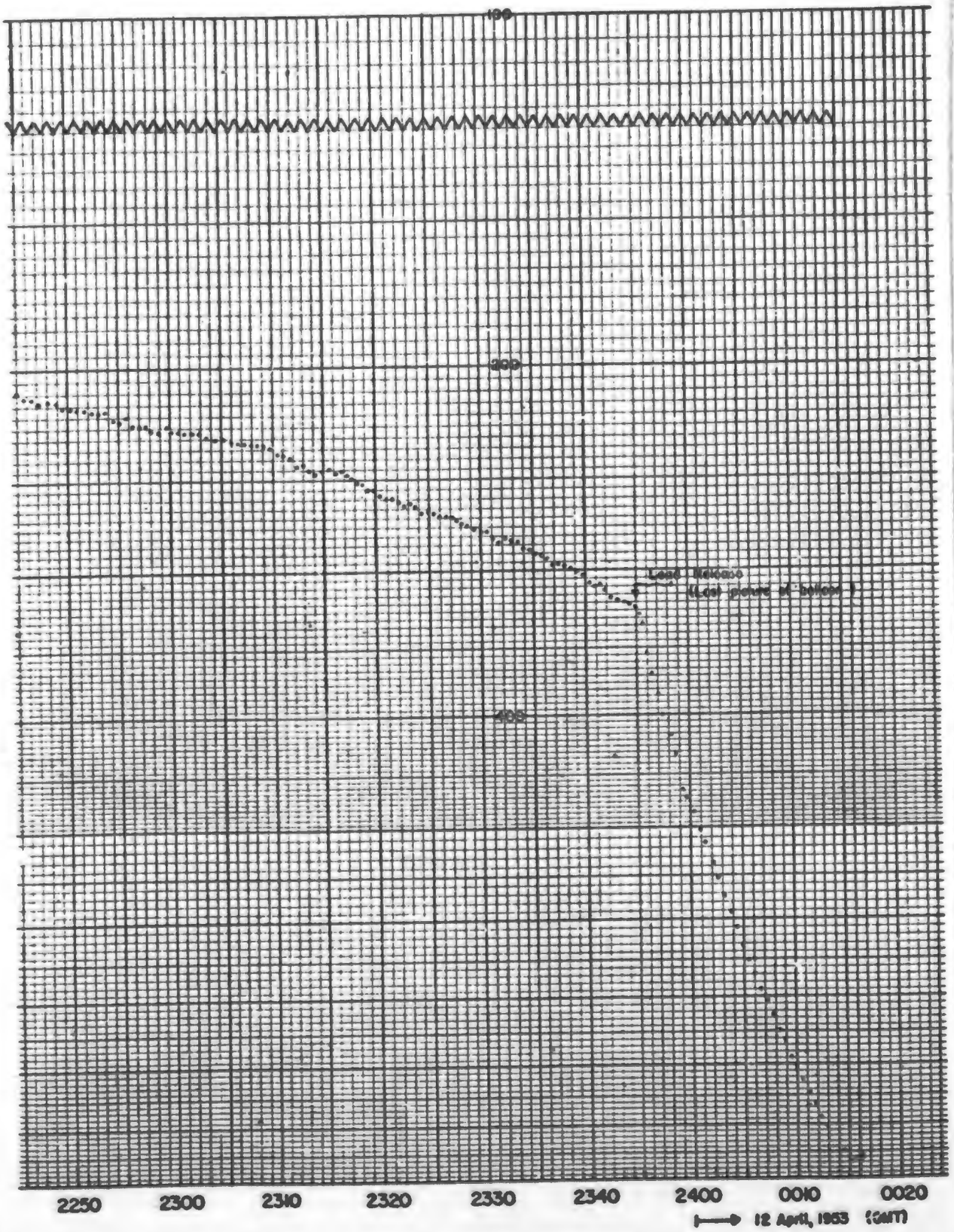

TIME - PRESSURE - ALTITUDE
FLIGHT No. 68
11 April, 1953
Launched at MINNEAPOLIS, Minn.
Gross Load : 713 lbs.
Free Lift : 80 lbs.
Gross Lift : 793 lbs.
—— Altitude data from telemetered ofland cycle record
www indicates portion of ofland cycle record read from up camera record.
PRESSURE IN MILLIBARS
100
200
400
600
800
1000
20 K
120 ft/min
10 K
180 ft/min
1530
1540
1550
1600
1610
1620
1630
1640
1650
GREENWICH MEAN TIME


100
200
300
400
500
600
30K
20K
510 ft/min
1700
1710
1720
1730
1740
1750
1800
1810
1820


40K
200
510 ft/min.
30K
400
600
1830
1840
1850
1900
1910
1920
1930
1940


100
Indicates portions read from op camera film record
45.5 K
200
400
1950
2000
2010
2020
2030
2040
2050
2100
2110


100
200
300
2120
2130
2140
2150
2200
2210
2220
2230
2240

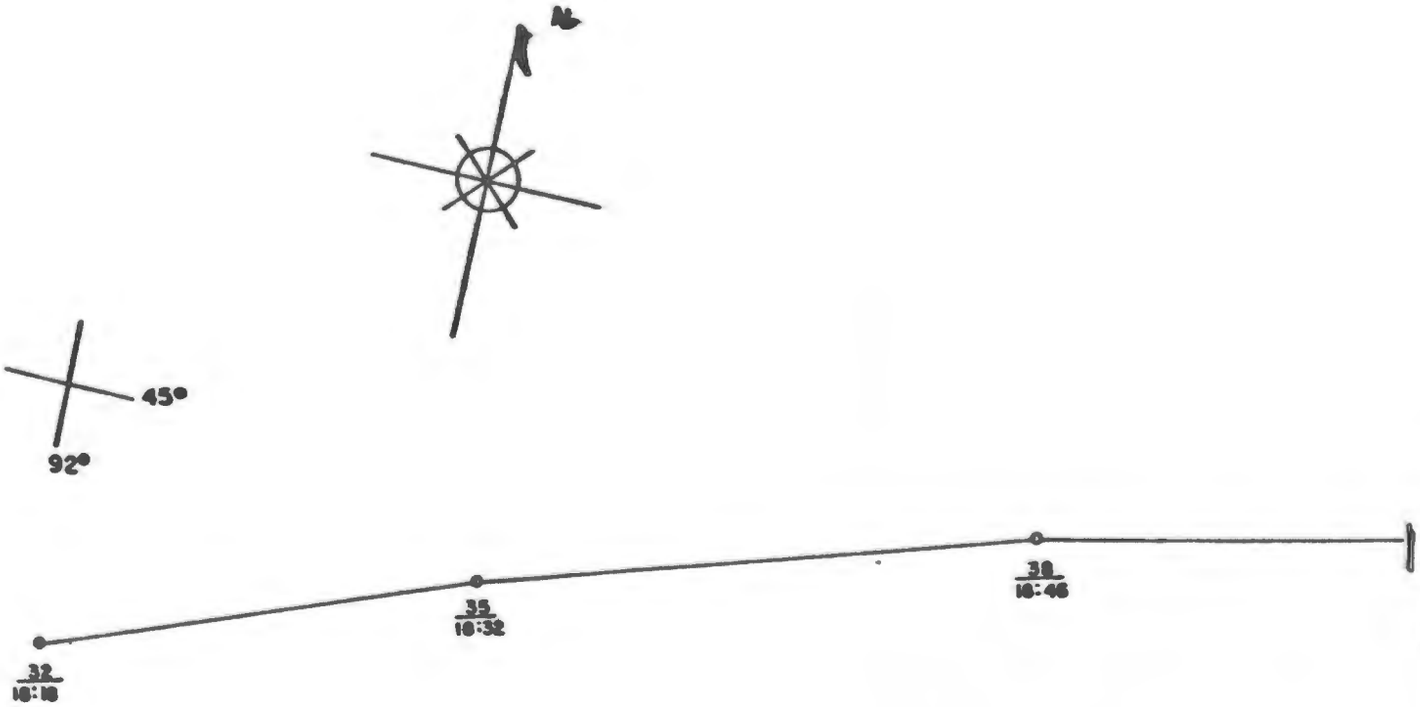

100
200
300
400
Last Release
(Last picture of balloon)
2250
2300
2310
2320
2330
2340
2400
0010
0020
12 April, 1953 (GMT)

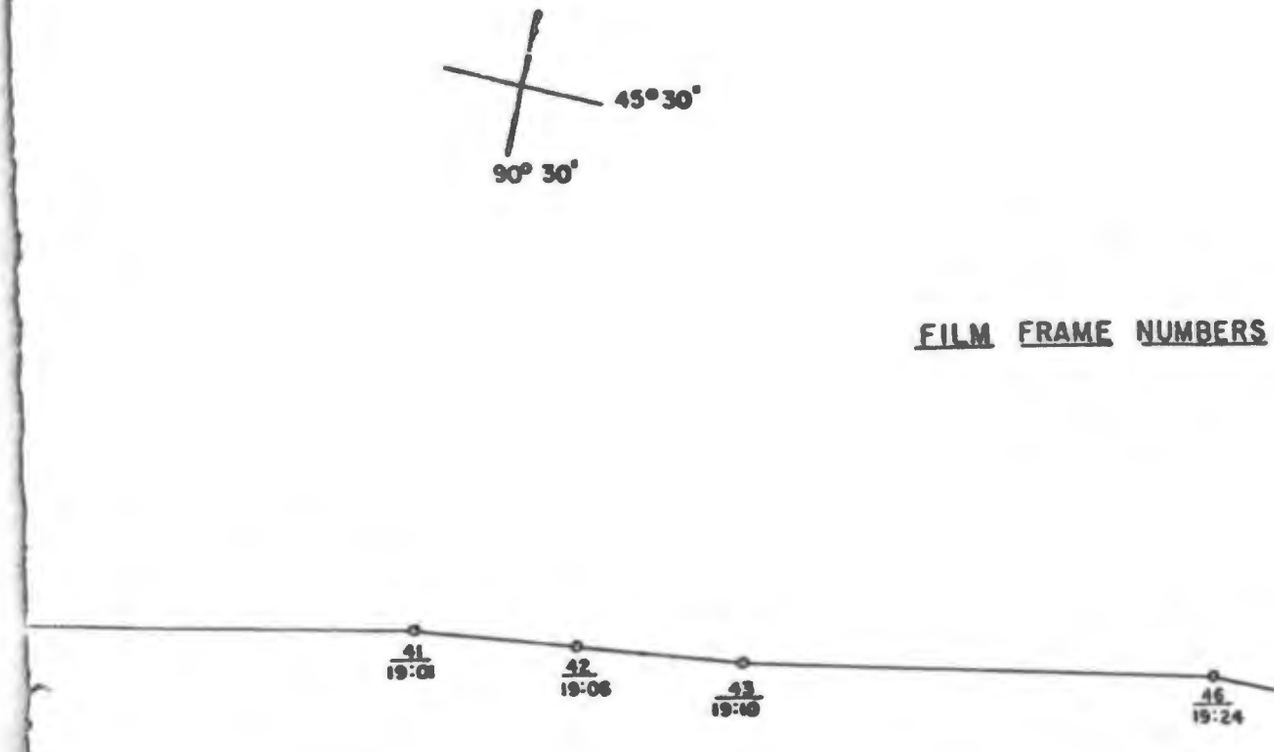
+ LAUNCH SITE LAT. 45° 07' LONG. 93° 10.5'

FLIGHT 68

LAUNCHED 15:38 G.M.T.
11 APRIL, 1953

TRAJECTORY FROM FILM DATA


N
45°
92°
32
18:18
35
18:32
38
18:46



2

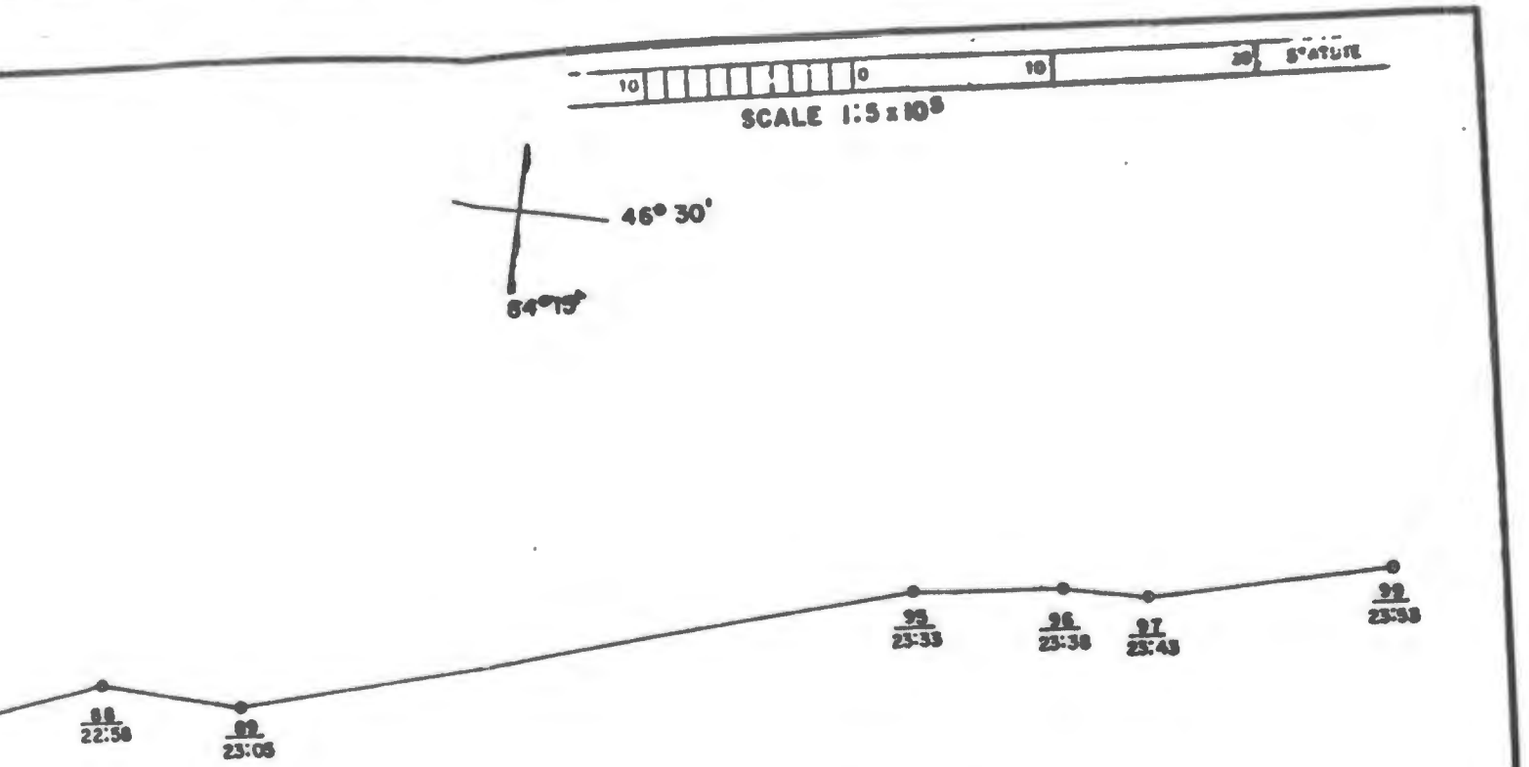
71

NUMBERS

90°
45°

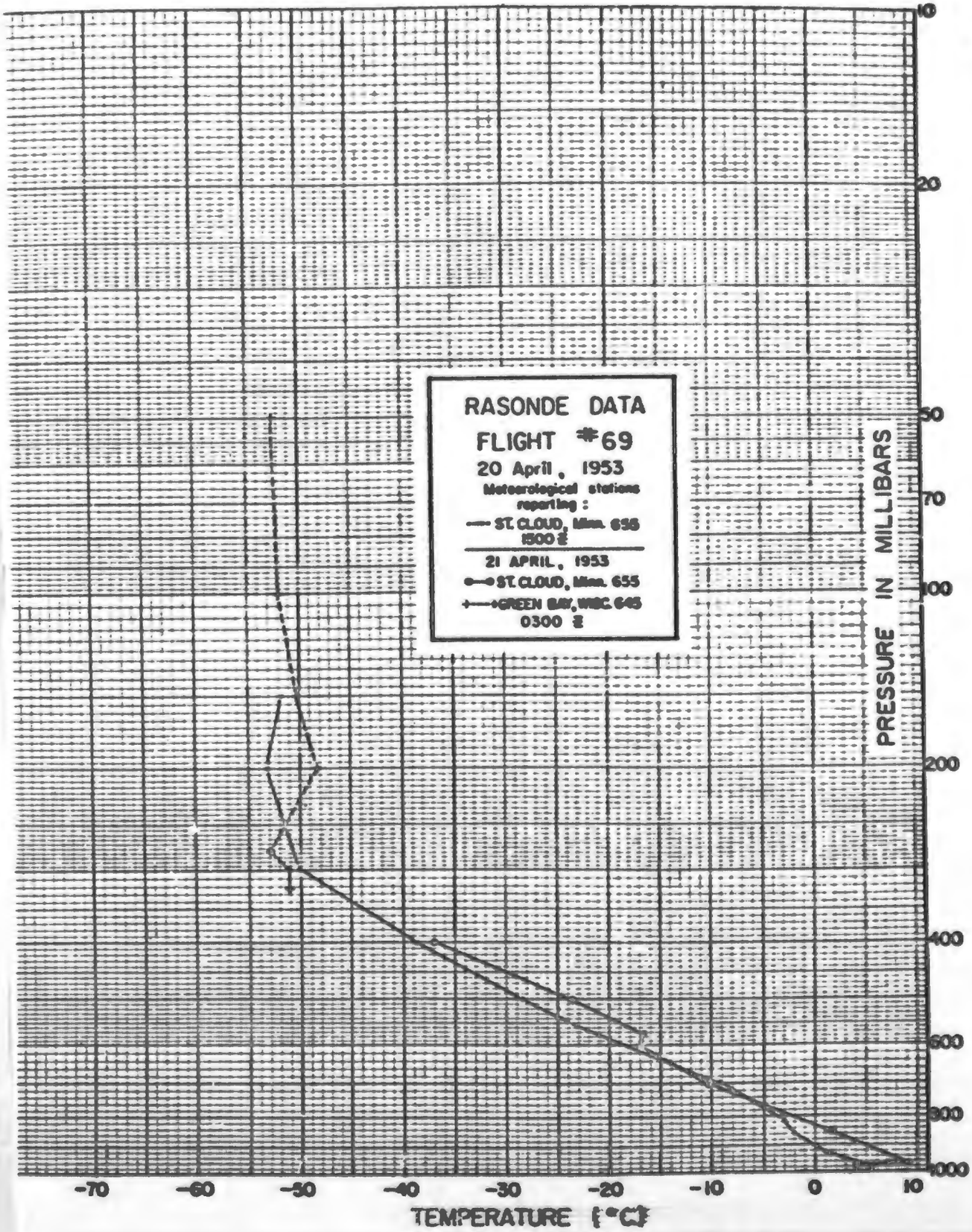
46°
86°

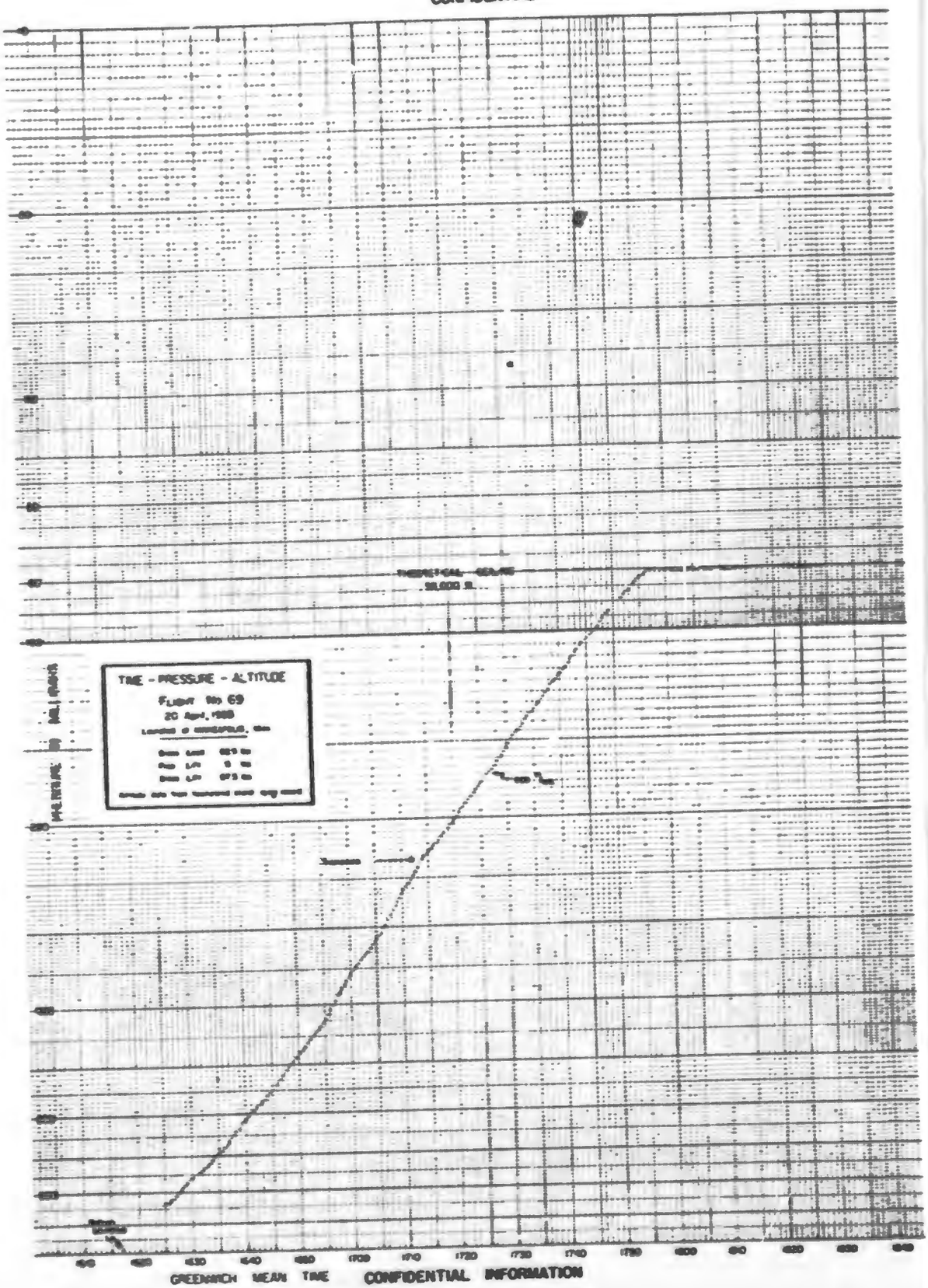
NOTE - THE

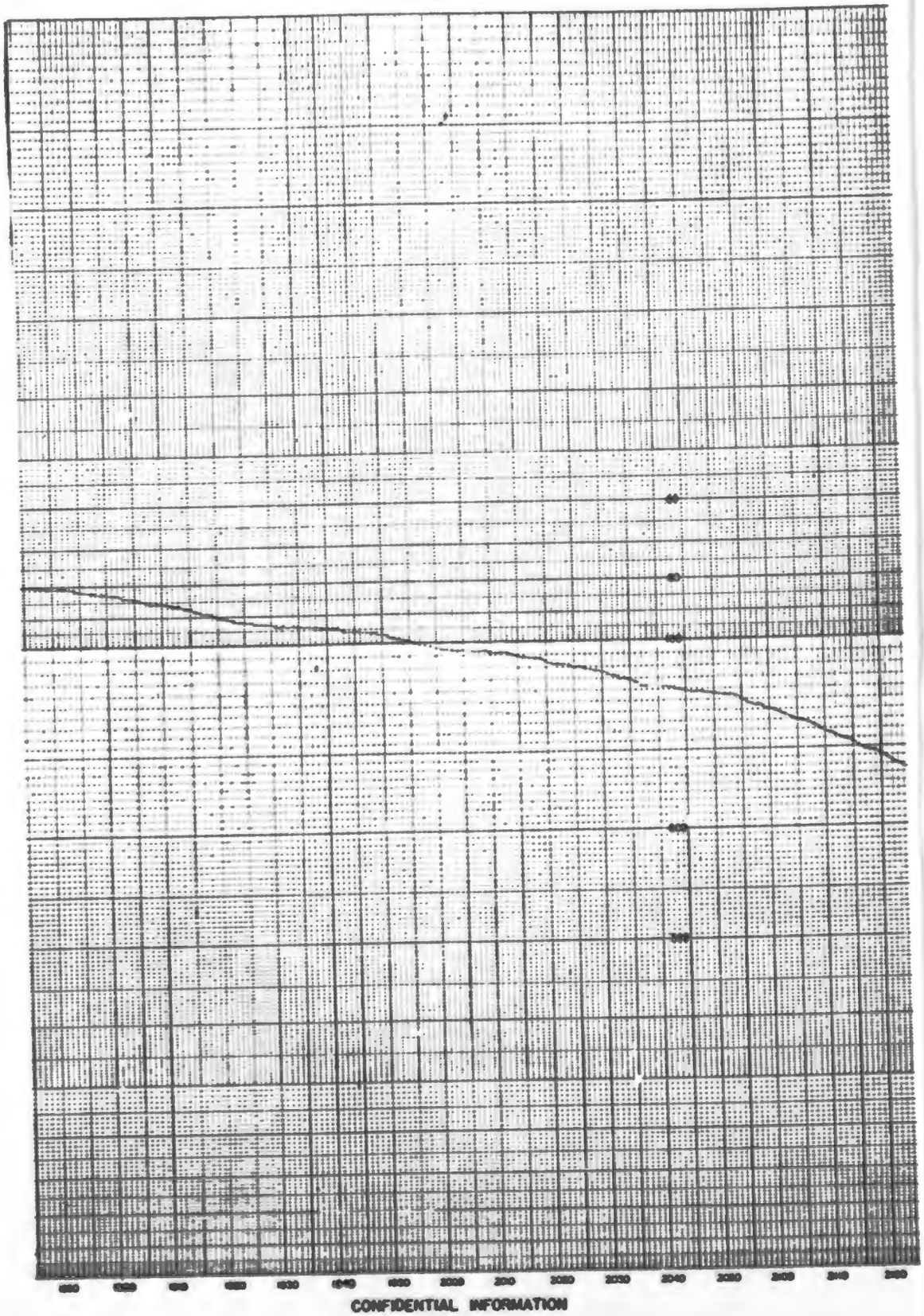


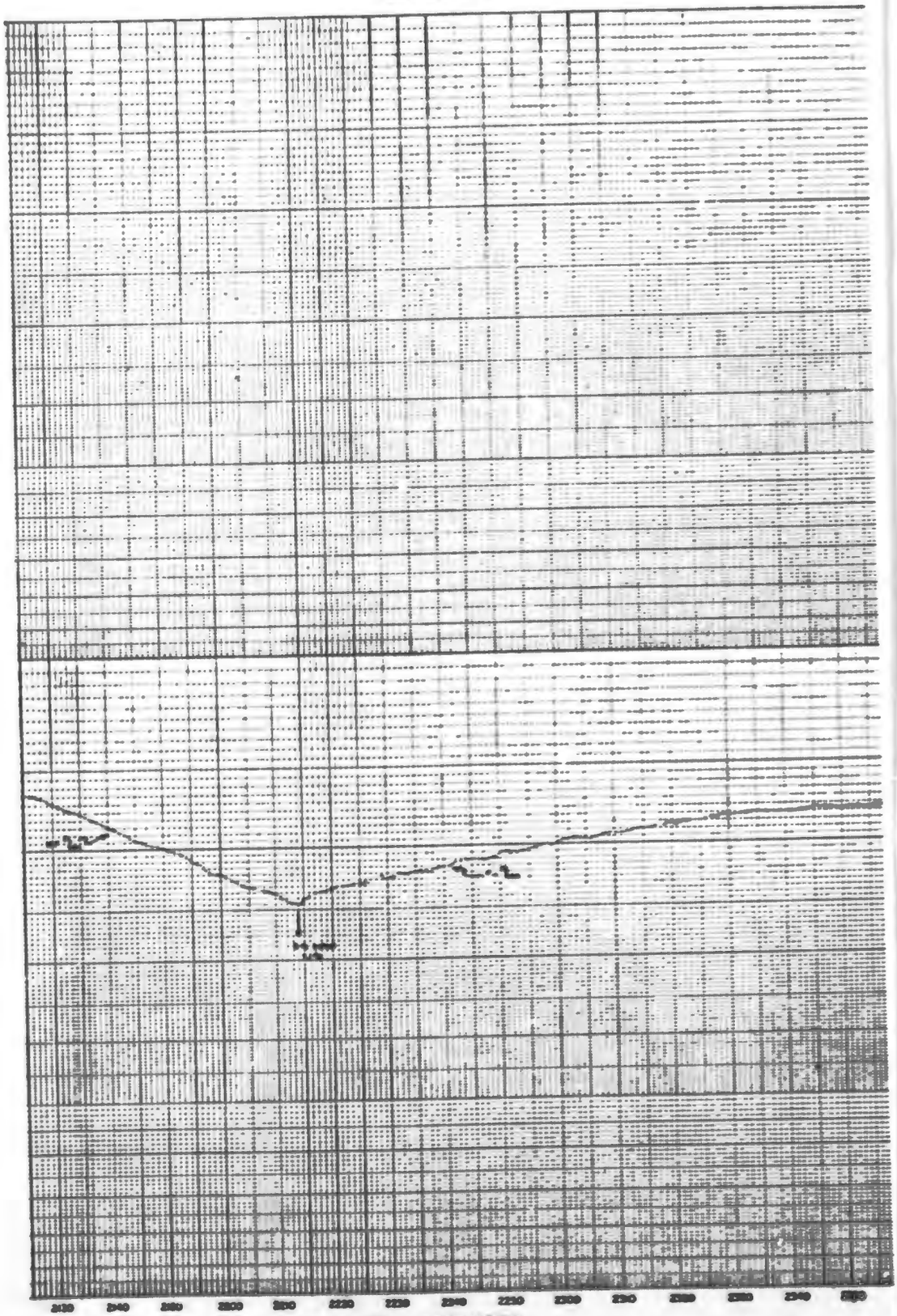
NOTE - THE TIMES INDICATED ARE APPROXIMATE

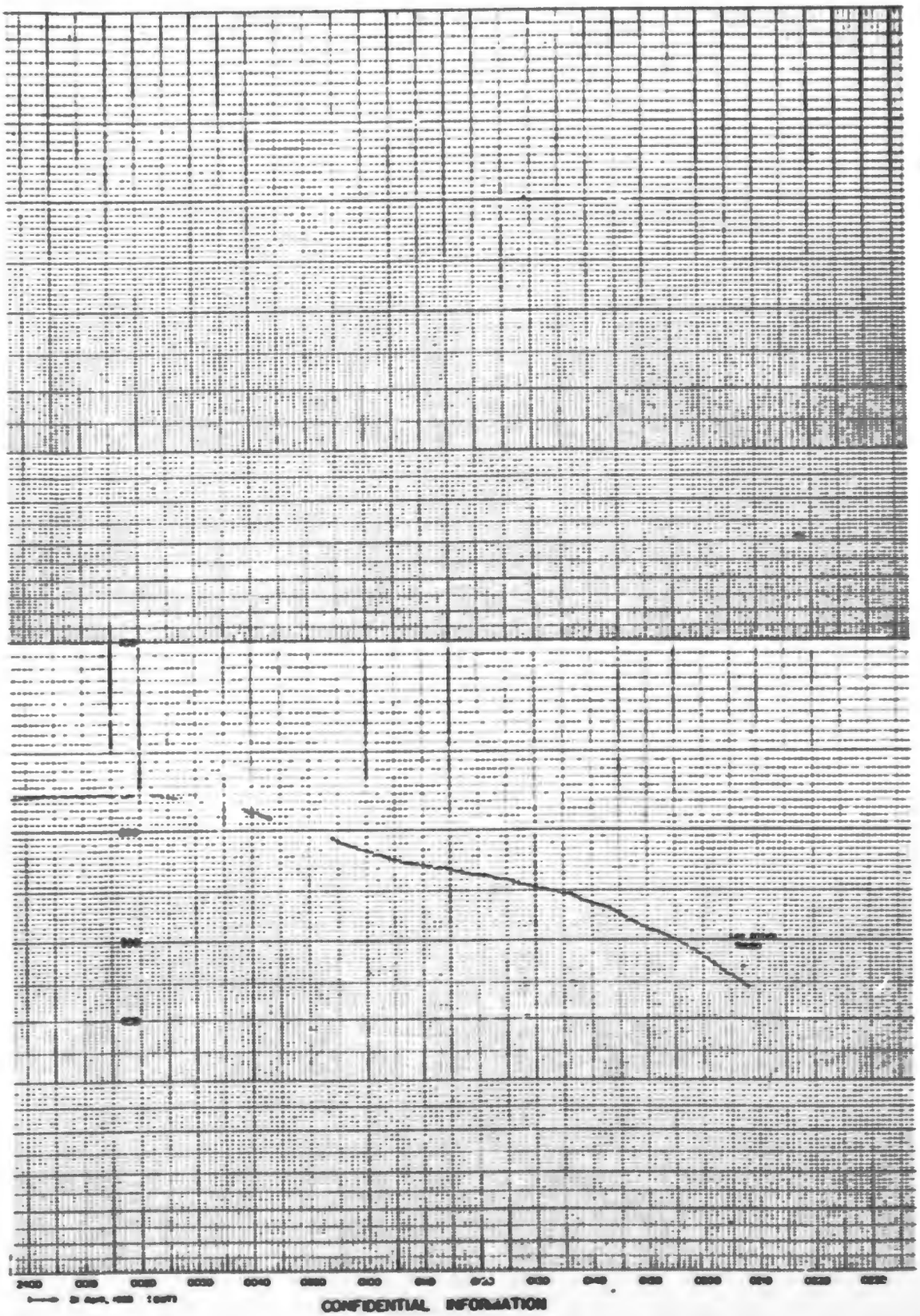
4

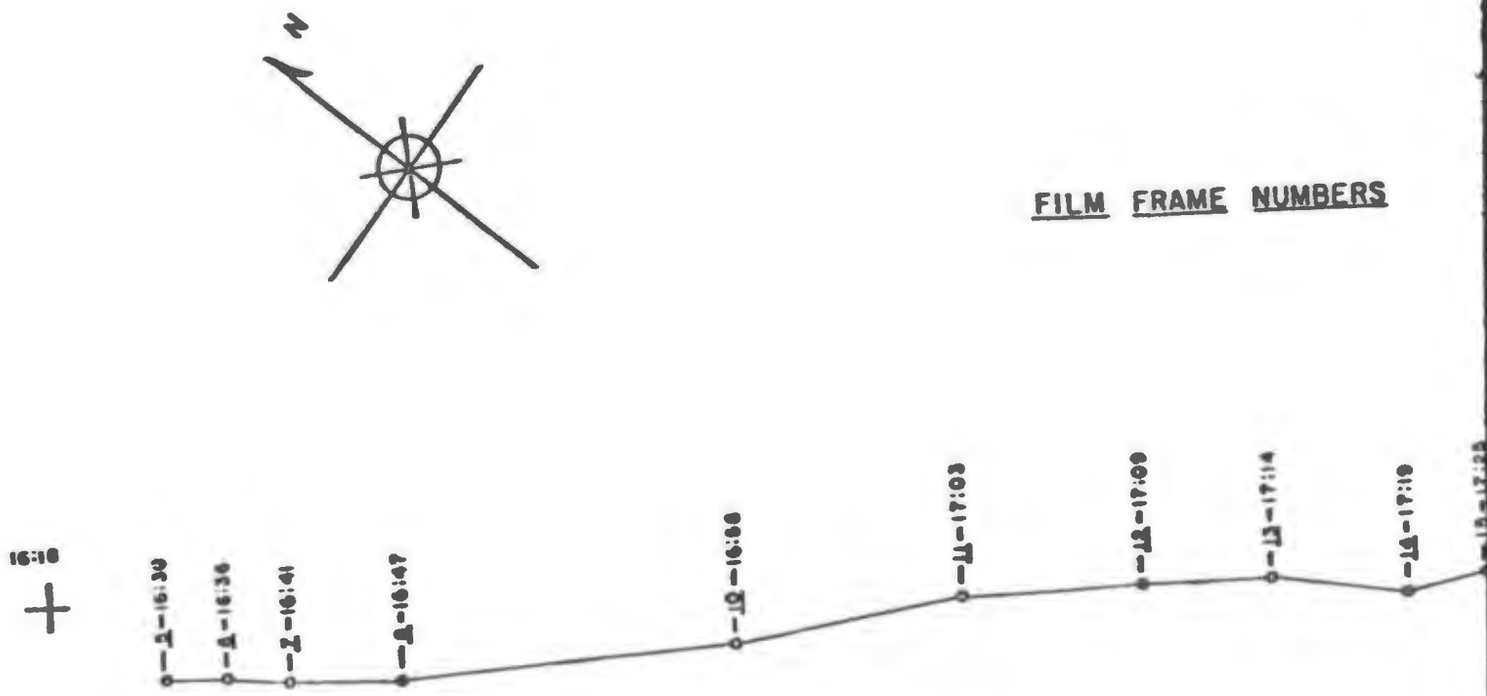

RASONDE DATA
FLIGHT #69
20 April, 1953
Meteorological stations reporting:
ST. CLOUD, Minn. 656
1500 Z
21 APRIL, 1953
ST. CLOUD, Minn. 655
GREEN BAY, WISC. 645
0300 Z
PRESSURE IN MILLIBARS
10
20
50
70
100
200
400
600
800
1000
-70
-60
-50
-40
-30
-20
-10
0
10
TEMPERATURE (°C)


TIME - PRESSURE - ALTITUDE
Flight No 69
20 April, 1960
THEORETICAL GEOLINE
30,000 ft
PRESSURE (MILLIBARS)
GREENWICH MEAN TIME









LAUNCHED AT
U of M AIRPORT
MPLS. MINN.

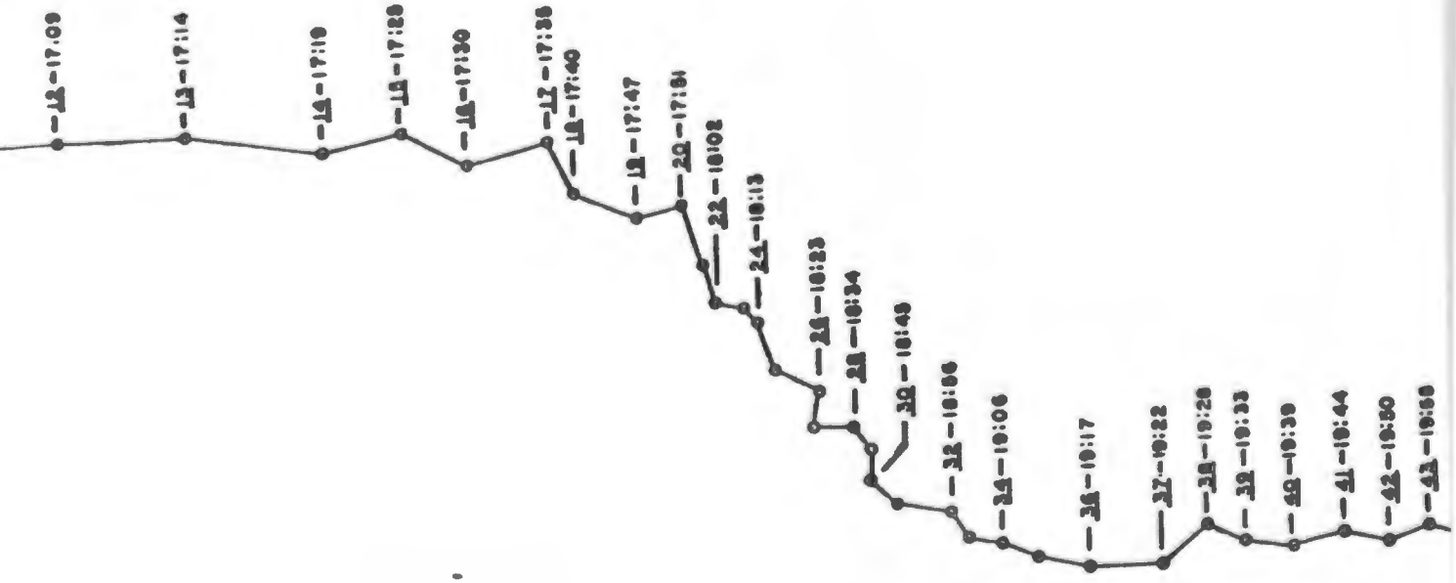
+ LAUNCH SITE LAT. 45° 07' LONG. 93° 10.5'

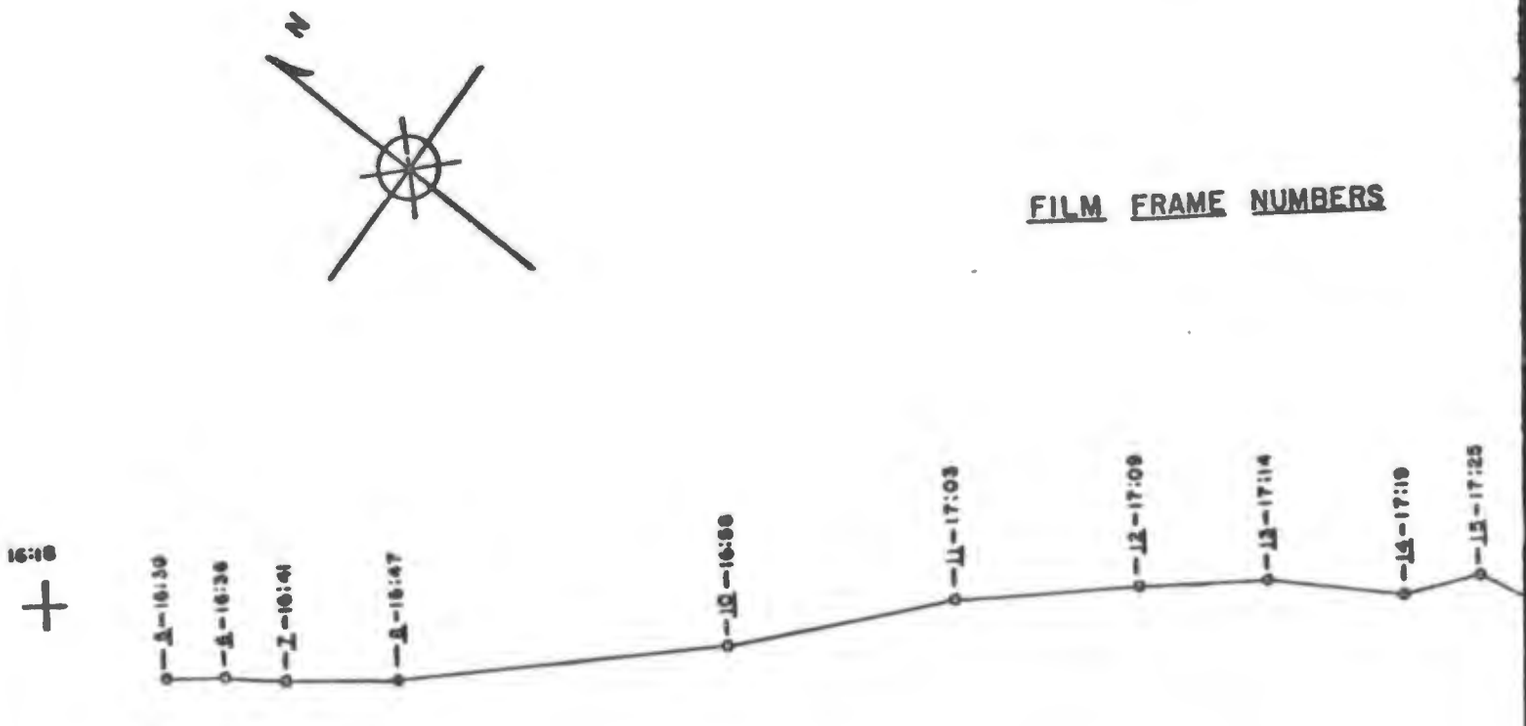
FLIGHT 69

LAUNCHED 16:18 GMT
20 APRIL, 1953

TRAJECTORY FROM FILM DATA

M FRAME NUMBERS





LAUNCHED AT
U of M AIRPORT
MPLS. MINN.

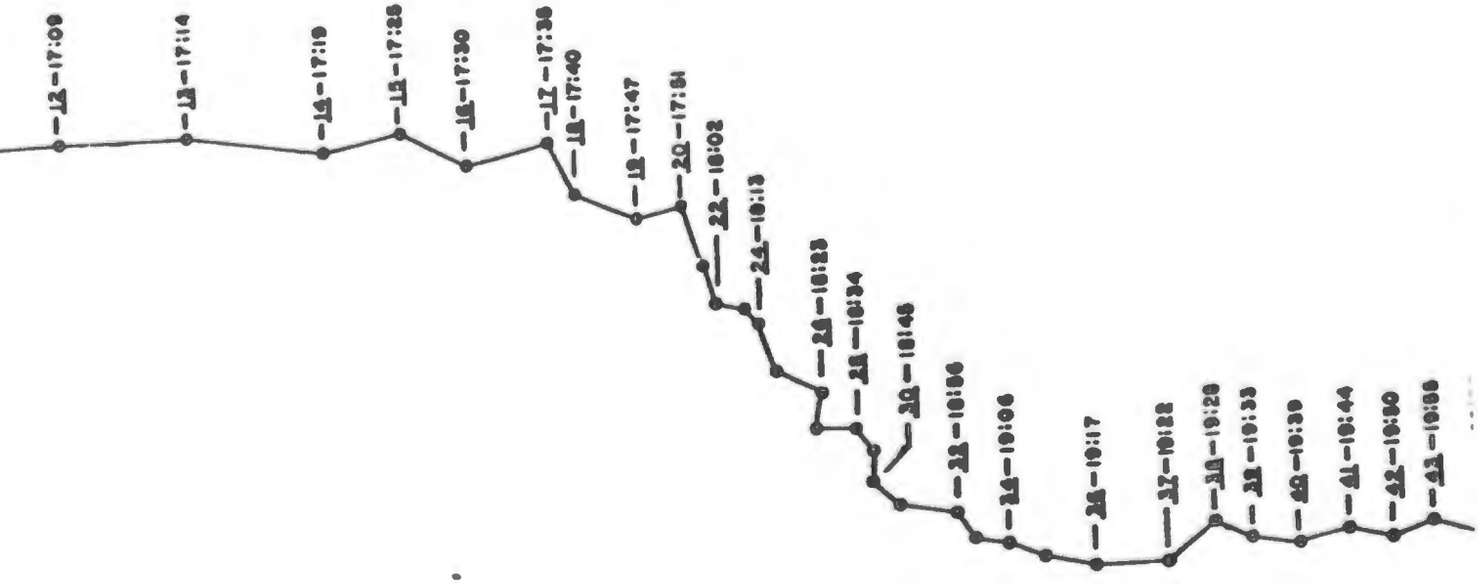
+ LAUNCH SITE LAT. 45° 07' LONG. 93° 10.5'

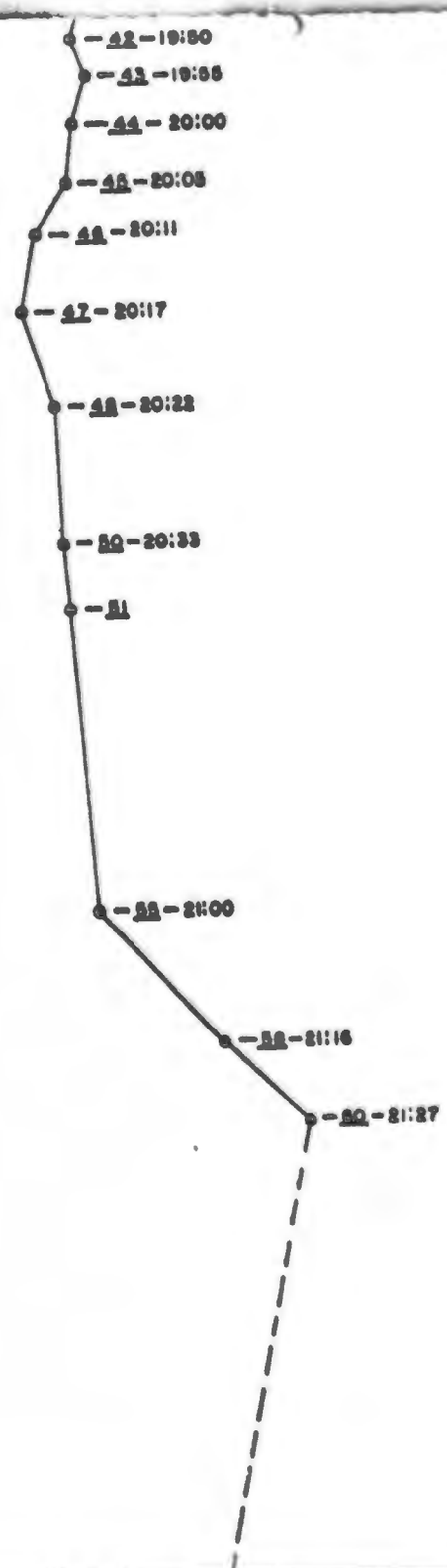
FLIGHT 69

LAUNCHED 16:18 G.M.T.
20 APRIL, 1953

TRAJECTORY FROM FILM DATA

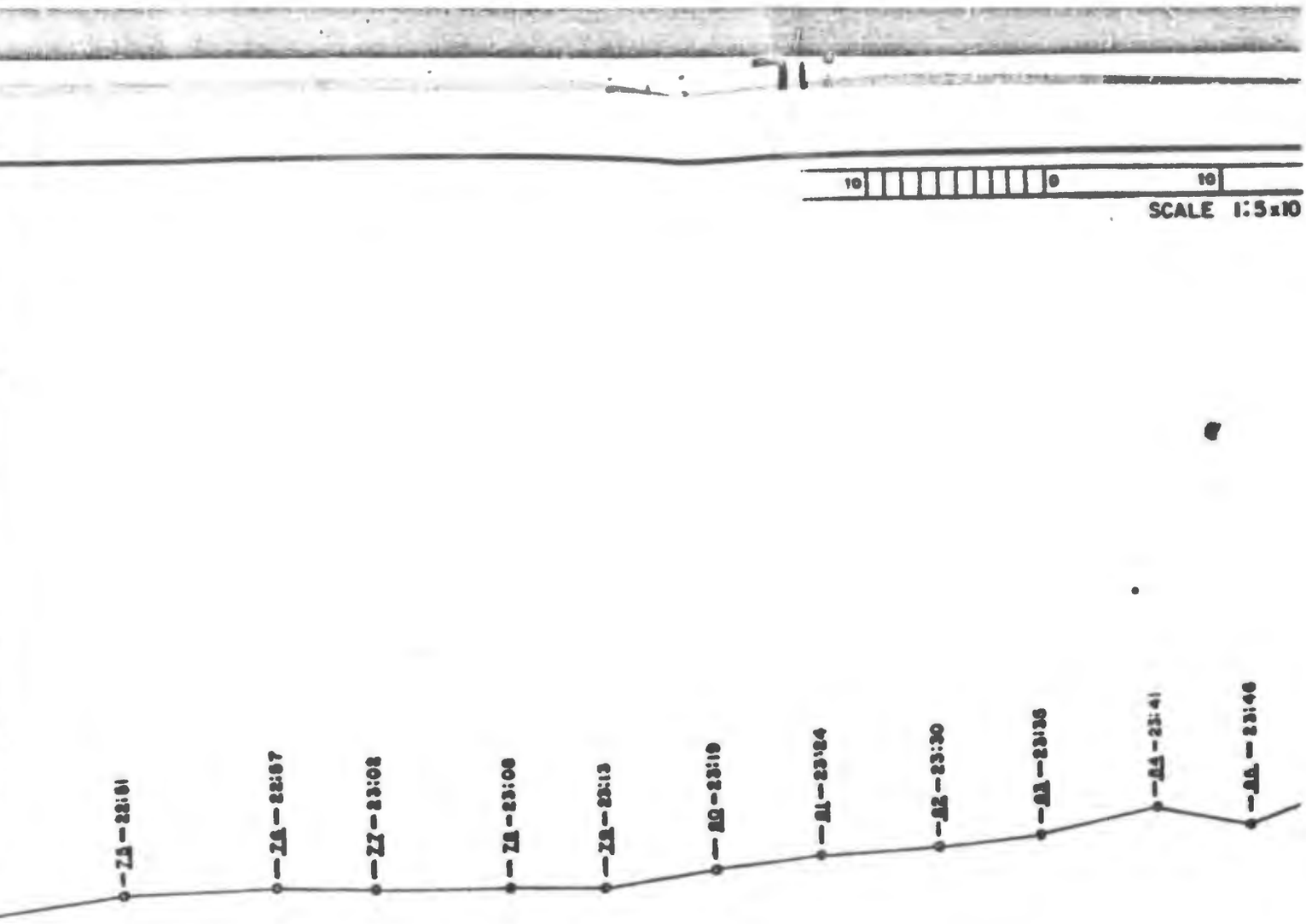
M FRAME NUMBERS



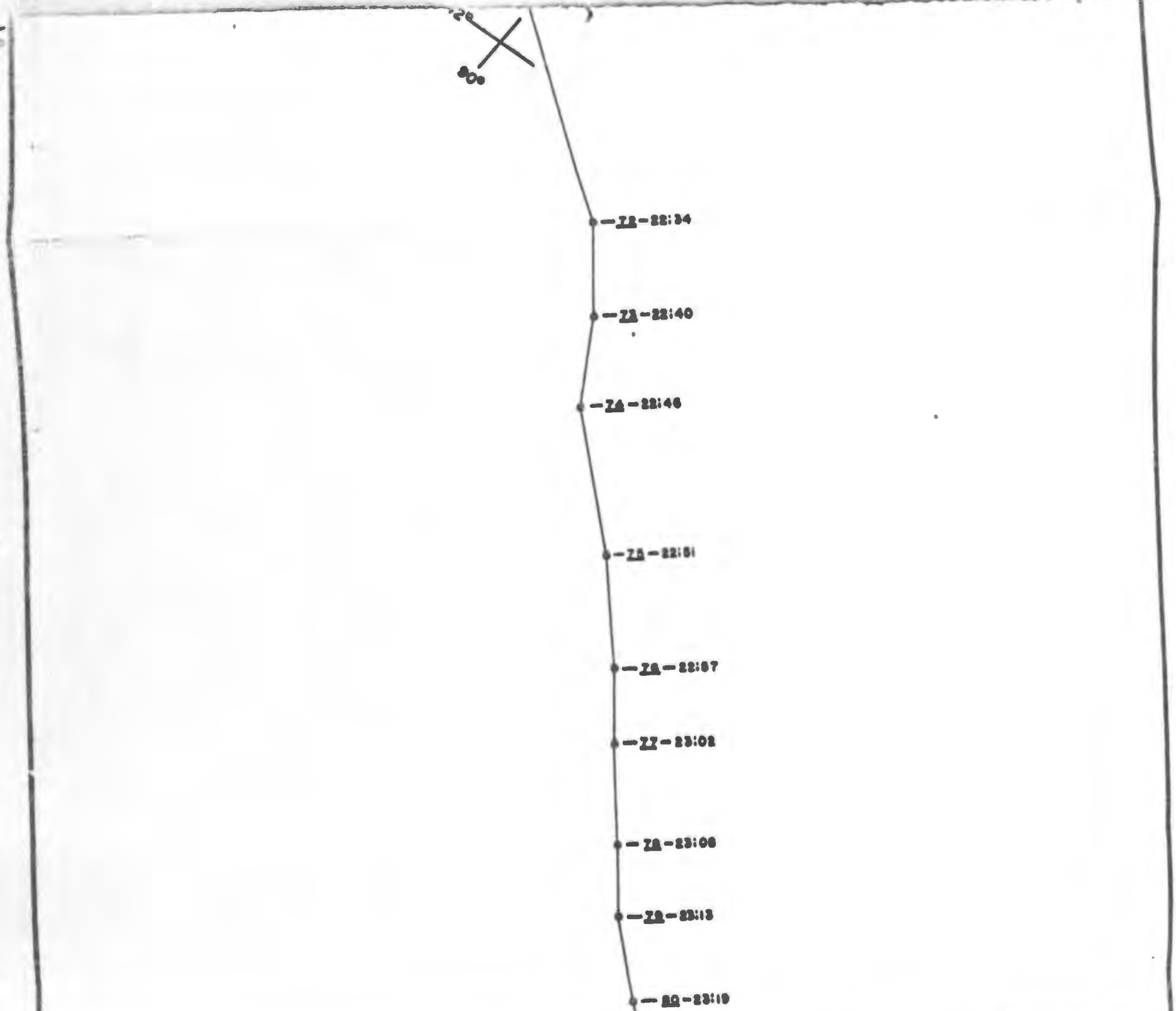

42 - 19:50
43 - 19:55
44 - 20:00
45 - 20:05
46 - 20:11
47 - 20:17
48 - 20:22
50 - 20:33
51
55 - 21:00
56 - 21:16
60 - 21:27

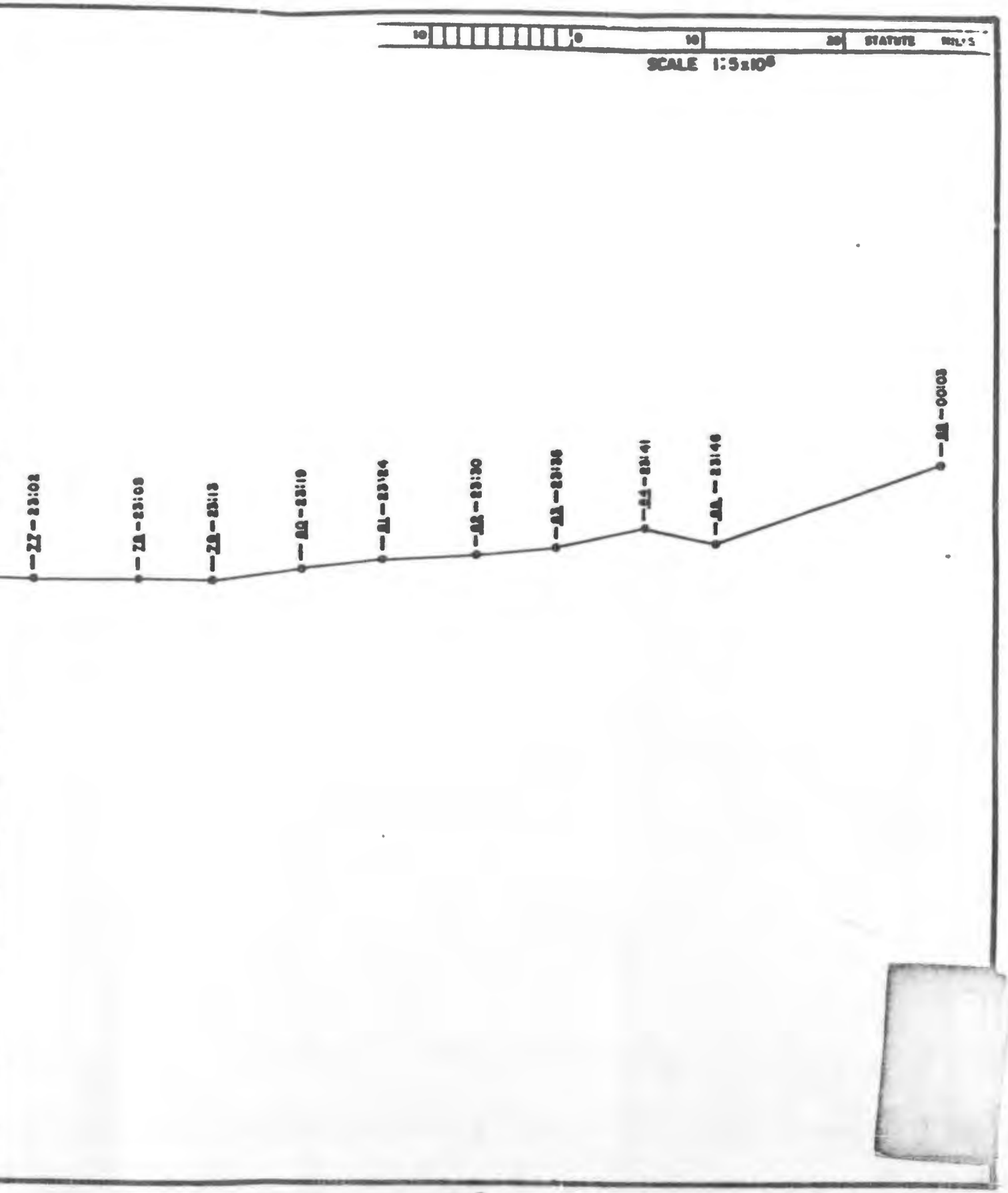
21:50
21:58
22:08
22:07

18 - 22:13
19 - 22:18
20 - 22:24
42°
40°
21 - 22:34
22 - 22:40
23 - 22:46
24 - 22:51
25 - 22:57
26 - 23:02


10
0
10
SCALE 1:5x10
Z5 — 22:01
Z6 — 22:07
Z7 — 22:02
Z8 — 22:08
Z9 — 22:13
Z10 — 22:19
Z11 — 22:24
Z12 — 22:30
Z13 — 22:35
Z14 — 22:41
Z15 — 22:46

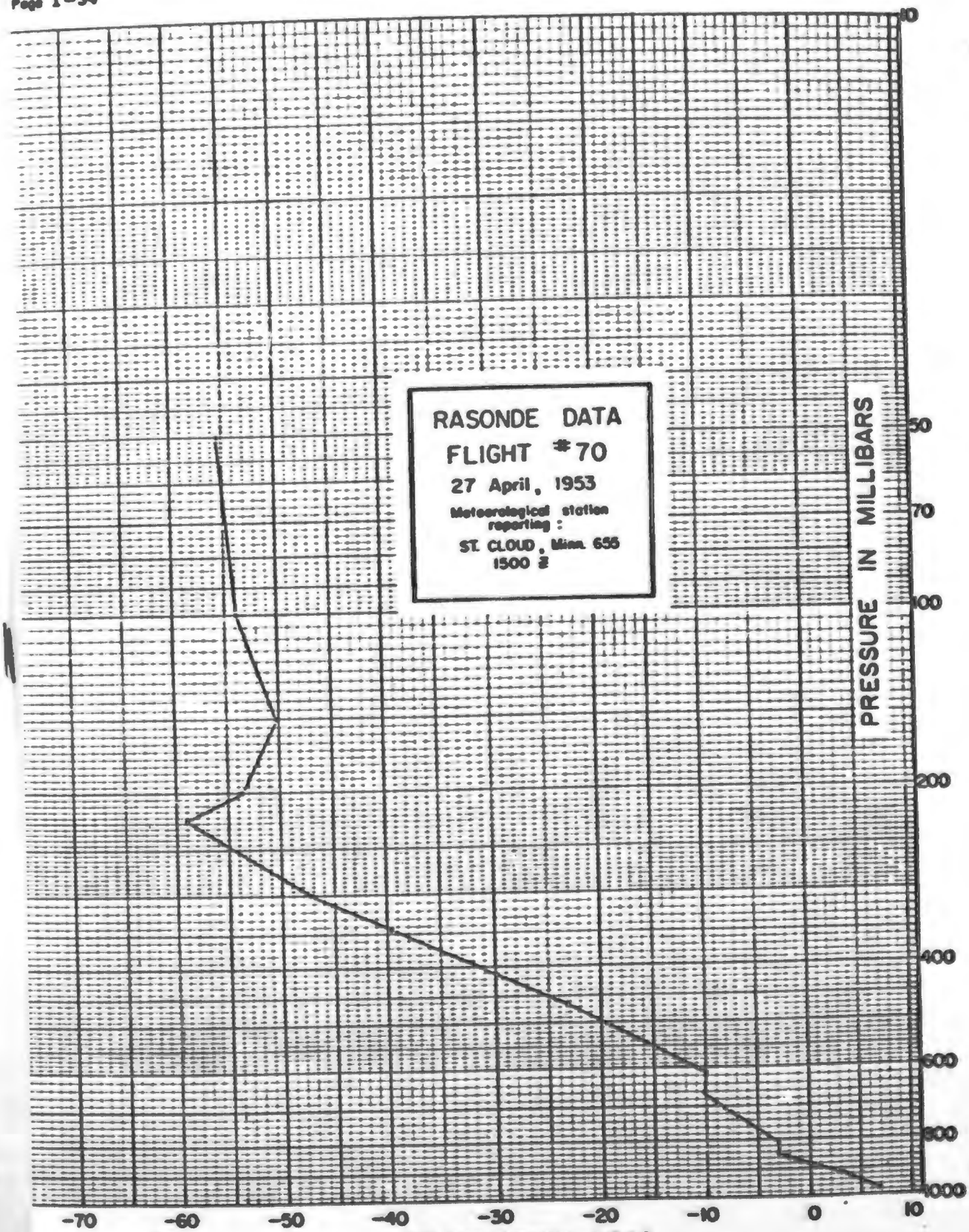
3


400
72-22:34
73-22:40
74-22:46
75-22:51
76-22:57
77-23:02
78-23:08
79-23:13
80-23:19

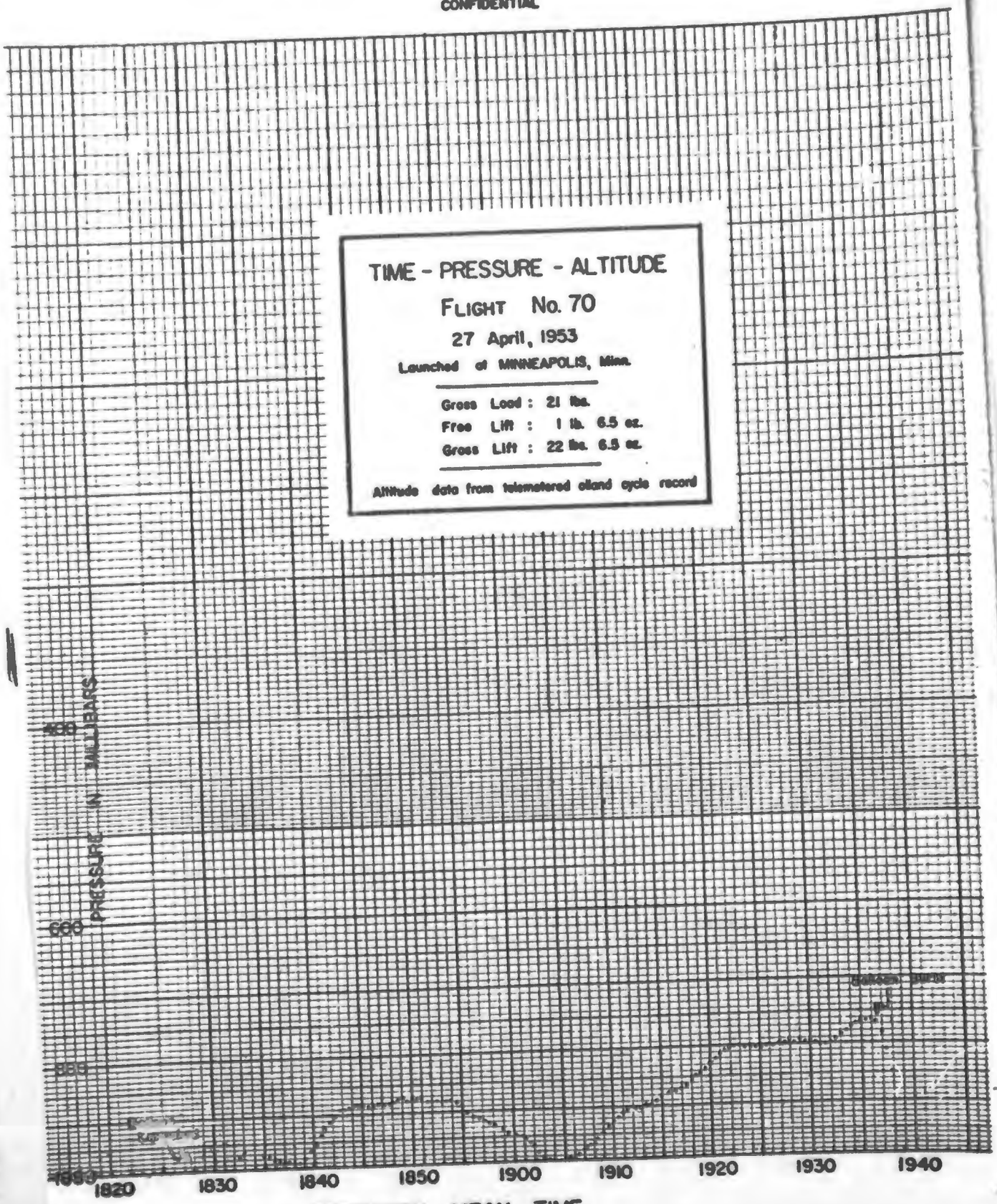

10
0
10
20
STATUTE MILES
SCALE 1:5x10^6
27 - 23:02
28 - 23:08
29 - 23:13
30 - 23:19
31 - 23:24
32 - 23:30
33 - 23:36
34 - 23:41
35 - 23:48
36 - 00:03

2

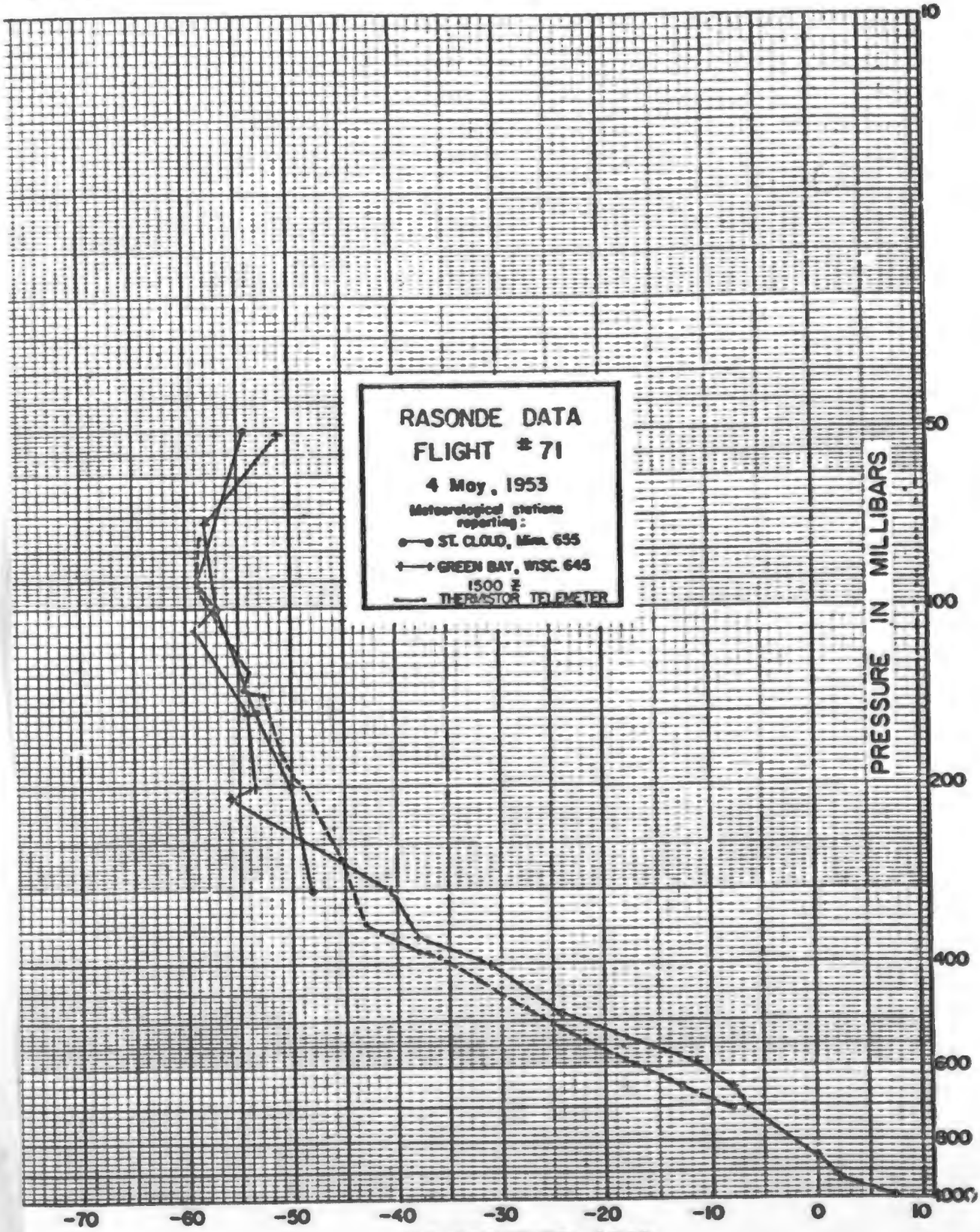
CONFIDENTIAL



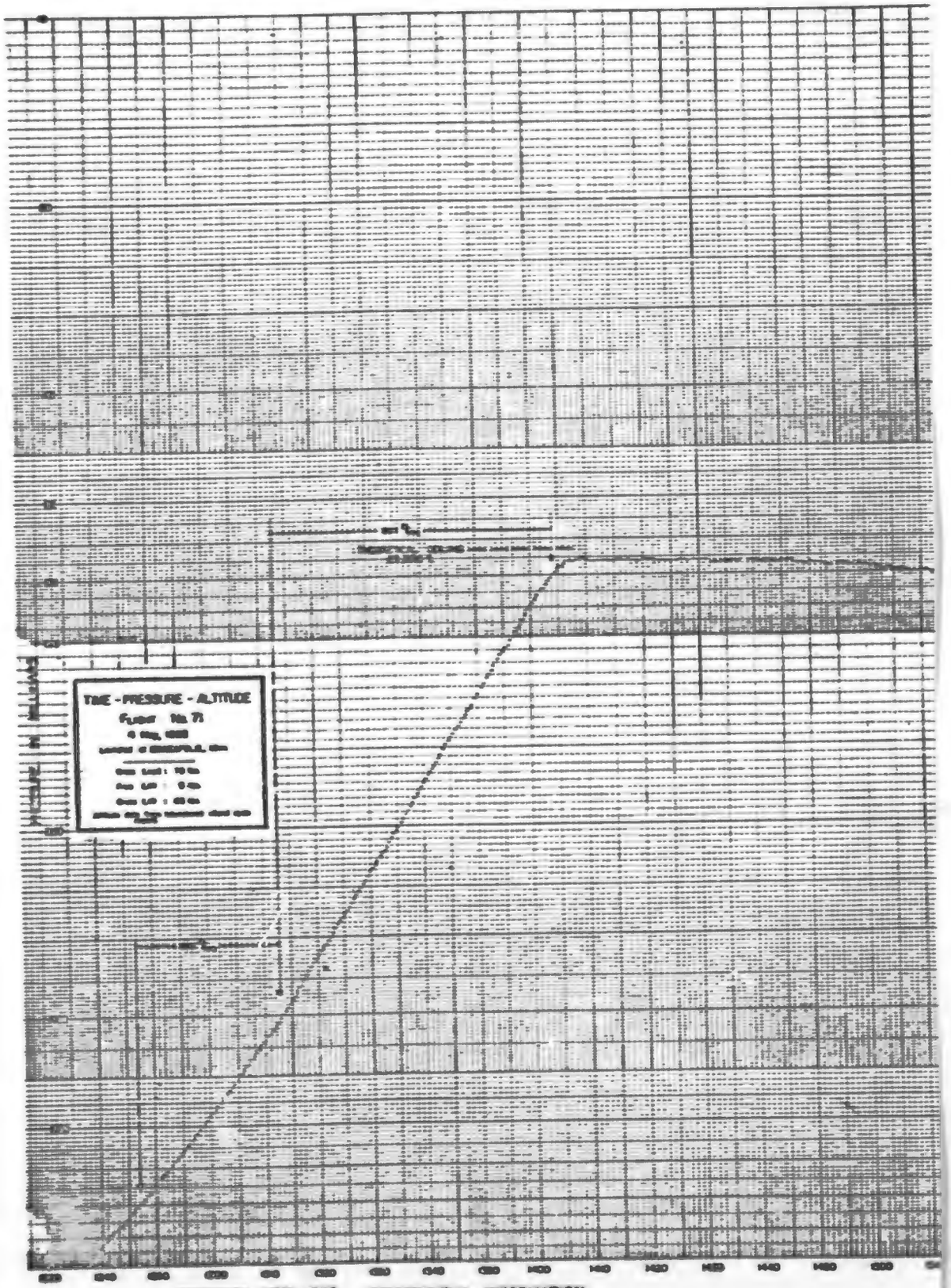
CONFIDENTIAL INFORMATION

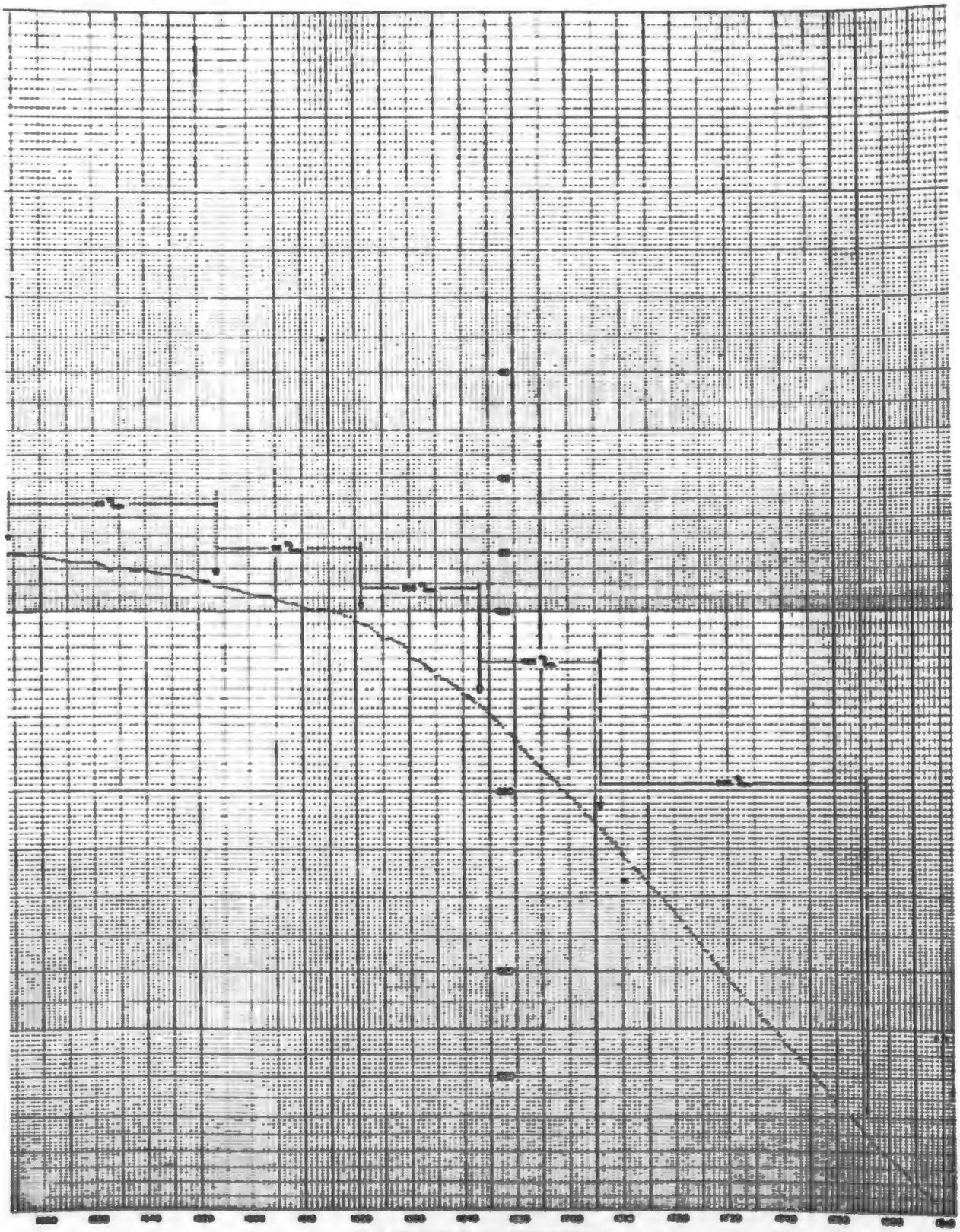

TIME - PRESSURE - ALTITUDE
FLIGHT No. 70
27 April, 1953
Launched at MINNEAPOLIS, Minn.
Gross Load : 21 lbs.
Free Lift : 1 lb. 6.5 oz.
Gross Lift : 22 lbs. 6.5 oz.
Altitude data from telemetered aneroid cycle record
PRESSURE IN MILLIBARS
400
600
800
1000
1820
1830
1840
1850
1900
1910
1920
1930
1940
GREENWICH MEAN TIME

CONFIDENTIAL

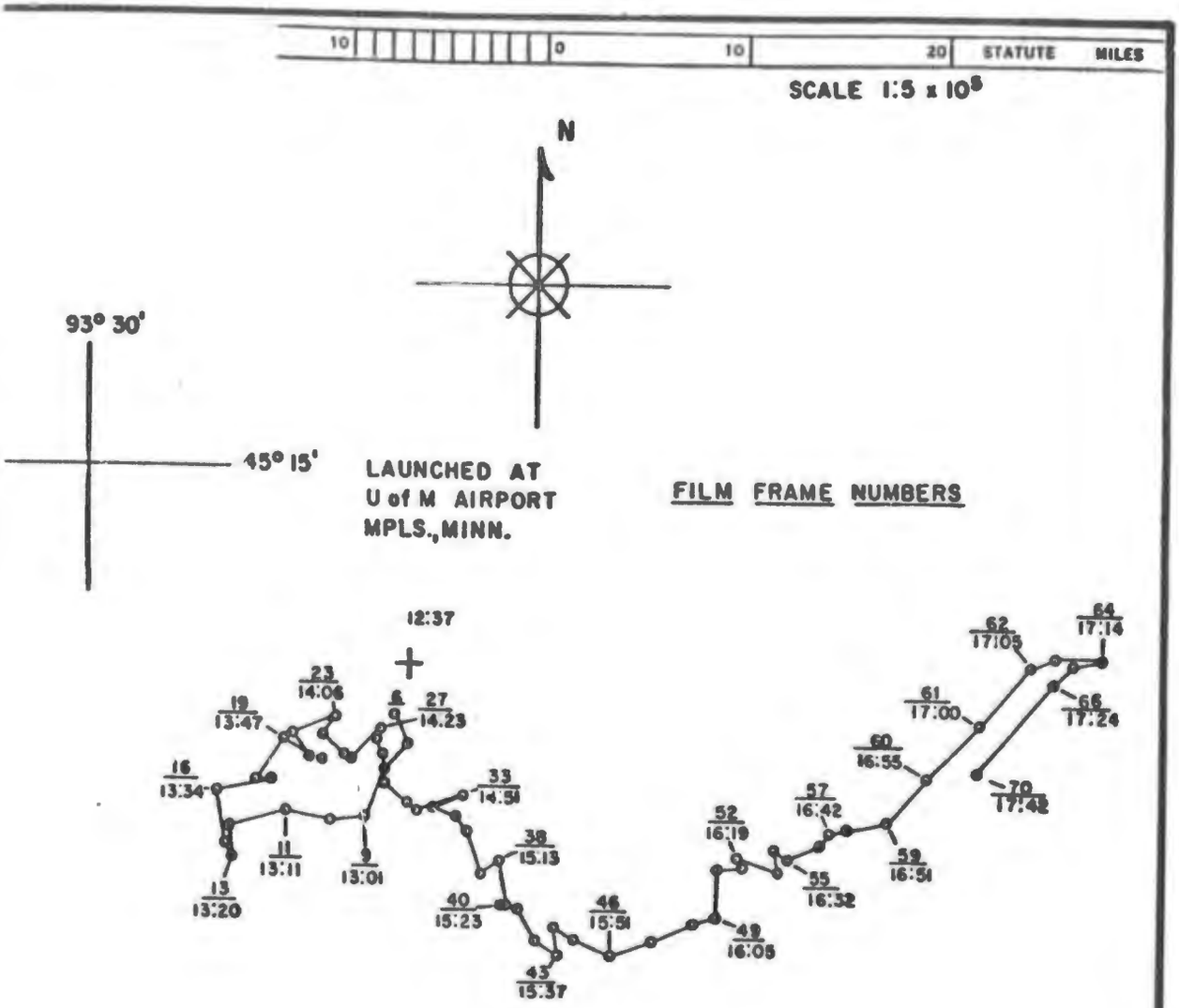


CONFIDENTIAL INFORMATION


TIME - PRESSURE - ALTITUDE
GREENWICH MEAN TIME



CONFIDENTIAL

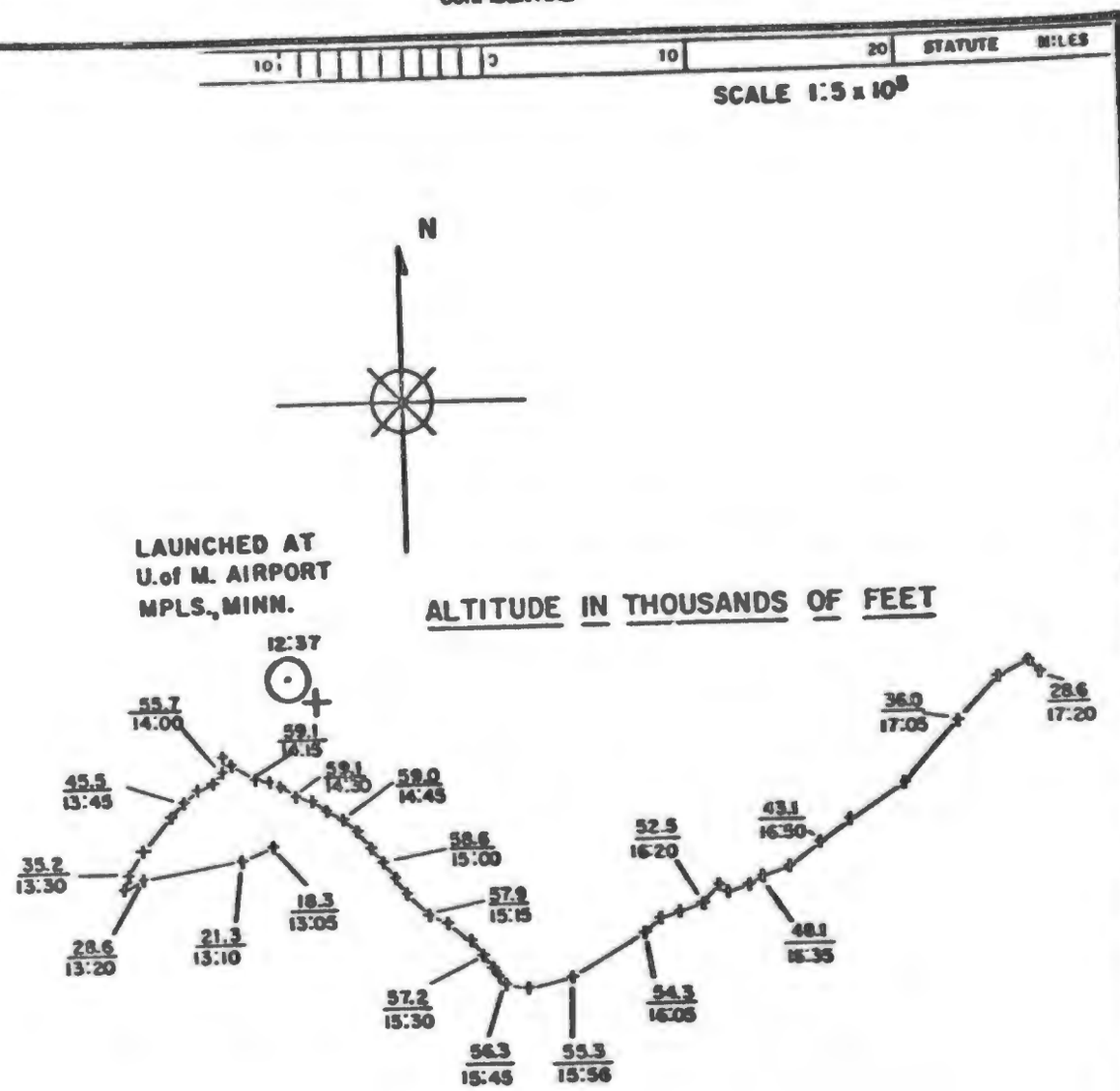


+ LAUNCH SITE LAT. 45° 07.'. LONG. 93° 10.5'

FLIGHT 71

LAUNCHED 12:37 G.M.T.
4 MAY, 1953

TRAJECTORY FROM FILM DATA



⊙ THEODOLITE SITE LAT. 45° 08' LONG. 93° 12.5'

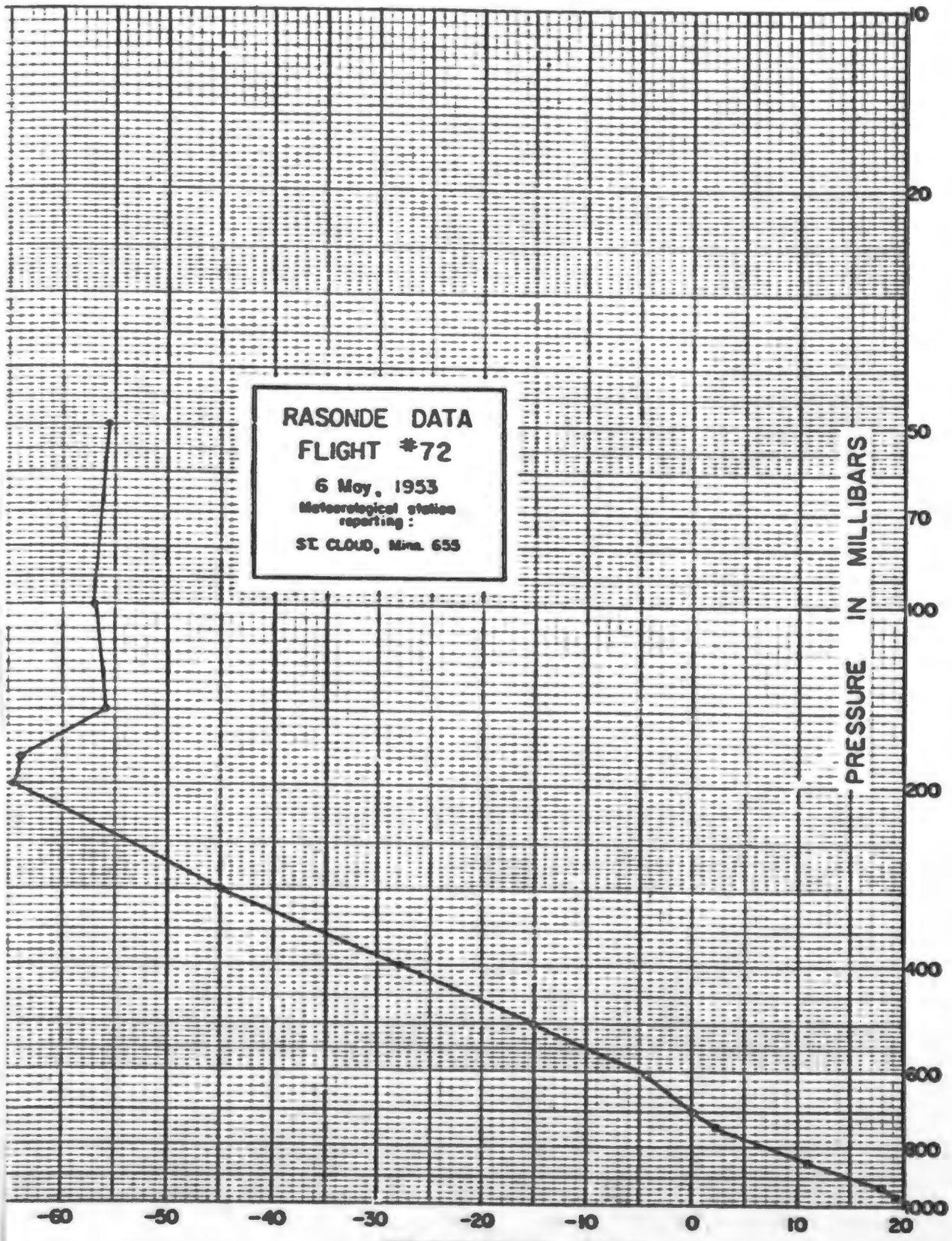
+ LAUNCH SITE LAT. 45°07' LONG. 93°10.5'

FLIGHT 71

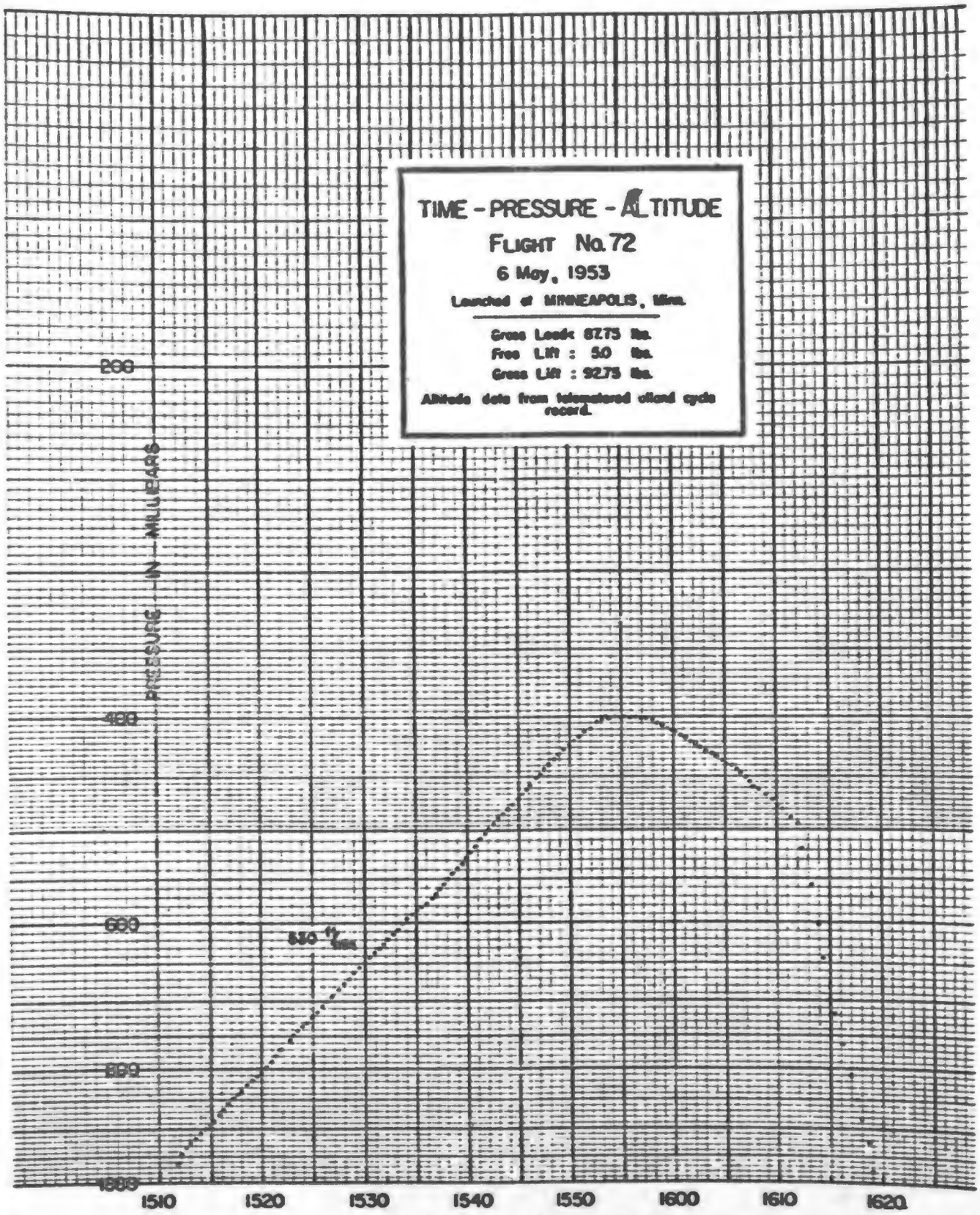
LAUNCHED 12:37 GMT.
4 MAY, 1953.

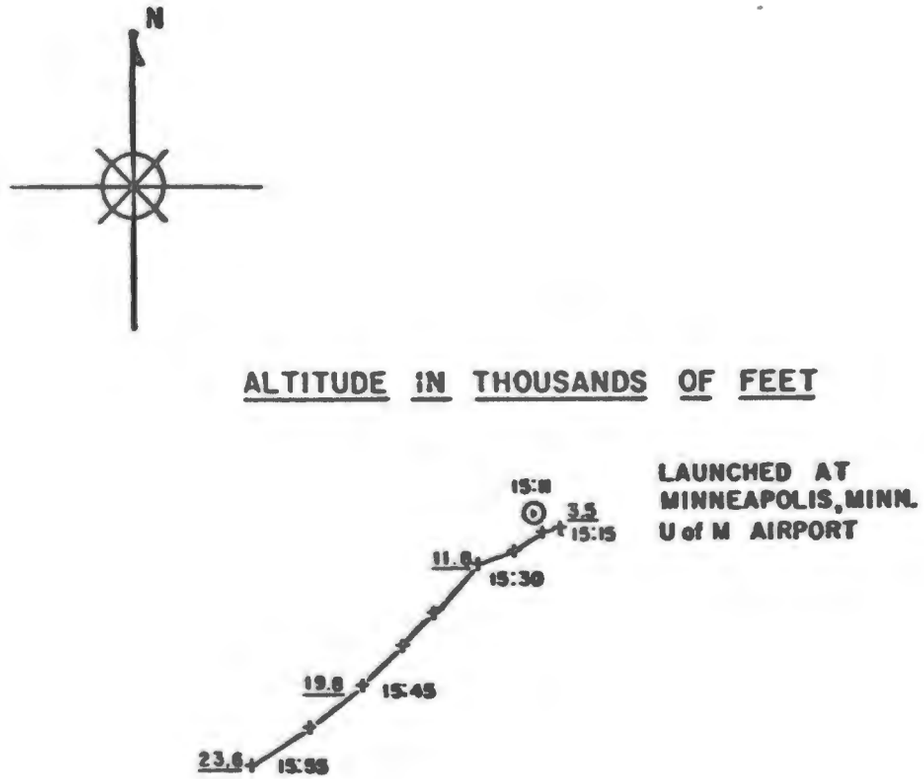
TRAJECTORY FROM THEODOLITE

CONFIDENTIAL



CONFIDENTIAL INFORMATION


TIME - PRESSURE - ALTITUDE
FLIGHT No. 72
6 May, 1953
Launched at MINNEAPOLIS, Minn.
Gross Load: 87.75 lbs.
Free Lift : 5.0 lbs.
Gross Lift : 92.75 lbs.
Altitude data from telemetered ofland cycle record.
PRESSURE - IN - MILLIBARS
200
400
600
800
1000
530 ft/min
1510
1520
1530
1540
1550
1600
1610
1620
GREENWICH MEAN TIME.

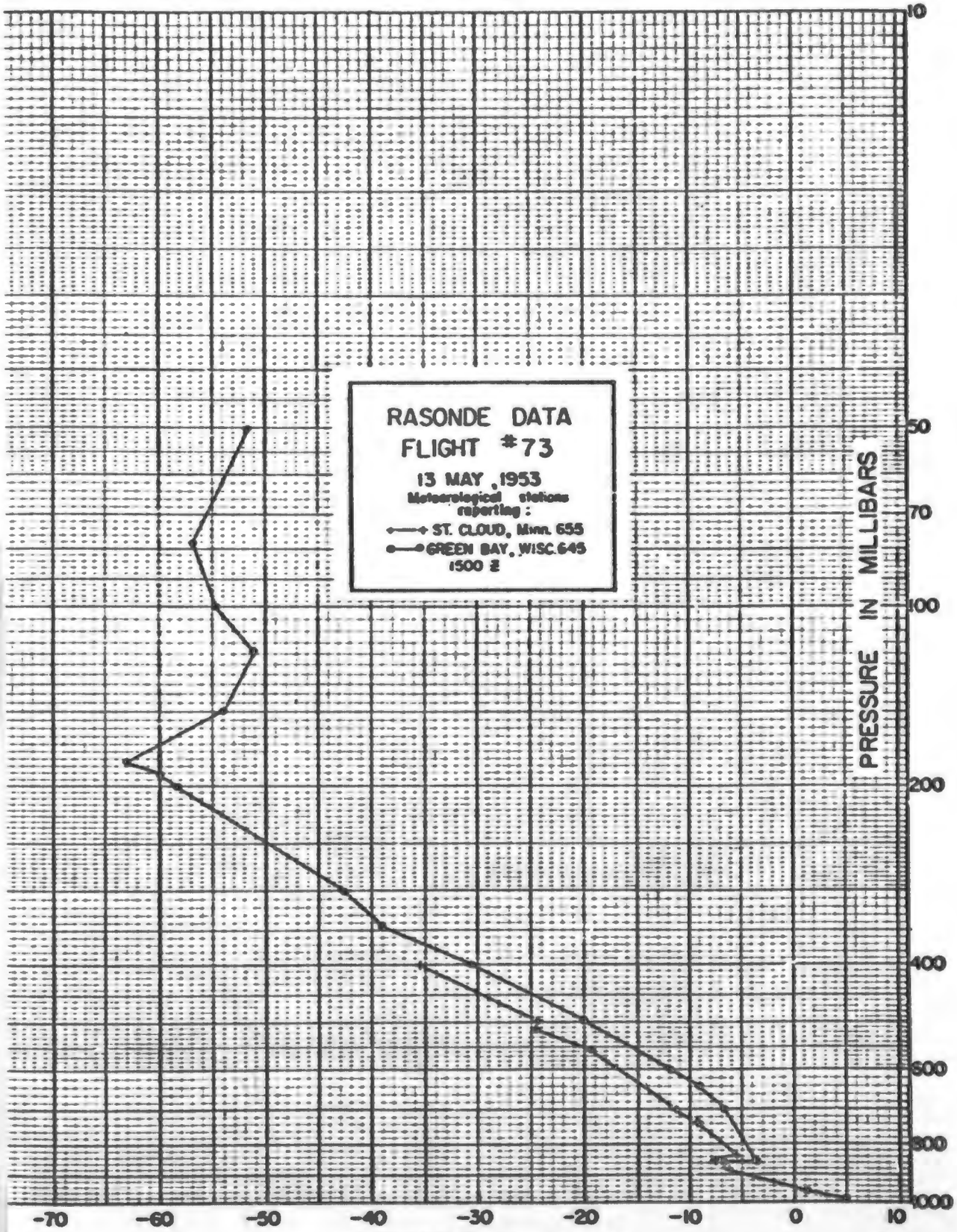


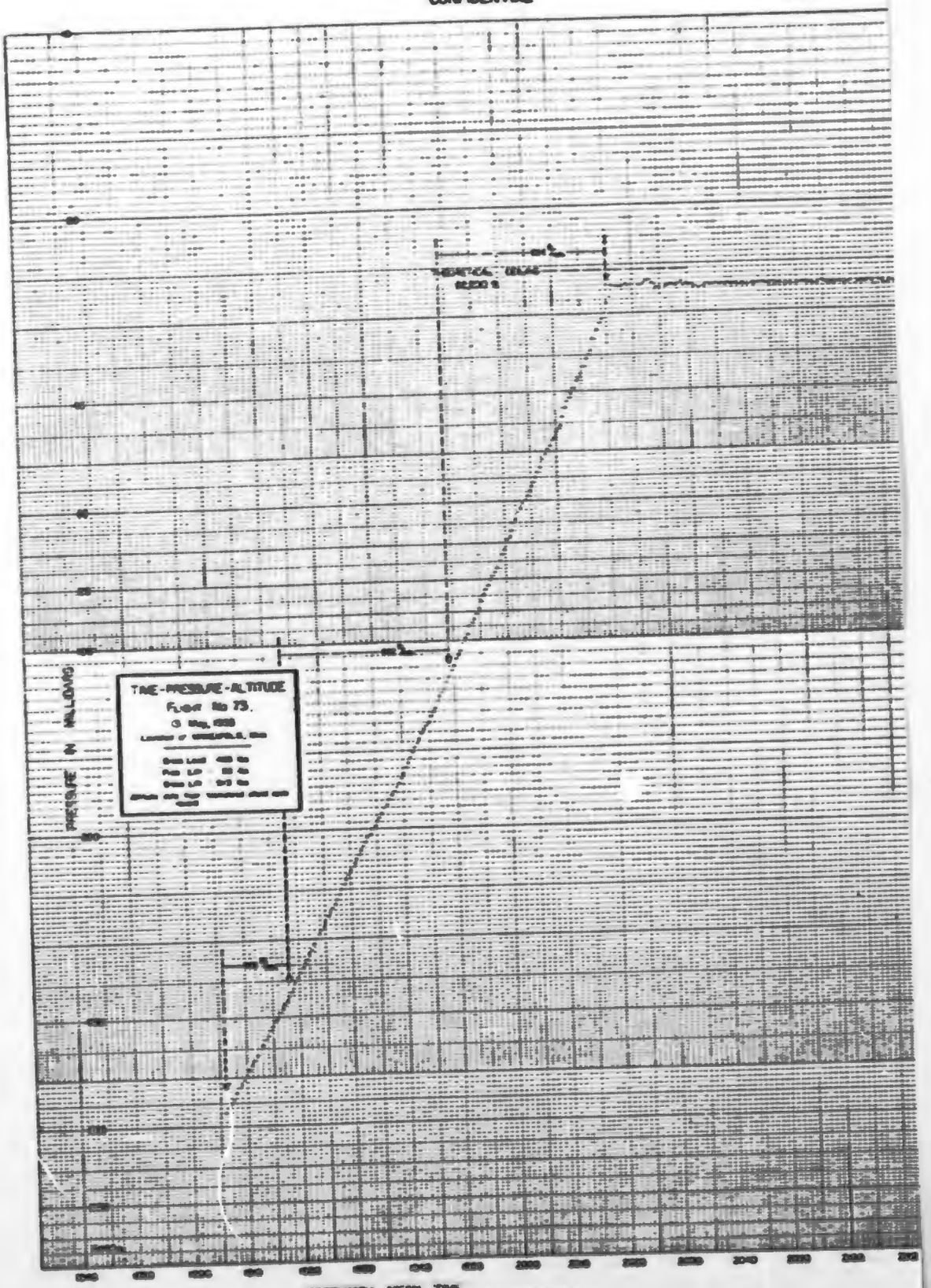
⊙ THEODOLITE SITE LAT. 45° 06' LONG. 93° 12.5'

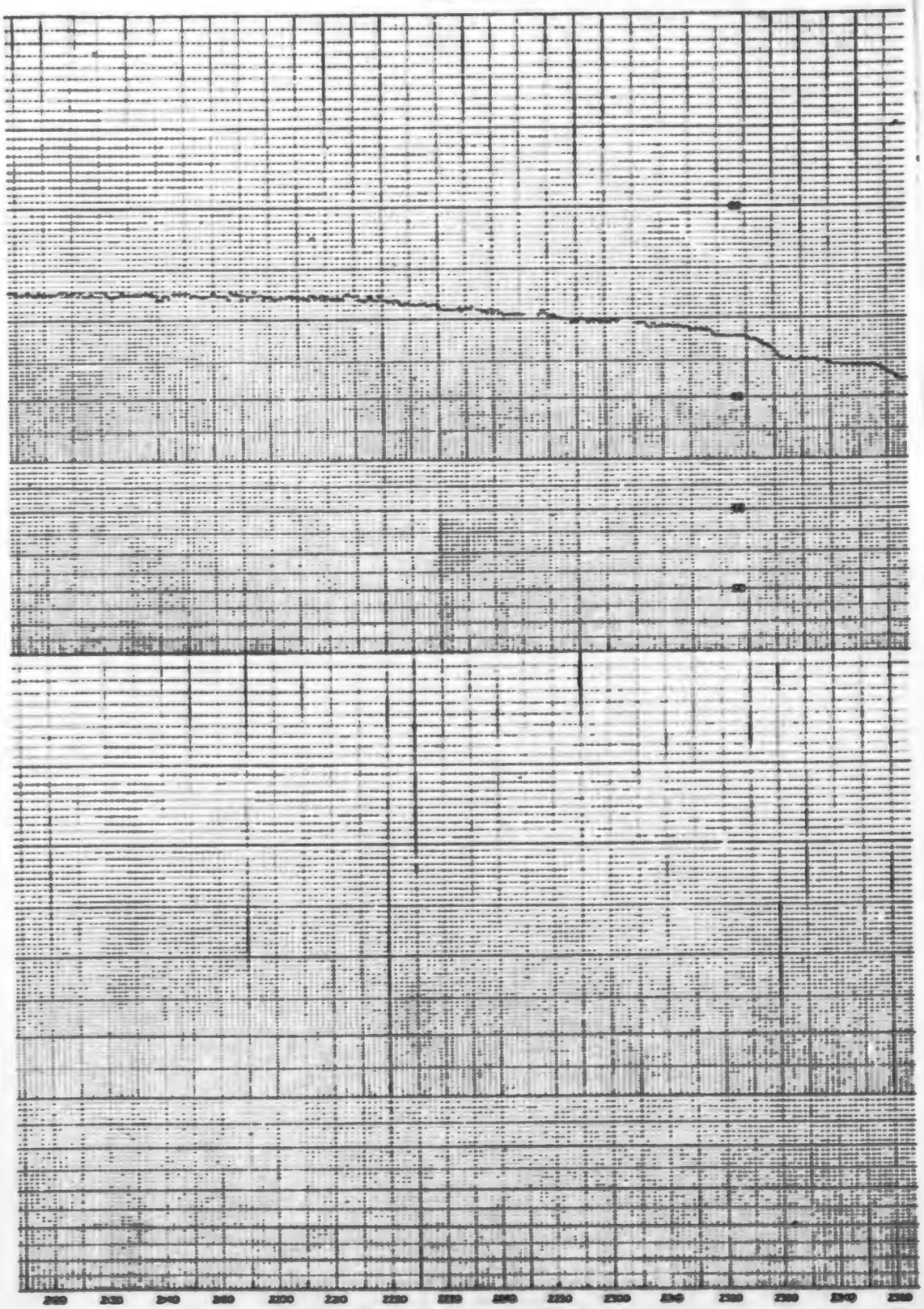
FLIGHT 72

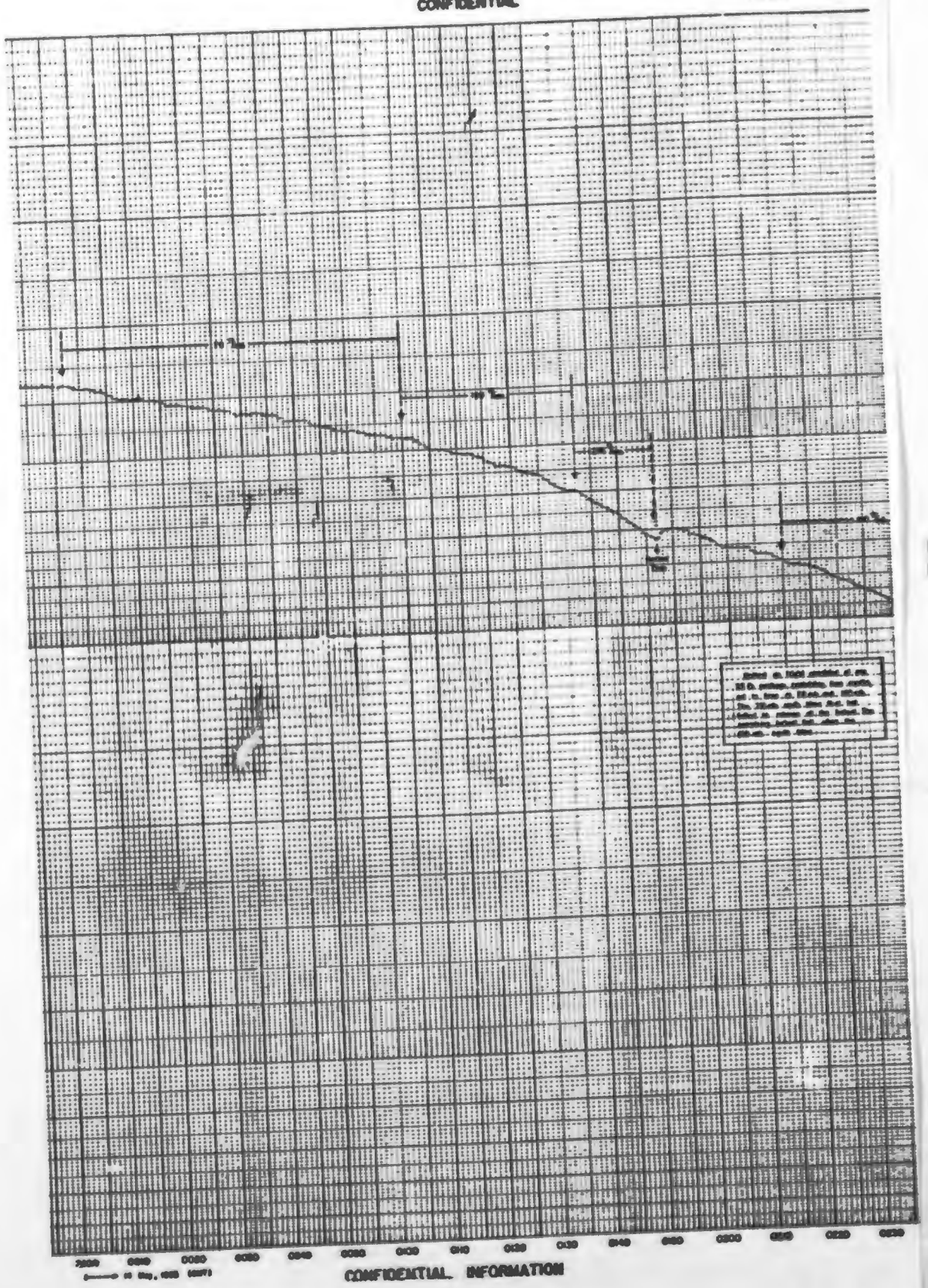
LAUNCHED 15:11 G.M.T.
6 MAY, 1953

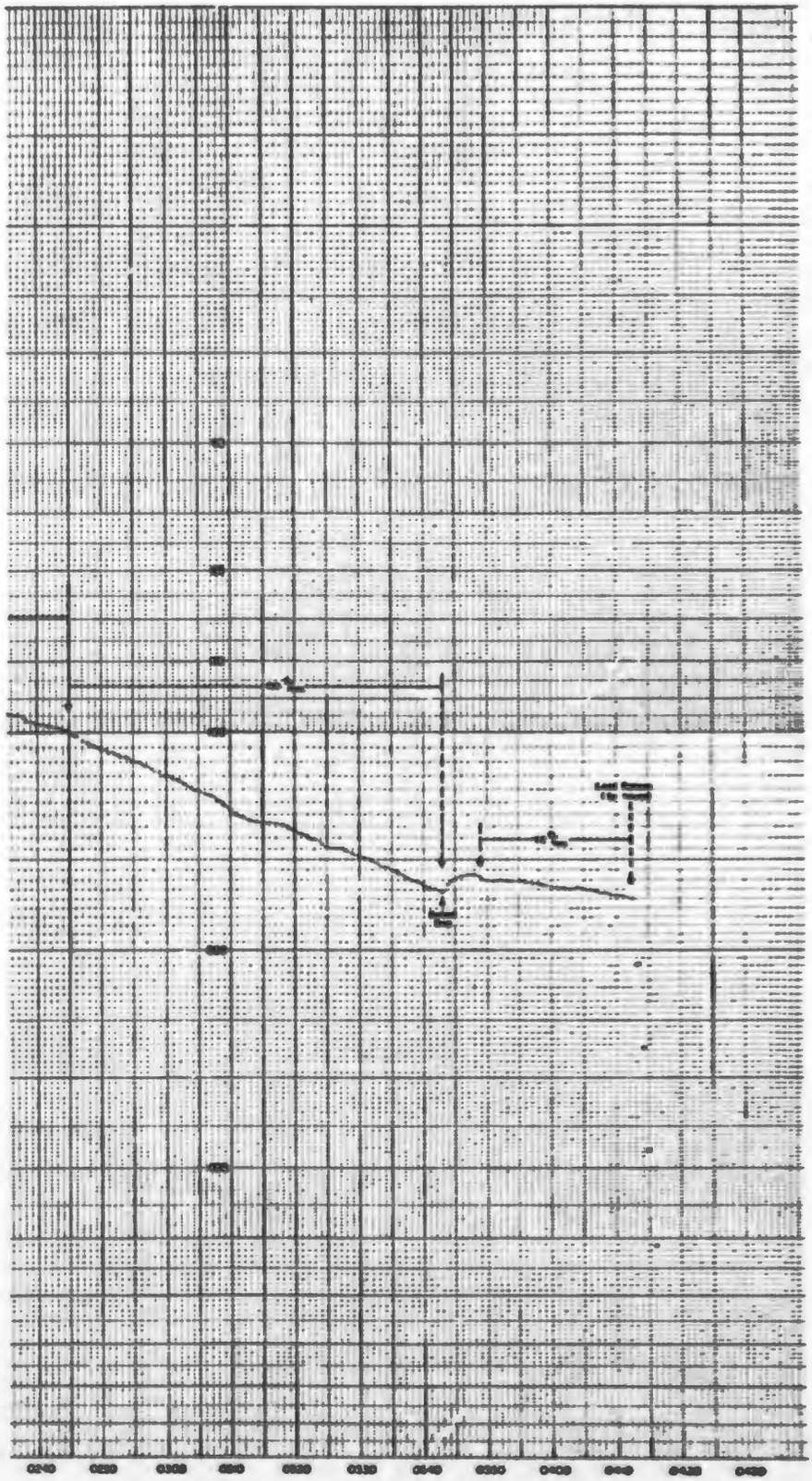
TRAJECTORY FROM THEODOLITE

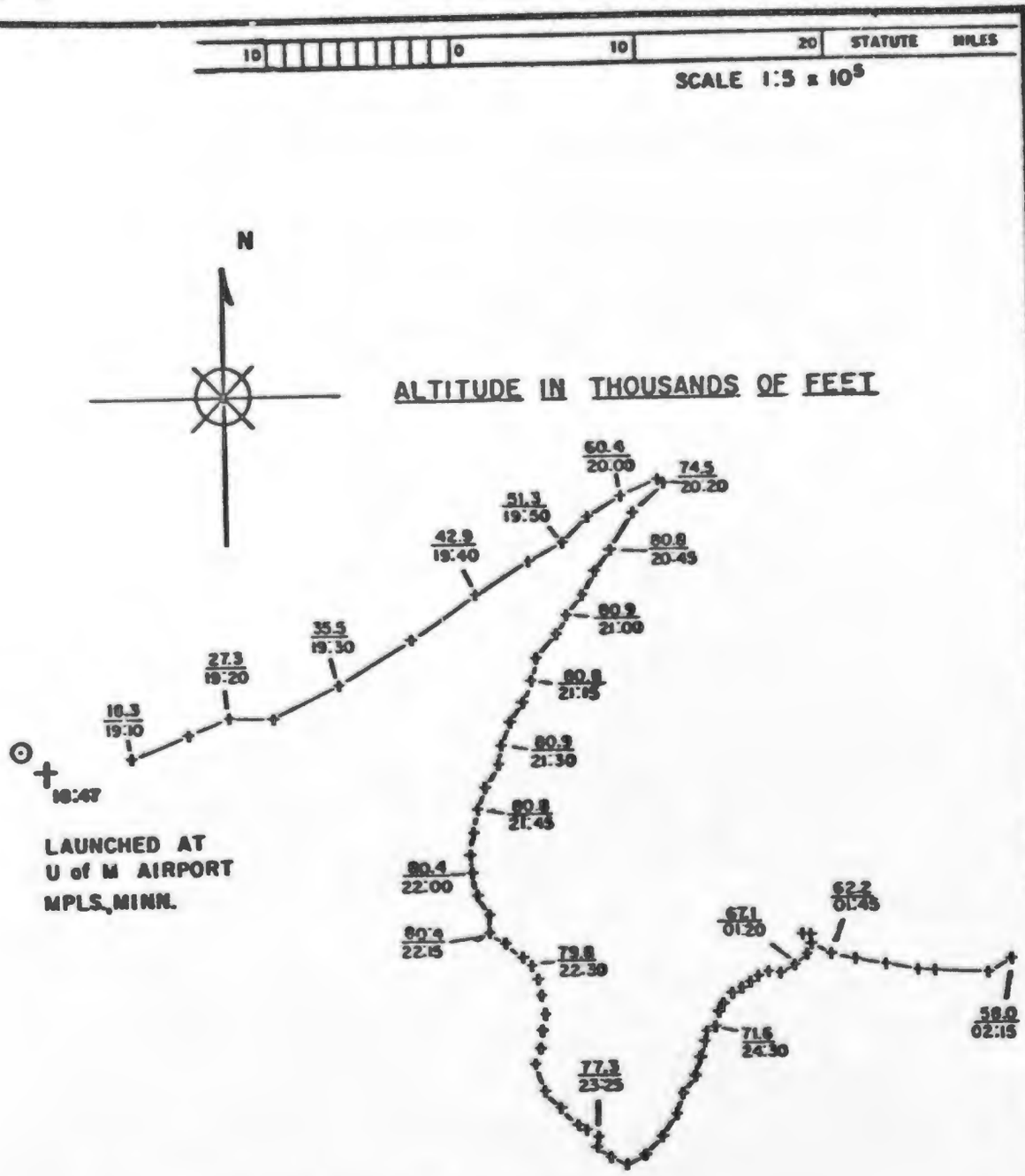

RASONDE DATA
FLIGHT #73
13 MAY, 1953
Meteorological stations reporting:
ST. CLOUD, Minn. 655
GREEN BAY, WISC. 645
1500 Z
PRESSURE IN MILLIBARS
10
50
70
100
200
400
600
800
1000
-70
-60
-50
-40
-30
-20
-10
0
10
TEMPERATURE (°C)


TIME-PRESSURE-ALTITUDE
PRESSURE IN MILLIBARS
GREENWICH MEAN TIME









⊙ THEODOLITE SITE LAT. 45° 08' LONG. 93° 12.5'

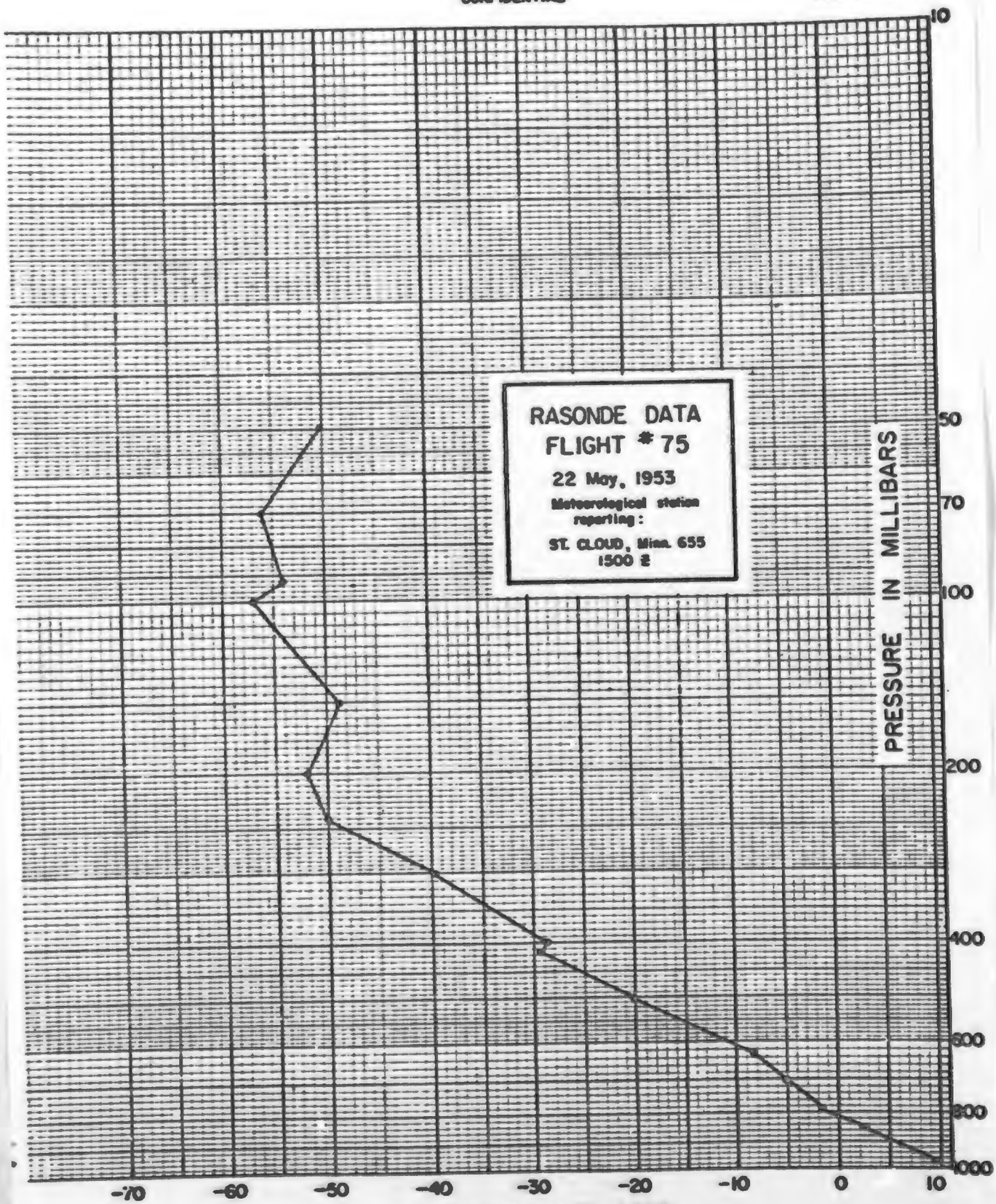
+ LAUNCH SITE LAT. 45° 07' LONG. 93° 10.5'

FLIGHT 73

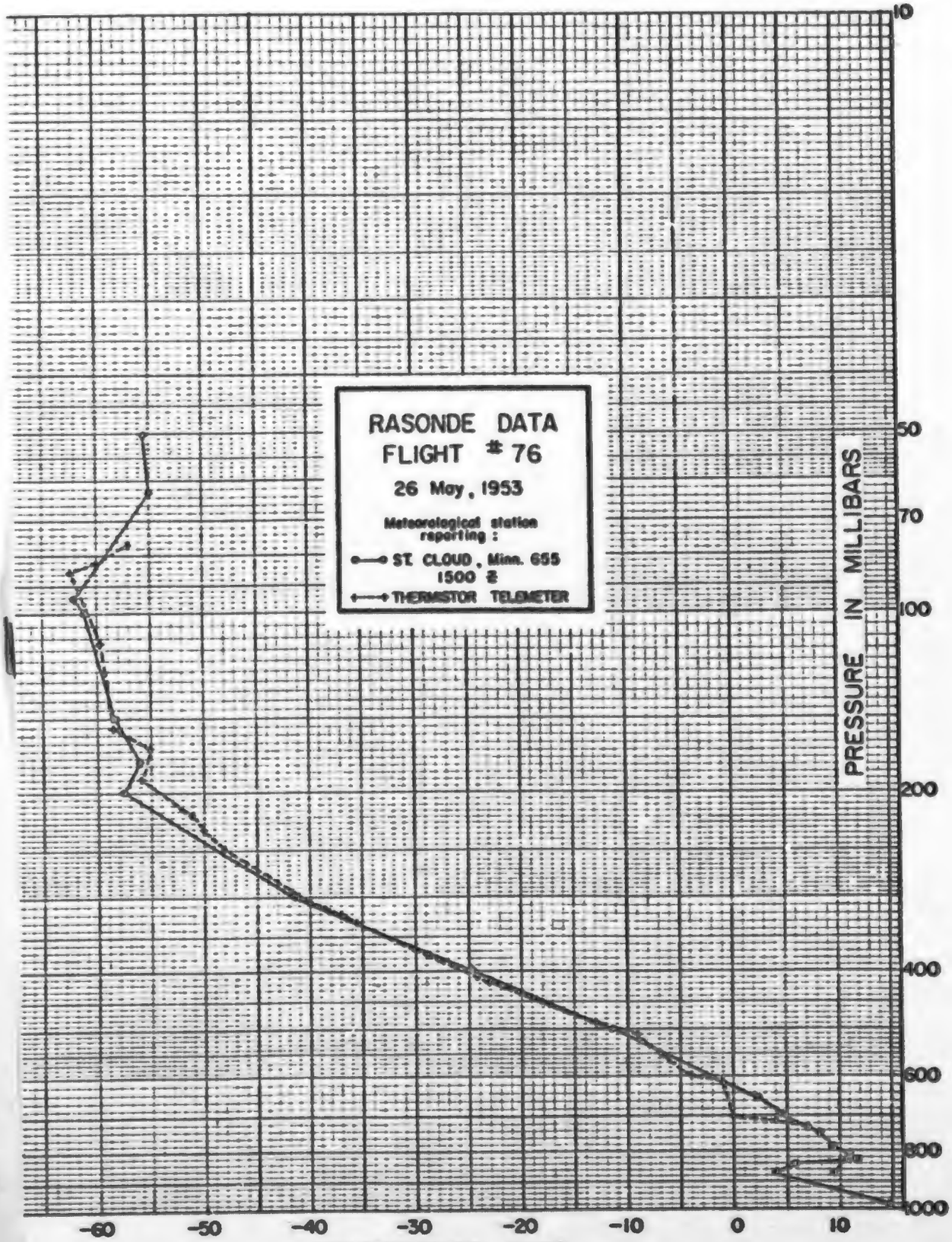
LAUNCHED 1847 G.M.T.

13 MAY, 1953

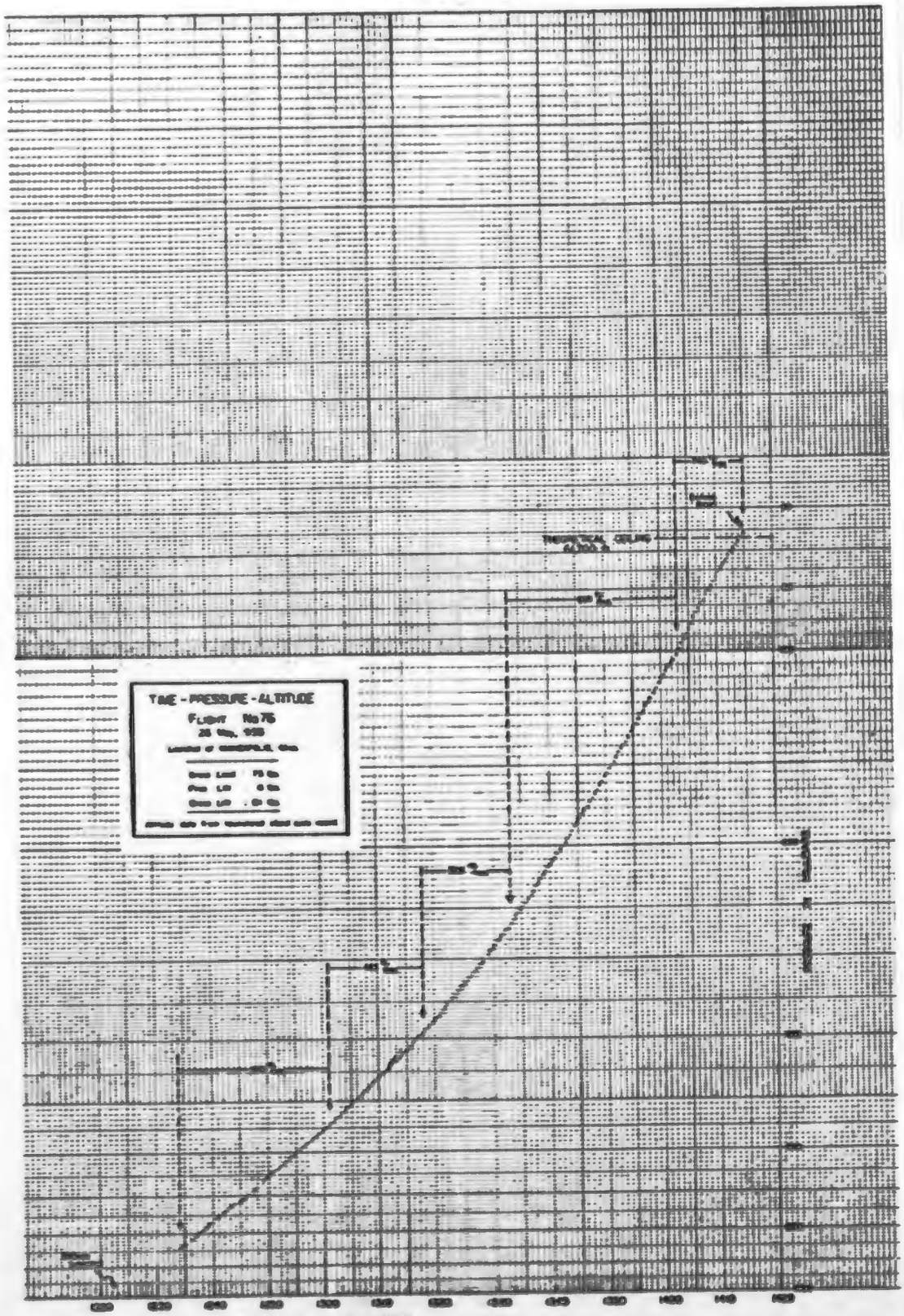
TRAJECTORY FROM THEODOLITE


RASONDE DATA
FLIGHT # 75
22 May, 1953
Meteorological station reporting:
ST. CLOUD, Minn. 655
1500 Z
PRESSURE IN MILLIBARS
10
50
70
100
200
400
600
800
1000
-70
-60
-50
-40
-30
-20
-10
0
10
TEMPERATURE (°C)

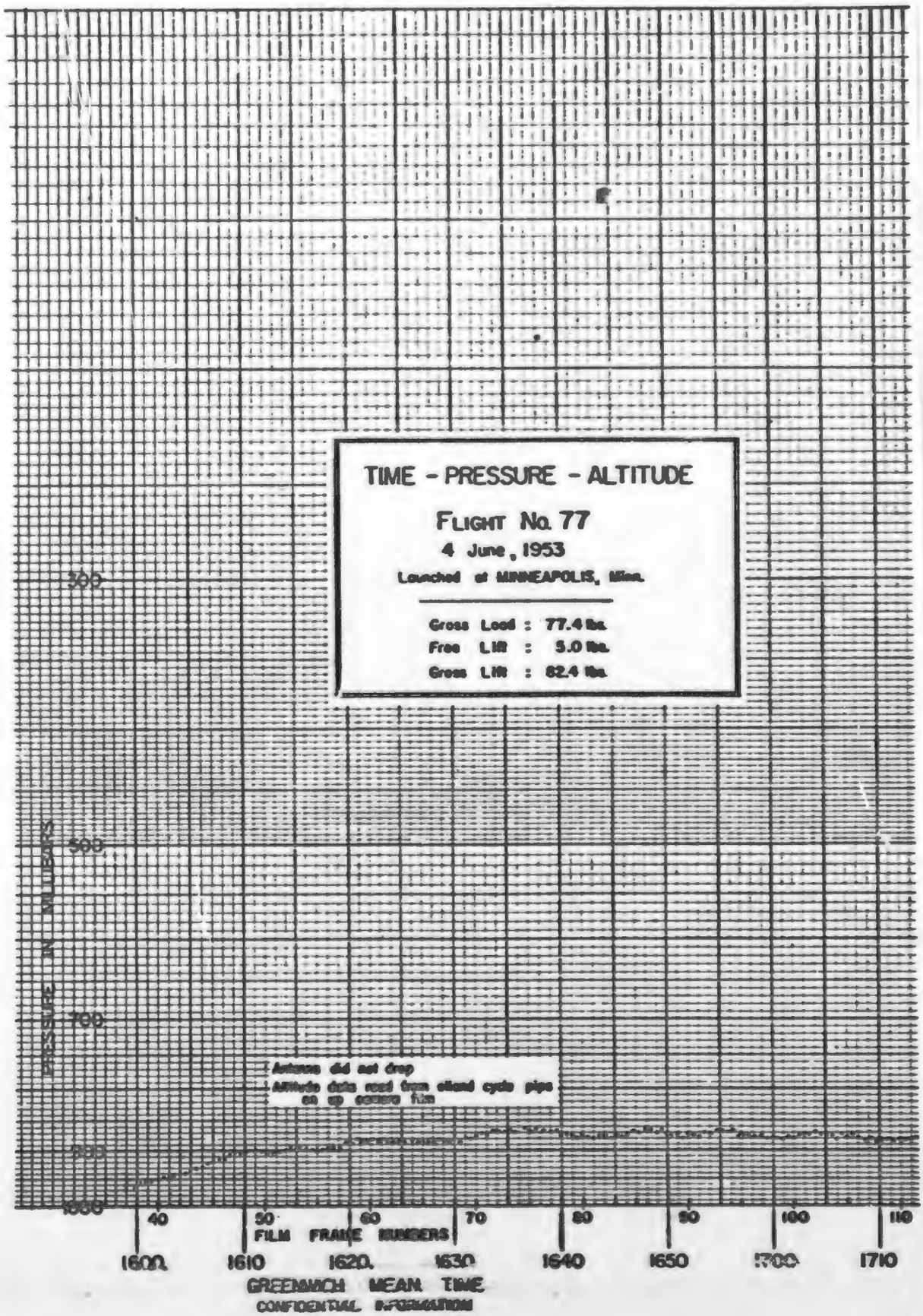
CONFIDENTIAL



CONFIDENTIAL INFORMATION



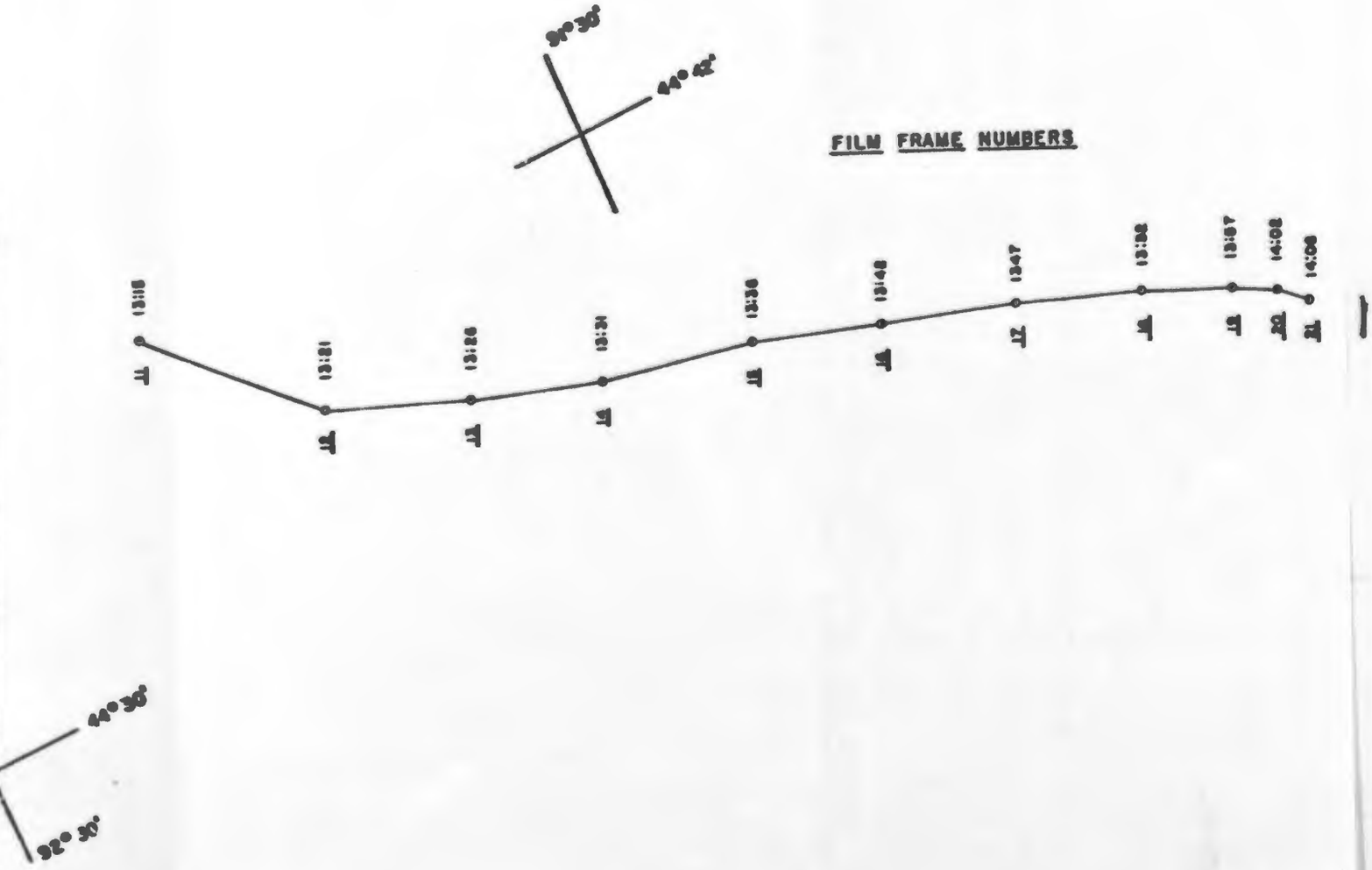
GREENWICH MEAN TIME

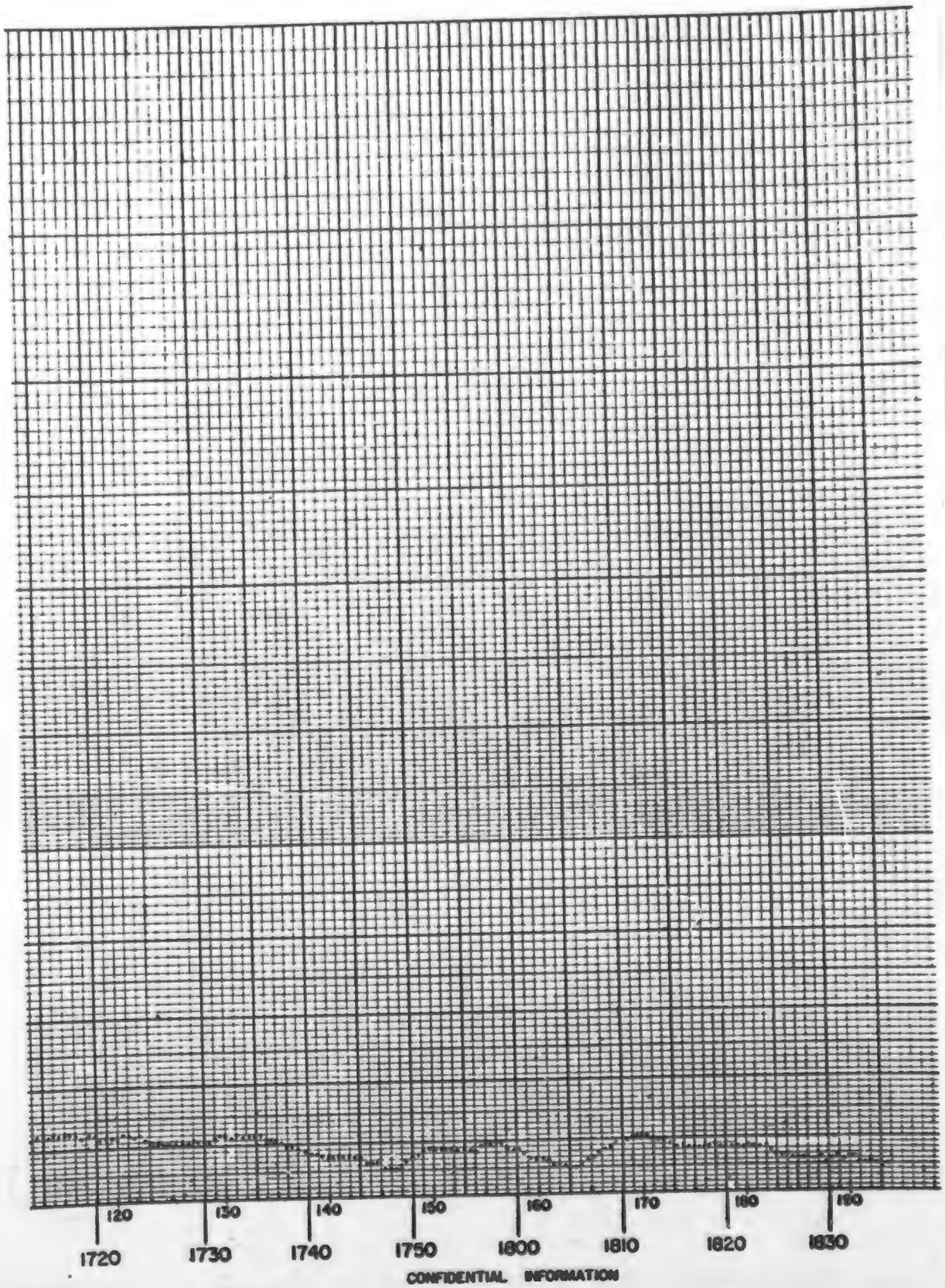

TIME - PRESSURE - ALTITUDE
FLIGHT No. 77
4 June, 1953
Launched at MINNEAPOLIS, Minn.
Gross Load : 77.4 lbs.
Free Lift : 5.0 lbs.
Gross Lift : 82.4 lbs.
PRESSURE IN MILLIBARS
300
500
700
900
1000
Antenna did not drop
Altitude data read from chard cycle pipe on up camera film
40
50
60
70
80
90
100
110
FILM FRAME NUMBERS
1600
1610
1620
1630
1640
1650
1700
1710
GREENWICH MEAN TIME

FLIGHT 76

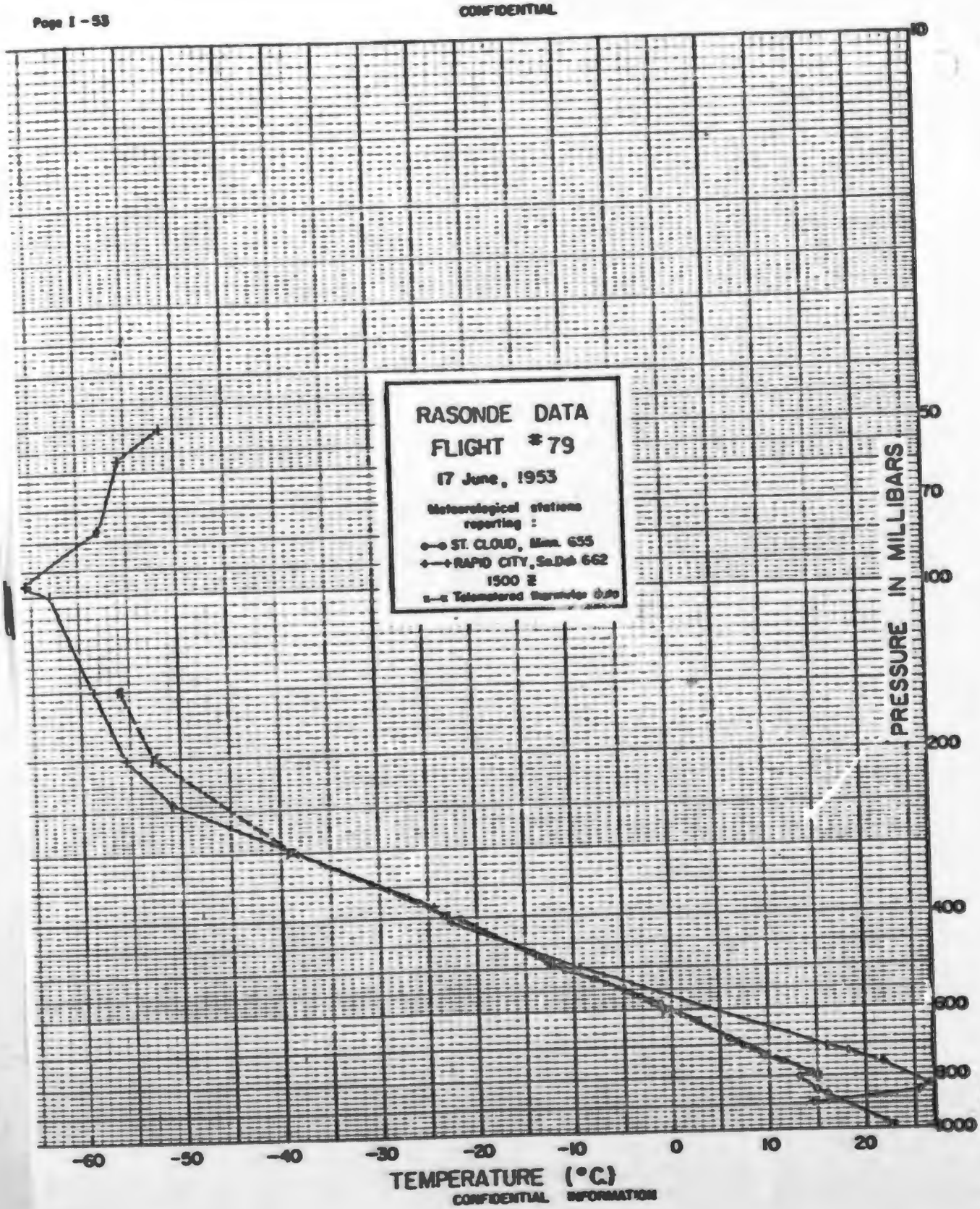
LAUNCHED 12:23 G.M.T.
26 MAY, 1953

TRAJECTORY FROM FILM DATA

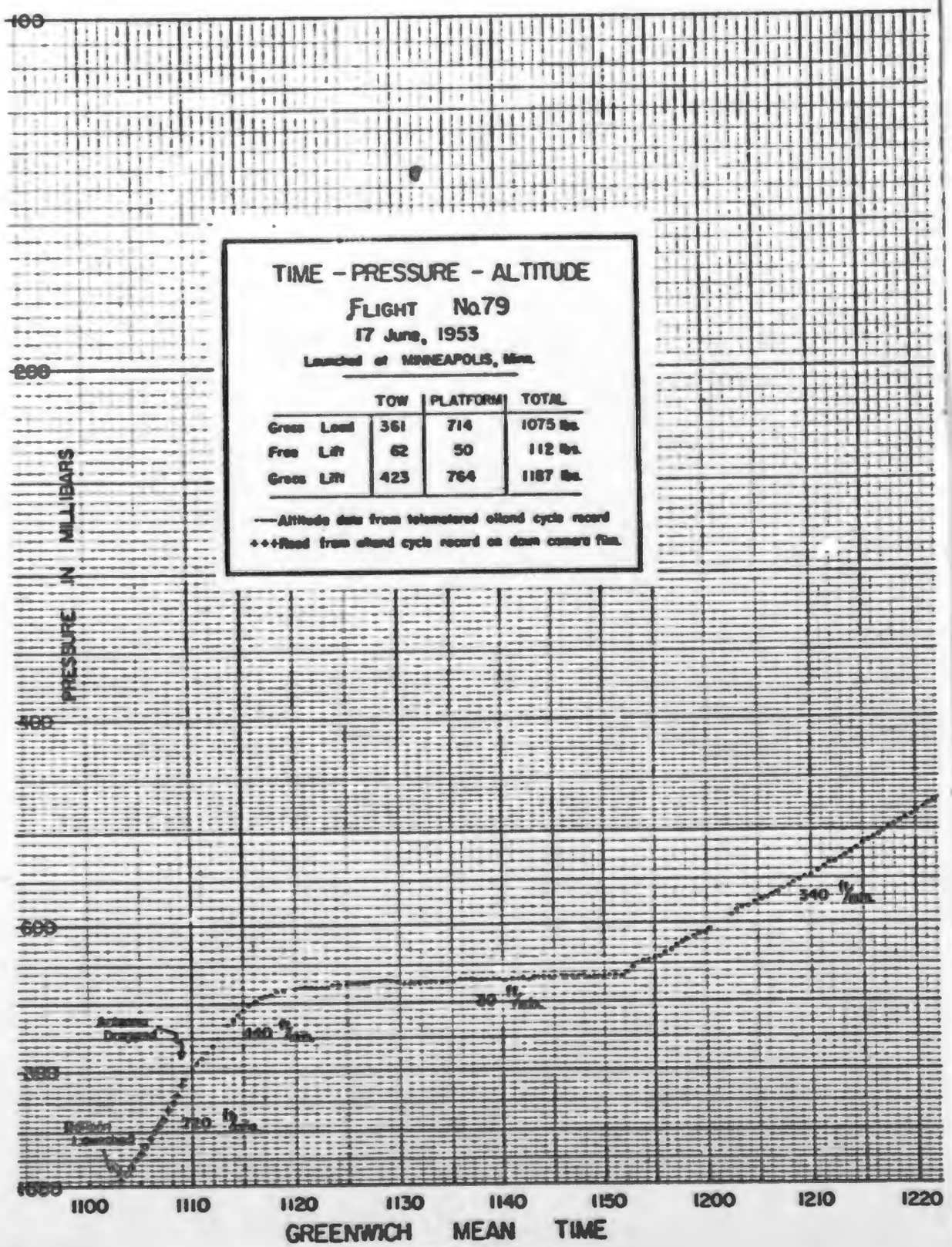

10
0
10
20
STATUTE MILES
SCALE 1:5x10^6
94° 30'
44° 42'
FILM FRAME NUMBERS
13:18
13:31
13:28
13:31
13:38
13:48
13:47
13:52
13:57
14:02
14:06
44° 30'
92° 30'

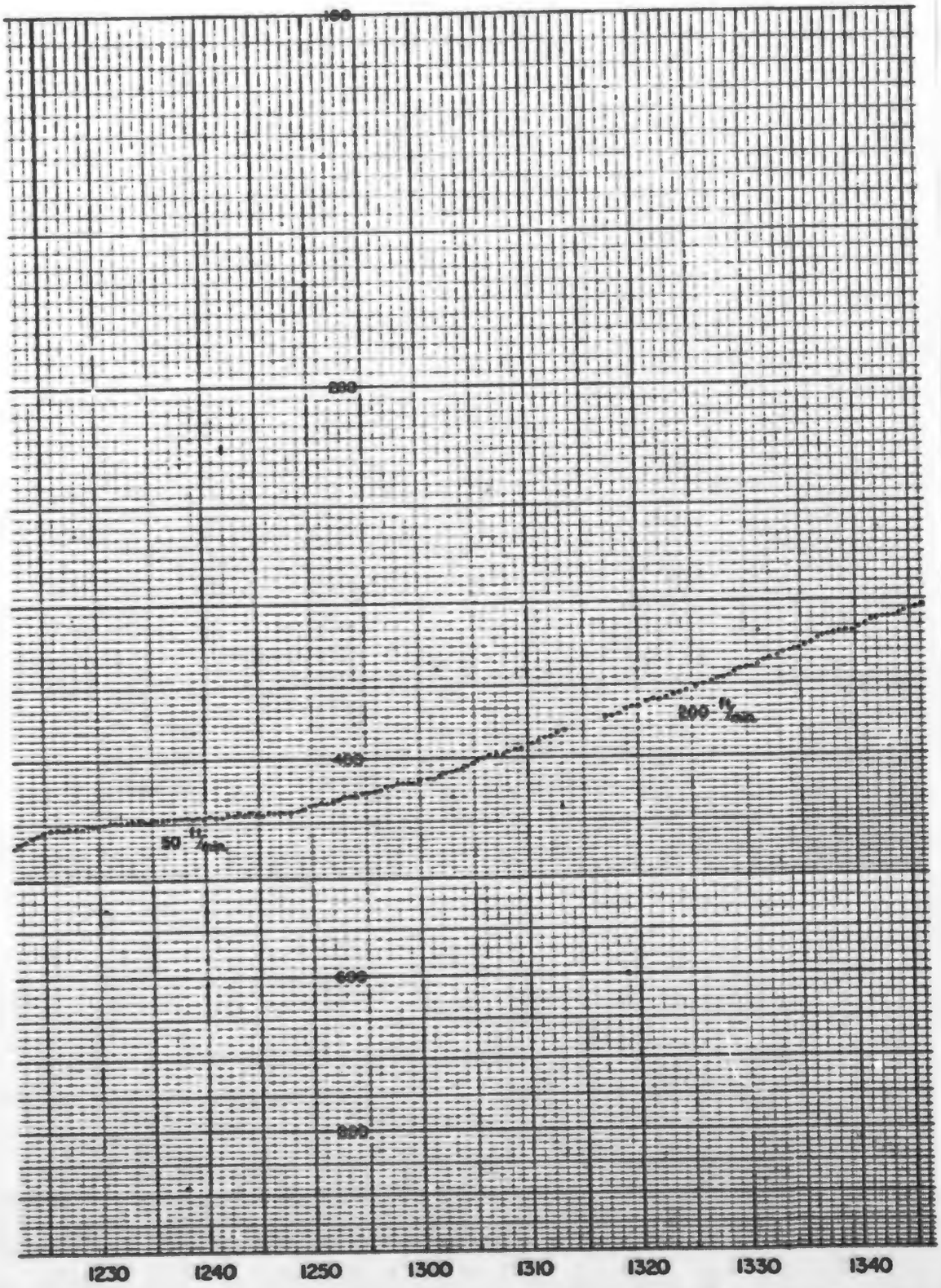

120
130
140
150
160
170
180
190
1720
1730
1740
1750
1800
1810
1820
1830

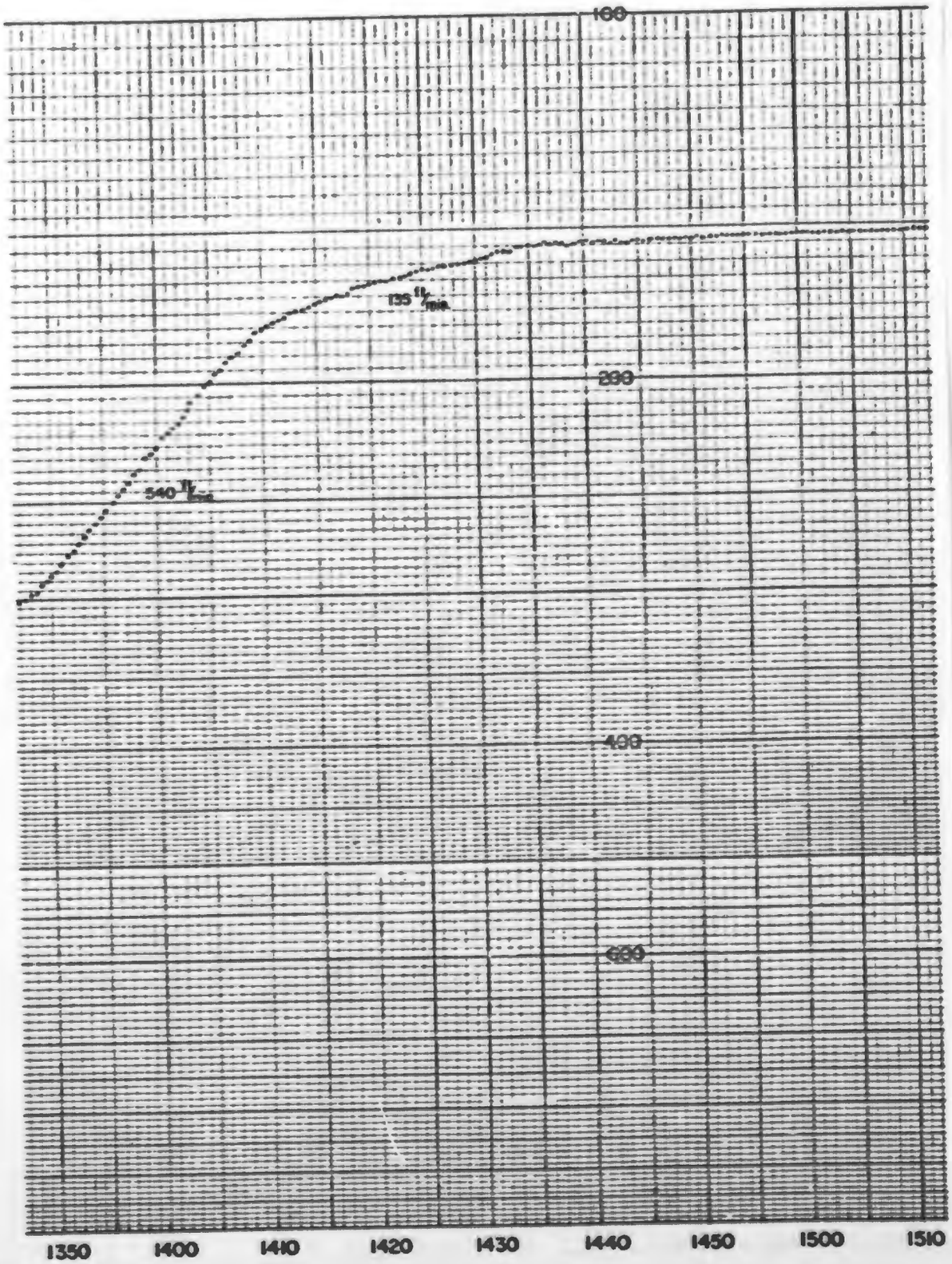
CONFIDENTIAL

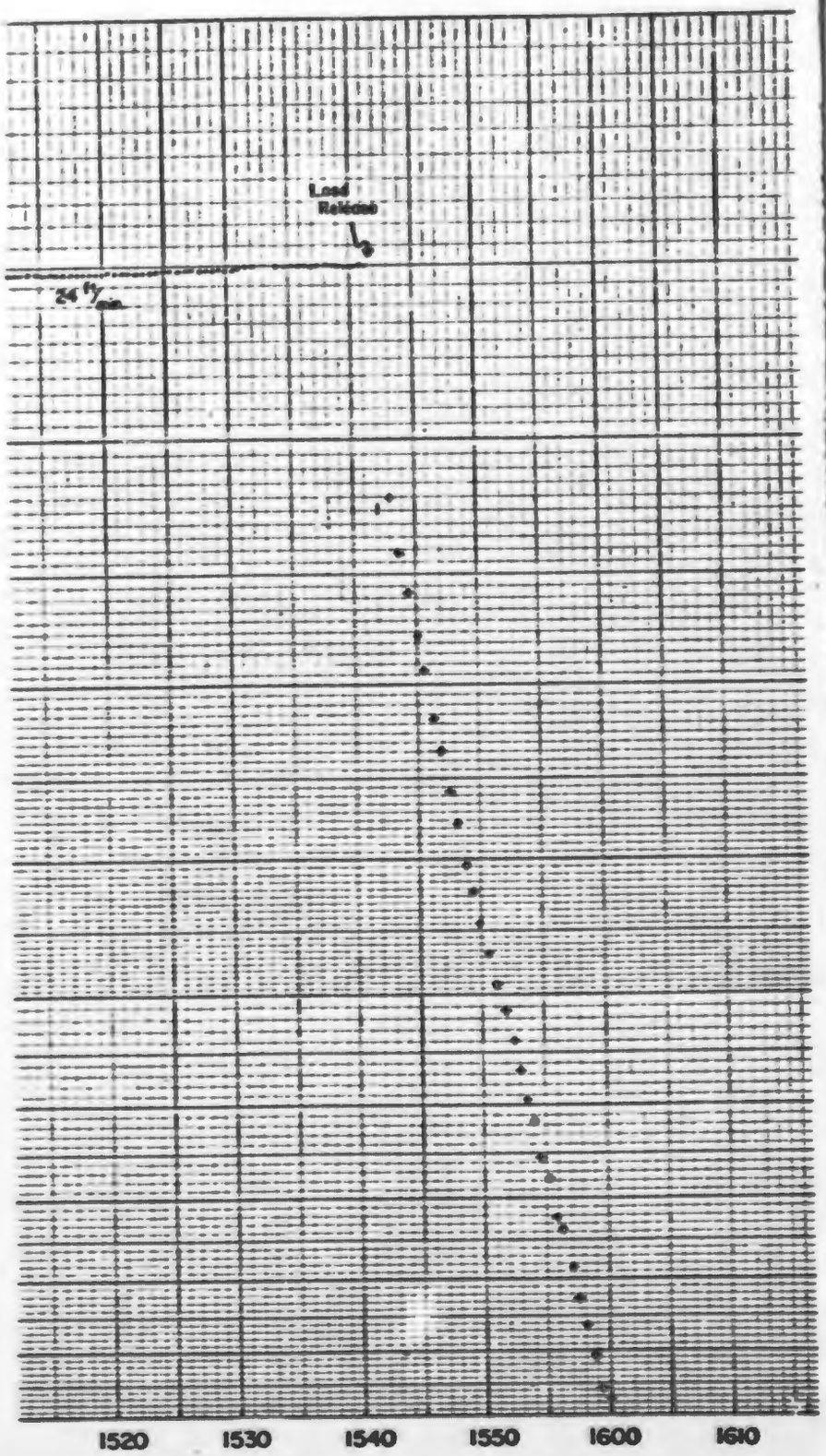


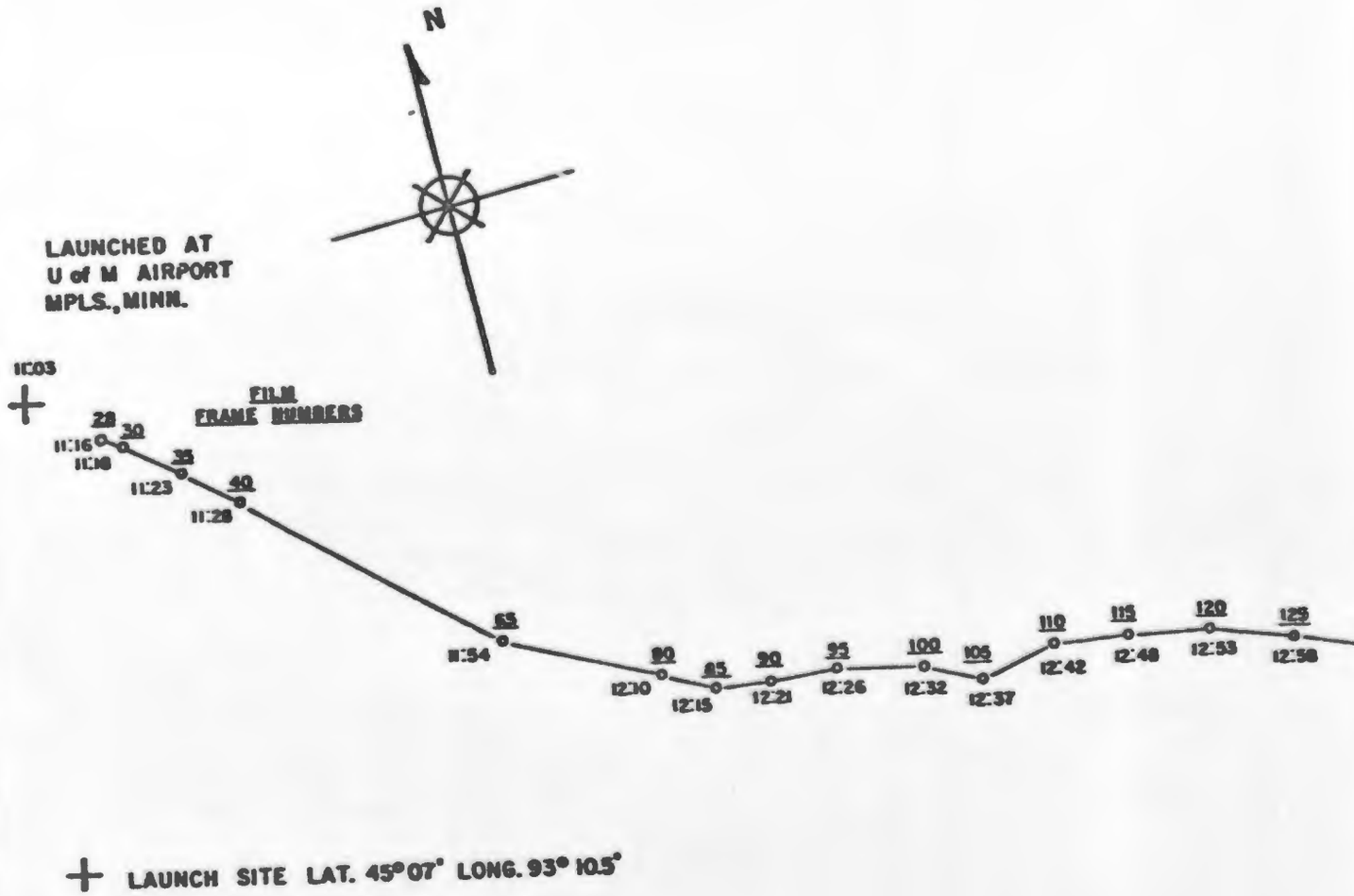
CONFIDENTIAL INFORMATION


TIME - PRESSURE - ALTITUDE
FLIGHT No.79
17 June, 1953
Launched at MINNEAPOLIS, Minn.
TOW
PLATFORM
TOTAL
Gross Load 361 714 1075 lbs.
Free Lift 62 50 112 lbs.
Gross Lift 423 764 1187 lbs.
---Altitude data from telemetered ofland cycle record
+++Read from ofland cycle record on down camera film.
PRESSURE IN MILLIBARS
100
200
400
600
1000
1100
1110
1120
1130
1140
1150
1200
1210
1220
GREENWICH MEAN TIME
340 ft/min.
80 ft/min.
160 ft/min.
720 ft/min.


100
200
300
400
500
600
800
50 ft/min
200 ft/min
1230
1240
1250
1300
1310
1320
1330
1340


100
200
300
400
500
135 ft/min
540 ft/min
1350
1400
1410
1420
1430
1440
1450
1500
1510

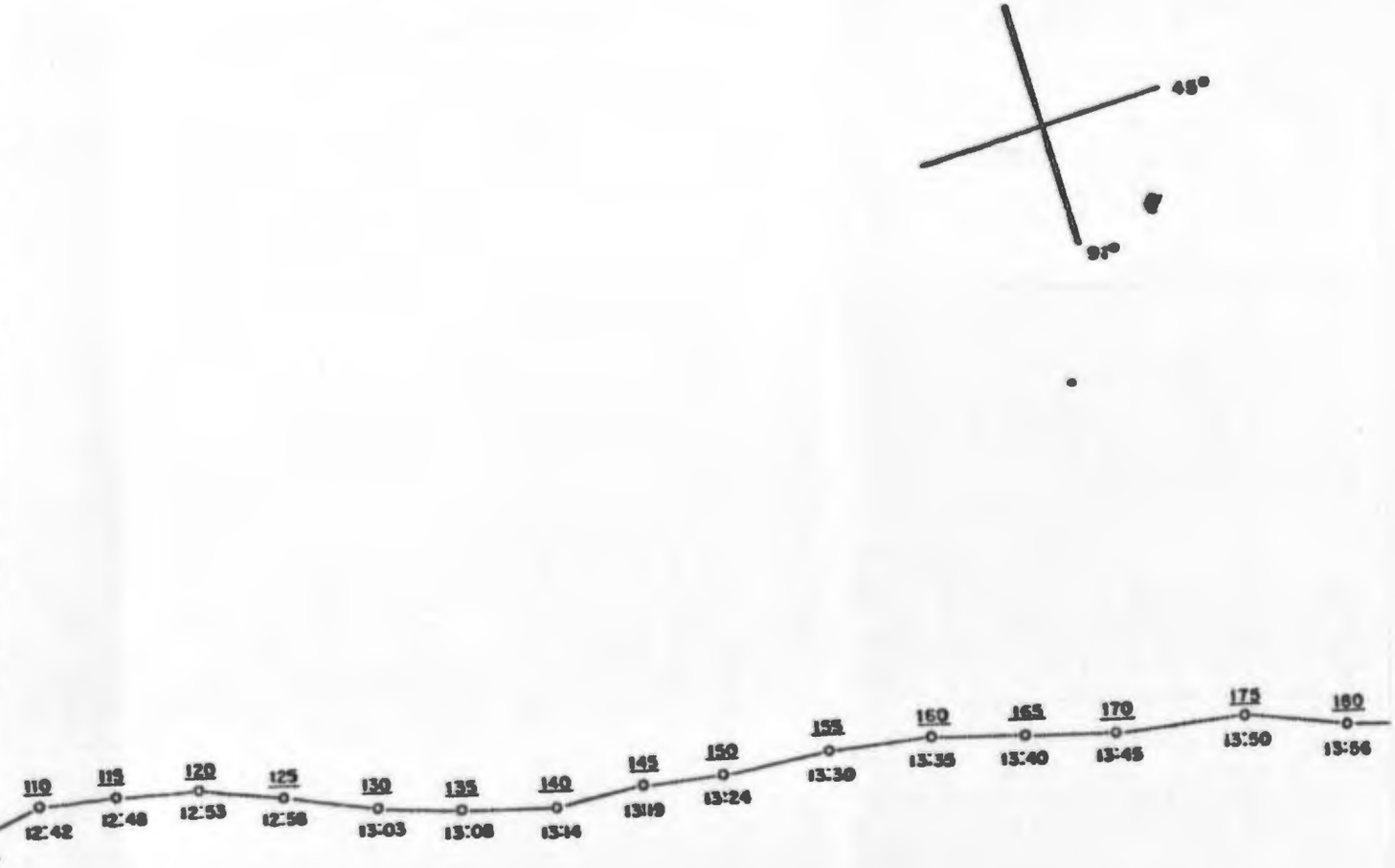

Load Released
24 ft/min
1520
1530
1540
1550
1600
1610

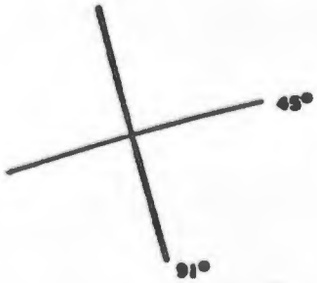


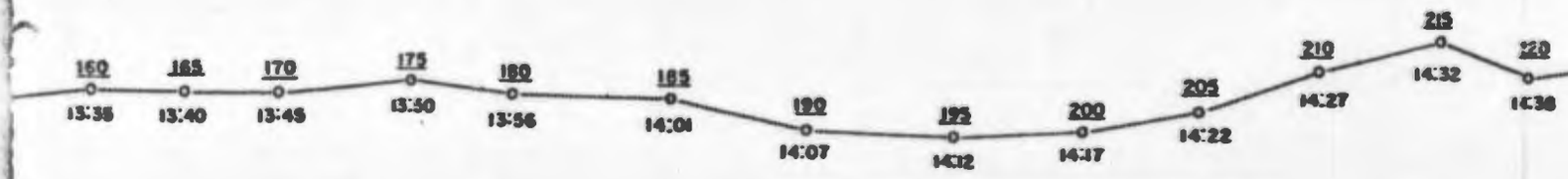
+ LAUNCH SITE LAT. 45° 07' LONG. 93° 10.5'

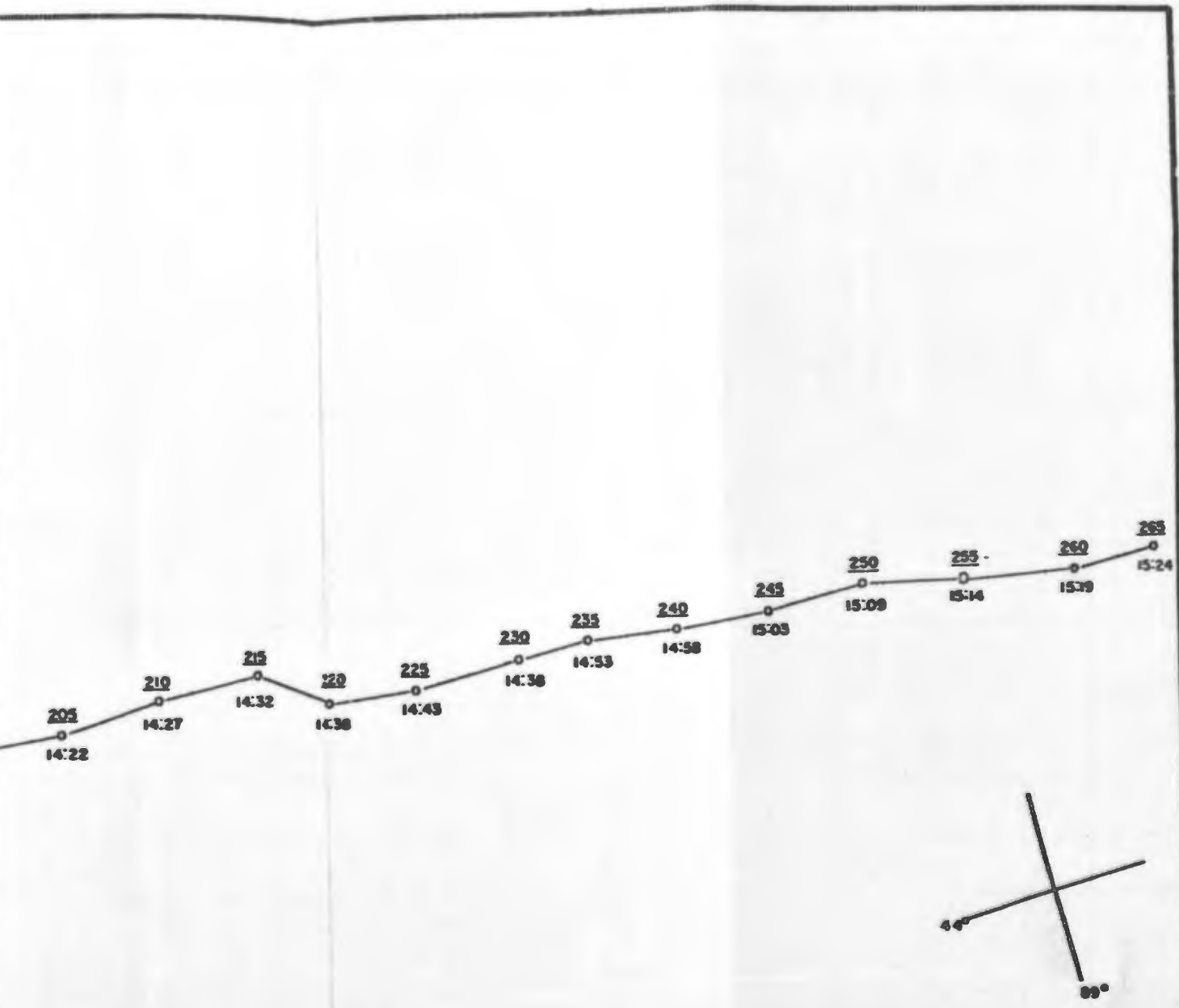
FLIGHT 79
LAUNCHED 11:03 G.M.T.
17 JUNE, 1953

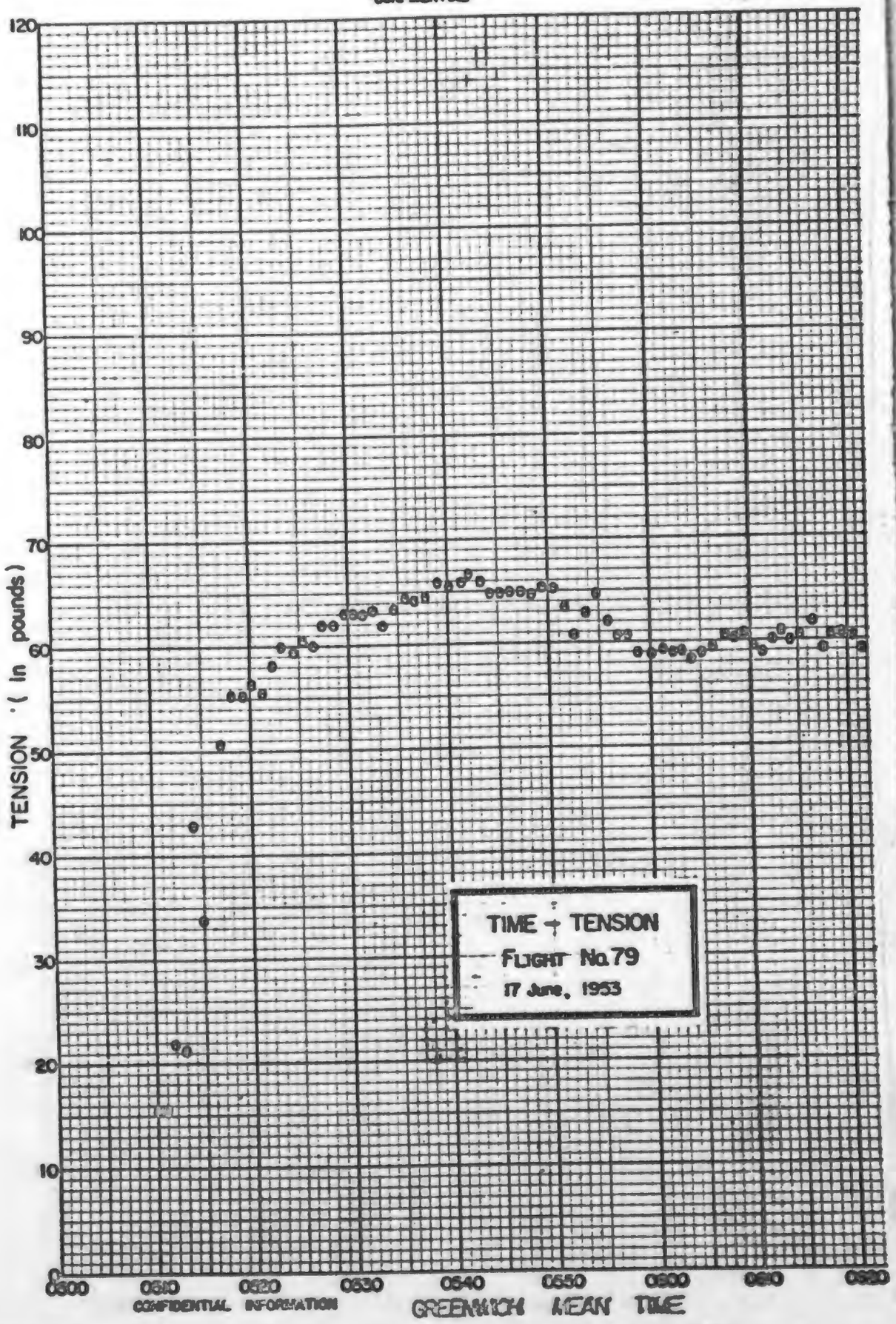
TRAJECTORY FROM FILM DATA

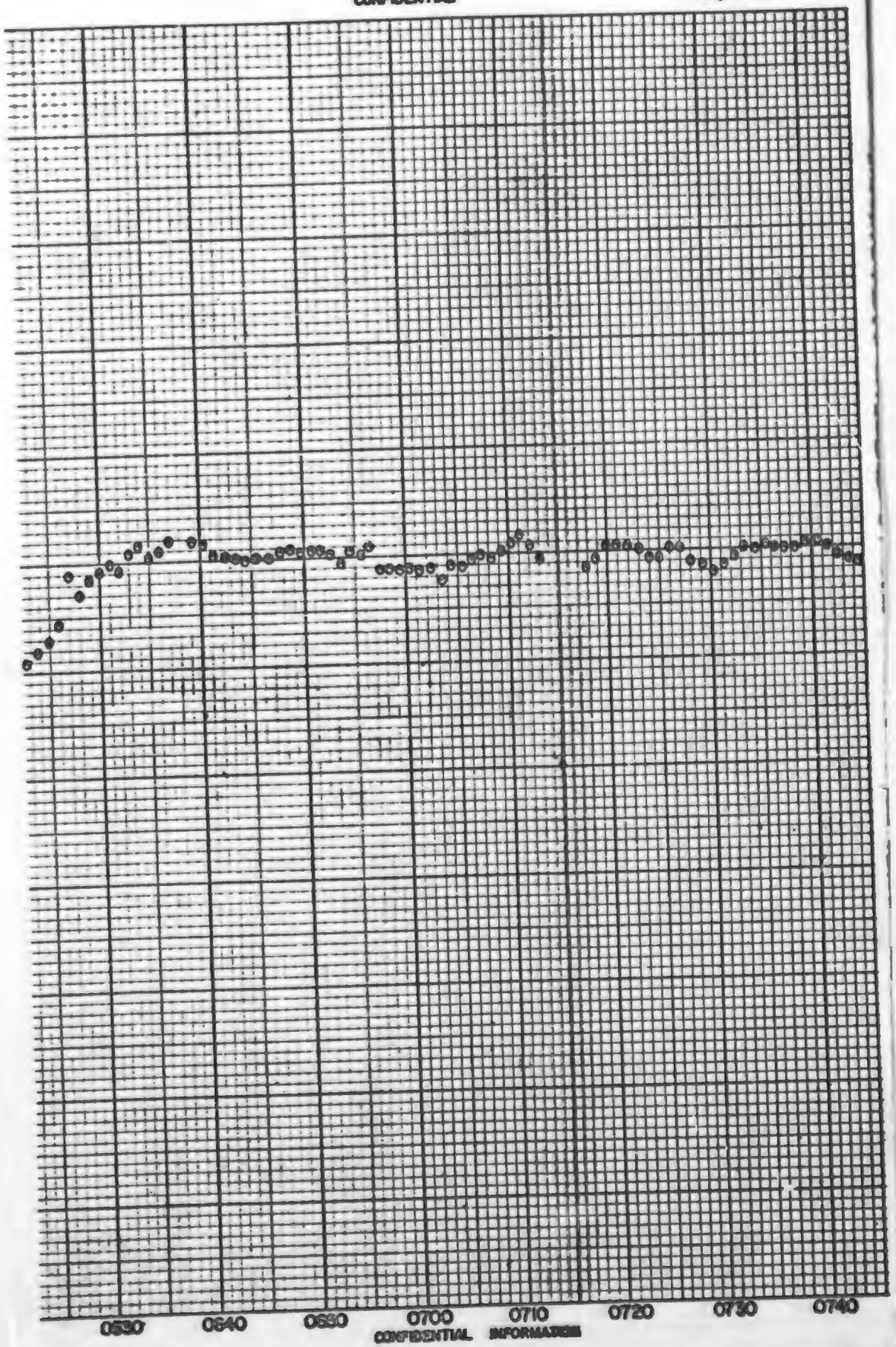

45°
90°
110
12:42
115
12:48
120
12:53
125
12:58
130
13:03
135
13:08
140
13:14
145
13:19
150
13:24
155
13:30
160
13:35
165
13:40
170
13:45
175
13:50
180
13:56

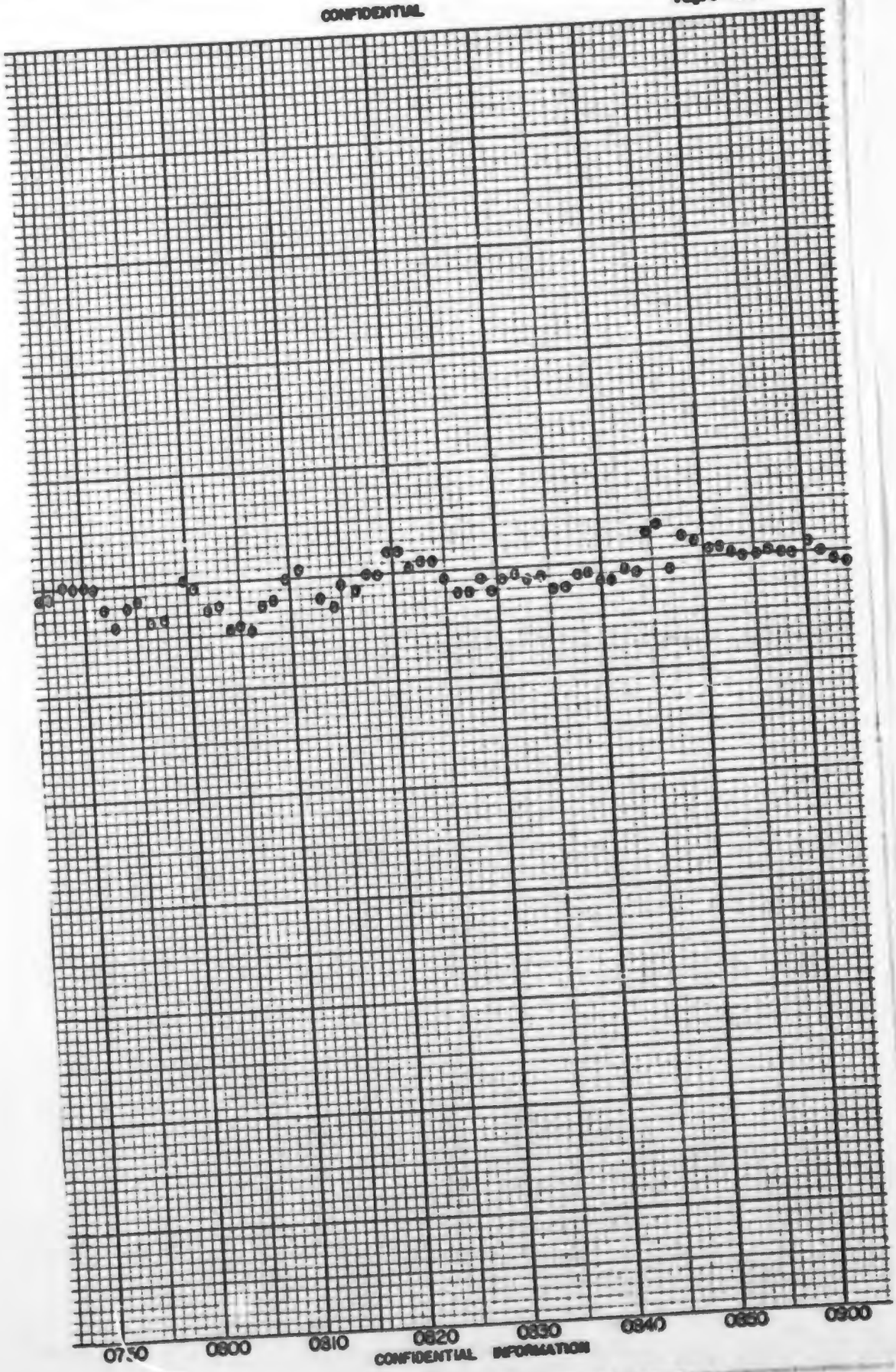

45°
91°

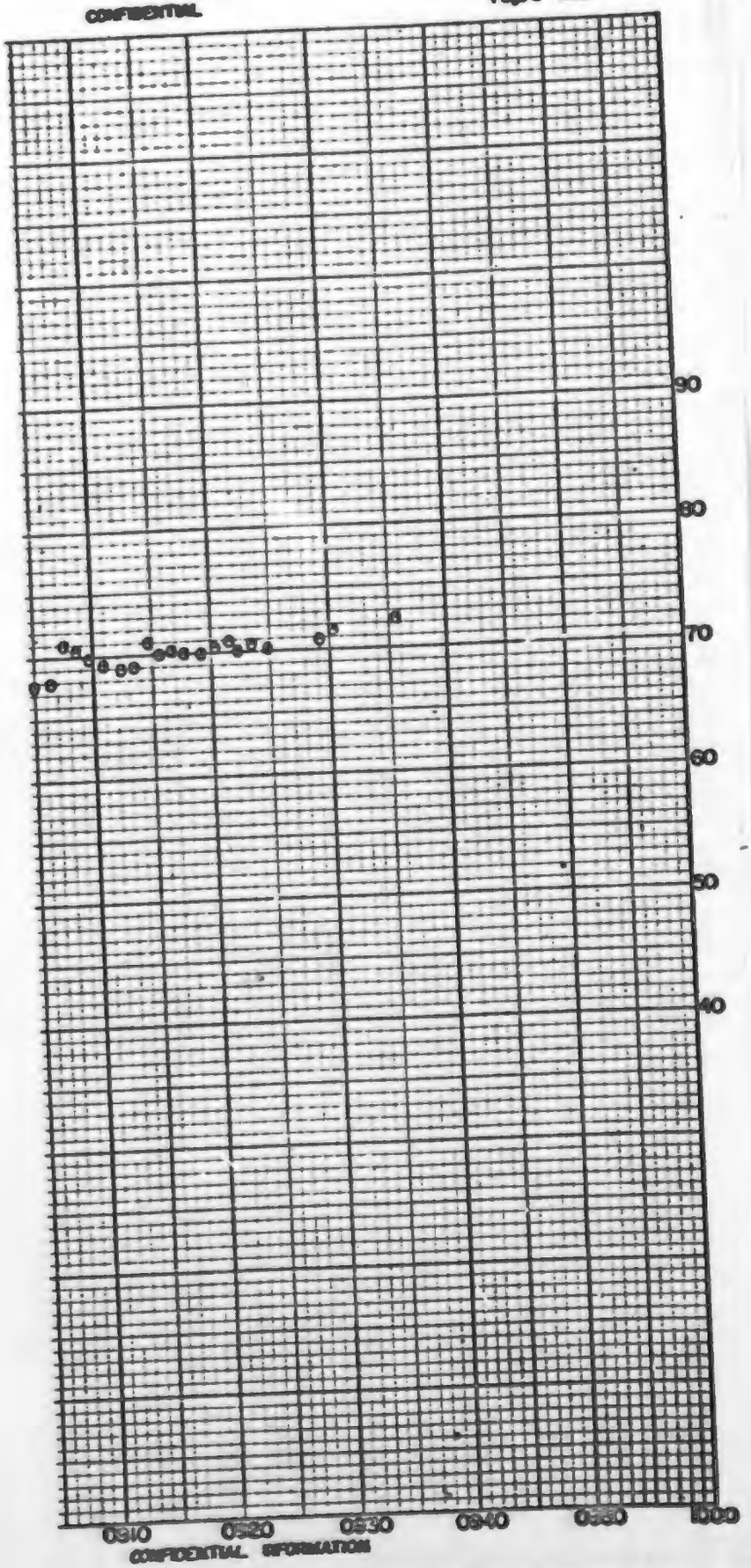

160
13:35
165
13:40
170
13:45
175
13:50
180
13:56
185
14:01
190
14:07
195
14:12
200
14:17
205
14:22
210
14:27
215
14:32
220
14:38

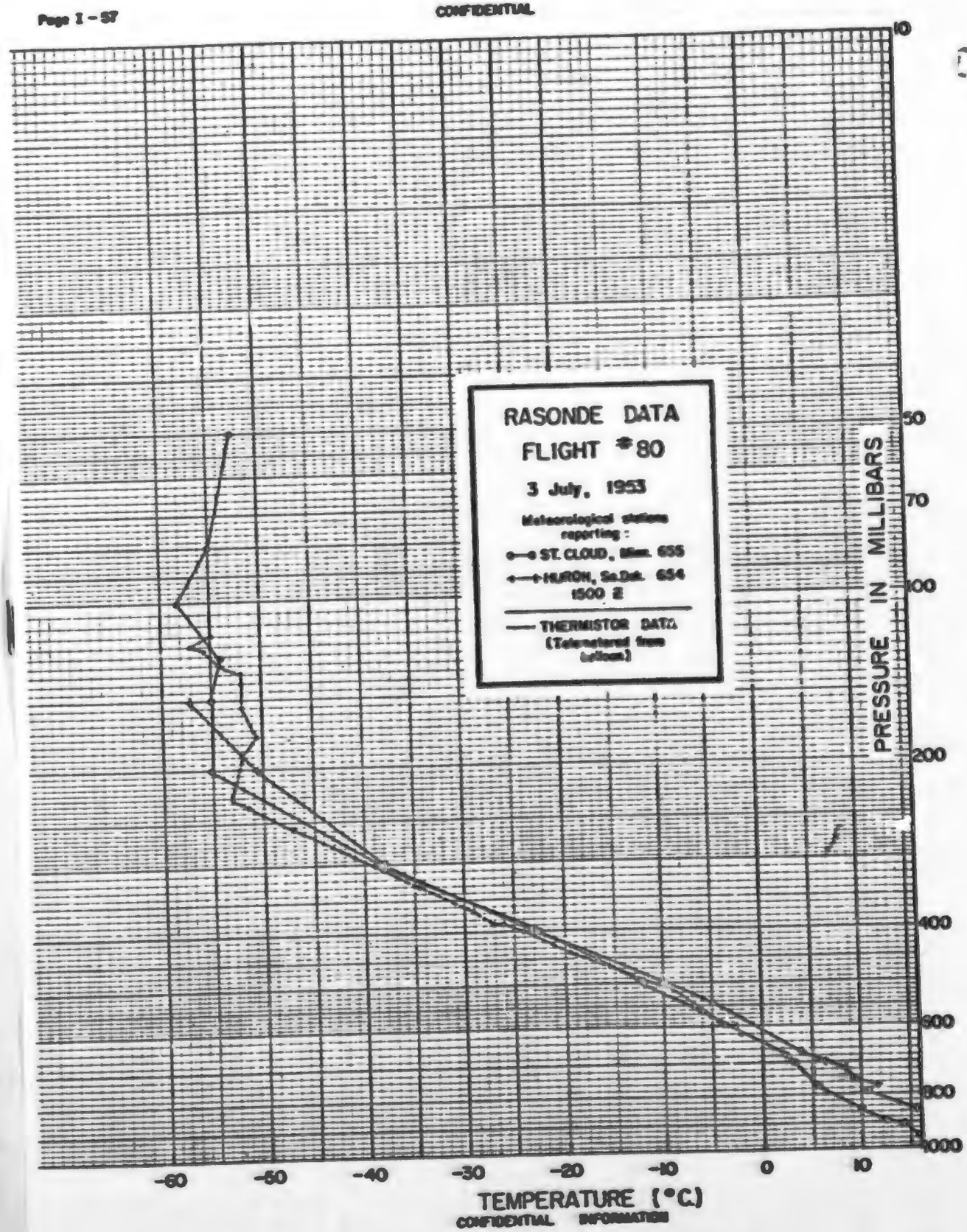

205
14:22
210
14:27
215
14:32
220
14:38
225
14:43
230
14:48
235
14:53
240
14:58
245
15:03
250
15:09
255
15:14
260
15:19
265
15:24
44°
89°

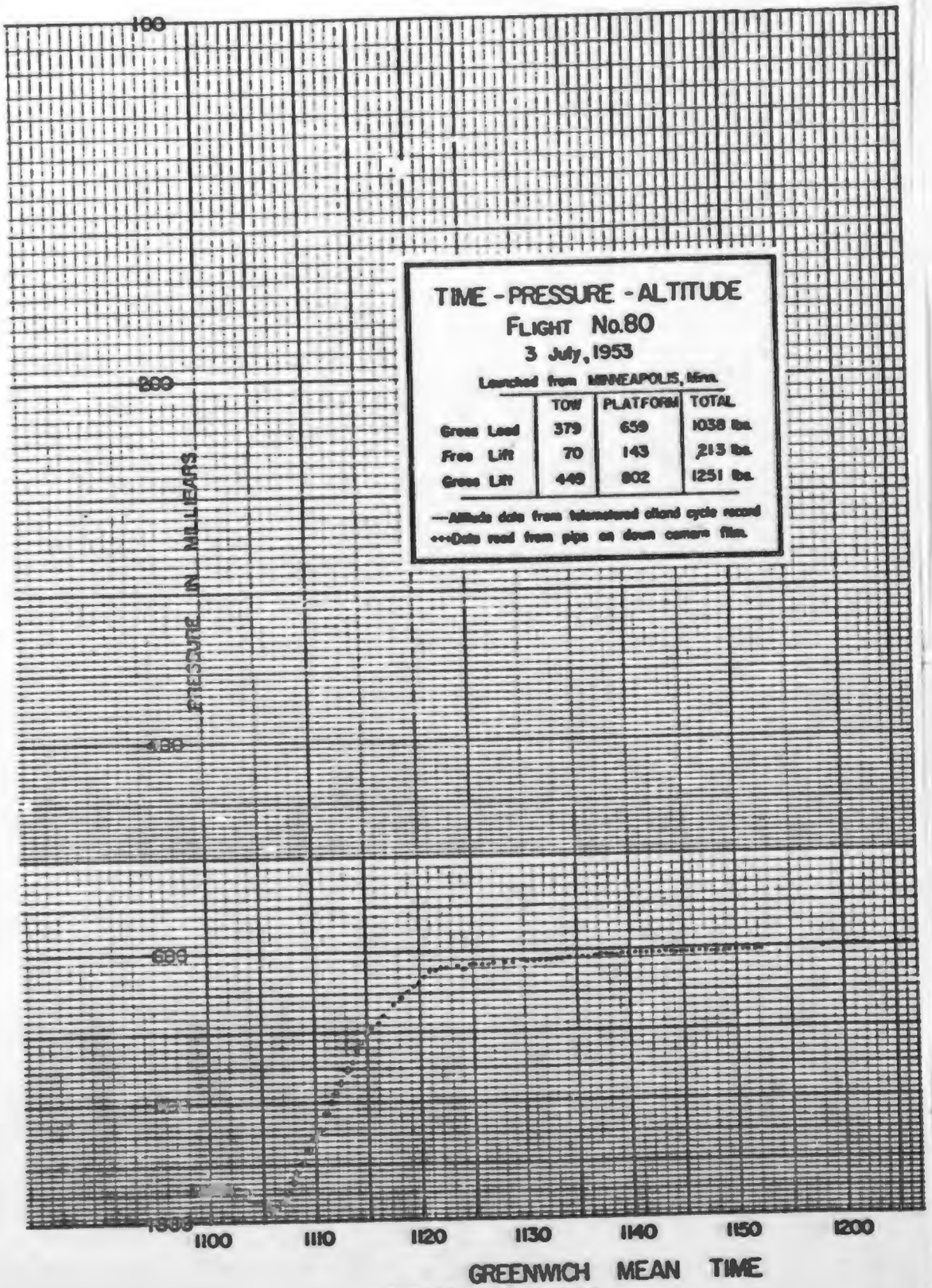

TIME + TENSION
FLIGHT No. 79
17 June, 1953
TENSION (in pounds)
120
110
100
90
80
70
60
50
40
30
20
10
0
0500
0510
0520
0530
0540
0550
0600
0610
0620
GREENWICH MEAN TIME

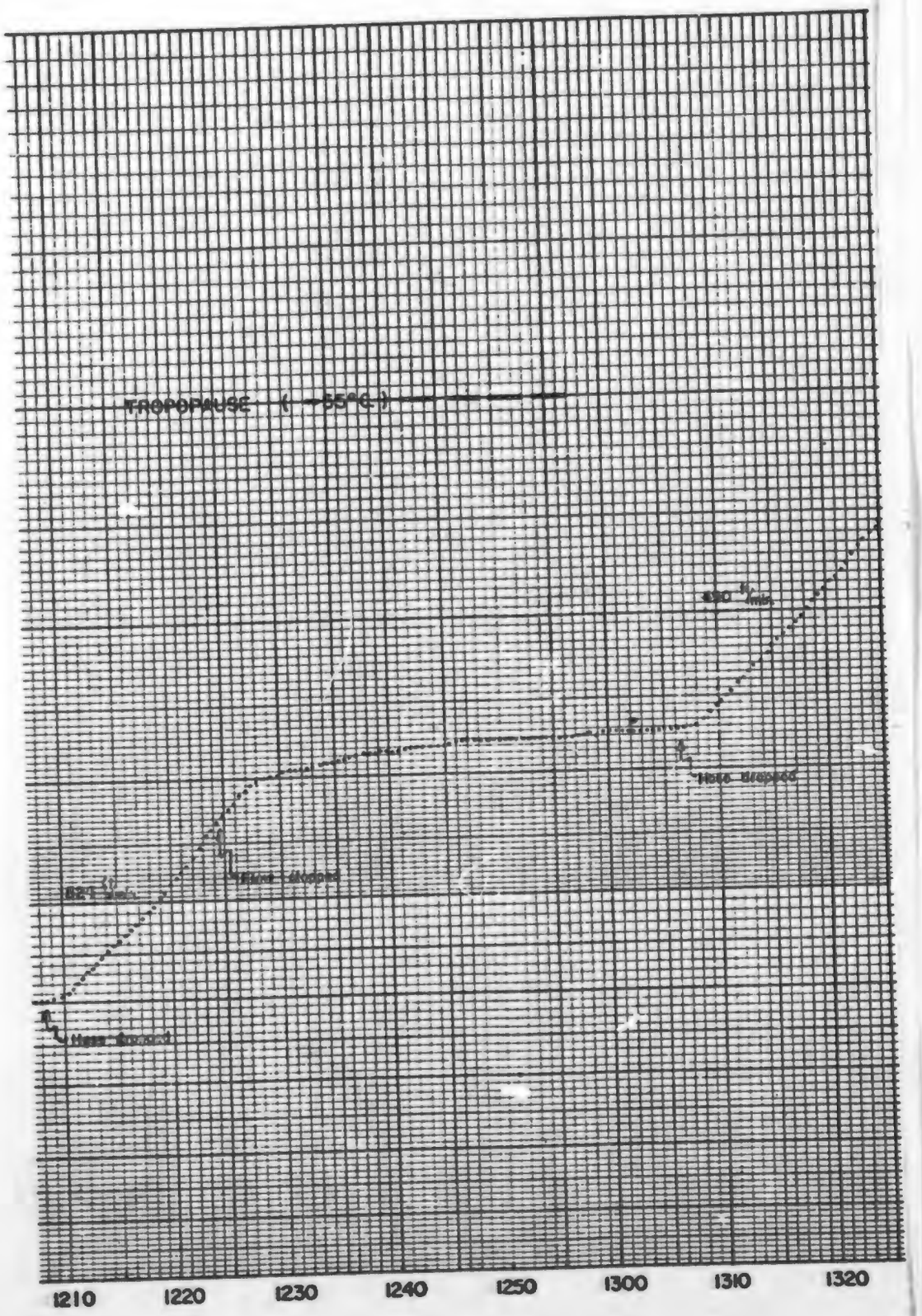

0630
0640
0650
0700
0710
0720
0730
0740

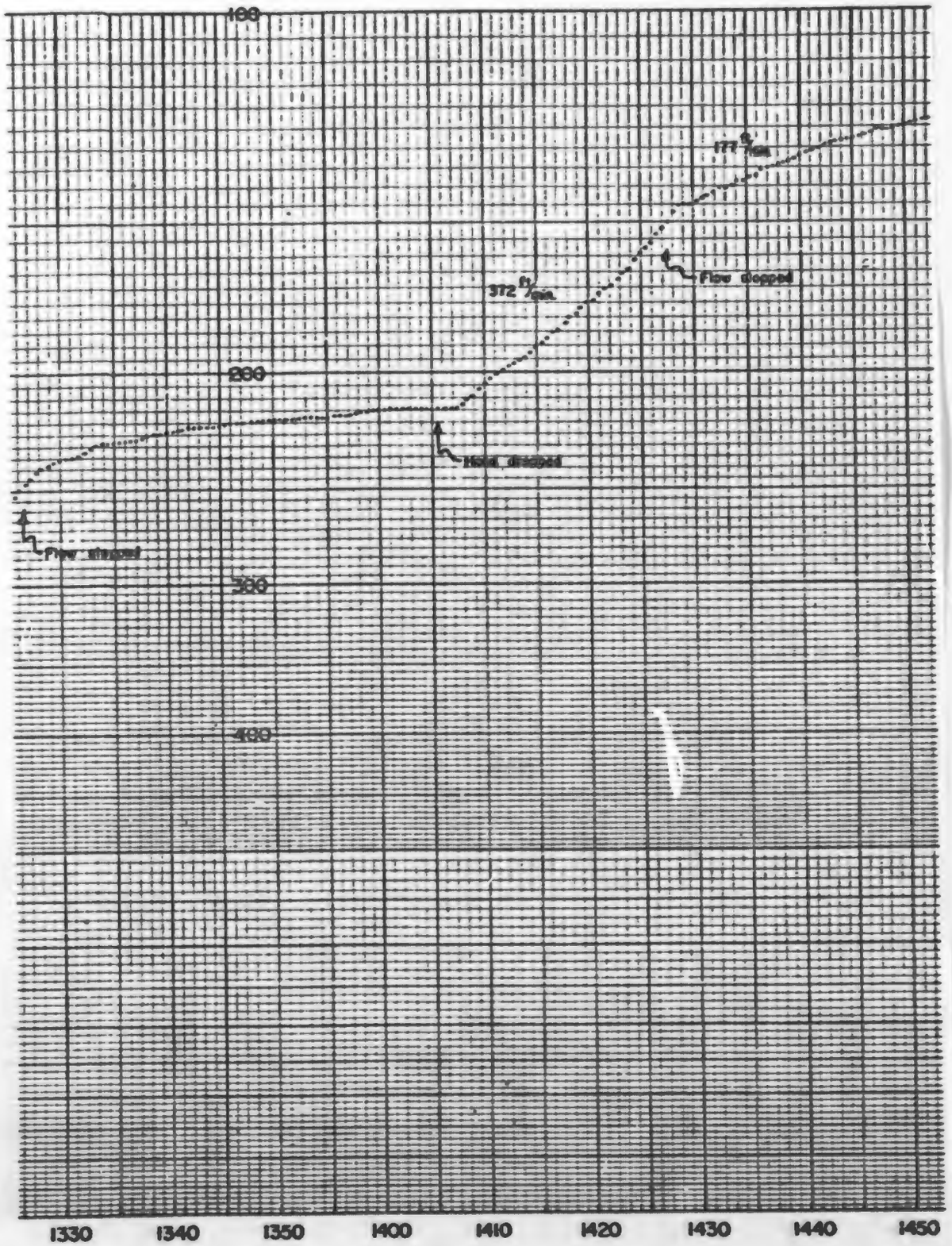

0750
0800
0810
0820
0830
0840
0850
0900

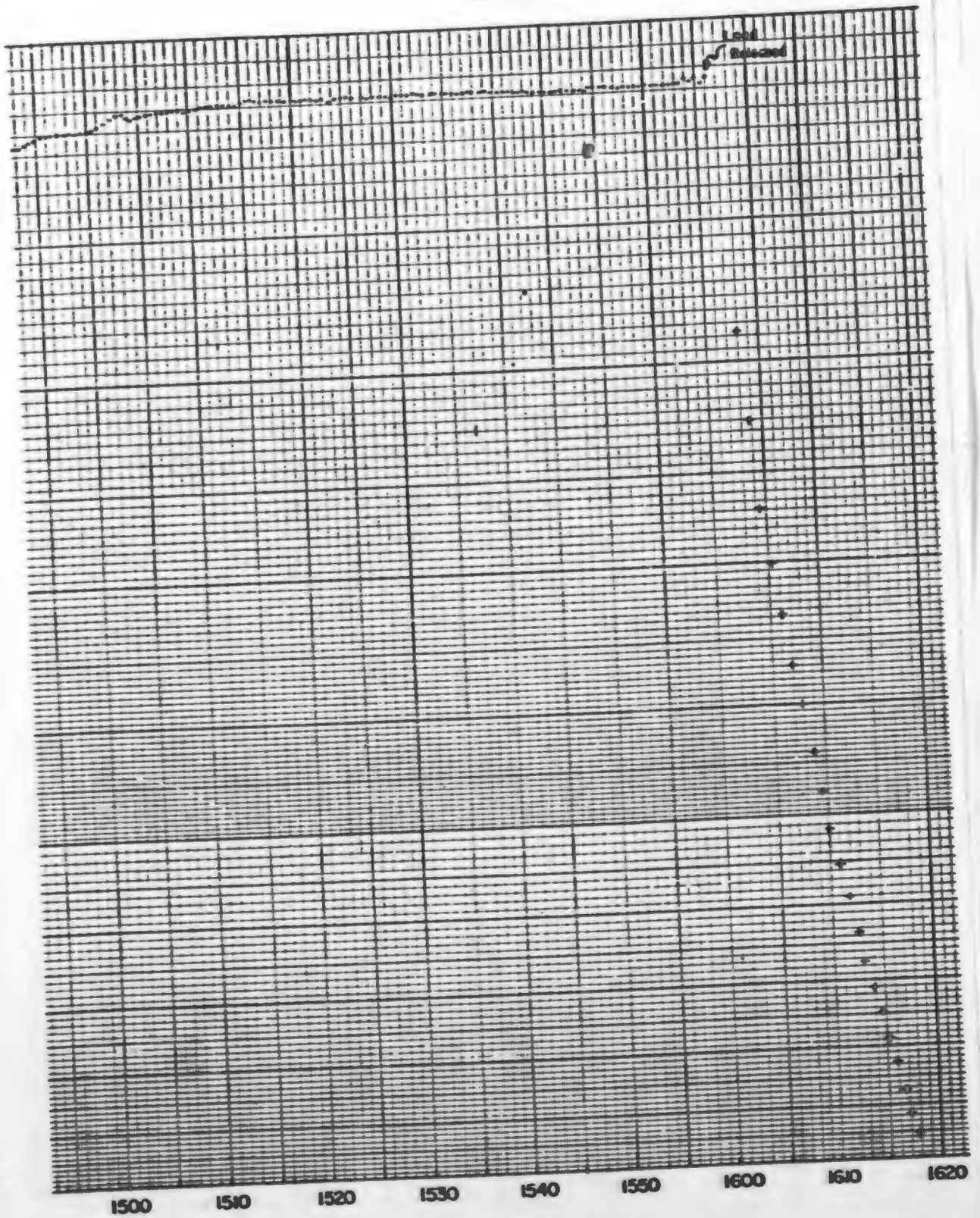

90
80
70
60
50
40
0910
0920
0930
0940
0950
1000

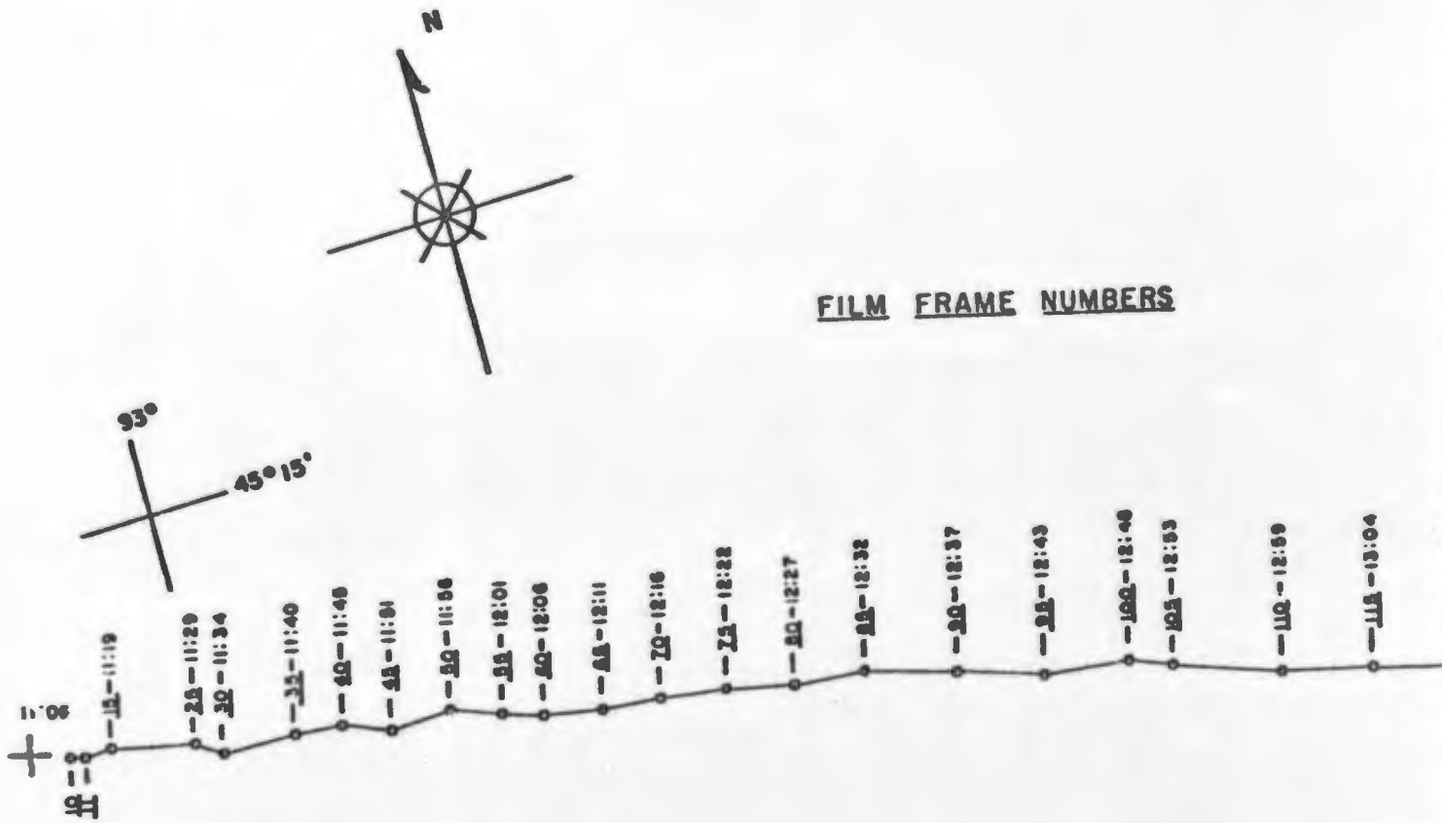

RASONDE DATA
FLIGHT #80
3 July, 1953
Meteorological stations reporting:
ST. CLOUD, Minn. 655
HURON, So.Dak. 654
1500 Z
THERMISTOR DATA
(Telemetered from balloon)
PRESSURE IN MILLIBARS
10
50
70
100
200
400
600
800
1000
-60
-50
-40
-30
-20
-10
0
10
TEMPERATURE (°C)


TIME - PRESSURE - ALTITUDE
FLIGHT No.80
3 July, 1953
Launched from MINNEAPOLIS, Minn.
TOW
PLATFORM
TOTAL
Gross Load
379
659
1038 lbs.
Free Lift
70
143
213 lbs.
Gross Lift
449
802
1251 lbs.
---Altitude data from telemetered altitude cycle record
•••Data read from pips on down camera film.
PRESSURE IN MILLIBARS
100
200
400
600
1100
1110
1120
1130
1140
1150
1200
GREENWICH MEAN TIME


TROPOPAUSE (-55°C)
1210
1220
1230
1240
1250
1300
1310
1320


100
200
300
400
177 ft/min
372 ft/min
Flow dropped
Hold dropped
Flow stopped
1330
1340
1350
1400
1410
1420
1430
1440
1450


Load
Released
1500
1510
1520
1530
1540
1550
1600
1610
1620



FILM FRAME NUMBERS

LAUNCHED AT
U of M AIRPORT

+ LAUNCH SITE LAT. 45° 07' LONG 93° 10.5'

FLIGHT 80

LAUNCHED 11:06 G.M.T.
3 JULY, 1953

TRAJECTORY FROM FILM DATA

IUMBERS

100 - 12:48
105 - 12:53
110 - 12:58
115 - 13:04
120 - 13:09
125 - 13:15
130 - 13:20
135 - 13:25
140 - 13:30
145 - 13:36
150 - 13:41
155 - 13:47
160 - 13:52
165 - 13:57
170 - 14:02

—165—13:57

—170—14:02

—175—14:08

—180—14:13

—185—14:18

—190—14:24

—195—14:29

—200—14:35

—205—14:41

—210—14:46

—215—14:51

—220—14:56

—225—15:02

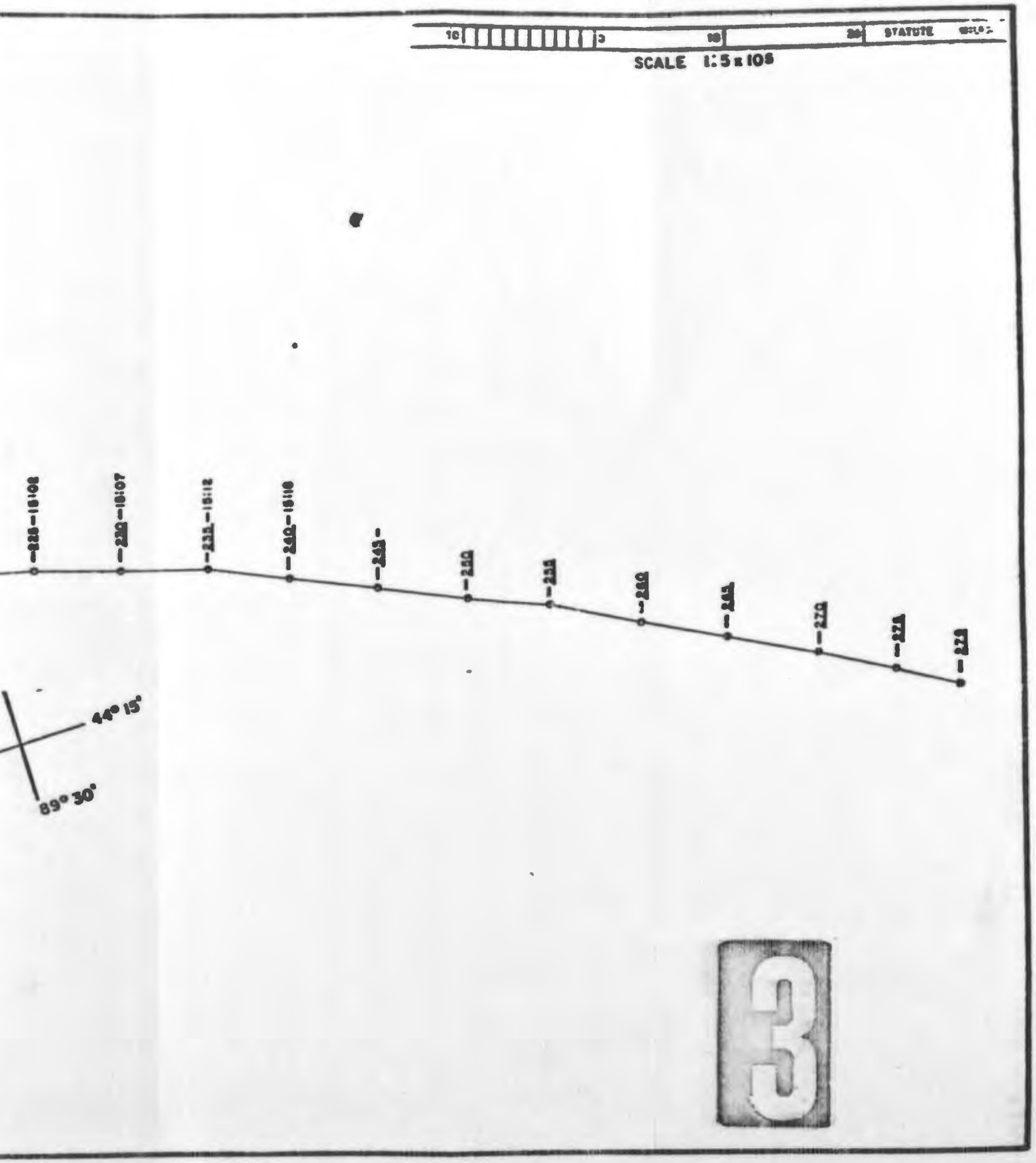
7

10
5
15
SCALE 1:5 x 10

210 — 14:46
215 — 14:51
220 — 14:56
225 — 15:02
230 — 15:07
235 — 15:12
240 — 15:18
245 —
250
255
260
265
44° 15'
89° 30'

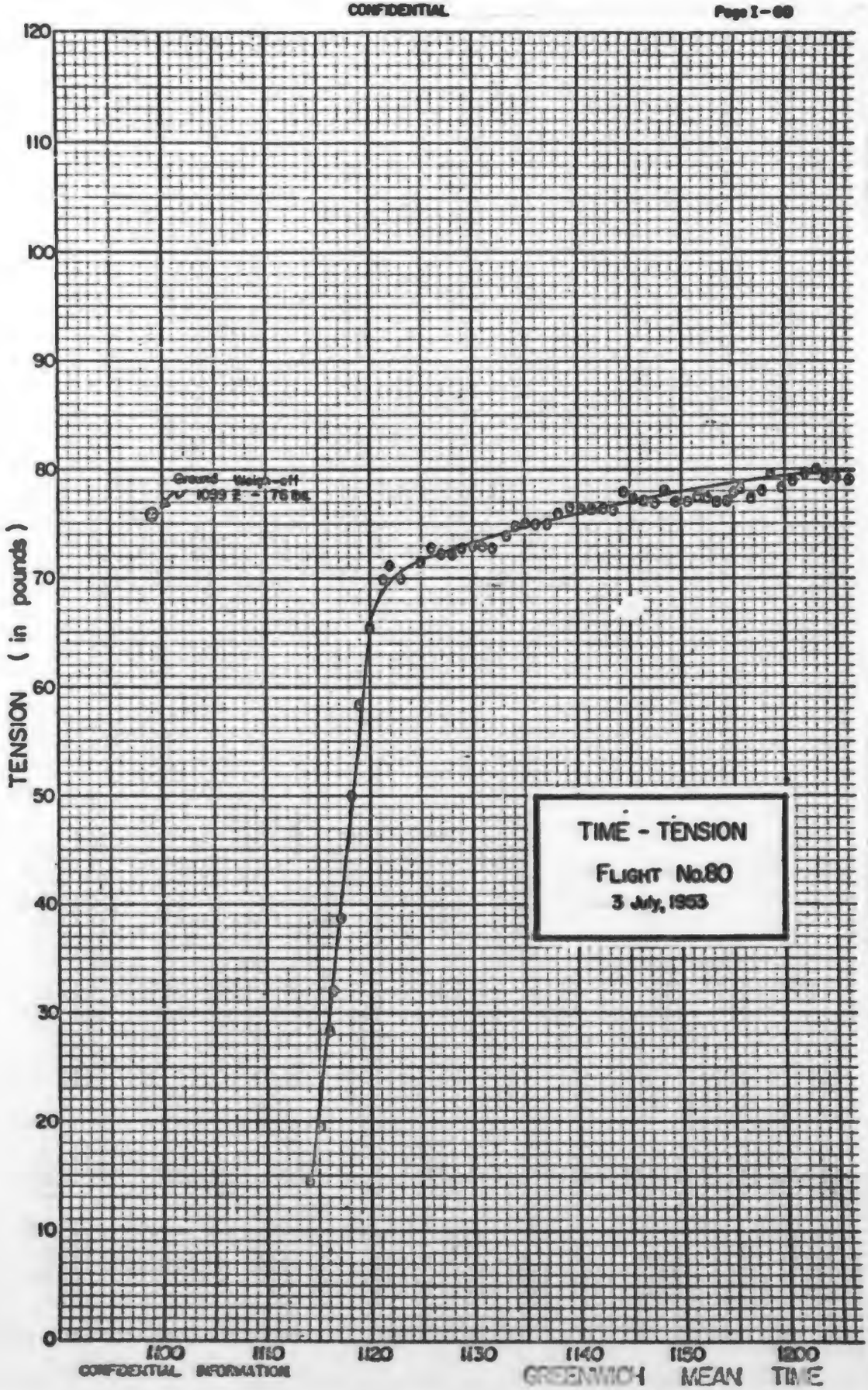
2

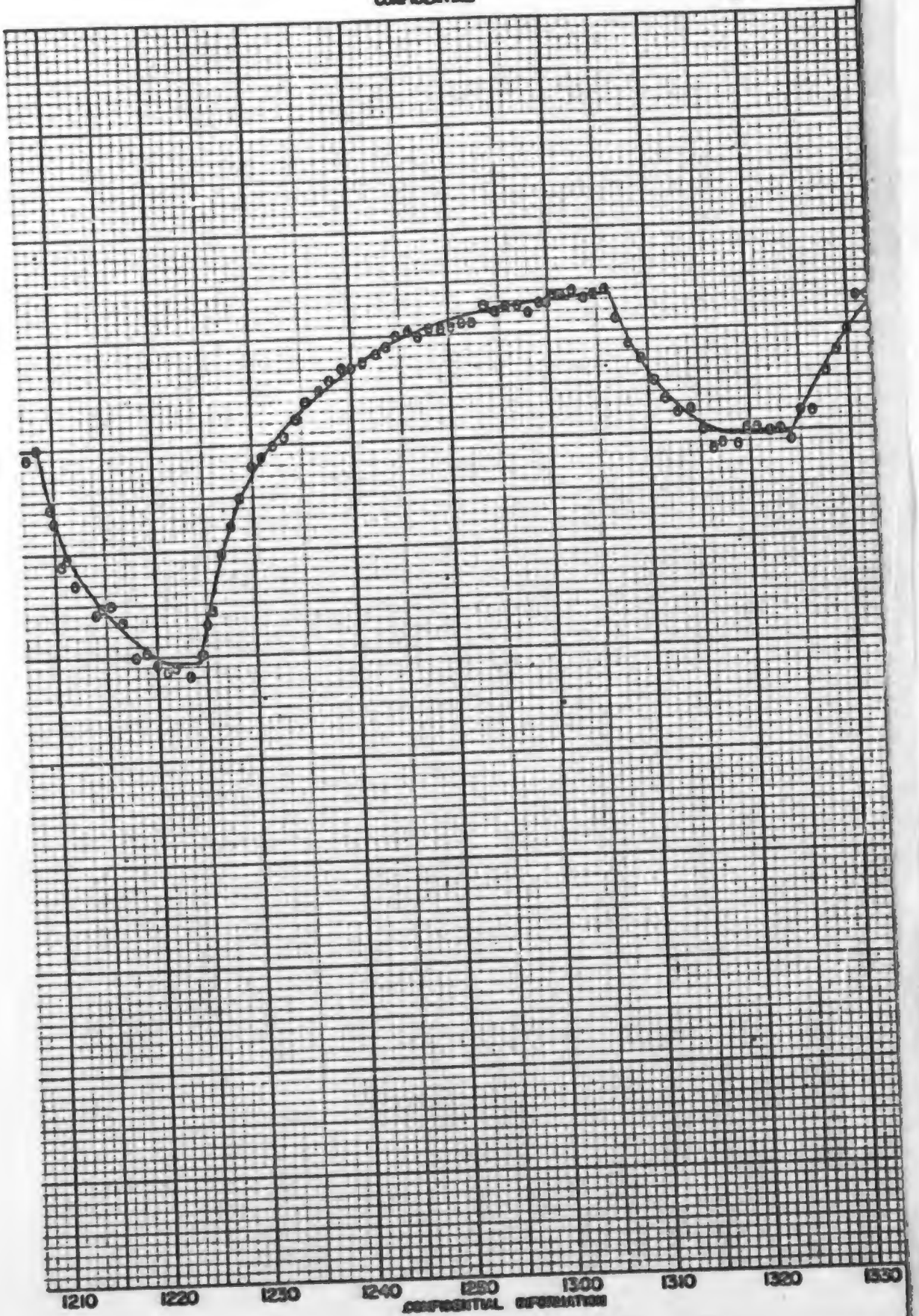
185 — 14:19
190 — 14:24
195 — 14:29
200 — 14:36
205 — 14:41
210 — 14:46
215 — 14:51
220 — 14:56
225 — 15:02
230 — 15:07
235 — 15:12
240 — 15:18
44° 15'
89° 30'

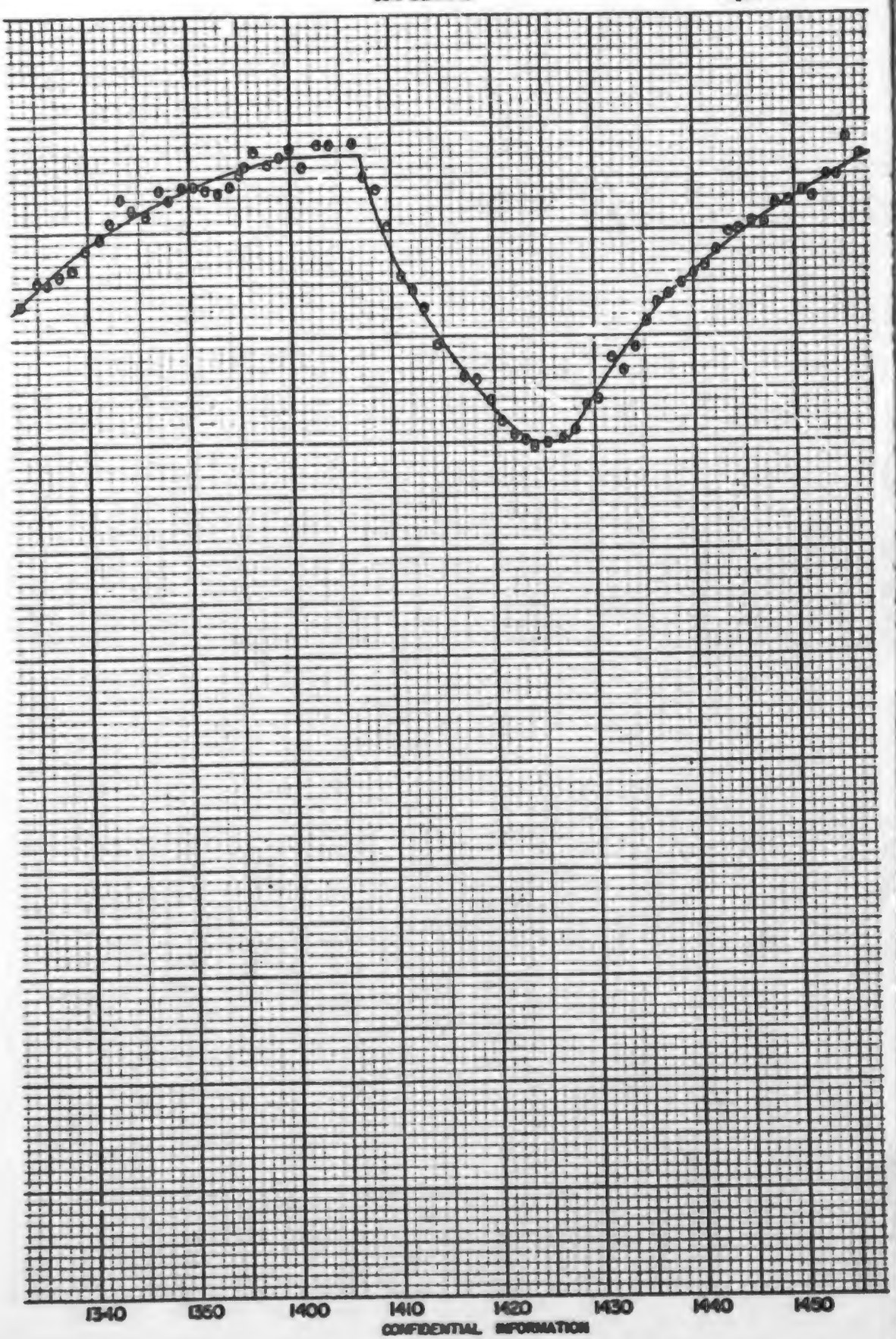

10
0
10
20
STATUTE
SCALE 1:5 x 10⁵
225
230
235
240
245
250
255
260
265
270
275
280
44° 15'
89° 30'

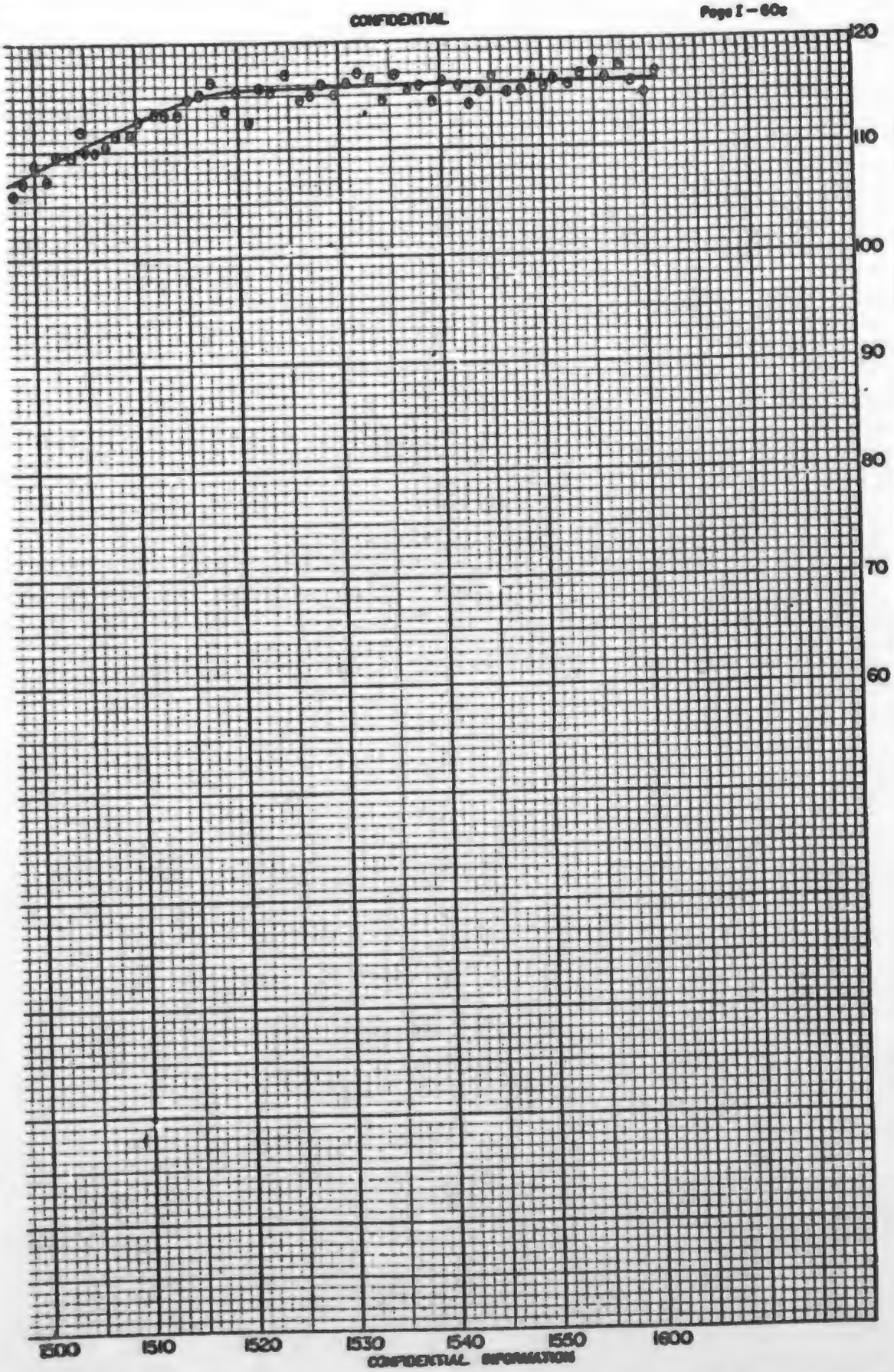
3

2

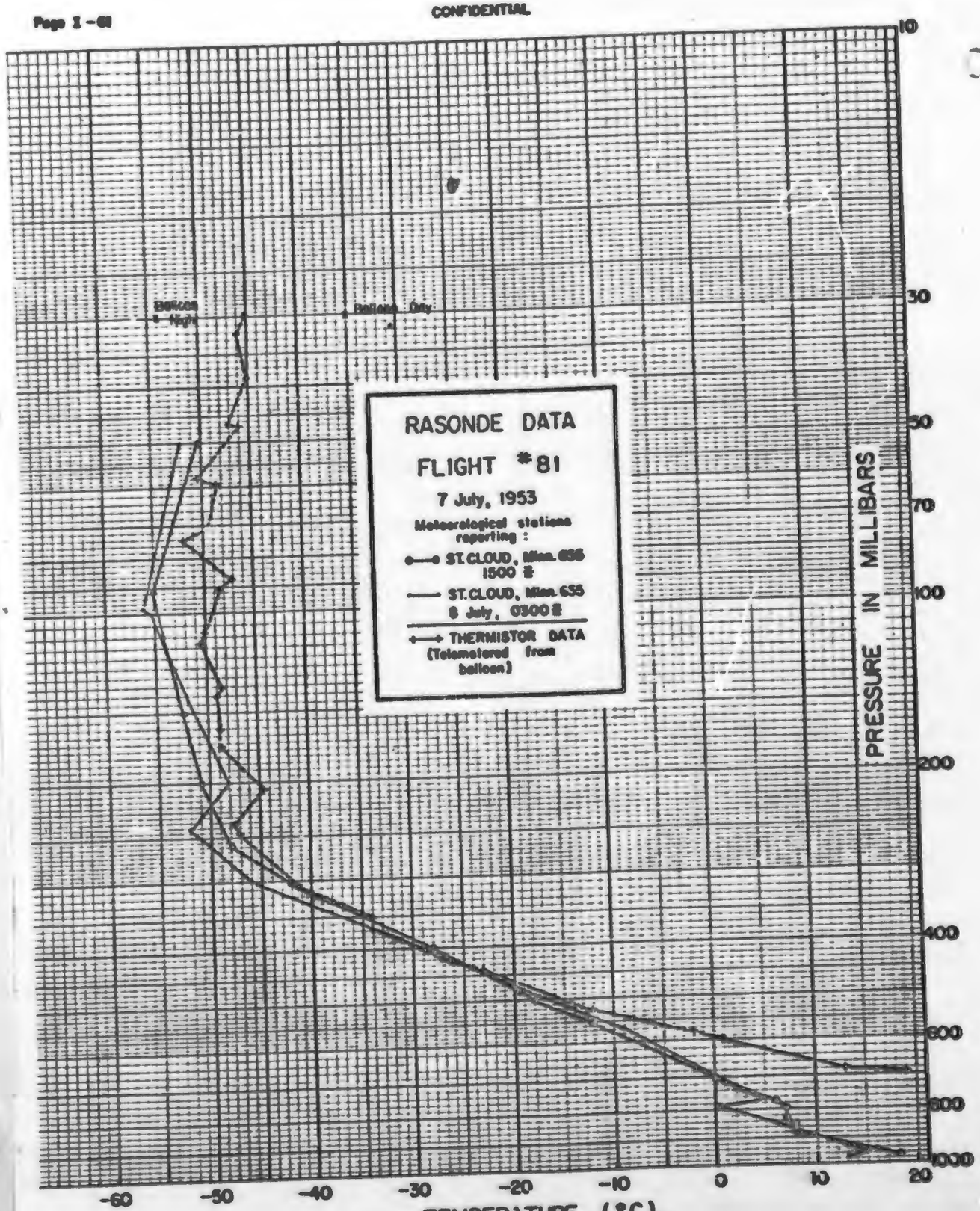

TIME - TENSION
FLIGHT No.80
3 July, 1953
Ground Weigh-off
1093 # - 76 lbs.
TENSION (in pounds)
0
10
20
30
40
50
60
70
80
90
100
110
120
1100
1110
1120
1130
1140
1150
1200
GREENWICH MEAN TIME


1210
1220
1230
1240
1250
1300
1310
1320
1330

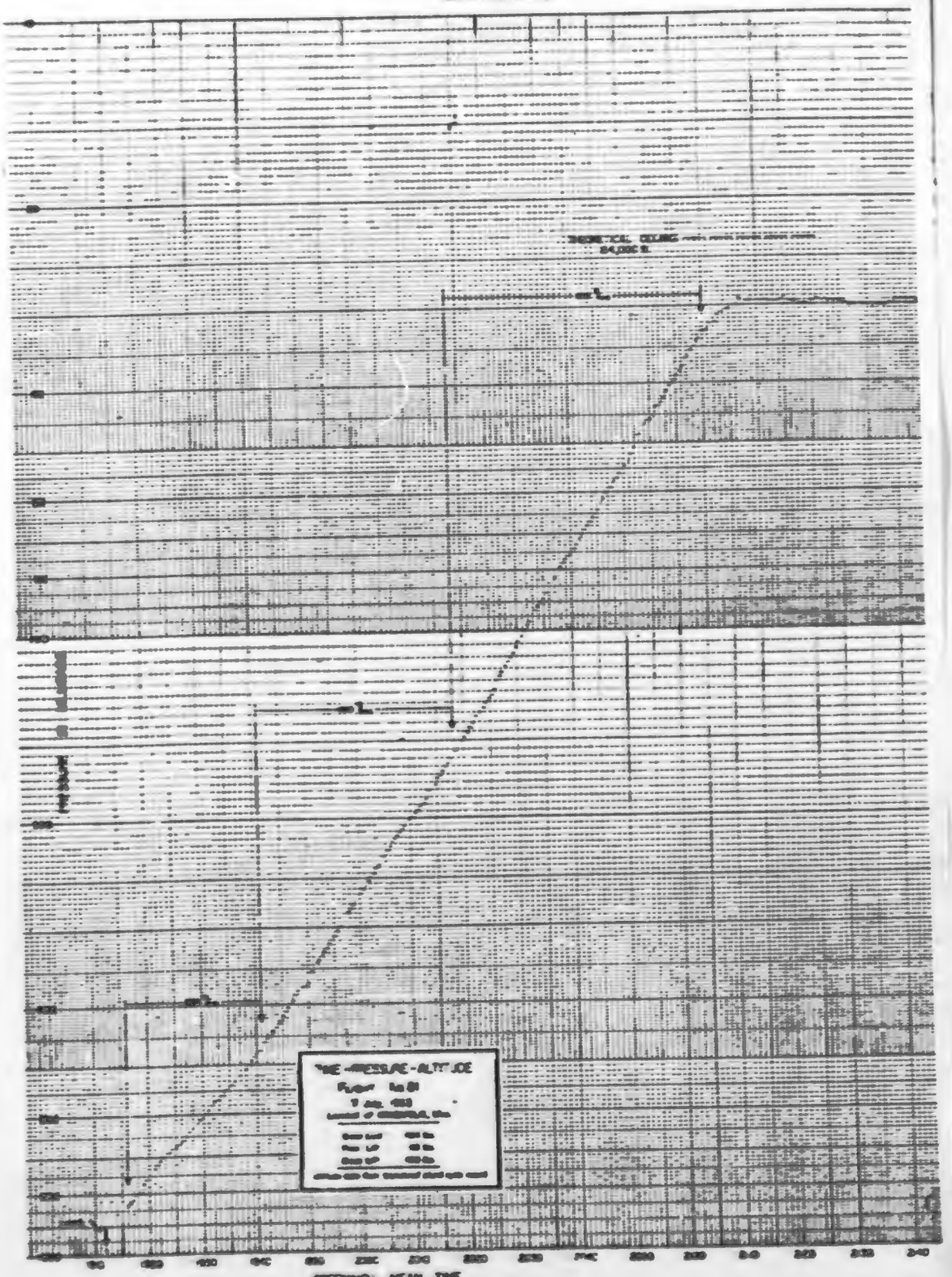

1340
1350
1400
1410
1420
1430
1440
1450

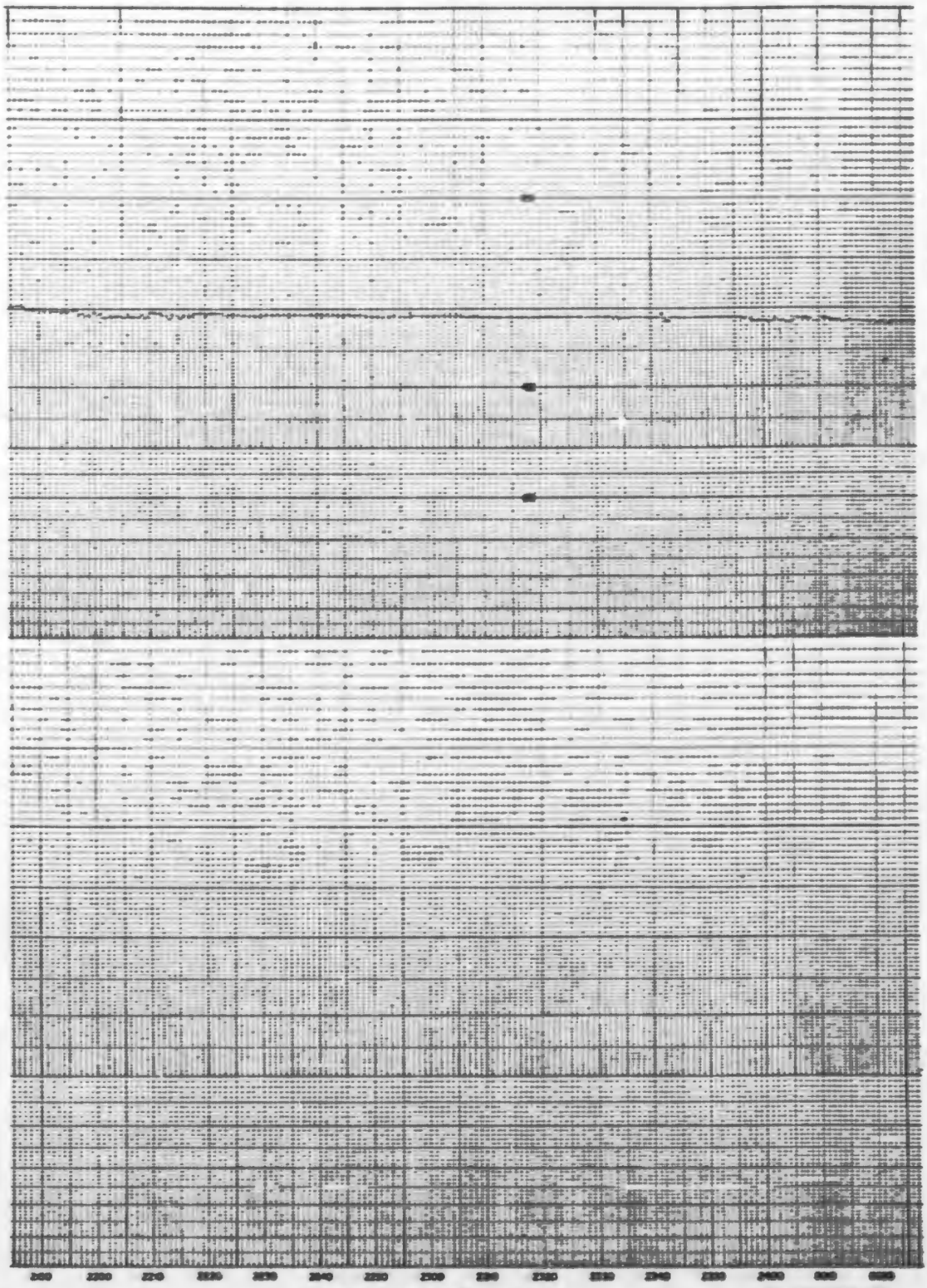

120
110
100
90
80
70
60
1500
1510
1520
1530
1540
1550
1600

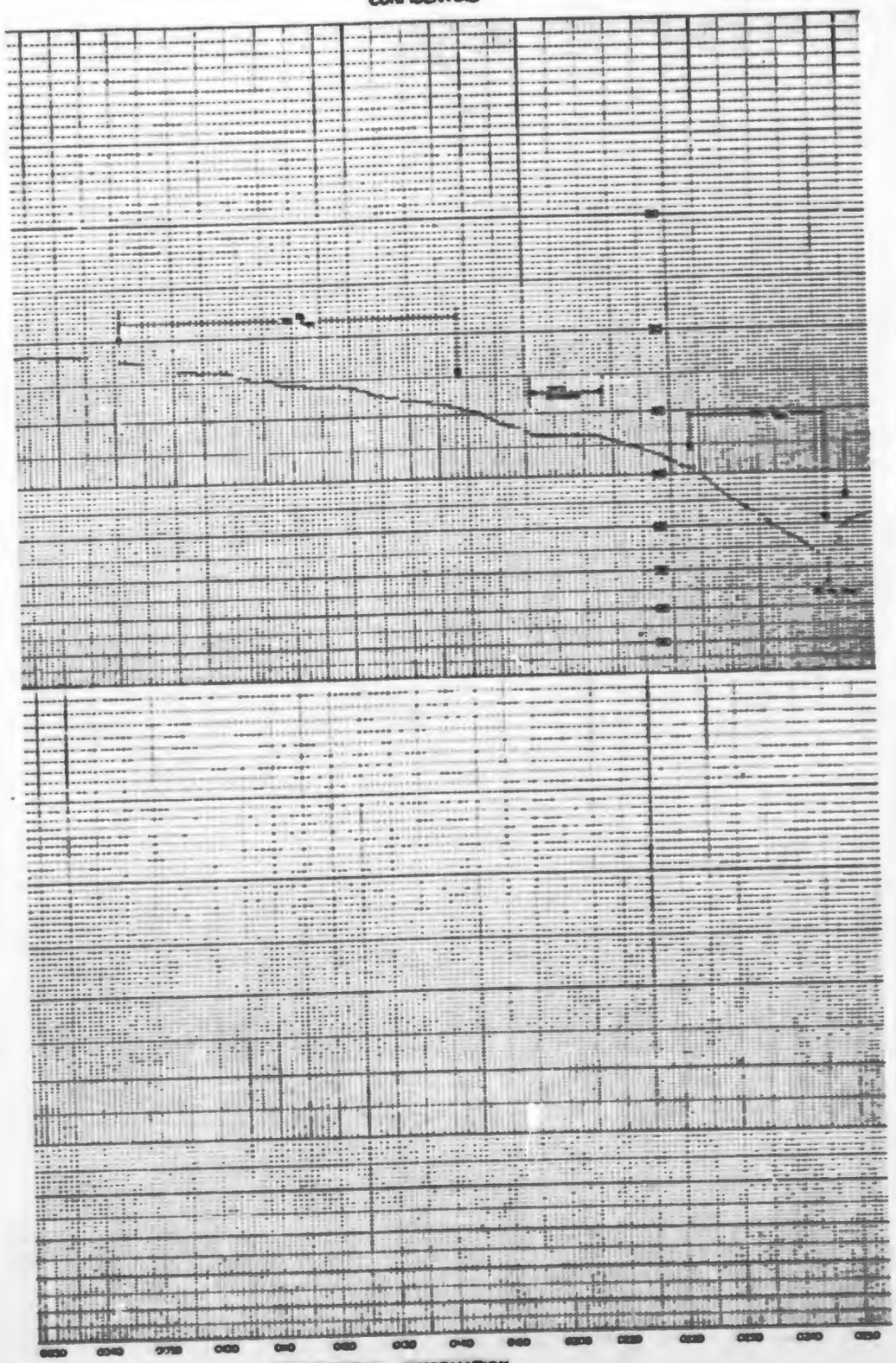
CONFIDENTIAL

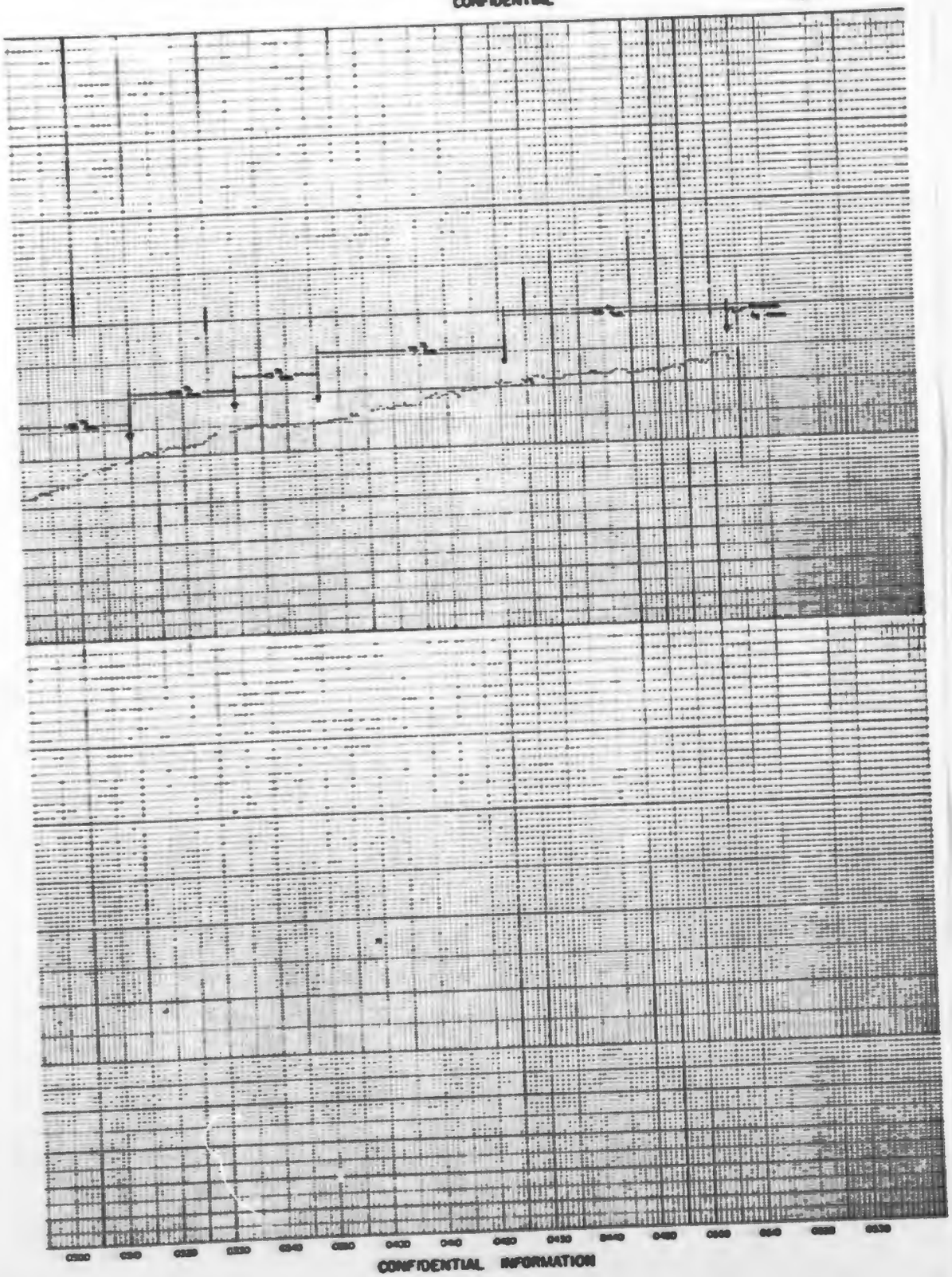


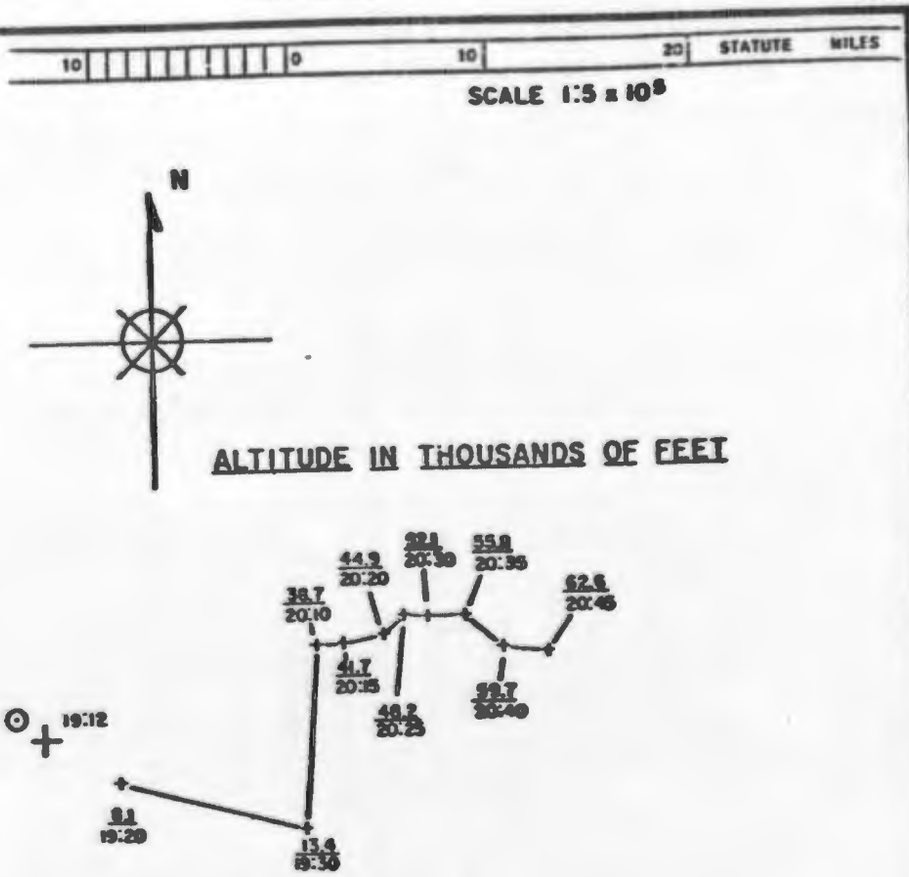
CONFIDENTIAL INFORMATION


GREENWICH MEAN TIME









LAUNCHED AT
U of M AIRPORT
MPLS., MINN.

⊙ THEODOLITE SITE LAT. 45° 08' LONG. 93° 12.5'

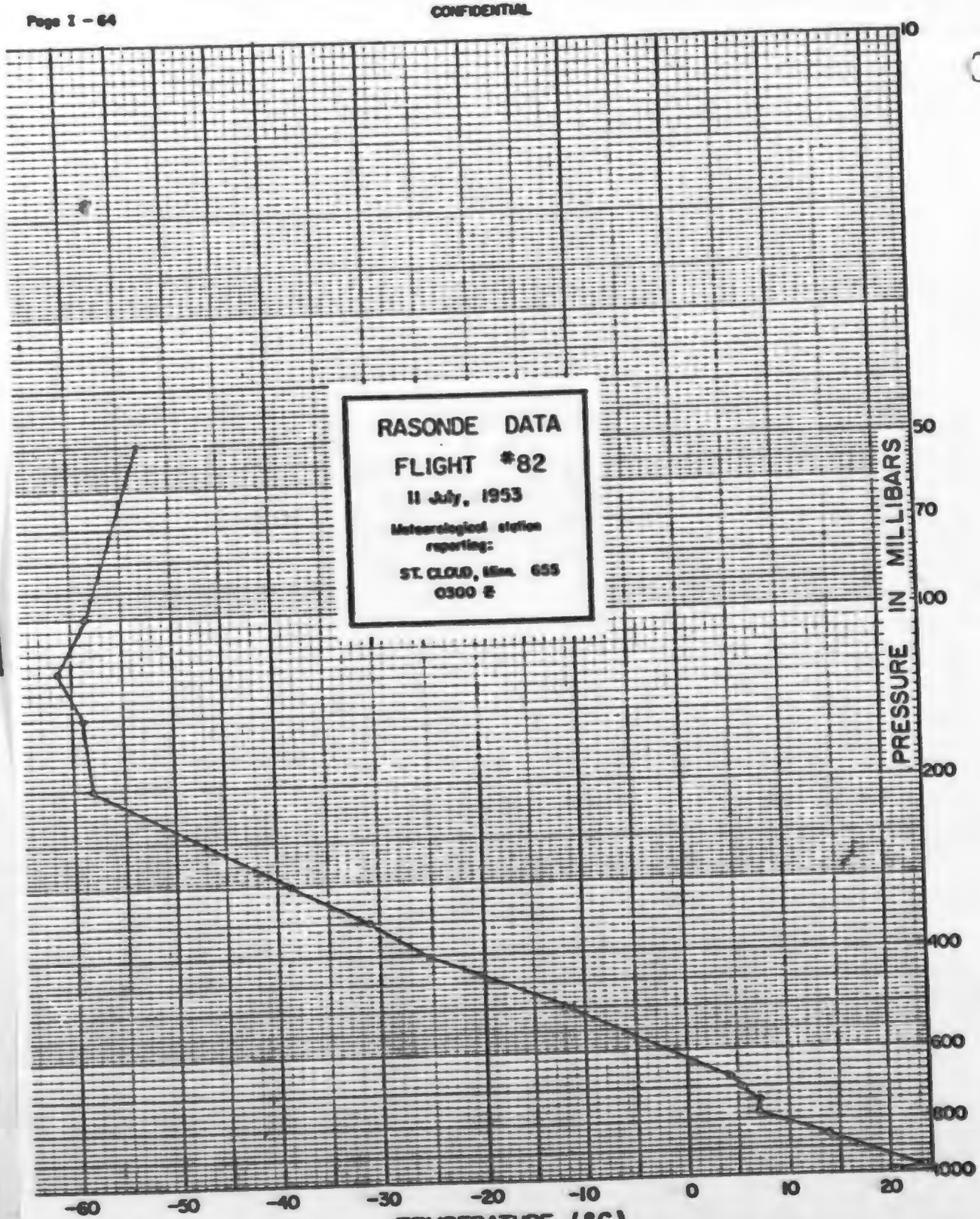
+ LAUNCH SITE LAT. 45° 07' LONG. 93° 10.5'

FLIGHT 81

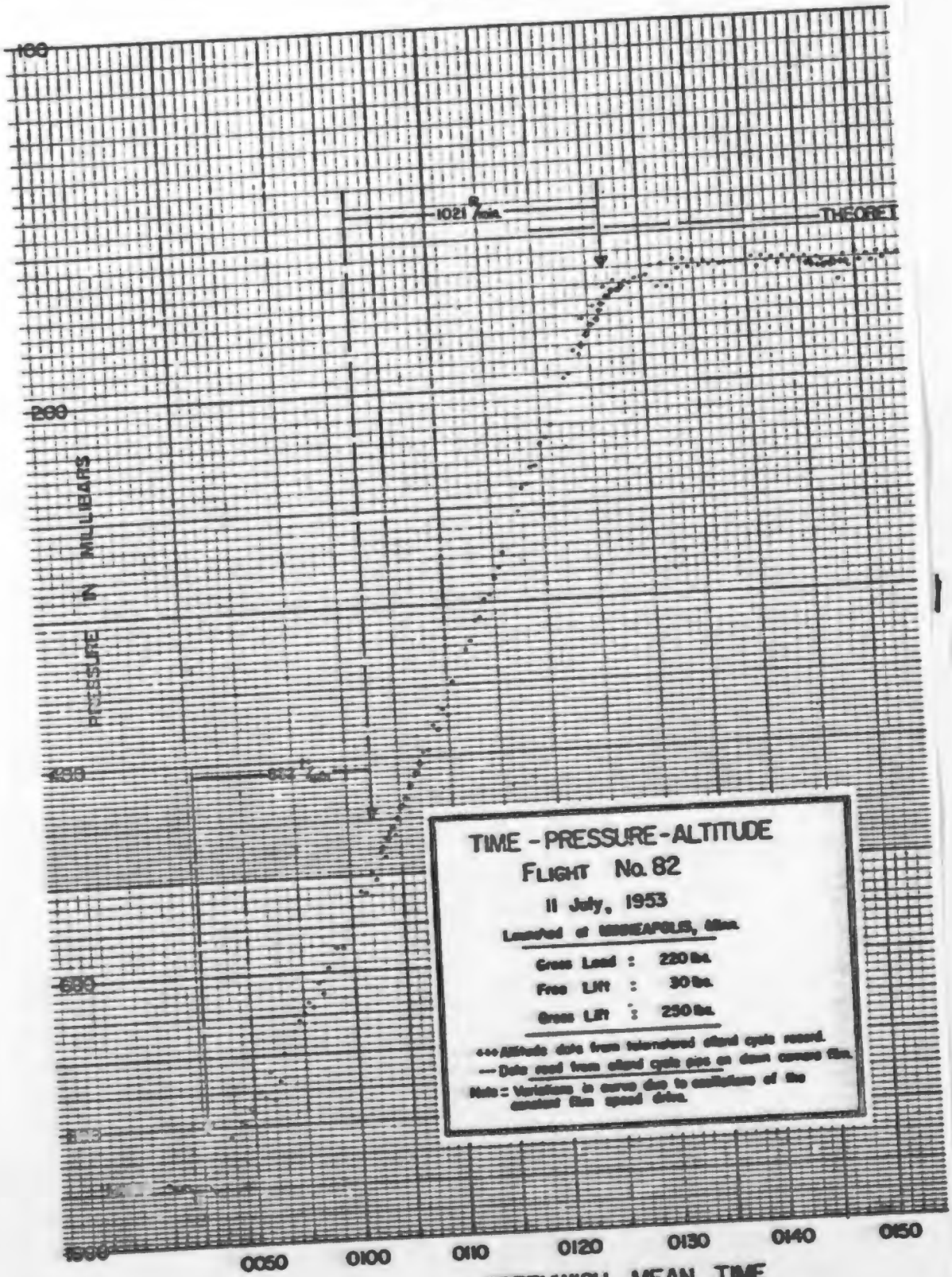
LAUNCHED 19:12 G.M.T.
7 JULY, 1954

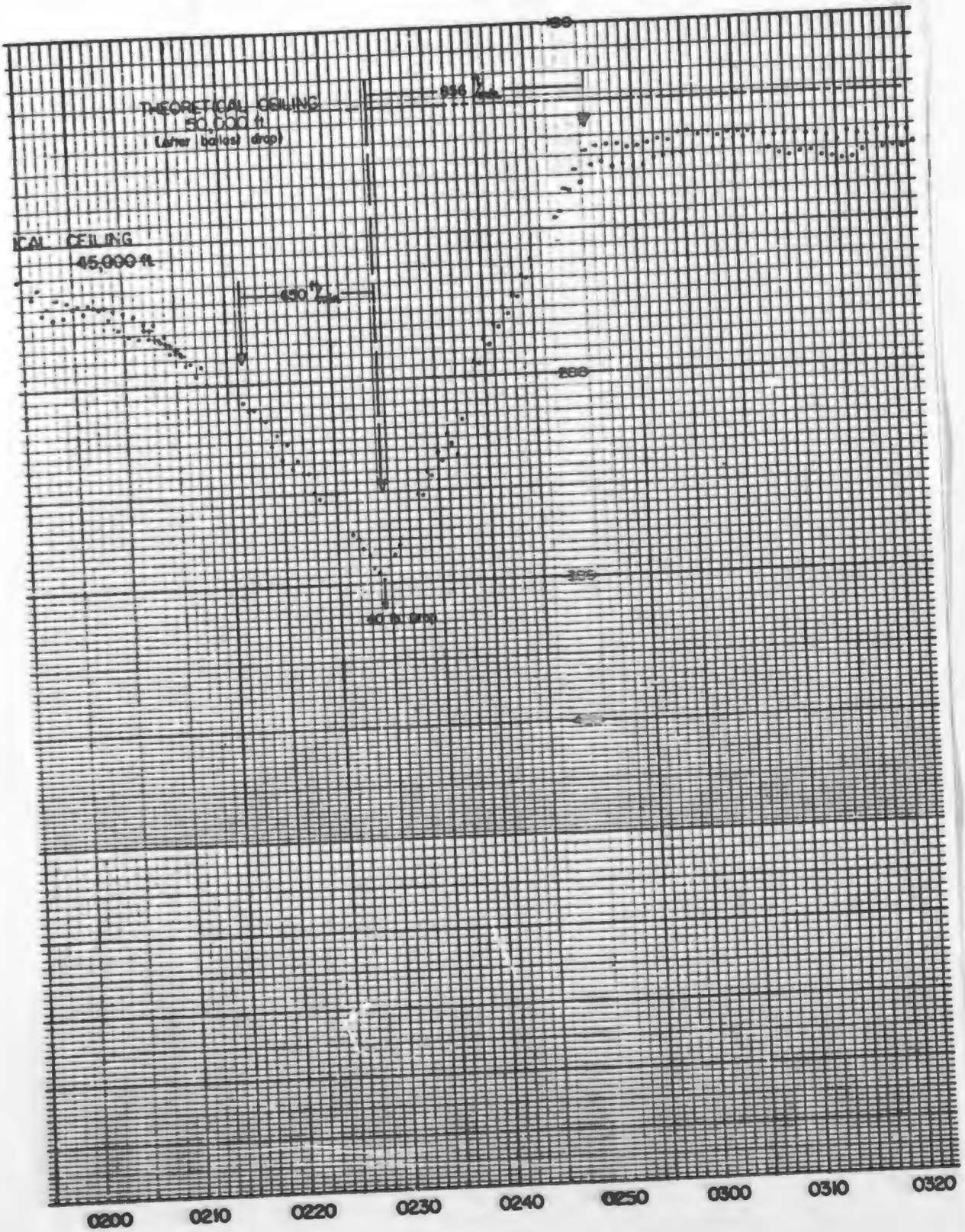
TRAJECTORY FROM THEODOLITE

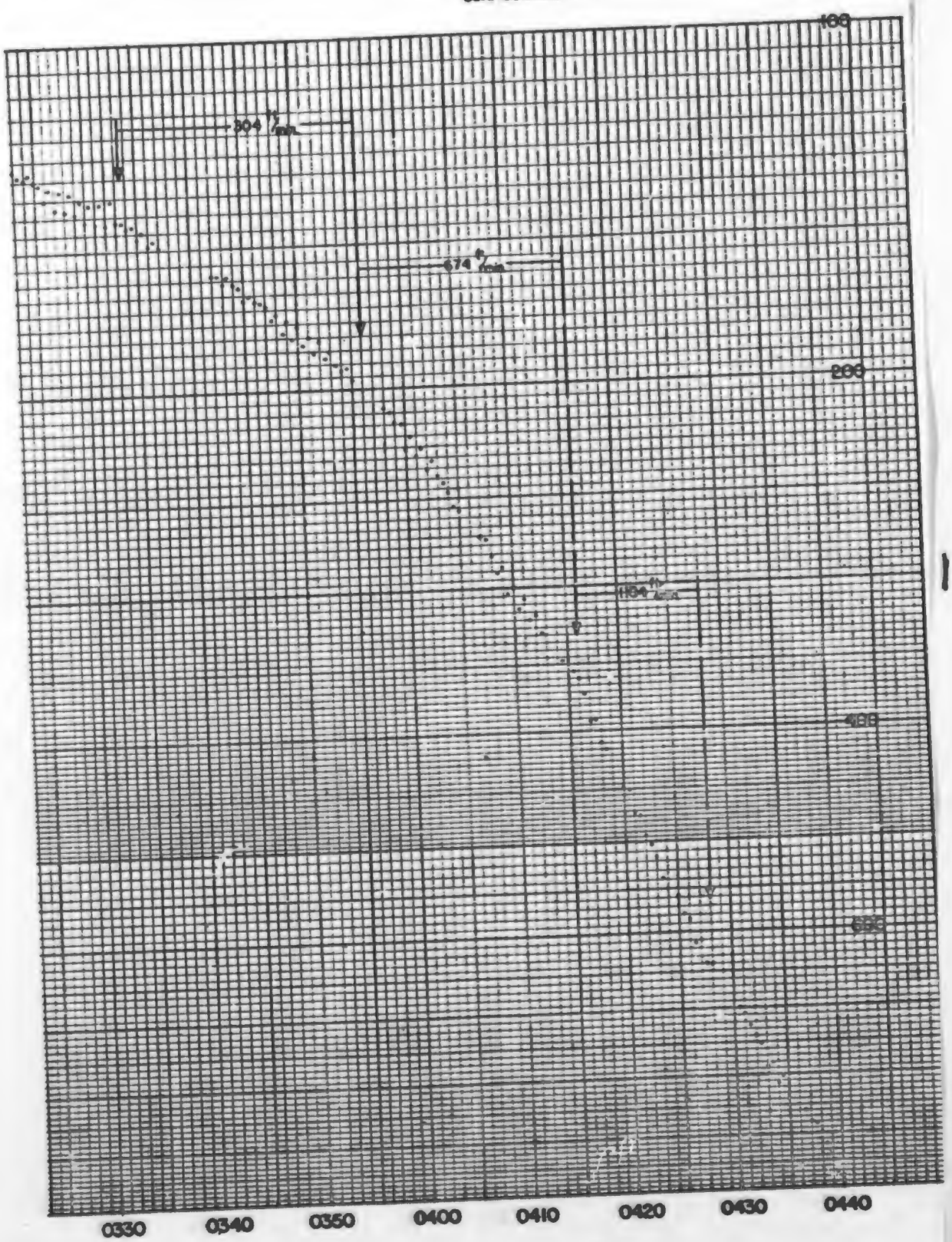
CONFIDENTIAL



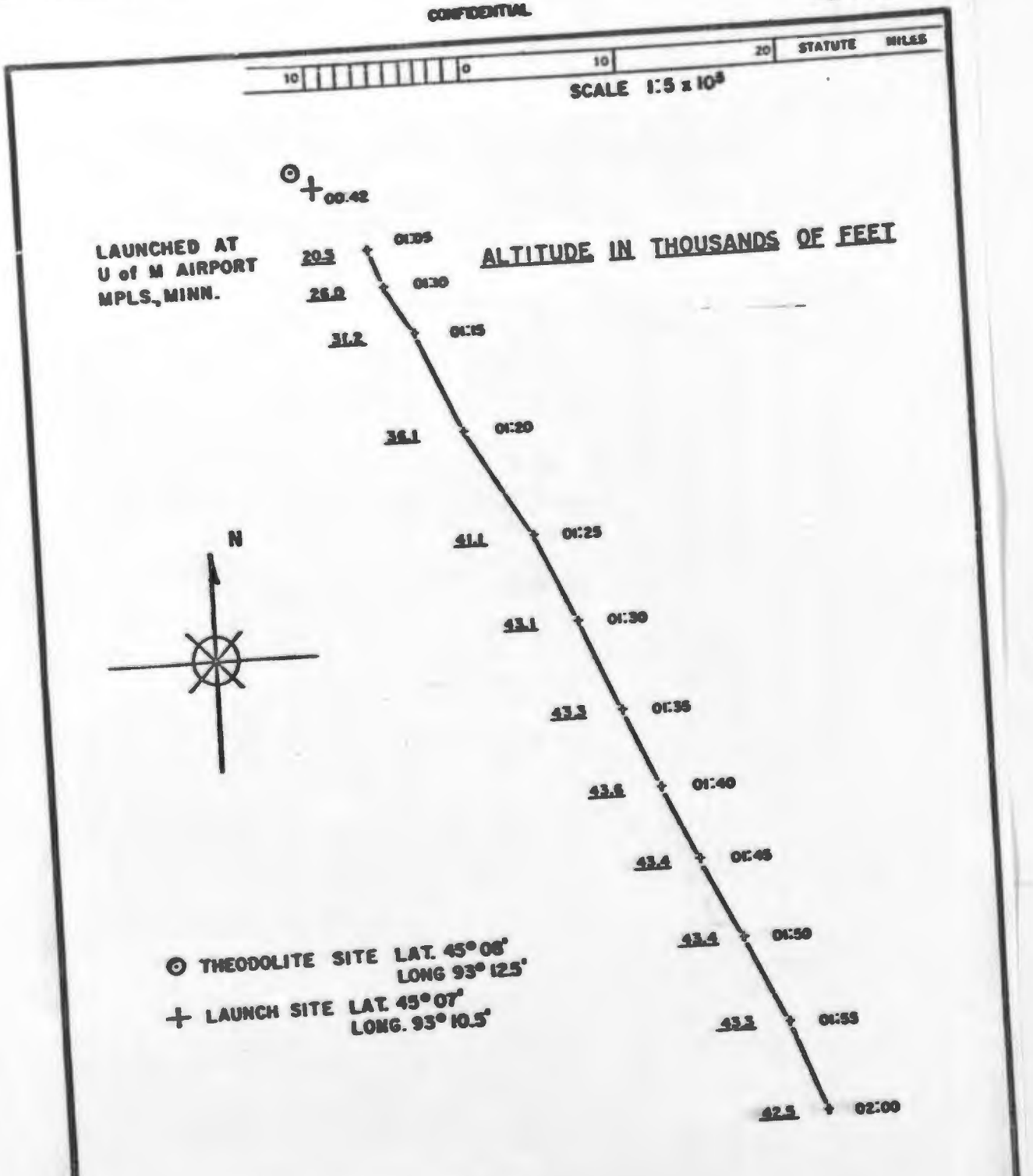
CONFIDENTIAL INFORMATION


100
200
PRESSURE IN MILLIBARS
1021 mb.
THEORET
812 mb.
TIME - PRESSURE - ALTITUDE
FLIGHT No. 82
11 July, 1953
Launched at MINNEAPOLIS, Minn.
Gross Load : 220 lbs.
Free Lift : 30 lbs.
Gross Lift : 250 lbs.
+++ Altitude data from telemetered altitude cycle record.
— Data read from altitude cycle pips on drum camera film.
Note: Variations in curve due to oscillations of the camera film speed drive.
0050
0100
0110
0120
0130
0140
0150
GREENWICH MEAN TIME


THEORETICAL CEILING
50,000 ft
(after ballast drop)
ICAL CEILING
45,000 ft
650 ft/min
40 lb BALLAST
0200
0210
0220
0230
0240
0250
0300
0310
0320


100
200
300
400
500
304 ft/min
674 ft/min
1104 ft/min
0330
0340
0350
0400
0410
0420
0430
0440

CONFIDENTIAL



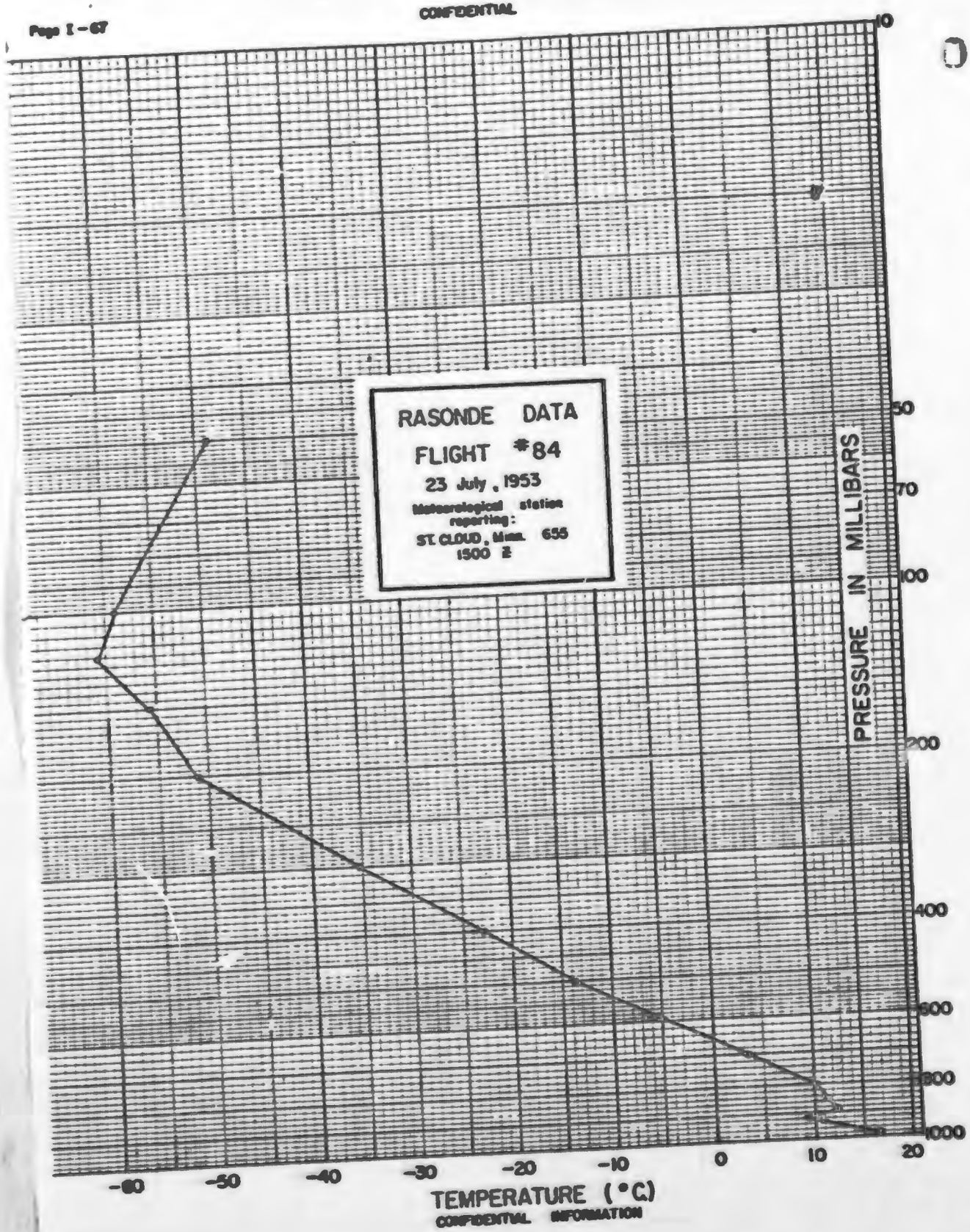
FLIGHT 82

LAUNCHED 00:42 GMT
11 JULY, 1953

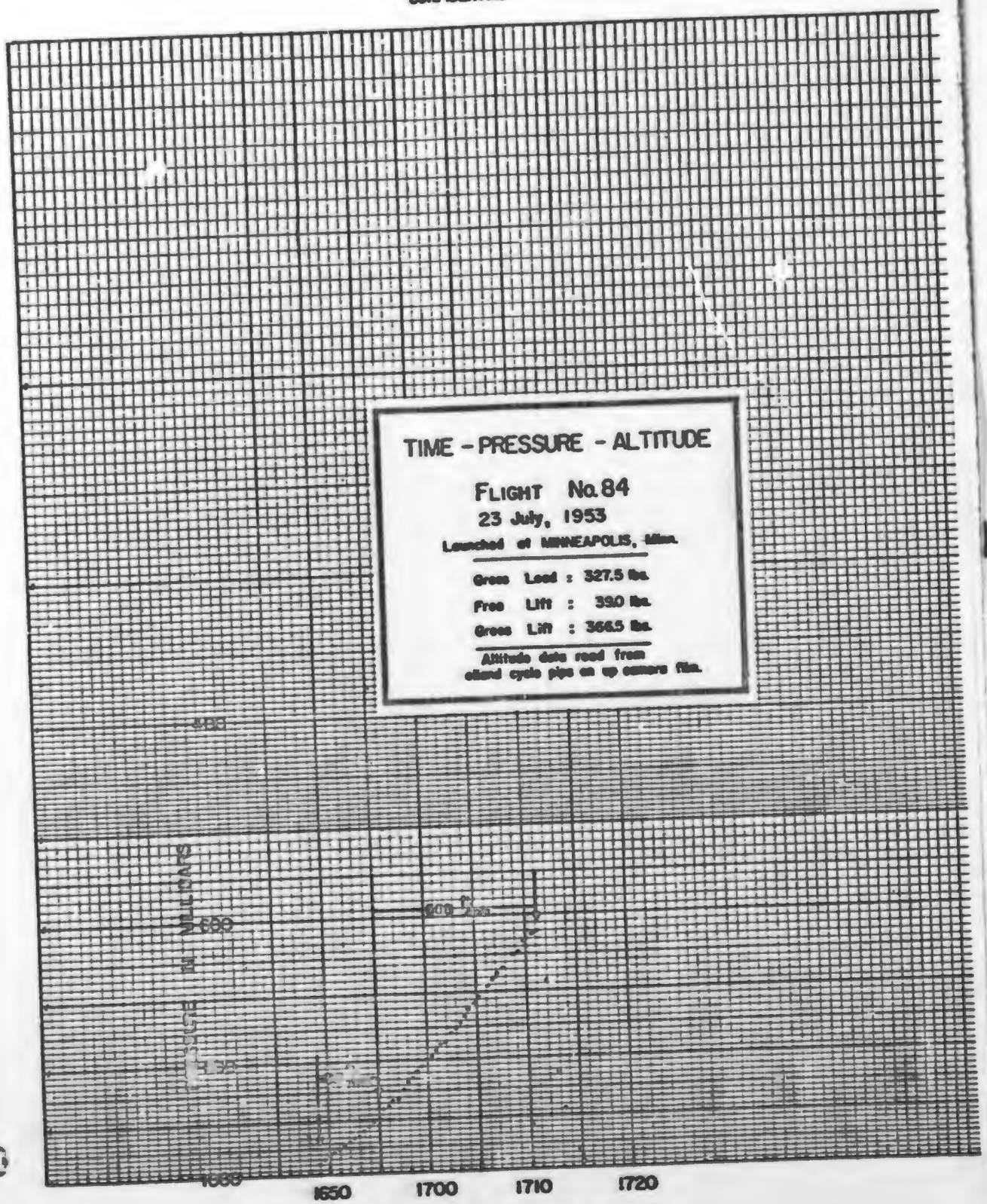
TRAJECTORY FROM THEODOLITE

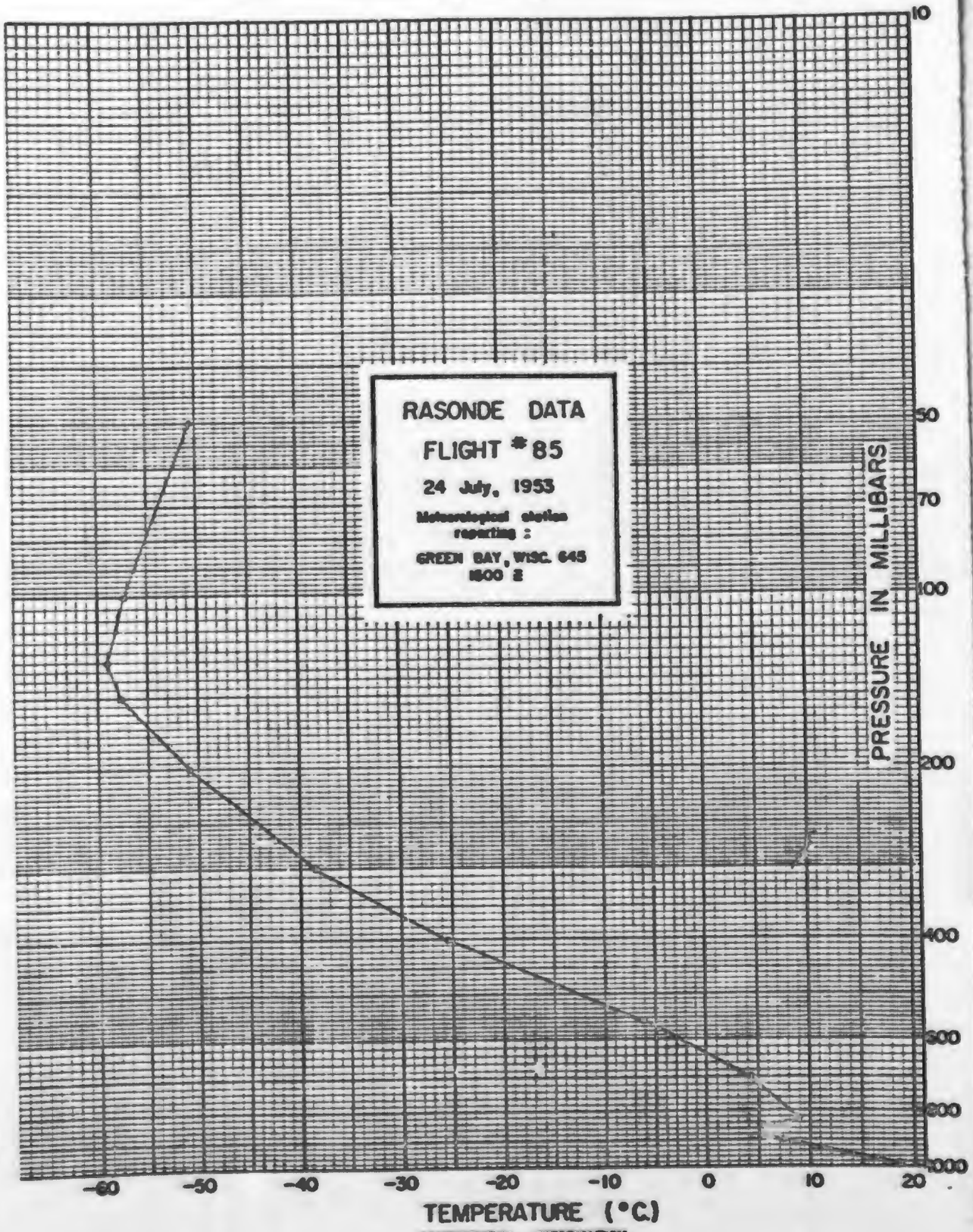
CONFIDENTIAL INFORMATION

CONFIDENTIAL

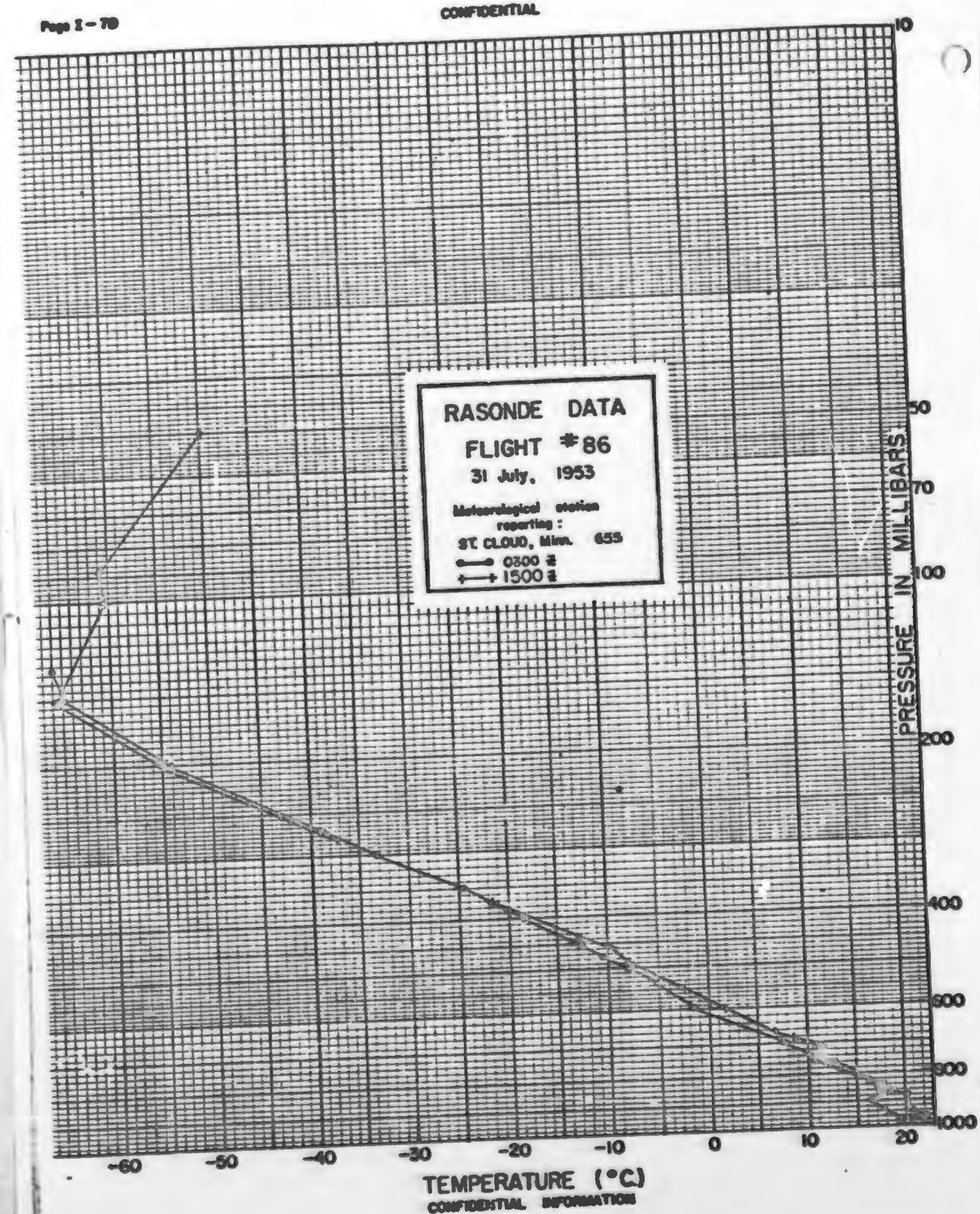


CONFIDENTIAL INFORMATION

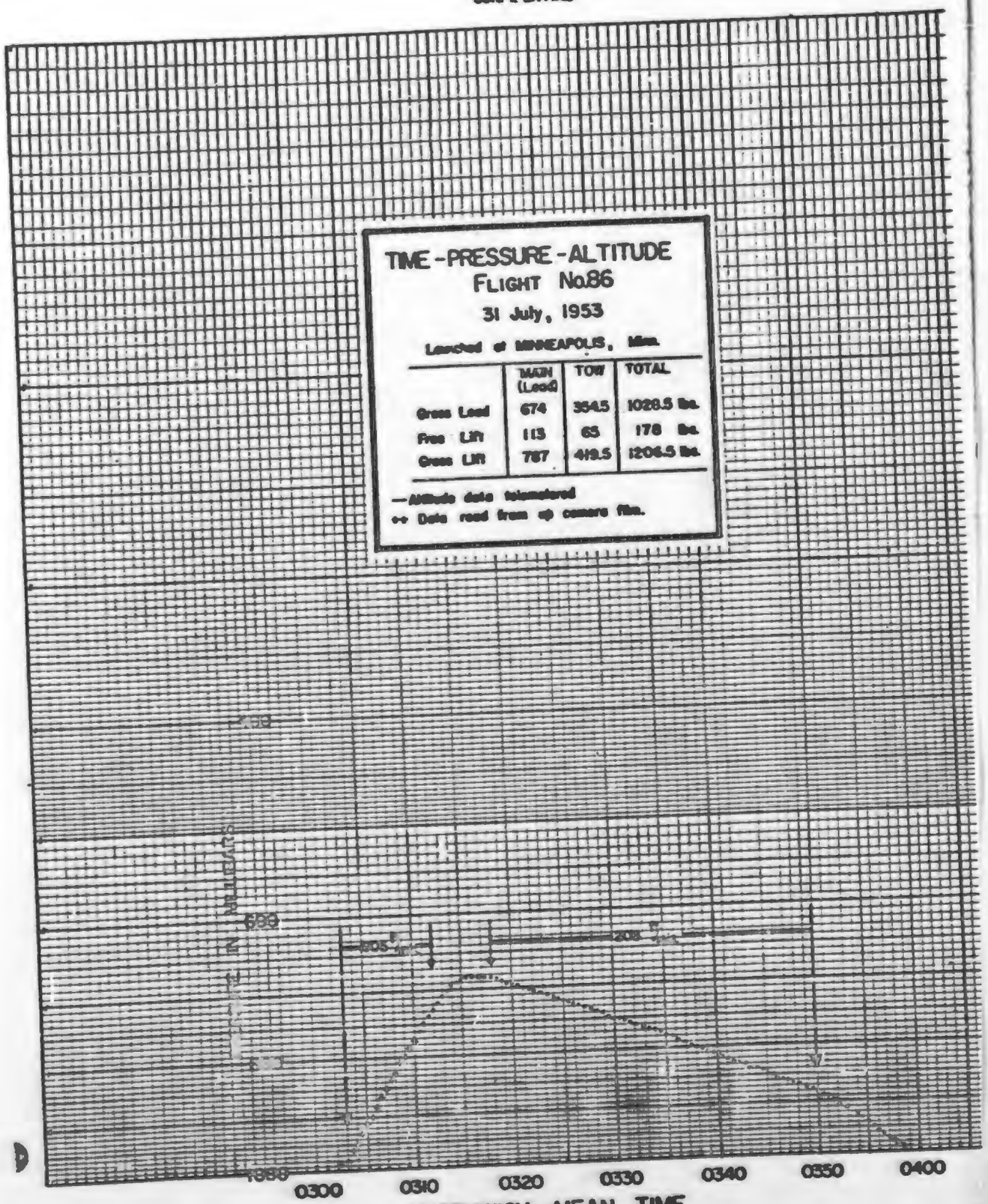

TIME - PRESSURE - ALTITUDE
FLIGHT No. 84
23 July, 1953
Launched at MINNEAPOLIS, Minn.
Gross Load : 327.5 lbs.
Free Lift : 39.0 lbs.
Gross Lift : 366.5 lbs.
Altitude data read from
chand cycle pips on up camera film.
PRESSURE IN MILLIBARS
600
1650
1700
1710
1720
GREENWICH MEAN TIME


RASONDE DATA
FLIGHT # 85
24 July, 1953
Meteorological station reporting :
GREEN BAY, WISC. 645
1600 Z
PRESSURE IN MILLIBARS
10
50
70
100
200
400
600
800
1000
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

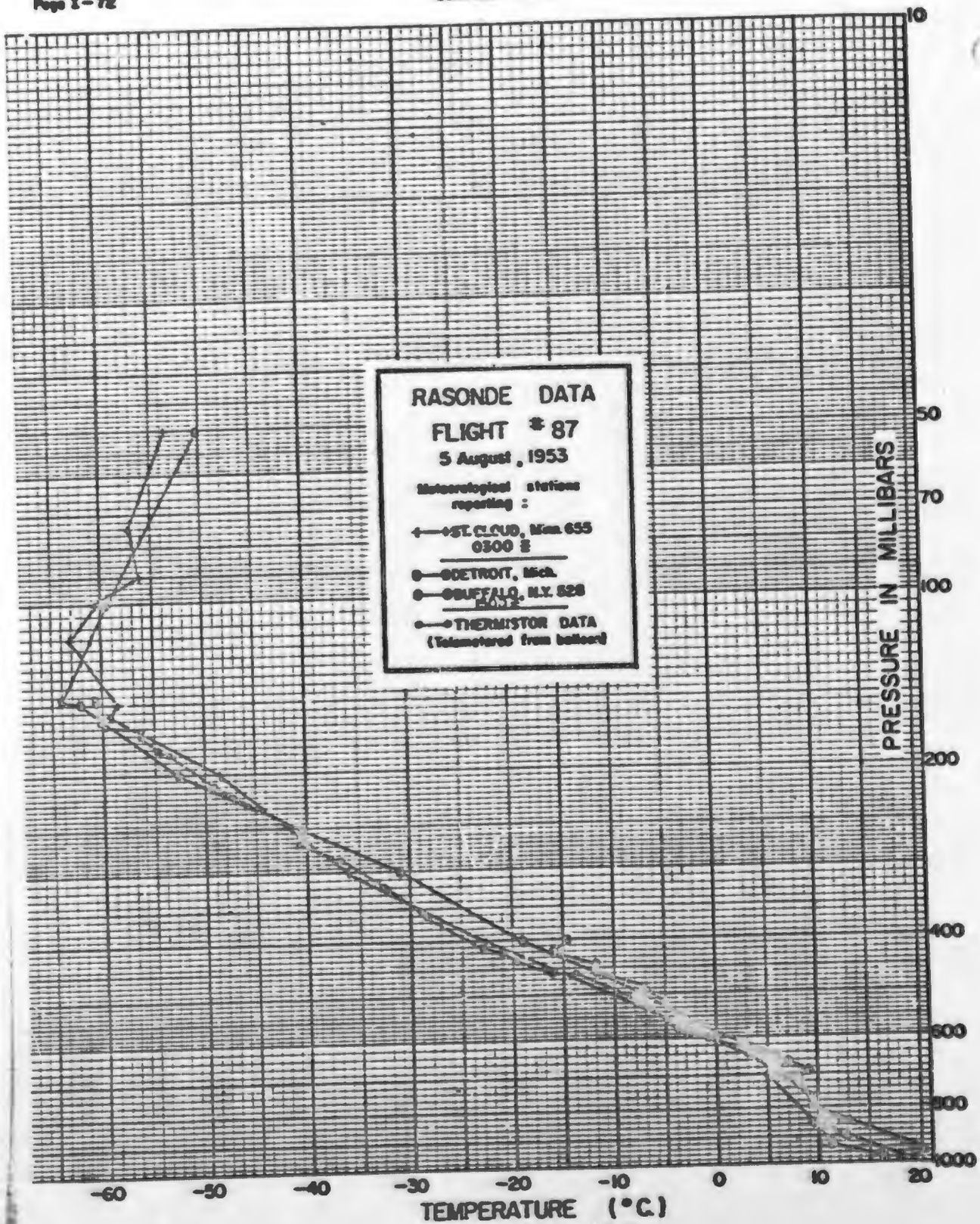
CONFIDENTIAL



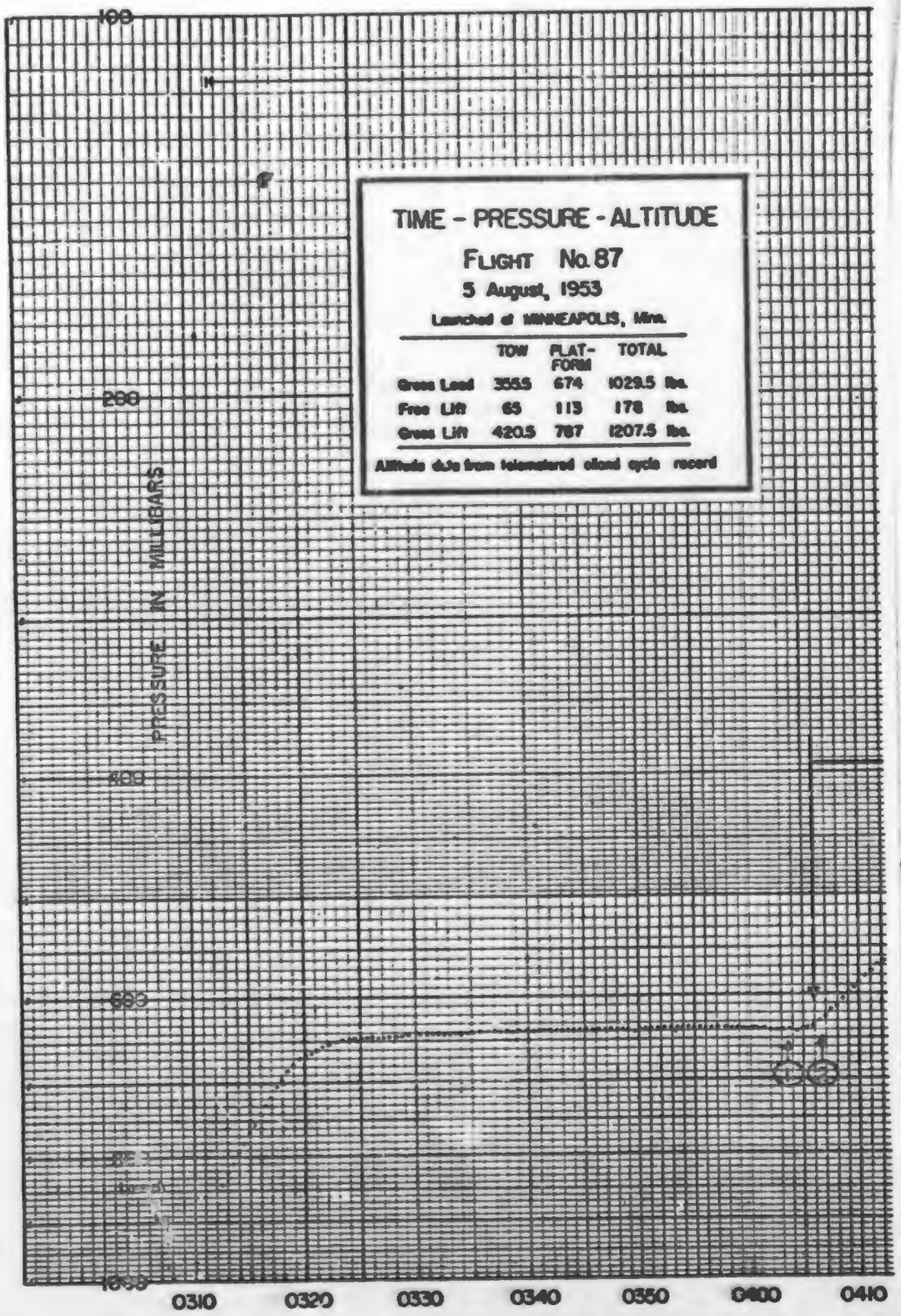
CONFIDENTIAL INFORMATION

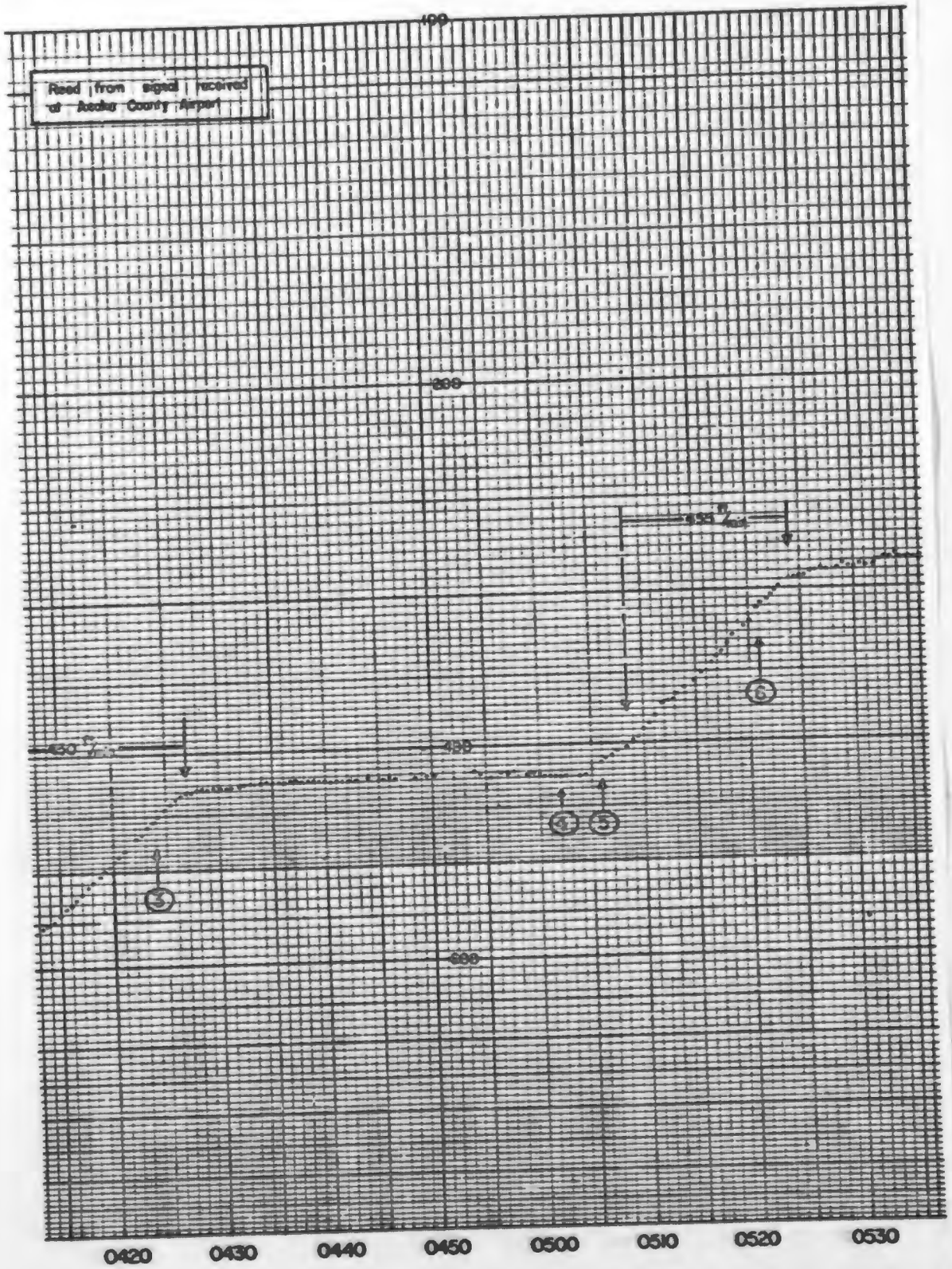

TIME-PRESSURE-ALTITUDE
FLIGHT No.86
31 July, 1953
Launched at MINNEAPOLIS, Minn.
MAIN (Load)
TOW
TOTAL
Gross Load 674 354.5 1028.5 lbs.
Free Lift 113 65 178 lbs.
Gross Lift 787 419.5 1206.5 lbs.
—Altitude data telemetered
++ Data read from up camera film.
ALTITUDE IN MILLIBARS
600
1000
0300
0310
0320
0330
0340
0350
0400
GREENWICH MEAN TIME

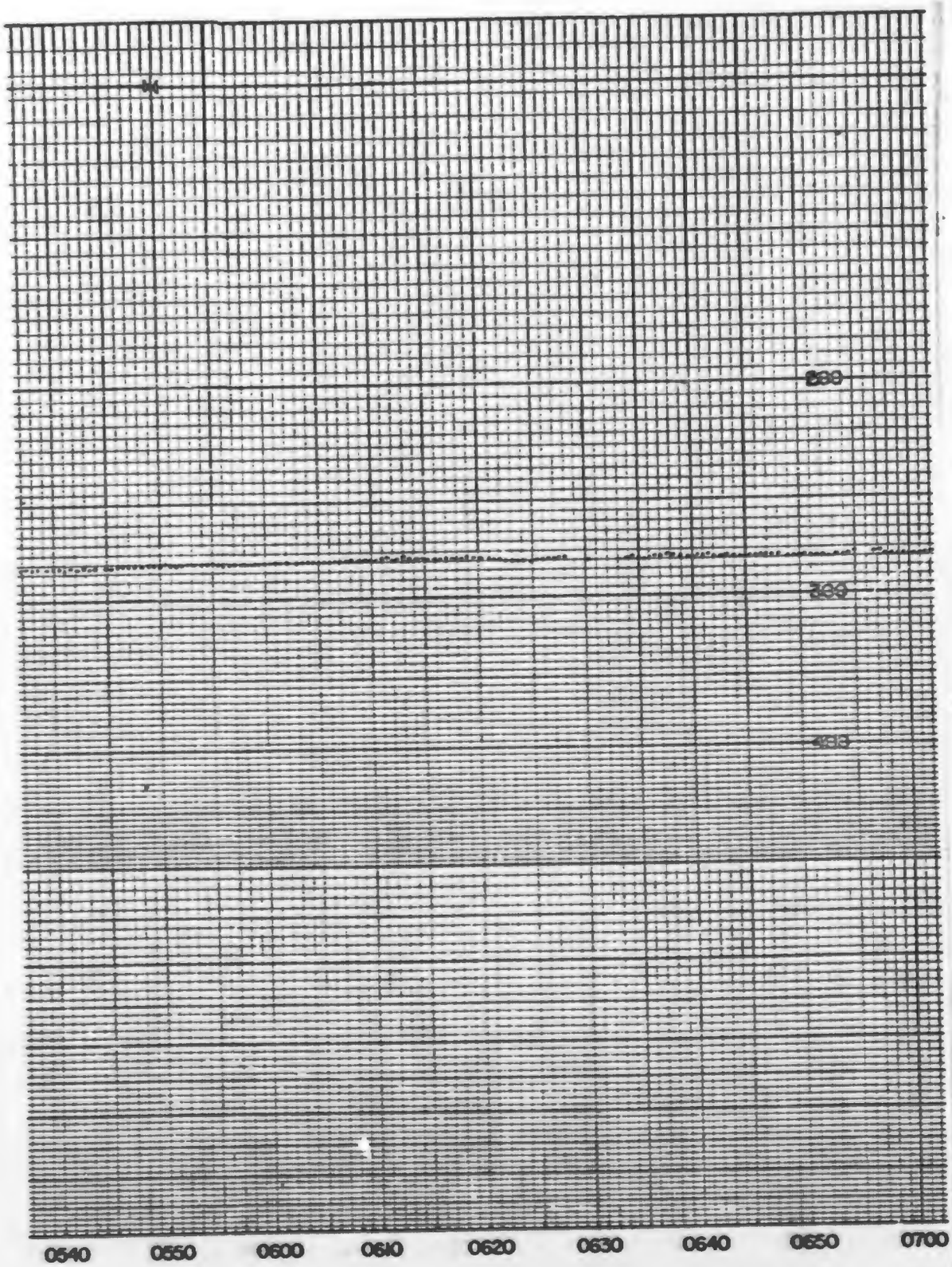
CONFIDENTIAL



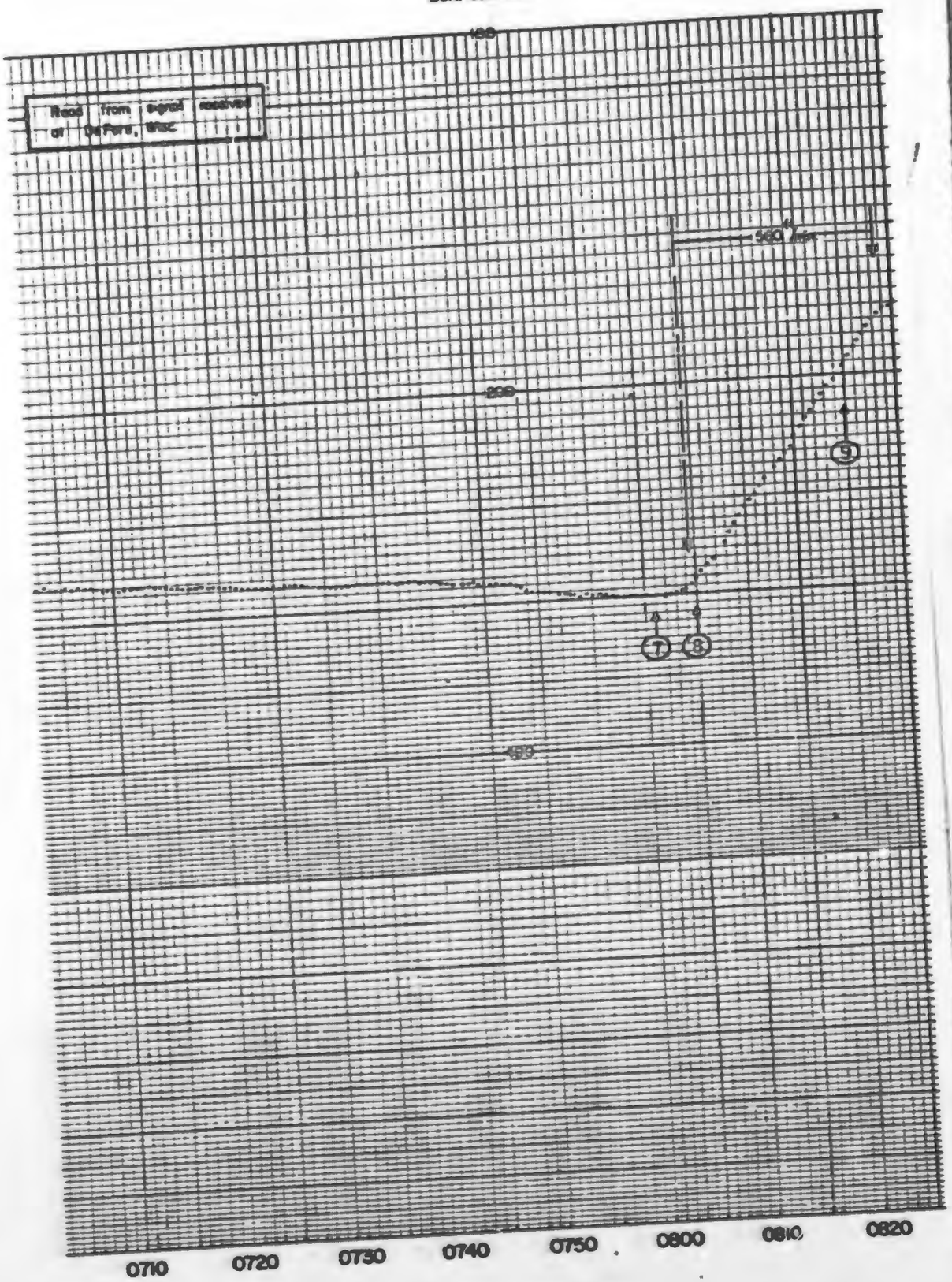
CONFIDENTIAL INFORMATION


TIME - PRESSURE - ALTITUDE
FLIGHT No. 87
5 August, 1953
Launched at MINNEAPOLIS, Minn.
TOW
PLAT-FORM
TOTAL
Gross Load 355.5 674 1029.5 lbs.
Free Lift 65 113 178 lbs.
Gross Lift 420.5 787 1207.5 lbs.
Altitude data from telemetered cloud cycle record
100
200
300
400
500
600
700
800
900
1000
PRESSURE IN MILLIBARS
0310
0320
0330
0340
0350
0400
0410
GREENWICH MEAN TIME

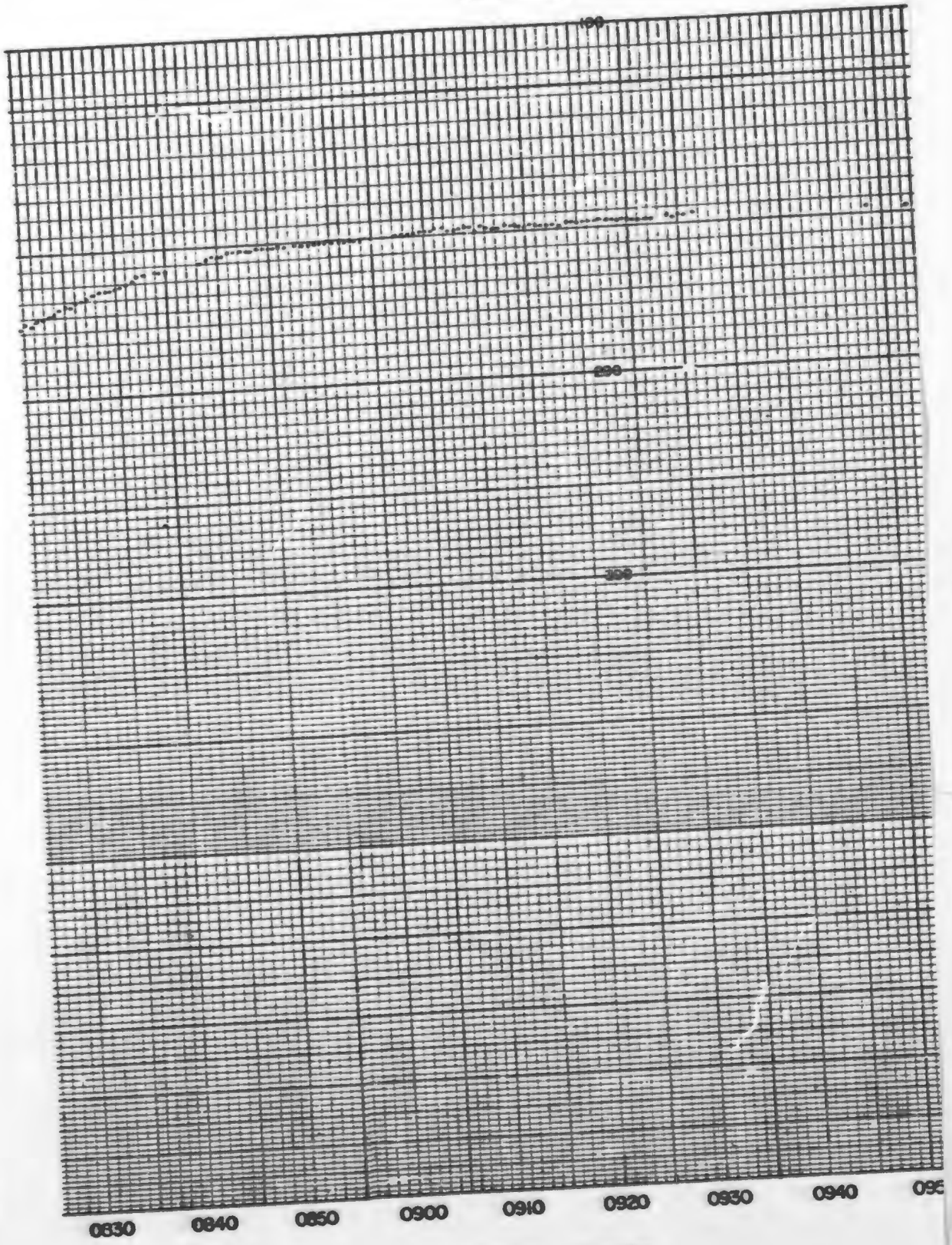

100
Read from signal received at Reeder County Airport
200
300
400
500
600
0420
0430
0440
0450
0500
0510
0520
0530

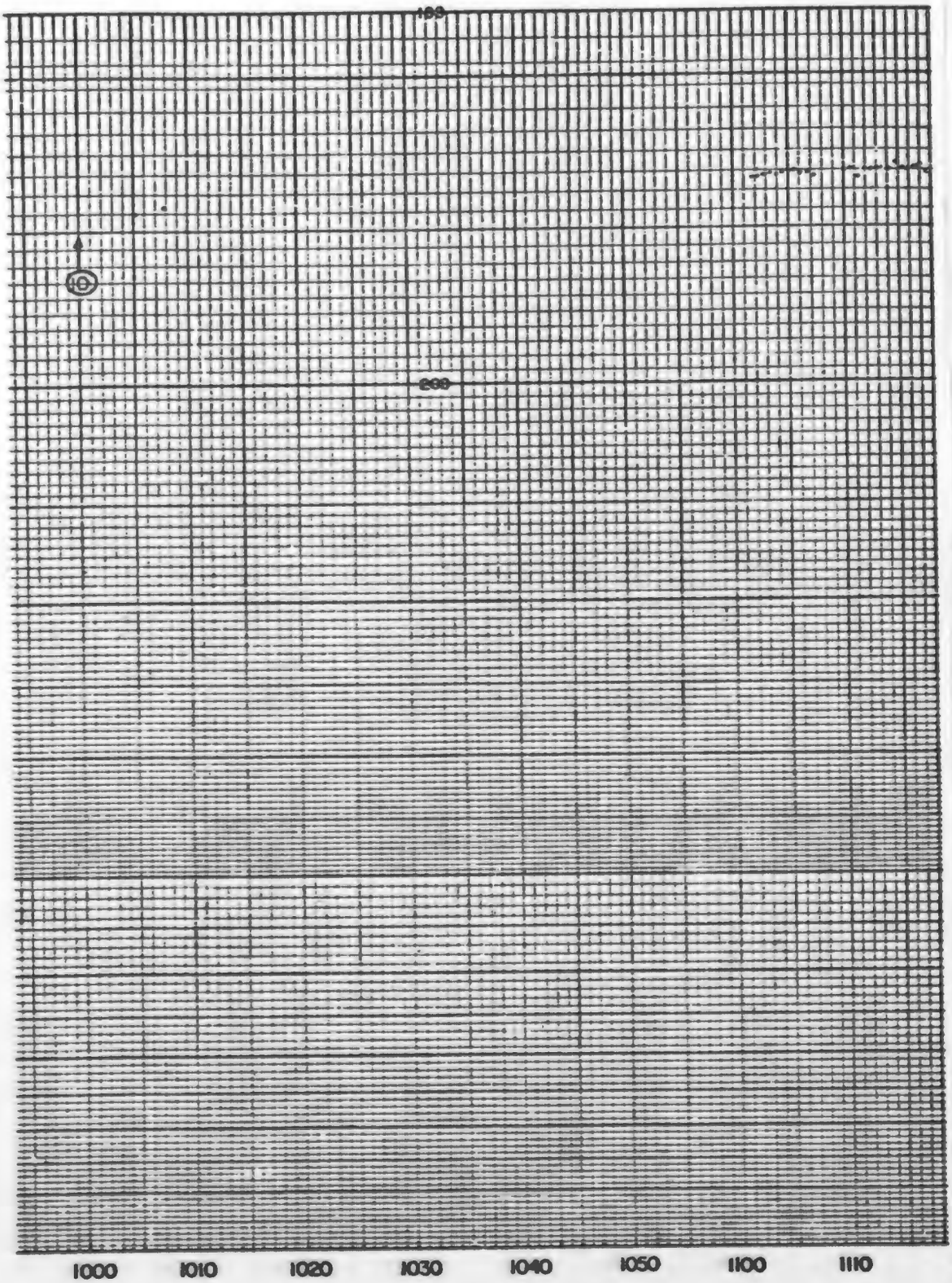

94
200
300
400
0540
0550
0600
0610
0620
0630
0640
0650
0700

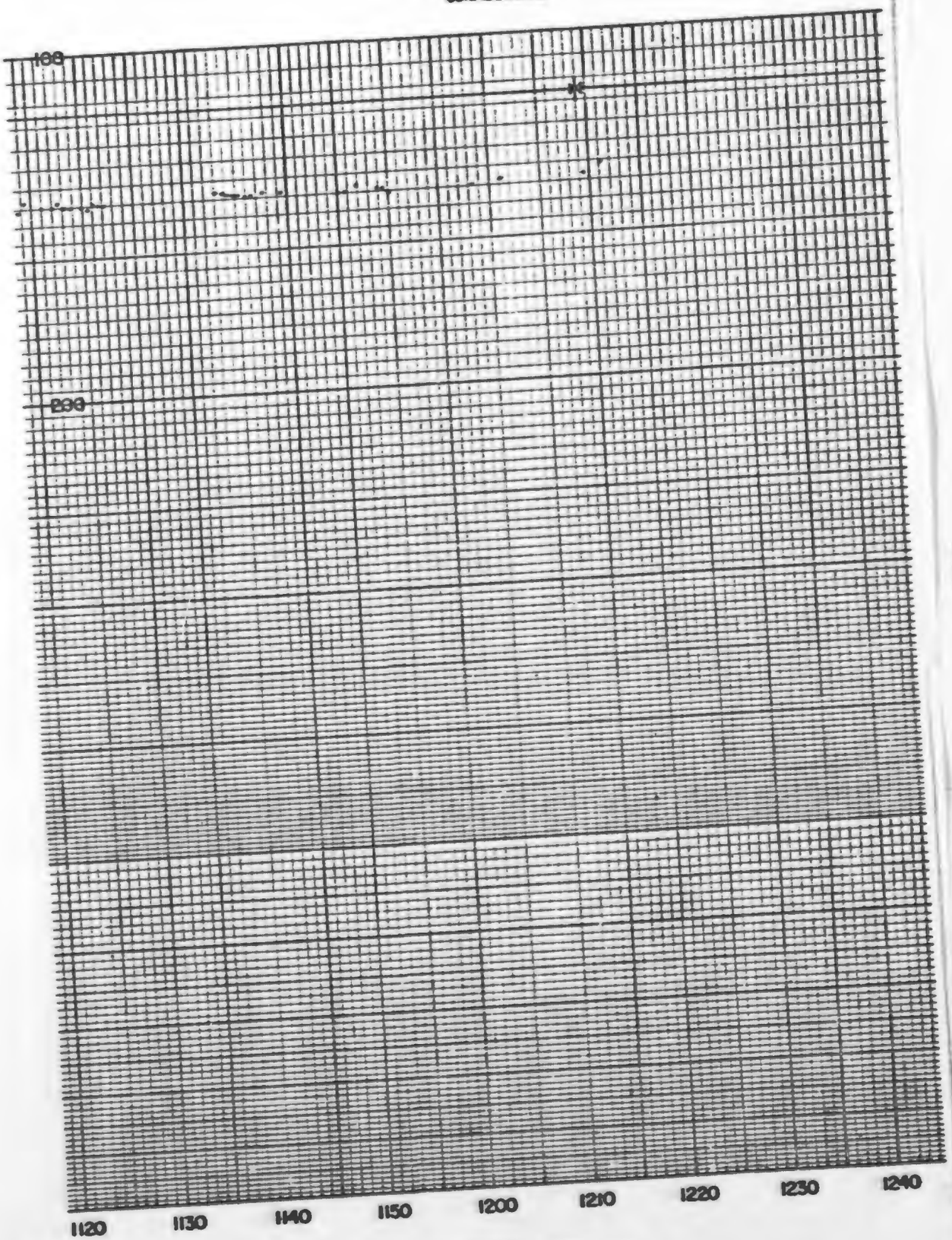
CONFIDENTIAL

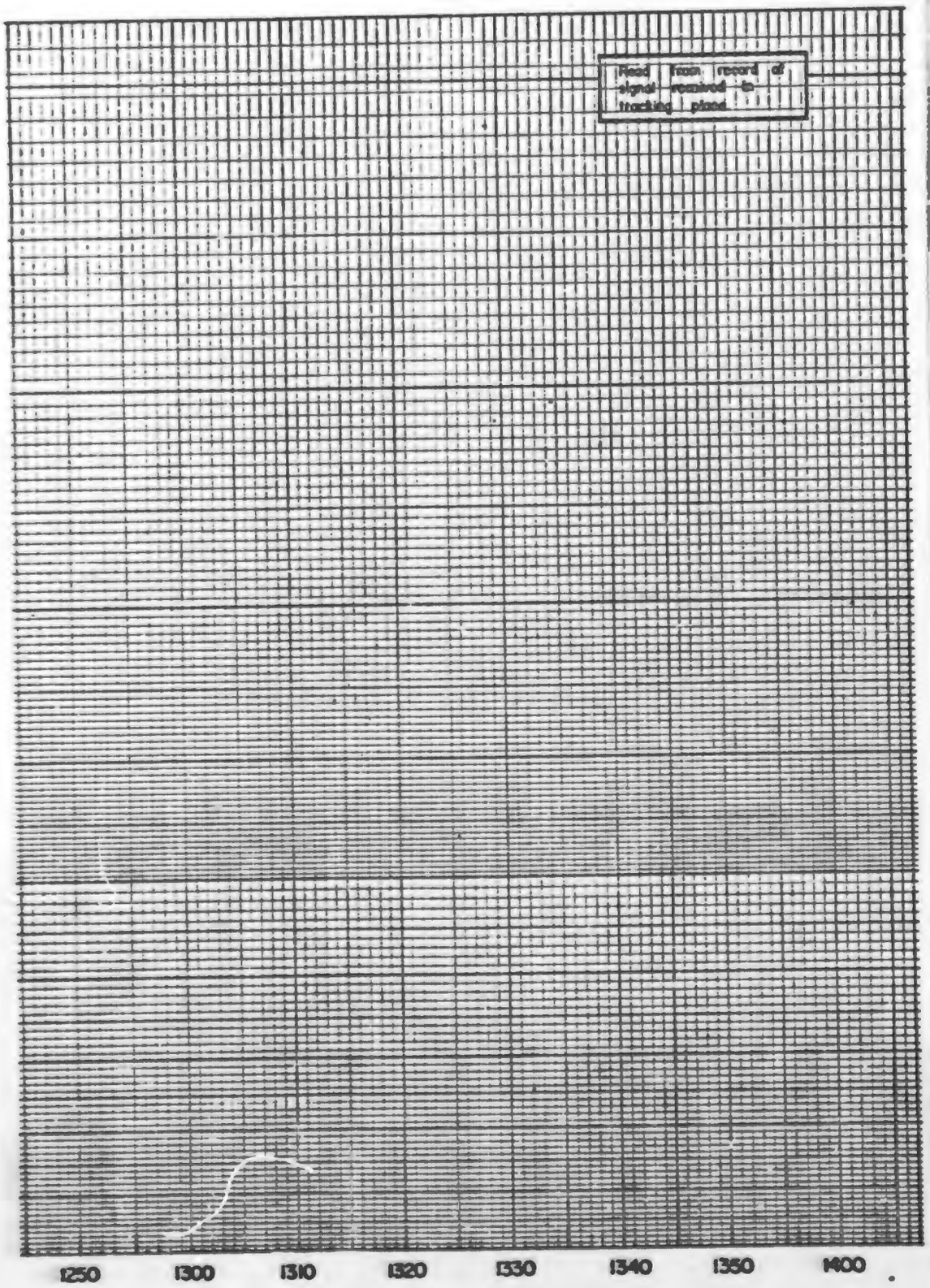


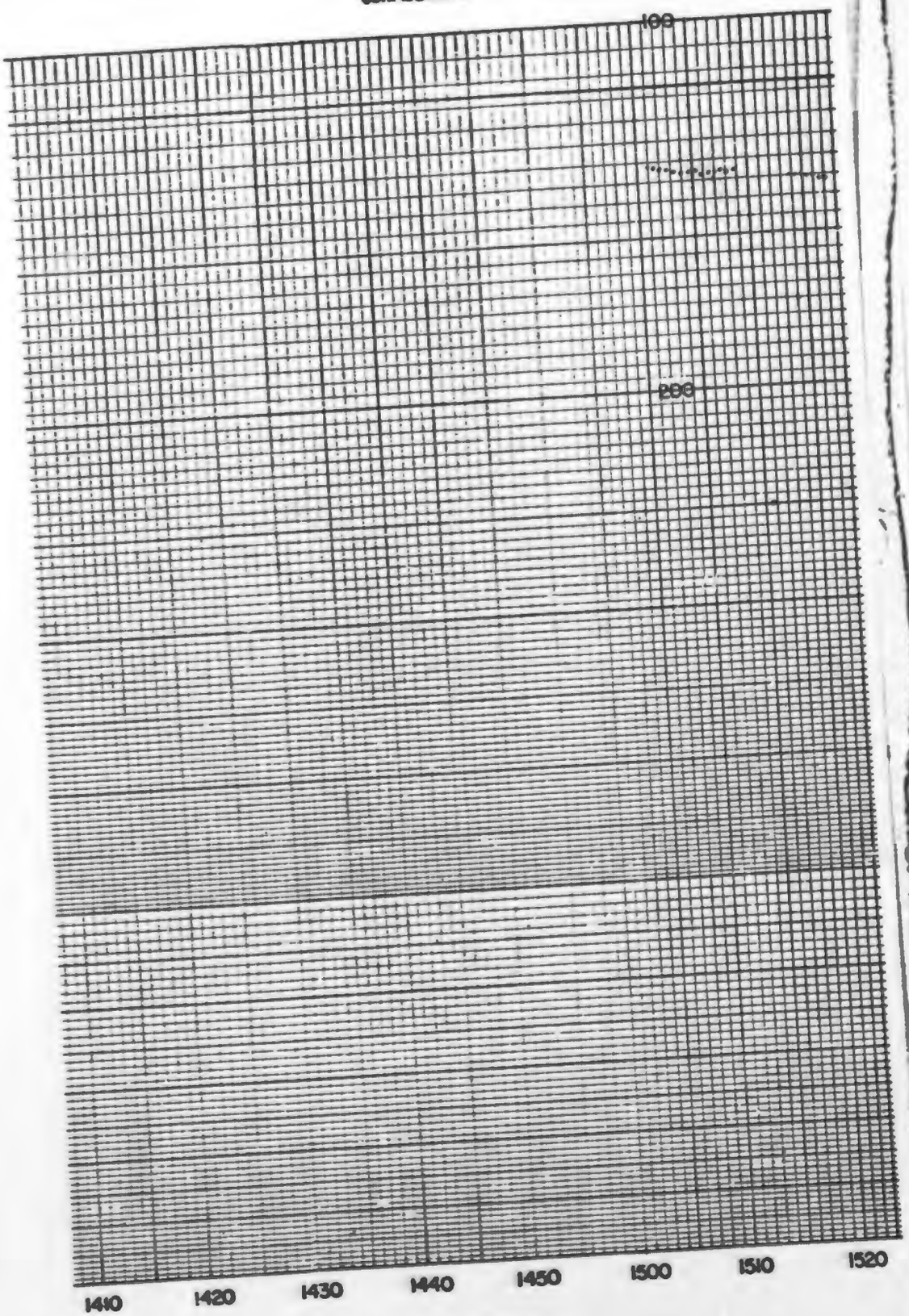
CONFIDENTIAL INFORMATION

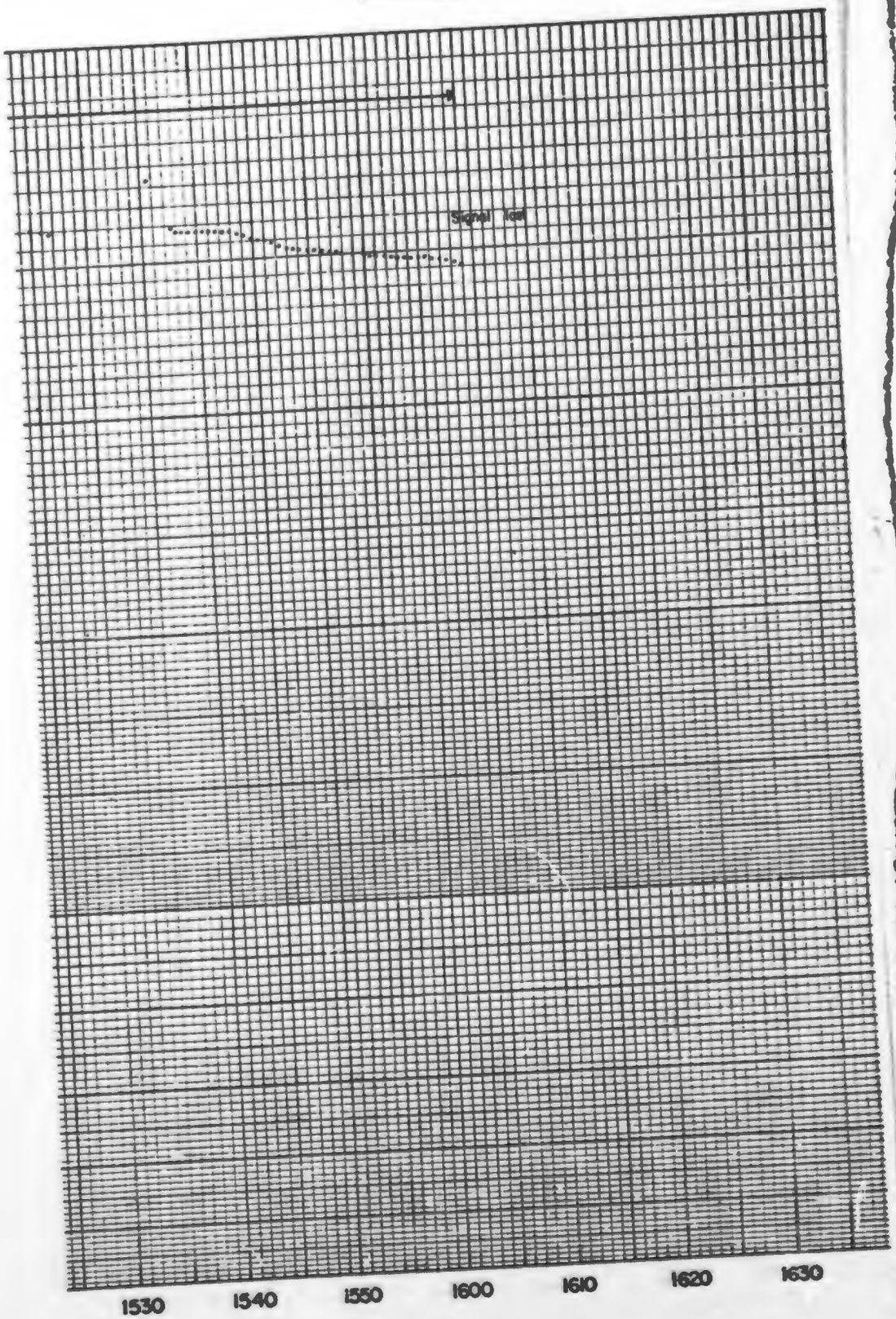

100
200
300
0830
0840
0850
0900
0910
0920
0930
0940

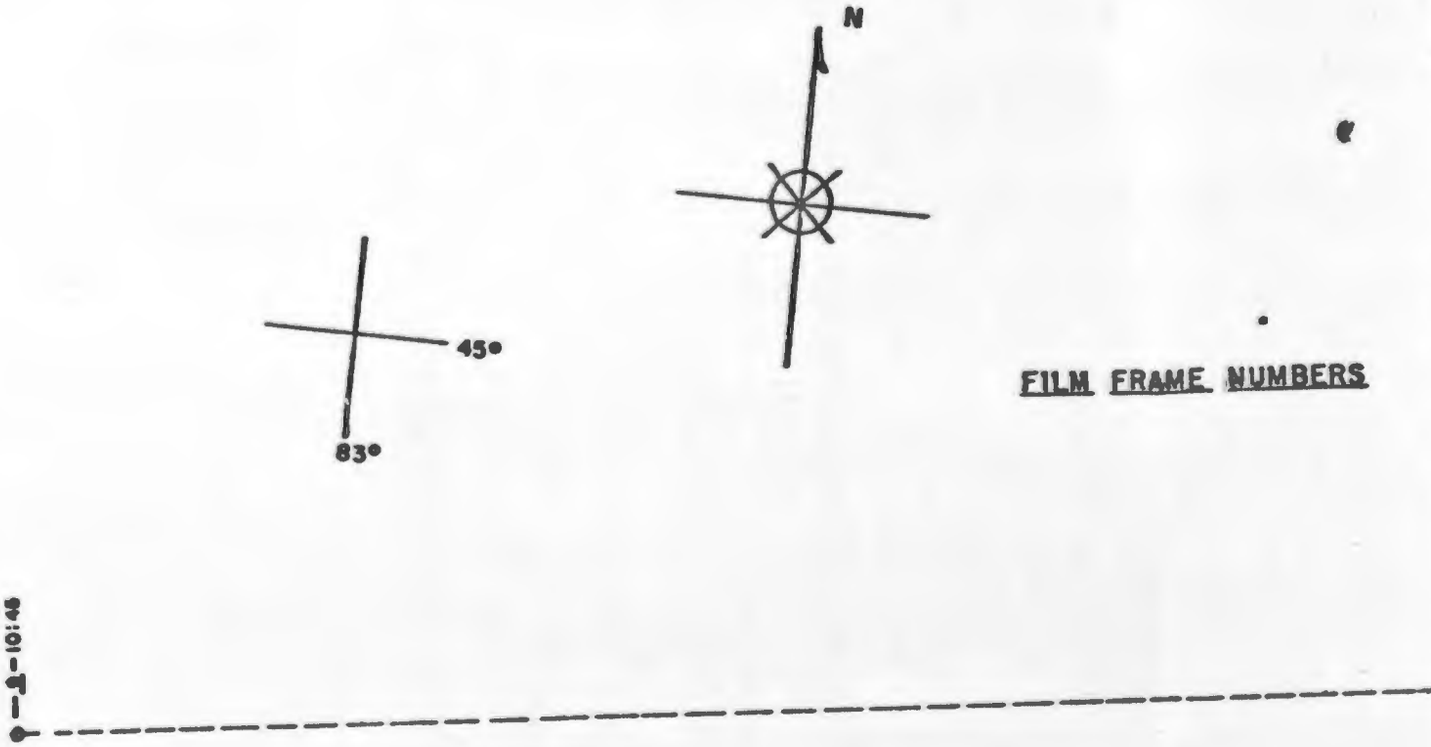

100
10
200
1000
1010
1020
1030
1040
1050
1100
1110


100
200
1120
1130
1140
1150
1200
1210
1220
1230
1240


Read from record of signal received to tracking plane
1250
1300
1310
1320
1330
1340
1350
1400


100
200
1410
1420
1430
1440
1450
1500
1510
1520


Signal lost
1530
1540
1550
1600
1610
1620
1630



FILM FRAME NUMBERS

LAUNCHED AT
U of M AIRPORT
MPLS, MINN.

LAUNCH SITE LAT. 45°07' LONG. 93°10.5'

FLIGHT 87

LAUNCHED 03:07 GMT
5 AUGUST, 1953

TRAJECTORY FROM FILM DATA

FILM FRAME NUMBERS

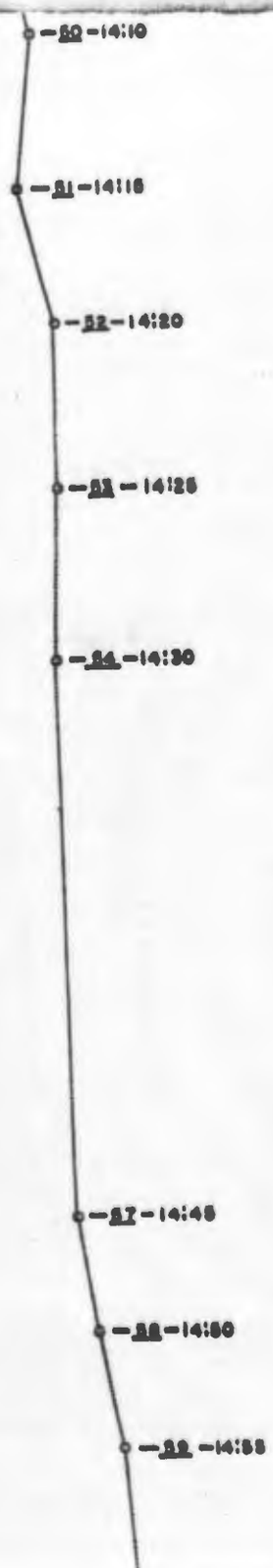
42-13:30
41-13:35
40-13:20
37-13:35

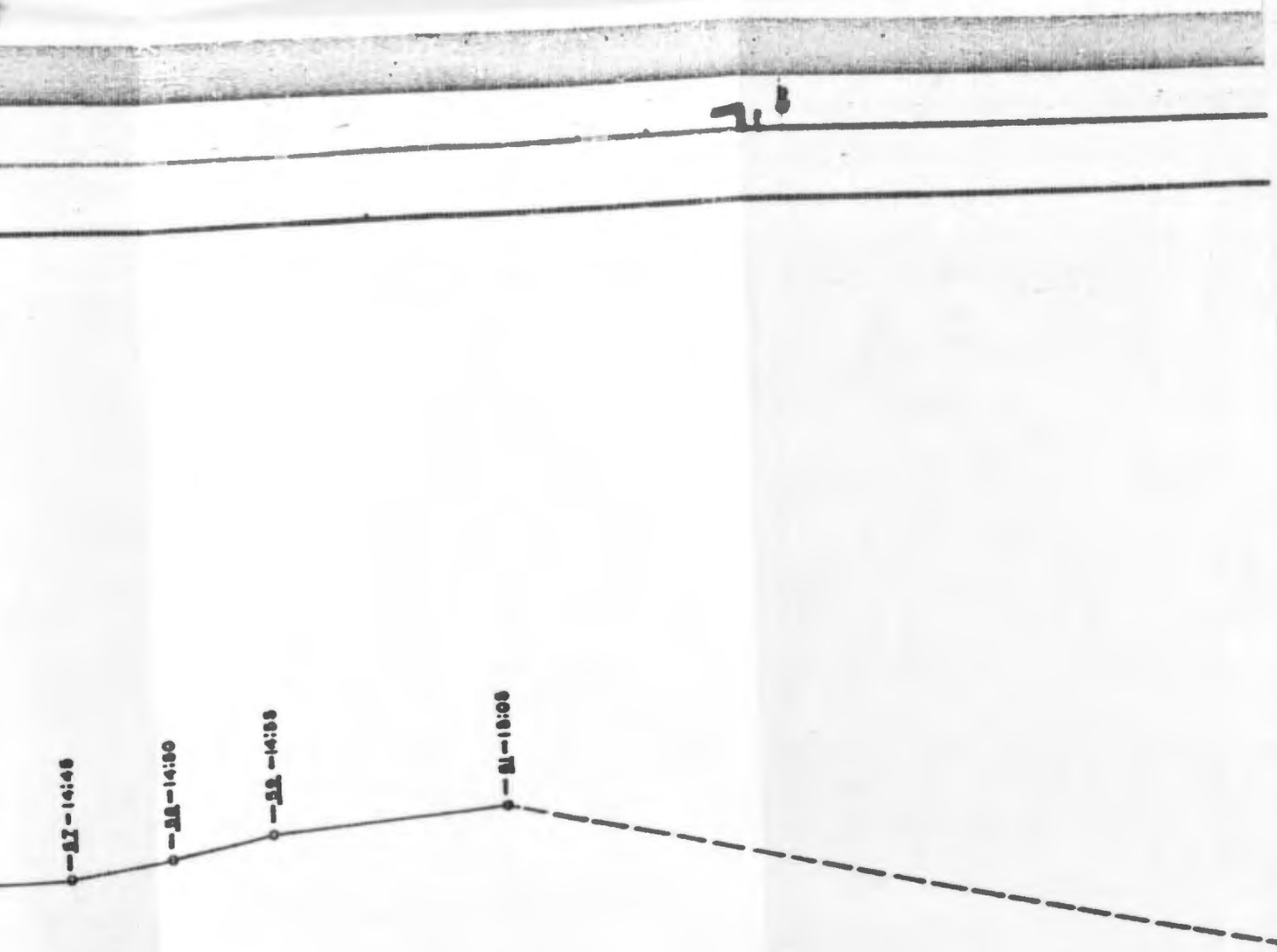
2

71

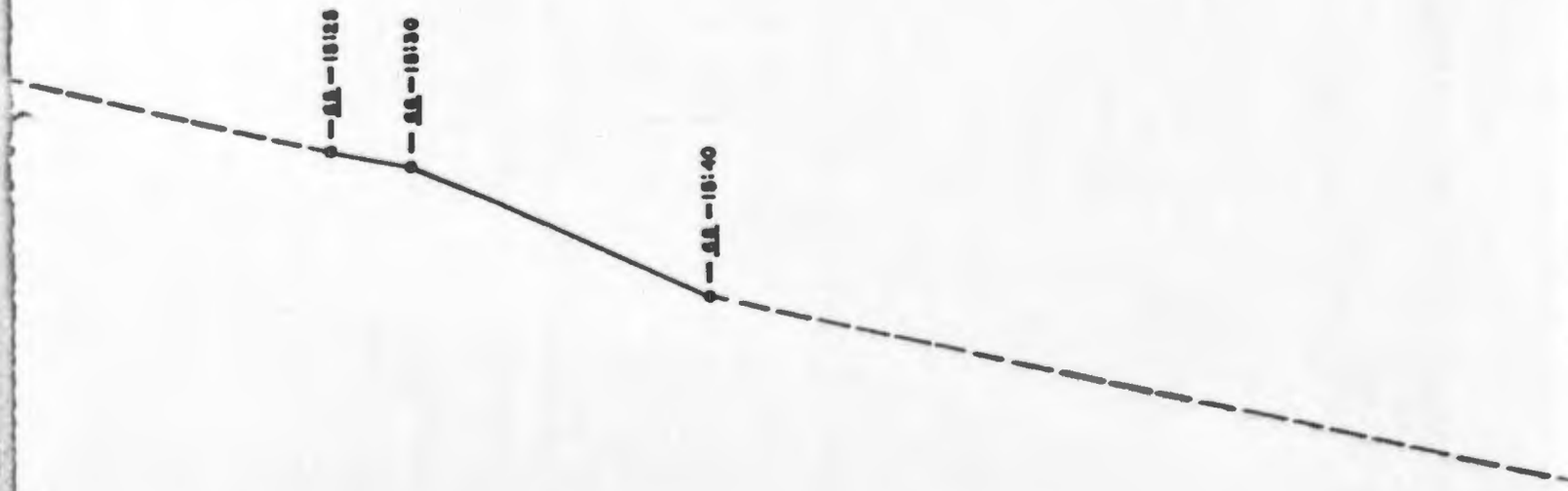
40 - 13:20
41 - 13:25
42 - 13:30
43 - 13:35
44 - 13:40
45 - 13:45
46 - 13:50
47 - 13:55
48 - 14:00
49 - 14:05
50 - 14:10
79°
44° 30'

1 2

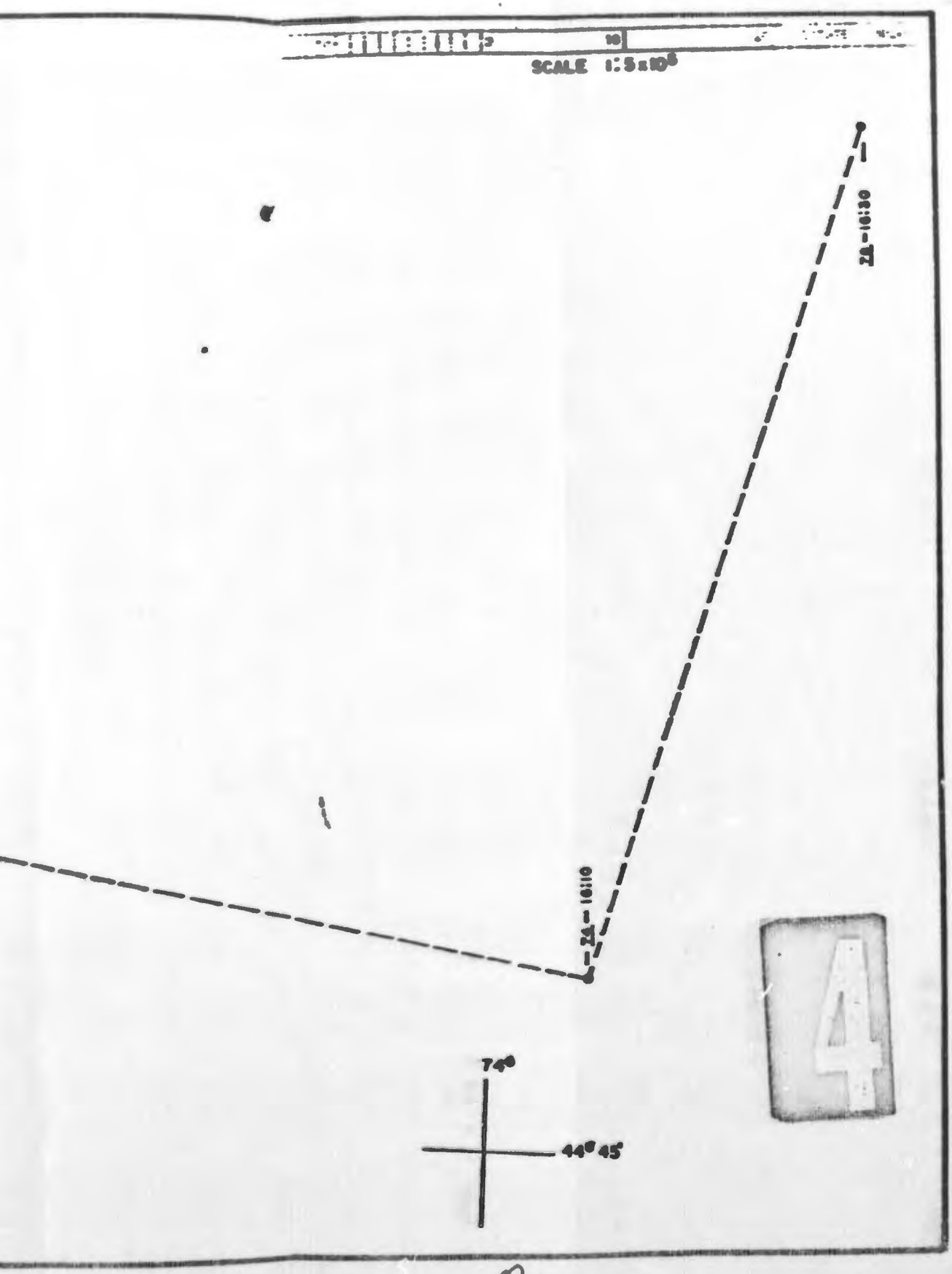

50 - 14:10
51 - 14:15
52 - 14:20
53 - 14:25
54 - 14:30
57 - 14:45
58 - 14:50
59 - 14:55

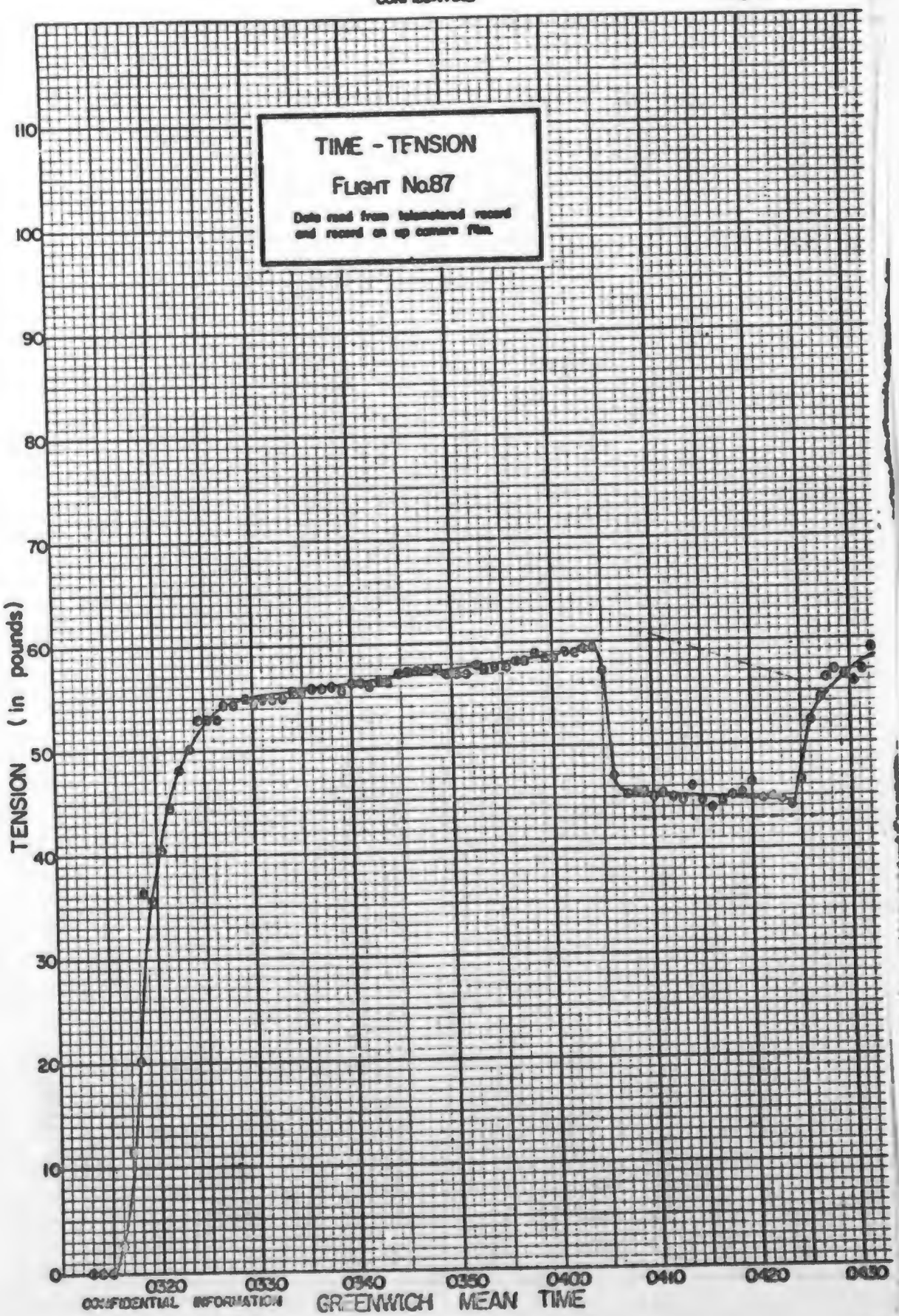


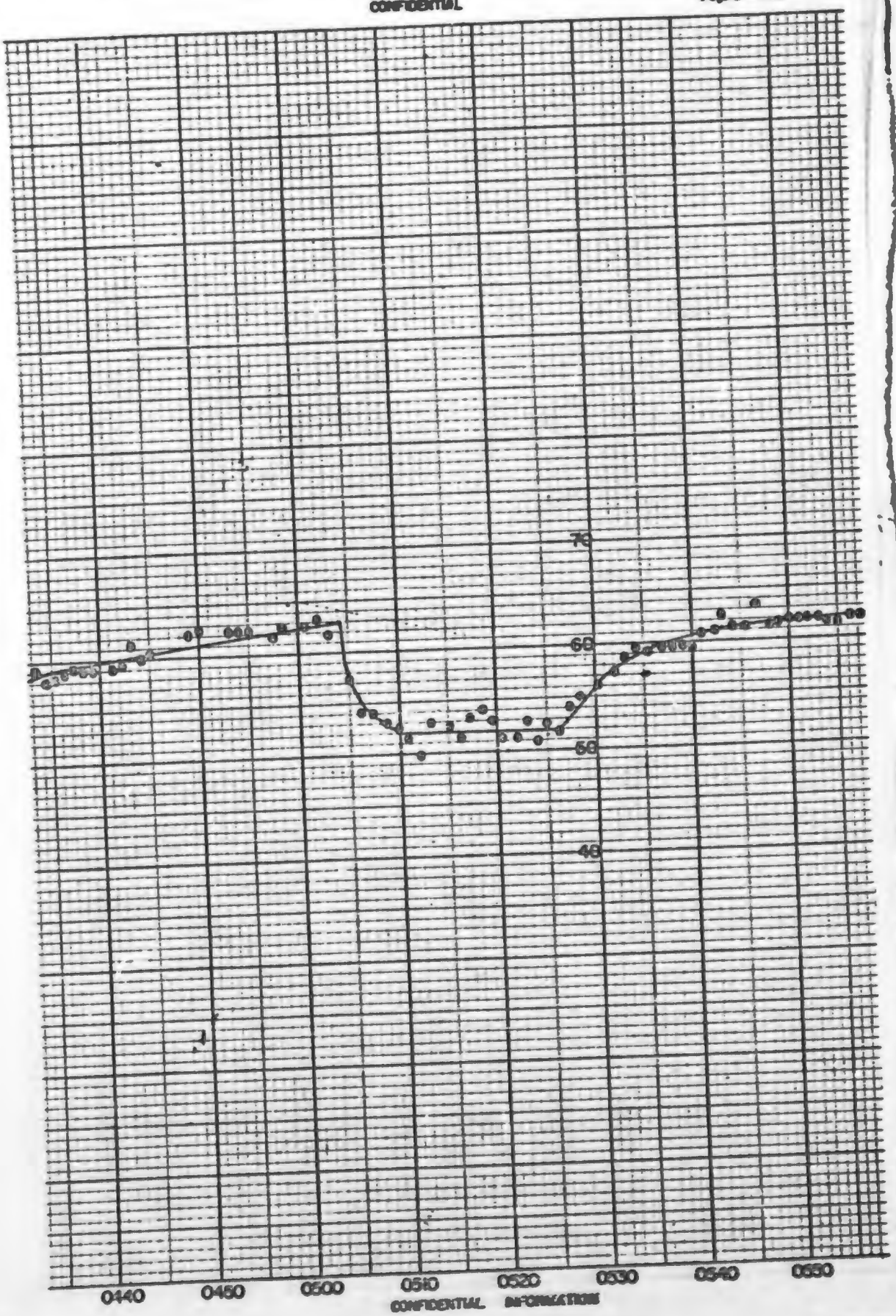
THE TIMES INDE

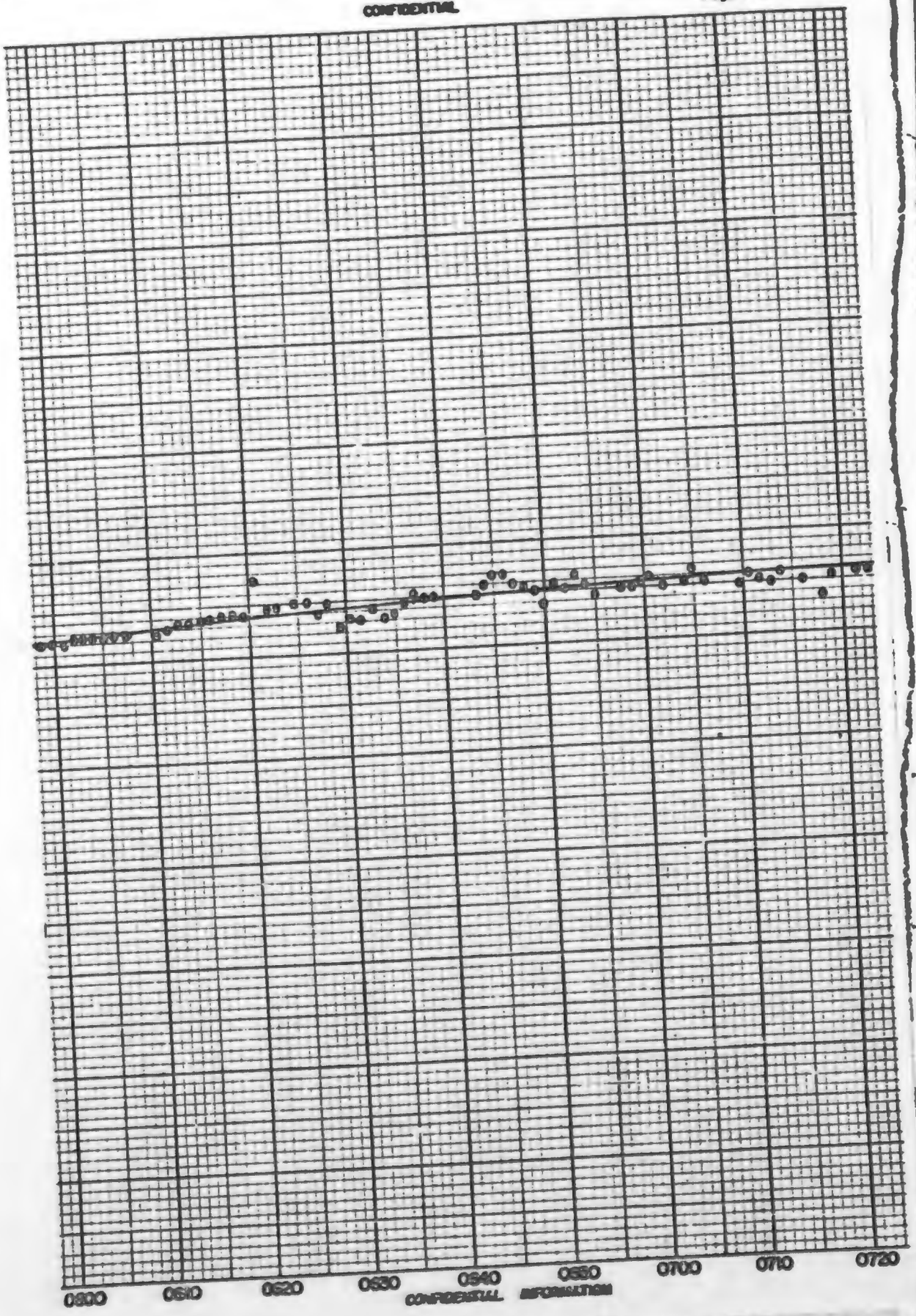


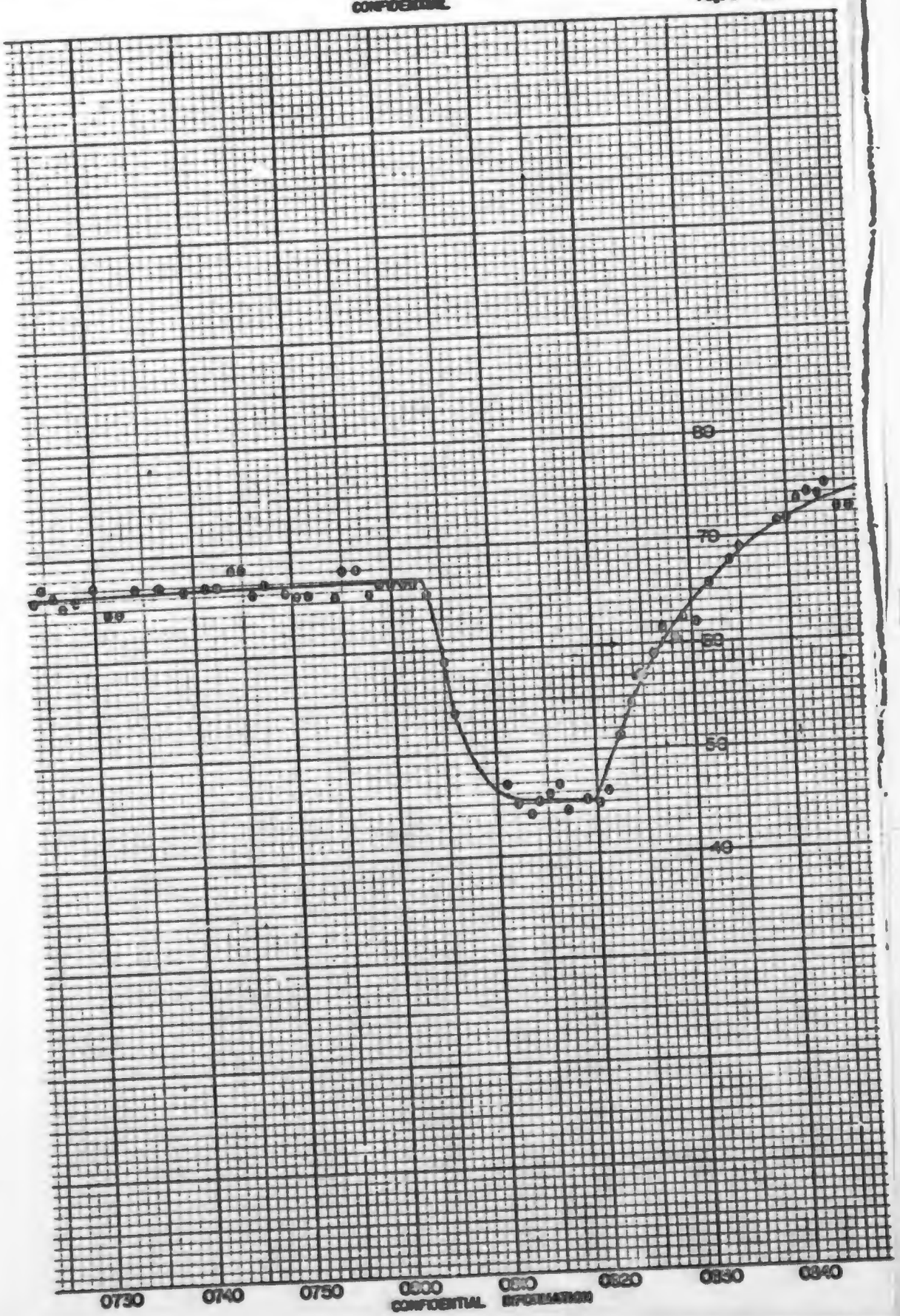
THE TIMES INDICATED ARE APPROXIMATE

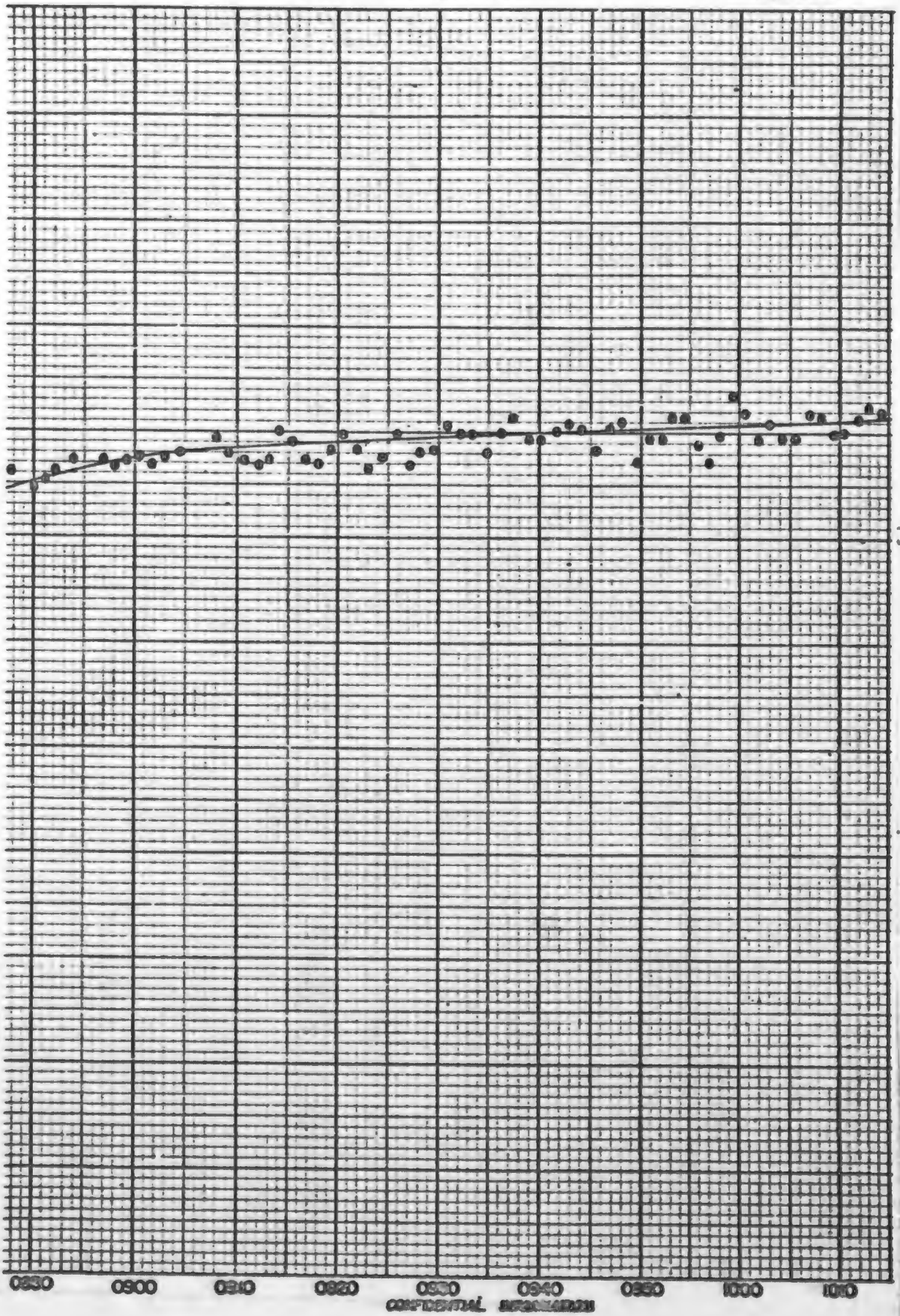

SCALE 1:5x10^6
10
ZE-16:30
ZA-16:10
74°
44° 45'

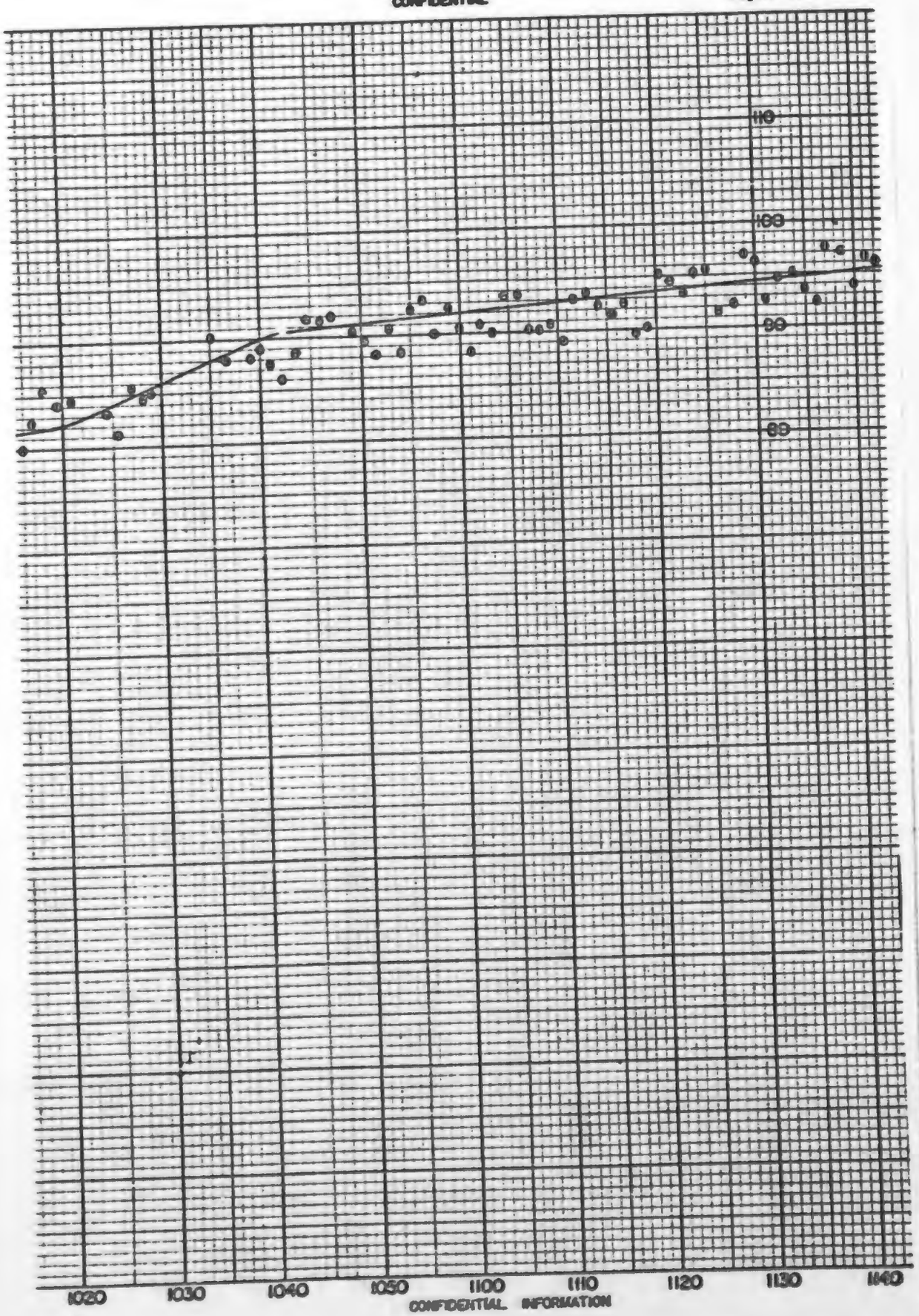

TIME - TENSION
FLIGHT No.87
Data read from telemetered record and record on up camera film.
TENSION (in pounds)
0
10
20
30
40
50
60
70
80
90
100
110
0320
0330
0340
0350
0400
0410
0420
0430
GREENWICH MEAN TIME

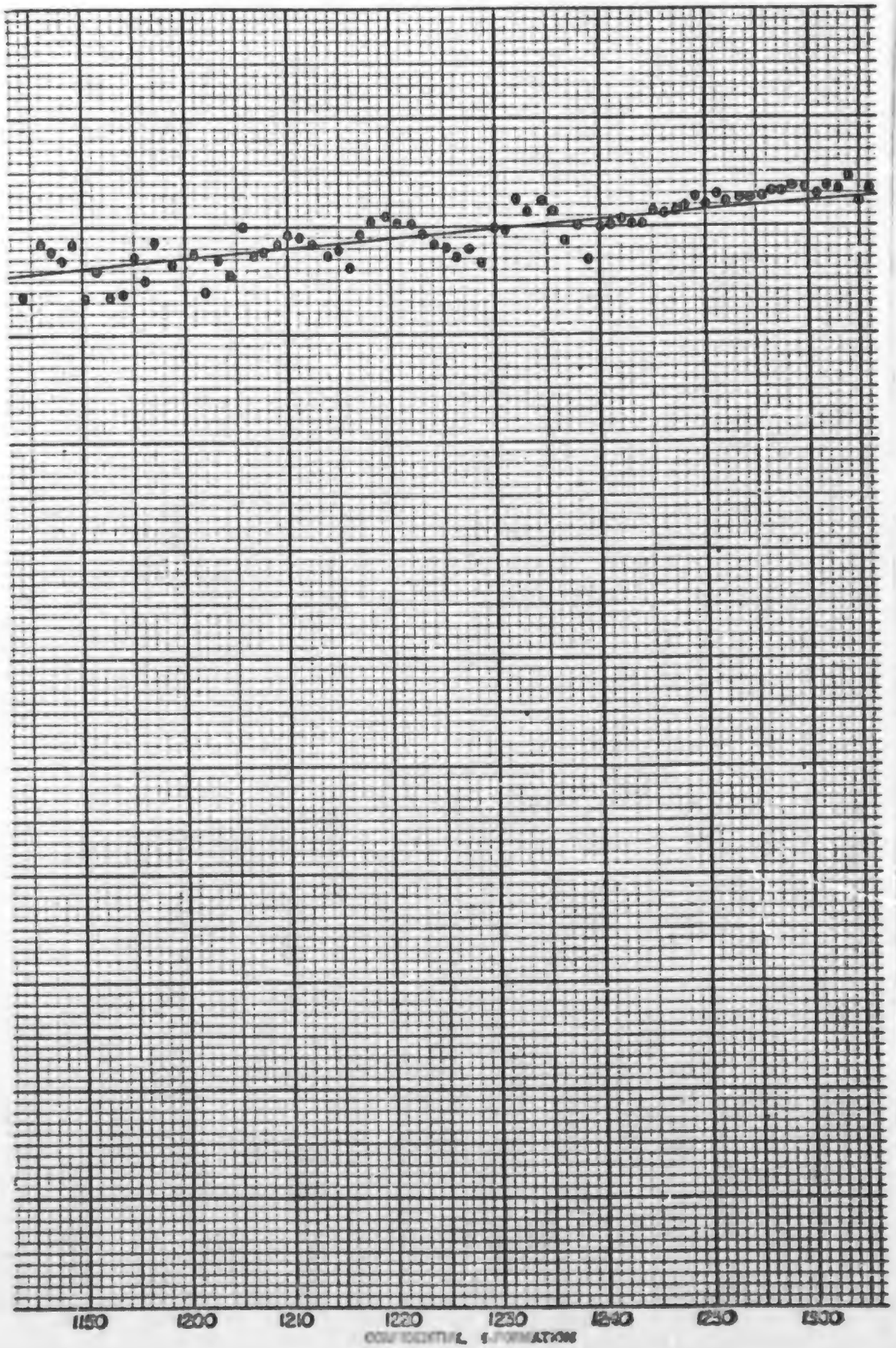

70
60
50
40
0440
0450
0500
0510
0520
0530
0540
0550

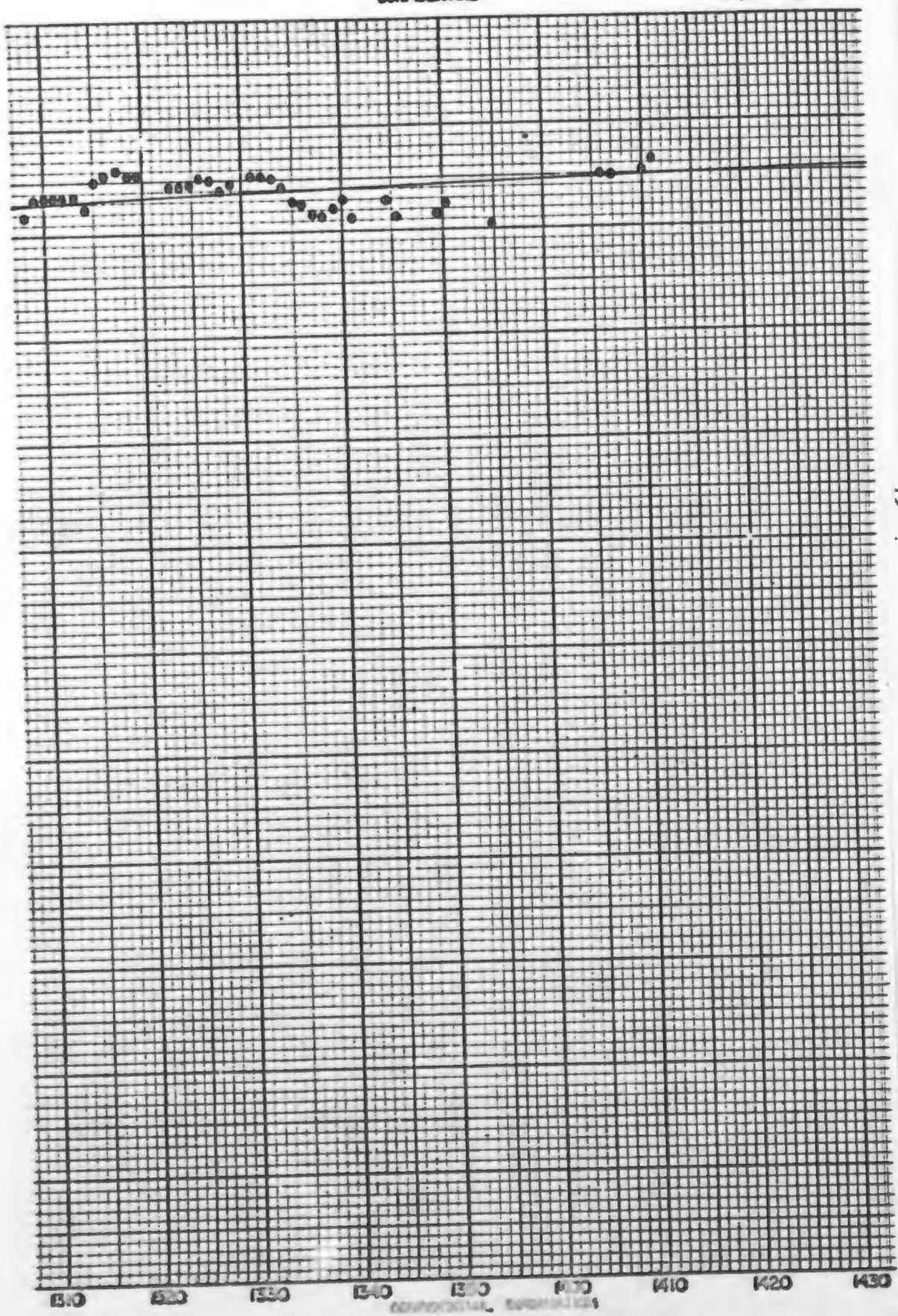

0600
0610
0620
0630
0640
0650
0700
0710
0720

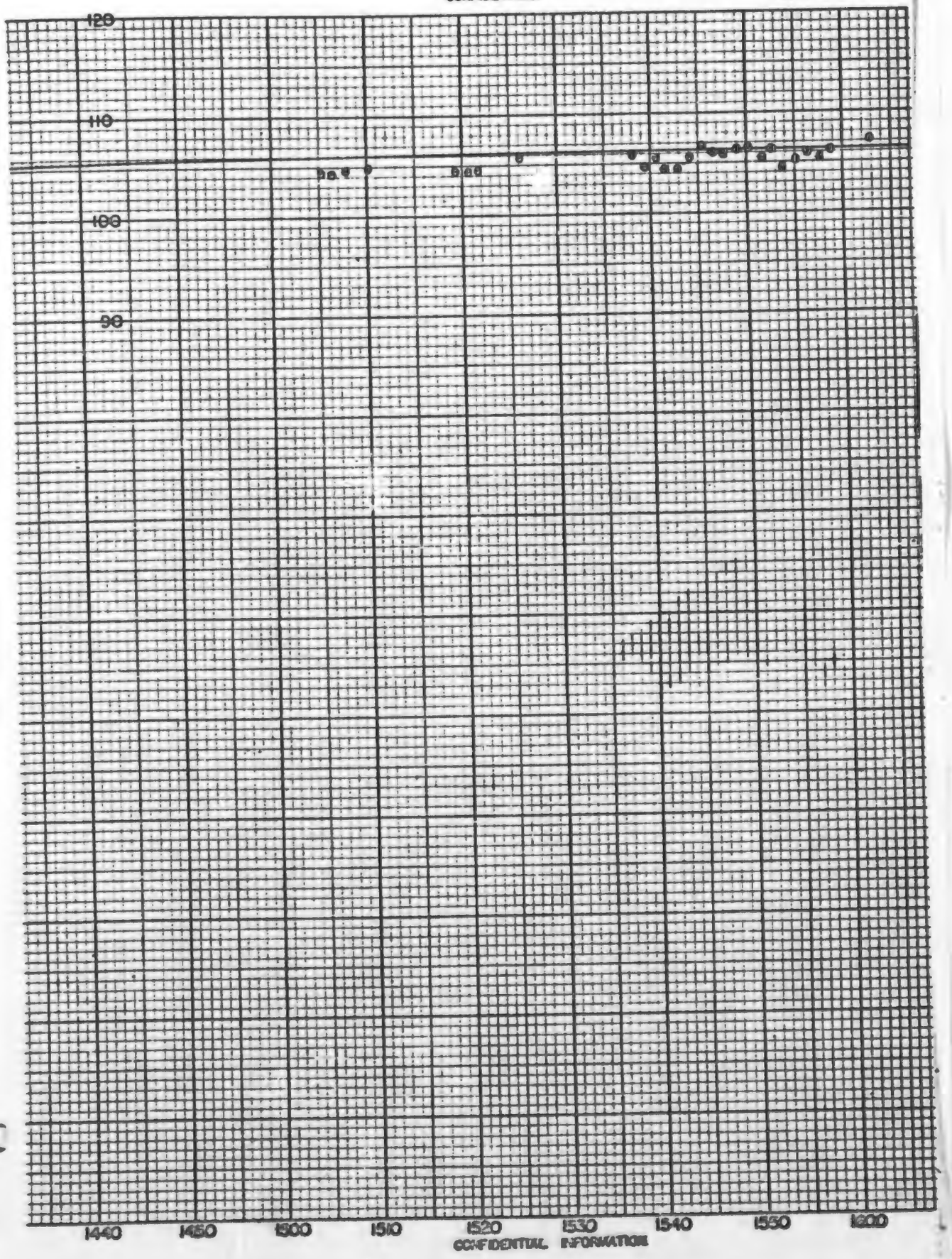

80
70
60
50
40
0730
0740
0750
0800
0810
0820
0830
0840

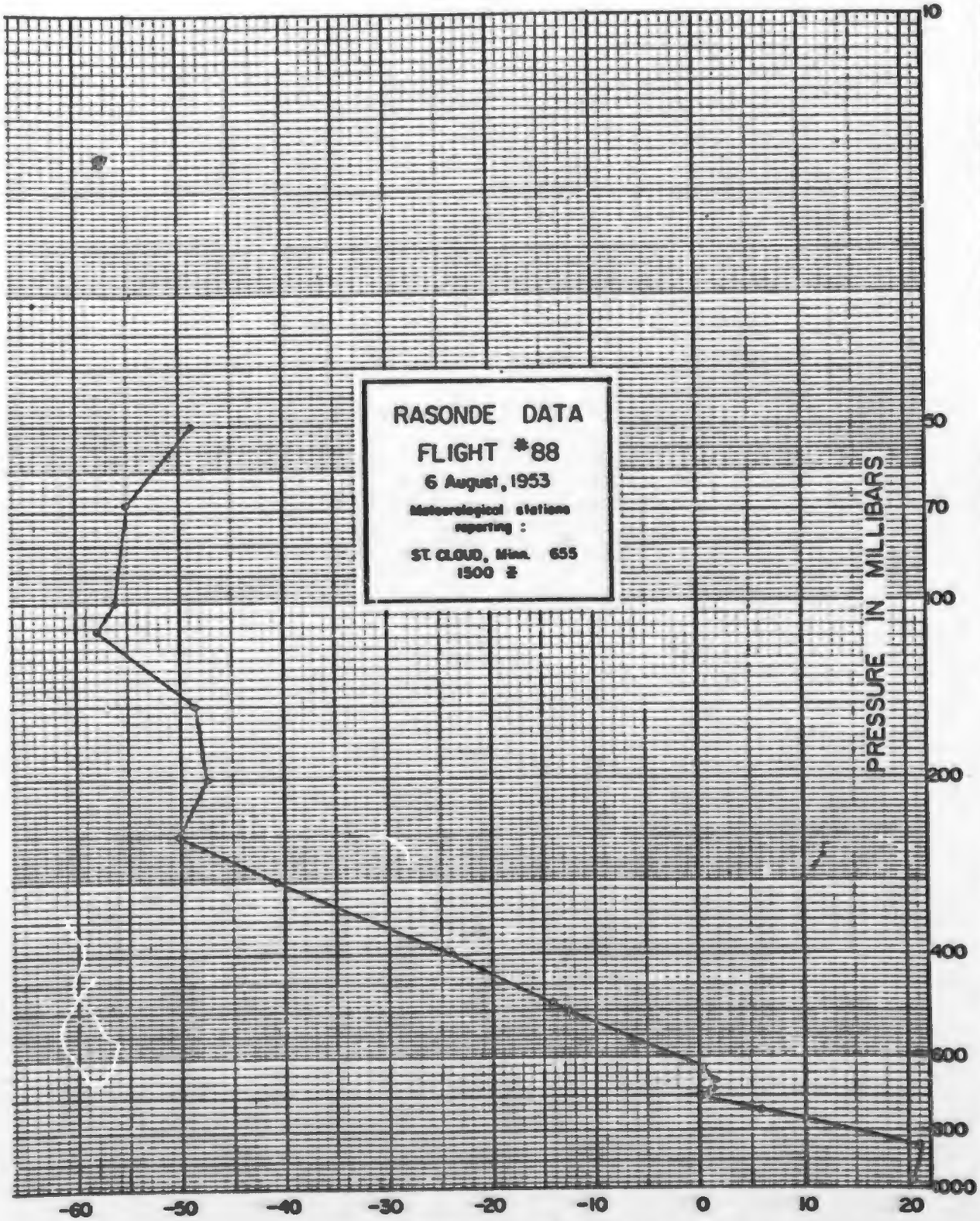

0830
0900
0910
0920
0930
0940
0950
1000
1010


110
100
90
80
1020
1030
1040
1050
1100
1110
1120
1130
1140

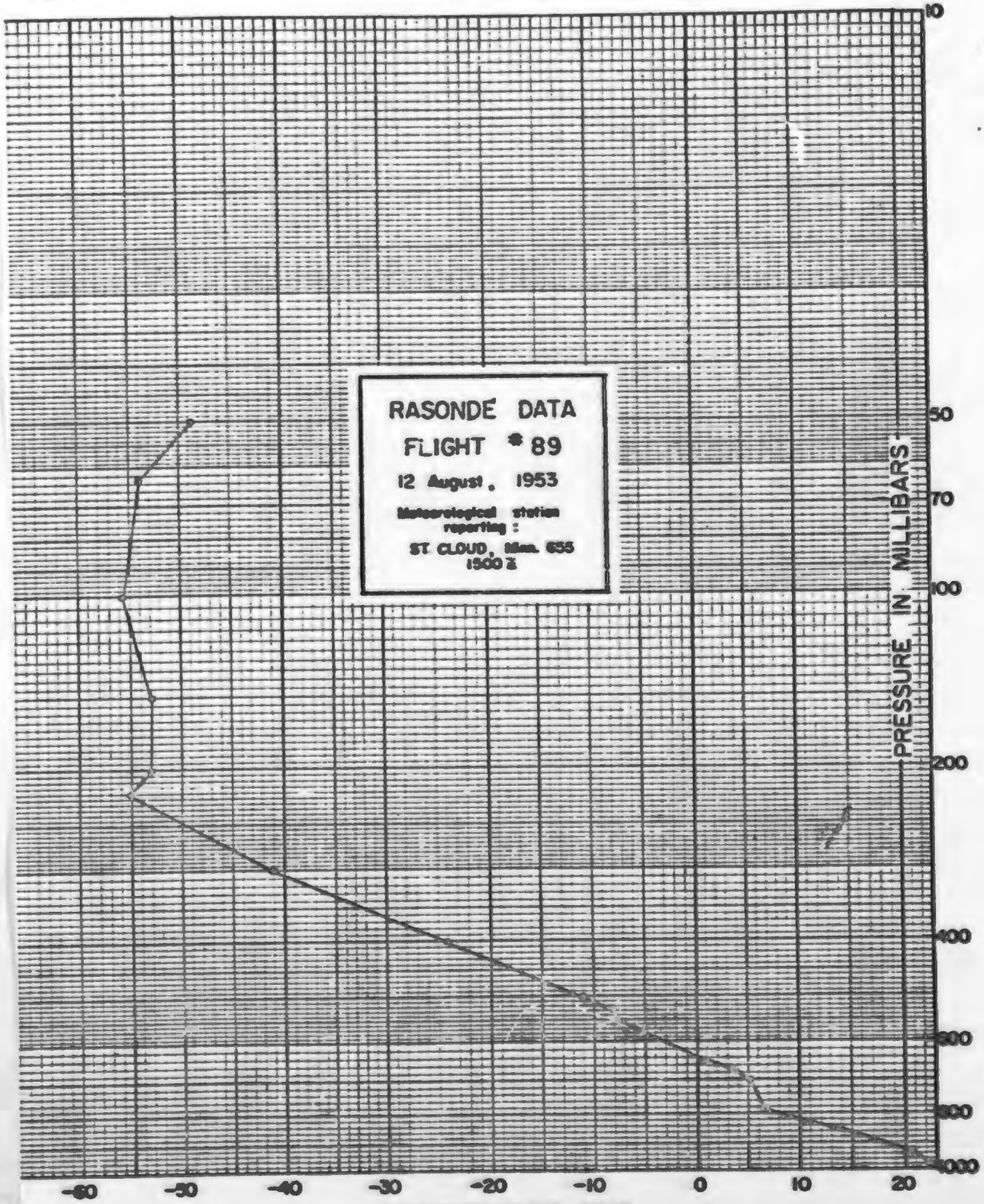

1150
1200
1210
1220
1230
1240
1250
1300


1310
1320
1330
1340
1350
1360
1410
1420
1430

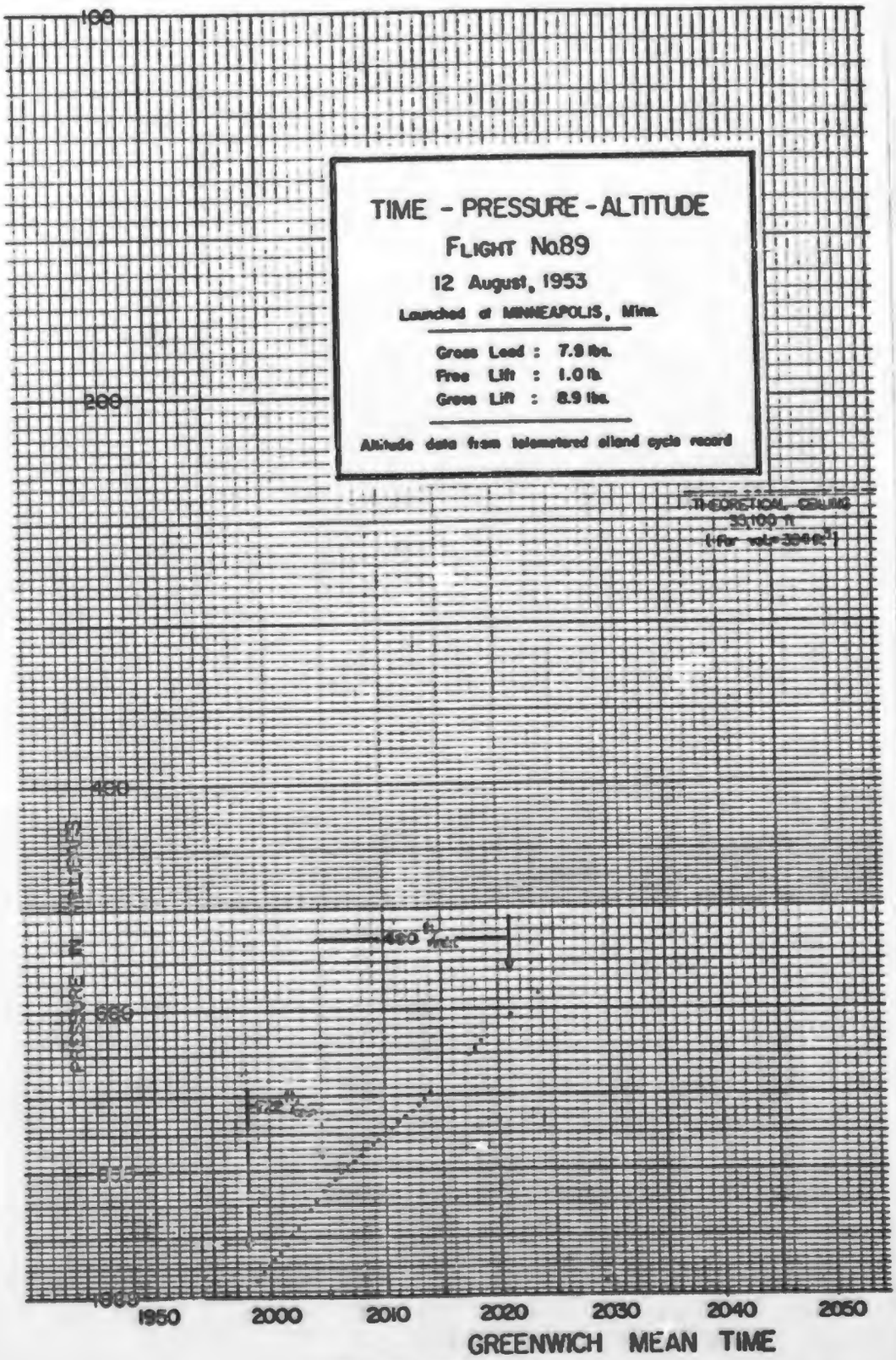

120
110
100
90
1440
1450
1500
1510
1520
1530
1540
1550
1600

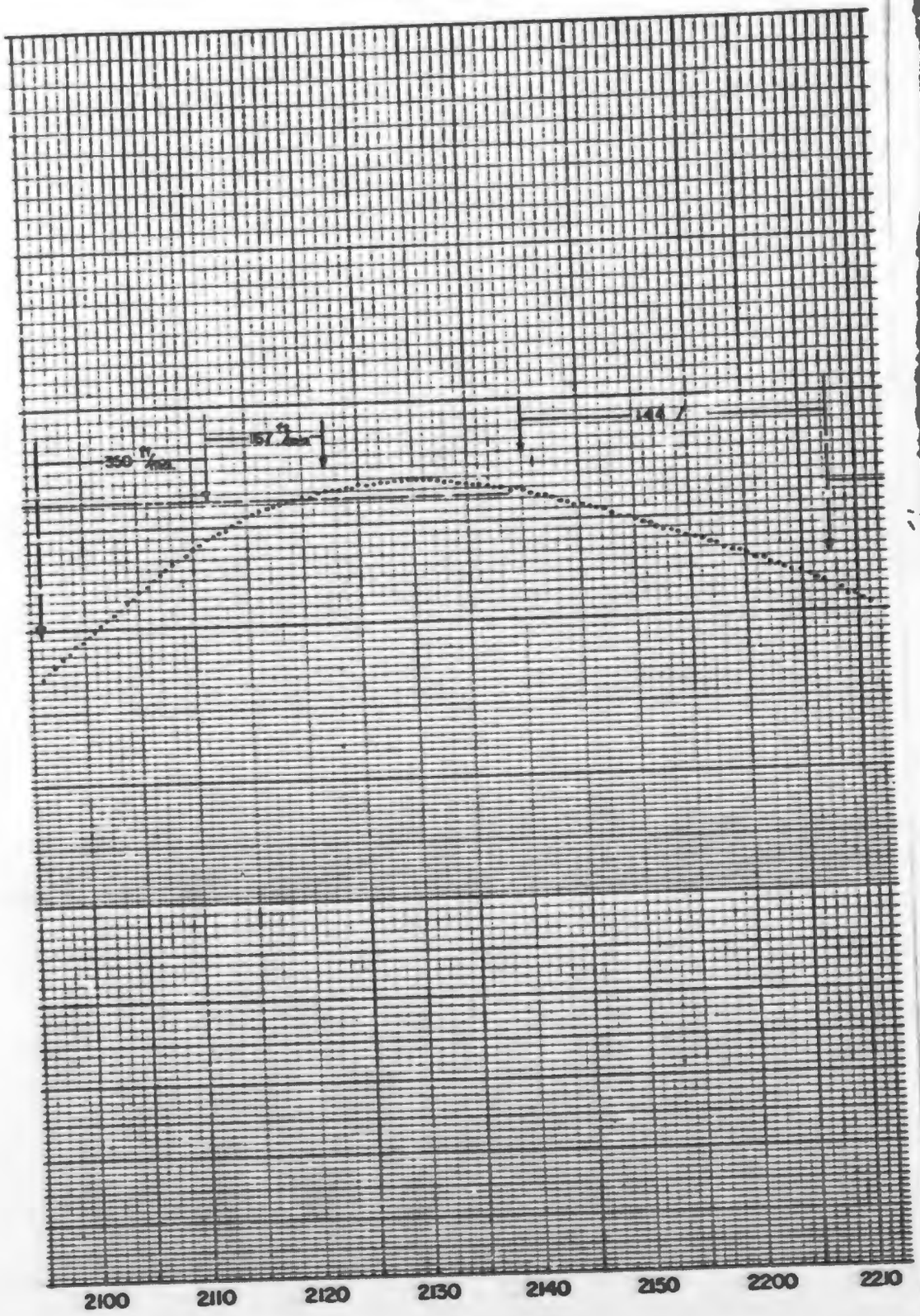

RASONDE DATA
FLIGHT #88
6 August, 1953
Meteorological stations reporting :
ST. CLOUD, Minn. 655
1500 Z
PRESSURE IN MILLIBARS
10
50
70
100
200
400
600
800
1000
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C)

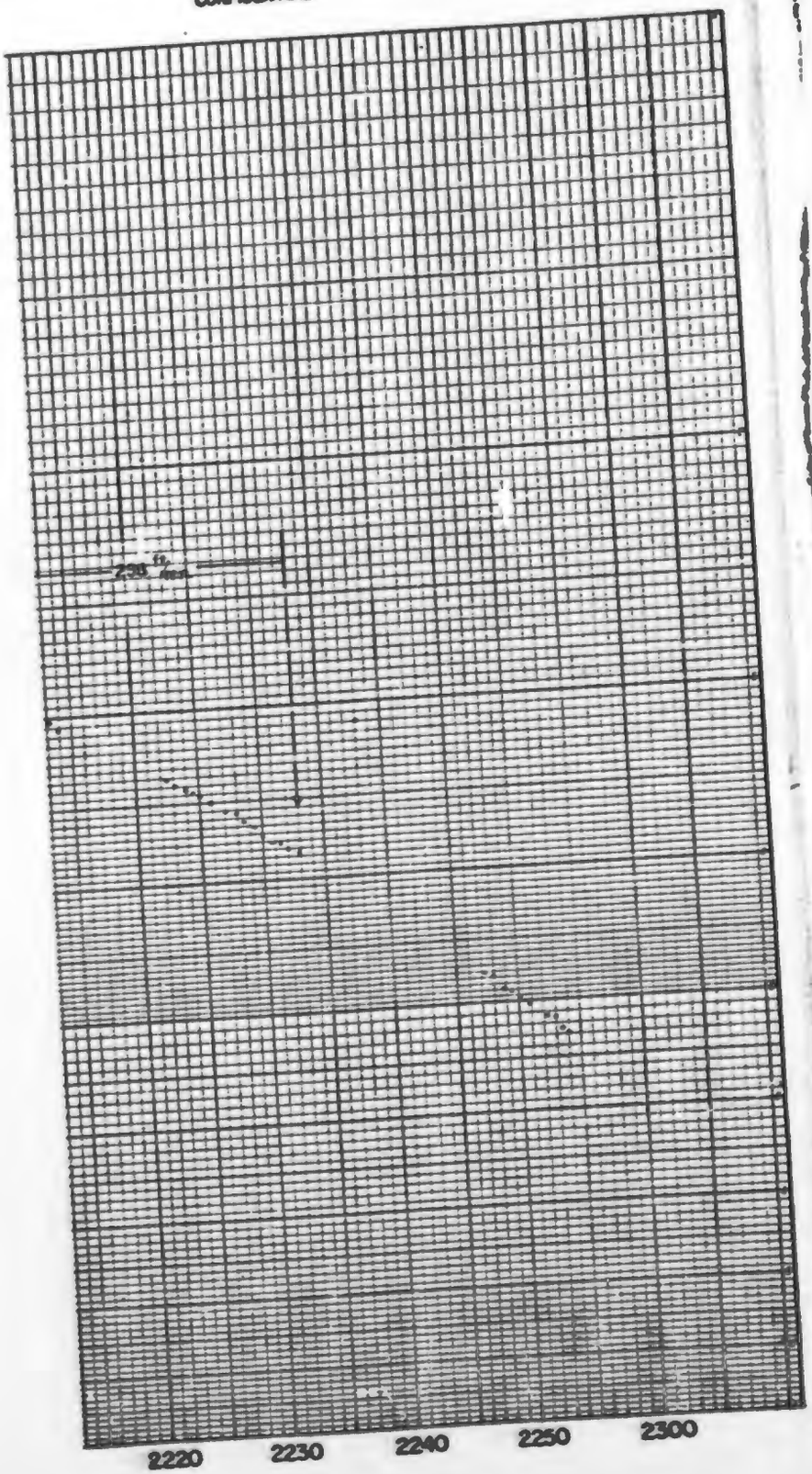
CONFIDENTIAL

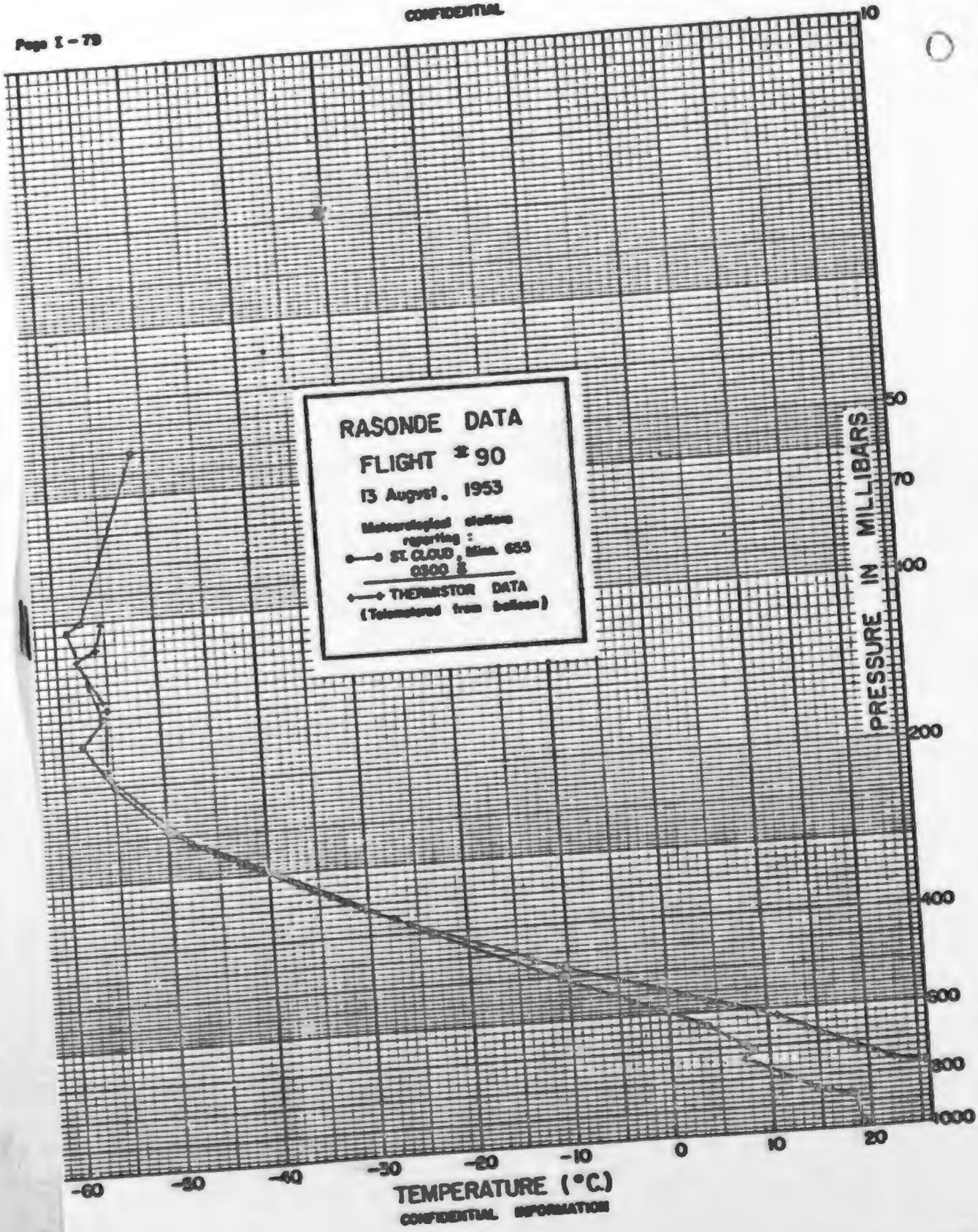


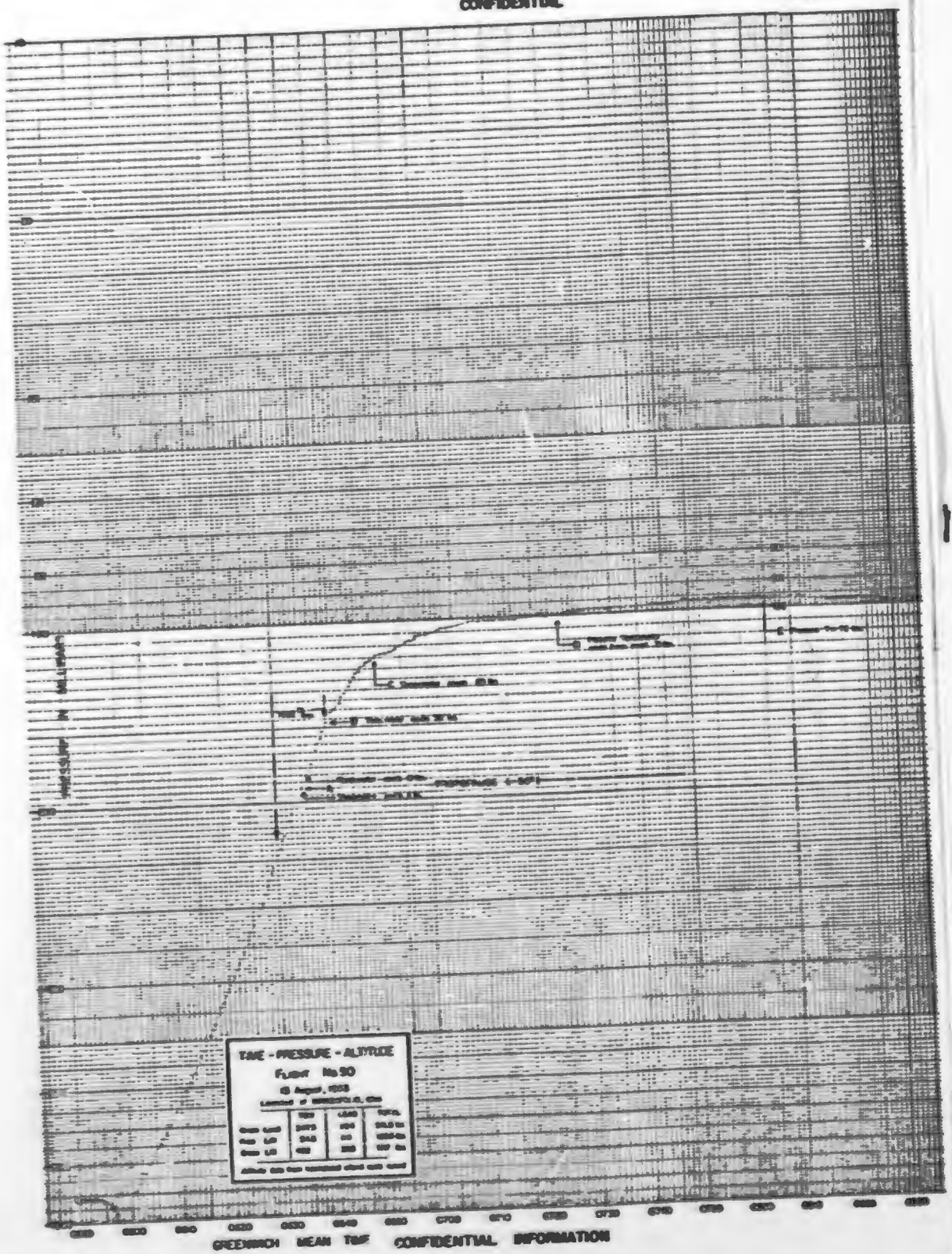
CONFIDENTIAL INFORMATION

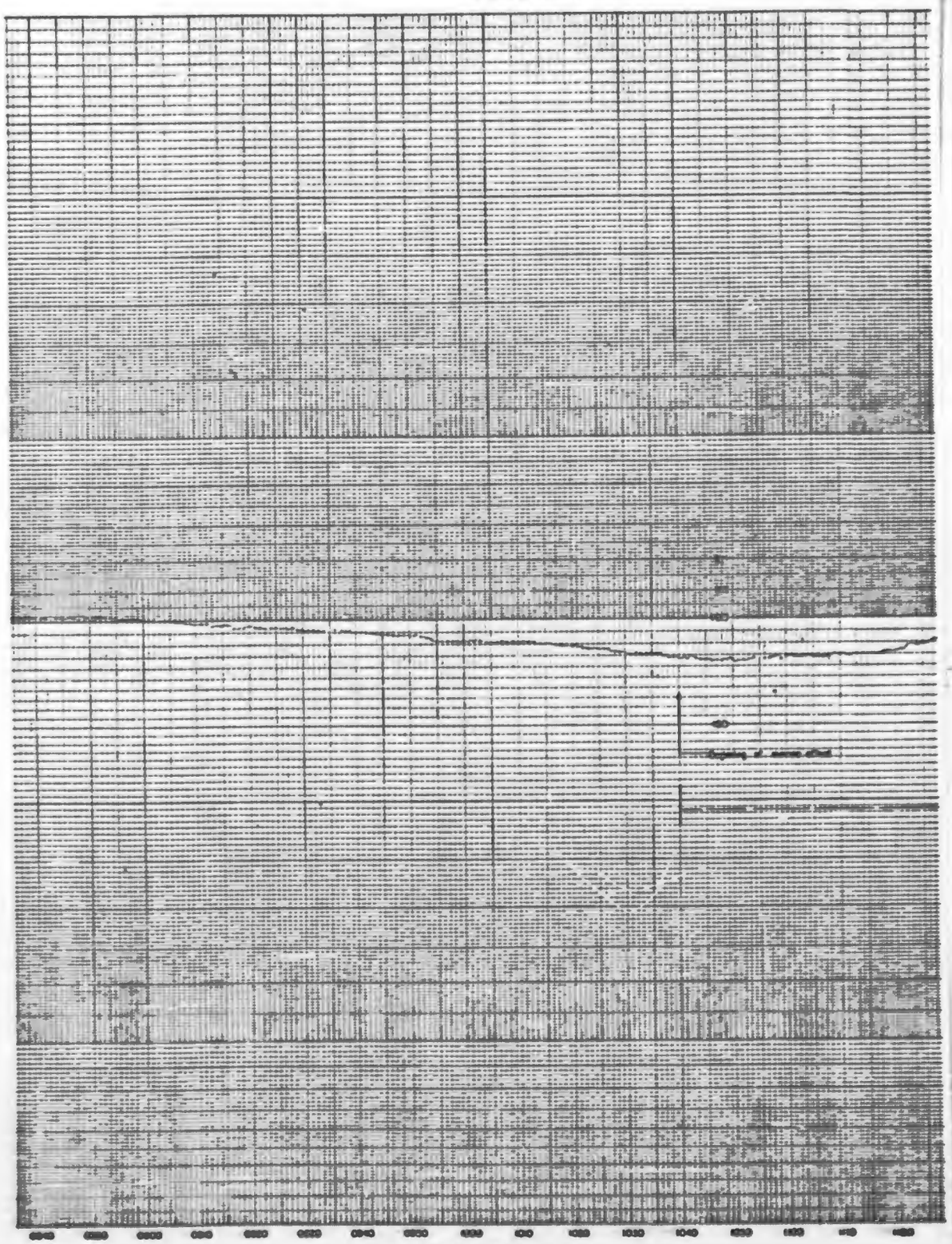

TIME - PRESSURE - ALTITUDE
FLIGHT No.89
12 August, 1953
Launched at MINNEAPOLIS, Minn.
Gross Load : 7.9 lbs.
Free Lift : 1.0 lb.
Gross Lift : 8.9 lbs.
Altitude data from telemetered aneroid cycle record
THEORETICAL CEILING
33,100 ft
(Fr vol = 304 ft³)
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
480 ft/min
1950
2000
2010
2020
2030
2040
2050
GREENWICH MEAN TIME

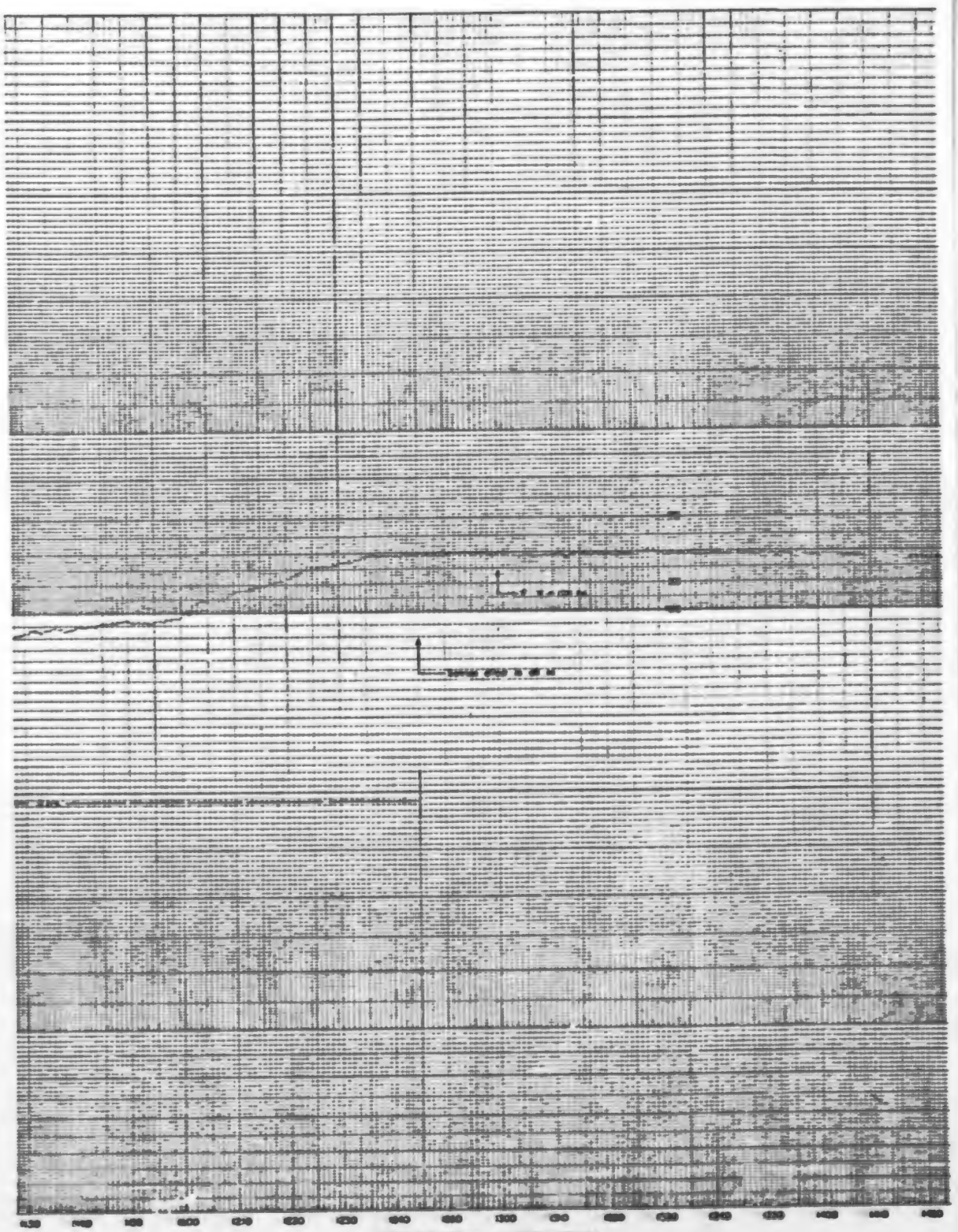

350 ft/min
157 ft/min
144
2100
2110
2120
2130
2140
2150
2200
2210

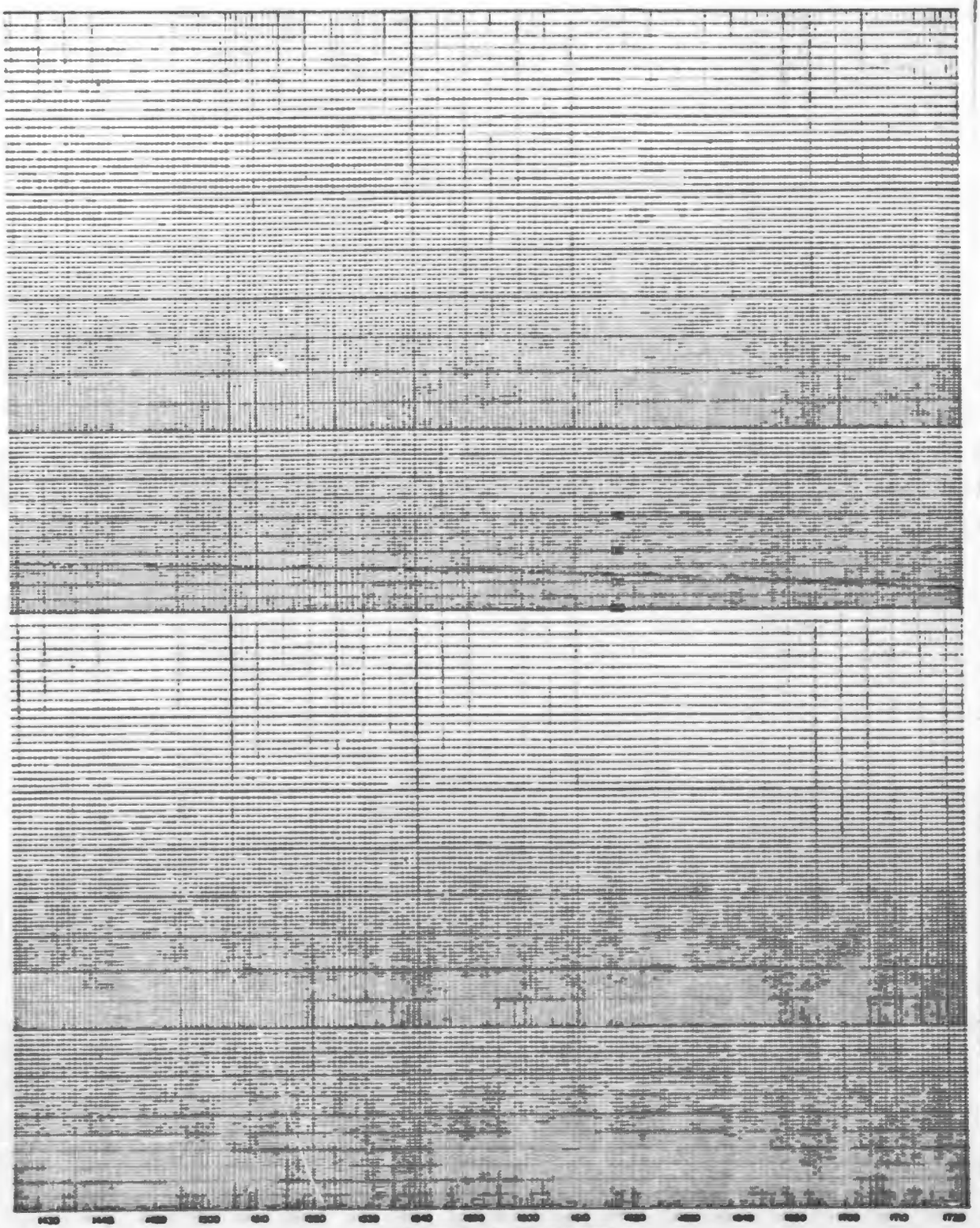

230 ft/sec
2300
2250
2240
2230
2220

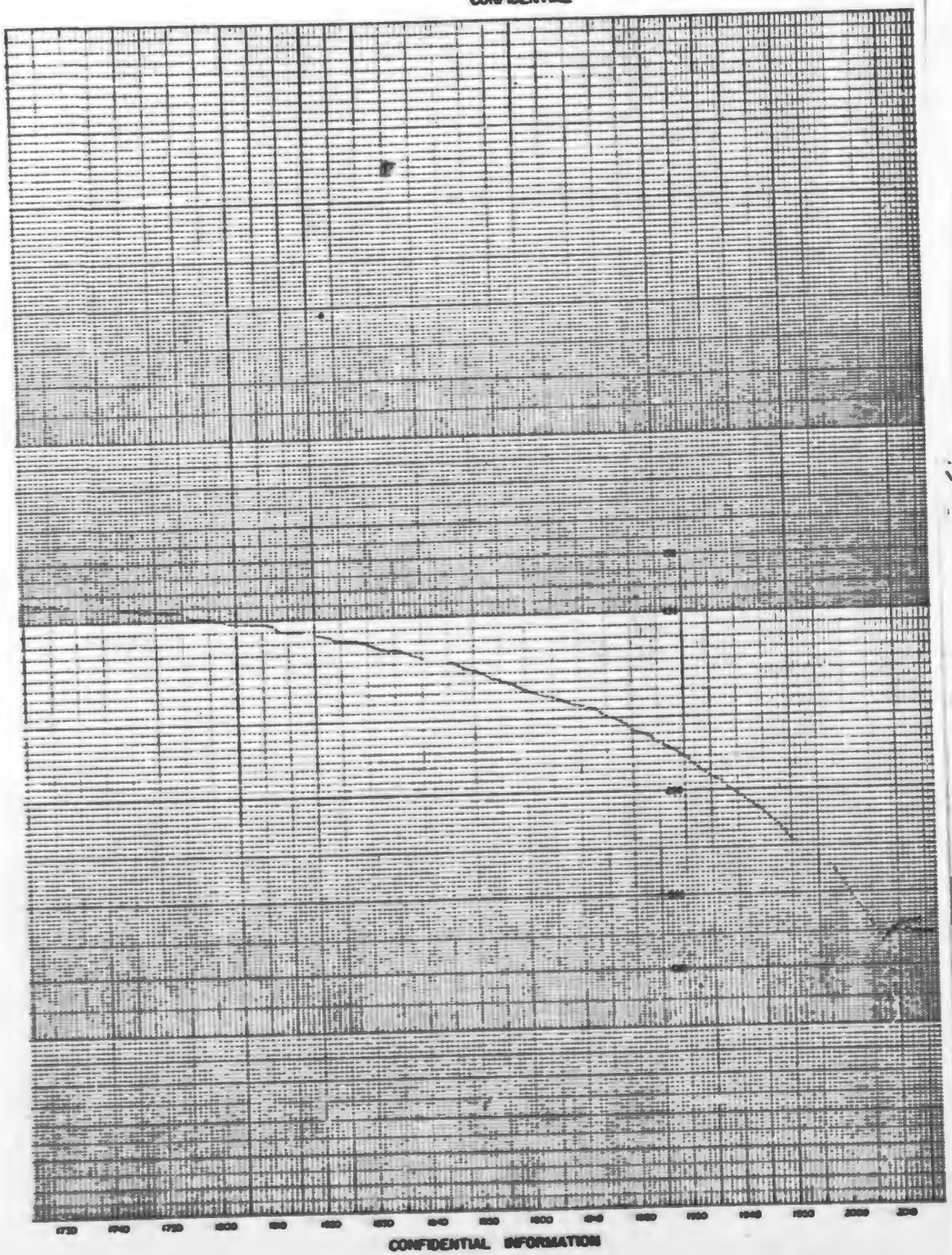

RASONDE DATA
FLIGHT # 90
13 August, 1953
Meteorological stations reporting :
ST. CLOUD, Minn. 655
0500 Z
THERMISTOR DATA
(Telemetered from balloon)
PRESSURE IN MILLIBARS
10
50
70
100
200
400
600
800
1000
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

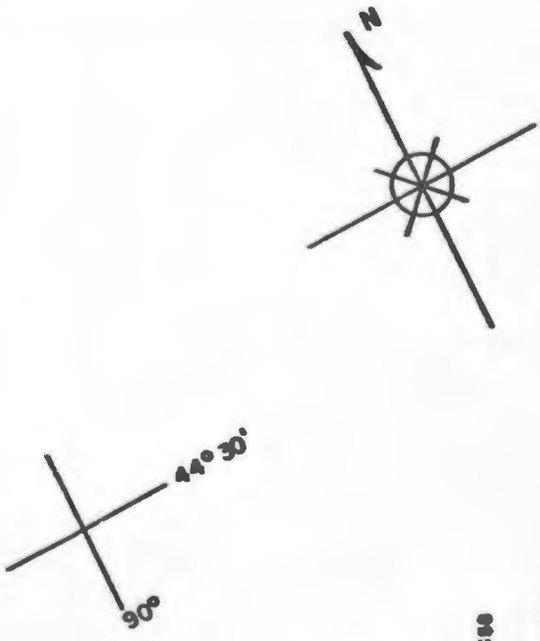

TIME - PRESSURE - ALTITUDE
Flight No 50
GREENWICH MEAN TIME











FILM FRAME NUMBERS

LAUNCHED AT
U of M AIRPORT
MPLS, MINN.

LAUNCH SITE LAT. 45° 07' LONG 93° 10.5'

FLIGHT 90

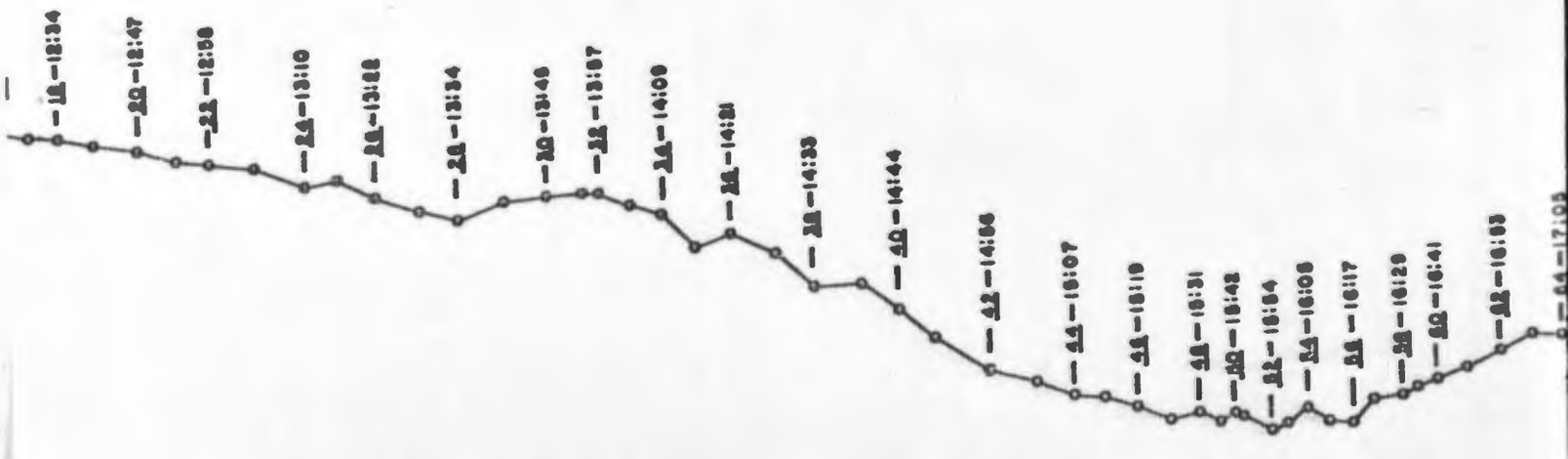
LAUNCHED 05:57 G.M.T.
13 AUGUST, 1953

TRAJECTORY FROM FILM DATA

BERS

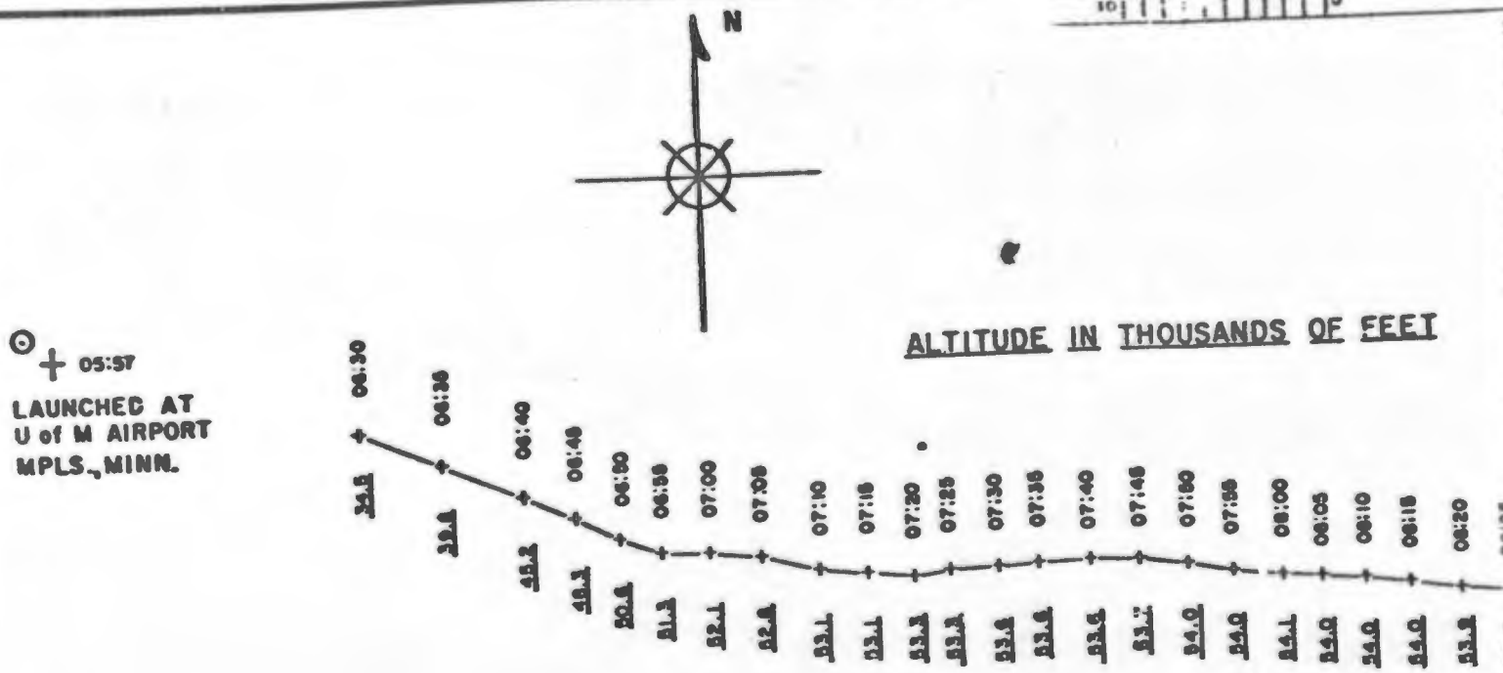
30-13:46
32-13:57
34-14:09
36-14:21
38-14:33
40-14:44
42-14:56
44-15:07
46-15:19
48-15:31
50-15:42
52-15:54
54-16:05
56-16:17
58-16:29
60-16:41
62-16:53
64-17:05
66-17:18
68-17:30
70-17:42
72-17:53

FILM FRAME NUMBERS



10.5°

SCALE 1:5x10⁶



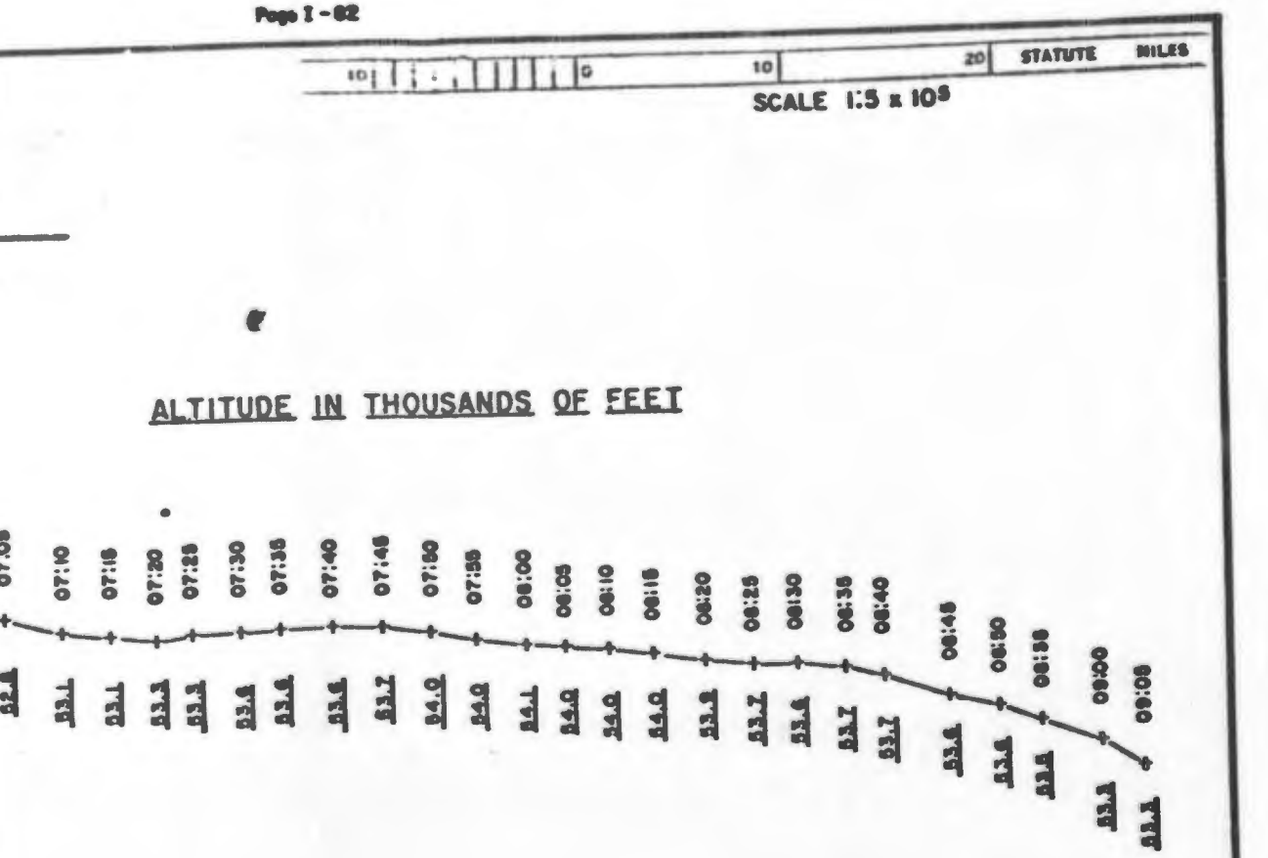
⊙ THEODOLITE SITE LAT. 45° 08' LONG. 93° 12.5'

+ LAUNCH SITE LAT. 45° 07' LONG. 93° 10.5'

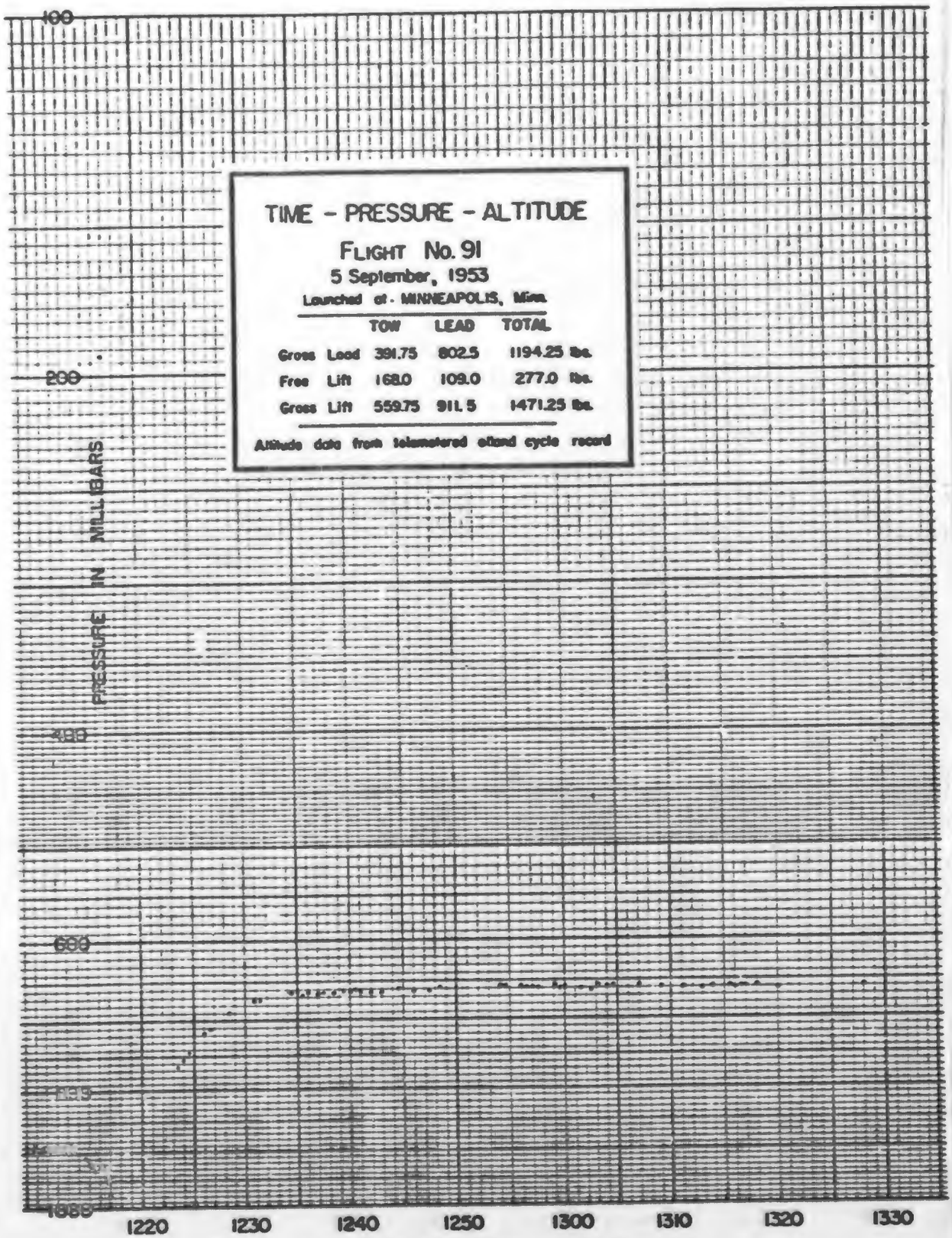
FLIGHT 90

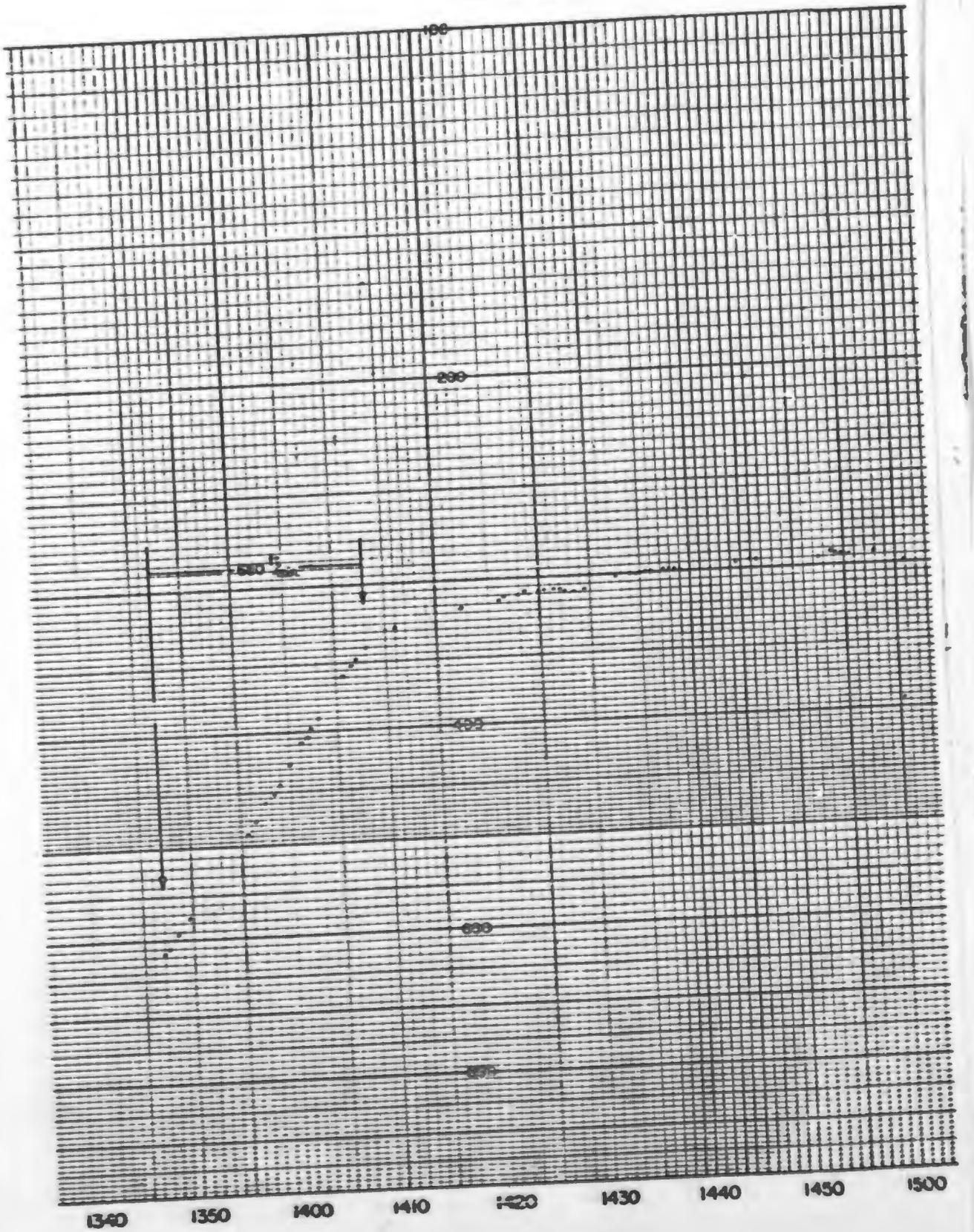
LAUNCHED 05:57 G.M.T.
13 AUGUST, 1953

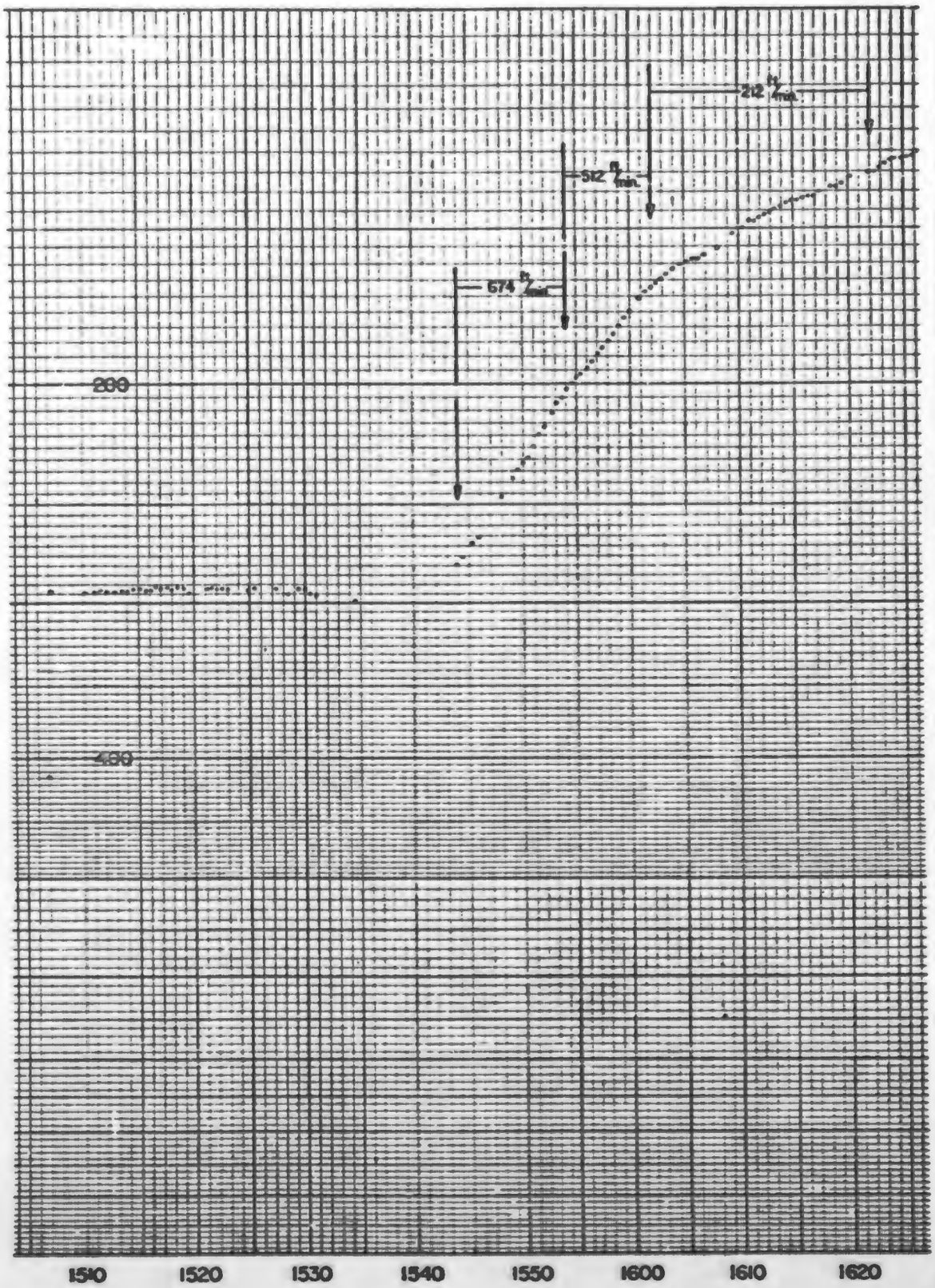
TRAJECTORY FROM THEODOLITE

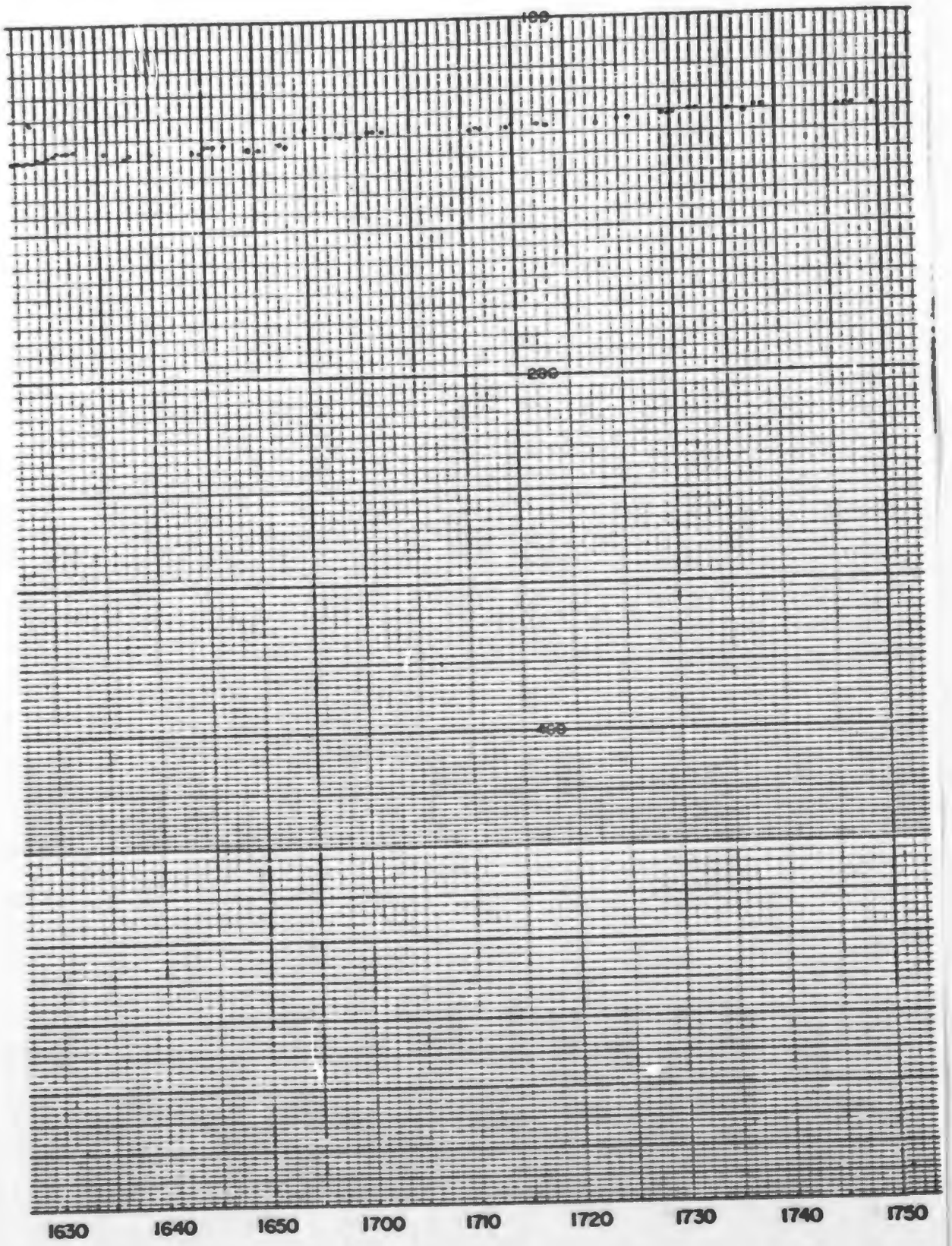

10
0
10
20
STATUTE MILES
SCALE 1:5 x 10⁵
ALTITUDE IN THOUSANDS OF FEET
07:05
07:10
07:15
07:20
07:25
07:30
07:35
07:40
07:45
07:50
07:55
08:00
08:05
08:10
08:15
08:20
08:25
08:30
08:35
08:40
08:45
08:50
08:55
09:00
09:05
53.1
53.1
53.3
53.3
53.5
53.6
53.6
53.7
54.0
54.0
54.1
54.0
54.0
54.0
53.9
53.7
53.6
53.7
53.7
53.6
53.6
53.6
53.3
53.3

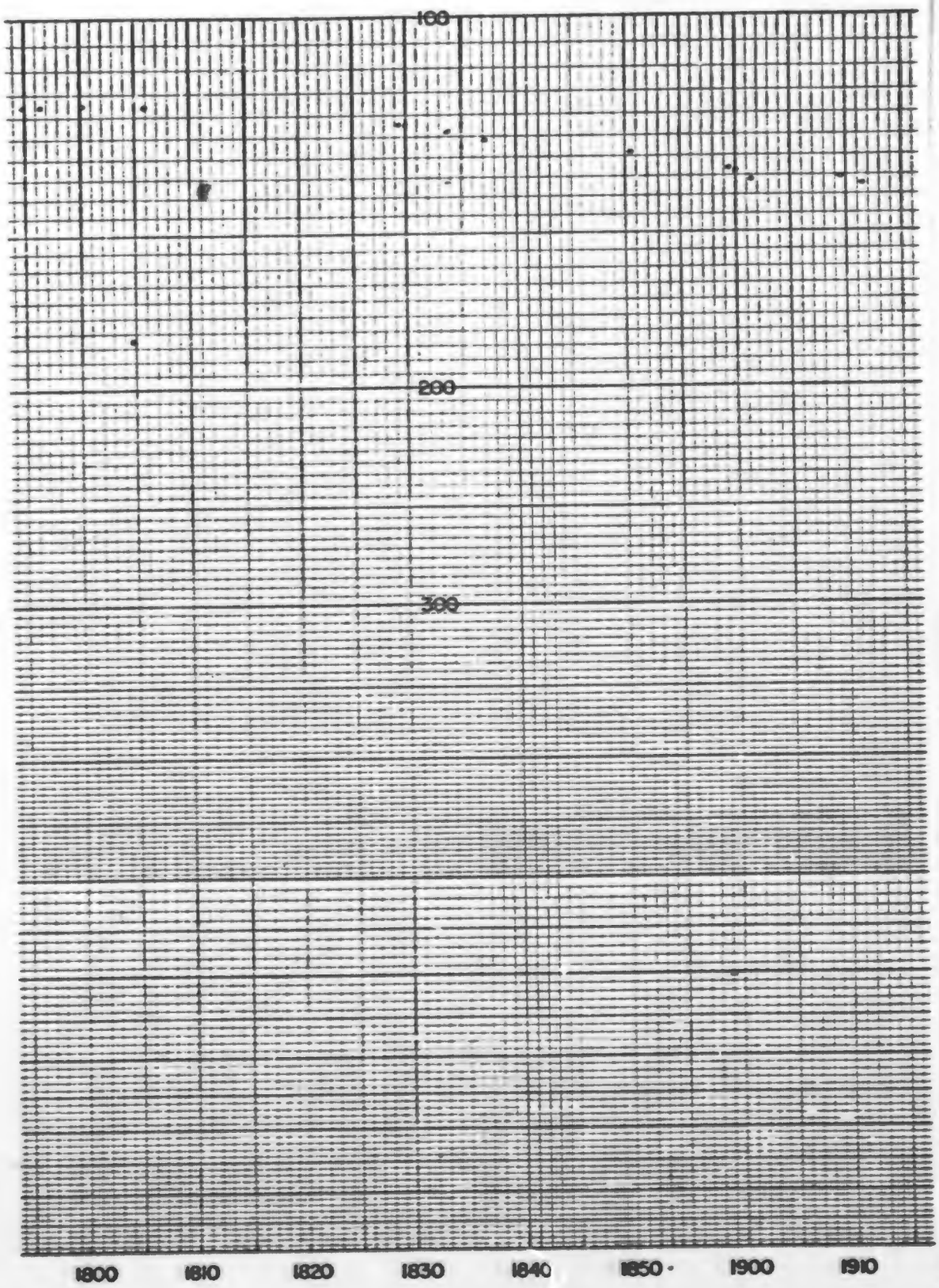
12.5'

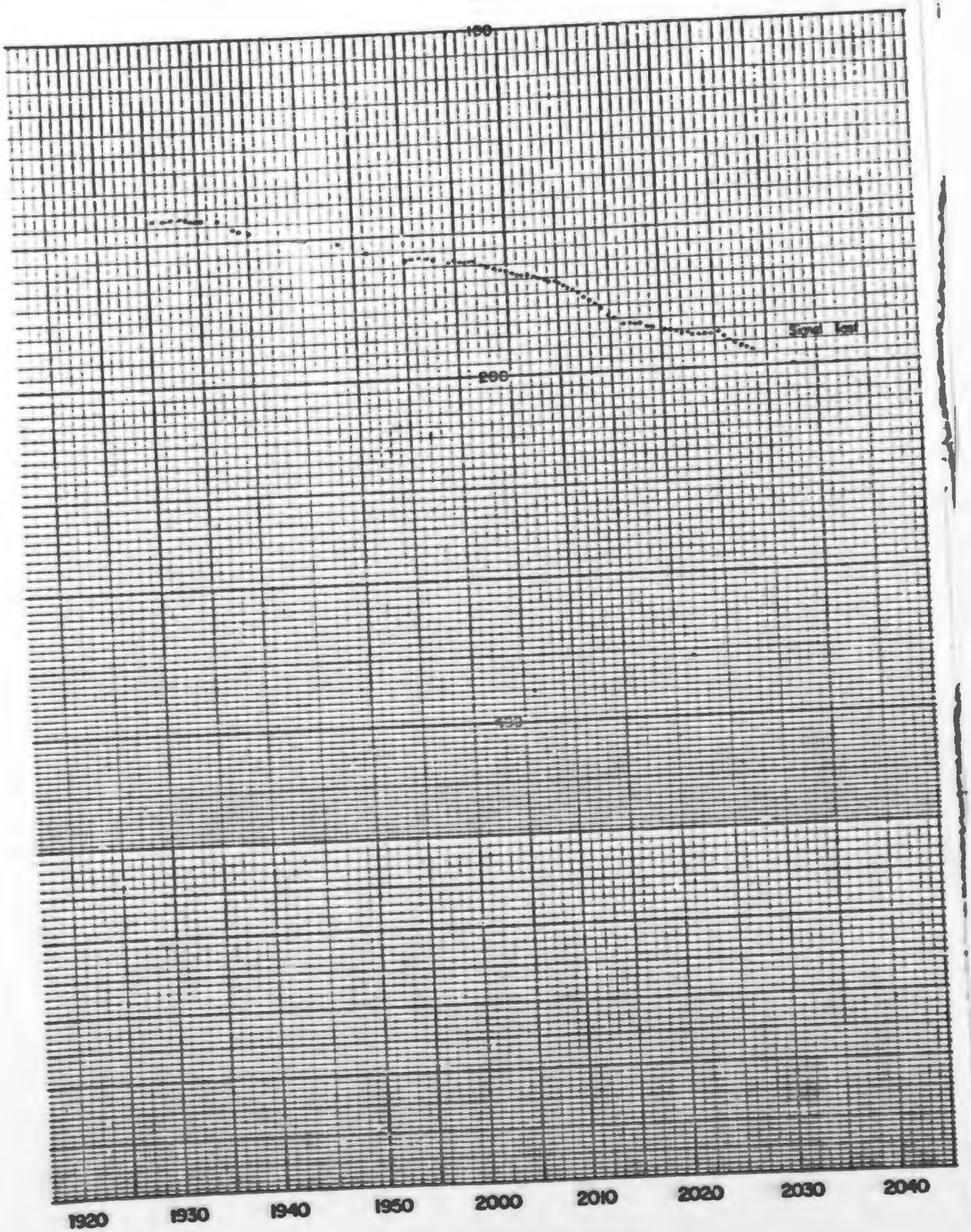

TIME - PRESSURE - ALTITUDE
FLIGHT No. 91
5 September, 1953
Launched at - MINNEAPOLIS, Minn.
TOW LEAD TOTAL
Gross Load 391.75 802.5 1194.25 lbs.
Free Lift 168.0 109.0 277.0 lbs.
Gross Lift 559.75 911.5 1471.25 lbs.
Altitude data from telemetered altitude cycle record
100
200
400
600
1000
PRESSURE IN MILLIBARS
1220
1230
1240
1250
1300
1310
1320
1330
GREENWICH MEAN TIME


100
200
300
400
500
600
1340
1350
1400
1410
1420
1430
1440
1450
1500

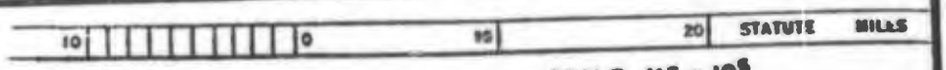

212 ft Z max.
512 ft Z max.
574 ft Z max.
200
400
1510
1520
1530
1540
1550
1600
1610
1620


100
200
400
1630
1640
1650
1700
1710
1720
1730
1740
1750

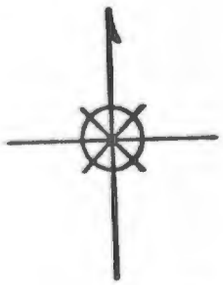

100
200
300
1800
1810
1820
1830
1840
1850
1900
1910


100
200
300
Signal lost
1920
1930
1940
1950
2000
2010
2020
2030
2040

CONFIDENTIAL

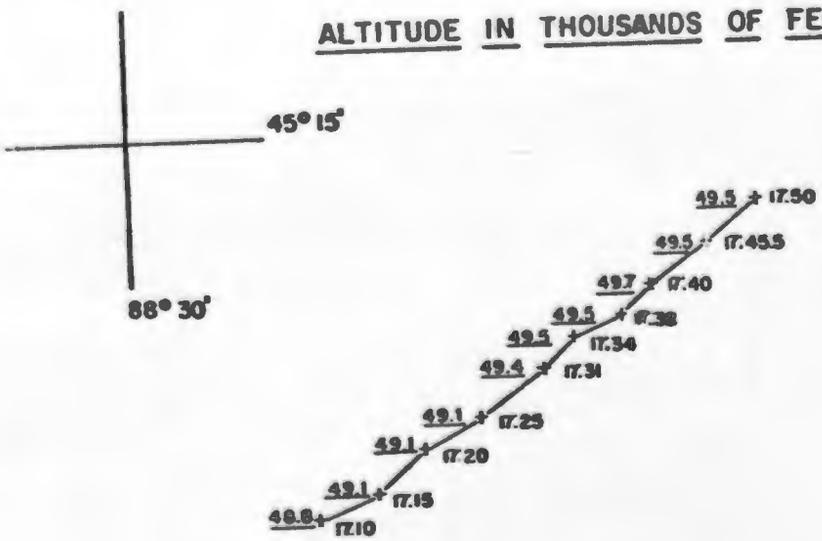


SCALE 1:5 x 10^5



LAUNCHED AT
MINNEAPOLIS, MINN.

ALTITUDE IN THOUSANDS OF FEET

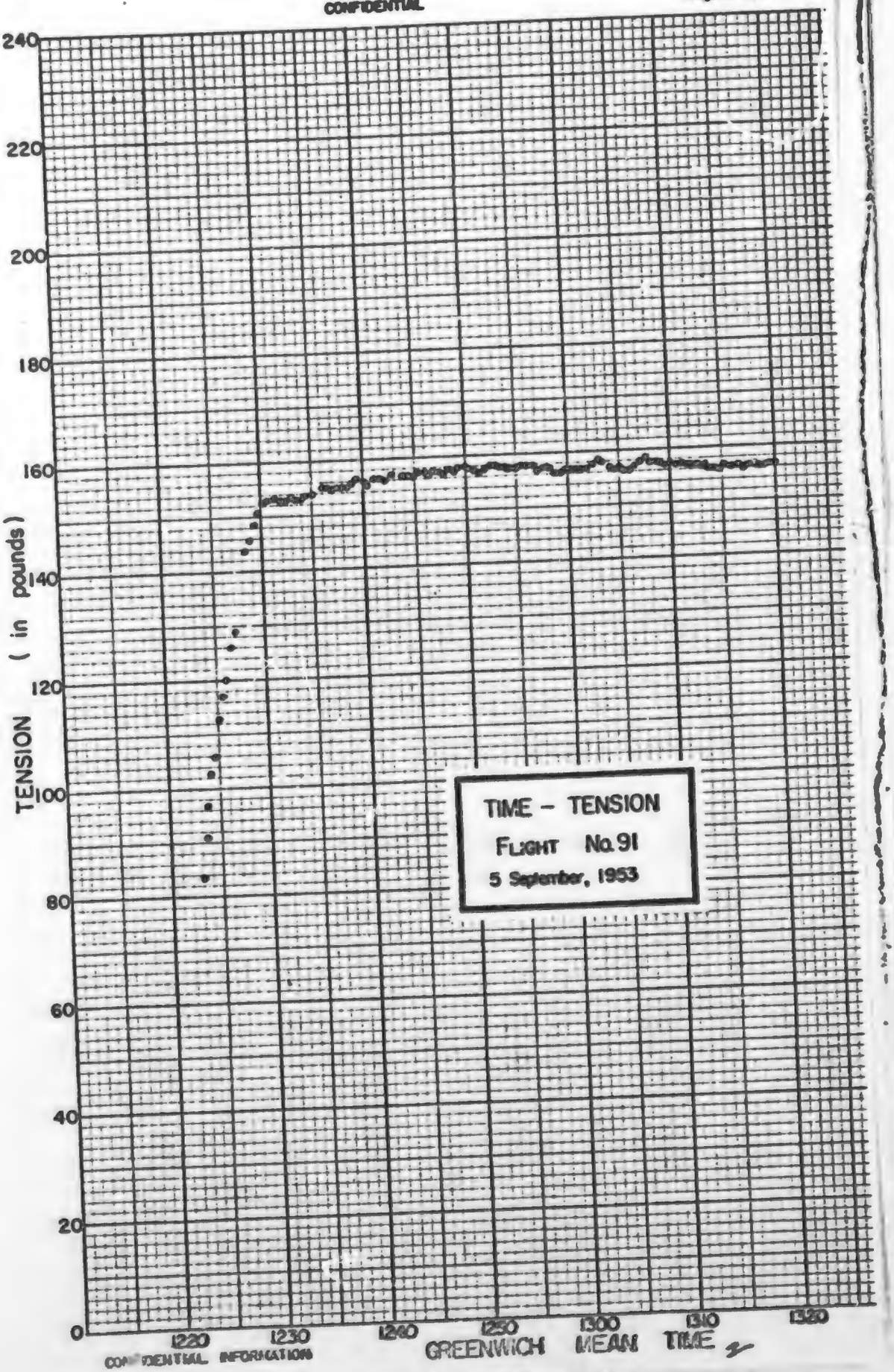


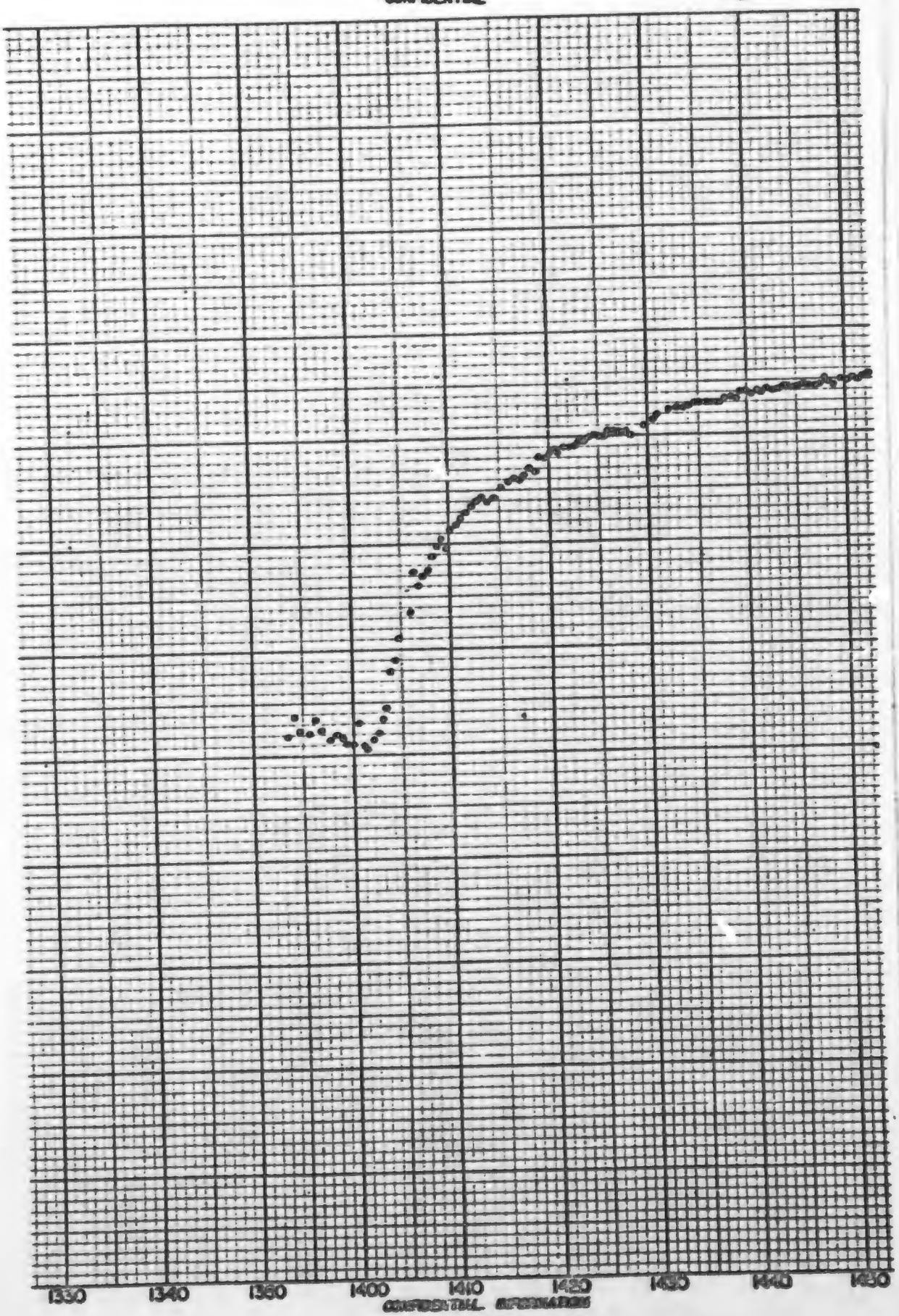
THEODOLITE SITE LAT. 44° 27.2' LONG. 88° 04.2'
DE PERE, WIS.

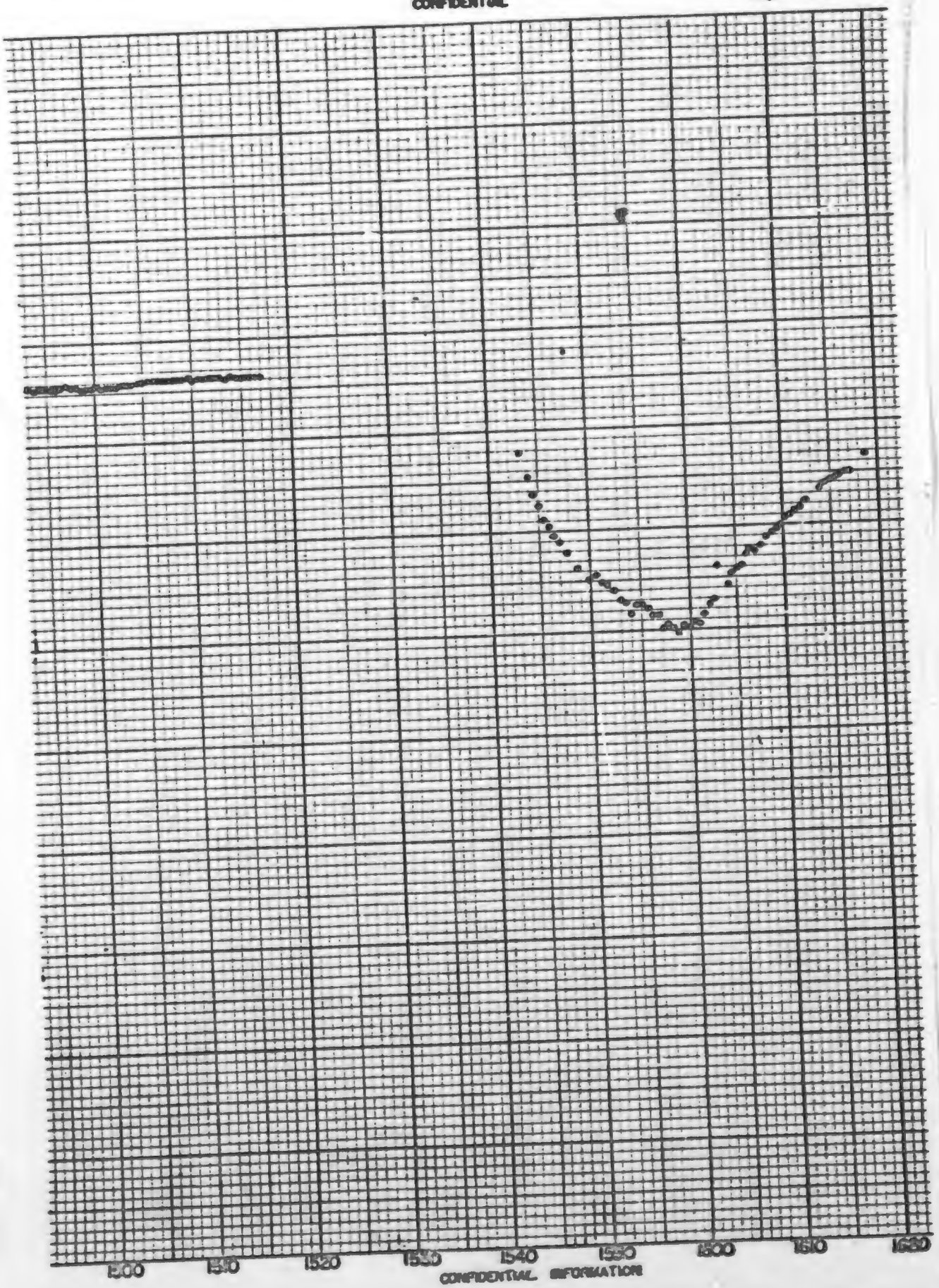
FLIGHT 91

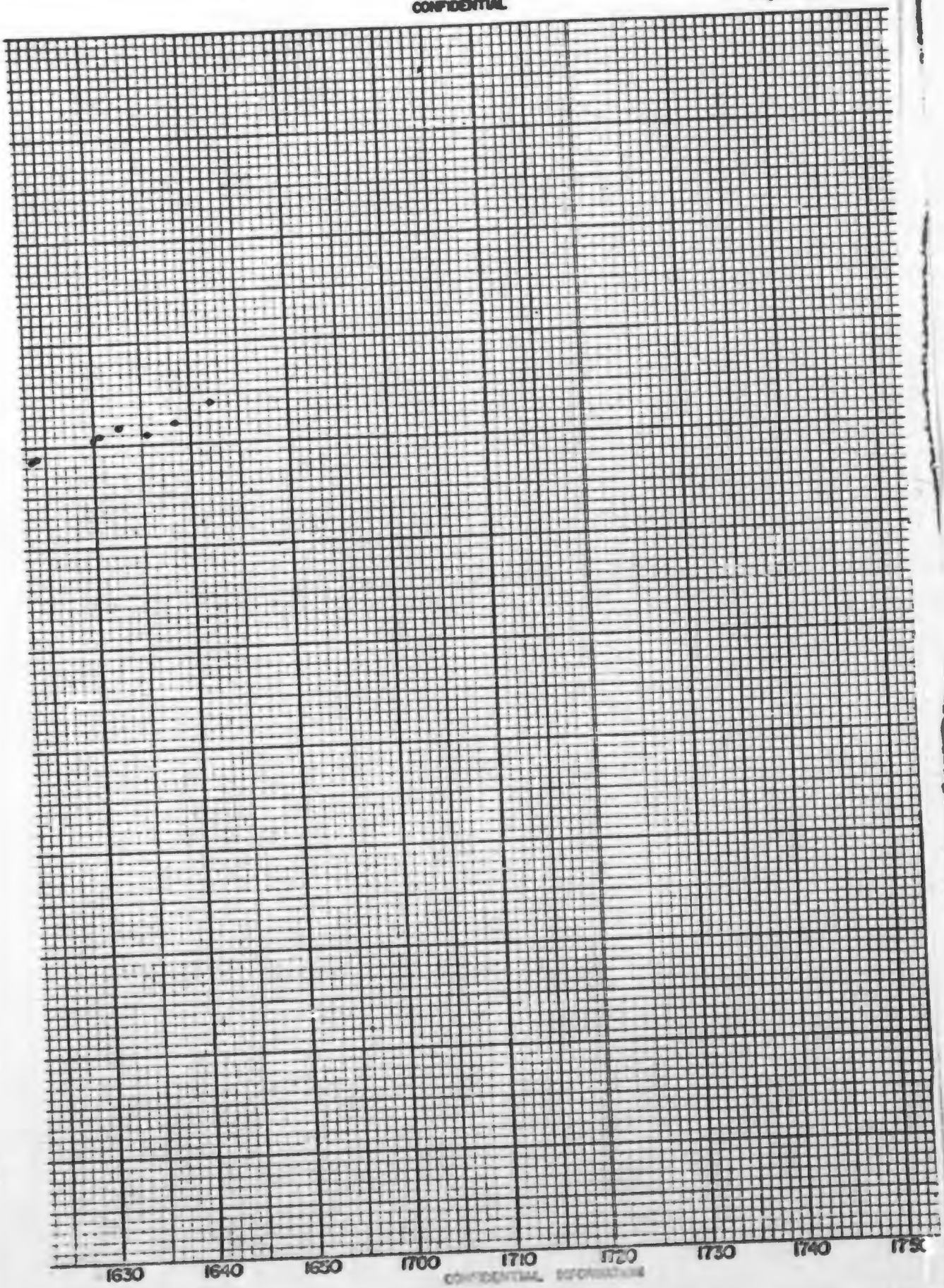
LAUNCHED 12:17 GMT.
5 SEPTEMBER, 1953

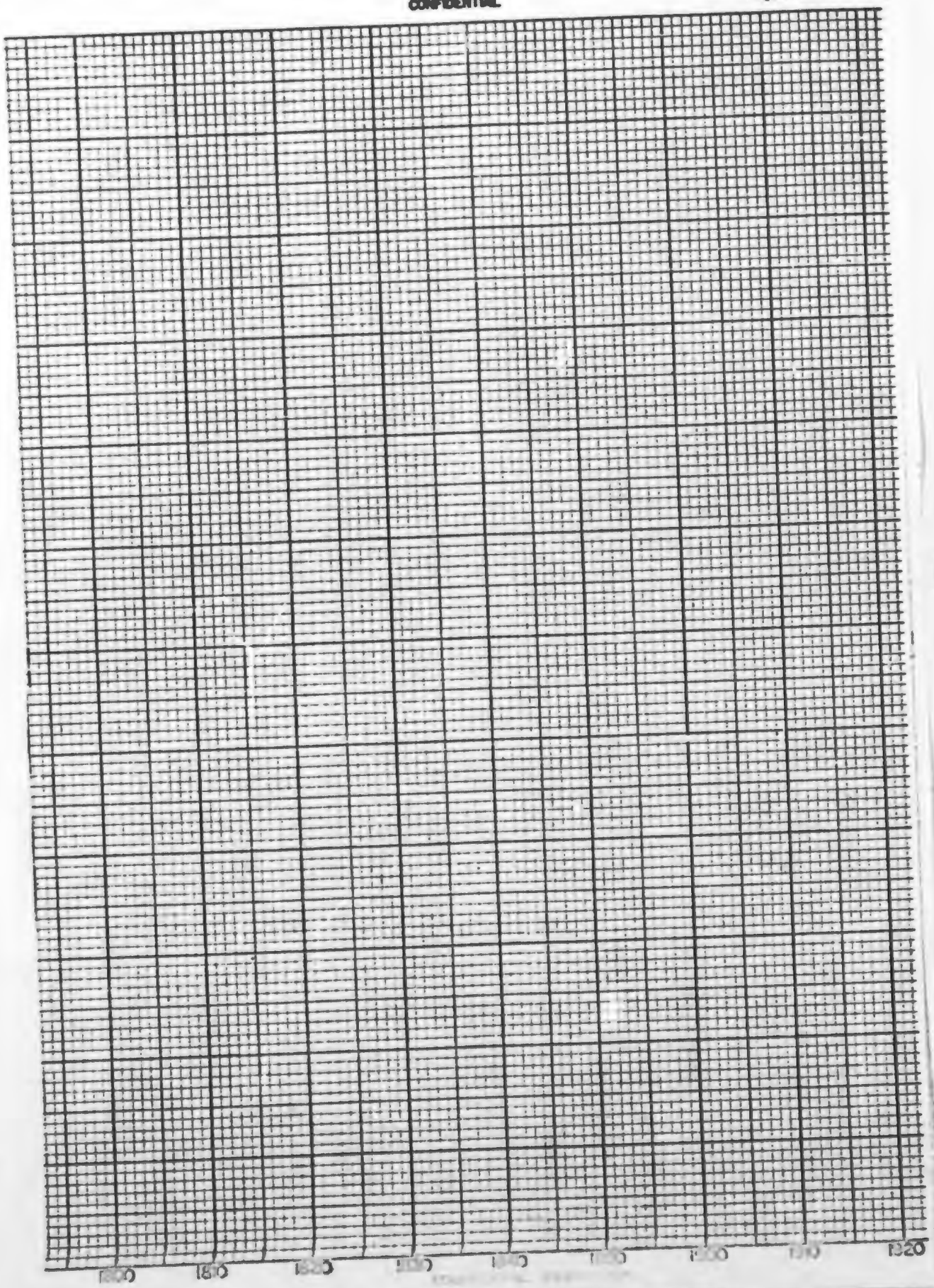
TRAJECTORY FROM THEODOLITE

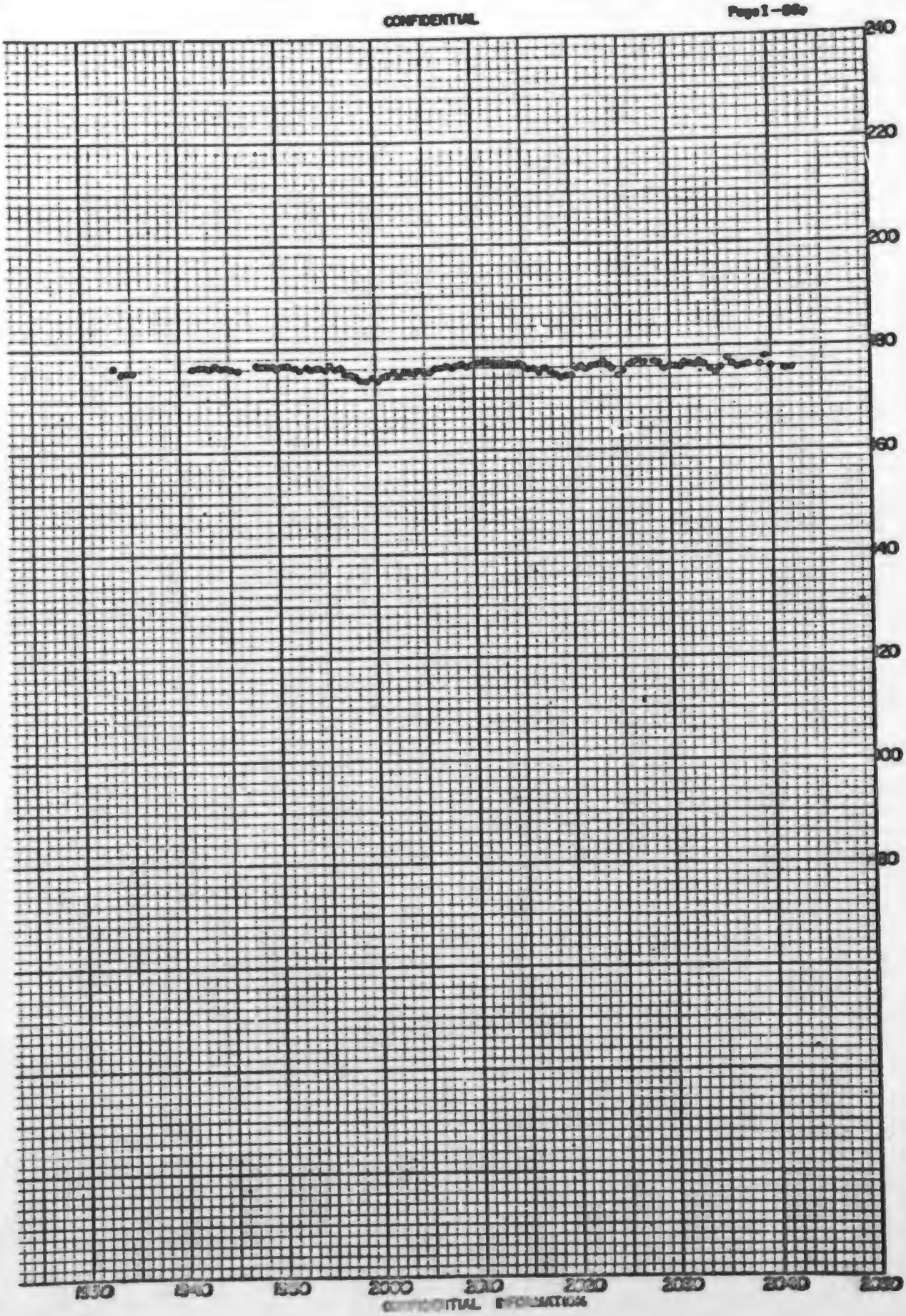

TIME - TENSION
FLIGHT No. 91
5 September, 1953
TENSION (in pounds)
240
220
200
180
160
140
120
100
80
60
40
20
0
1220
1230
1240
1250
1300
1310
1320
GREENWICH MEAN TIME


1330
1340
1350
1400
1410
1420
1430
1440
1450


1500
1510
1520
1530
1540
1550
1560
1570
1580


1630
1640
1650
1700
1710
1720
1730
1740
1750


1320
1310
1300
1290
1280
1270
1260
1250
1240
1230
1220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200
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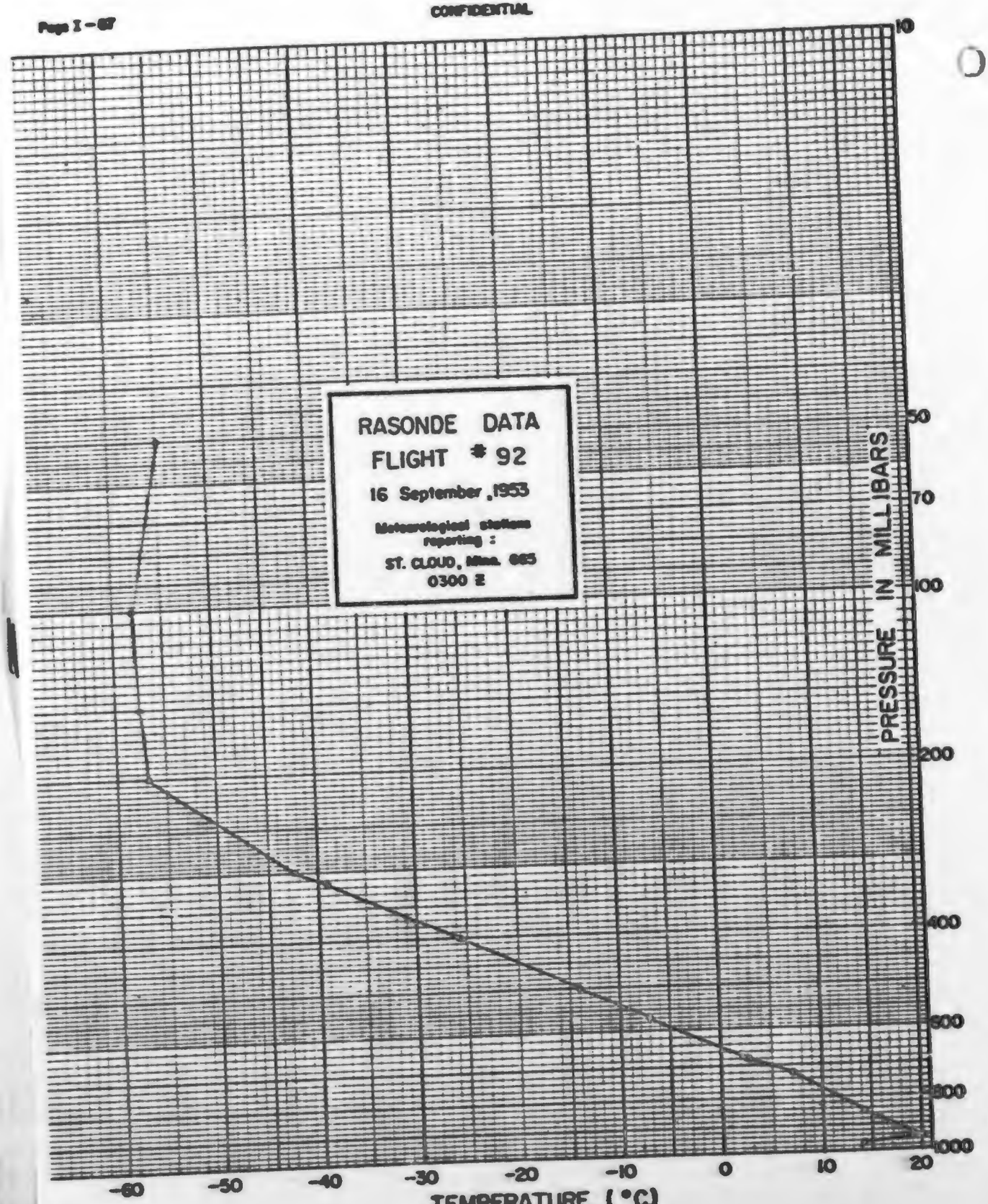
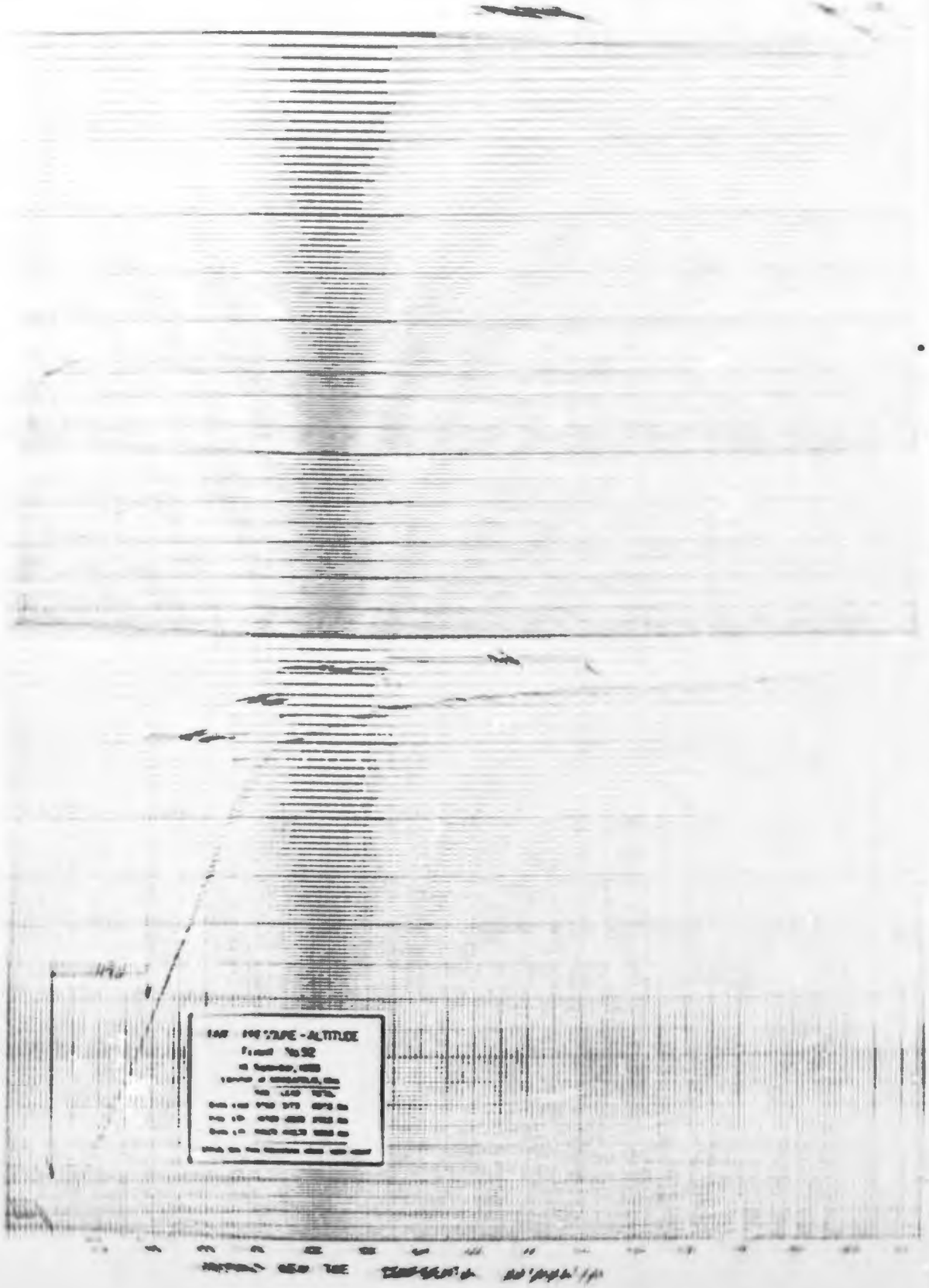
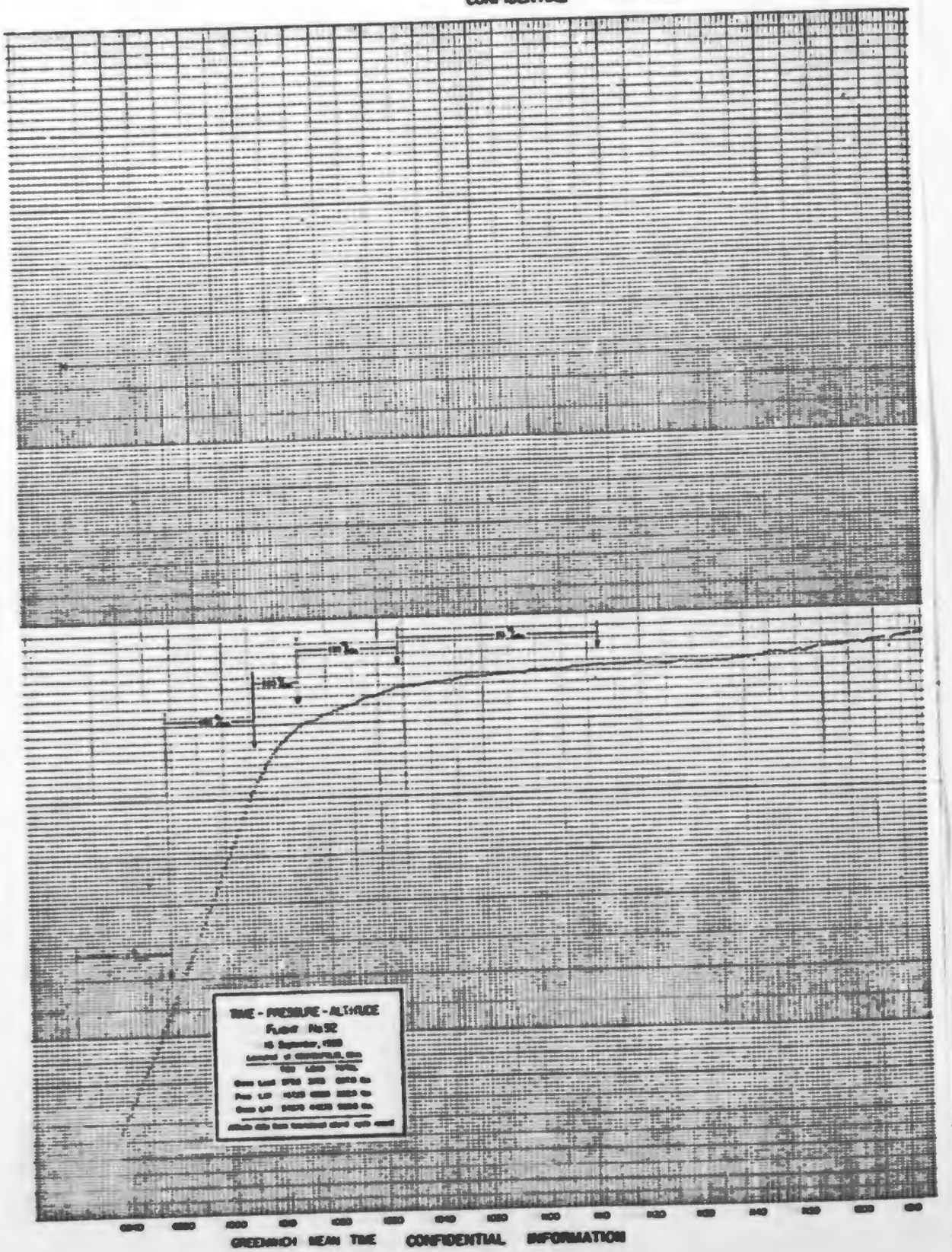
160
140
120
100
80
1930
1940
1950
2000
2010
2020
2030
2040
2050

CONFIDENTIAL

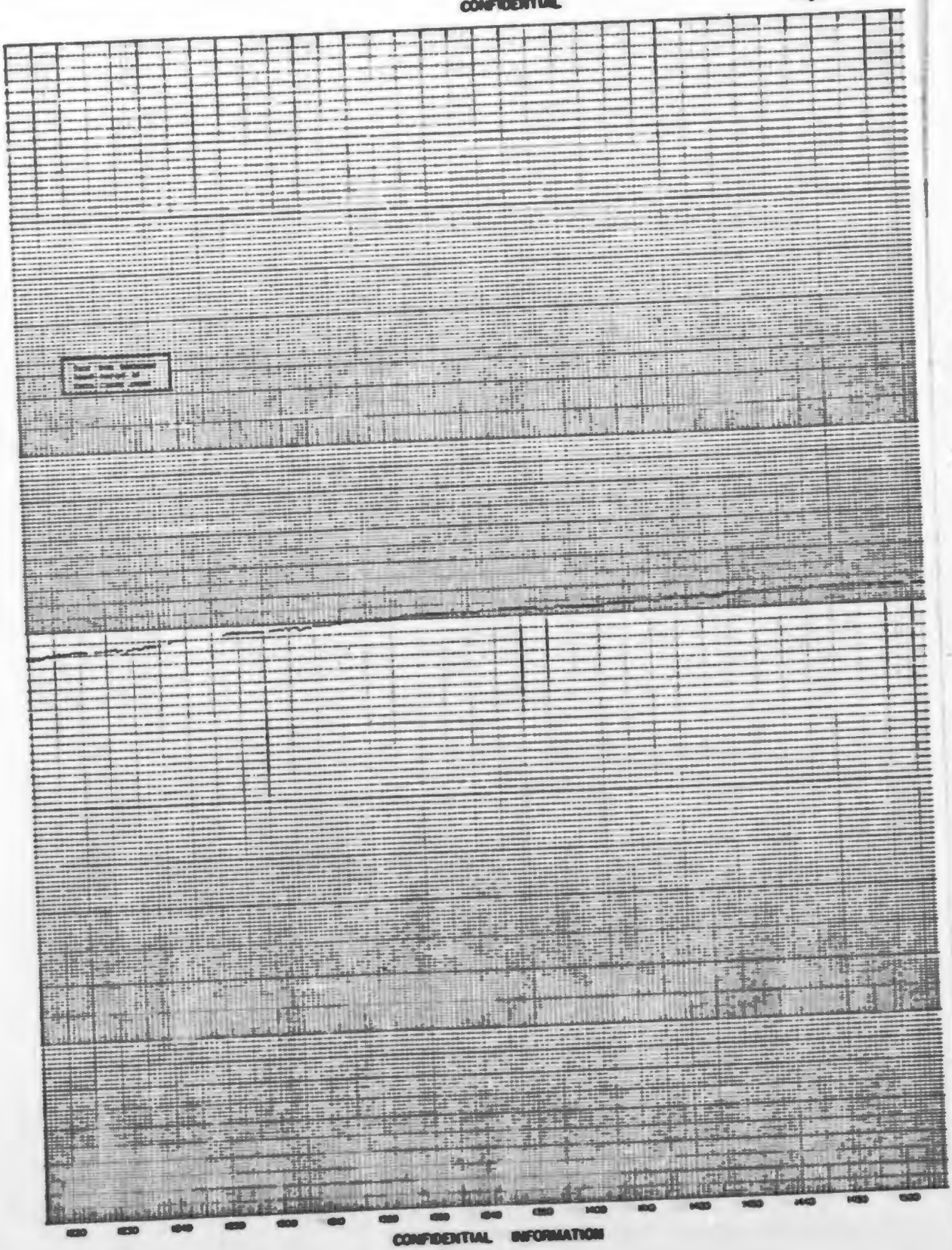


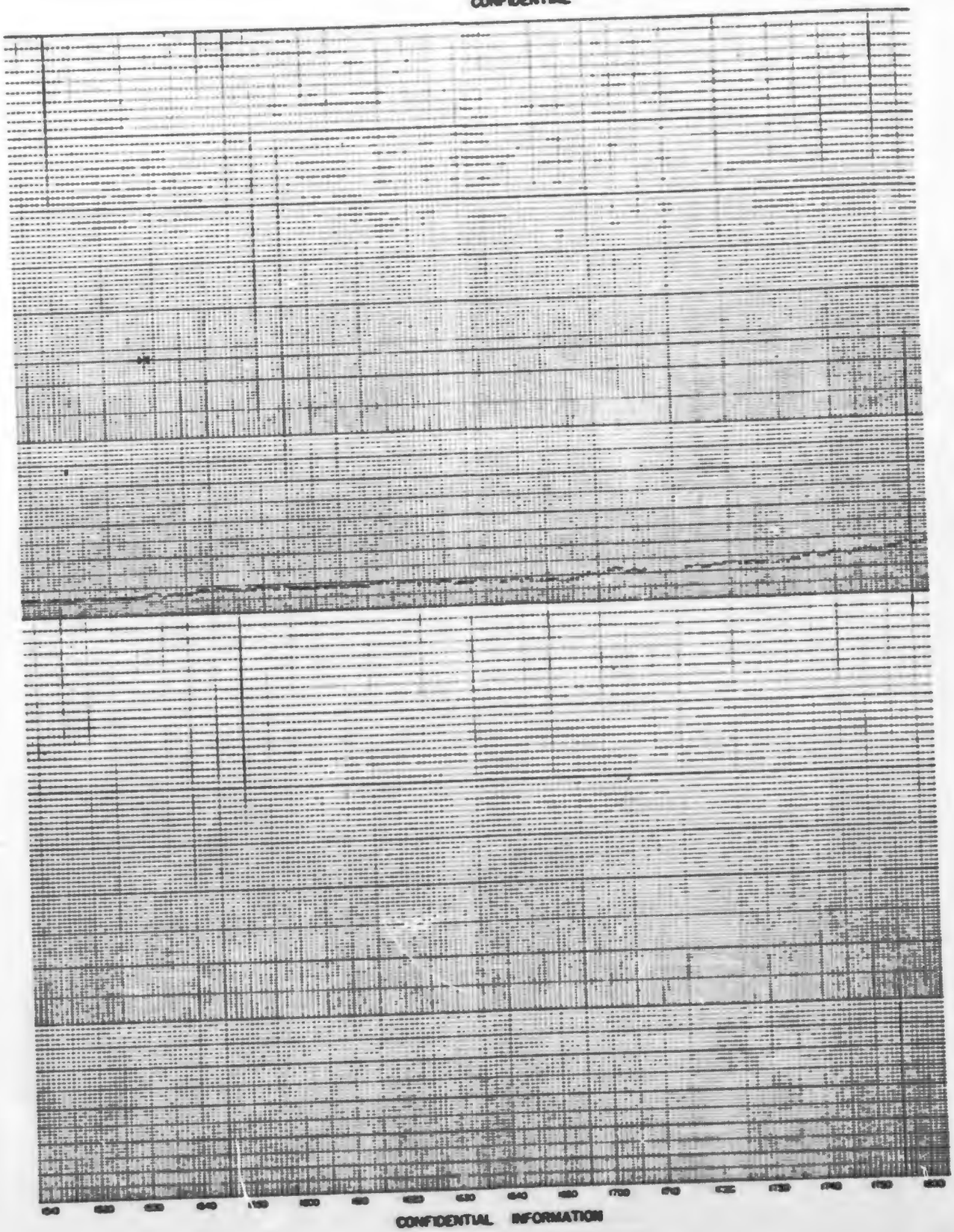
CONFIDENTIAL INFORMATION

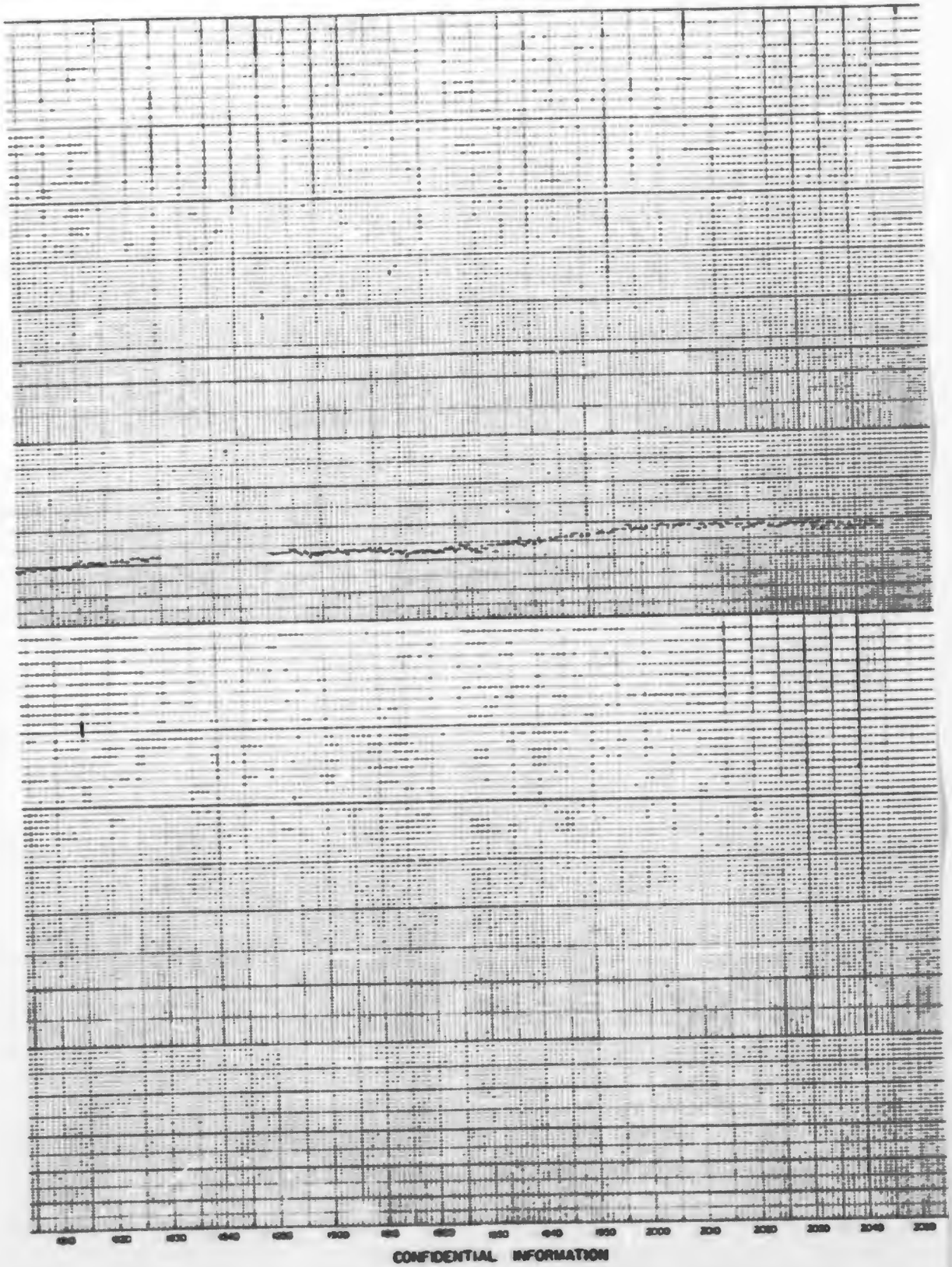


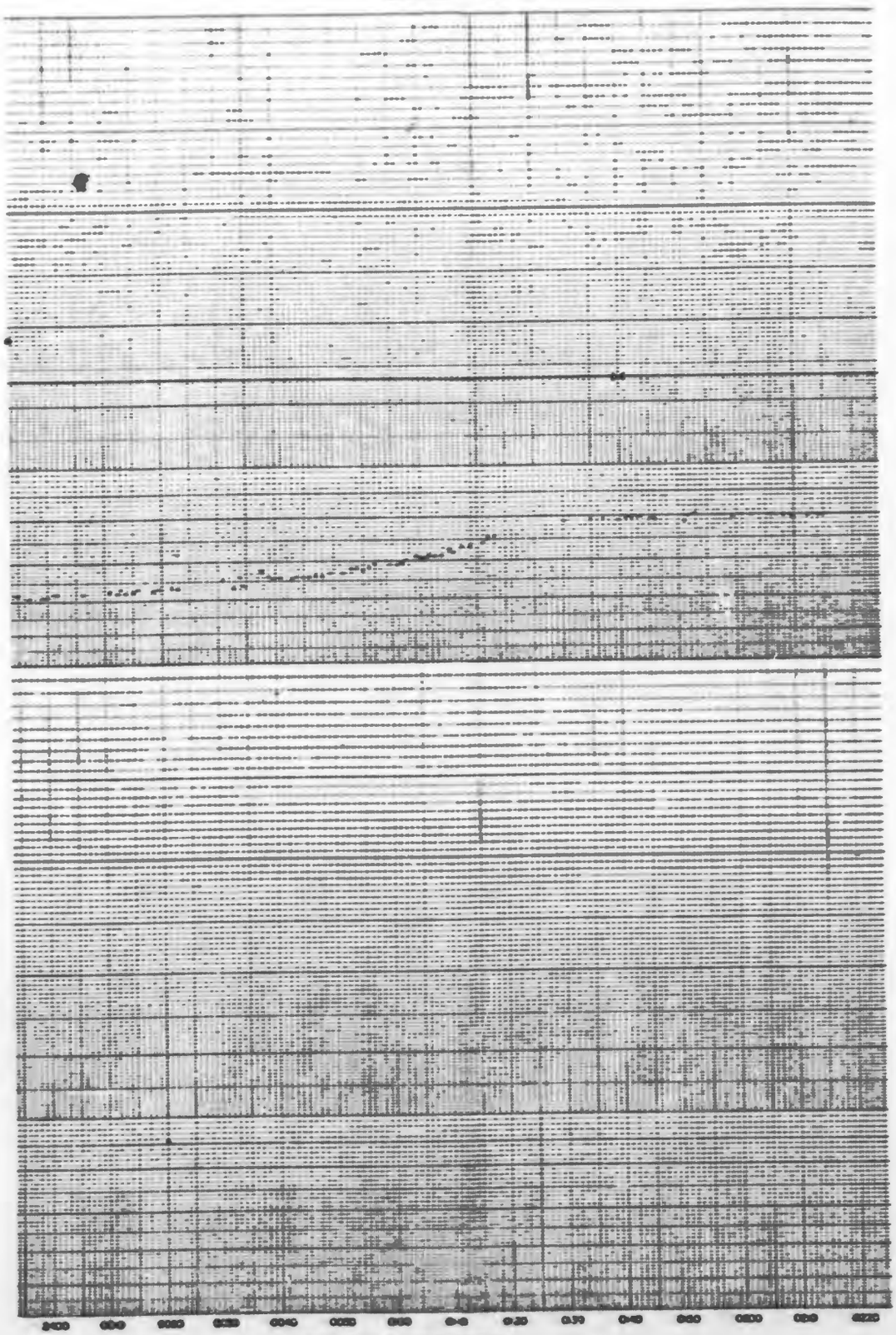


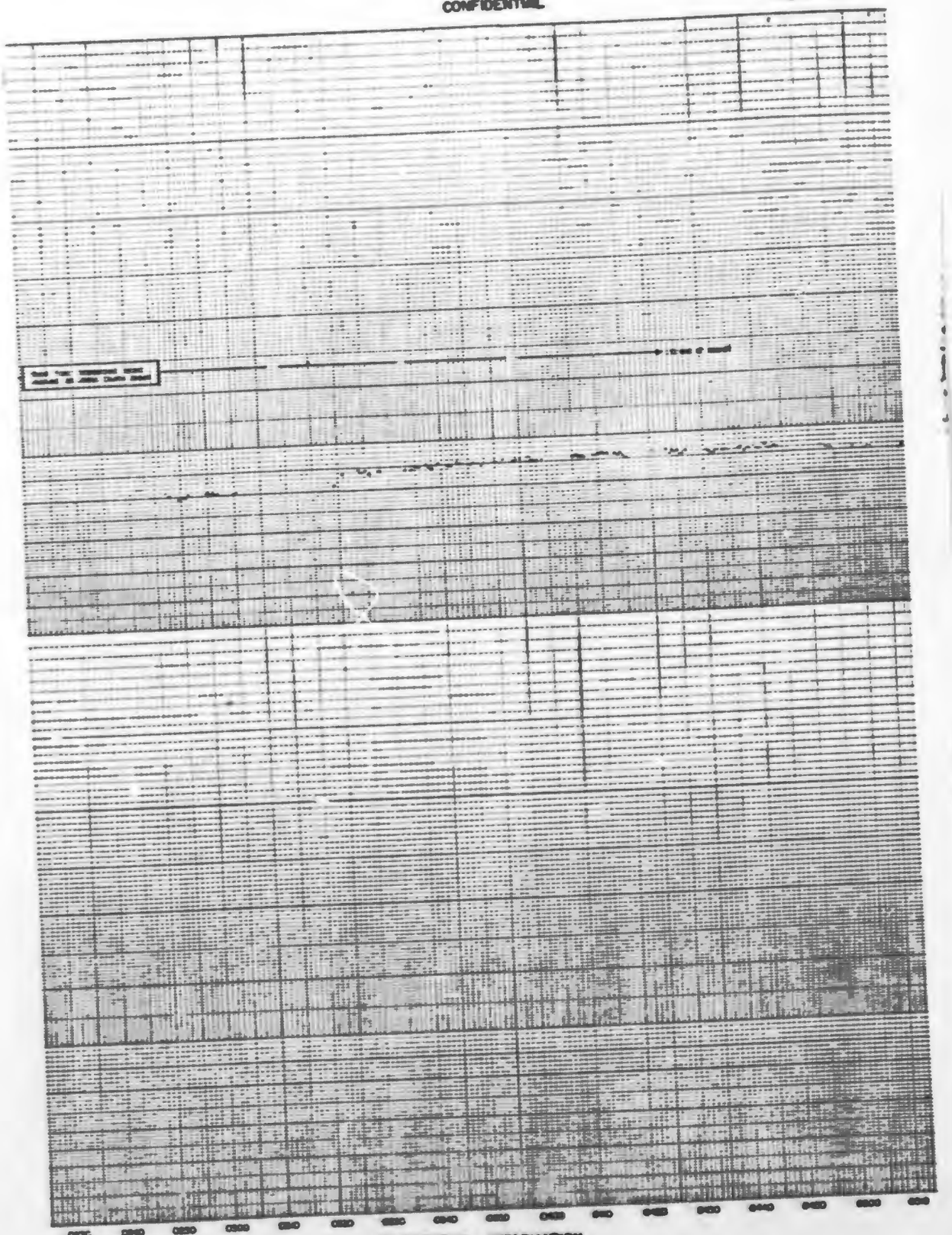
GREENWICH MEAN TIME CONFIDENTIAL INFORMATION

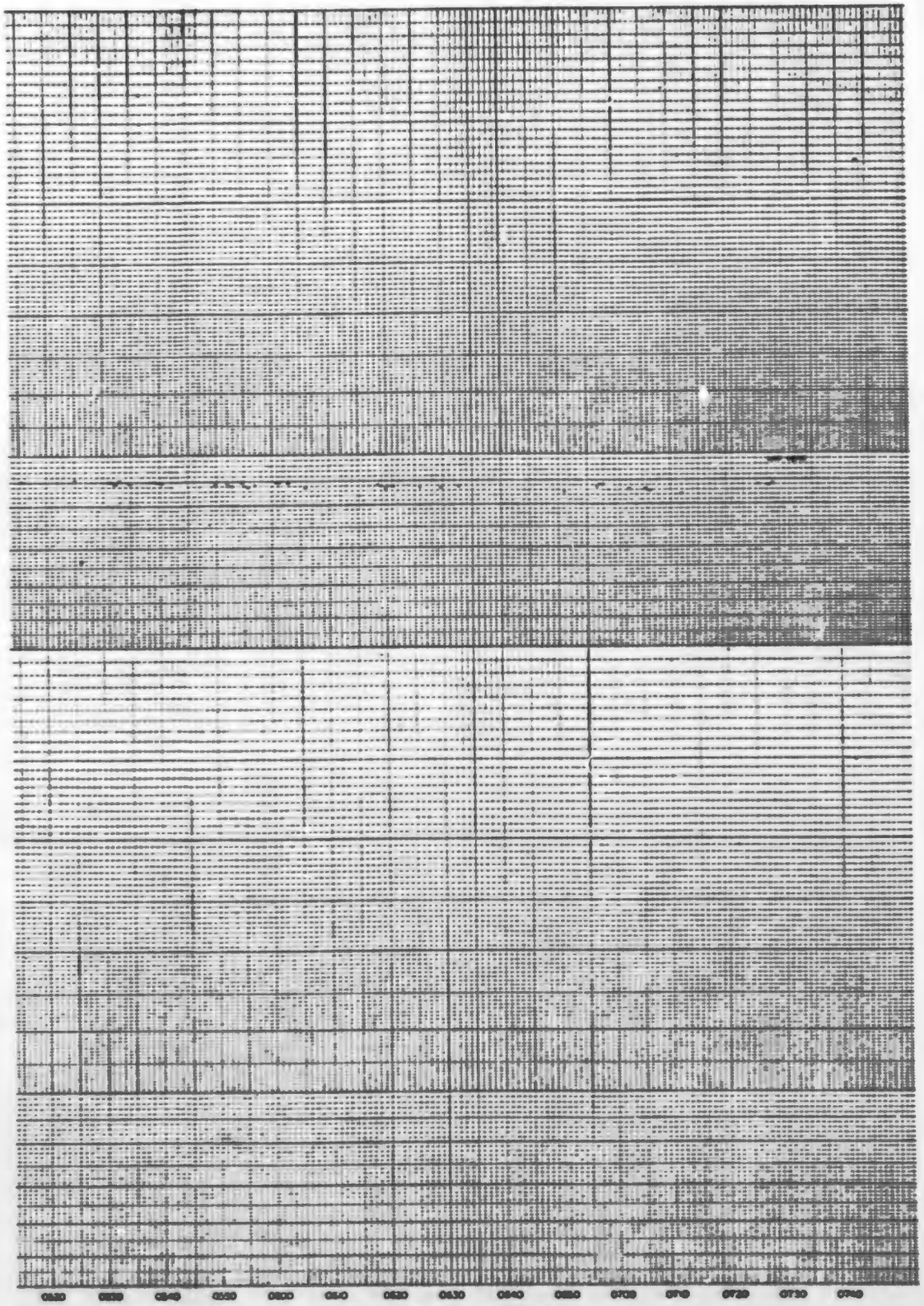


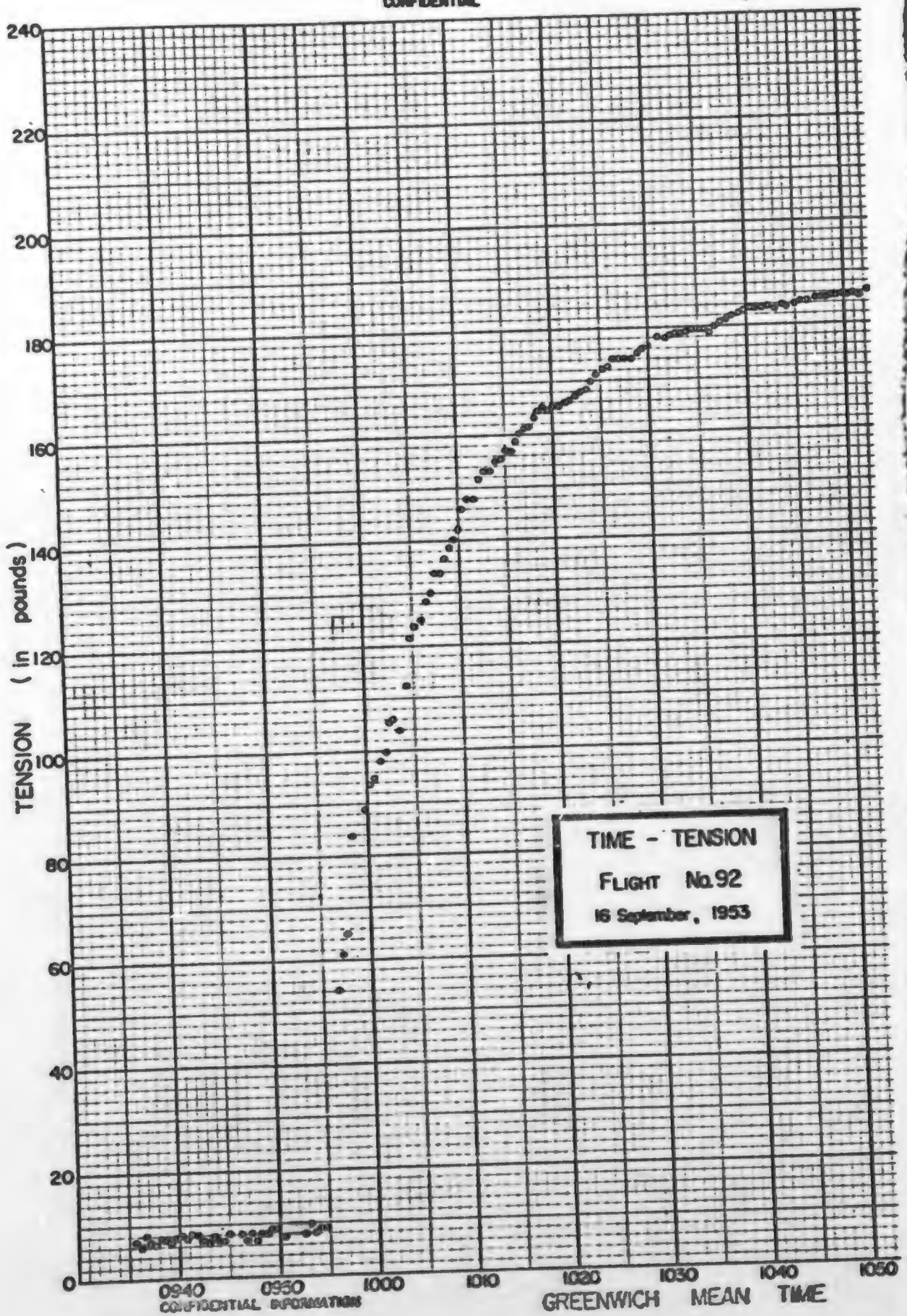


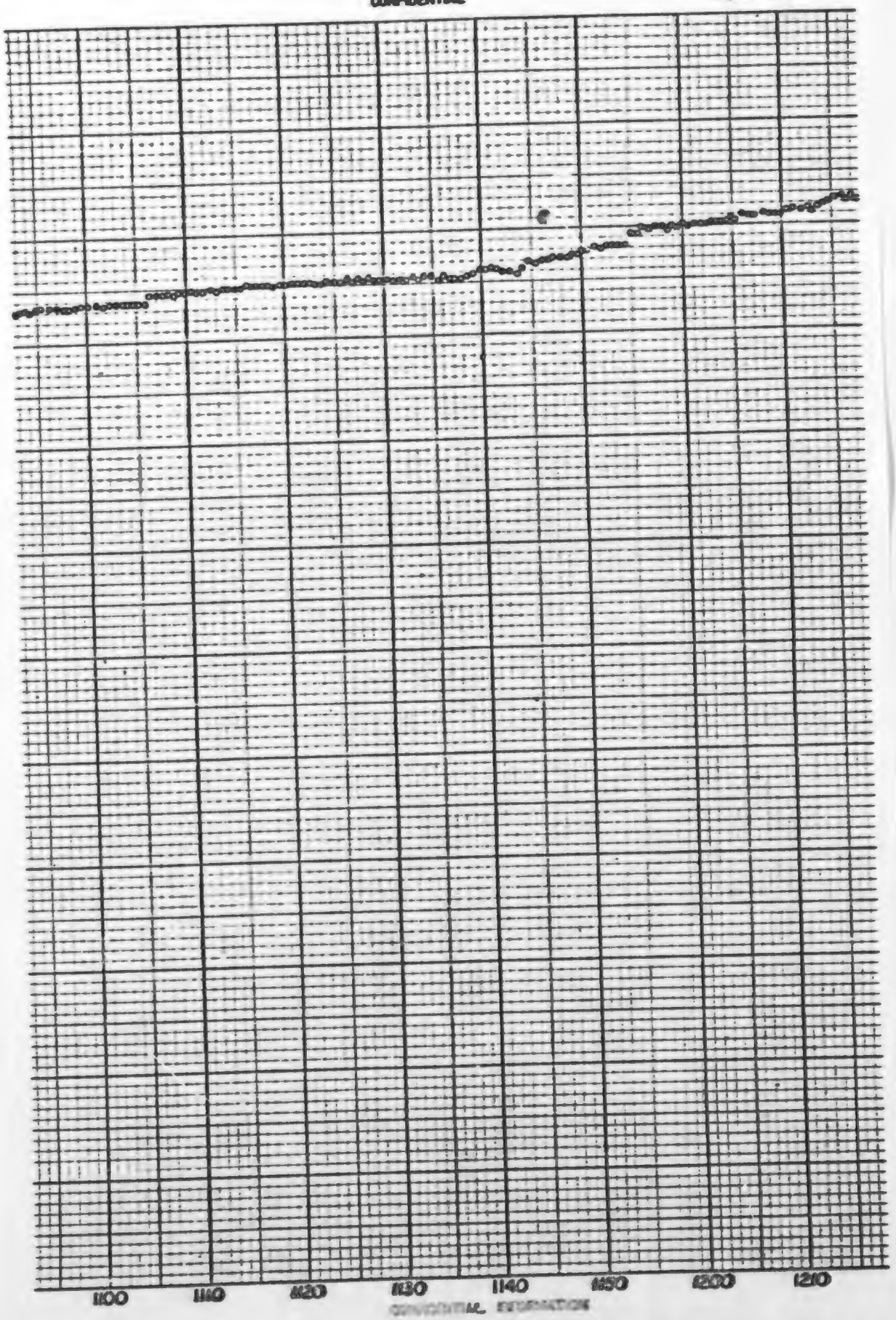


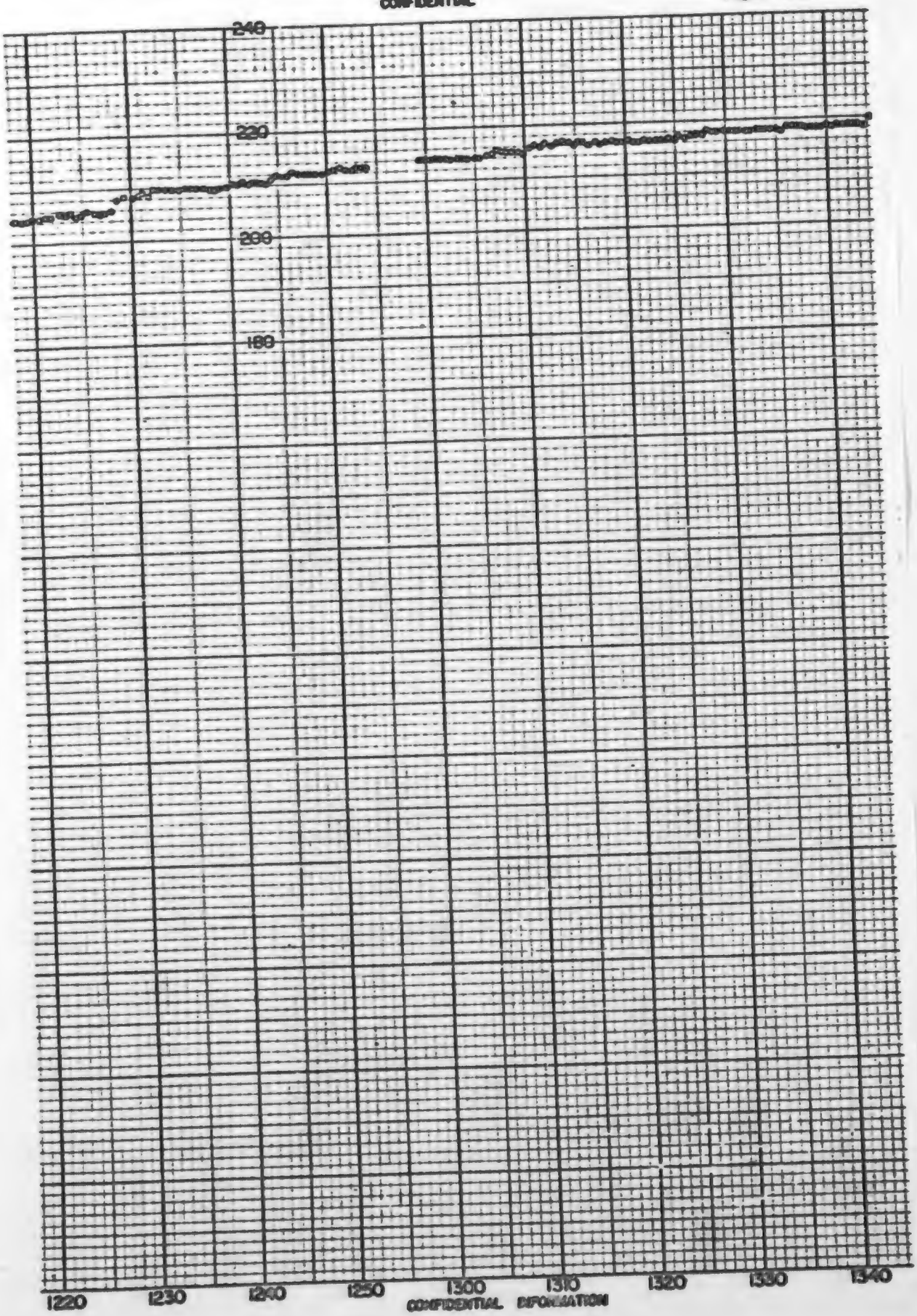


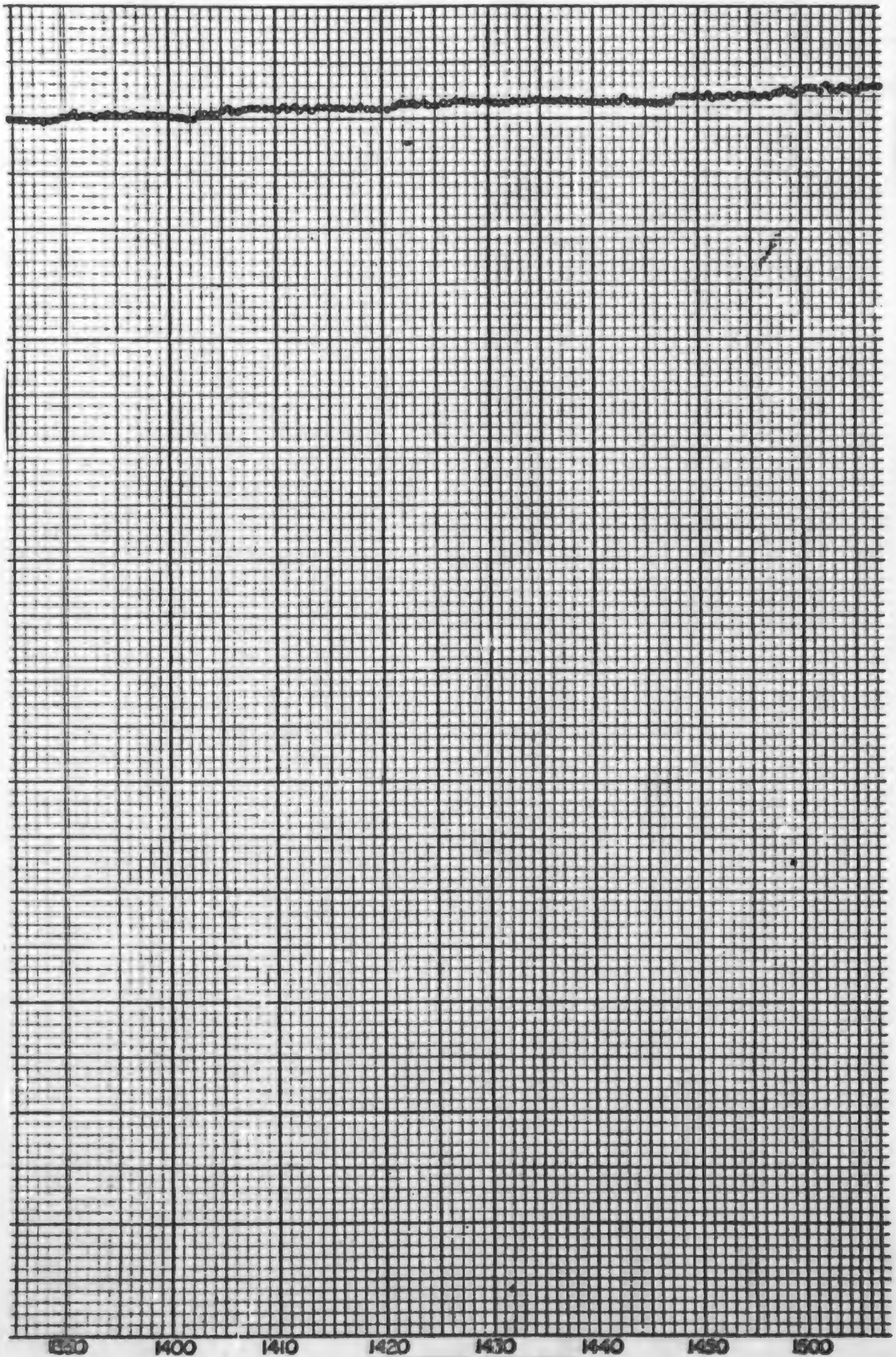


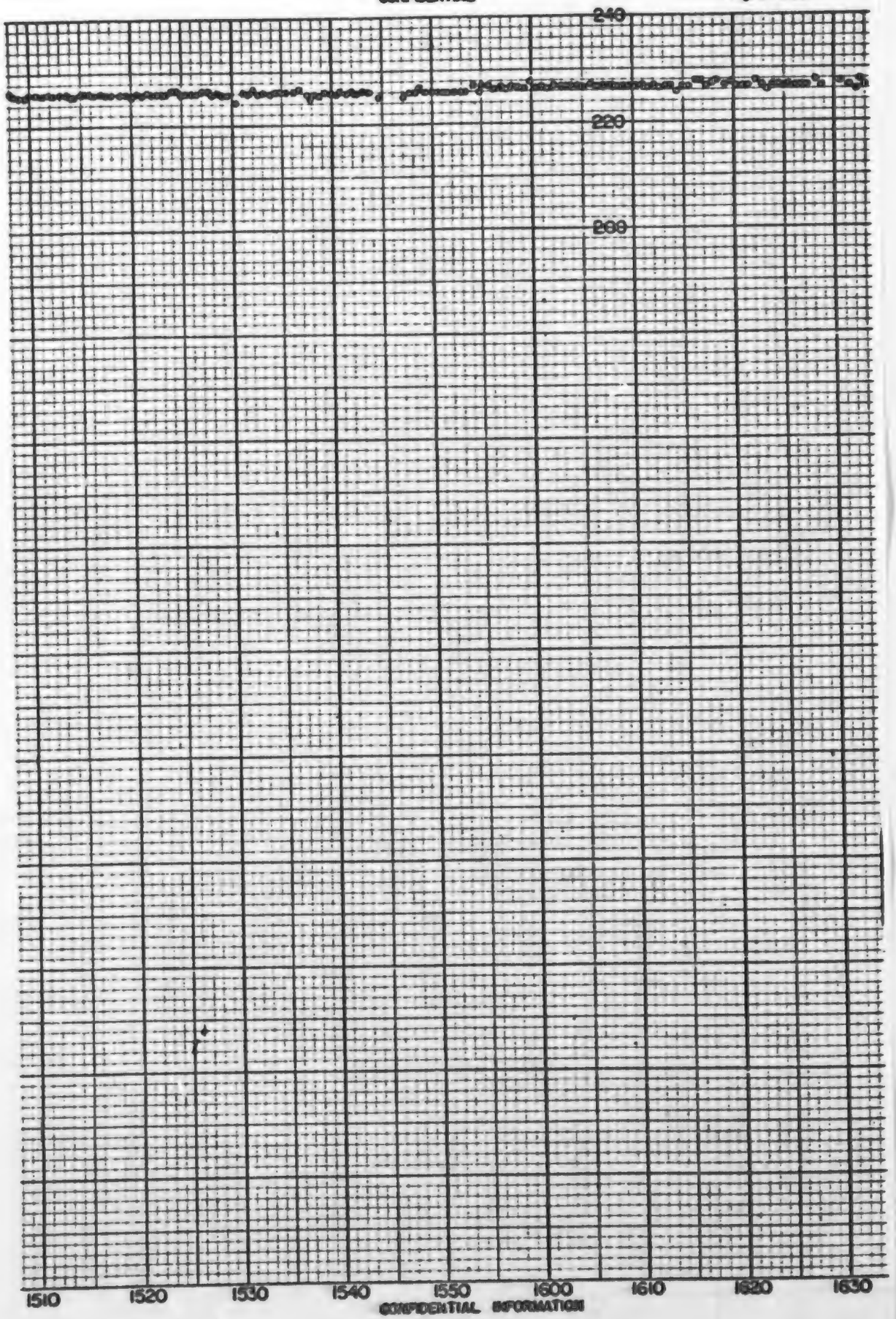

0530
0540
0550
0600
0610
0620
0630
0640
0650
0700
0710
0720
0730
0740

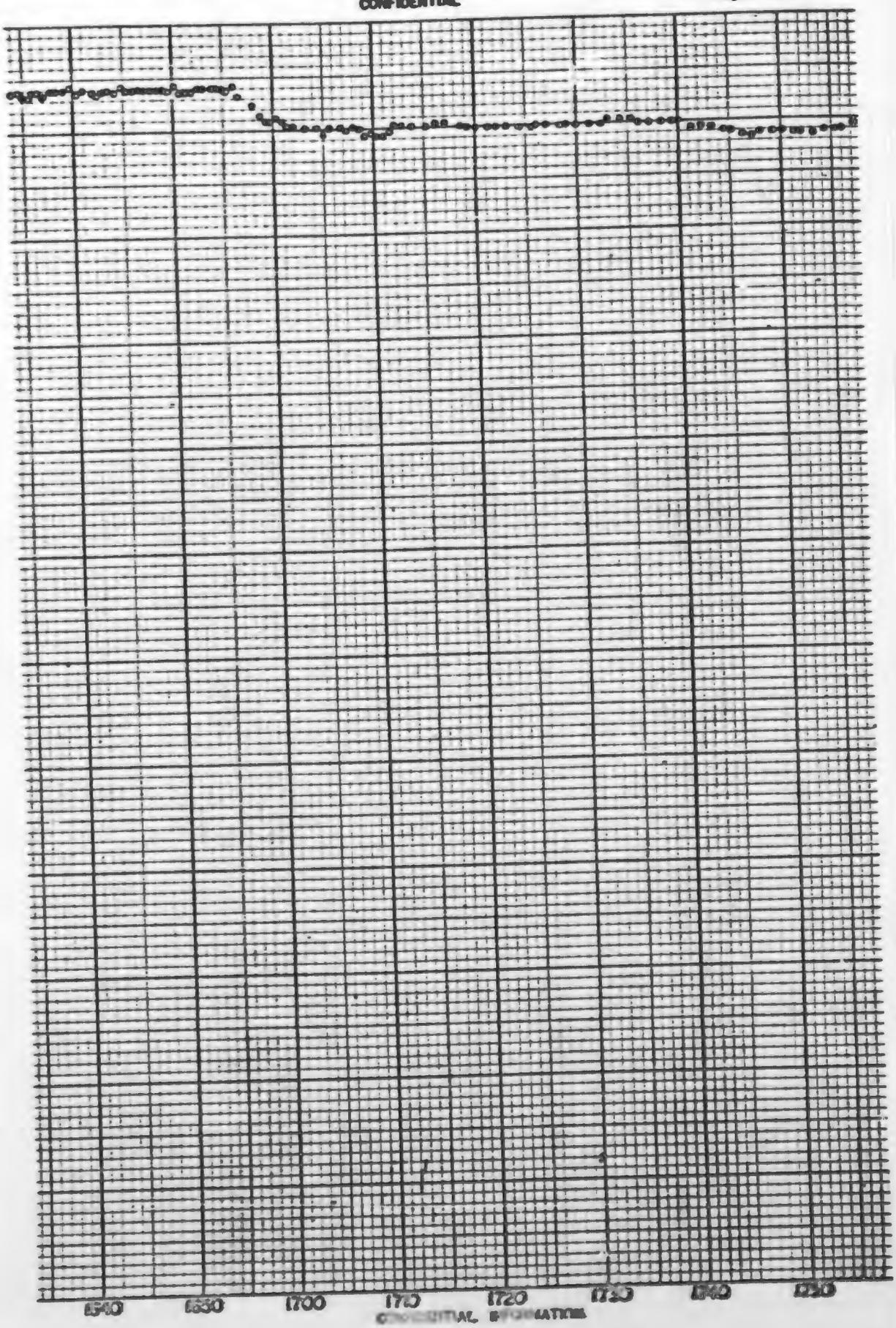

TIME - TENSION
FLIGHT No. 92
16 September, 1953
TENSION (in pounds)
240
220
200
180
160
140
120
100
80
60
40
20
0
0940
0950
1000
1010
1020
1030
1040
1050
GREENWICH MEAN TIME

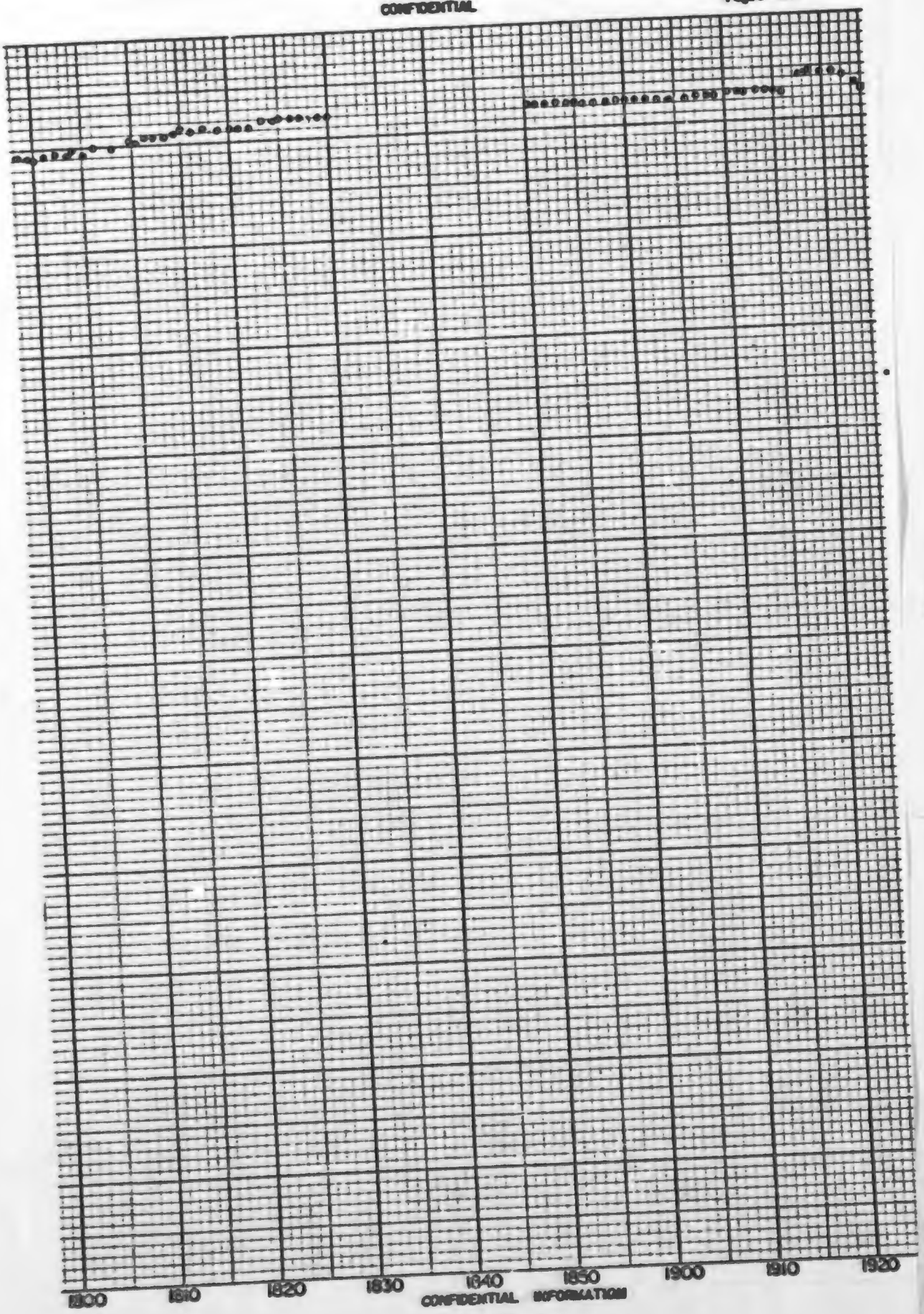

1100
1110
1120
1130
1140
1150
1200
1210

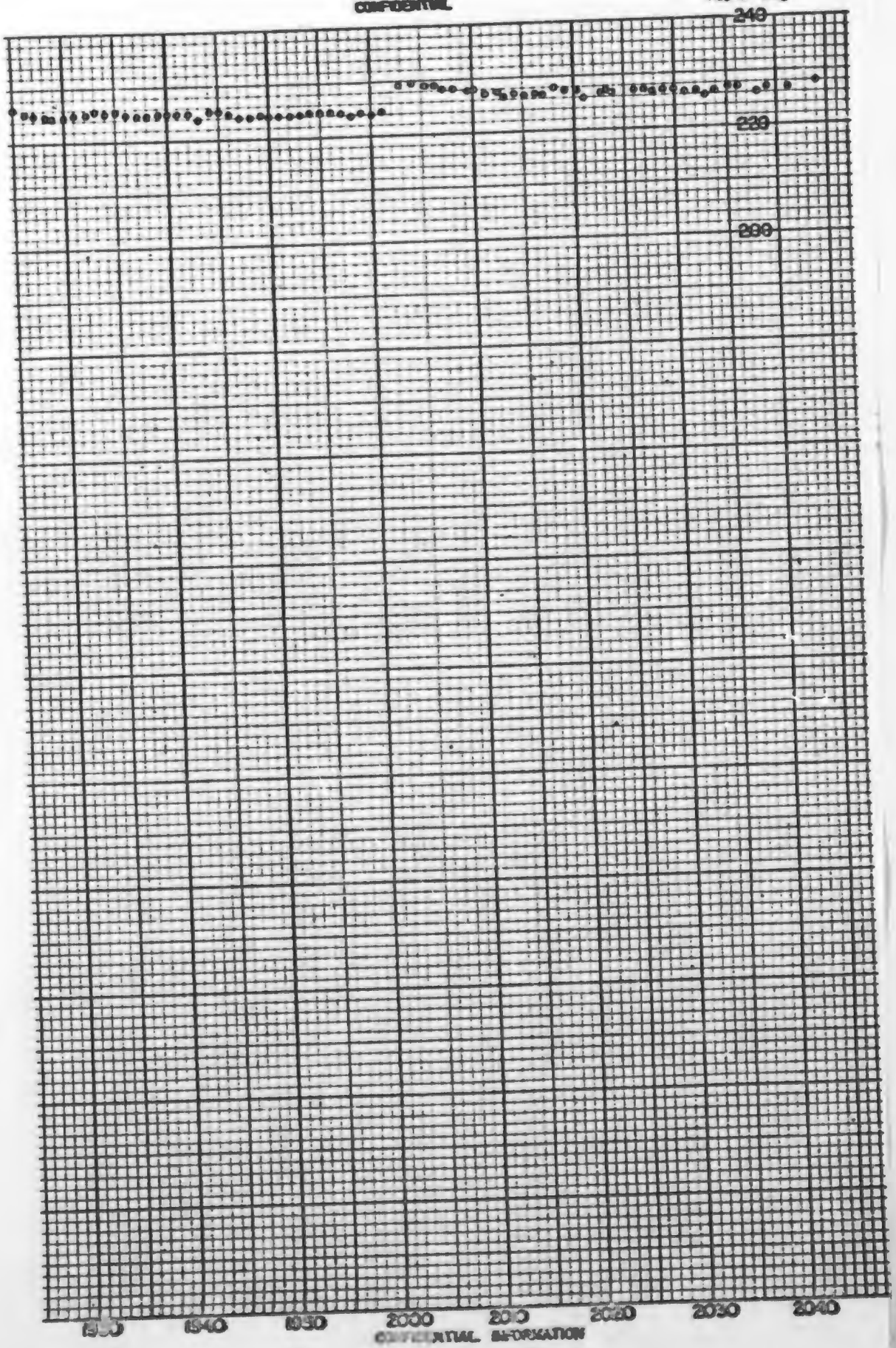

240
220
200
180
1220
1230
1240
1250
1300
1310
1320
1330
1340

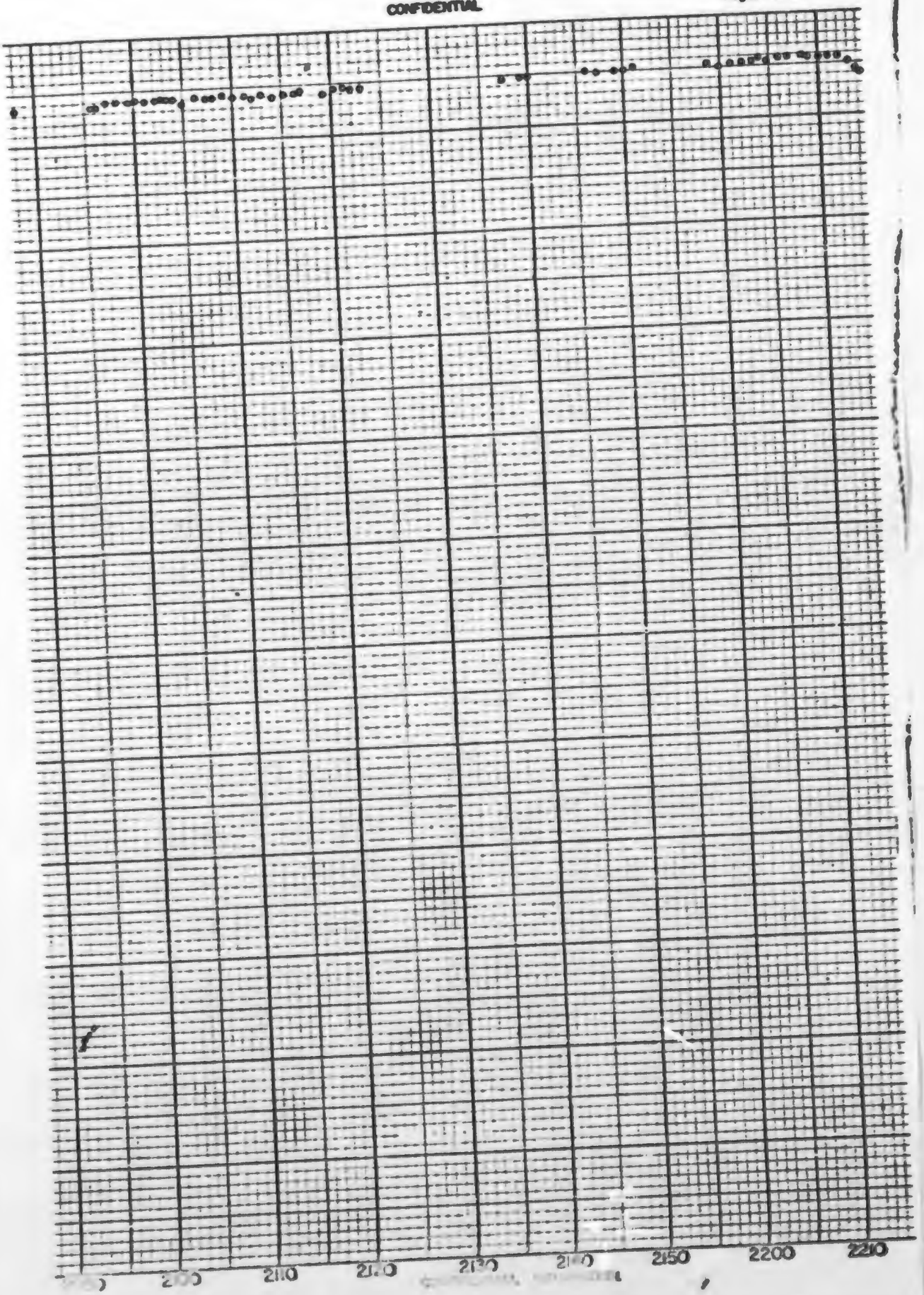

1400
1410
1420
1430
1440
1450
1500

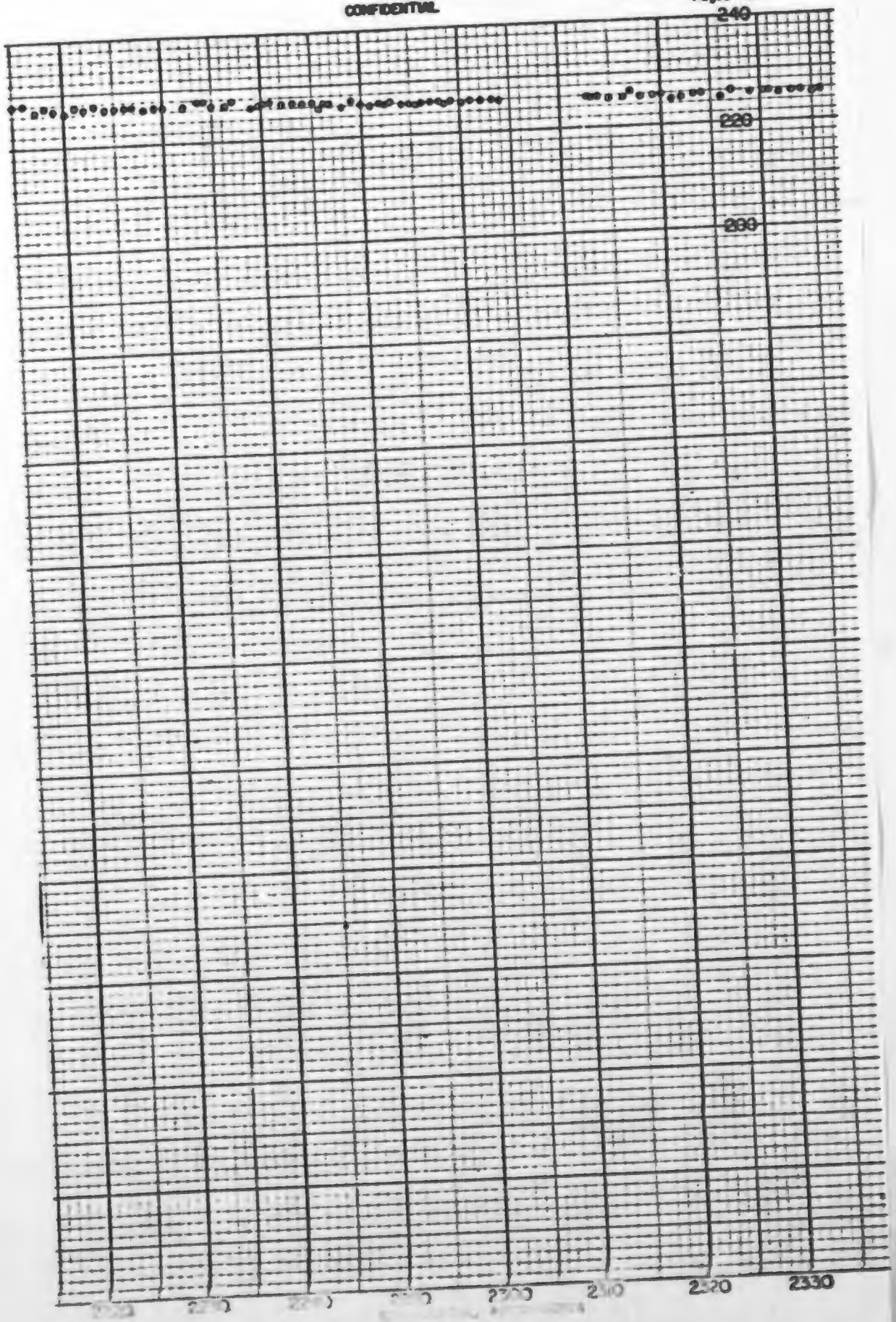

240
220
200
1510
1520
1530
1540
1550
1600
1610
1620
1630

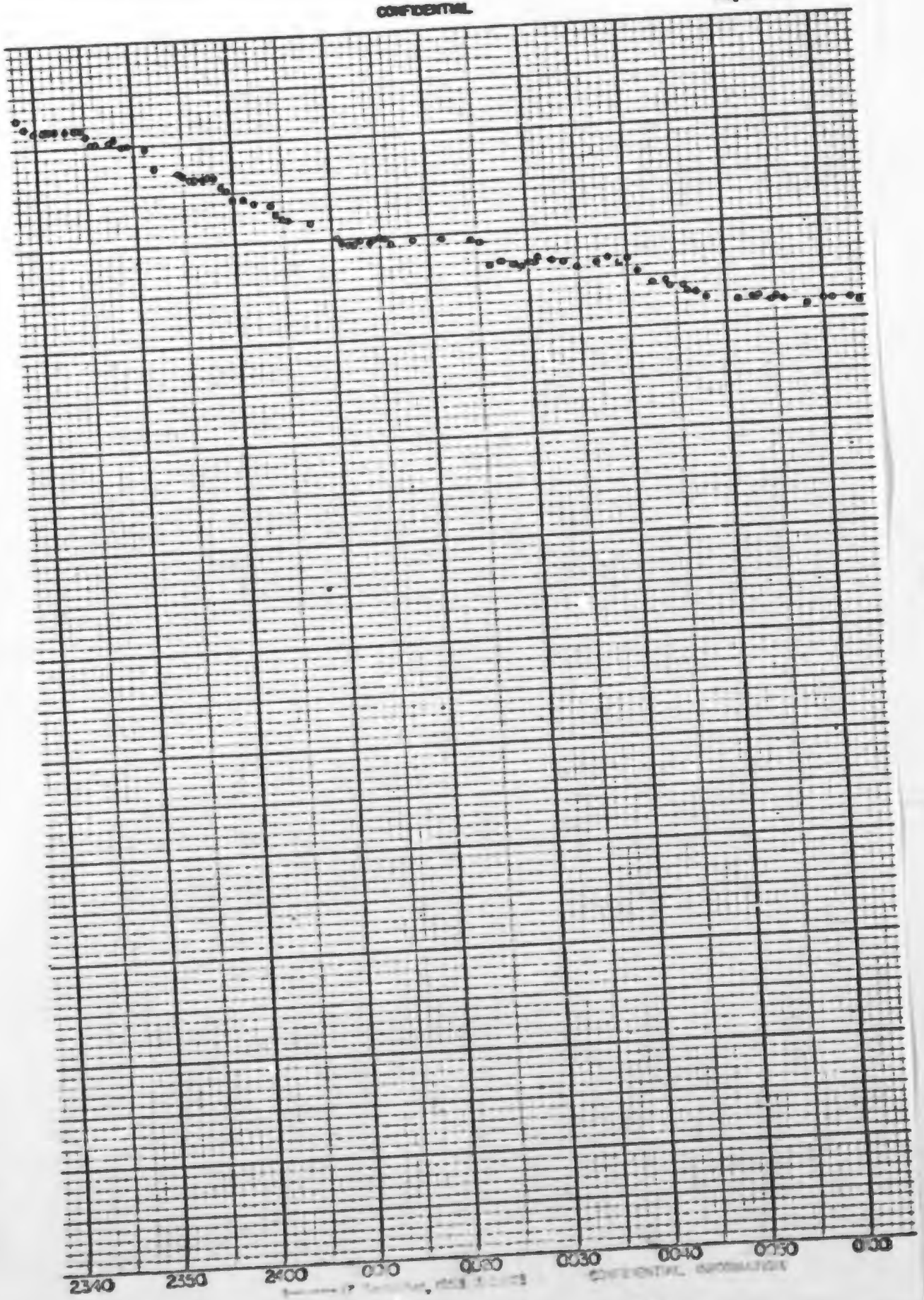

1540
1630
1700
1710
1720
1730
1740
1750

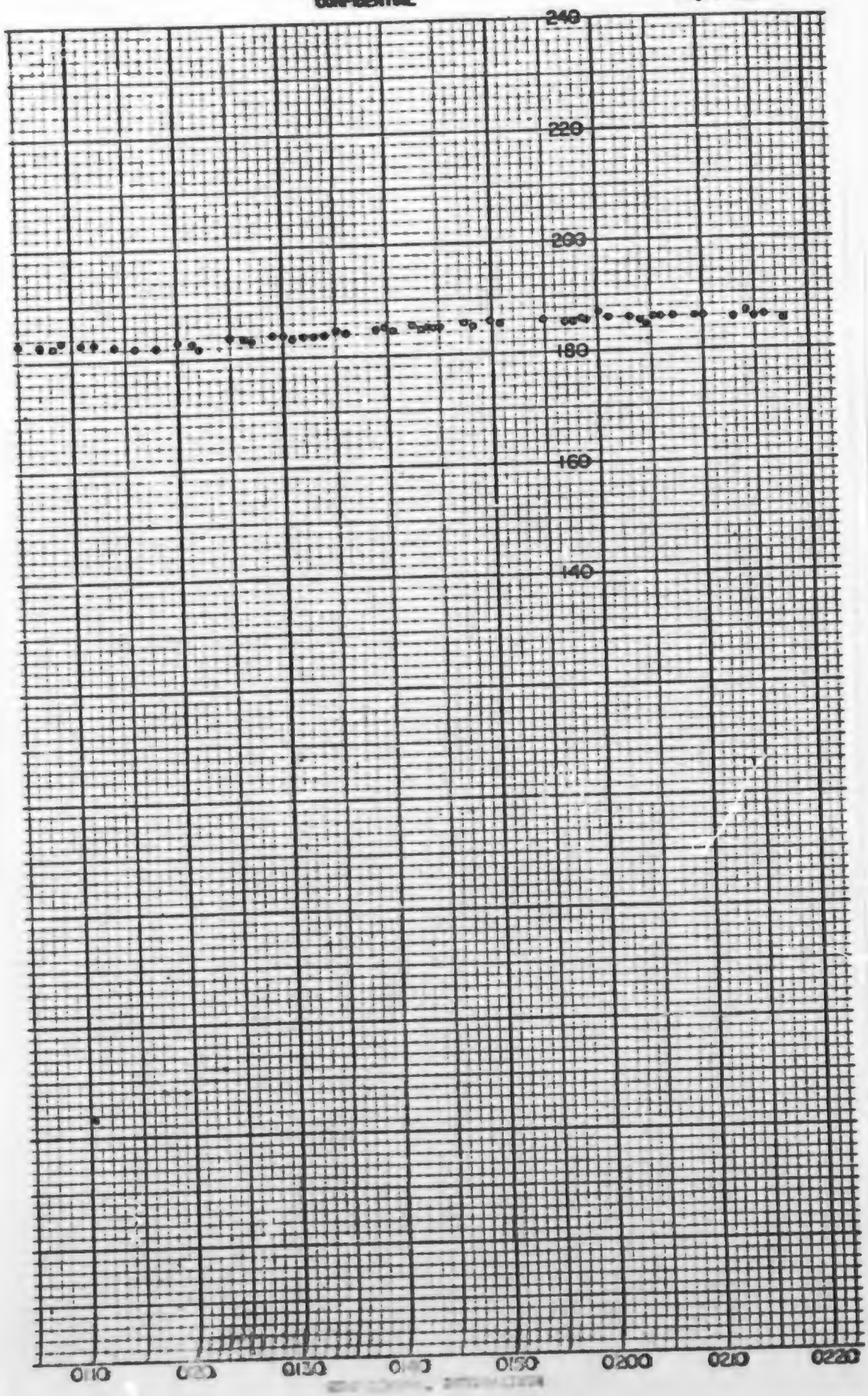

1800
1810
1820
1830
1840
1850
1900
1910
1920

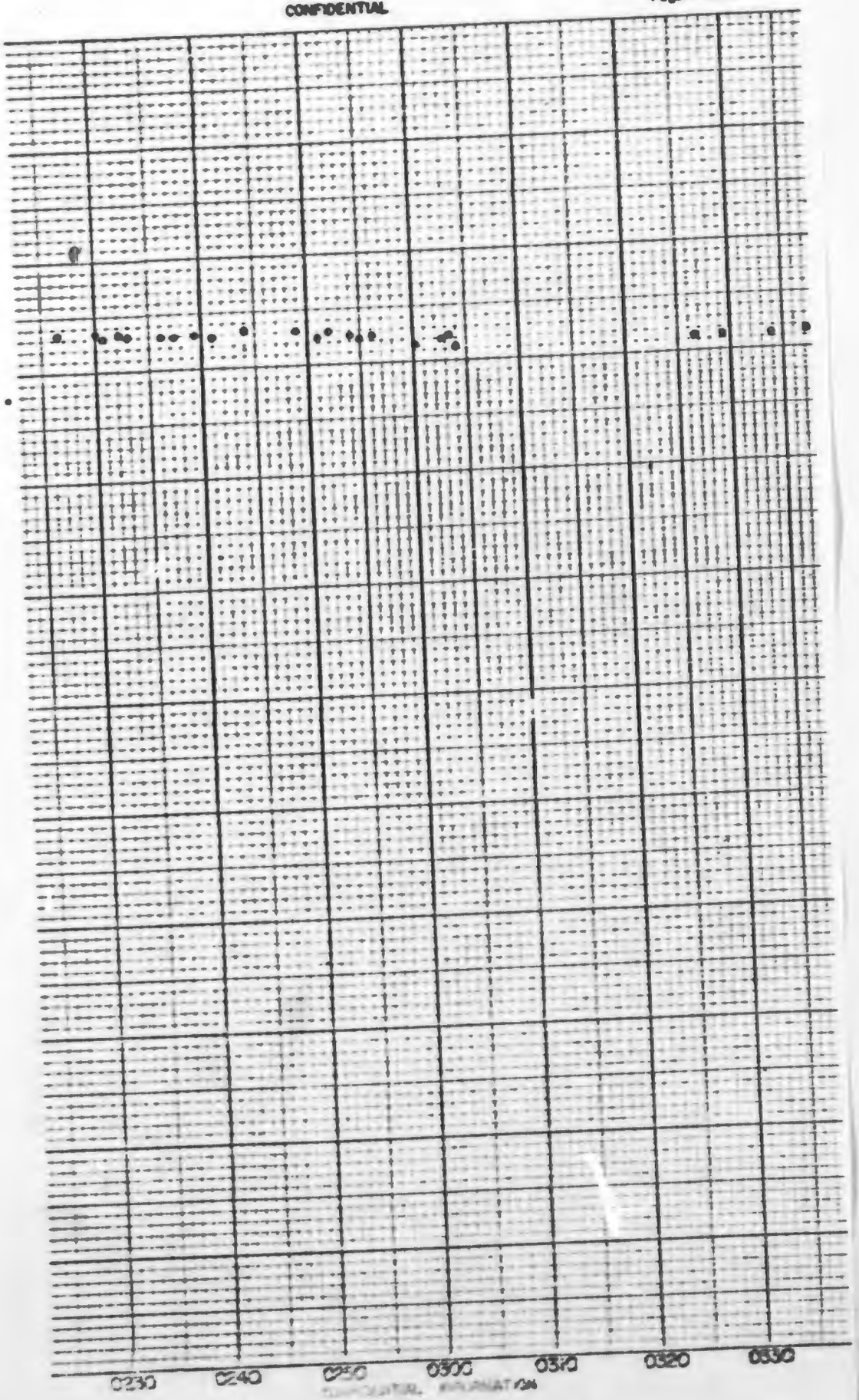

240
220
200
1940
1950
2000
2010
2020
2030
2040

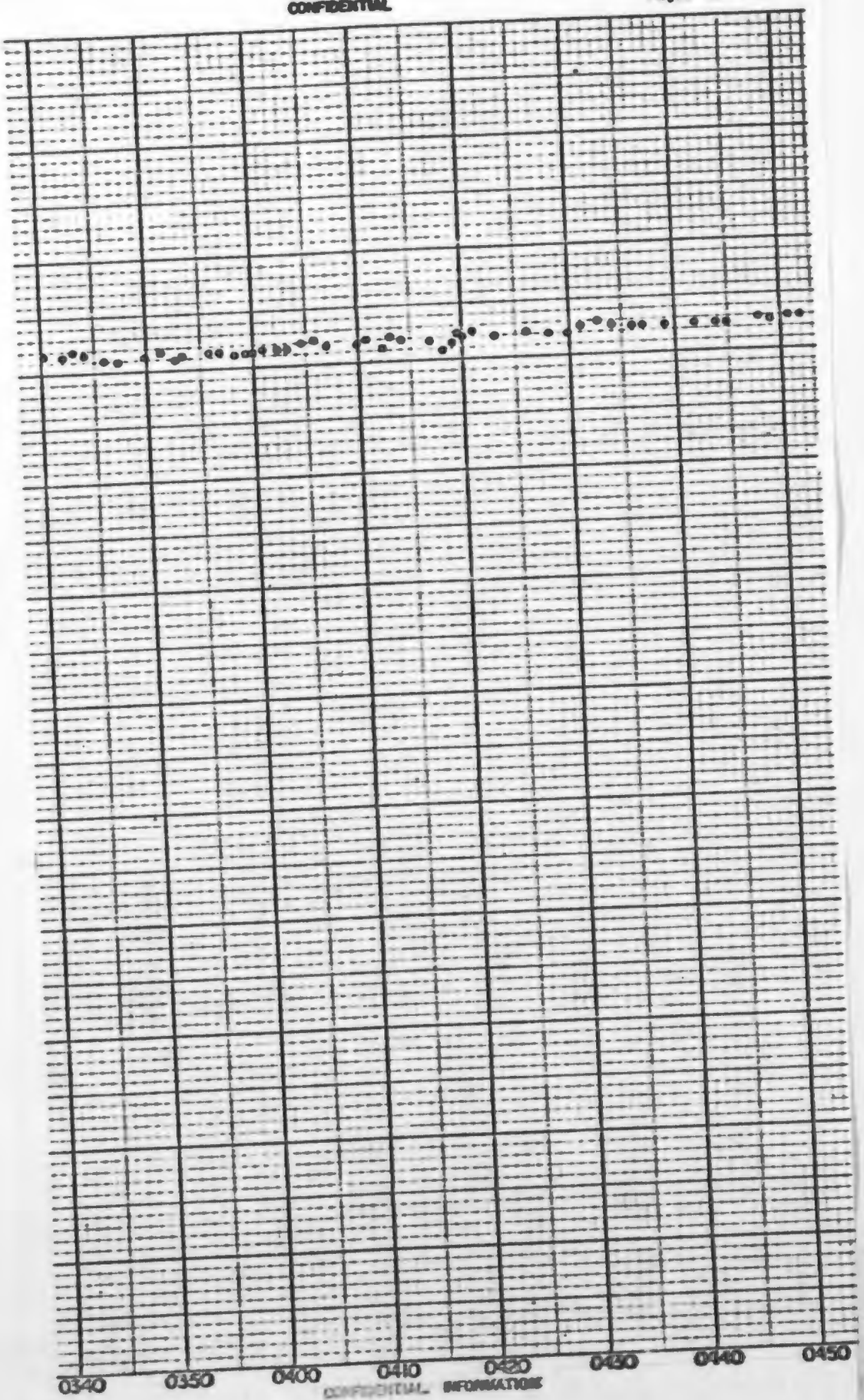

2150
2200
2210

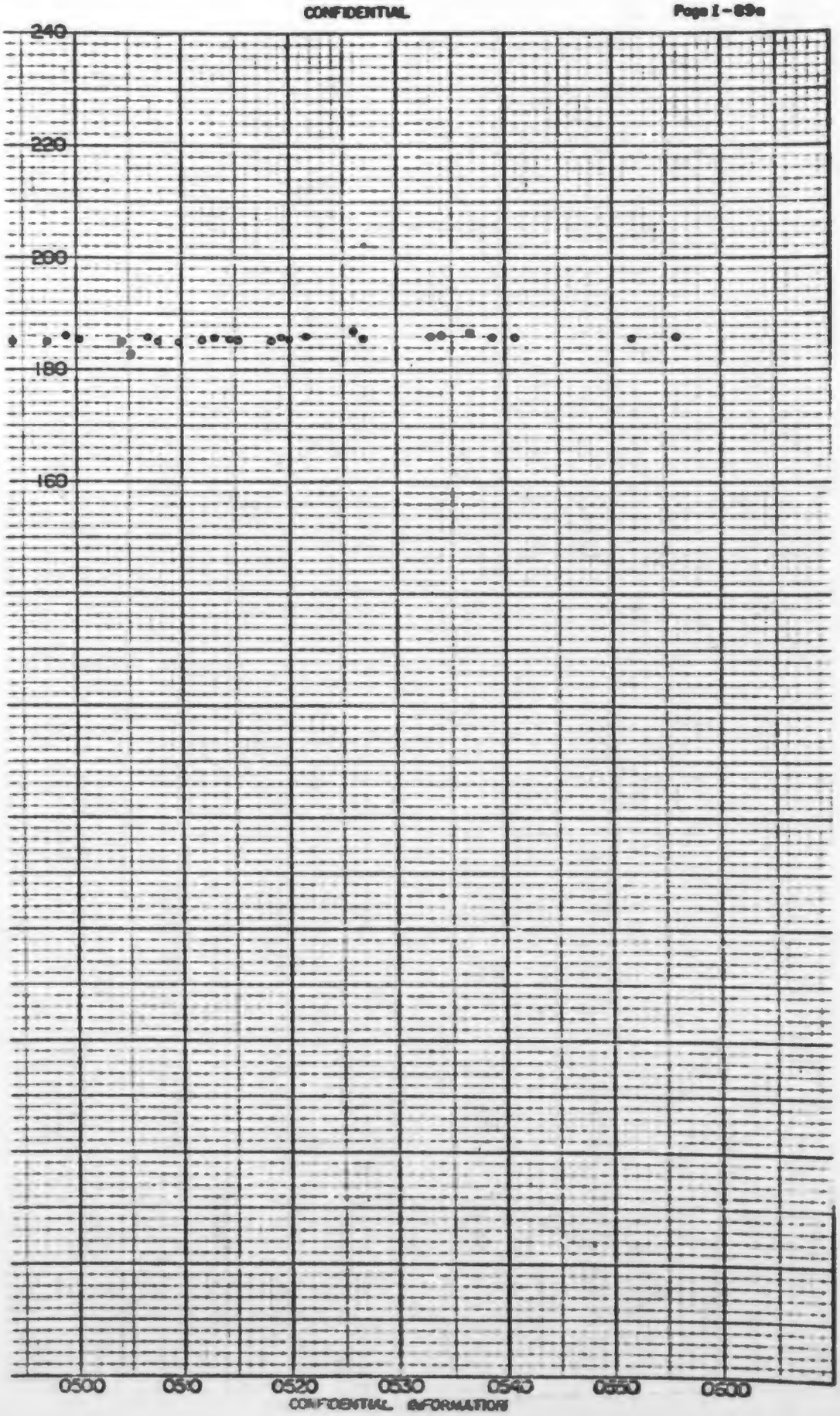

240
220
200
2320
2330


2340
2350
2400
0010
0020
0030
0040
0050
0100

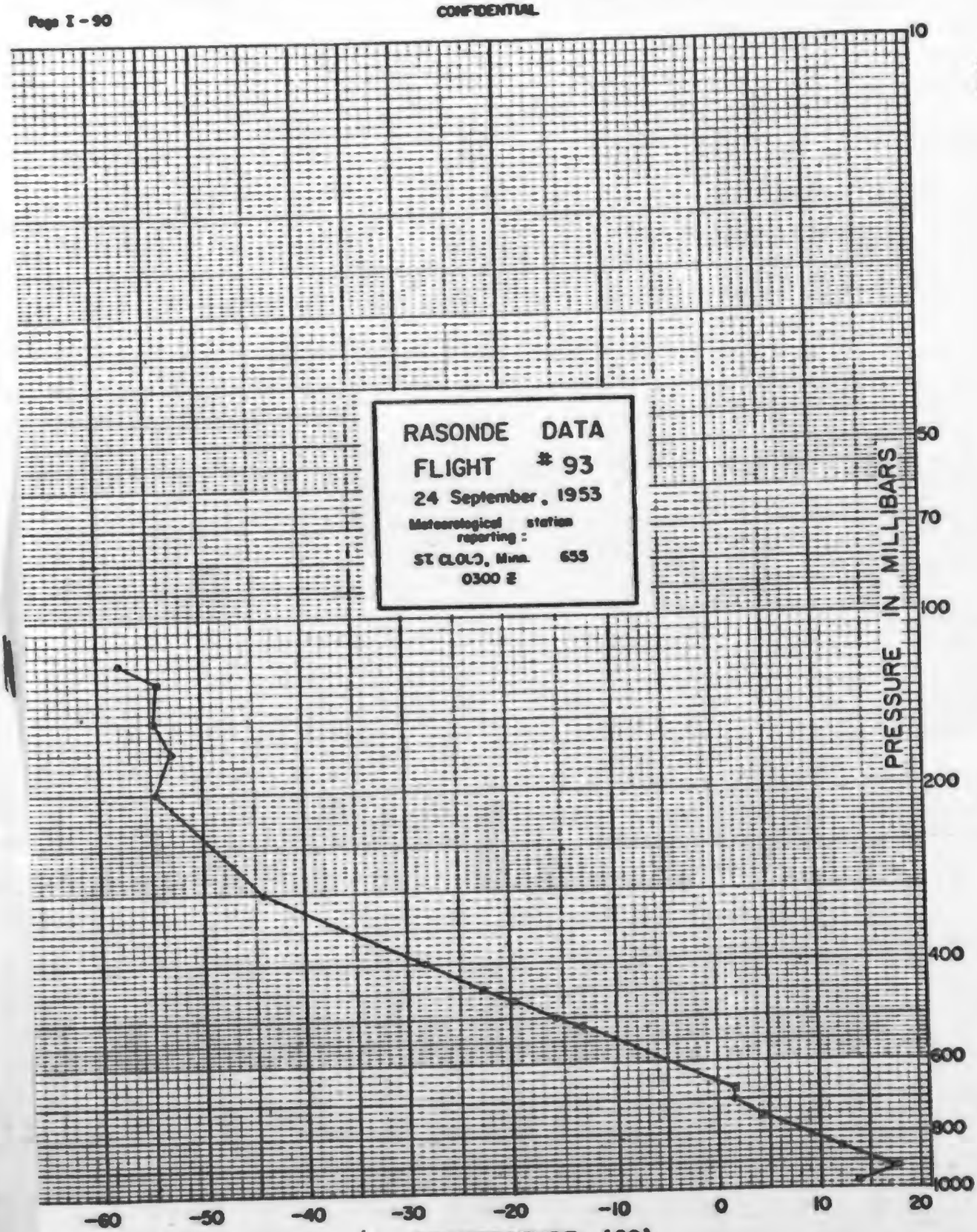

240
220
200
180
160
140
0100
0150
0200
0250


0230
0240
0250
0300
0310
0320
0330

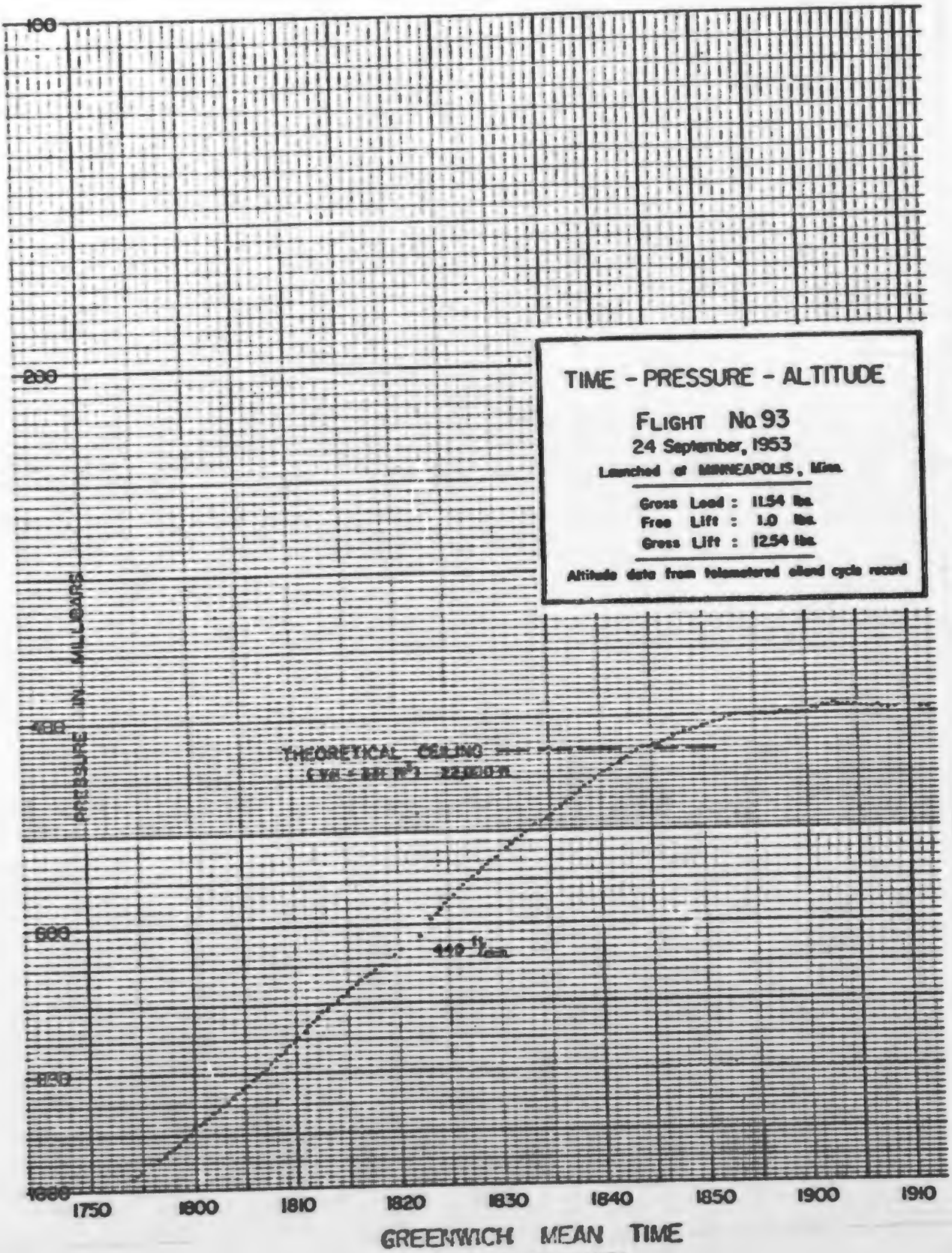

0340
0350
0400
0410
0420
0430
0440
0450

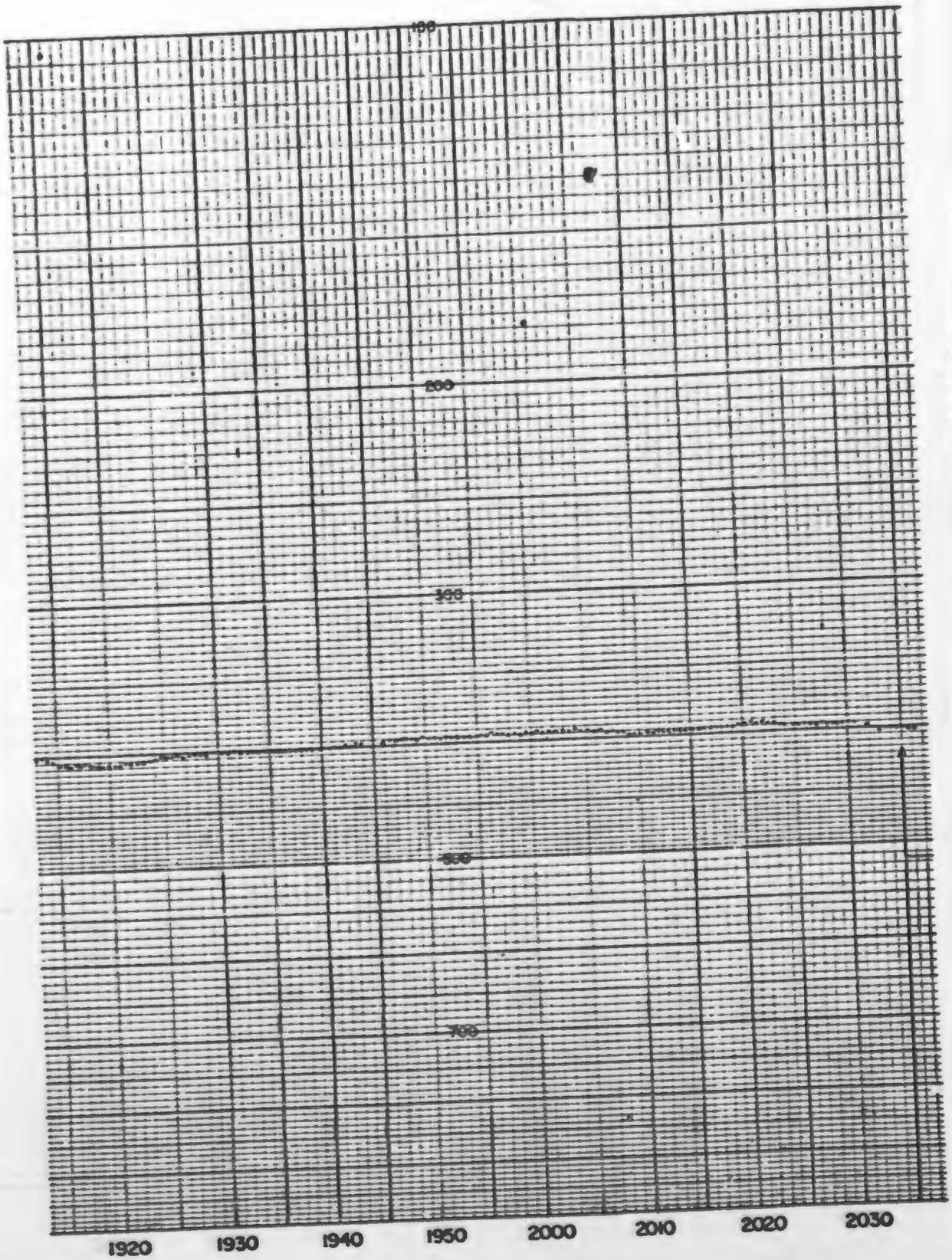

240
220
200
180
160
0500
0510
0520
0530
0540
0550
0600

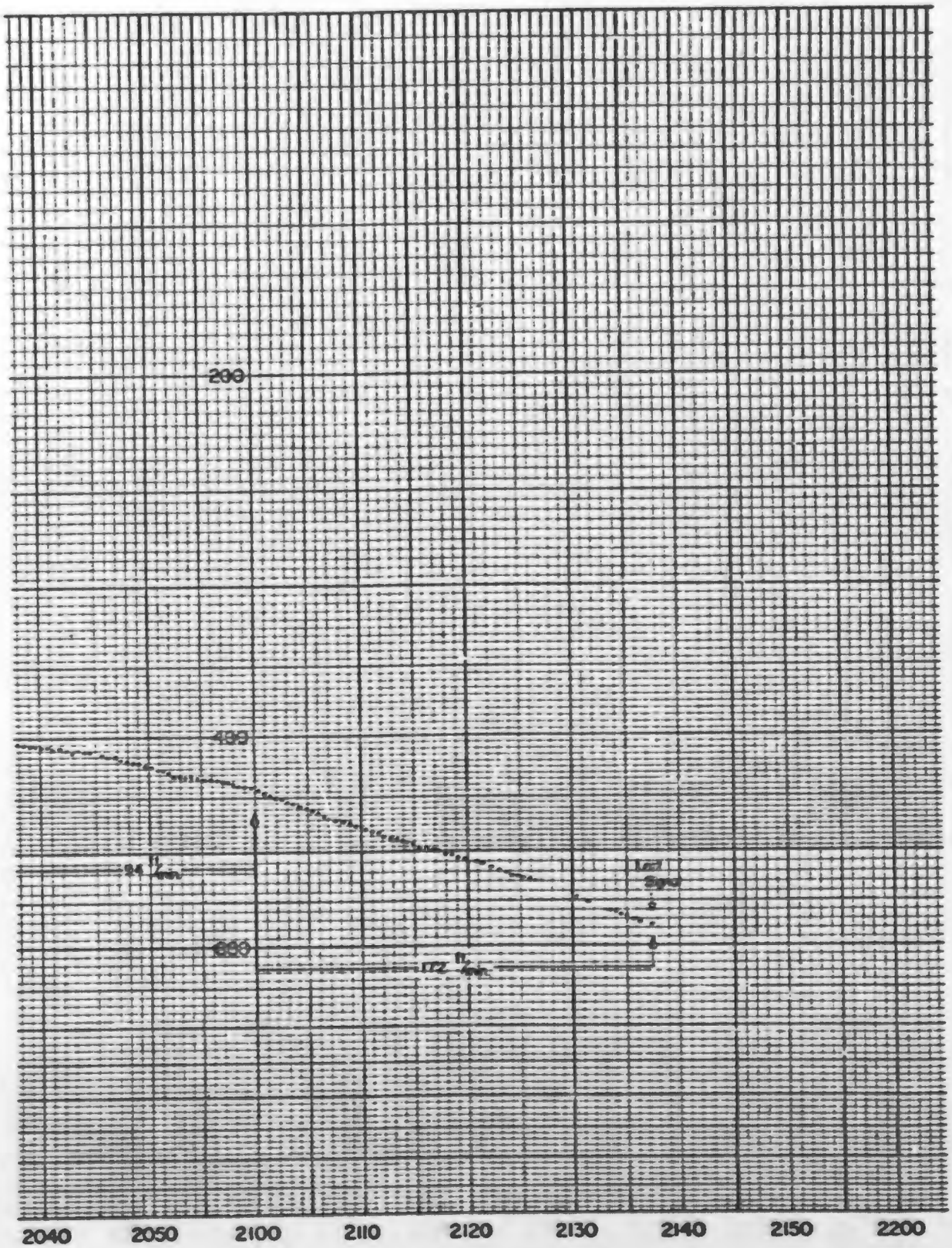
CONFIDENTIAL



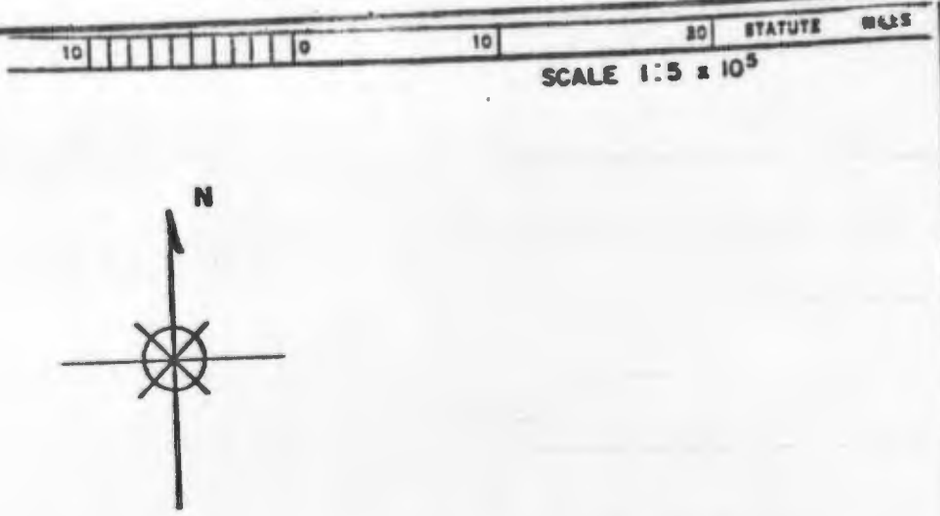
CONFIDENTIAL INFORMATION


TIME - PRESSURE - ALTITUDE
FLIGHT No. 93
24 September, 1953
Launched at MINNEAPOLIS, Minn.
Gross Load : 11.54 lbs.
Free Lift : 1.0 lbs.
Gross Lift : 12.54 lbs.
Altitude data from telemetered ascend cycle record
PRESSURE IN MILLIBARS
100
200
300
600
800
1000
THEORETICAL CEILING
440 ft/min
1750
1800
1810
1820
1830
1840
1850
1900
1910
GREENWICH MEAN TIME


100
200
300
500
700
1920
1930
1940
1950
2000
2010
2020
2030


200
400
600
94 ft/min
172 ft/min
Last Sight
2040
2050
2100
2110
2120
2130
2140
2150
2200

CONFIDENTIAL



⊙ THEODOLITE SITE LAT. 45°08' LONG. 93°12.5'

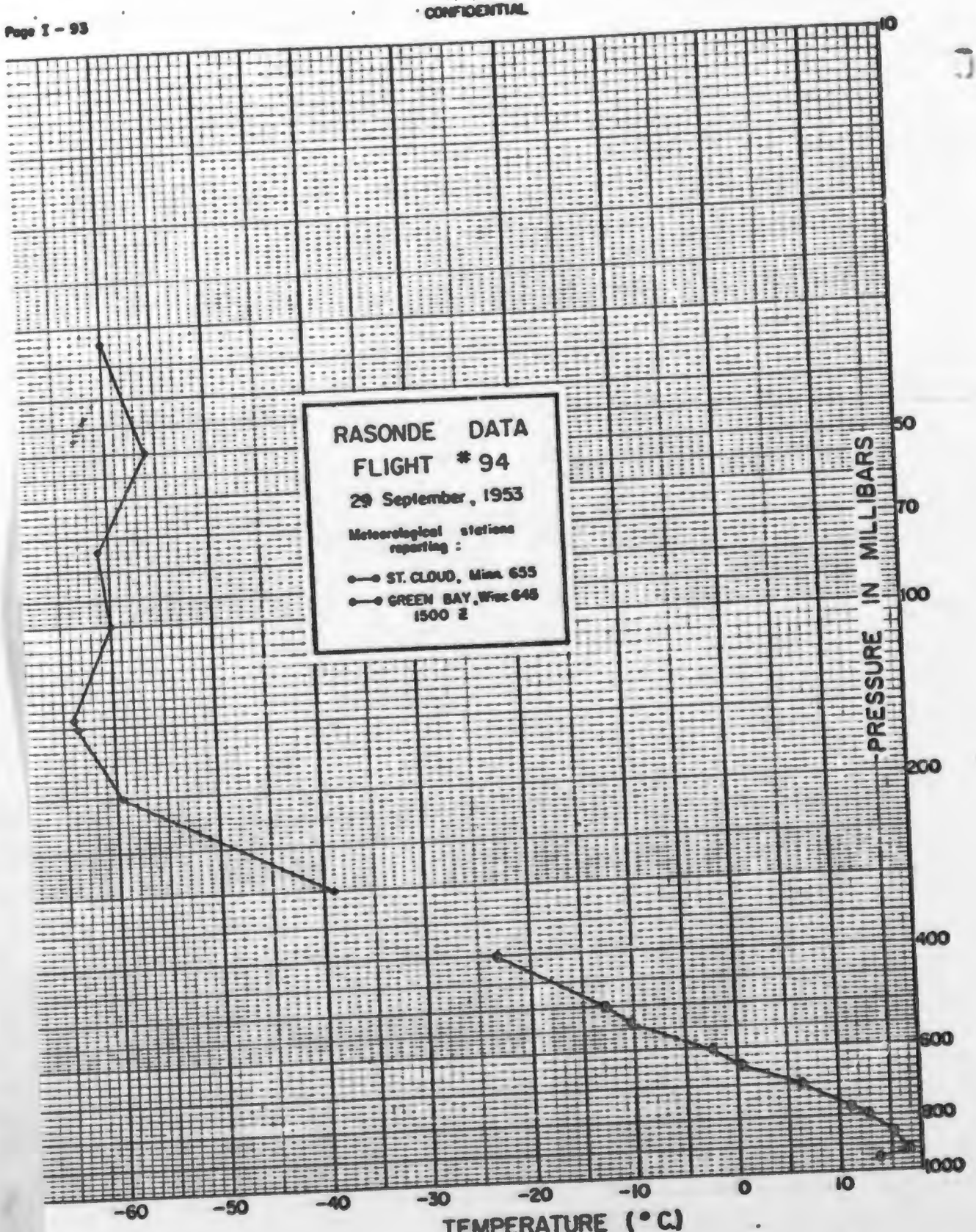
+ LAUNCH SITE LAT. 45°07' LONG. 93°10.5'

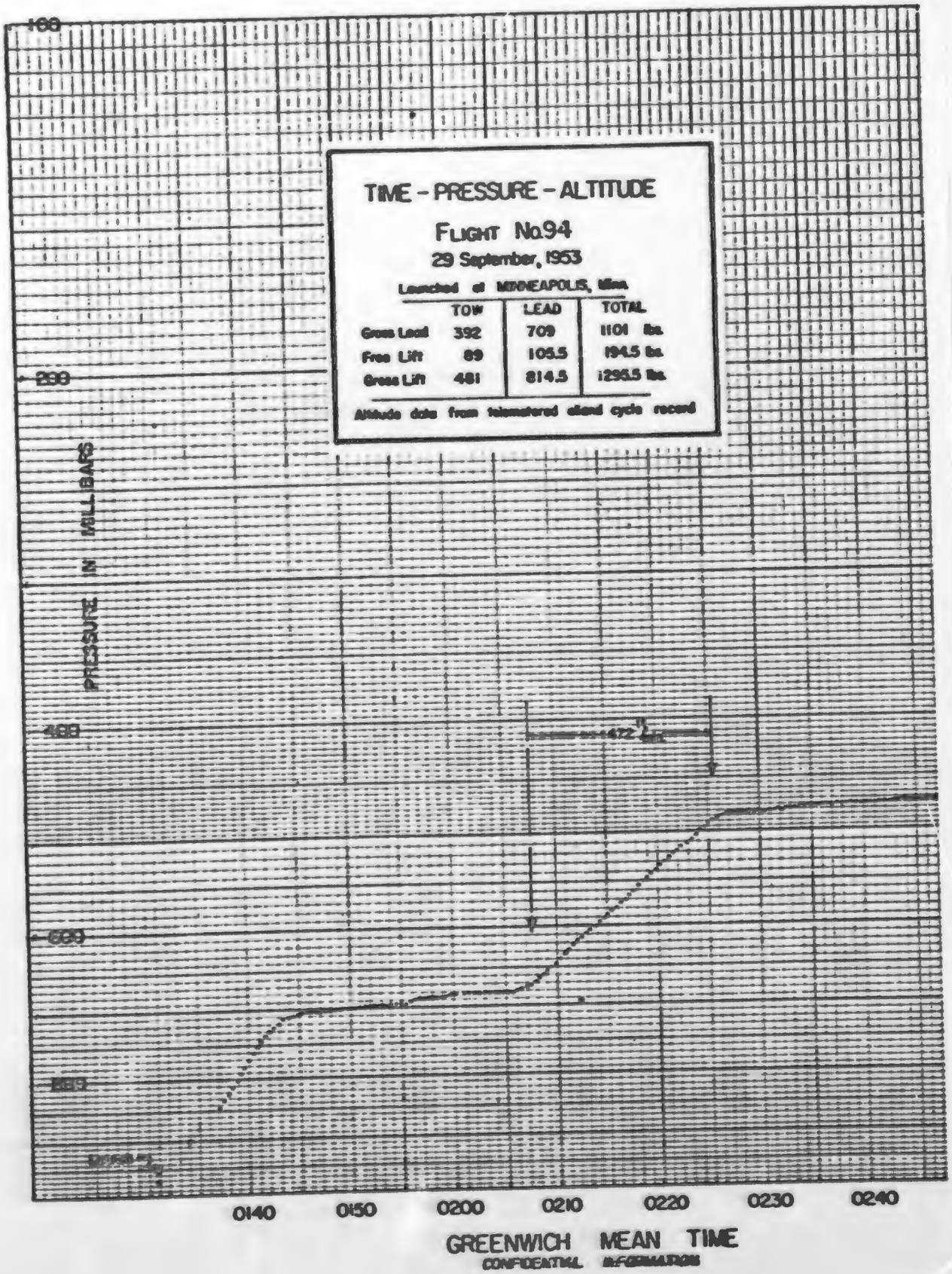
FLIGHT 93

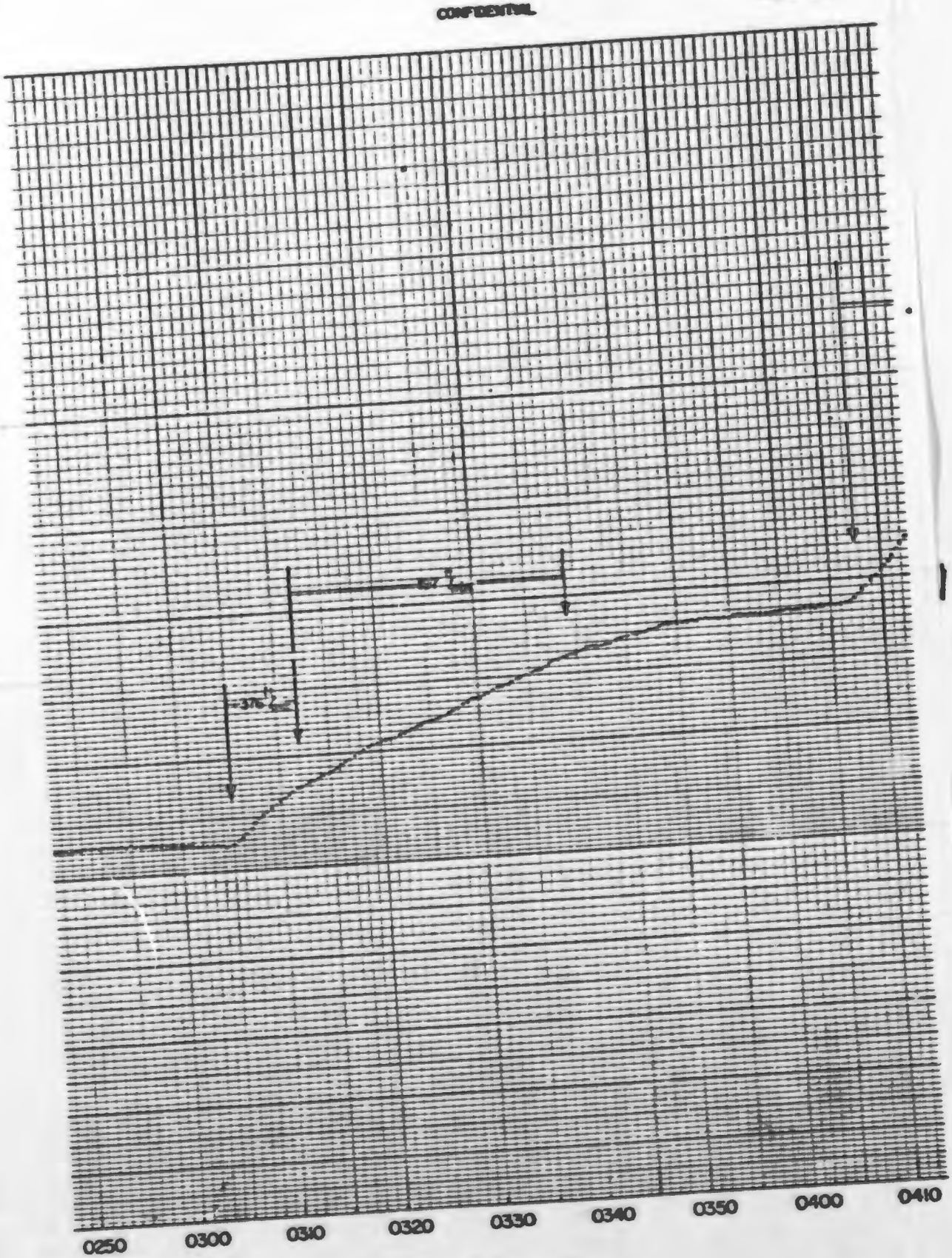
LAUNCHED 17:54 G.M.T.
24 SEPTEMBER, 1953

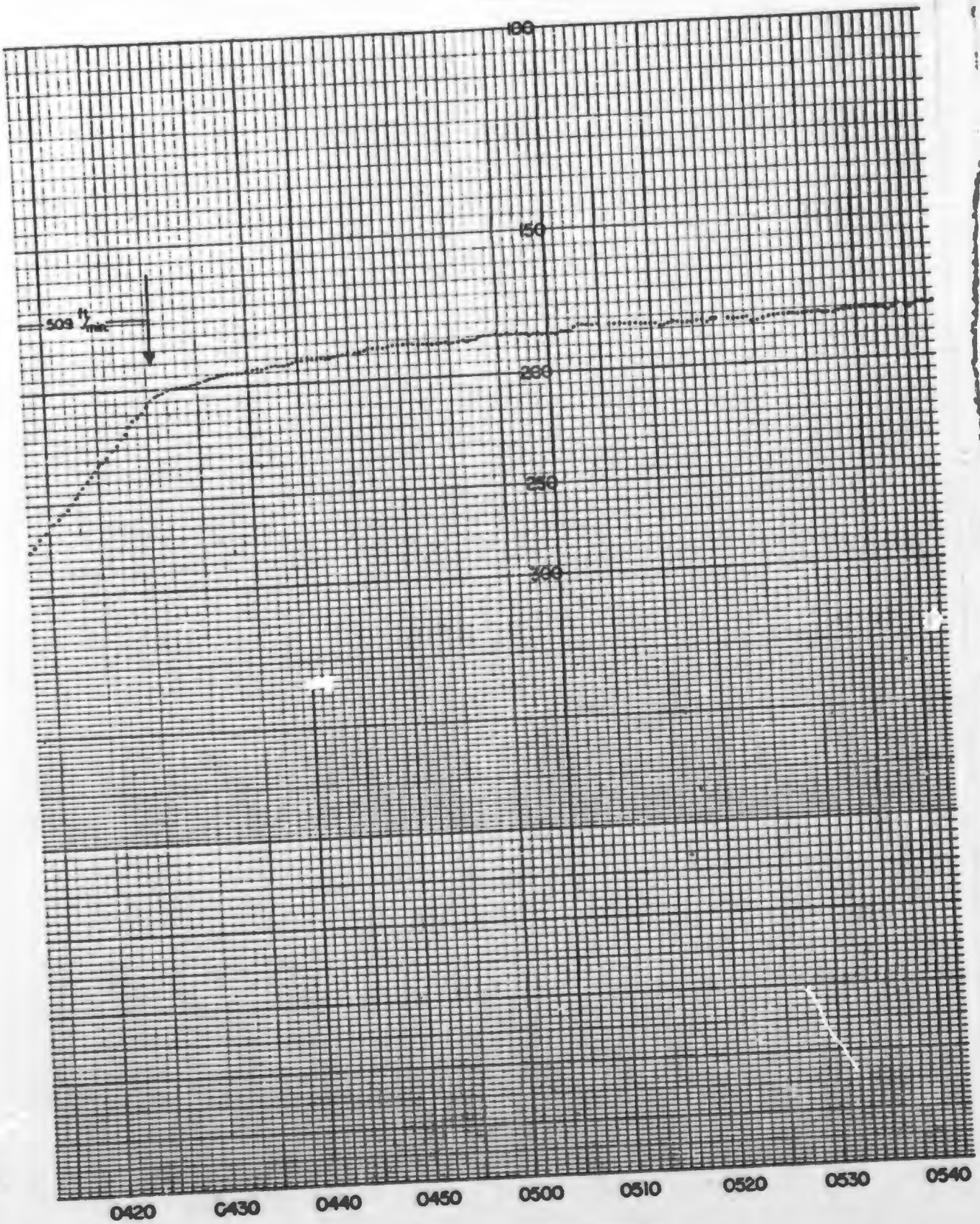
TRAJECTORY FROM THEODOLITE

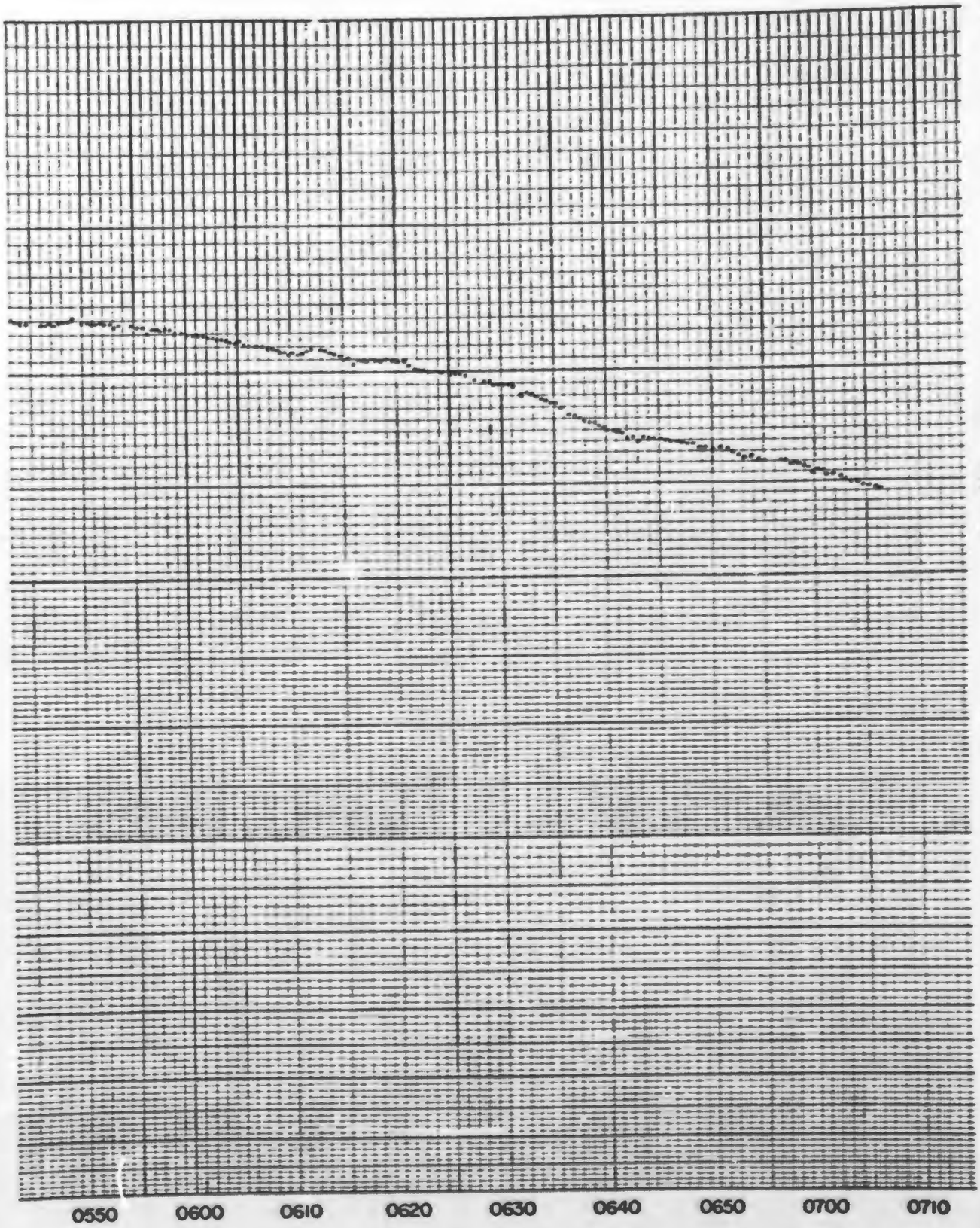
CONFIDENTIAL INFORMATION


RASONDE DATA
FLIGHT # 94
29 September, 1953
Meteorological stations reporting :
ST. CLOUD, Minn. 655
GREEN BAY, Wisc. 648
1500 Z
PRESSURE IN MILLIBARS
10
50
70
100
200
400
600
800
1000
-60
-50
-40
-30
-20
-10
0
10
TEMPERATURE (° C)

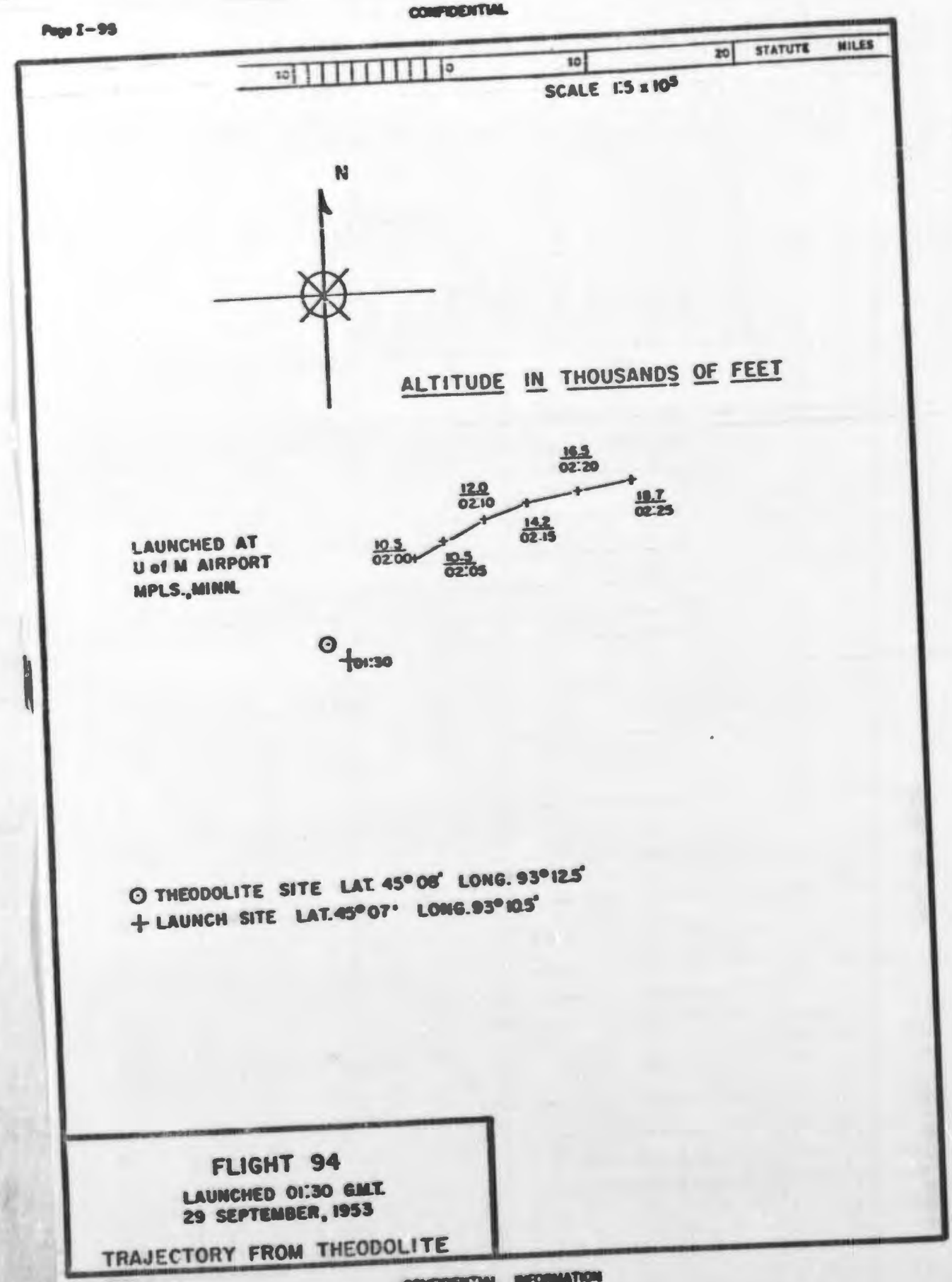

TIME - PRESSURE - ALTITUDE
FLIGHT No.94
29 September, 1953
Launched at MINNEAPOLIS, Minn.
TOW LEAD TOTAL
Gross Load 392 709 1101 lbs.
Free Lift 89 105.5 194.5 lbs.
Gross Lift 481 814.5 1295.5 lbs.
Altitude data from telemetered dead cycle record
PRESSURE IN MILLIBARS
100
200
400
600
800
472 ft
0140
0150
0200
0210
0220
0230
0240
GREENWICH MEAN TIME


0250
0300
0310
0320
0330
0340
0350
0400
0410


100
150
509 ft/min
200
250
300
0420
0430
0440
0450
0500
0510
0520
0530
0540


0550
0600
0610
0620
0630
0640
0650
0700
0710

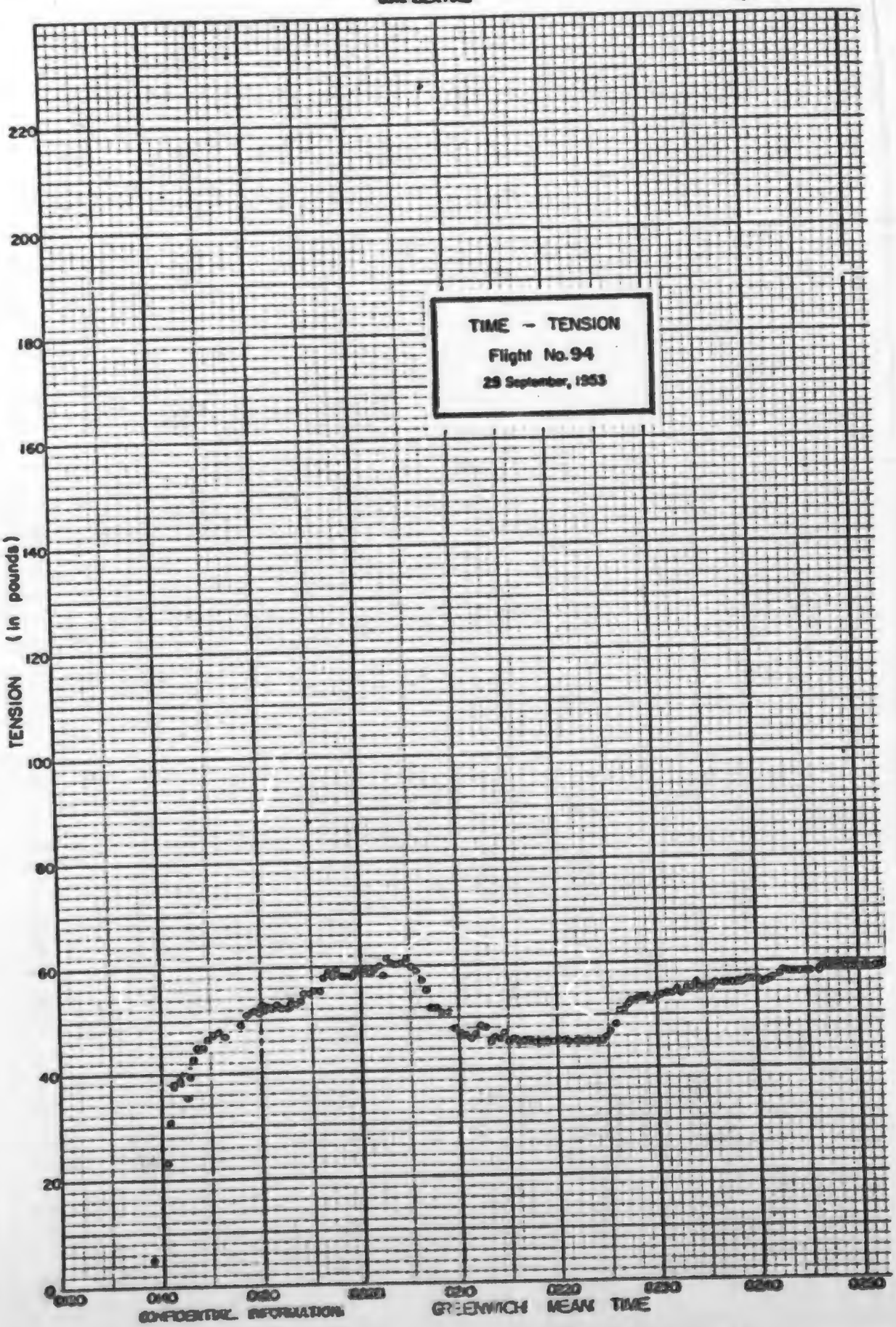
CONFIDENTIAL

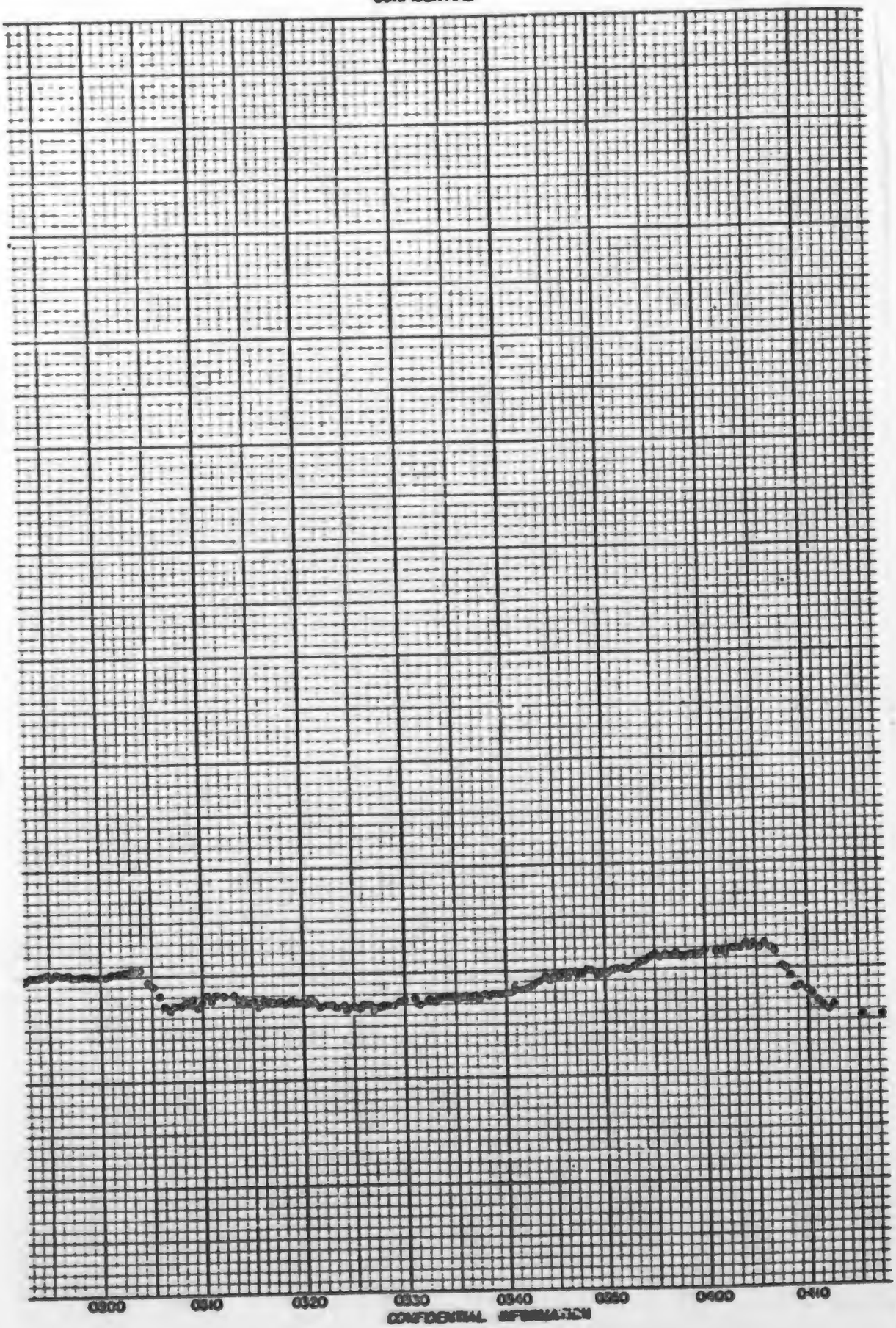


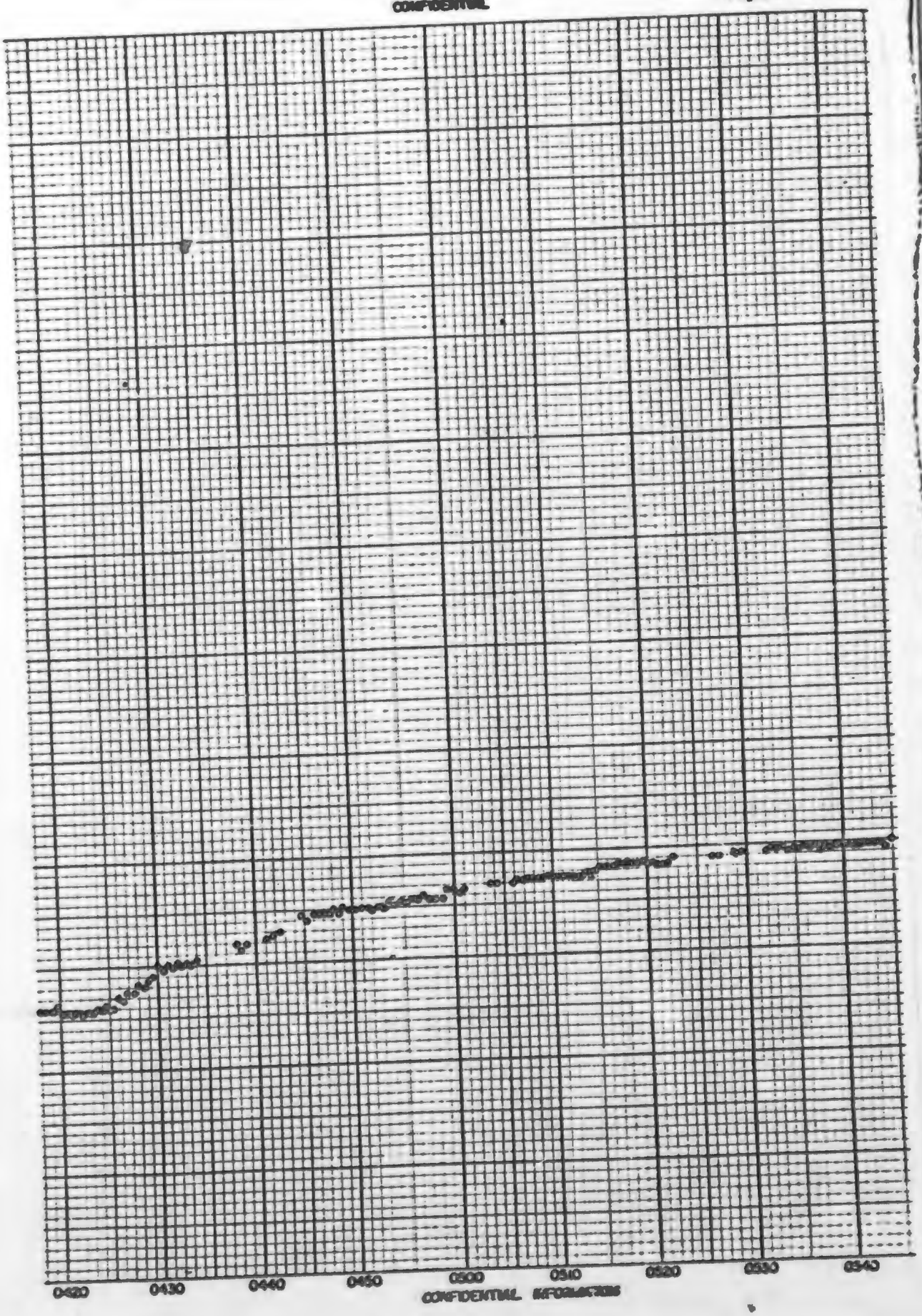
FLIGHT 94
LAUNCHED 01:30 G.M.T.
29 SEPTEMBER, 1953

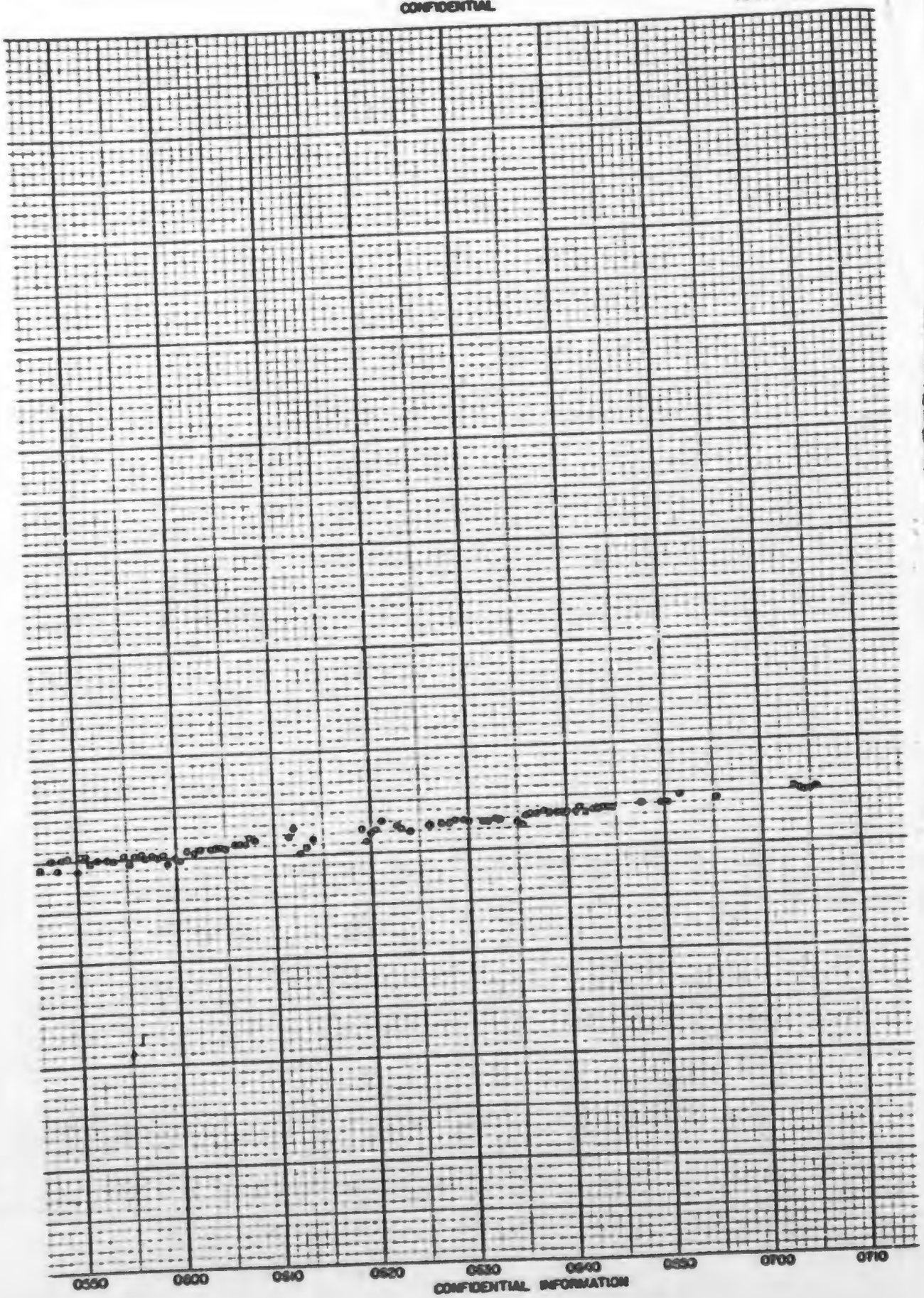
TRAJECTORY FROM THEODOLITE

CONFIDENTIAL INFORMATION

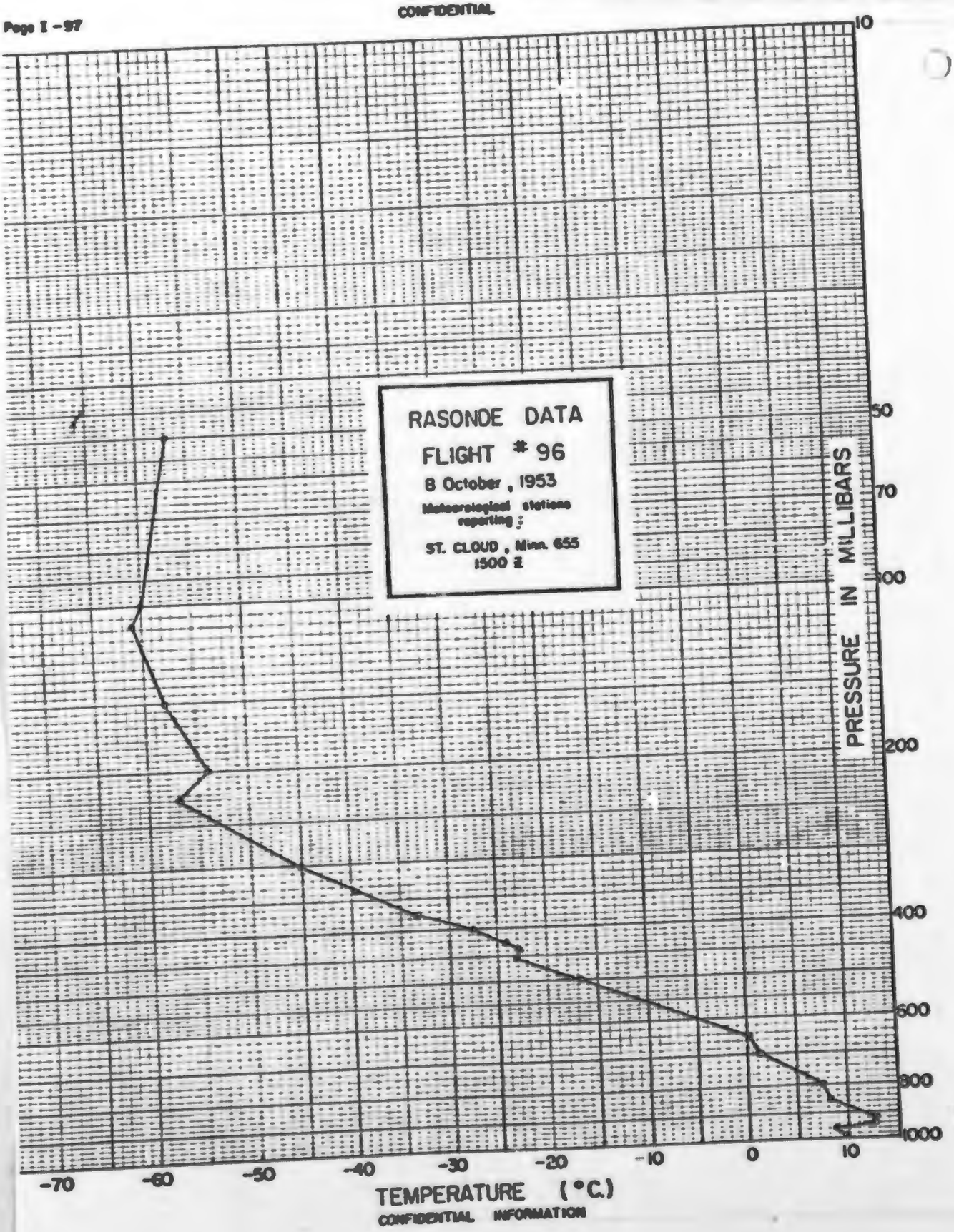

TIME - TENSION
Flight No. 94
29 September, 1953
TENSION (in pounds)
0
20
40
60
80
100
120
140
160
180
200
220
0010
0040
0020
0210
0220
0250
0310
0350
GREENWICH MEAN TIME


0300
0310
0320
0330
0340
0350
0400
0410


0420
0430
0440
0450
0500
0510
0520
0530
0540

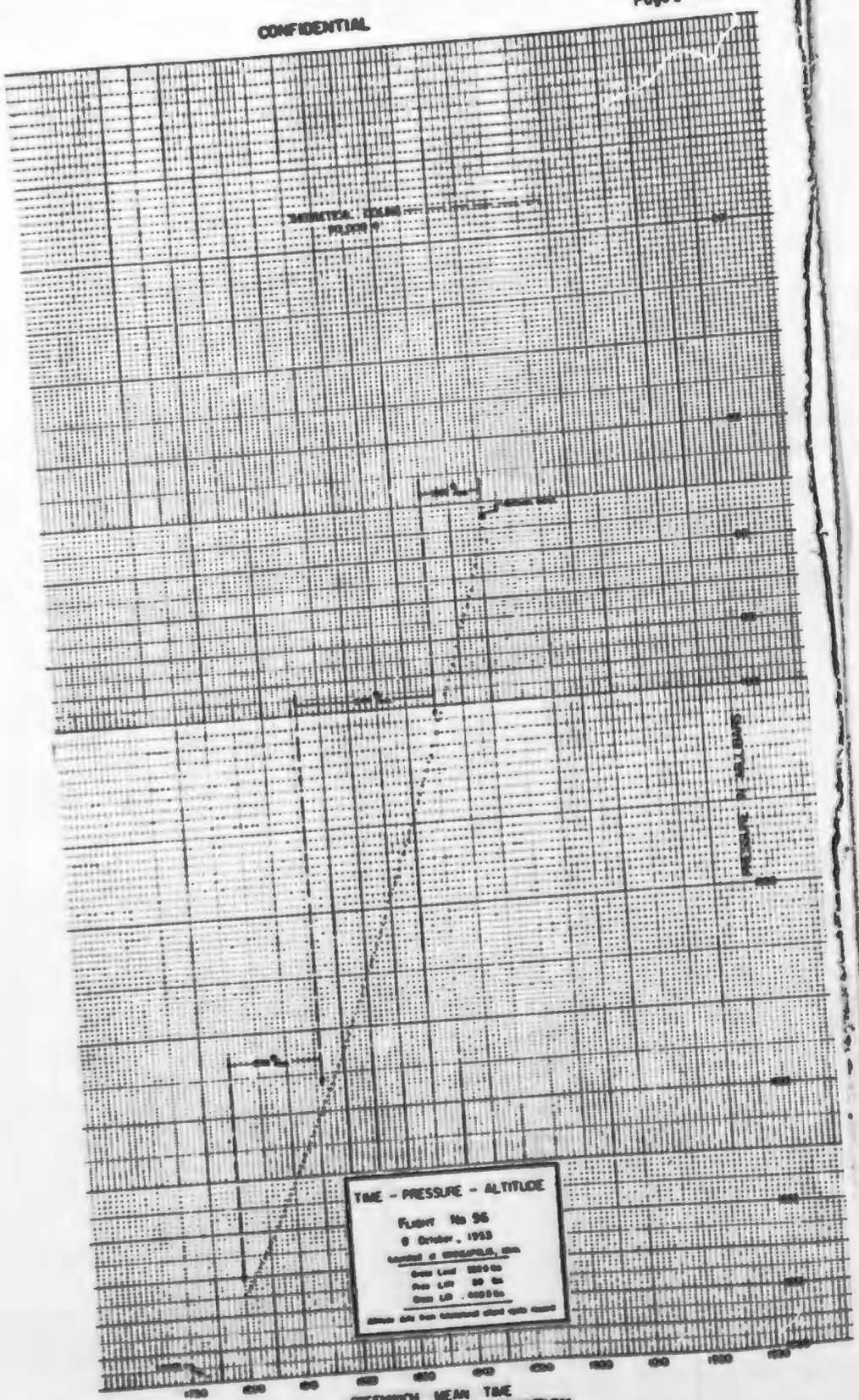

0550
0600
0610
0620
0630
0640
0650
0700
0710

CONFIDENTIAL



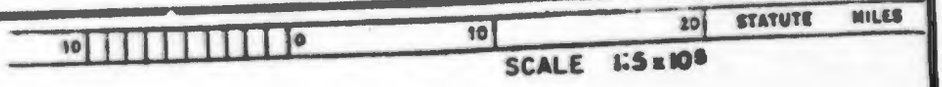
CONFIDENTIAL INFORMATION

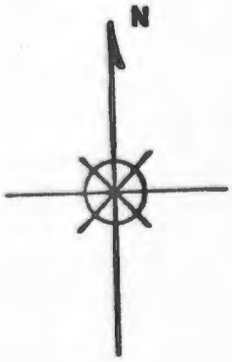
CONFIDENTIAL



CONFIDENTIAL INFORMATION

CONFIDENTIAL





FILM FRAME NUMBERS

LAUNCHED AT
U of M AIRPORT
MPLS, MINN.

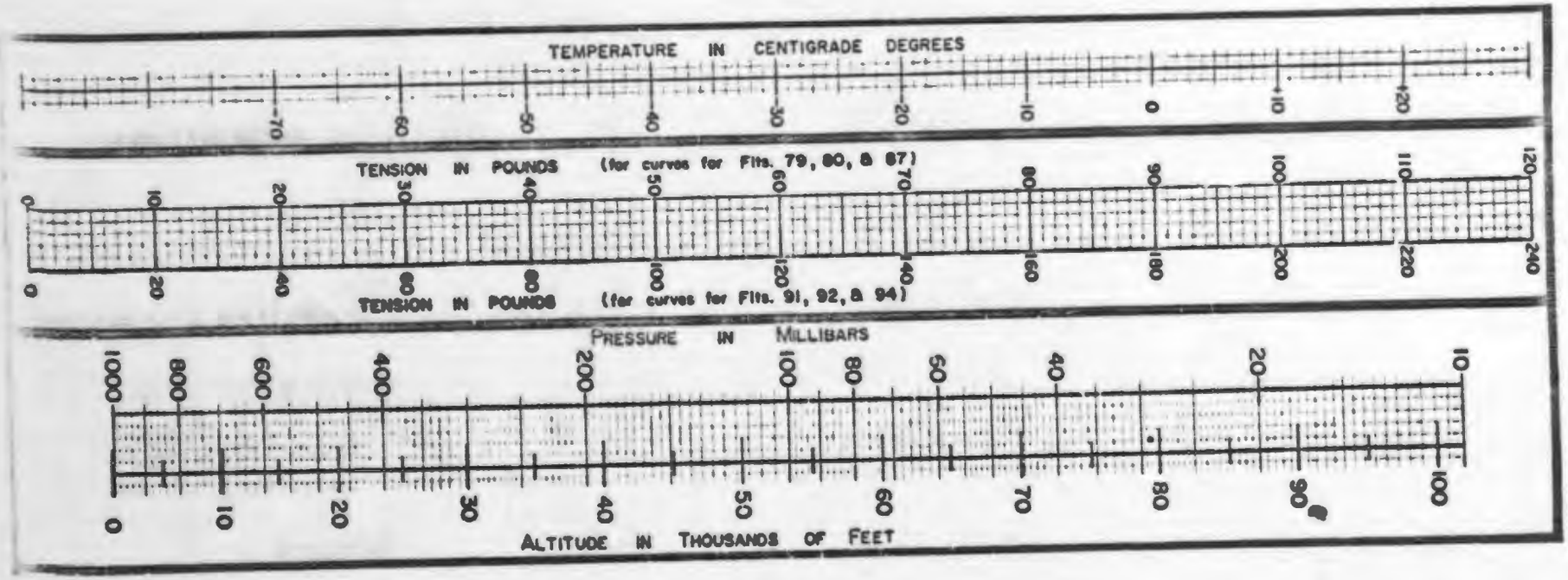
NOTE— THE TIMES INDICATED ARE APPROXIMATE

+ LAUNCH SITE LAT 45° 07' LONG 93° 10.5'

FLIGHT 96

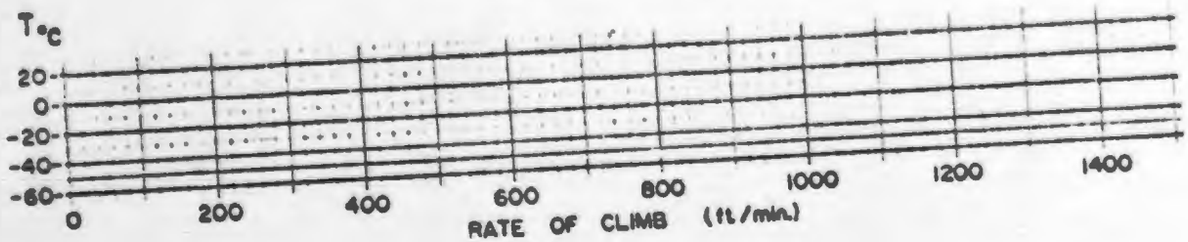
LAUNCHED 17:52 G.M.T.
8 OCTOBER, 1953

TRAJECTORY FROM FILM DATA

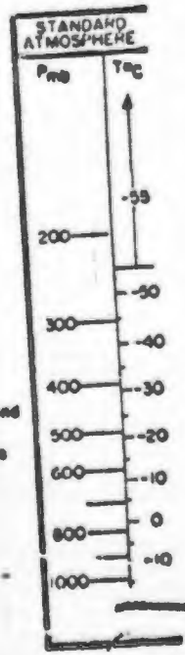

TEMPERATURE IN CENTIGRADE DEGREES
-70 -60 -50 -40 -30 -20 -10 0 +10 +20
TENSION IN POUNDS (for curves for Flts. 79, 80, & 87)
0 10 20 30 40 50 60 70 80 90 100 110 120
0 20 40 60 80 100 120 140 160 180 200 220 240
TENSION IN POUNDS (for curves for Flts. 91, 92, & 94)
PRESSURE IN MILLIBARS
1000 800 600 400 200 100 80 60 40 20 10
0 10 20 30 40 50 60 70 80 90 100
ALTITUDE IN THOUSANDS OF FEET

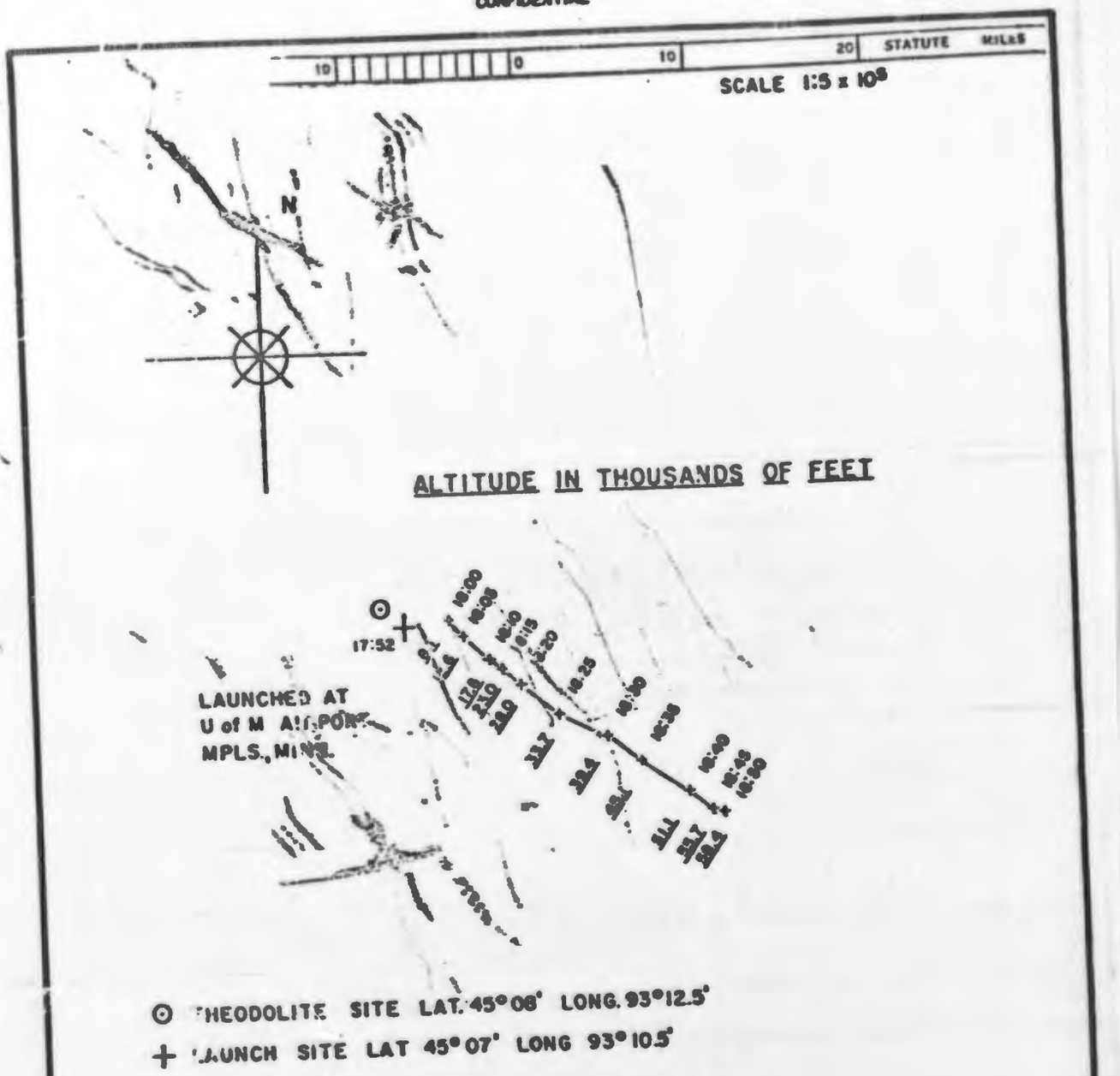
RATE OF CLIMB READER

Univ of Minnesota Balloon Project 2/8/56



At intersection of temperature, and time grid through point, rate of climb corresponds to slope of line on coordinates of 1 log pressure cycle = 108 minutes.



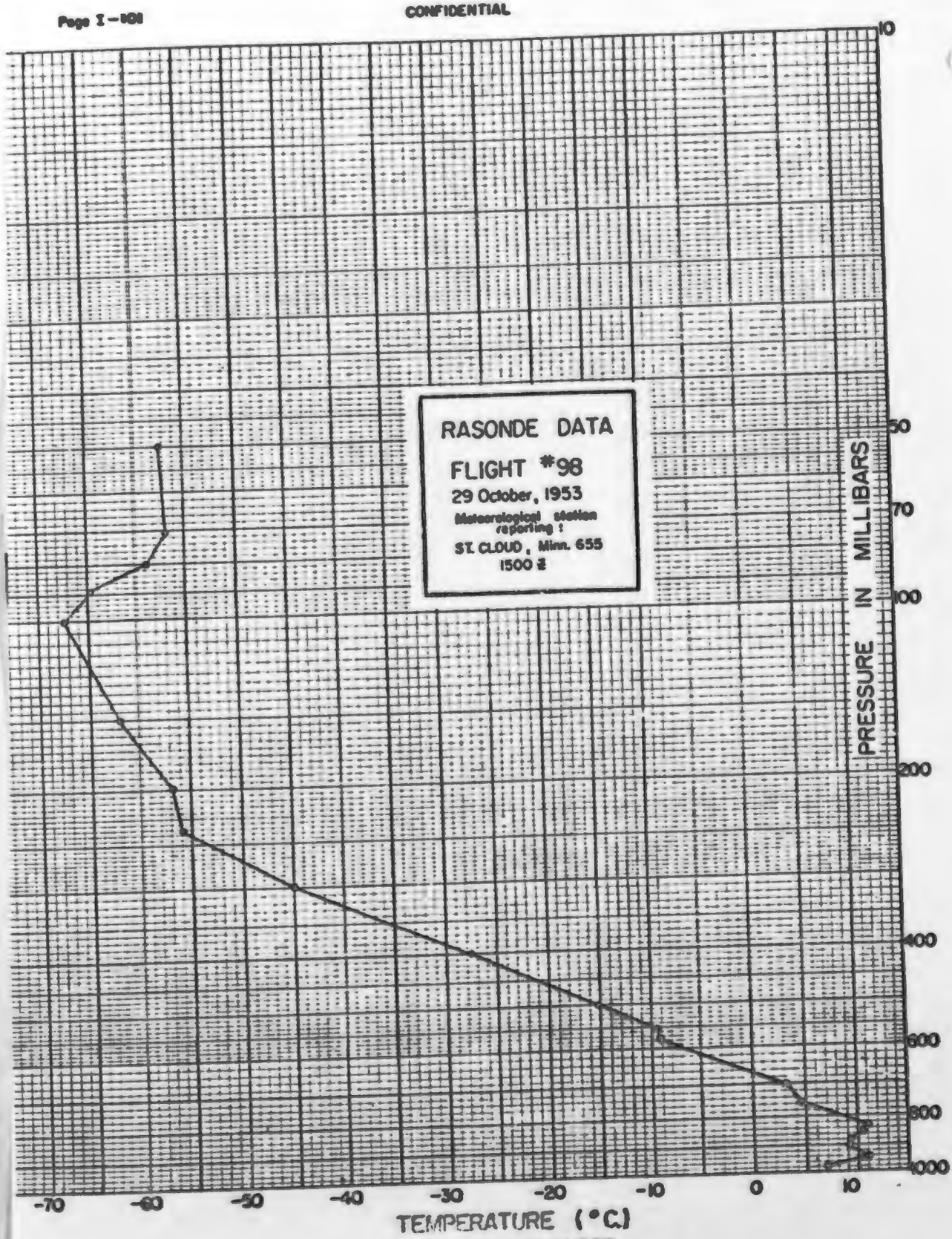


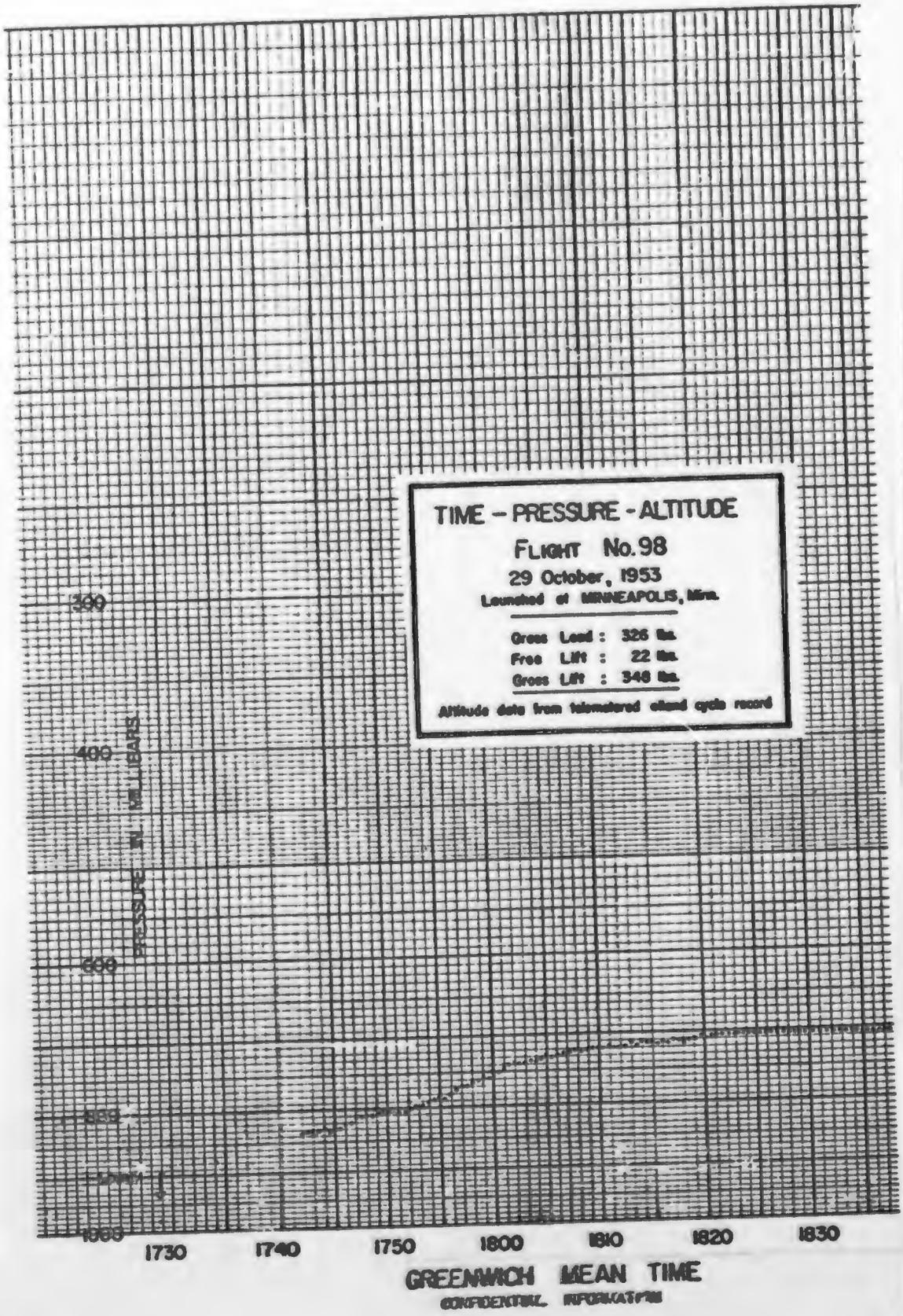
FLIGHT 96

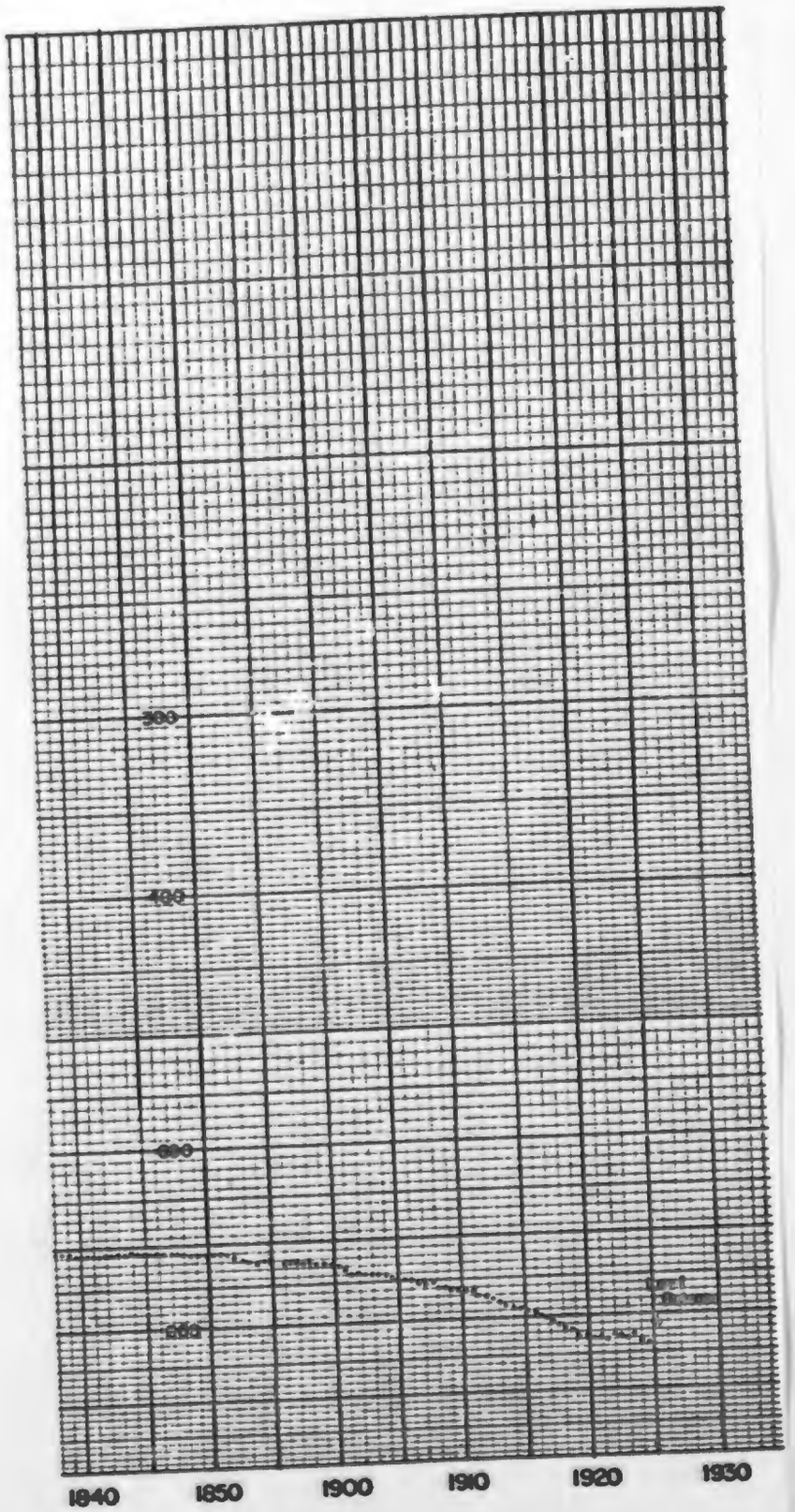
LAUNCHED 17:52 G.M.T.
8 OCTOBER, 1953

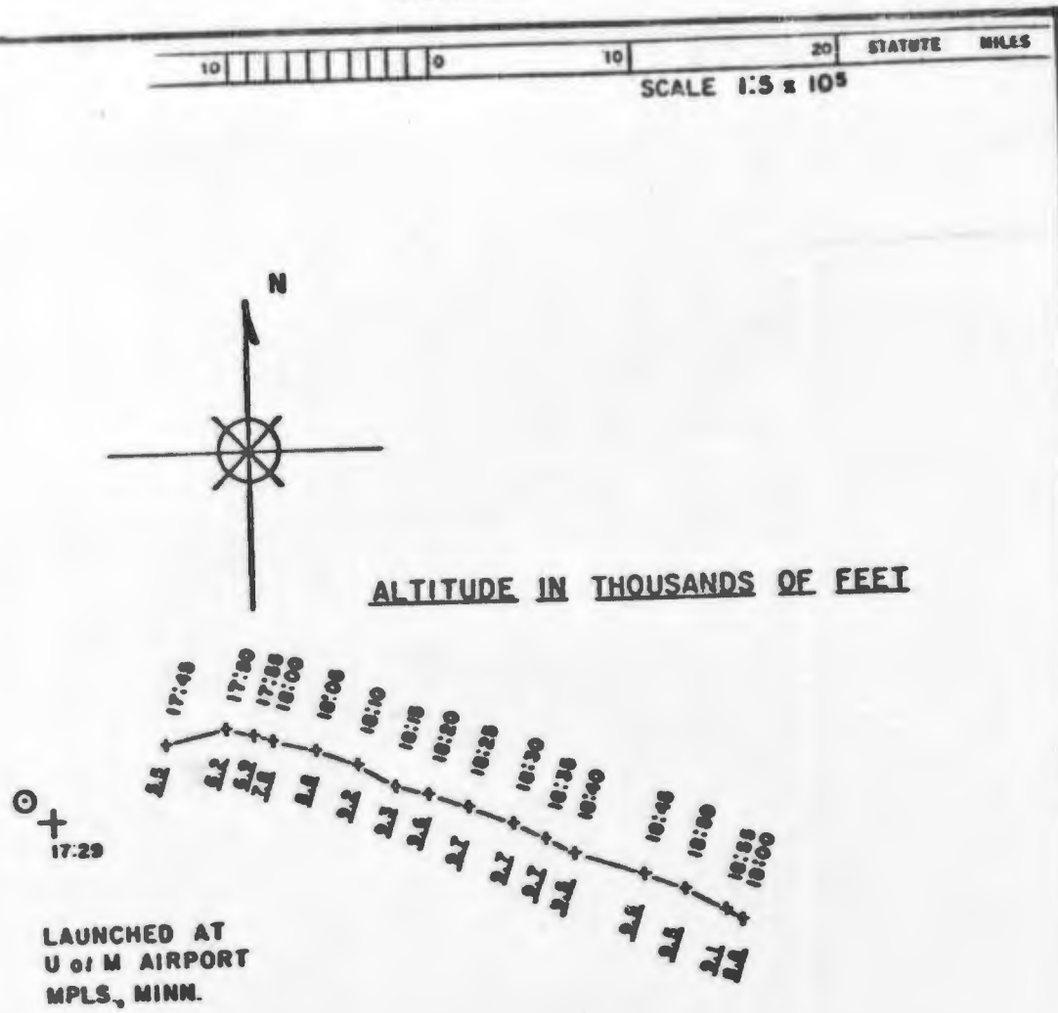
TRAJECTORY FROM THEODOLITE

CONFIDENTIAL




TIME - PRESSURE - ALTITUDE
FLIGHT No. 98
29 October, 1953
Launched at MINNEAPOLIS, Minn.
Gross Load : 326 lbs.
Free Lift : 22 lbs.
Gross Lift : 348 lbs.
Altitude data from telemetered cloud cycle record
300
400
600
PRESSURE IN MILLIBARS
1730
1740
1750
1800
1810
1820
1830
GREENWICH MEAN TIME


300
400
500
600
1840
1850
1900
1910
1920
1930

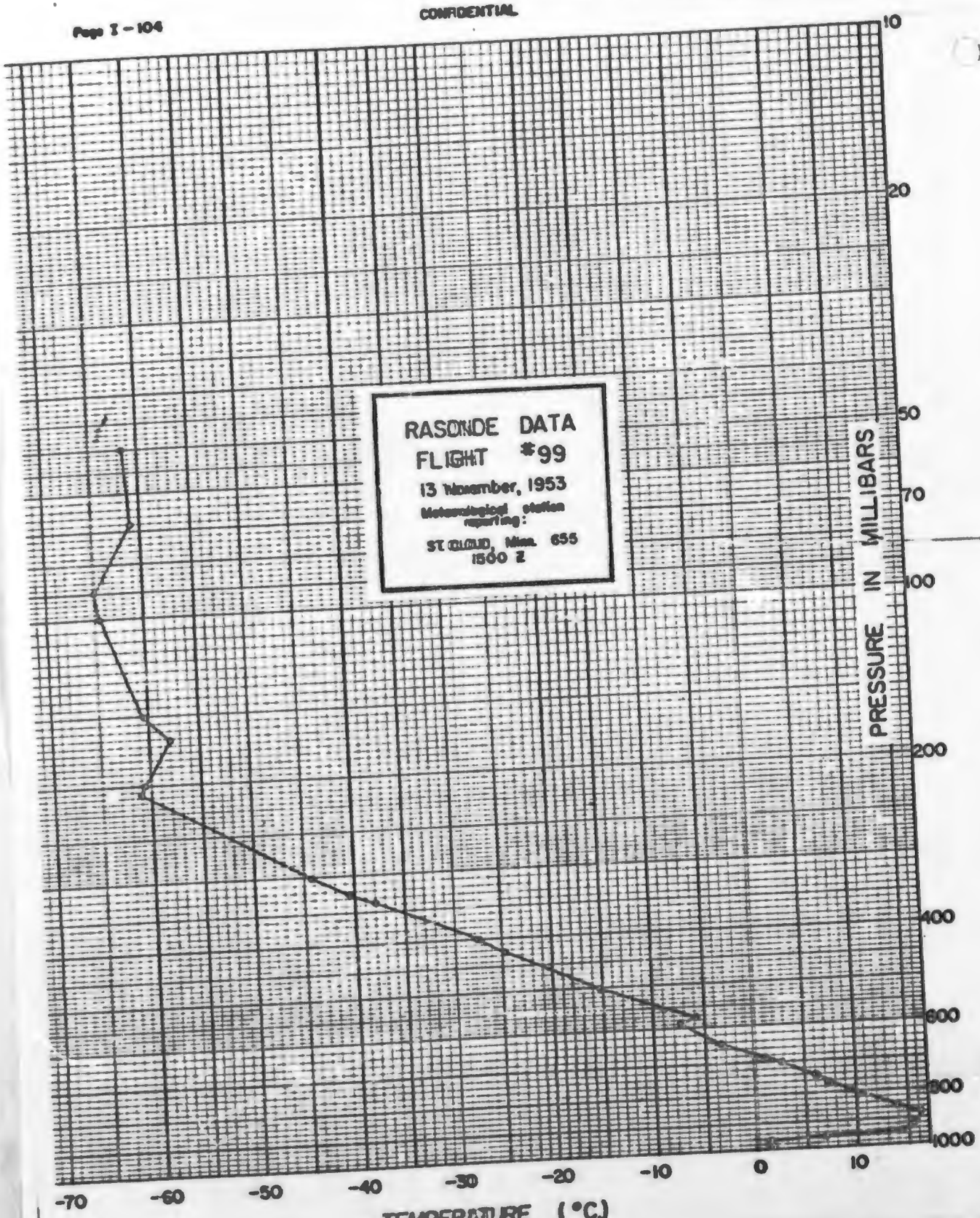


FLIGHT 98

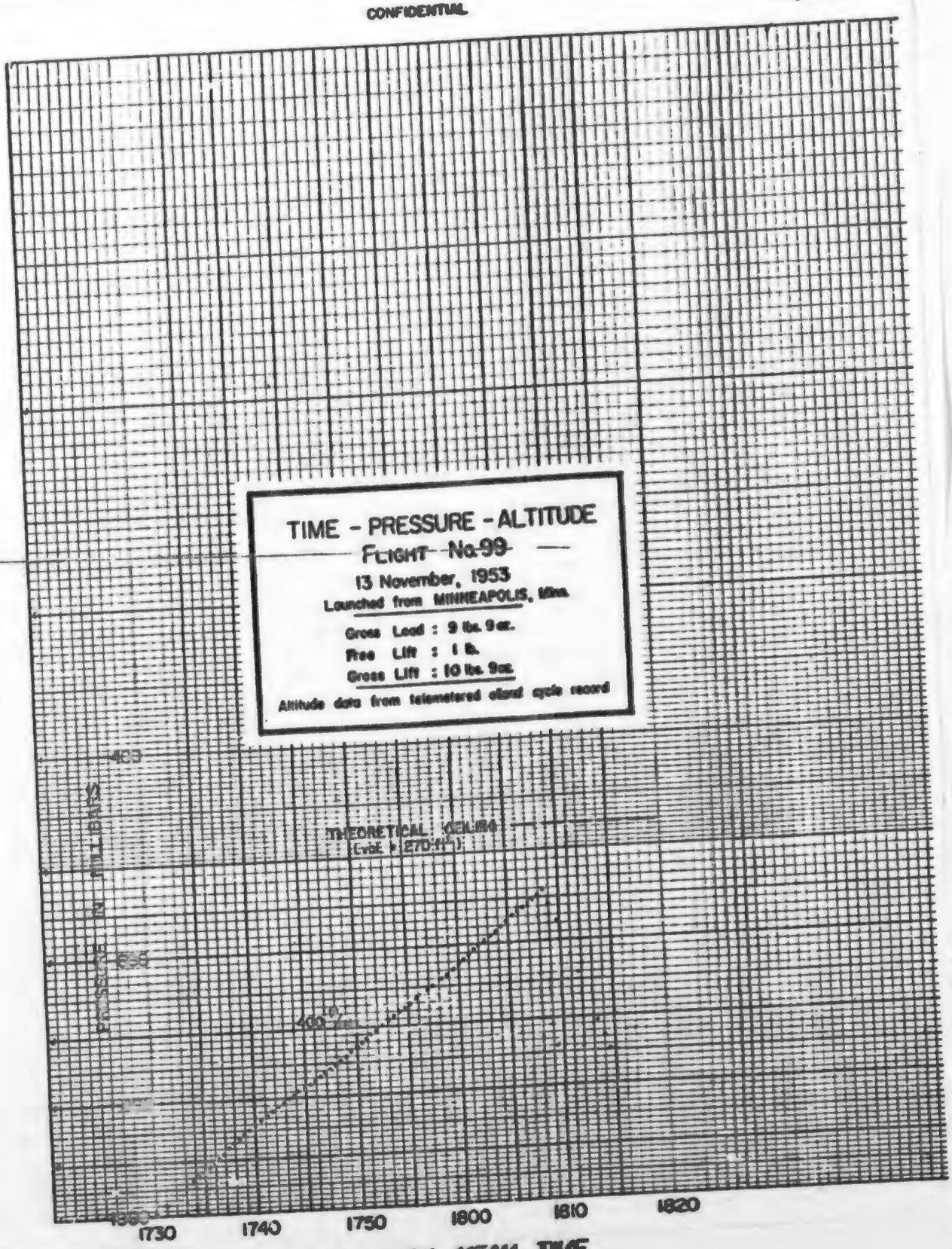
LAUNCHED 17:29 G.M.T.
29 OCTOBER, 1953

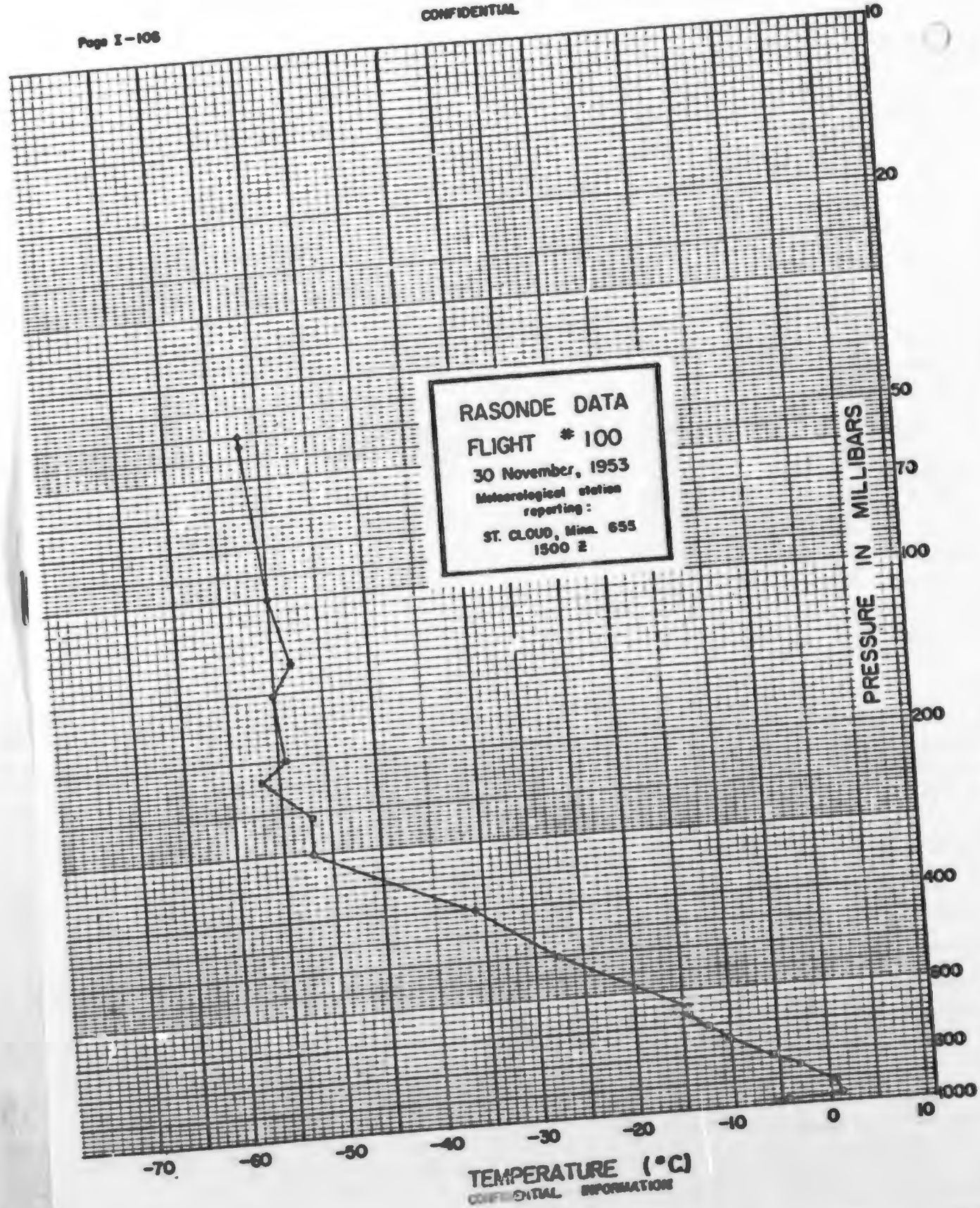
TRAJECTORY FROM THEODOLITE

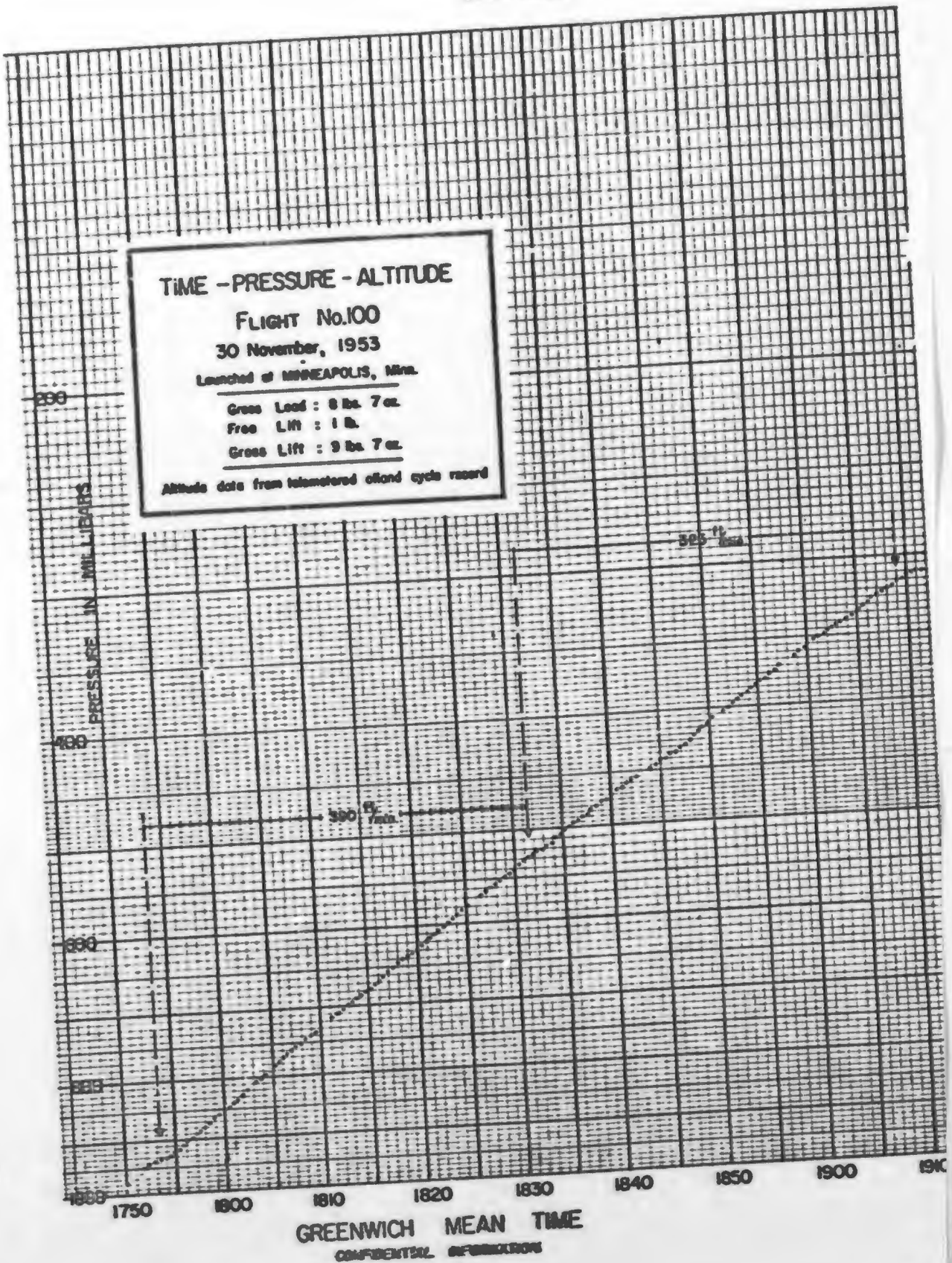
CONFIDENTIAL



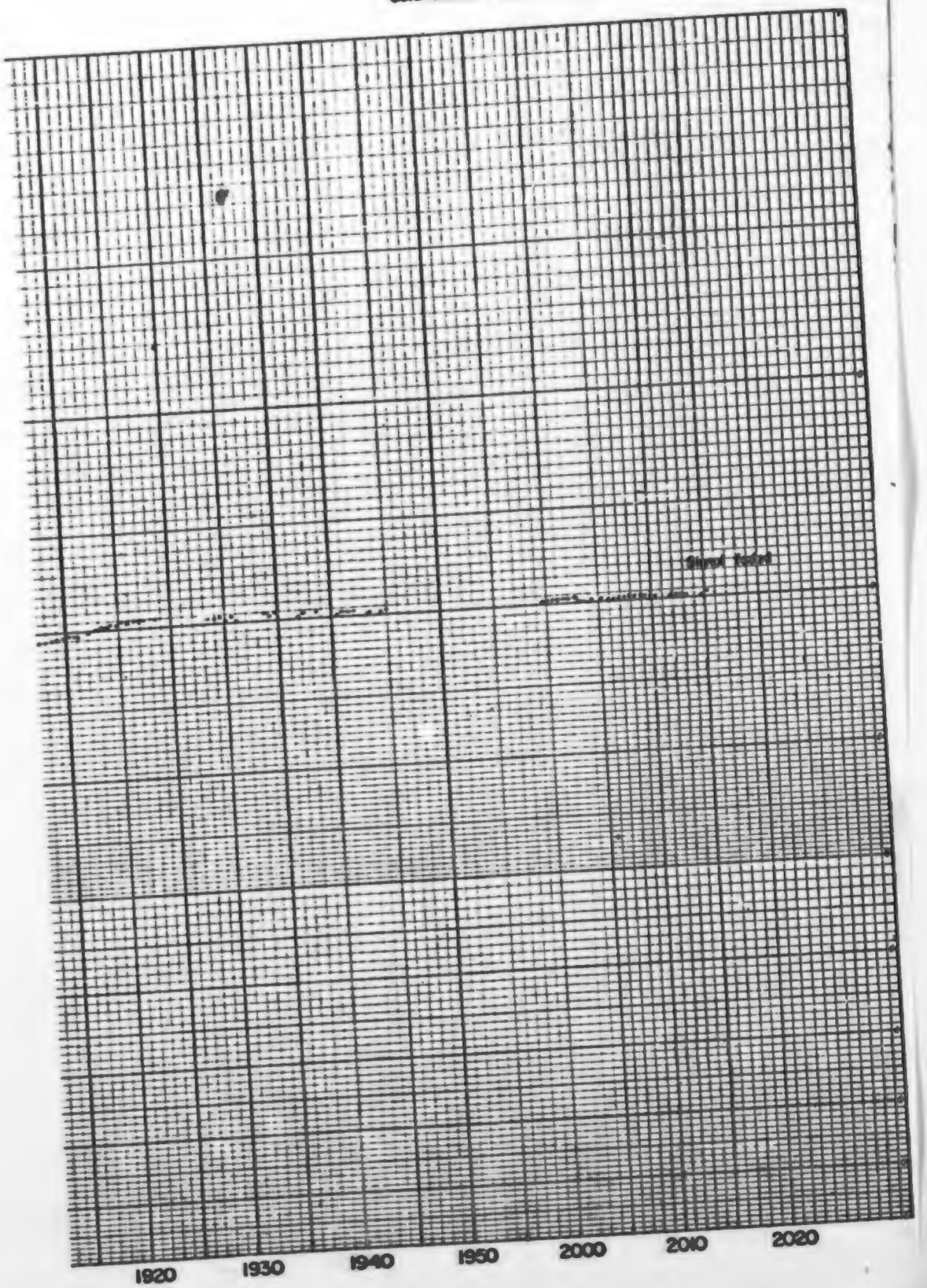
CONFIDENTIAL INFORMATION


TIME - PRESSURE - ALTITUDE
FLIGHT No. 99
13 November, 1953
Launched from MINNEAPOLIS, Minn.
Gross Load : 9 lbs. 9 oz.
Free Lift : 1 lb.
Gross Lift : 10 lbs. 9 oz.
Altitude data from telemetered aland cycle record
THEORETICAL CEILING
PRESSURE IN MILLIBARS
400
1730
1740
1750
1800
1810
1820
GREENWICH MEAN TIME

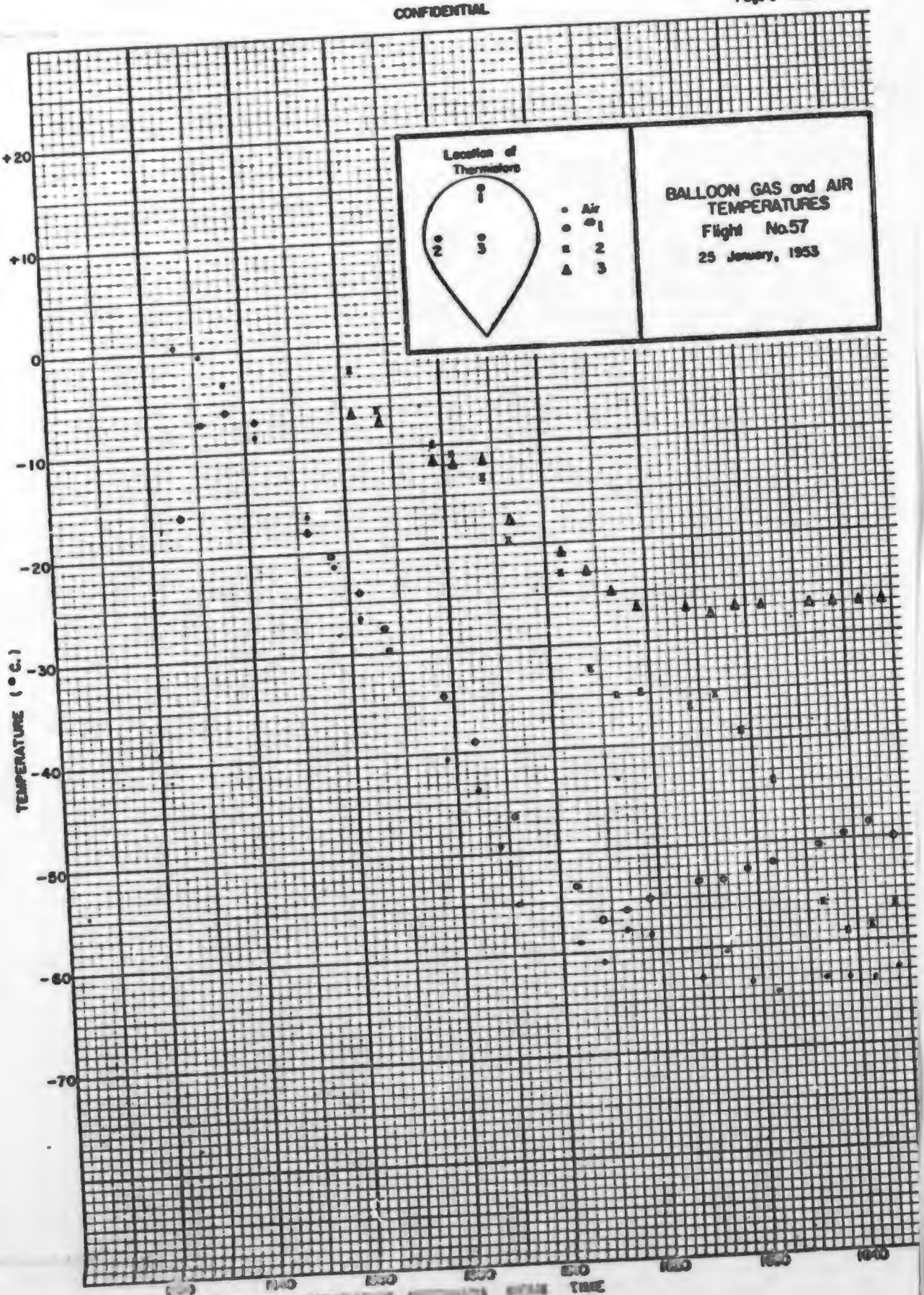

RASONDE DATA
FLIGHT # 100
30 November, 1953
Meteorological station reporting:
ST. CLOUD, Minn. 655
1500 Z
PRESSURE IN MILLIBARS
10
20
50
70
100
200
400
600
800
1000
-70
-60
-50
-40
-30
-20
-10
0
10
TEMPERATURE (°C)

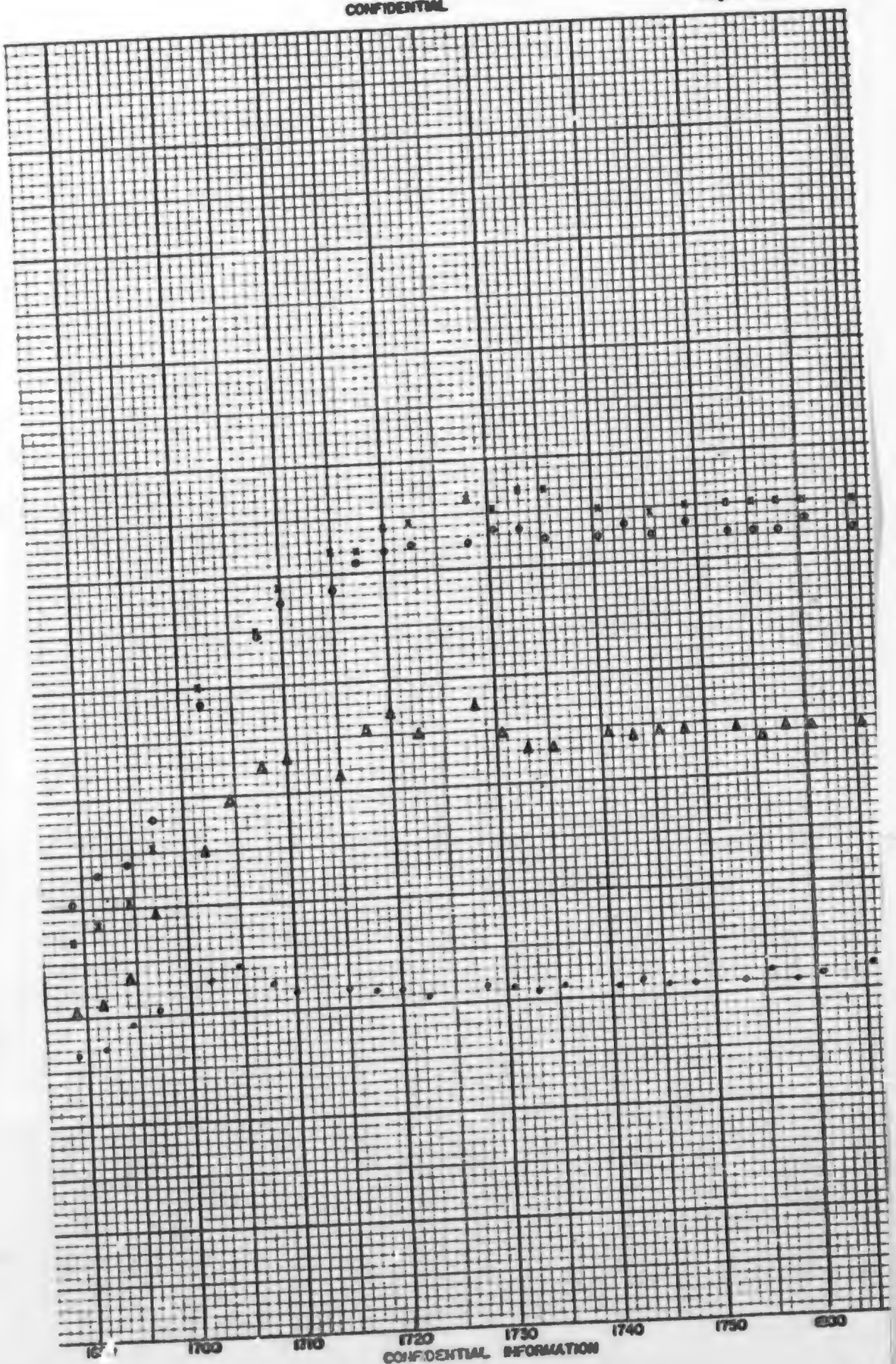

TIME - PRESSURE - ALTITUDE
FLIGHT No.100
30 November, 1953
Launched at MINNEAPOLIS, Minn.
Gross Load : 8 lbs. 7 oz.
Free Lift : 1 lb.
Gross Lift : 9 lbs. 7 oz.
Altitude data from telemetered ofland cycle record
PRESSURE IN MILLIBARS
200
400
600
800
1000
1750
1800
1810
1820
1830
1840
1850
1900
GREENWICH MEAN TIME

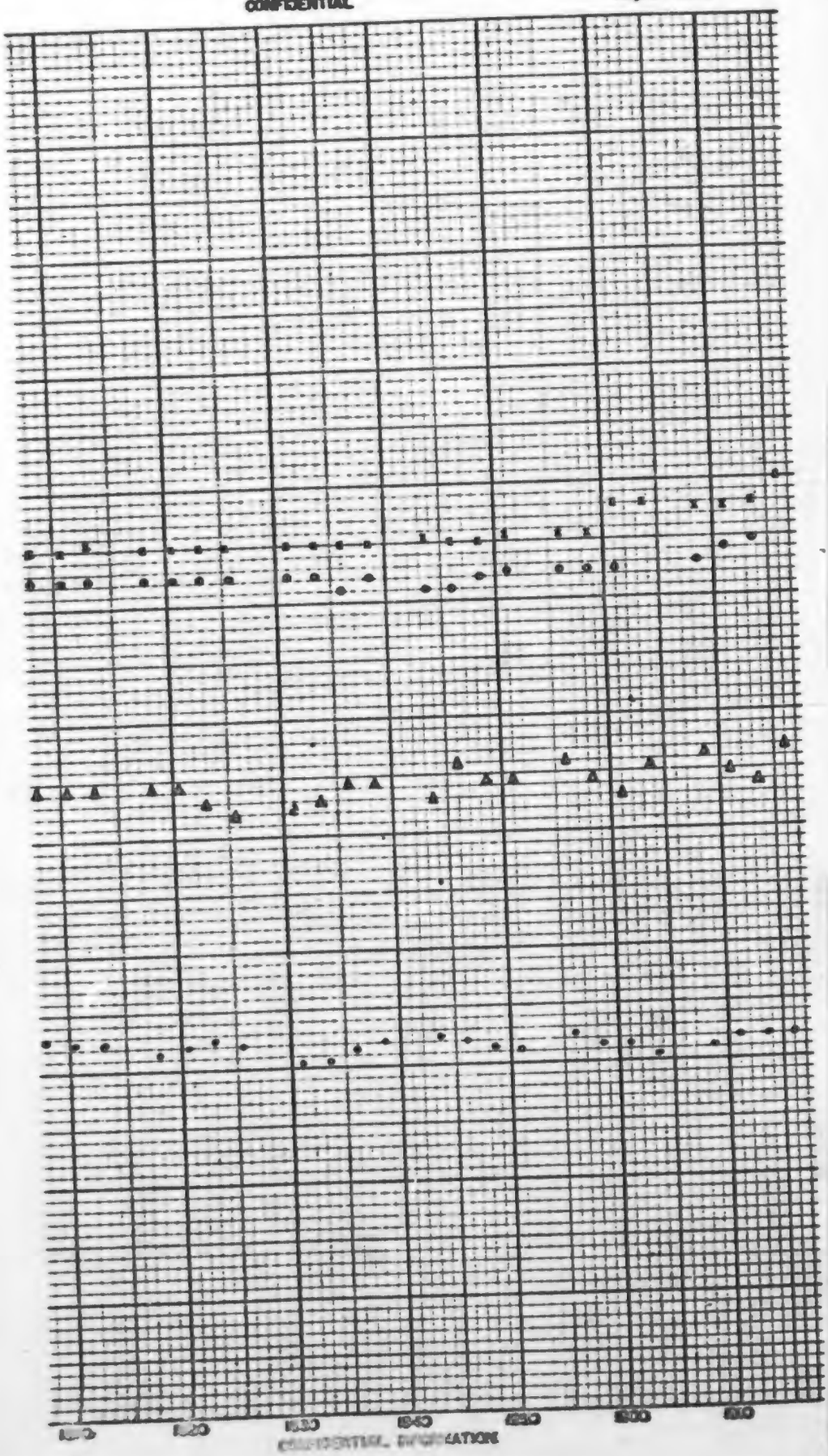
CONFIDENTIAL

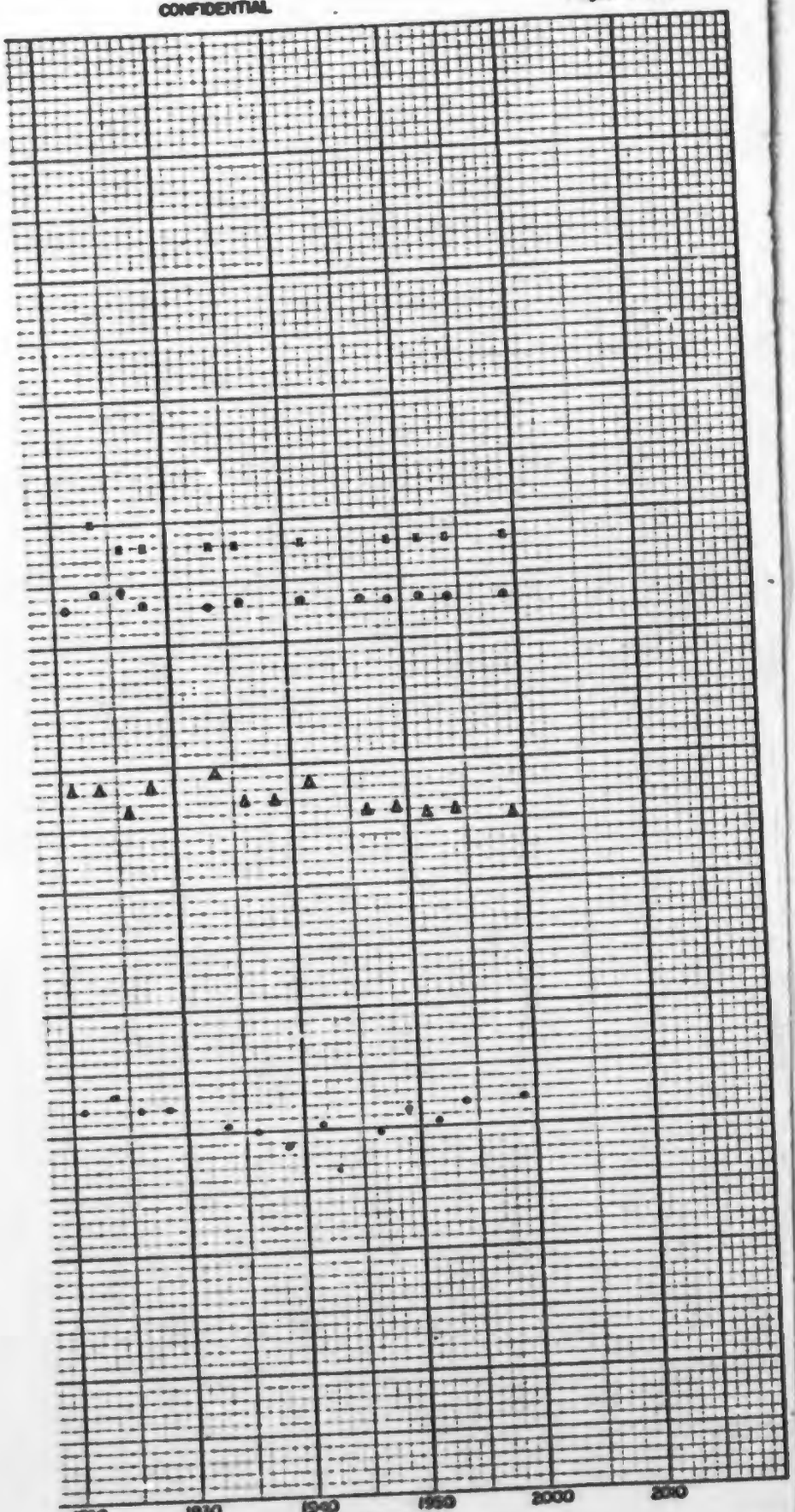


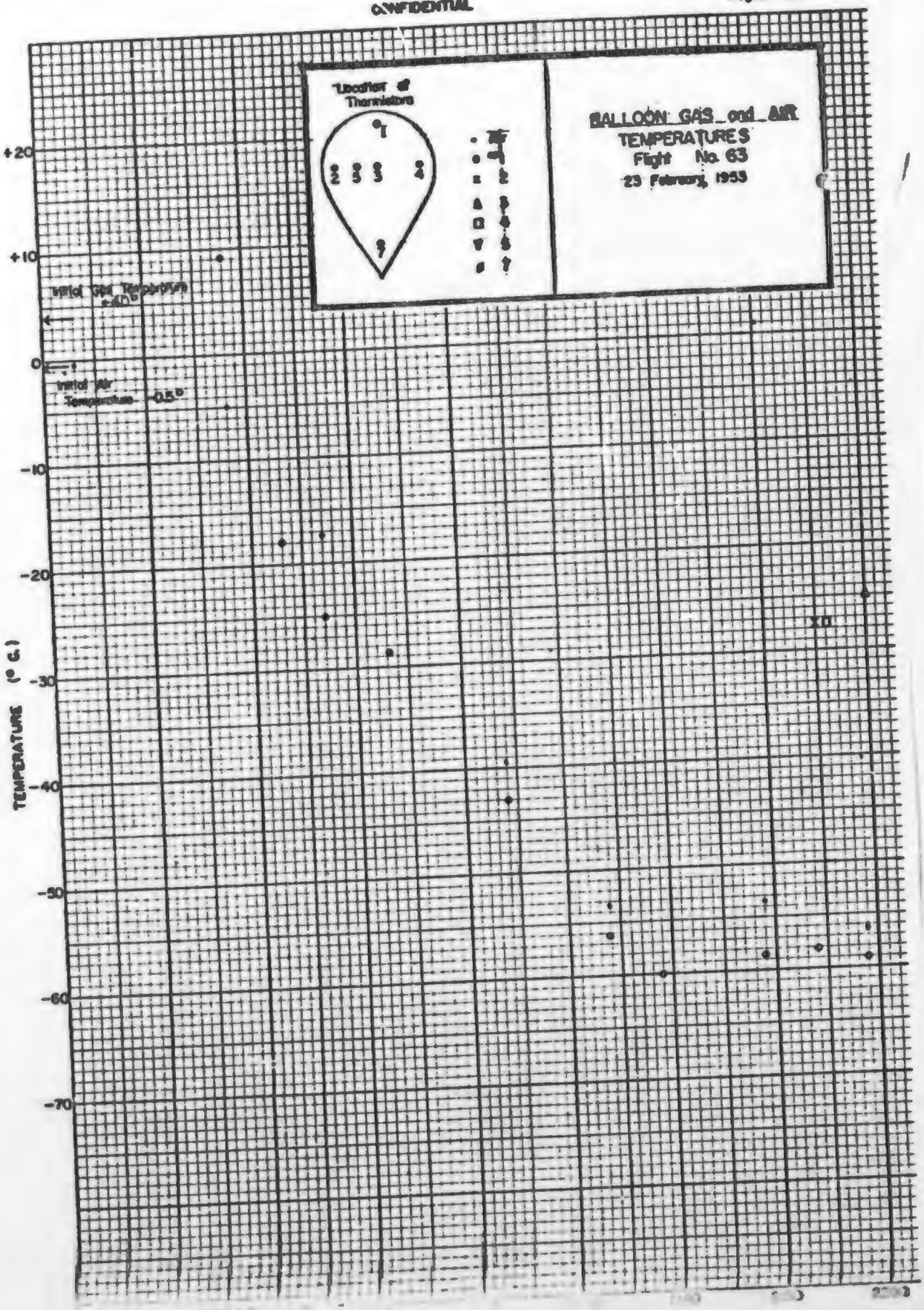
CONFIDENTIAL INFORMATION

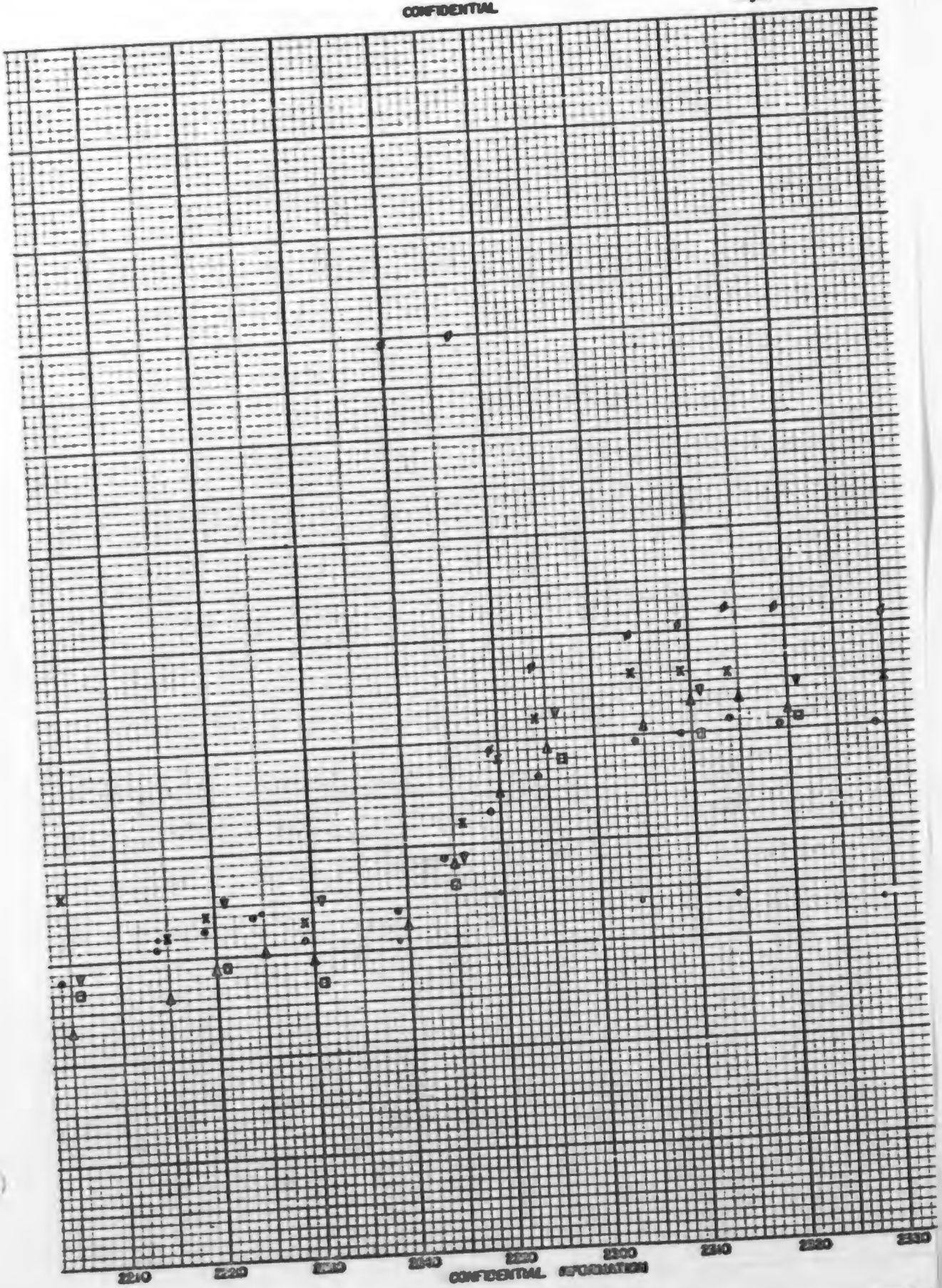

Location of Thermistors
1
2
3
Air
1
2
3
BALLOON GAS and AIR TEMPERATURES
Flight No.57
25 January, 1953
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
TEMPERATURE (°C.)
1940
TIME

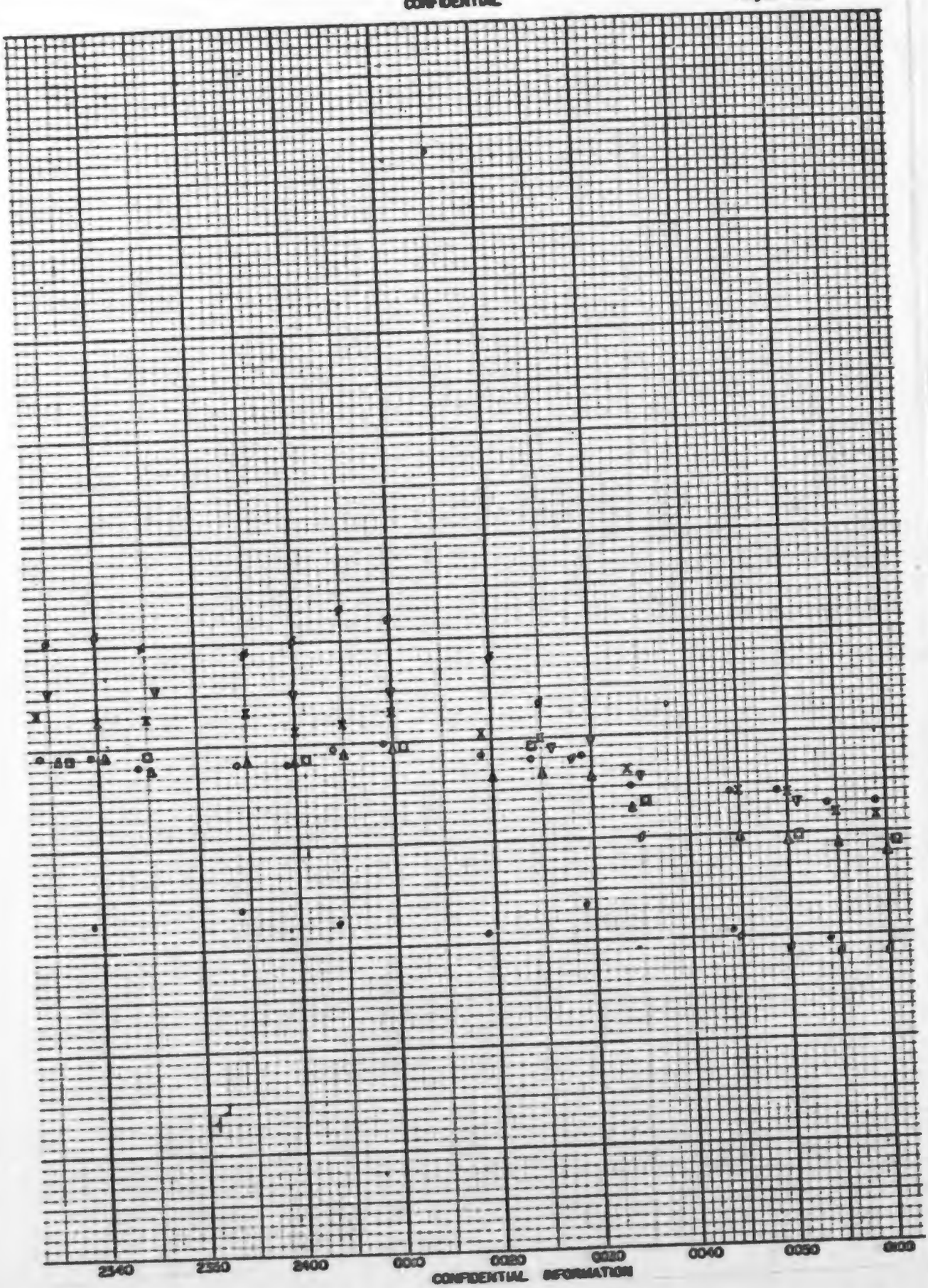

1700
1710
1720
1730
1740
1750
1800

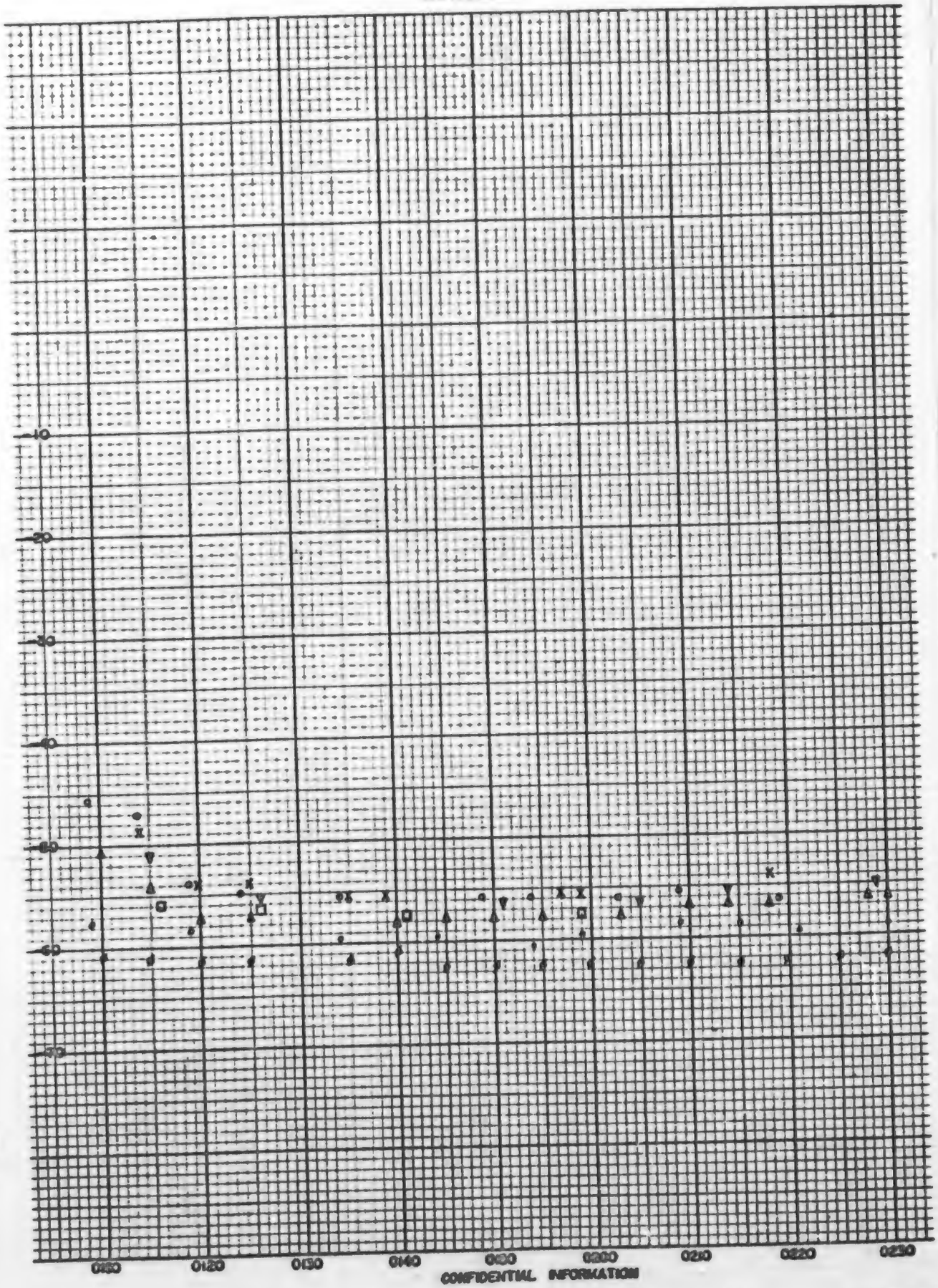

1520
1530
1540
1550
1600
1610

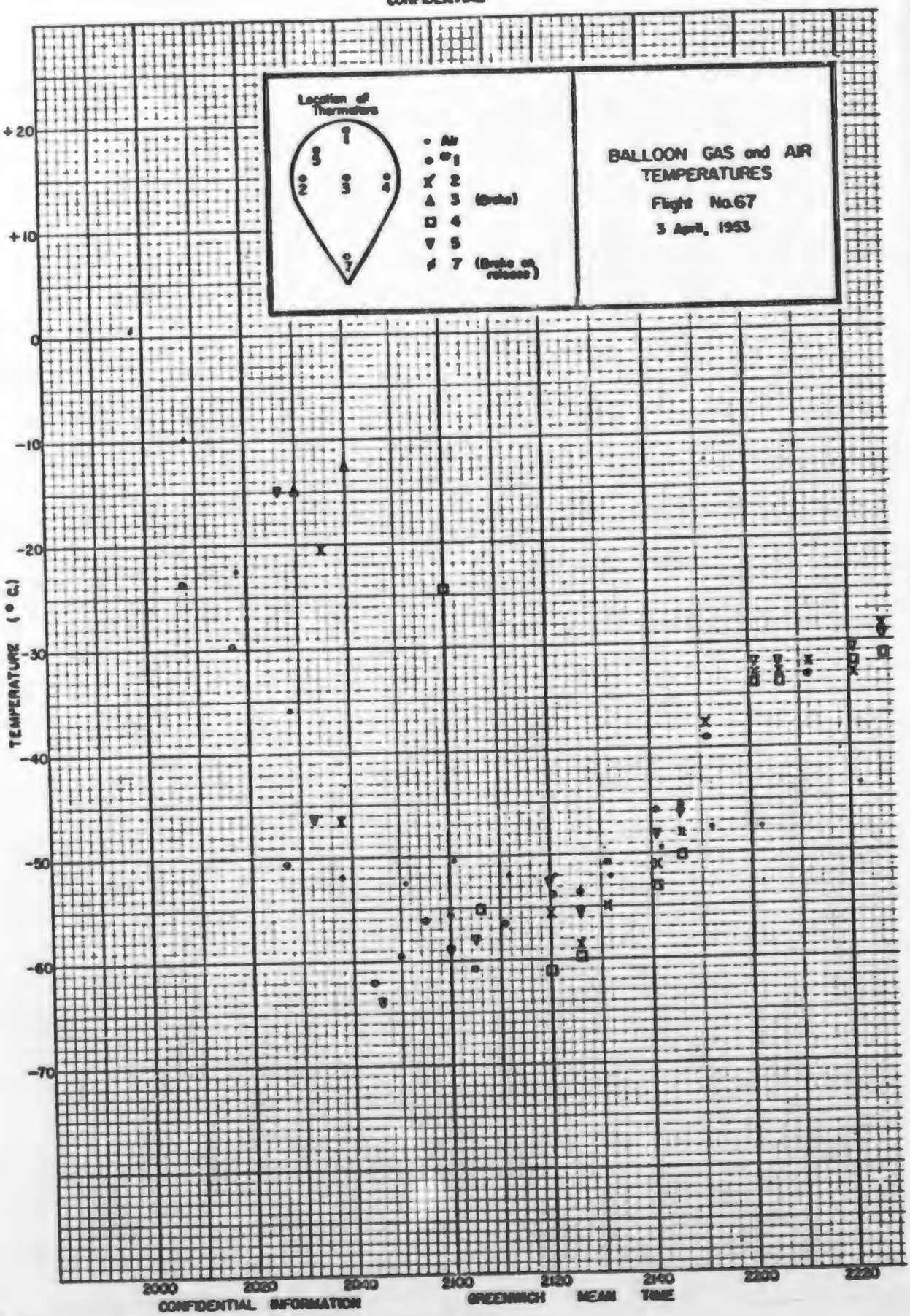

1920
1930
1940
1950
2000
2010

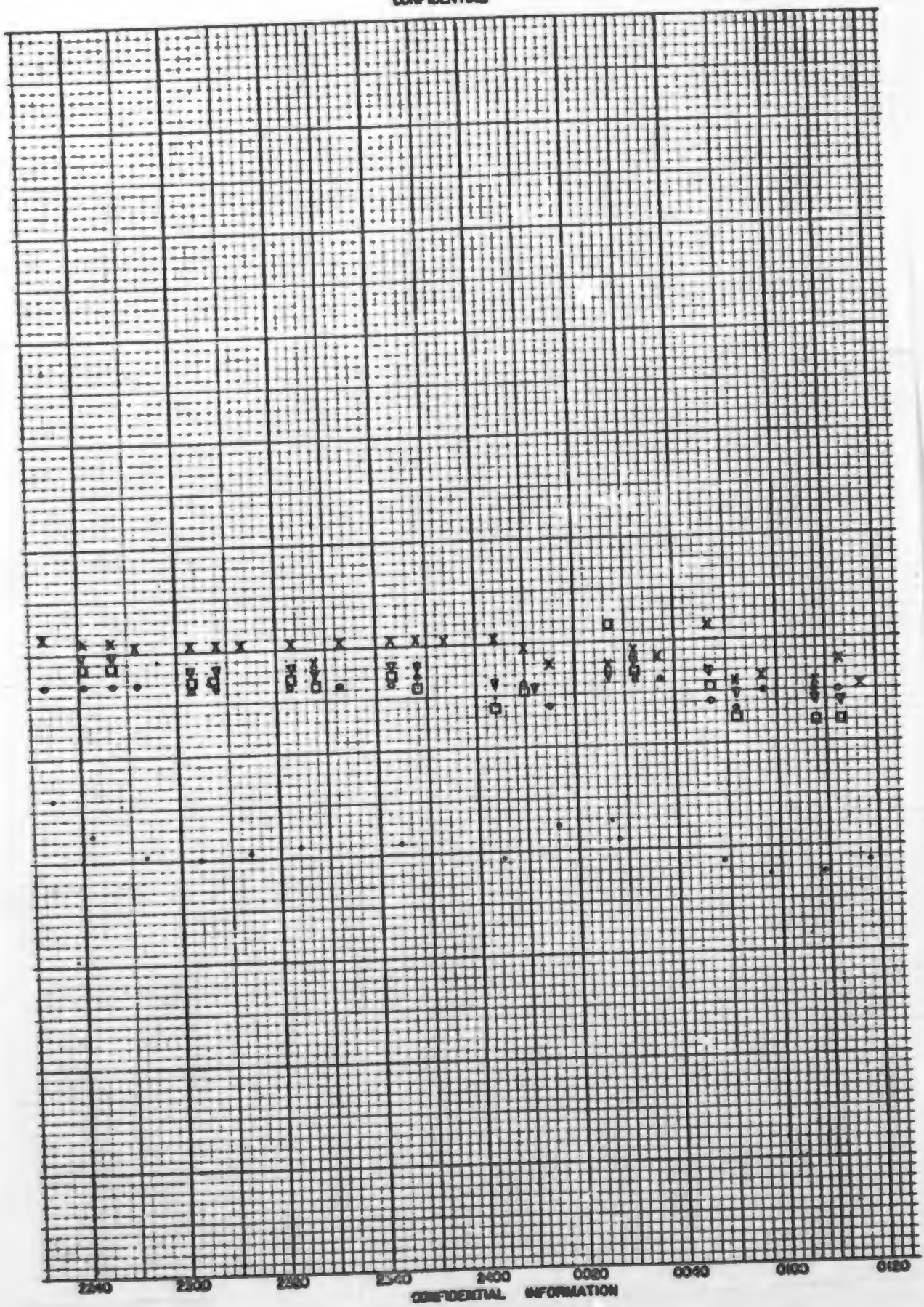

Location of Thermistors
1
2
3
4
5
6
7
Air
Gas
1
2
3
4
5
6
7
BALLOON GAS and AIR TEMPERATURES
Flight No. 63
23 February, 1953
Initial Gas Temperature -40°
Initial Air Temperature -0.5°
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
TEMPERATURE (° C.)

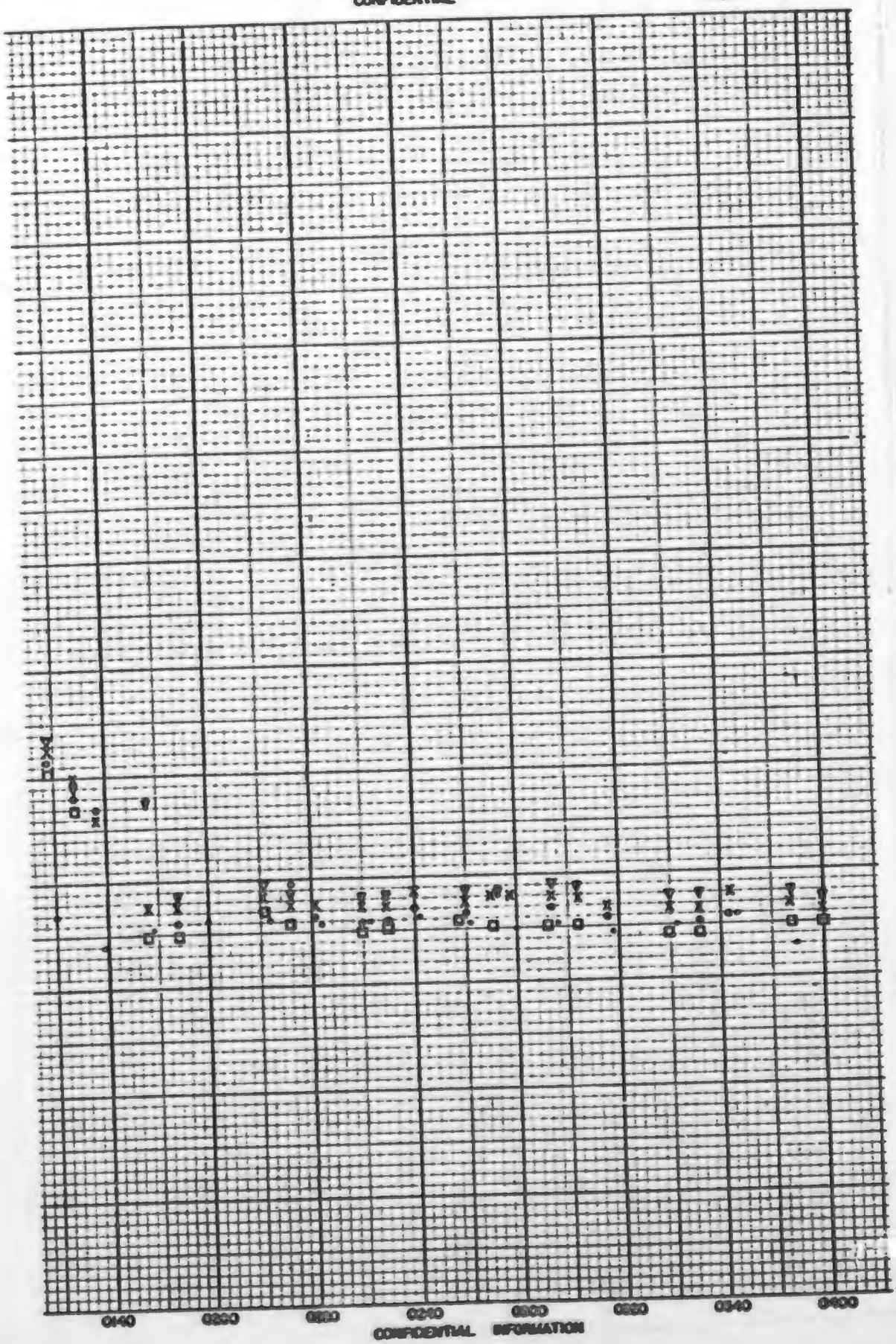

2210
2220
2230
2240
2250
2260
2270
2280
2290
2300
2310
2320
2330

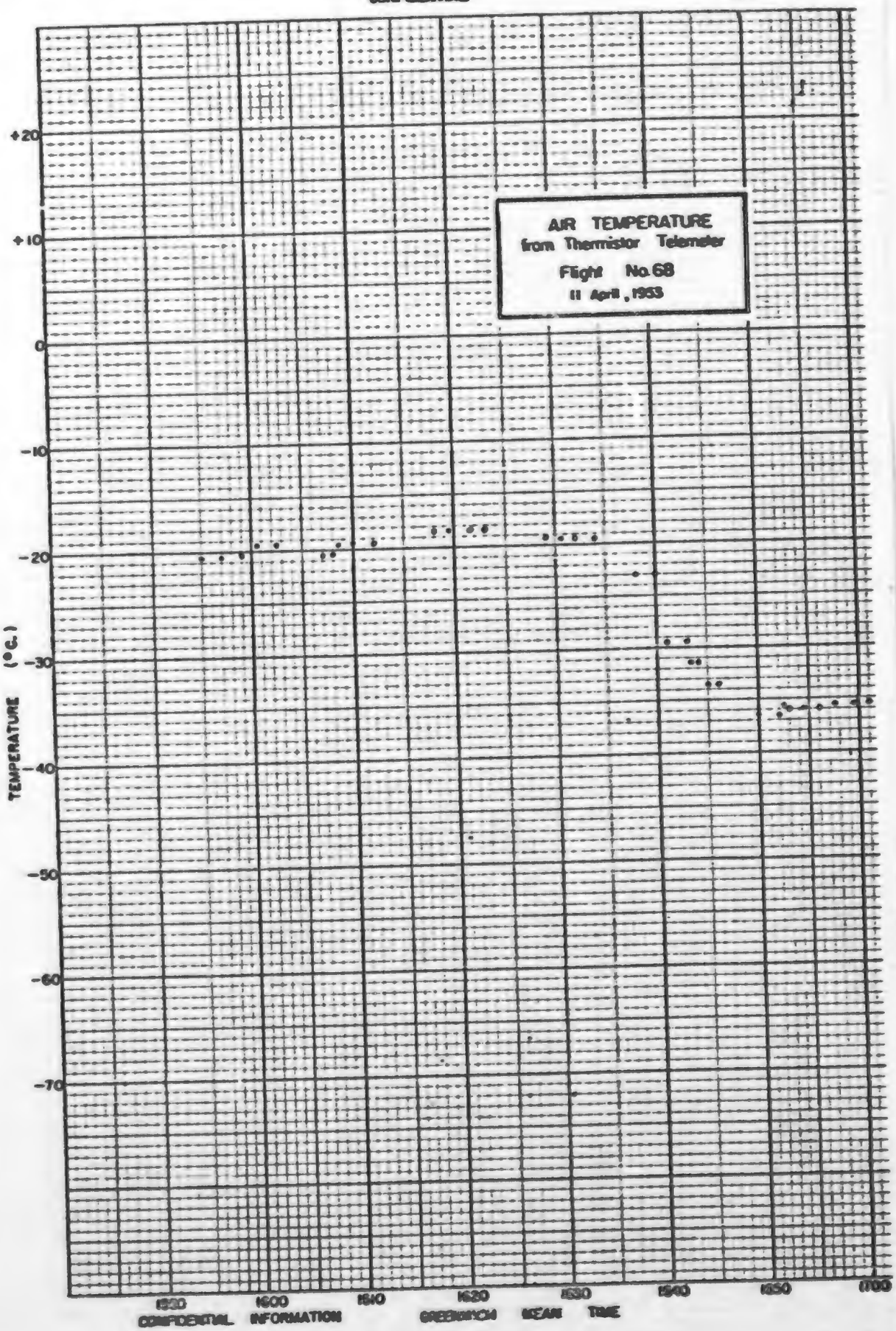

2340
2350
2400
0010
0020
0030
0040
0050
0100

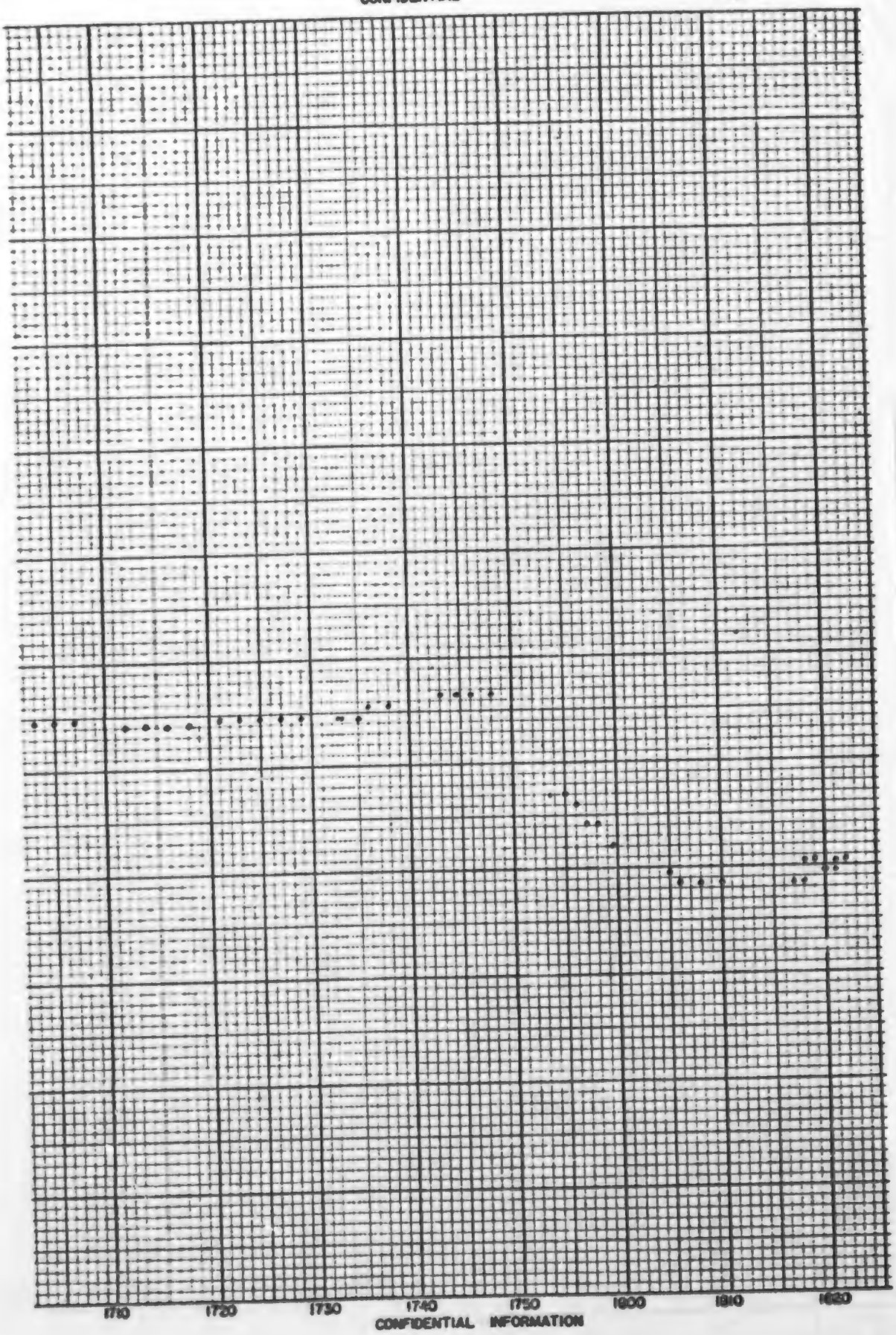

-10
-20
-30
-40
-50
-60
-70
0110
0120
0130
0140
0150
0200
0210
0220
0230

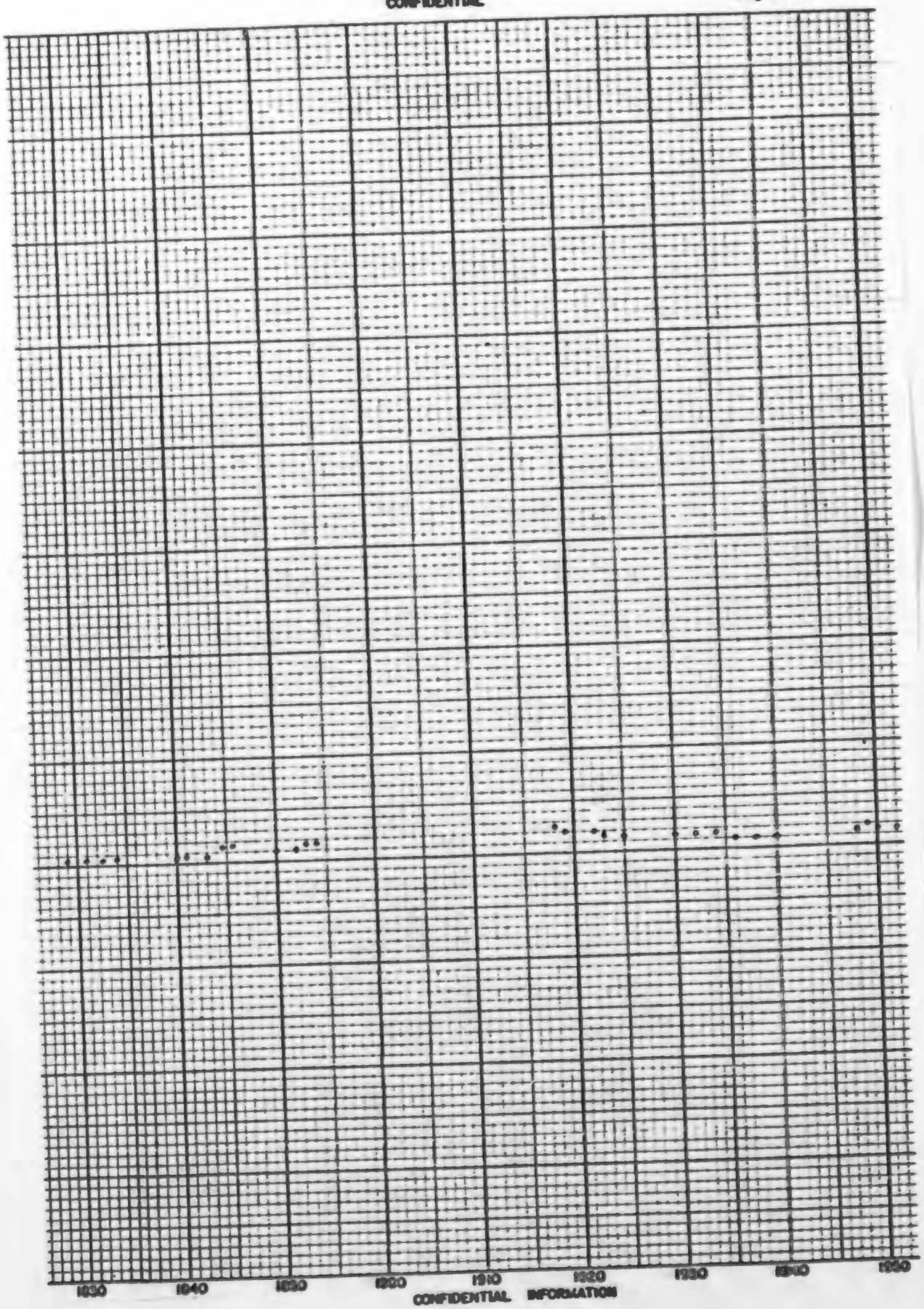

Location of Thermistors
1
2
3
4
5
7
Air
1
2
3 (Brake)
4
5
7 (Brake on release)
BALLOON GAS and AIR TEMPERATURES
Flight No.67
3 April, 1953
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
TEMPERATURE (° C.)
2000
2020
2040
2100
2120
2140
2200
2220
GREENWICH MEAN TIME

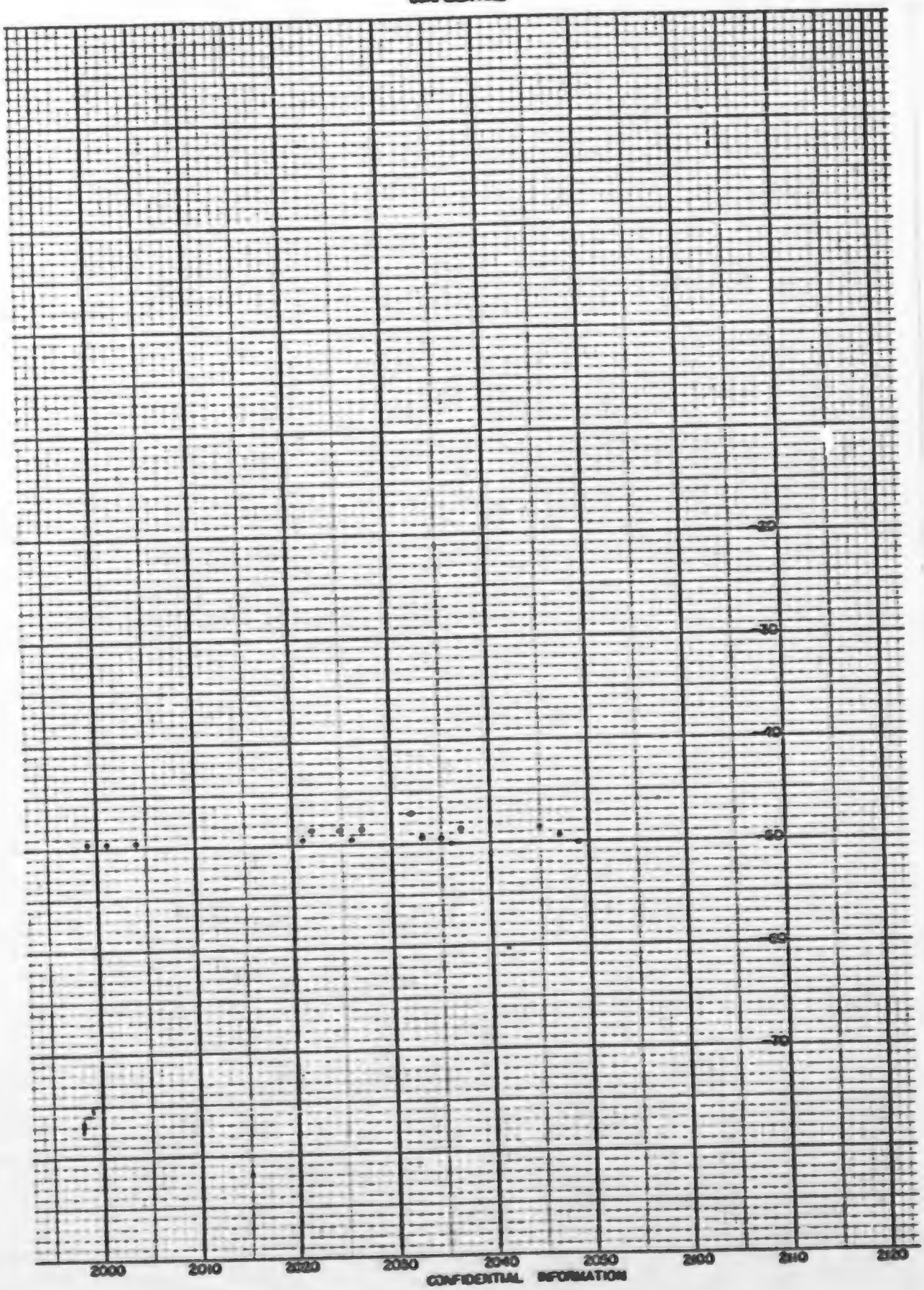

2240
2300
2320
2340
2400
0020
0040
0100
0120

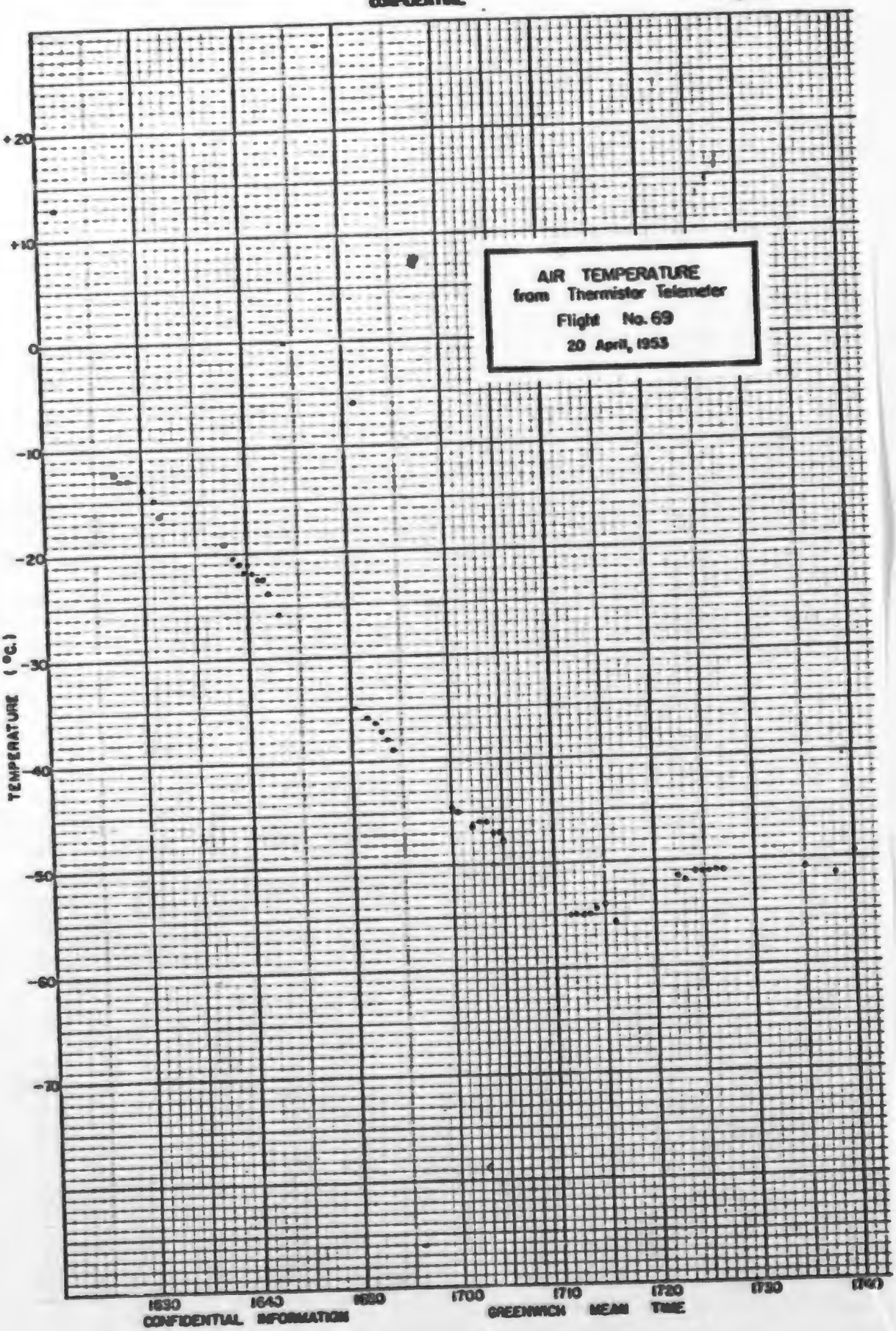

0140
0200
0220
0240
0300
0320
0340
0400

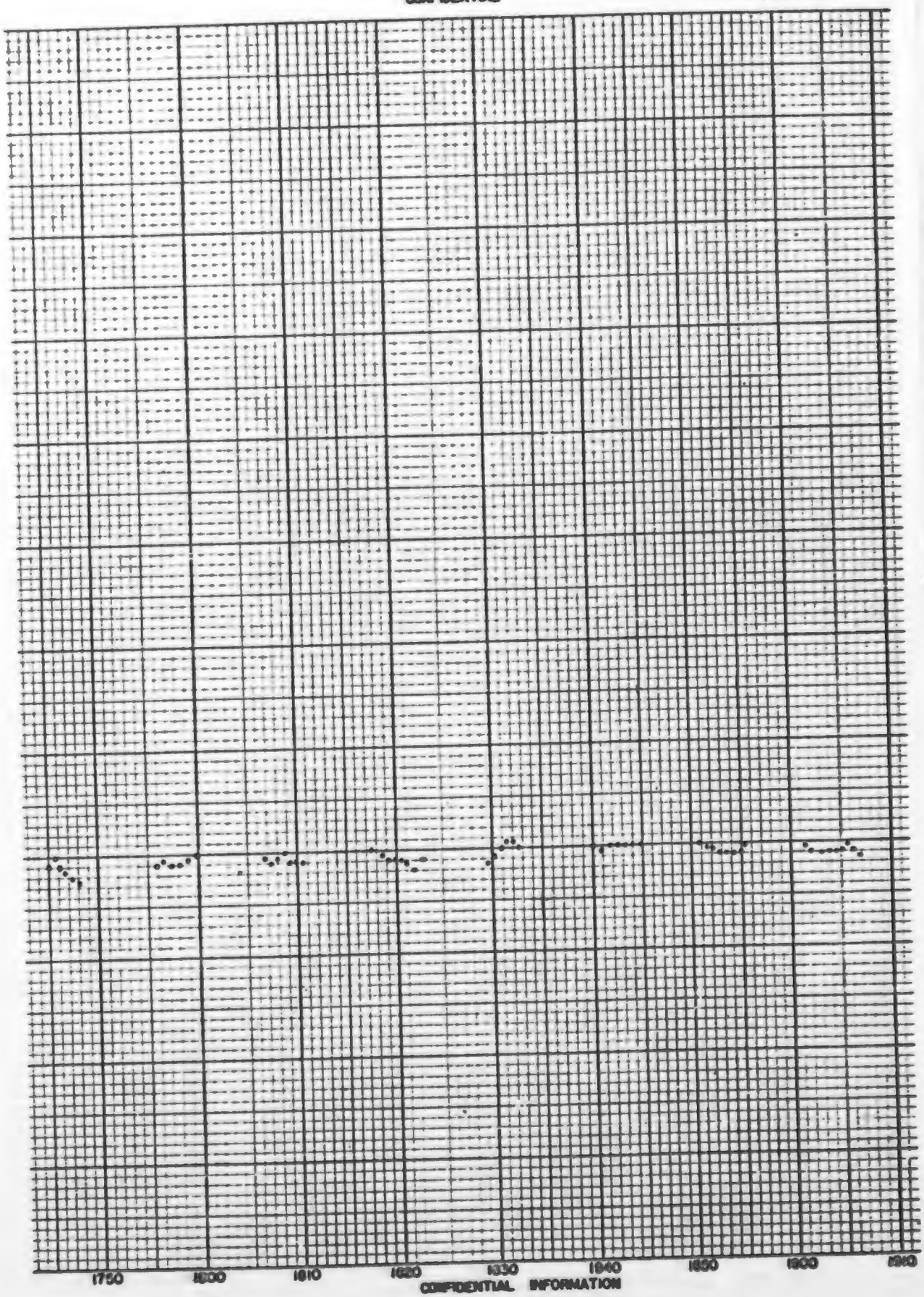

AIR TEMPERATURE
from Thermistor Telemeter
Flight No. 68
11 April, 1953
TEMPERATURE (°C.)
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
1520
1600
1610
1620
1630
1640
1650
1700
GREENWICH MEAN TIME

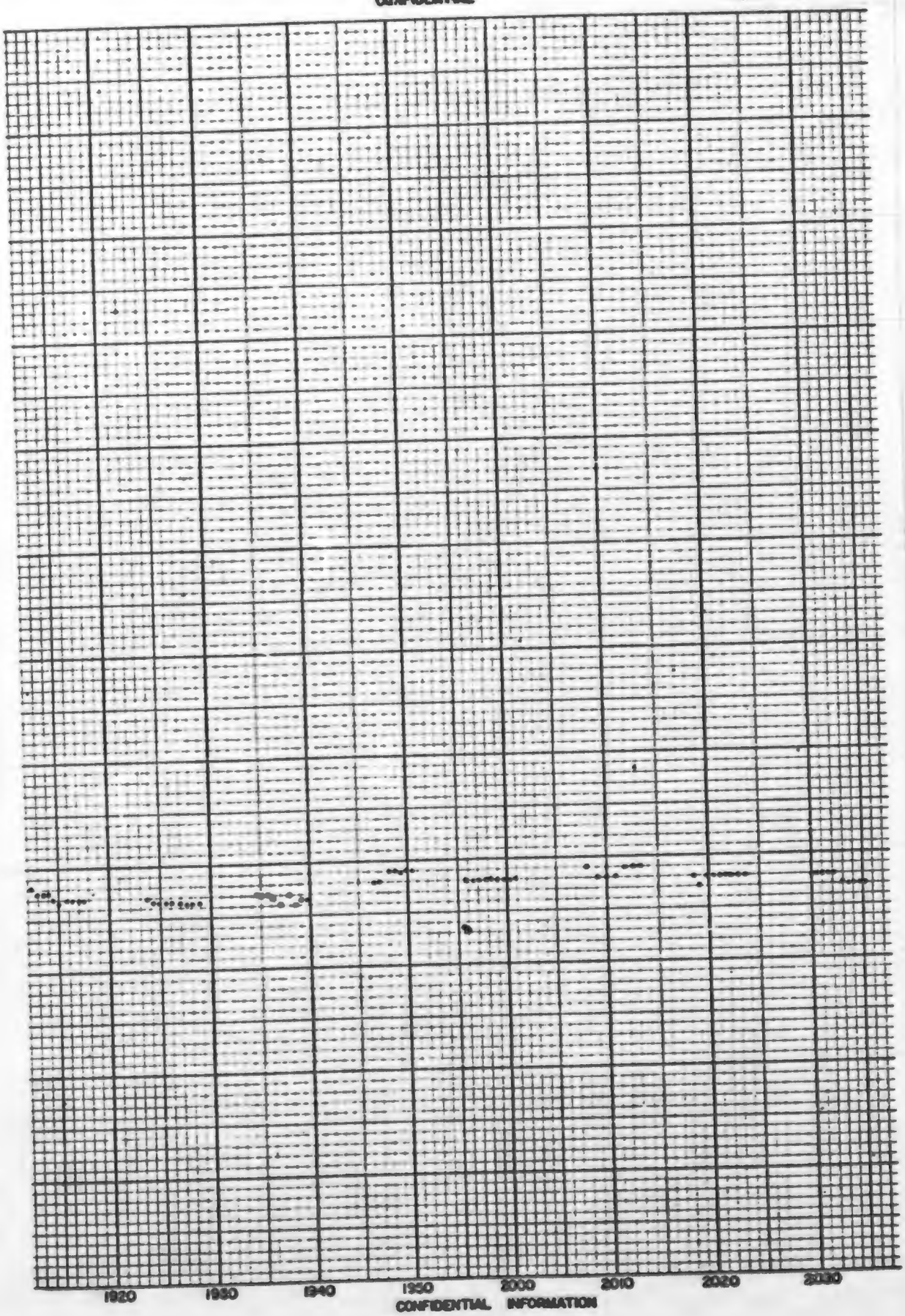

1710
1720
1730
1740
1750
1900
1910
1920

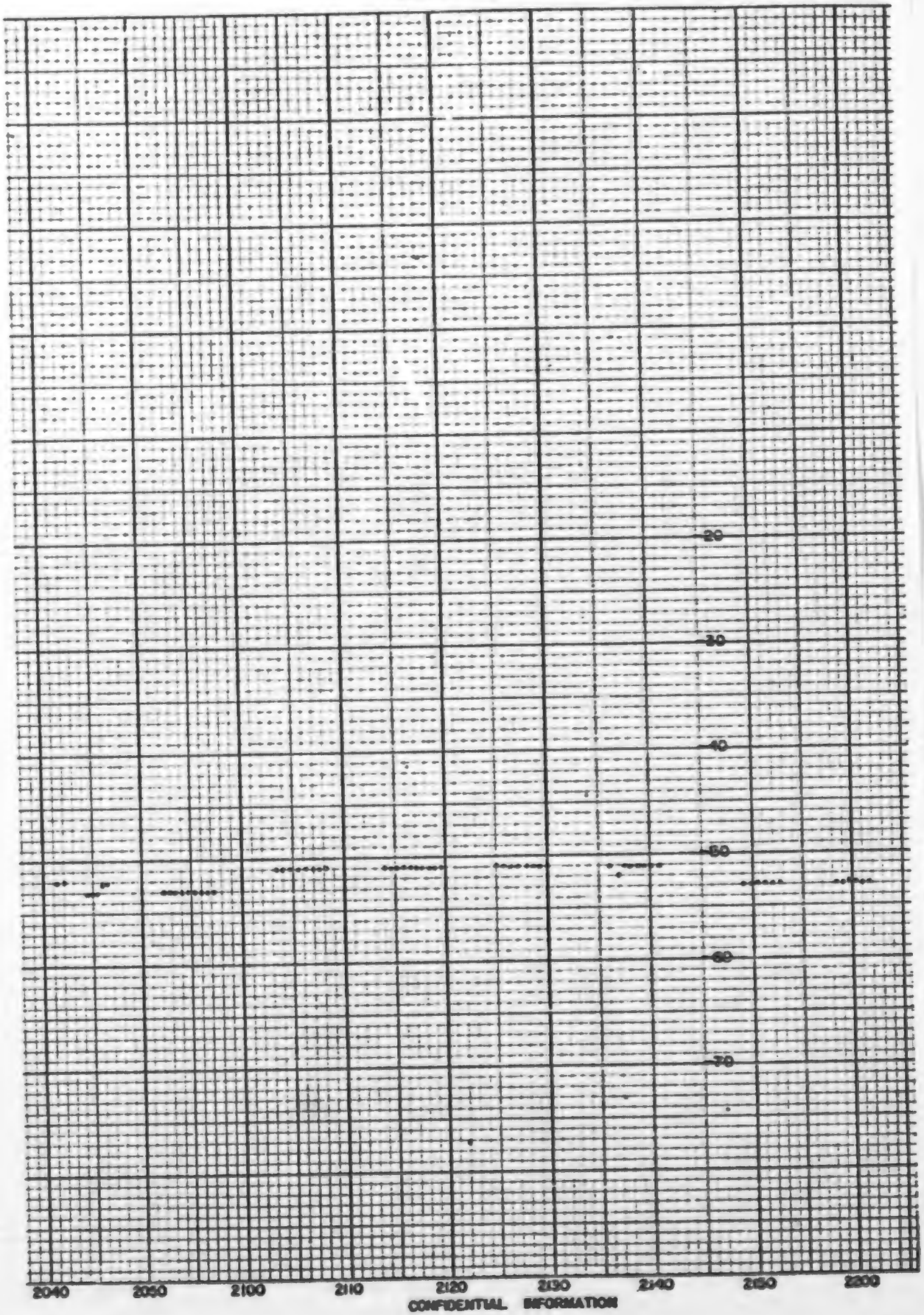

1830
1840
1850
1900
1910
1920
1930
1940
1950

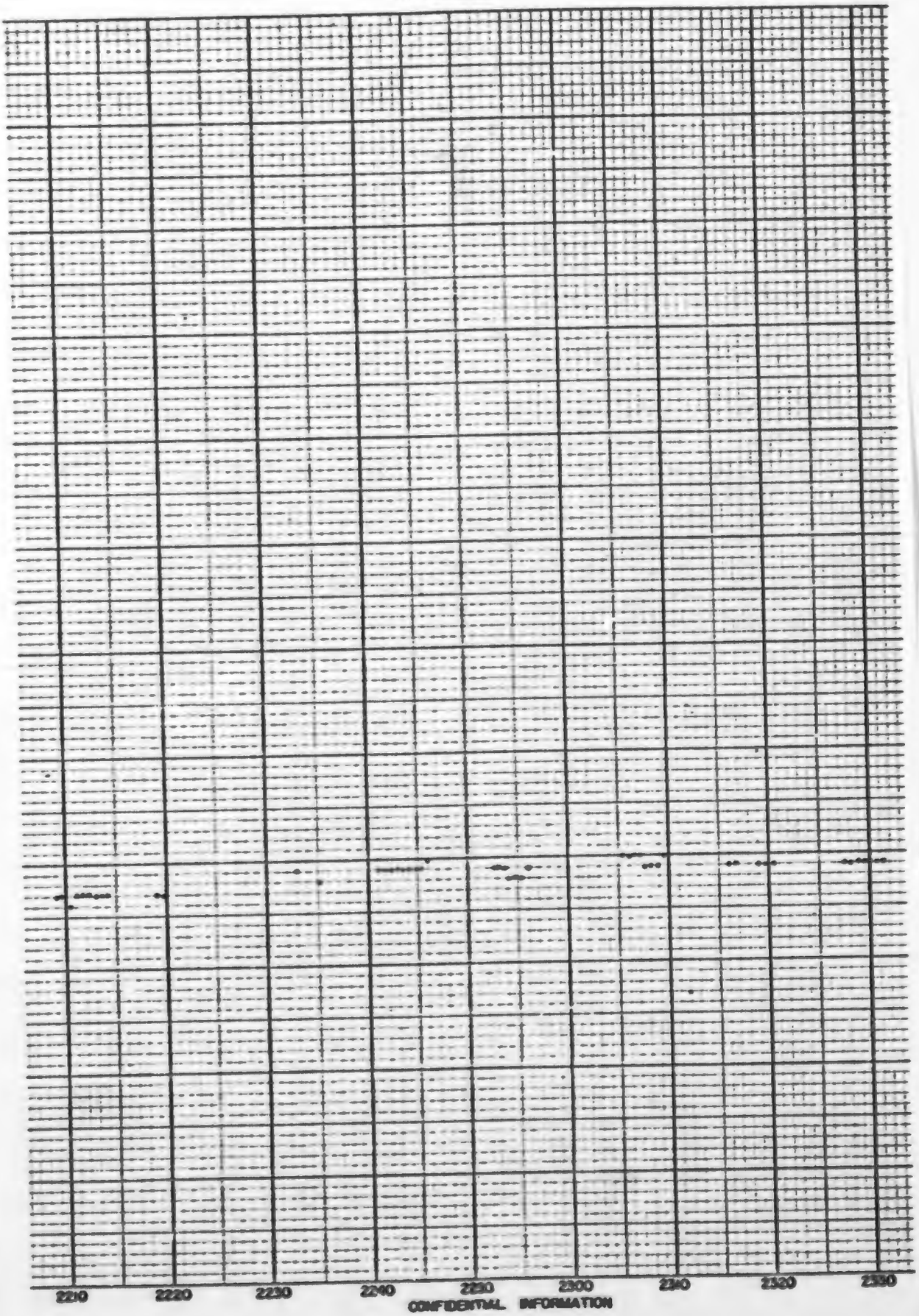

-20
-30
-40
-50
-60
-70
2000
2010
2020
2030
2040
2050
2060
2110
2120

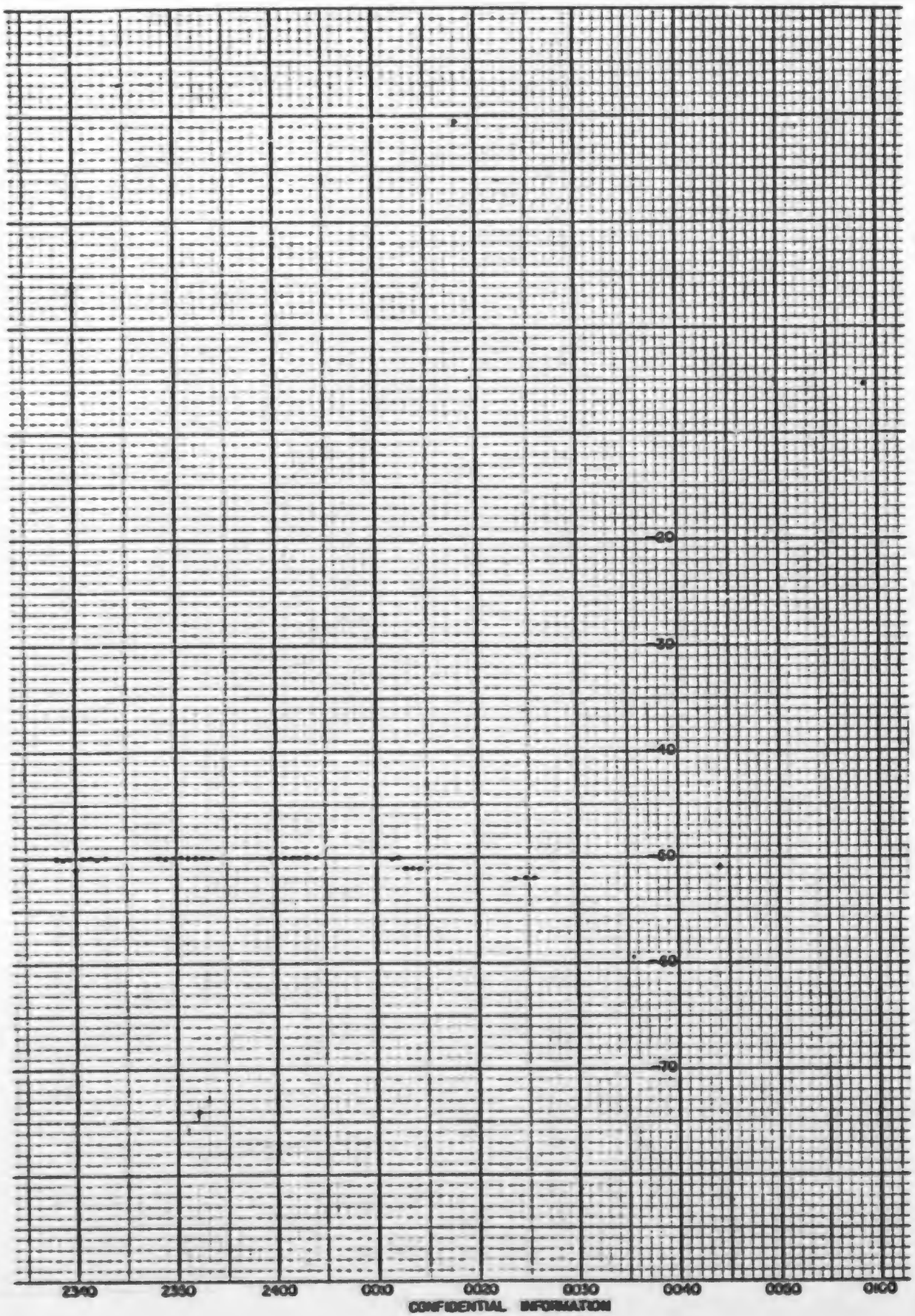

AIR TEMPERATURE
from Thermistor Telemeter
Flight No. 69
20 April, 1953
TEMPERATURE (°C.)
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
1630
1640
1650
1700
1710
1720
1730
1740
GREENWICH MEAN TIME

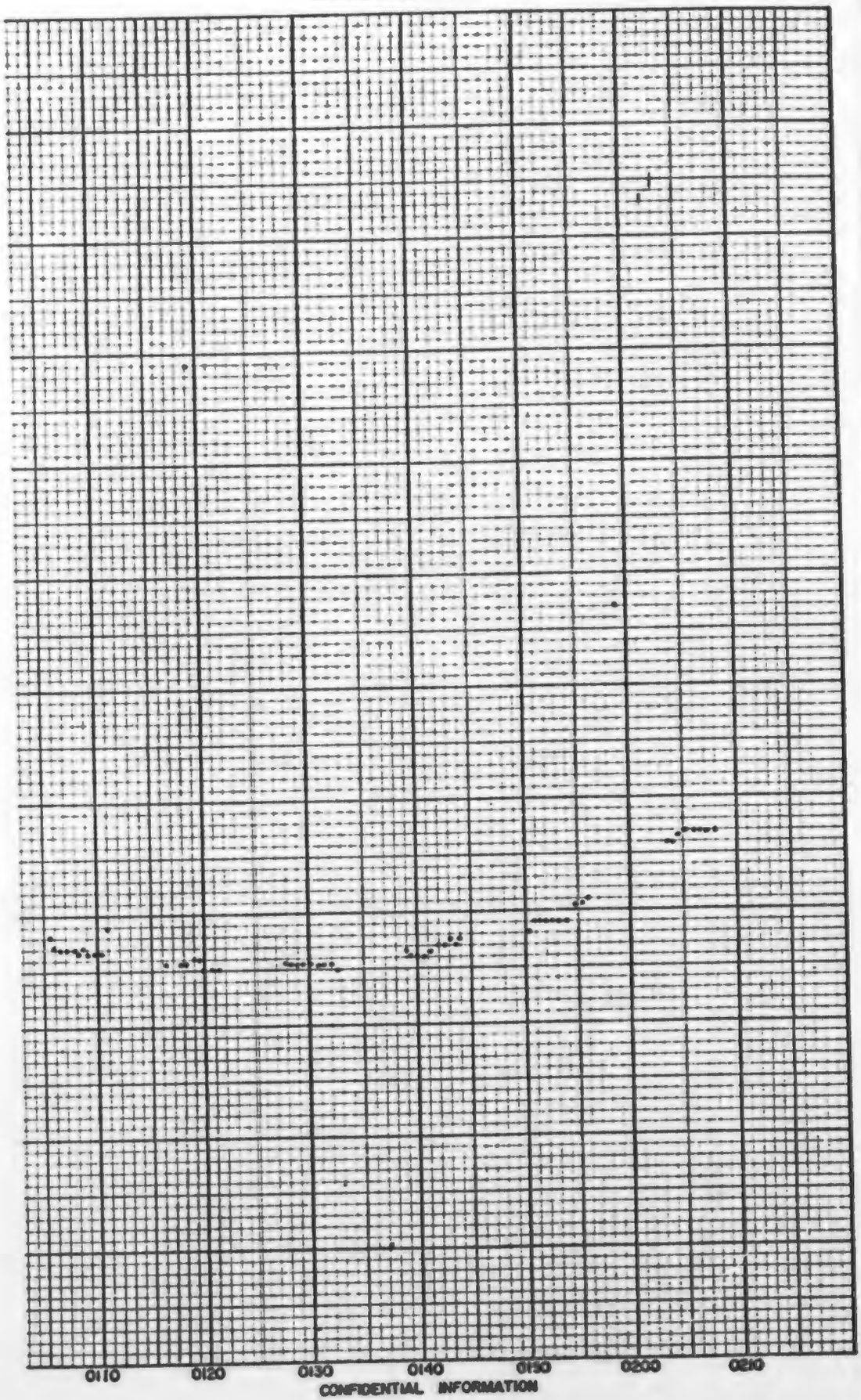

1750
1800
1810
1820
1830
1840
1850
1900
1910

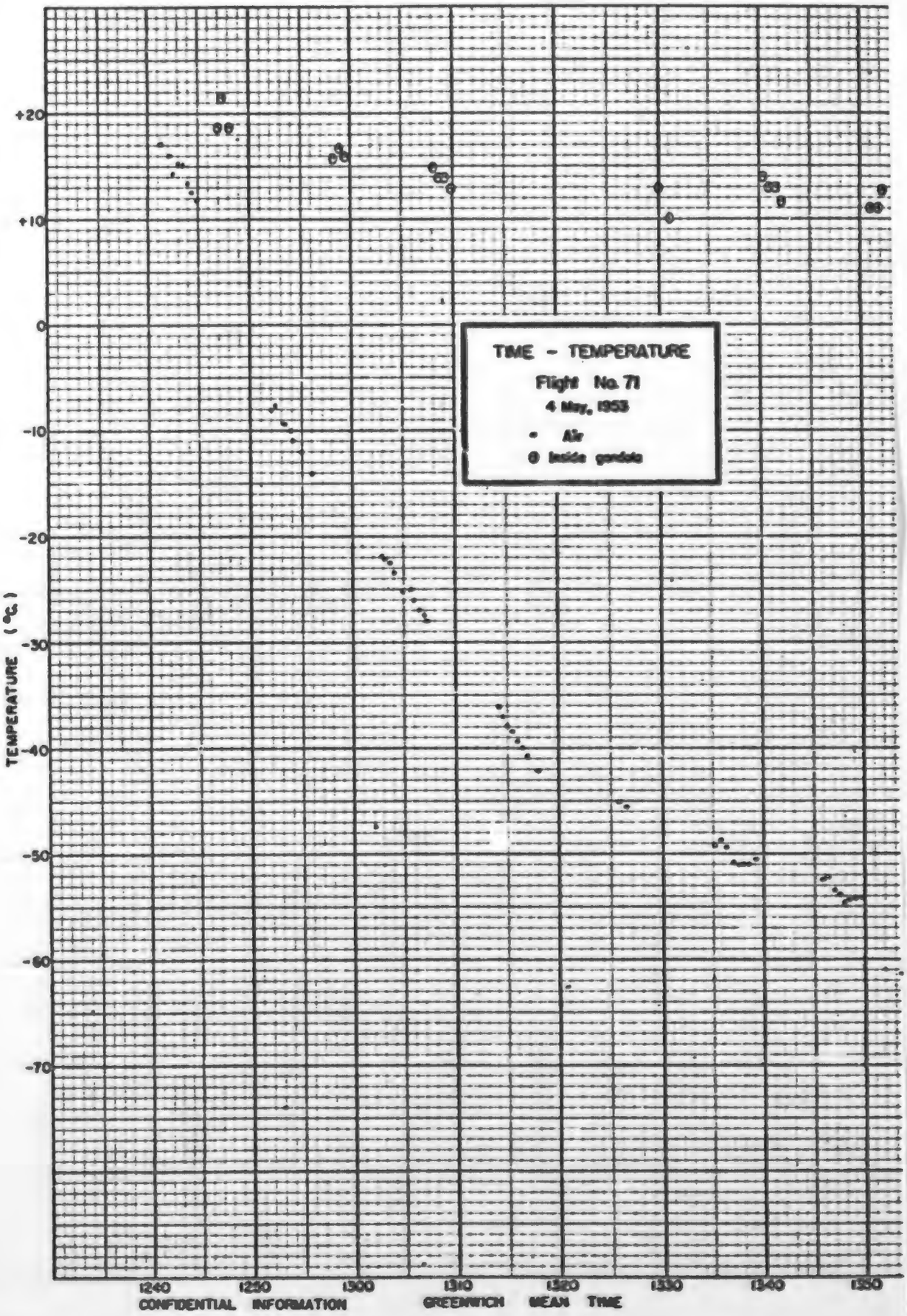

1920
1930
1940
1950
2000
2010
2020
2030

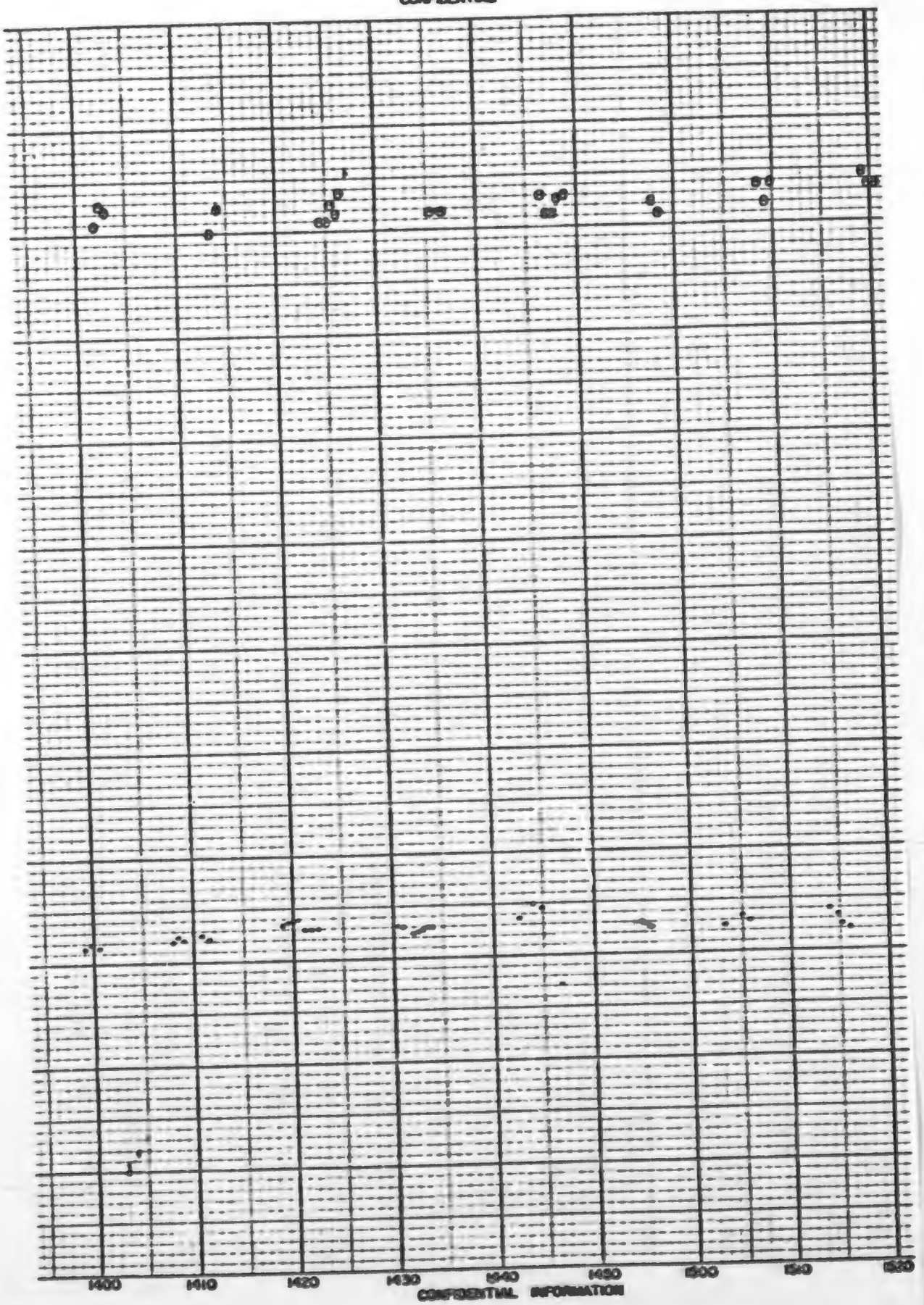

-20
-30
-40
-50
-60
-70
2040
2050
2100
2110
2120
2130
2140
2150
2200

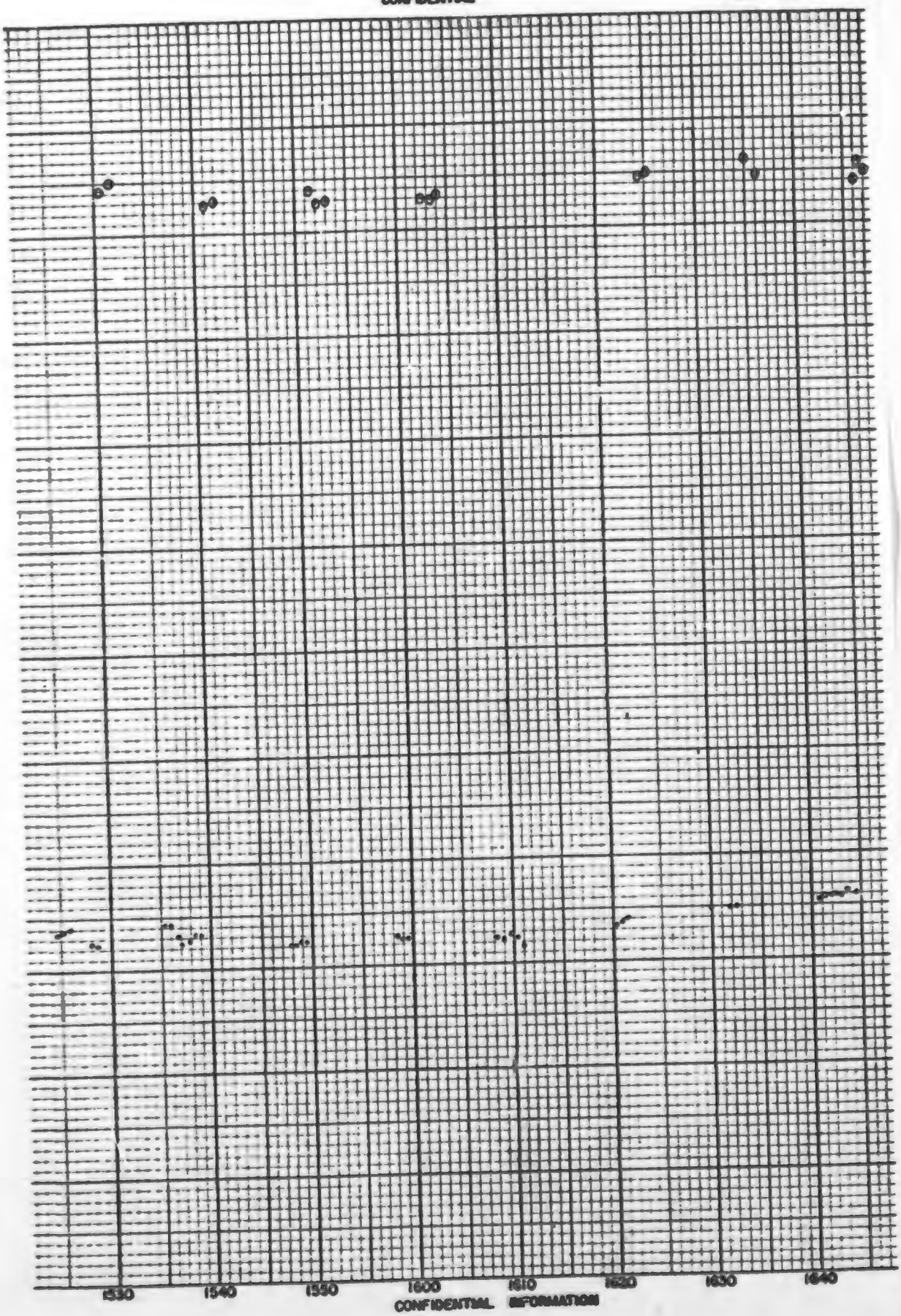

2210
2220
2230
2240
2250
2300
2310
2320
2330

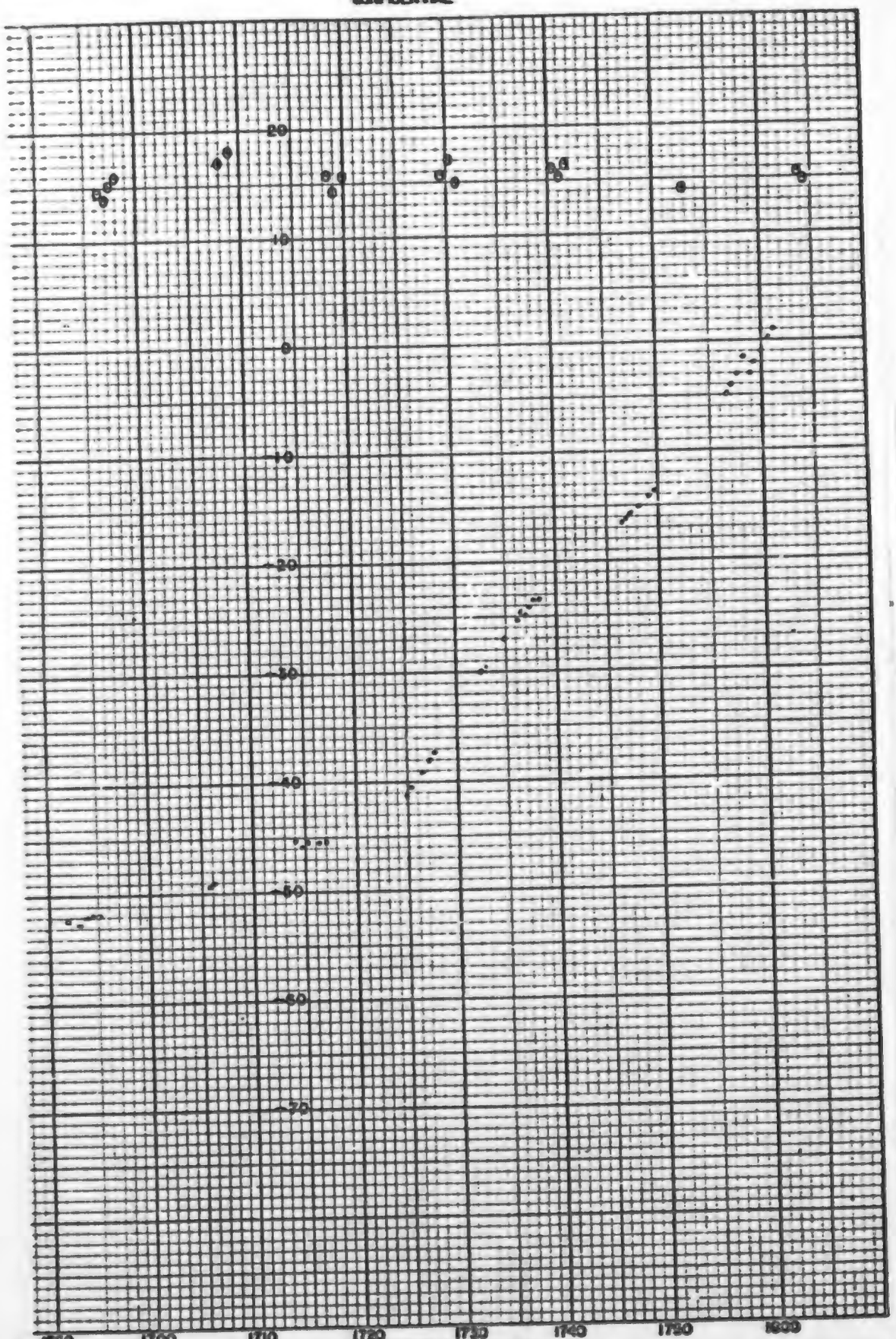

-20
-30
-40
-50
-60
-70
2340
2350
2400
0010
0020
0030
0040
0050
0100

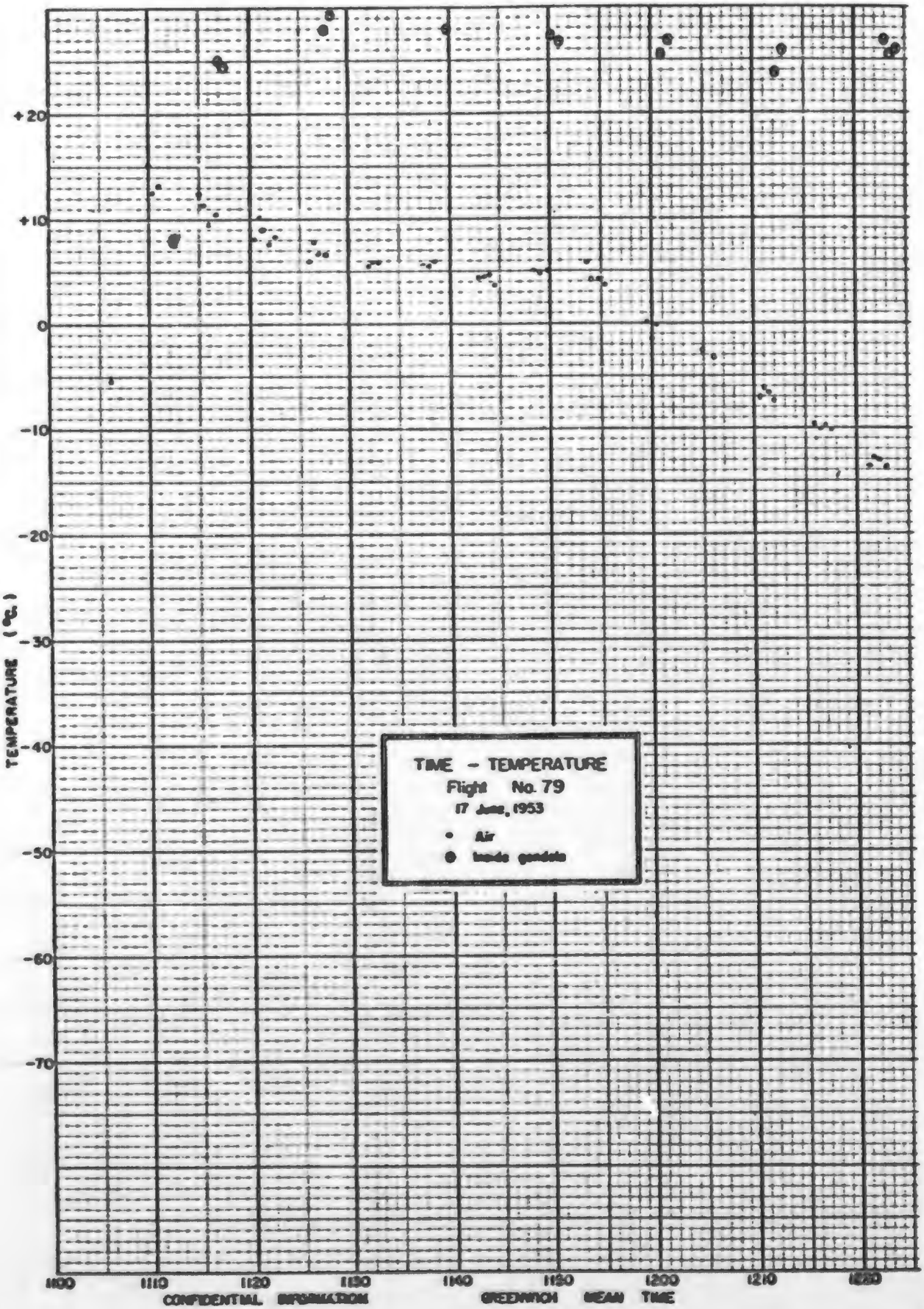

0110
0120
0130
0140
0150
0200
0210


TIME - TEMPERATURE
Flight No. 71
4 May, 1953
• Air
⊖ Inside gondola
TEMPERATURE (°C.)
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
1240
1250
1300
1310
1320
1330
1340
1350
CONFIDENTIAL INFORMATION
GREENWICH MEAN TIME

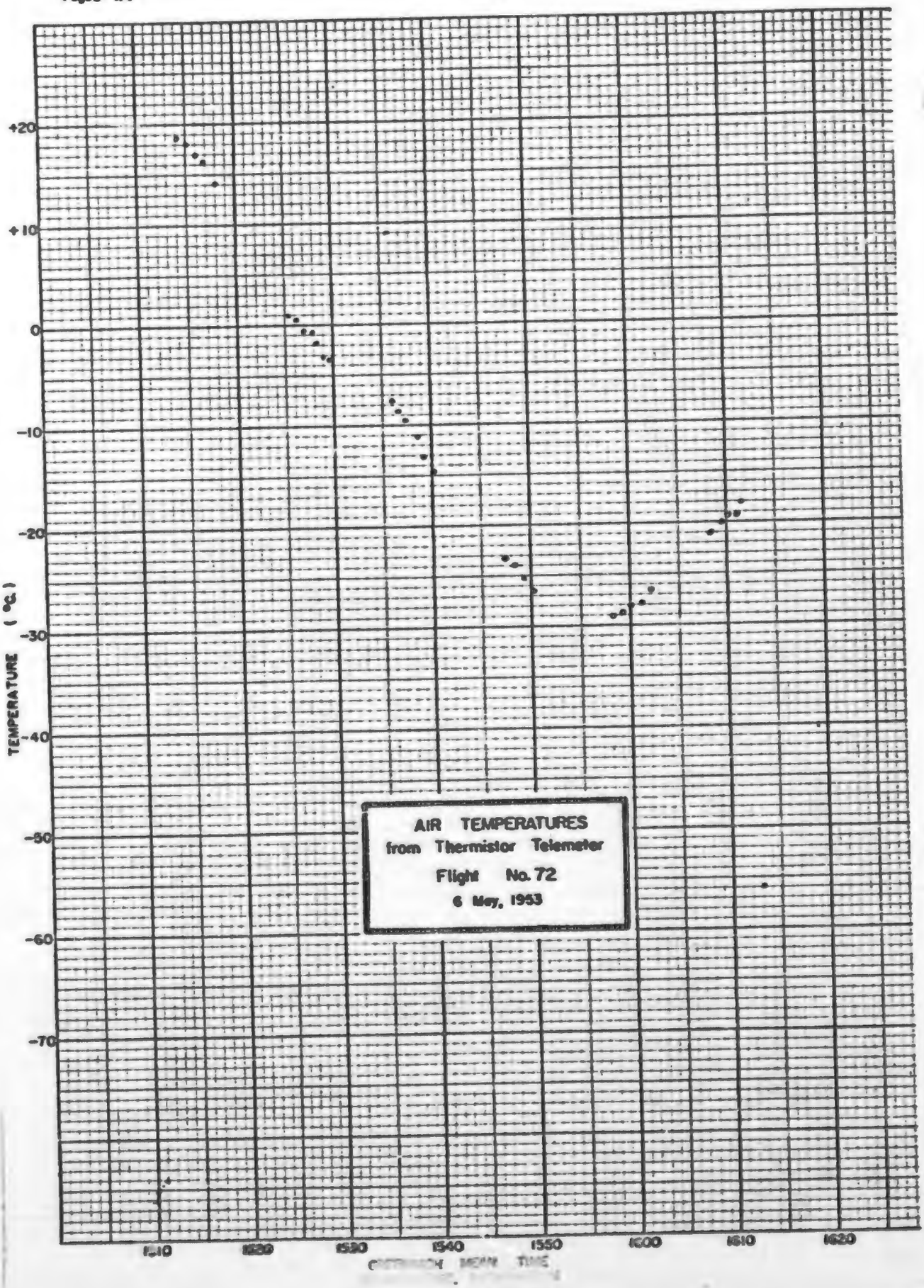

1400
1410
1420
1430
1440
1450
1500
1510
1520

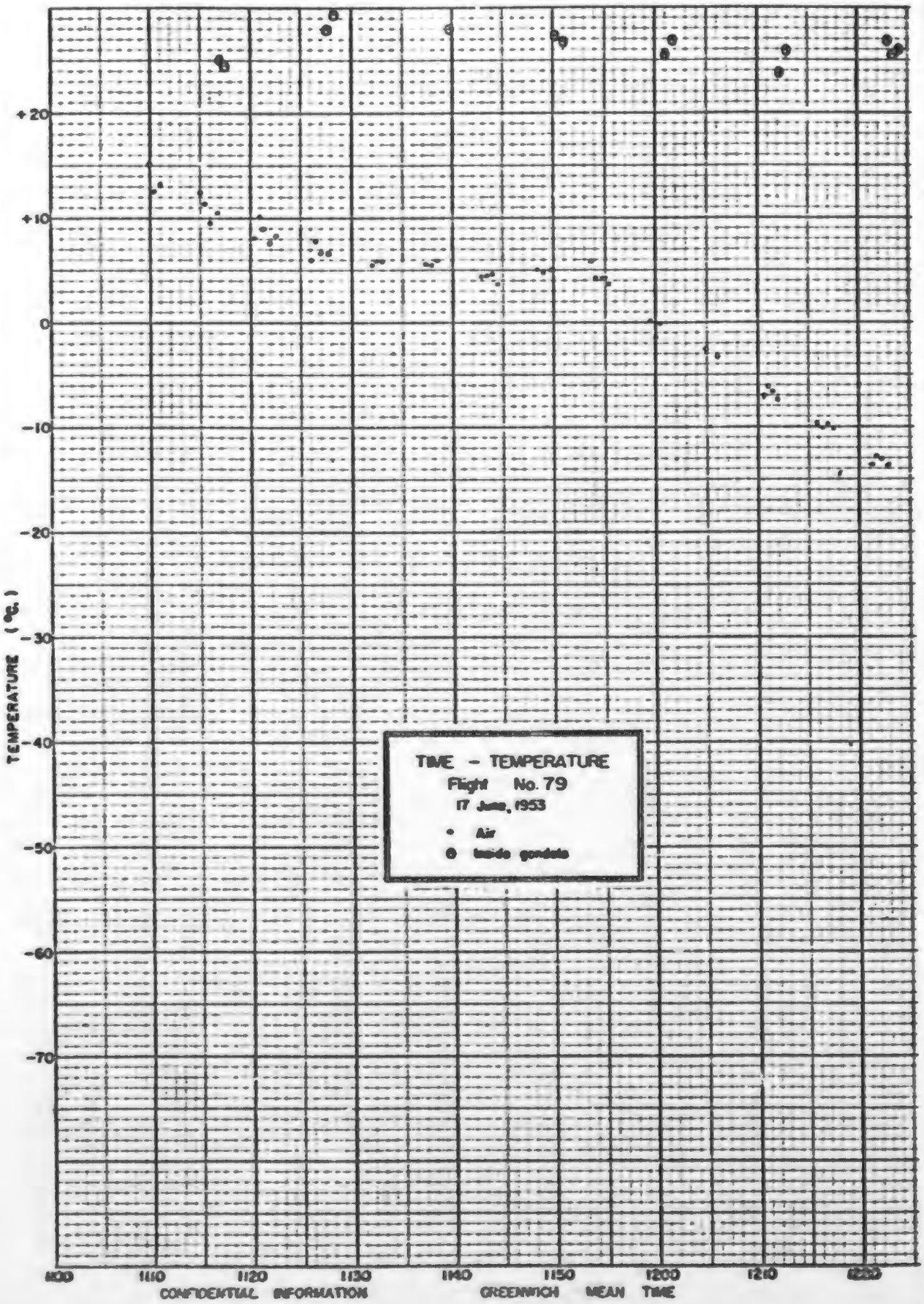

1530
1540
1550
1600
1610
1620
1630
1640

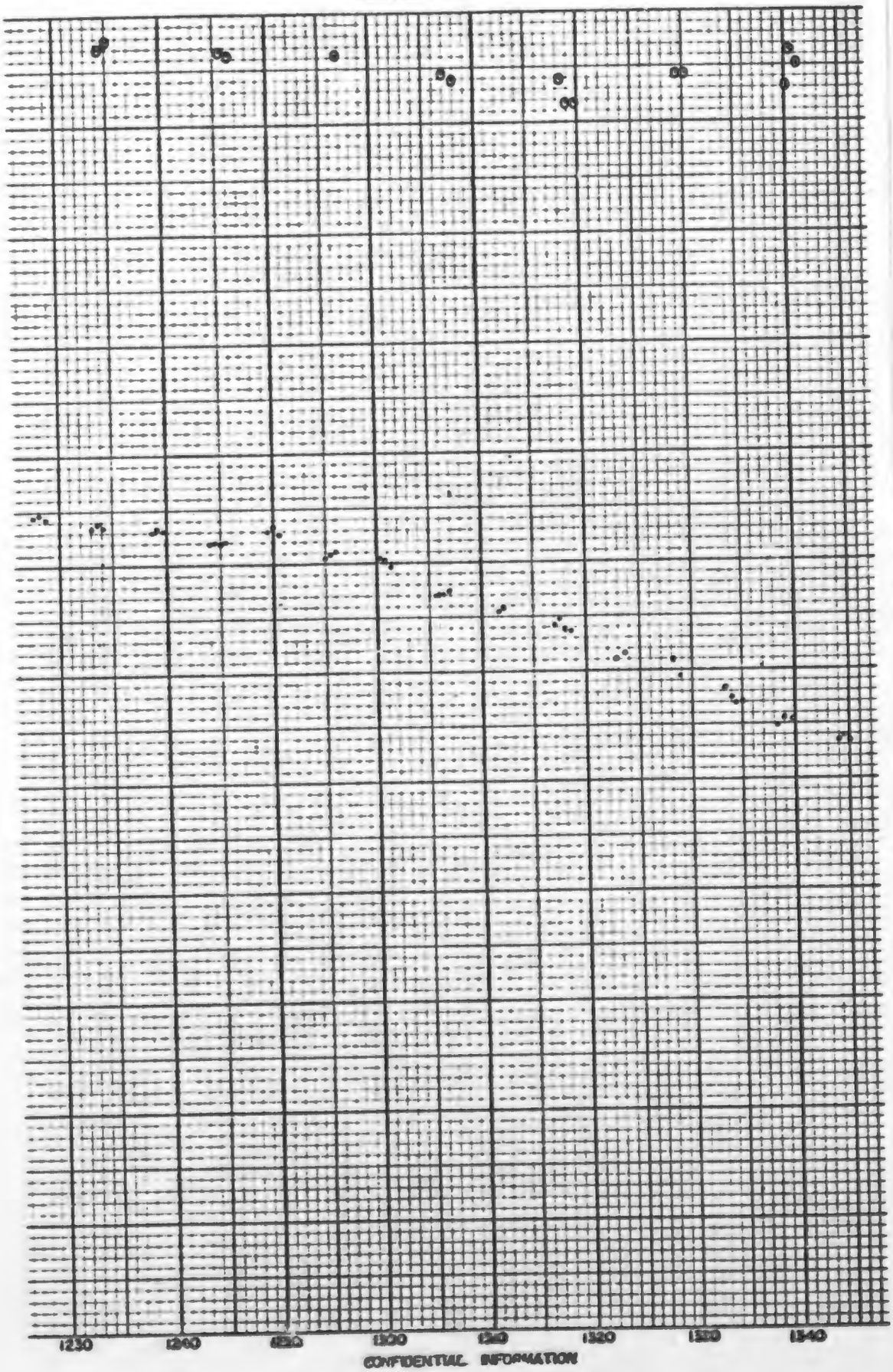

20
10
0
-10
-20
-30
-40
-50
-60
-70
1690
1700
1710
1720
1730
1740
1750
1800

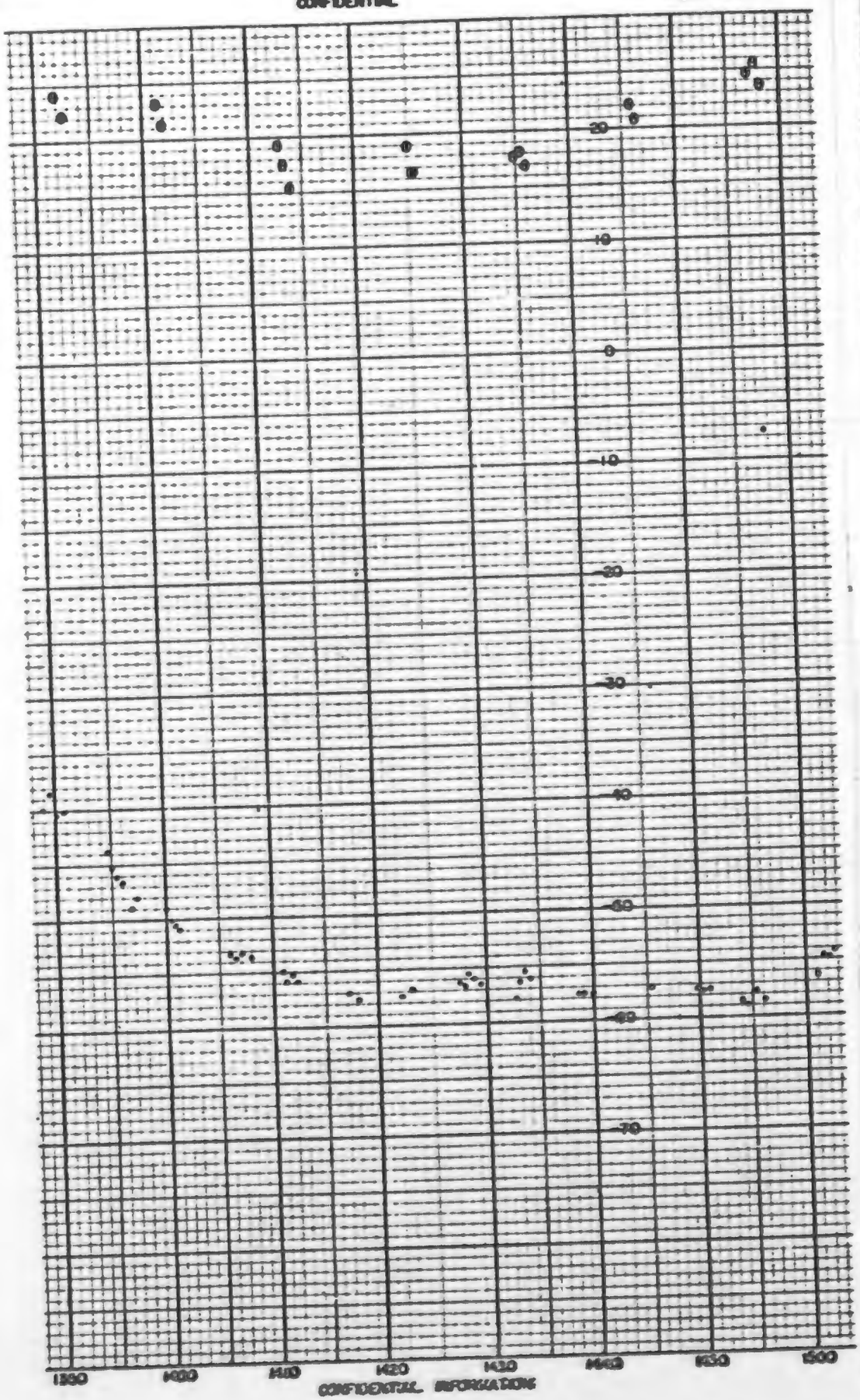

TIME - TEMPERATURE
Flight No. 79
17 June, 1953
Air
Inside gondola
TEMPERATURE (°C.)
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
1100
1110
1120
1130
1140
1150
1200
1210
1220
GREENWICH MEAN TIME

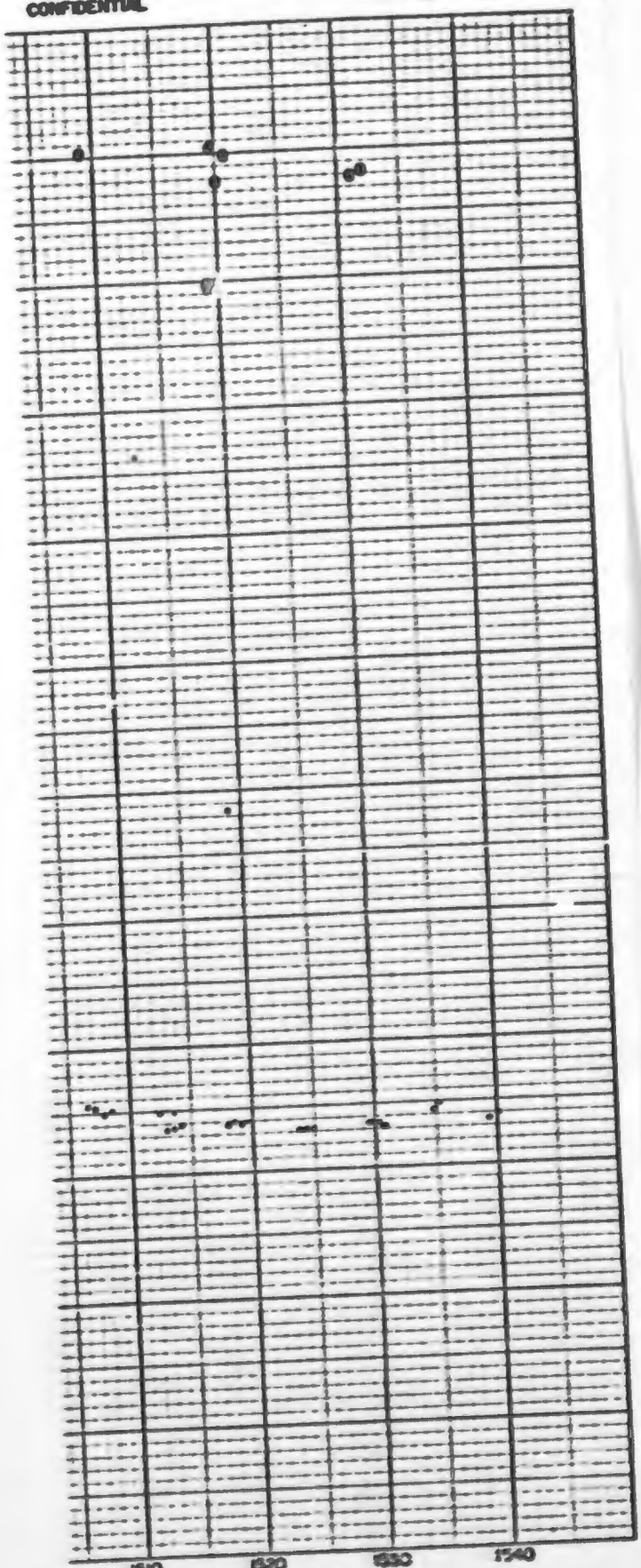
CONFIDENTIAL

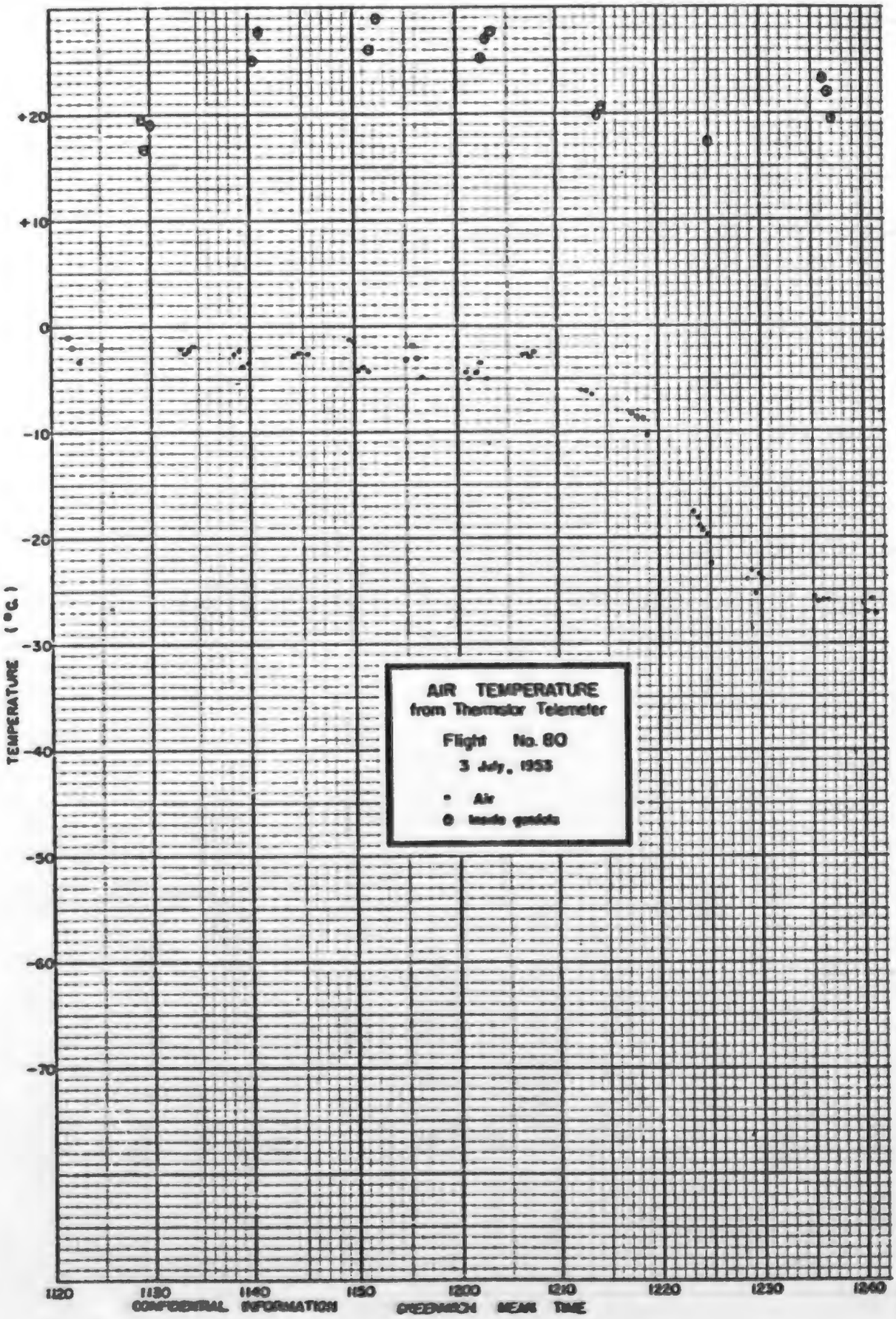


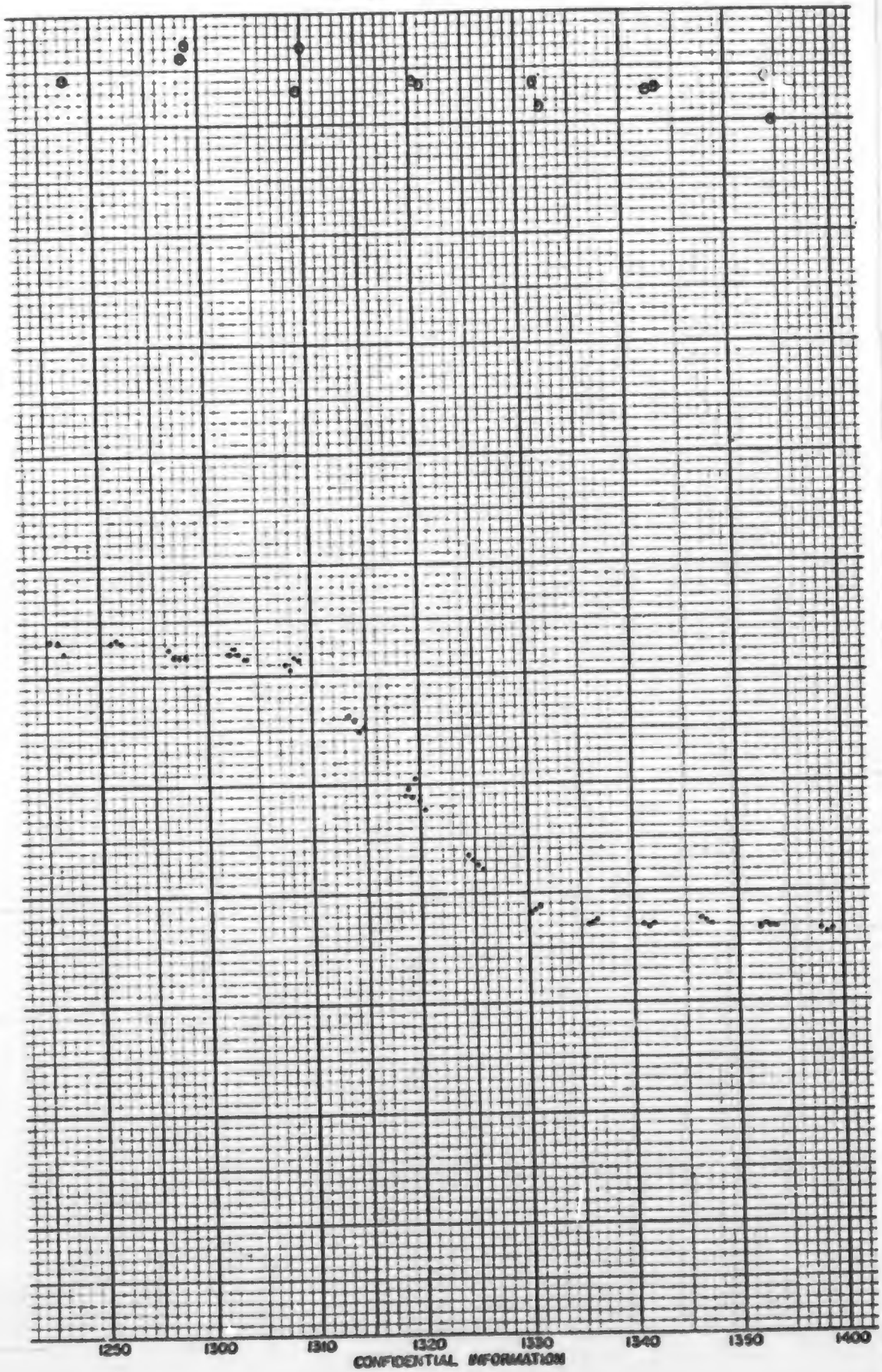

TIME - TEMPERATURE
Flight No. 79
17 June, 1953
• Air
⊙ Inside gondola
TEMPERATURE (°C.)
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
1100
1110
1120
1130
1140
1150
1200
1210
1220
GREENWICH MEAN TIME

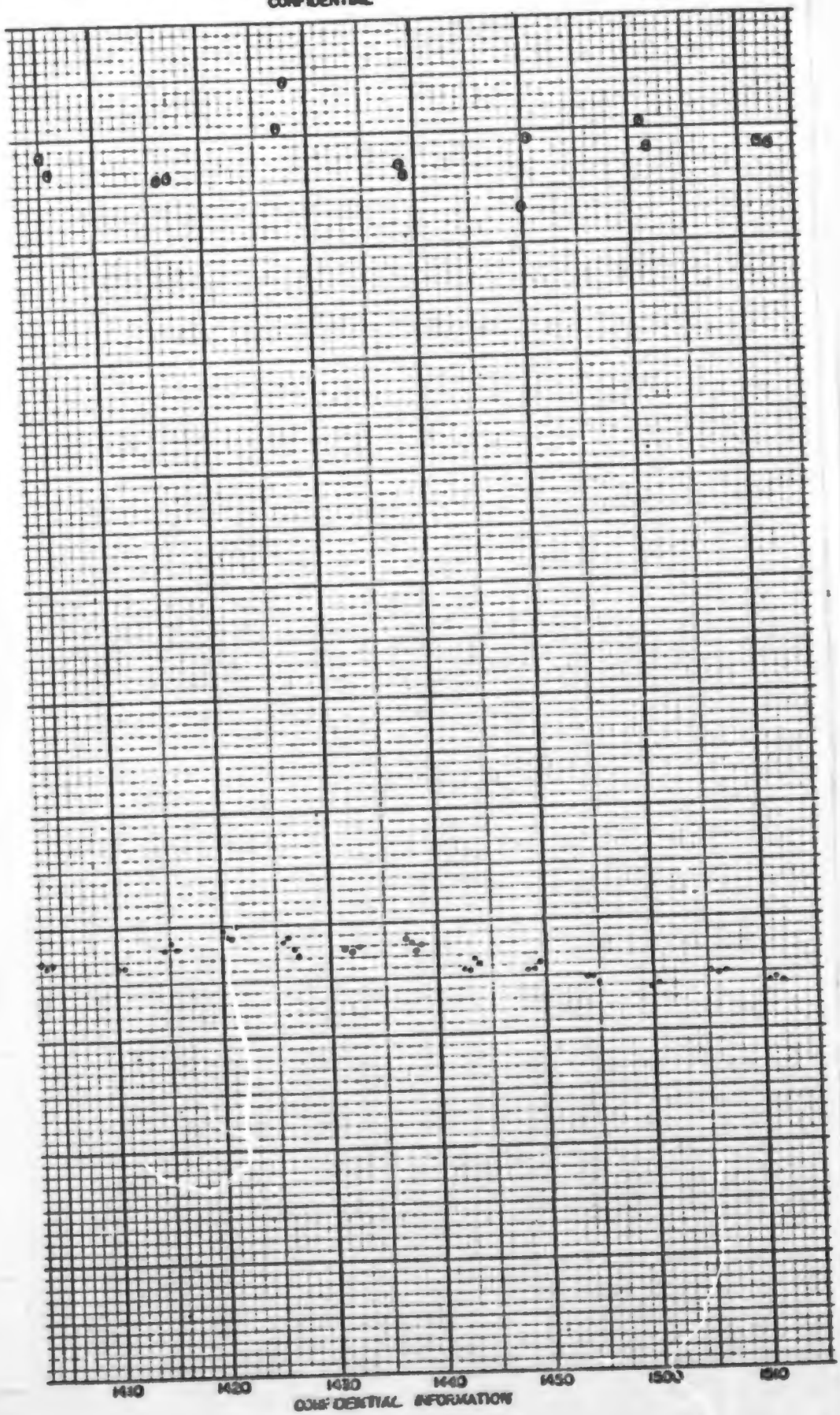

1230
1240
1250
1300
1310
1320
1330
1340

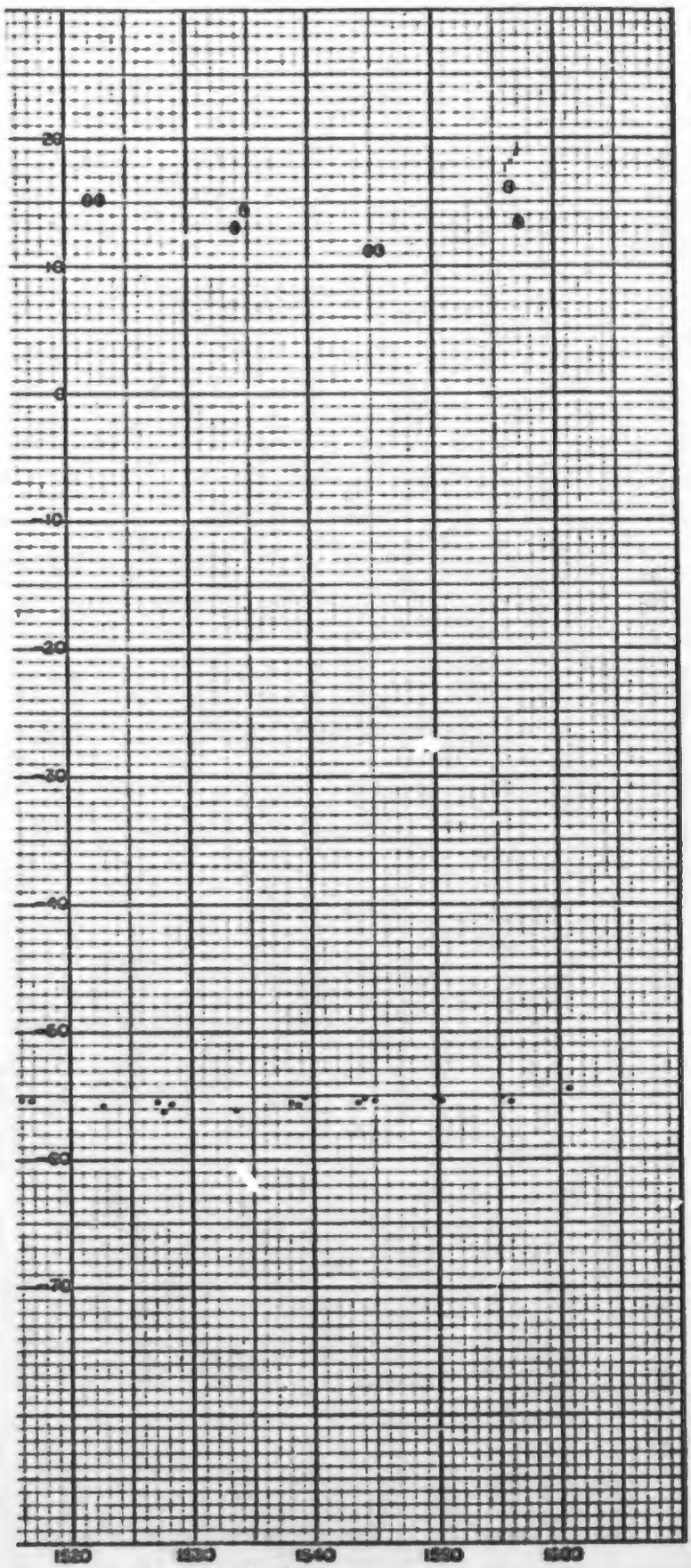

20
10
0
-10
-20
-30
-40
-50
-60
-70
1390
1400
1410
1420
1430
1440
1450
1500

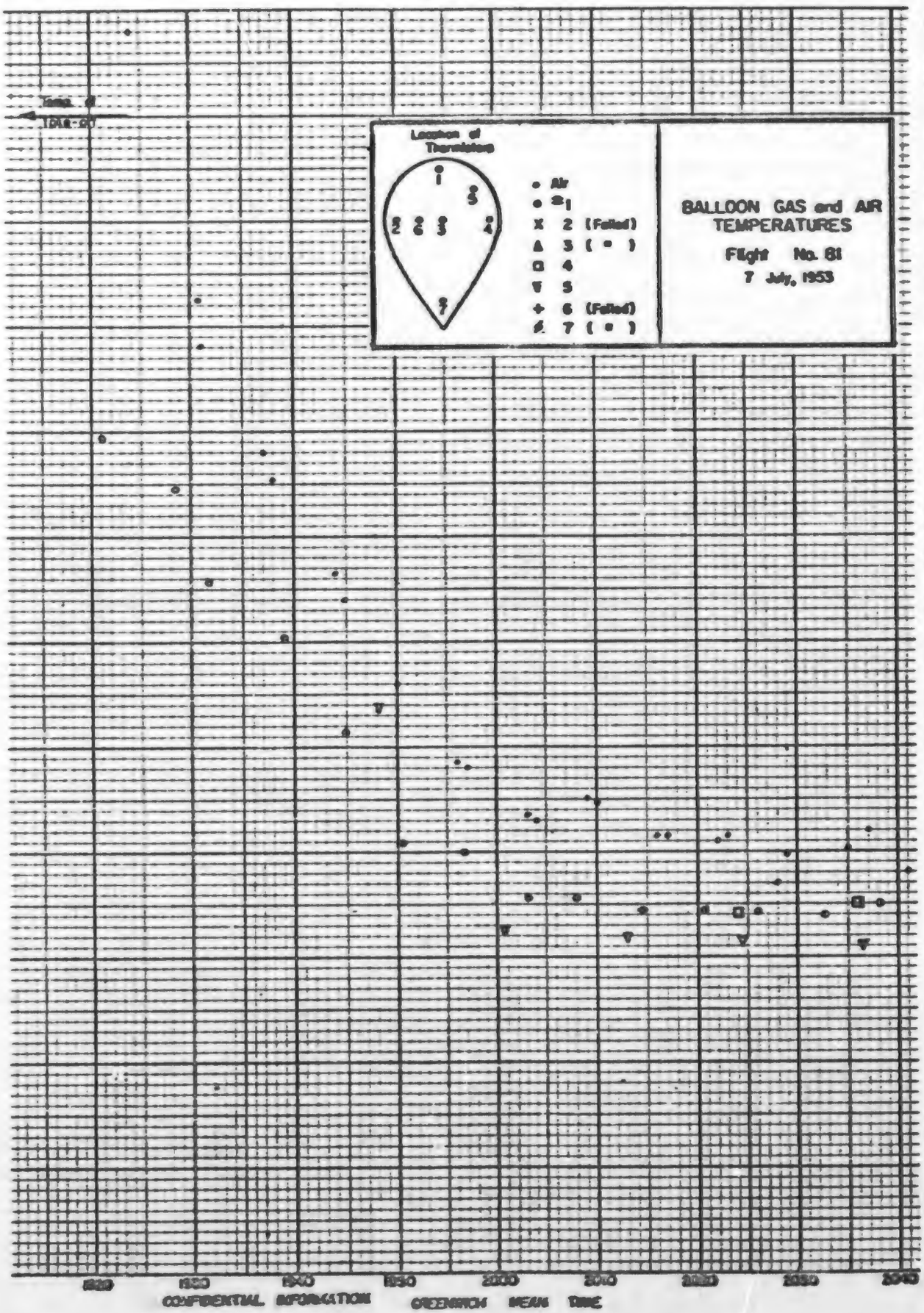

1510
1520
1530
1540

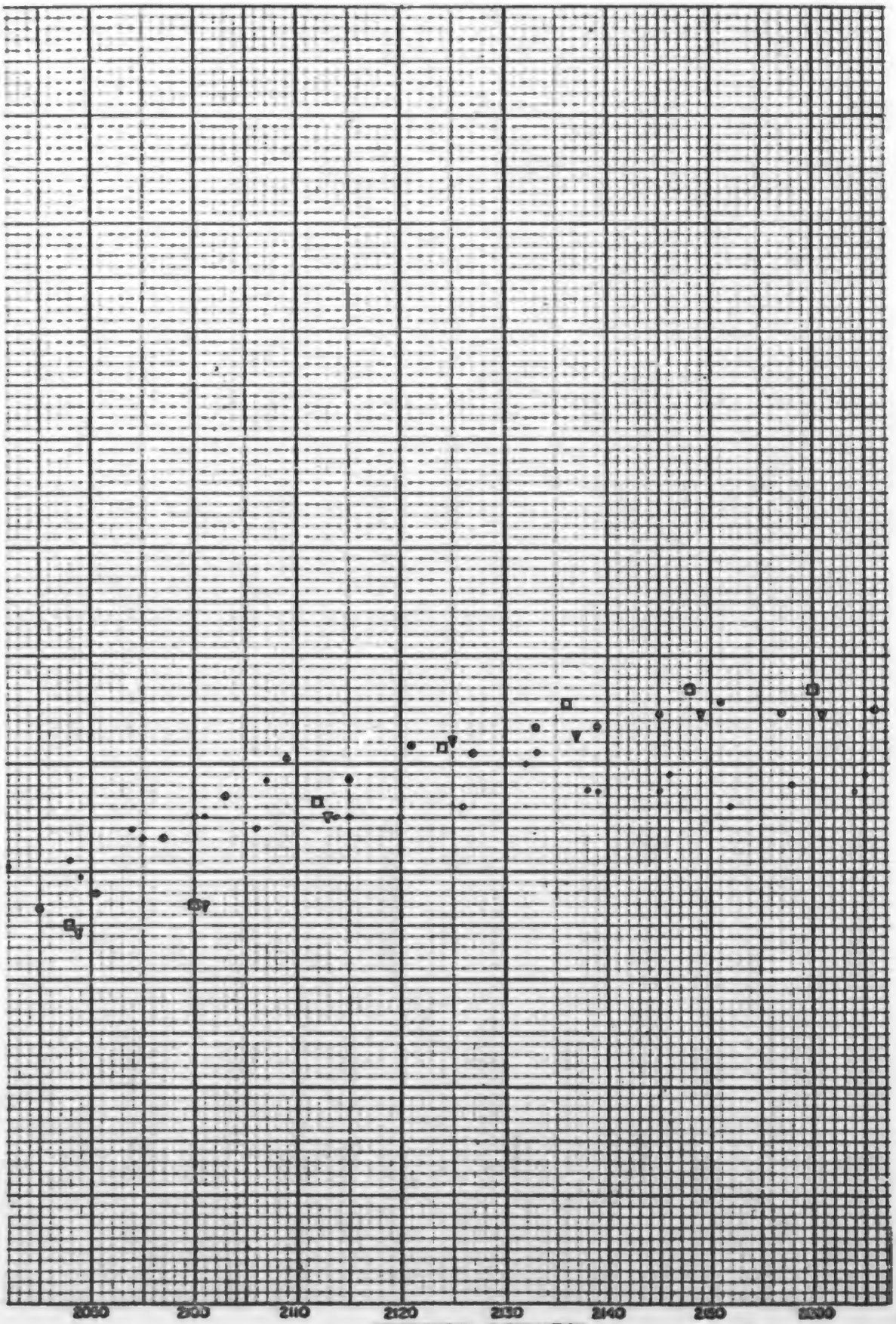

AIR TEMPERATURE
from Thermistor Telemeter
Flight No. 80
3 July, 1953
• Air
⊖ Inside gondola
TEMPERATURE (°C.)
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
1120
1130
1140
1150
1200
1210
1220
1230
1240
GREENWICH MEAN TIME

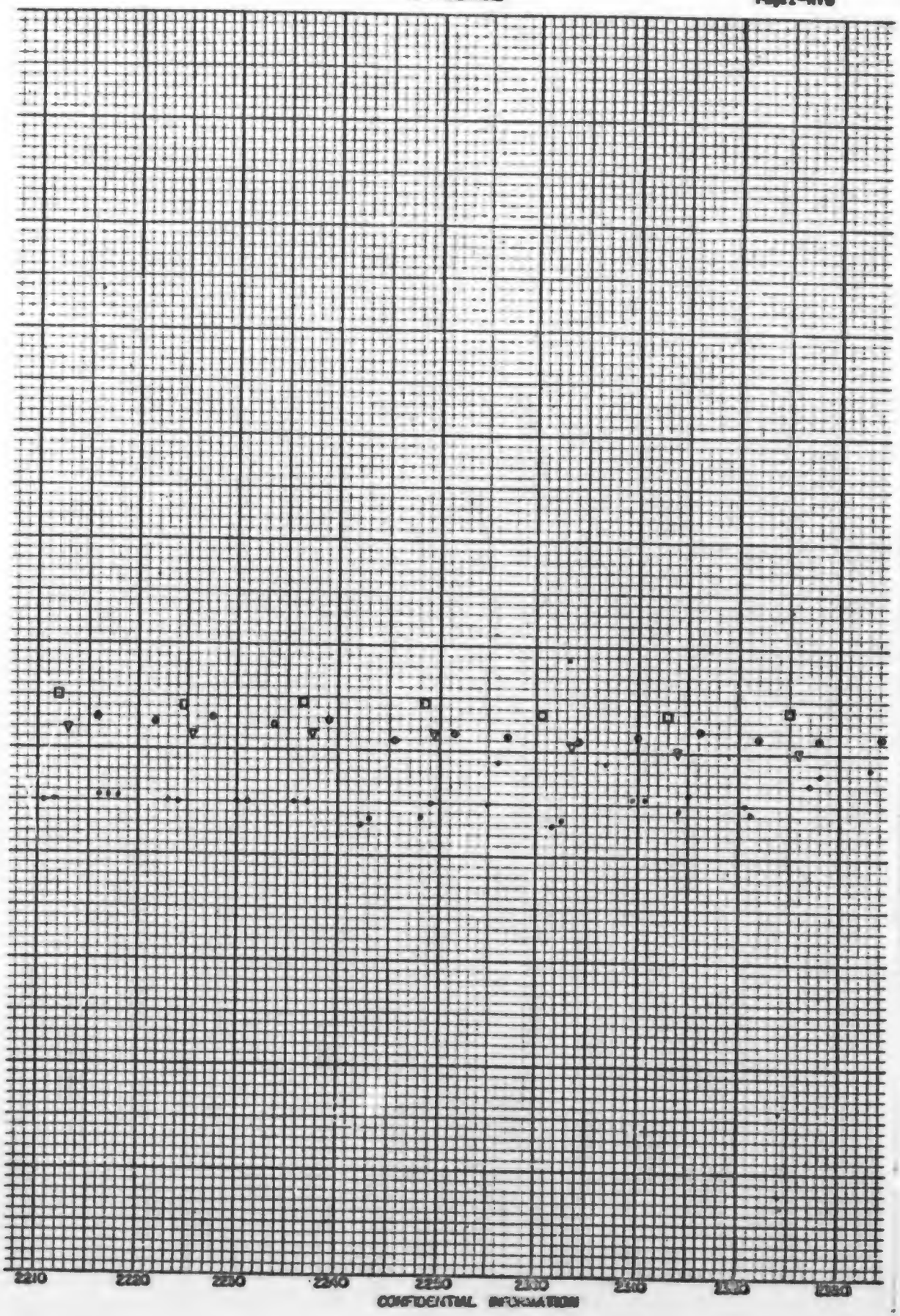

a
b
1250
1300
1310
1320
1330
1340
1350
1400

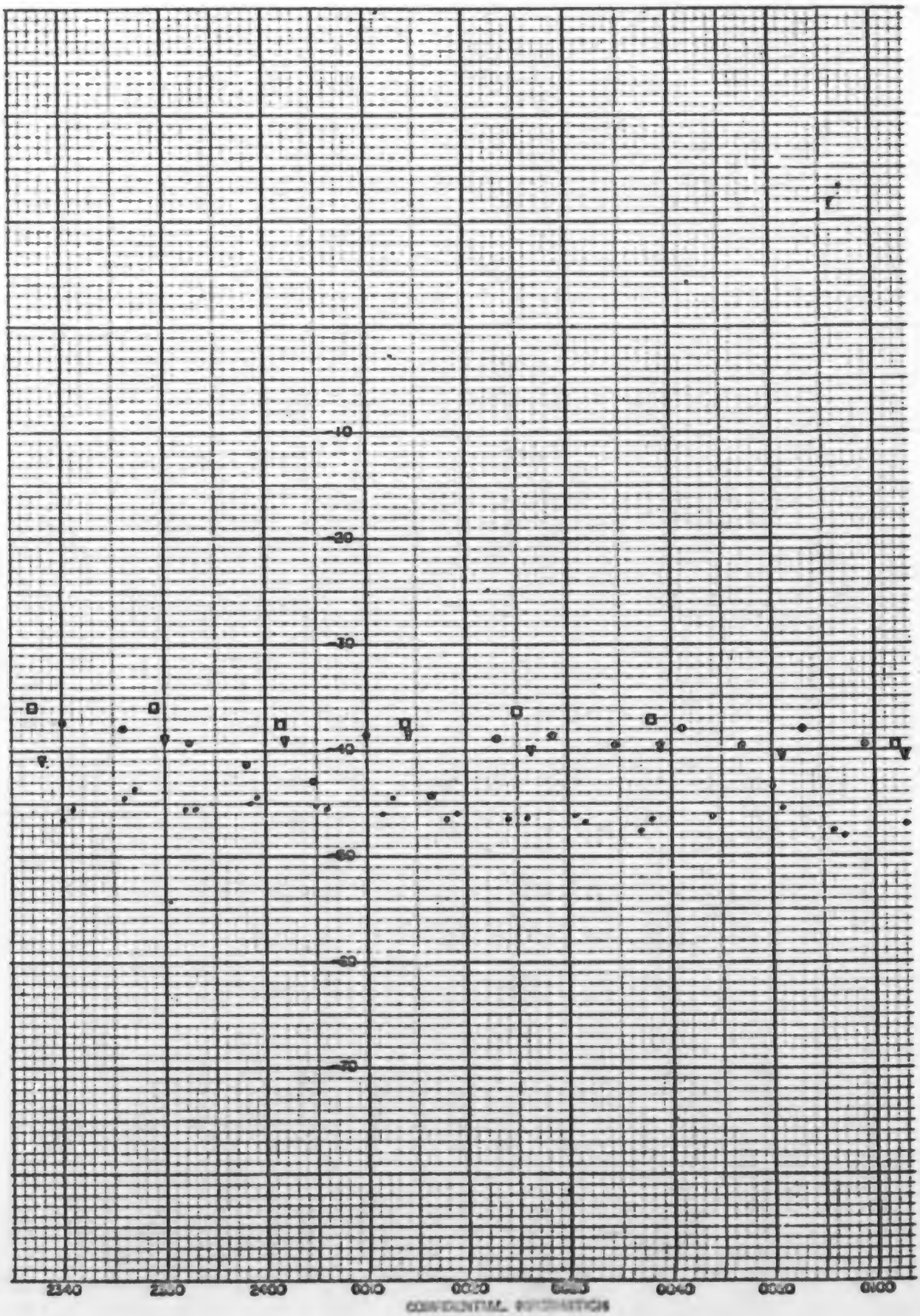

1410
1420
1430
1440
1450
1500
1510

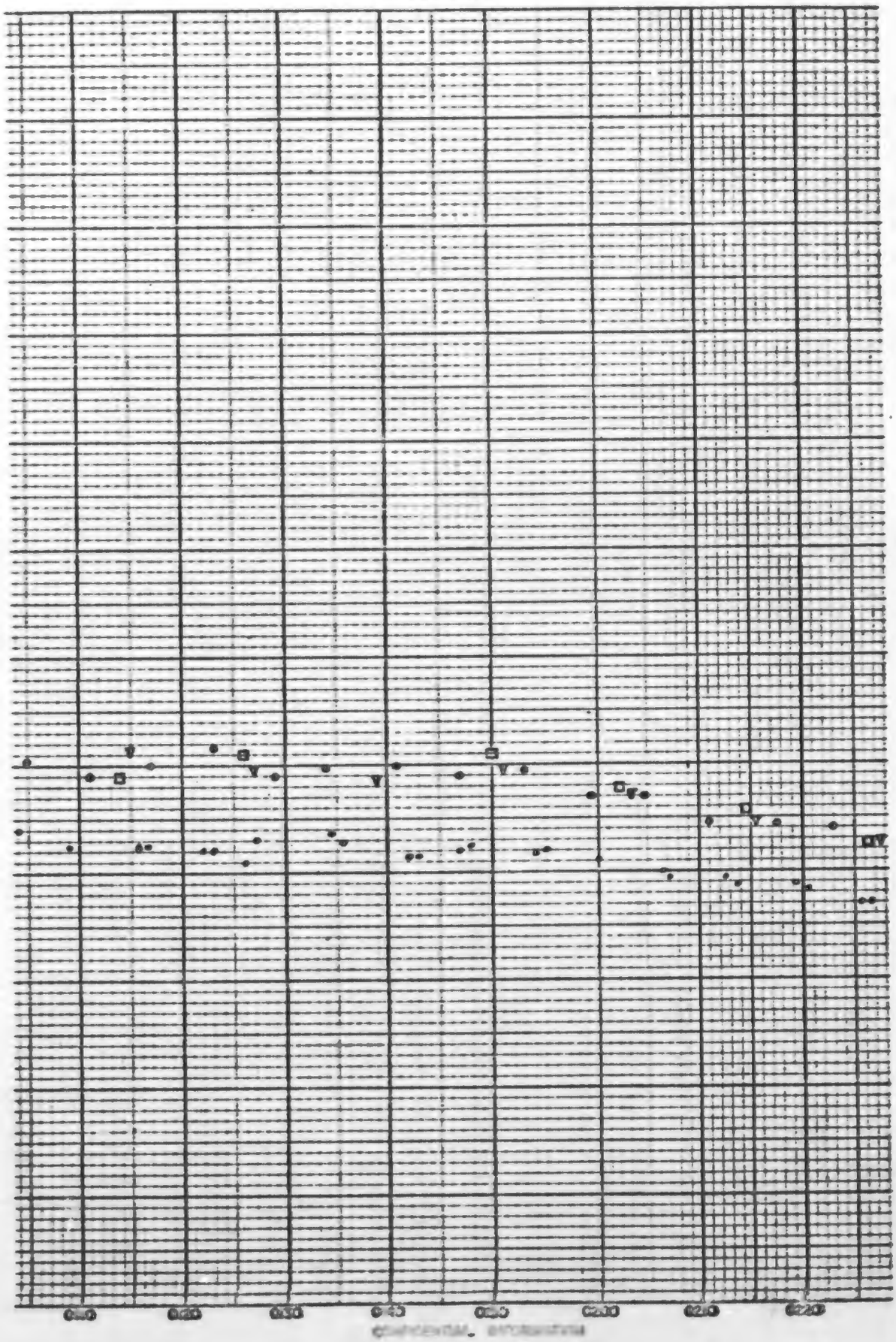

20
10
0
-10
-20
-30
-40
-50
-60
-70
1520
1530
1540
1550
1560

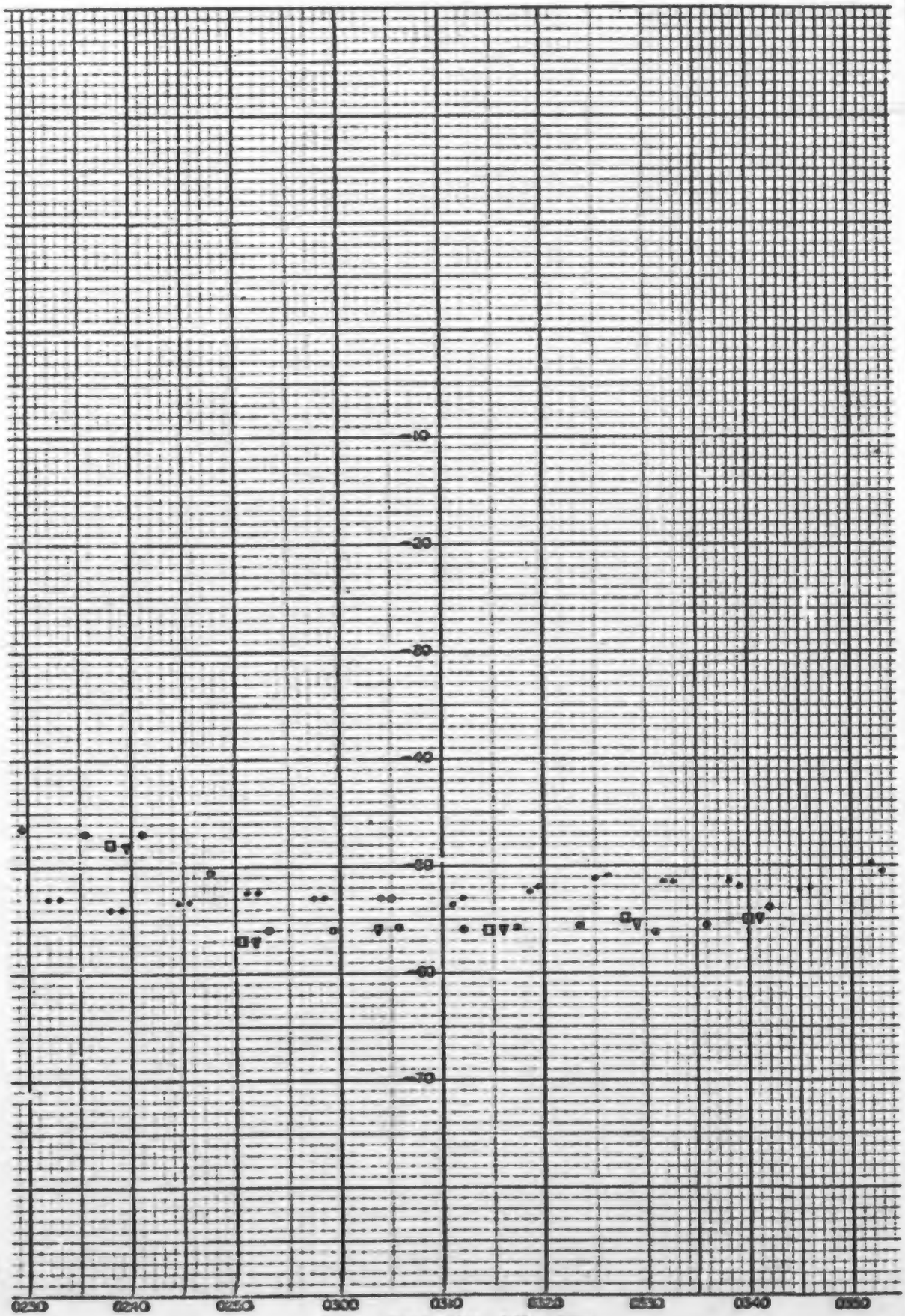

Location of Thermistors
1
2
3
4
5
6
7
• Air
• 1
X 2 (Failed)
Δ 3 (")
□ 4
∇ 5
+ 6 (Failed)
7 (")
BALLOON GAS and AIR TEMPERATURES
Flight No. 81
7 July, 1953
1920
1930
1940
1950
2000
2010
2020
2030
2040
CONFIDENTIAL INFORMATION
GREENWICH MEAN TIME

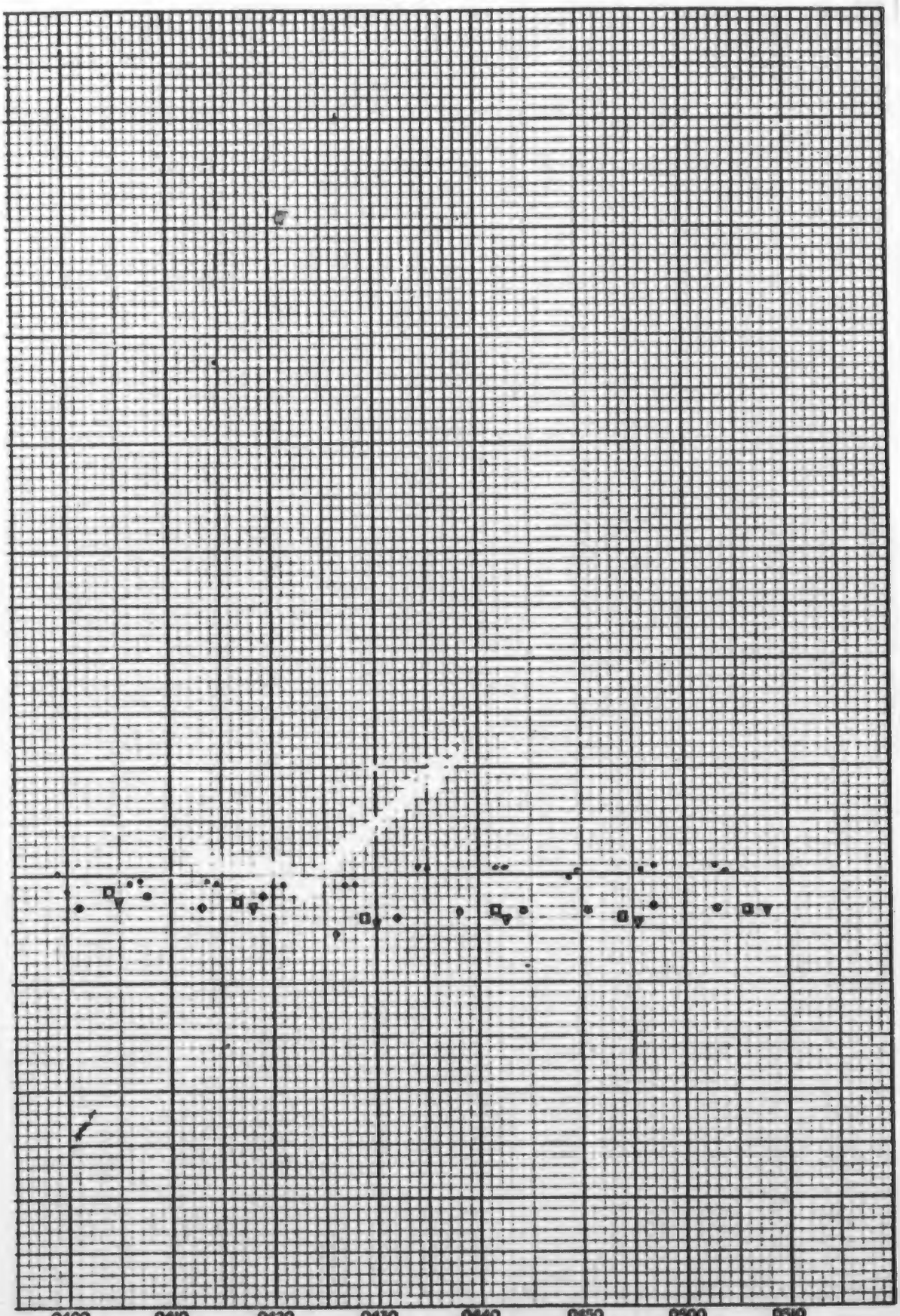

2050
2100
2110
2120
2130
2140
2150
2200

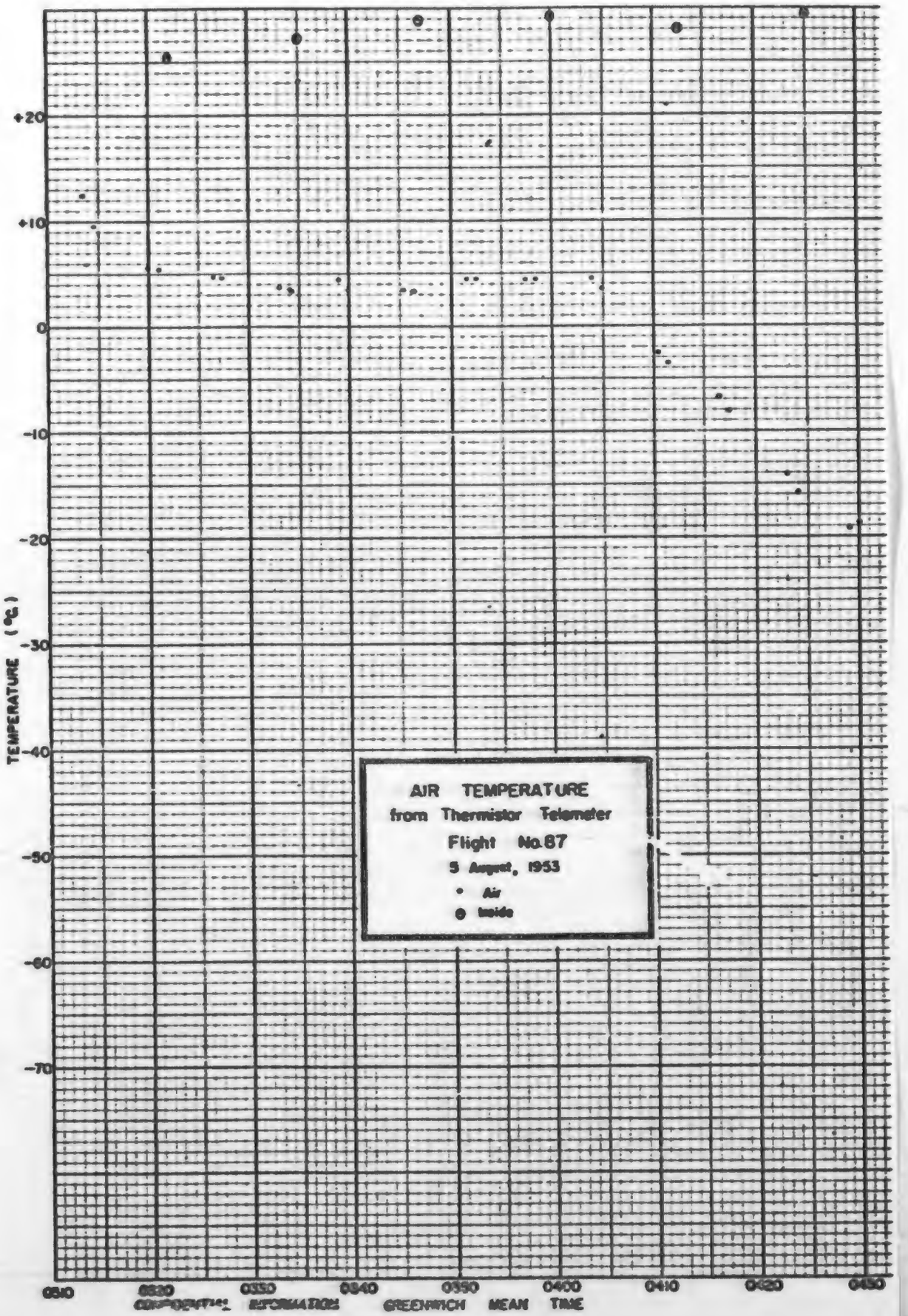

2210
2220
2230
2240
2250
2260
2270
2280
2290

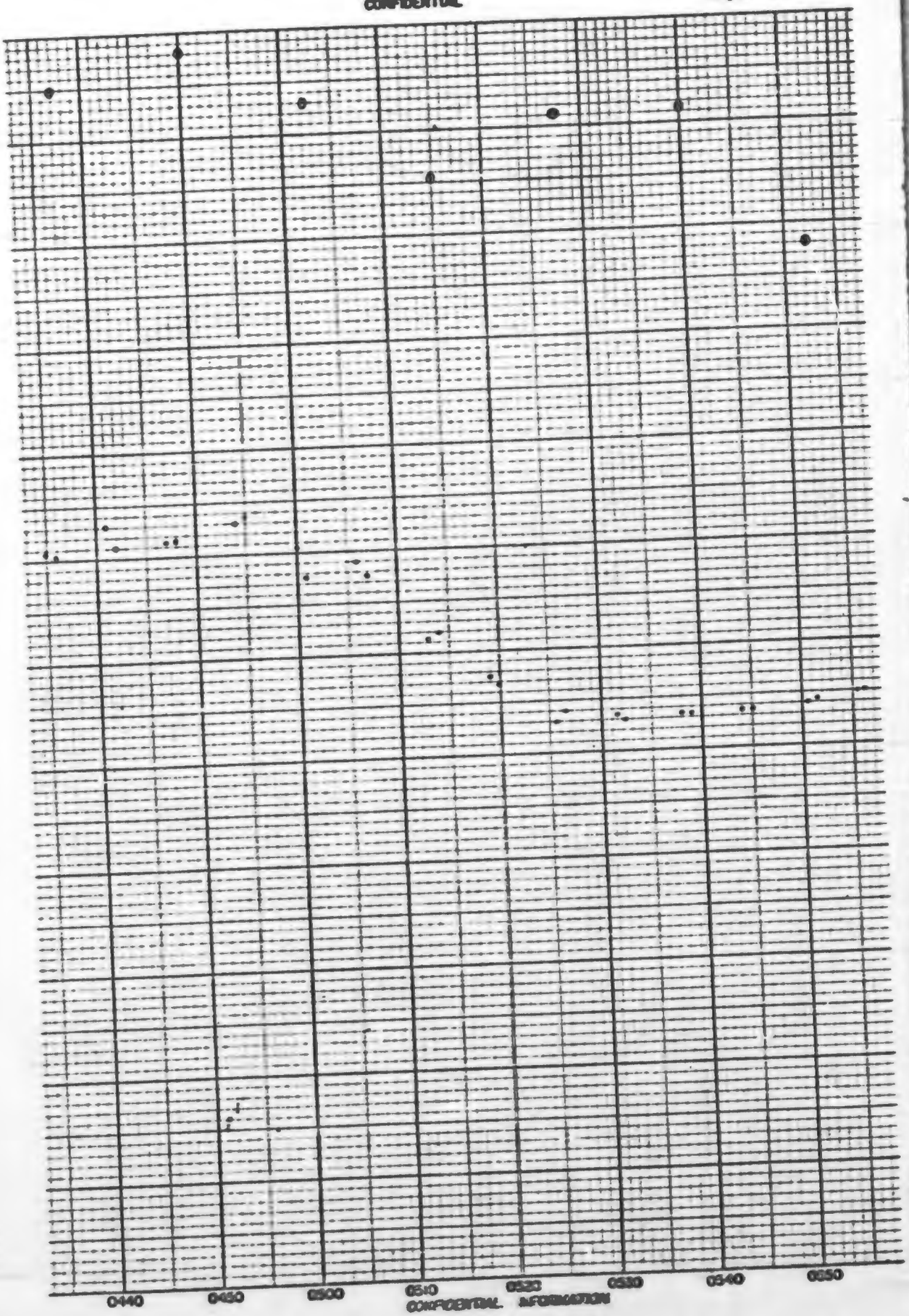

-10
-20
-30
-40
-50
-60
-70
2340
2400
2400
0010
0020
0030
0040
0050
0100

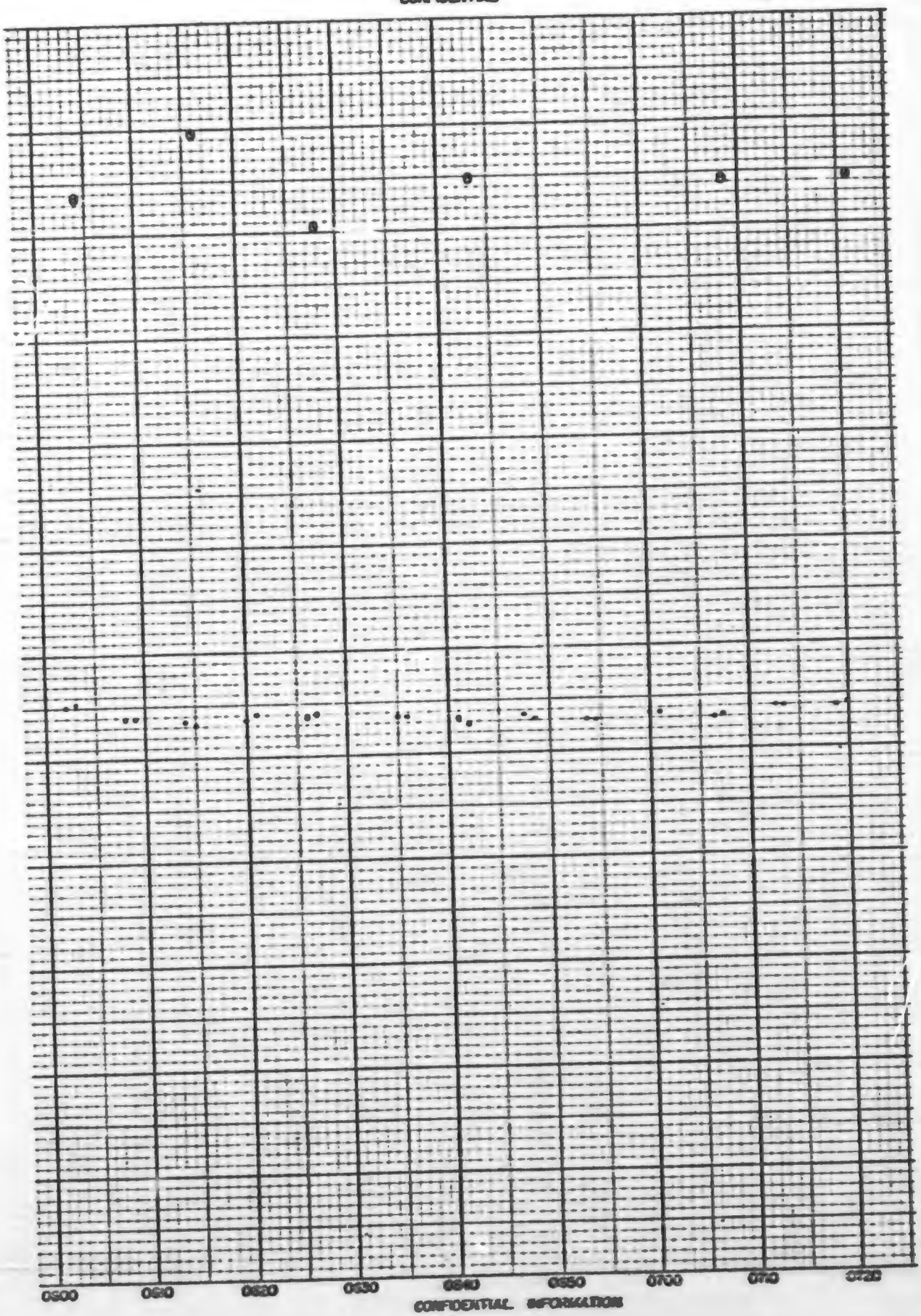


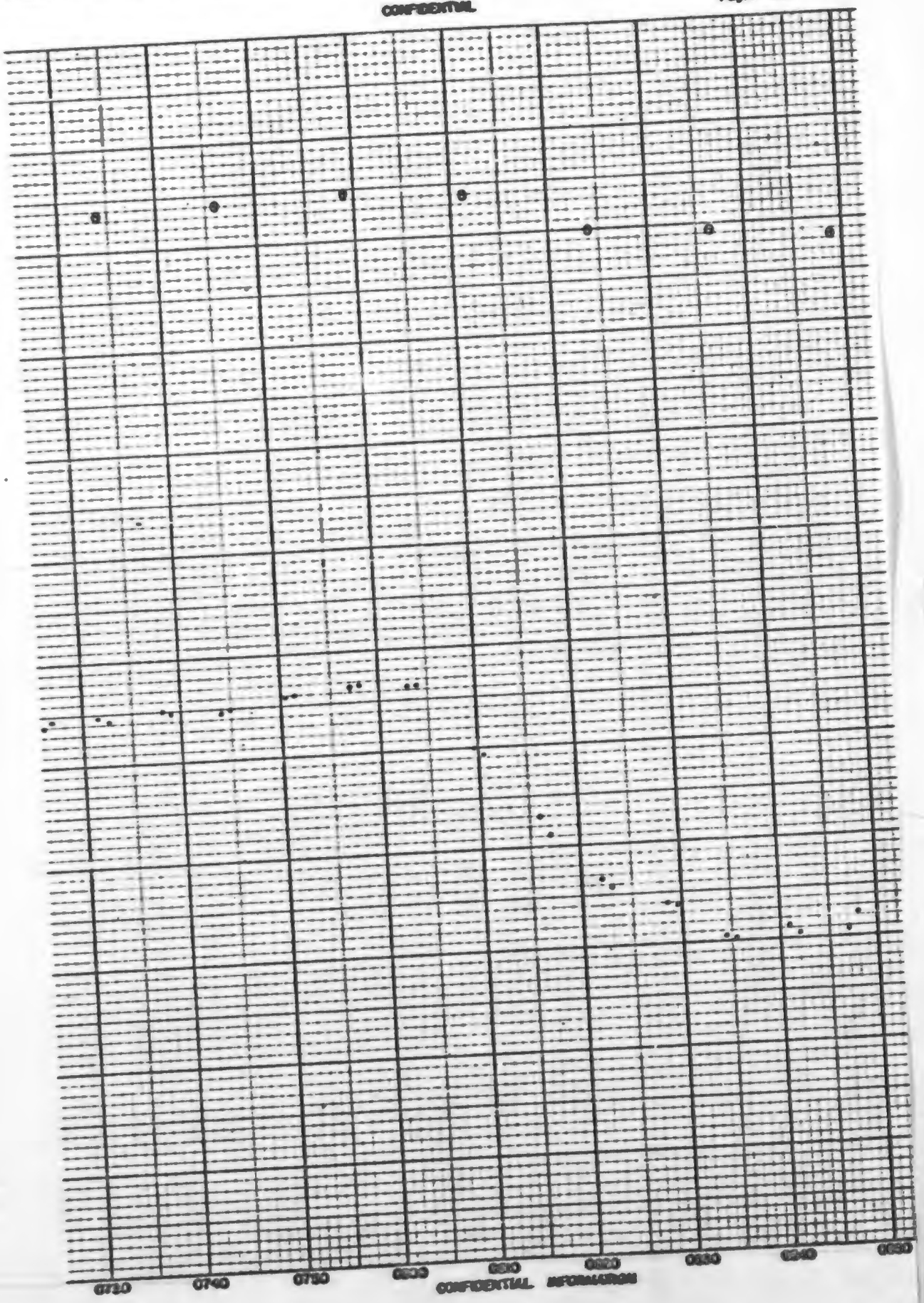

-10
-20
-30
-40
-50
-60
-70
0230
0240
0250
0300
0310
0320
0330
0340
0350

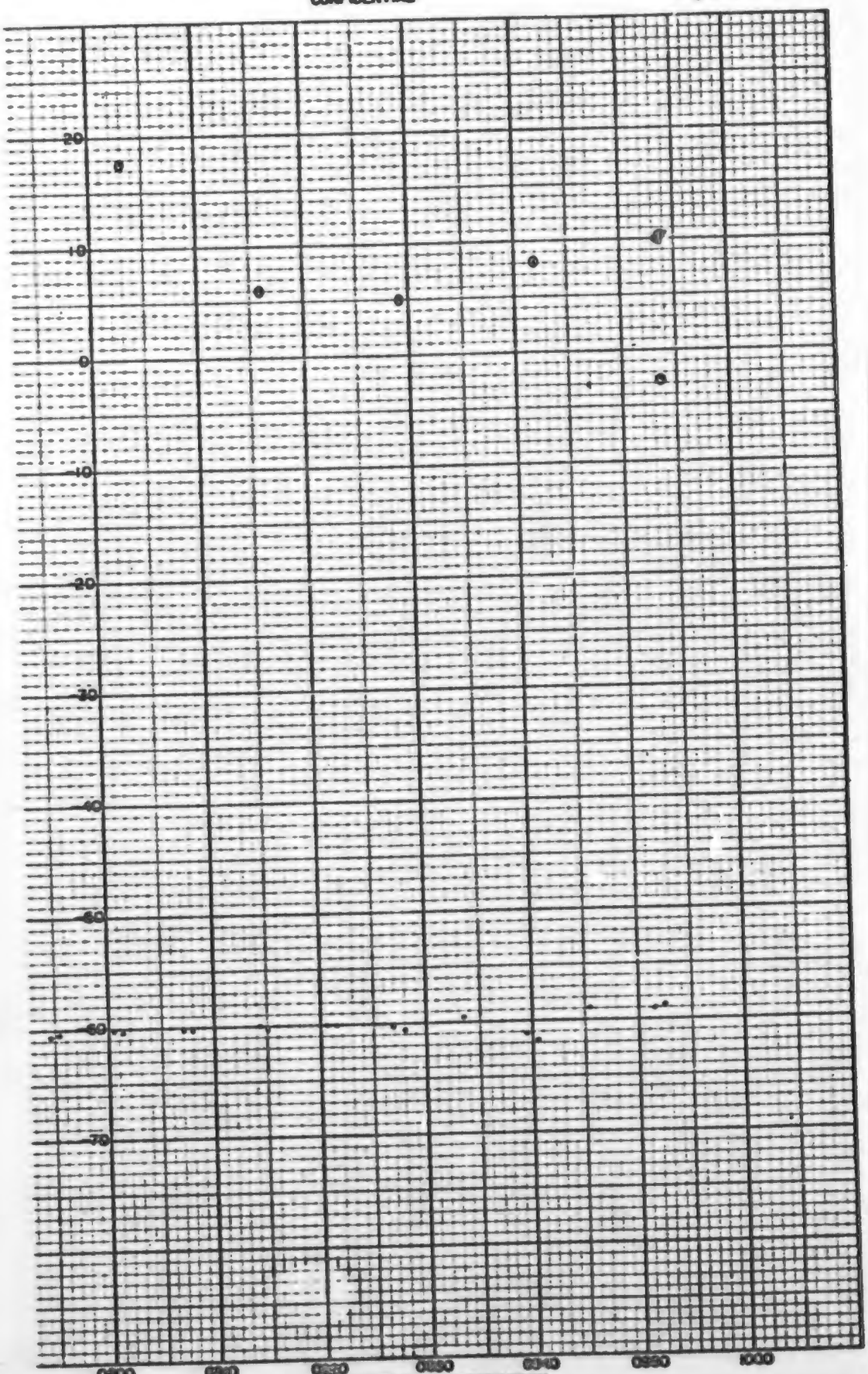

0400
0410
0420
0430
0440
0450
0500
0510

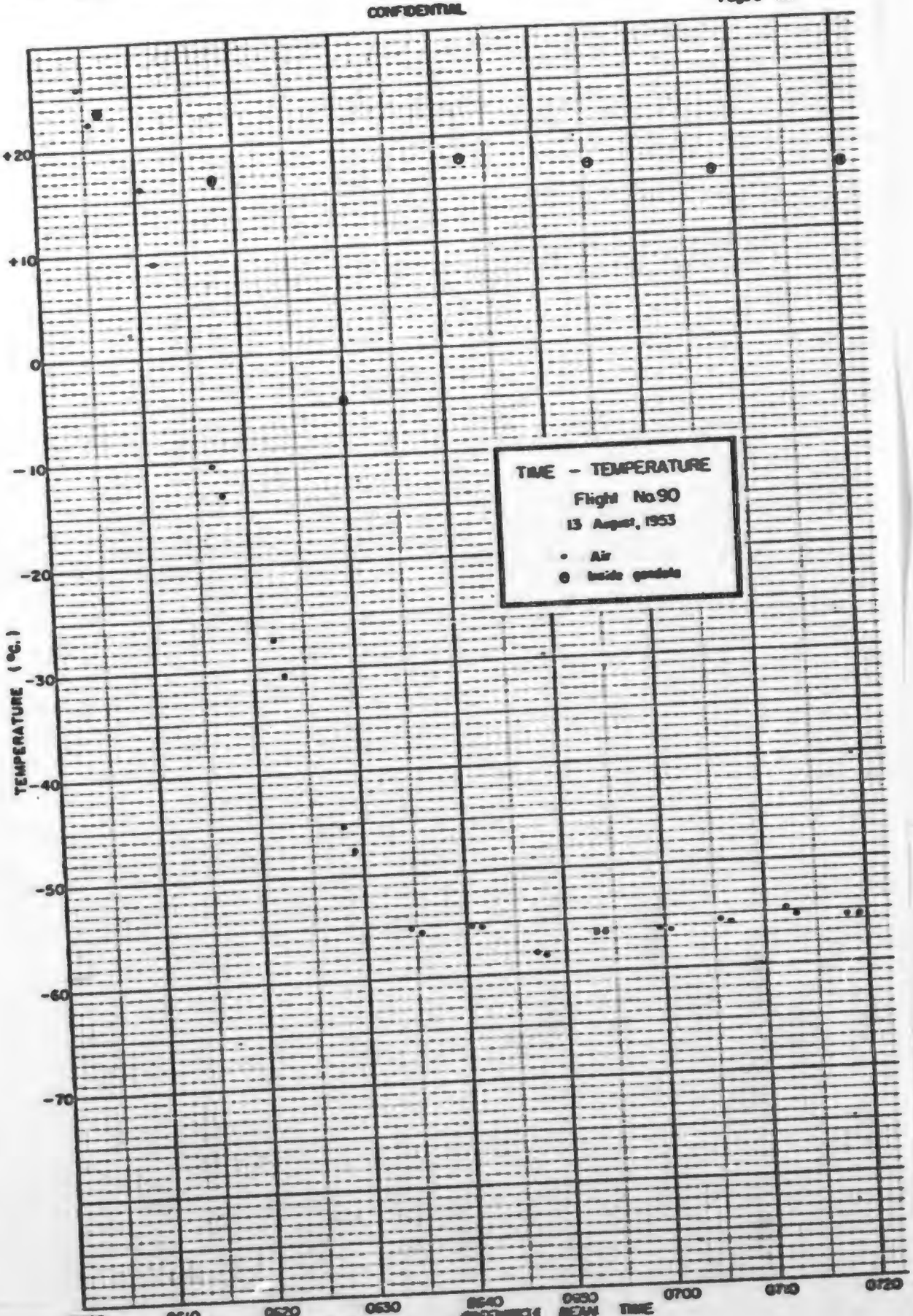

AIR TEMPERATURE
from Thermistor Telemeter
Flight No. 87
5 August, 1953
• Air
⊖ Inside
TEMPERATURE (°C.)
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
0310
0320
0330
0340
0350
0400
0410
0420
0430
GREENWICH MEAN TIME

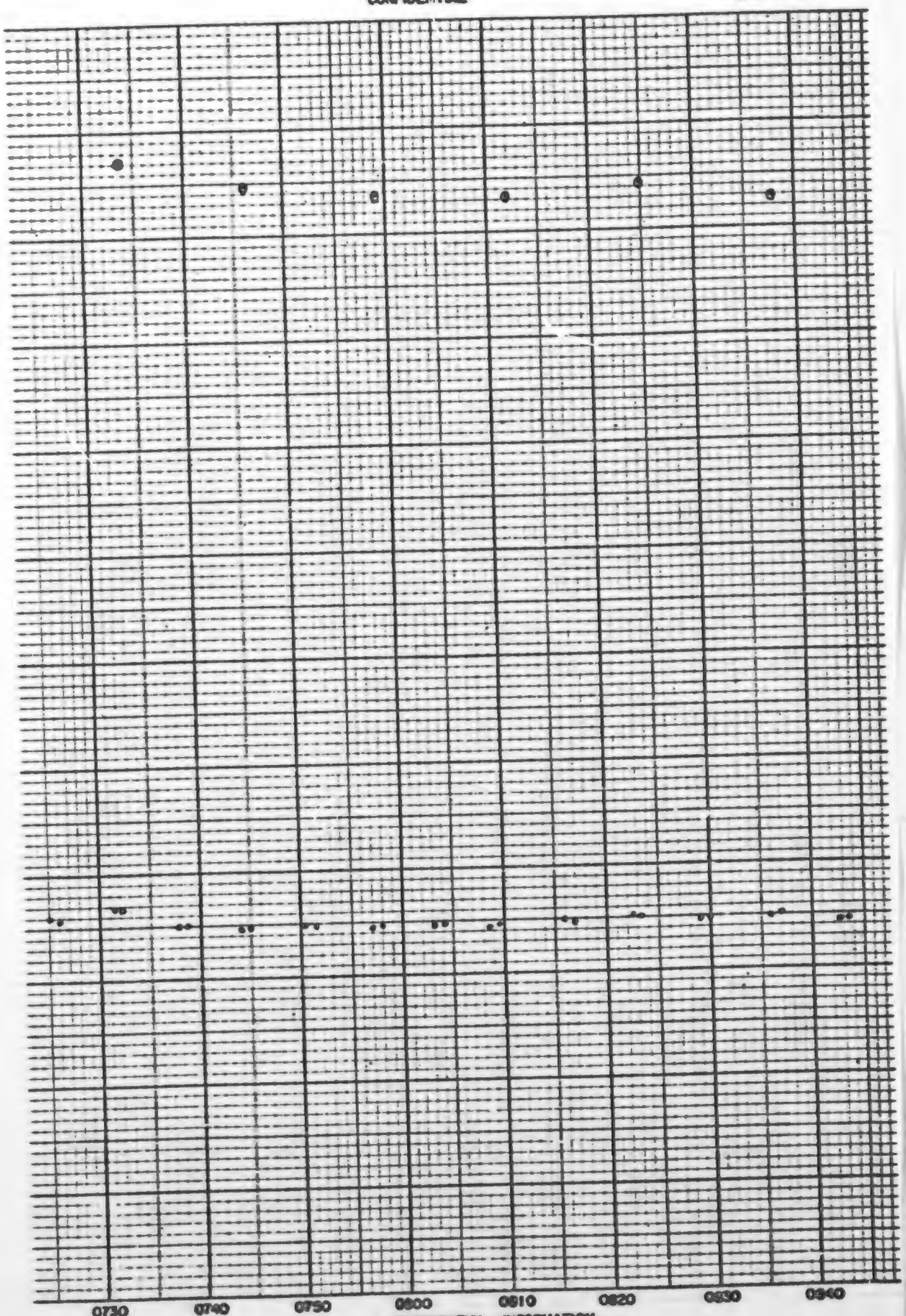

0440
0450
0500
0510
0520
0530
0540
0550

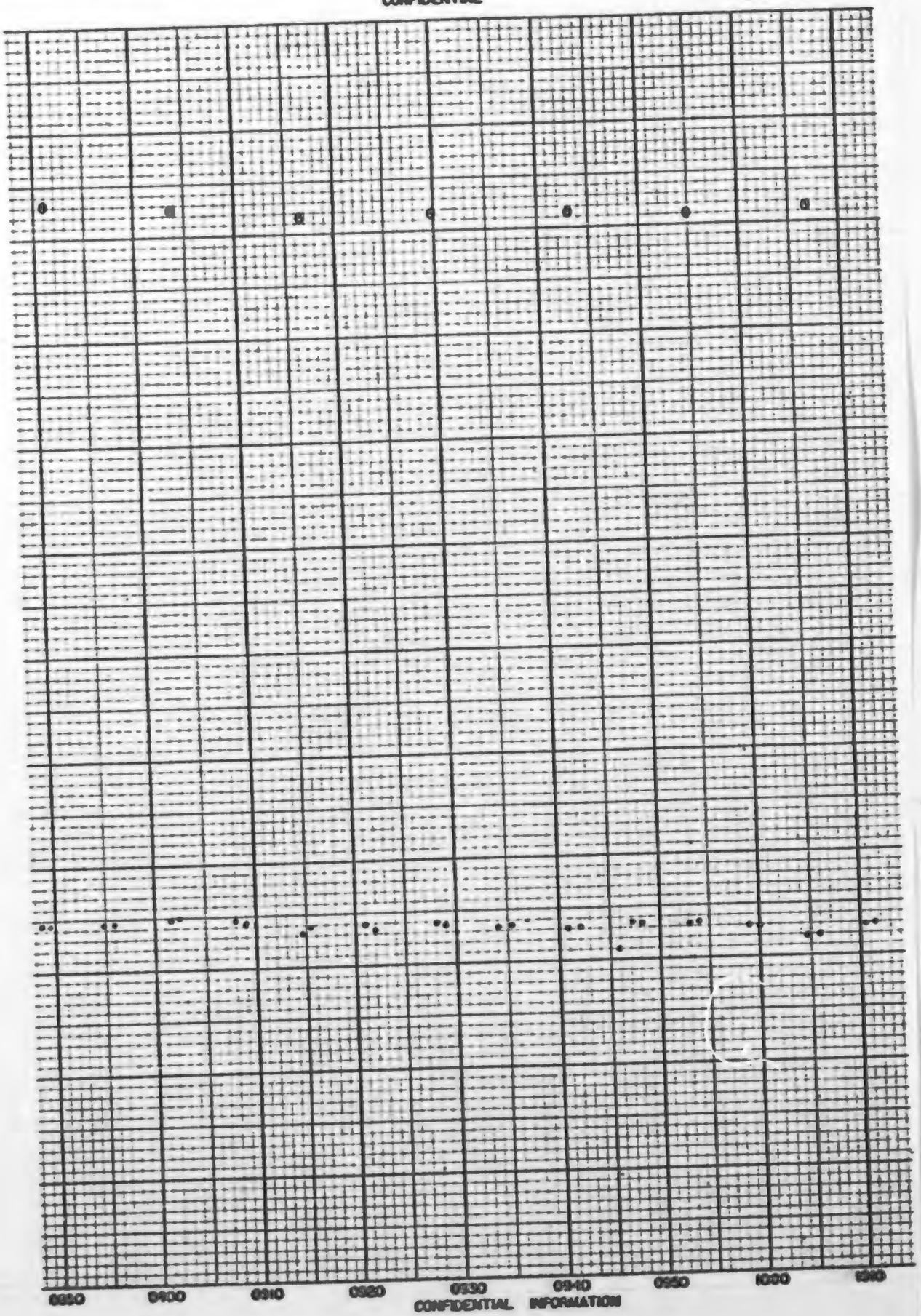

0500
0510
0520
0530
0540
0550
0700
0710
0720

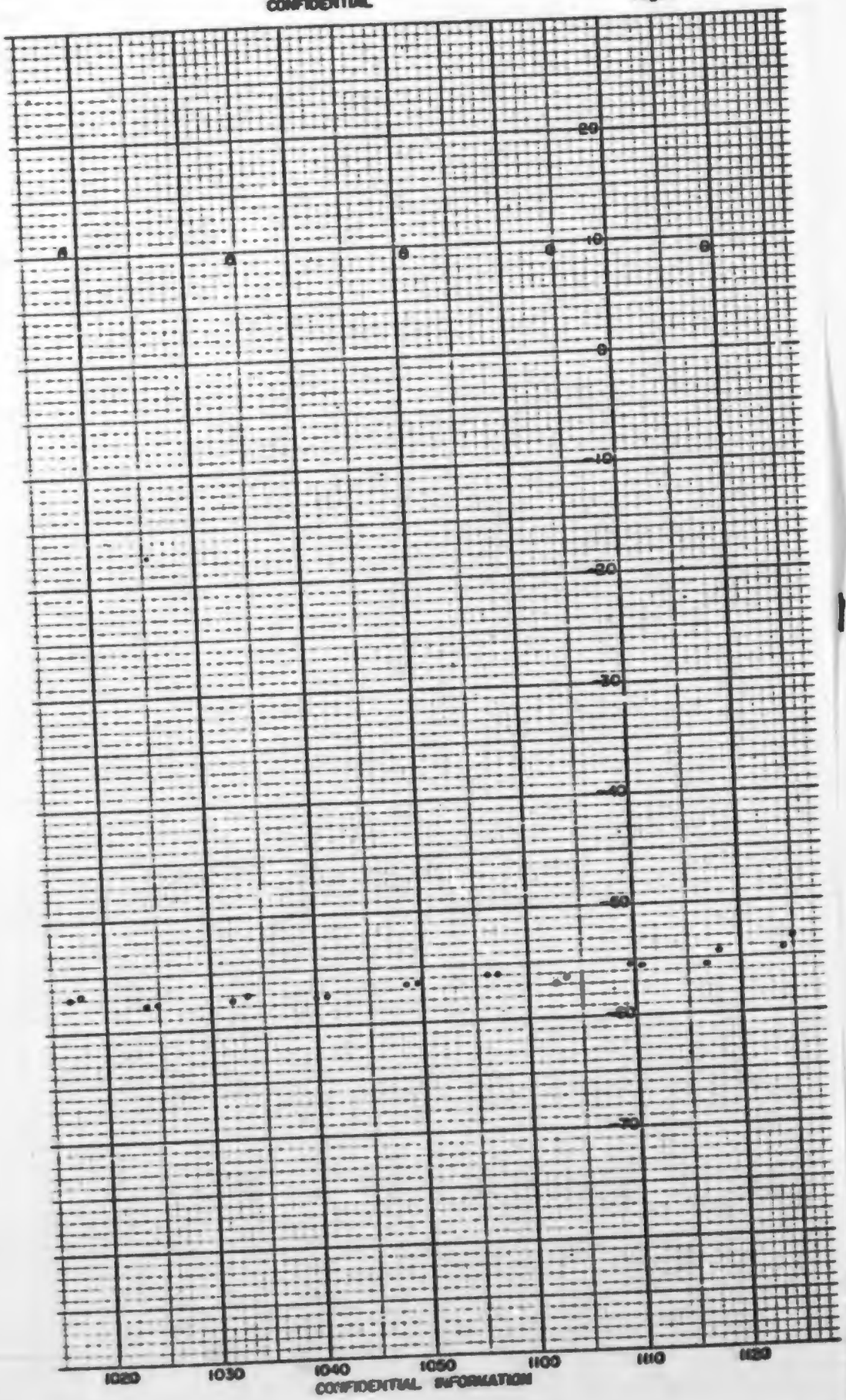

0720
0740
0760
0800
0820
0840
0860
CONFIDENTIAL
INFORMATION

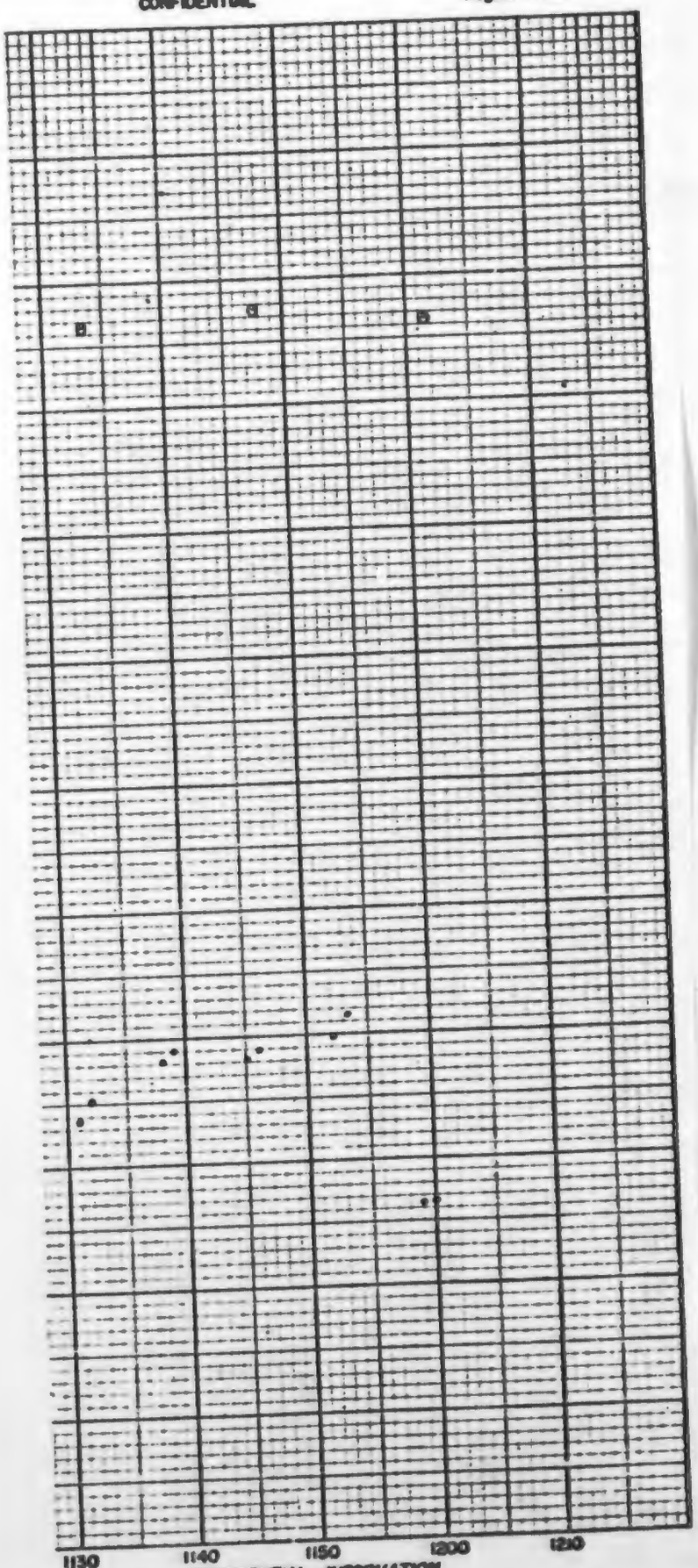

20
10
0
-10
-20
-30
-40
-50
-60
-70
0900
0910
0920
0930
0940
0950
1000

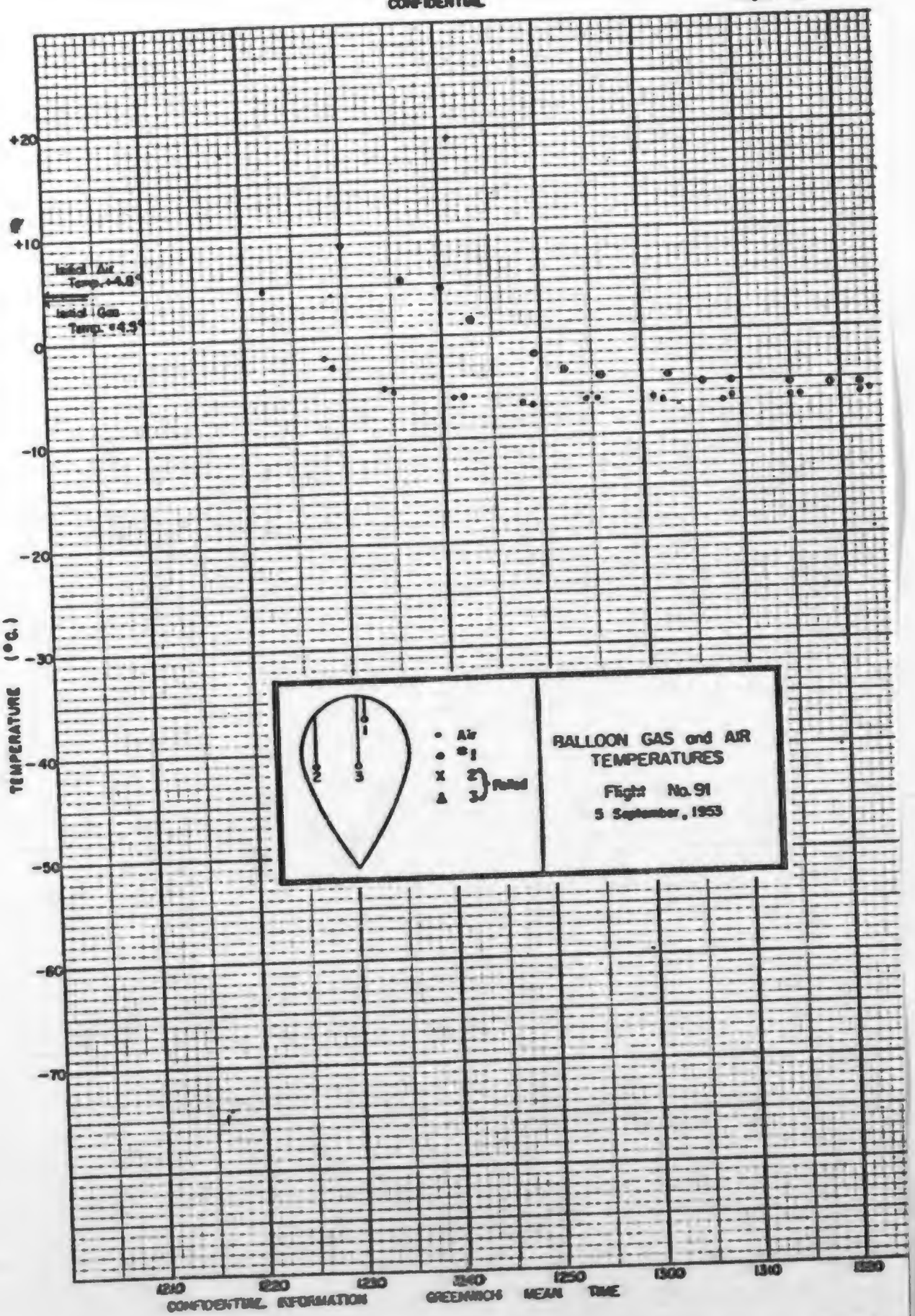

TIME - TEMPERATURE
Flight No. 90
13 August, 1953
• Air
⊖ Inside gondola
TEMPERATURE (°C.)
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
0600
0610
0620
0630
0640
0650
0700
0710
0720
GREENWICH MEAN TIME

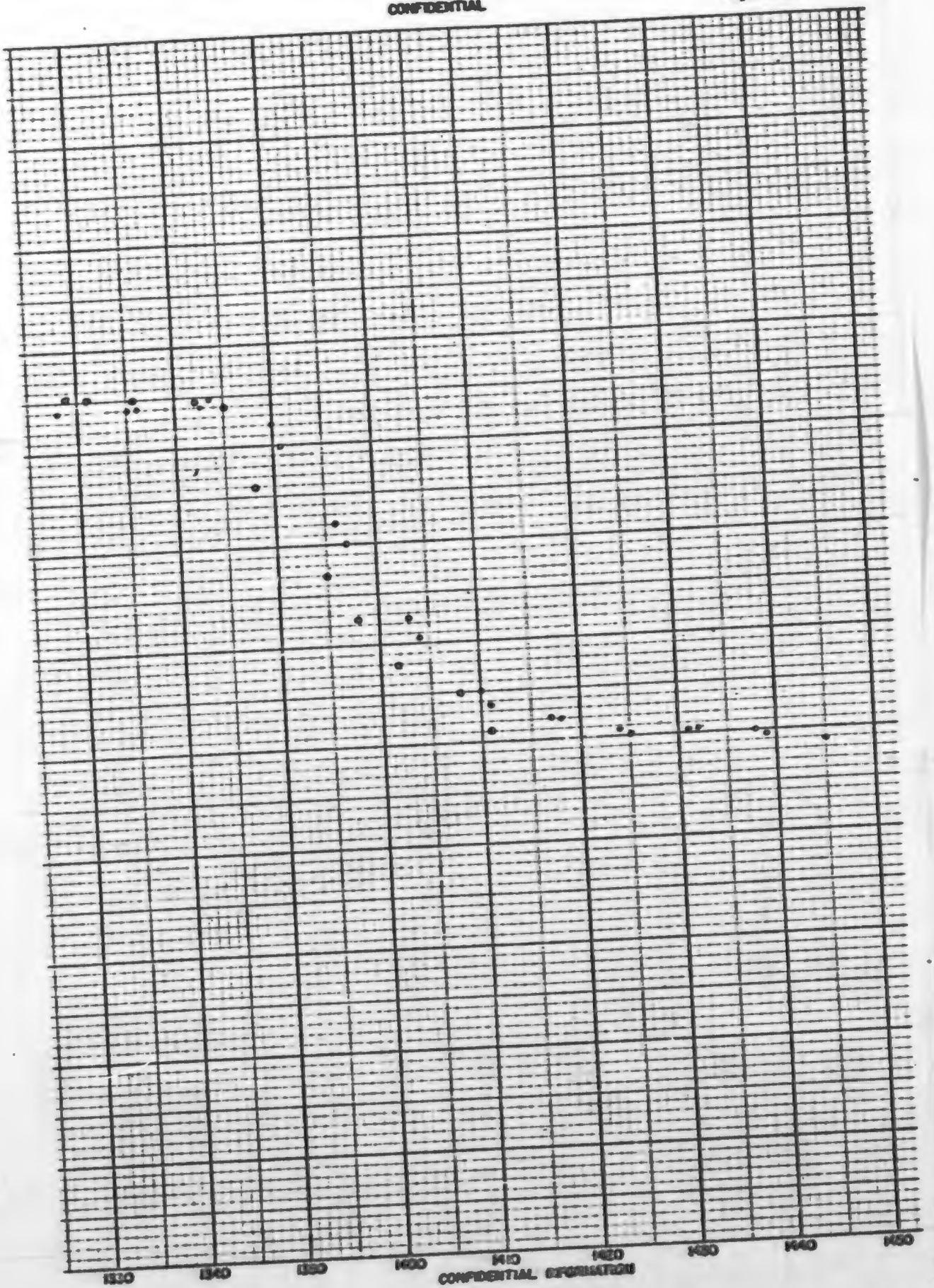

0730
0740
0750
0800
0810
0820
0830
0840

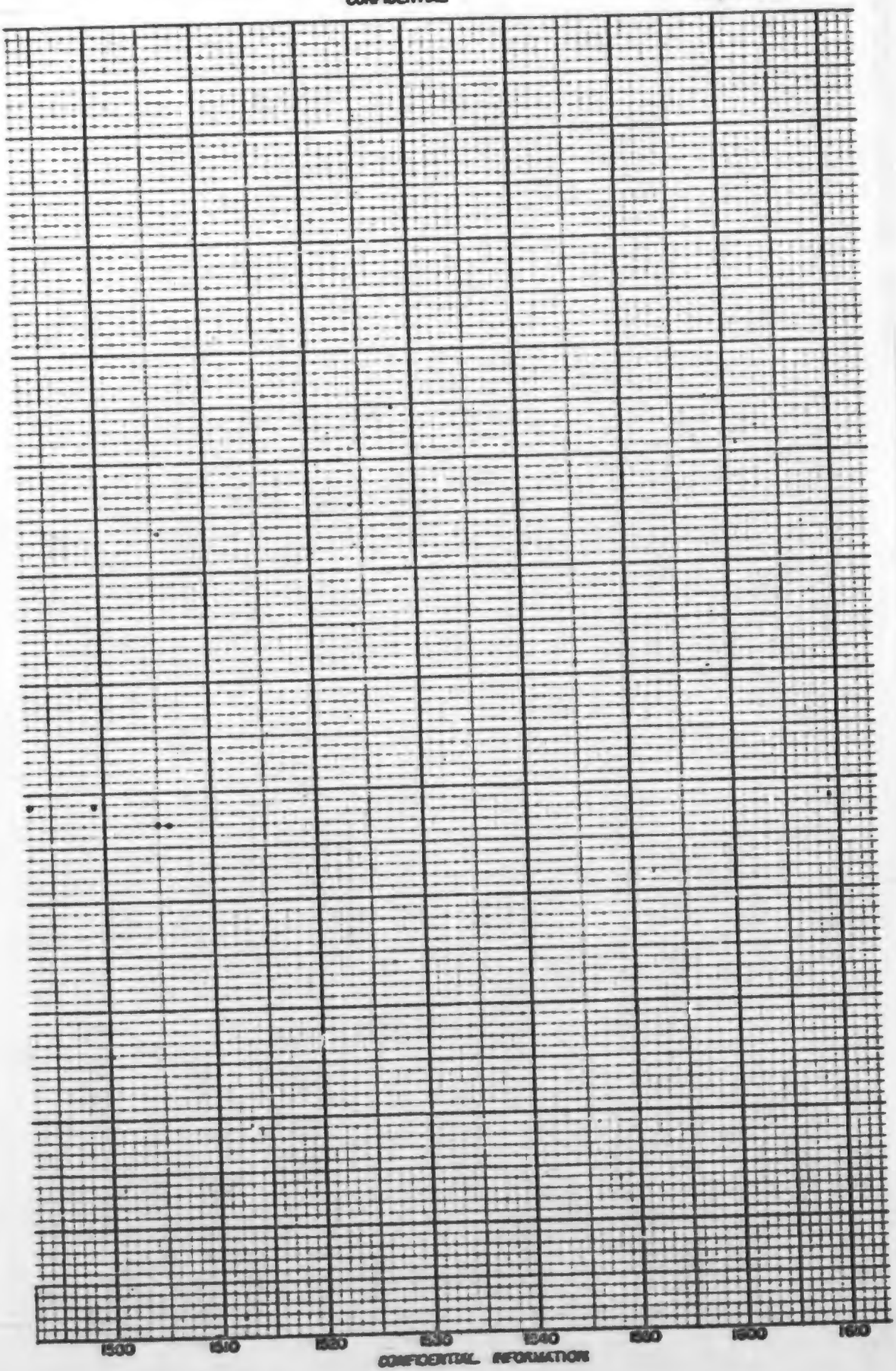

0350
0400
0410
0420
0430
0440
0450
1000
1010

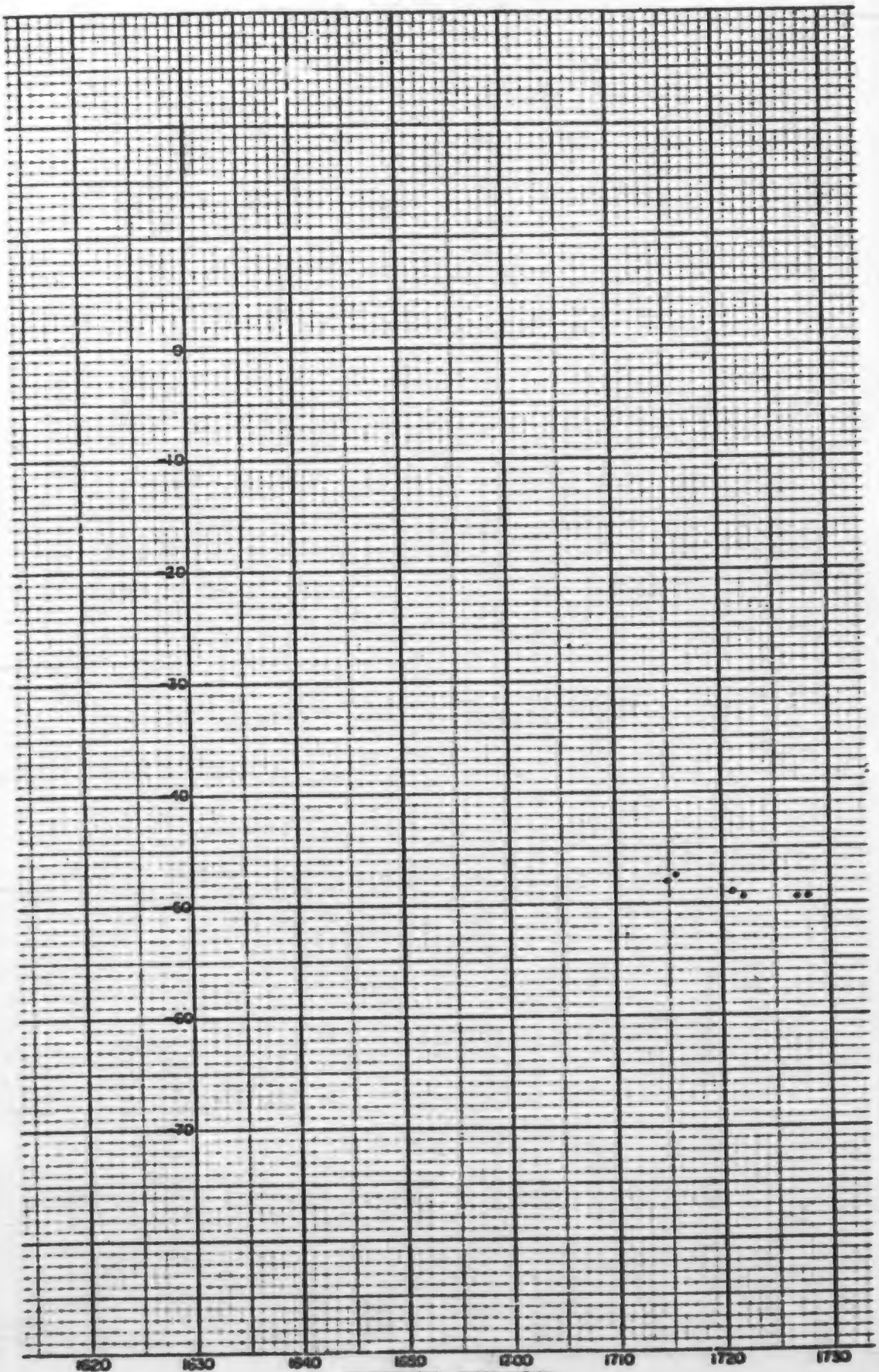

20
10
0
-10
-20
-30
-40
-50
-60
-70
1020
1030
1040
1050
1100
1110
1120

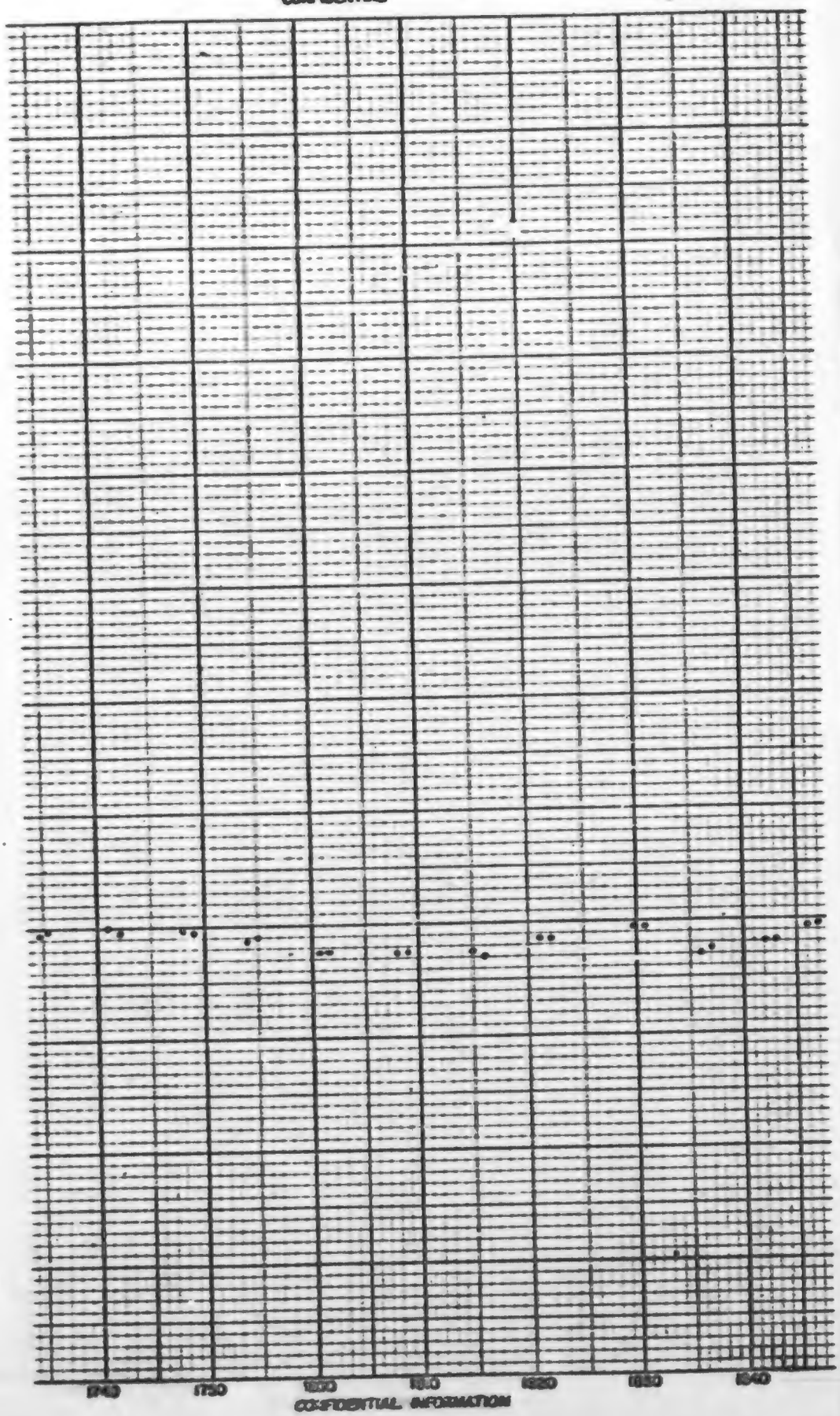

1130
1140
1150
1200
1210

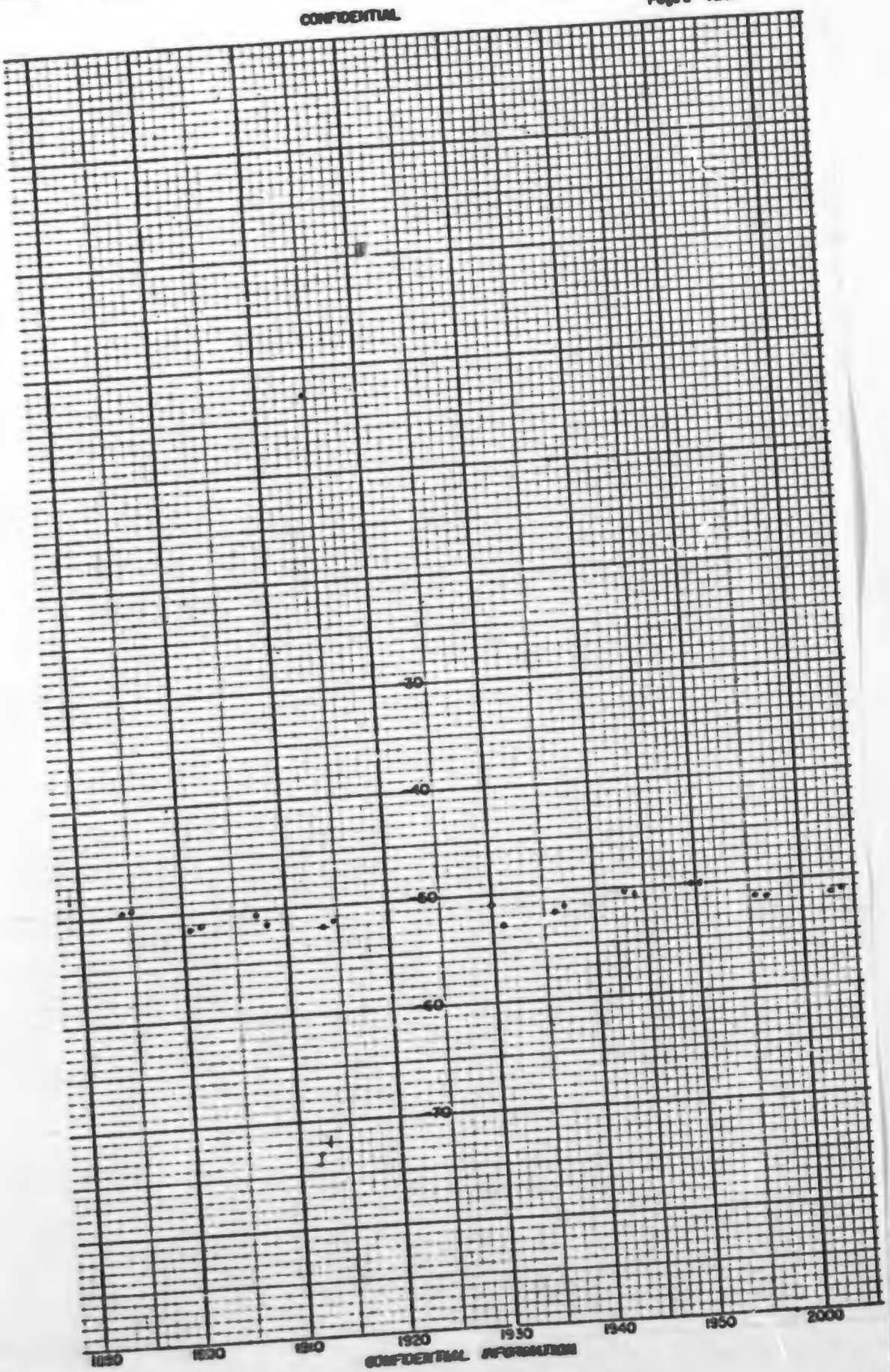

+20
+10
0
-10
-20
-30
-40
-50
-60
-70
TEMPERATURE (°C.)
Initial Air Temp. +4.8°
Initial Gas Temp. +4.9°
1
2
3
Air
1
2
3
Refill
BALLOON GAS and AIR TEMPERATURES
Flight No. 91
5 September, 1953
1210
1220
1230
1240
1250
1300
1310
1320
CONFIDENTIAL INFORMATION
GREENWICH MEAN TIME

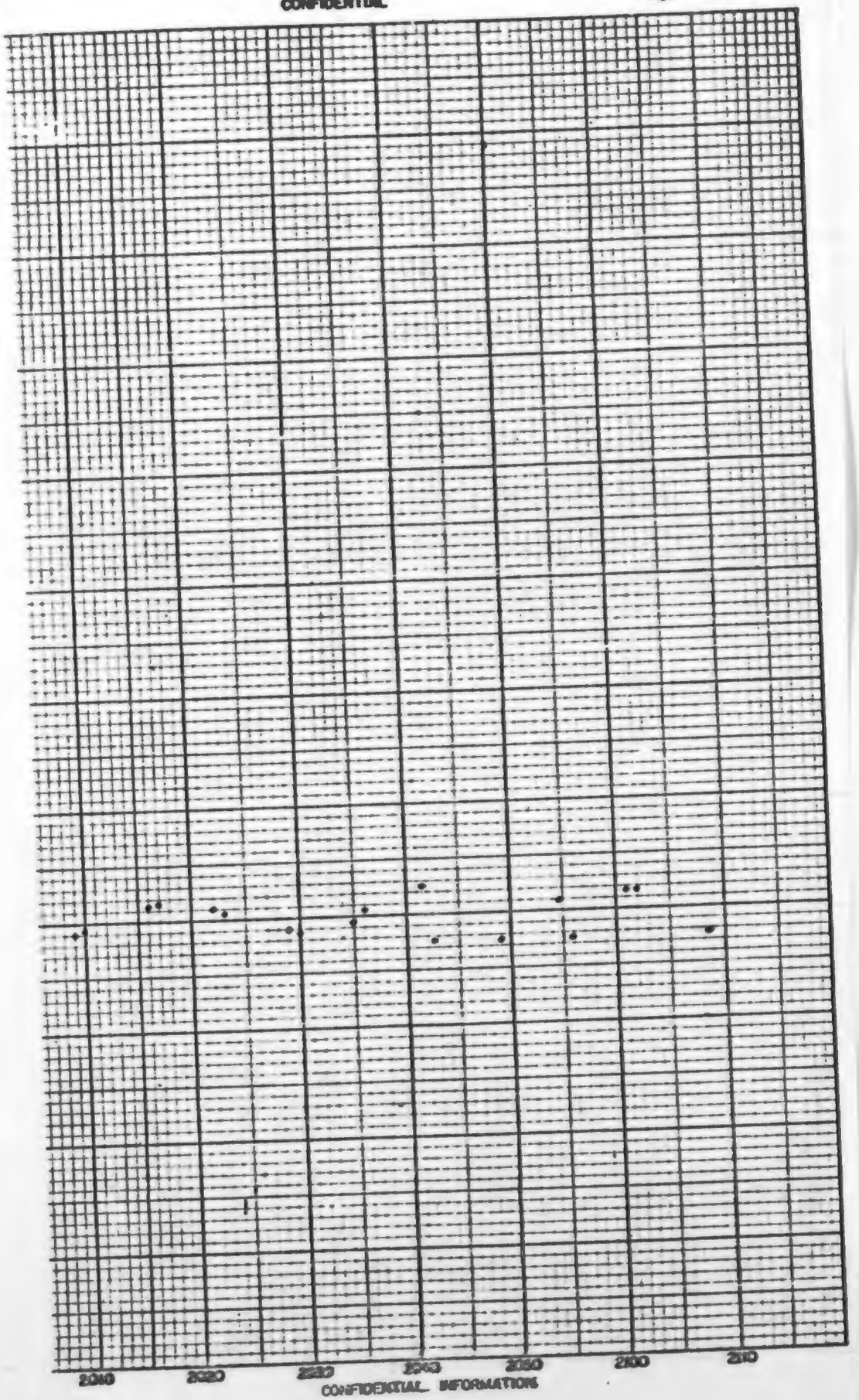

1330
1340
1350
1400
1410
1420
1430
1440
1450

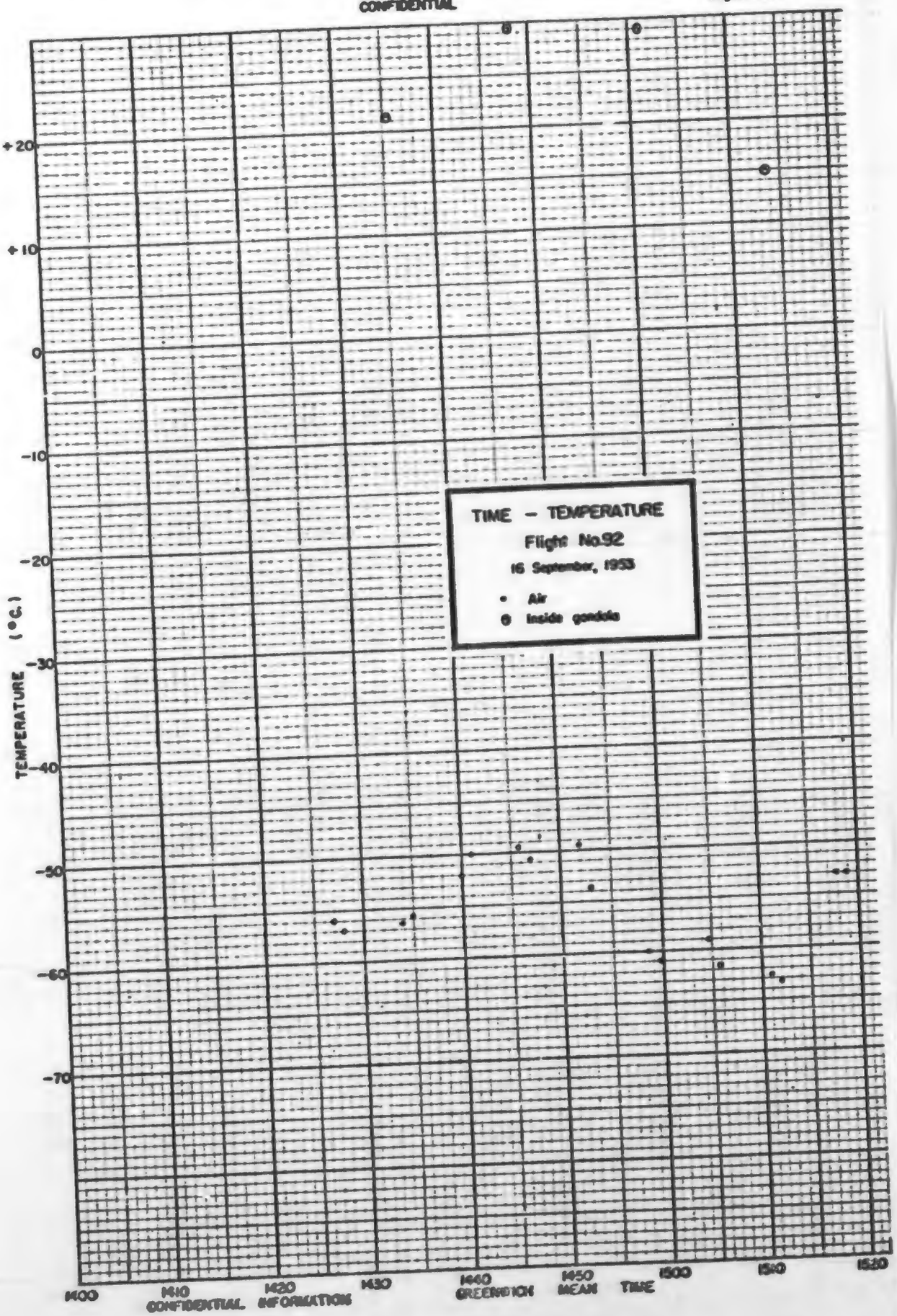

1500
1510
1520
1530
1540
1550
1560
1600

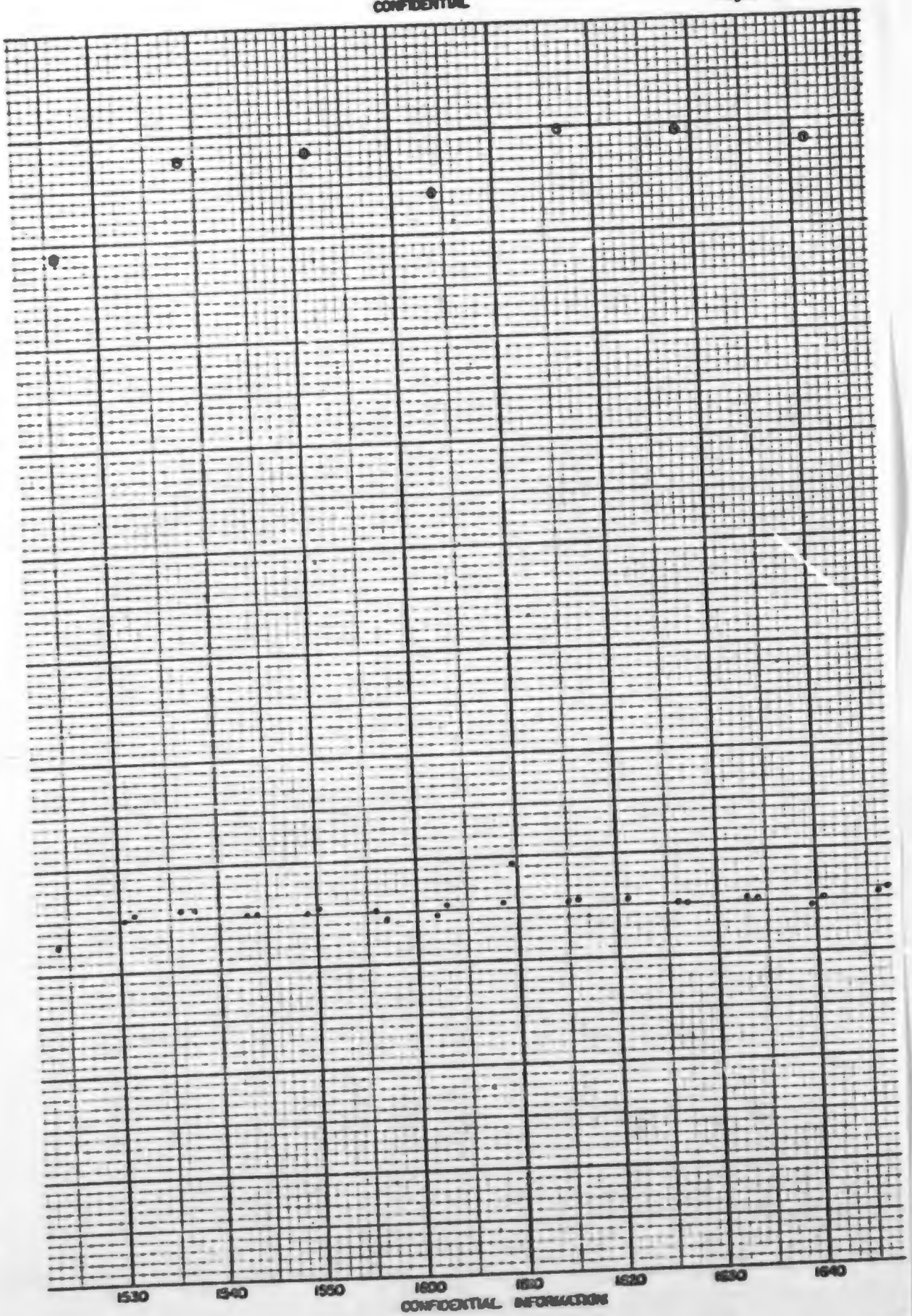

0
-10
-20
-30
-40
-50
-60
-70
1620
1630
1640
1650
1700
1710
1720
1730

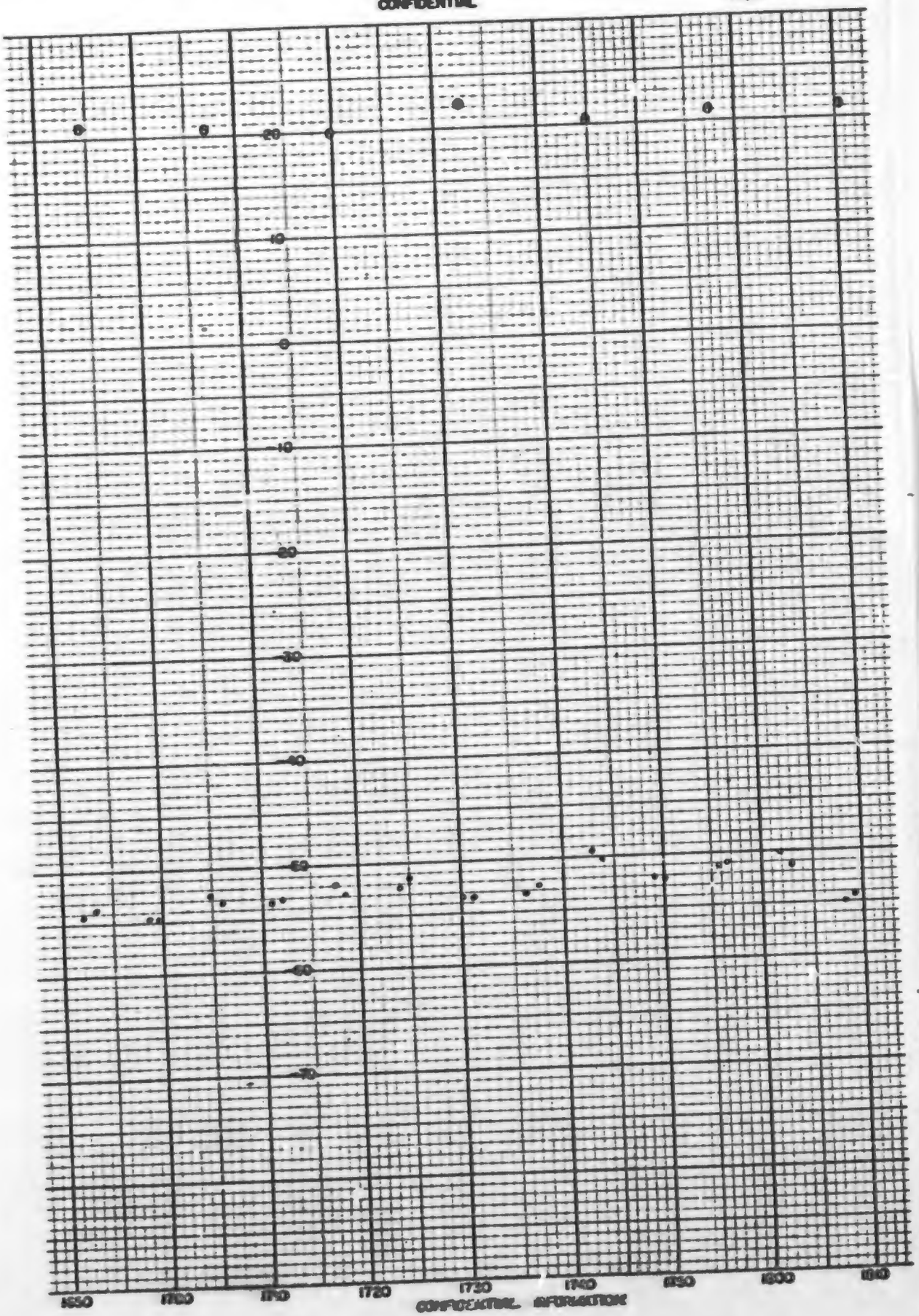

1740
1750
1800
1810
1820
1830
1840

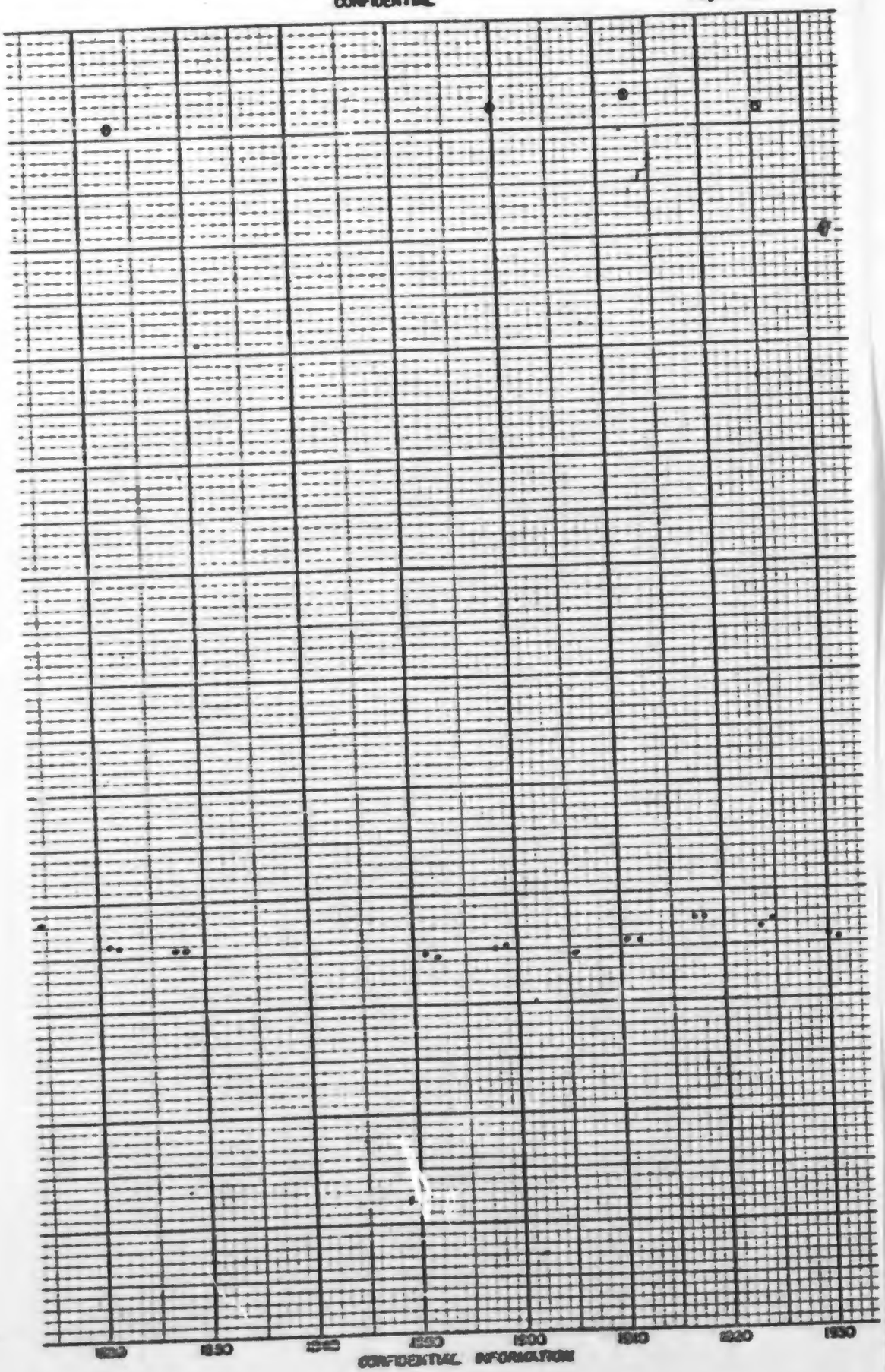

-30
-40
-50
-60
-70
1890
1900
1910
1920
1930
1940
1950
2000

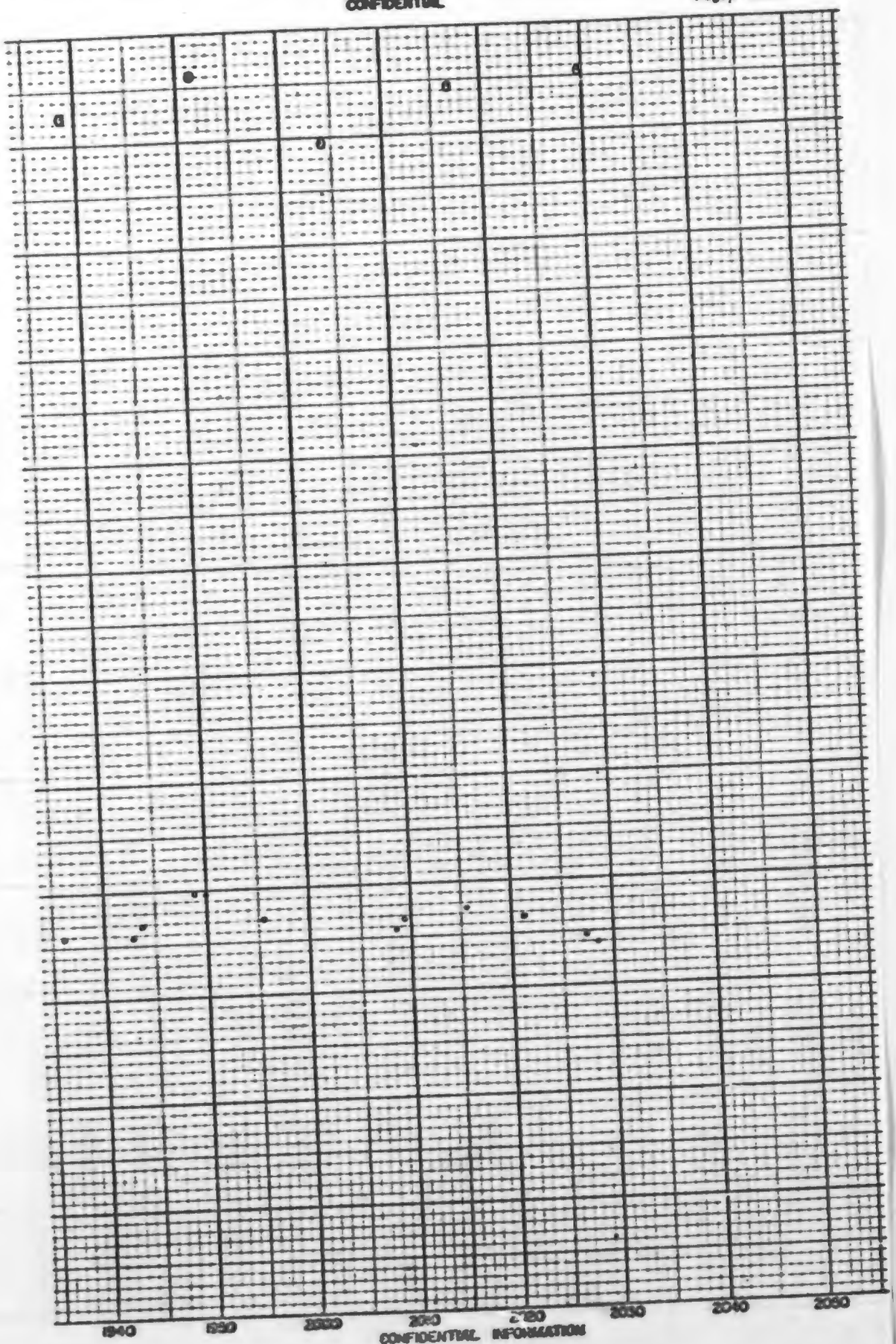

2010
2020
2030
2040
2050
2100
210

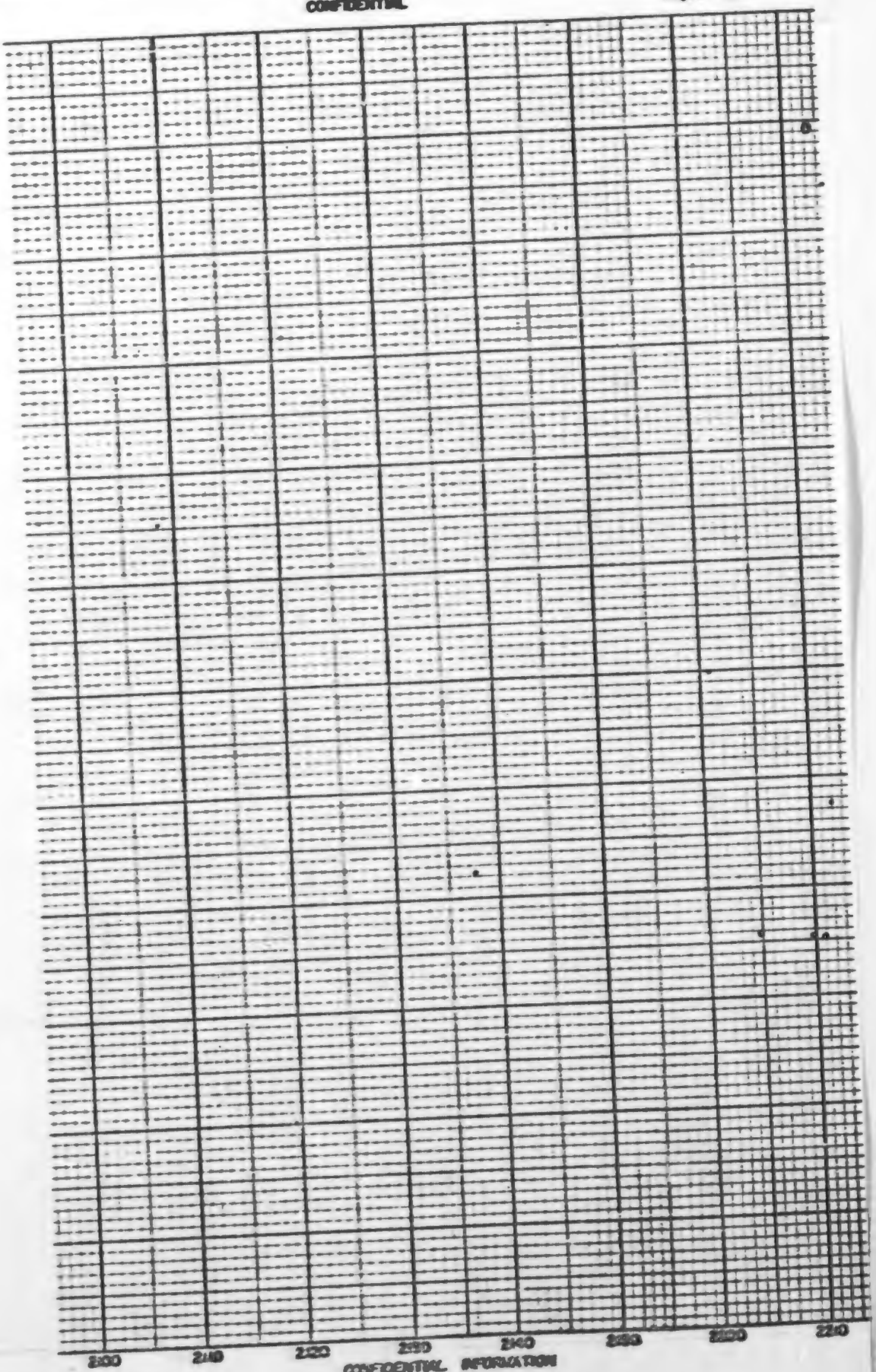

TIME - TEMPERATURE
Flight No.92
16 September, 1953
• Air
⊖ Inside gondola
TEMPERATURE (°C.)
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
1400
1410
1420
1430
1440
1450
1500
1510
1520
GREENWICH MEAN TIME

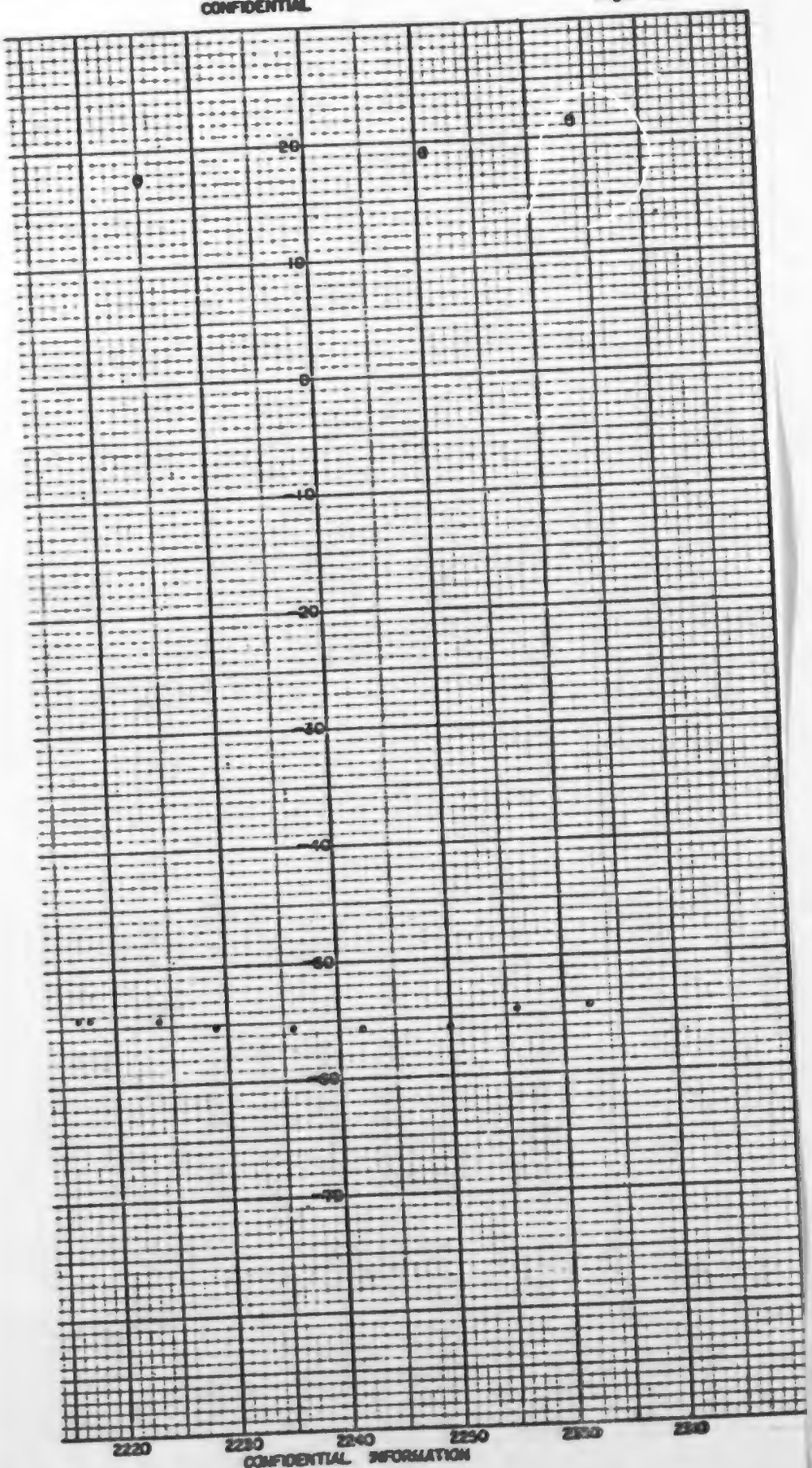

1530
1540
1550
1600
1610
1620
1630
1640

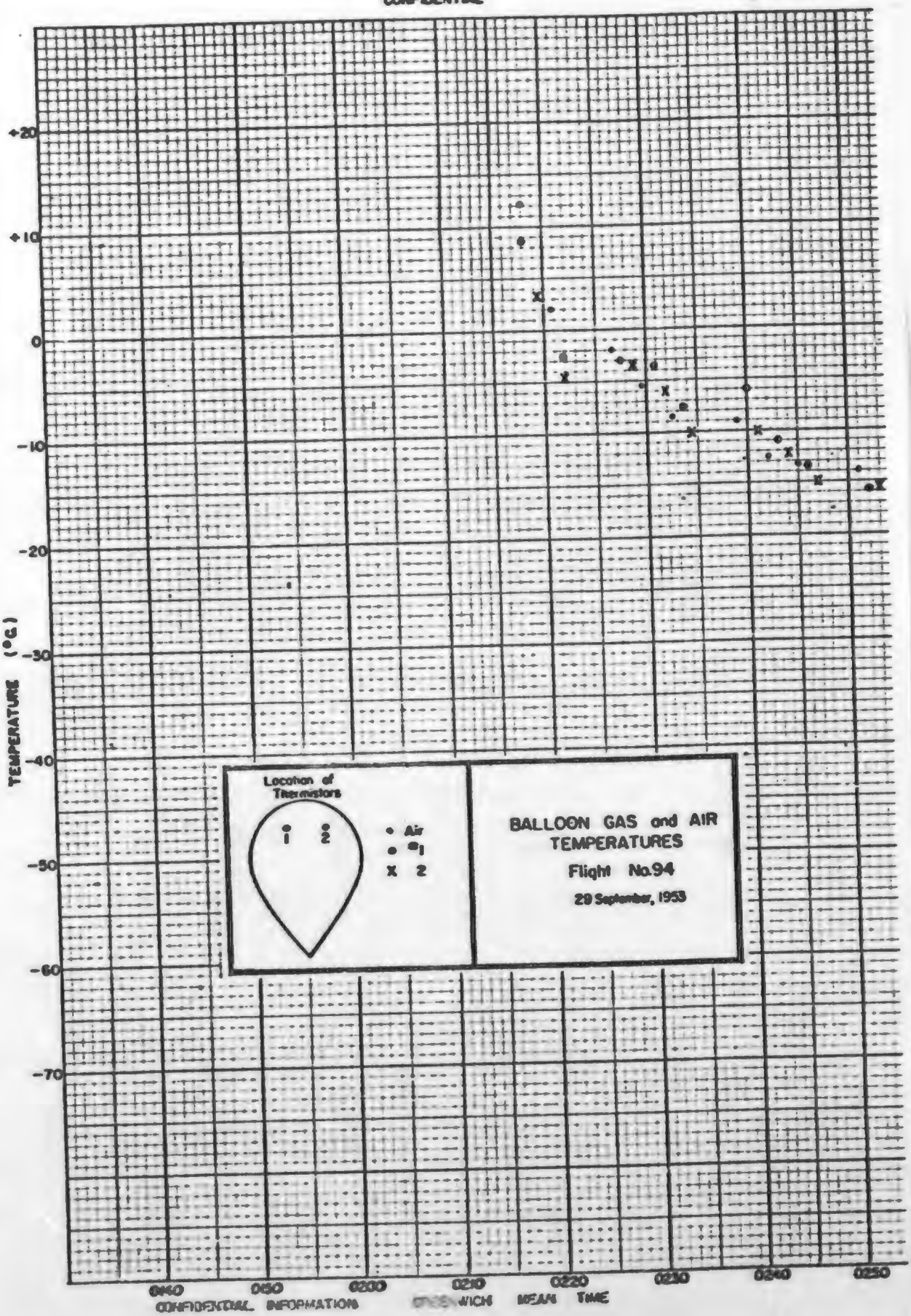

20
10
0
-10
-20
-30
-40
-50
-60
-70
1650
1700
1710
1720
1730
1740
1750
1800
1810

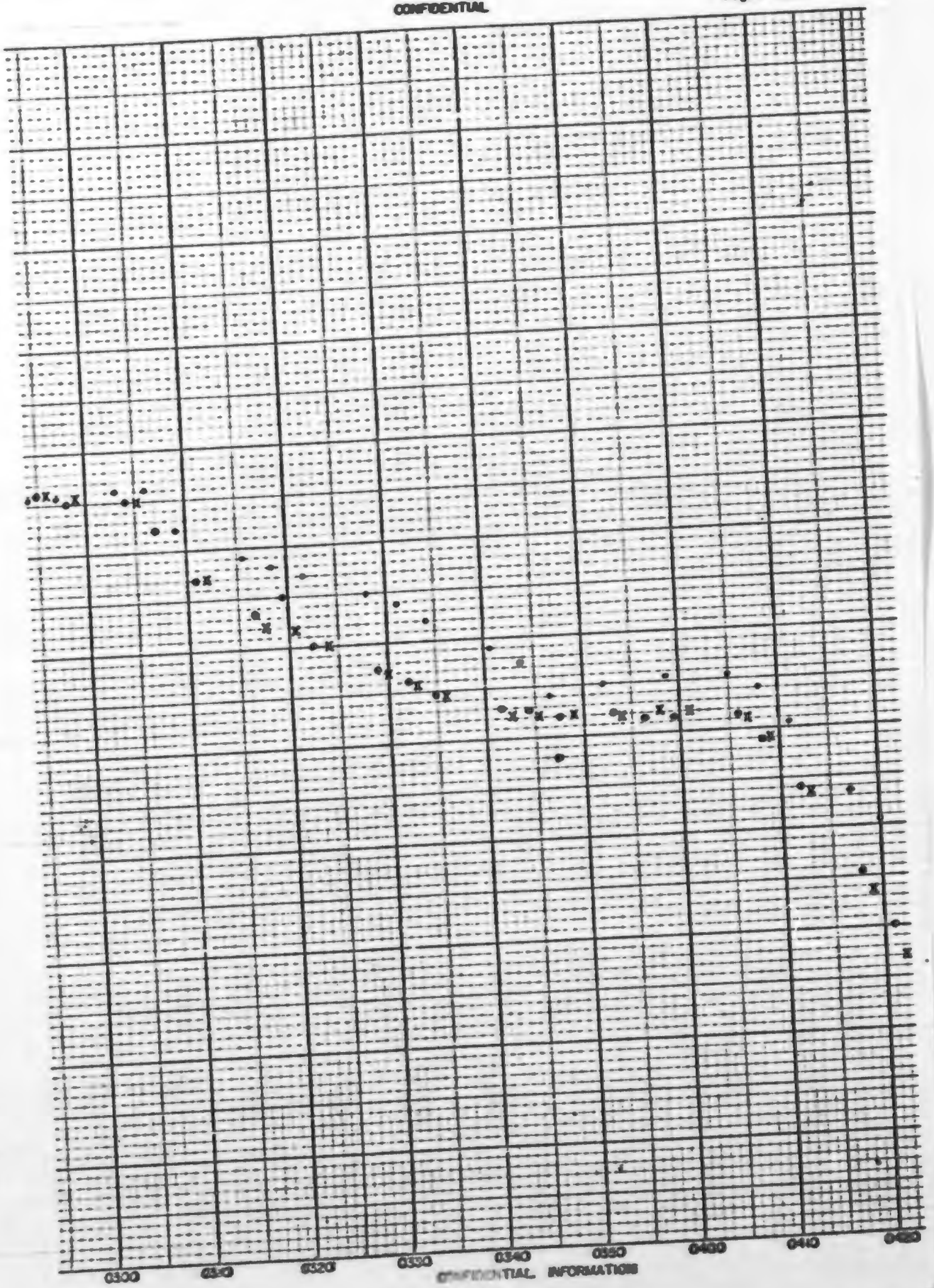

1820
1830
1840
1850
1900
1910
1920
1930


1940
1950
2000
2010
2020
2030
2040
2050


2100
2110
2120
2130
2140
2150
2160
2170


20
10
0
-10
-20
-30
-40
-50
-60
-70
2220
2230
2240
2250
2260
2270


+20
+10
0
-10
-20
-30
-40
-50
-60
-70
TEMPERATURE (°C.)
Location of Thermistors
1
2
• Air
• 1
X 2
BALLOON GAS and AIR TEMPERATURES
Flight No.94
29 September, 1953
0140
0150
0200
0210
0220
0230
0240
0250
GREENWICH MEAN TIME


0300
0310
0320
0330
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0350
0400
0410
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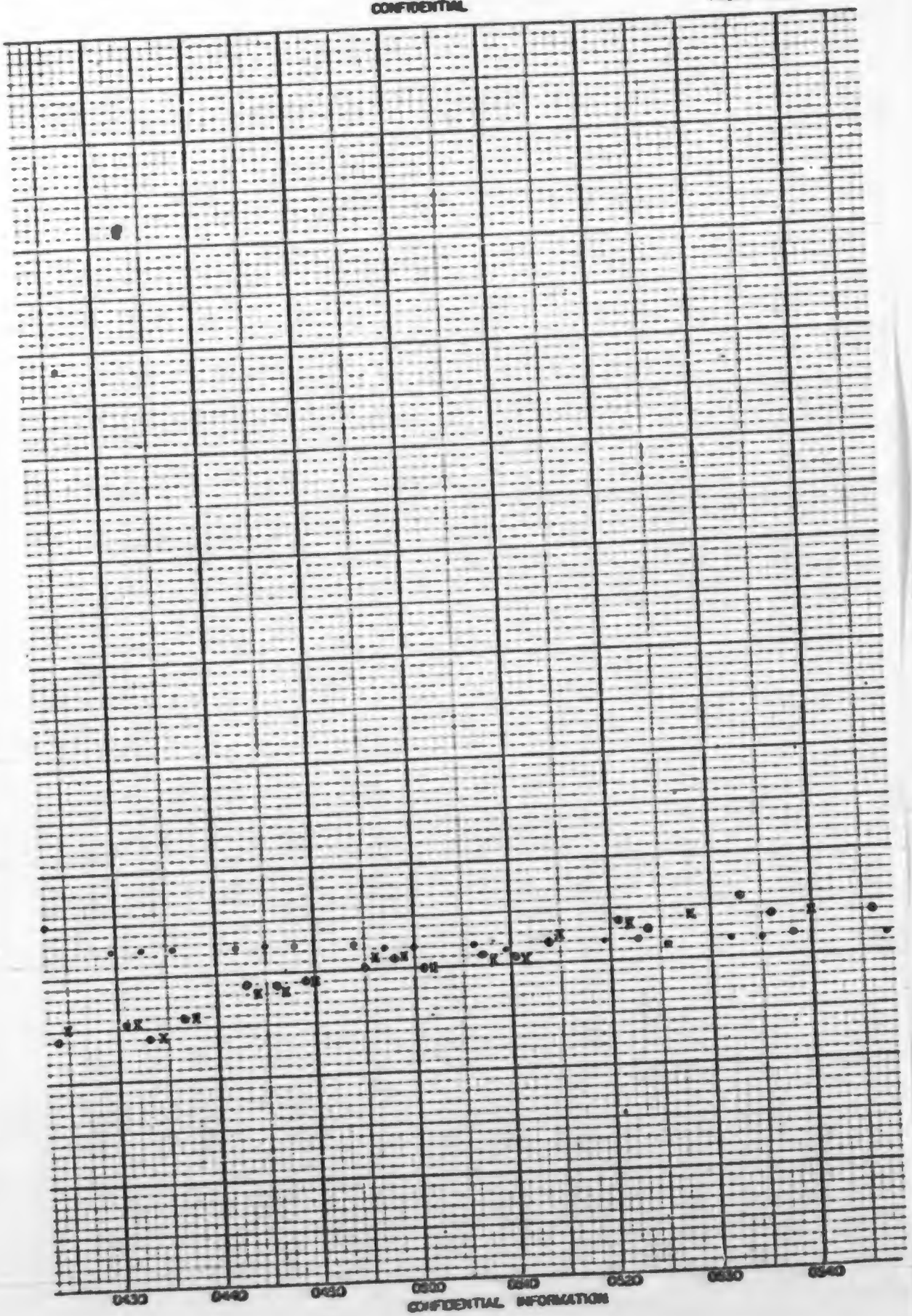
0430
0440
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0500
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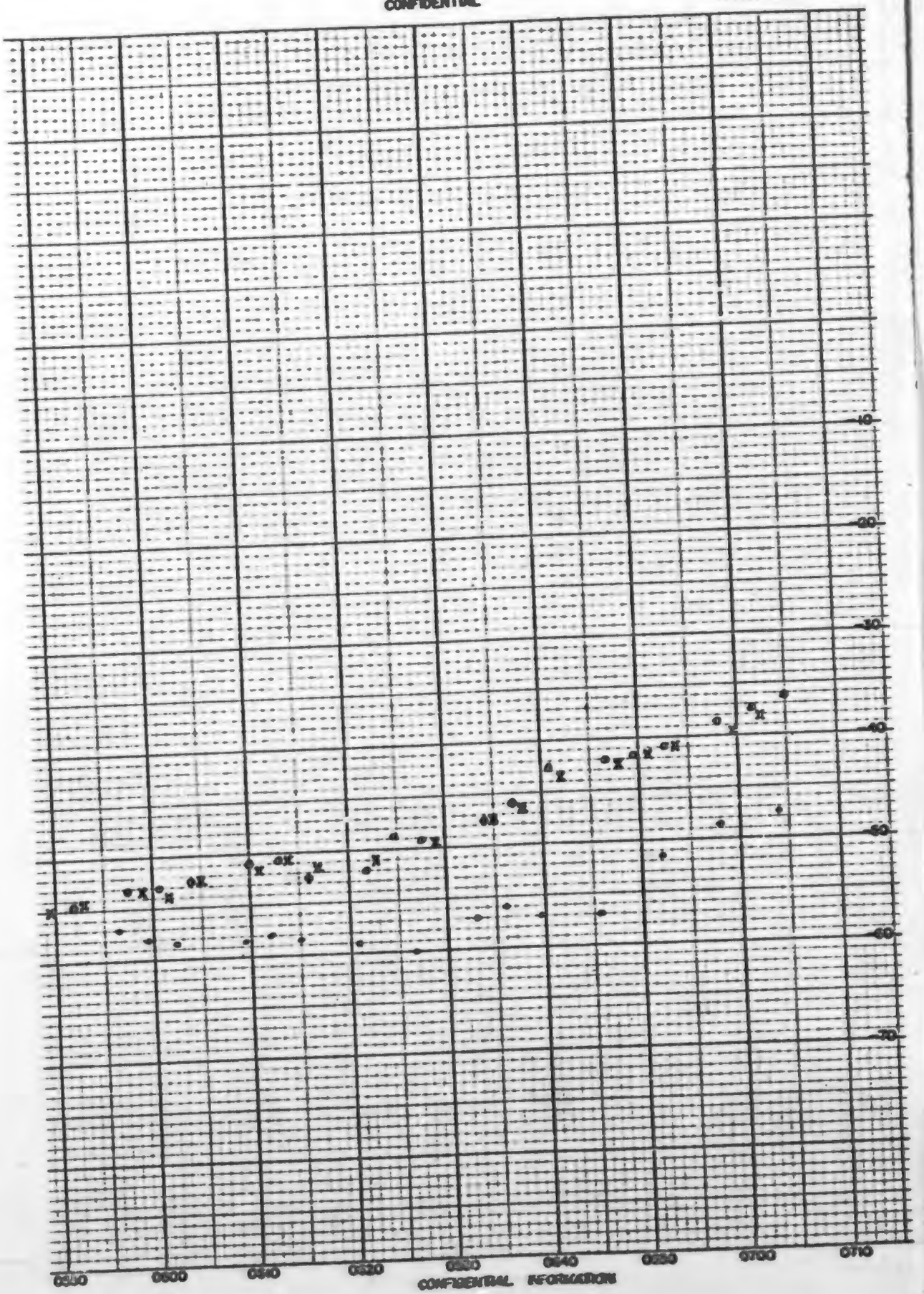
0530
0540


-10
-20
-30
-40
-50
-60
-70
0550
0600
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0630
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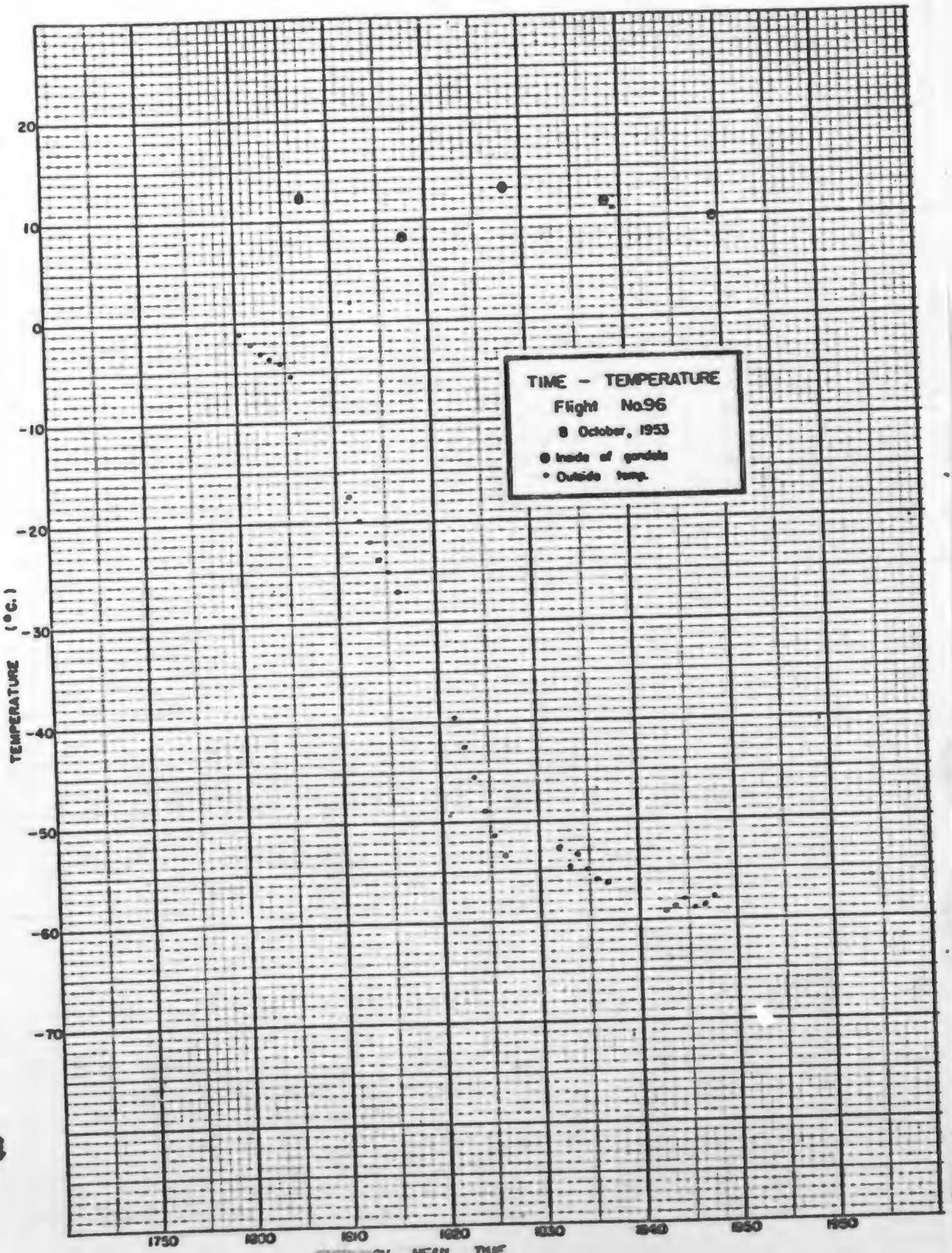
0700
0710


TIME - TEMPERATURE
Flight No.96
8 October, 1953
● Inside of gondola
• Outside temp.
TEMPERATURE (°C.)
20
10
0
-10
-20
-30
-40
-50
-60
-70
1750
1800
1810
1820
1830
1840
1850
1860
GREENWICH MEAN TIME

Section II

METEOROLOGICAL STUDY

A. Introduction

The balloon flights numbered 56 through 100 comprised a rather wide range in types of experimental flight conditions, so that the various wind measurements derived from the trajectories are quite scattered. Flights from Pierre, So. Dakota, during the winter and early spring of 1953 were the only high level (60,000 ft) flights made in this group and only for a limited number of these are trajectories available. The remaining flights have been made in the troposphere or lower stratosphere and the period at constant altitude ranges from one-half to several hours. In addition to the University flights two trajectories were obtained from General Mills flights on which University cameras were flown.

These few high level flights, by a comparison with the Texas series previously reported, show a latitudinal difference in the winter high level flow. The high level trajectories and the winter thermal structure in the stratosphere are discussed below in section B.

The lower level wind data has been analyzed by a more systematic method to determine the structure of the flow in the troposphere and one of the earlier stratosphere flights has been similarly analyzed to compare the characteristics of atmospheric flow at different levels. Two of the step flights ascended slowly through a region of wind maximum and yielded some information on the vertical structure. The observations and the discussion of wind structure will be found in sections C and D.

and therefore

$$V_{zonal} = (2\omega\rho r)^{-1}\frac{\partial p}{\partial \omega \rho}$$

The validity of the geostrophic relationship rests on empirical evidence although it can be argued that just this equilibrium or balance of forces would be achieved by an almost frictionless atmosphere in which the pressure patterns are large-scale and persistent. For this reason the geostrophic wind equation is considered particularly useful in describing the relationship between the mean wind and pressure distributions.

Since the atmosphere is very nearly in hydrostatic equilibrium, the geostrophic wind equation also specifies a relationship between the change in wind with elevation and the horizontal temperature gradient. From the geostrophic wind equation, differentiating with respect to z and reversing the order of differentiation and vector operations,

$$\vec{k} \times \frac{\partial}{\partial z}(\rho \vec{V}_h) = f^{-1}\nabla_h \frac{\partial p}{\partial z}$$

Substituting from the hydrostatic equation for $\frac{\partial p}{\partial z}$, $\frac{\partial p}{\partial z} = -\frac{mg}{RT}$

$$\vec{k} \times \frac{\partial}{\partial z}(\rho \vec{V}_h) = mg/RT^2 f \; \nabla_h T$$

Thus the vector of the vertical wind shear (actually momentum change) is proportional to the horizontal temperature gradient. As an example of the relationship known as the thermal wind, a west wind increases with height in a layer in which the warmer air is to the south and decreases with elevation if the warmer air is to the north.

B. <u>The winter zonal flow above sixty thousand feet</u>

The Texas flights and the Pierre flights were made during the same winter season so that a comparison should provide some estimate of the latitudinal variation of the zonal flow. Unfortunately, clouds prevented

Another portion of the meteorological work has been devoted to the computation of the atmospheric infrared flux. For a number of flight days the effective warming of polyethylene fabric has been computed and the seasonal variation of the infrared warming of polyethylene has also been investigated. The various infrared studies are discussed in Section IV, Volume IX.

*In meteorological practice it is quite frequently assumed that the relationship between fields of pressure and the horizontal wind may be adequately expressed by the geostrophic wind equation. The basis for this assumption and the less familiar consequence of the geostrophic wind equation, the relation between the change in wind with elevation and the temperature field, will be reviewed for the reader without a meteorological background as introduction to the next section.

The geostrophic wind equation simply states that the wind is parallel to the isobars, the speed inversely proportional to the spacing between the isobars and the sine of the latitude. In vector notation where the subscript H is used to denote the horizontal component and f = the Coriolis parameter $(2\omega \sin\phi)$,

$$\vec{k} \times \vec{V} = (f\rho)^{-1} \nabla_H p$$

Hence, as will be noted later, the zonal component of the wind will be directly proportional to the slope of the meridional pressure profile plotted on a scale of the cosine of latitude. Since

$$V_{zonal} = \frac{1}{2\omega \sin\phi} \left(\frac{1}{r} \frac{\partial p}{\partial \phi} \right)$$; where r is the radius of the earth,

* This remaining portion of section A is by way of an introduction to several common meteorological concepts which are employed in the next section.

and therefore

$$V_{zonal} = (2\omega\rho r)^{-1}\frac{\partial p}{\partial \log \rho}$$

The validity of the geostrophic relationship rests on empirical evidence although it can be argued that just this equilibrium or balance of forces would be achieved by an almost frictionless atmosphere in which the pressure patterns are large-scale and persistent. For this reason the geostrophic wind equation is considered particularly useful in describing the relationship between the mean wind and pressure distributions.

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Substituting from the hydrostatic equation for $\frac{\partial p}{\partial z}$, $\frac{\partial p}{\partial z} = -\frac{mg}{RT}$

$$\vec{k} \times \frac{\partial}{\partial z}(\rho \vec{V}_n) = {}^{mg}/_{RT^2 f}\,\nabla_n T$$

Thus the vector of the vertical wind shear (actually momentum change) is proportional to the horizontal temperature gradient. As an example of the relationship known as the thermal wind, a west wind increases with height in a layer in which the warmer air is to the south and decreases with elevation if the warmer air is to the north.

B. <u>The winter zonal flow above sixty thousand feet</u>

The Texas flights and the Pierre flights were made during the same winter season so that a comparison should provide some estimate of the latitudinal variation of the zonal flow. Unfortunately, clouds prevented

actual flow measurements in all but two Pierre flights, Nos. 57 and 67. In both of these cases very light easterly flow was observed at 80,000 ft. The recovery points for Flights 56, 68, and 69 also provide some estimate of the high level winds; the vector for the movement during ascent and descent below 50 mb was estimated from the upper air maps and then subtracted from the total vector to the down point to obtain a vector movement for the upper portion of the flight. This estimate proved to be rather crude but did indicate very light winds above 50 mb.

The very general picture of the zonal flow in winter provided by these data is shown in Table I.

Table I

Latitudinal variation of the mean zonal flow in winter from University flights.

Elevation (thousands of ft)	Latitude (30°N)	(45°N)
80	22 kts westerly	Light
60	Light	20 kts westerly

At 30° latitude the west wind appears to increase above 60,000 ft while at the same levels the west wind decreases with elevation at latitude 45°. Since the number of flights is quite small, it seemed advisable to somehow investigate the representativeness of these observations. One method is to compare the pressure field and thermal structure implied by the wind observations of Table I with synoptic observations, but current radiosonde data transmitted by teletype terminates at 50 mb which is just at the base of the layer to be investigated. However, it was found that even though teletype data will only provide a direct check on the values at the lower levels of Table I, the observed thermal structure may

be extrapolated to obtain a reasonable picture of the temperature and pressure fields above.

Radiosonde data for the month of January 1953 were used to construct, along the 90° meridian, temperature and contour profiles for the 50 mb surface, Figures II-1 and II-2. So as to obtain sufficient data for a smooth average, each point is the mean of three or more reporting stations; the stations used for each point are listed on the diagram. The abscissa of Figure II-1 is the cosine of latitude and the slope of the profile, therefore, will be directly proportional to the mean zonal geostrophic wind speed.

In Figure II-2 the mean zonal temperature profile of the layer 50-100 mb is given as well as the temperature at the 50 mb surface. The former value will, for purposes of extrapolation, be considered as the representative temperature for the 71 mb surface.

The meridional profile of the 50 mb surface does agree with the wind observations at 60,000 ft in Table I. The slope is zero or positive at 30° latitude and is negative, indicating a west wind, at 45° latitude. If now the geostrophic west wind is to increase with height at 30° latitude, the meridional temperature gradient of Figure II-2 must reverse above 50 mb, and if the west wind is to decrease with elevation at 45° latitude, the meridional temperature gradient at 45° cannot reverse. This is, of course, just what is suggested by the linear extrapolation of the temperature lapse rate from 71 to 50 mb, Figure II-3. The increase of temperature with elevation is greatest at low latitudes. The isothermal lapse rate to about 30 mb at latitude 45° is actually verified on some of the Pierre flights for which the air temperatures were measured.

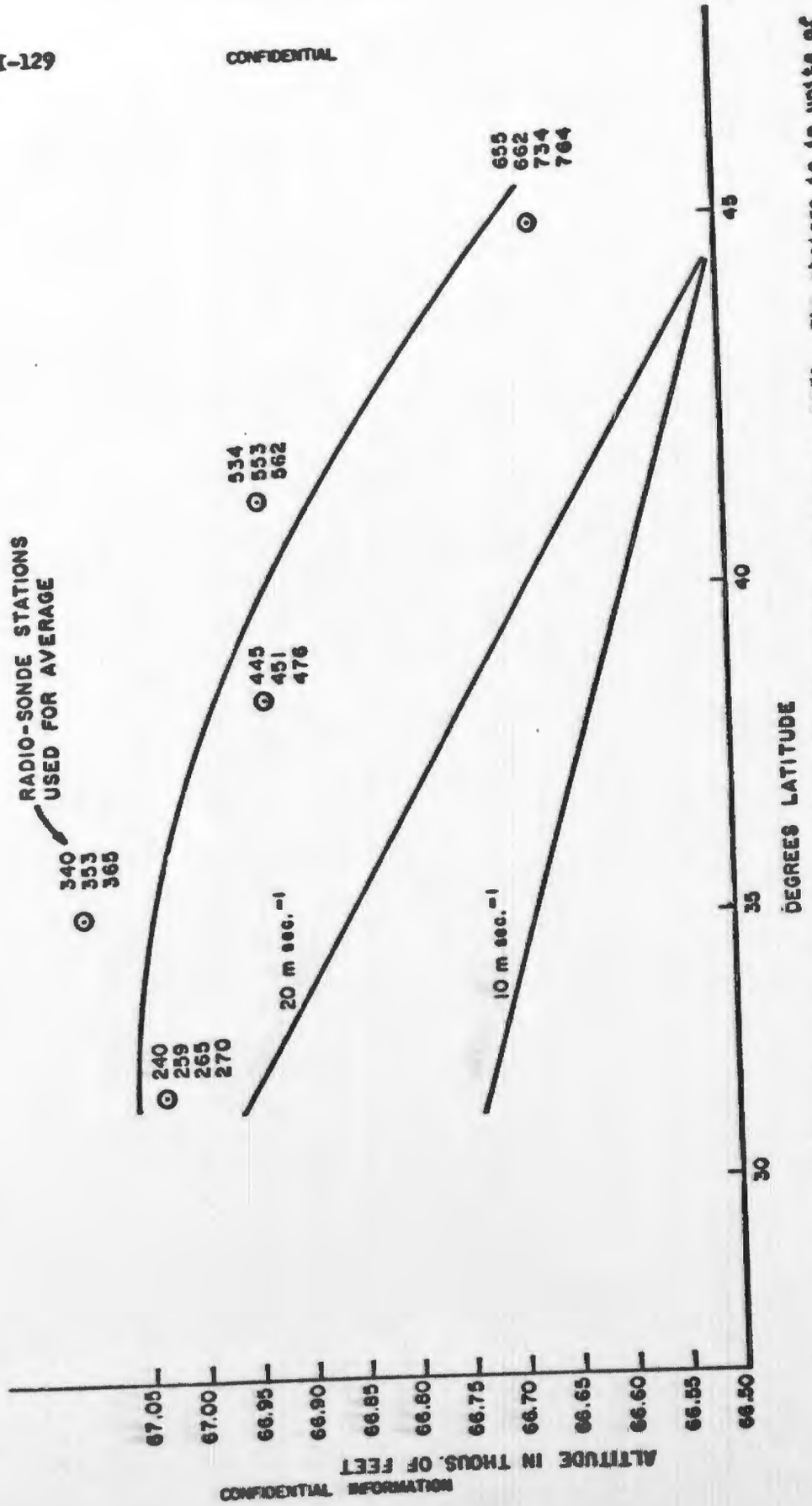


Figure II-1. Mean meridional profile (90°W) of the 50 mb surface for January, 1953. The abscissa is in units of the cosine of the latitude so that the slope is directly proportional to the zonal geostrophic wind.

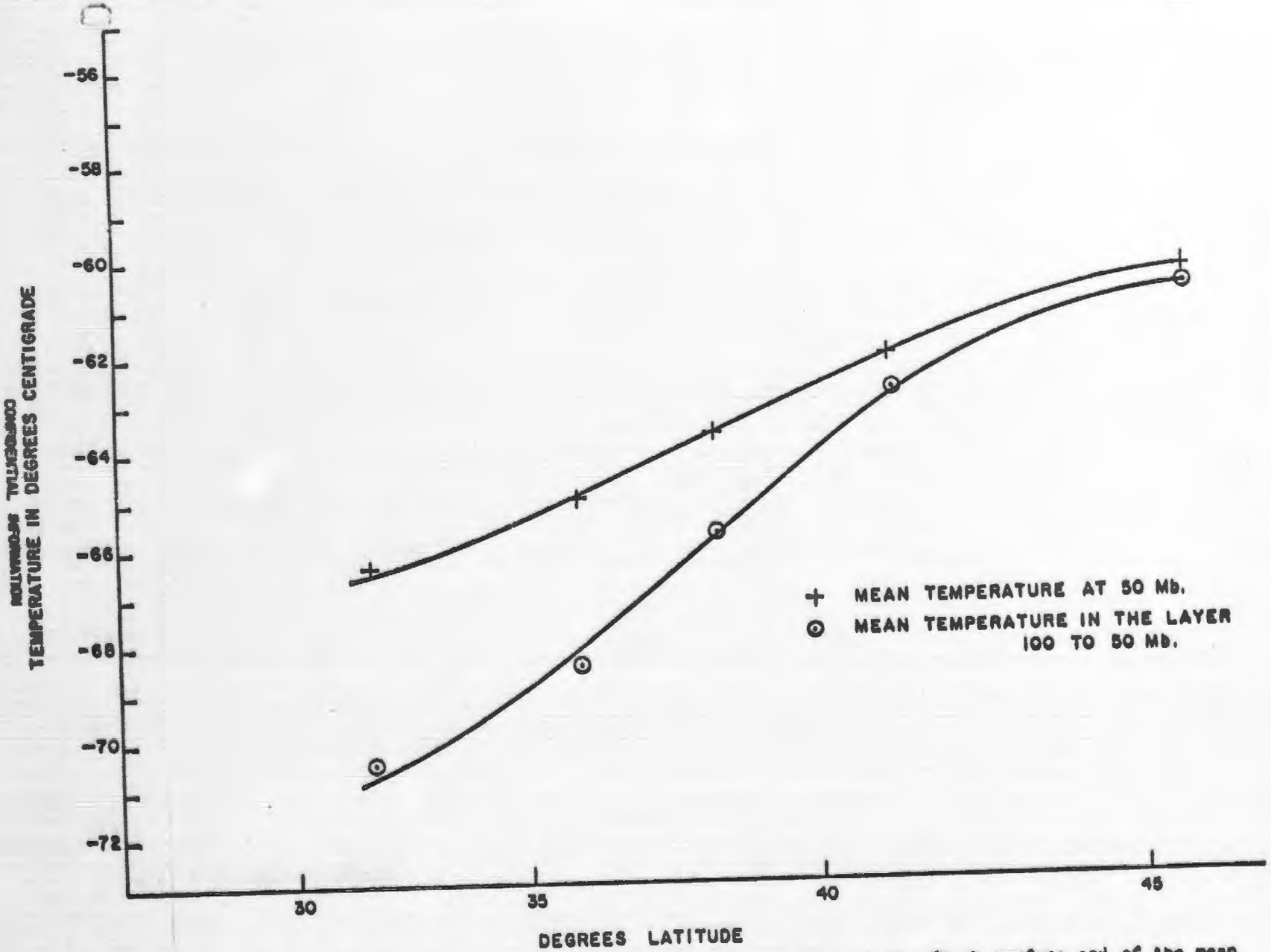


Figure II-2. Mean meridional profile (90°W) of the temperature at the 50 mb surface and of the mean temperature in the layer (100 - 50 mb) for January, 1953.

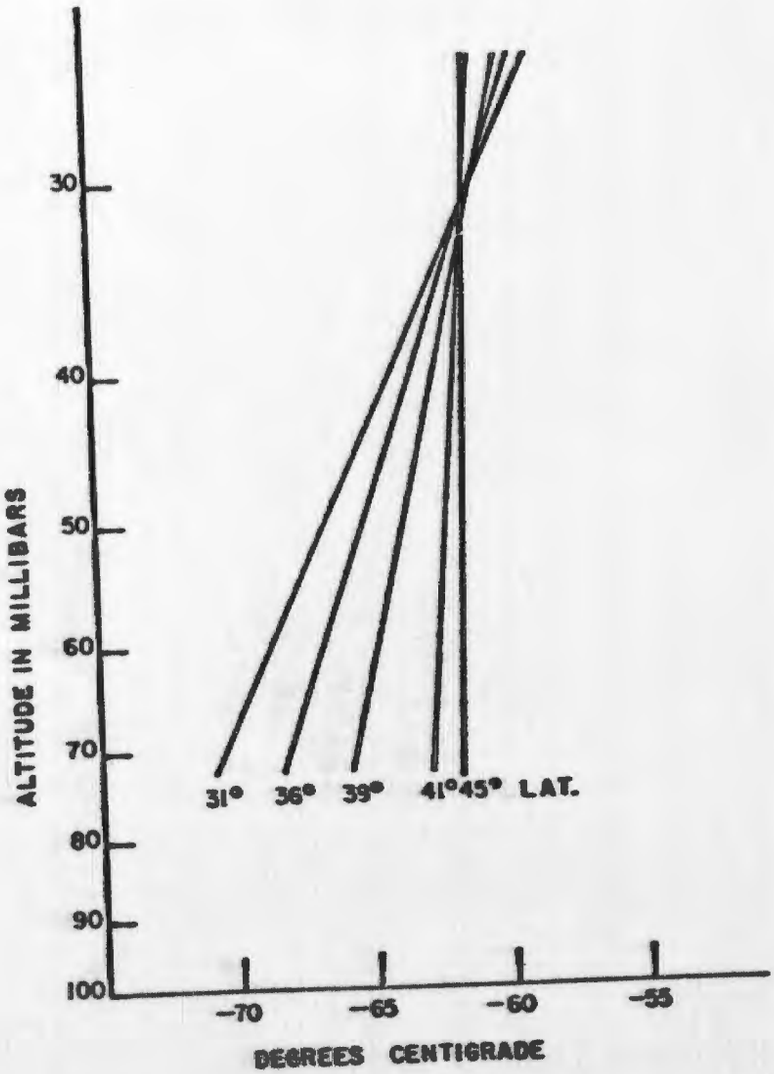


Figure II-3. Mean temperature lapse rate 71 - 50 mb for January, 1953, as a function of latitude. The lapse rates have been extrapolated to 25 mb to show the probable reversal of the North-South temperature gradient at higher levels.

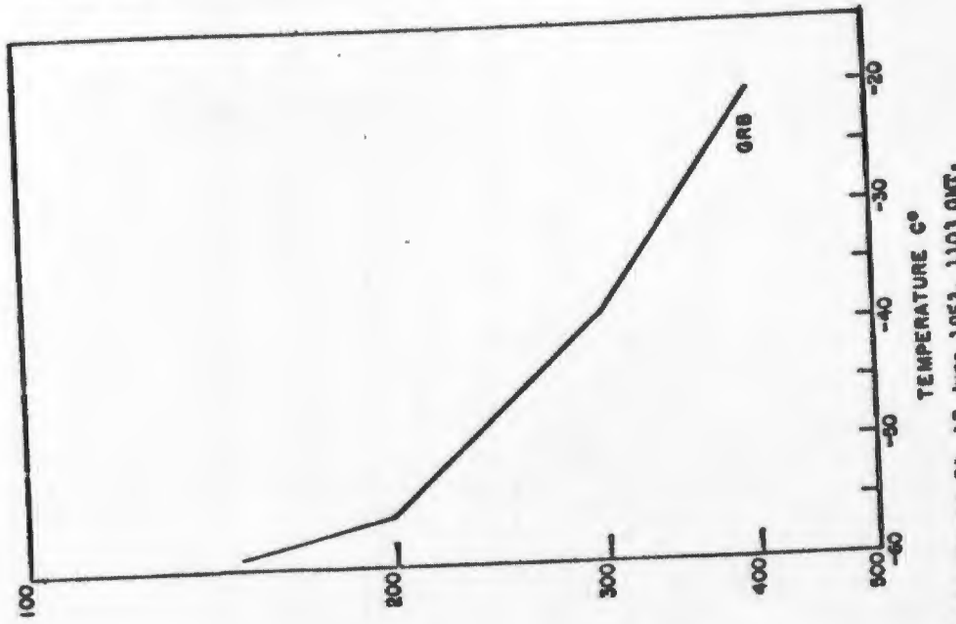
Qualitatively the observed and extrapolated temperature field is in agreement with the wind observations in Table I. However, an even greater latitudinal difference in the lapse rate than indicated by Figure II-3 will be required to produce the observed zonal flow at the 80,000-ft level at 30° latitude.

C. Measurements of the Vertical Wind Structure

On two step flights, Nos. 79 and 80, the balloon system ascended slowly through a region of wind maximum yielding detailed information on the vertical structure. With the usual ascent rates of the balloon there is considerable sway of the load and camera which causes an error in the position fixes and velocity measurements during ascent, but in these cases with ascent rates less than 500 ft/min the camera sway does not seriously affect the results. The vertical wind structure determined on these flights is shown in Figures II-4 and II-5. The vertical temperature structure from nearby radiosonde measurements are included for comparison.

An estimate of the inaccuracy of the data may be gained by considering the position fixes from the odd-numbered frames separately from the even-numbered frames. Differences in the two velocity curves so obtained may be due to actual wind differences, but, in any event, the error in measurement cannot be any greater than the differences between the two curves.

With this possible error in mind, one can conclude from the velocity structure shown in Figs. II-4 and II-5, that a multiple wind maximum with intermediate regions of strong shear can be observed as shown by Flight 79. Both these summer flights show a region of highest winds in which the wind velocity is fairly constant with elevation (over 5,000 ft deep) just above



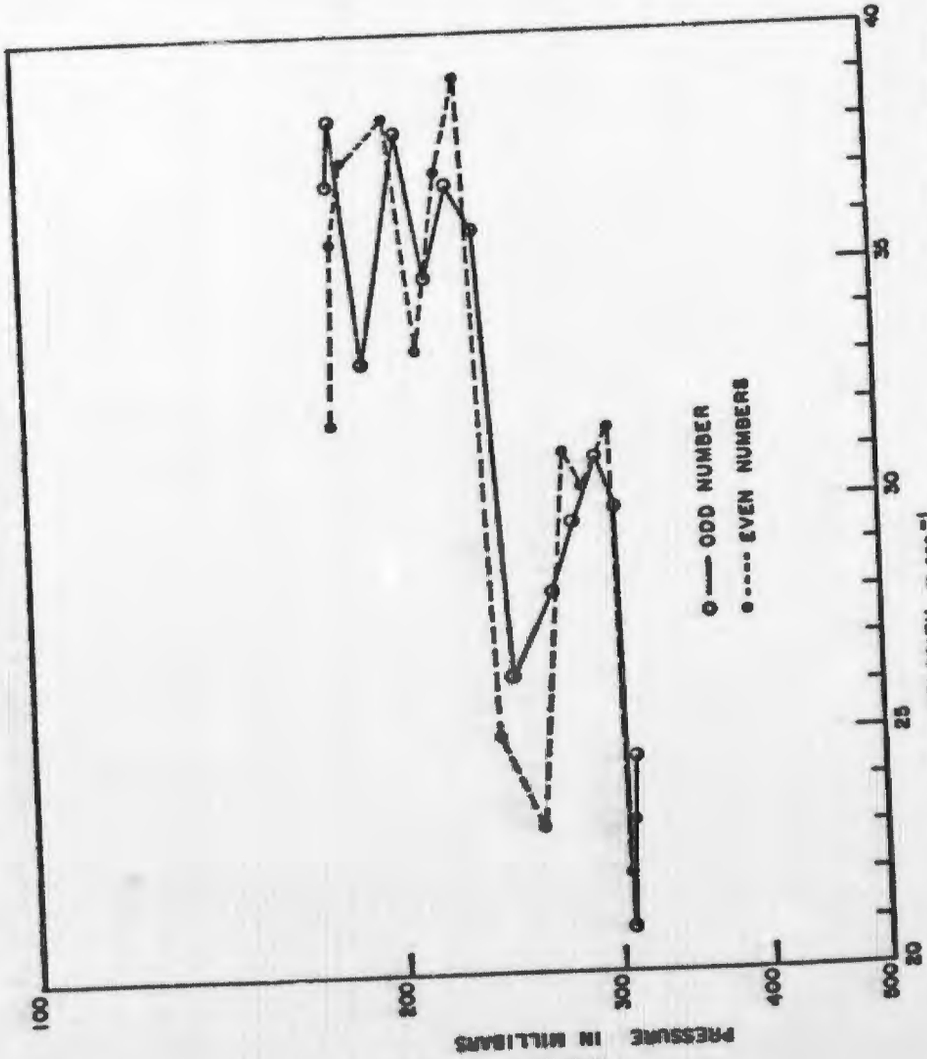


Figure II-4. Vertical profile of the velocity at the wind maximum measured by Flight 79, 17 June 1953, 1103 GMT. The temperature sounding at Green Bay is given for comparison.

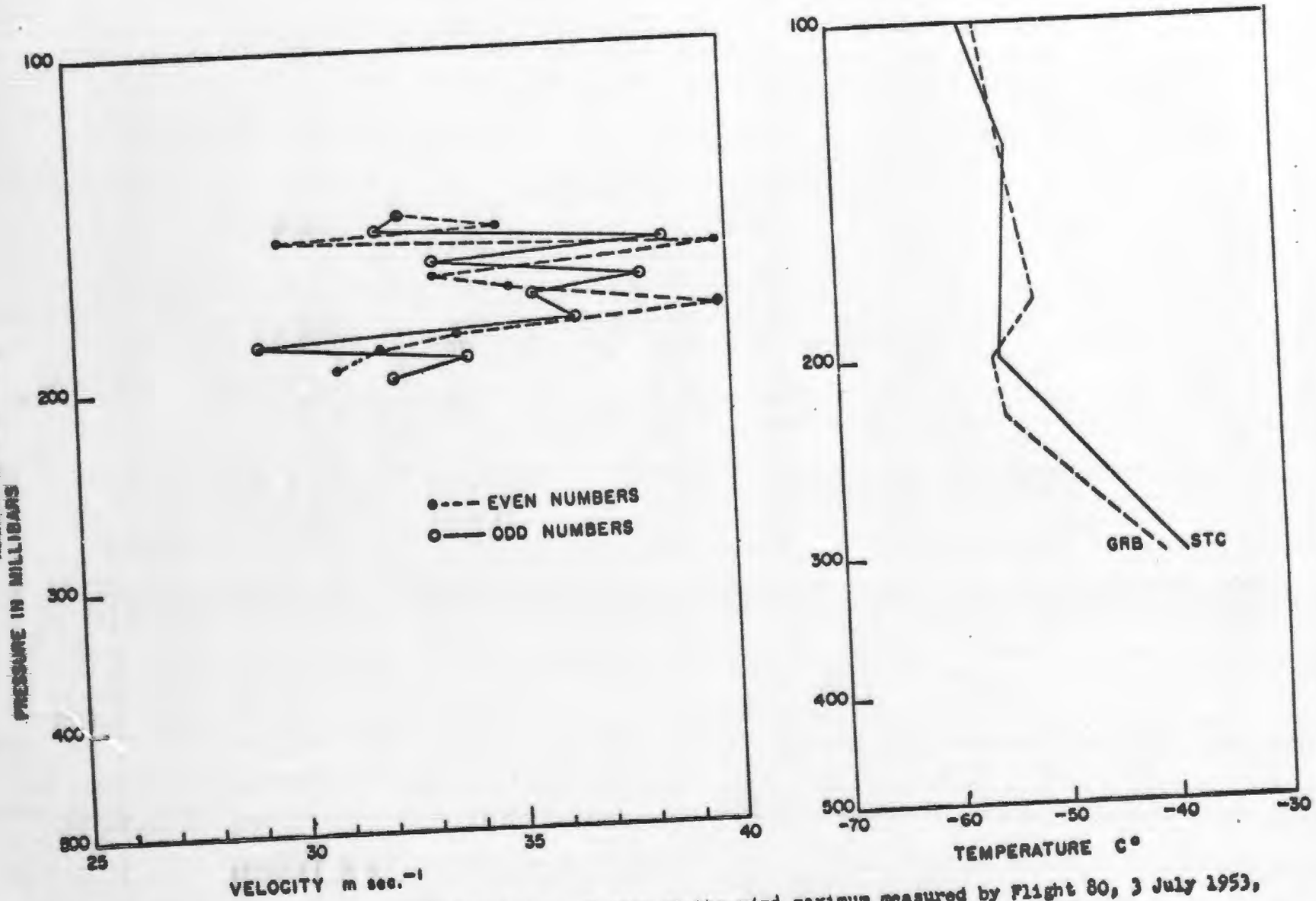


Figure II-5. Vertical profile of the velocity at the wind maximum measured by Flight 80, 3 July 1953, 1500 GMT. The temperature soundings at St. Cloud and Green Bay are given for comparison.

a region of strong vertical wind shear. Unlike the previous measurements the wind maximum for both these cases extends above the tropopause, a condition which was commonly observed on a number of the flights this past summer.

D. Measurements of the Horizontal Structure of the Wind

1. Background

In the previous reports an attempt was made to characterize the flow in the upper stratosphere (80,000 ft) by the variability or variance of the velocity fluctuations with different periods. Three general classes of periods were used: the intermediate range was chosen from one to three hours and the fluctuations with periods greater or smaller than this range were called either large or small scale, respectively. In all the flights analyzed the variance was found to have an almost constant value of the order 1-2, m^2sec^{-2} in all classes of periods. This result, indicating a flat spectral distribution for the variance, was interpreted to mean that the large-scale motion at these elevations is not readily distinguishable from the small-scale motions. A further conclusion was that the shorter period wind fluctuations at high levels seem to be the same magnitude as the short period tropospheric fluctuations reported by various investigators. (Volumes IV, VII)

This crude spectral analysis is not entirely satisfactory for a number of reasons. The variance in any class will depend upon the exact range of spectral interval treated and it is difficult to compare results from different sources unless a complete spectral analysis is made. A broad spectral interval may also hide maxima and minima and, in fact, will tend to yield the flat

spectrum observed. During the period covered by this report a new method of spectral analysis of the velocity fluctuations has been used. No new high level data has been treated, but Flight 24 has been reanalyzed by this new method.

All the new wind data analyzed are from lower level flights, but the importance for the high level study is that one is now able to compare, quantitatively, the characteristics of the flow at high levels and lower levels.

2. Methods of Analysis

The method used in this report for the analysis of the time series of wind observations is one which has been employed in communication theory for the analysis of noise. Recent statistical development of the method, stimulating its application to meteorological problems, is largely due to Tukey (1949), although the same method had been used in the analysis of turbulent flow by G. I. Taylor in 1938.

The aim of the method in this case is to provide some sort of a description of the spectral distribution (distribution with frequency) of the amplitude of representative velocity fluctuations. The method is statistical and the term representative velocity fluctuations refers to the value of the velocity variance. Since the variance is the product of two velocities which is proportional to energy, the name "power spectrum" has been given to such a function representing the distribution with frequency of the kinetic energy.

The method of analysis consists in first forming the lagged product, $R(\tau)$, of the velocity components $V(t)$ (sometimes called the autocorrelation function).

$$R(\tau) = \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{T} V(t)\, V(t+\tau)\, dt \qquad (1.)$$

As shown by Taylor, the cosine transform of the function $R(\tau)$ will yield the power spectrum $S(f)$, the power per unit spectral interval,

$$S(f) = 4 \int_0^{\infty} R(\tau) \cos(2\pi f \tau)\, d\tau \qquad (2.)$$

In practice one has a finite record of discrete observations and the theory of Tukey is principally concerned with the statistical problem of estimating $S(f)$ from a limited record.

The procedure used here follows that given by Tukey; instead of $R(\tau)$ as in equation (1), the autocorrelation function R_p is determined from a discrete record,

$$R_p = \frac{1}{N-p} \sum_{i=1}^{N-p} V_i(t)\, V_{i+p}(t) \; ; \quad p = 0, 1 \ldots m, \qquad (3.)$$

where Δt is the time interval between observations; m the number of lags chosen for the analysis, and N the number of observations. The choice of m, it will appear, depends upon the amount of data and the resolution desired. The spectral density is first estimated by the expressions E_h obtained by a formal application of the cosine transform,

$$E_h = 4\Delta t \left\{ \frac{R_0}{2} + \sum_{p=1}^{m-1} R_p \cos \frac{ph\pi}{m} + \frac{R_m}{2} \right\} \qquad (4.)$$

Several important effects of the finite estimate must be considered before interpreting E_h as the desired function $S(f)$ where $f = h/2\Delta t m$. The spectrum is limited at high frequencies by the sampling interval; the maximum frequency

$f_{max} = 1/2\Delta t$. Velocity fluctuations at higher frequencies than f_{max} will appear in the lower frequency region, with reduced power. Tukey has also shown that the E_h will include substantial negative and positive contributions from nearby frequency bands on either side of $h/2\Delta t m$. The final spectral estimates are, therefore, corrected for this characteristic of the "spectral window" of E_h by taking a running average as follows:

$$S_o = 0.54\ E_o + 0.46\ E_1$$

$$S_1 = 0.23\ E_o + 0.54\ E_1 + 0.23\ E_2$$

$$S_h = 0.23\ E_{h-1} + 0.54\ E_h + 0.23\ E_{h\ 1}$$

$$S_m = 0.46\ E_{m-1} + 0.54\ E_m$$

S_h will be the final estimate of the power or variance in the spectral band

$$\frac{h-1/2}{2\Delta t m} \leq f \leq \frac{h+1/2}{2\Delta t m}$$

There will still be some contributions from nearby frequencies in the S(f) but their effect is small except for sharp power peaks.

The reliability of the estimate of variance, S(f), is calculated by an extension of the statistical procedures for computing confidence limits for variance. The ratio of the estimated power to the true power is assumed to be distributed as chi-square over $\frac{2N'}{m}$ degrees of freedom, where N' is the number of effective velocity measurements, $N' \sim N - \frac{m}{2}$. Thus resolution and reliability are seen to be inversely related, the values N, Δt, and m in a given series will be selected by the compromise desired for a given record.

For most purposes, at least ten degrees of freedom will be required to detect differences in the power spectrum. and in some cases it is

advisable to use a different analysis for different portions of the spectrum (e.g., Panofsky; 1953). Actually, the available balloon data is limited so that the choice of N and Δt were set by the experiment not by the design of the analysis.

One modification of the described procedure was employed. The large-scale motions of the troposphere will have periods of the order of days. A daylight trajectory of 10 or 12 hours duration is just beginning to measure significant contributions from the long-period motion, and the total variance obtained for a trajectory is, therefore, quite dependent upon the total length of the observation. The longest period motions or that portion highly dependent upon the length of the record was first removed by fitting a linear trend to the time series of the velocity components. The record finally analyzed was the departure from the linear fit. The variance removed by the linear fit, σ_2^2 was then used to provide an estimate of the power in the low frequency region. This power was assumed to be distributed in the frequency range, $0 \leq f \leq \frac{1}{2\Delta tN}$ *, where Δ tN is the total length of observation, and the value $2\Delta tN\sigma_2^2$ is plotted as the estimate of S(f) at $f = \frac{1}{4\Delta tN}$. This value of S(f), of course, has no statistical significance but is a useful descriptive estimate of the power of the large-scale motions. The value S_o needs some modification now since it applies only in the interval $\frac{1}{2\Delta tN} \leq f \leq \frac{1}{4\Delta t_m}$, and the adjusted value of S(f) at the center of this frequency interval will be $\frac{N}{N-2m} S_o$ Our spectral density function S(f) still follows the relation that the area under the curve is equal to the velocity variance,

---

* Since a linear trend can very nearly fit a half-period of sinusoidal velocity fluctuation.

$$\sum_{f=0}^{\frac{1}{2\Delta t}} S_h \, \Delta f = R_0^2 + \sigma_e^2$$

where $R_0^2 + \sigma_e^2$ is the total variance of the original set of observations.

3. Data and Interpretation.

Two long trajectories, one at the 200 mb level and one at 60,000 ft, were analyzed, as well as several short period lower level flights. The resulting spectral density functions are plotted in Figures II-6 and II-7, and the pertinent flight data is given in Table II. Because of the extreme range in power and frequency investigated, the coordinates used are fxS(f) versus log f. This transformation is area preserving; the area under the curve is still proportional to the power in any frequency interval. As suggested by Panofsky (1953), the this appears to be a natural plot for the power spectrum of atmospheric motions.

The power spectra for the two long flights in which the observation interval is five minutes are given in Figure II-6. The spectral density curves were drawn fitting by eye a simplest curve within the 95% confidence limits of the analysis. For both flights the power increased with increasing frequency at about $f \geq 2$ cycles hr^{-1}. An analysis of the effects of error (which will be found in the appendix) showed that this result could be caused by the errors in positioning of the balloon. The analysis also shows that errors should not affect the spectrum at $f < 2$ cycles hr^{-1}. And, therefore, the unreliable portion of the spectrum is disregarded.

Flight 24 was chosen for the complete analysis because it seemed fairly typical of the high level trajectories. The 60,000-ft flow, according to

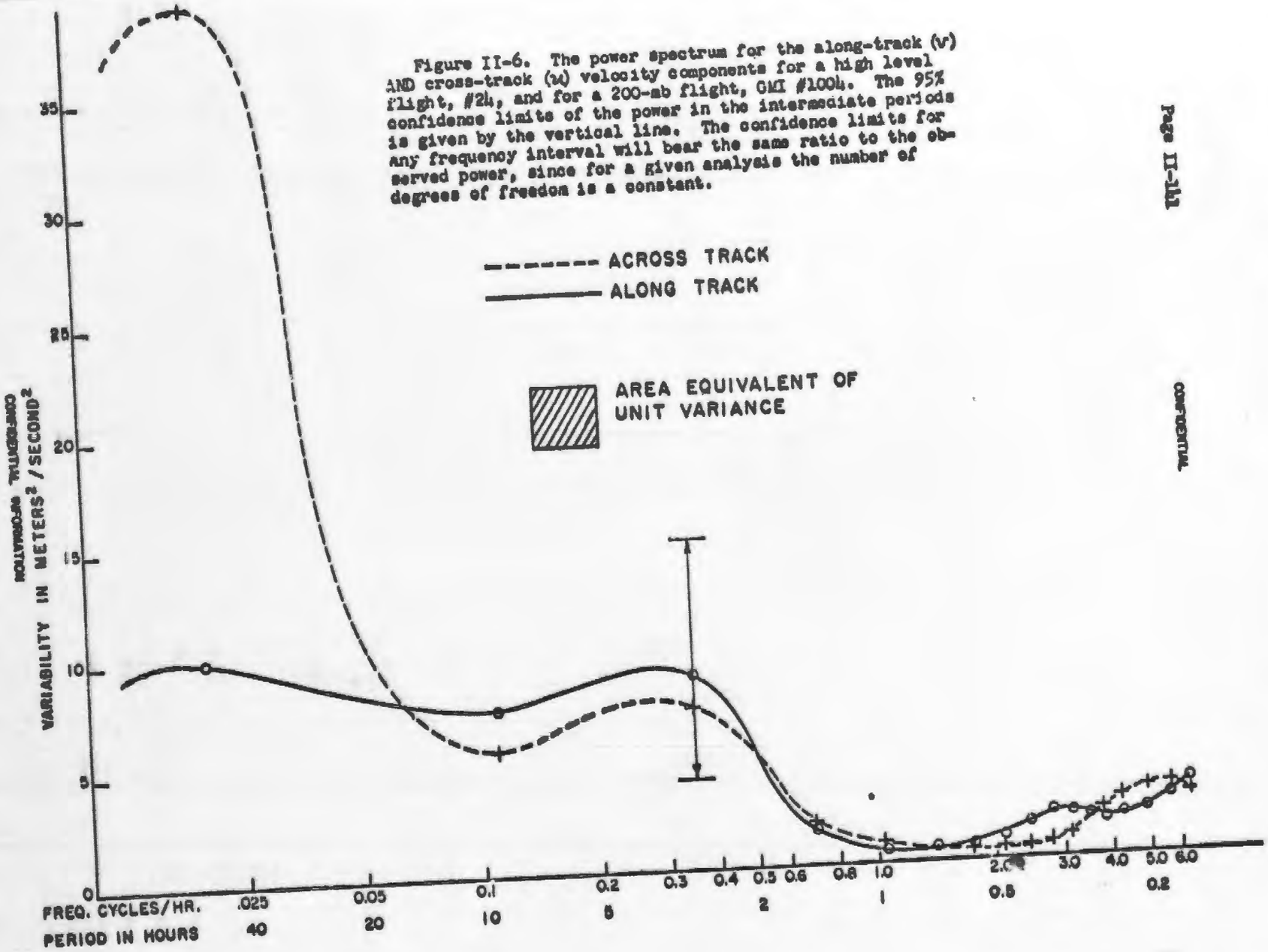


Figure II-6. The power spectrum for the along-track (v) AND cross-track (u) velocity components for a high level flight, #24, and for a 200-mb flight, GMI #1004. The 95% confidence limits of the power in the intermediate periods is given by the vertical line. The confidence limits for any frequency interval will bear the same ratio to the observed power, since for a given analysis the number of degrees of freedom is a constant.

Figure II-7. Example of a high frequency spectrum; the power spectrum of the components of the velocity fluctuation observed at three levels (38,000; 24,000; 14,000) on Flight 80, 3 July 1953. The resolution is so poor that only the lower level of 95% significance for the power at 5 cycles hr^{-1} at 38,000 ft can be shown on the diagram. The higher powers at 38,000 ft, however, appear significantly larger than at the lower levels by this test.

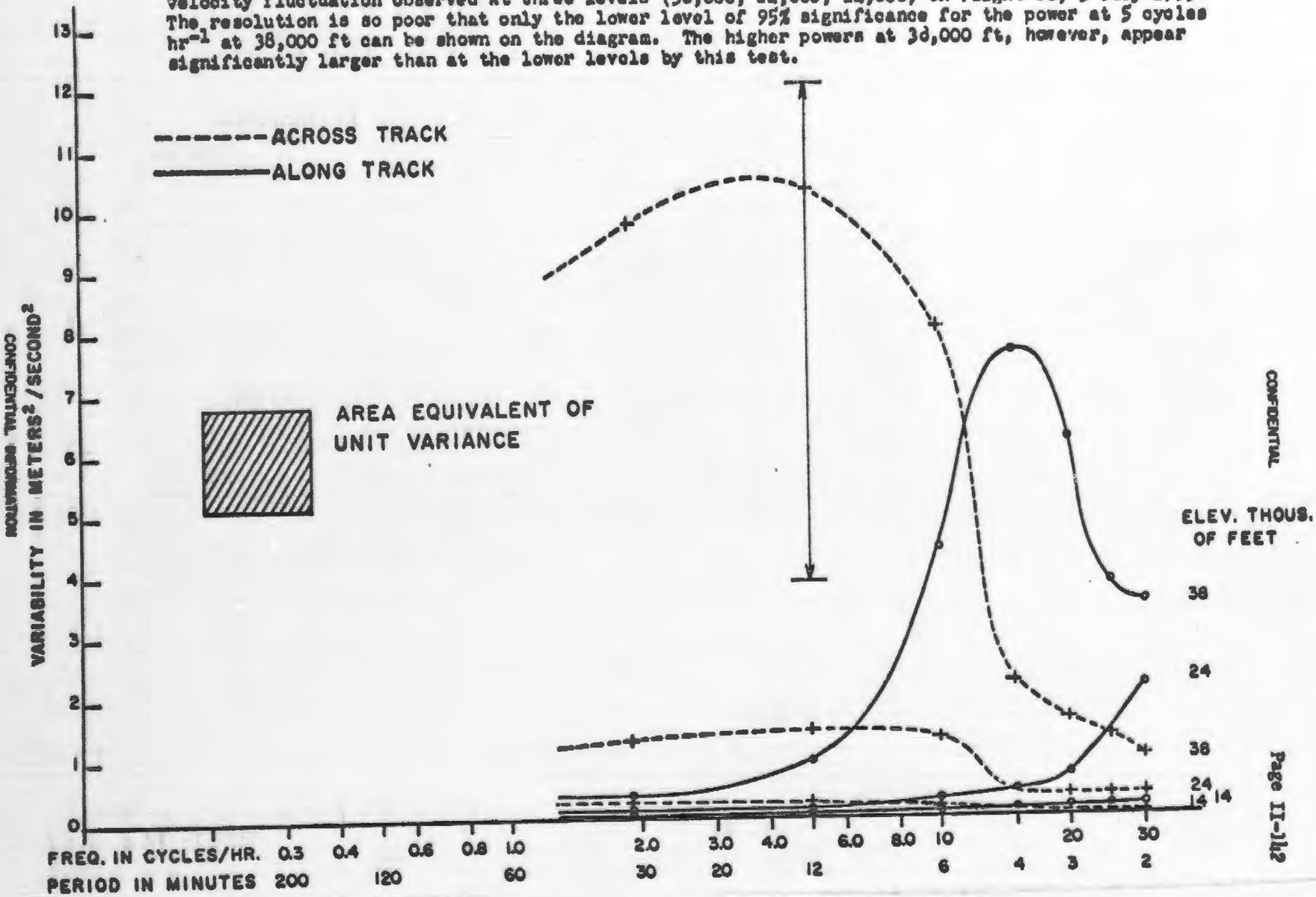


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TABLE II

Flight Data

FLIGHT	24	1004	80-1	80-2	80-3
DATE (day/month/year)	8/7/52	6/5/53	3/7/53	3/7/53	3/7/53
MEAN LOCAL TIME (0000-2359)	1130	1200	0630	0730	0830
ALTITUDE (feet)	80,000	40,000	14,000	24,000	38,000
MEAN VELOCITY (meters/sec)	13	22	13	23	32
NO. OF OBS. - N	65	163	21	23	23
OBS. INTERVAL - t (minutes)	5	4.75	1	1	1
FLIGHT LENGTH - T (minutes)	325	774	21	23	23
NO. OF LAGS - m	12	18	6	6	6
DEGREES OF FREEDOM - F	11	18	5.5	6	6
RESOLUTION - $\frac{1}{2atm}$ (c/min)	.0083	.0058	.083	.083	.083
UPPER CONFIDENCE FACTOR (95%)	2.4	1.90	3.95	3.67	3.67
LOWER CONFIDENCE FACTOR (5%)	.56	.62	.46	.48	.48
ESTIMATED POSITION ERROR (Max) (meters)	720	600	25	45	65
SOURCE	Theodolite	County maps Scale: $\frac{1}{2}$" = 1 mi	(Trace: position of picture center) Tracing scale: approx 4" = 1 mi		

CONFIDENTIAL

CONFIDENTIAL INFORMATION

Figure II-6, is characterized by a very flat spectrum with no apparent difference between the two velocity components. This flat spectrum may extend to the highest frequencies shown, $f > 12$ cycles hr^{-1}, but this result is obscured by error.

The power spectrum for lower level flow shown by GMI No. 1004 is about the same as for No. 24, at high frequencies, but much greater power at lower frequencies, $f \geq 1$ cycle hr^{-1}. Both components of the lower level flow increase at intermediate frequencies, $0.1 \leq f \leq 0.5$ cycle hr^{-1}, but at the lowest frequency the cross-track component of the velocity variance is much greater than the component parallel to the trajectory. The meaning of this last result may be clearer by pointing out that the trajectory travels through 90° of arc with a radius of 500 miles and the centrifugal acceleration (or cross-track velocity variance) is much larger than the acceleration in the direction of the flow.

Flight 80 was a step flight with three short portions of level flight at different elevations which provide further information on the wind structure in the lower atmosphere. Here photographs were available every minute and more accurate positioning was attained by mapping the trajectory, tracing directly from the enlargement of the film. Thus the high frequency end of the spectrum can be investigated. However, the length of record is less than an hour in all cases and the confidence limits of the result are quite broad. The power spectrum (Figure II-7) for Flight 80 shows for the first two steps that the region of low power extends to the highest frequencies observed and substantiates the previous point that the high power shown at high frequencies in Figure II-6 is due to the effects of error.

The spectrum of the velocity variance at the highest elevation is very difficult to interpret. In this case, the power in both components is almost as high as that observed for the large scale motion at 200 mb. The lower 95% confidence limit is indicated to illustrate the magnitude of the difference which must be explained. One possible cause which cannot be entirely dismissed is that the apparent velocity fluctuations are due to camera tilt acquired during flight, and just reflects the rotation of the camera. The record is too short to eliminate this hypothesis statistically but no great relationship appeared upon comparing the balloons' deviation from a regular path and the azimuth angle of the camera. If this high power at high frequencies is real, a plausible explanation would be that it represents the effects of convection. It may be seen from the plotted radiosonde report that there was a very deep layer with a steep lapse rate, almost approaching the dry adiabatic. The first two steps were made at 0631 and 0731 local time, while the last level was made at about 0900, so that during this time convection would be expected to increase. Then too, as will be noted from the preceding section on vertical structure, this observation is made in a region of strong vertical wind shear just below the wind maximum and horizontal fluctuations in the velocity field would certainly result from even small vertical displacements.

4. Conclusions

a. Structure of High Level Flow

The flat spectral distribution of the velocity fluctuations of the 80,000-ft flow which was suggested by the previous studies has been verified by the new method of spectral analysis. The lack of high power

at low frequencies is quite distinct from the characteristics of tropospheric motions where the greatest fluctuations are associated with motions of the period at least as great as a day. It is, of course, this characteristic of the tropospheric flow that makes it possible to draw weather maps and successfully track and extrapolate flow patterns with the present spacing of upper air observations. The "noise" does not seriously interfere with the desired information. In the upper stratosphere, on the other hand, the longer period motion cannot be distinguished from the high frequency "noise". It is doubtful, therefore, that even if the current wind network could regularly obtain synoptic data to 80,000 ft, it would be possible to construct daily weather maps for this level because many of the wind variations on such a chart would be associated with systems smaller than the distance between wind reports.

b. Structure of Tropospheric Flow

The spectral density analysis of the lower level flow shows the greatest power at the low frequencies associated with the larger-scale or synoptic-scale flow. The highest frequency region investigated, which just borders the frequencies generally termed turbulent flow (e.g. Panofsky, 1953), is a region of low power. The one exception of high power at high frequencies may be unique because the trajectory was made in a region of strong vertical shear and relatively unstable temperature lapse rate.

The intermediate frequency region (motion with periods of 1 to 10 hours) is a region of relatively high power. The importance of this observation to the theoretical meteorologist may be seen by the following:

Conventional upper observations, since they are made only at 12-hour

intervals, cannot be expected to detect and track fluctuations with periods less than 12 hours. It is evidently necessary to also classify as "noise" these fluctuations of intermediate period. Therefore, the fact that these intermediate fluctuations are almost equal in amplitude to the along-track velocity fluctuations, means that the "noise" may interfere with the measurement of accelerations. For example, the cross-isobar wind component during a short time interval may not be related to the large-scale flow pattern. Quantities dependent upon the measurement of accelerations such as the vorticity change will be highly dependent upon the definition of scale.

APPENDIX

Effect of Position Error on the Spectral Analysis

A complete analysis also requires some estimate of the effects of errors in the basic data. This is particularly important when a comparison is made of spectral density functions for which the basic data is obtained under different operational methods or conditions.

For an ideal case we will assume a time sequence which consists entirely of errors which are presumed to be a finite random selection from a normal distribution with zero mean and variance σ_e^2. Then on the average, the lagged variance of such a series of errors will be:

$$R_0 (error) = \sigma_e^2$$

$$R_p (error) = 0 \qquad \text{for } p \neq 0$$

and the power spectrum S_h (error) = $2\Delta t\, \sigma_e^2$ for all h. Thus, on the average, the error component appears as a constant determined by the observation interval and the error variance. This constant function is nearly

realized in any particular situation which satisfies the fore-specified assumptions if a sufficiently large number of observations is available. If now a time sequence consists of fluctuations and error of the type being considered, then the true powers of the fluctuations are obtained by subtracting $2\Delta t\, \sigma_e^2$ from each computed value of S or equivalently by subtracting σ_e^2 from R_o (observed) before computing the spectral density.

In the present case the errors in the position fixes may reasonably be considered to be randomly selected and normally distributed. However, the velocity errors which depend on the position fix errors, although normally distributed, are not randomly selected in time. This is due to the fact that any pair of consecutive velocities are partially determined by a common position fix. It can be shown that on the average the lagged variance for velocity error will be

$$R_o \text{ (error)} = 2\sigma_e^2$$

$$R_1 \text{ (error)} = -\sigma_e^2$$

$$R_p \text{ (error)} = 0 \quad \text{for } p \neq 1, \neq 0$$

where σ_e^2 is the error variance of the velocity due to single position fix error. From this we obtain

$$E_h \text{ (Velocity error)} = 4\Delta t\, \sigma_e^2 \left(1 - \cos\frac{\pi h}{m}\right); \quad 0 \leq h \leq m$$

as the average first estimate of error power. Thus the contribution of position fix error to a velocity fluctuation power spectrum increases with frequency to a maximum of $8\Delta t\, \sigma_e^2$ at $f = \frac{1}{2\Delta t}$. If σ_e^2 is known, the best estimate of power is obtained by subtracting R_o (error) and R_1 (error) from the corresponding lagged variances of the velocity record.

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