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TEMPERATURE IN CENTIGRADE DEGREES
+50
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
ALTITUDE IN THOUSANDS OF FEET
0
10
20
30
40
50
60
70
80
90
100
PRESSURE IN MILLIBARS
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10

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

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FOR PERIOD JUNE 15, 1952 to DECEMBER 22, 1952
WITH THE
OFFICE OF NAVAL RESEARCH

AND SPONSORED JOINTLY
BY THE ARMY, NAVY AND AIR FORCE

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

Date: Oct 16th 1953 J. O. Robertson
By direction of
Chief of Naval Research (Code 461)

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

PROGRESS REPORT ON CONTRACT #710(01)

From June 15, 1952 to December 22, 1952

VOLUME VII

CONFIDENTIAL SECURITY INFORMATION

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Time-Temperature Charts — Pages I-99 - I-112

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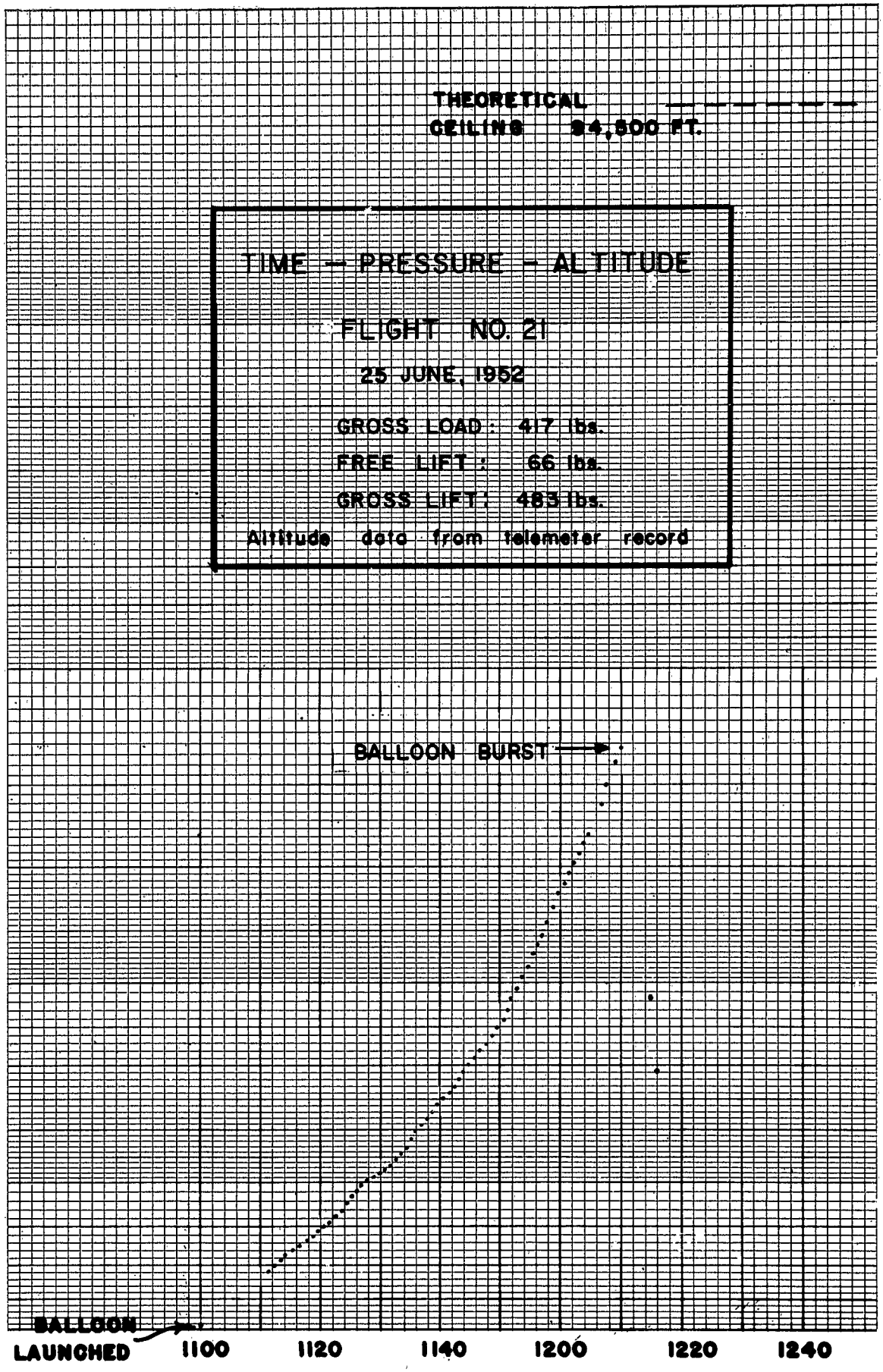
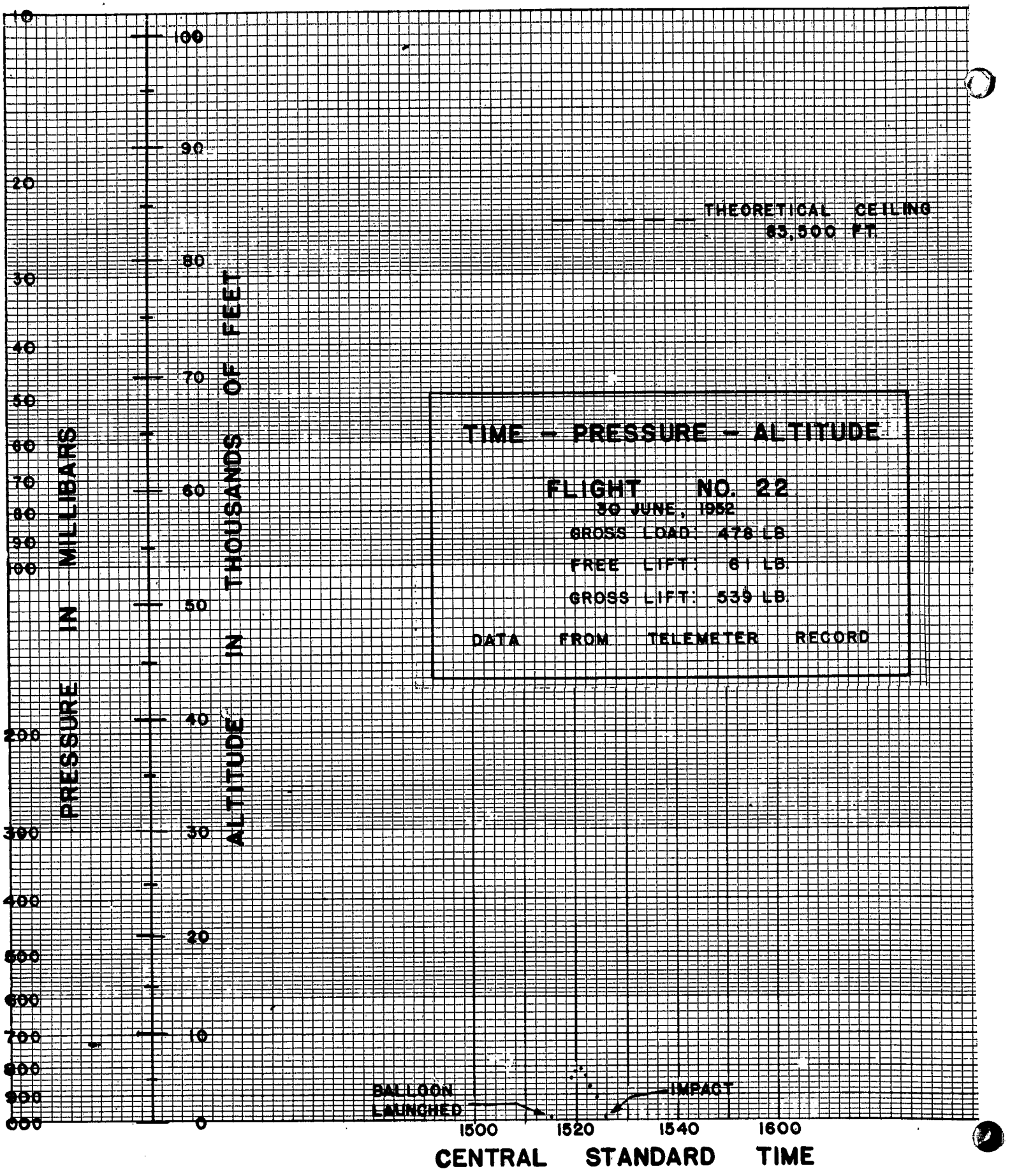
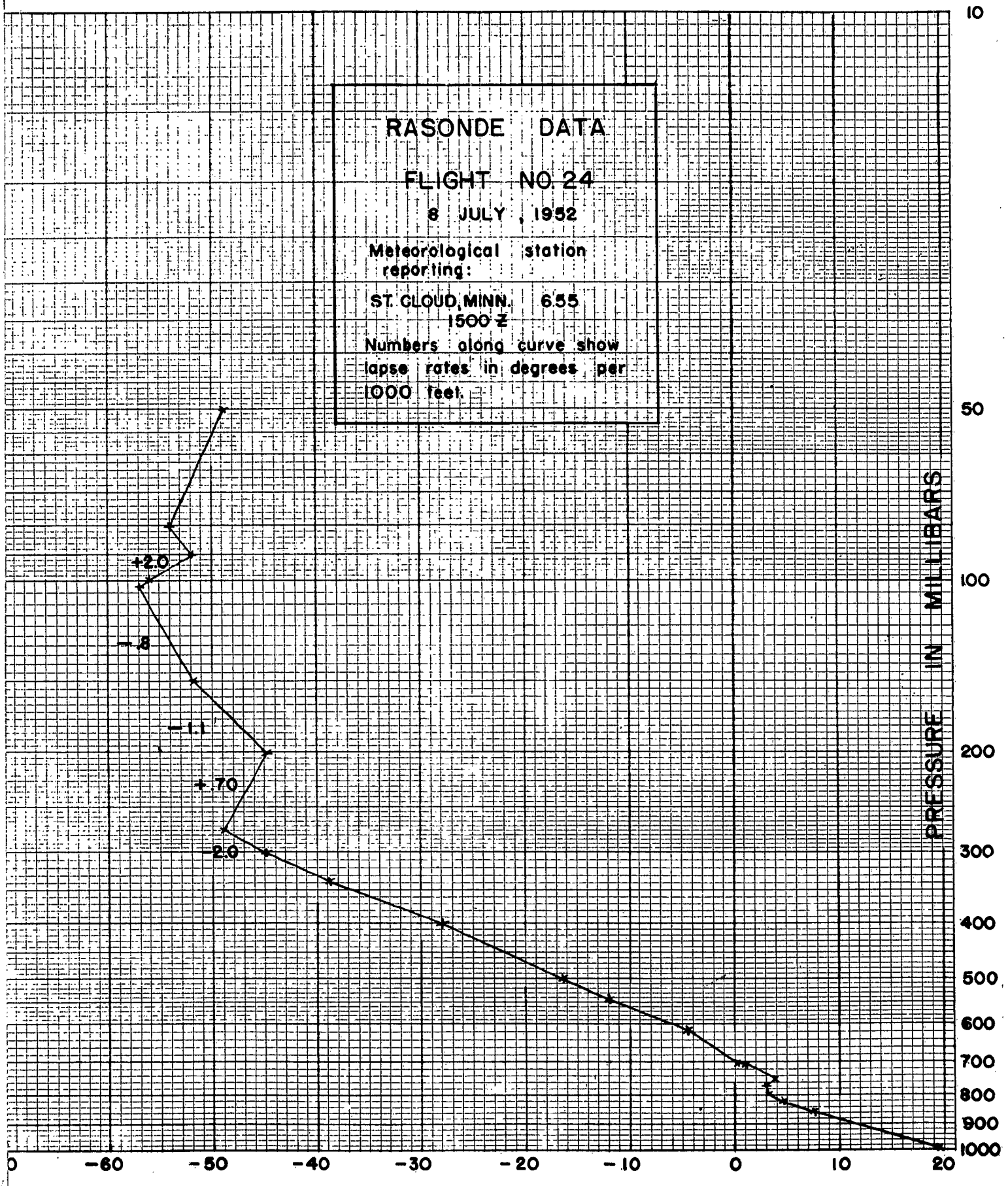
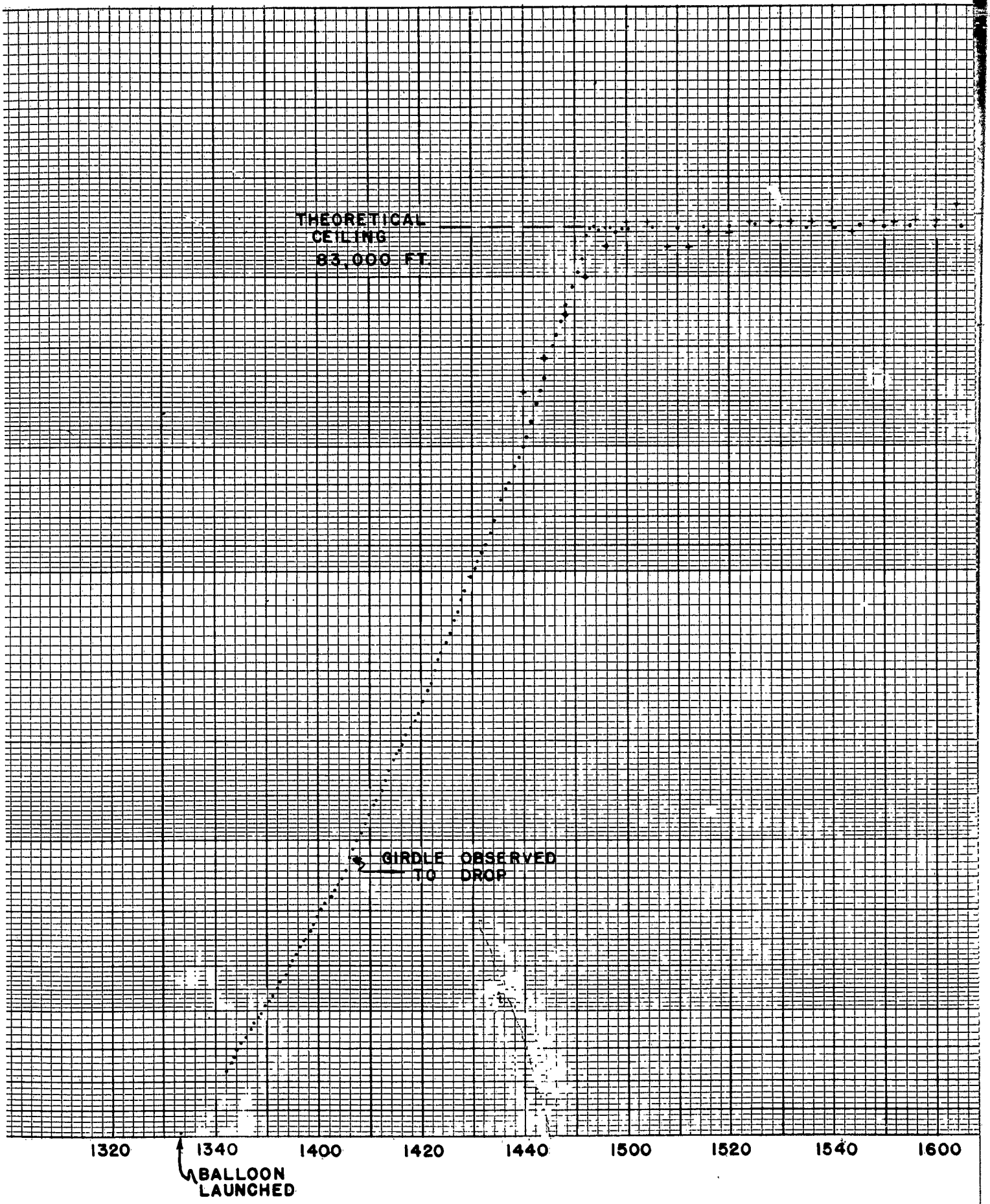
Part B - Winds in the Upper Troposphere and Lower Stratosphere — Pages II-139 - II-145

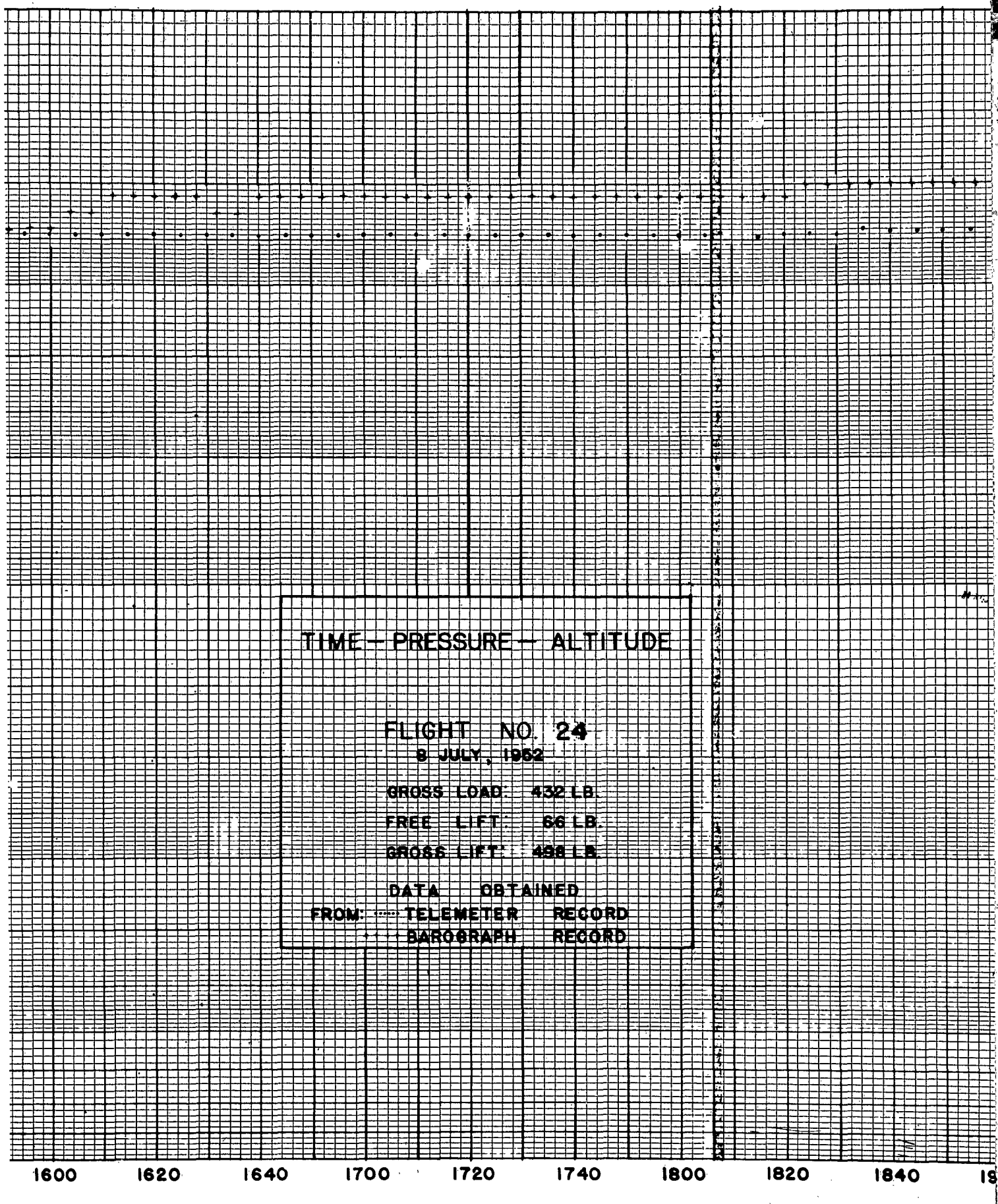

THEORETICAL
CEILING 94,500 FT.
TIME -- PRESSURE - ALTITUDE
FLIGHT NO. 21
25 JUNE, 1952
GROSS LOAD: 417 lbs.
FREE LIFT: 66 lbs.
GROSS LIFT: 483 lbs.
Altitude data from telemeter record
BALLOON BURST
BALLOON LAUNCHED
1100
1120
1140
1200
1220
1240
CENTRAL STANDARD TIME

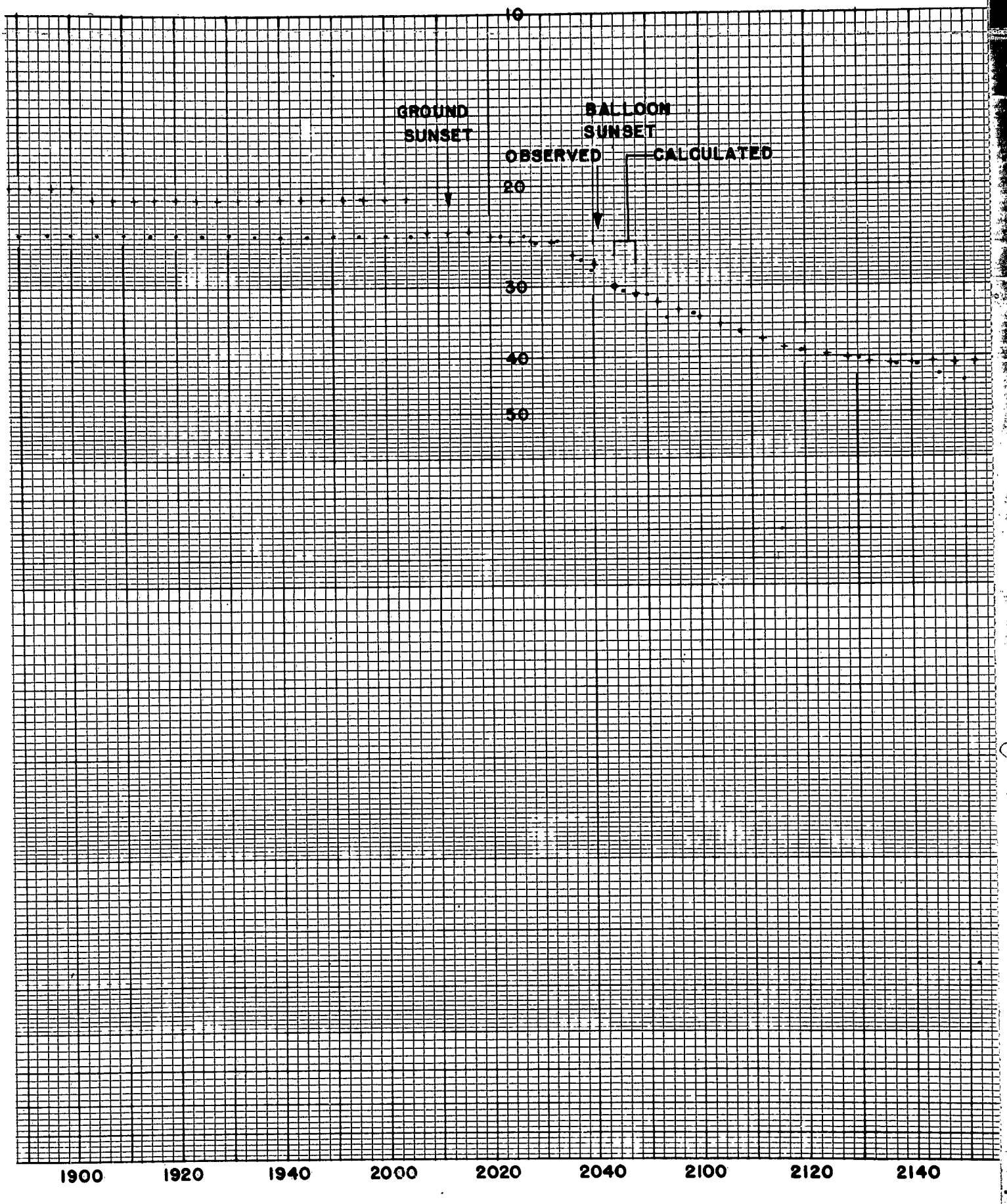
CONFIDENTIAL

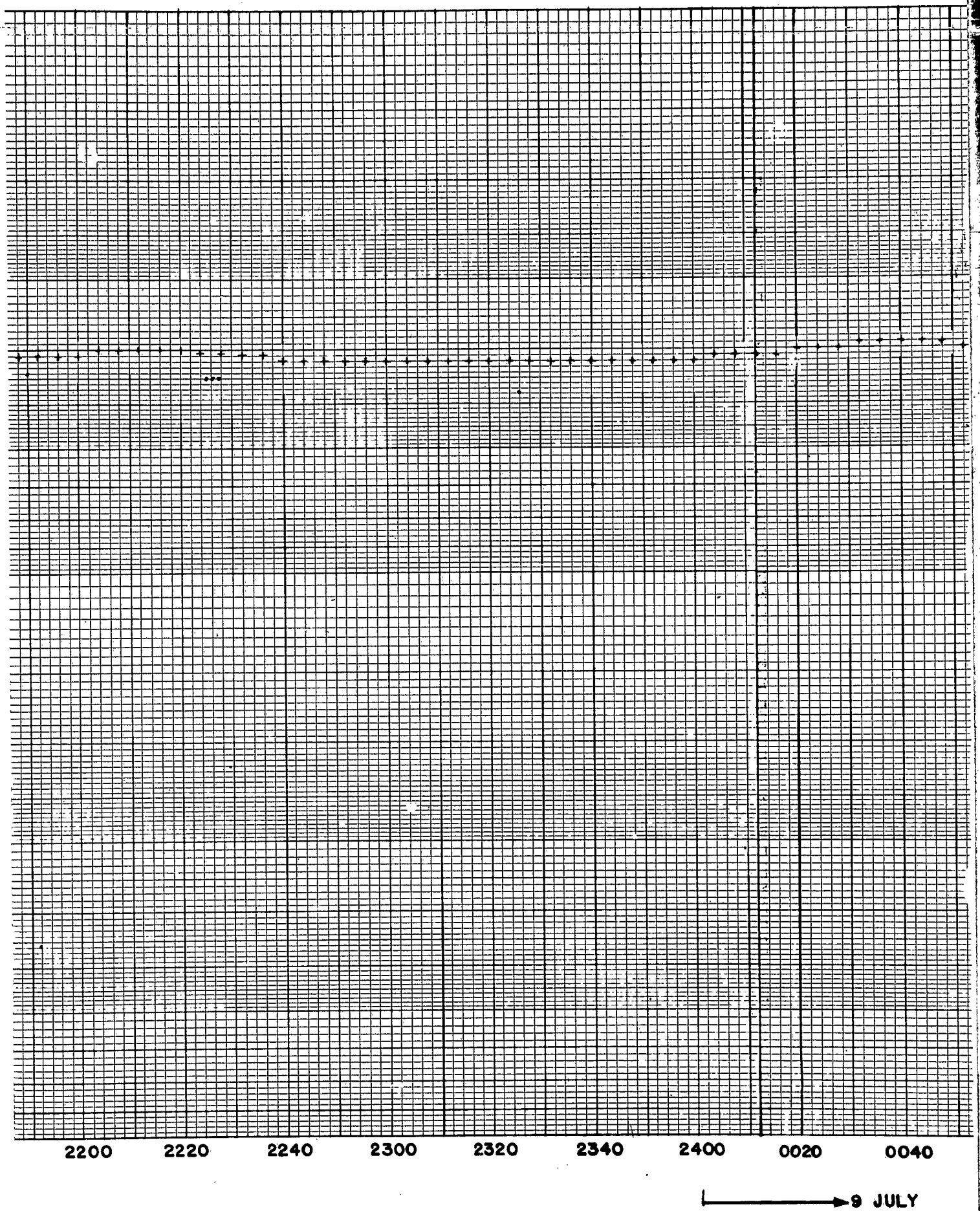


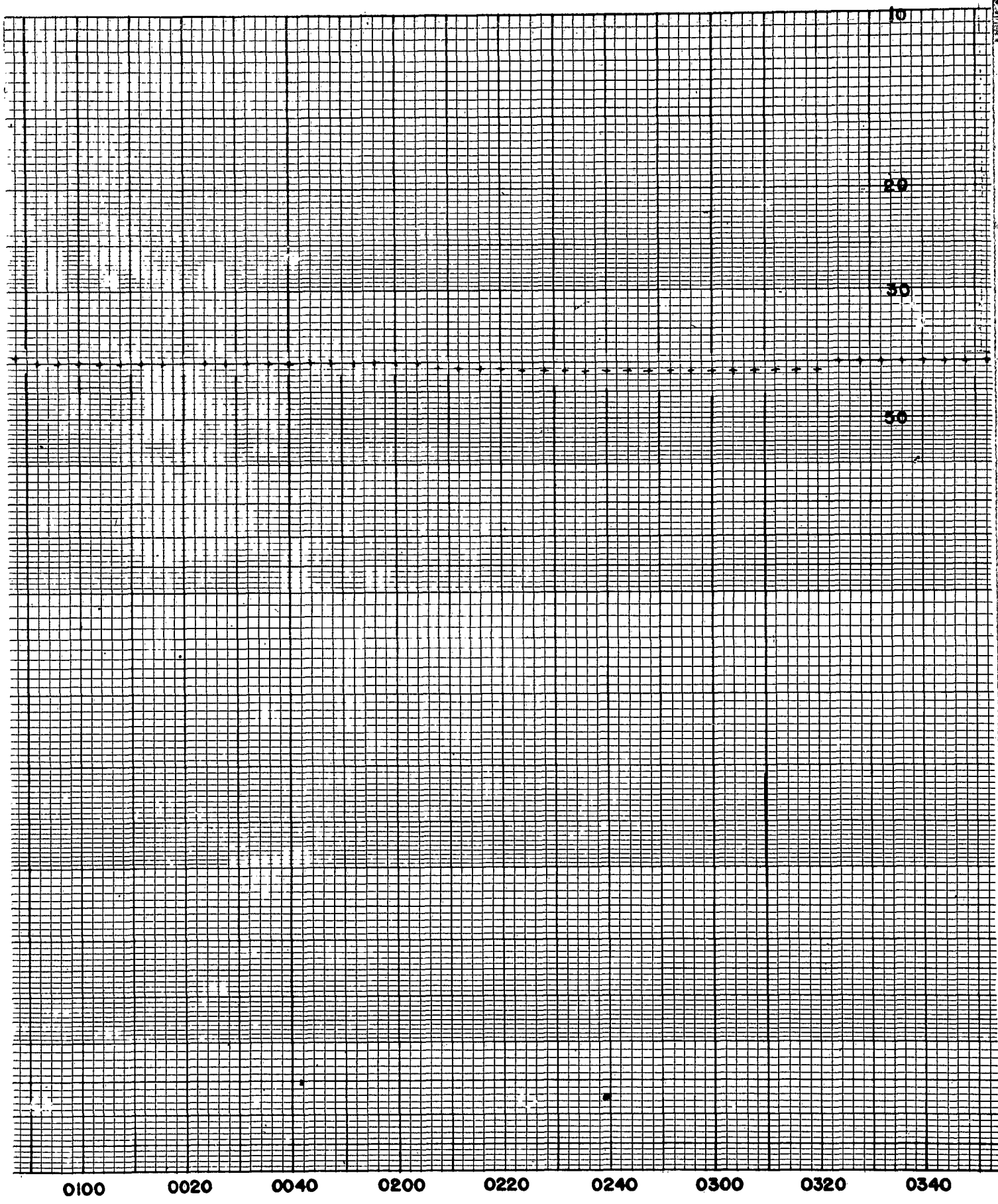

RASONDE DATA
FLIGHT NO. 24
8 JULY , 1952
Meteorological station reporting:
ST. CLOUD, MINN. 6.55
1500 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
+2.0
-.8
-1.1
+.70
-2.0
10
50
100
200
300
400
500
600
700
800
900
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (° C.)

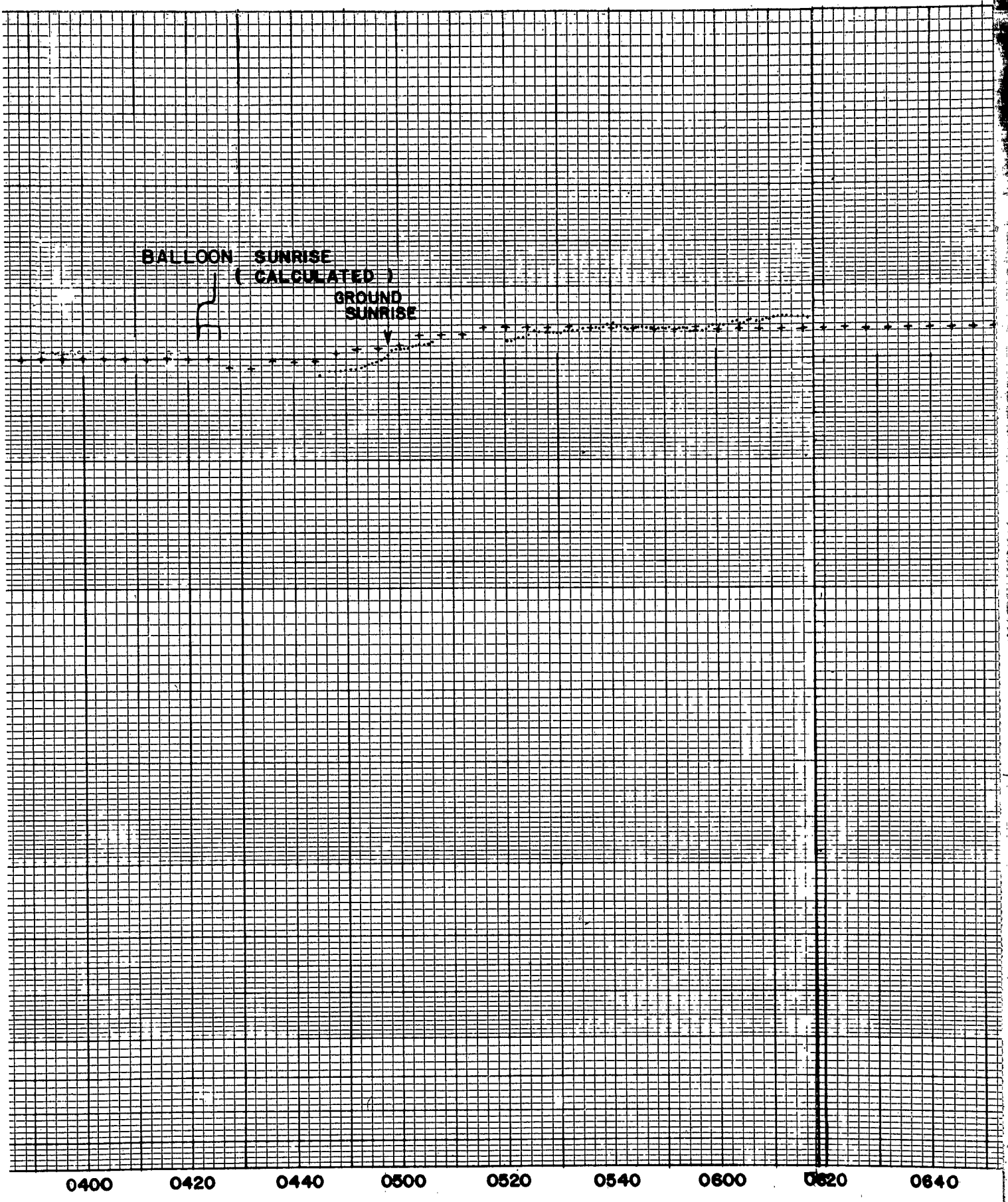

THEORETICAL
CEILING
83,000 FT.
GIRDLE OBSERVED
TO DROP
1320
1340
1400
1420
1440
1500
1520
1540
1600
BALLOON
LAUNCHED

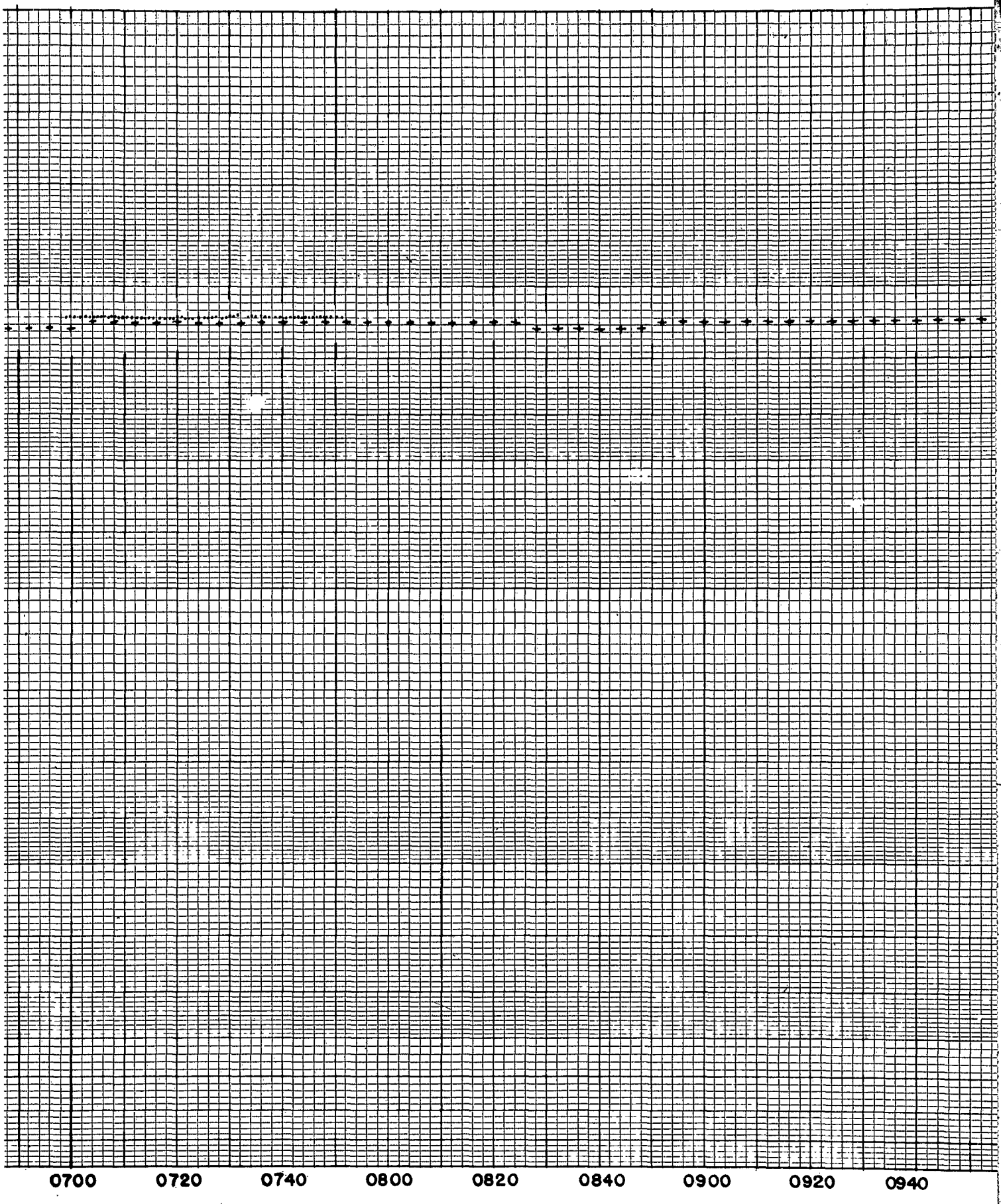

TIME – PRESSURE – ALTITUDE
FLIGHT NO. 24
8 JULY, 1952
GROSS LOAD: 432 LB.
FREE LIFT: 66 LB.
GROSS LIFT: 498 LB.
DATA OBTAINED
FROM: ····· TELEMETER RECORD
· · · · BAROGRAPH RECORD
1600
1620
1640
1700
1720
1740
1800
1820
1840
CENTRAL STANDARD TIME

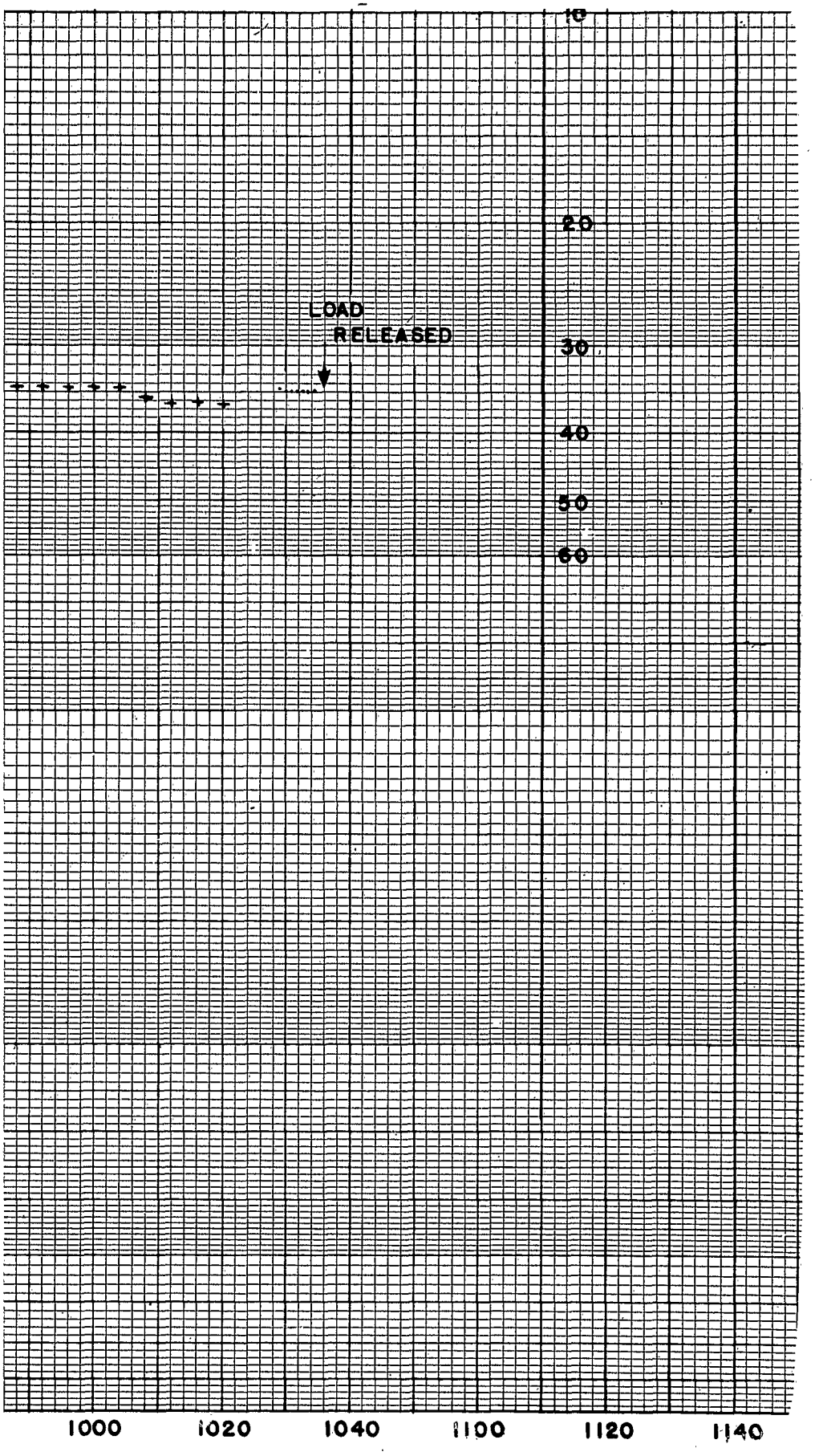

10
20
30
40
50
GROUND
SUNSET
BALLOON
SUNSET
OBSERVED
CALCULATED
1900
1920
1940
2000
2020
2040
2100
2120
2140


2200
2220
2240
2300
2320
2340
2400
0020
0040
9 JULY


10
20
30
40
0100
0020
0040
0200
0220
0240
0300
0320
0340

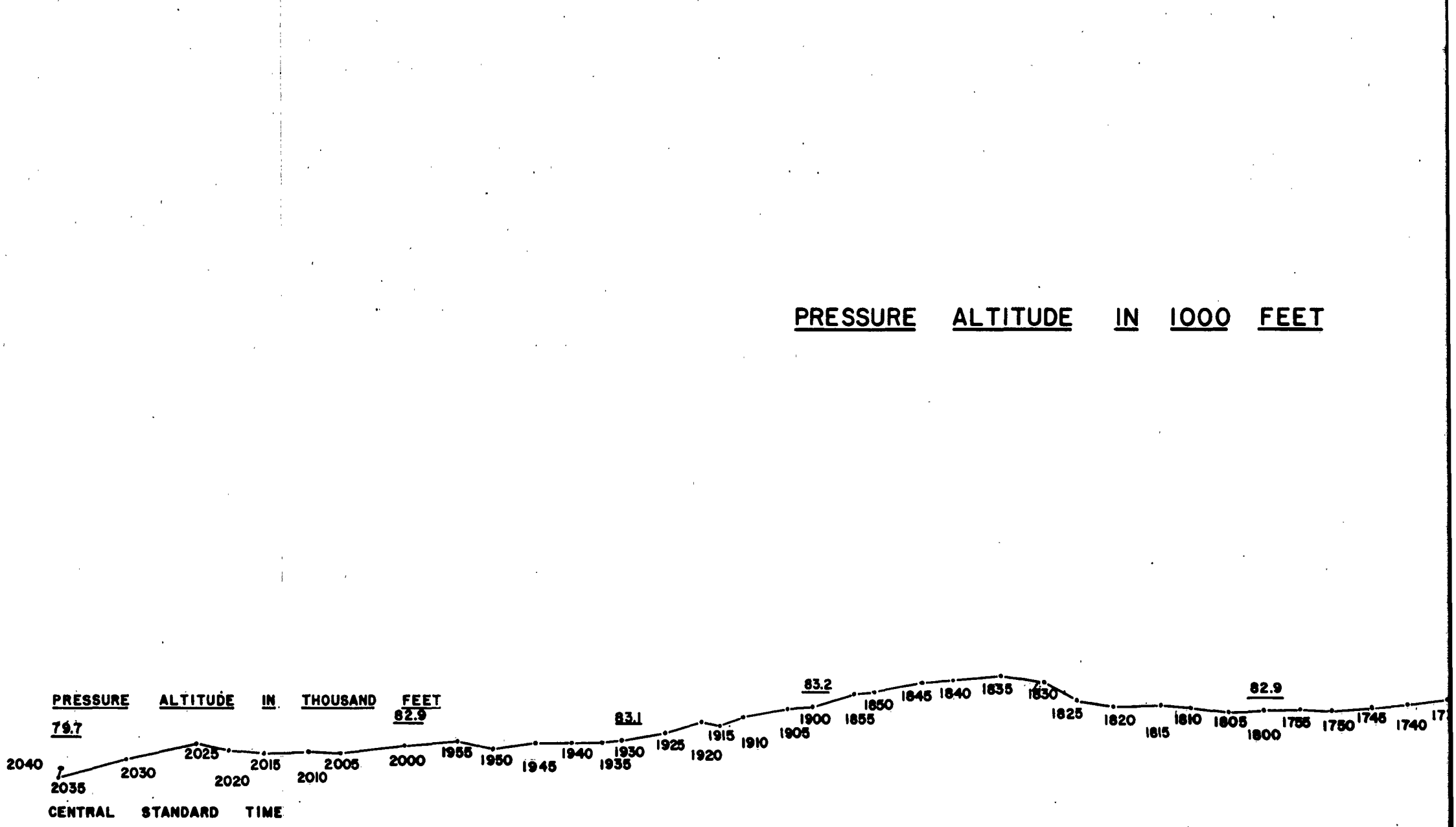

BALLOON SUNRISE
(CALCULATED)
GROUND
SUNRISE
0400
0420
0440
0500
0520
0540
0600
0620
0640


0700
0720
0740
0800
0820
0840
0900
0920
0940

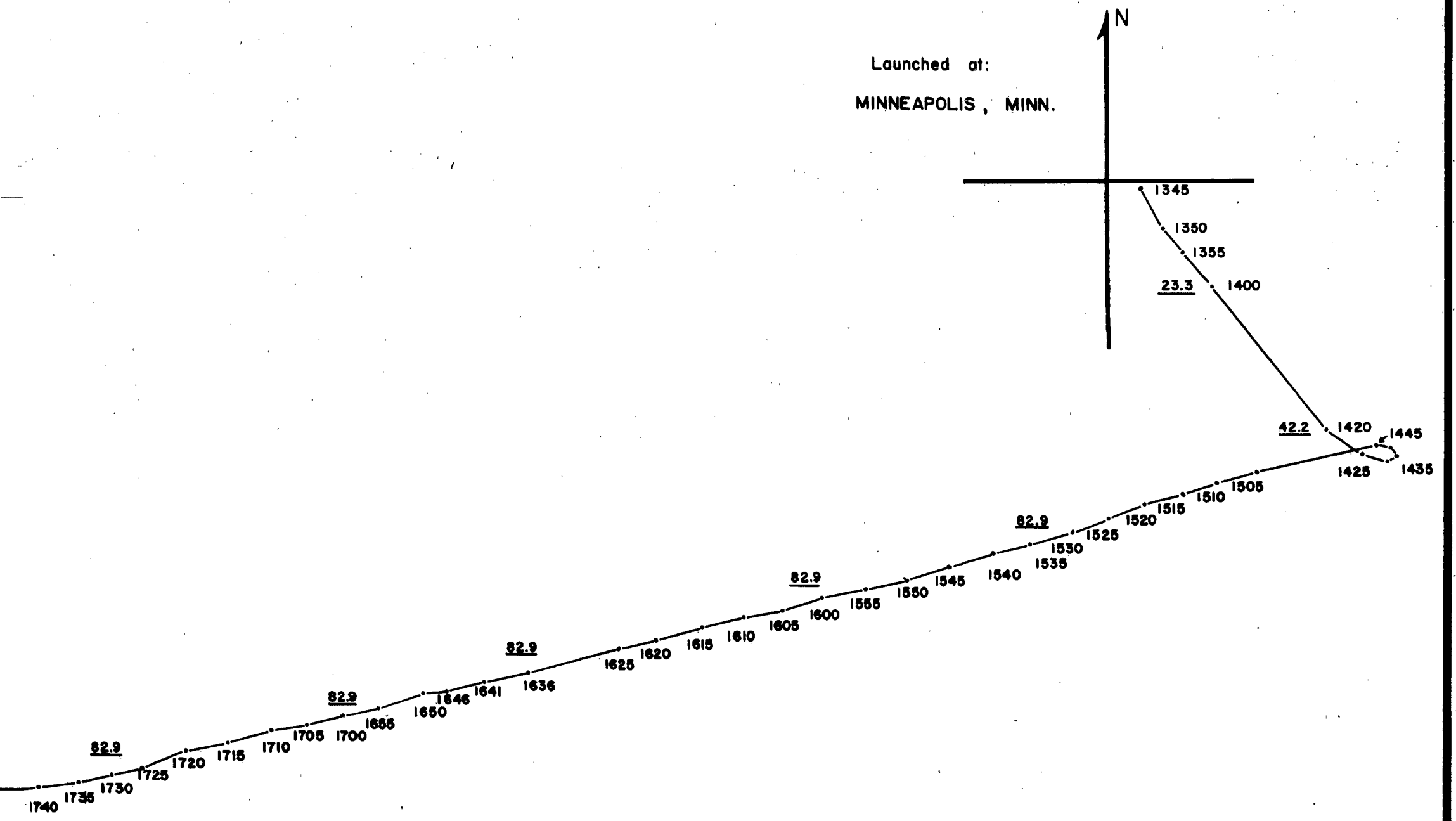

10
20
LOAD
RELEASED
30
40
50
60
1000
1020
1040
1100
1120
1140

CONFIDENTIAL SECURITY INFORMATION

PRESSURE ALTITUDE IN 1000 FEET



CONFIDENTIAL SECURITY INFORMATION



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CENTRAL STANDARD TIME

10 0 10 20 STATUTE MILES

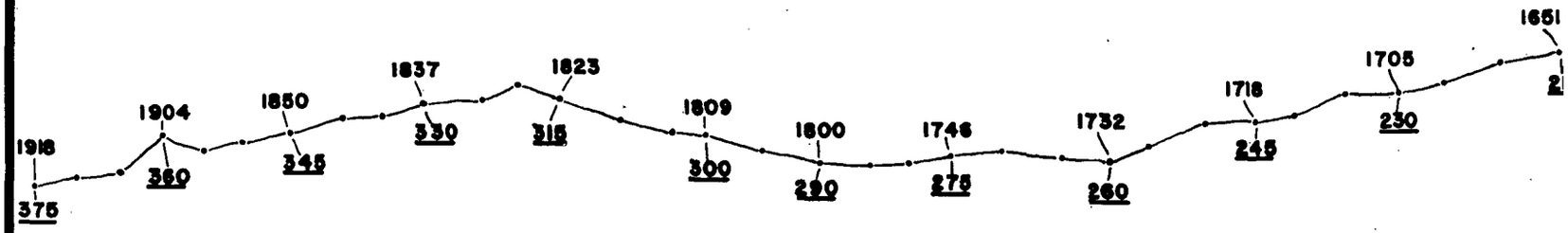
FLIGHT NO. 24

LAUNCHED 1333 CST
8 JULY, 1952

TRAJECTORY FROM THEODOLITE FIXES

CONFIDENTIAL SECURITY INFORMATION

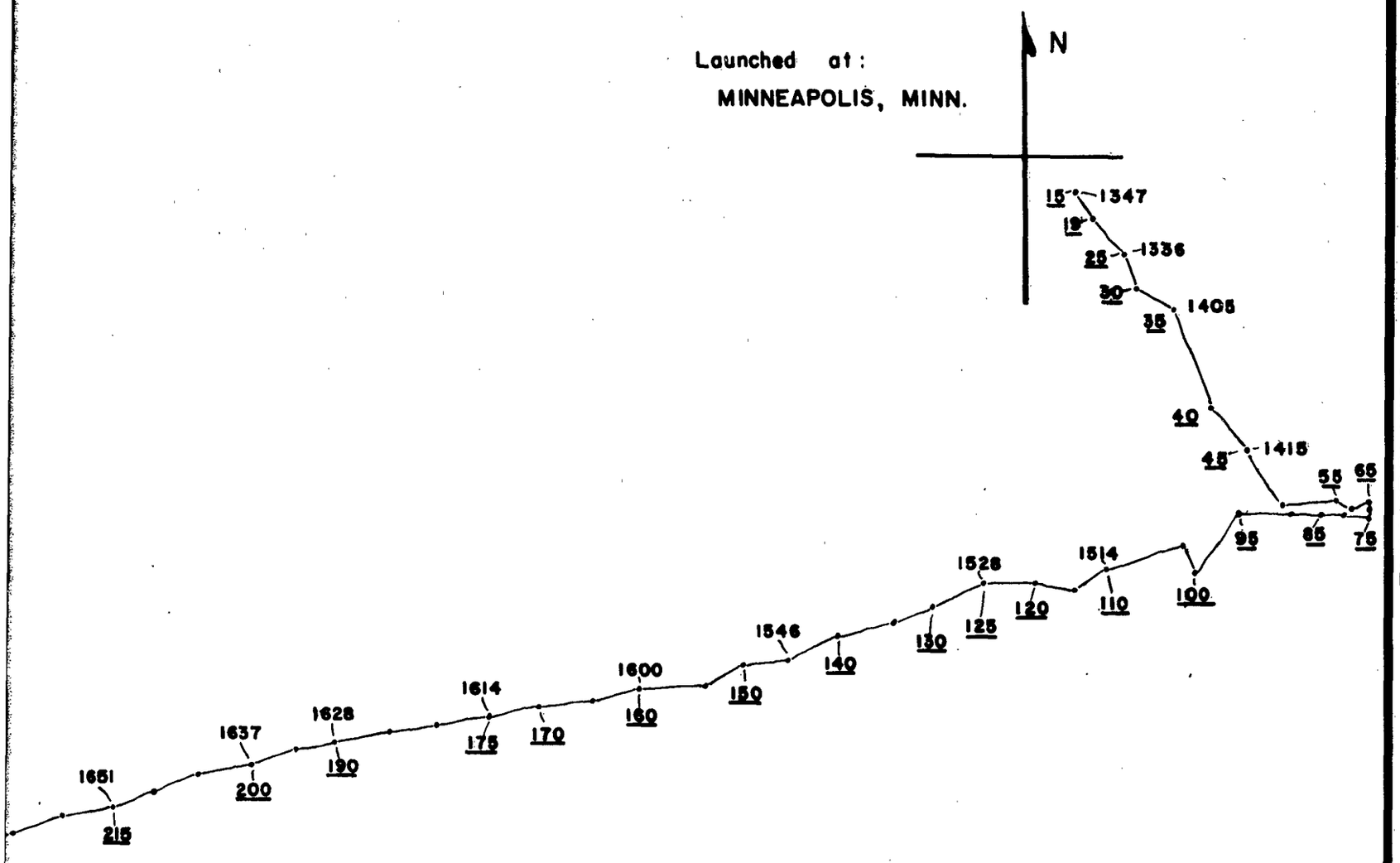
CENTRAL STANDARD TIME



FILM FRAME NUMBER

1

10



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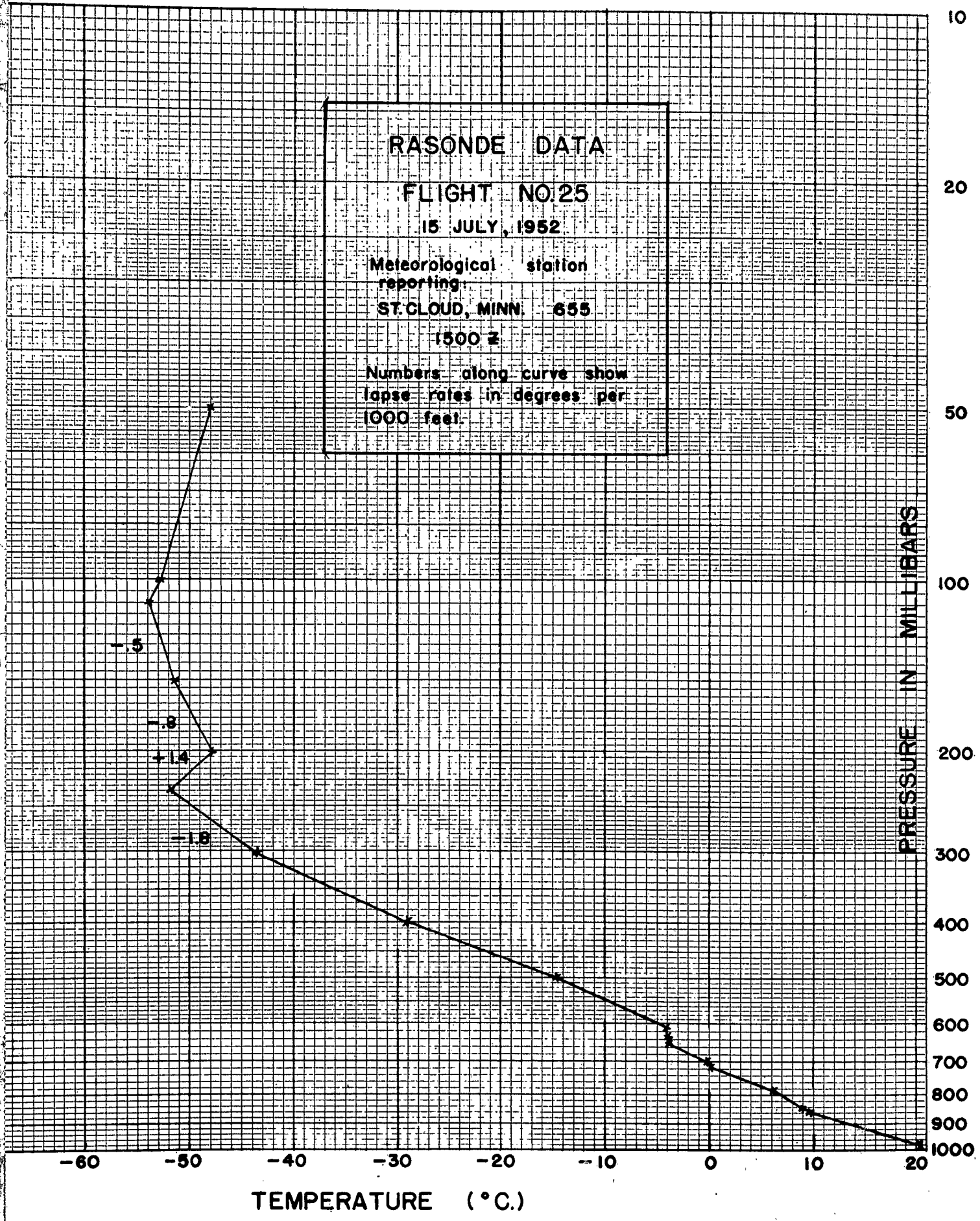
FLIGHT NO. 24

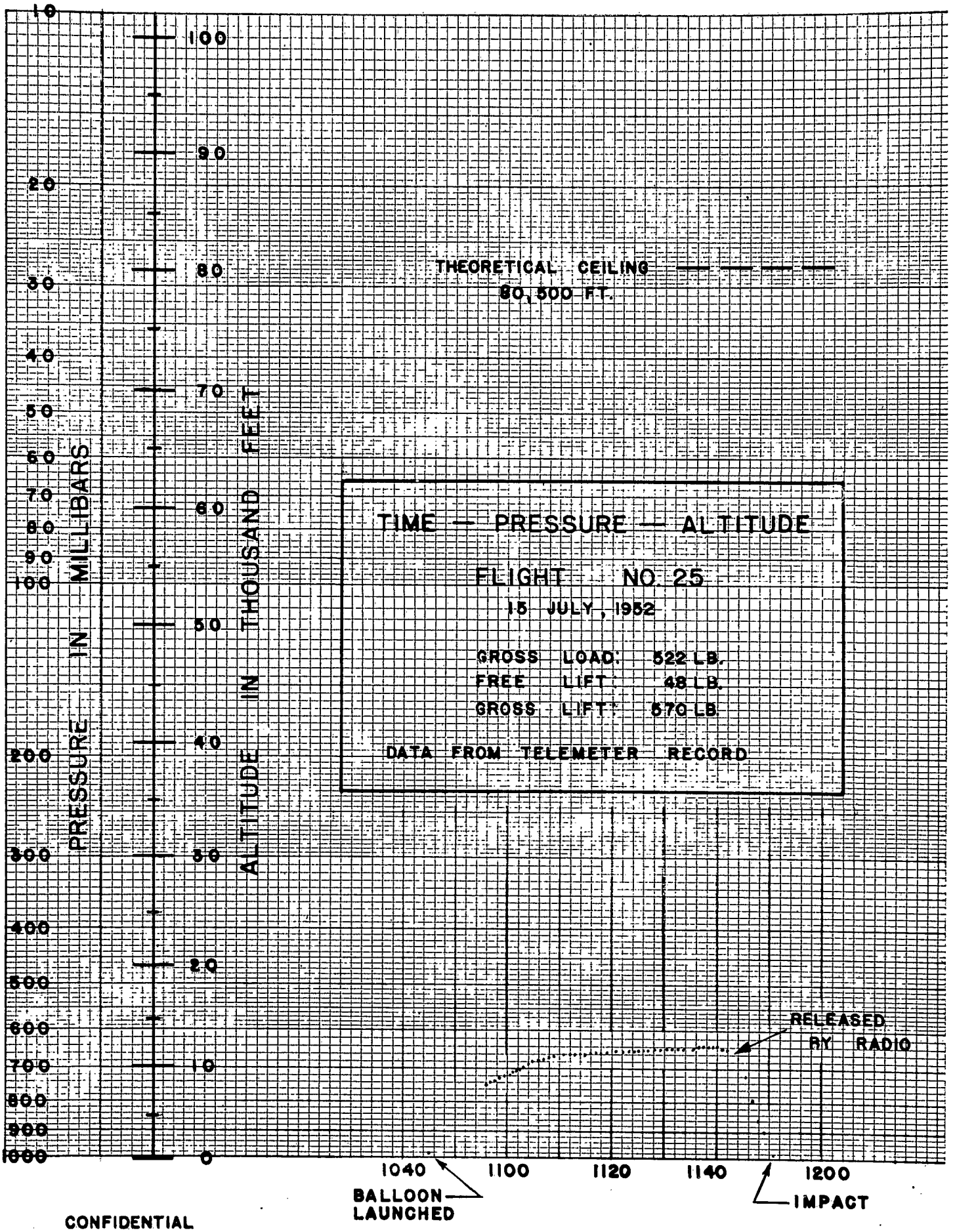
LAUNCHED 1333 CST

8 JULY, 1953

TRAJECTORY FROM DOWN PICTURES

10 0 10 20 STATUTE MILES


RASONDE DATA
FLIGHT NO. 25
15 JULY, 1952
Meteorological station reporting:
ST. CLOUD, MINN. 655
1500 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
-.5
-.8
+1.4
-1.8
10
20
50
100
200
300
400
500
600
700
800
900
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)



CONFIDENTIAL
SECURITY INFORMATION

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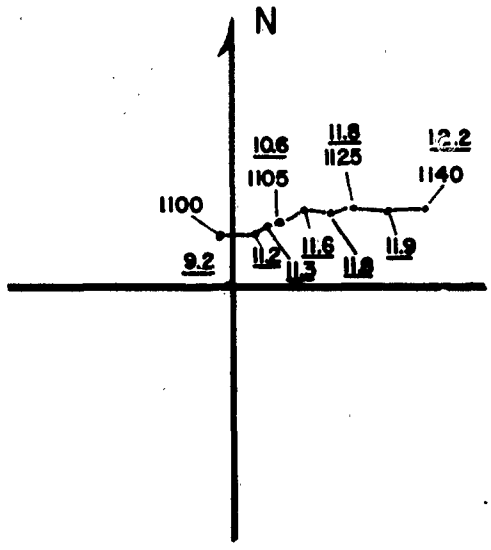
Launched at :

MINNEAPOLIS, MINN.



CENTRAL STANDARD TIME

PRESSURE ALTITUDE IN 1000 FT.

FLIGHT NO. 25

LAUNCHED 1045

15 JULY, 1952

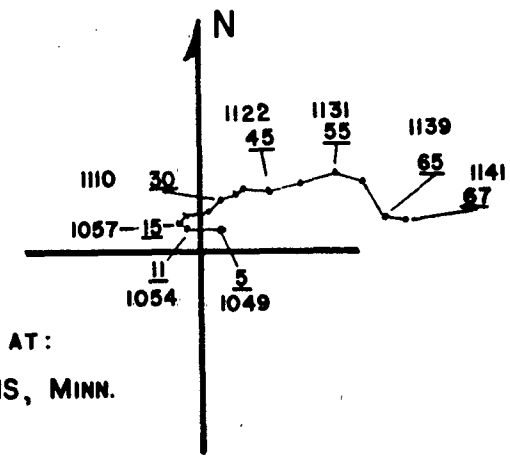
TRAJECTORY FROM THEODOLITE FIXES

SCALE 1:5×10^5

CONFIDENTIAL SECURITY INFORMATION

10 0 10 20 STATUTE MILES

CONFIDENTIAL



CENTRAL STANDARD TIME

FILM FRAME NUMBER

LAUNCHED AT:
MINNEAPOLIS, MINN.

FLIGHT NO. 25

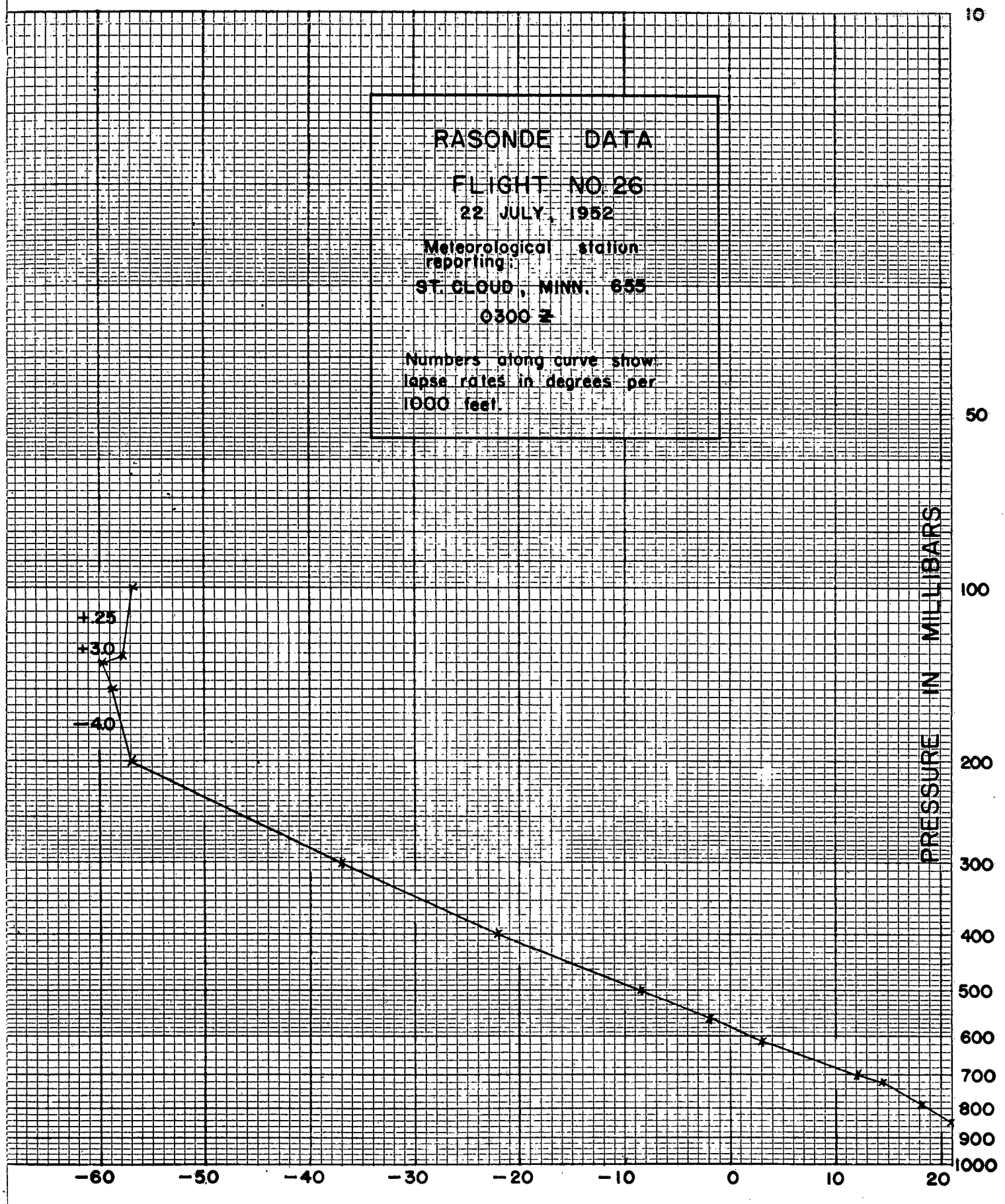
LAUNCHED 1045 CST
15 JULY, 1952

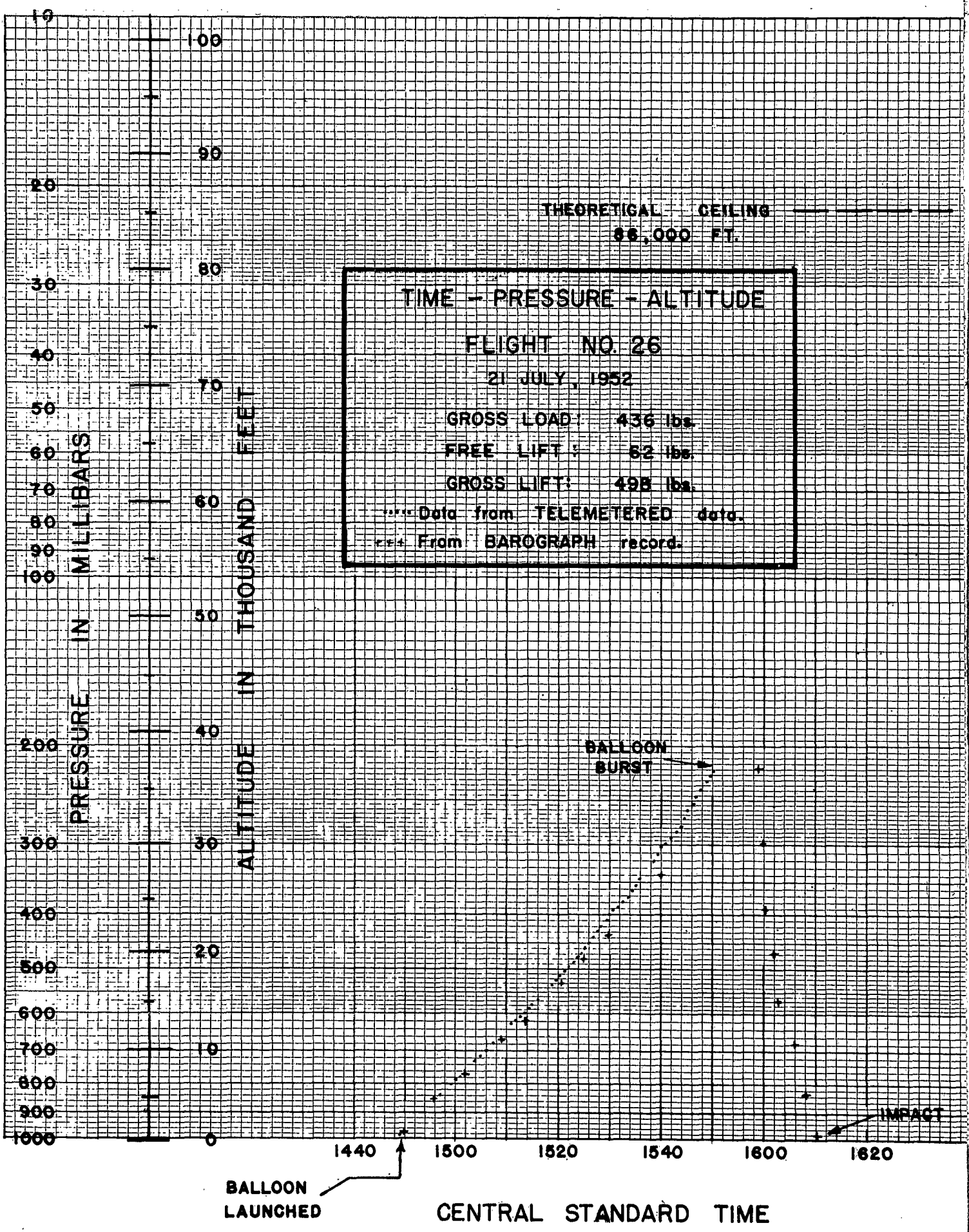
TRAJECTORY FROM DOWN PICTURES

SCALE 1:5 x 10^5

CONFIDENTIAL SECURITY INFORMATION

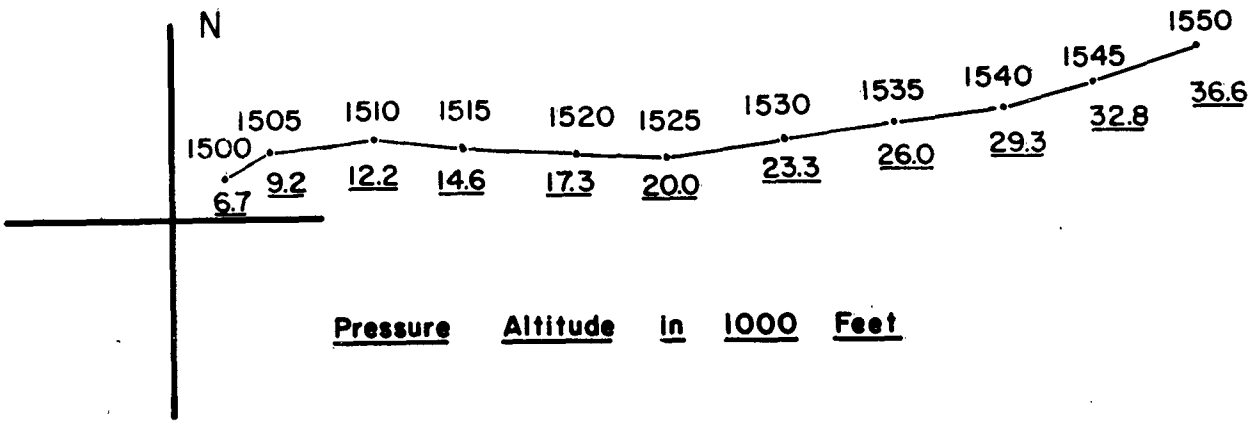
10 0 10 20 STATUTE MILES


RASONDE DATA
FLIGHT NO. 26
22 JULY, 1952
Meteorological station reporting:
ST. CLOUD, MINN. 655
0300 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
+2.5
+3.0
-4.0
10
50
100
200
300
400
500
600
700
800
900
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)


THEORETICAL CEILING
86,000 FT.
TIME - PRESSURE - ALTITUDE
FLIGHT NO. 26
21 JULY, 1952
GROSS LOAD: 436 lbs.
FREE LIFT: 62 lbs.
GROSS LIFT: 498 lbs.
.... Data from TELEMETERED data.
r-r-r From BAROGRAPH record.
PRESSURE IN MILLIBARS
ALTITUDE IN THOUSAND FEET
BALLOON BURST
IMPACT
BALLOON LAUNCHED
CENTRAL STANDARD TIME
1440
1500
1520
1540
1600
1620

Launched at:
MINNEAPOLIS, Minn.

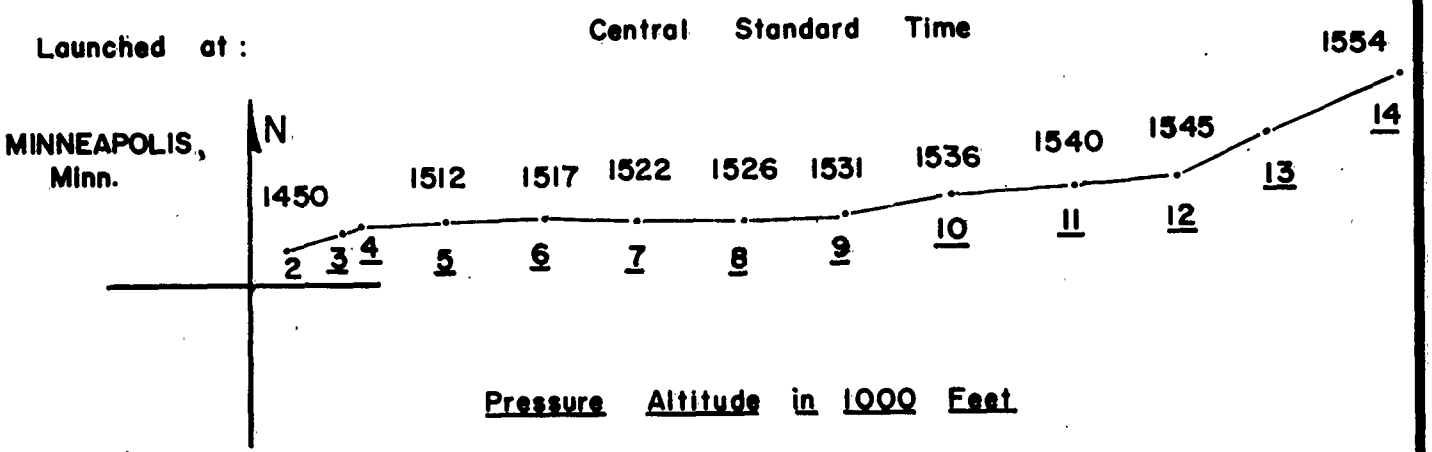
Central Standard Time



Pressure Altitude in 1000 Feet

FLIGHT NO. 26
LAUNCHED 1449 CST
21 JULY, 1952
TRAJECTORY FROM THEODOLITE FIXES
SCALE 1:5 x 10^6

10 0 10 20 STATUTE MILES



FLIGHT NO. 26

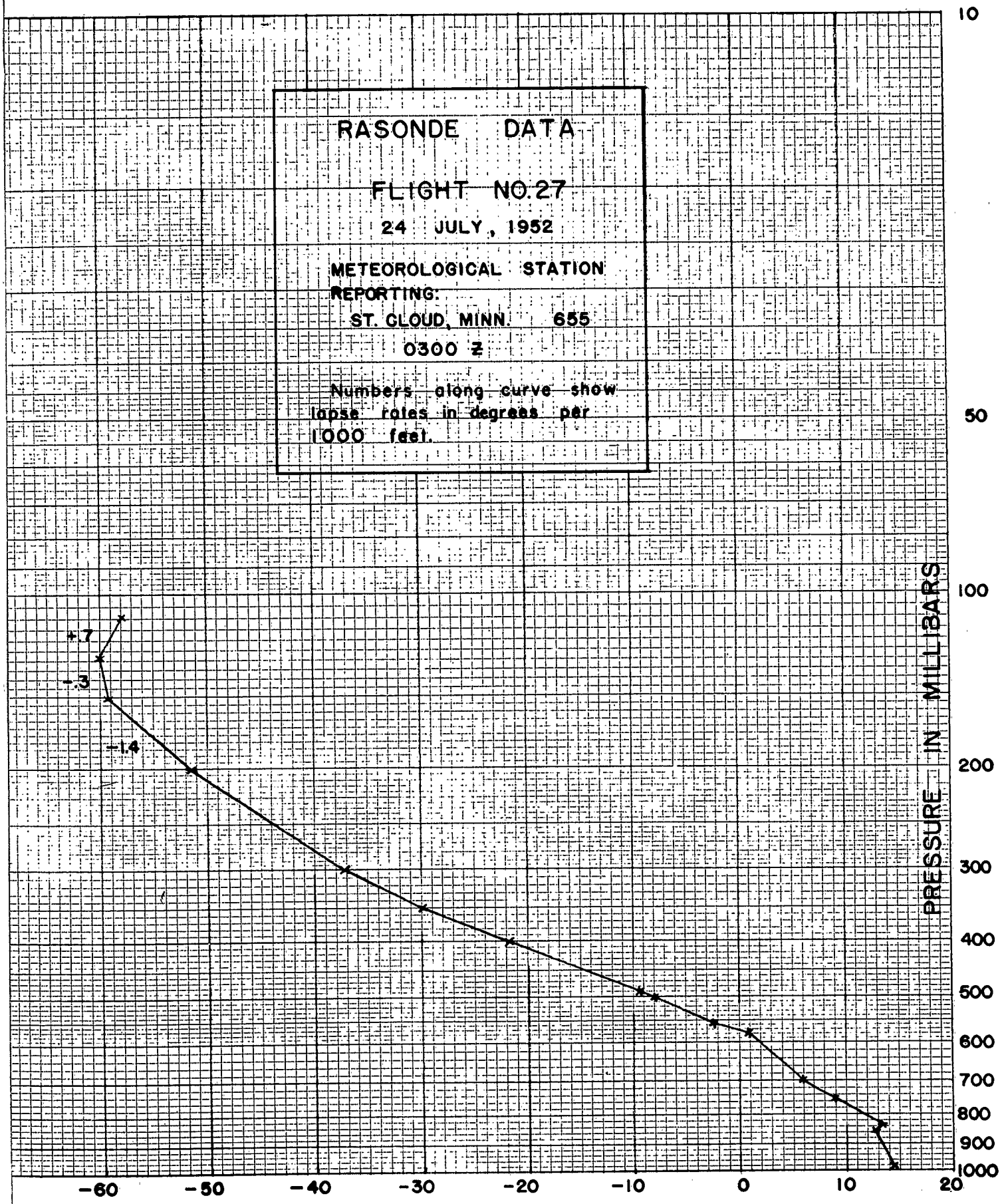
LAUNCHED 1449 CST

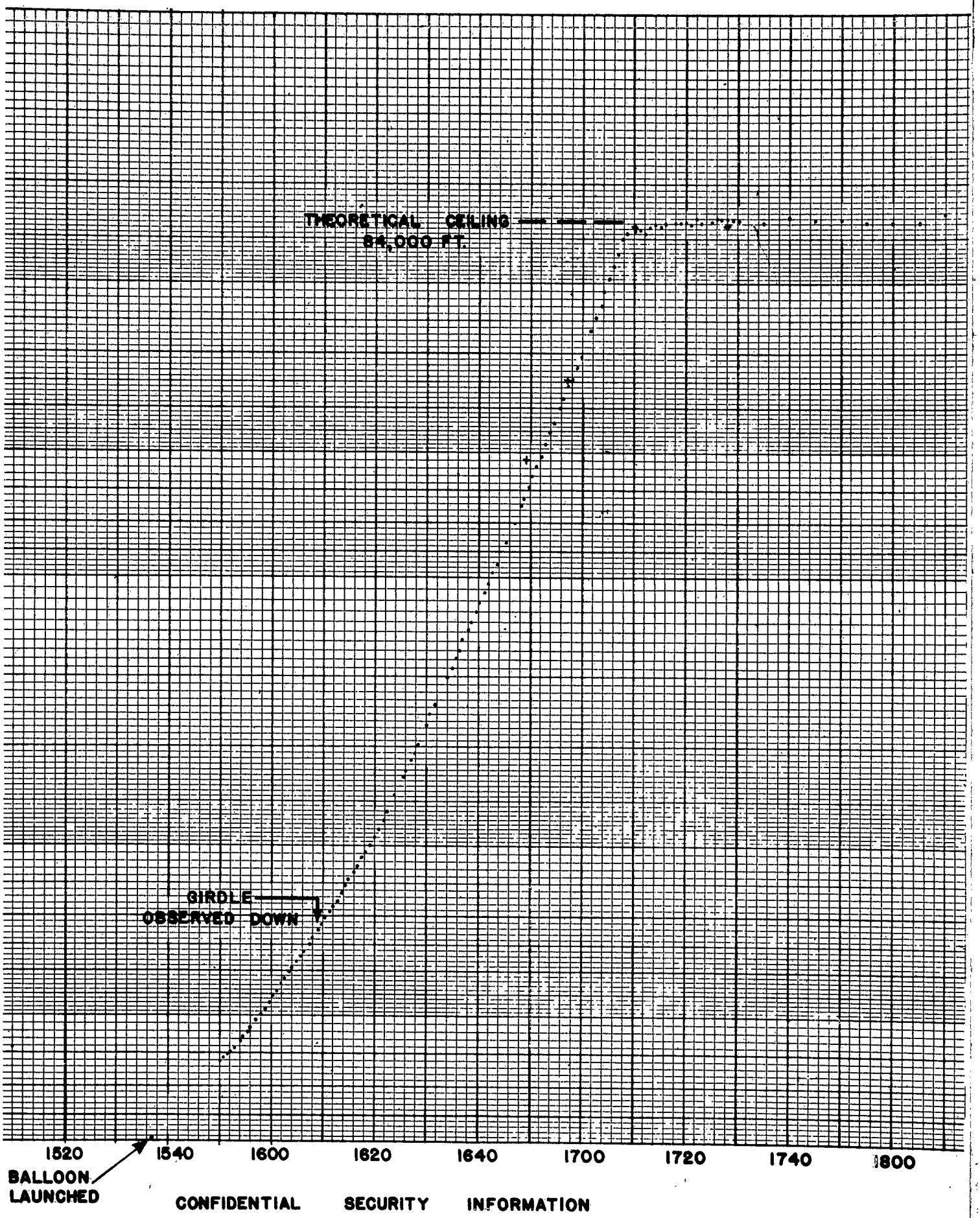
21 JULY, 1952

TRAJECTORY FROM DOWN PICTURES

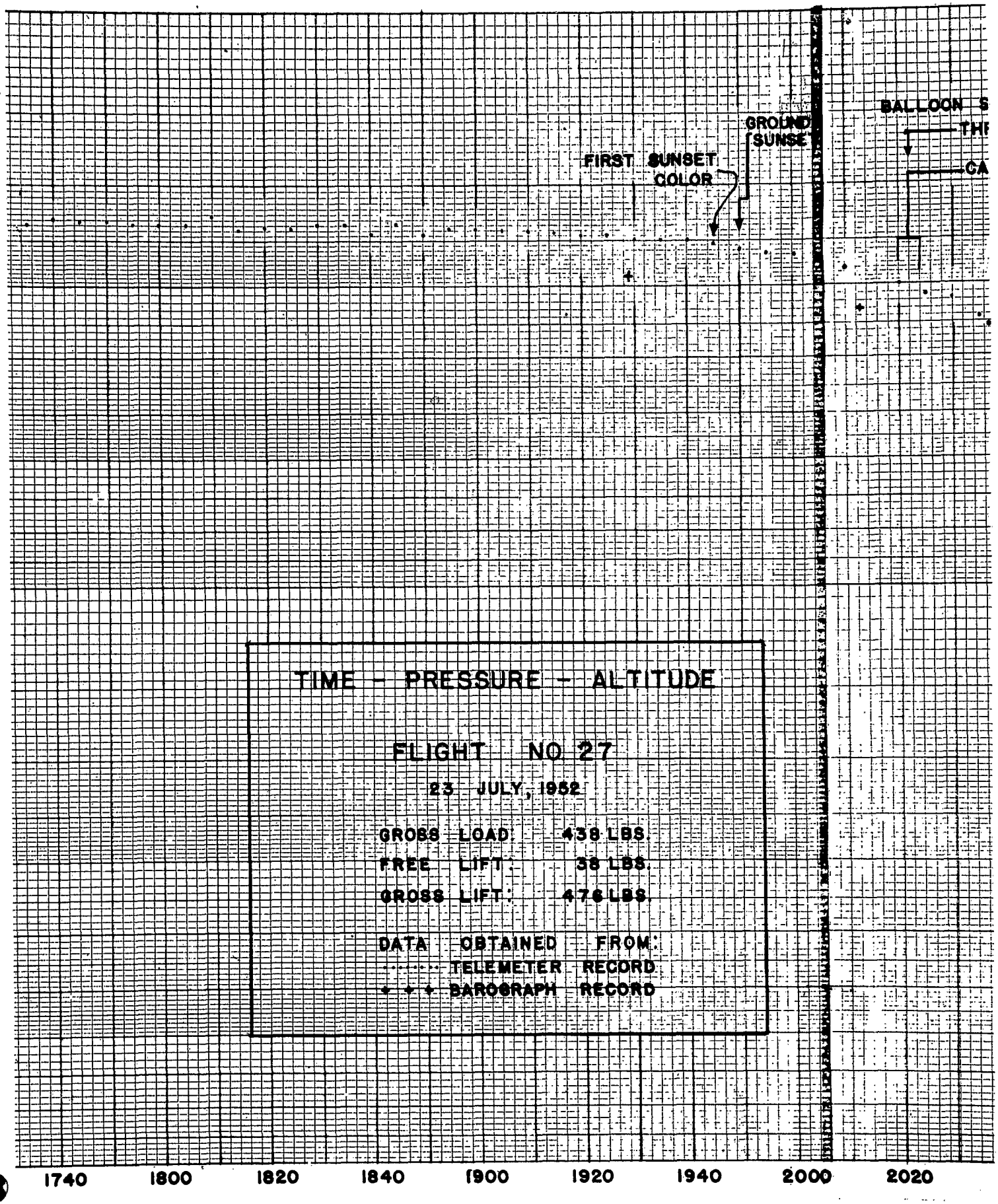
SCALE 1:5×10^5

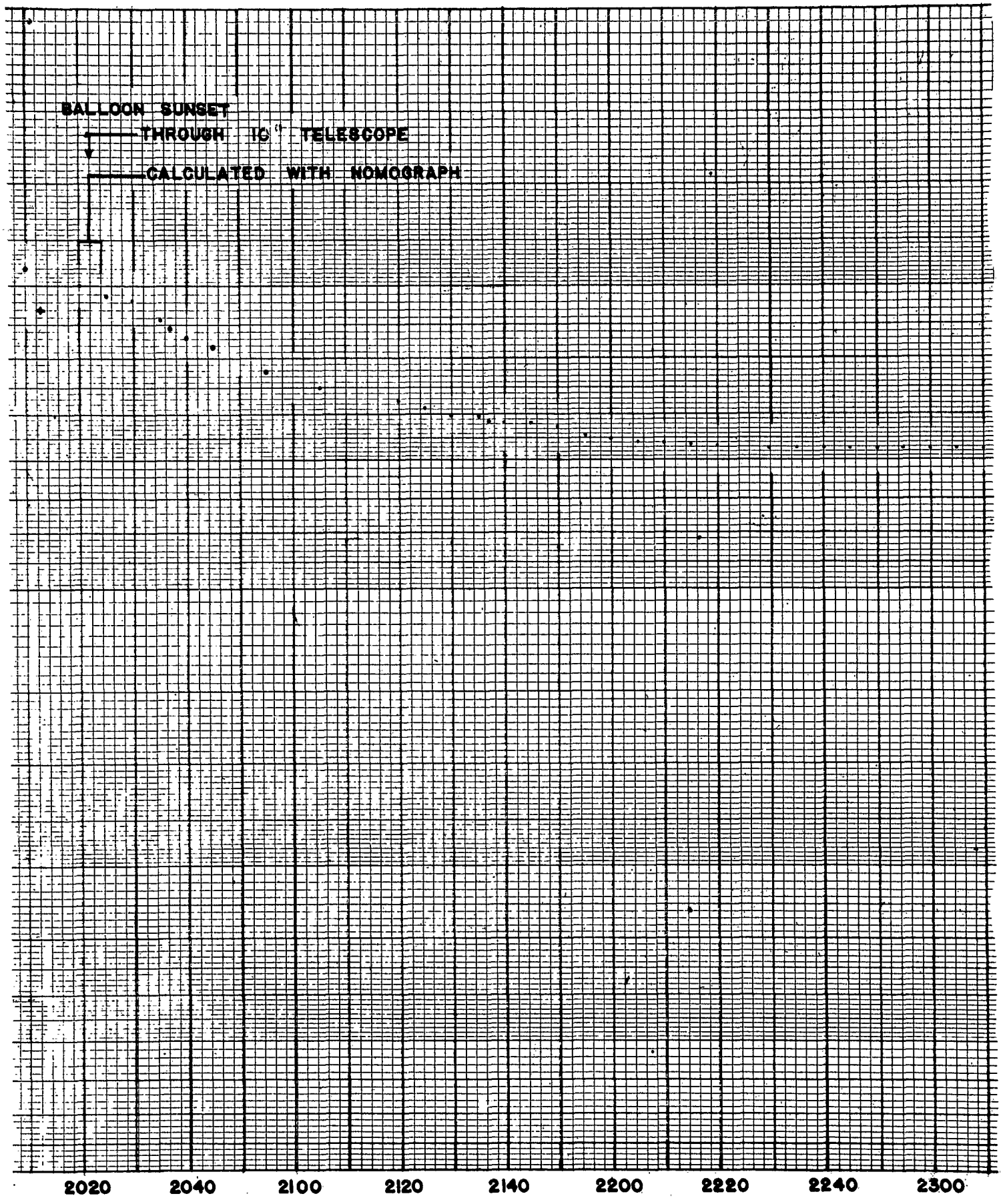
10 0 10 20 STATUTE MILES

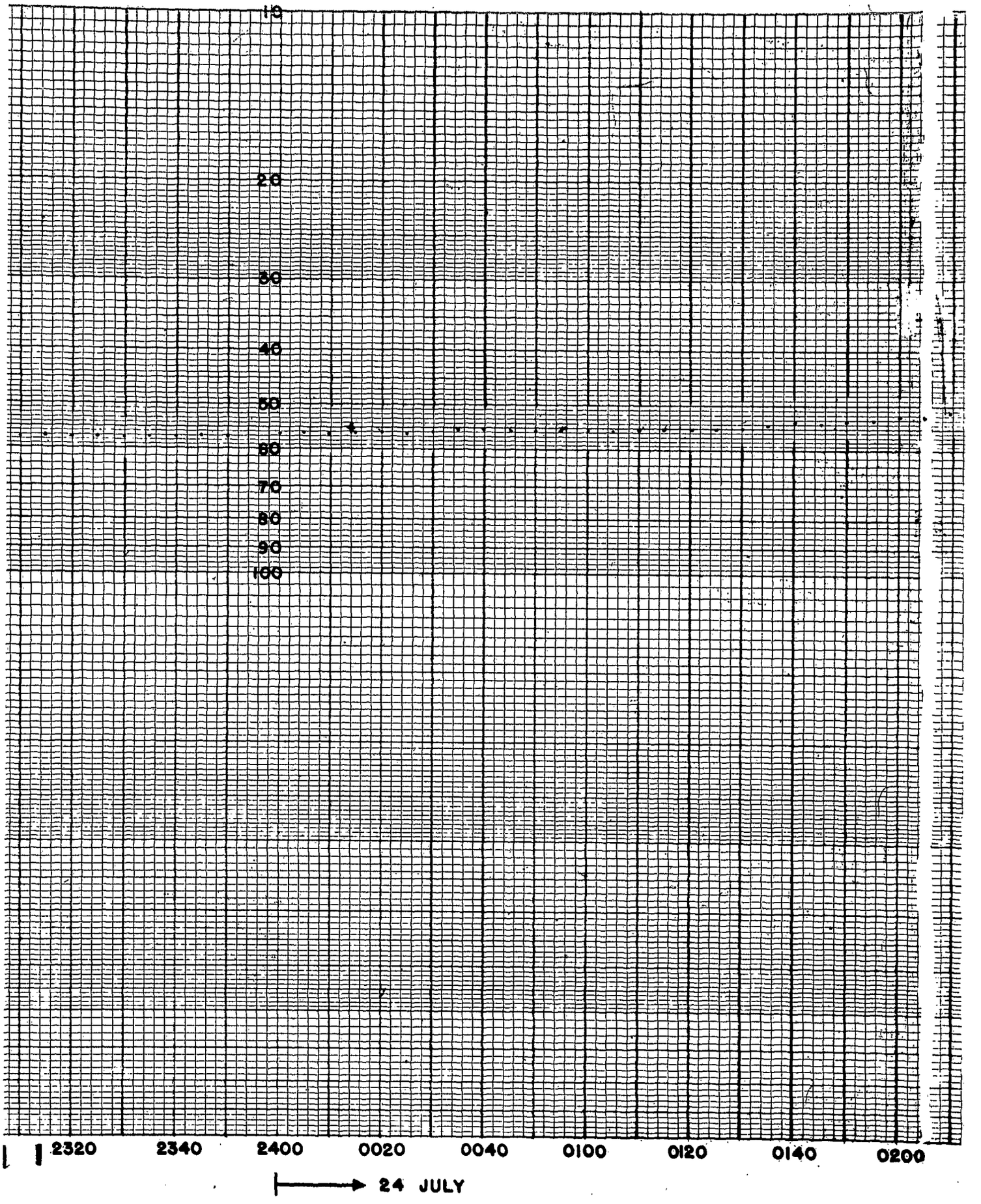

RASONDE DATA
FLIGHT NO. 27
24 JULY, 1952
METEOROLOGICAL STATION REPORTING:
ST. CLOUD, MINN. 655
0300 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
+.7
-.3
-1.4
10
50
100
200
300
400
500
600
700
800
900
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

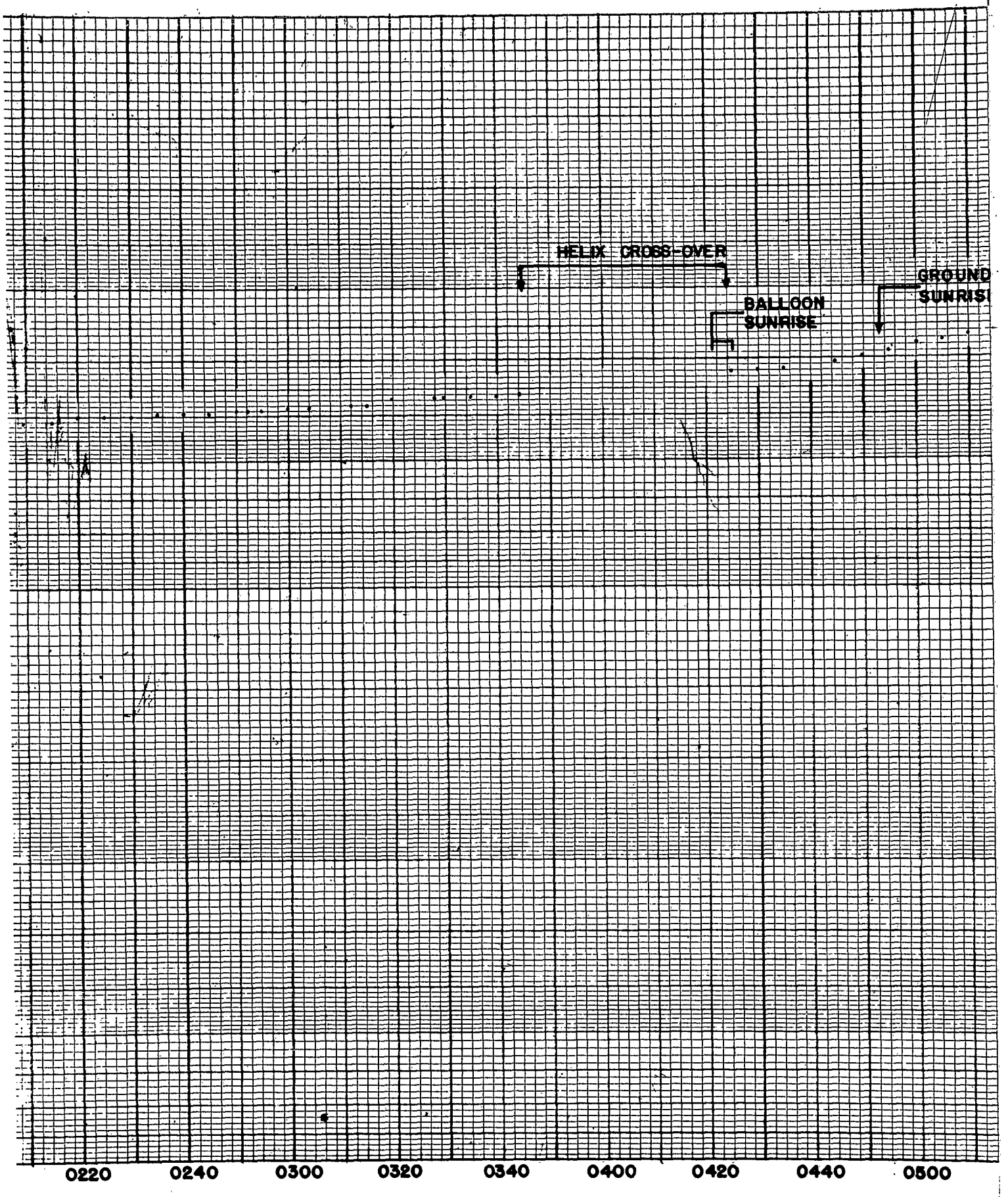


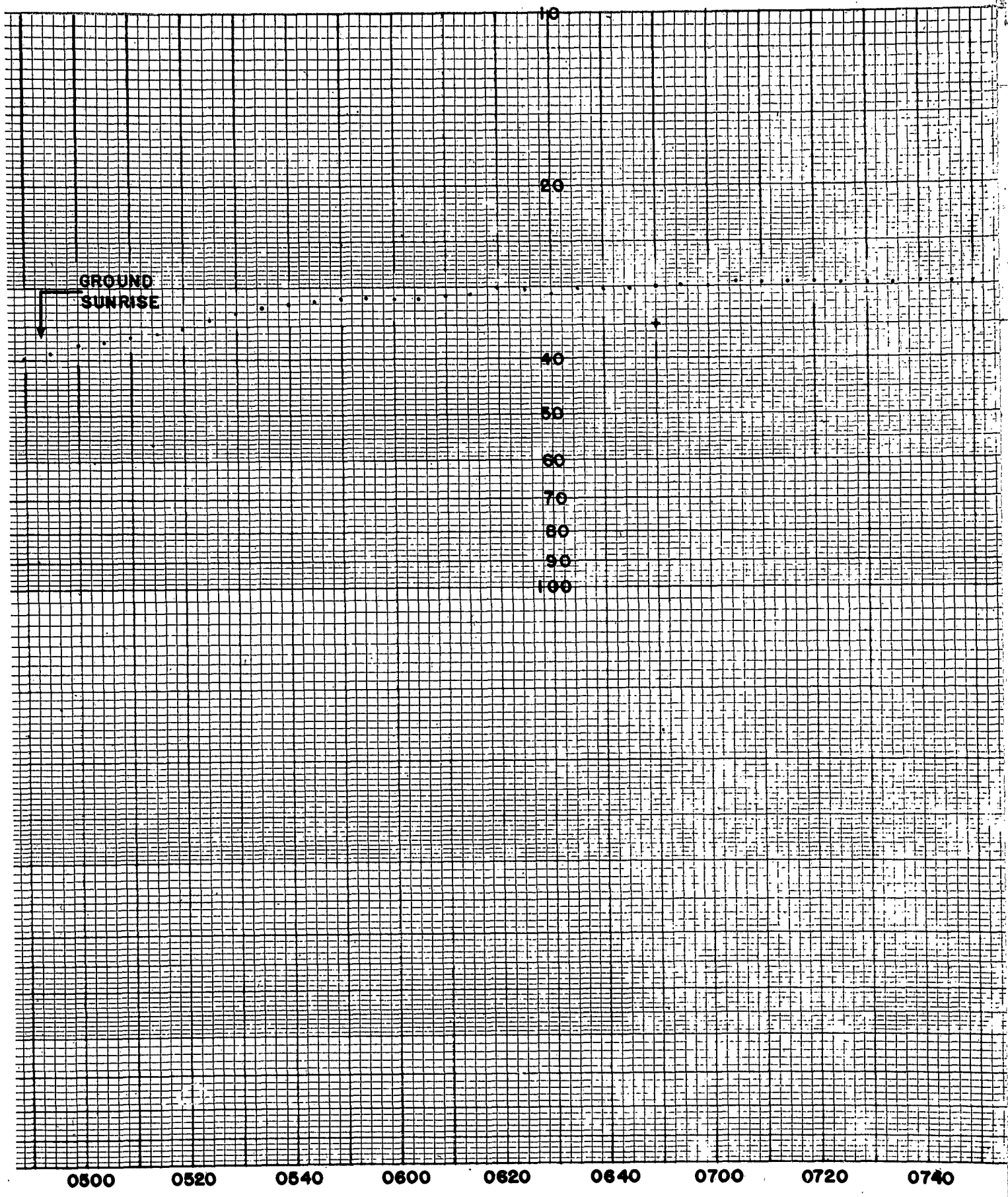
CONFIDENTIAL SECURITY INFORMATION

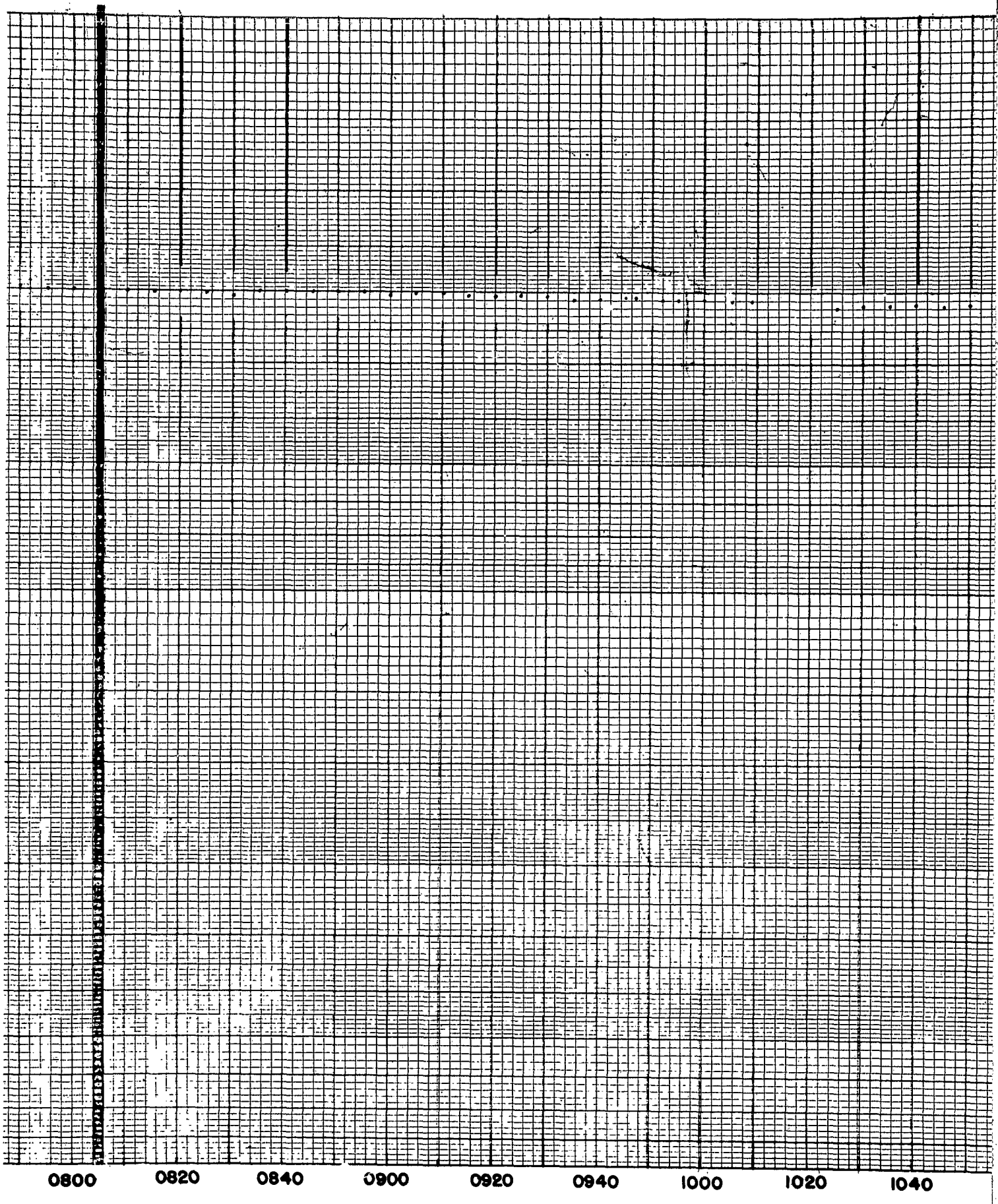

BALLOON S
THE
CA
GROUND
SUNSE
FIRST SUNSET
COLOR
TIME - PRESSURE - ALTITUDE
FLIGHT NO 27
23 JULY, 1952
GROSS LOAD: 438 LBS.
FREE LIFT: 38 LBS.
GROSS LIFT: 476 LBS.
DATA OBTAINED FROM:
TELEMETER RECORD
BAROGRAPH RECORD
1740
1800
1820
1840
1900
1920
1940
2000
2020
CENTRAL STANDARD TIME

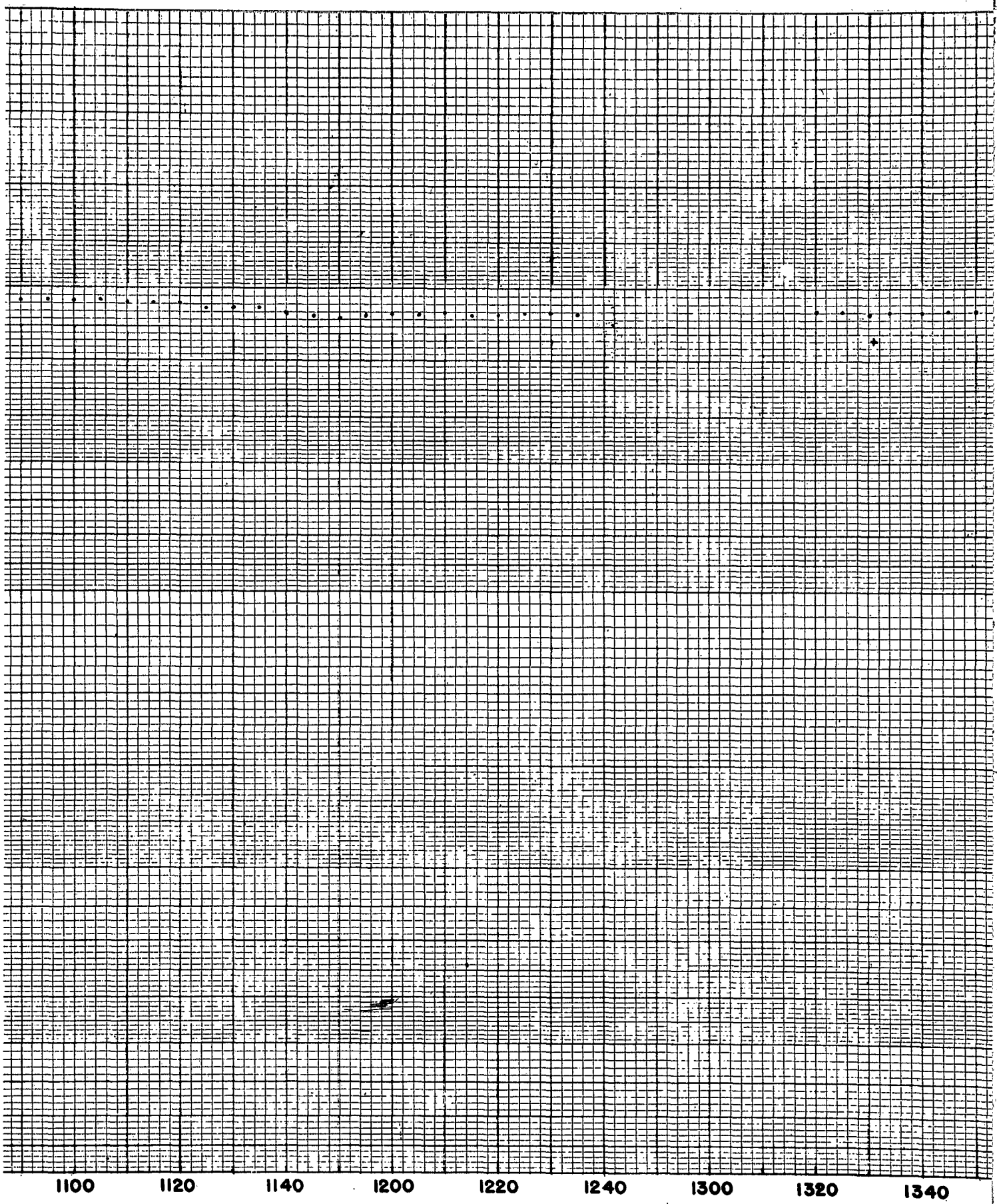

BALLOON SUNSET
THROUGH 10" TELESCOPE
CALCULATED WITH NOMOGRAPH
2020
2040
2100
2120
2140
2200
2220
2240
2300

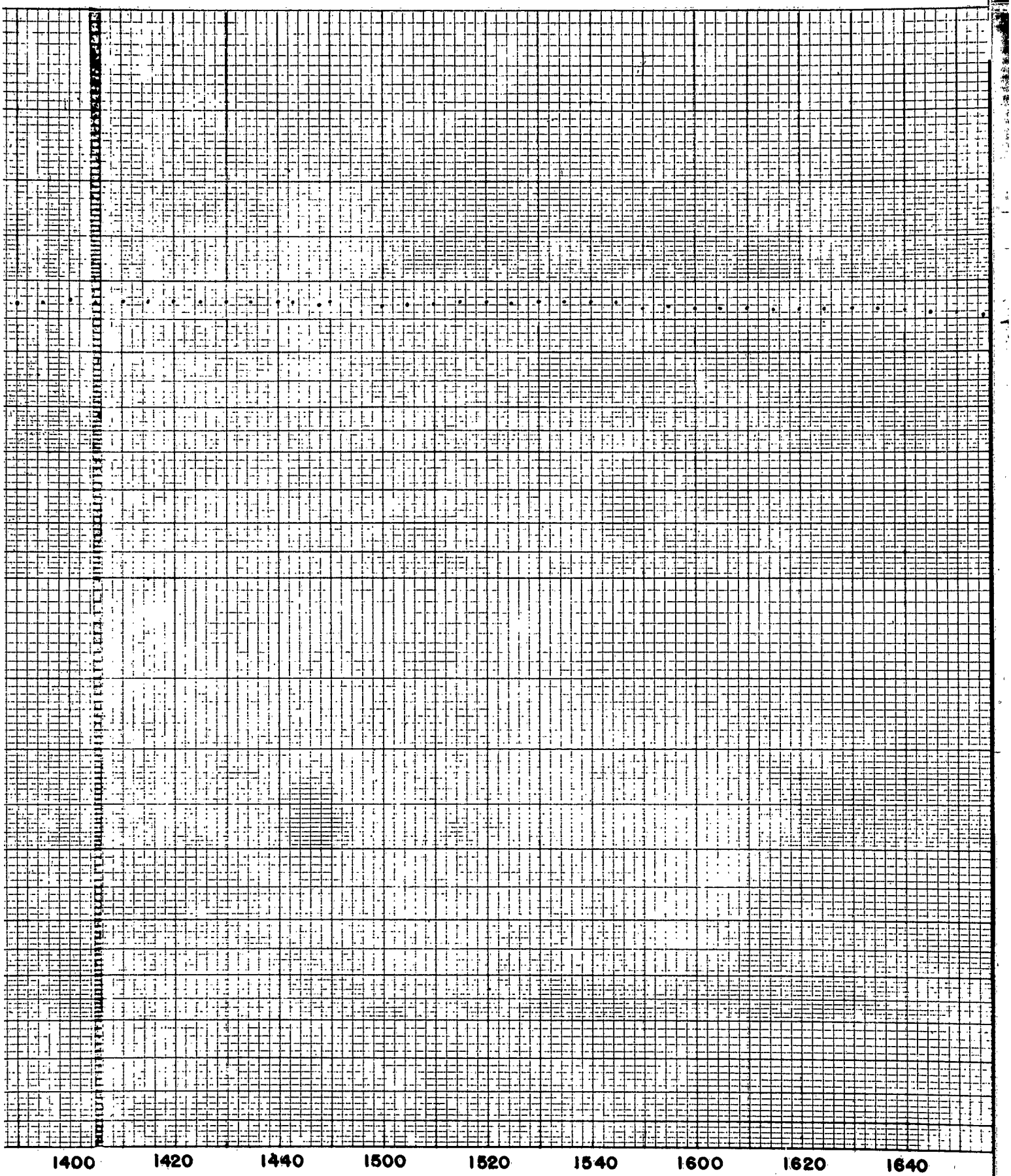

10
20
30
40
50
60
70
80
90
100
2320
2340
2400
0020
0040
0100
0120
0140
0200
24 JULY

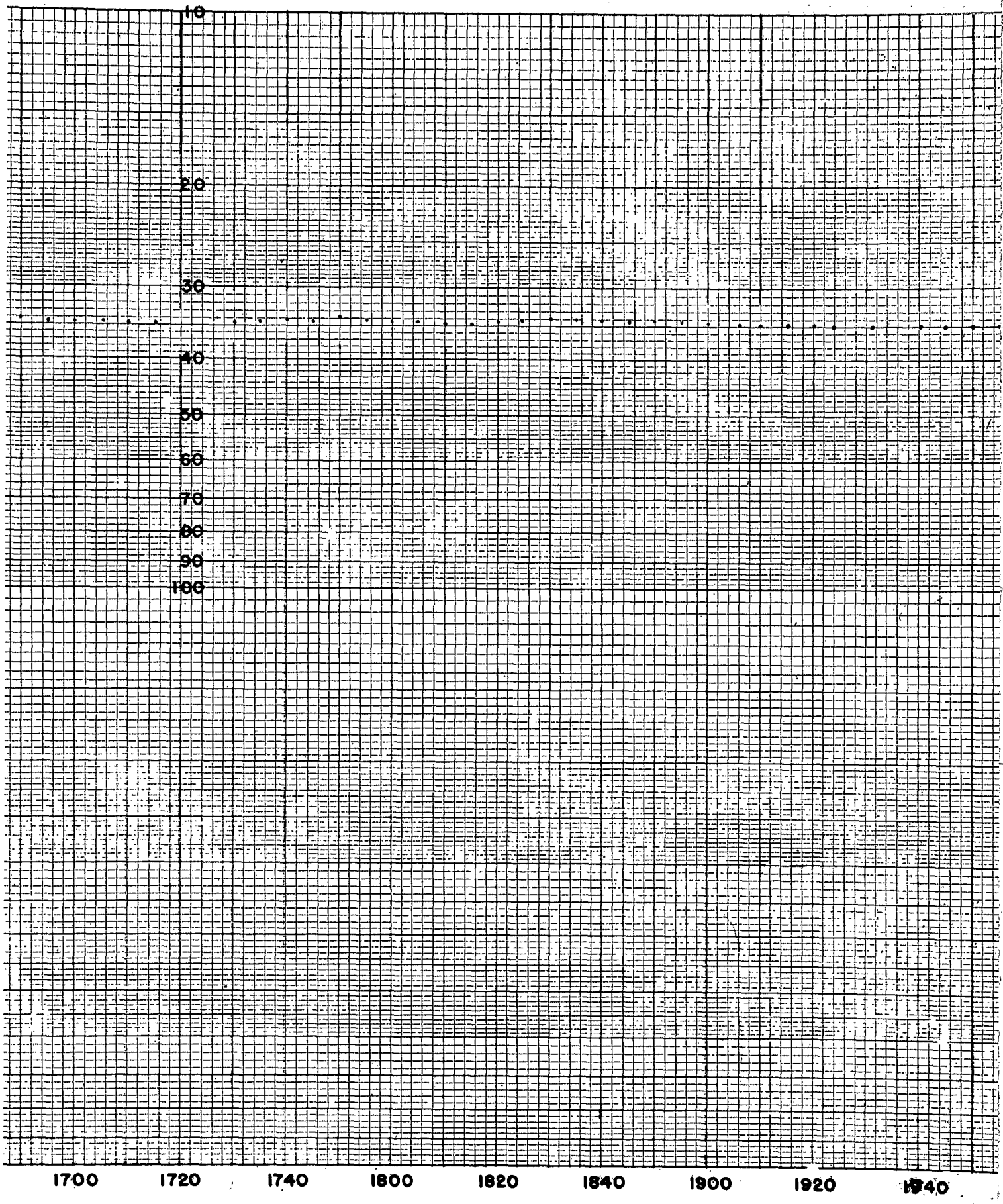

HELIX CROSS-OVER
BALLOON SUNRISE
GROUND SUNRISE
0220
0240
0300
0320
0340
0400
0420
0440
0500

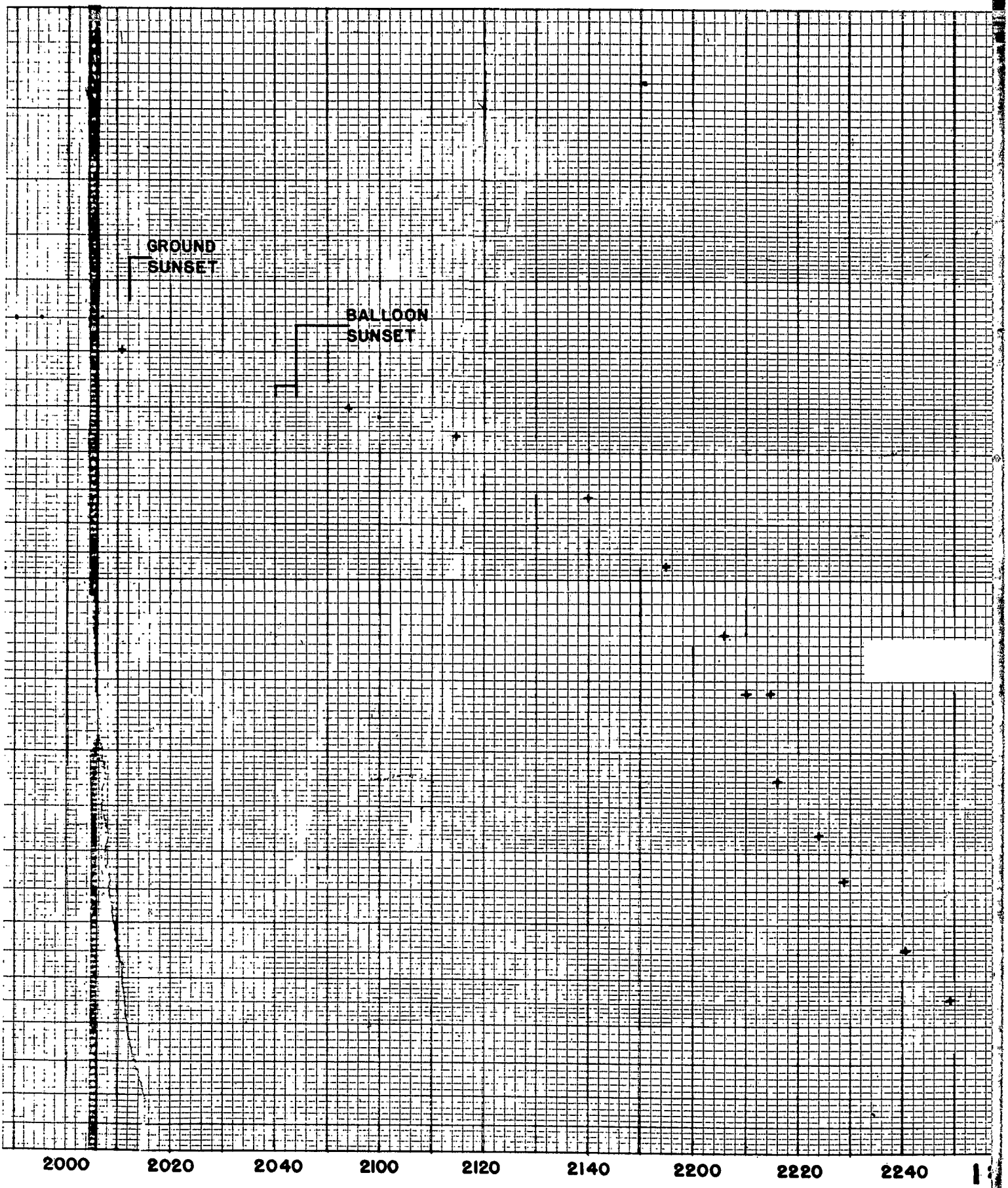

10
20
GROUND
SUNRISE
40
50
60
70
80
90
100
0500
0520
0540
0600
0620
0640
0700
0720
0740

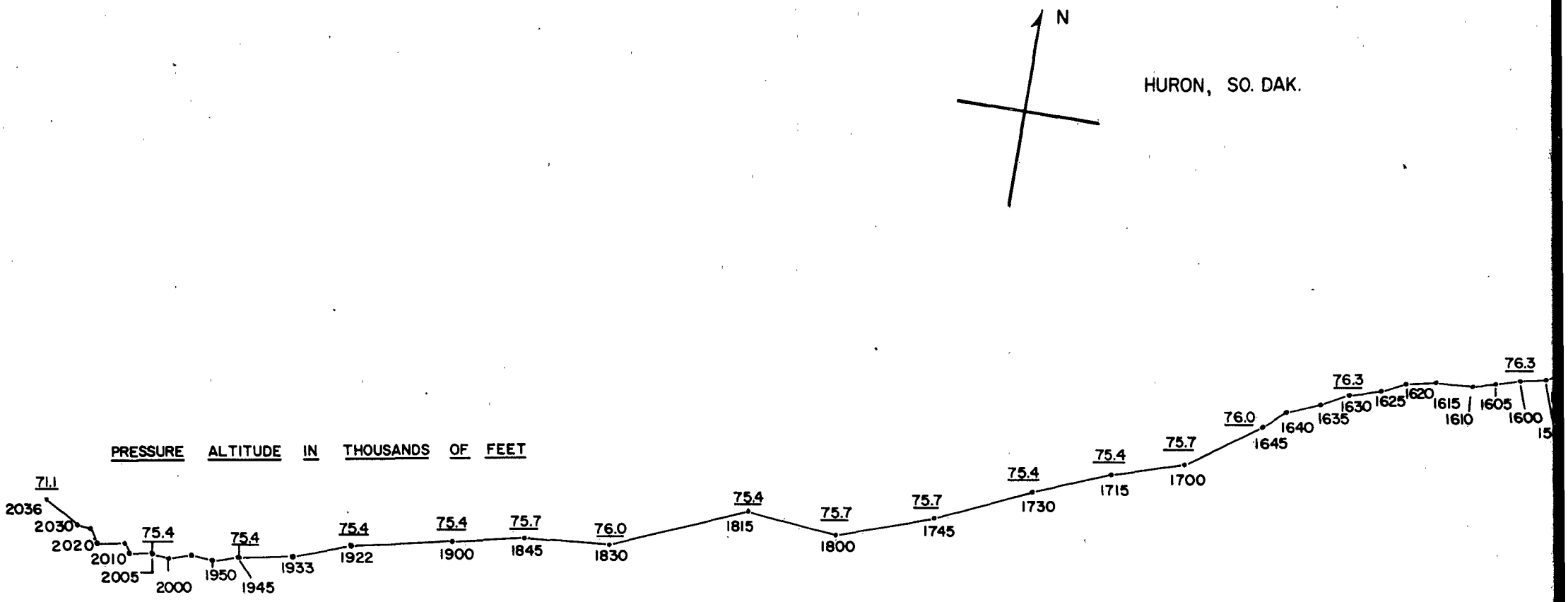

0800
0820
0840
0900
0920
0940
1000
1020
1040


1100
1120
1140
1200
1220
1240
1300
1320
1340
CENTRAL STANDARD TIME
24 JULY


1400
1420
1440
1500
1520
1540
1600
1620
1640


10
20
30
40
50
60
70
80
90
100
1700
1720
1740
1800
1820
1840
1900
1920
1940


GROUND
SUNSET
BALLOON
SUNSET
2000
2020
2040
2100
2120
2140
2200
2220
2240



1

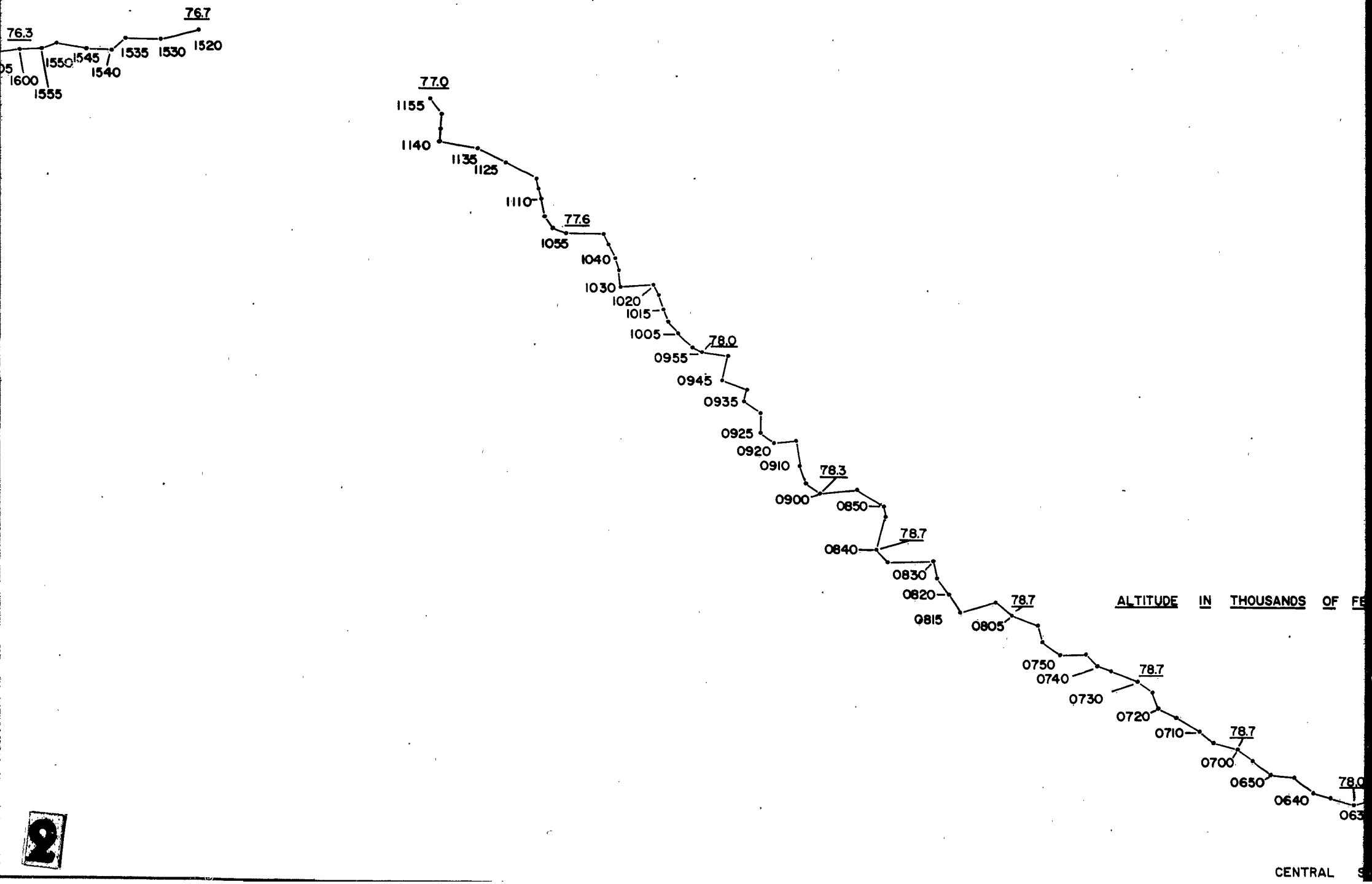
FLIGHT NO. 27

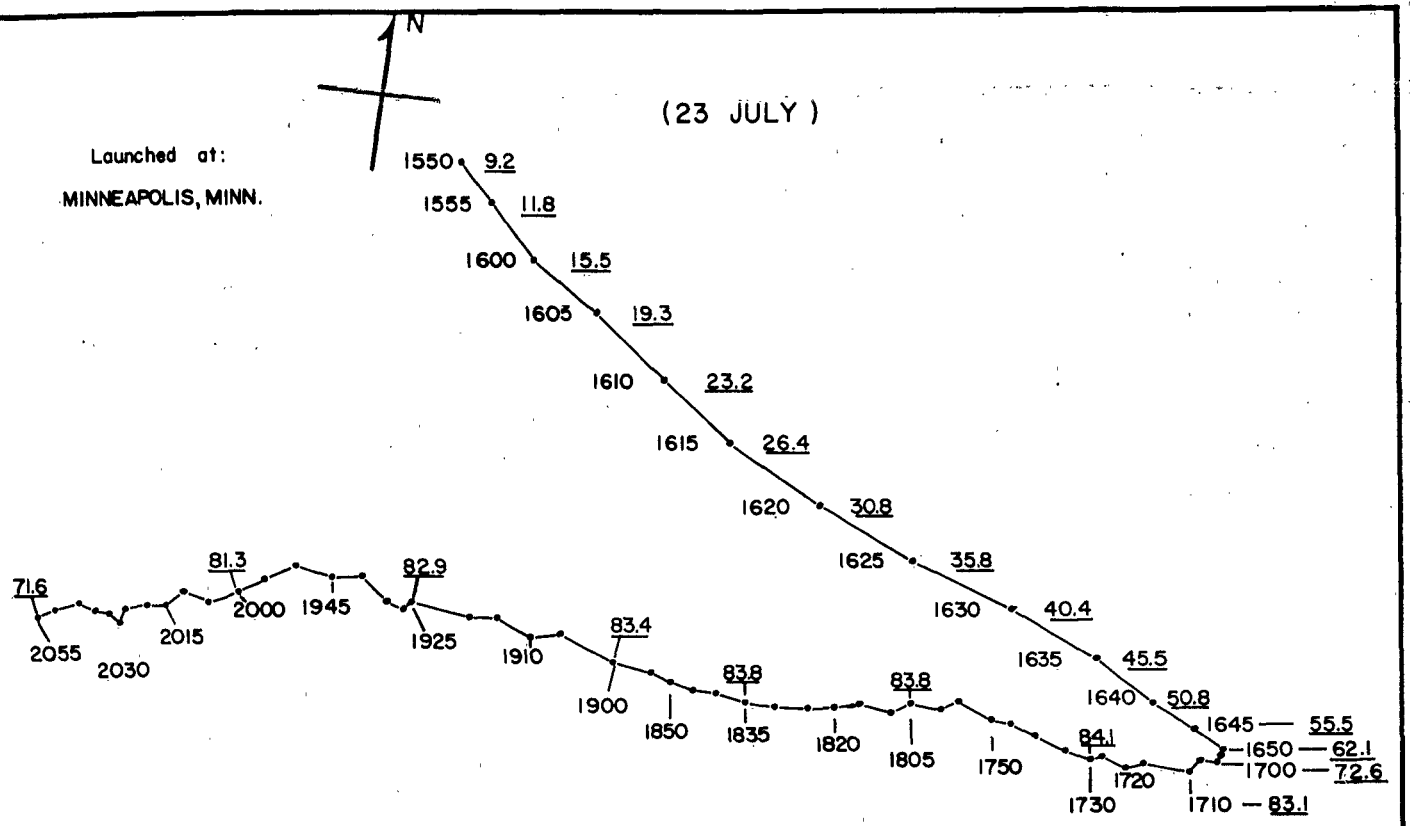
LAUNCHED 1537
23 JULY, 1952

TRAJECTORY FROM THEODOLITE FIXES

CONFIDENTIAL SECURITY INFORMATION

10 0 10 20 STATUTE MILES

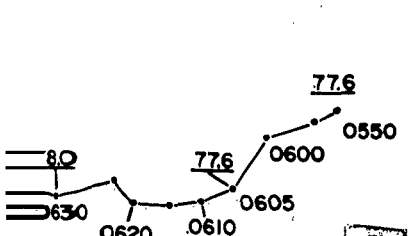

76.3
1600
1555
1550
1545
1540
1535
1530
1520
76.7
77.0
1155
1140
1135
1125
1110
77.6
1055
1040
1030
1020
1015
1005
78.0
0955
0945
0935
0925
0920
0910
78.3
0900
0850
78.7
0840
0830
0820
0815
0805
78.7
0750
0740
78.7
0730
0720
0710
78.7
0700
0650
0640
ALTITUDE IN THOUSANDS OF FE

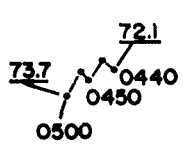


(READINGS FROM 1650 TO 2055 TAKEN AT FIVE MINUTE INTERVALS)

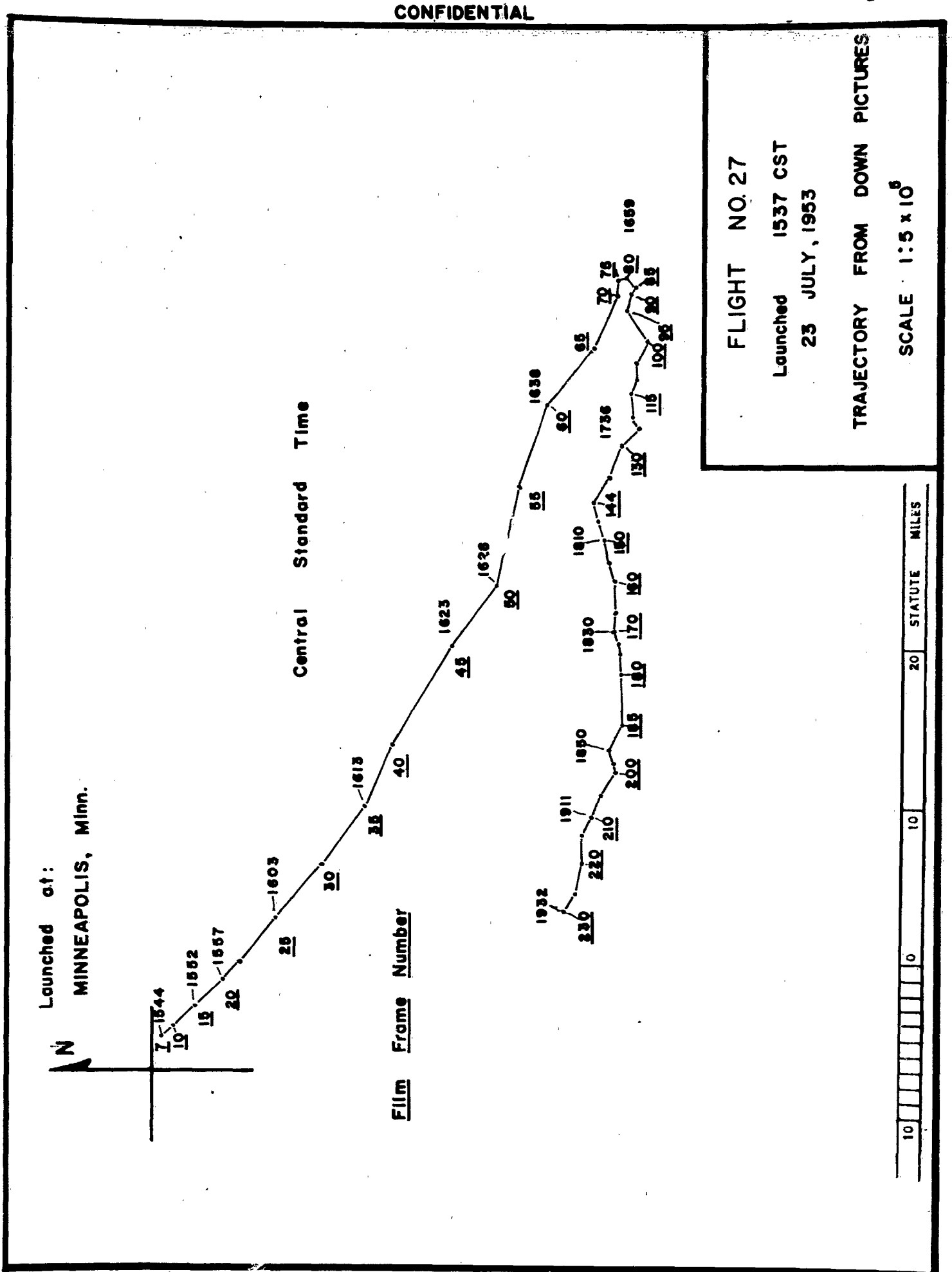
FEET

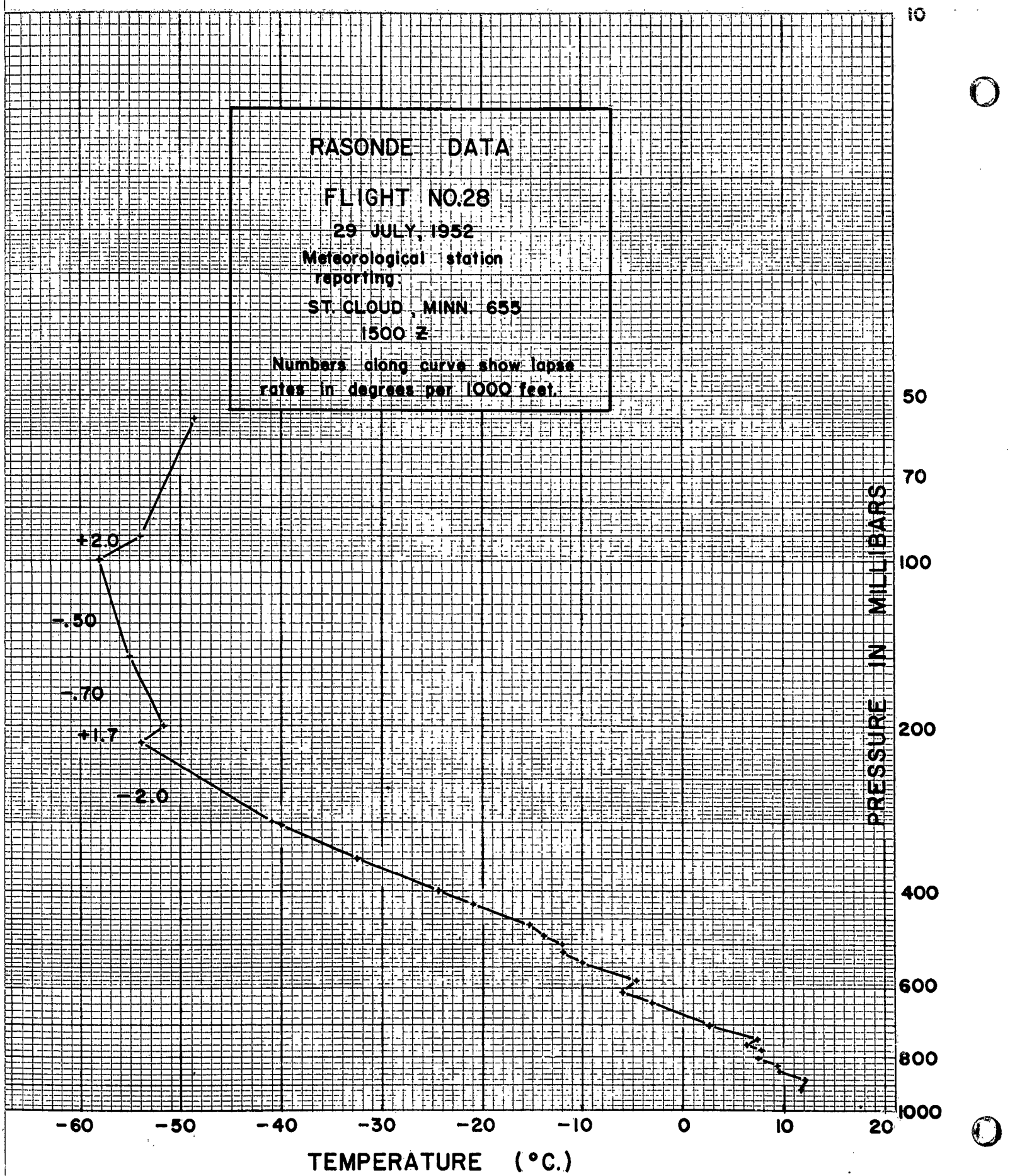
(24 JULY)

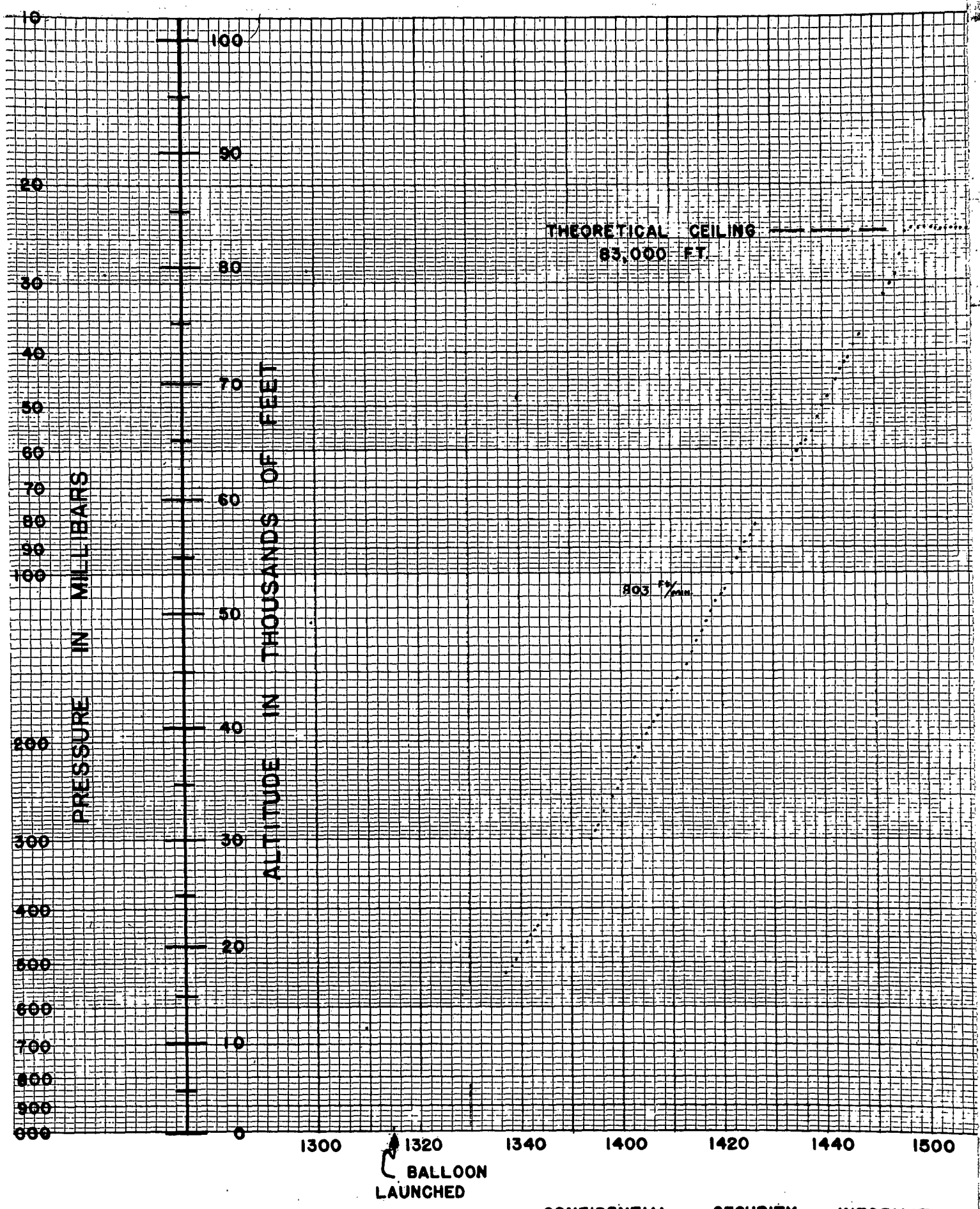


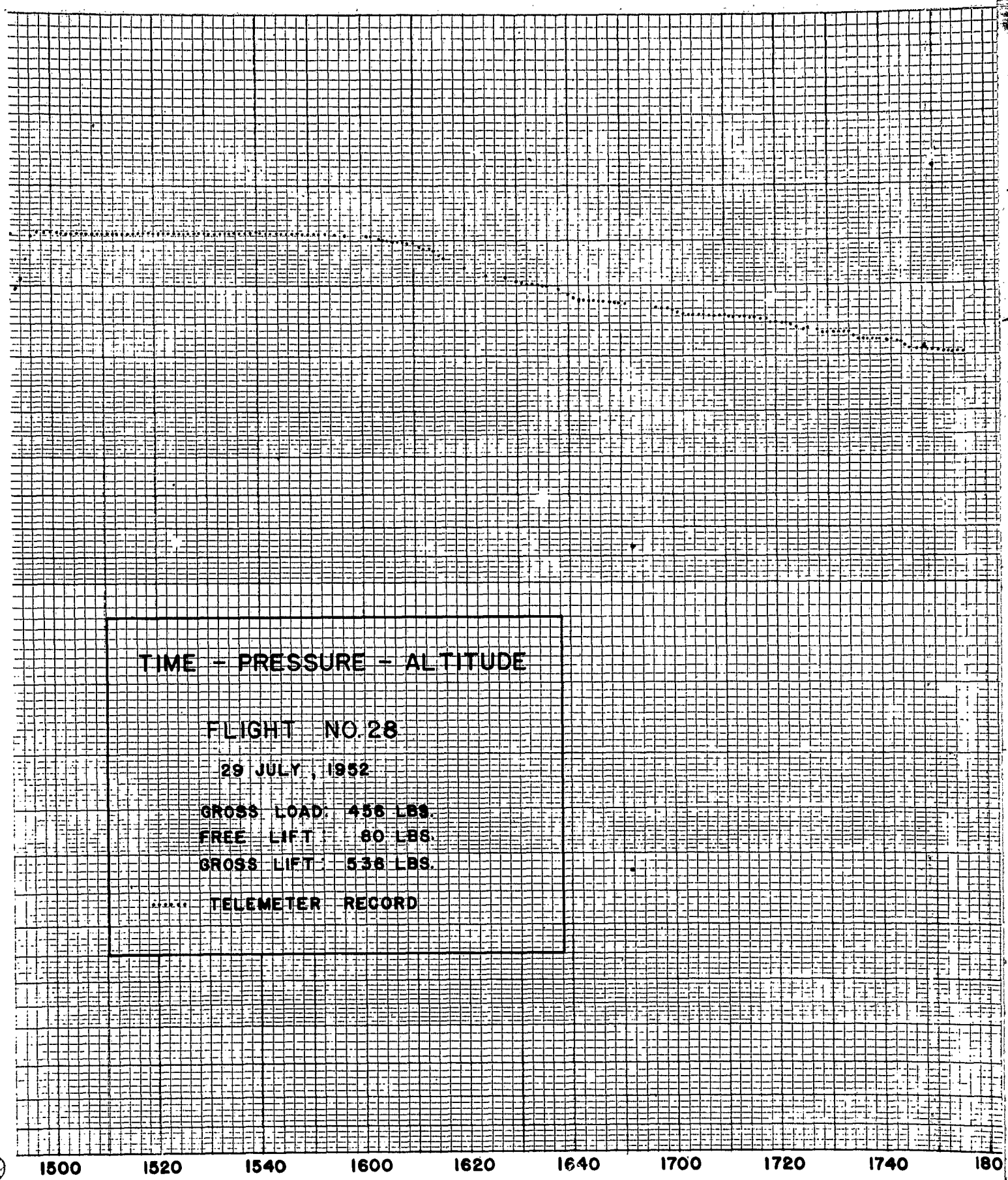


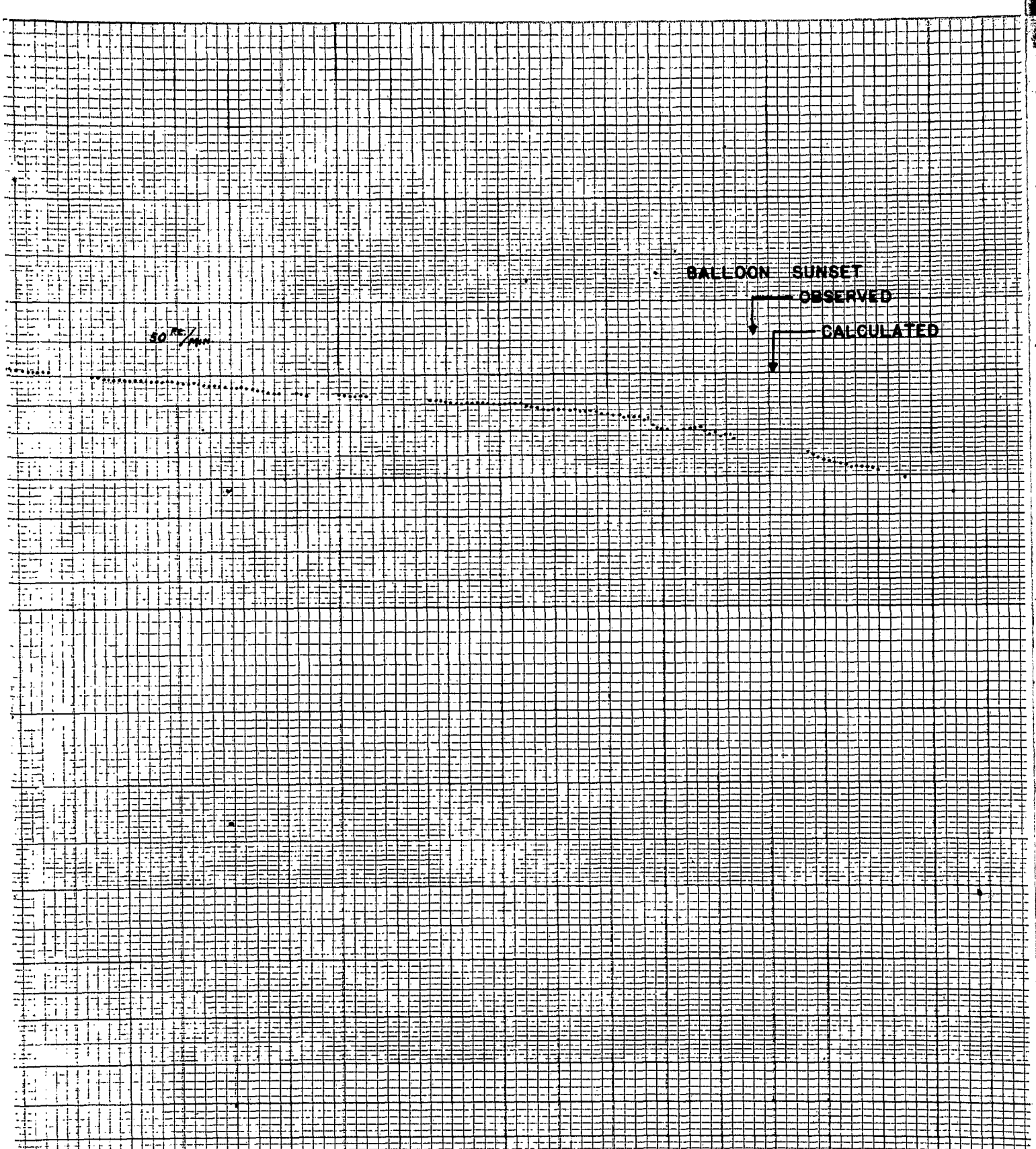
STANDARD TIME

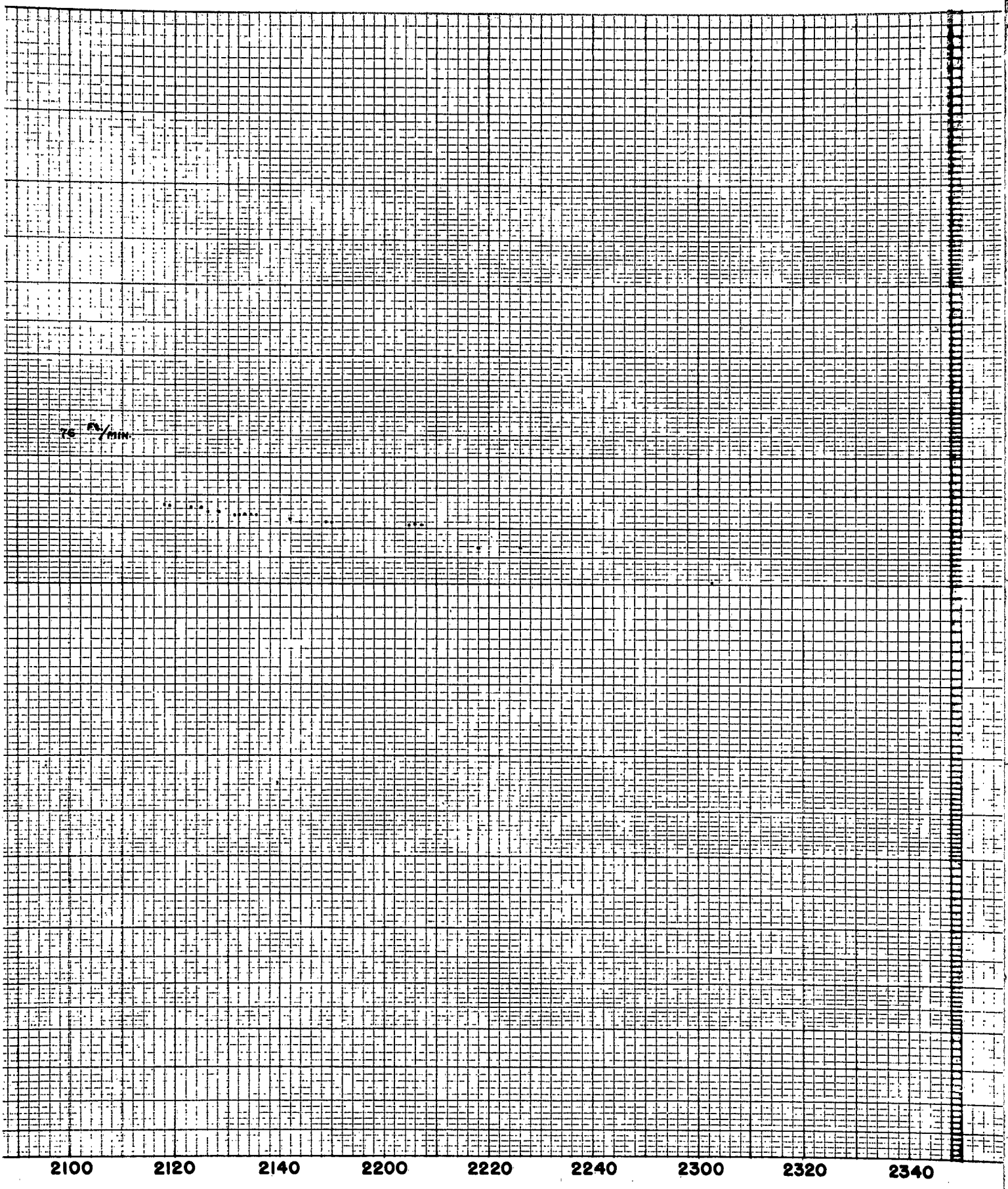

FLIGHT NO. 27
Launched 1537 CST
23 JULY, 1953
TRAJECTORY FROM DOWN PICTURES
SCALE 1:5 x 10⁶
Launched at:
MINNEAPOLIS, Minn.
N
Central Standard Time
Film Frame Number
1544
1552
1557
1603
1613
1623
1628
1638
1659
1736
1810
1830
1850
1911
1932
10 0 10 20 STATUTE MILES

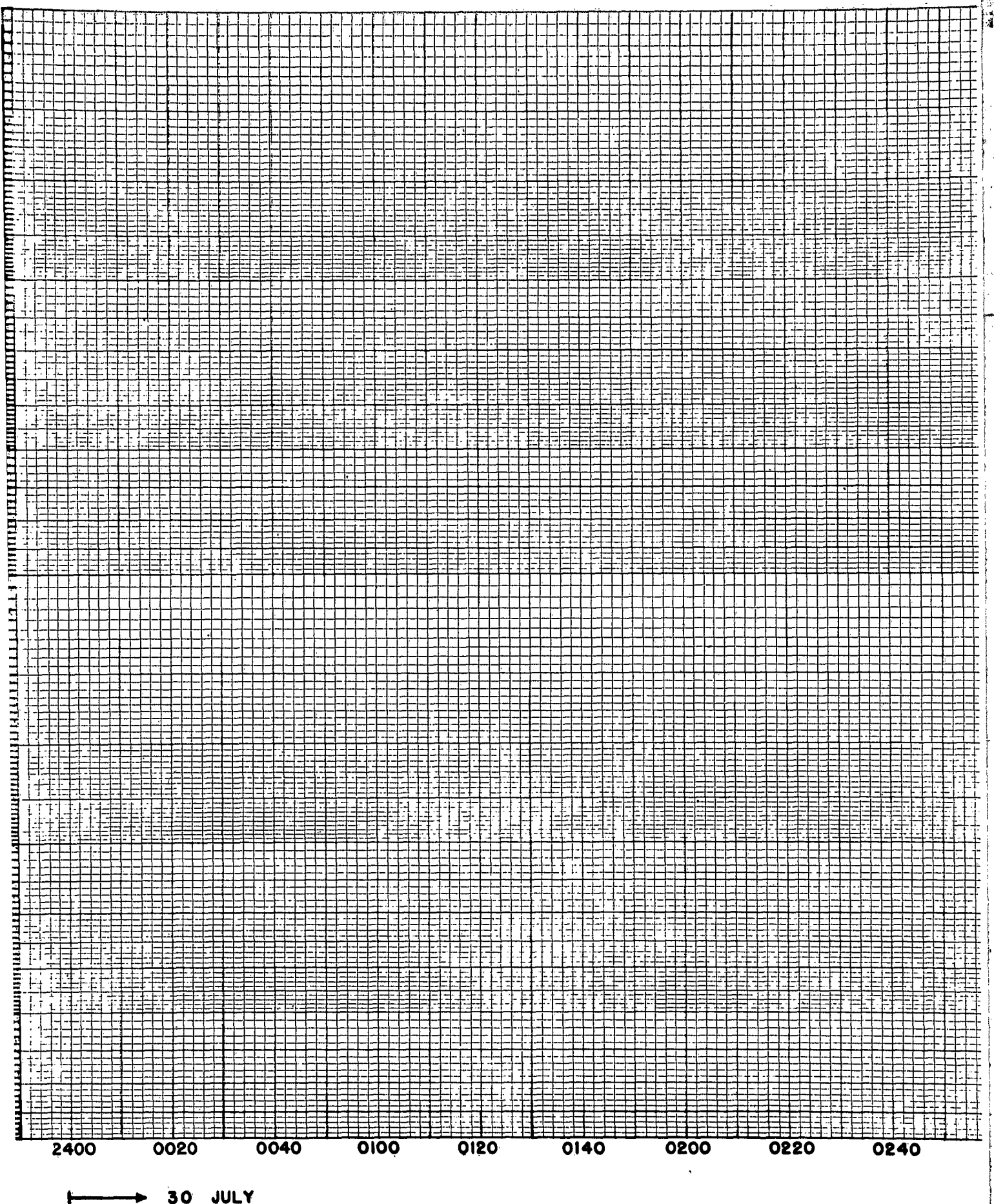

RASONDE DATA
FLIGHT NO.28
29 JULY, 1952
Meteorological station reporting
ST. CLOUD, MINN. 655
1500 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
+2.0
-.50
-.70
+1.7
-2.0
10
50
70
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)


PRESSURE IN MILLIBARS
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
000
ALTITUDE IN THOUSANDS OF FEET
100
90
80
70
60
50
40
30
20
10
0
THEORETICAL CEILING
83,000 FT.
803 Ft/min.
1300
1320
1340
1400
1420
1440
1500
BALLOON LAUNCHED


TIME - PRESSURE - ALTITUDE
FLIGHT NO. 28
29 JULY, 1952
GROSS LOAD: 456 LBS.
FREE LIFT: 80 LBS.
GROSS LIFT: 536 LBS.
..... TELEMETER RECORD
1500
1520
1540
1600
1620
1640
1700
1720
1740
180
CENTRAL STANDARD TIME


BALLOON SUNSET
OBSERVED
CALCULATED
50 M./MIN.
1800
1820
1840
1900
1920
1940
2000
2020
2040


75 Ft/min.
2100
2120
2140
2200
2220
2240
2300
2320
2340


2400
0020
0040
0100
0120
0140
0200
0220
0240
30 JULY

CONFIDENTIAL SECURITY INFORMATION

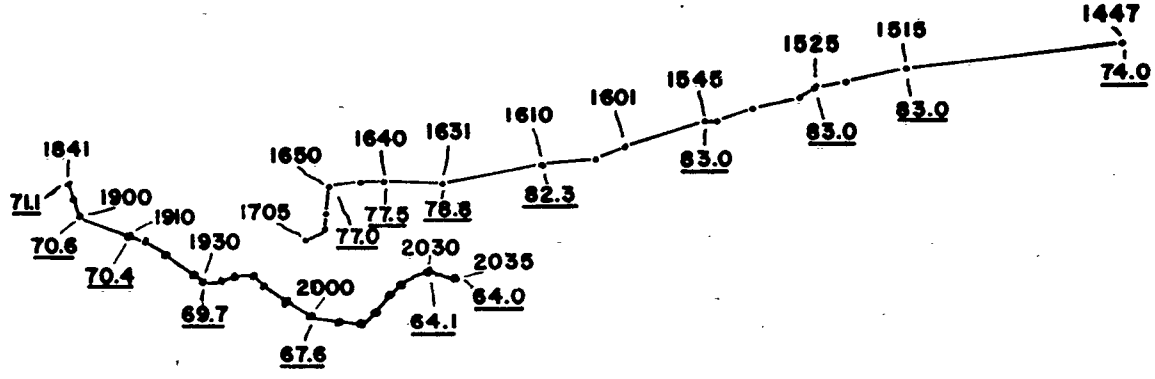
CONFIDENTIAL

N

Launched at :

MINNEAPOLIS , Minn.

CENTRAL STANDARD TIME



PRESSURE ALTITUDE IN 1000 FT.

10 0 10 20 STATUTE MILES

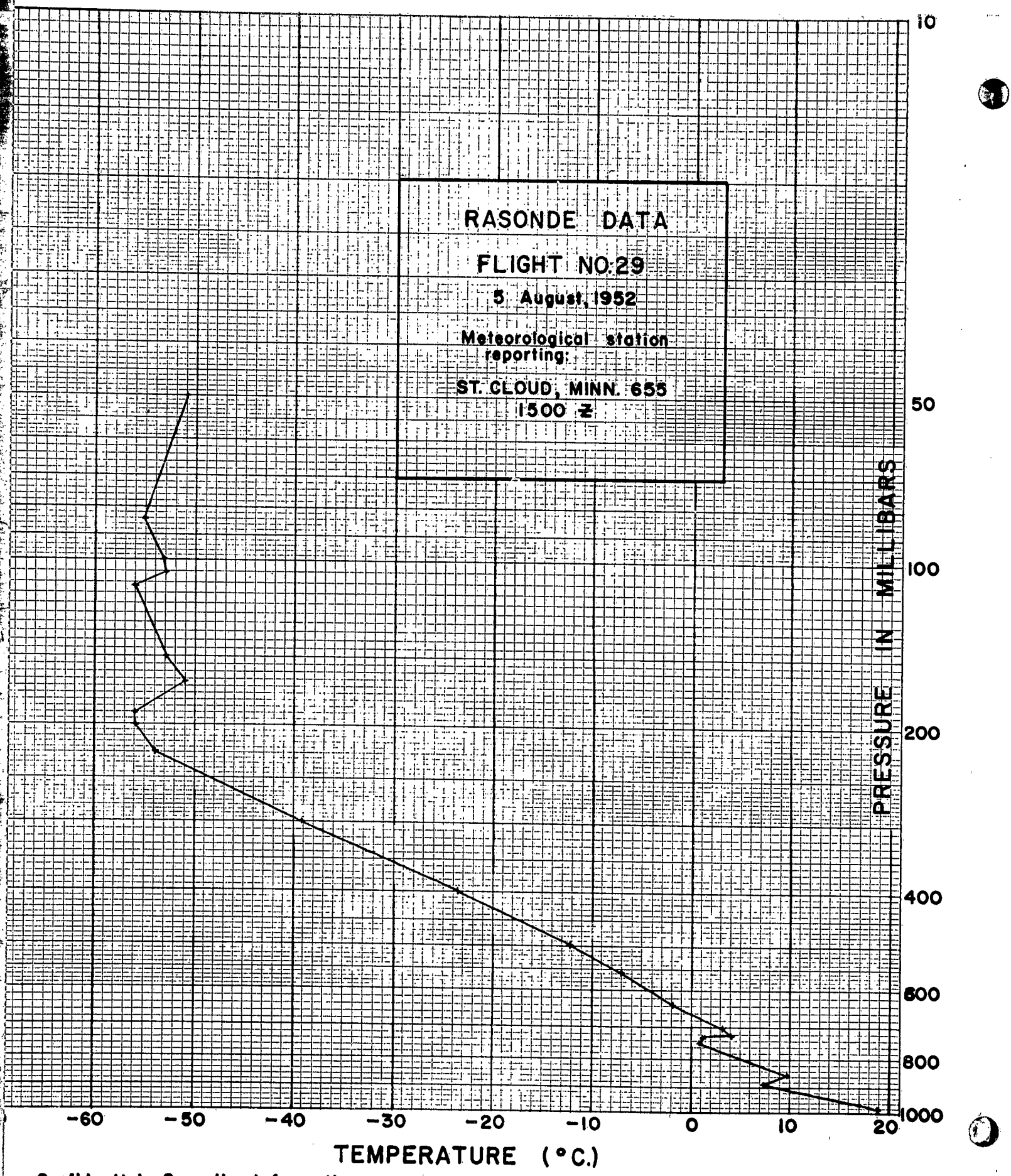
FLIGHT NO. 28

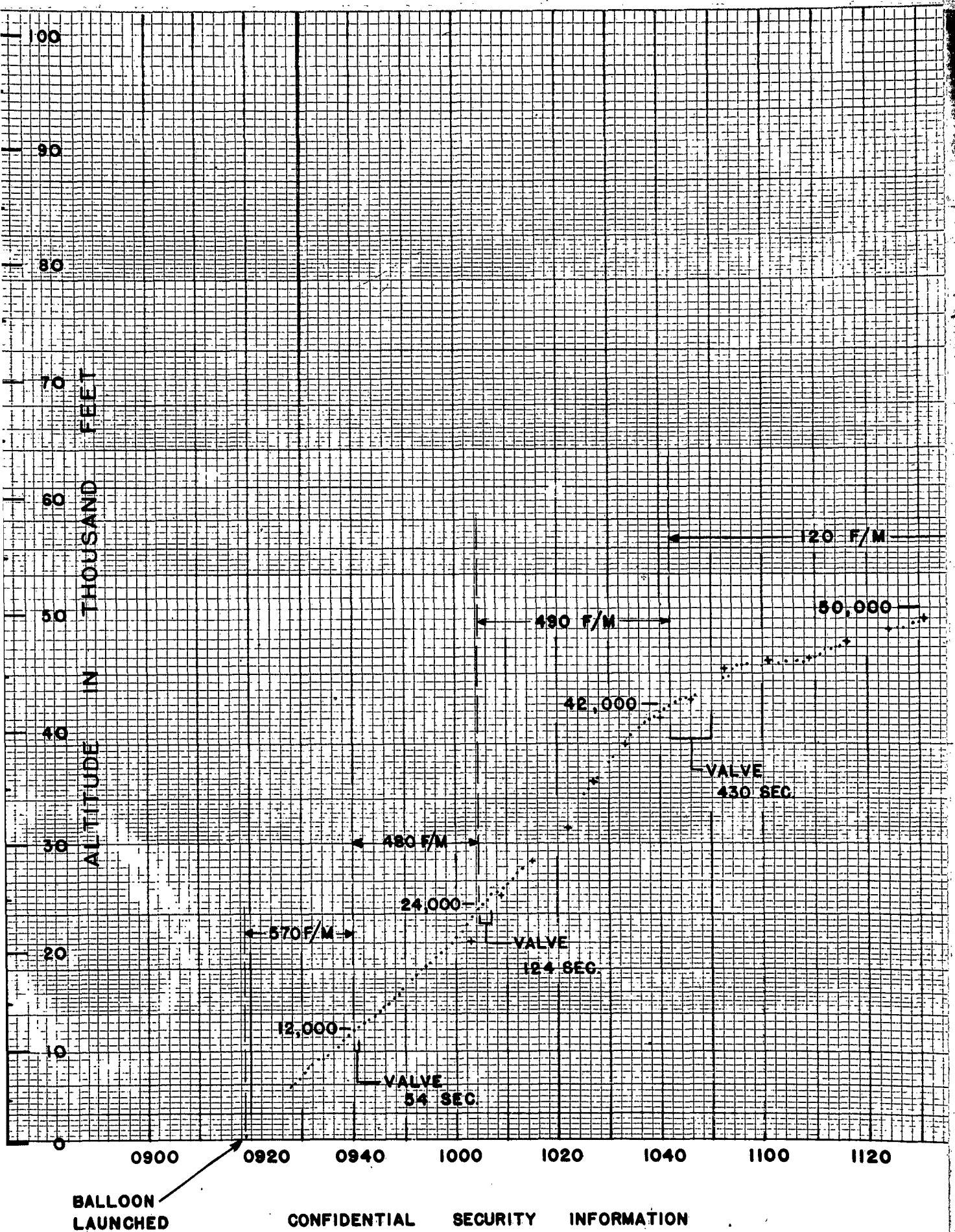
LAUNCHED 1315 CST

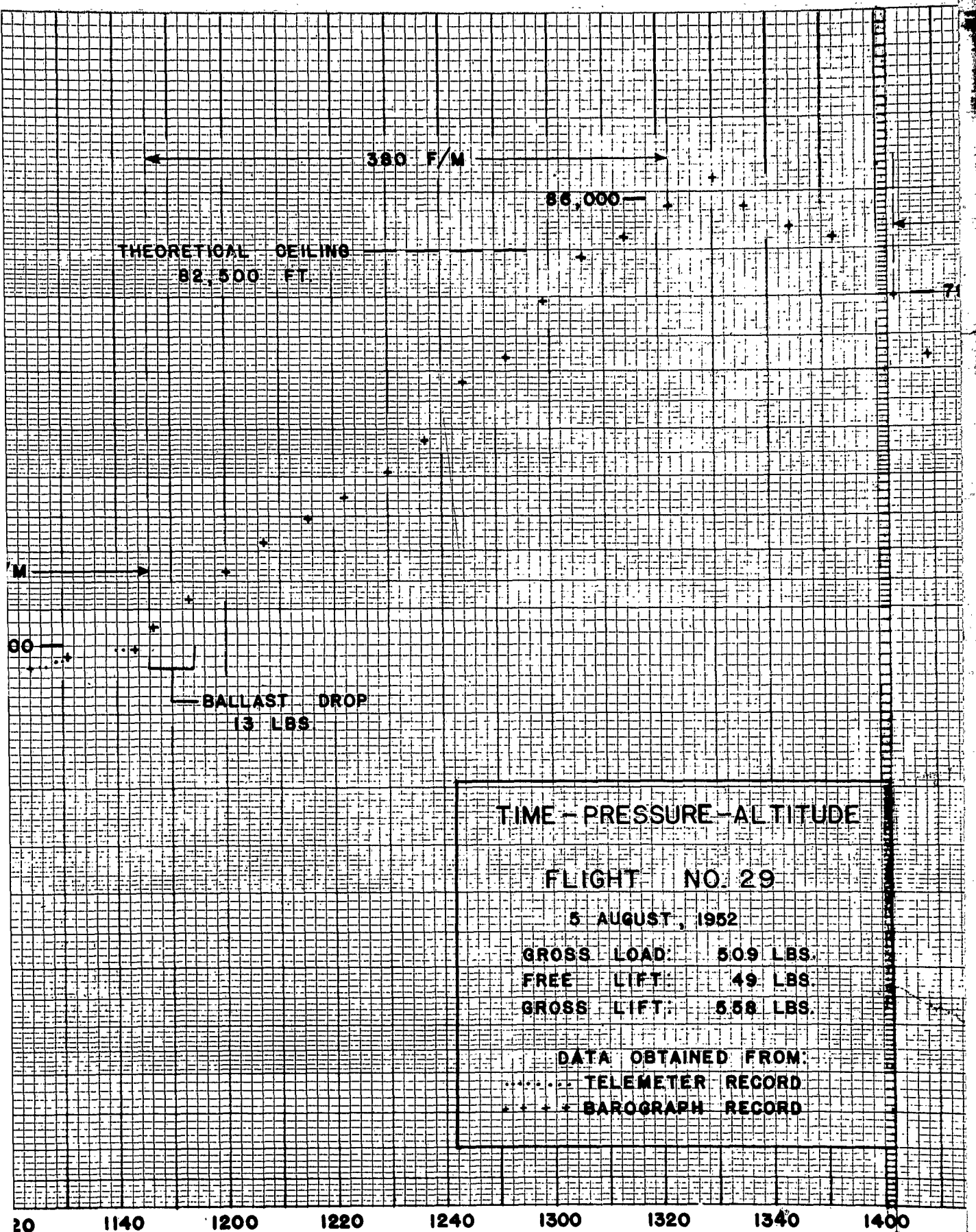
29 JULY, 1952

TRAJECTORY FROM THEODOLITE FIXES

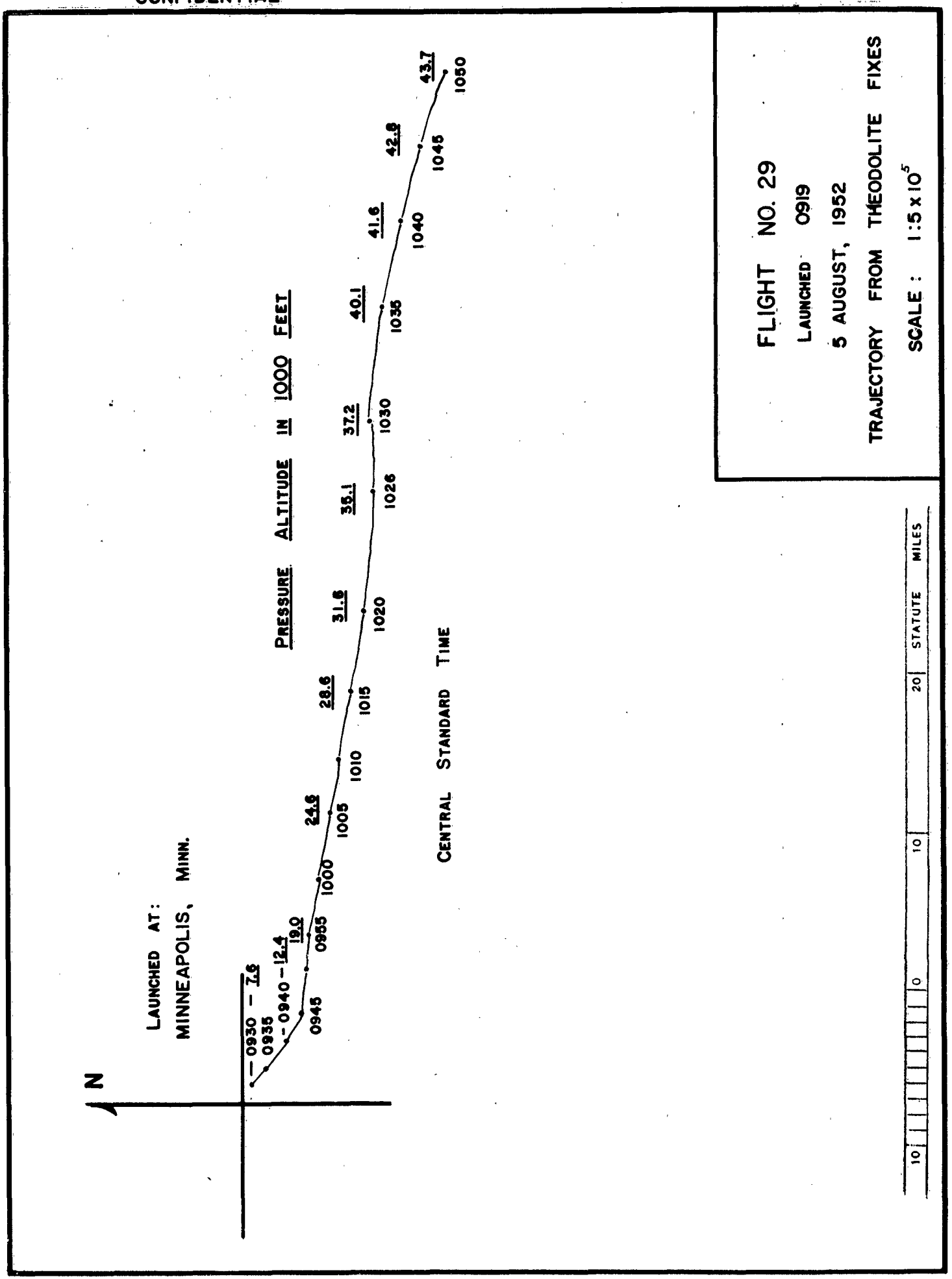
SCALE $1:5 \times 10^5$

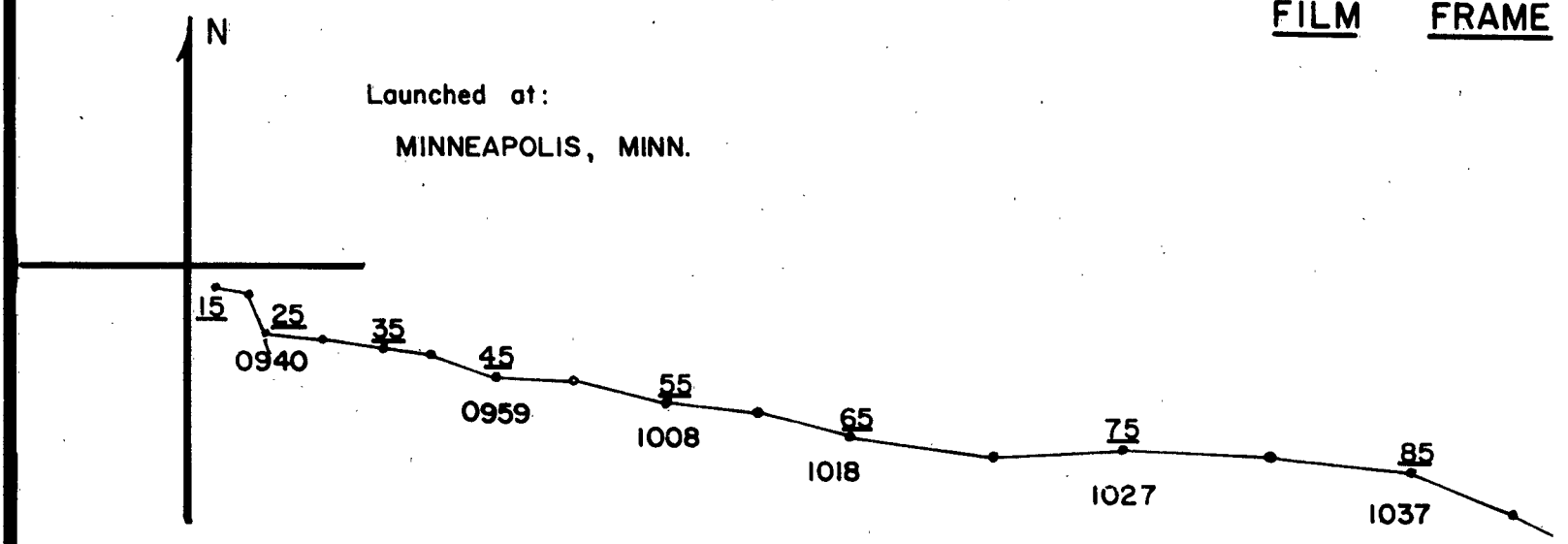

RASONDE DATA
FLIGHT NO. 29
5 August, 1952
Meteorological station reporting:
ST. CLOUD, MINN. 655
1500 Z
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)


ALTITUDE IN THOUSAND FEET
100
90
80
70
60
50
40
30
20
10
0
0900
0920
0940
1000
1020
1040
1100
1120
120 F/M
490 F/M
480 F/M
570 F/M
50,000
42,000
24,000
12,000
VALVE
430 SEC.
VALVE
124 SEC.
VALVE
54 SEC.
BALLOON
LAUNCHED


380 F/M
86,000
THEORETICAL CEILING
82,500 FT.
BALLAST DROP
13 LBS.
TIME - PRESSURE - ALTITUDE
FLIGHT NO. 29
5 AUGUST, 1952
GROSS LOAD: 509 LBS.
FREE LIFT: 49 LBS.
GROSS LIFT: 558 LBS.
DATA OBTAINED FROM:
TELEMETER RECORD
BAROGRAPH RECORD
1140
1200
1220
1240
1300
1320
1340
1400
CENTRAL STANDARD TIME

CONFIDENTIAL





CONFIDENTIAL SECURITY INFORMATION

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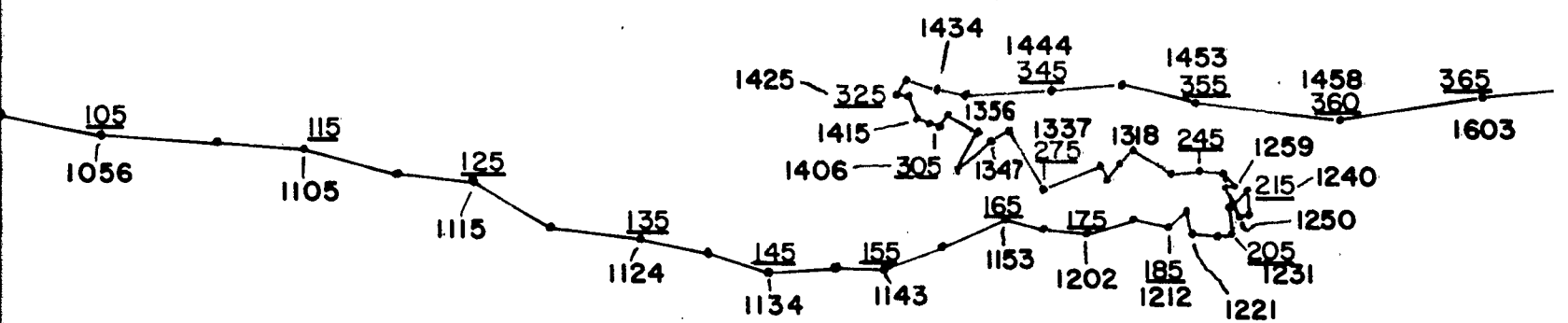
CONFIDENTIAL SECURITY INFORMATION

RS



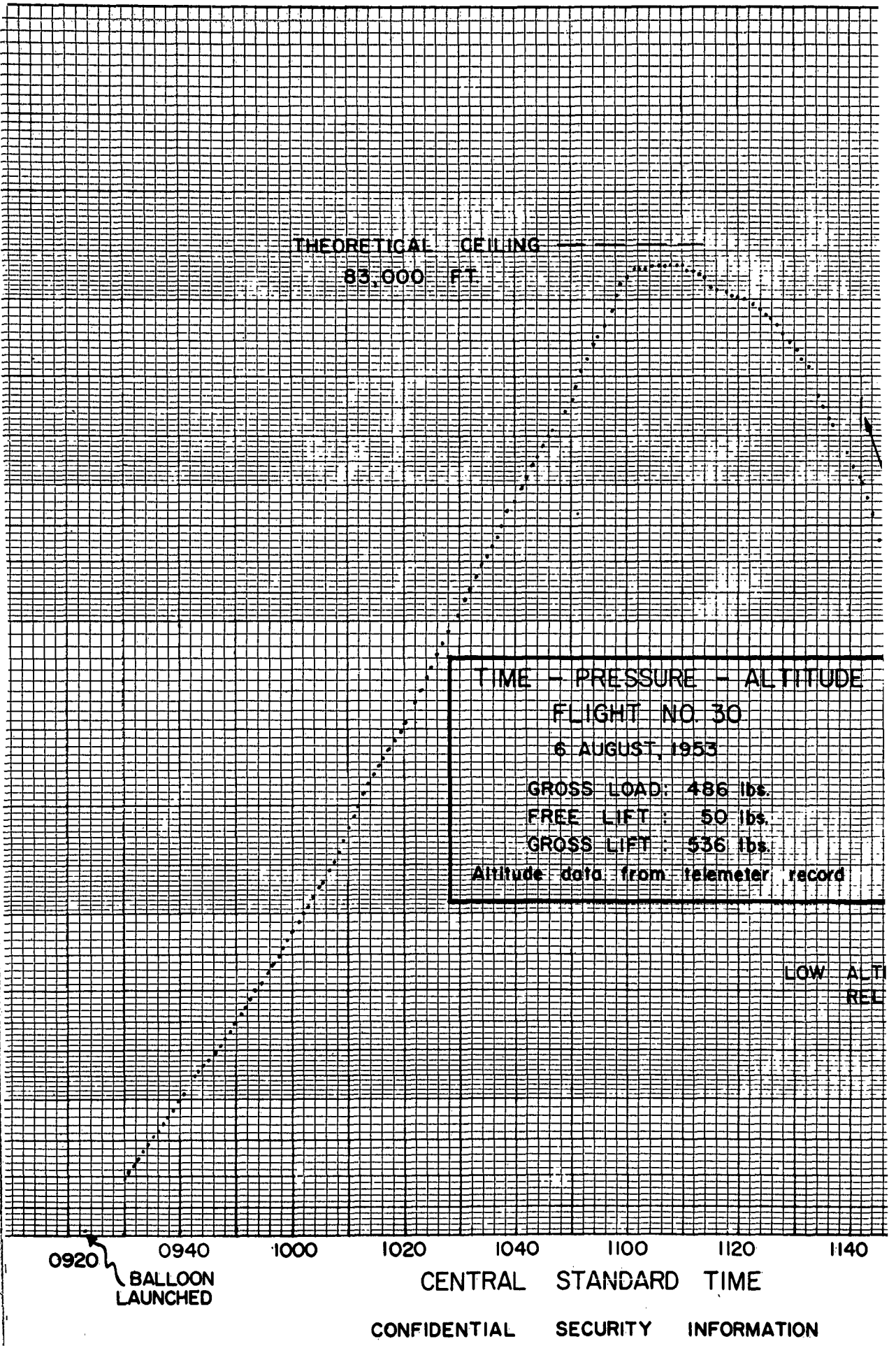
10 0 10 20 STATUTE MILES

FLIGHT

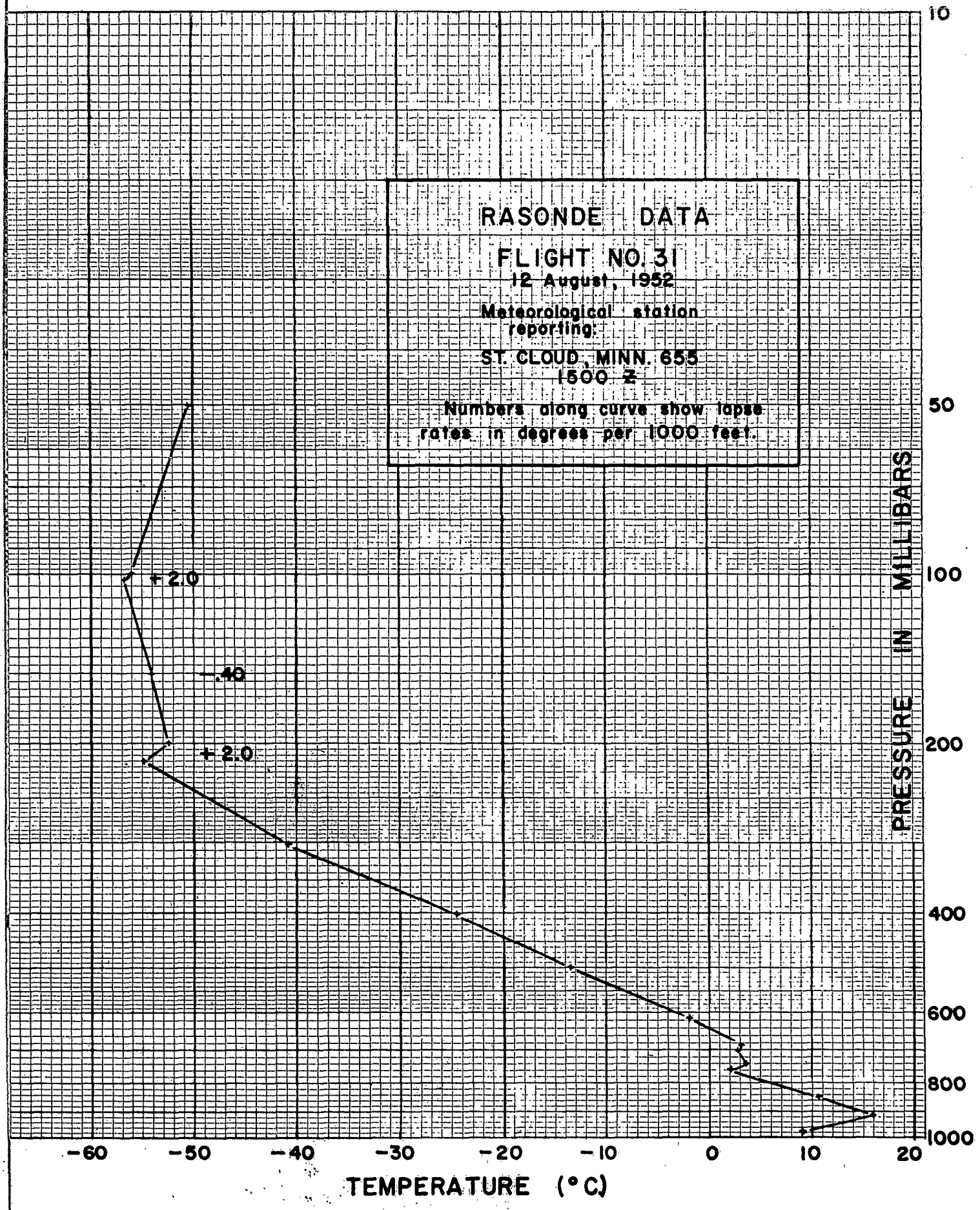
LAUNCHED 09

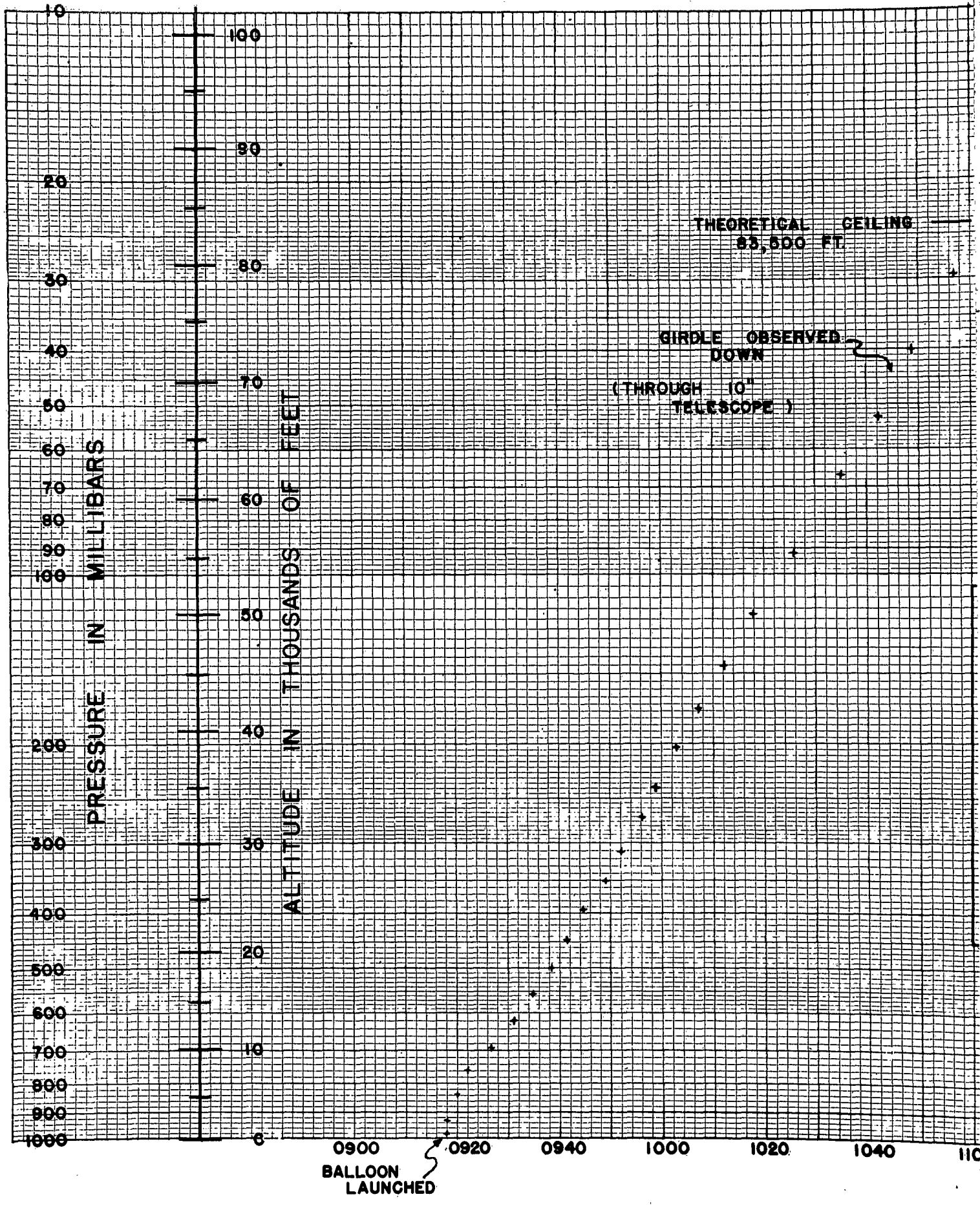
5 AUGUST,

TRAJECTORY FROM

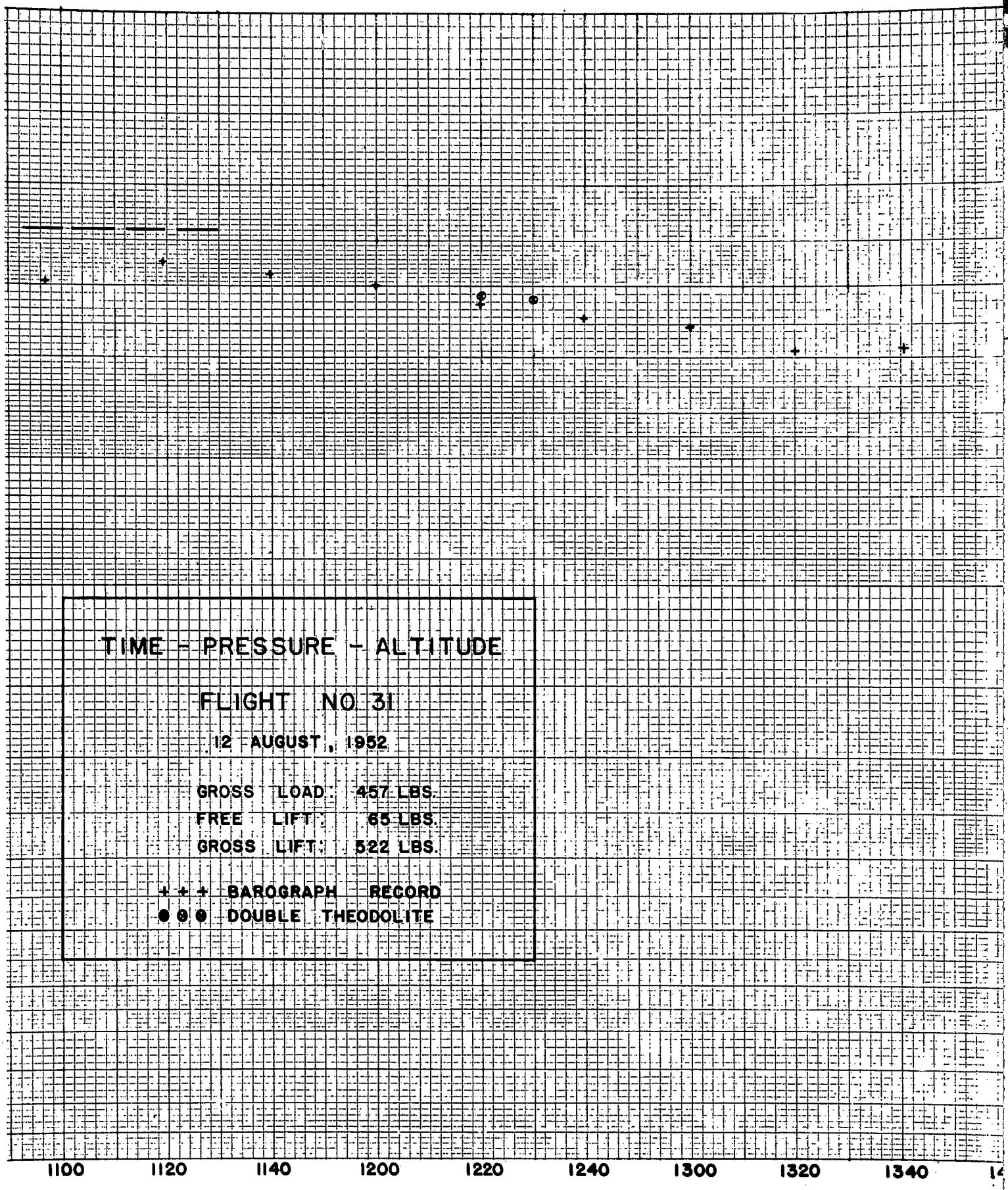


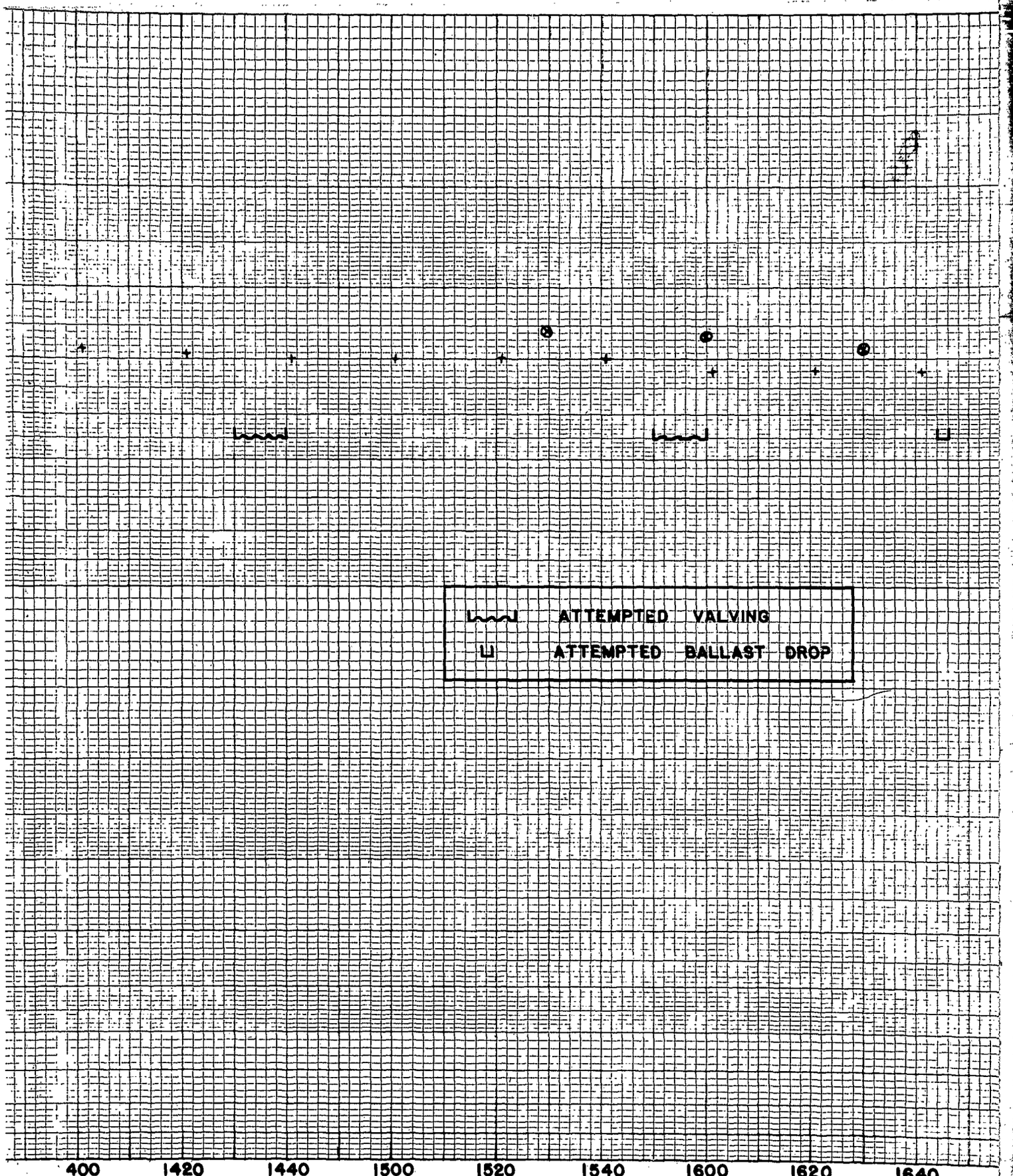
CONFIDENTIAL

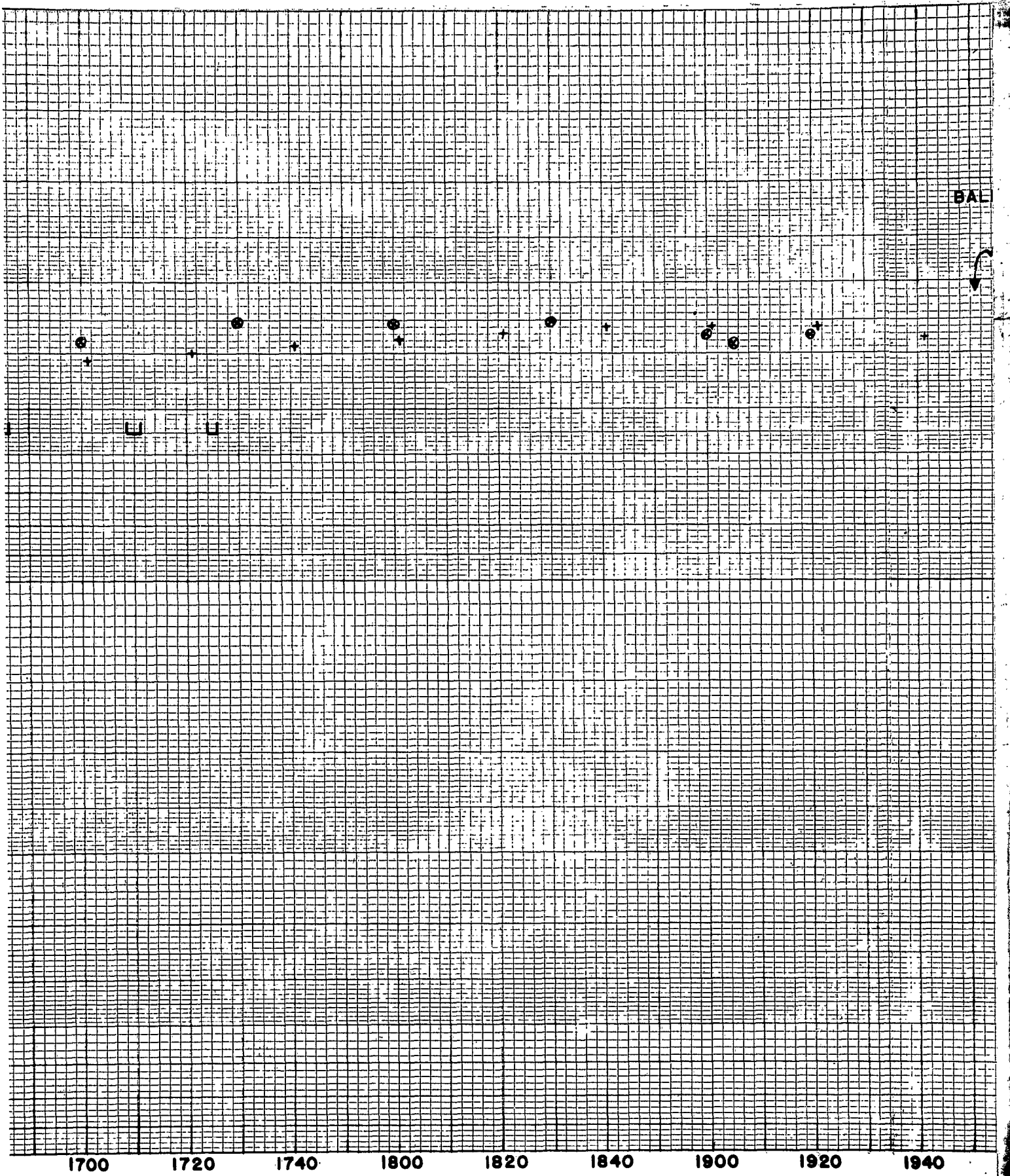

RASONDE DATA
FLIGHT NO. 31
12 August, 1952
Meteorological station reporting:
ST. CLOUD, MINN. 655
1500 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
+2.0
-.40
+2.0
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C)

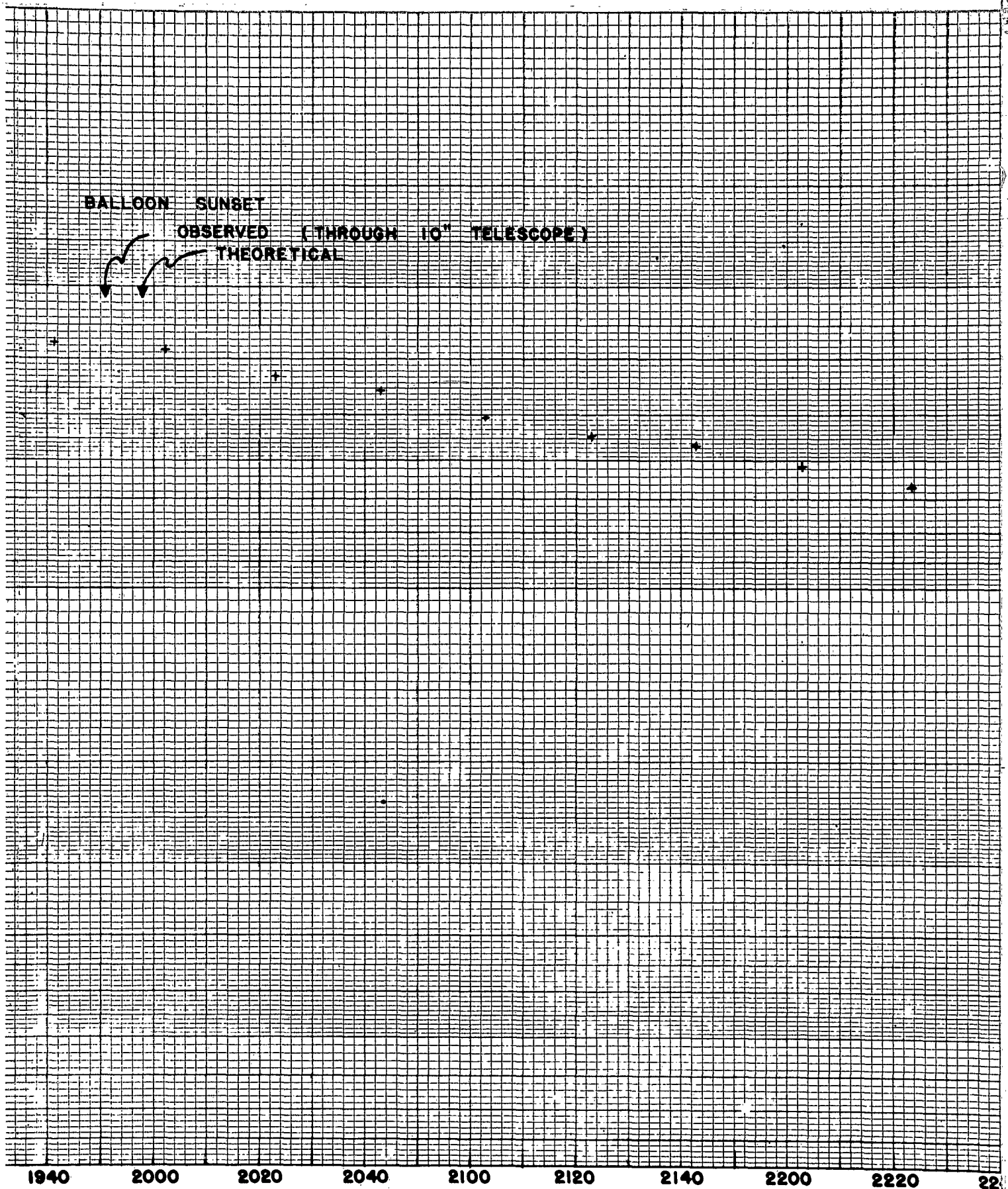


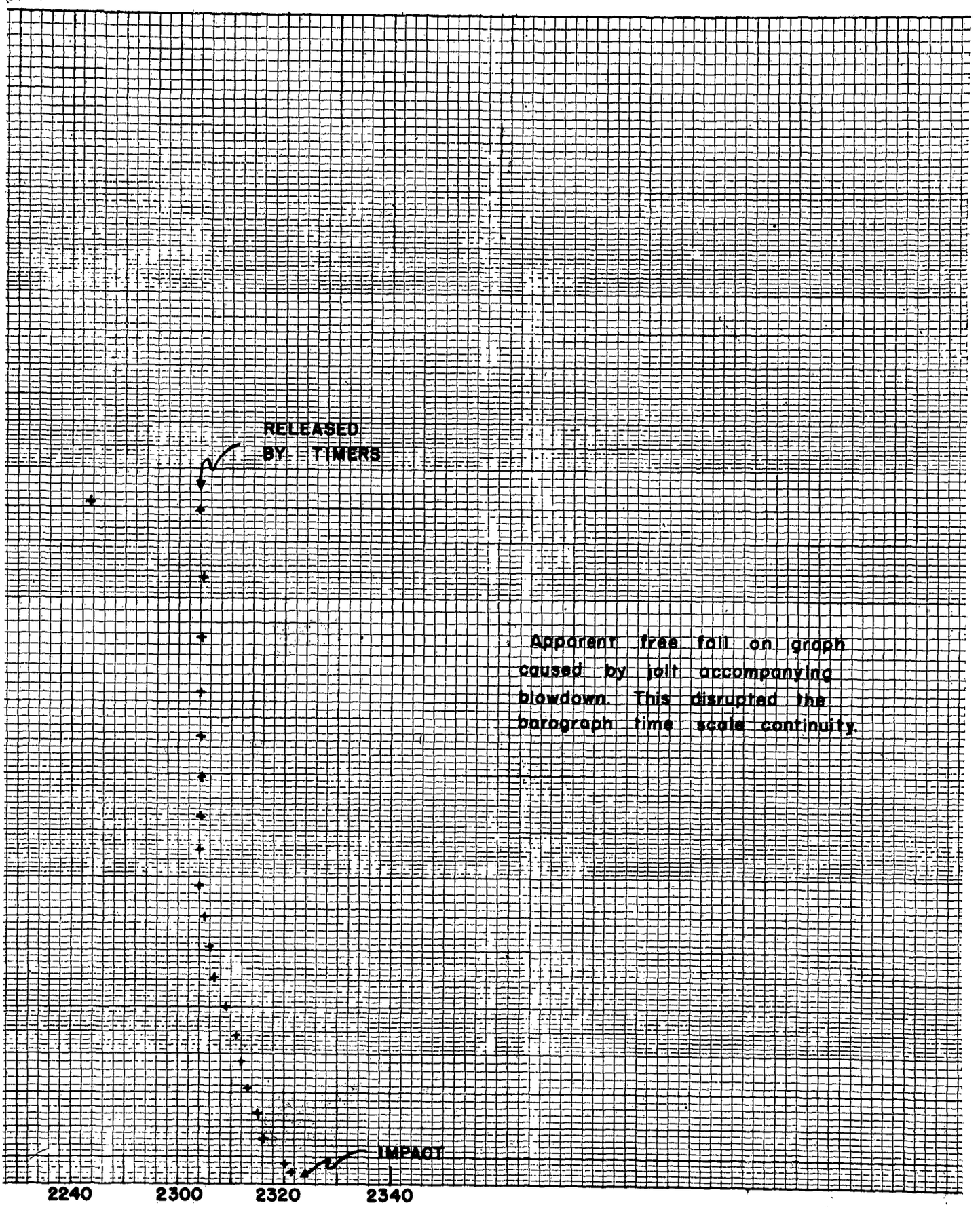
CONFIDENTIAL SECURITY INFORMATION


TIME - PRESSURE - ALTITUDE
FLIGHT NO 31
12 AUGUST, 1952
GROSS LOAD: 457 LBS.
FREE LIFT: 65 LBS.
GROSS LIFT: 522 LBS.
+ + + BAROGRAPH RECORD
● ● ● DOUBLE THEODOLITE
1100
1120
1140
1200
1220
1240
1300
1320
1340
CENTRAL STANDARD TIME


ATTEMPTED VALVING
ATTEMPTED BALLAST DROP
400
1420
1440
1500
1520
1540
1600
1620
1640

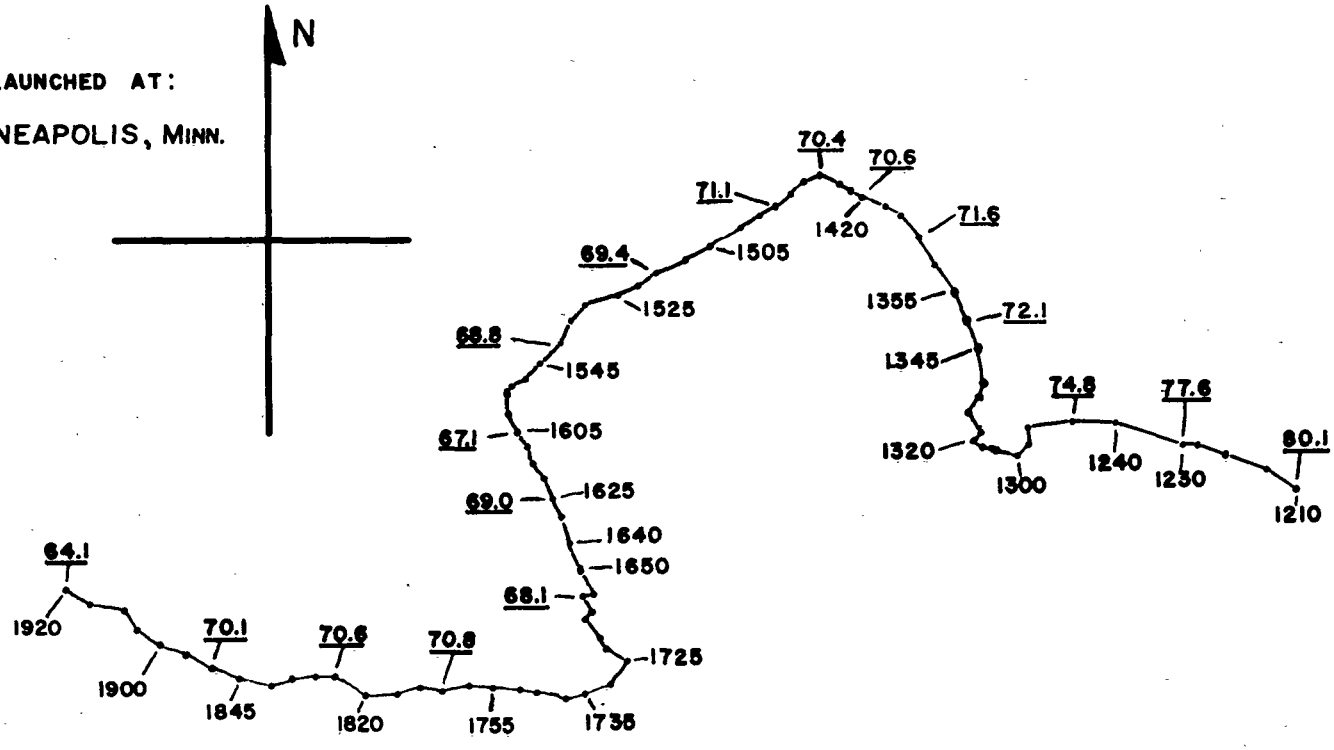

BAL
1700
1720
1740
1800
1820
1840
1900
1920
1940

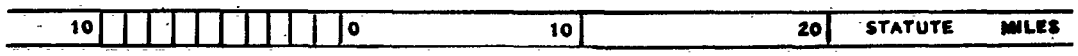

BALLOON SUNSET
OBSERVED (THROUGH 10" TELESCOPE)
THEORETICAL
1940
2000
2020
2040
2100
2120
2140
2200
2220
22


RELEASED
BY TIMERS
Apparent free fall on graph caused by jolt accompanying blowdown. This disrupted the barograph time scale continuity.
IMPACT
2240
2300
2320
2340

CONFIDENTIAL

CONFIDENTIAL SECURITY INFORMATION





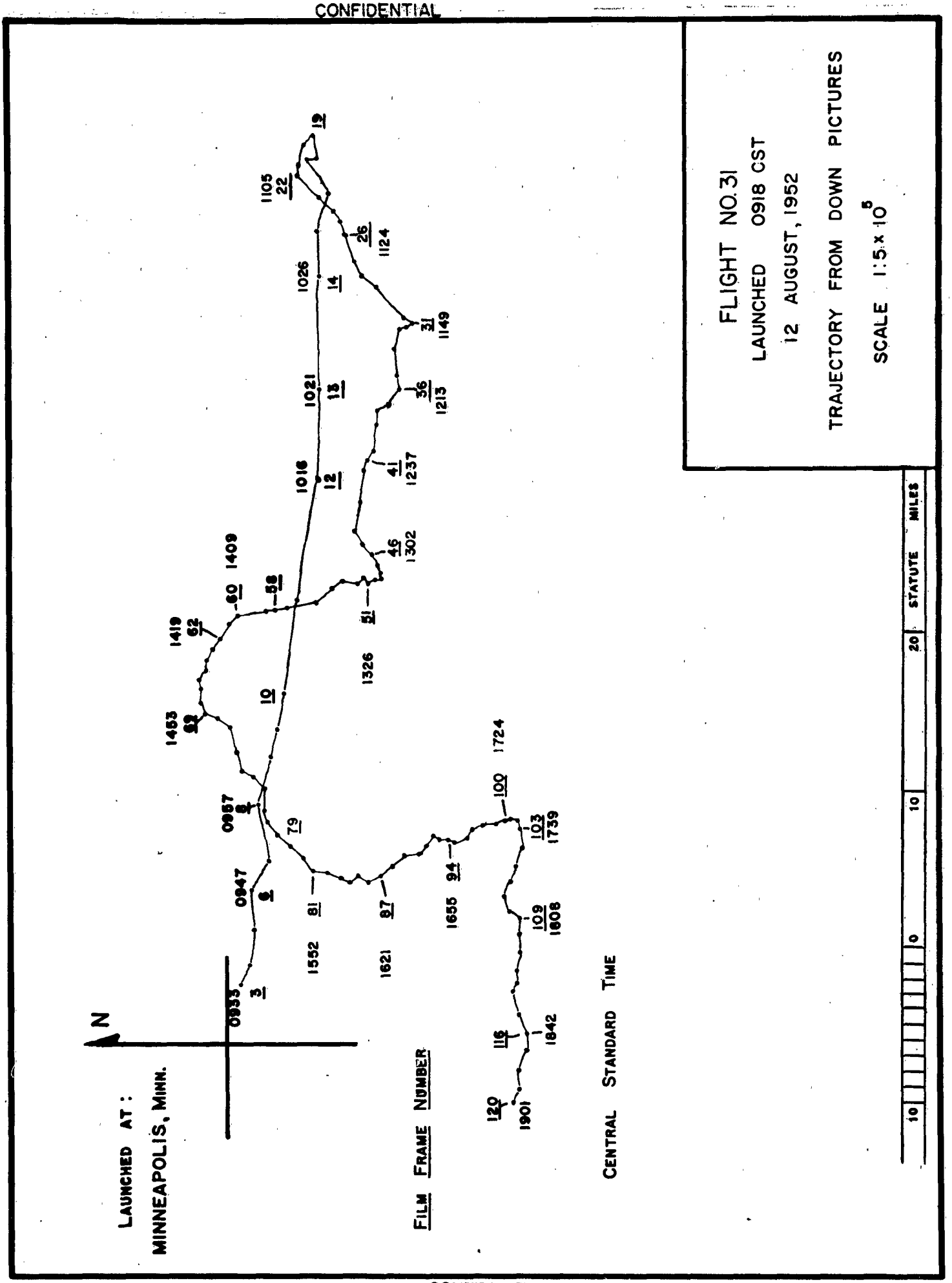
FLIGHT NO. 31

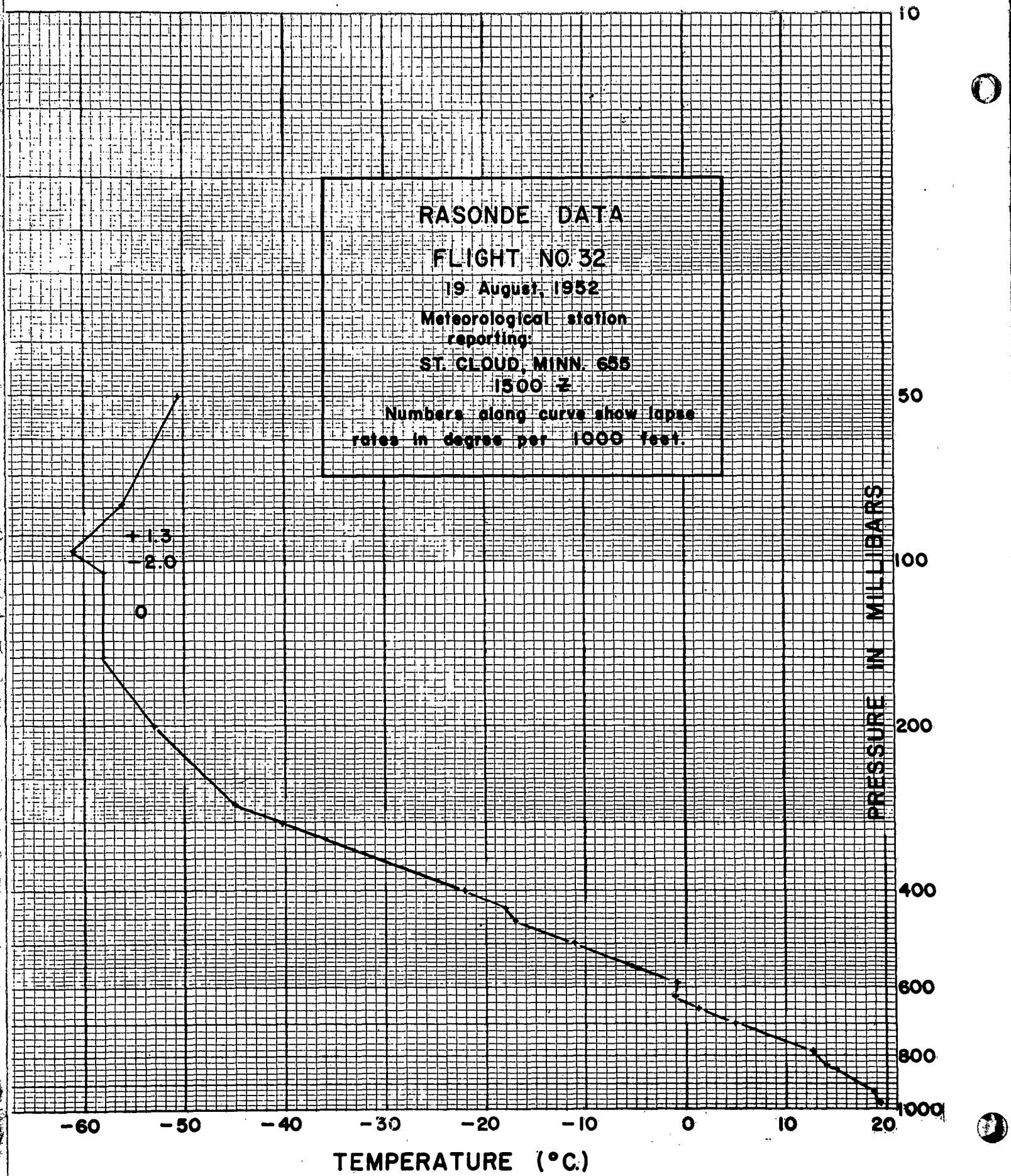
LAUNCHED 0918 CST

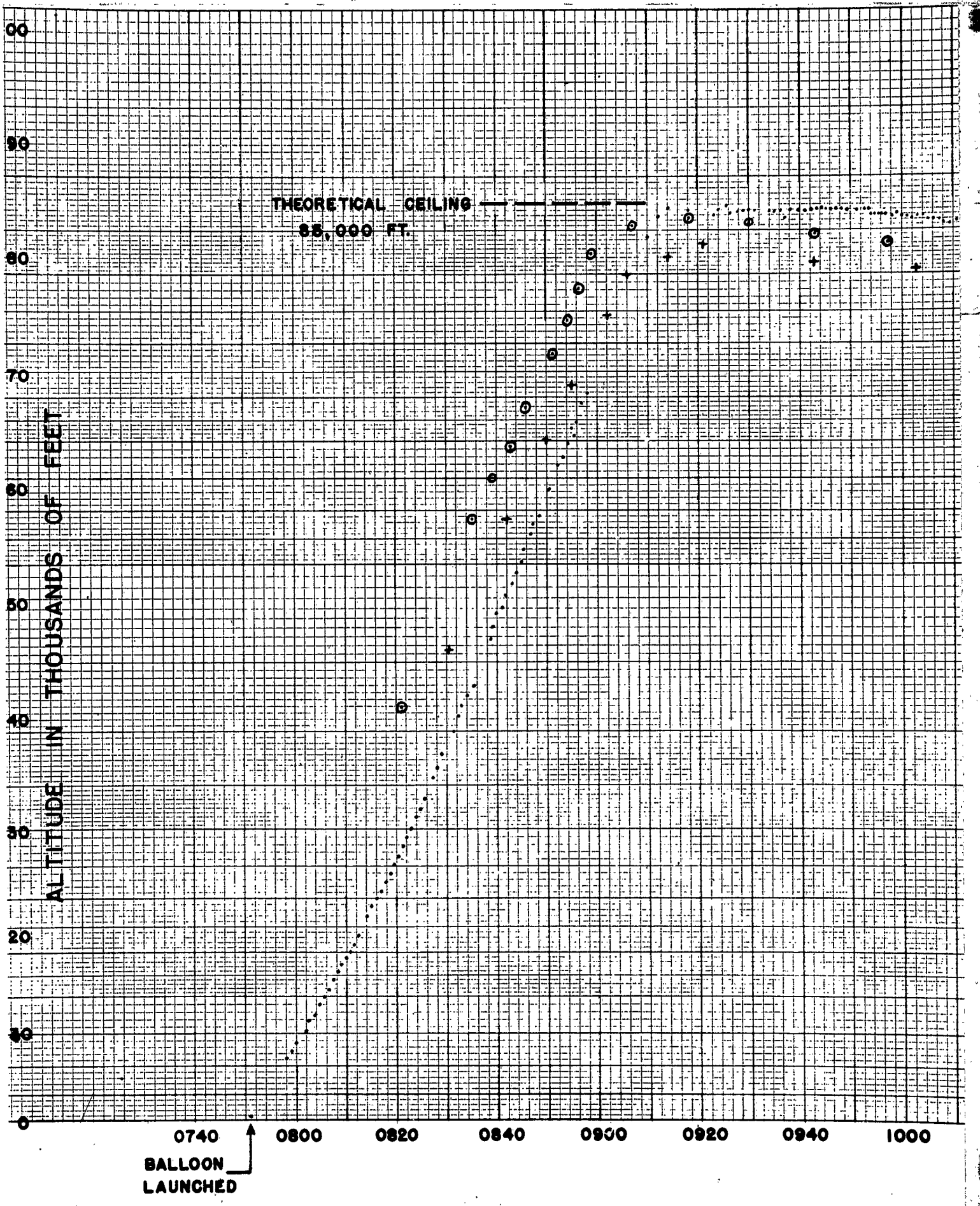
12 AUGUST, 1952

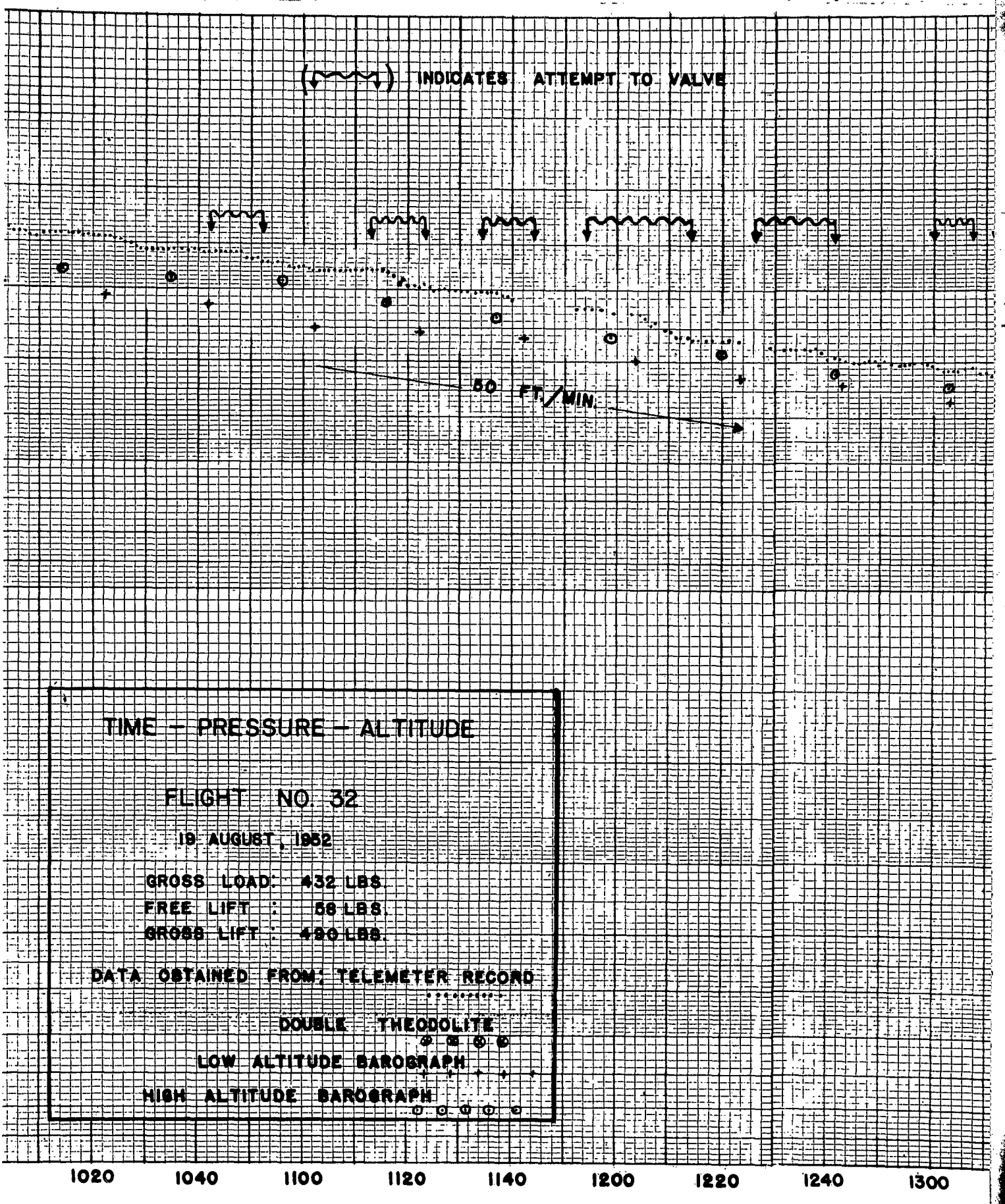
TRAJECTORY FROM THEODOLITE FIXES

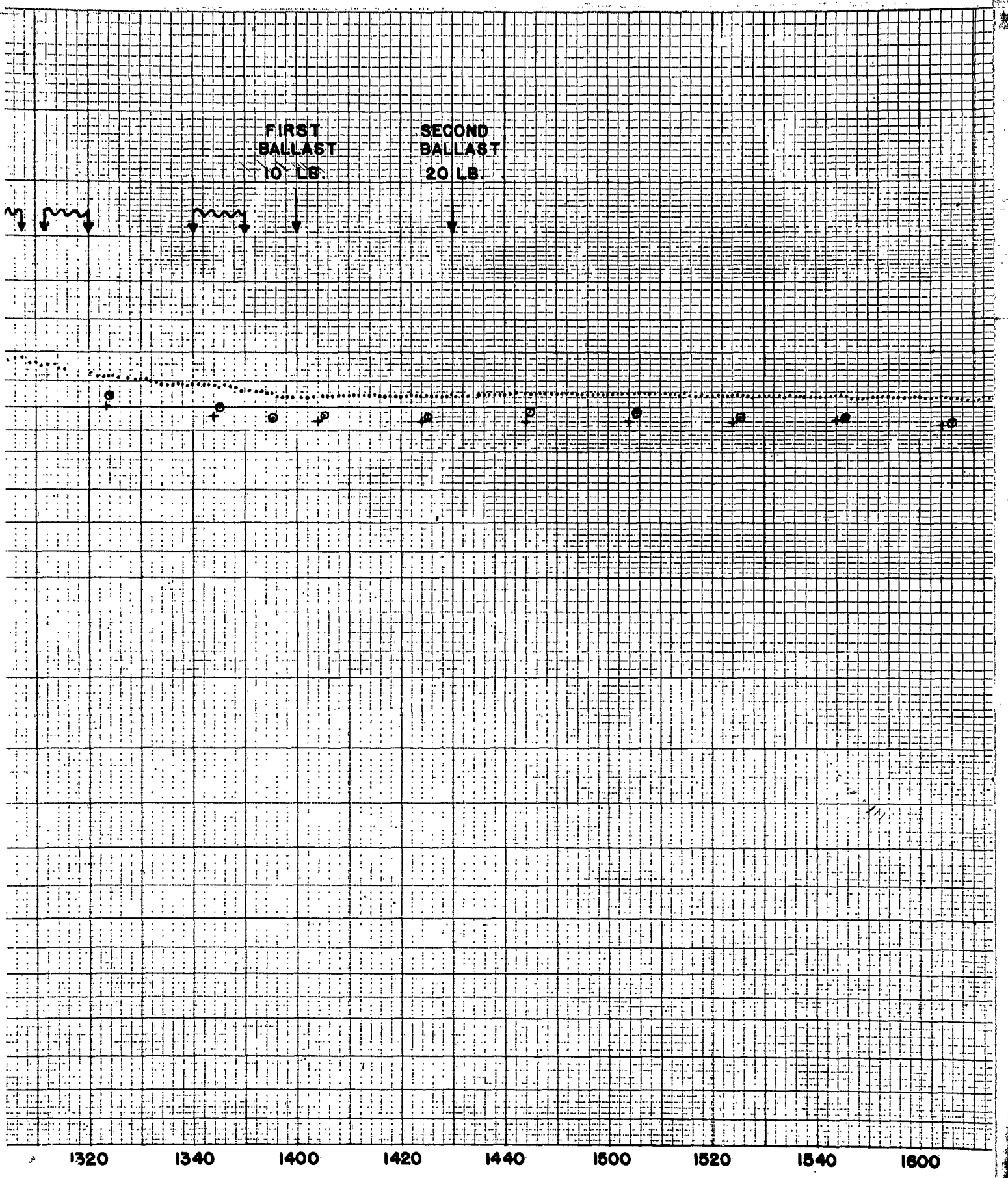
SCALE $1:5 \times 10^5$

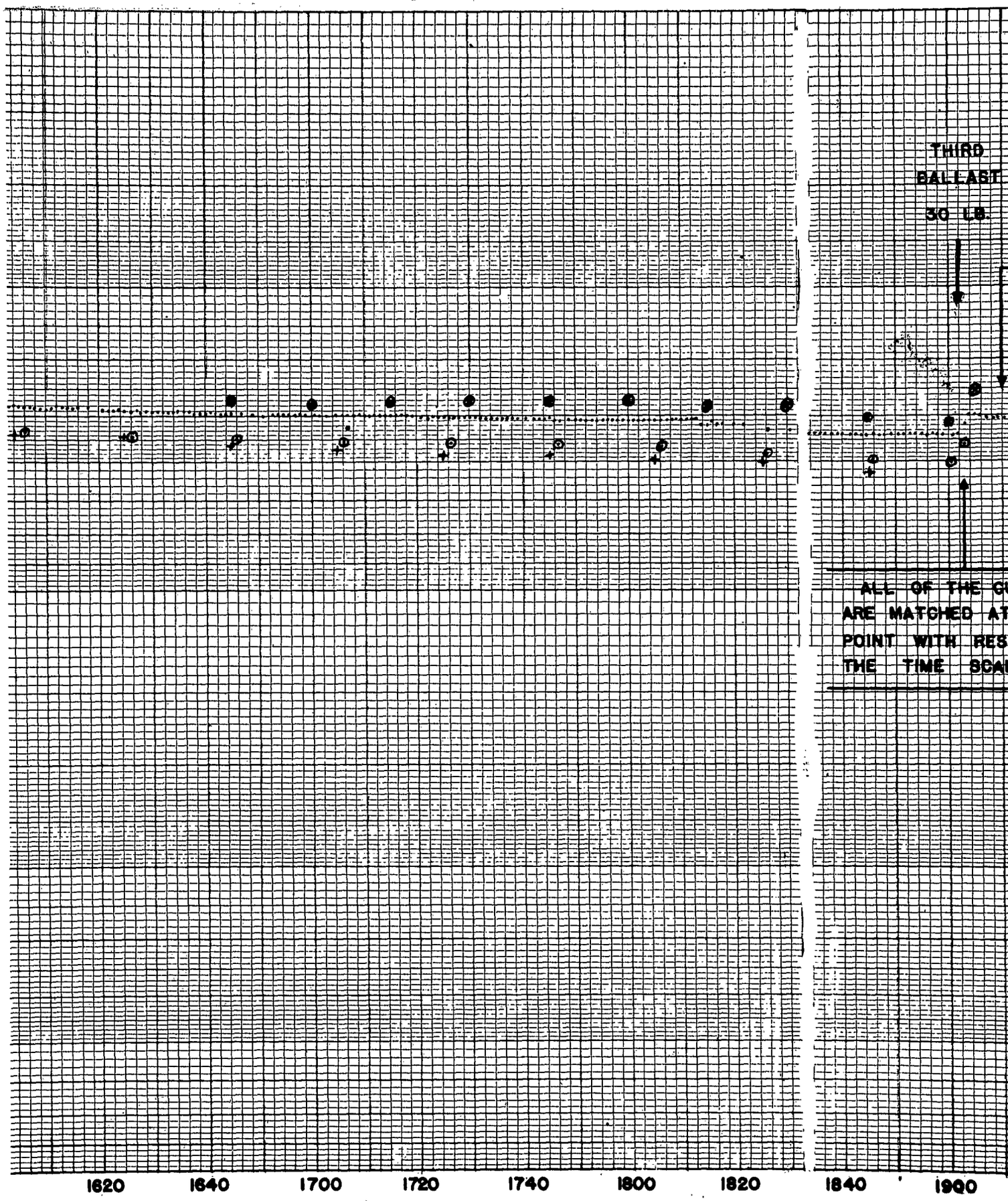

FLIGHT NO.31
LAUNCHED 0918 CST
12 AUGUST, 1952
TRAJECTORY FROM DOWN PICTURES
SCALE 1:5 x 10^5
10 0 10 20 STATUTE MILES
N
LAUNCHED AT:
MINNEAPOLIS, MINN.
FILM FRAME NUMBER
CENTRAL STANDARD TIME
0933
3
0947
6
0957
9
1016
12
1021
15
1026
14
1105
22
19
1124
26
1149
31
1213
36
1237
41
1302
46
1326
51
1409
60
1419
62
1453
63
1552
81
1621
87
1655
94
1724
100
1739
103
1608
109
1842
116
1901
120

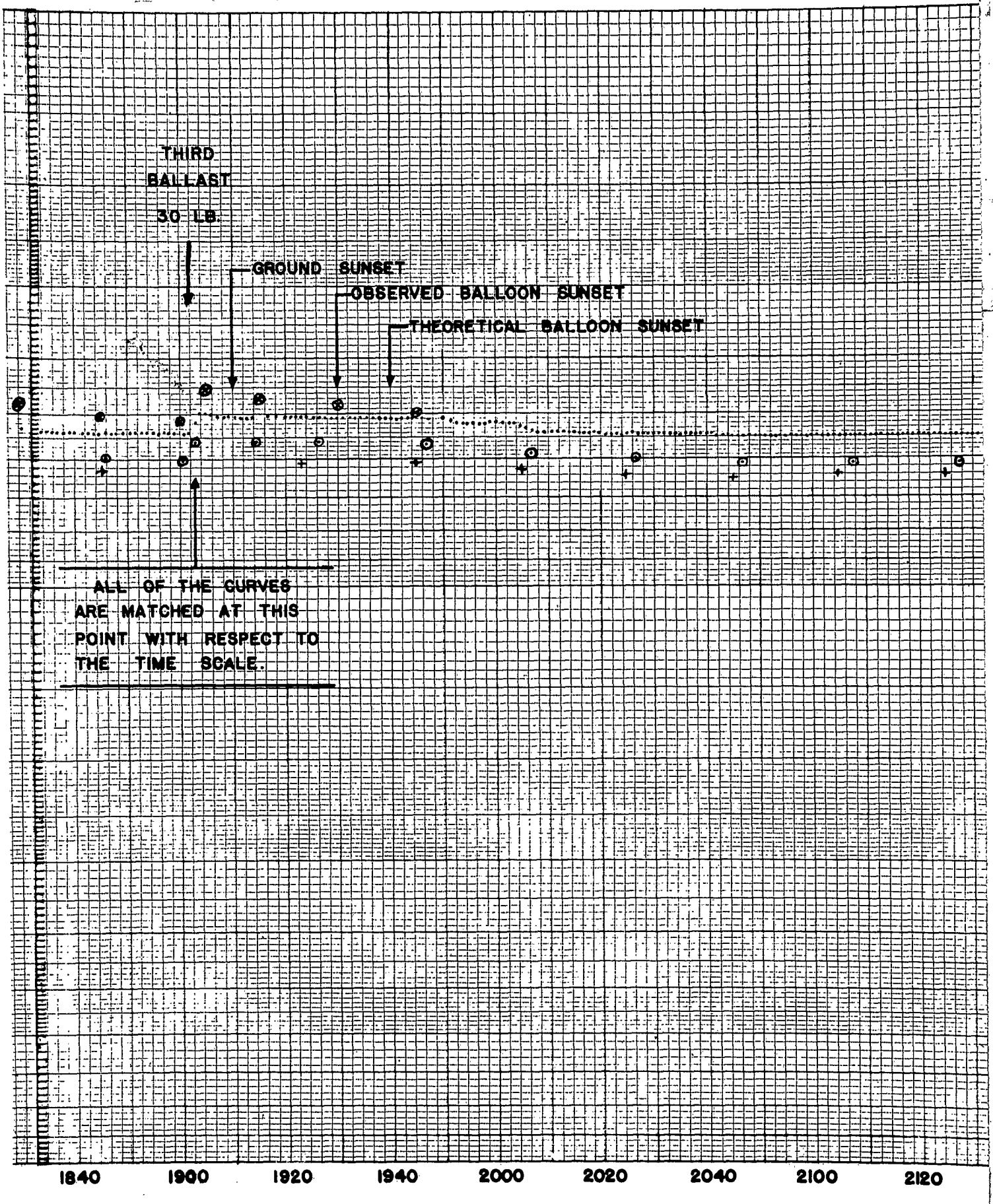

RASONDE DATA
FLIGHT NO. 32
19 August, 1952
Meteorological station reporting:
ST. CLOUD, MINN. 655
1500 Z
Numbers along curve show lapse rates in degree per 1000 feet.
+1.3
-2.0
0
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

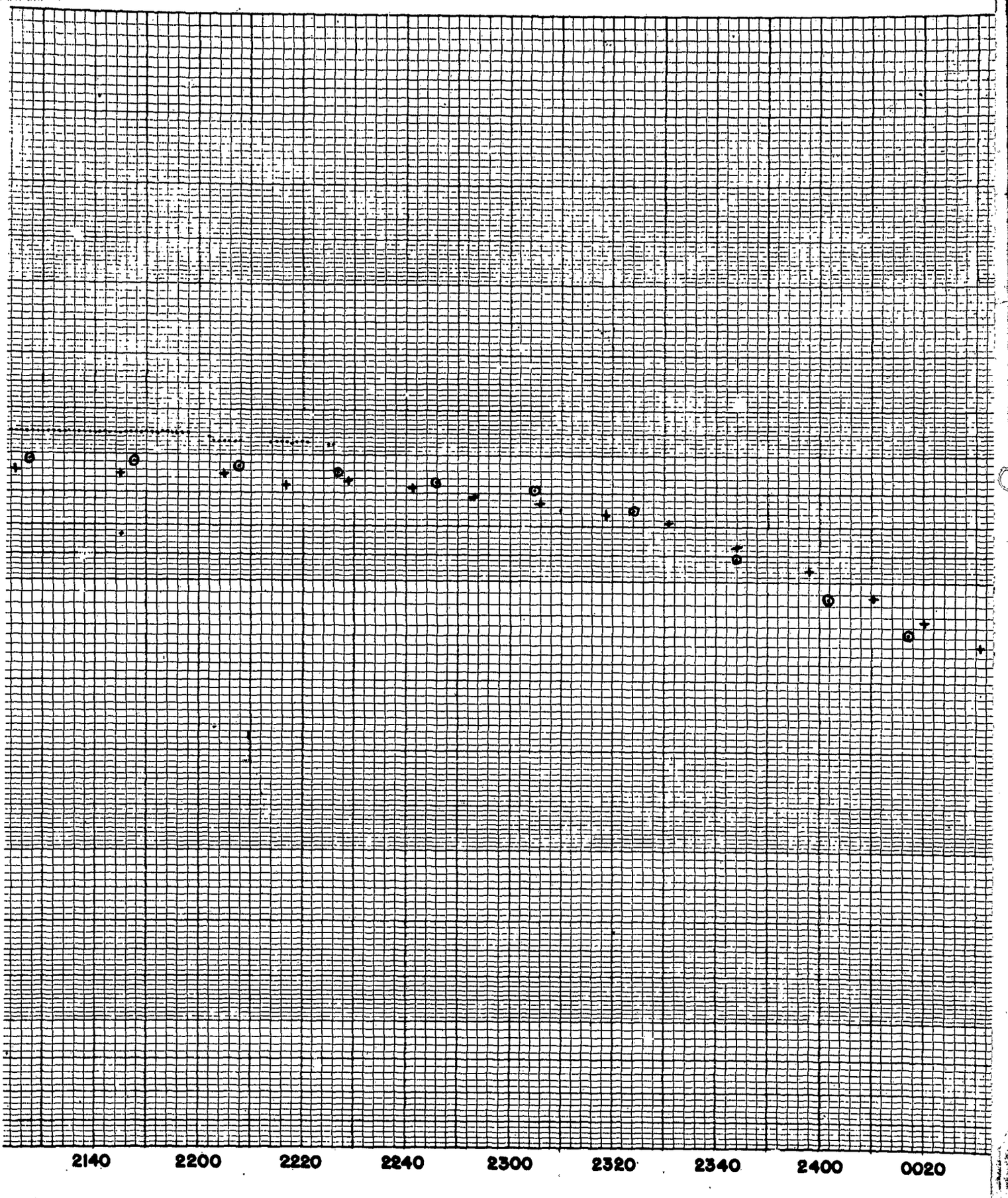

THEORETICAL CEILING
85,000 FT.
ALTITUDE IN THOUSANDS OF FEET
90
80
70
60
50
40
30
20
10
0
0740
0800
0820
0840
0900
0920
0940
1000
BALLOON LAUNCHED

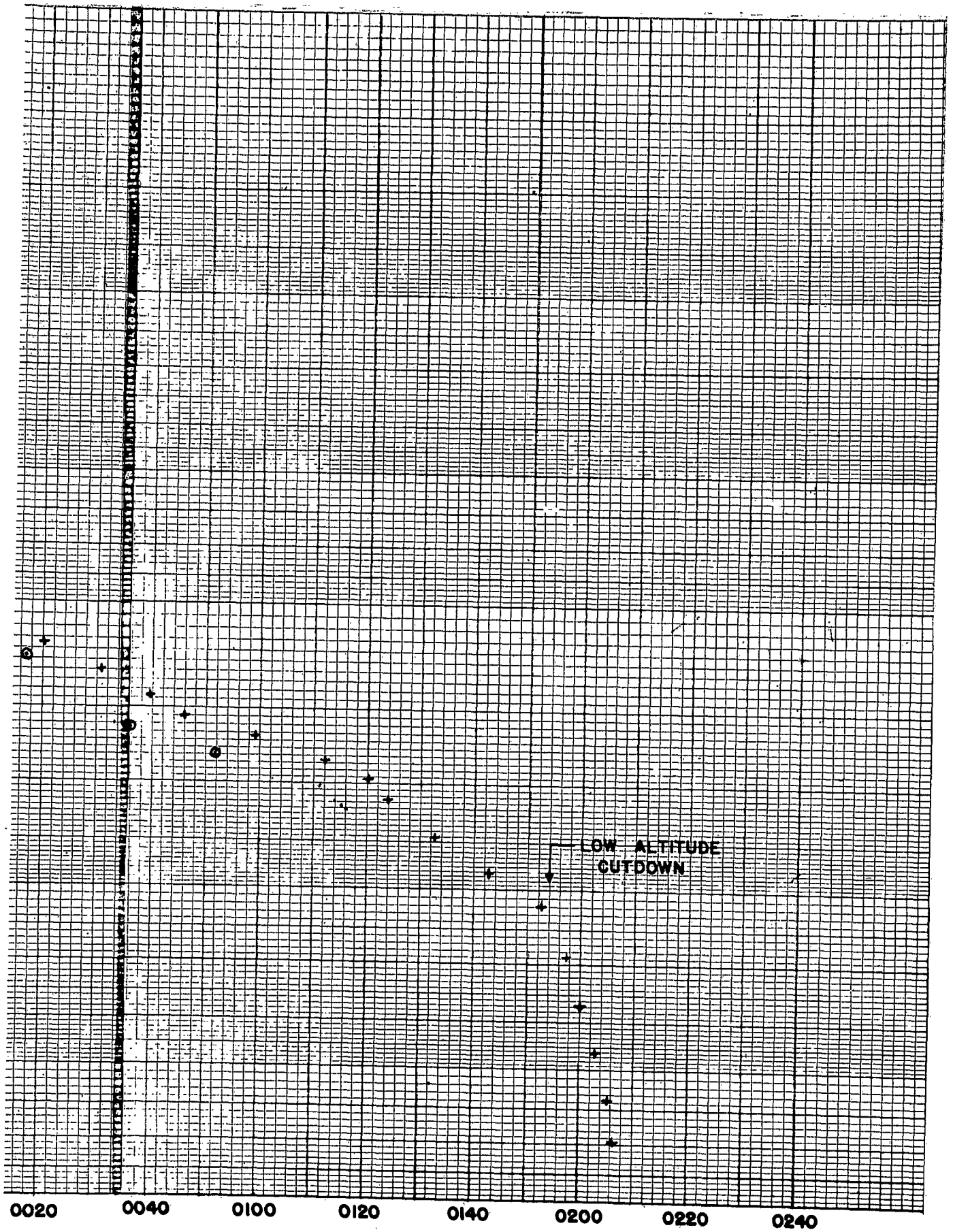

(↓~~~) INDICATES ATTEMPT TO VALVE
50 FT./MIN.
TIME – PRESSURE – ALTITUDE
FLIGHT NO. 32
19 AUGUST, 1952
GROSS LOAD: 432 LBS.
FREE LIFT : 58 LBS.
GROSS LIFT : 490 LBS.
DATA OBTAINED FROM: TELEMETER RECORD
DOUBLE THEODOLITE
LOW ALTITUDE BAROGRAPH
HIGH ALTITUDE BAROGRAPH
1020
1040
1100
1120
1140
1200
1220
1240
1300
CENTRAL STANDARD TIME


FIRST
BALLAST
10 LB.
SECOND
BALLAST
20 LB.
1320
1340
1400
1420
1440
1500
1520
1540
1600

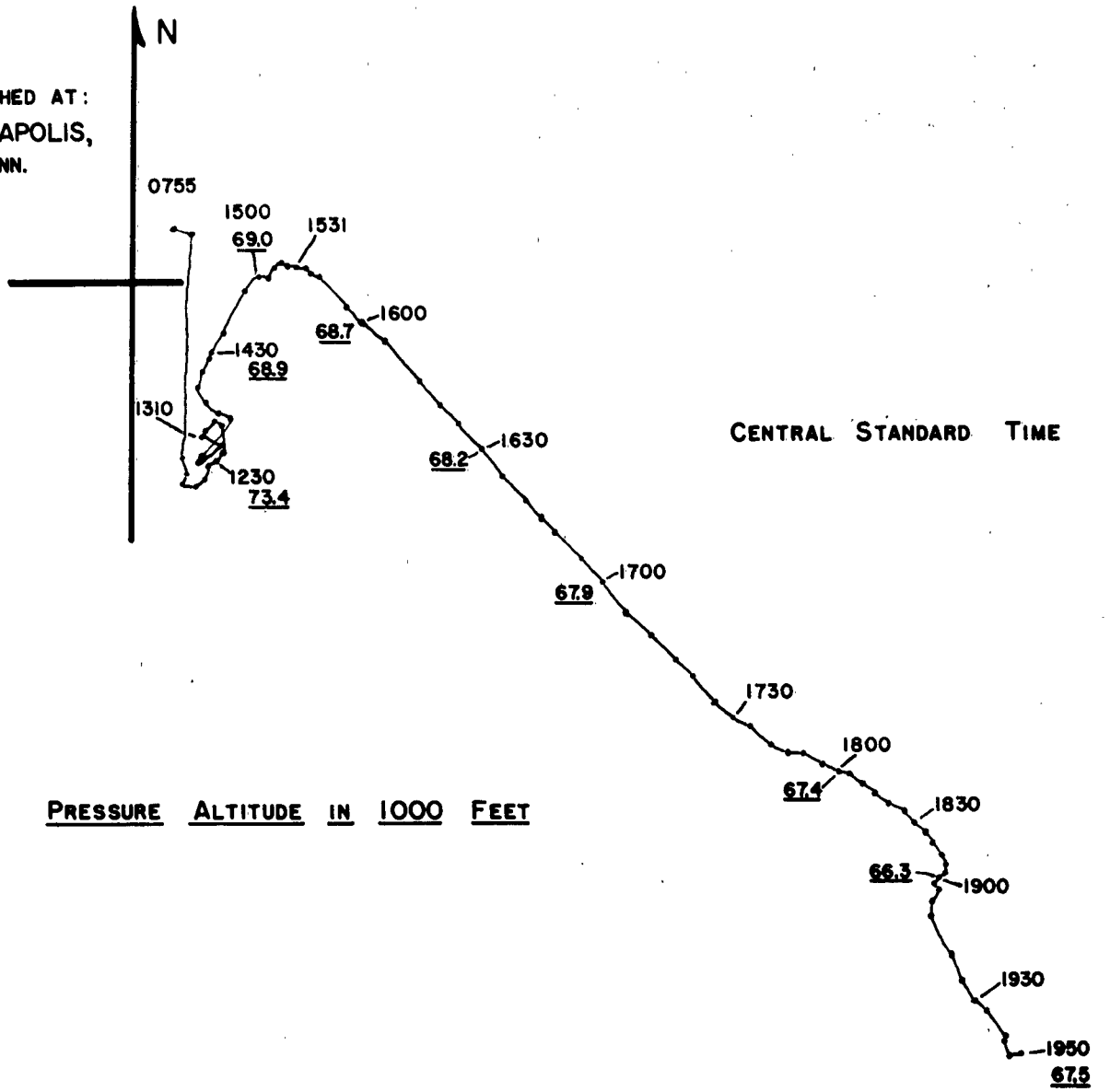

THIRD
BALLAST
30 LB.
ALL OF THE CU
ARE MATCHED AT
POINT WITH RESI
THE TIME SCAL
1620
1640
1700
1720
1740
1800
1820
1840
1900


THIRD
BALLAST
30 LB.
GROUND SUNSET
OBSERVED BALLOON SUNSET
THEORETICAL BALLOON SUNSET
ALL OF THE CURVES
ARE MATCHED AT THIS
POINT WITH RESPECT TO
THE TIME SCALE.
1840
1900
1920
1940
2000
2020
2040
2100
2120


2140
2200
2220
2240
2300
2320
2340
2400
0020


LOW ALTITUDE
CUTDOWN
0020
0040
0100
0120
0140
0200
0220
0240

CONFIDENTIAL



FLIGHT NO. 32

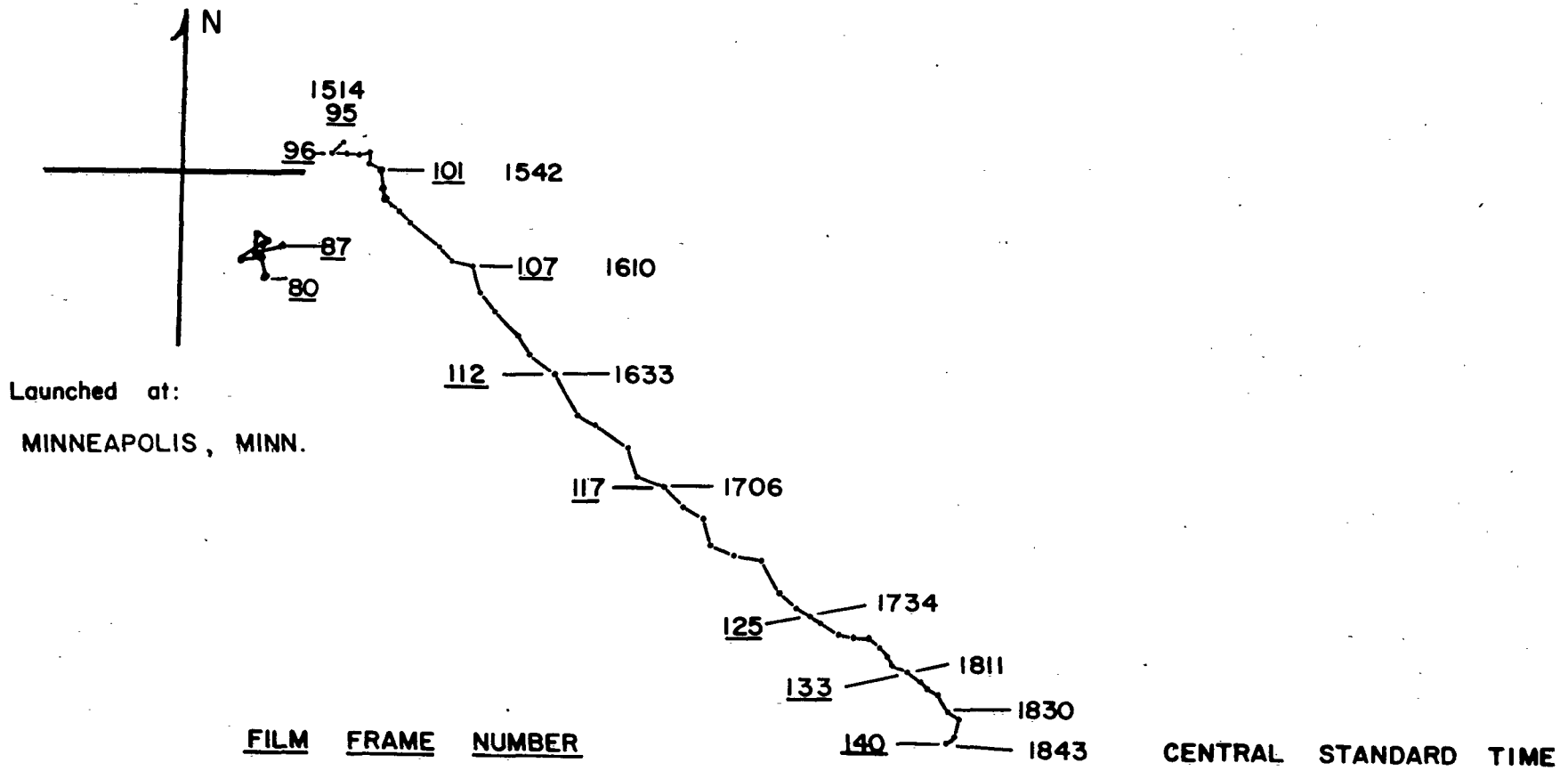
LAUNCHED 0751 CST

19 AUGUST, 1952

TRAJECTORY FROM THEODOLITE FIXES

SCALE 1:5 x 10^5

10 0 10 20 STATUTE MILES



CONFIDENTIAL SECURITY INFORMATION

10 0 10 20 STATUTE MILES

FLIGHT NO. 32

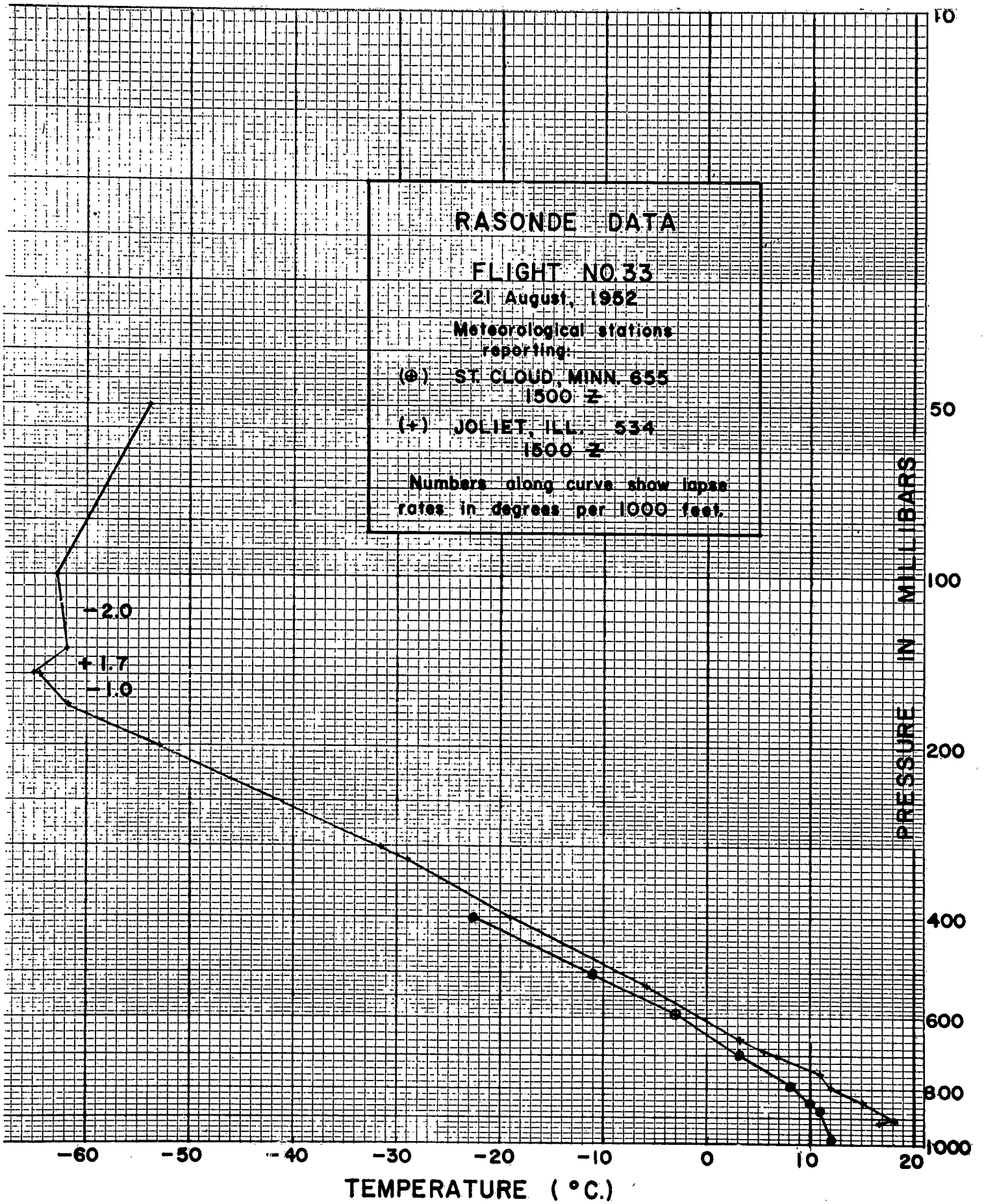
LAUNCHED 0751 CST

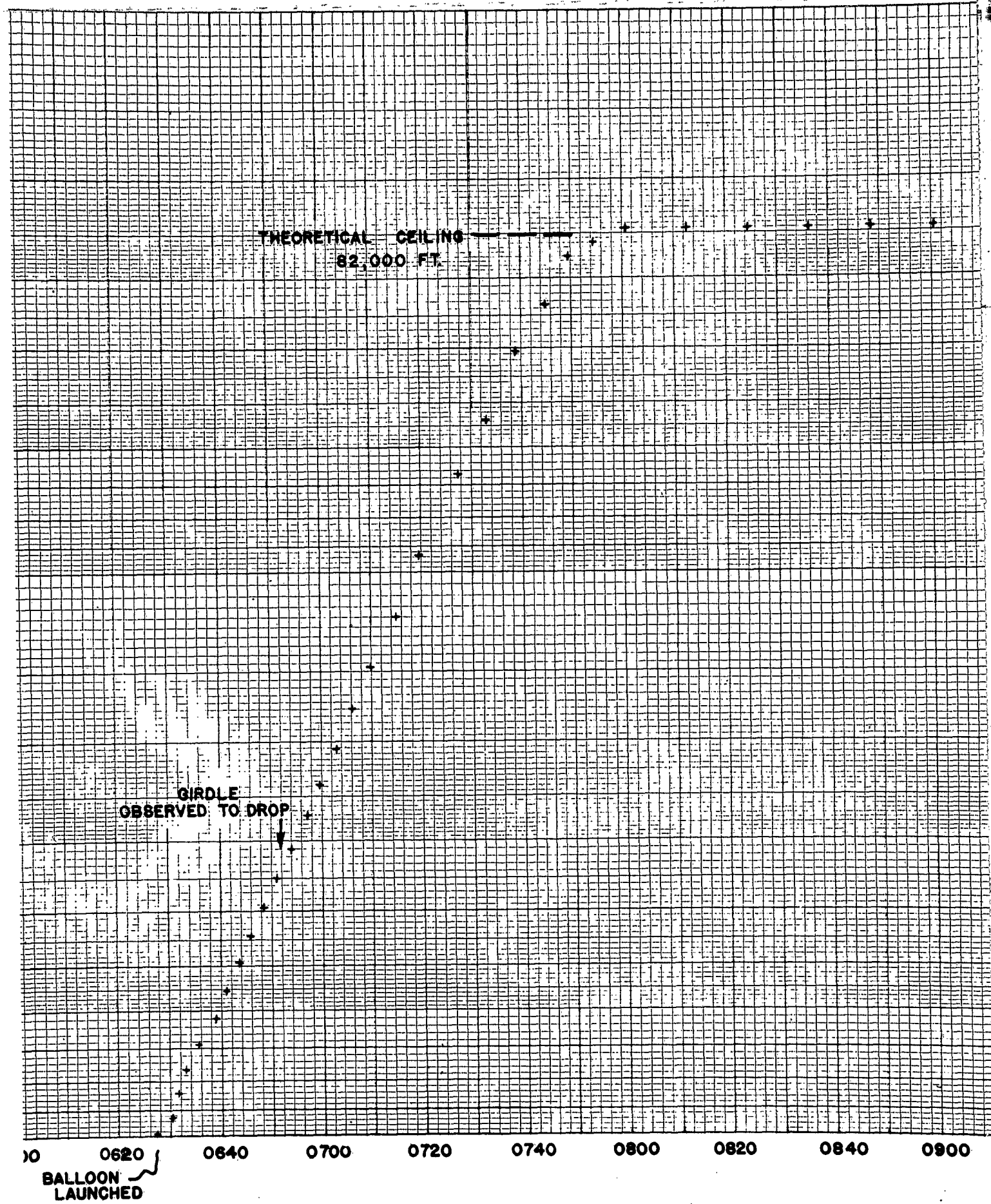
19 AUGUST, 1952

TRAJECTORY FROM DOWN PICTURES

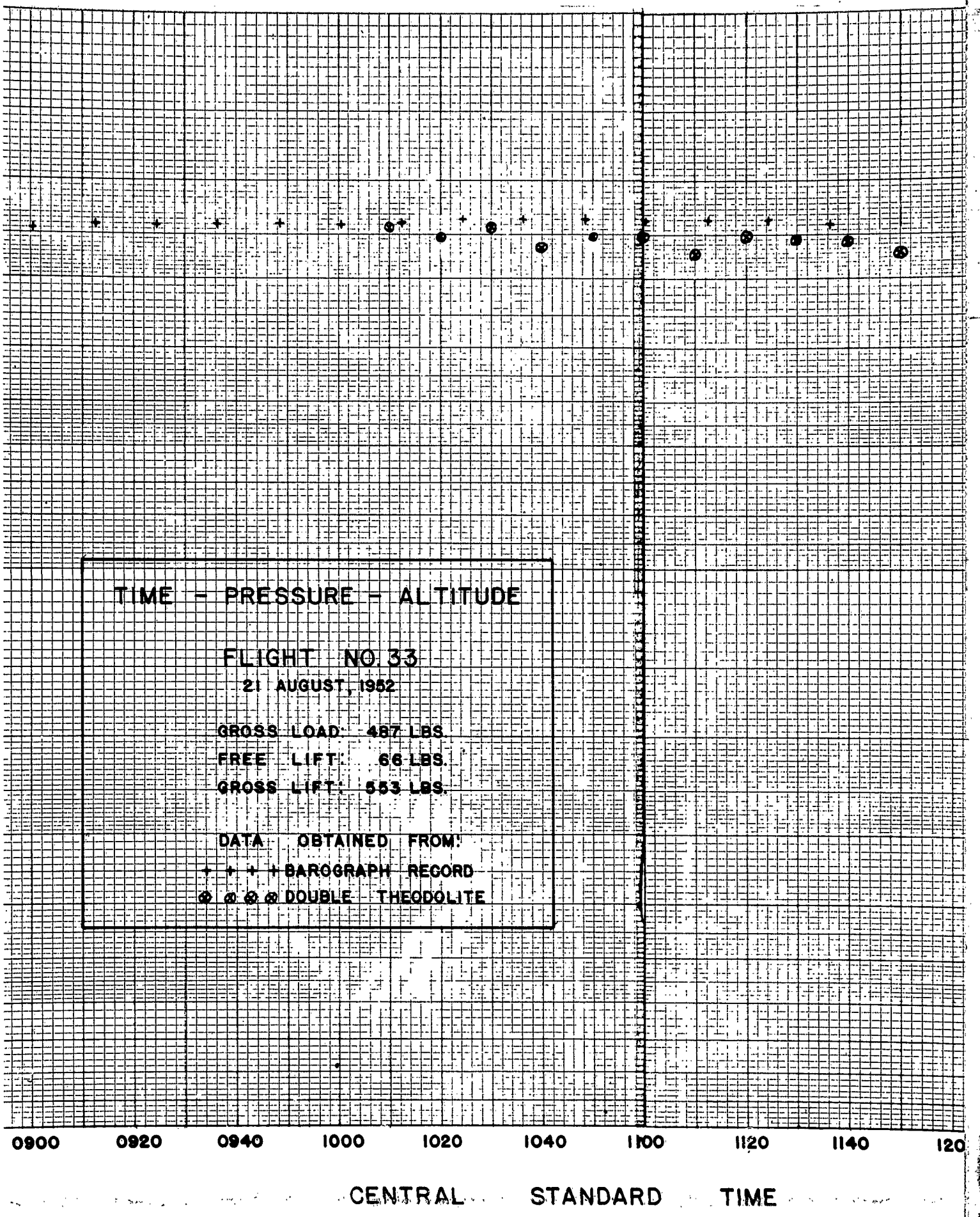
SCALE $1{:}5 \times 10^5$

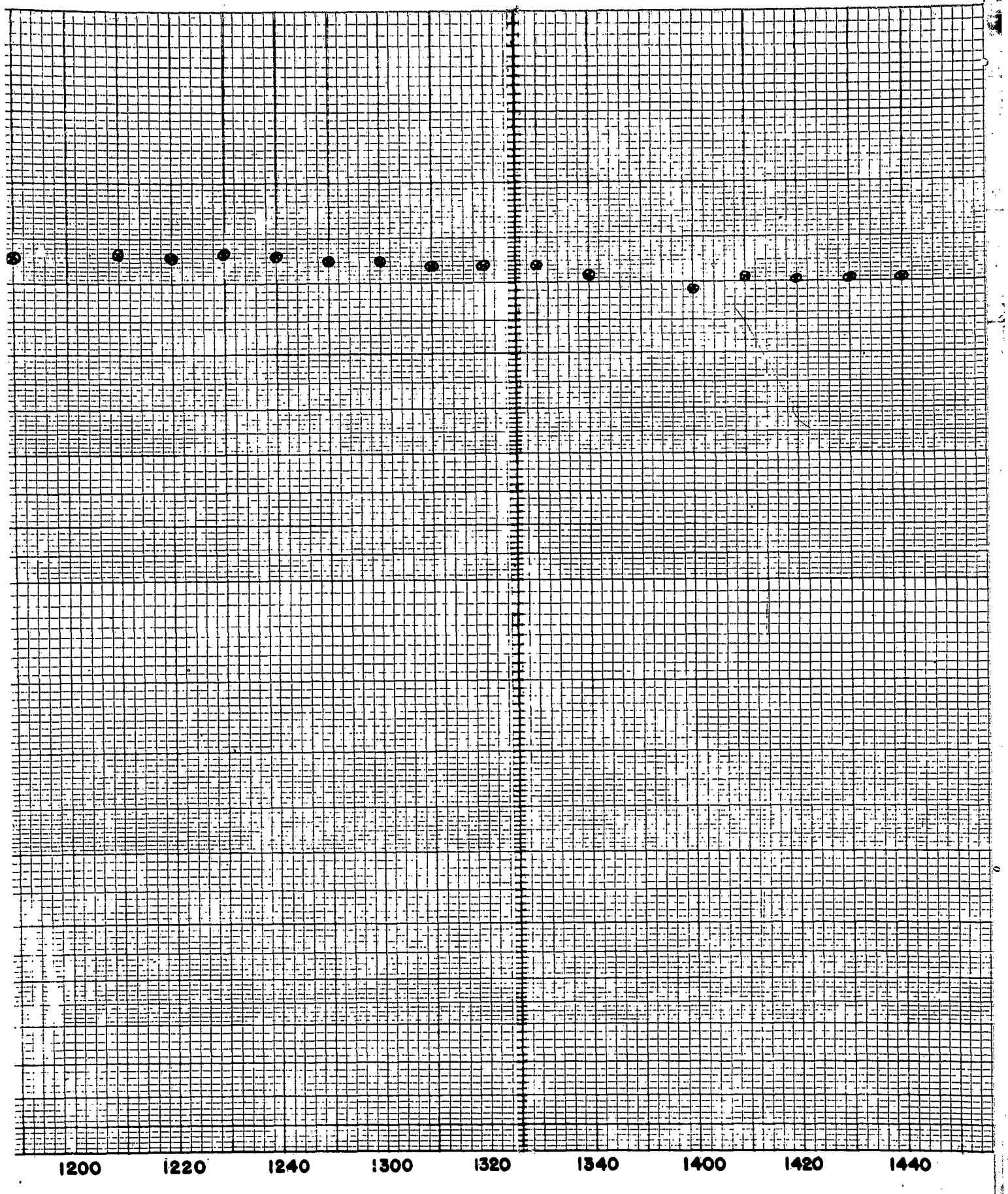
CONFIDENTIAL SECURITY INFORMATION

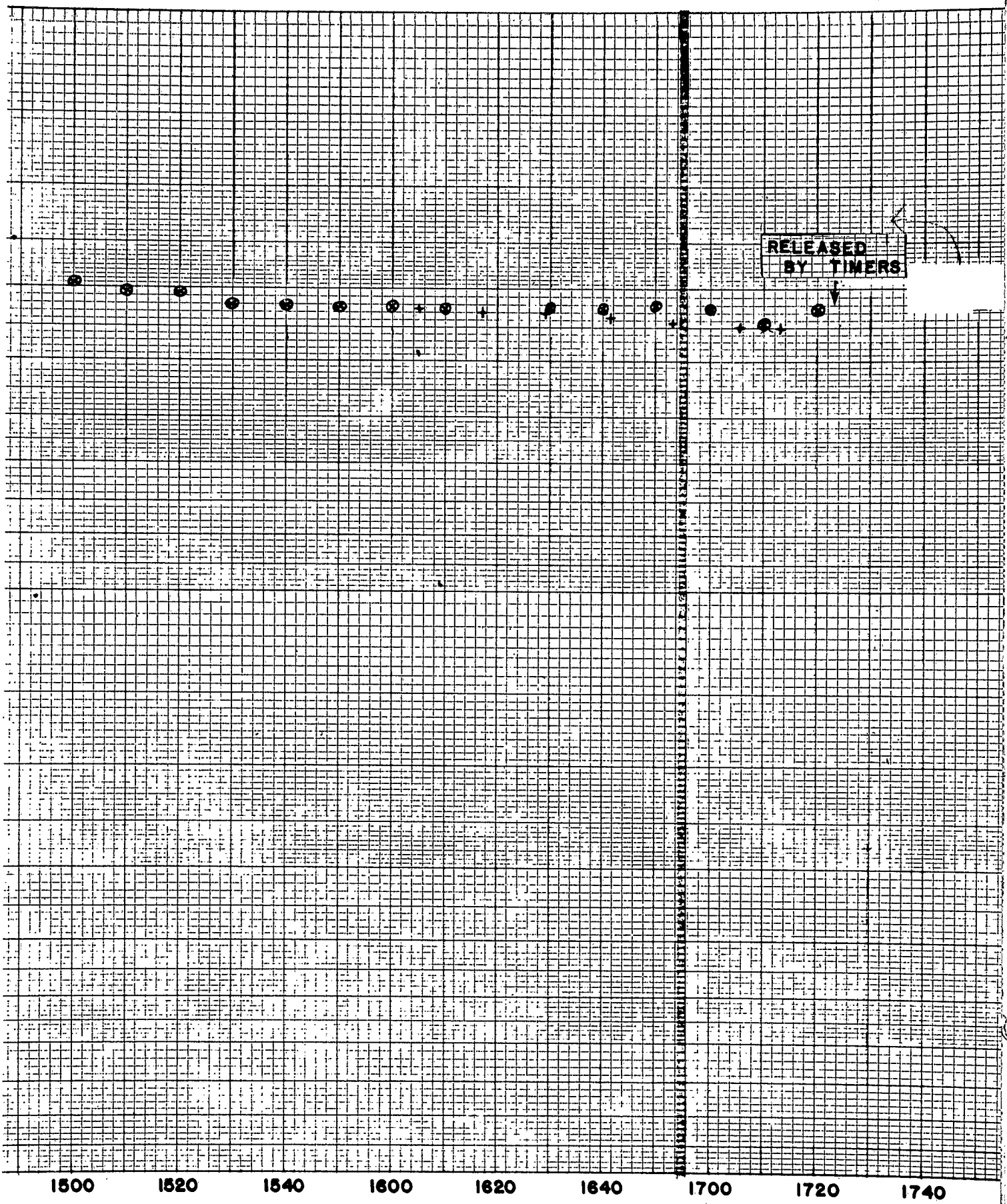

RASONDE DATA
FLIGHT NO.33
21 August, 1952
Meteorological stations reporting.
(⊕) ST. CLOUD, MINN. 655
1500 Z
(+) JOLIET, ILL. 534
1500 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
-2.0
+1.7
-1.0
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

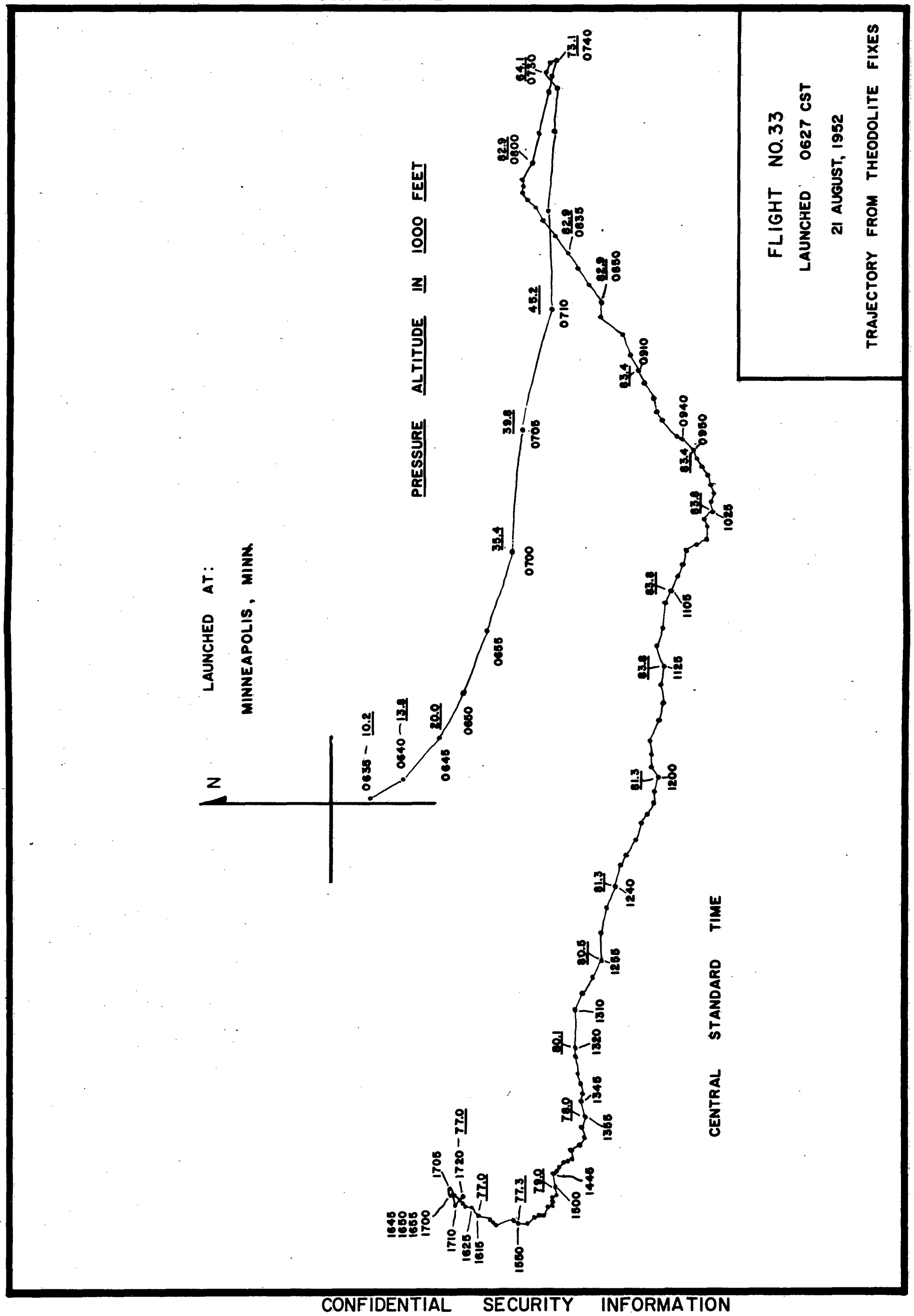


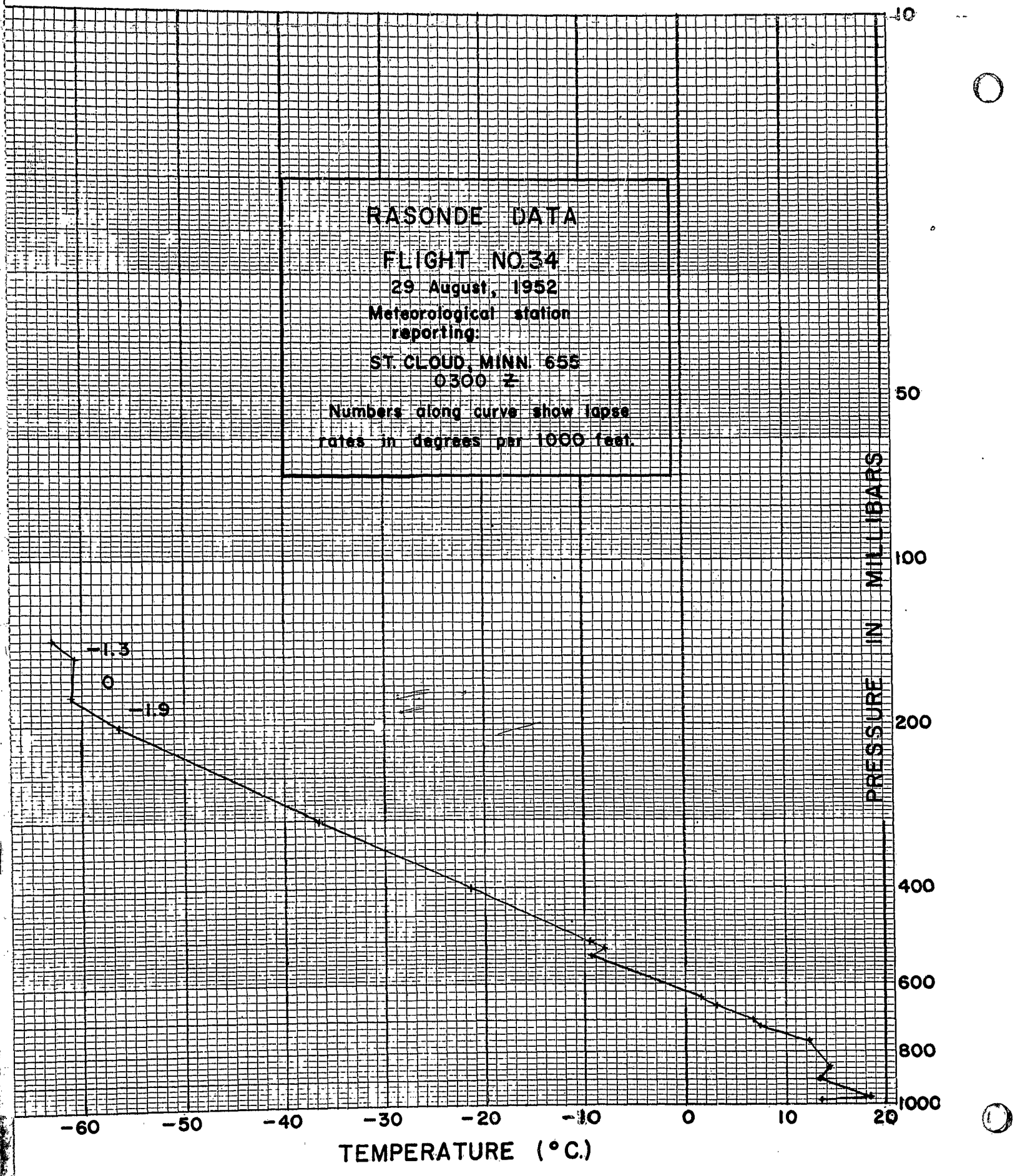
CONFIDENTIAL SECURITY INFORMATION

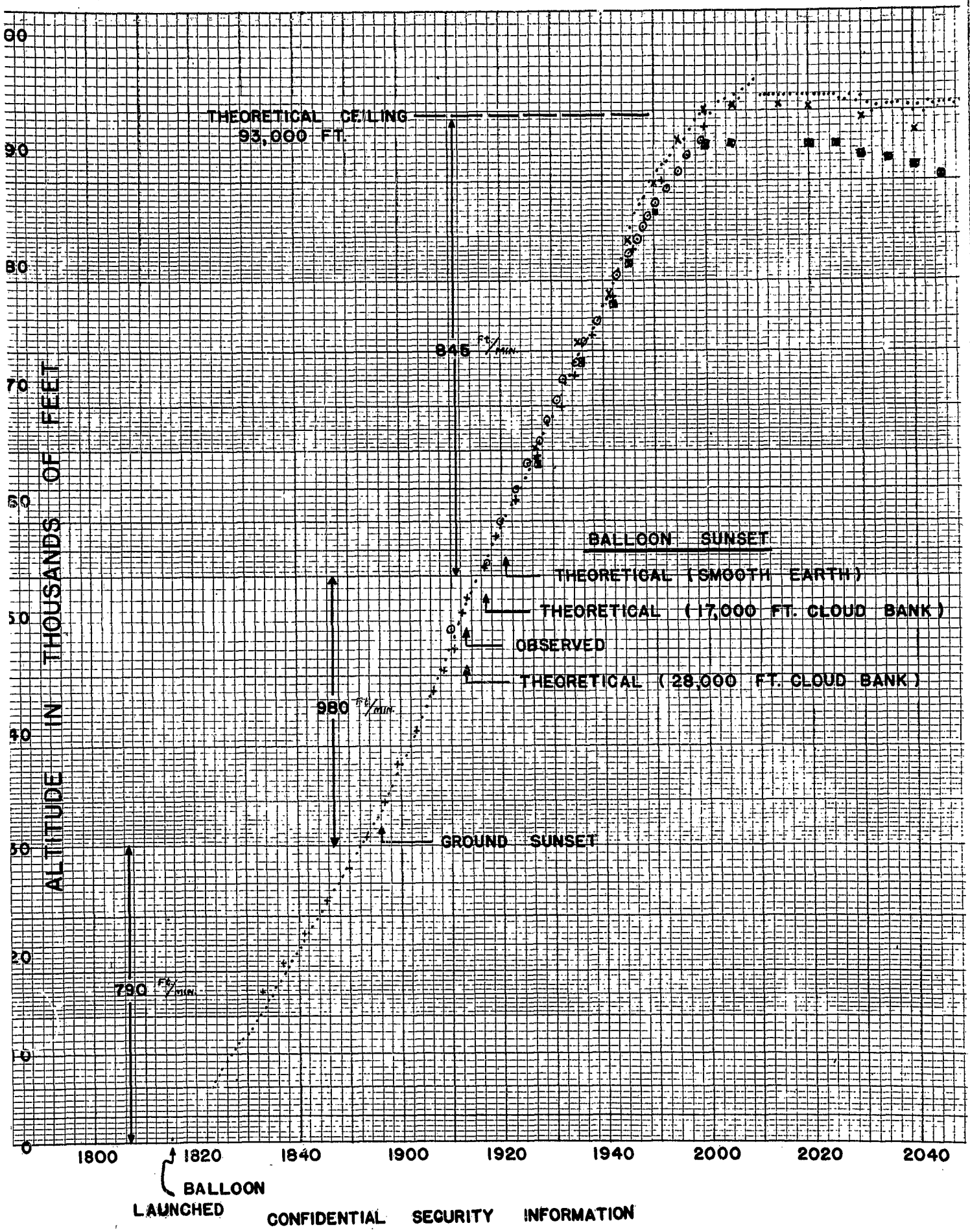

TIME - PRESSURE - ALTITUDE
FLIGHT NO. 33
21 AUGUST, 1952
GROSS LOAD: 487 LBS.
FREE LIFT: 66 LBS.
GROSS LIFT: 553 LBS.
DATA OBTAINED FROM:
+ + + + BAROGRAPH RECORD
⊗ ⊗ ⊗ ⊗ DOUBLE THEODOLITE
0900
0920
0940
1000
1020
1040
1100
1120
1140
120
CENTRAL STANDARD TIME


1200
1220
1240
1300
1320
1340
1400
1420
1440

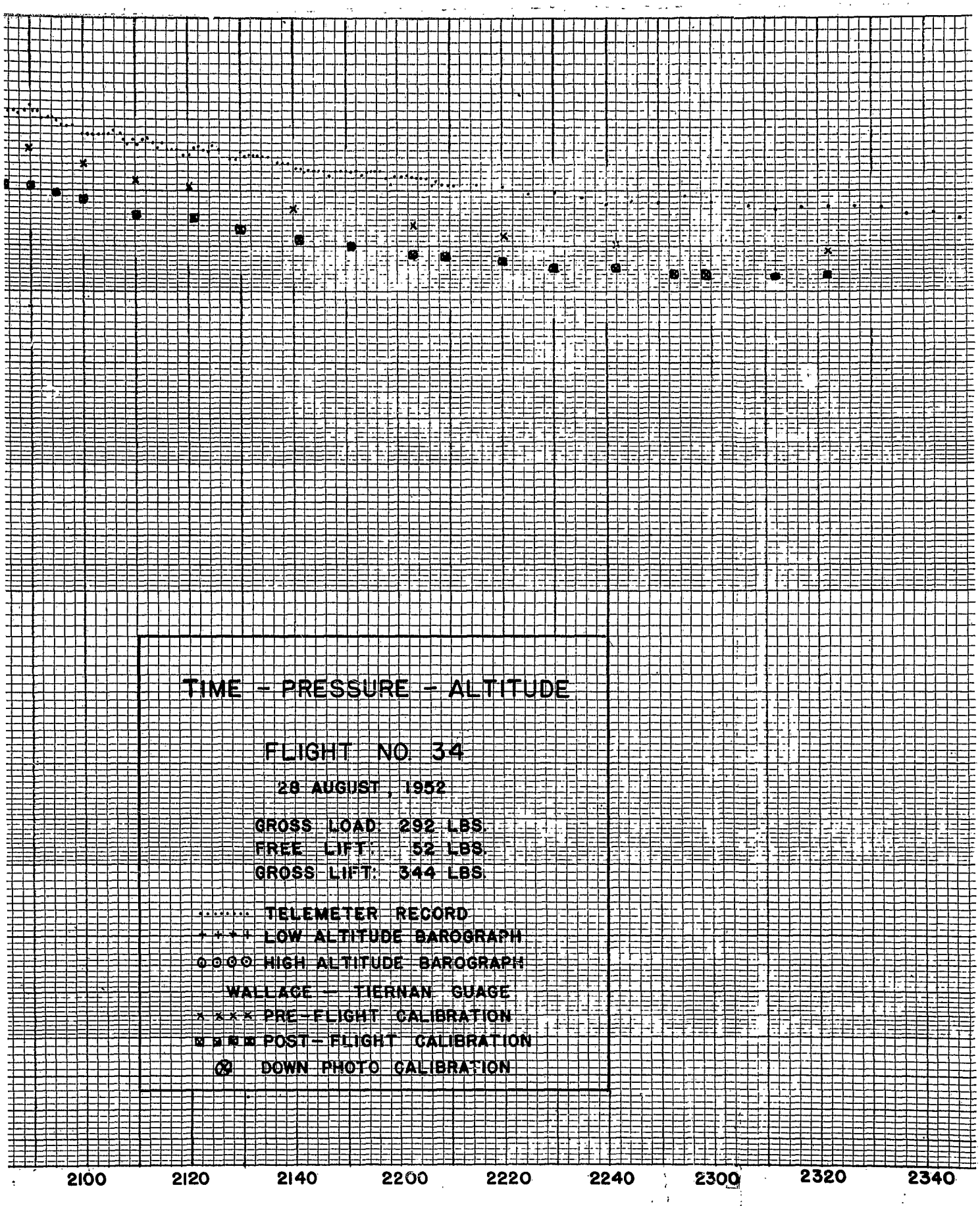

RELEASED
BY TIMERS
1500
1520
1540
1600
1620
1640
1700
1720
1740

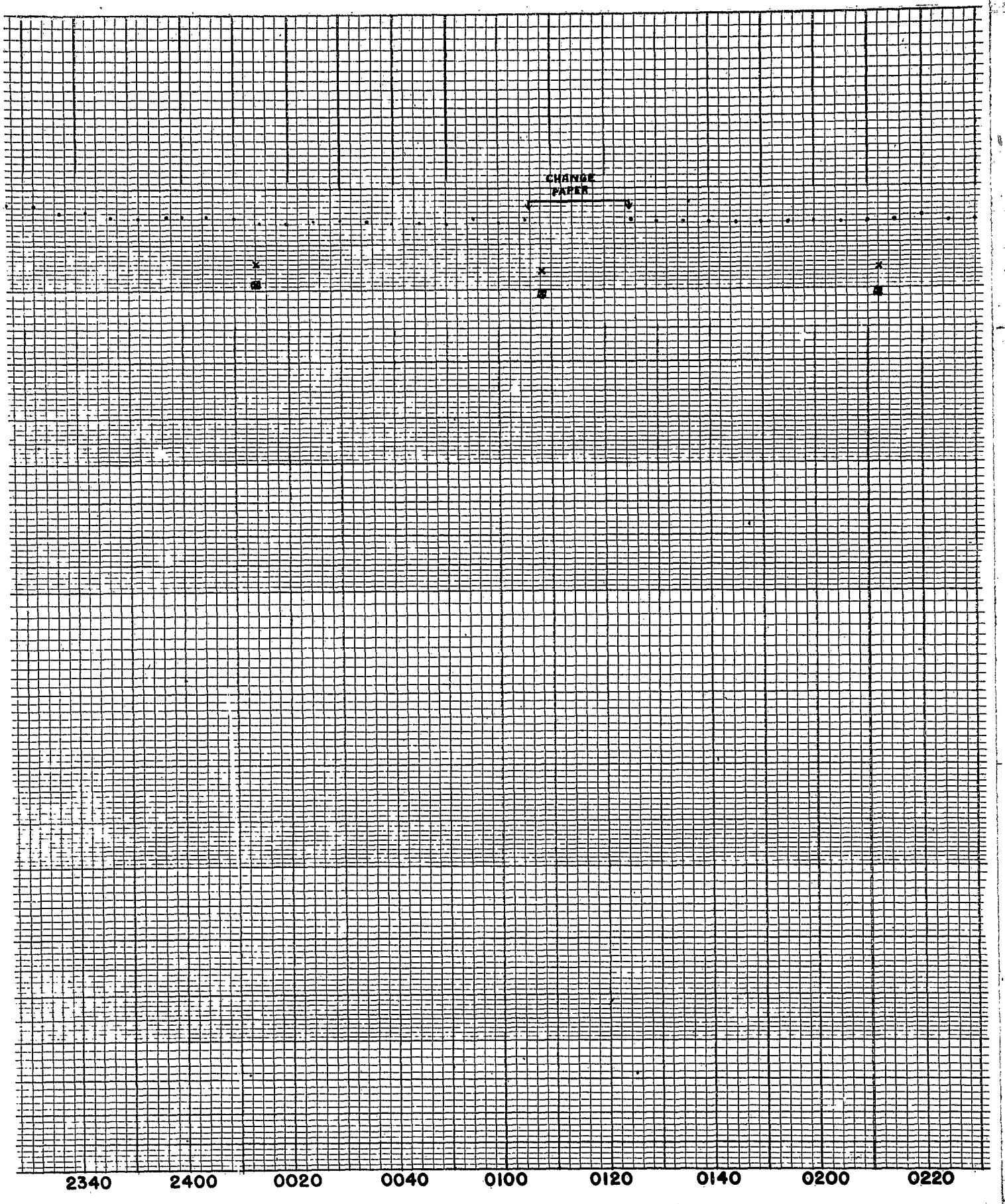

FLIGHT NO. 33
LAUNCHED 0627 CST
21 AUGUST, 1952
TRAJECTORY FROM THEODOLITE FIXES
PRESSURE ALTITUDE IN 1000 FEET
LAUNCHED AT:
MINNEAPOLIS, MINN.
N
CENTRAL STANDARD TIME


RASONDE DATA
FLIGHT NO.34
29 August, 1952
Meteorological station reporting:
ST. CLOUD, MINN. 655
0300 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
-1.3
0
-1.9
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

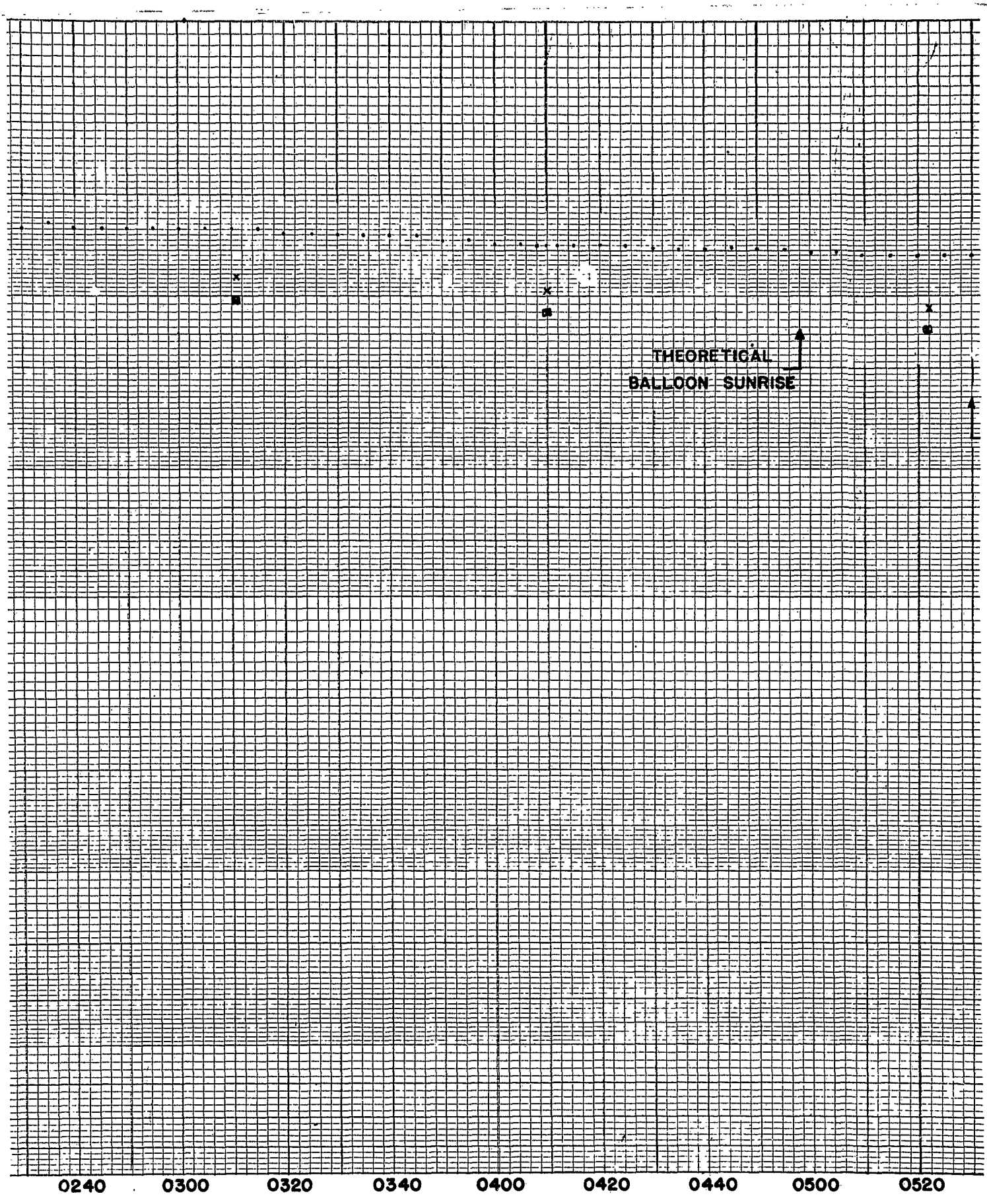


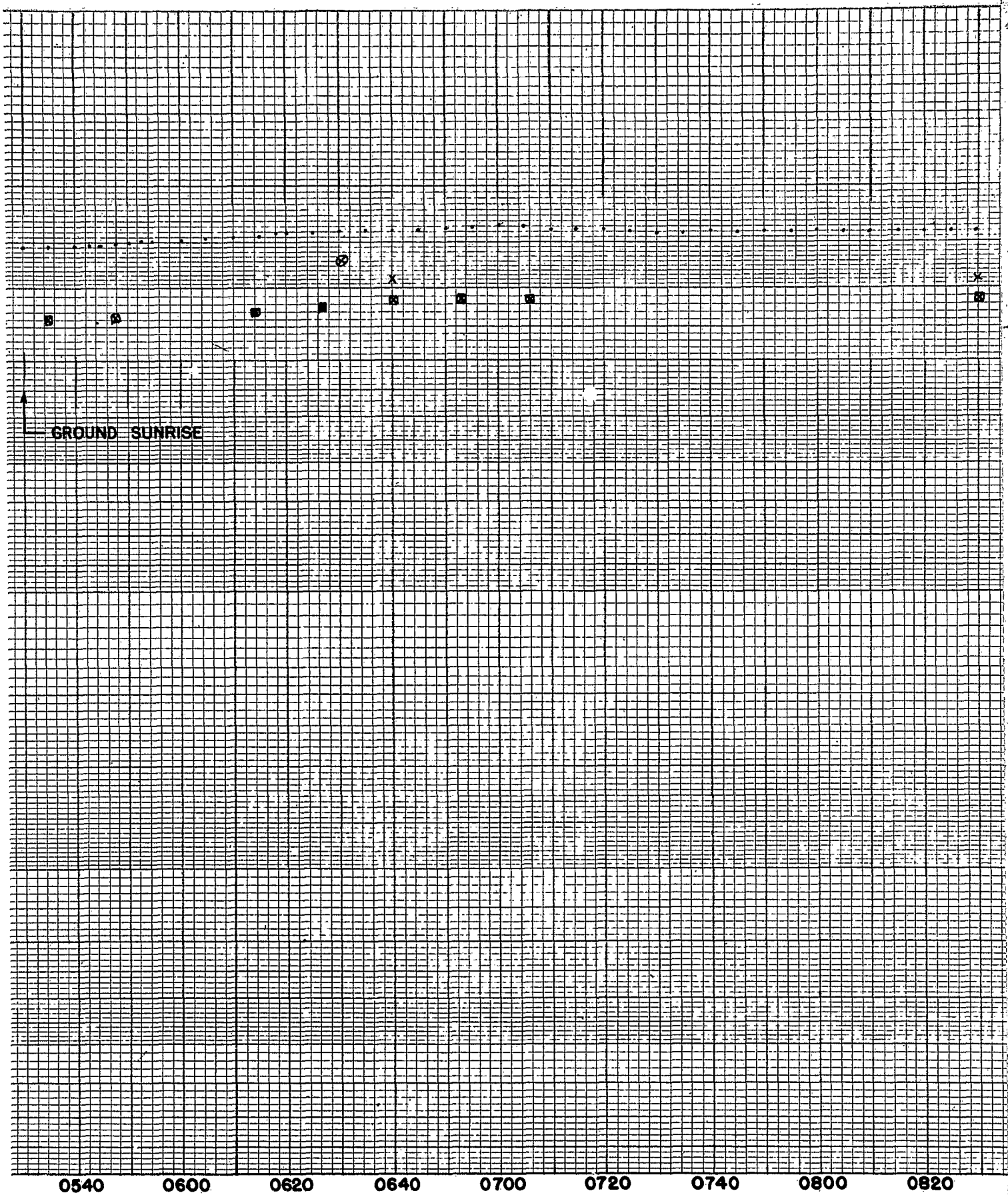
CONFIDENTIAL SECURITY INFORMATION

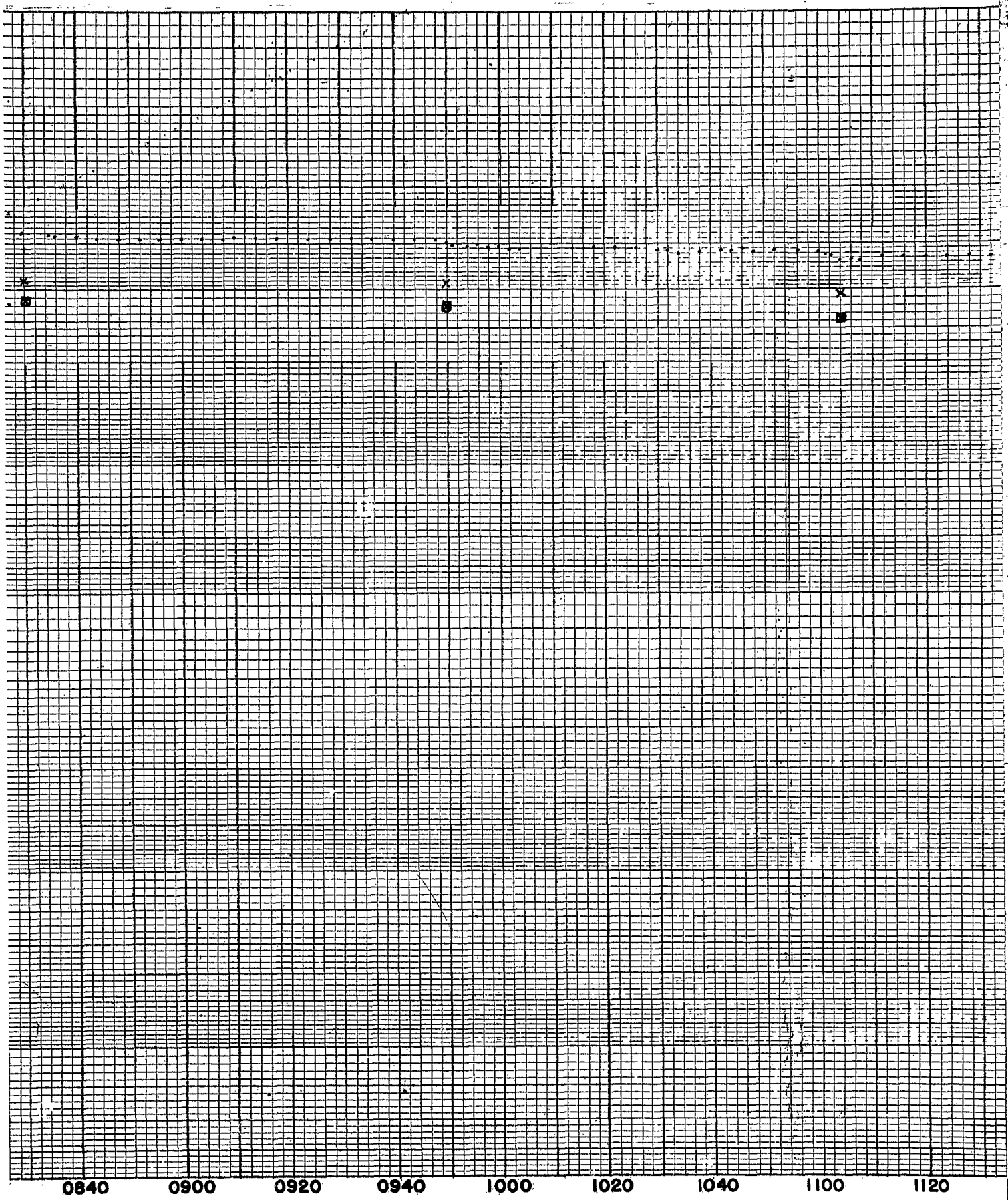

TIME - PRESSURE - ALTITUDE
FLIGHT NO. 34
28 AUGUST, 1952
GROSS LOAD: 292 LBS.
FREE LIFT: 52 LBS.
GROSS LIFT: 344 LBS.
TELEMETER RECORD
LOW ALTITUDE BAROGRAPH
HIGH ALTITUDE BAROGRAPH
WALLACE - TIERNAN GUAGE
PRE-FLIGHT CALIBRATION
POST-FLIGHT CALIBRATION
DOWN PHOTO CALIBRATION
2100
2120
2140
2200
2220
2240
2300
2320
2340
CENTRAL STANDARD TIME

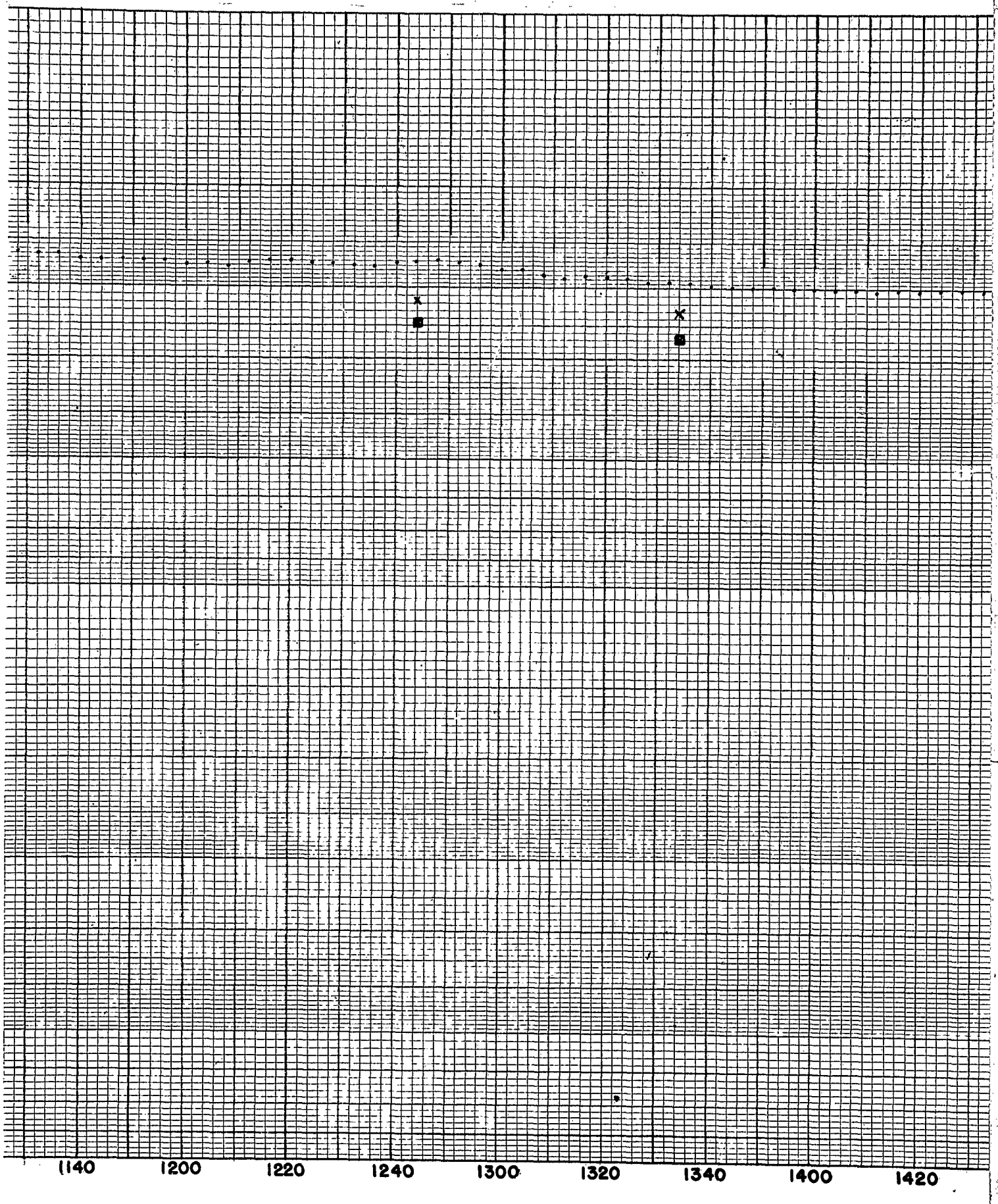


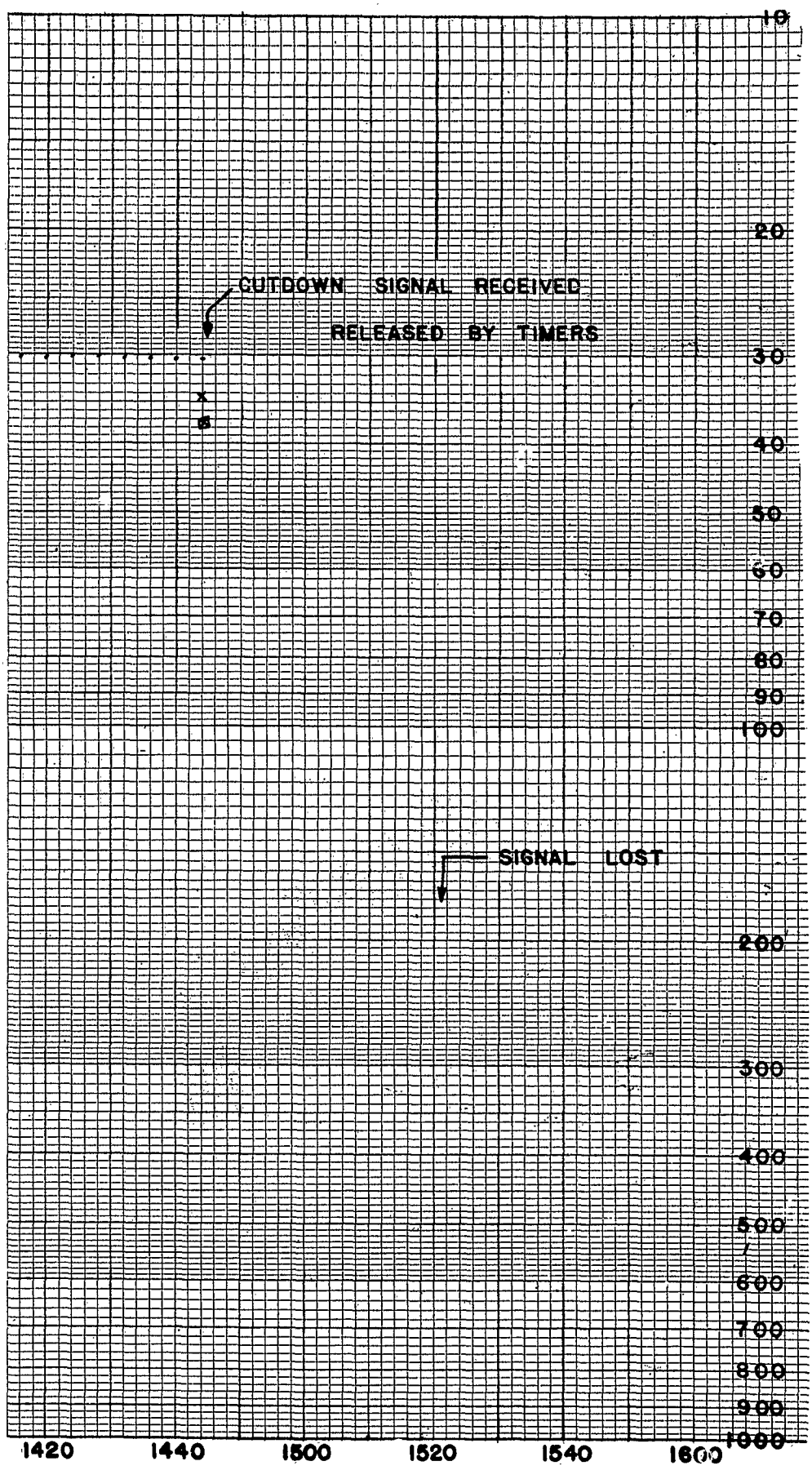
29 AUGUST


THEORETICAL
BALLOON SUNRISE
0240
0300
0320
0340
0400
0420
0440
0500
0520

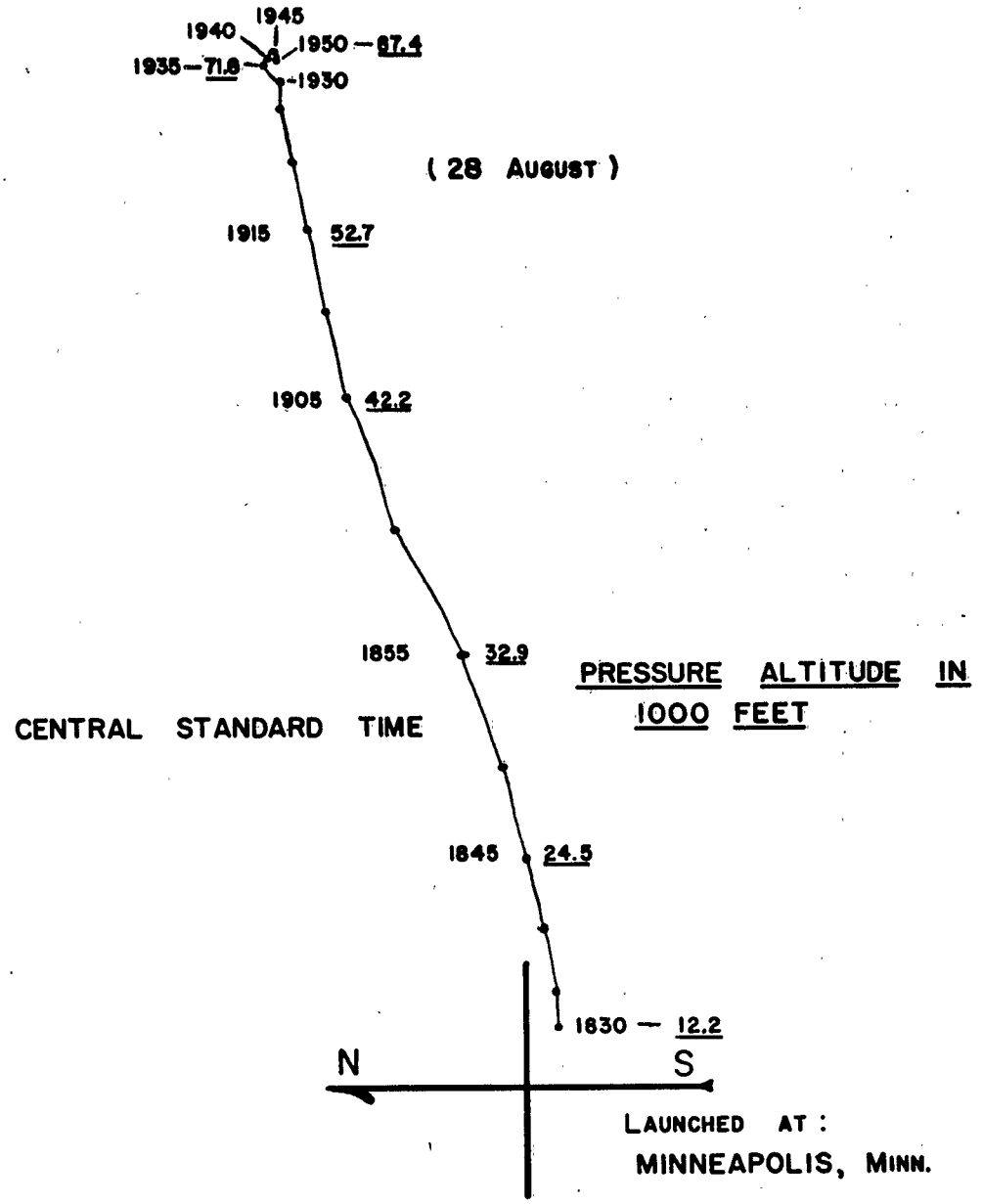

GROUND SUNRISE
0540
0600
0620
0640
0700
0720
0740
0800
0820

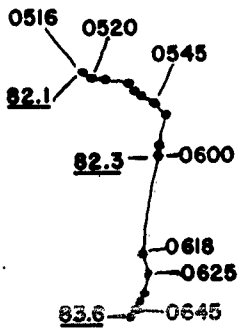

0840
0900
0920
0940
1000
1020
1040
1100
1120


1140
1200
1220
1240
1300
1320
1340
1400
1420


10
20
CUTDOWN SIGNAL RECEIVED
RELEASED BY TIMERS
30
40
50
60
70
80
90
100
SIGNAL LOST
200
300
400
500
600
700
800
900
1000
1420
1440
1500
1520
1540
1600

CONFIDENTIAL





FLIGHT NO. 34

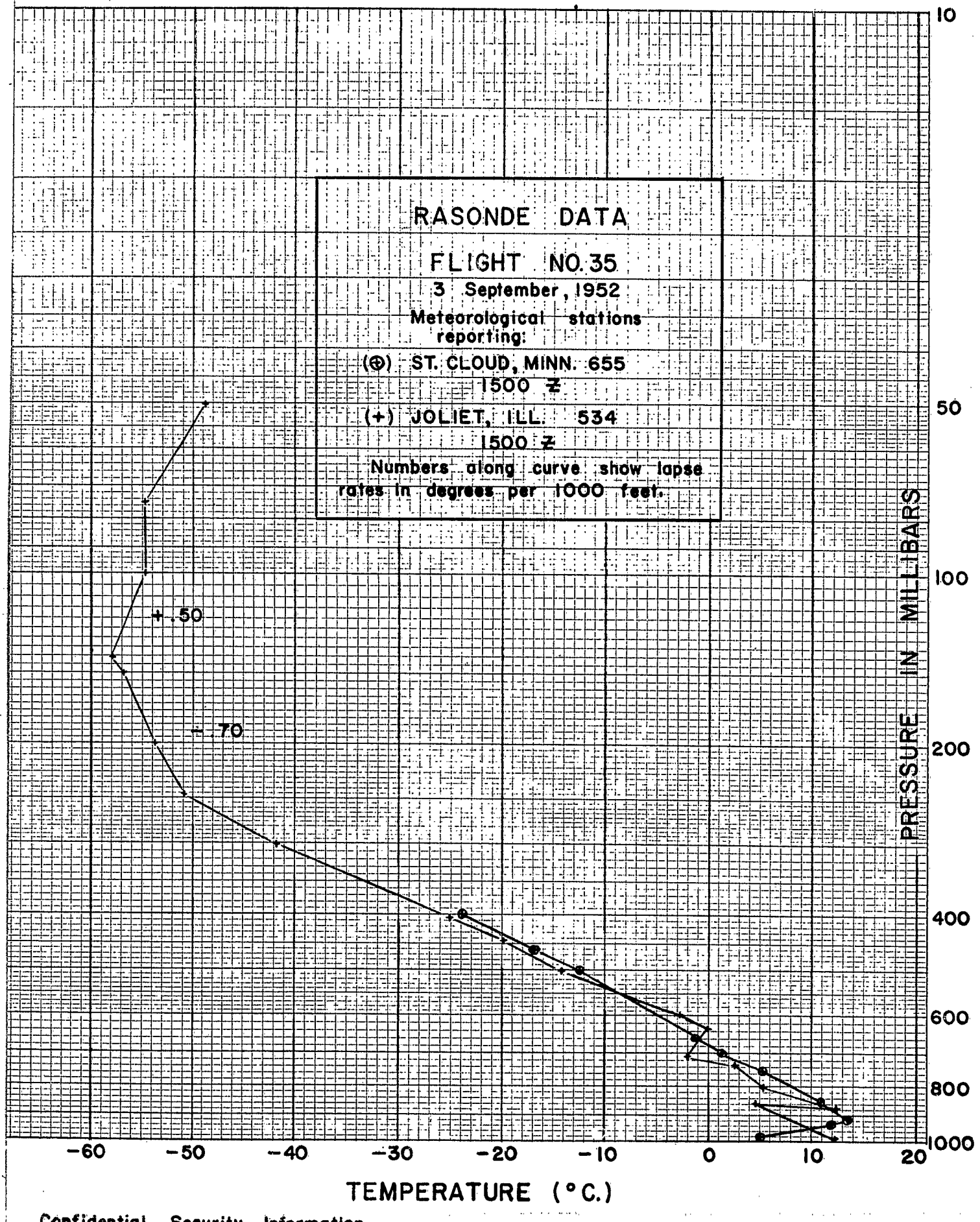
LAUNCHED 1815 CST

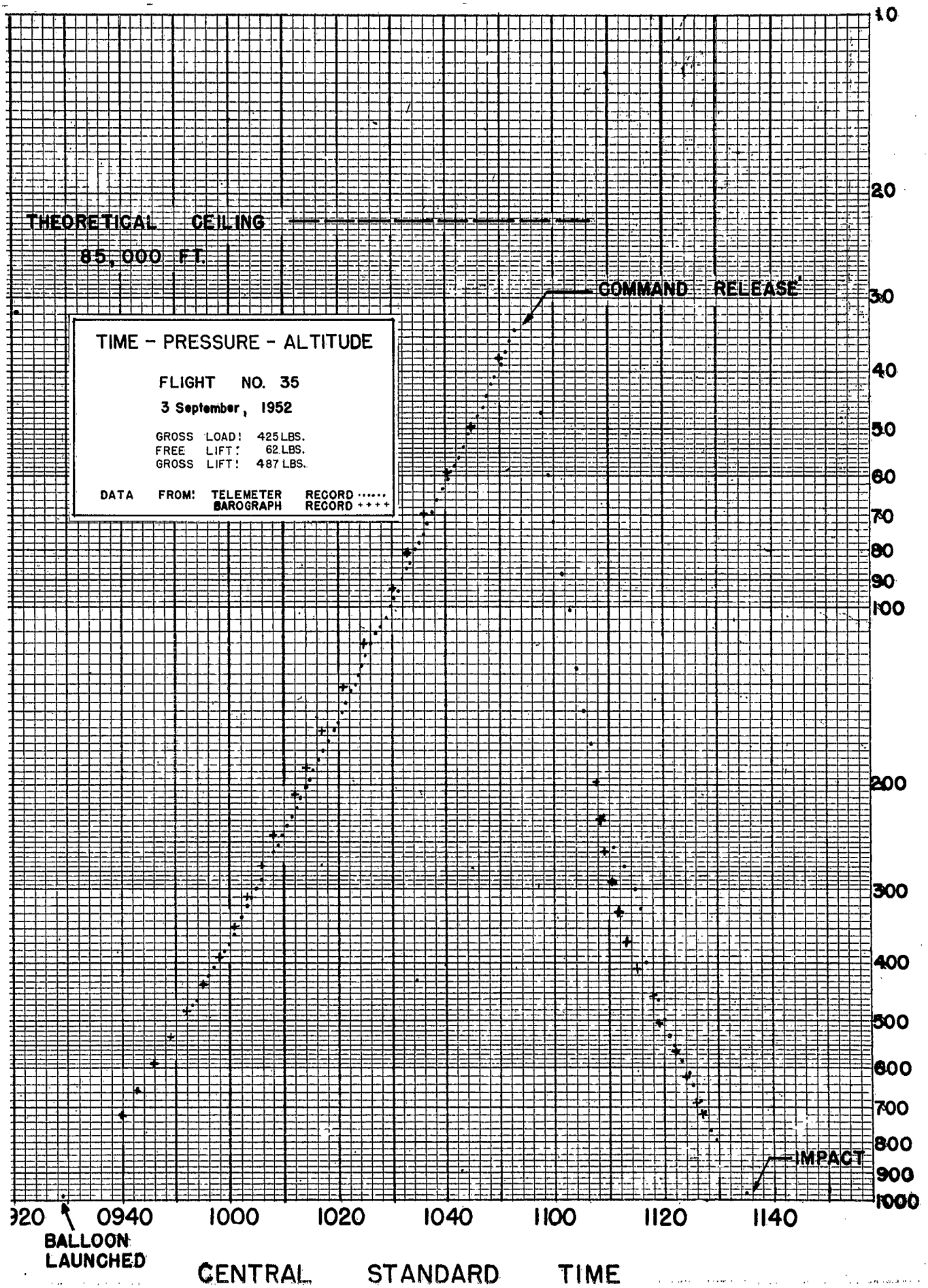
28 AUGUST, 1952

TRAJECTORY FROM THEODOLITE FIXES

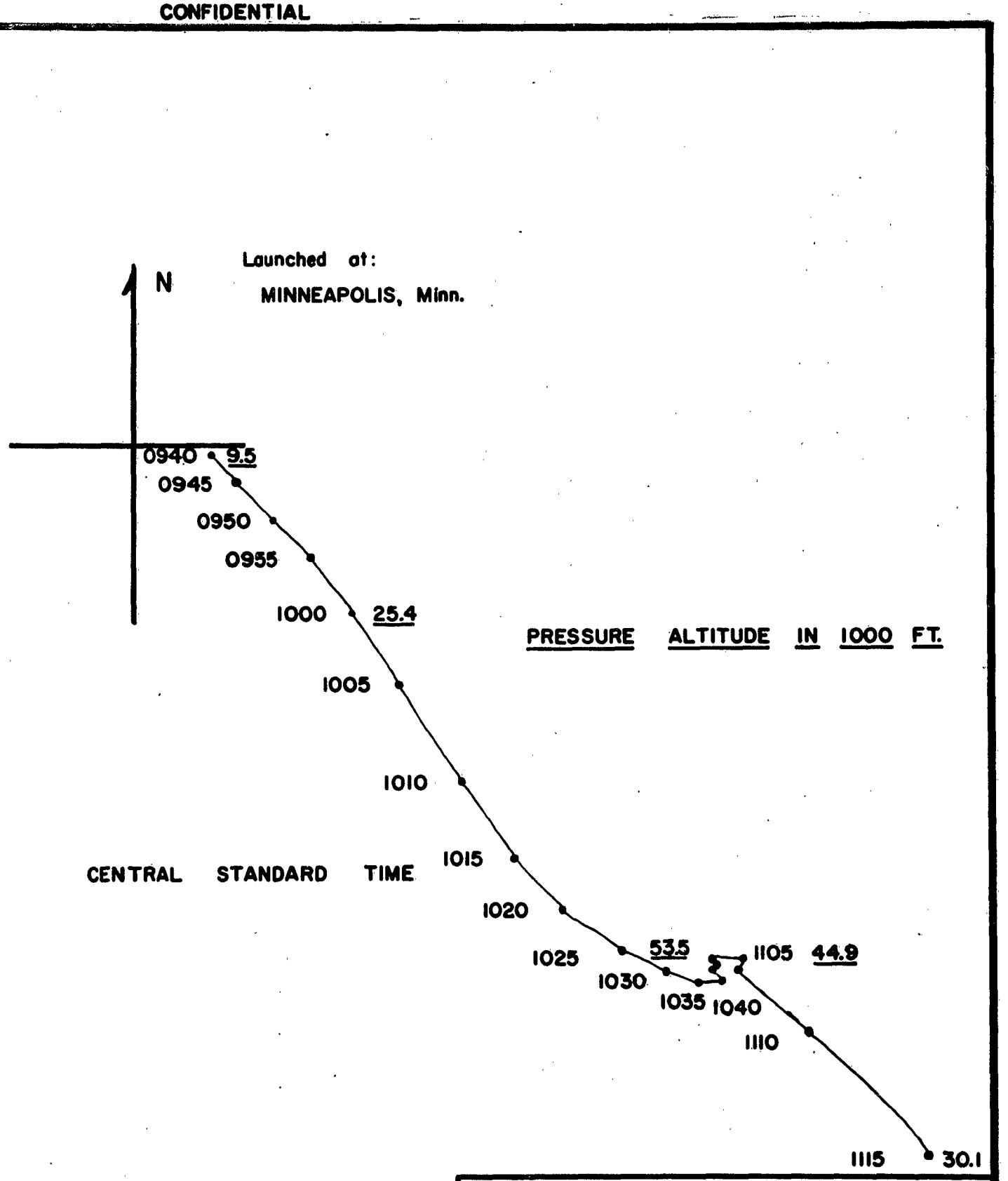
SCALE 1:5 x 10^5

10 0 10 20 STATUTE MILES


RASONDE DATA
FLIGHT NO. 35
3 September, 1952
Meteorological stations reporting:
(⊕) ST. CLOUD, MINN. 655
1500 Z
(+) JOLIET, ILL. 534
1500 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
+.50
+.70
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)


THEORETICAL CEILING
85,000 FT.
COMMAND RELEASE
IMPACT
TIME - PRESSURE - ALTITUDE
FLIGHT NO. 35
3 September, 1952
GROSS LOAD: 425 LBS.
FREE LIFT: 62 LBS.
GROSS LIFT: 487 LBS.
DATA FROM: TELEMETER RECORD .....
BAROGRAPH RECORD ++++
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
920
0940
1000
1020
1040
1100
1120
1140
BALLOON LAUNCHED
CENTRAL STANDARD TIME

CONFIDENTIAL



FLIGHT NO. 35

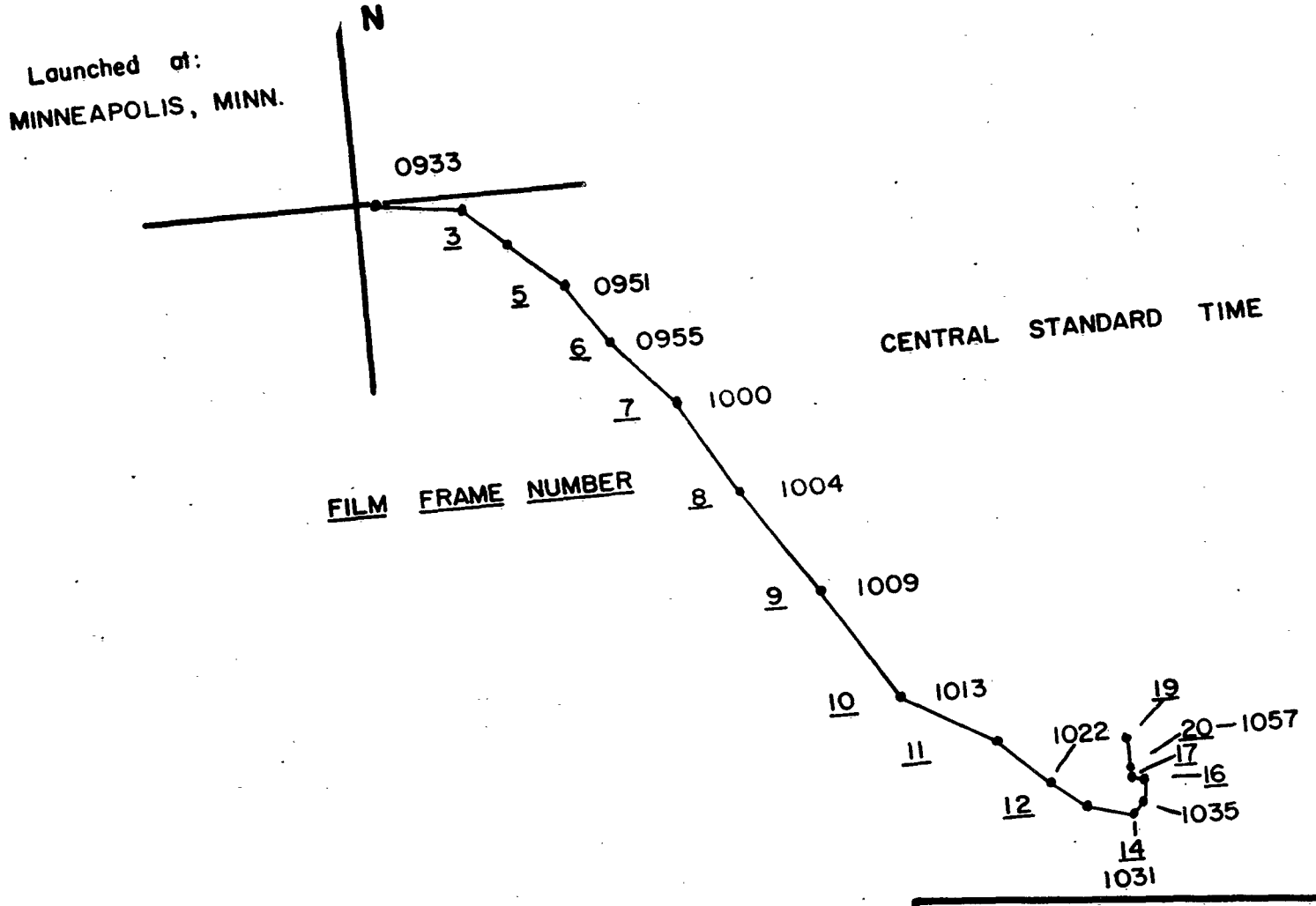
LAUNCHED 0929 CST

3 SEPTEMBER, 1952

TRAJECTORY FROM THEODOLITE FIXES

SCALE 1:5 x 10^5

10 0 10 20 STATUTE MILES



CONFIDENTIAL SECURITY INFORMATION

10 0 10 20 STATUTE MILES

FLIGHT NO. 35

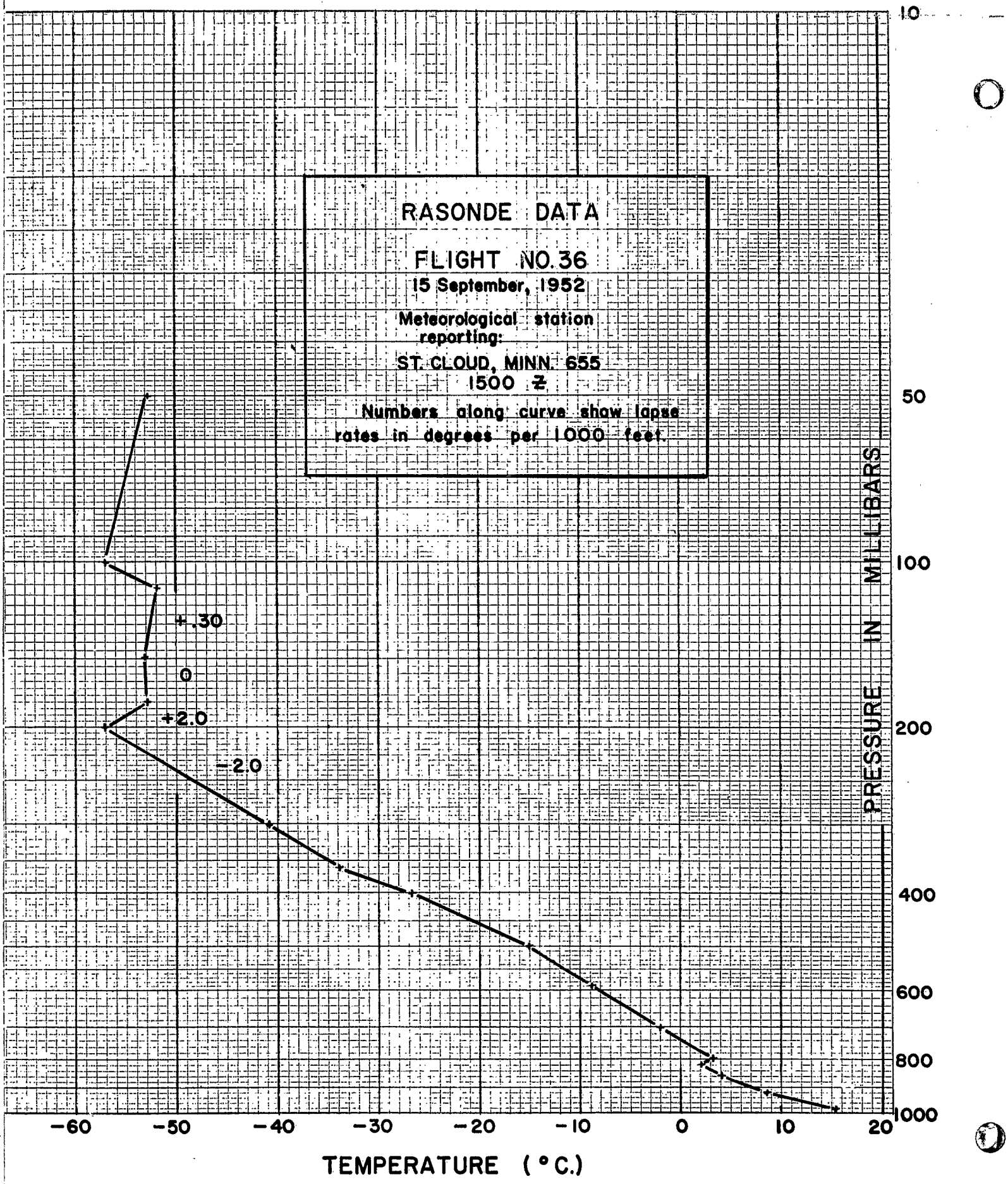
LAUNCHED 0929 C.S.T.

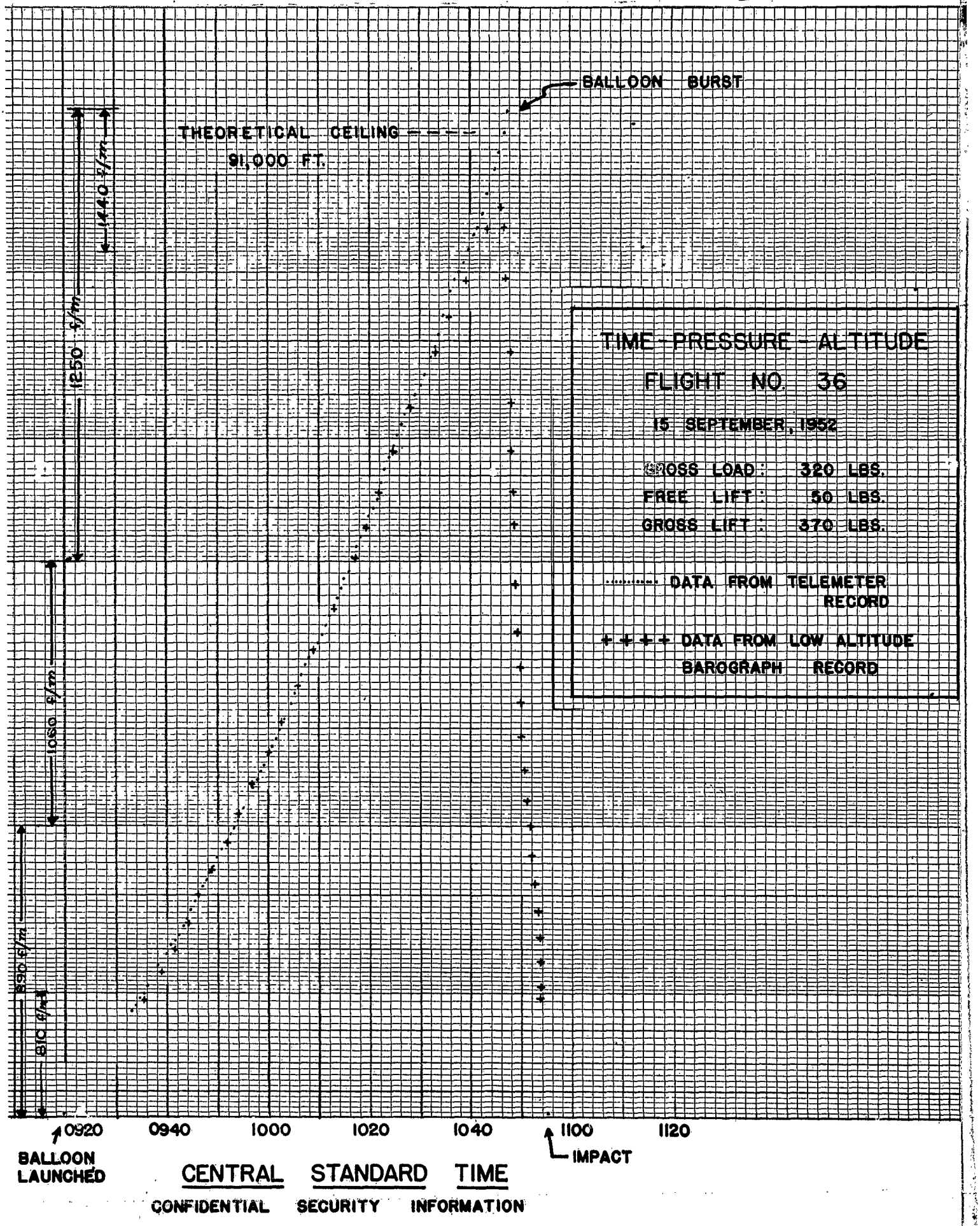
3 SEPTEMBER, 1952

TRAJECTORY FROM DOWN PICTURES

SCALE $1:5 \times 10^5$

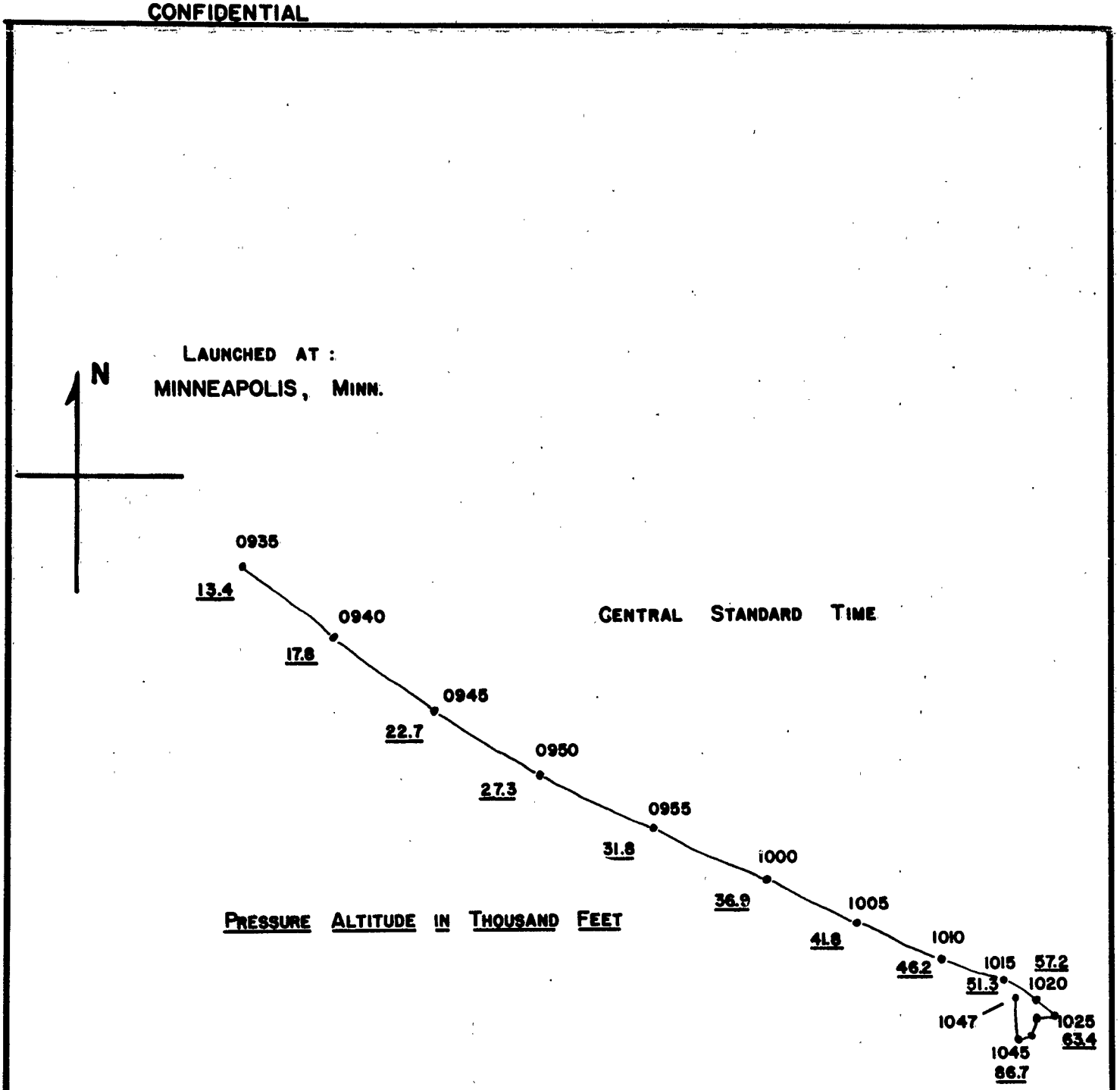
CONFIDENTIAL SECURITY INFORMATION


RASONDE DATA
FLIGHT NO. 36
15 September, 1952
Meteorological station reporting:
ST. CLOUD, MINN. 655
1500 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
+.30
0
+2.0
-2.0
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

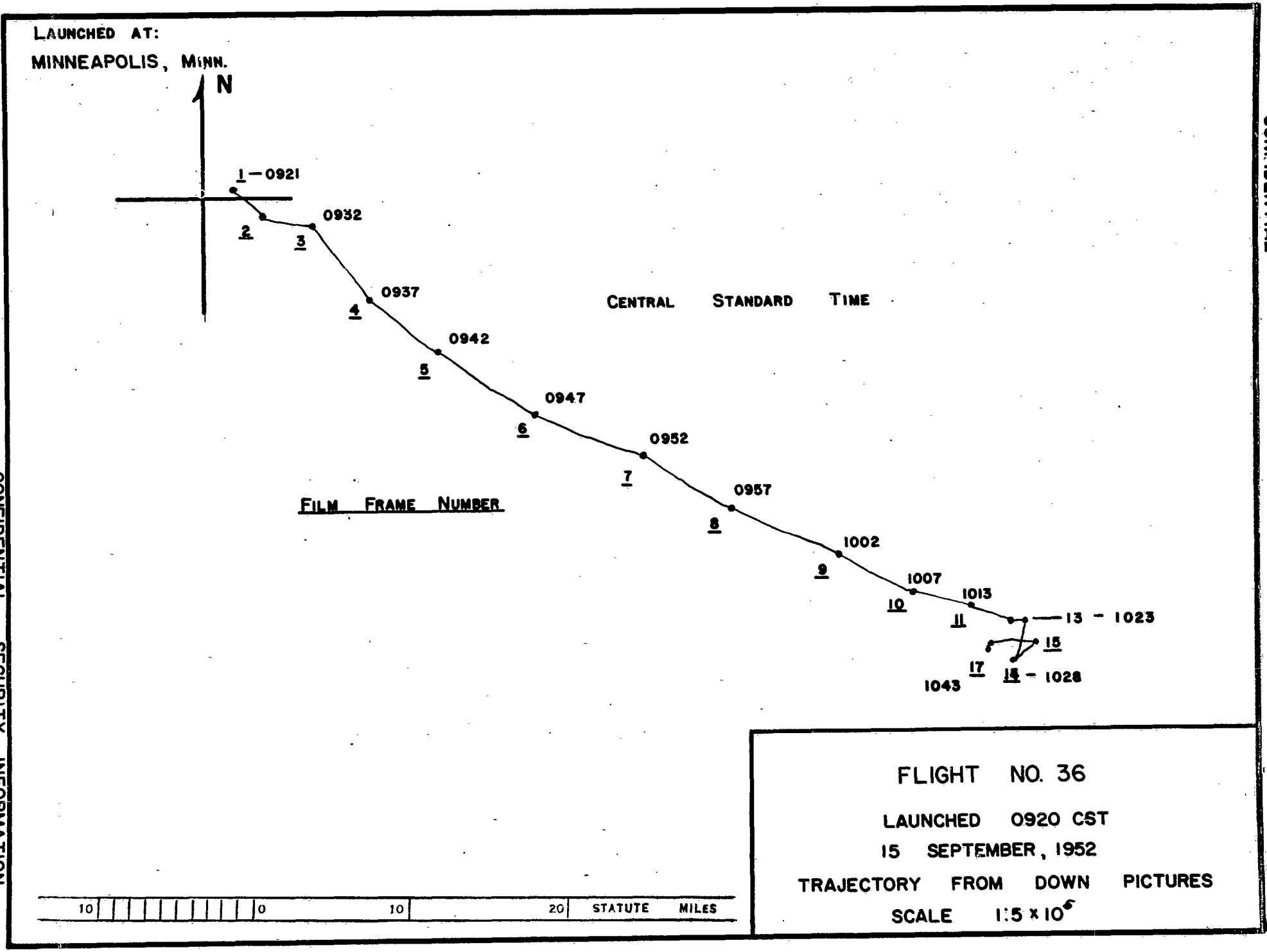


CONFIDENTIAL SECURITY INFORMATION

CONFIDENTIAL



CONFIDENTIAL SECURITY INFORMATION



FLIGHT NO. 36

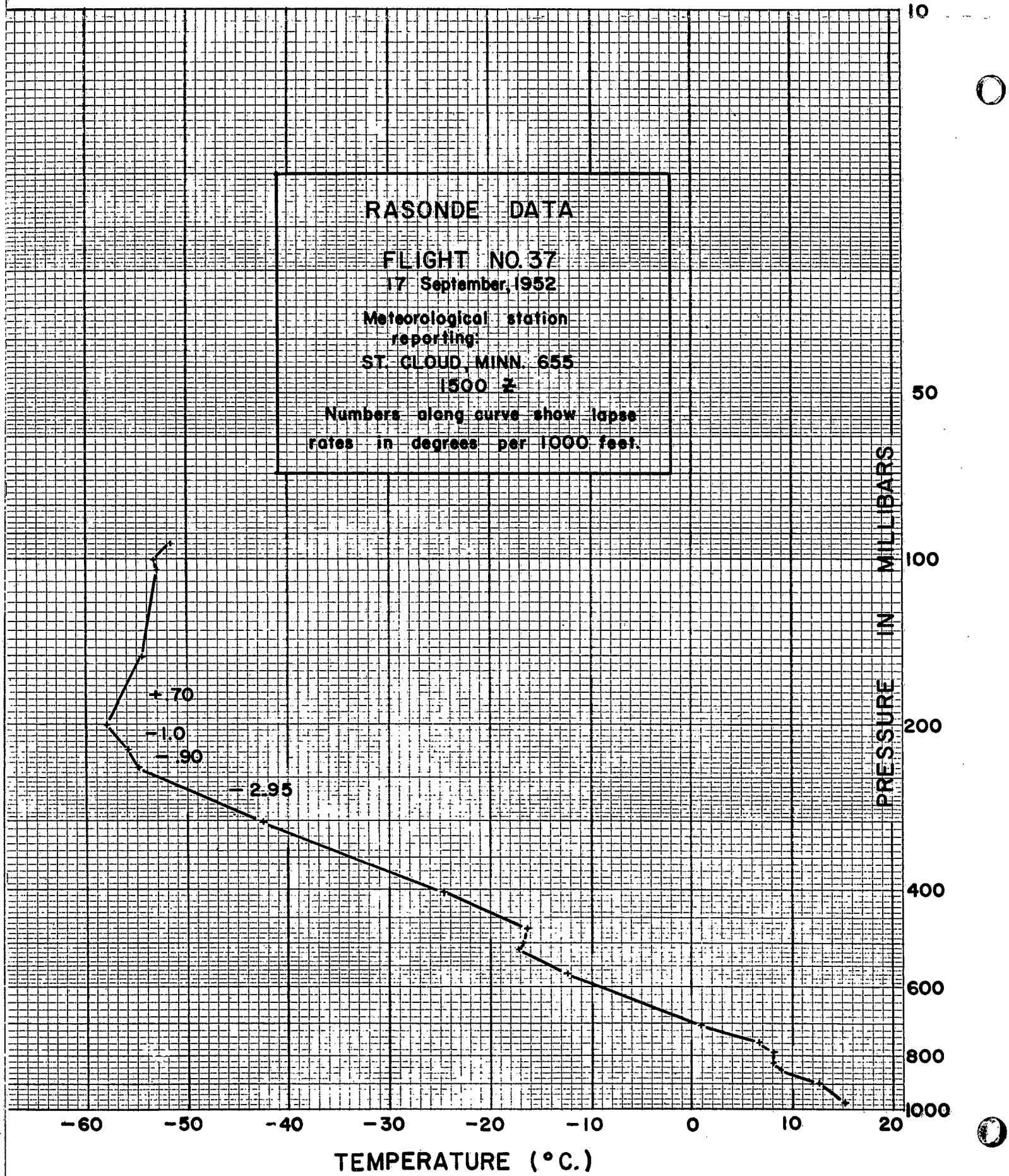
LAUNCHED 0920 CST

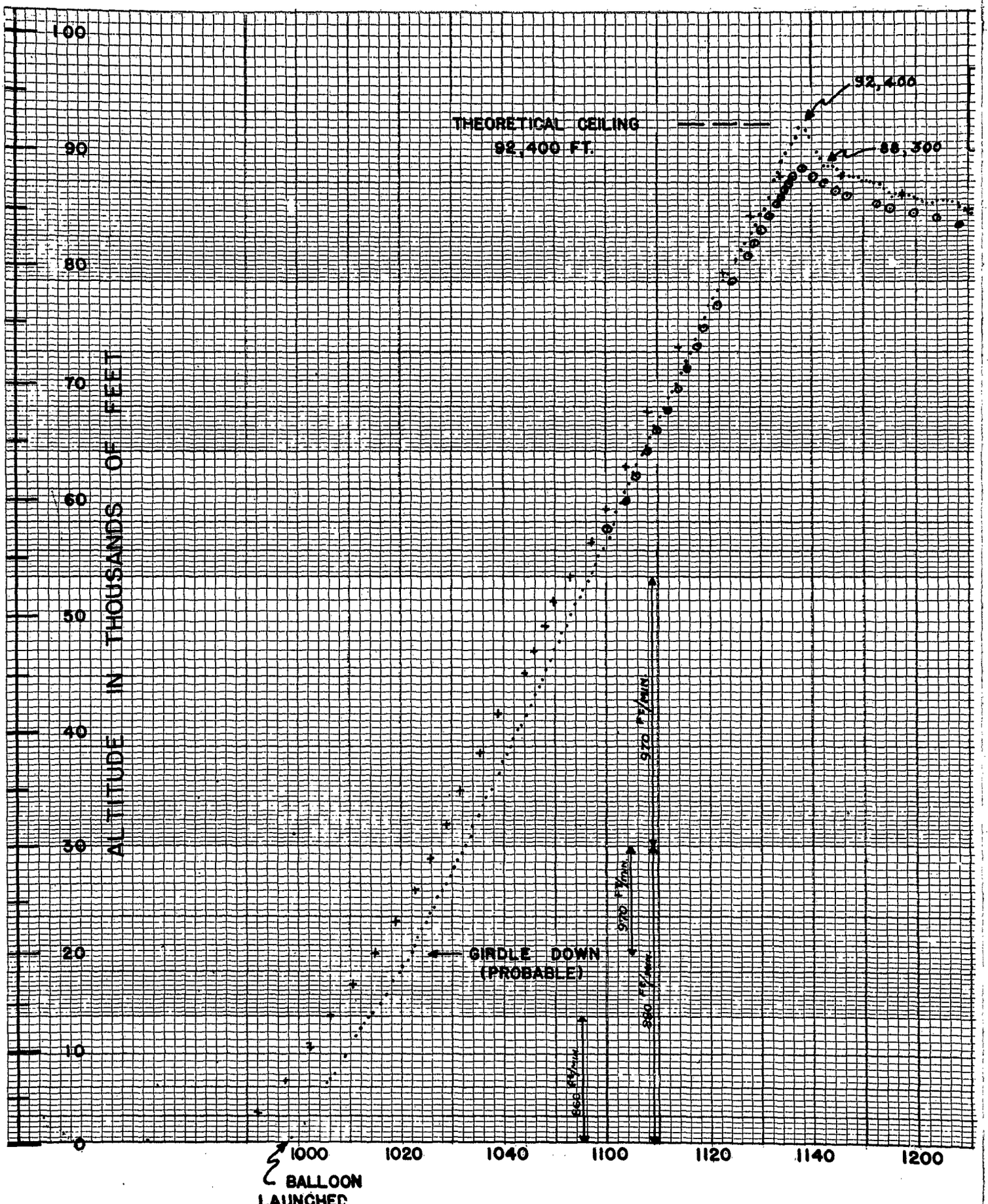
15 SEPTEMBER, 1952

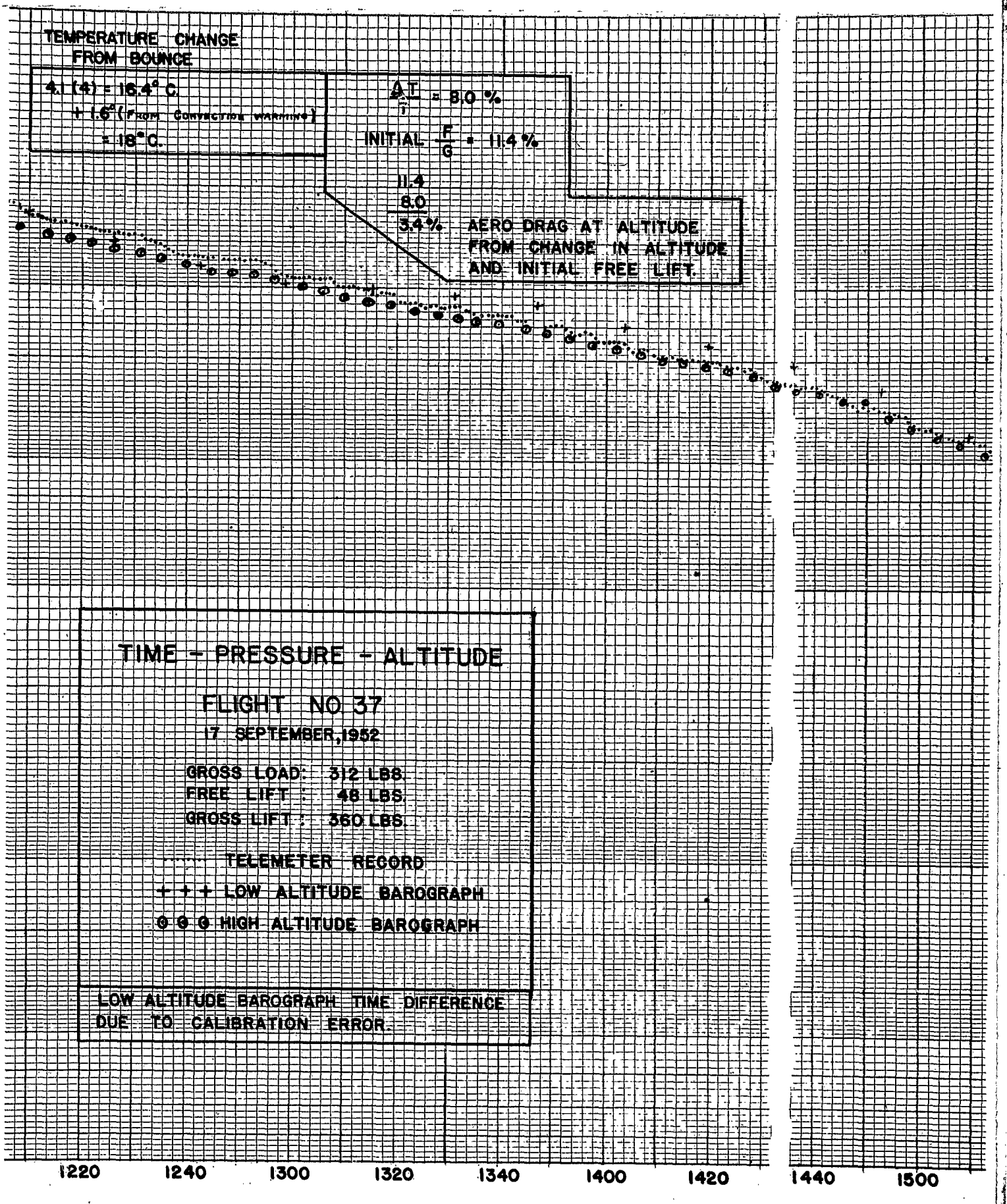
TRAJECTORY FROM DOWN PICTURES

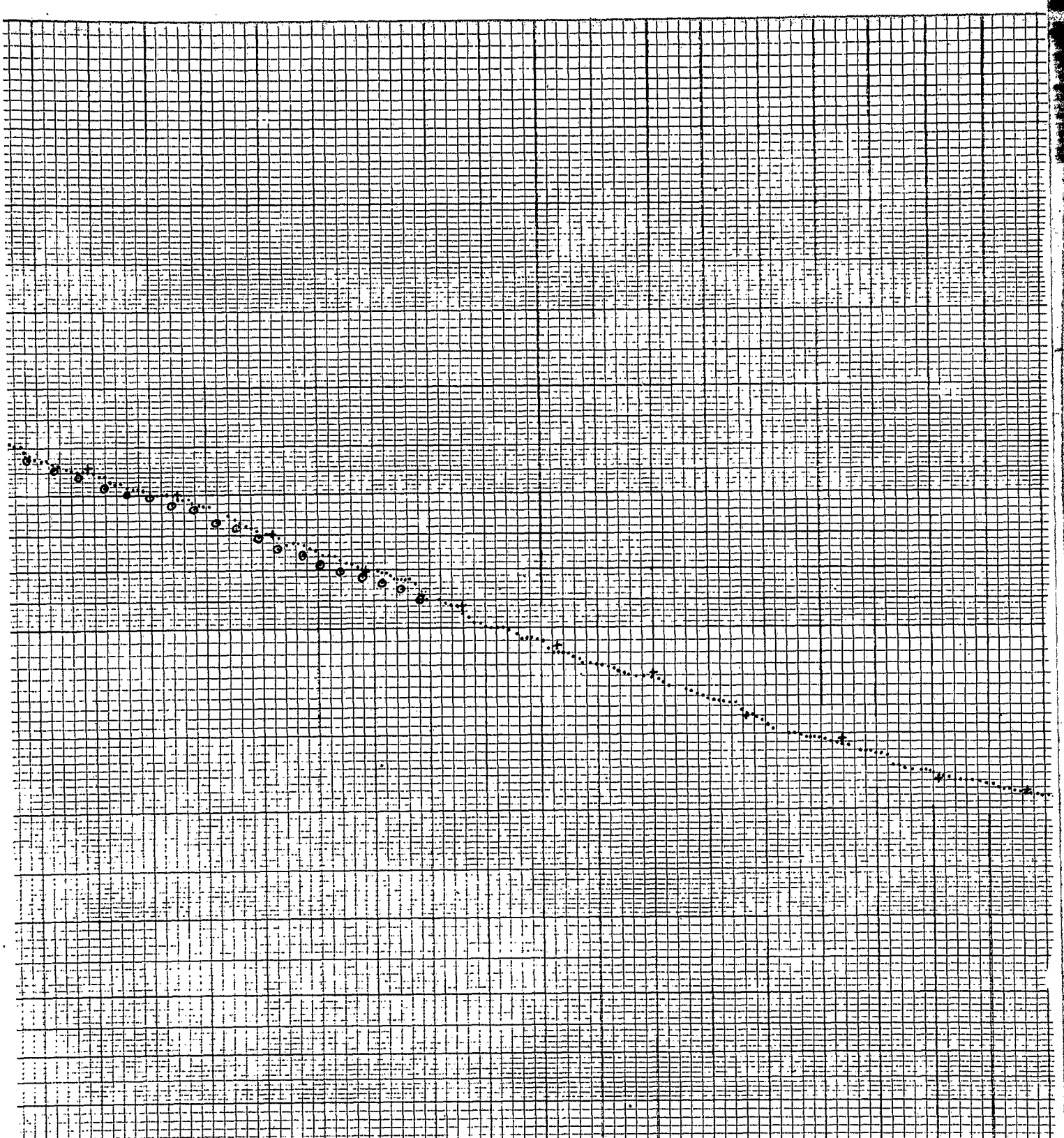
SCALE 1:5 x 10^6

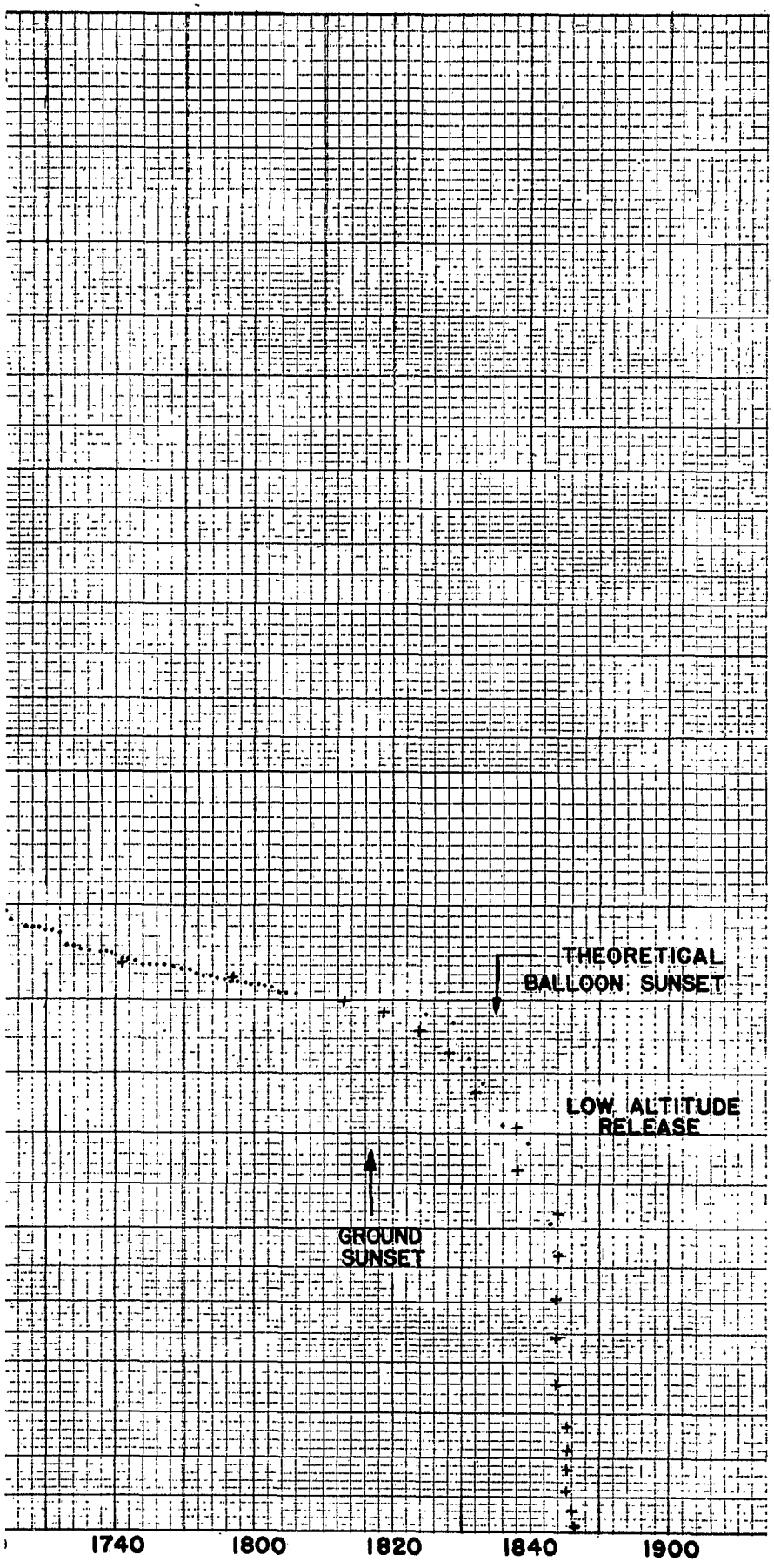
CONFIDENTIAL SECURITY INFORMATION


RASONDE DATA
FLIGHT NO. 37
17 September, 1952
Meteorological station reporting:
ST. CLOUD, MINN. 655
1500 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
+ 7.0
-1.0
- .90
- 2.95
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

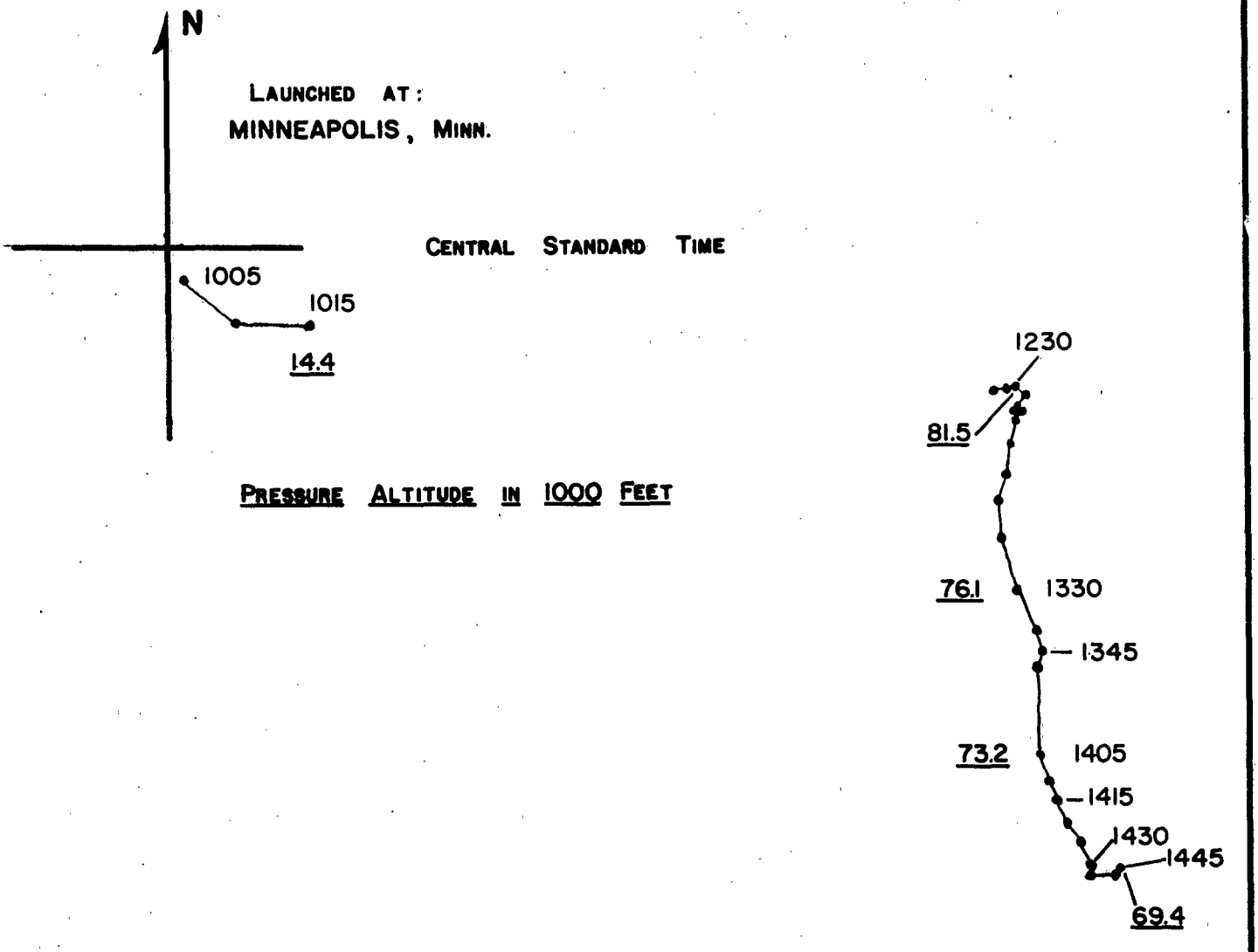

ALTITUDE IN THOUSANDS OF FEET
100
90
80
70
60
50
40
30
20
10
0
THEORETICAL CEILING
92,400 FT.
92,400
88,300
GIRDLE DOWN
(PROBABLE)
970 ft/min
970 ft/min
880 ft/min
866 ft/min
1000
1020
1040
1100
1120
1140
1200
BALLOON
LAUNCHED


TEMPERATURE CHANGE FROM BOUNCE
4.1 (4) = 16.4° C.
+ 1.6° (FROM CONVECTION WARMING)
= 18° C.
ΔT/T = 8.0 %
INITIAL F/G = 11.4 %
11.4
8.0
3.4% AERO DRAG AT ALTITUDE FROM CHANGE IN ALTITUDE AND INITIAL FREE LIFT.
TIME - PRESSURE - ALTITUDE
FLIGHT NO 37
17 SEPTEMBER, 1952
GROSS LOAD: 312 LBS.
FREE LIFT : 48 LBS.
GROSS LIFT : 360 LBS.
TELEMETER RECORD
+ + + LOW ALTITUDE BAROGRAPH
O O O HIGH ALTITUDE BAROGRAPH
LOW ALTITUDE BAROGRAPH TIME DIFFERENCE DUE TO CALIBRATION ERROR.
1220
1240
1300
1320
1340
1400
1420
1440
1500
CENTRAL STANDARD TIME


1500
1520
1540
1600
1620
1640
1700
1720
1740


THEORETICAL
BALLOON SUNSET
LOW ALTITUDE
RELEASE
GROUND
SUNSET
1740
1800
1820
1840
1900

CONFIDENTIAL

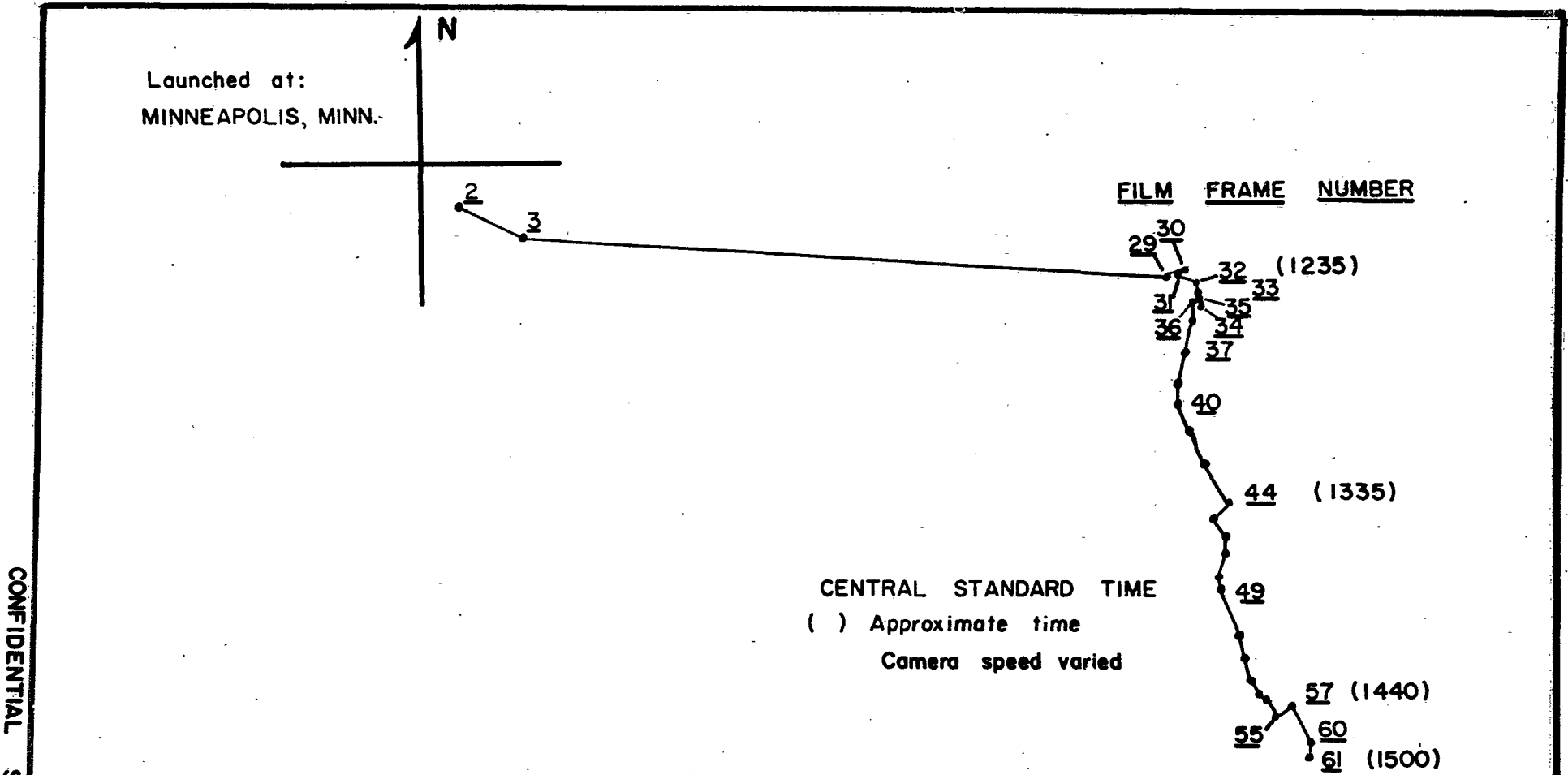


FLIGHT NO. 37
LAUNCHED 0958 CST
17 SEPTEMBER, 1952

TRAJECTORY FROM THEODOLITE FIXES
SCALE : $1:5\times10^5$

10 0 10 20 STATUTE MILES

CONFIDENTIAL



CONFIDENTIAL SECURITY INFORMATION

FLIGHT NO. 37

LAUNCHED 0958 C.S.T.

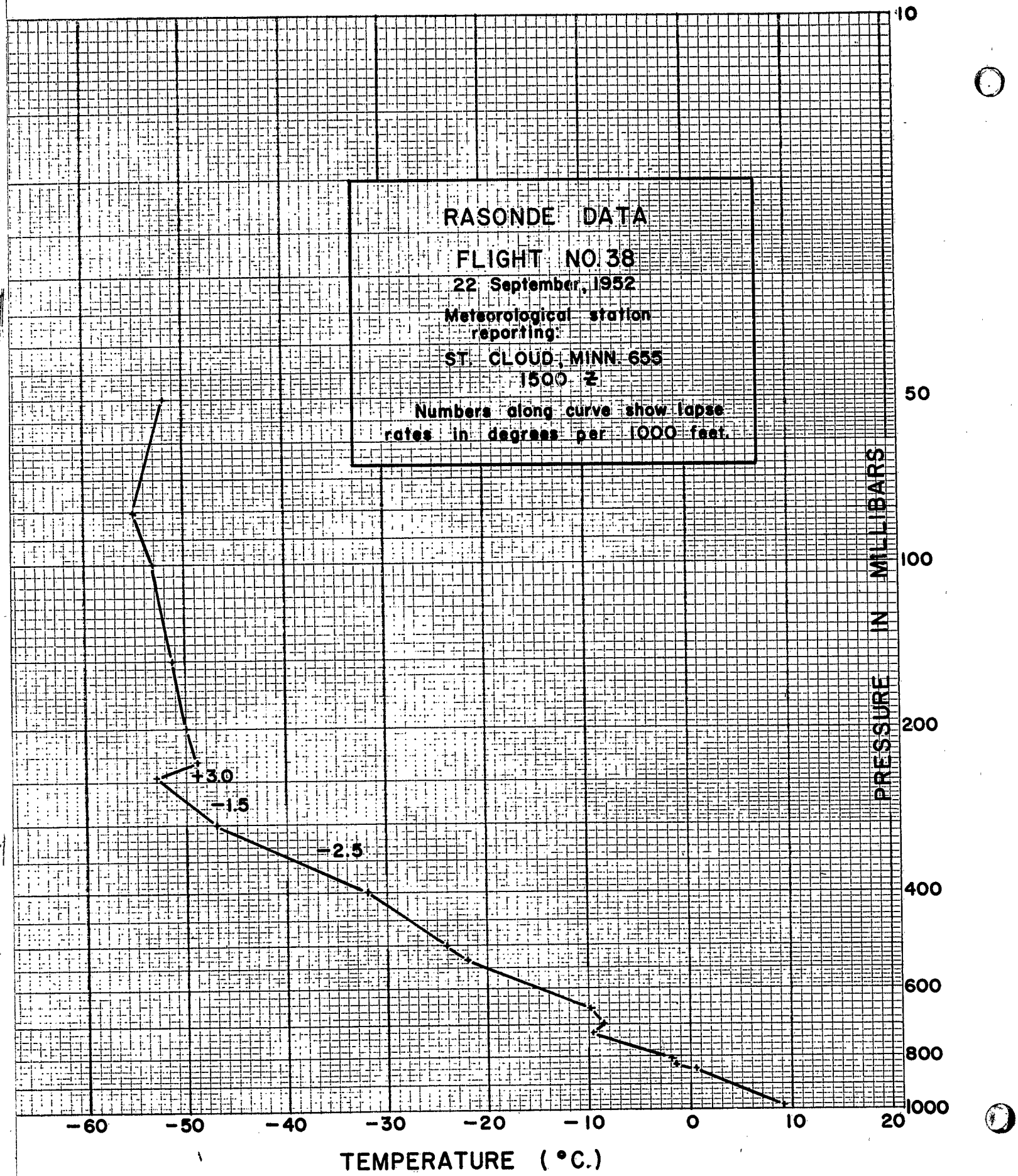
17 SEPTEMBER, 1952

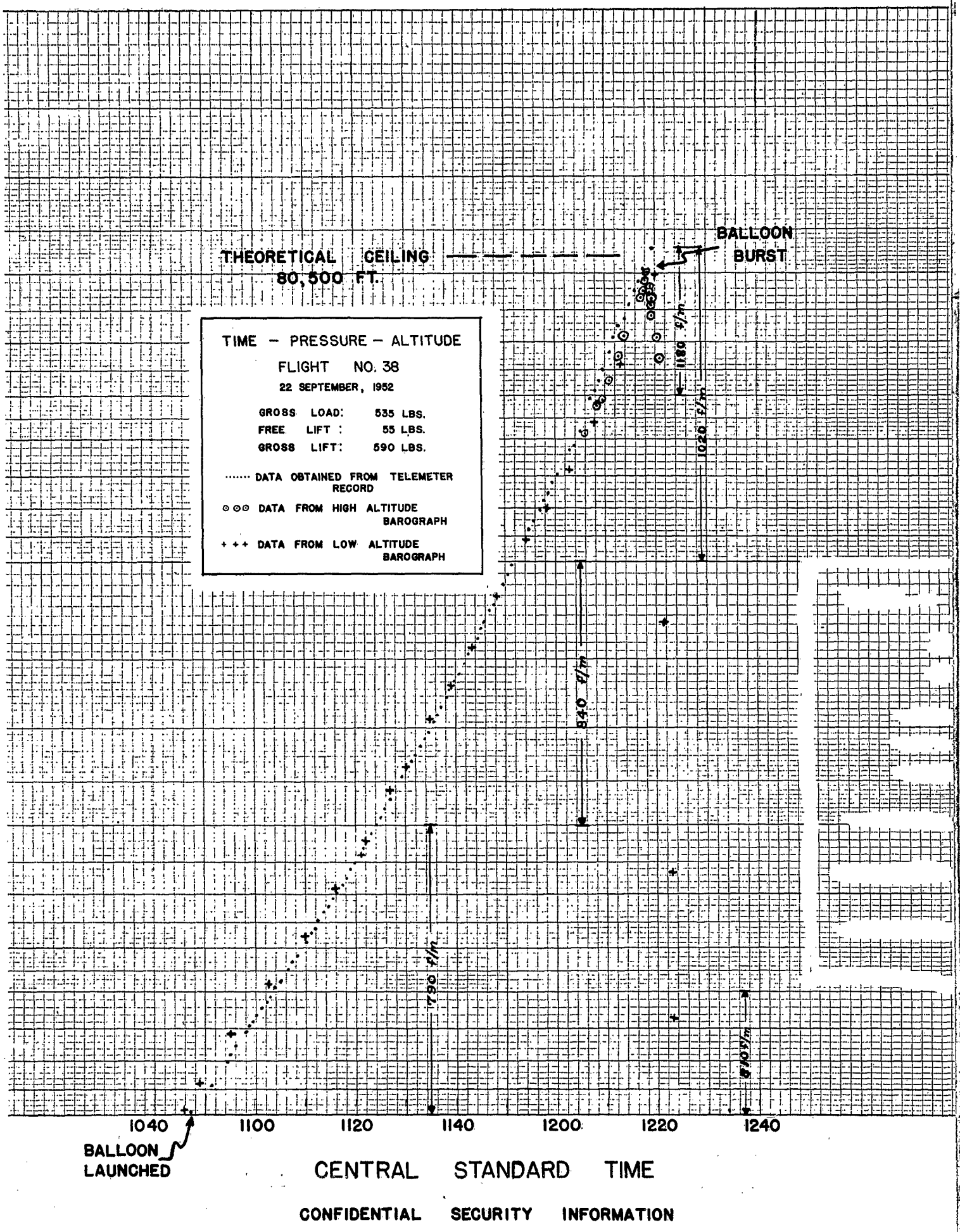
TRAJECTORY FROM DOWN PICTURES

SCALE 1:5 x 10^6

CONFIDENTIAL SECURITY INFORMATION

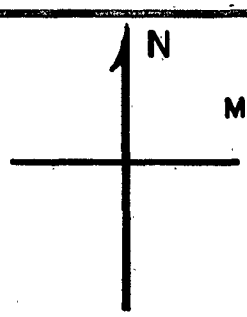
CONFIDENTIAL


RASONDE DATA
FLIGHT NO. 38
22 September, 1952
Meteorological station reporting:
ST. CLOUD, MINN. 655
1500 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
+3.0
-1.5
-2.5
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

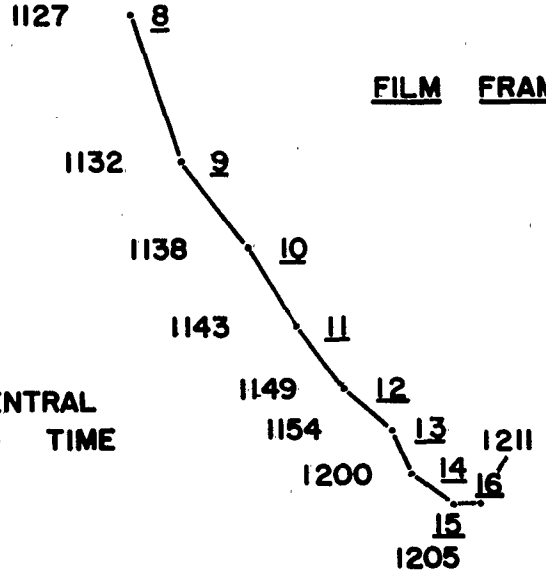


CONFIDENTIAL SECURITY INFORMATION

CONFIDENTIAL



Launched at:
MINNEAPOLIS, Minn.



FLIGHT NO. 38

LAUNCHED 1047

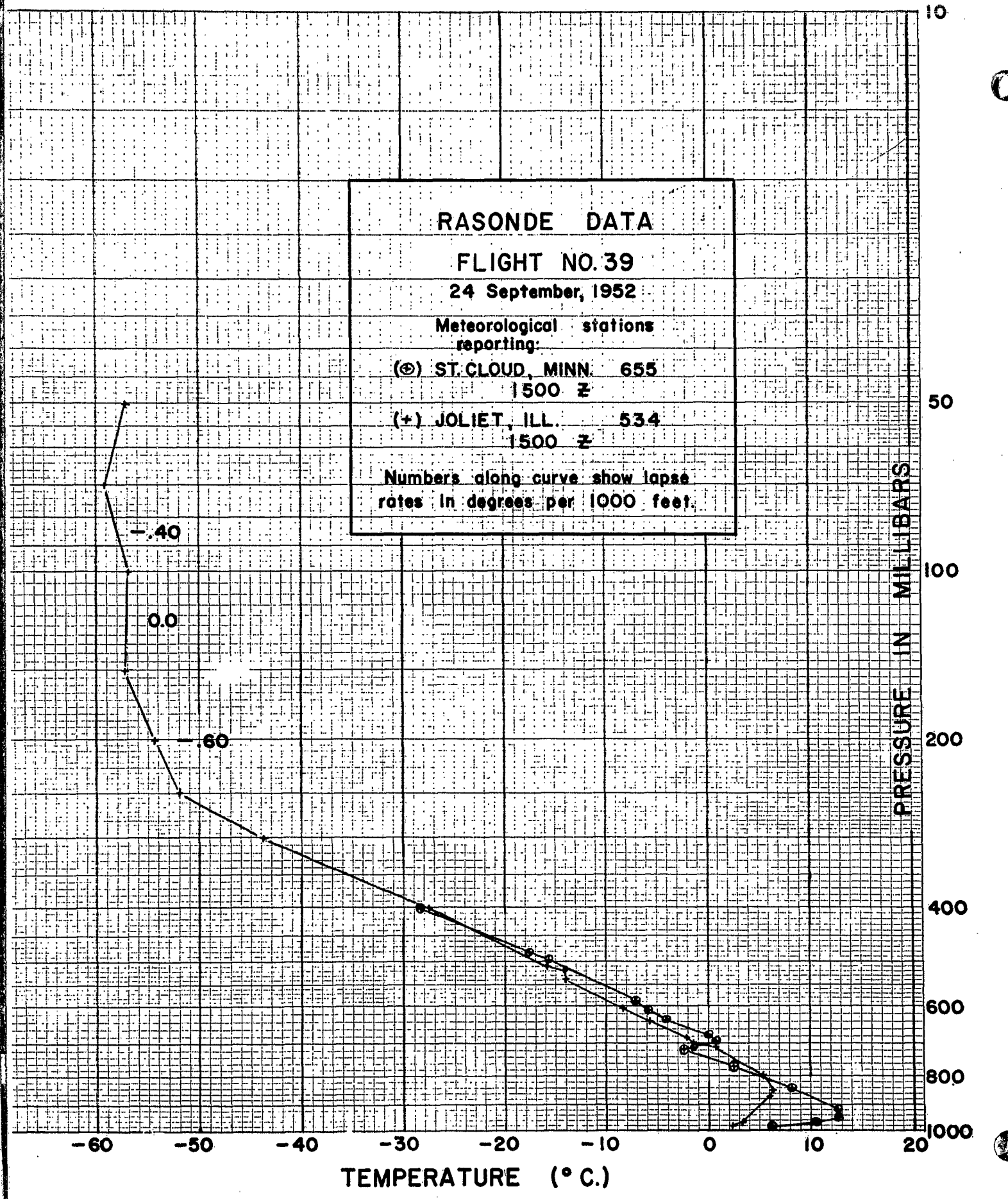
22 SEPTEMBER, 1952

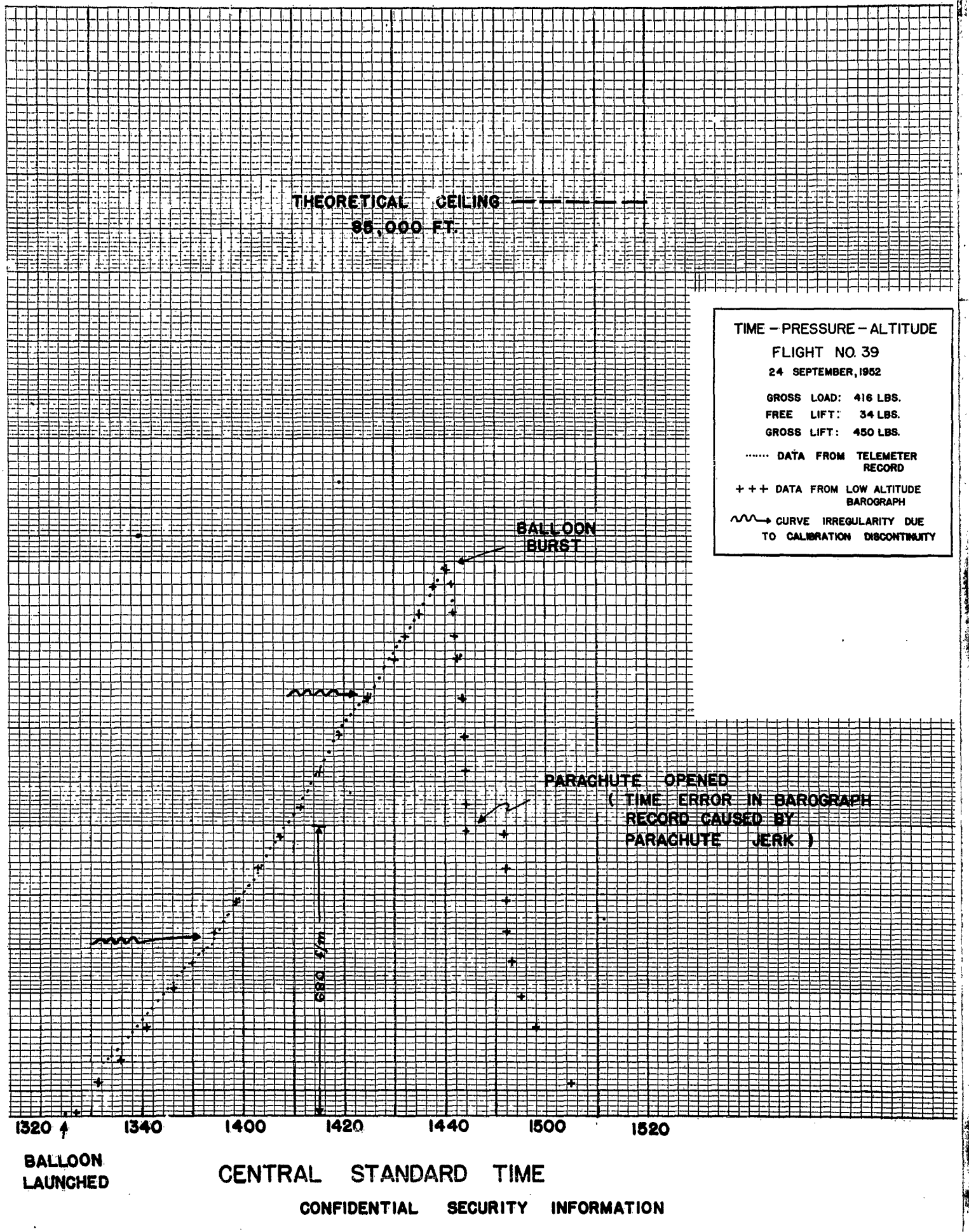
TRAJECTORY FROM DOWN PICTURES

SCALE 1:5 x 10^6

10 0 10 20 STATUTE MILES

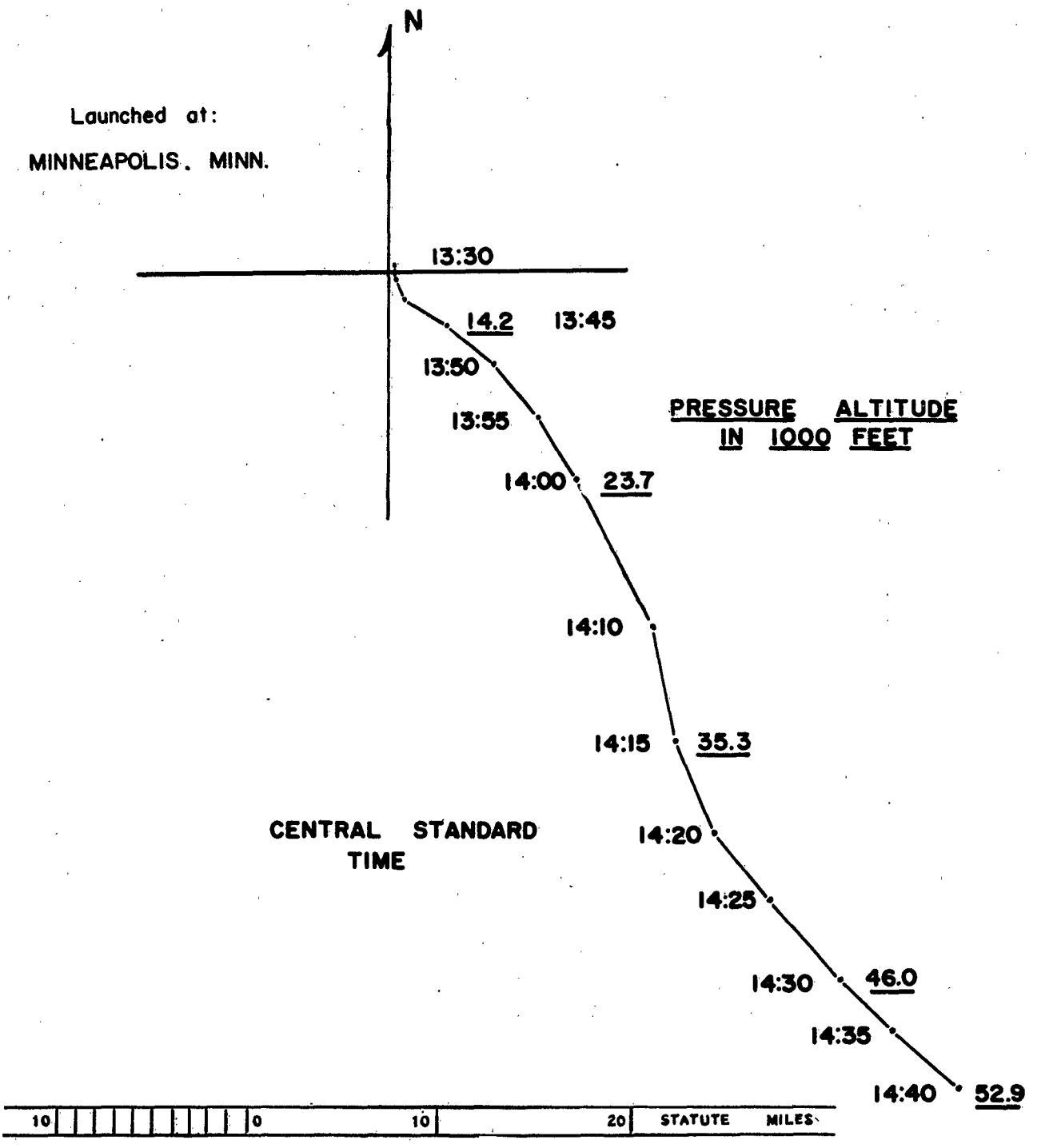
CONFIDENTIAL SECURITY INFORMATION


RASONDE DATA
FLIGHT NO. 39
24 September, 1952
Meteorological stations reporting:
(⊕) ST. CLOUD, MINN. 655
1500 Z
(+) JOLIET, ILL. 534
1500 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
-.40
0.0
-.60
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (° C.)



CONFIDENTIAL SECURITY INFORMATION

CONFIDENTIAL



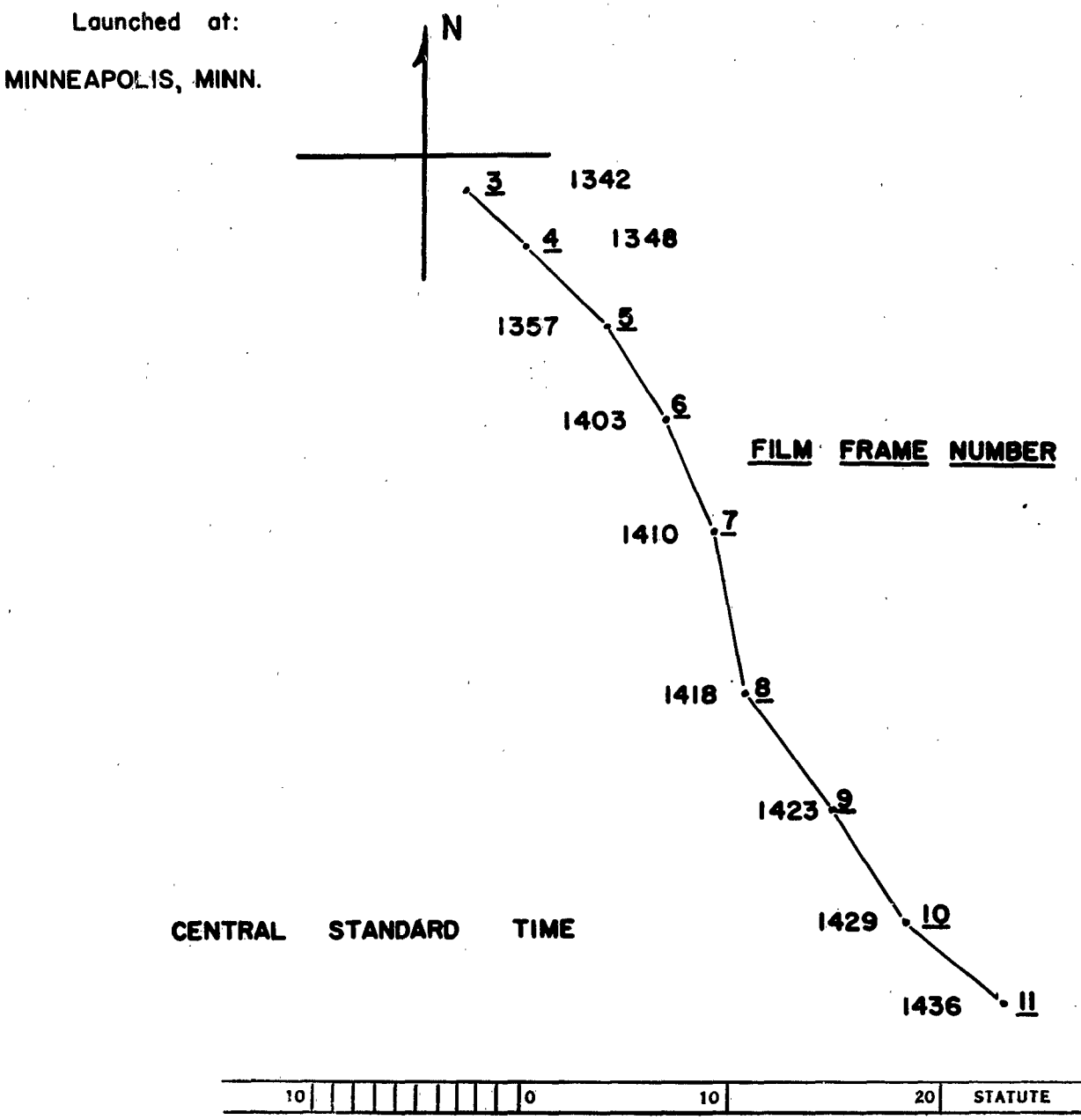
FLIGHT NO. 39
LAUNCHED 1325
24 SEPTEMBER, 1952

TRAJECTORY FROM THEODOLITE FIXES

SCALE: $1:5\times10^{5}$

CONFIDENTIAL SECURITY INFORMATION

CONFIDENTIAL



FLIGHT NO. 39

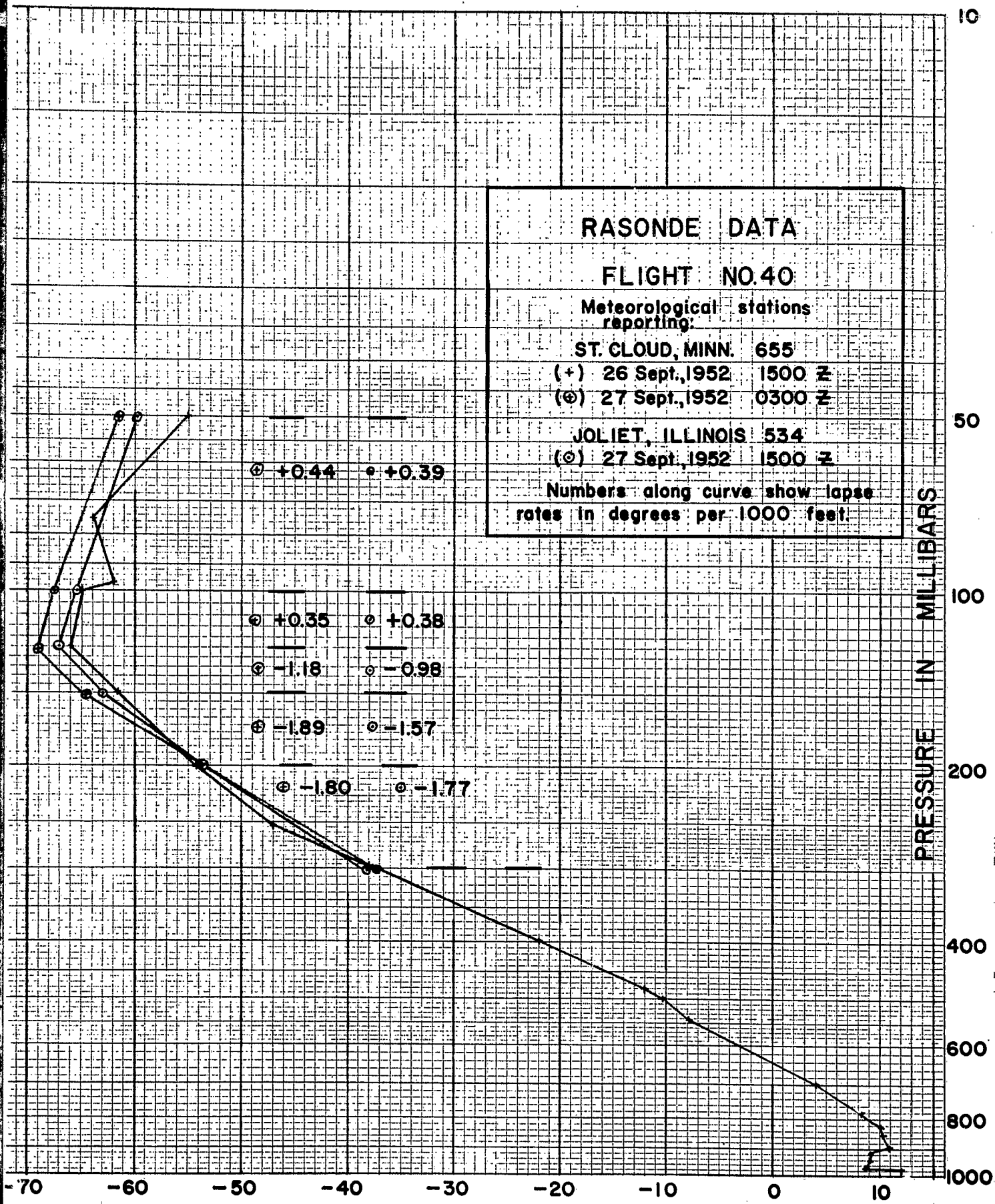
LAUNCHED 13:25 CST

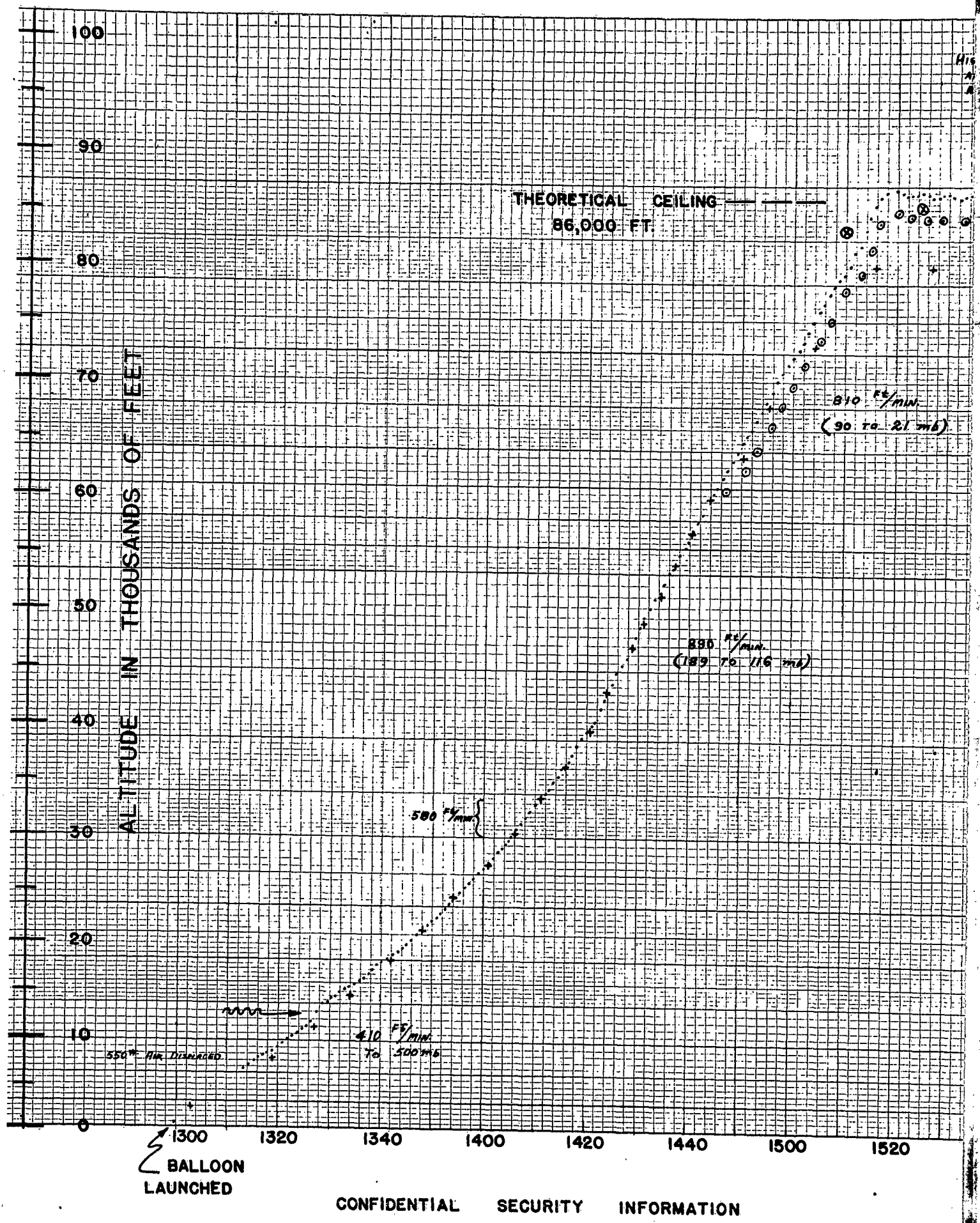
24 NOVEMBER, 1952

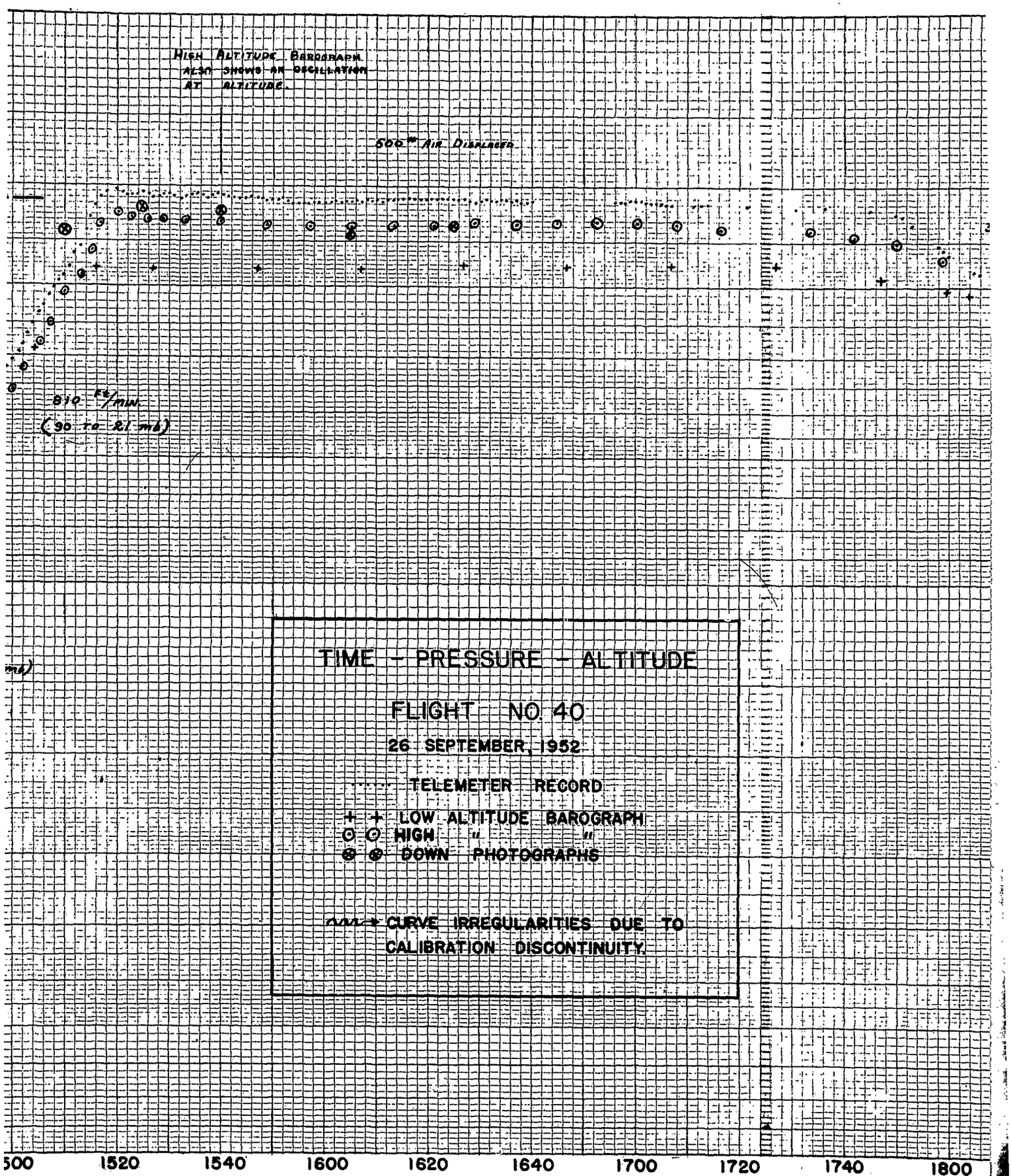
TRAJECTORY FROM DOWN PICTURES

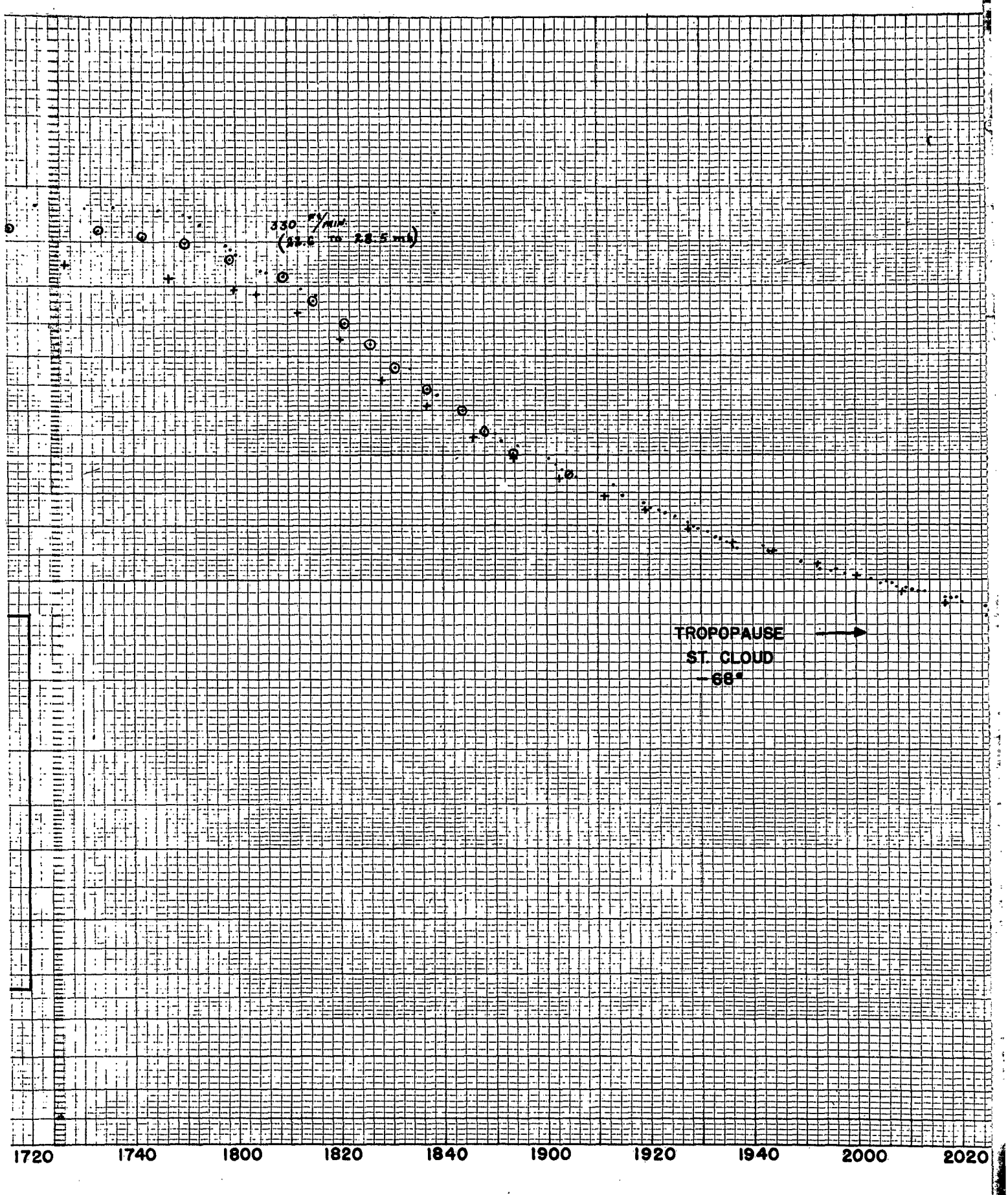
SCALE : $1:5\times10^{5}$

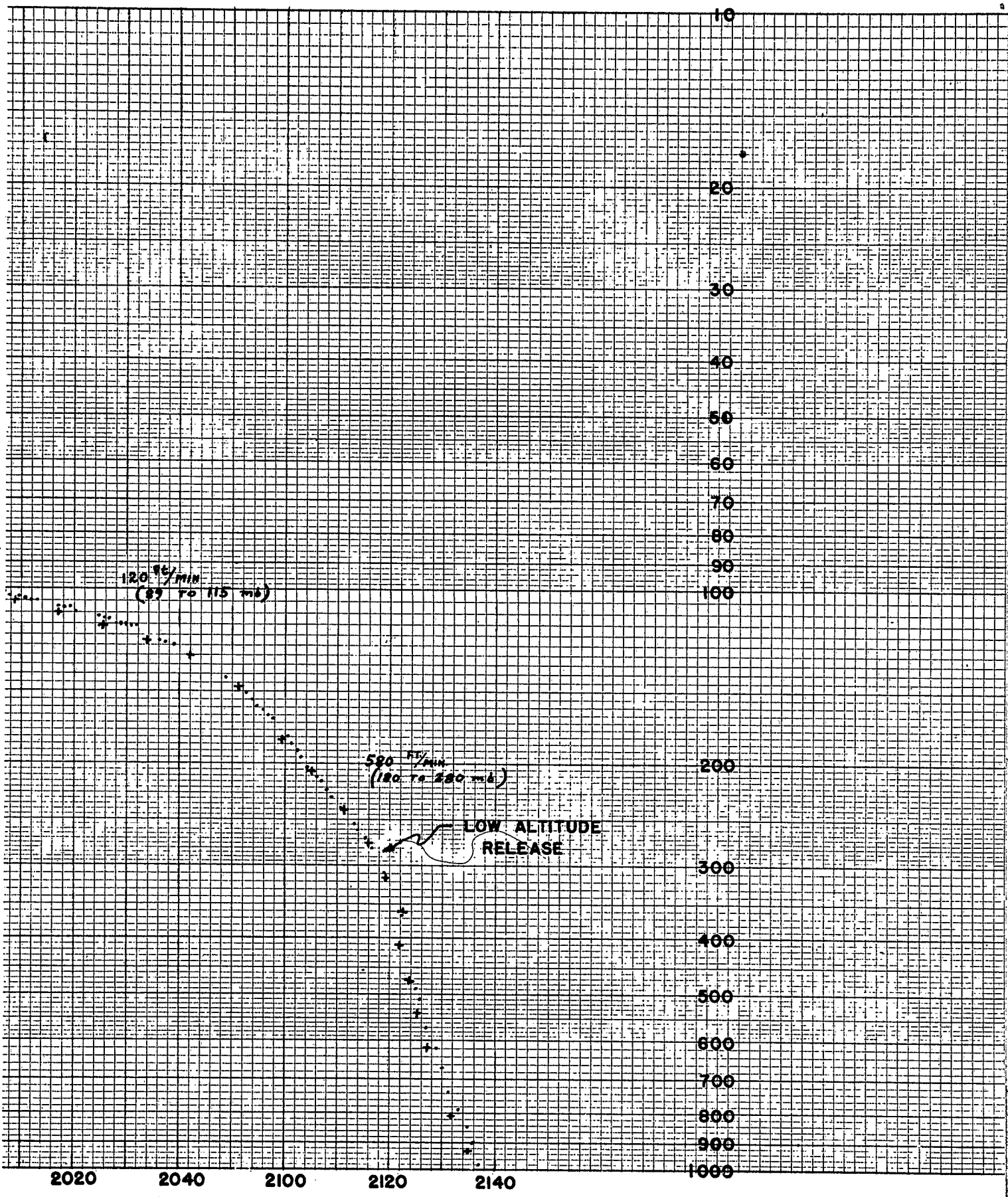
CONFIDENTIAL SECURITY INFORMATION

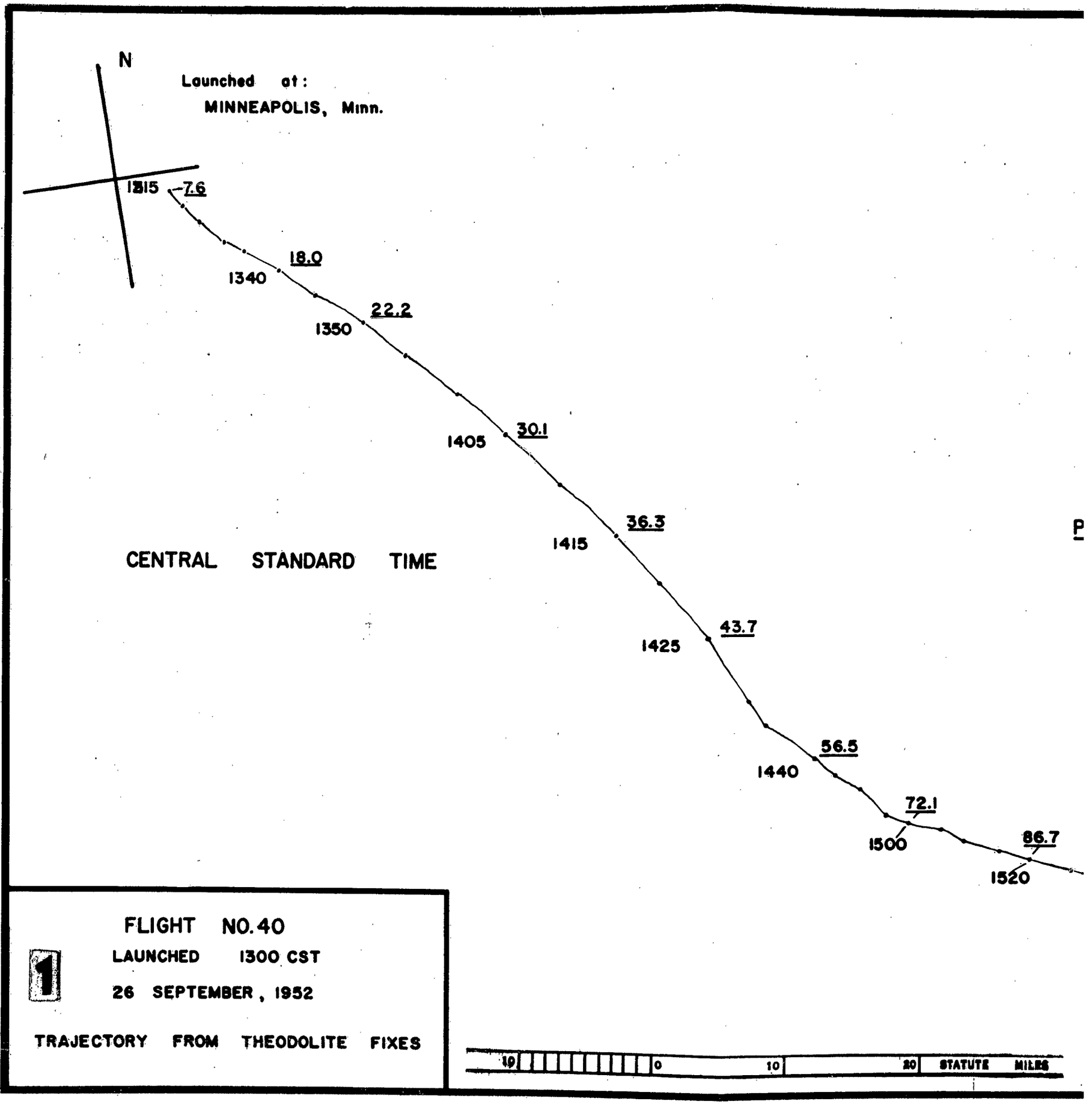

RASONDE DATA
FLIGHT NO.40
Meteorological stations reporting:
ST. CLOUD, MINN. 655
(+) 26 Sept.,1952 1500 Z
(⊕) 27 Sept.,1952 0300 Z
JOLIET, ILLINOIS 534
(⊙) 27 Sept.,1952 1500 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
⊕ +0.44
• +0.39
⊕ +0.35
⊘ +0.38
⊕ −1.18
⊙ −0.98
⊕ −1.89
⊙ −1.57
⊕ −1.80
⊙ −1.77
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-70
-60
-50
-40
-30
-20
-10
0
10
TEMPERATURE (°C.)


100
90
80
70
60
50
40
30
20
10
0
ALTITUDE IN THOUSANDS OF FEET
THEORETICAL CEILING
86,000 FT.
810 ft/min.
(90 to 21 mb)
830 ft/min.
(189 to 116 mb)
580 ft/min.
410 ft/min.
To 500 mb
550 m. Air Displaced
1300
1320
1340
1400
1420
1440
1500
1520
BALLOON
LAUNCHED


HIGH ALTITUDE BAROGRAPH ALSO SHOWS AN OSCILLATION AT ALTITUDE.
500 mb AIR DISPLACED
810 Ft/min (90 to 81 mb)
TIME - PRESSURE - ALTITUDE
FLIGHT NO. 40
26 SEPTEMBER, 1952
..... TELEMETER RECORD
+ + LOW ALTITUDE BAROGRAPH
⊙ ⊙ HIGH " "
⊗ ⊗ DOWN PHOTOGRAPHS
CURVE IRREGULARITIES DUE TO CALIBRATION DISCONTINUITY.
1500
1520
1540
1600
1620
1640
1700
1720
1740
1800
CENTRAL STANDARD TIME


330 ft/min
(22.6 to 28.5 mb)
TROPOPAUSE
ST. CLOUD
-68°
1720
1740
1800
1820
1840
1900
1920
1940
2000
2020

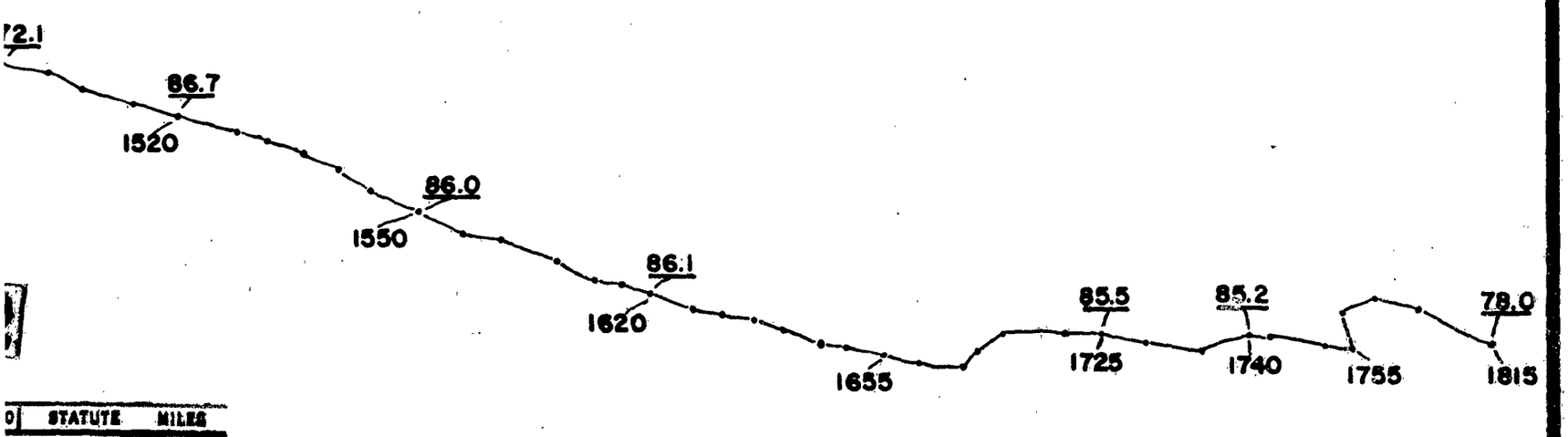

10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
2020
2040
2100
2120
2140
120 FT/MIN
(89 TO 115 MPH)
580 FT/MIN
(180 TO 280 MPH)
LOW ALTITUDE
RELEASE



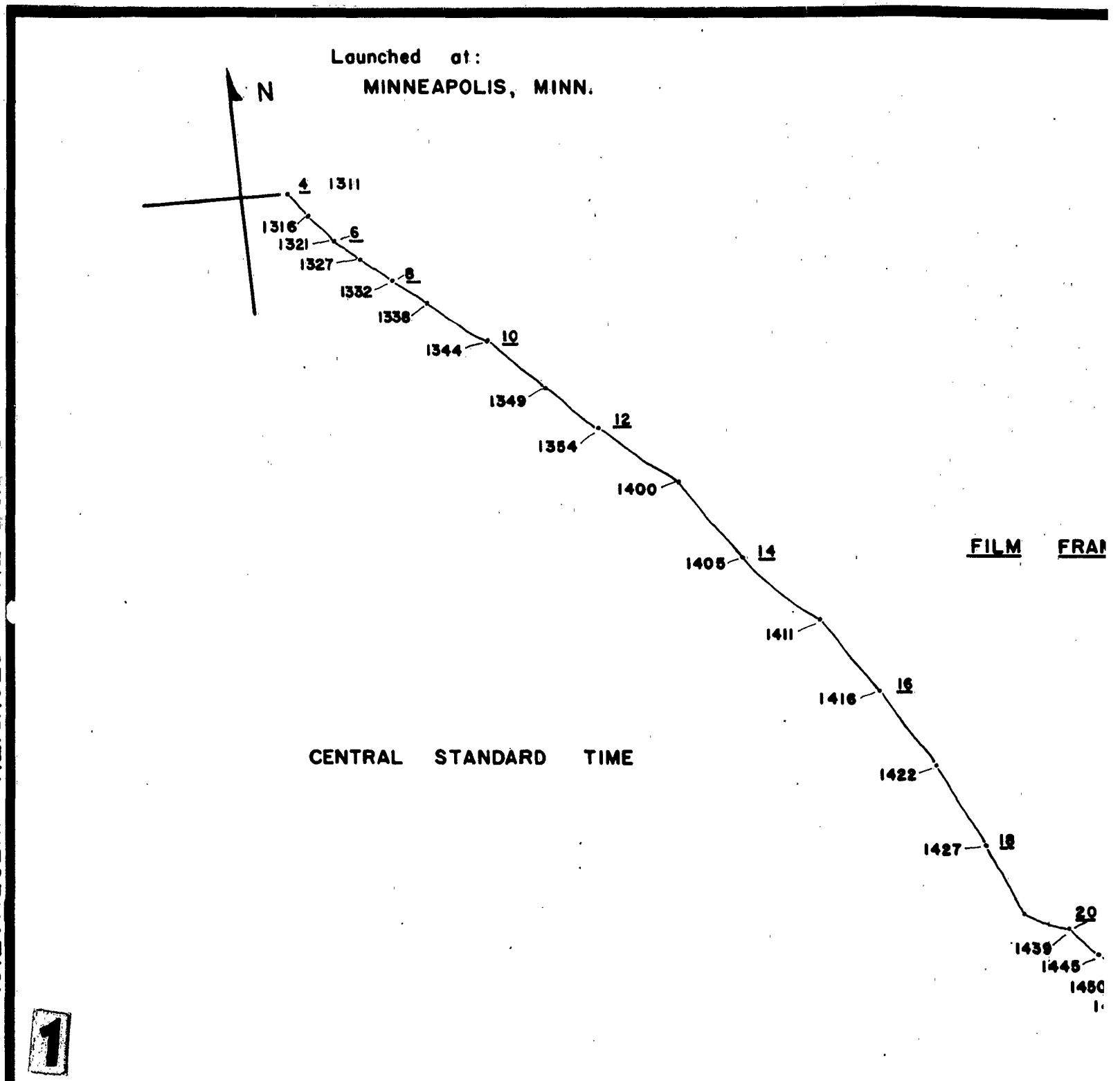
CONFIDENTIAL SECURITY INFORMATION

CONFIDENTIAL

PRESSURE ALTITUDE IN 1000 FEET



CONFIDENTIAL SECURITY INFORMATION



FLIGHT NO. 40

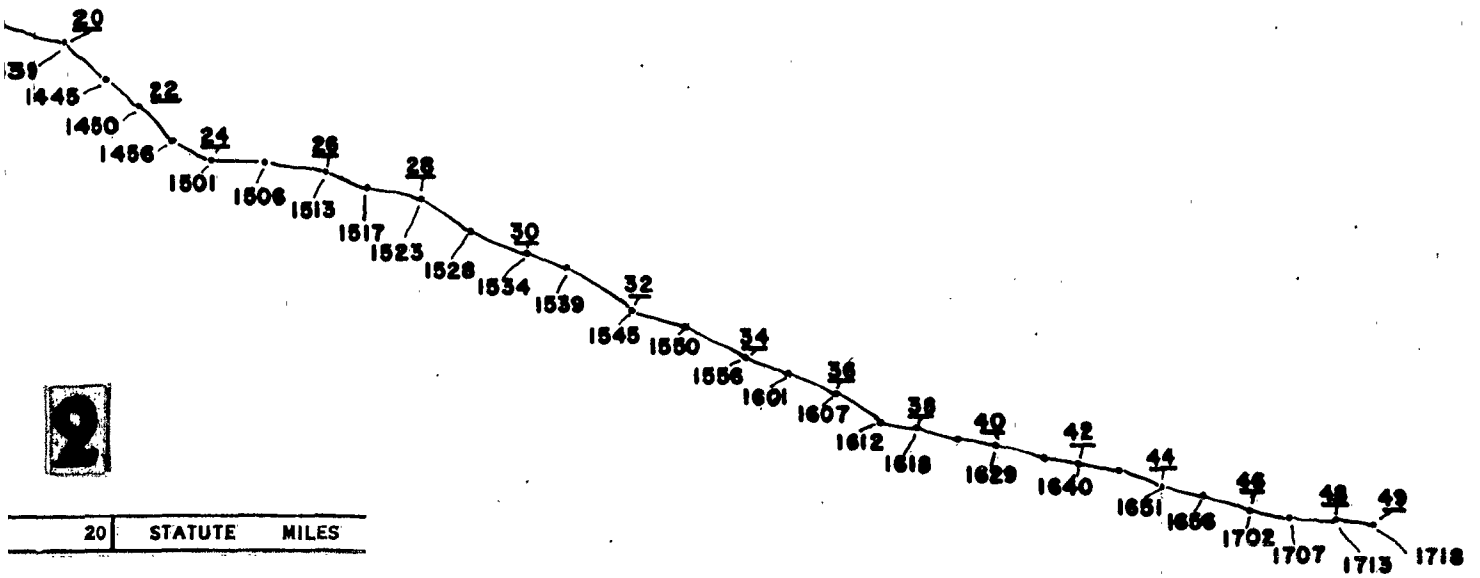
LAUNCHED 1300 CST

26 SEPTEMBER, 1952

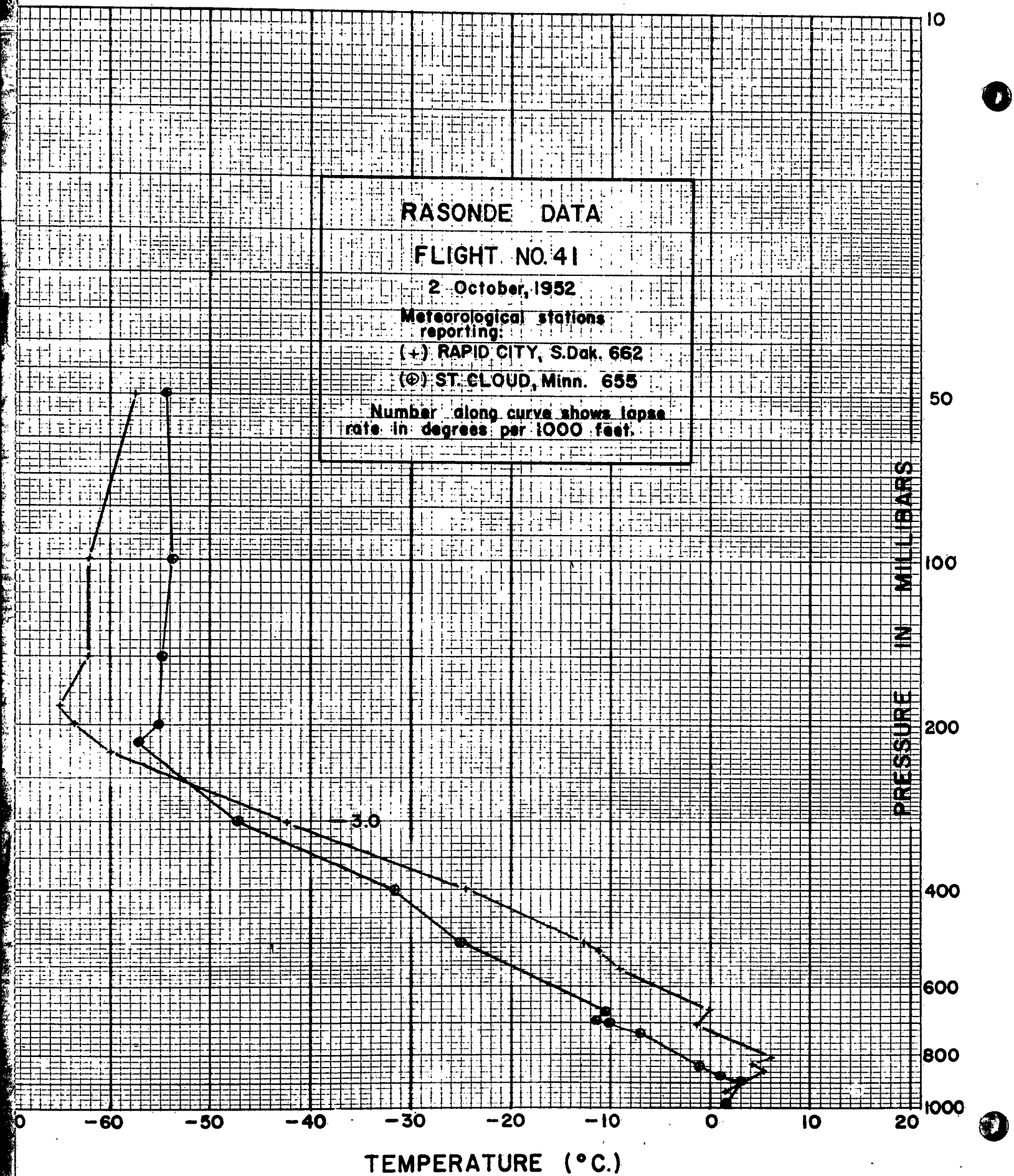
TRAJECTORY FROM DOWN PICTURES

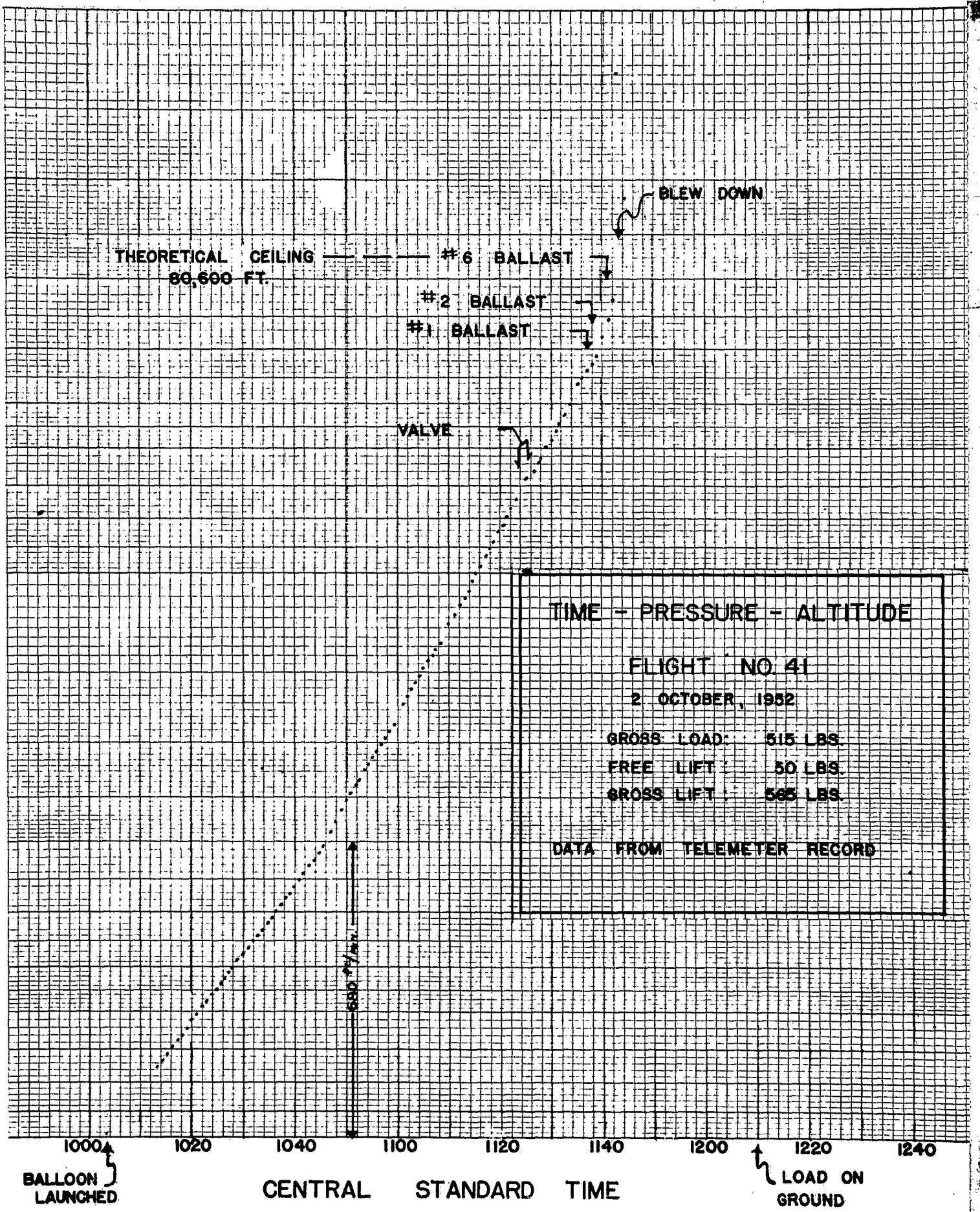
CONFIDENTIAL

FRAME NUMBER



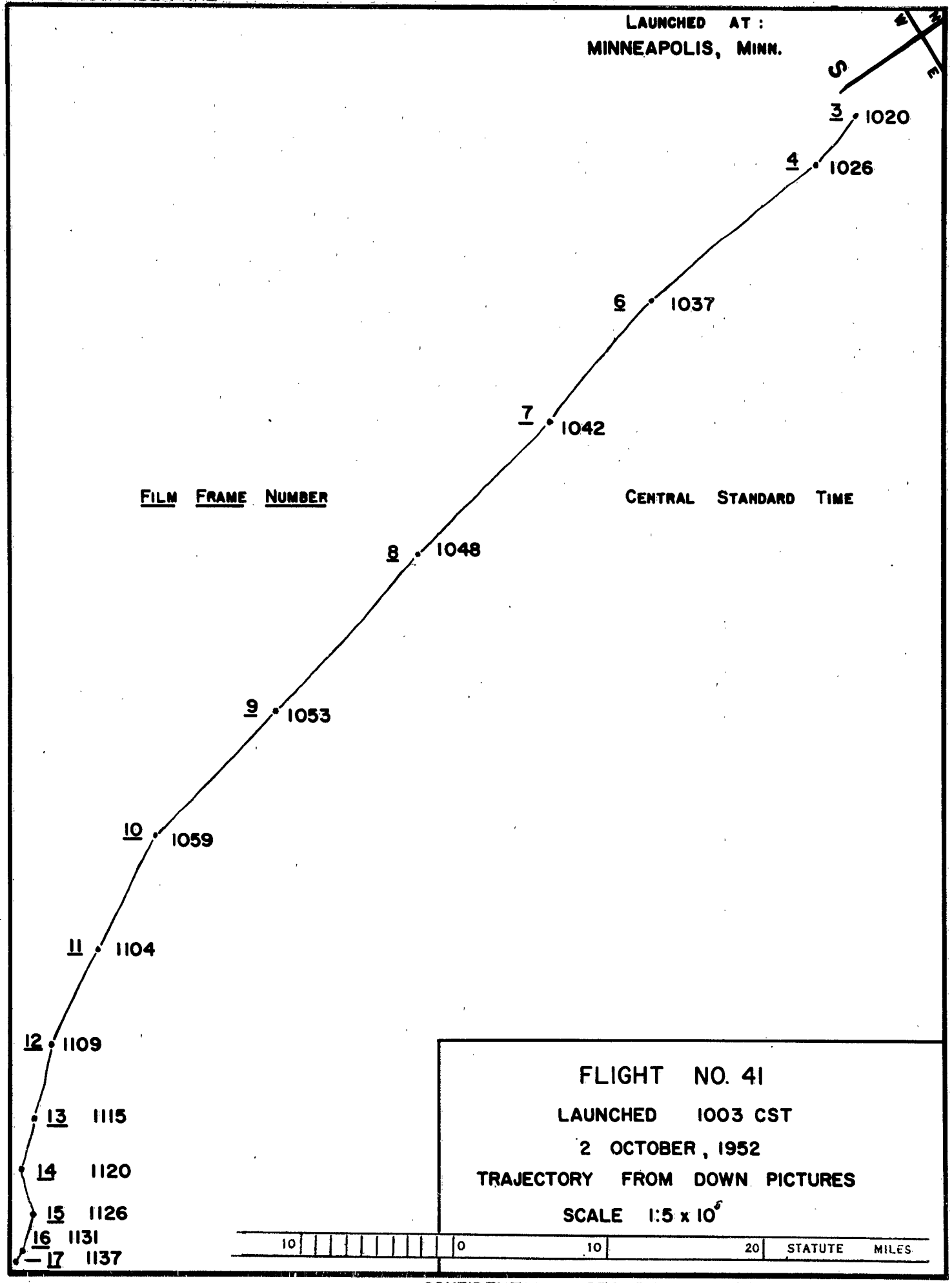
20 STATUTE MILES

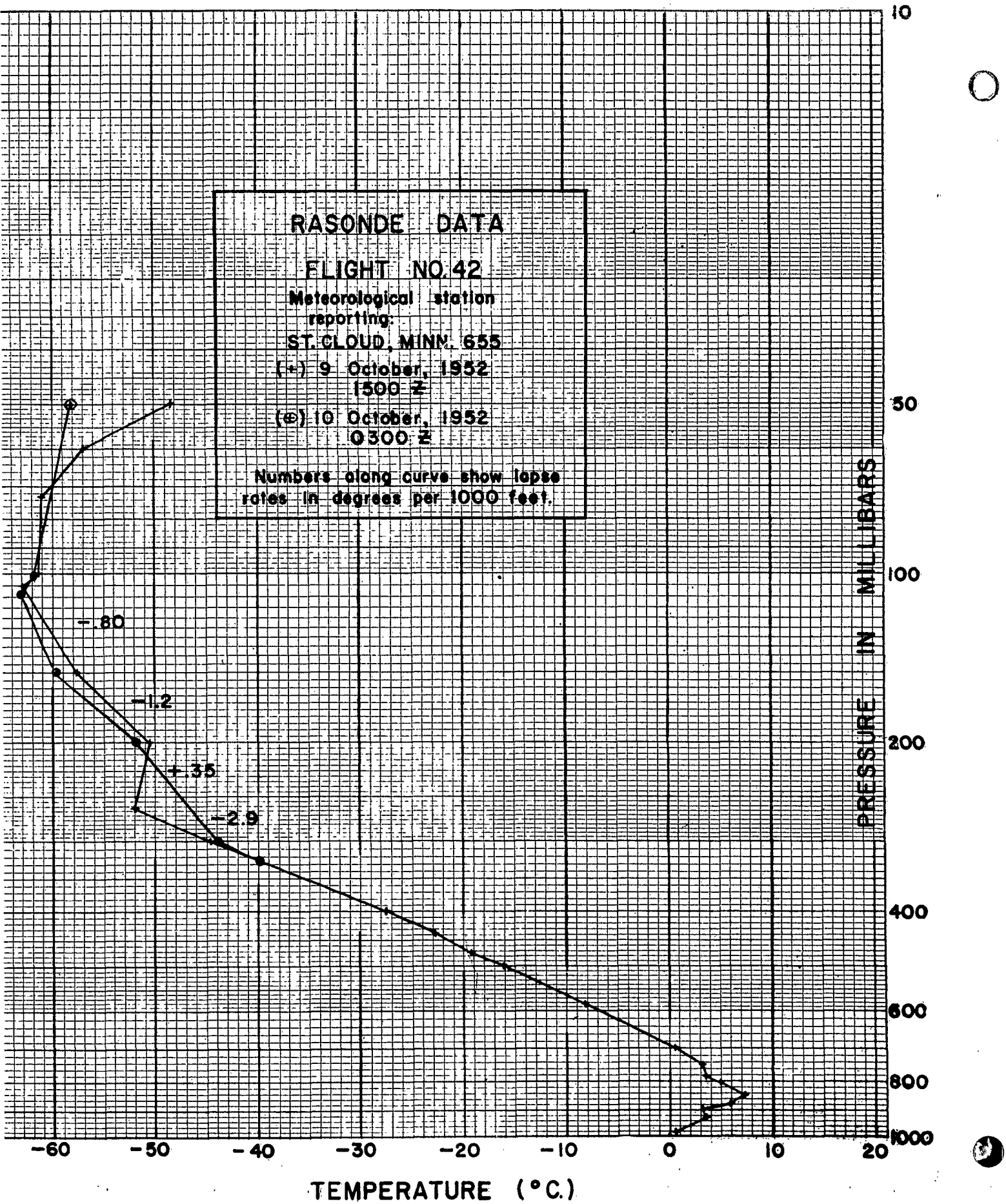

RASONDE DATA
FLIGHT NO. 41
2 October, 1952
Meteorological stations reporting:
(+) RAPID CITY, S.Dak. 662
(⊕) ST. CLOUD, Minn. 655
Number along curve shows lapse rate in degrees per 1000 feet.
-3.0
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
0
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

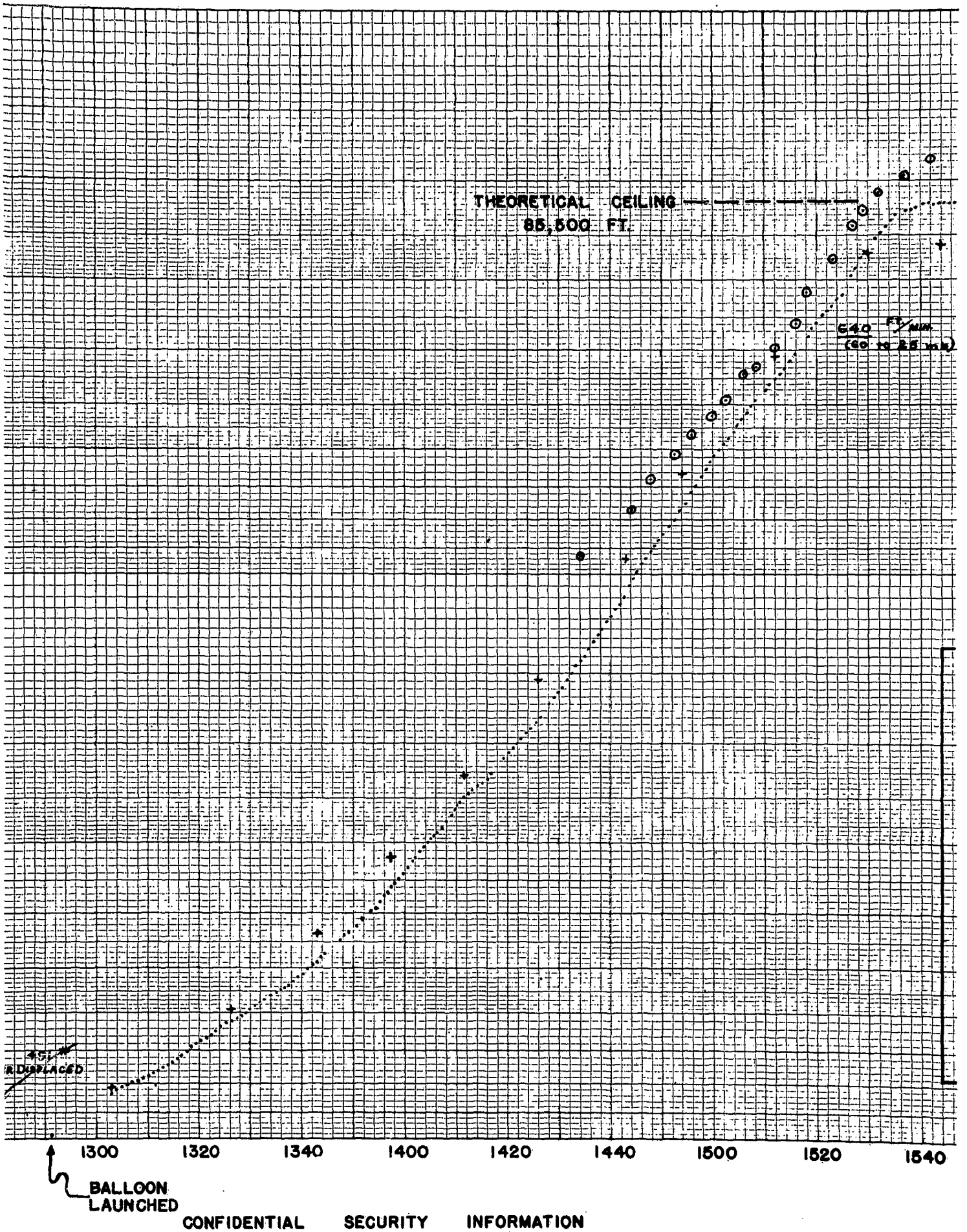


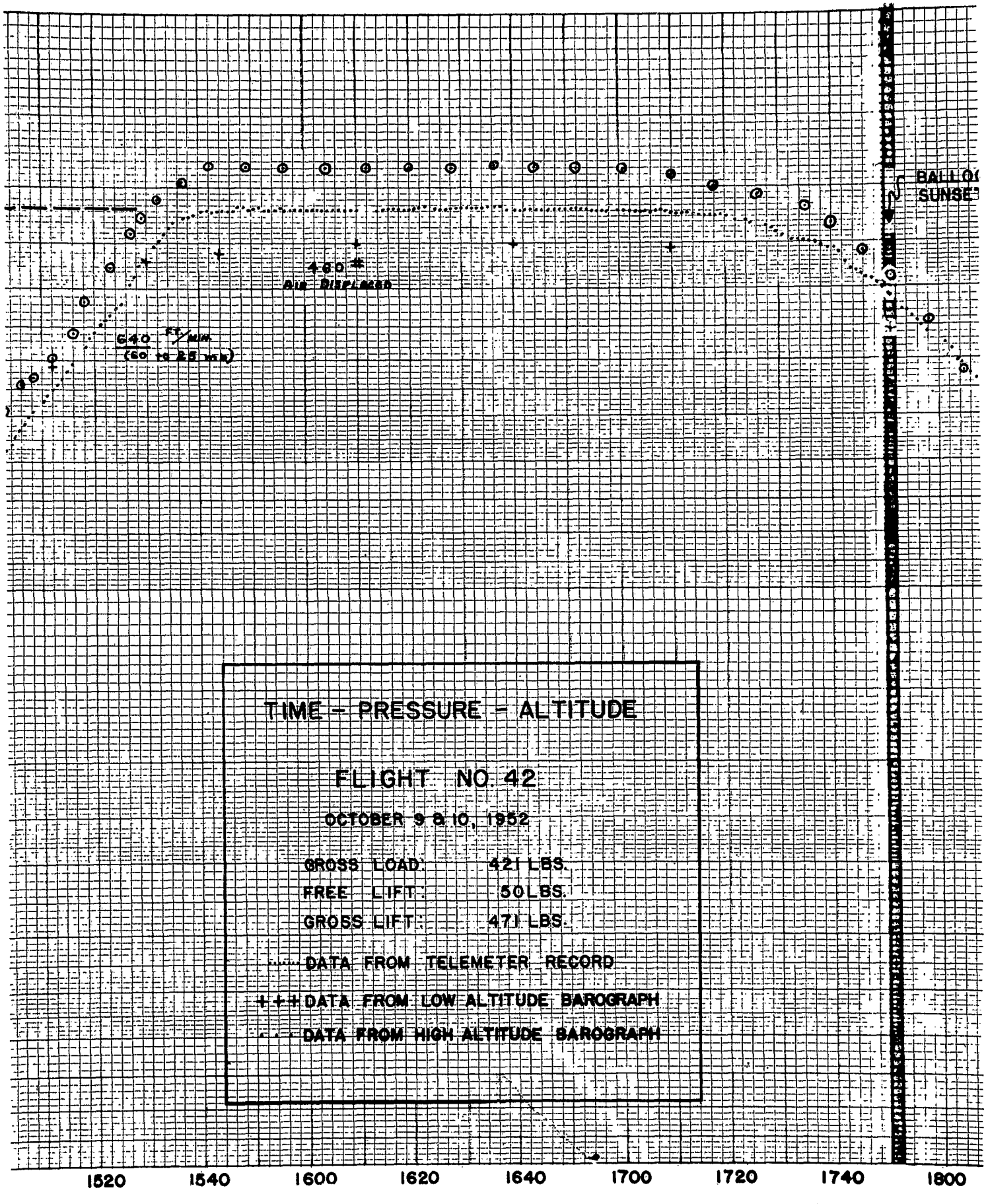
CONFIDENTIAL SECURITY INFORMATION

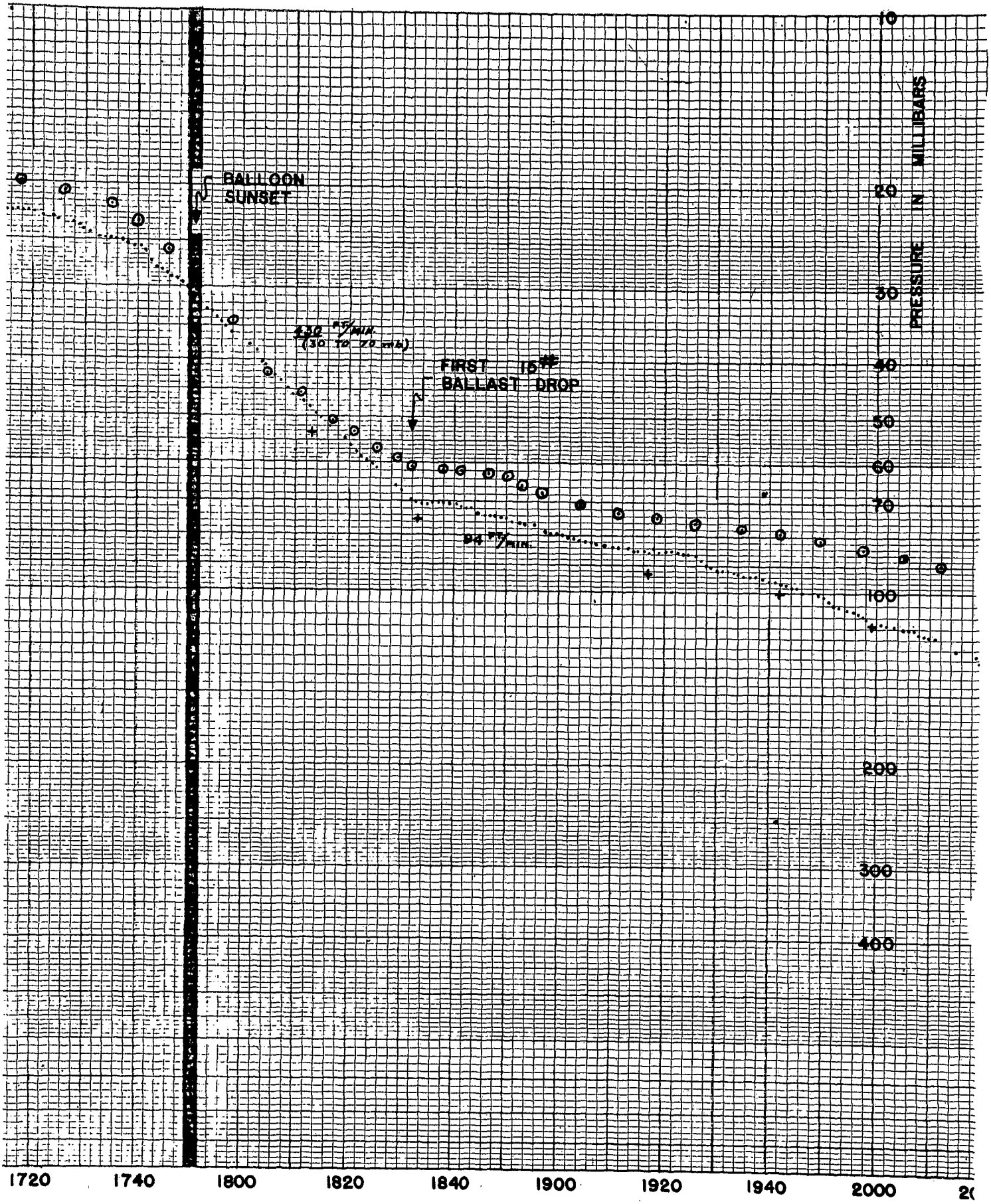
CONFIDENTIAL

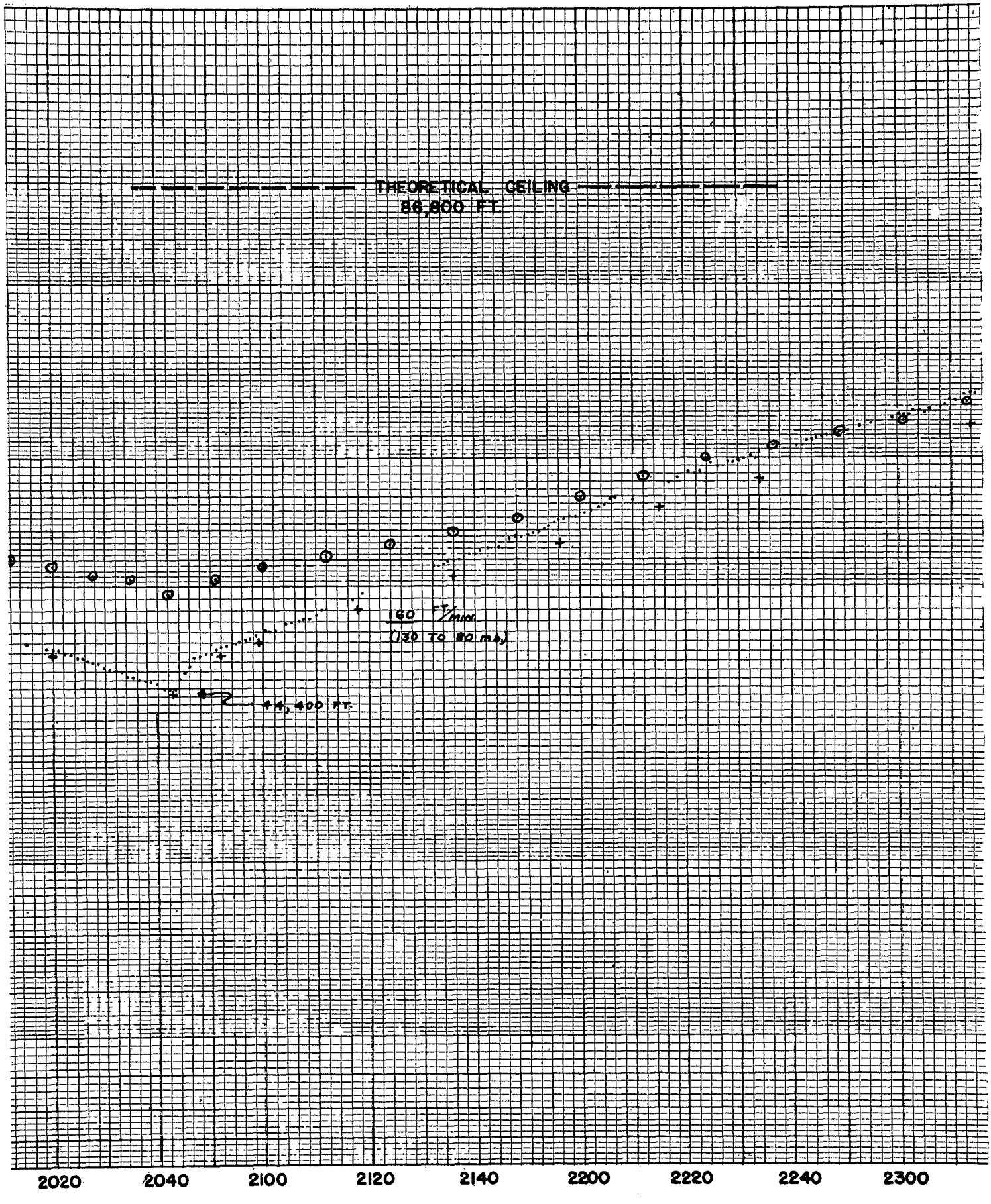


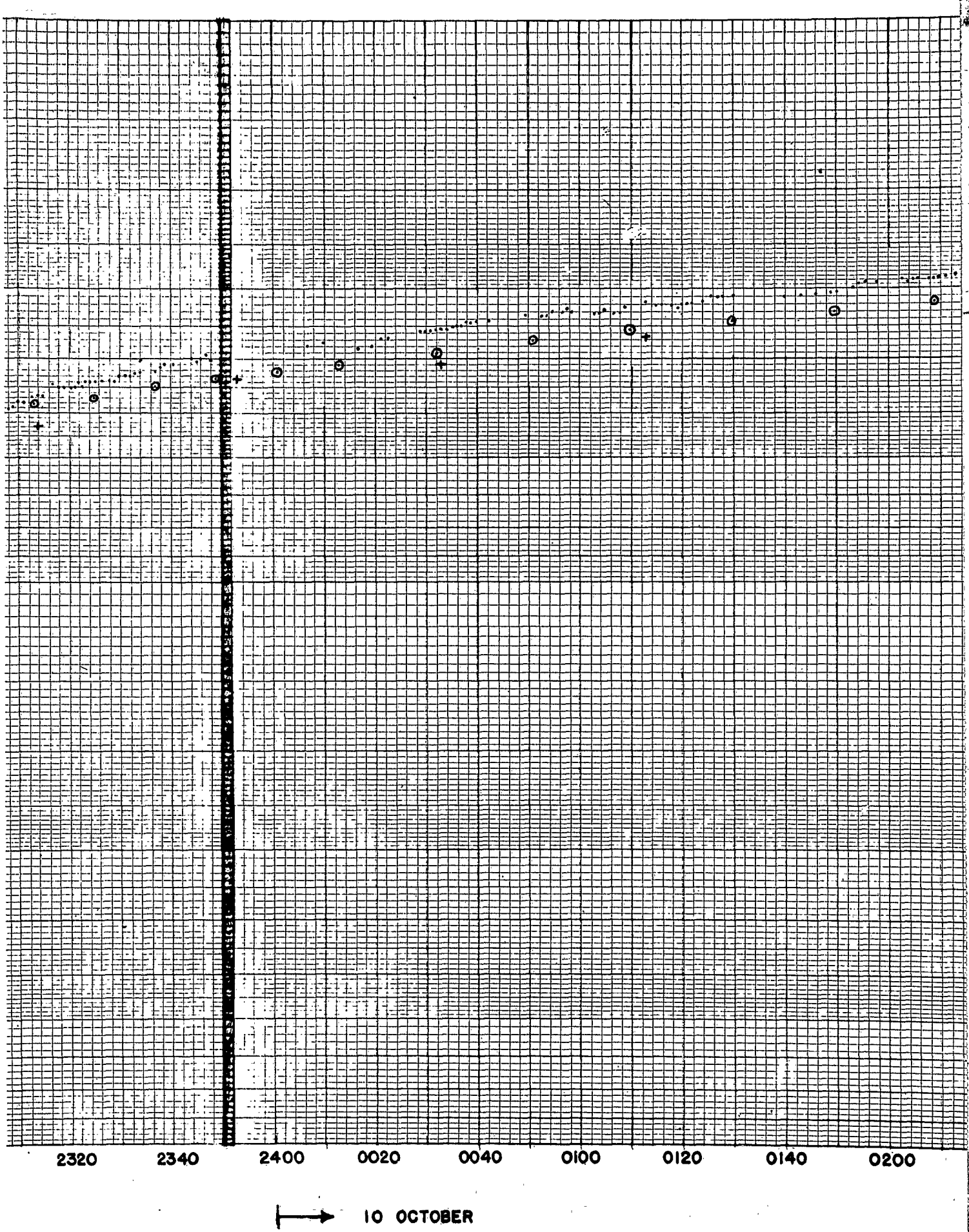

RASONDE DATA
FLIGHT NO. 42
Meteorological station reporting:
ST. CLOUD, MINN. 655
(+) 9 October, 1952
1500 Z
(⊕) 10 October, 1952
0300 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
-.80
-1.2
+.35
-2.9
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

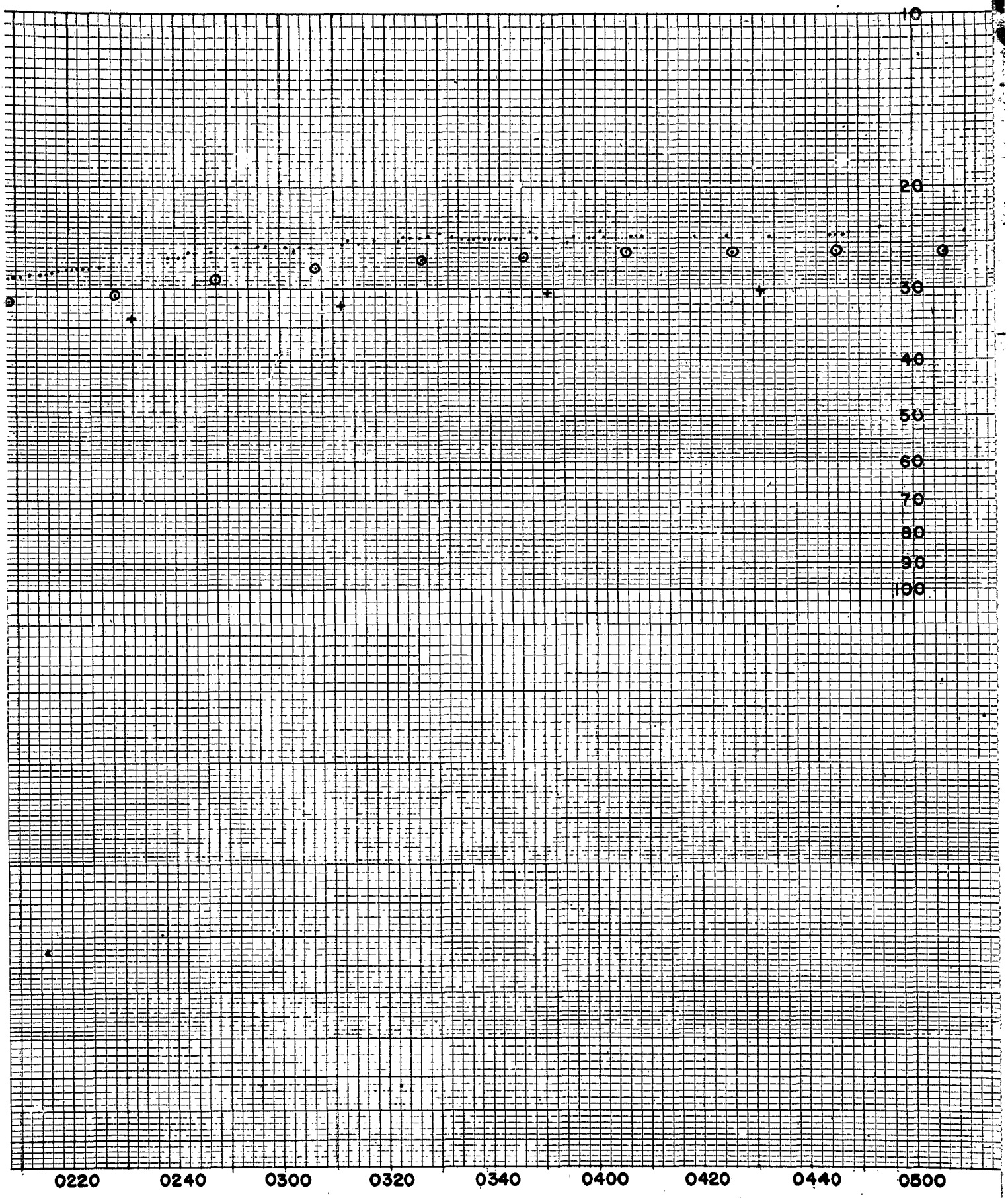

THEORETICAL CEILING
85,500 FT.
640 FT/MIN.
(60 TO 85 mb)
451 MM
REPLACED
1300
1320
1340
1400
1420
1440
1500
1520
1540
BALLOON
LAUNCHED

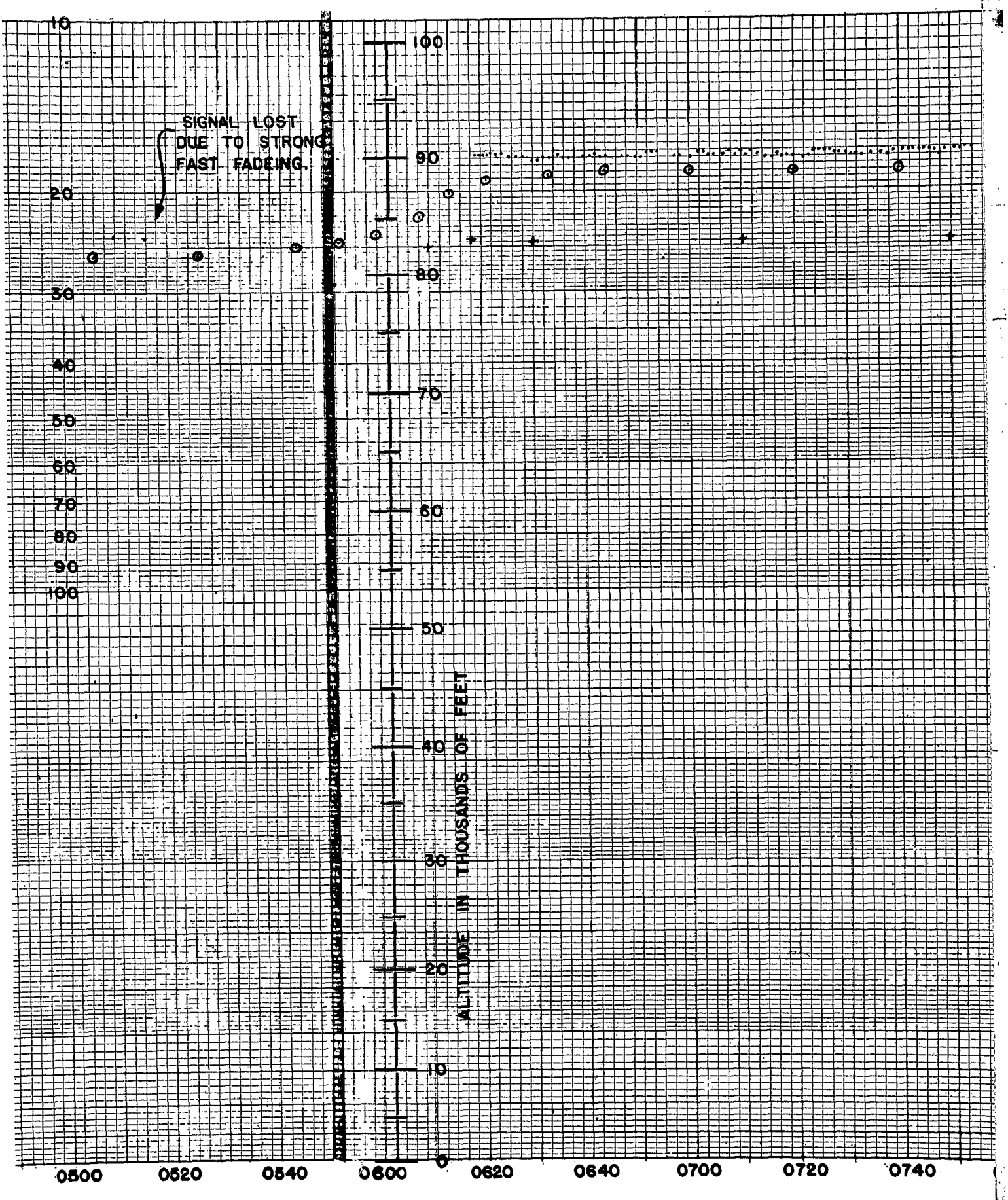

460 #
AIR DISPLACED
640 FT/MIN
(60 to 25 min)
BALLOO
SUNSE
TIME - PRESSURE - ALTITUDE
FLIGHT NO. 42
OCTOBER 9 & 10, 1952
GROSS LOAD 421 LBS.
FREE LIFT 50 LBS.
GROSS LIFT 471 LBS.
.....DATA FROM TELEMETER RECORD
+++DATA FROM LOW ALTITUDE BAROGRAPH
. . . DATA FROM HIGH ALTITUDE BAROGRAPH
1520
1540
1600
1620
1640
1700
1720
1740
1800
CENTRAL STANDARD TIME

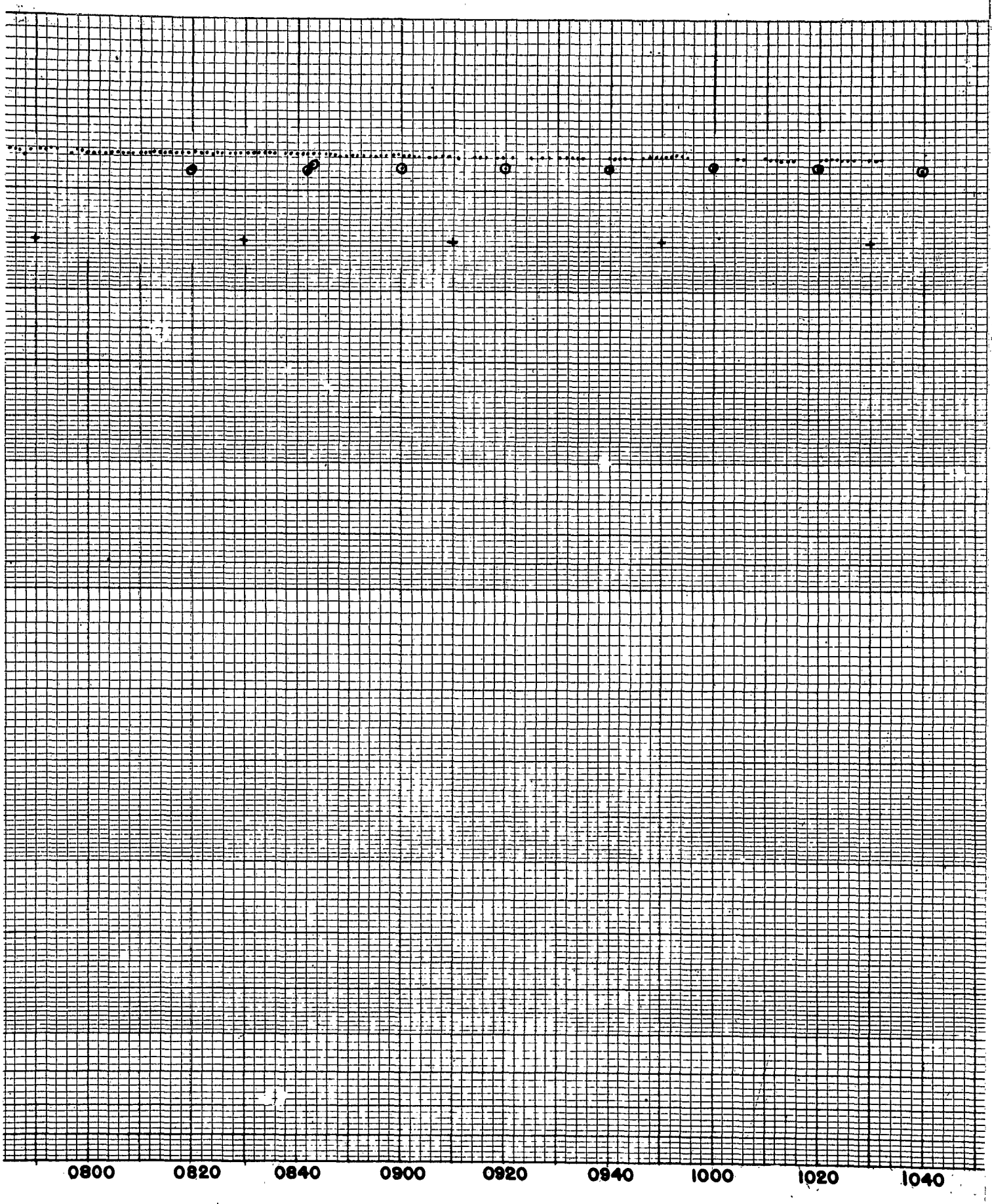

BALLOON SUNSET
430 FT/MIN. (30 TO 70 mb)
FIRST 15# BALLAST DROP
94 FT/MIN.
PRESSURE IN MILLIBARS
10
20
30
40
50
60
70
100
200
300
400
1720
1740
1800
1820
1840
1900
1920
1940
2000

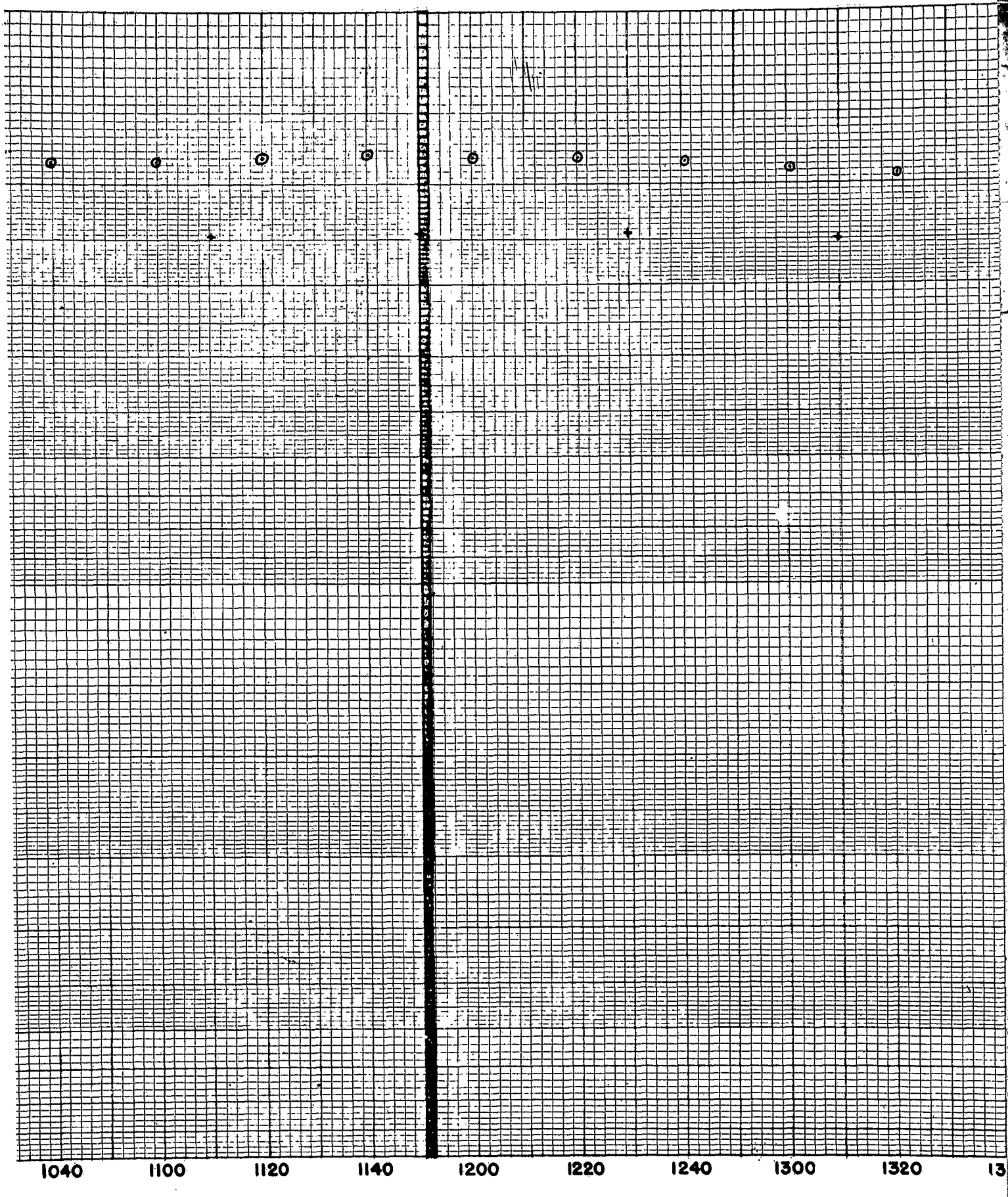

THEORETICAL CEILING
86,800 FT.
160 Ft/min.
(130 TO 80 mb)
44,400 FT.
2020
2040
2100
2120
2140
2200
2220
2240
2300

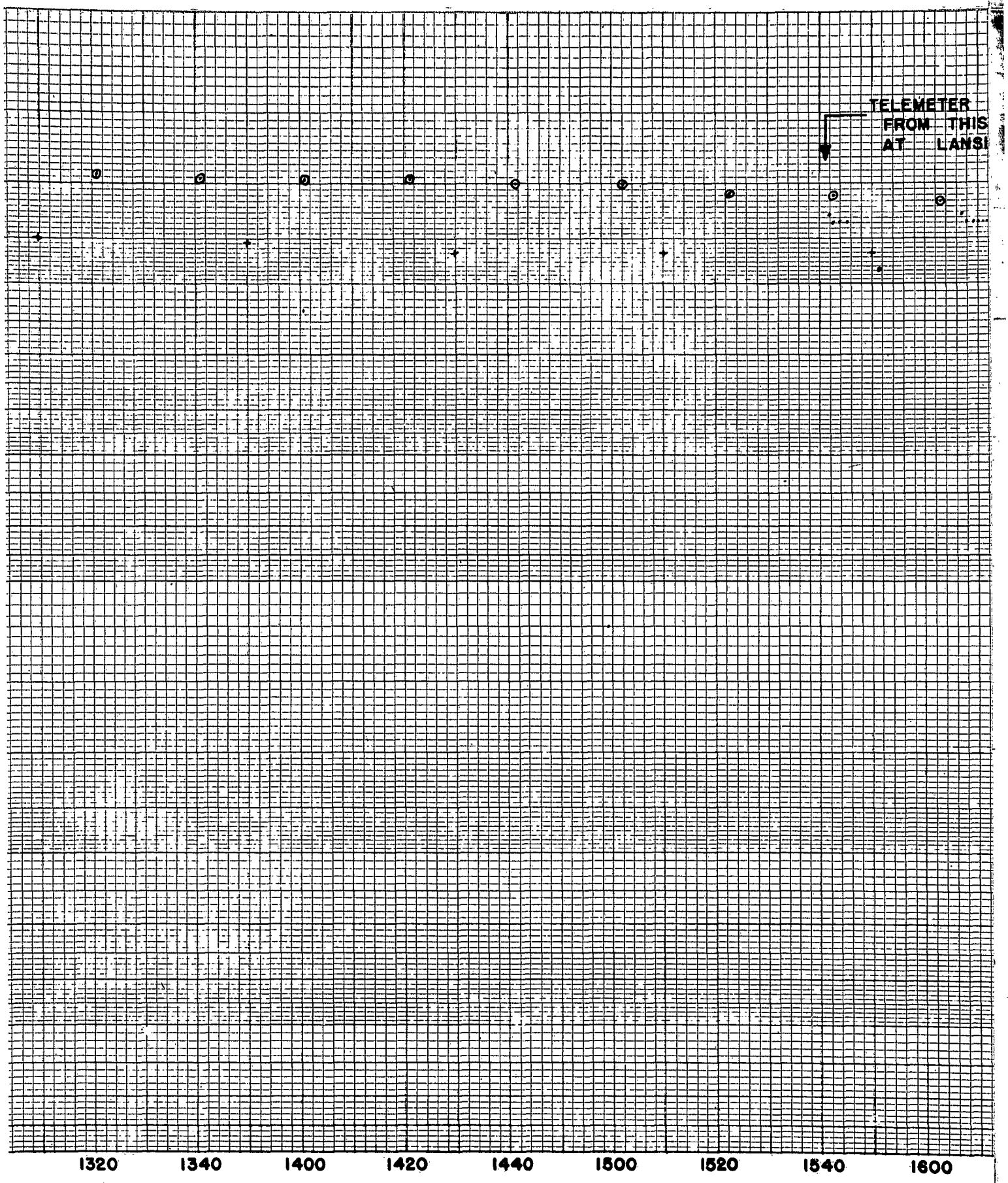

2320
2340
2400
0020
0040
0100
0120
0140
0200
10 OCTOBER

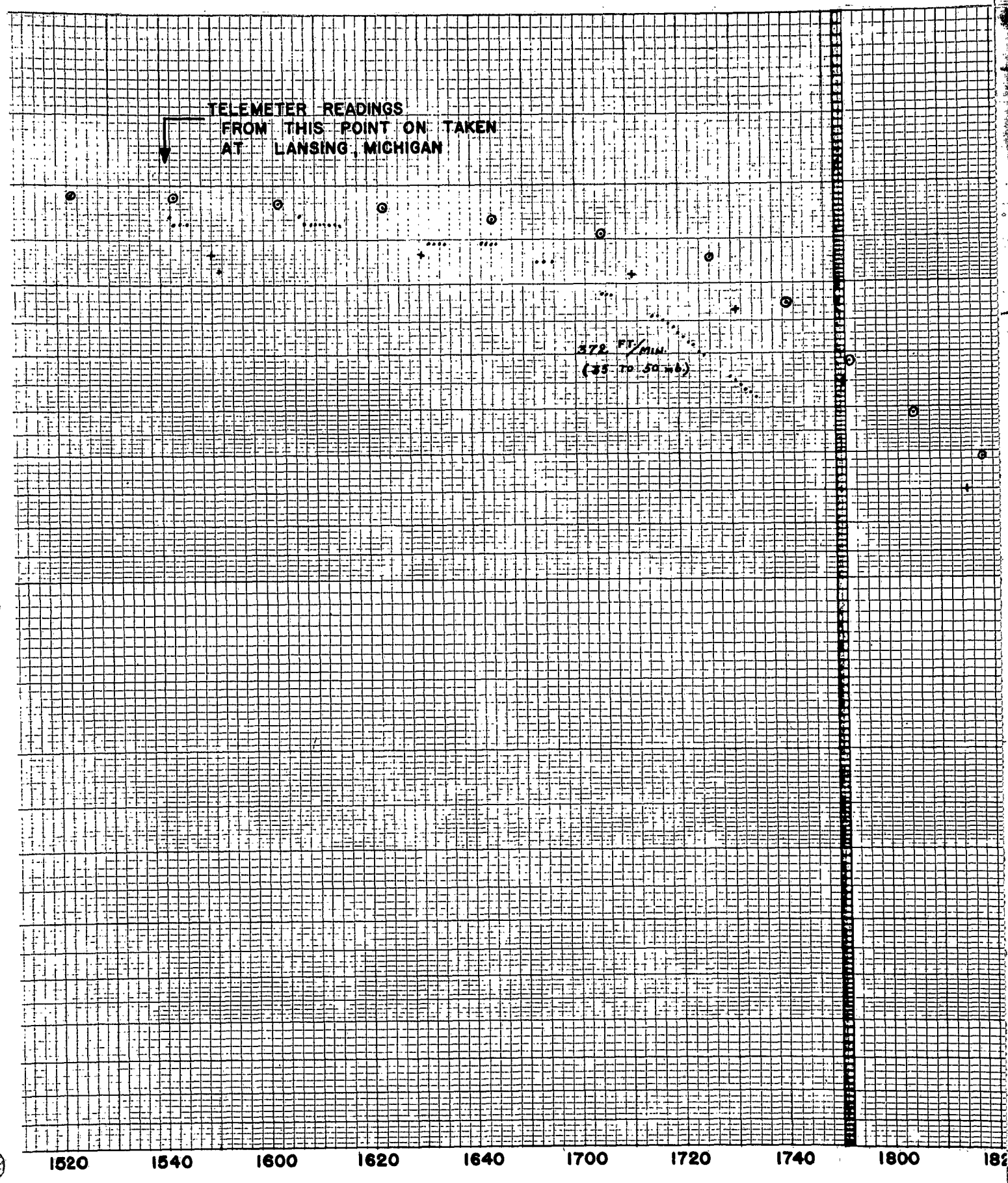

10
20
30
40
50
60
70
80
90
100
0220
0240
0300
0320
0340
0400
0420
0440
0500

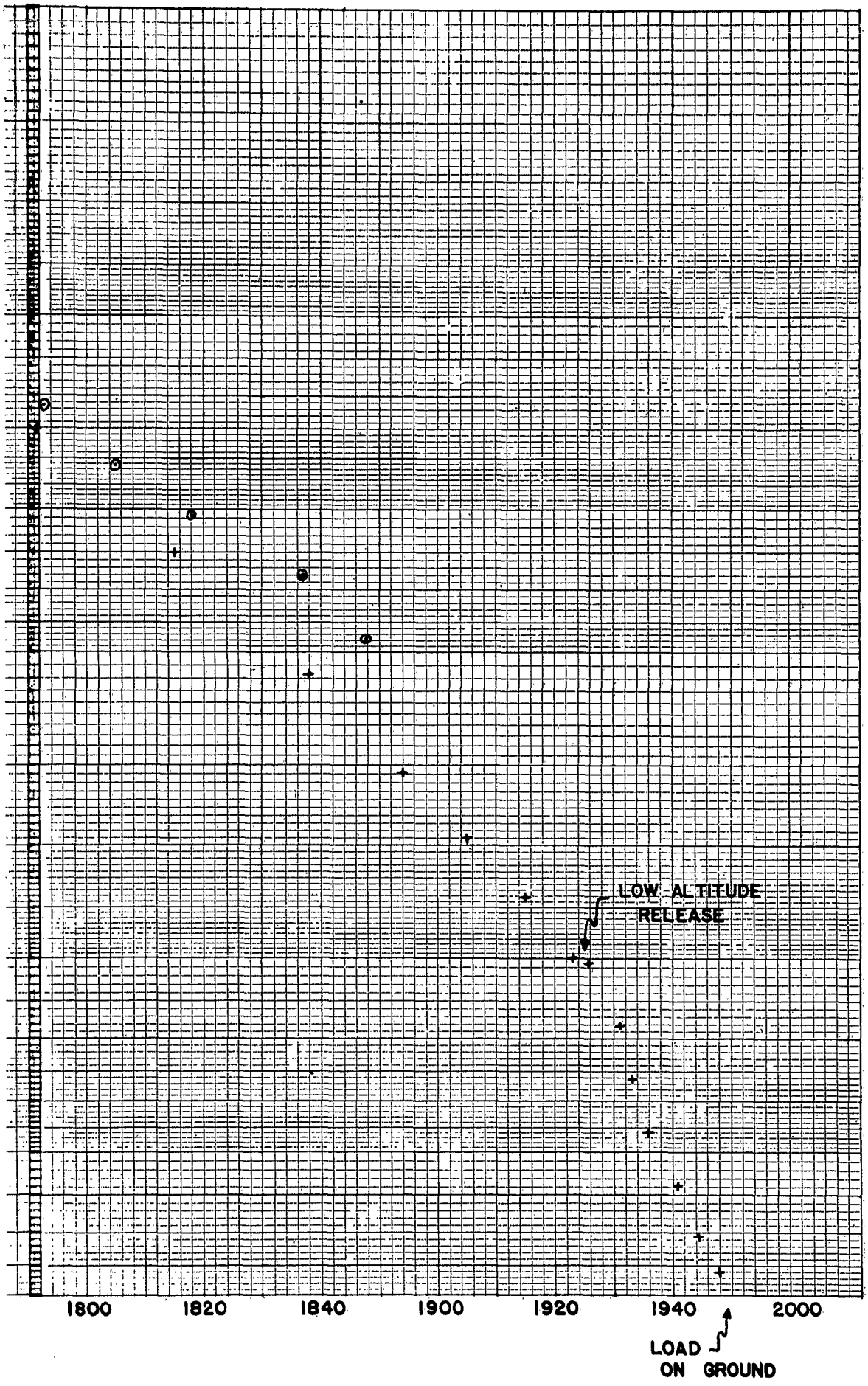

SIGNAL LOST DUE TO STRONG FAST FADEING.
10
20
30
40
50
60
70
80
90
100
100
90
80
70
60
50
40
30
20
10
0
ALTITUDE IN THOUSANDS OF FEET
0500
0520
0540
0600
0620
0640
0700
0720
0740


0800
0820
0840
0900
0920
0940
1000
1020
1040


1040
1100
1120
1140
1200
1220
1240
1300
1320
13

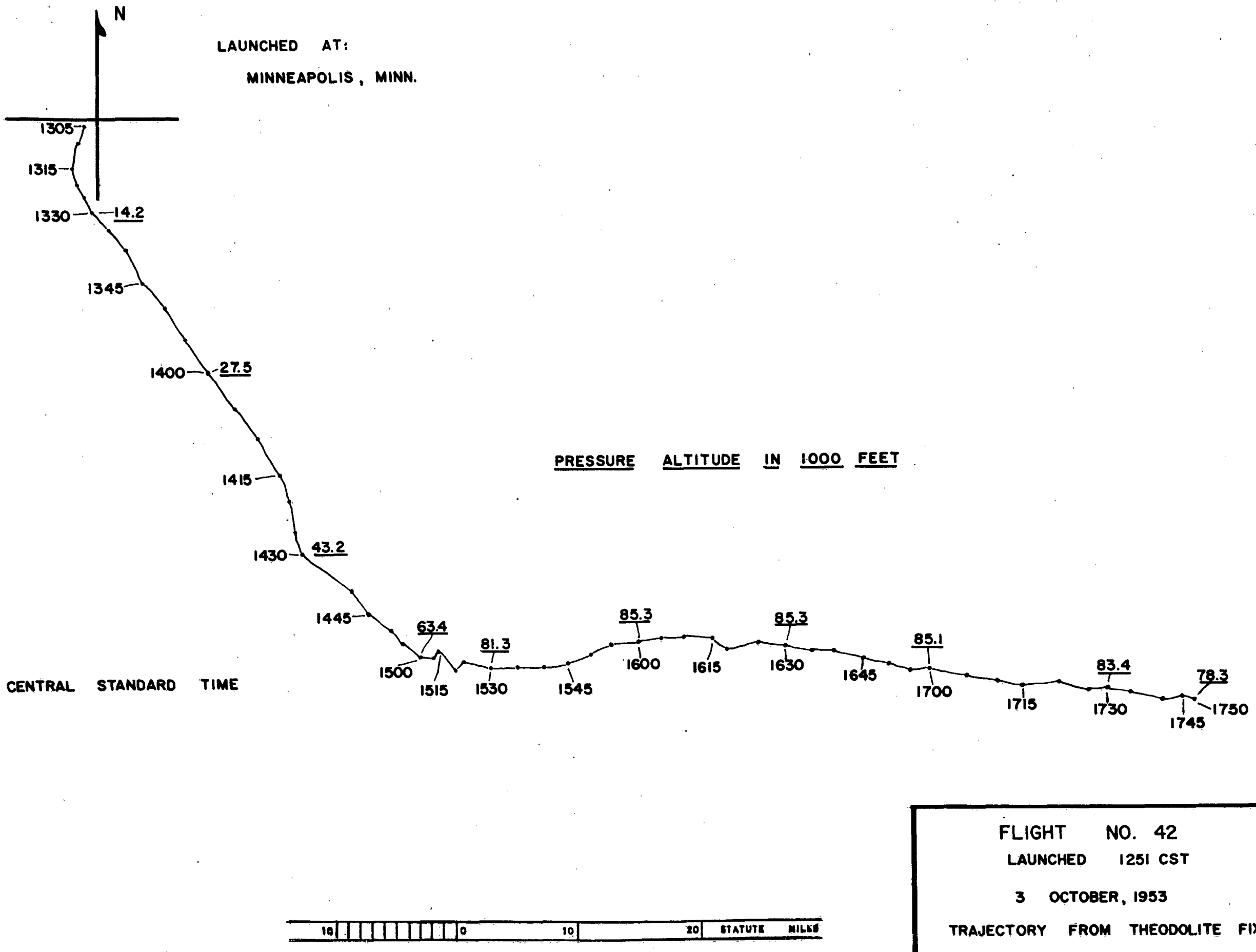

TELEMETER
FROM THIS
AT LANSI
1320
1340
1400
1420
1440
1500
1520
1540
1600


TELEMETER READINGS
FROM THIS POINT ON TAKEN
AT LANSING, MICHIGAN
372 FT/MIN.
(35 TO 50 mb.)
1520
1540
1600
1620
1640
1700
1720
1740
1800


LOW ALTITUDE
RELEASE
1800
1820
1840
1900
1920
1940
2000
LOAD
ON GROUND

CONFIDENTIAL SECURITY INFORMATION

CONFIDENTIAL

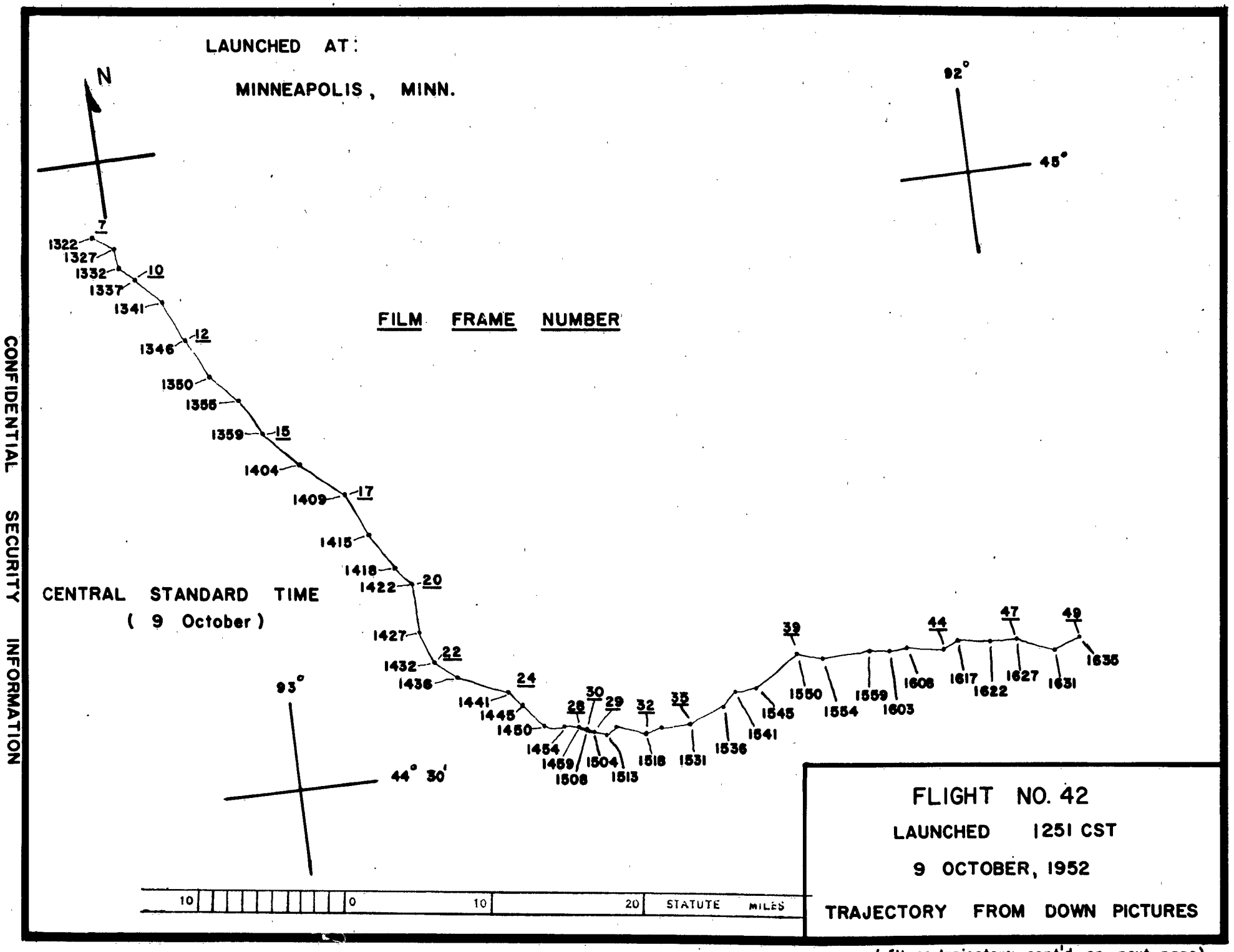


FLIGHT NO. 42

LAUNCHED 1251 CST

3 OCTOBER, 1953

TRAJECTORY FROM THEODOLITE FIXES



FLIGHT NO. 42

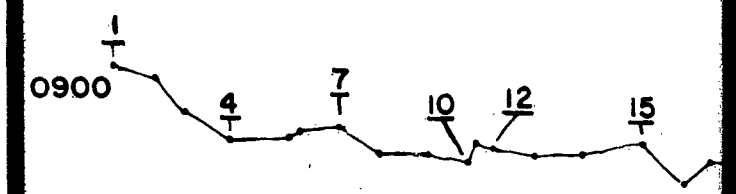
LAUNCHED 1251 CST

9 OCTOBER, 1952

TRAJECTORY FROM DOWN PICTURES

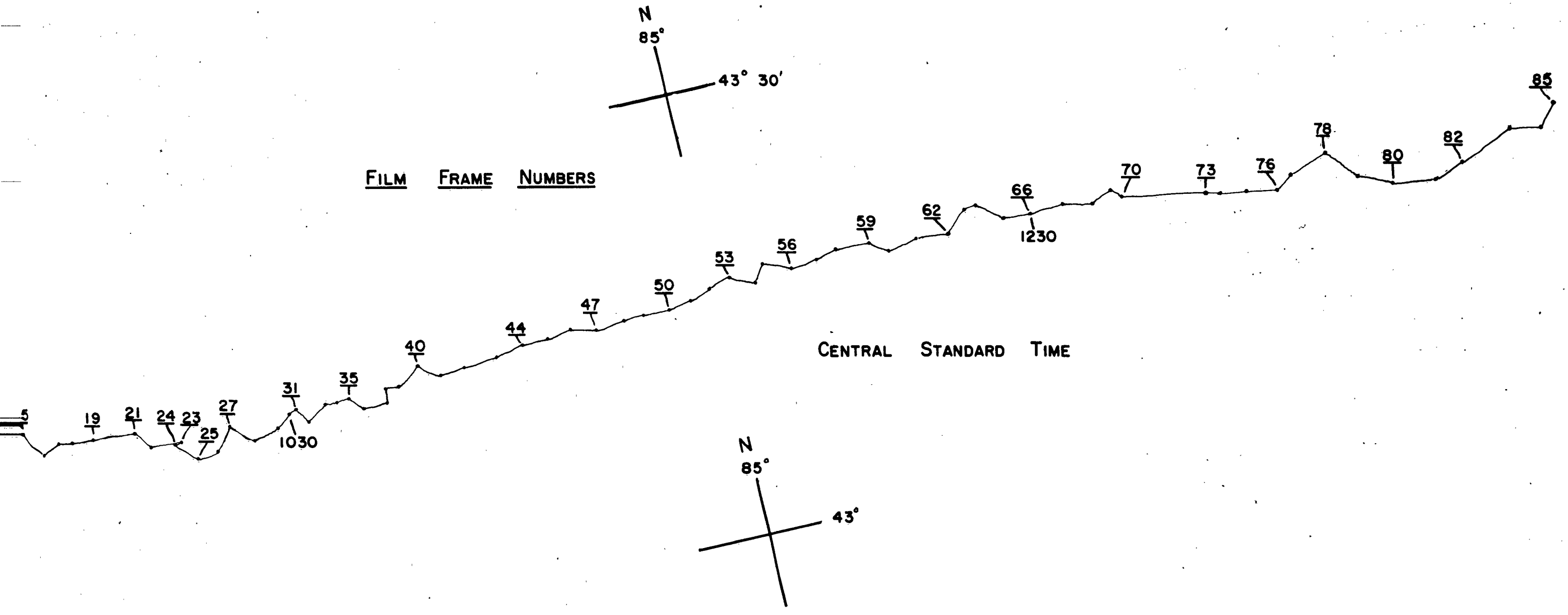
(flt. 42 trajectory cont'd on next page)

TRAJECTORY OF
10 OCTOBER



(CONT'D FROM PREVIOUS PAGE)

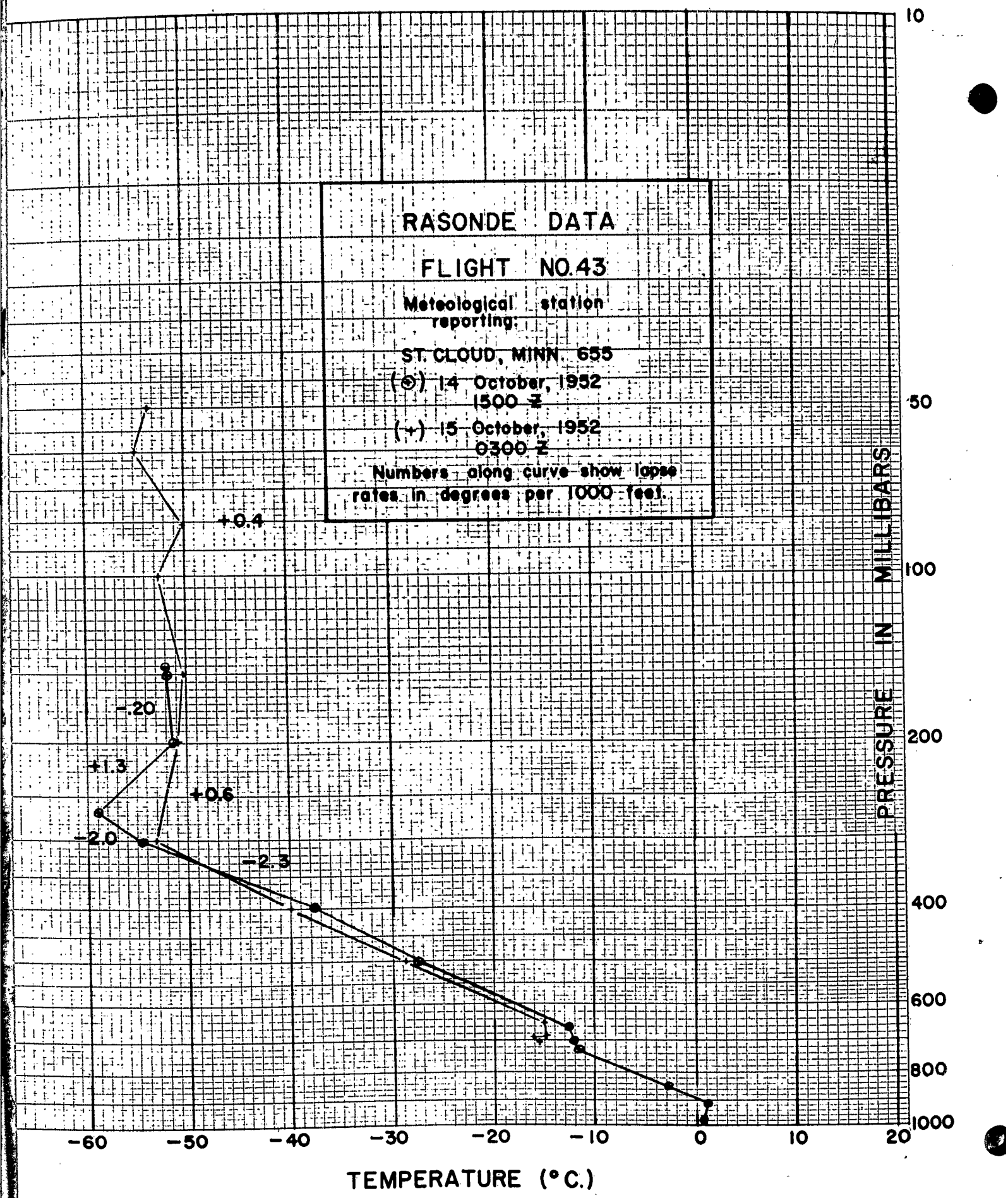
CONFIDENTIAL SECURITY INFORMATION

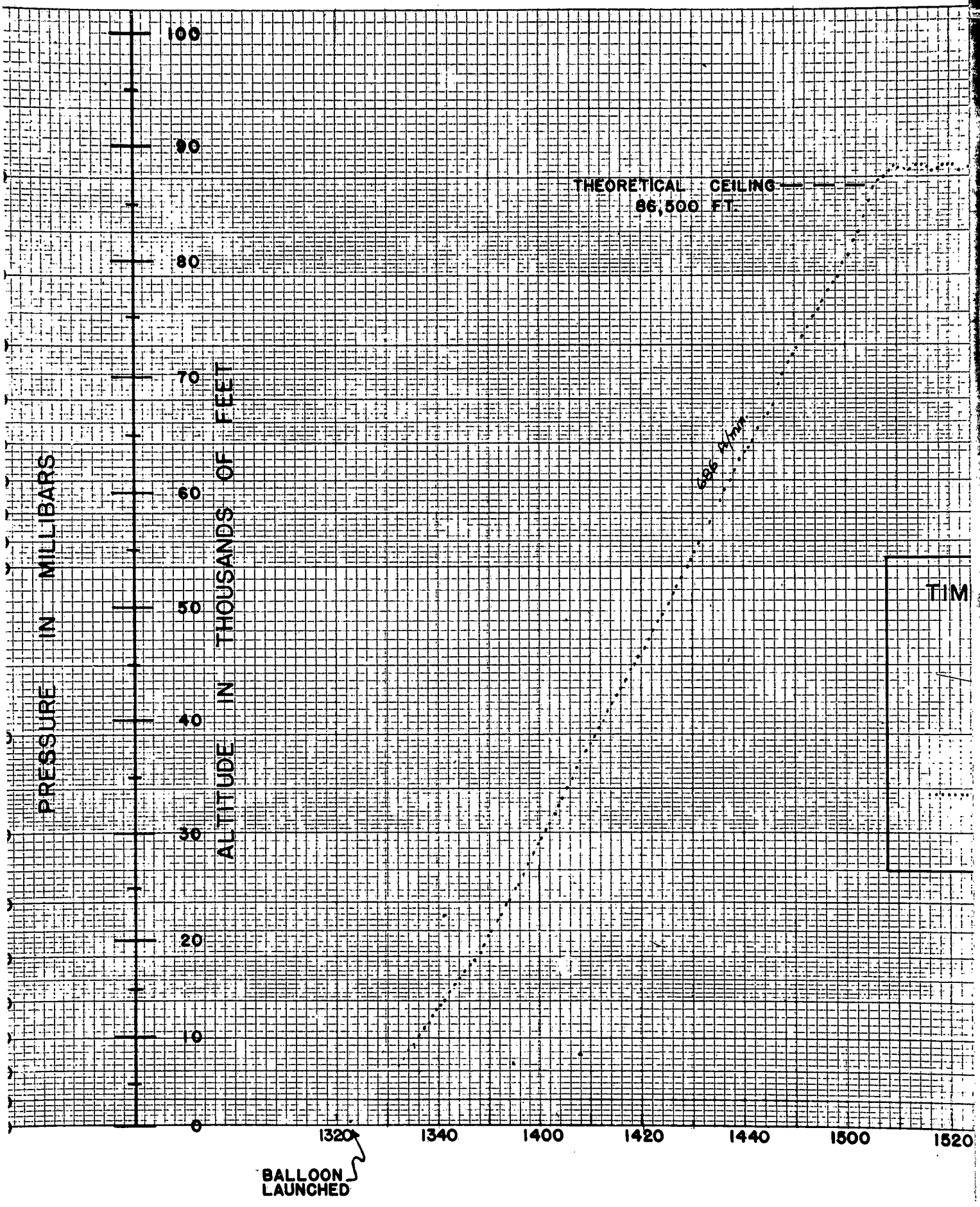


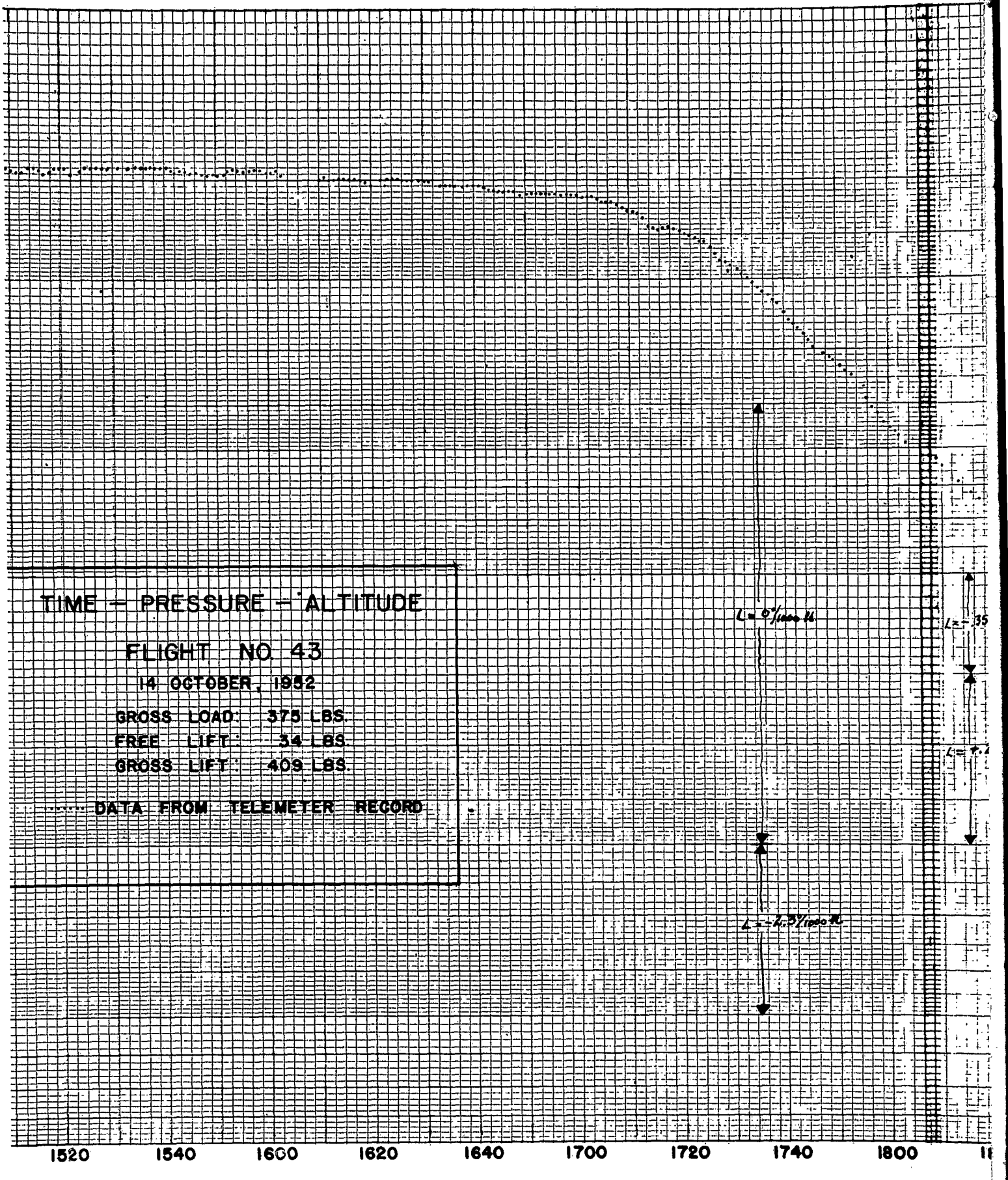
FLIGHT NO. 42

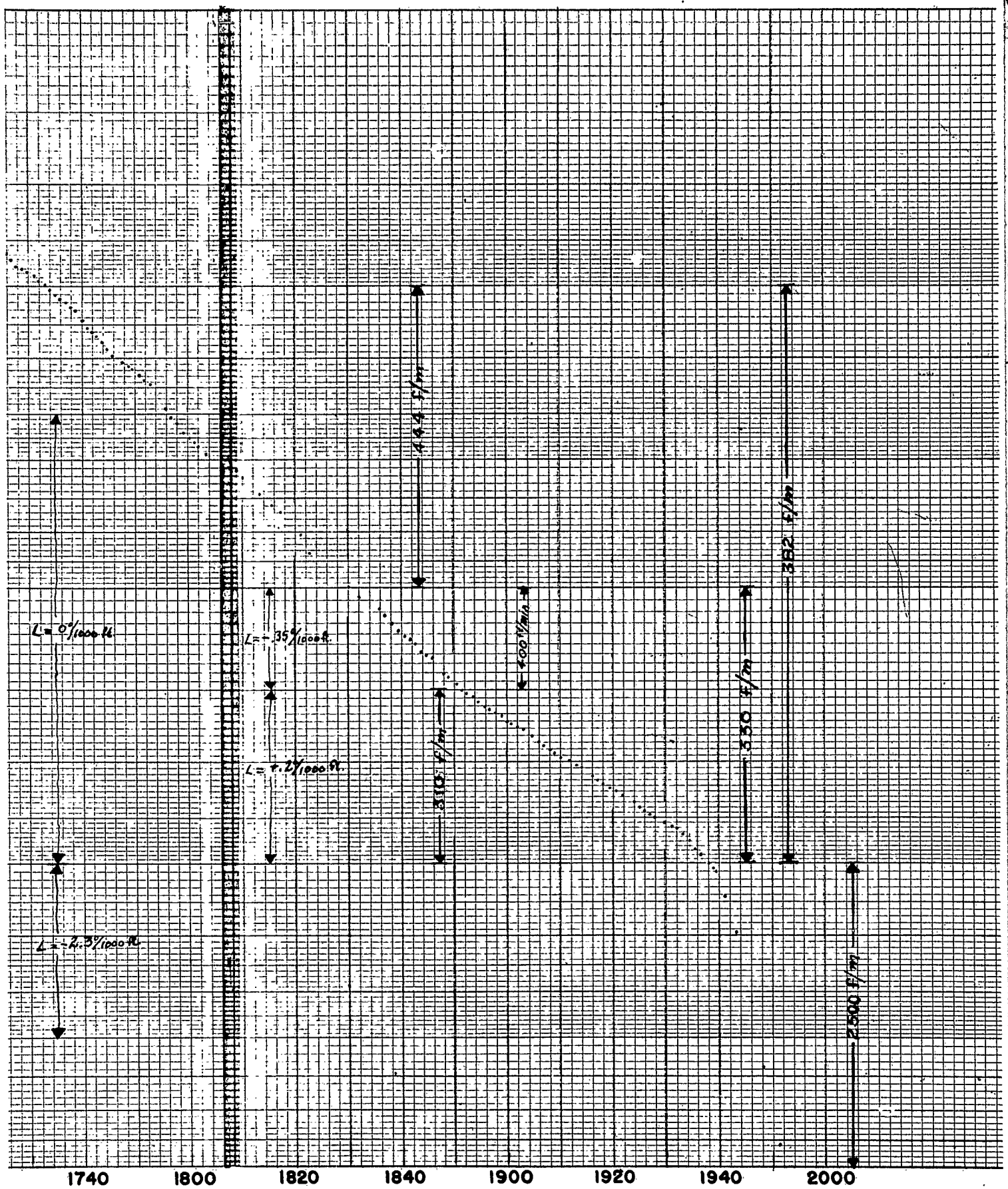
10 OCTOBER, 1952

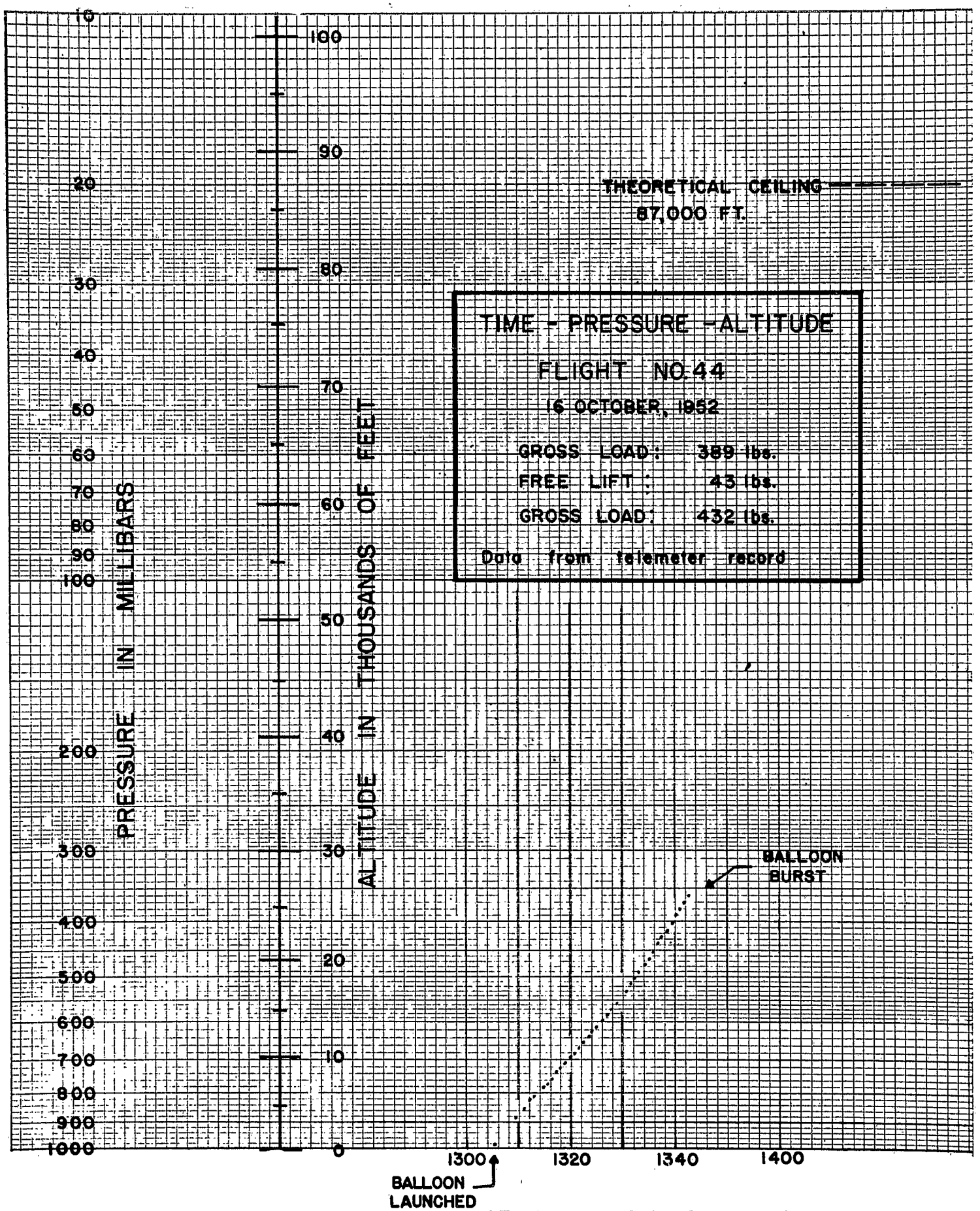
TRACTORY FROM DOWN PICTURES TAKEN DURING SECOND DAY OF FLIGHT.

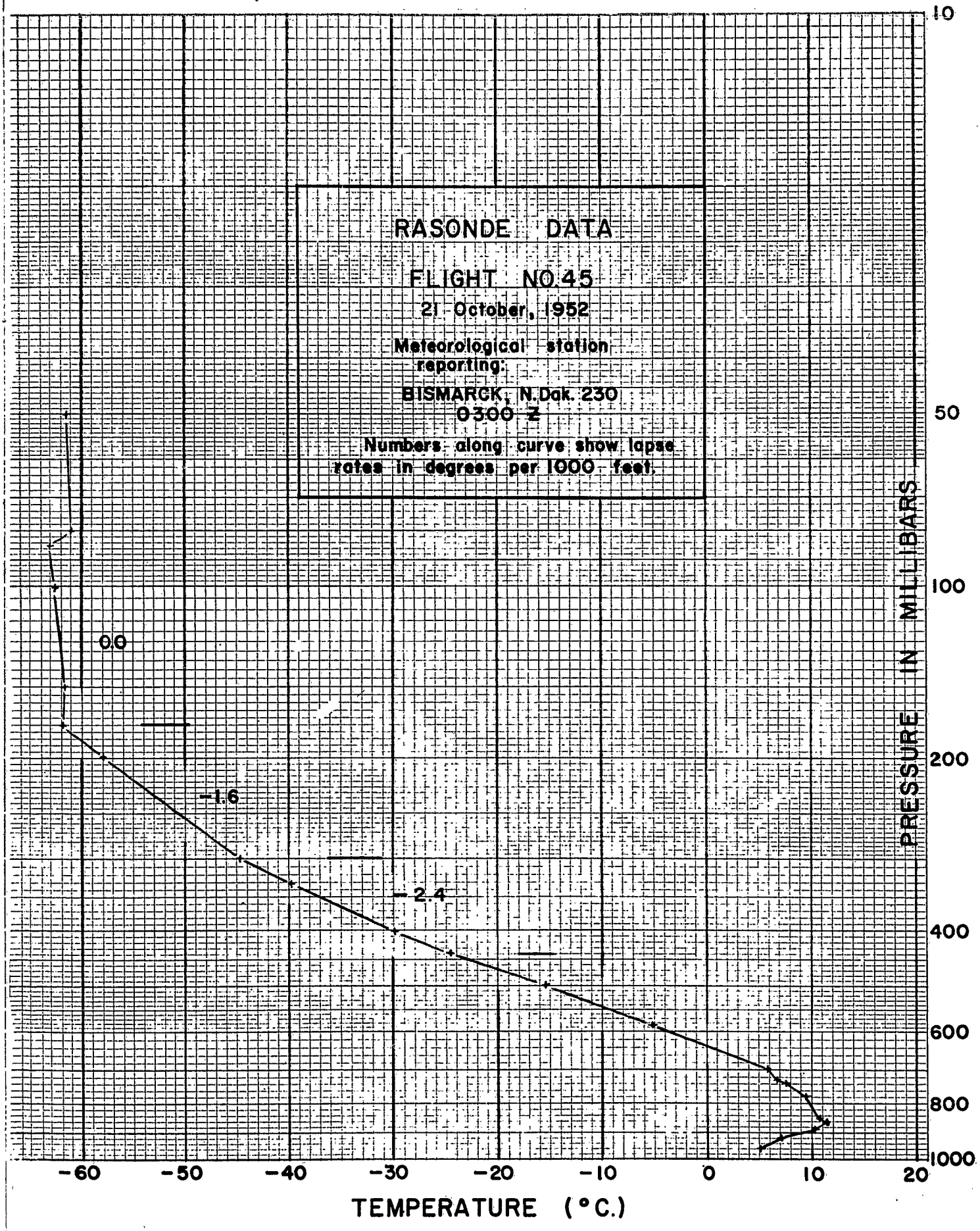

RASONDE DATA
FLIGHT NO.43
Meteological station reporting:
ST. CLOUD, MINN. 655
(⊙) 14 October, 1952
1500 Z
(+) 15 October, 1952
0300 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
+0.4
-.20
+1.3
+0.6
-2.0
-2.3
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

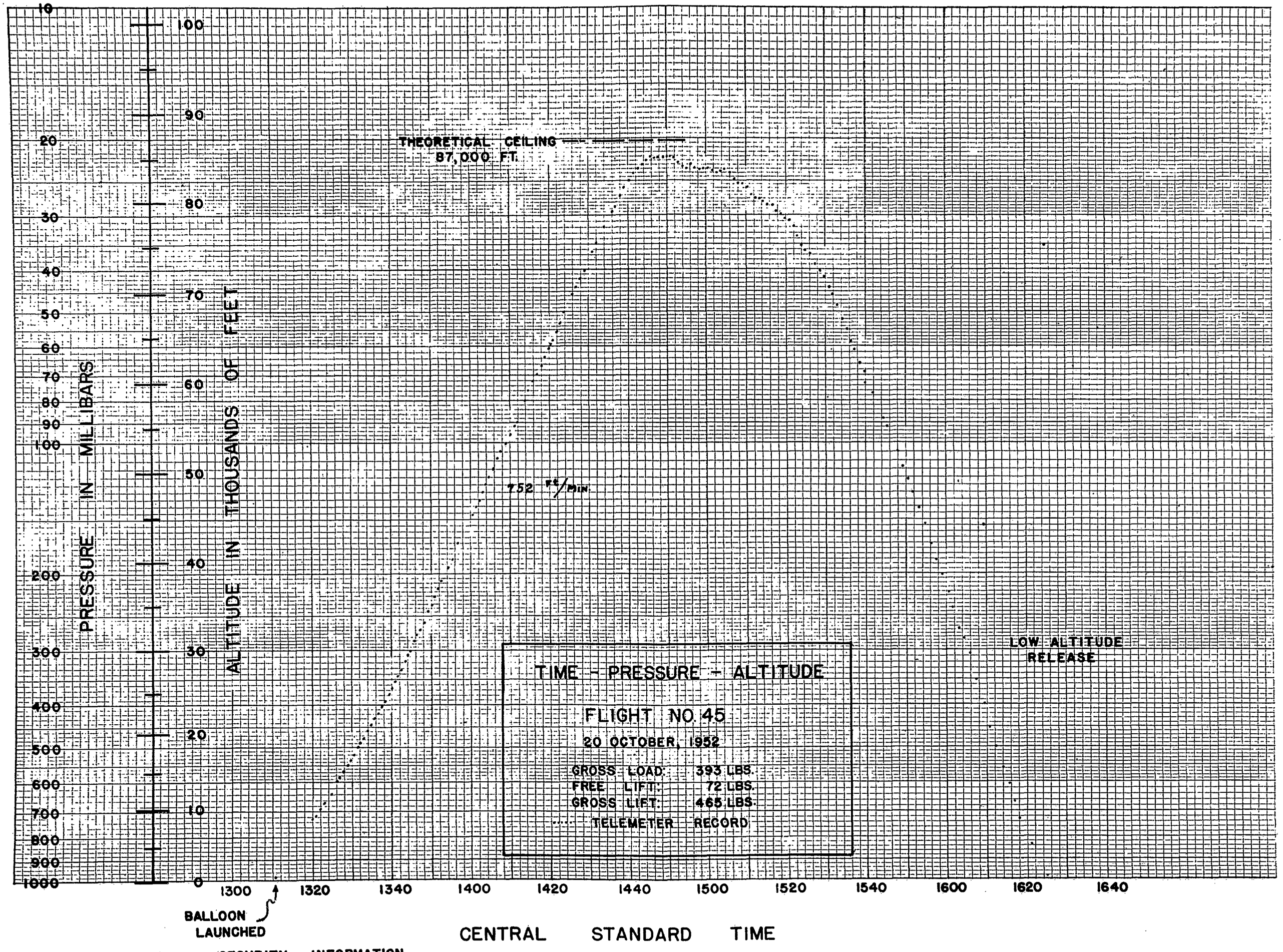

100
90
80
70
60
50
40
30
20
10
0
PRESSURE IN MILLIBARS
ALTITUDE IN THOUSANDS OF FEET
THEORETICAL CEILING
86,500 FT.
TIM
1320
1340
1400
1420
1440
1500
1520
BALLOON LAUNCHED


TIME – PRESSURE – ALTITUDE
FLIGHT NO. 43
14 OCTOBER, 1952
GROSS LOAD: 375 LBS.
FREE LIFT: 34 LBS.
GROSS LIFT: 409 LBS.
..... DATA FROM TELEMETER RECORD
L = 6'/1000 ft.
L = -2.3'/1000 ft.
1520
1540
1600
1620
1640
1700
1720
1740
1800
CENTRAL STANDARD TIME

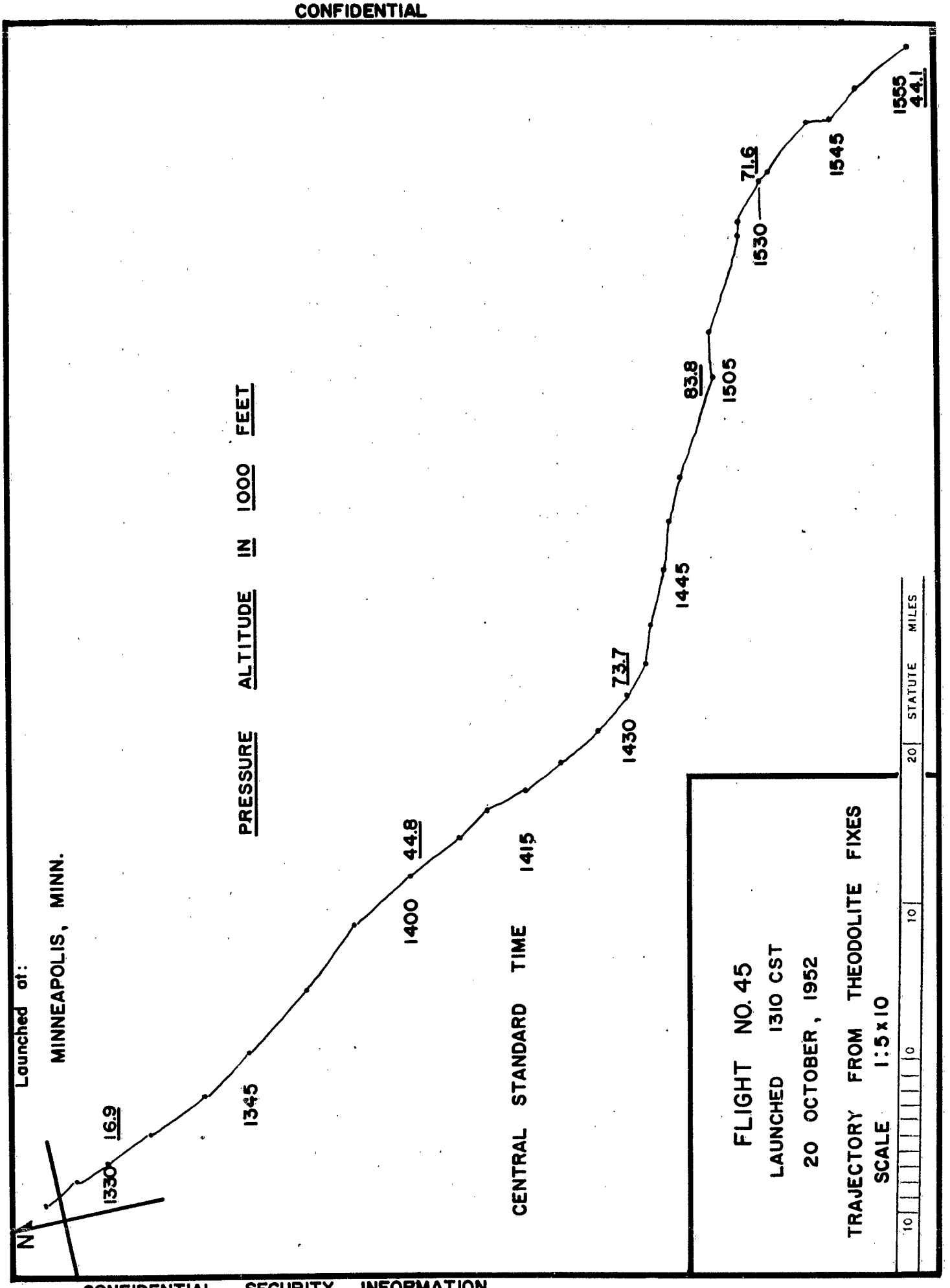

444 #/m
382 #/m
400 #/min
330 #/m
330 #/m
2500 #/m
L = 0°/1000 ft.
L = -.35°/1000 ft.
L = +.2°/1000 ft.
L = -2.3°/1000 ft.
1740
1800
1820
1840
1900
1920
1940
2000


TIME - PRESSURE - ALTITUDE
FLIGHT NO. 44
16 OCTOBER, 1952
GROSS LOAD: 389 lbs.
FREE LIFT: 43 lbs.
GROSS LOAD: 432 lbs.
Data from telemeter record
THEORETICAL CEILING
87,000 FT.
BALLOON BURST
BALLOON LAUNCHED
PRESSURE IN MILLIBARS
ALTITUDE IN THOUSANDS OF FEET
CENTRAL STANDARD TIME
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
100
90
80
70
60
50
40
30
20
10
0
1300
1320
1340
1400

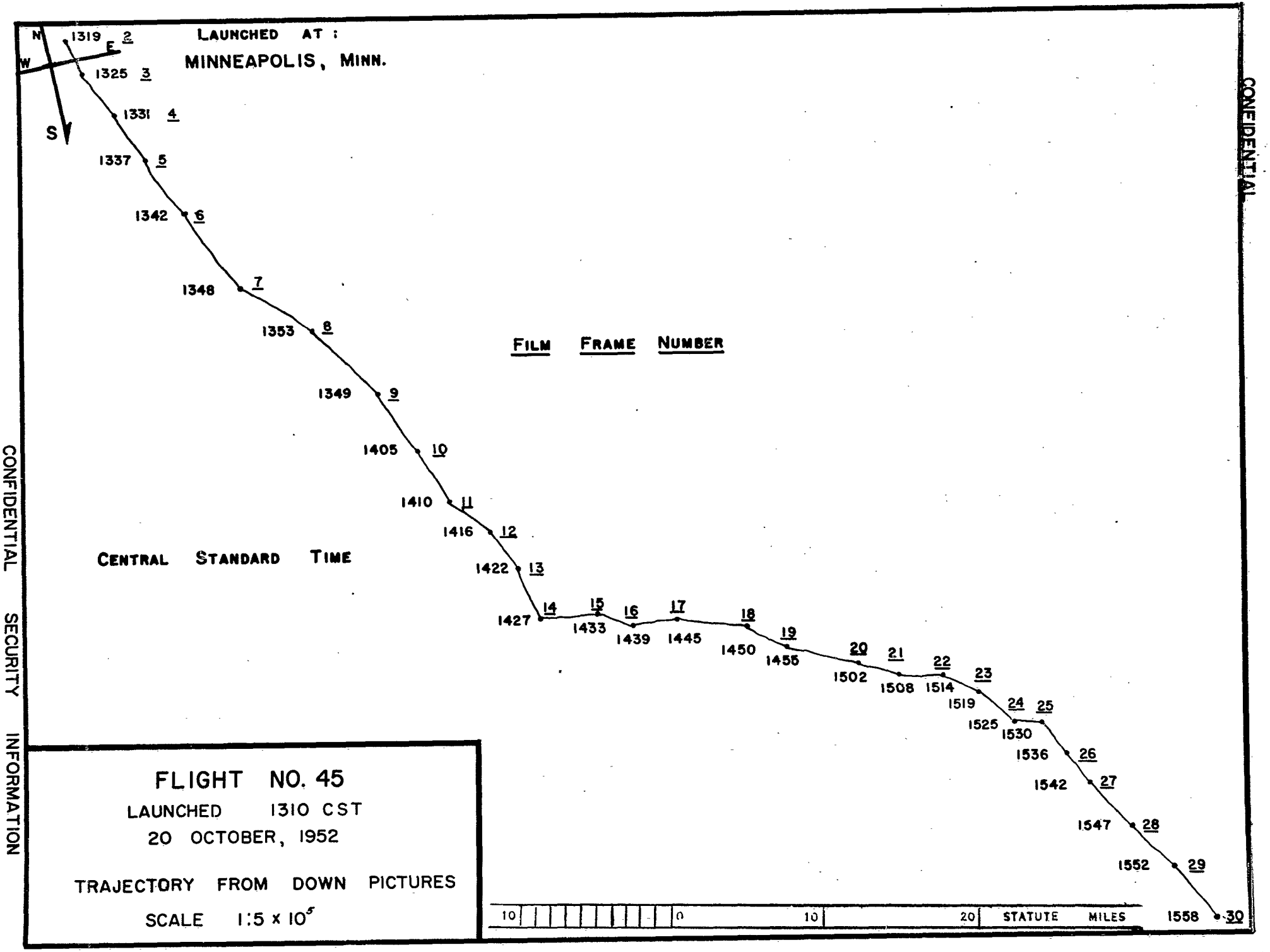

RASONDE DATA
FLIGHT NO.45
21 October, 1952
Meteorological station reporting:
BISMARCK, N.Dak. 230
0300 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
0.0
-1.6
-2.4
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)


PRESSURE IN MILLIBARS
ALTITUDE IN THOUSANDS OF FEET
10
100
90
20
80
30
40
70
50
60
70
60
80
90
100
50
200
40
300
30
400
20
500
600
10
700
800
900
1000
0
THEORETICAL CEILING
87,000 FT.
752 FT/MIN.
LOW ALTITUDE
RELEASE
TIME - PRESSURE - ALTITUDE
FLIGHT NO. 45
20 OCTOBER, 1952
GROSS LOAD: 393 LBS.
FREE LIFT: 72 LBS.
GROSS LIFT: 465 LBS.
TELEMETER RECORD
1300
1320
1340
1400
1420
1440
1500
1520
1540
1600
1620
1640
BALLOON LAUNCHED
CENTRAL STANDARD TIME

CONFIDENTIAL



CONFIDENTIAL SECURITY INFORMATION



FLIGHT NO. 45

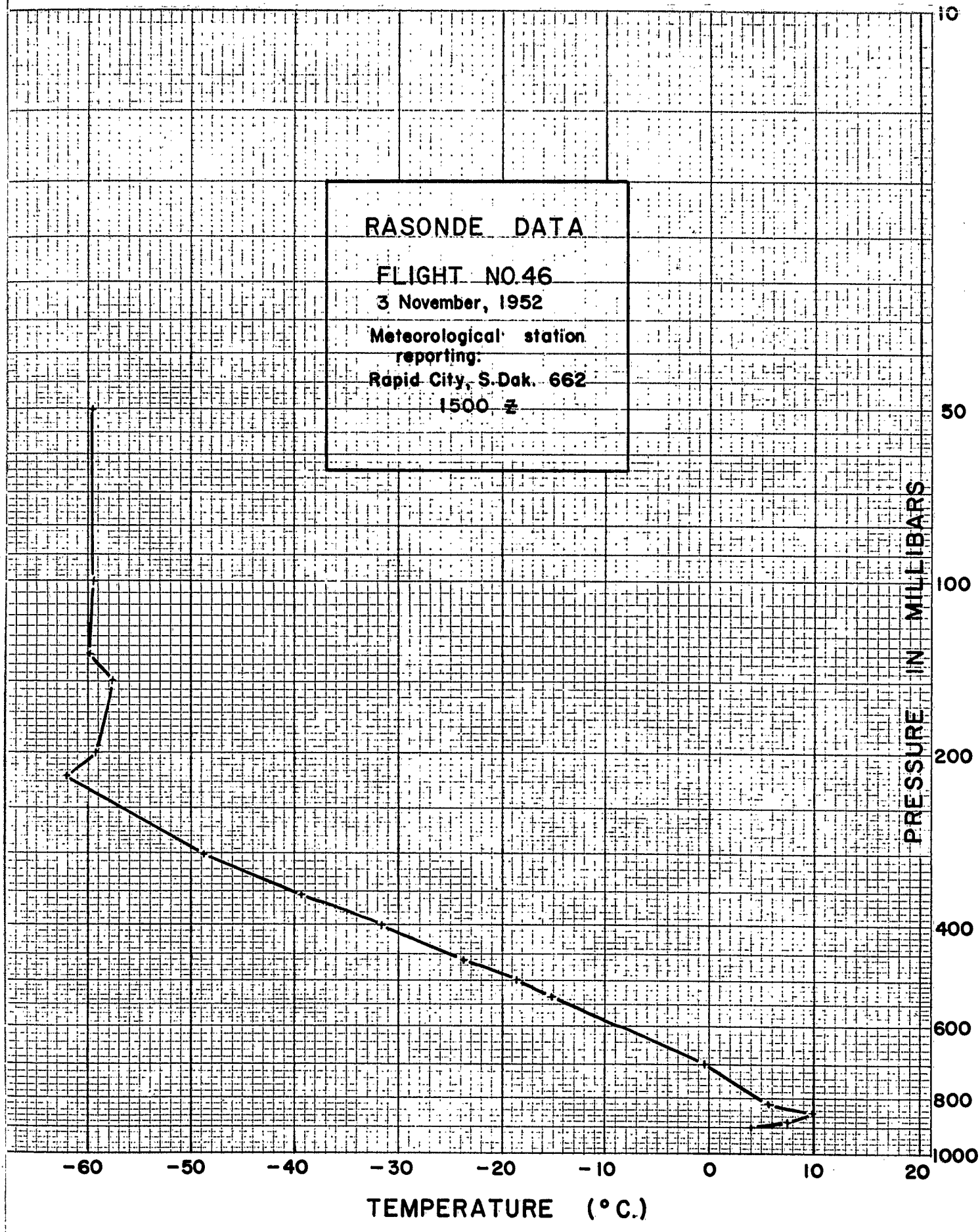
LAUNCHED 1310 CST

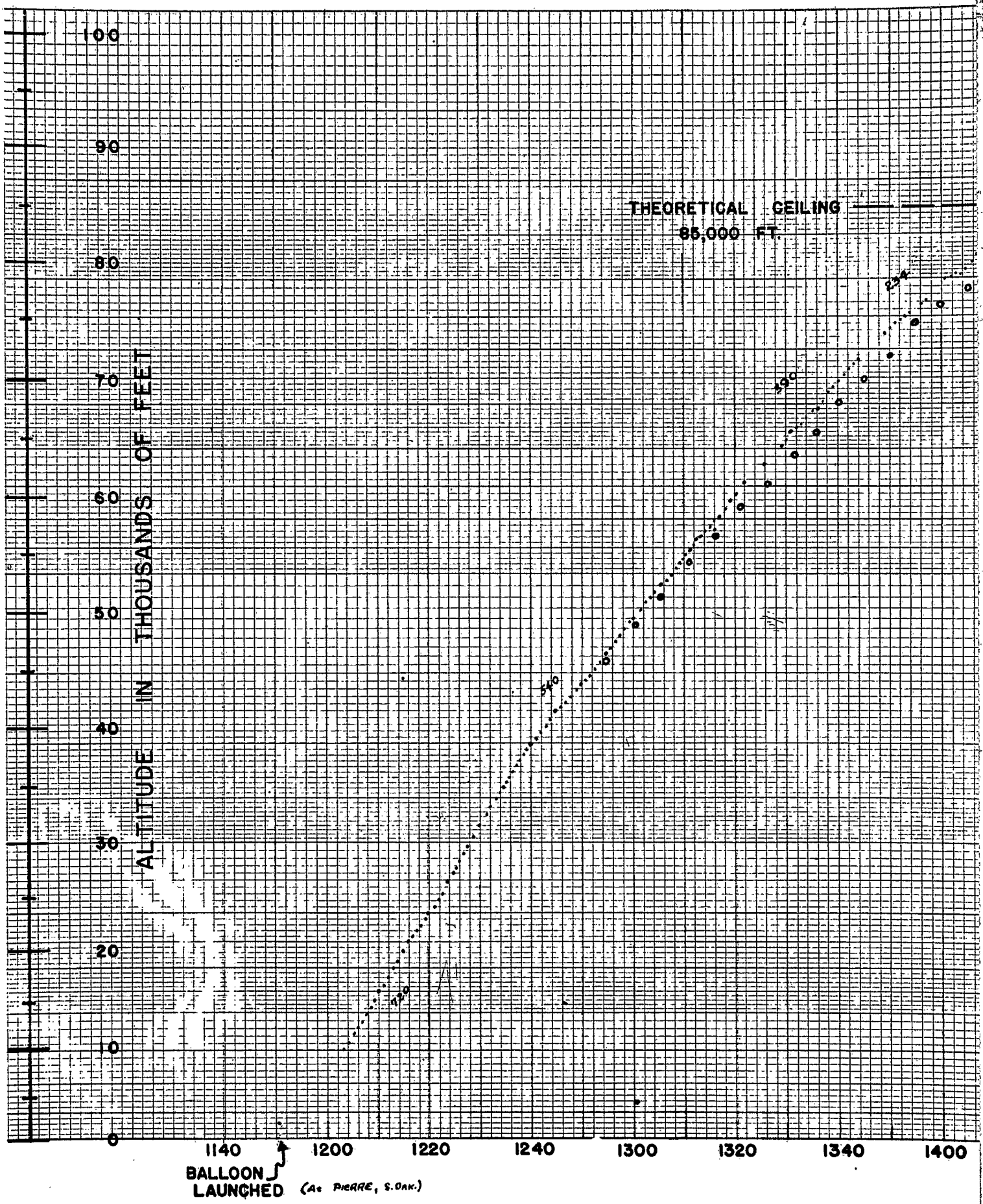
20 OCTOBER, 1952

TRAJECTORY FROM DOWN PICTURES

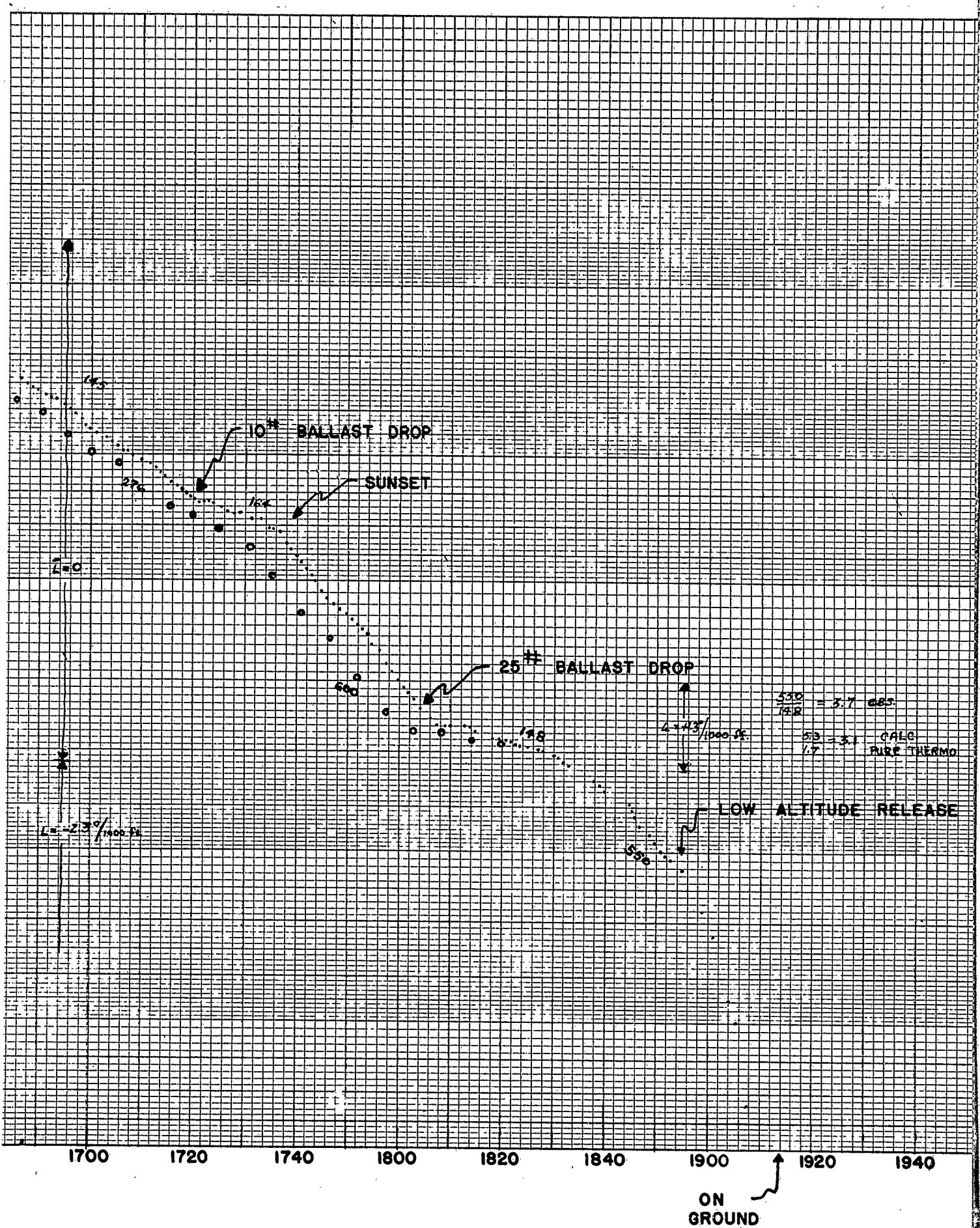
SCALE 1:5 x 10^5

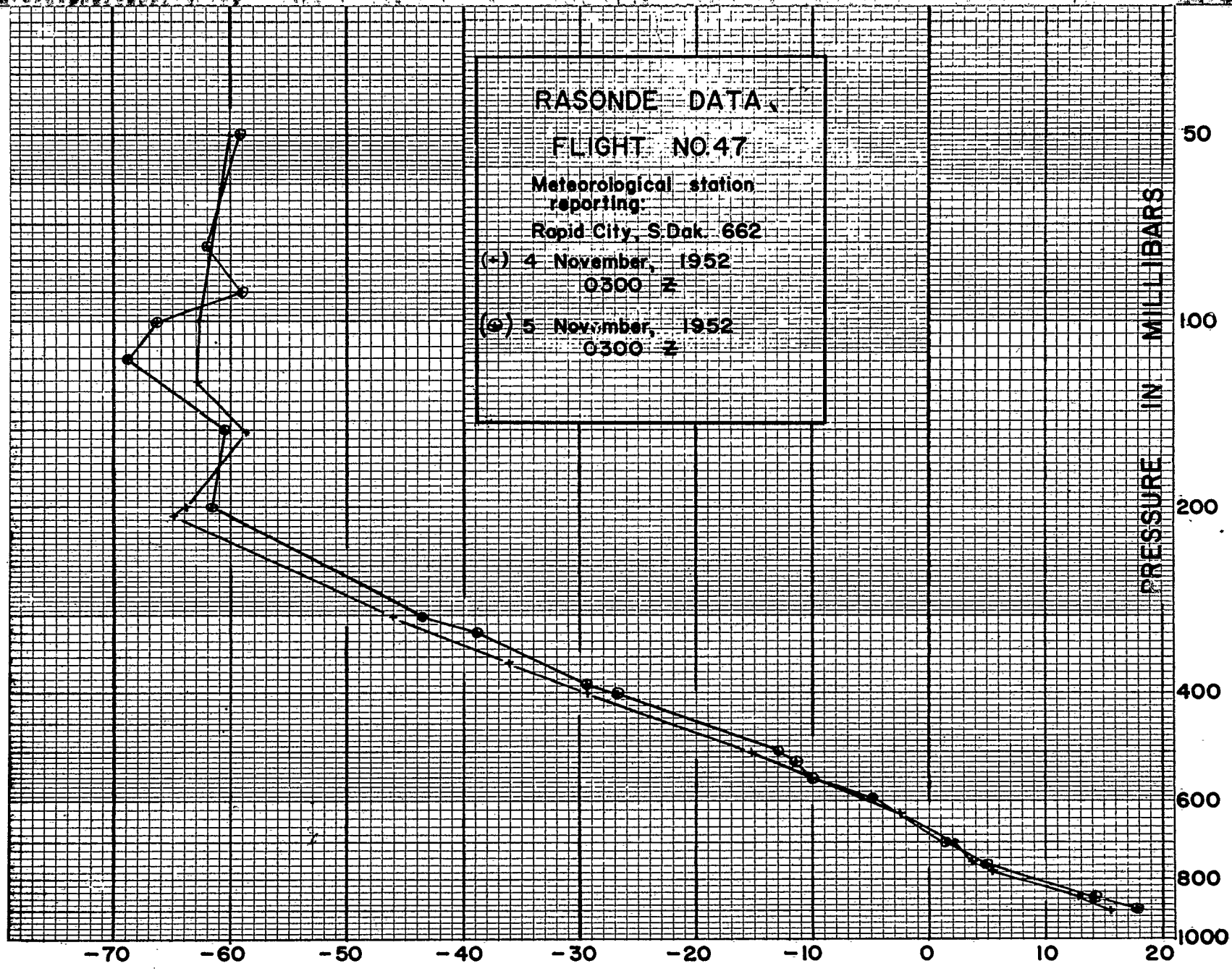
CONFIDENTIAL


RASONDE DATA
FLIGHT NO.46
3 November, 1952
Meteorological station reporting:
Rapid City, S.Dak. 662
1500 Z
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

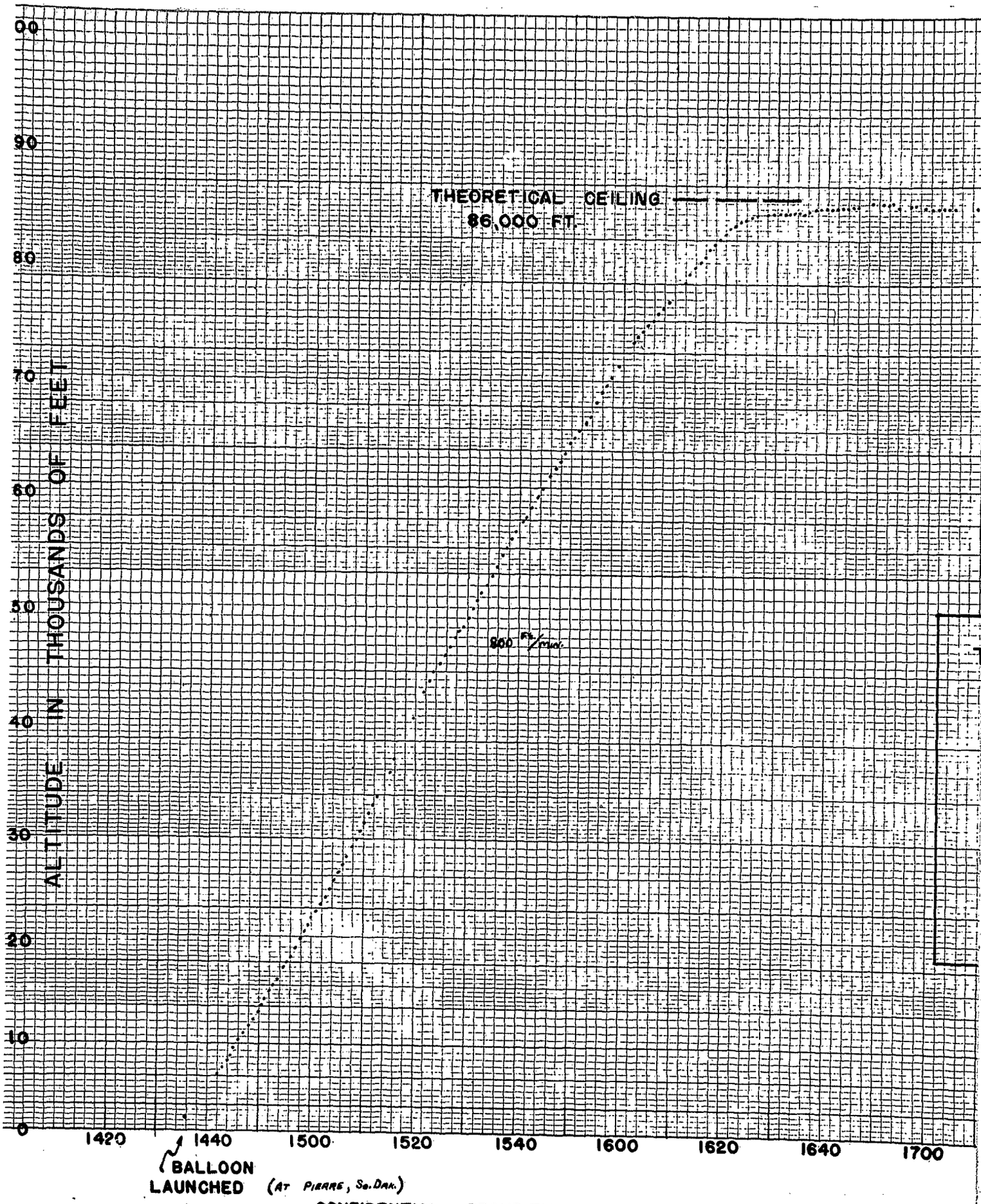


CONFIDENTIAL SECURITY INFORMATION

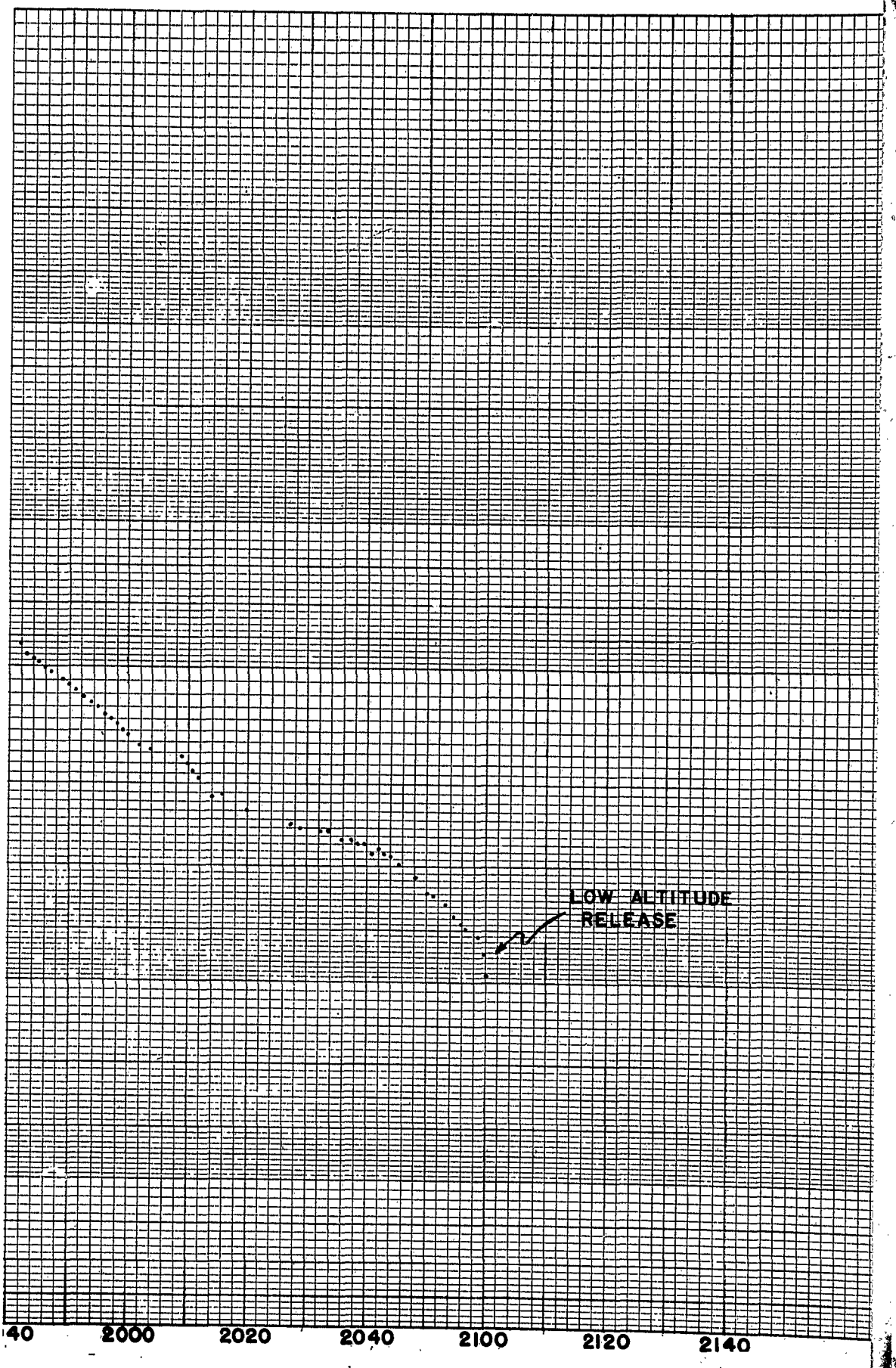

10# BALLAST DROP
SUNSET
25# BALLAST DROP
LOW ALTITUDE RELEASE
ON GROUND
1700
1720
1740
1800
1820
1840
1900
1920
1940



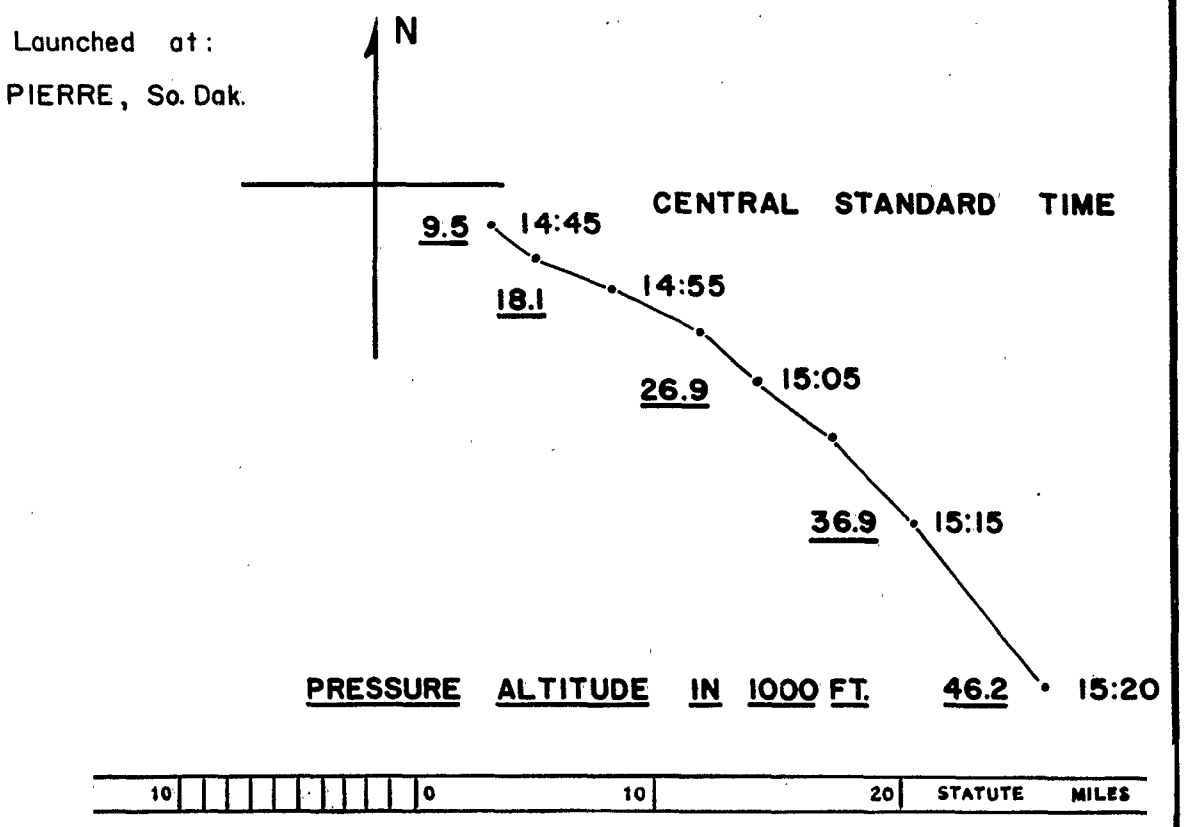
Confidential Security Information



CONFIDENTIAL SECURITY INFORMATION


LOW ALTITUDE
RELEASE
2000
2020
2040
2100
2120
2140

CONFIDENTIAL



FLIGHT NO. 47

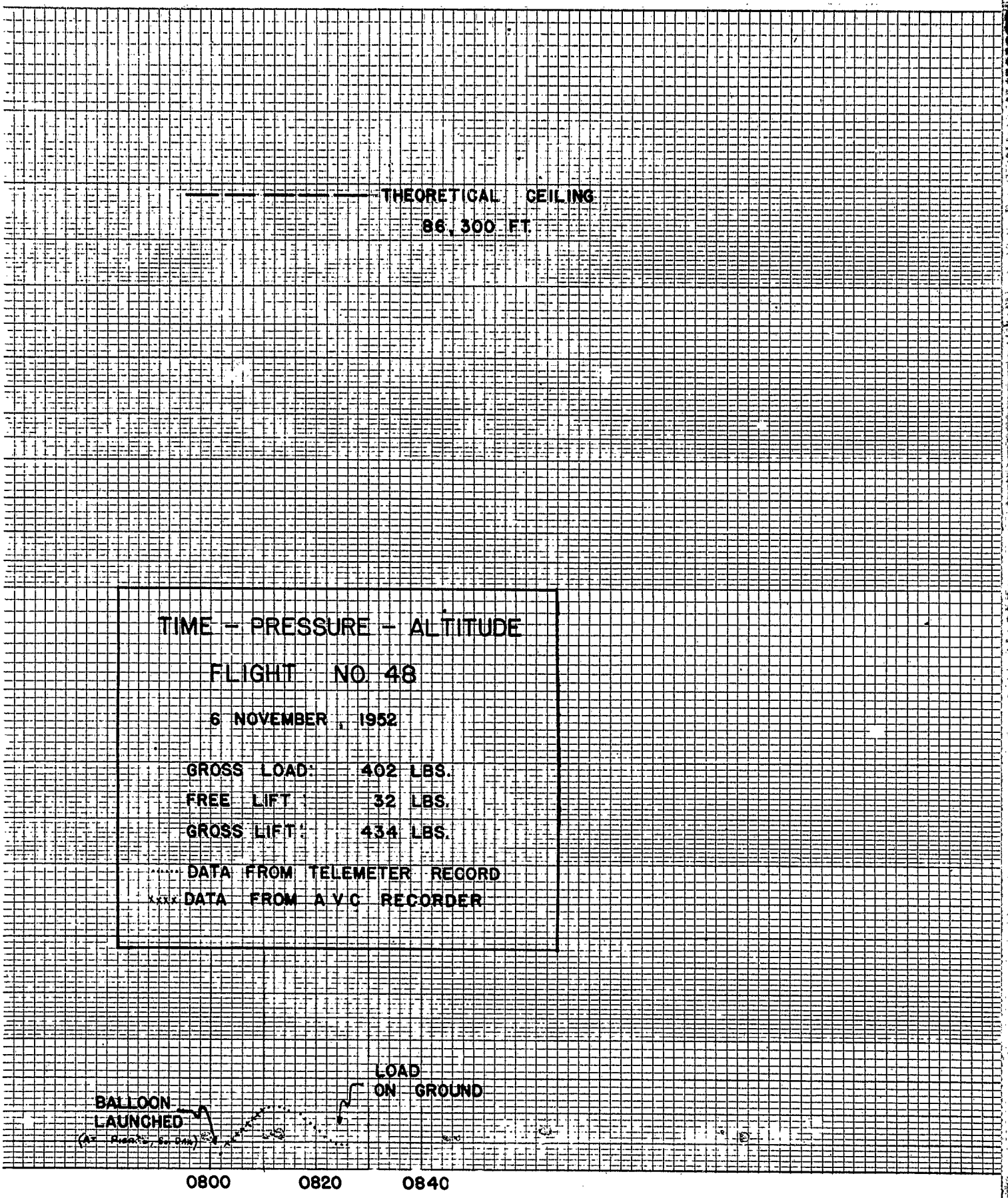
LAUNCHED FROM PIERRE, S.D.
at 1436 C.S.T.

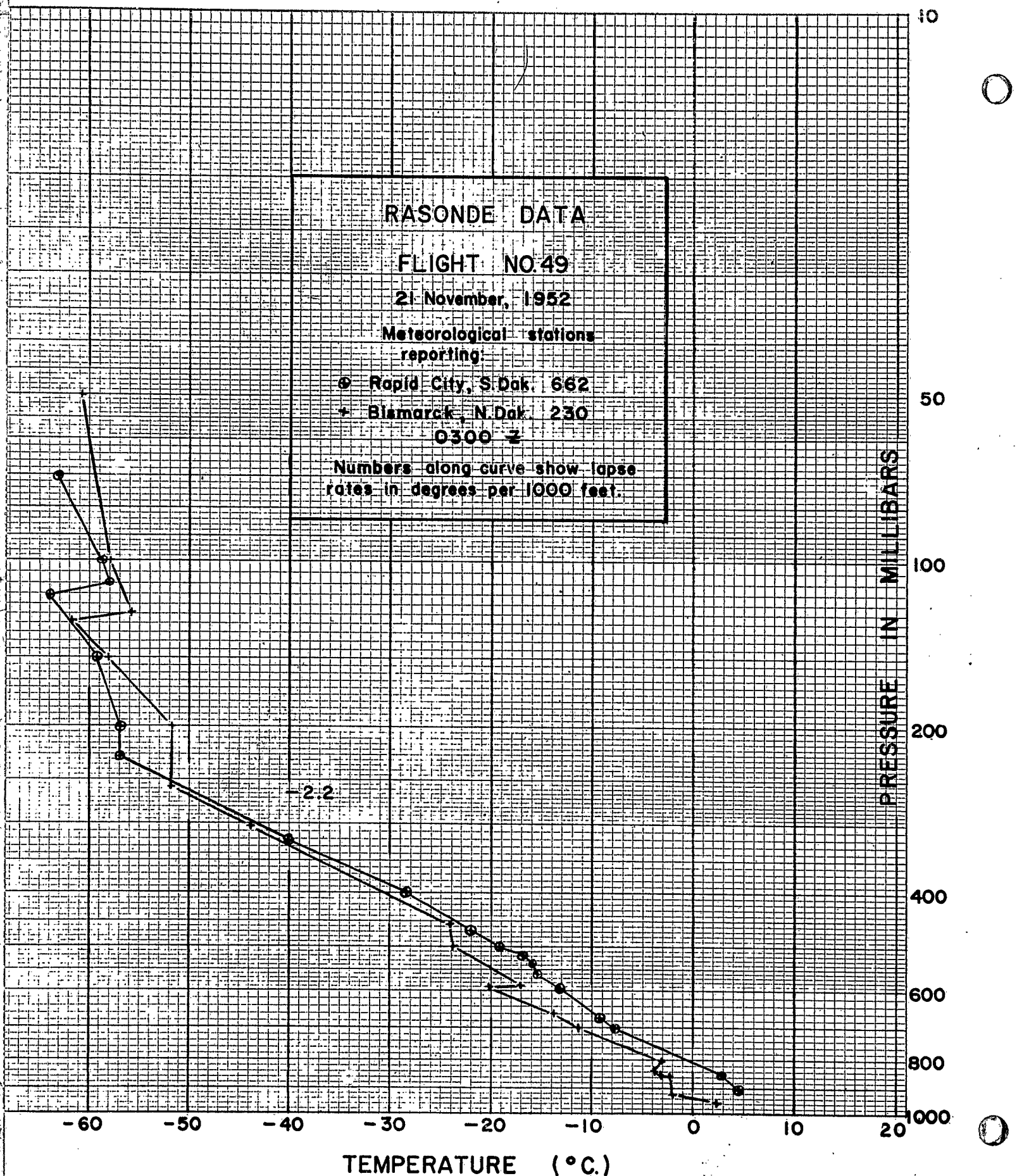
4 NOVEMBER, 1952

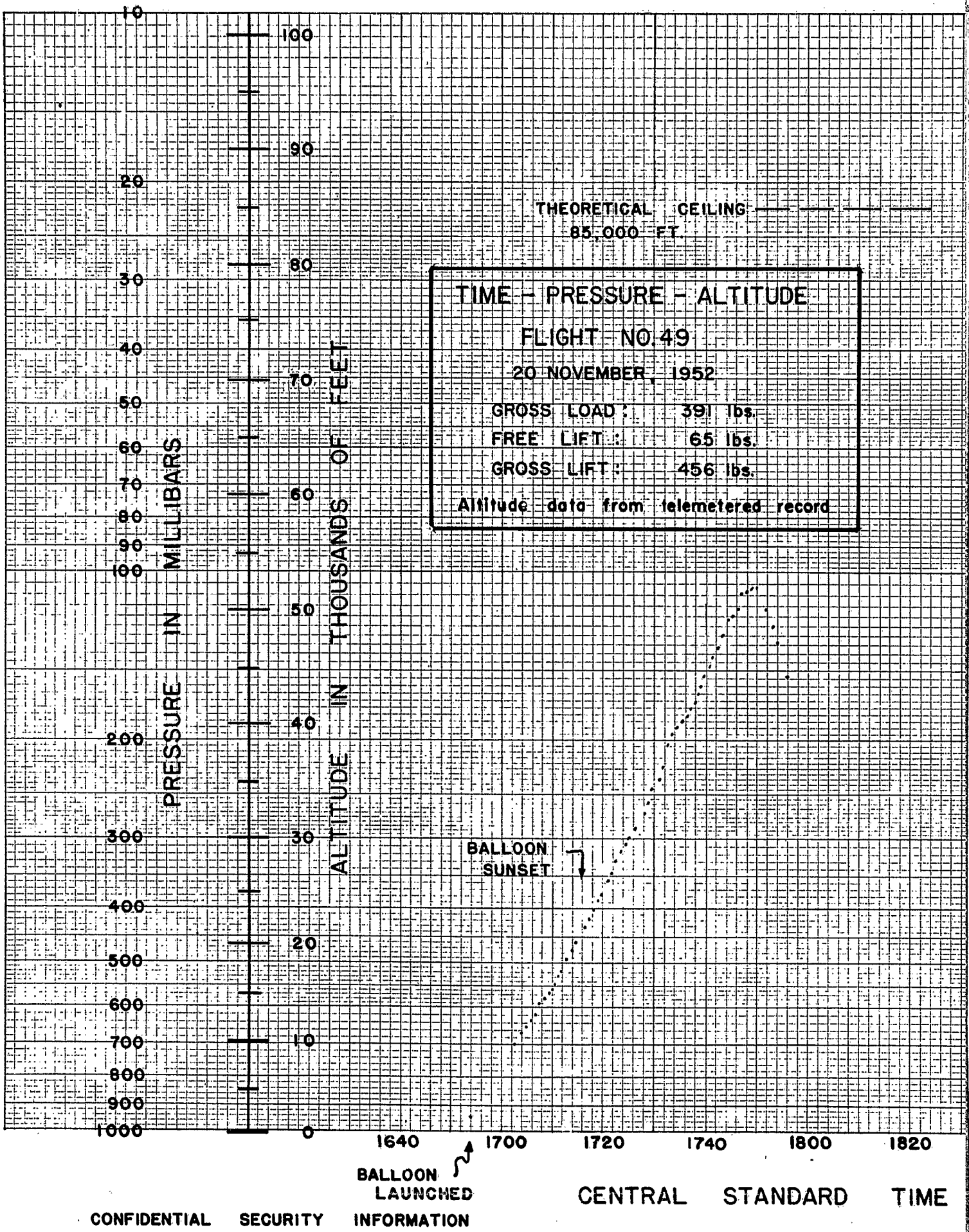
TRAJECTORY FROM THEODOLITE FIXES

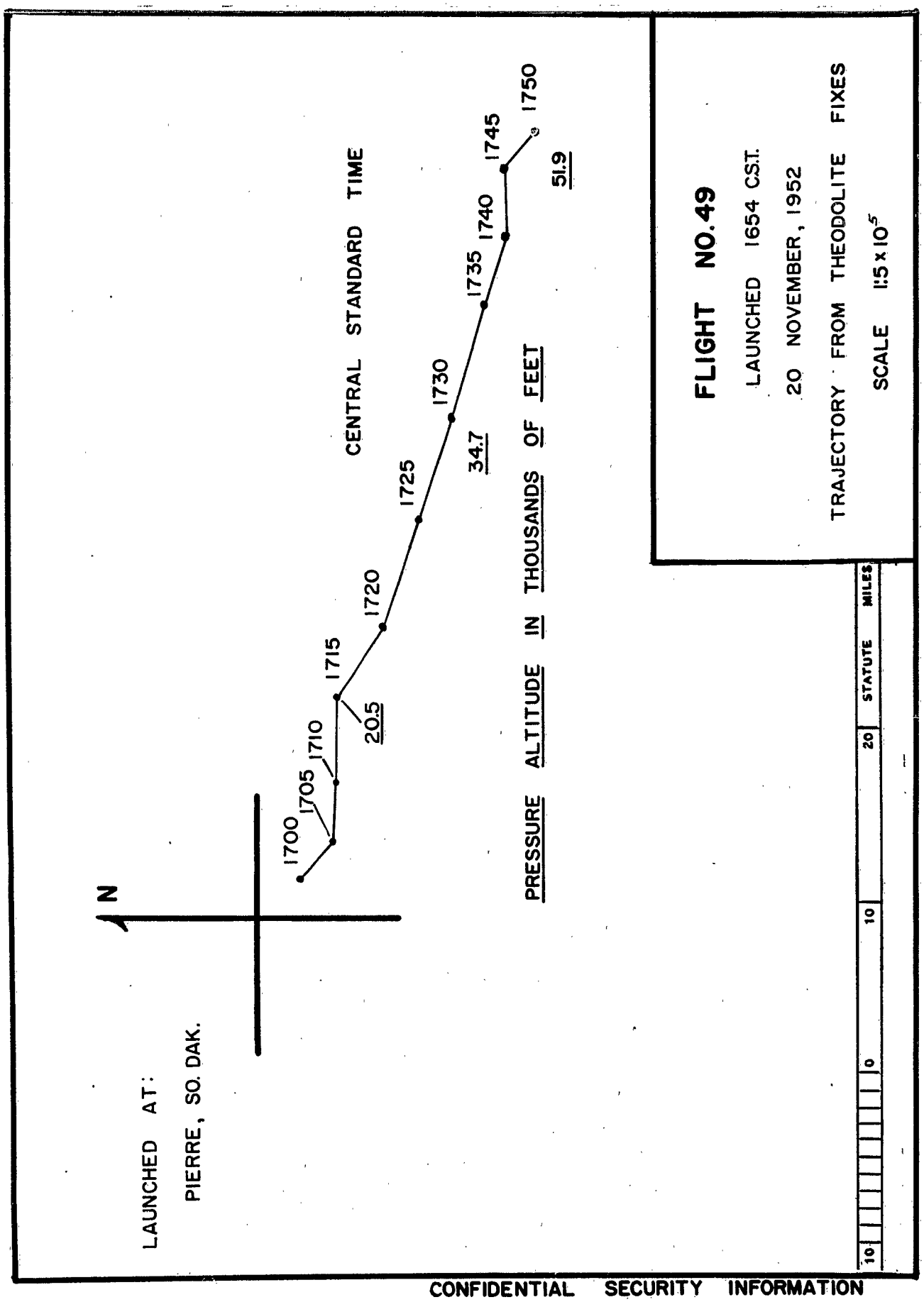
SCALE — $1:5 \times 10^5$

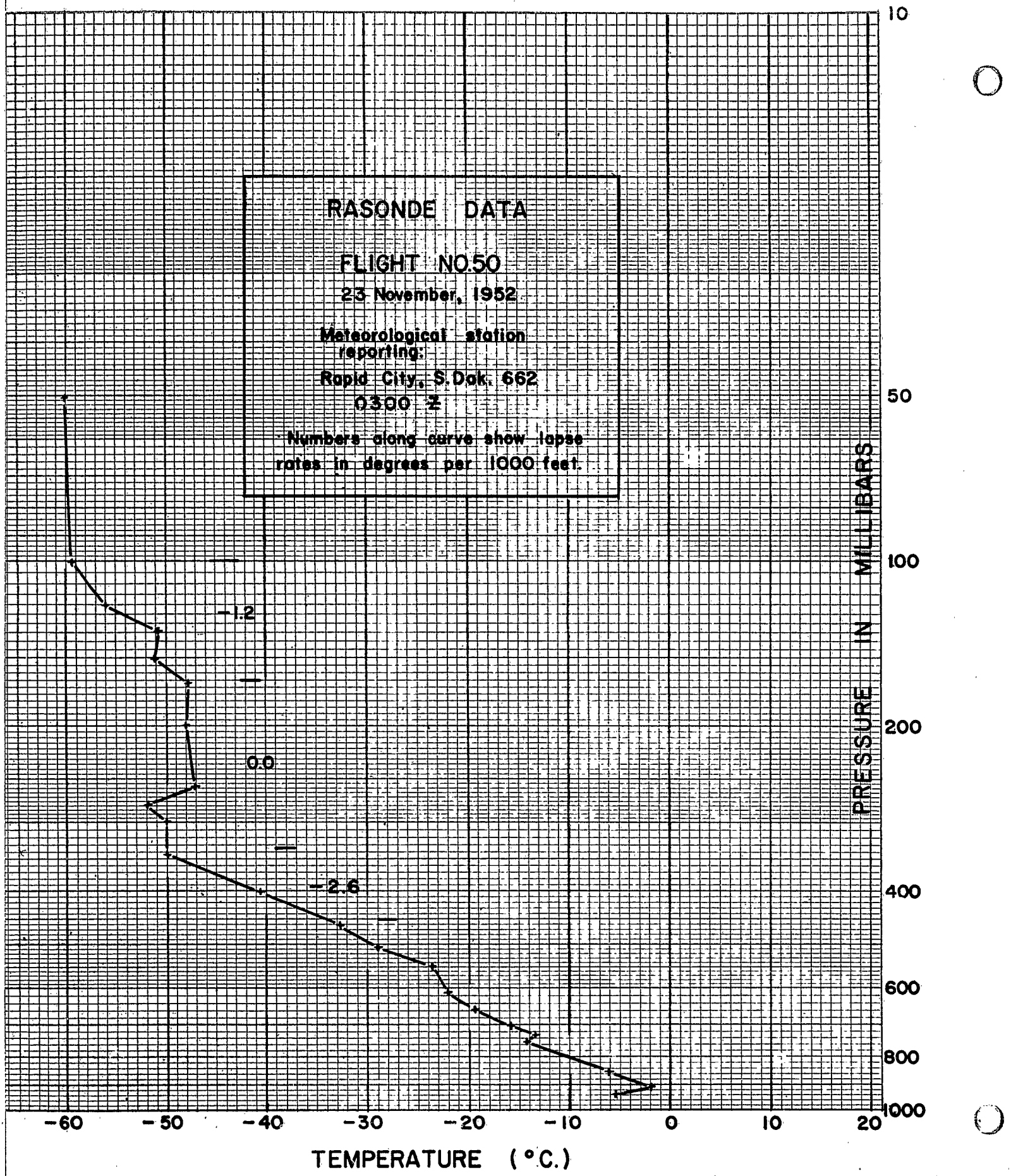
CONFIDENTIAL SECURITY INFORMATION

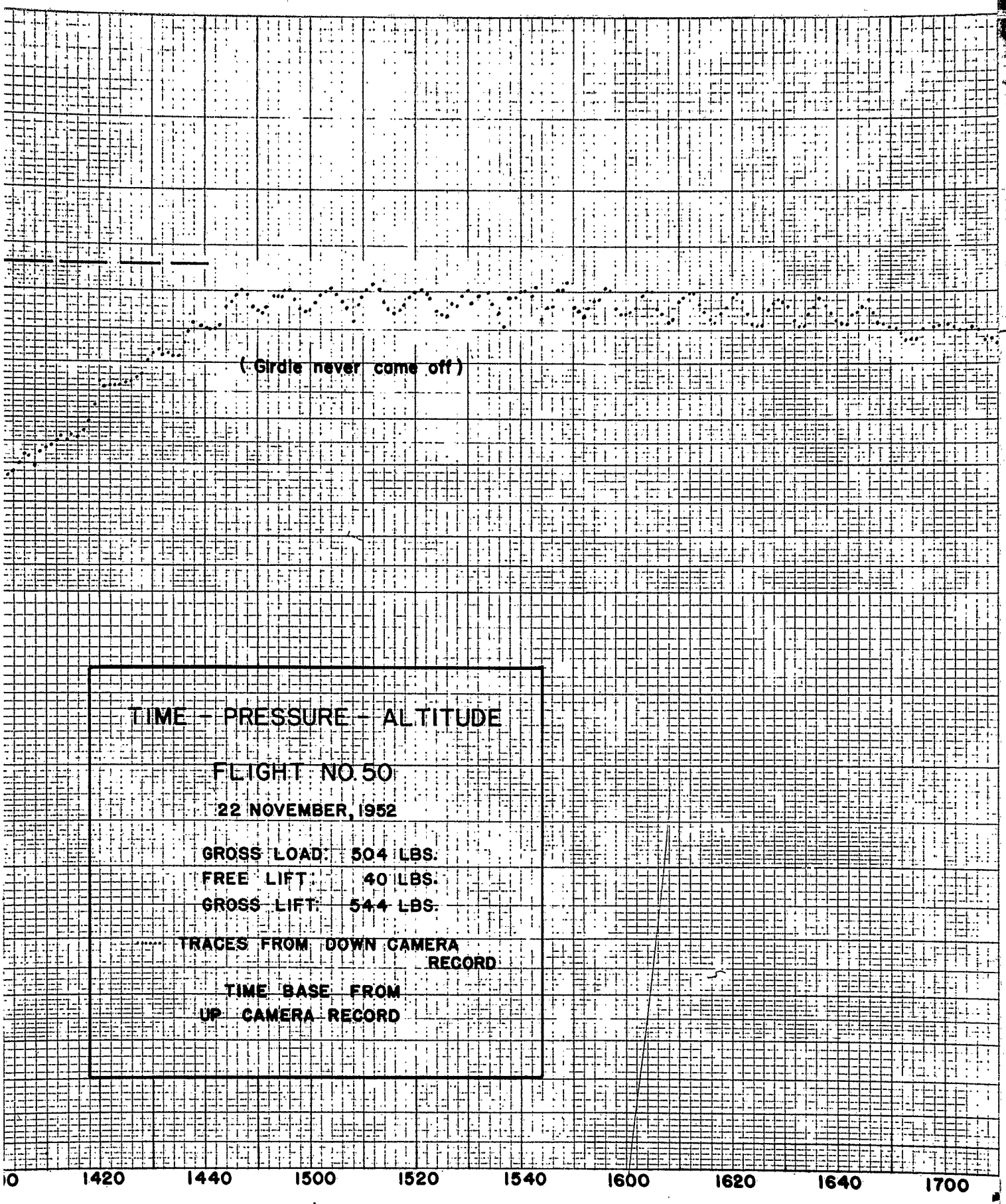

THEORETICAL CEILING
86,300 FT.
TIME - PRESSURE - ALTITUDE
FLIGHT NO. 48
6 NOVEMBER, 1952
GROSS LOAD: 402 LBS.
FREE LIFT: 32 LBS.
GROSS LIFT: 434 LBS.
..... DATA FROM TELEMETER RECORD
xxxx DATA FROM AVC RECORDER
LOAD ON GROUND
BALLOON LAUNCHED
0800
0820
0840
CENTRAL STANDARD TIME


RASONDE DATA
FLIGHT NO. 49
21 November, 1952
Meteorological stations reporting:
⊕ Rapid City, S. Dak. 662
+ Bismarck, N. Dak. 230
0300 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
-2.2
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

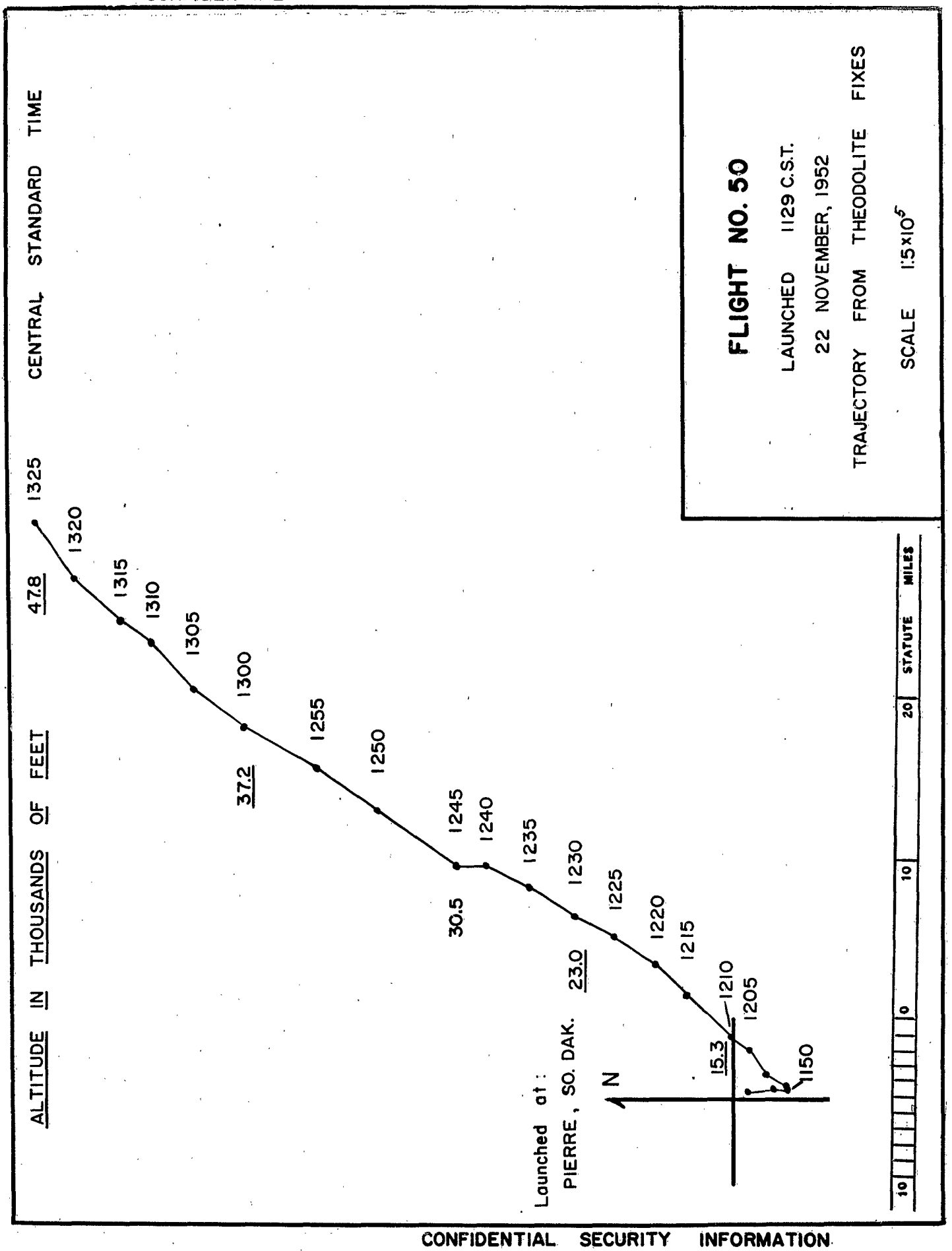

THEORETICAL CEILING
85,000 FT.
TIME - PRESSURE - ALTITUDE
FLIGHT NO. 49
20 NOVEMBER, 1952
GROSS LOAD : 391 lbs.
FREE LIFT : 65 lbs.
GROSS LIFT : 456 lbs.
Altitude data from telemetered record
PRESSURE IN MILLIBARS
ALTITUDE IN THOUSANDS OF FEET
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
100
90
80
70
60
50
40
30
20
10
0
BALLOON SUNSET
1640
1700
1720
1740
1800
1820
BALLOON LAUNCHED
CENTRAL STANDARD TIME


FLIGHT NO.49
LAUNCHED 1654 C.S.T.
20 NOVEMBER, 1952
TRAJECTORY FROM THEODOLITE FIXES
SCALE 1:5 x 10⁵
LAUNCHED AT:
PIERRE, SO. DAK.
N
1700
1705
1710
1715
1720
1725
1730
1735
1740
1745
1750
20.5
34.7
51.9
PRESSURE ALTITUDE IN THOUSANDS OF FEET
CENTRAL STANDARD TIME
10
0
10
20
STATUTE MILES

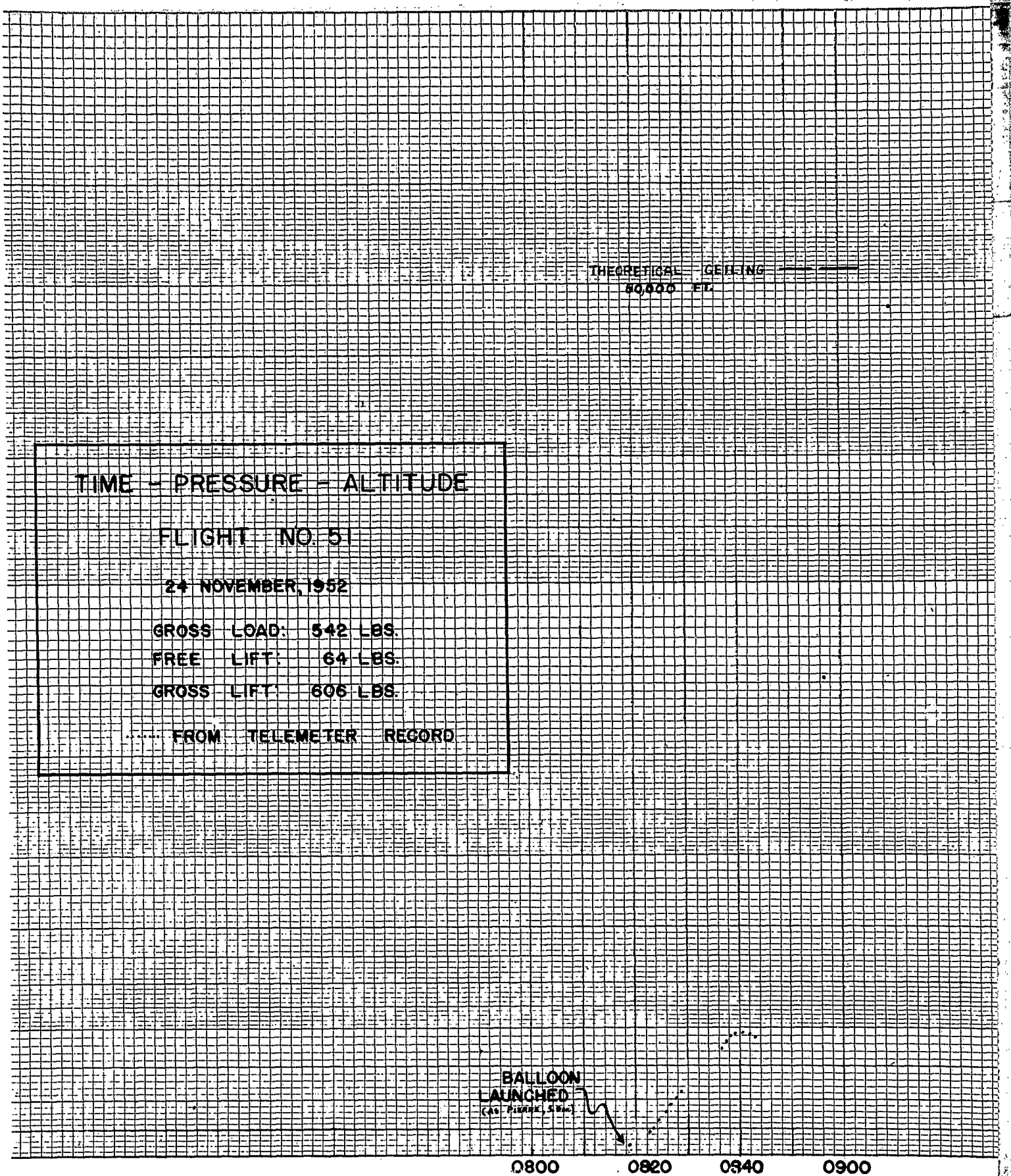

RASONDE DATA
FLIGHT NO.50
23 November, 1952
Meteorological station reporting:
Rapid City, S.Dak. 662
0300 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
-1.2
0.0
-2.6
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

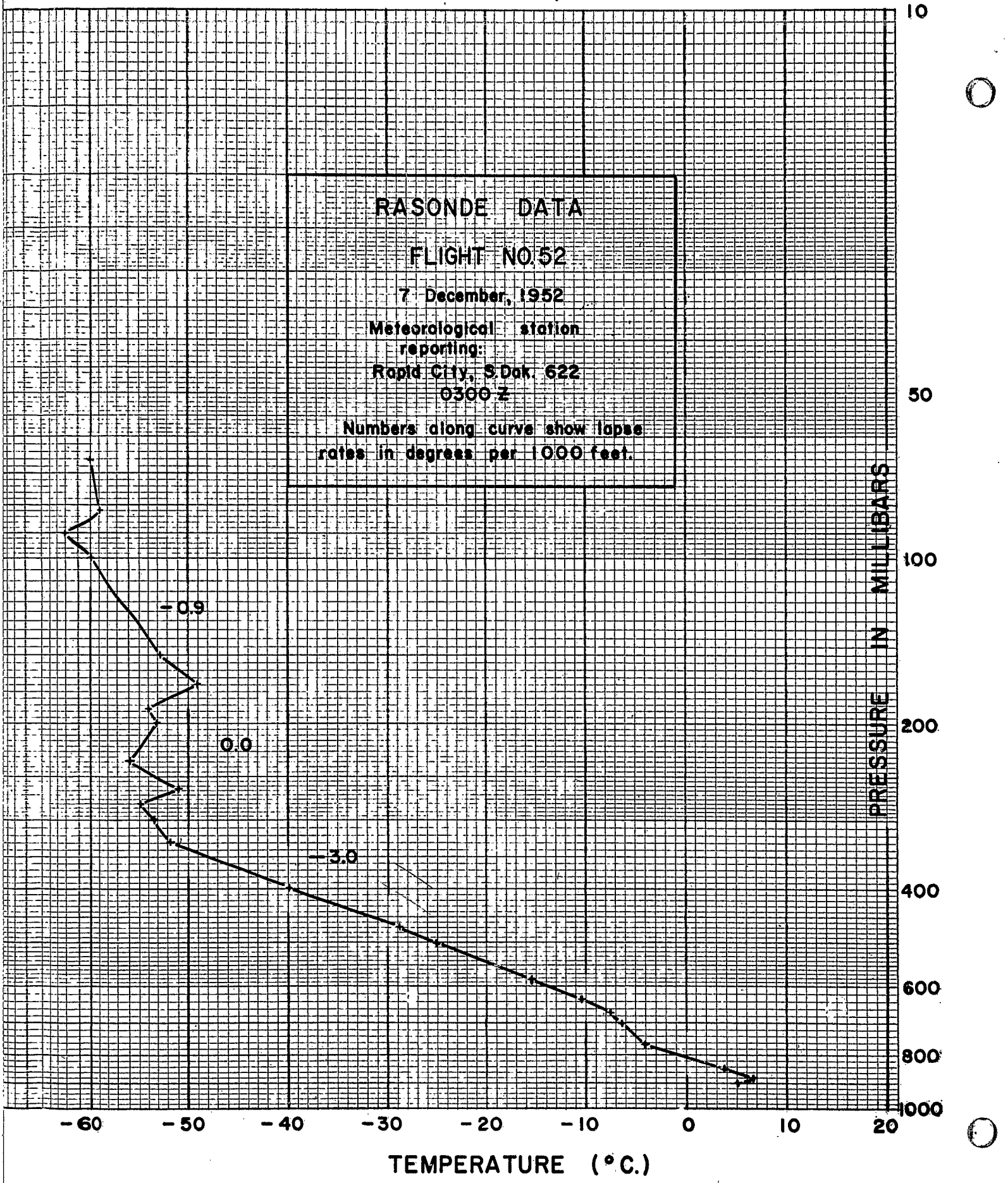

(Girdle never came off)
TIME - PRESSURE - ALTITUDE
FLIGHT NO. 50
22 NOVEMBER, 1952
GROSS LOAD: 504 LBS.
FREE LIFT: 40 LBS.
GROSS LIFT: 544 LBS.
TRACES FROM DOWN CAMERA RECORD
TIME BASE FROM UP CAMERA RECORD
1420
1440
1500
1520
1540
1600
1620
1640
1700
CENTRAL STANDARD TIME

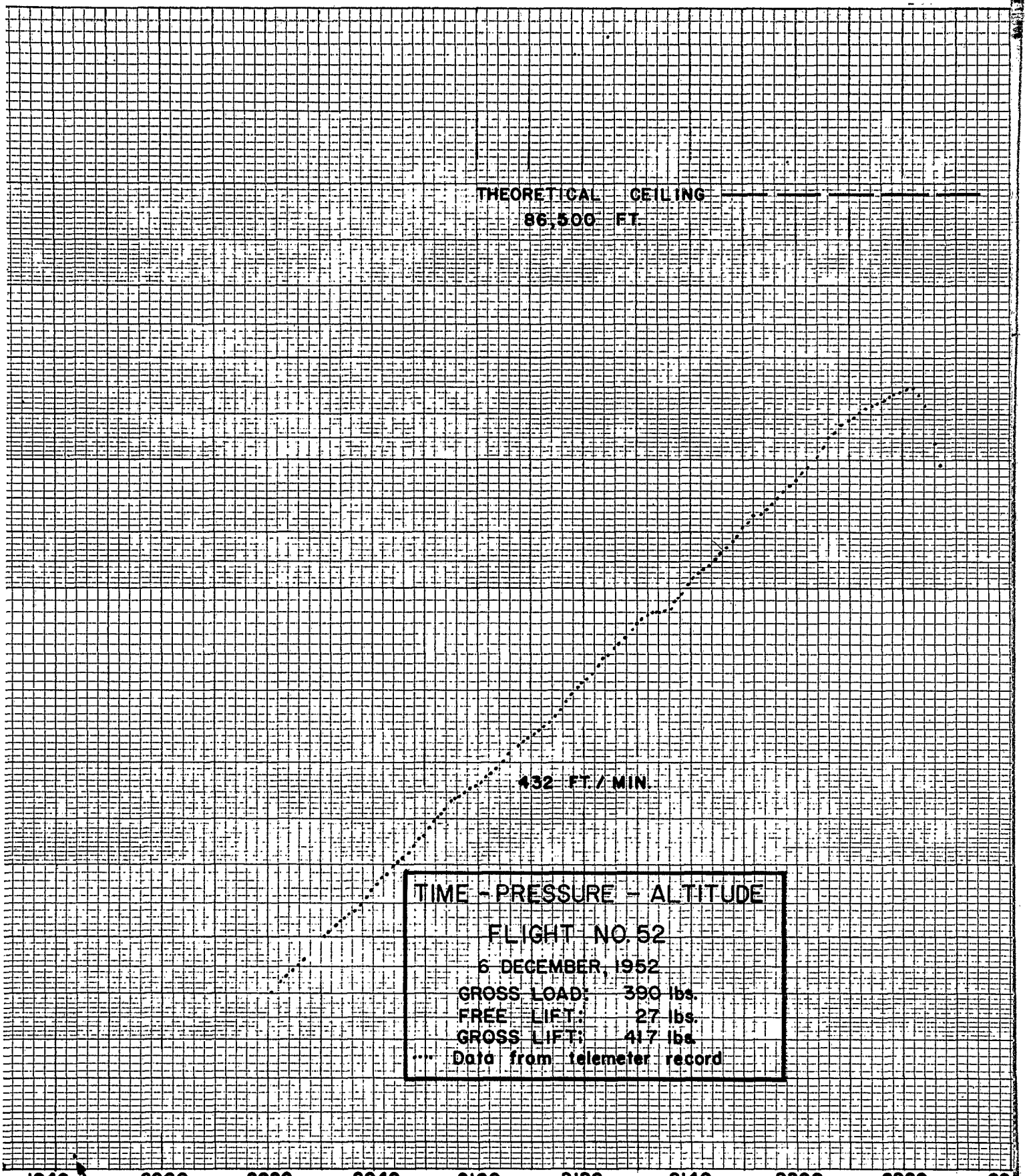
CONFIDENTIAL

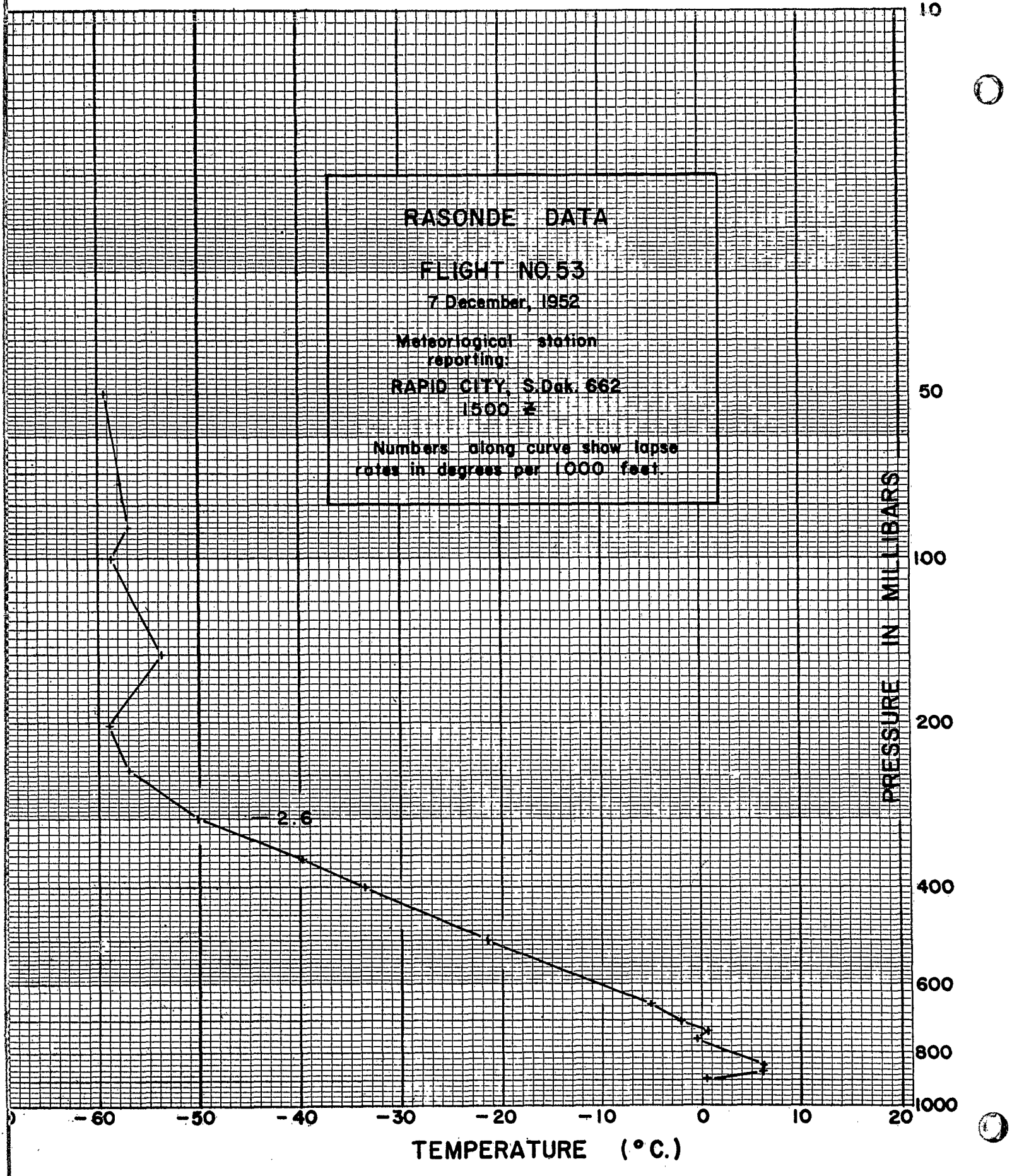


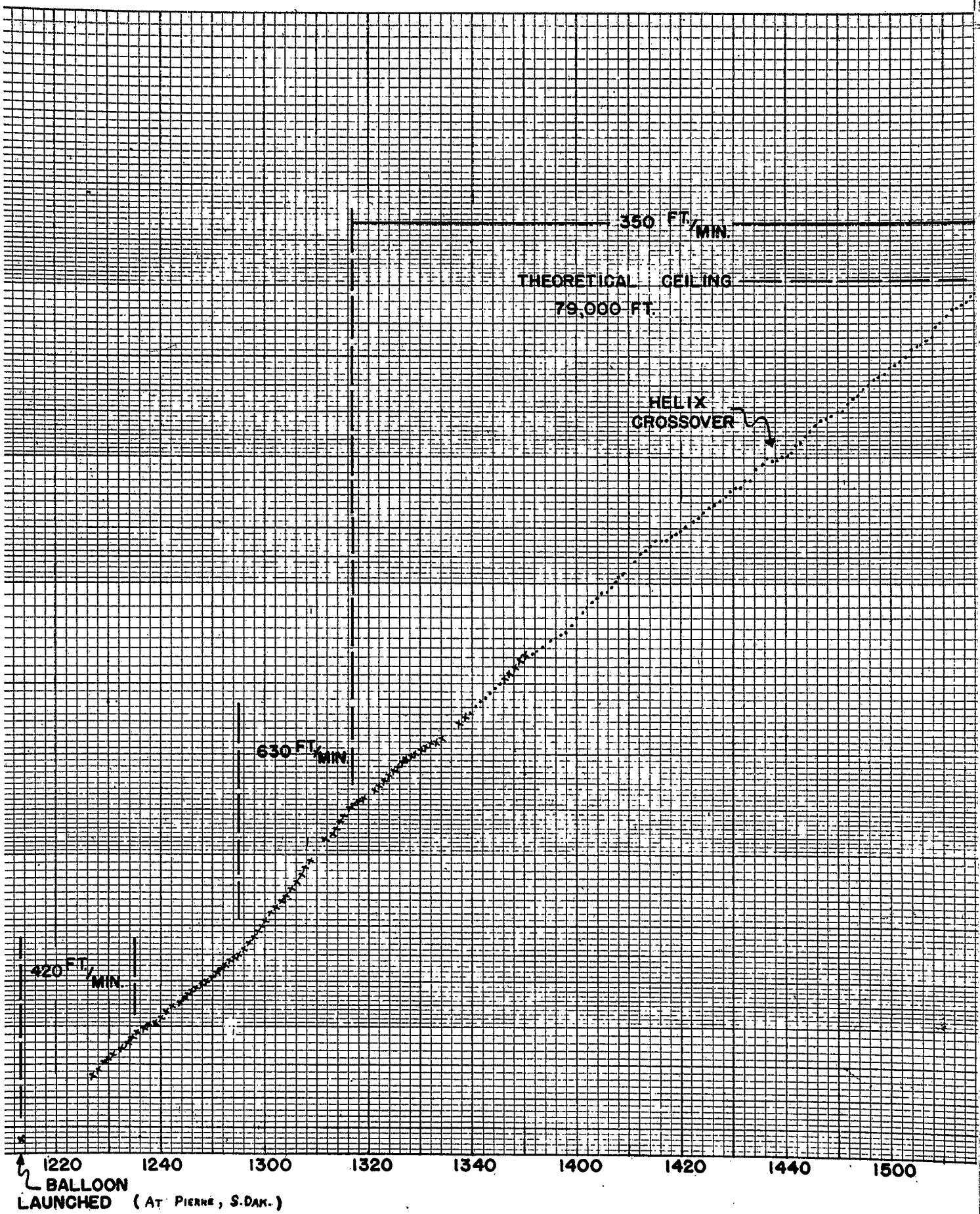
CONFIDENTIAL SECURITY INFORMATION

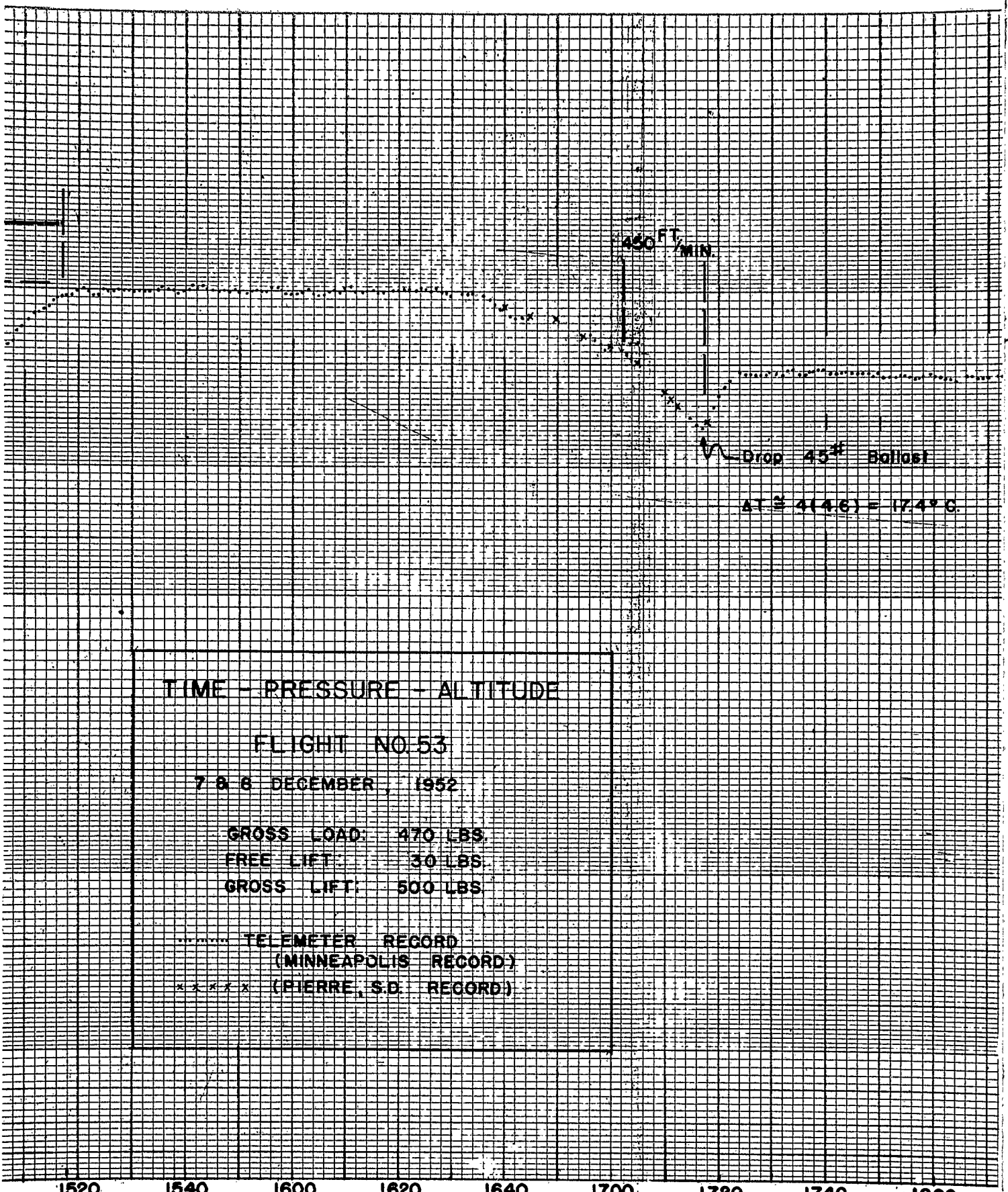

THEORETICAL CEILING
80,000 FT.
TIME - PRESSURE - ALTITUDE
FLIGHT NO. 51
24 NOVEMBER, 1952
GROSS LOAD: 542 LBS.
FREE LIFT: 64 LBS.
GROSS LIFT: 606 LBS.
..... FROM TELEMETER RECORD
BALLOON LAUNCHED
(At Pierre, S.Dak.)
0800
0820
0840
0900
CENTRAL STANDARD TIME

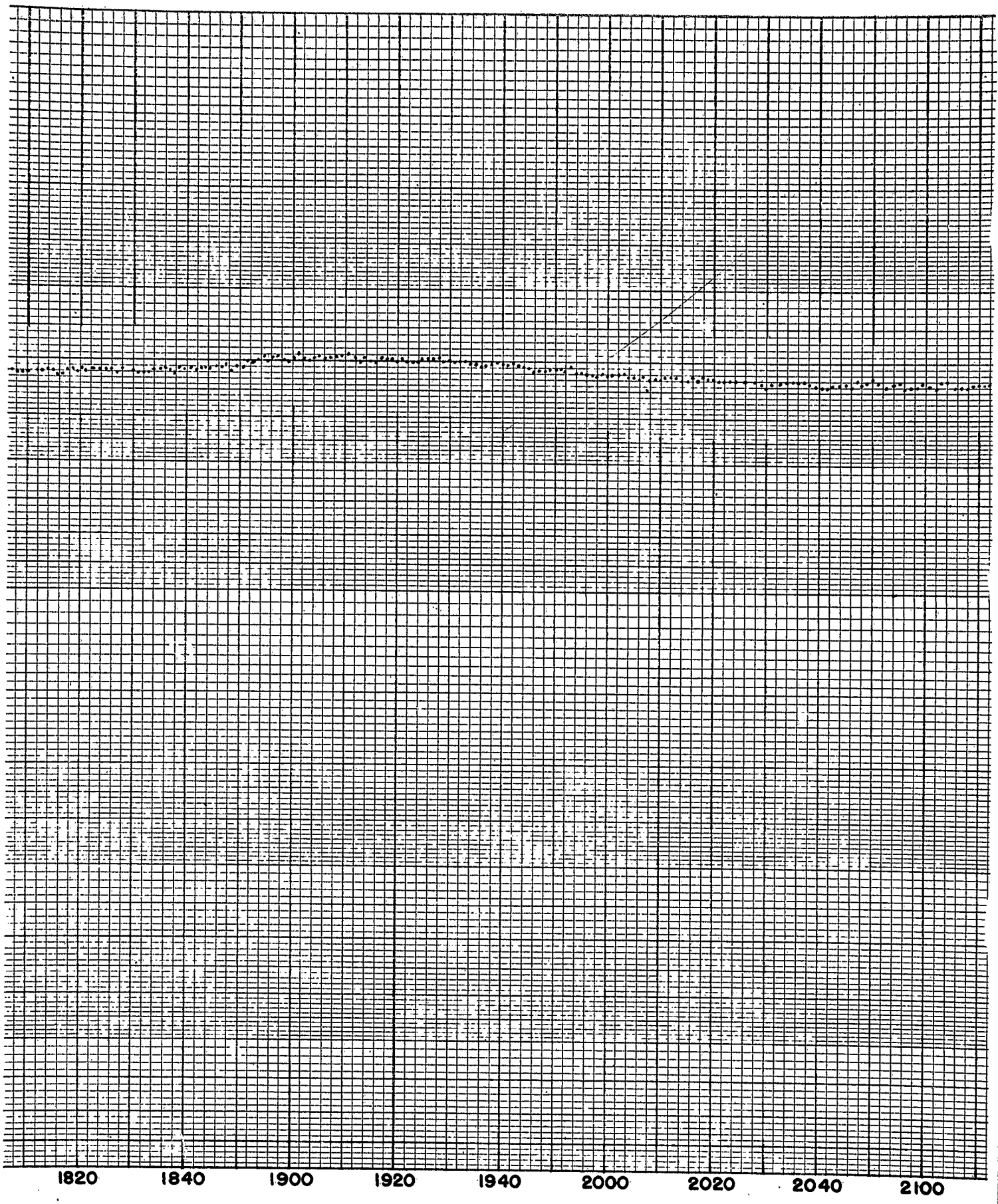

RASONDE DATA
FLIGHT NO. 52
7 December, 1952
Meteorological station reporting:
Rapid City, S.Dak. 622
0300 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
-0.9
0.0
-3.0
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

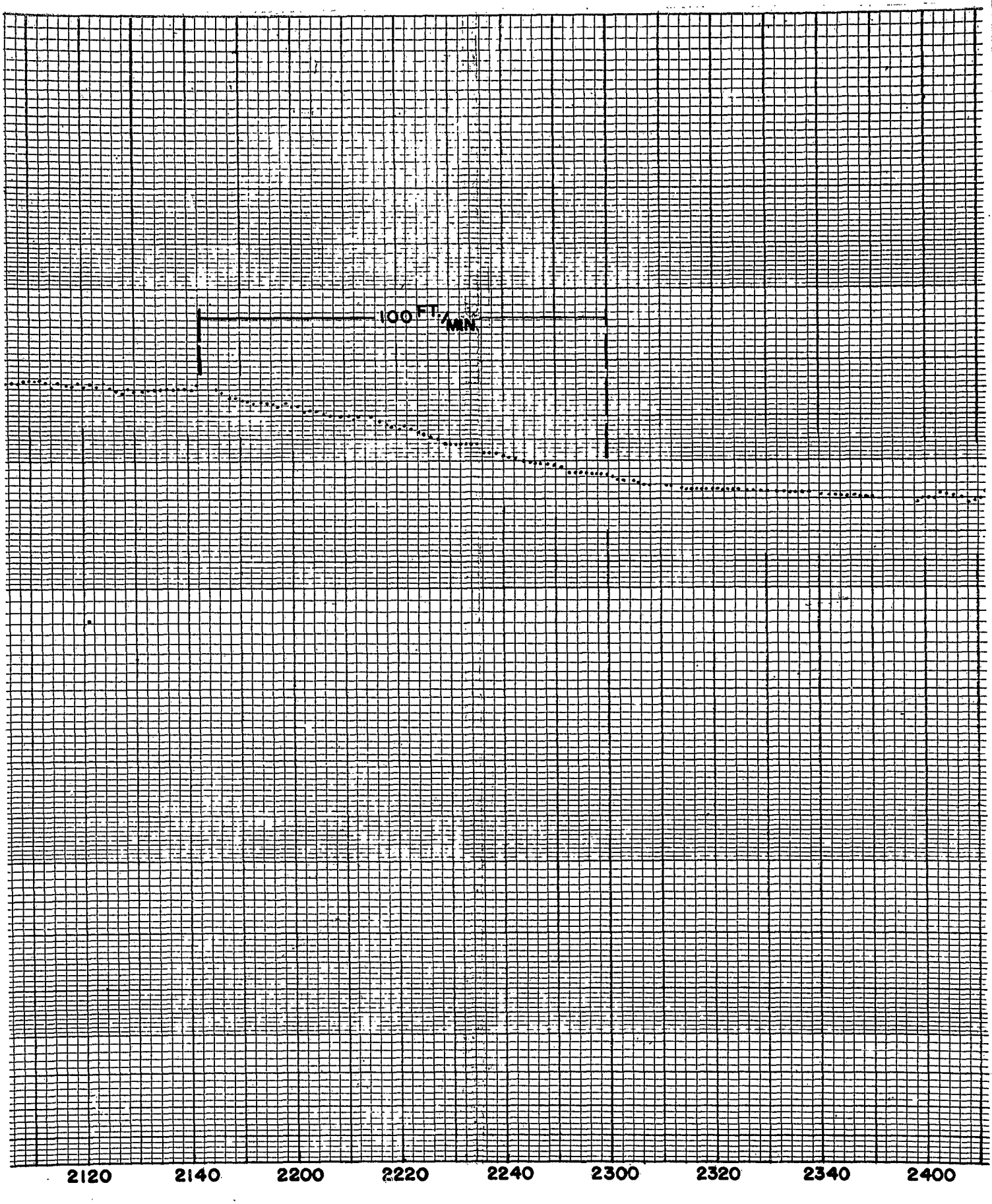

THEORETICAL CEILING
86,500 FT.
432 FT./MIN.
TIME - PRESSURE - ALTITUDE
FLIGHT NO. 52
6 DECEMBER, 1952
GROSS LOAD: 390 lbs.
FREE LIFT: 27 lbs.
GROSS LIFT: 417 lbs.
···· Data from telemeter record
1940
2000
2020
2040
2100
2120
2140
2200
2220
22
BALLOON LAUNCHED
CENTRAL STANDARD TIME

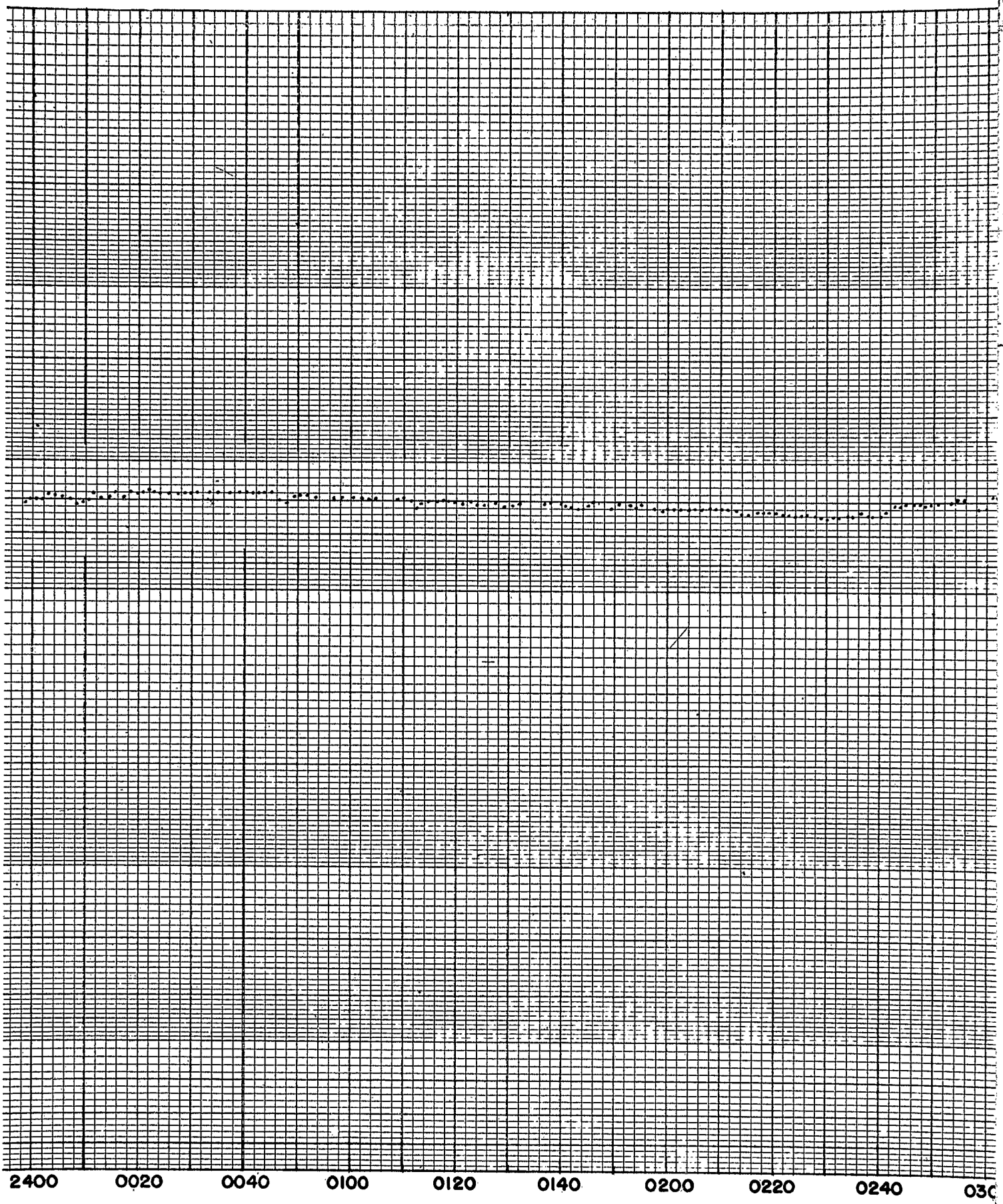

RASONDE DATA
FLIGHT NO. 53
7 December, 1952
Meteorological station reporting:
RAPID CITY, S.Dak. 662
1500 Z
Numbers along curve show lapse rates in degrees per 1000 feet.
2.6
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

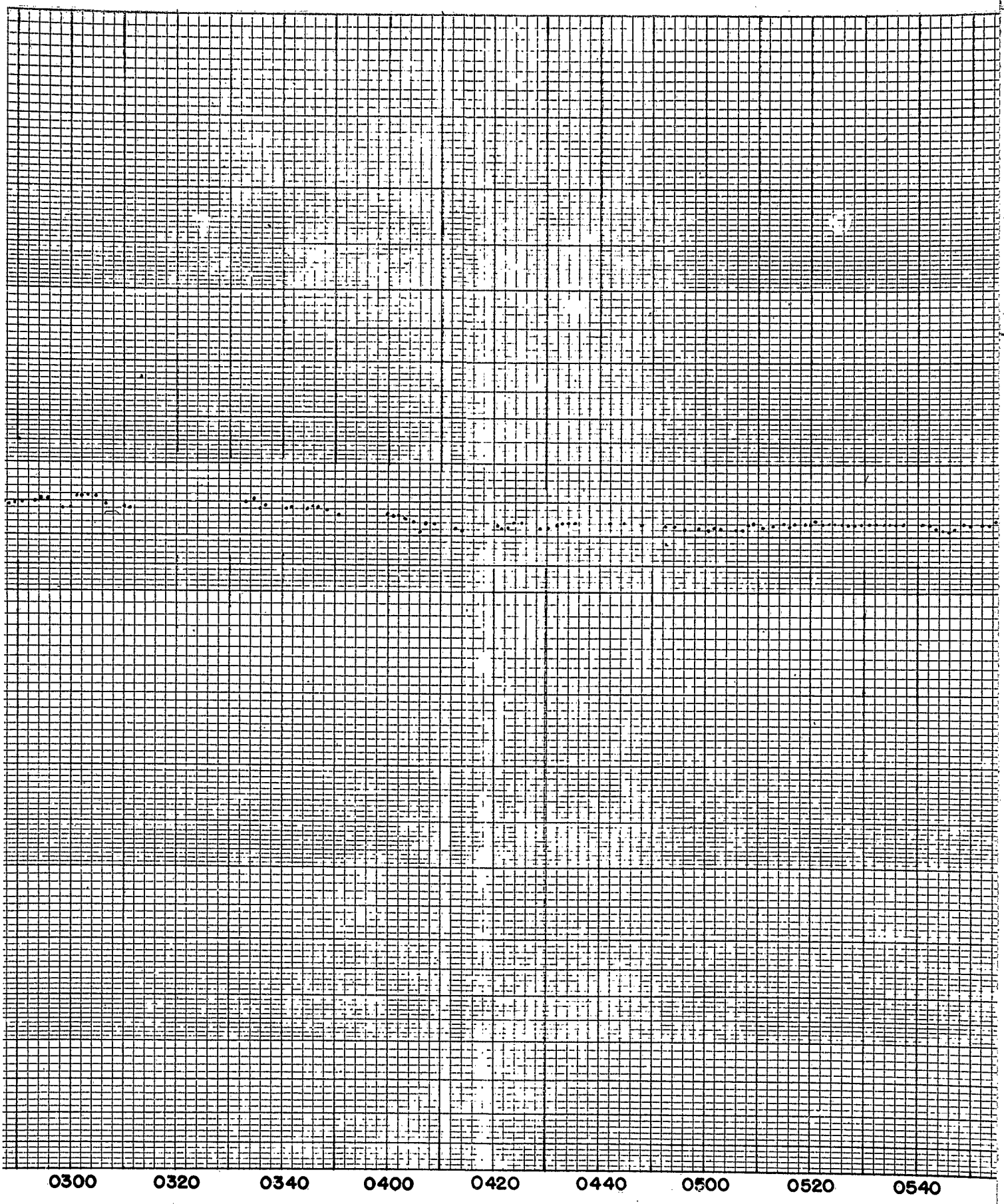

350 FT./MIN.
THEORETICAL CEILING
79,000 FT.
HELIX
CROSSOVER
630 FT./MIN.
420 FT./MIN.
1220
1240
1300
1320
1340
1400
1420
1440
1500
BALLOON
LAUNCHED (AT PIERRE, S.DAK.)

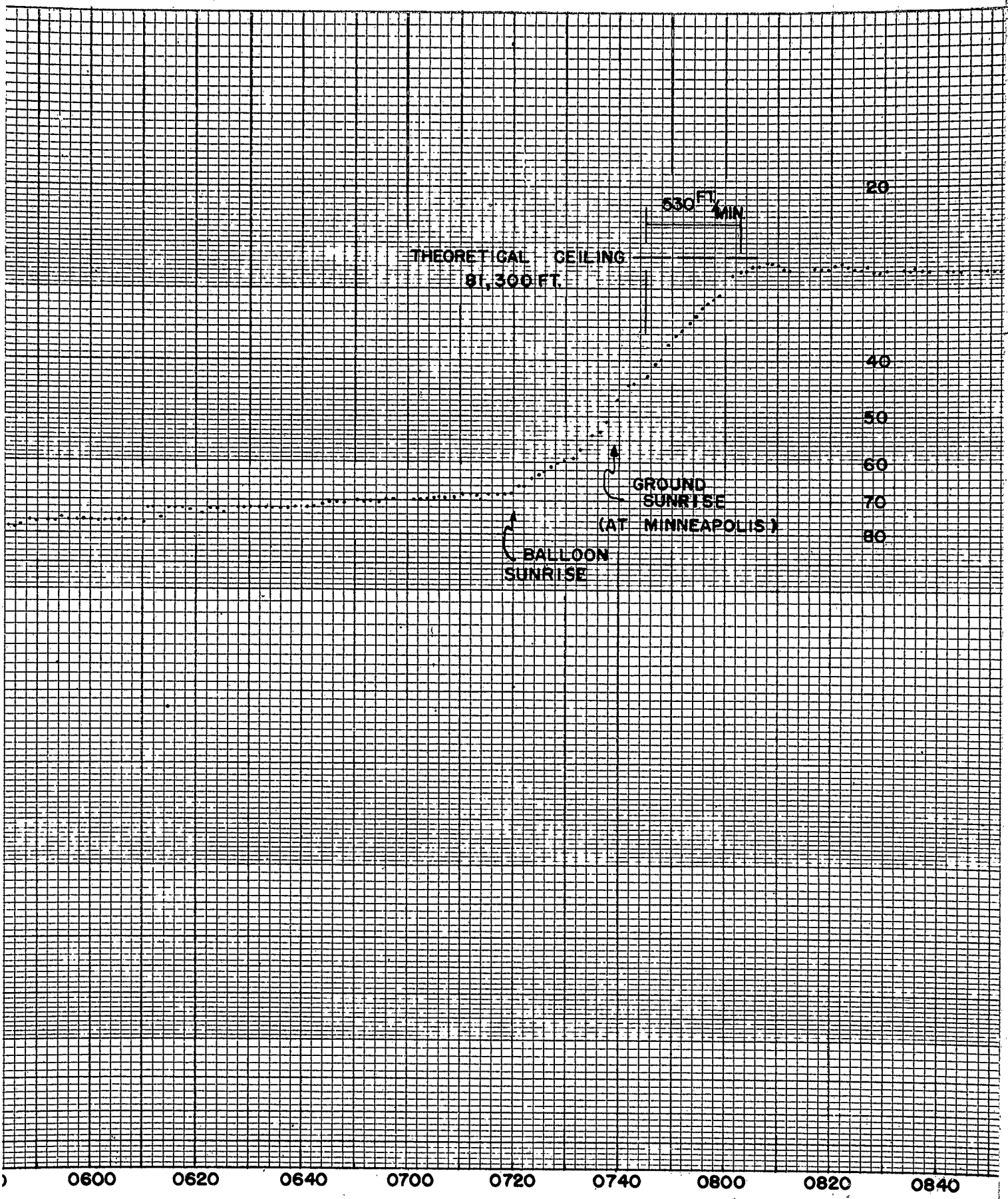

450 FT/MIN.
Drop 45# Ballast
ΔT ≅ 4(4.6) = 17.4° C.
TIME - PRESSURE - ALTITUDE
FLIGHT NO. 53
7 & 6 DECEMBER, 1952
GROSS LOAD: 470 LBS.
FREE LIFT: 30 LBS.
GROSS LIFT: 500 LBS.
..... TELEMETER RECORD (MINNEAPOLIS RECORD)
xxxxx (PIERRE, S.D. RECORD)
1520
1540
1600
1620
1640
1700
1720
1740
1800
CENTRAL STANDARD TIME

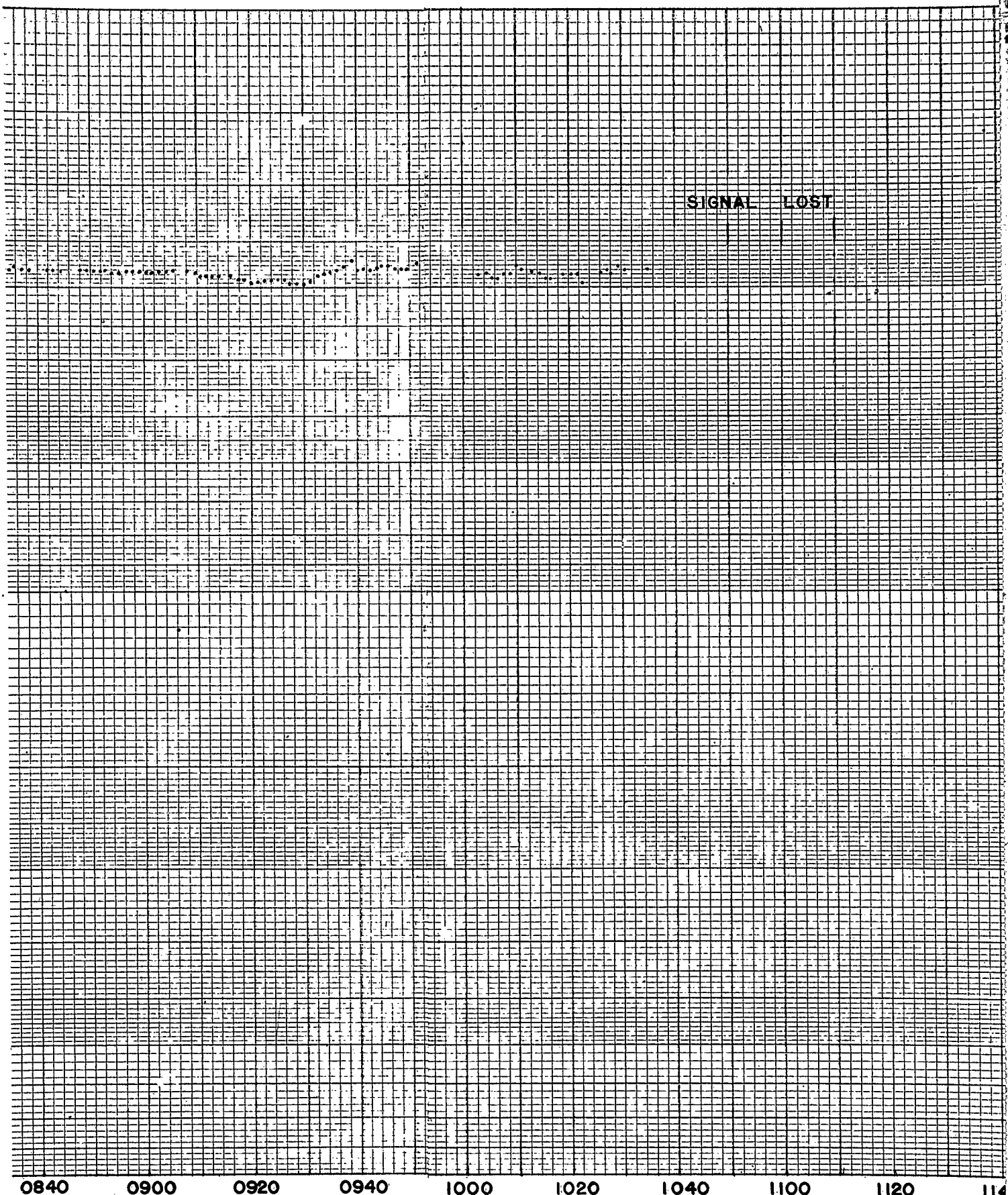

1820
1840
1900
1920
1940
2000
2020
2040
2100

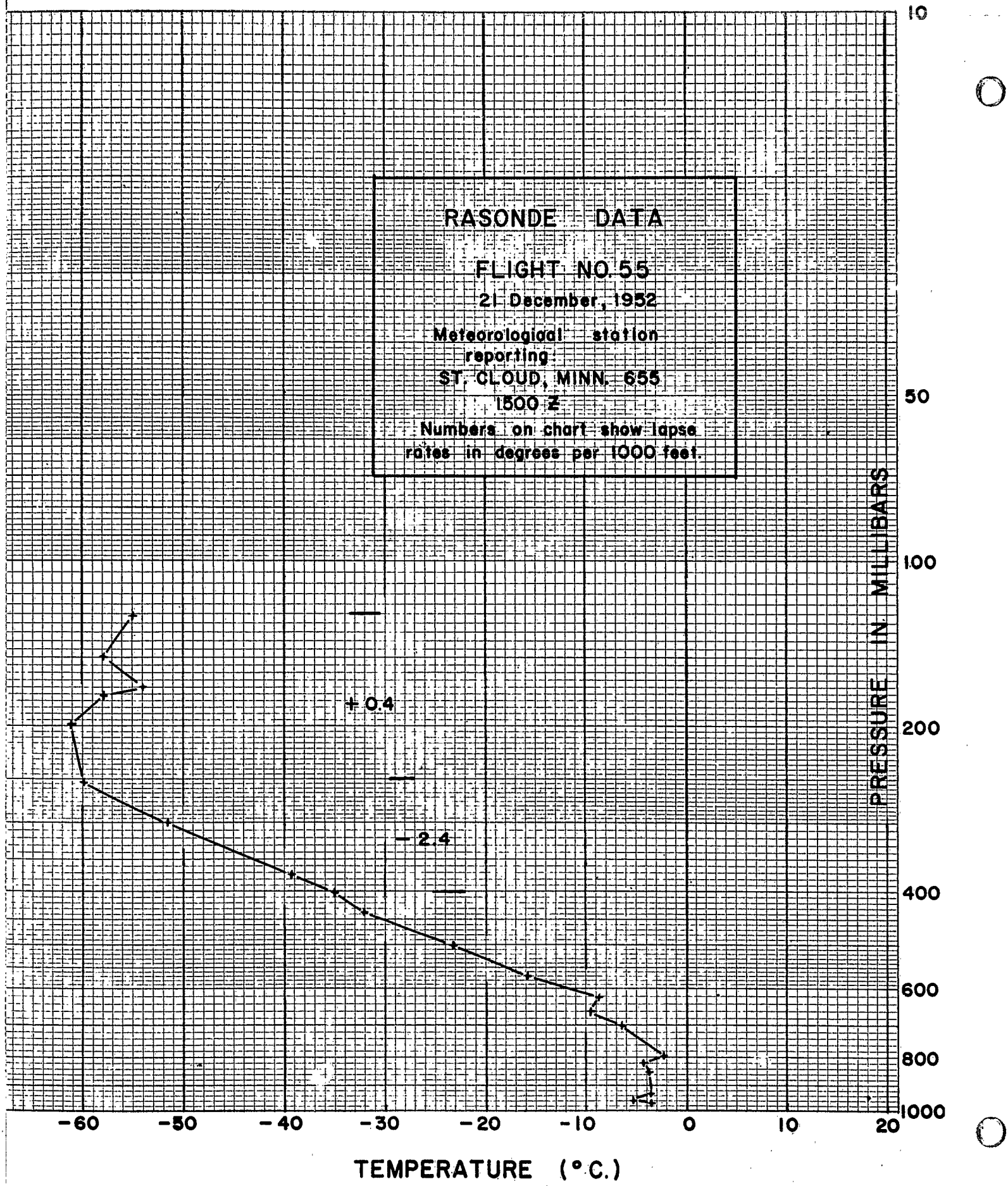

100 FT./MIN.
2120
2140
2200
2220
2240
2300
2320
2340
2400

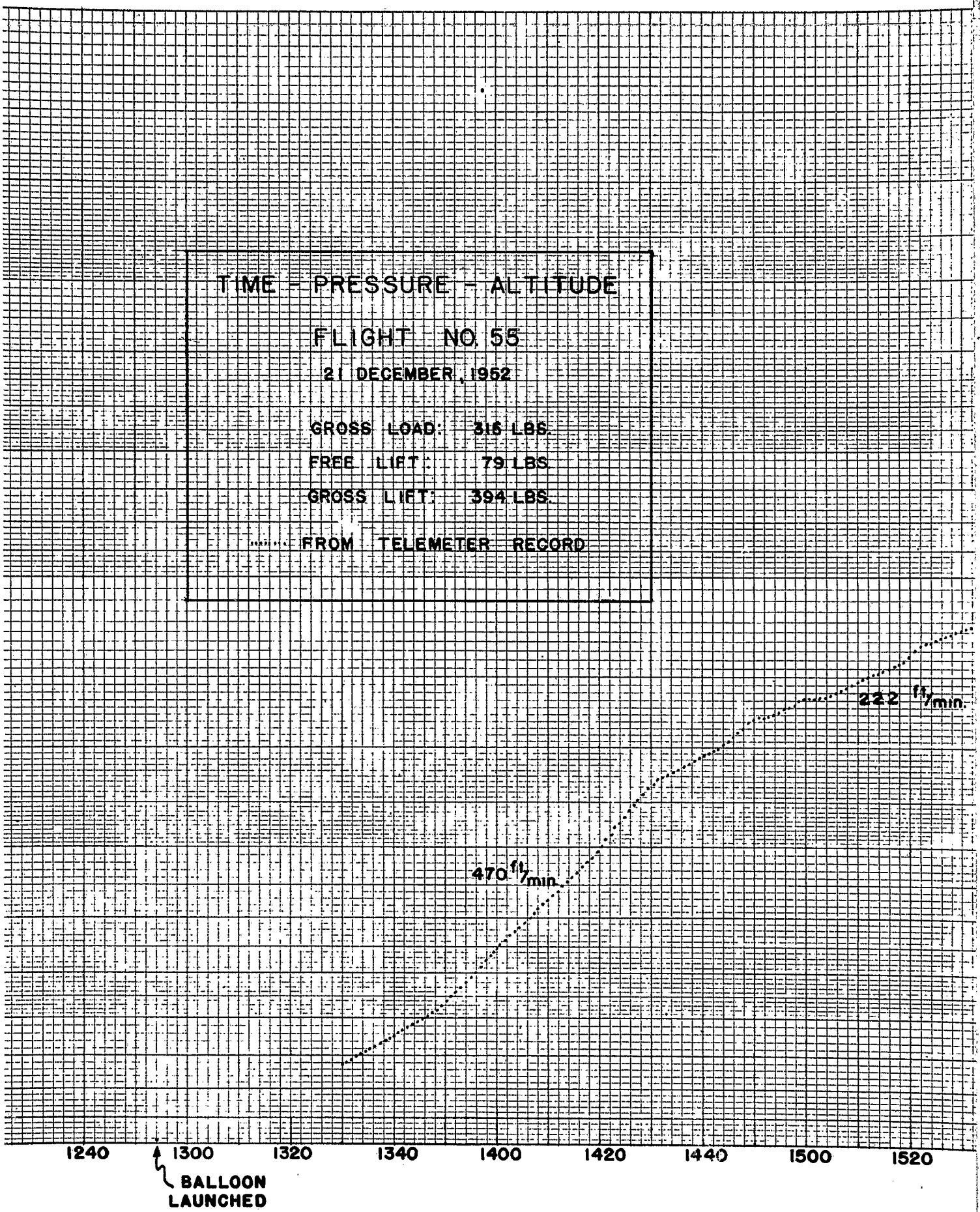

2400
0020
0040
0100
0120
0140
0200
0220
0240
8 DECEMBER

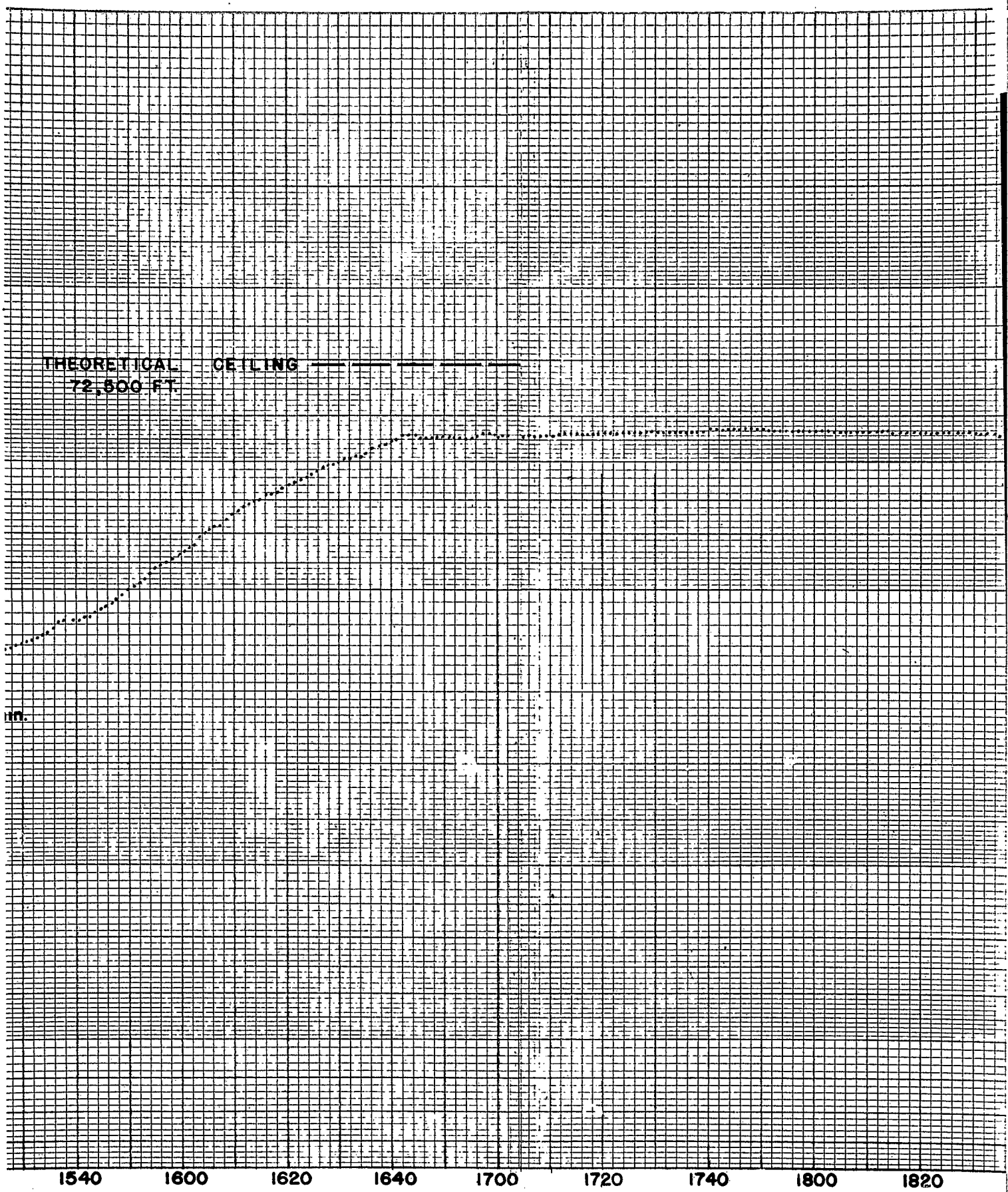

0300
0320
0340
0400
0420
0440
0500
0520
0540

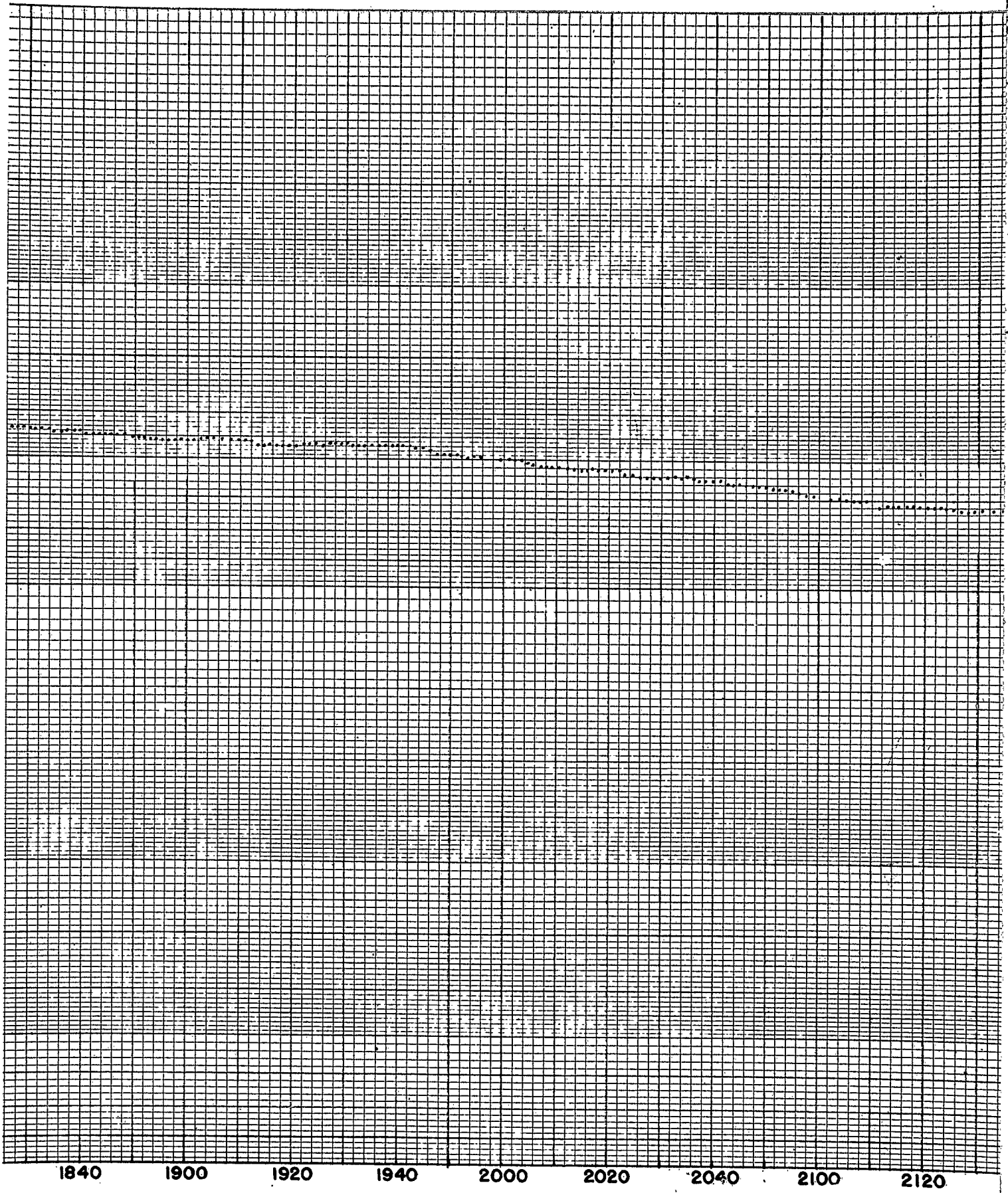

530 FT/MIN
THEORETICAL CEILING
91,300 FT.
20
40
50
60
70
80
GROUND SUNRISE
(AT MINNEAPOLIS)
BALLOON SUNRISE
0600
0620
0640
0700
0720
0740
0800
0820
0840

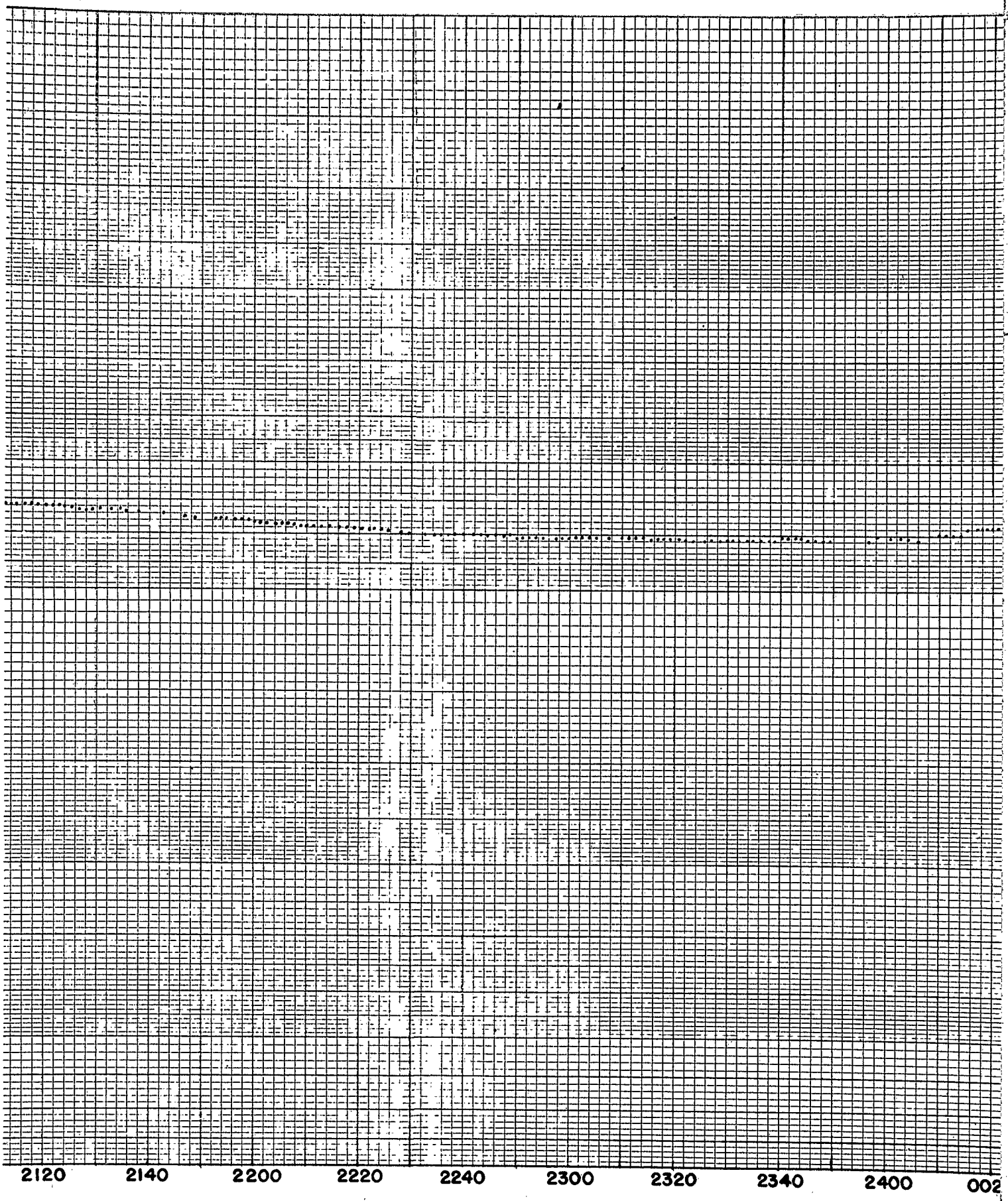

SIGNAL LOST
0840
0900
0920
0940
1000
1020
1040
1100
1120

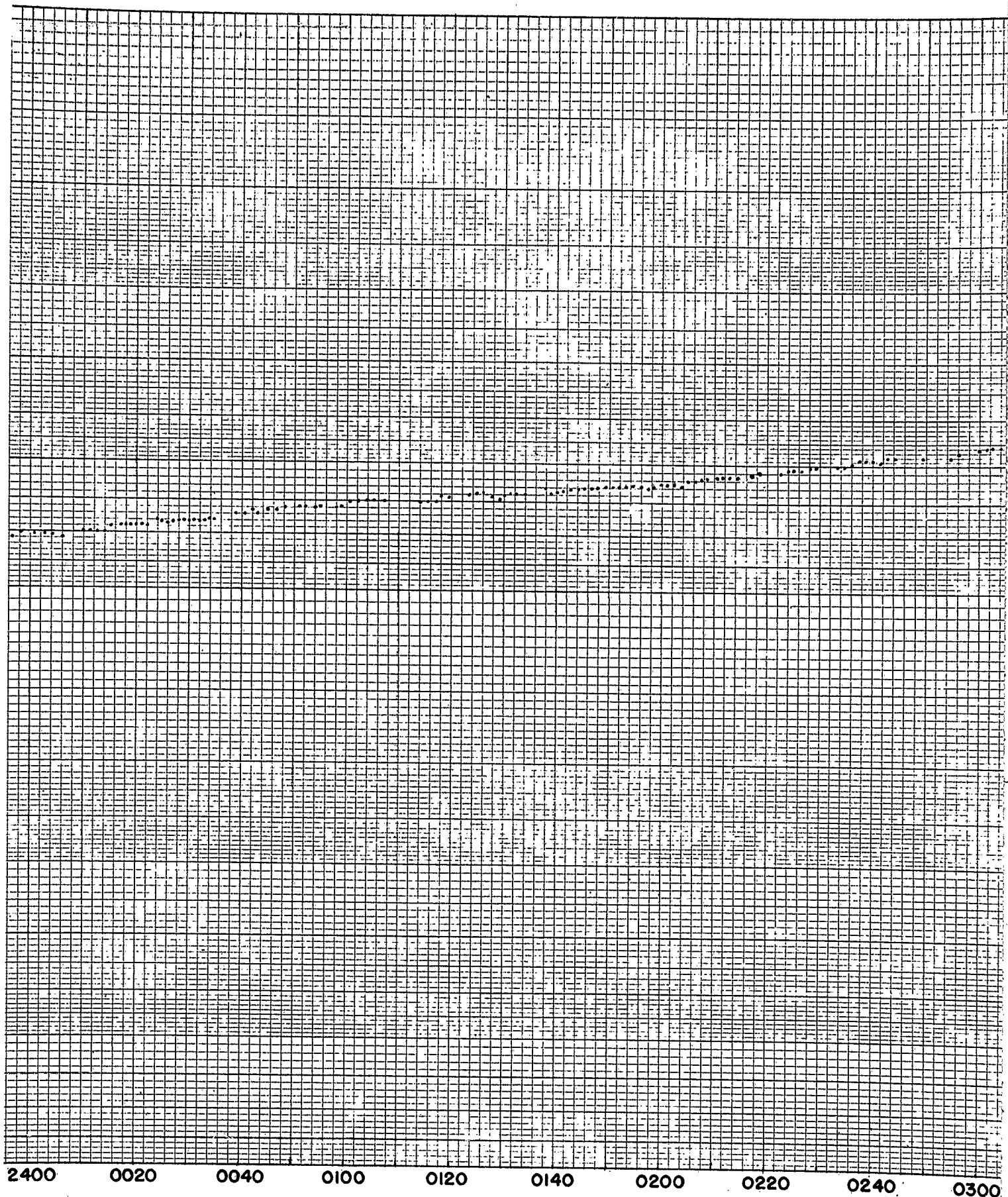

RASONDE DATA
FLIGHT NO. 55
21 December, 1952
Meteorological station reporting:
ST. CLOUD, MINN. 655
1500 Z
Numbers on chart show lapse rates in degrees per 1000 feet.
+ 0.4
— 2.4
10
50
100
200
400
600
800
1000
PRESSURE IN MILLIBARS
-60
-50
-40
-30
-20
-10
0
10
20
TEMPERATURE (°C.)

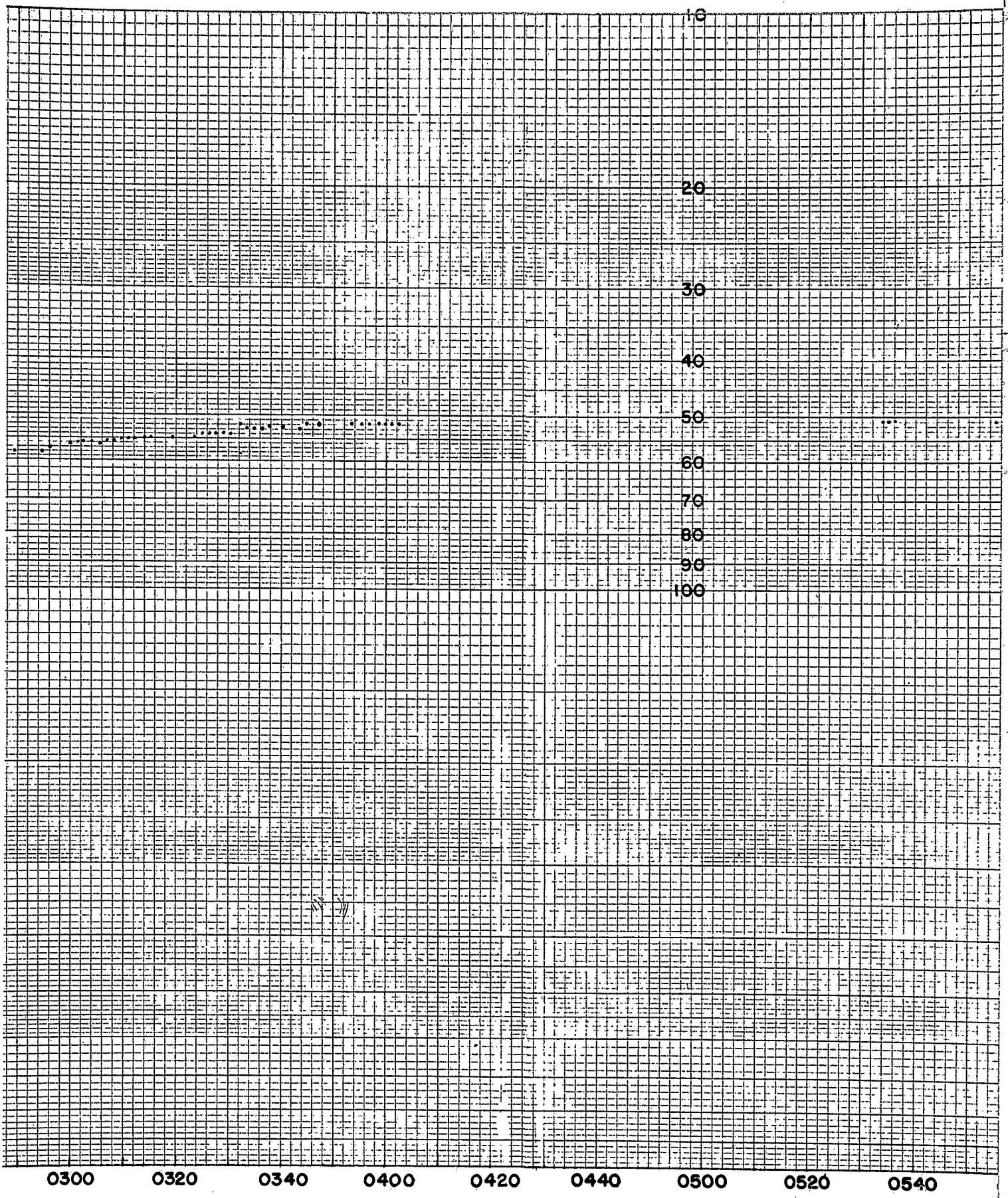

TIME - PRESSURE - ALTITUDE
FLIGHT NO. 55
21 DECEMBER, 1952
GROSS LOAD: 315 LBS.
FREE LIFT: 79 LBS.
GROSS LIFT: 394 LBS.
..... FROM TELEMETER RECORD
222 ft/min.
470 ft/min.
1240
1300
1320
1340
1400
1420
1440
1500
1520
BALLOON LAUNCHED

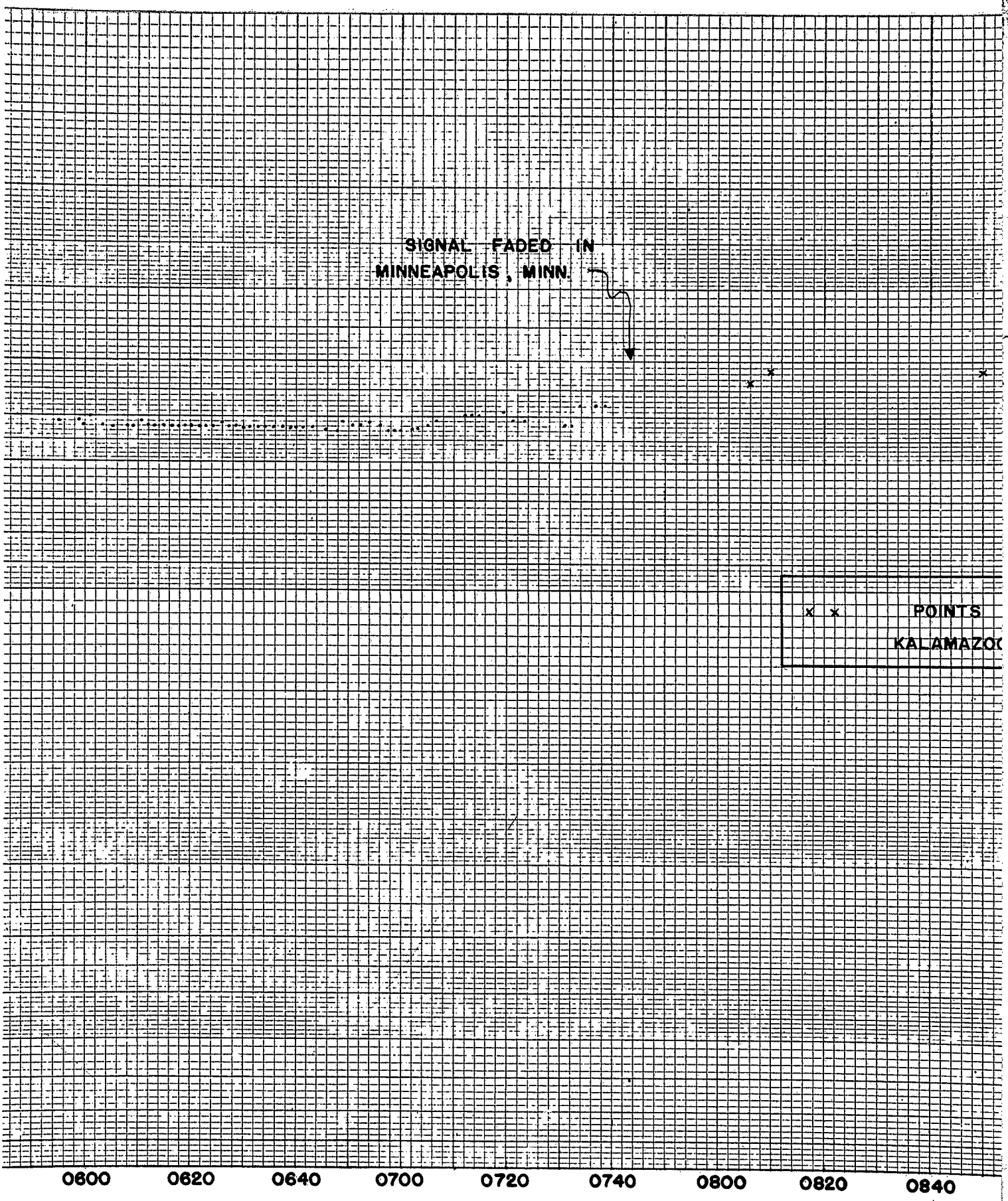

THEORETICAL CEILING
72,500 FT.
1540
1600
1620
1640
1700
1720
1740
1800
1820
CENTRAL STANDARD TIME

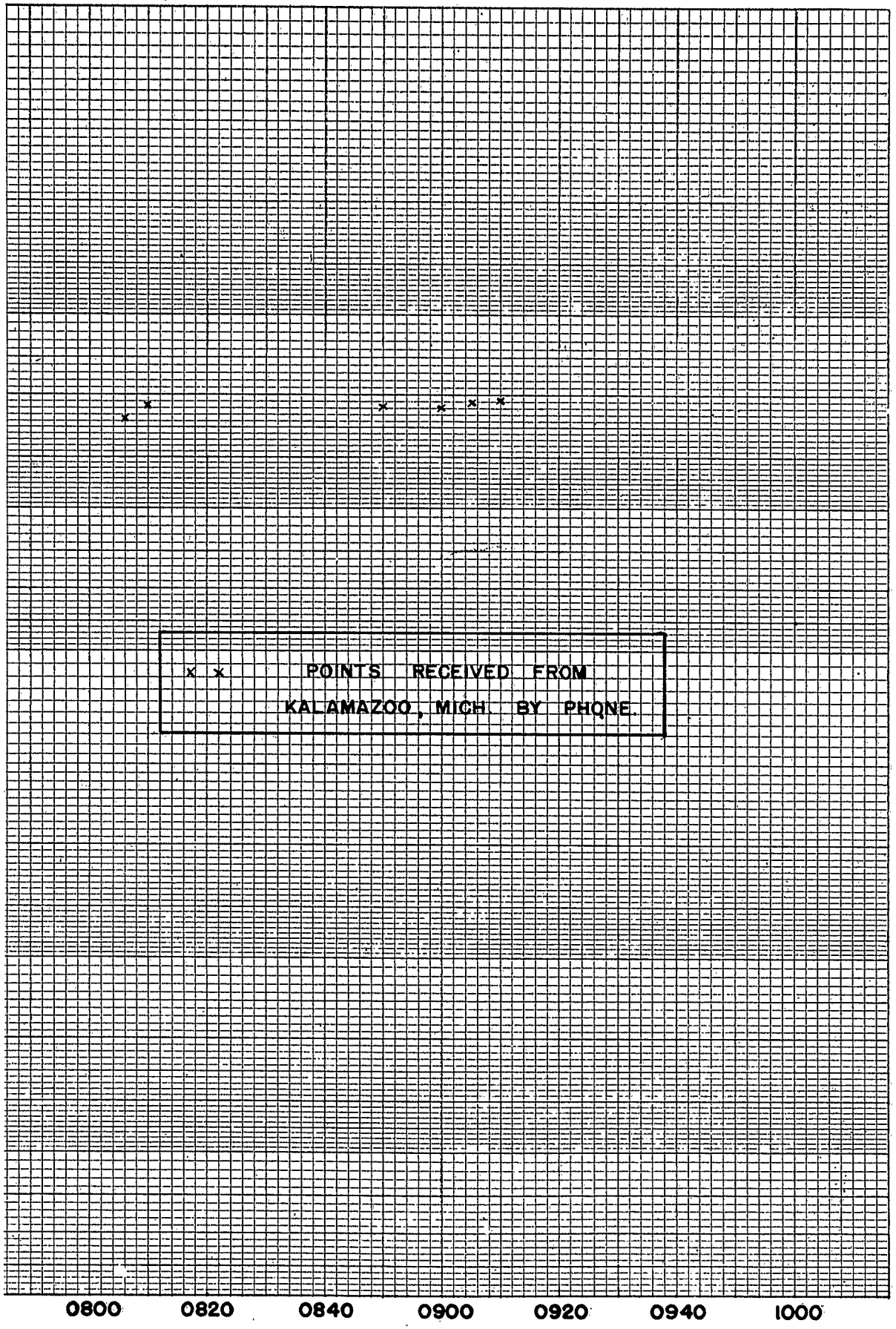

1840
1900
1920
1940
2000
2020
2040
2100
2120

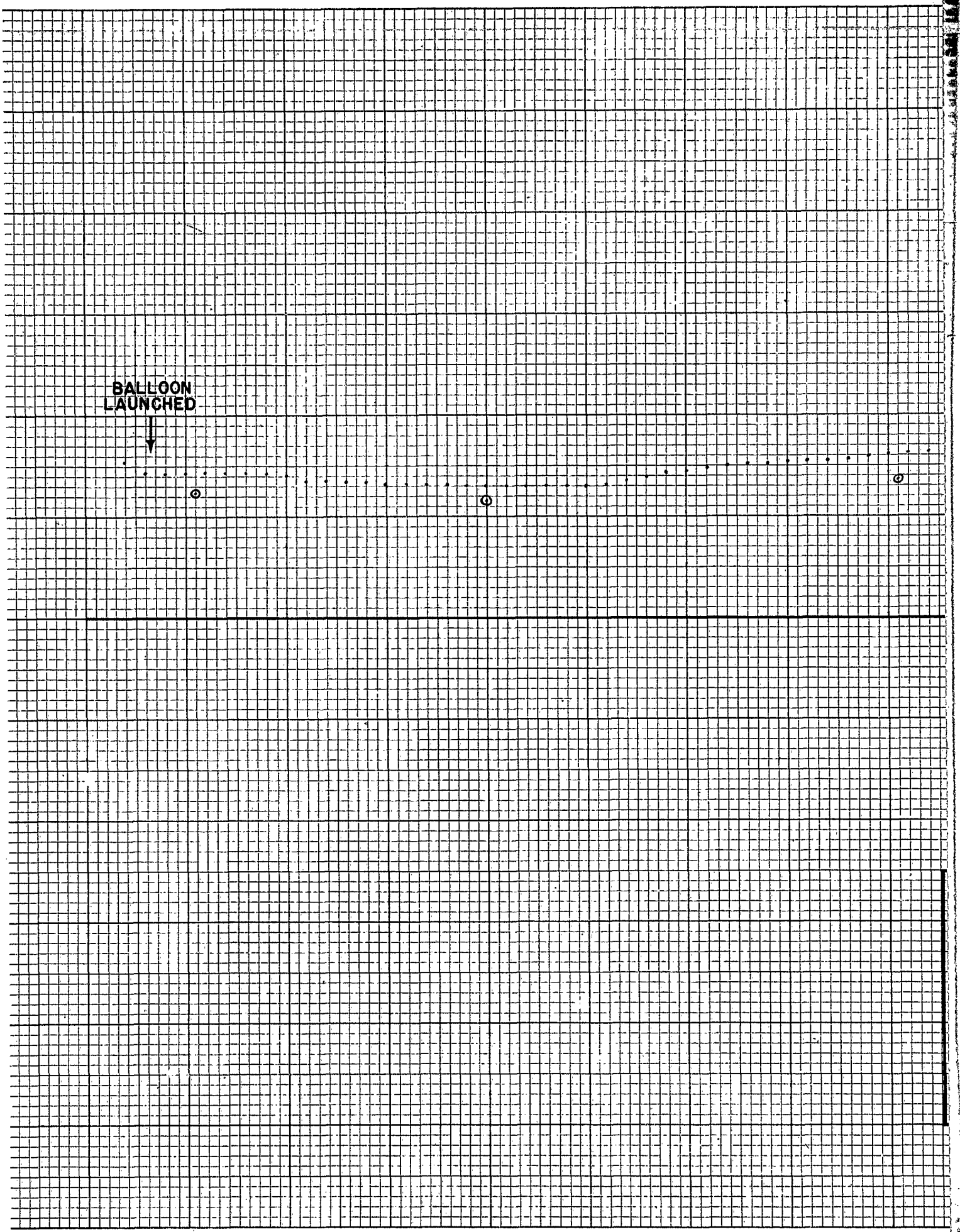

2120
2140
2200
2220
2240
2300
2320
2340
2400
002

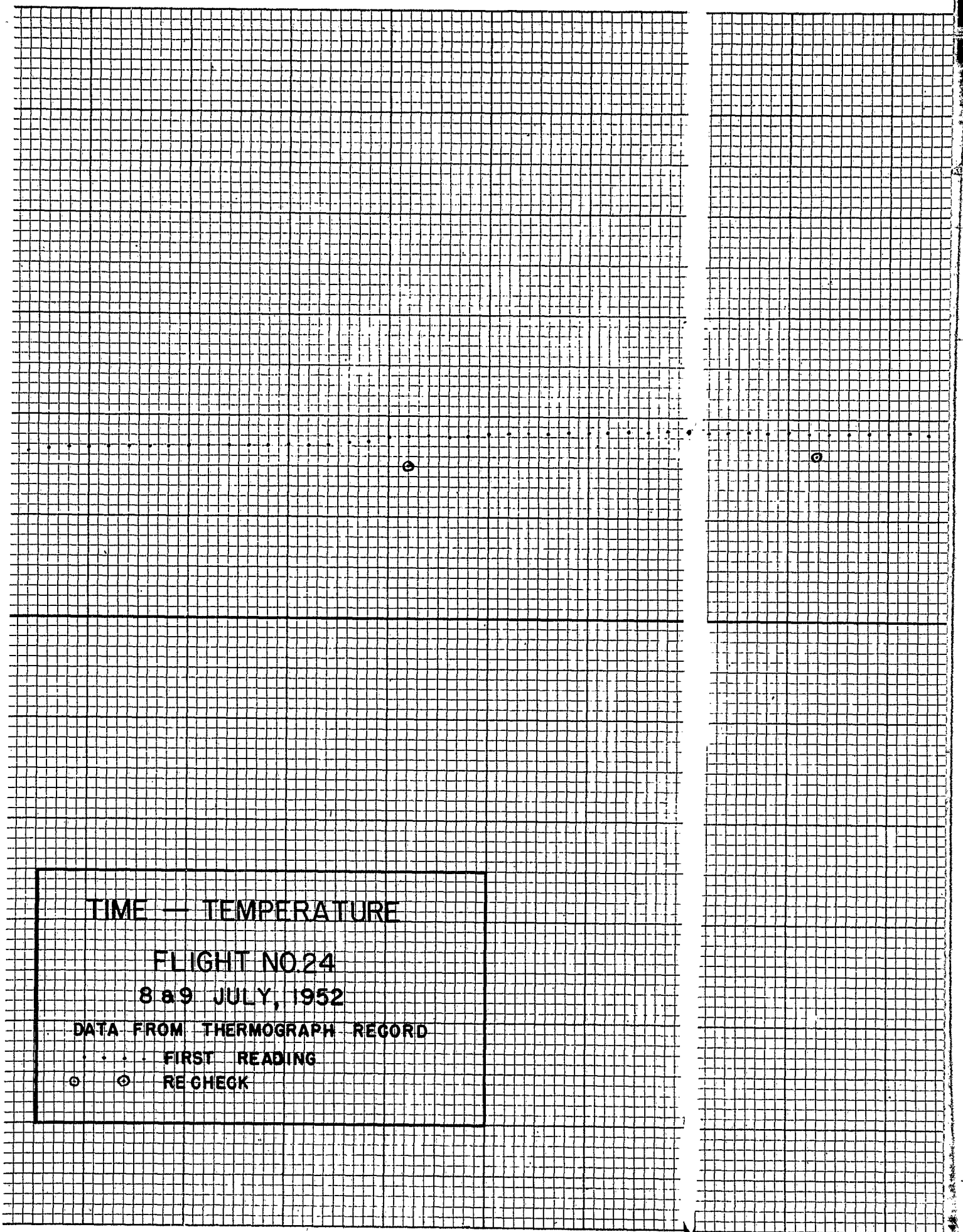

2400
0020
0040
0100
0120
0140
0200
0220
0240
0300
22 DECEMBER

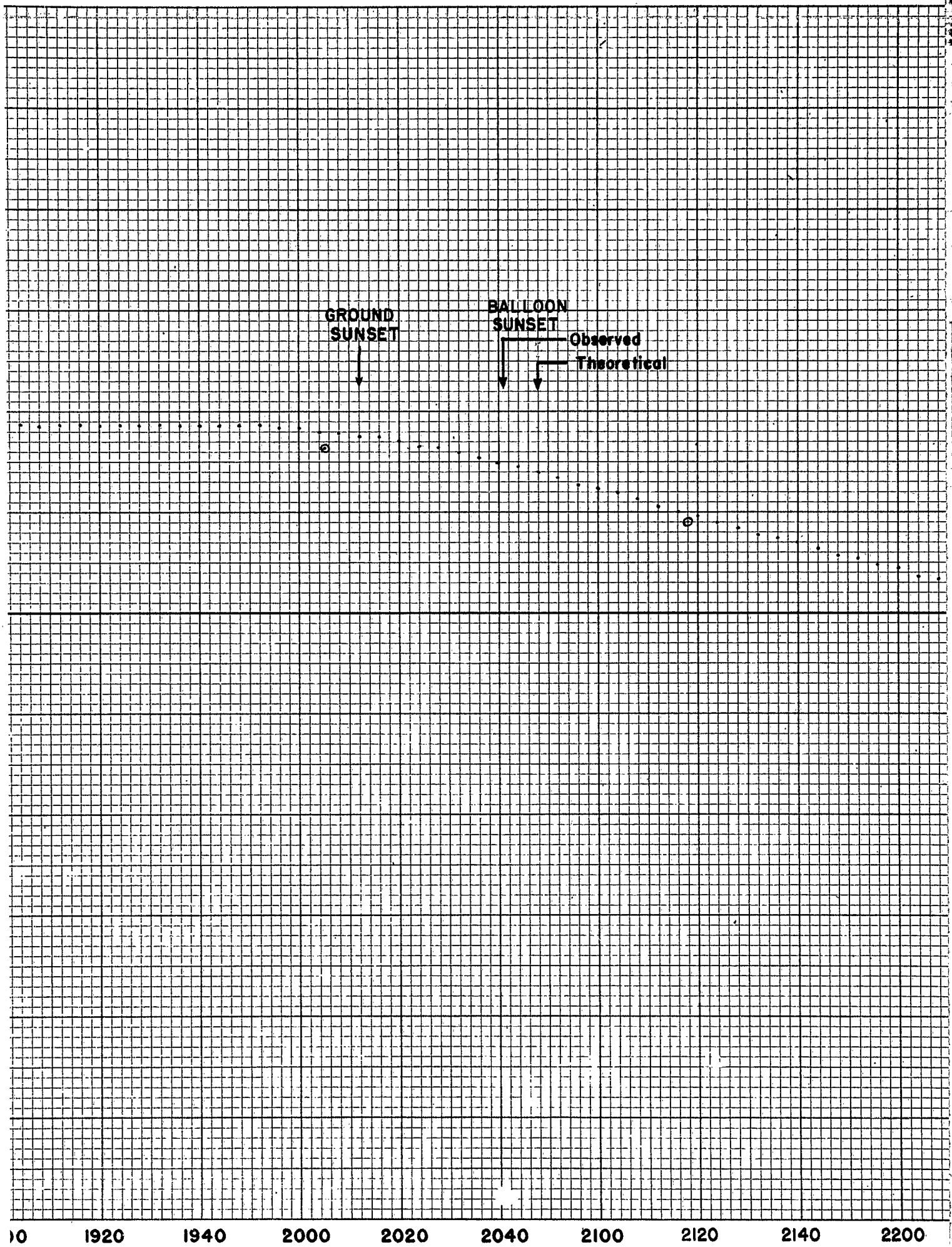

°C
20
30
40
50
60
70
80
90
100
0300
0320
0340
0400
0420
0440
0500
0520
0540

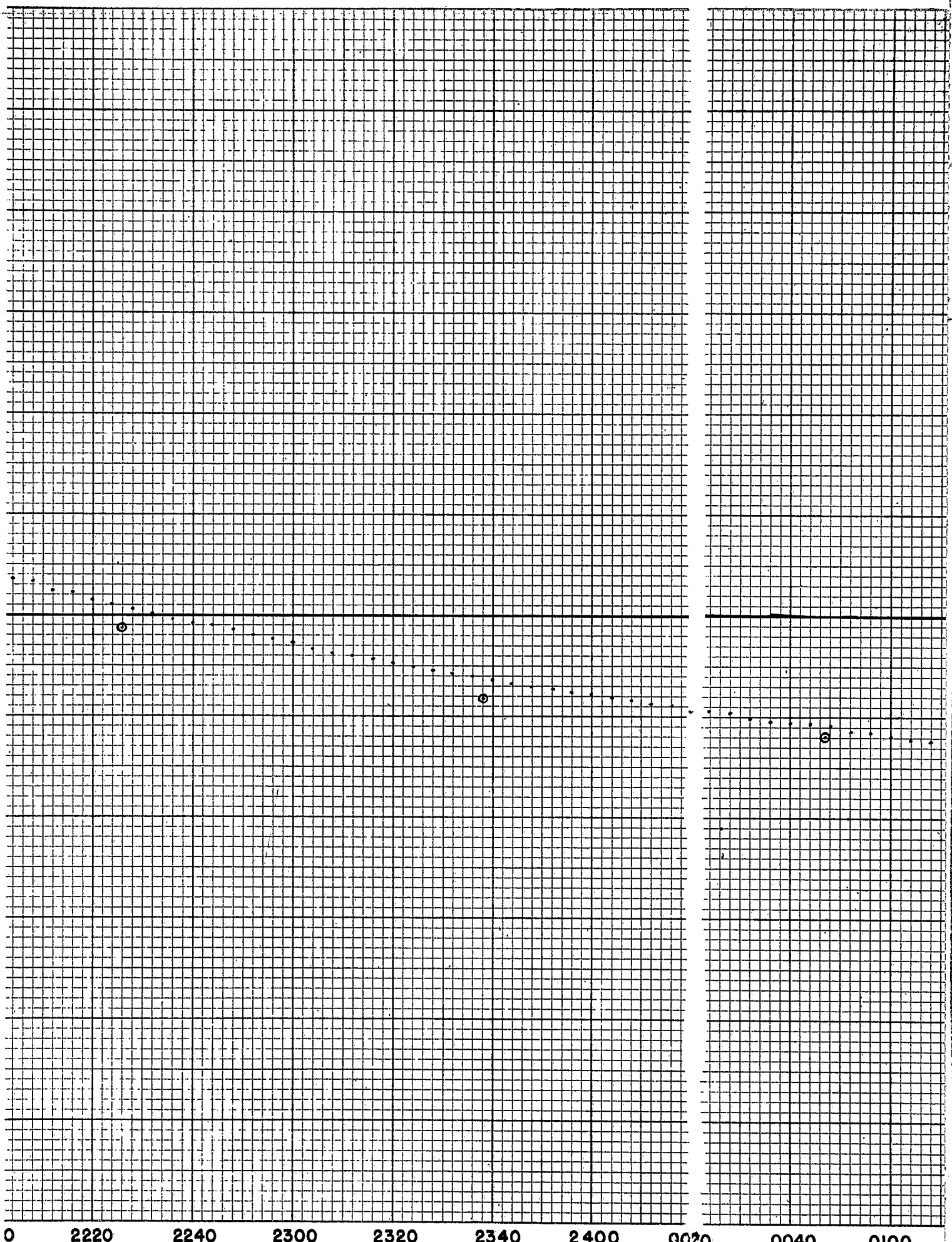

SIGNAL FADED IN
MINNEAPOLIS, MINN.
POINTS
KALAMAZO
0600
0620
0640
0700
0720
0740
0800
0820
0840

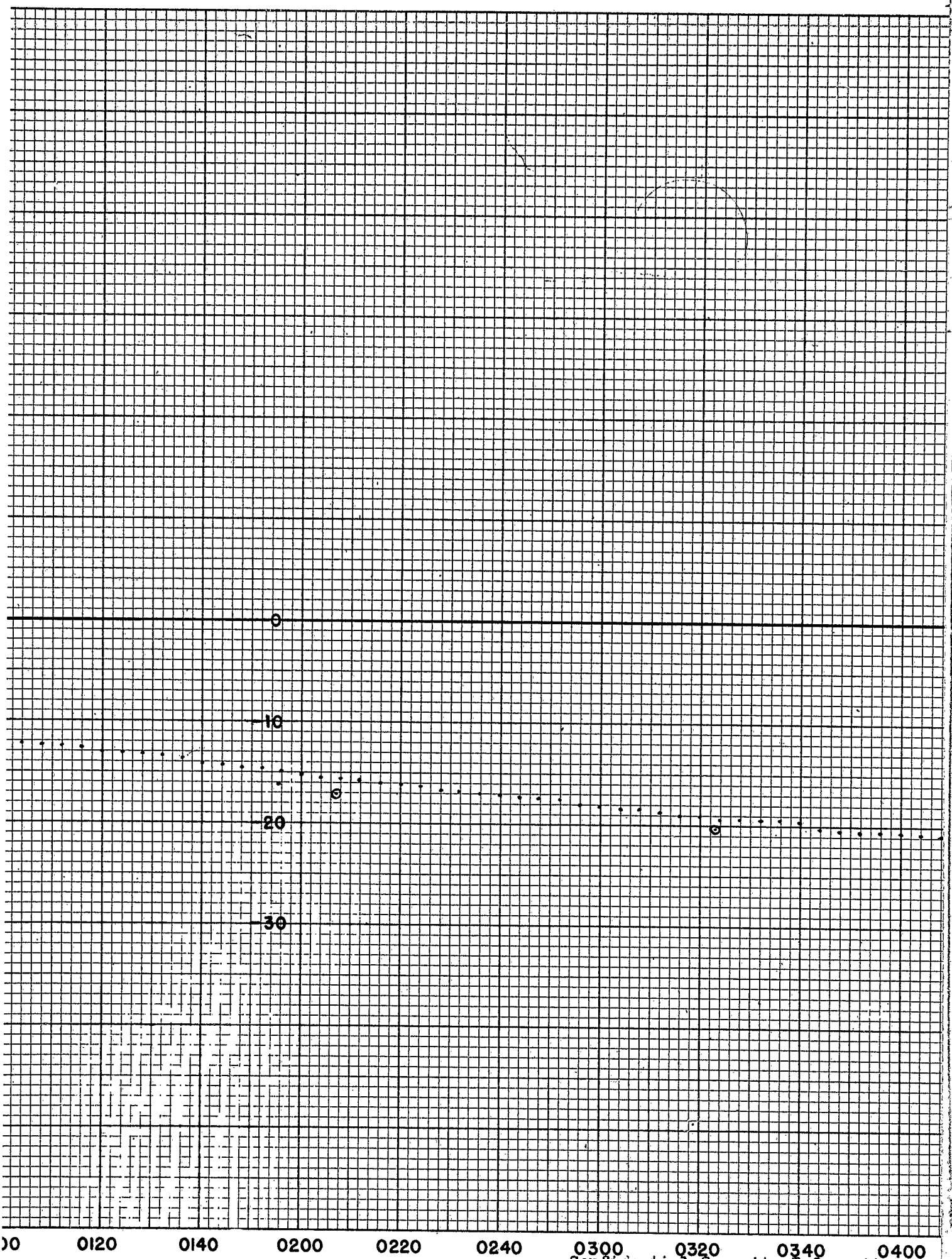

× ×
POINTS RECEIVED FROM
KALAMAZOO, MICH. BY PHONE.
0800
0820
0840
0900
0920
0940
1000

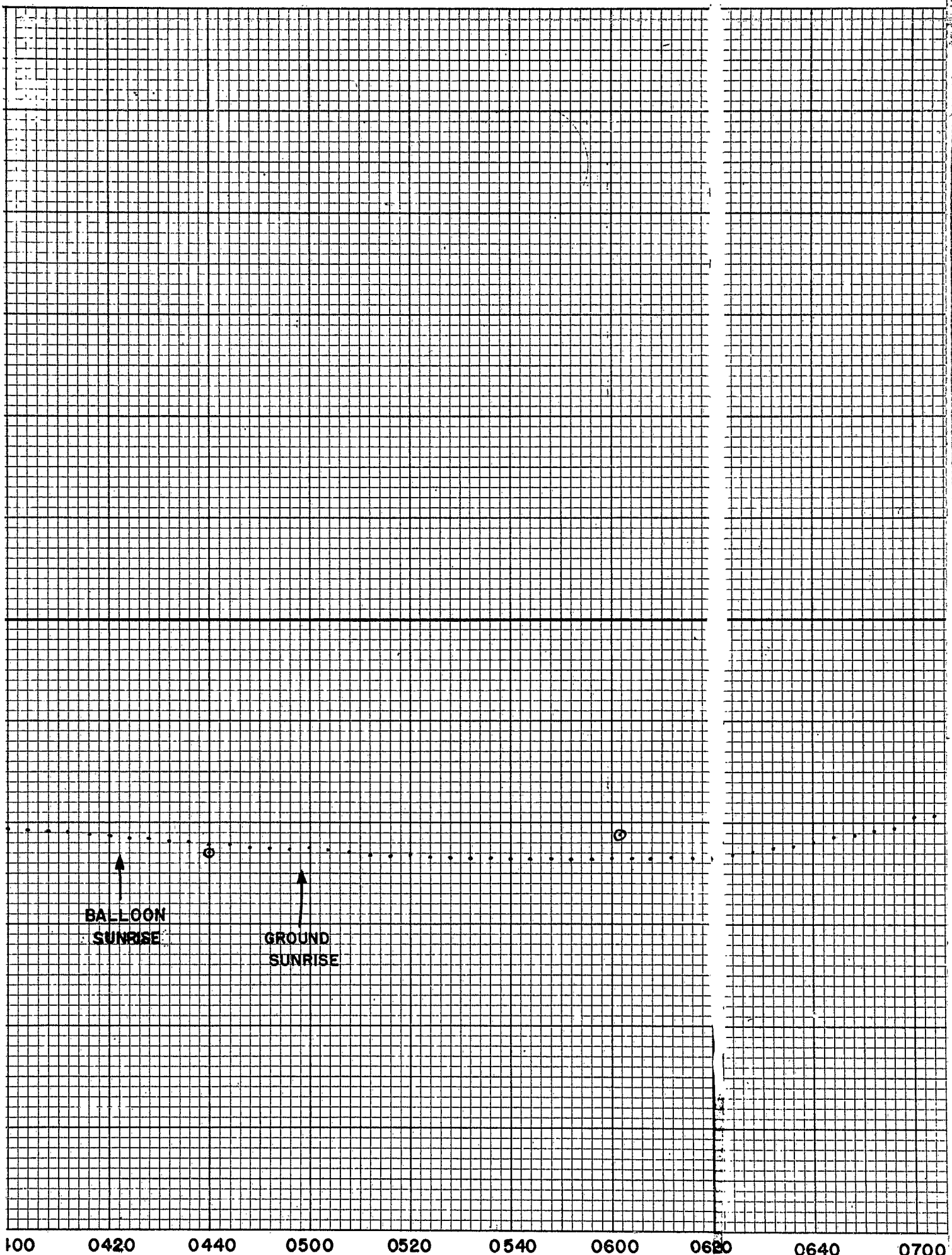

BALLOON
LAUNCHED
1320
1340
1400
1420
1440
1500
1520
1540
1600

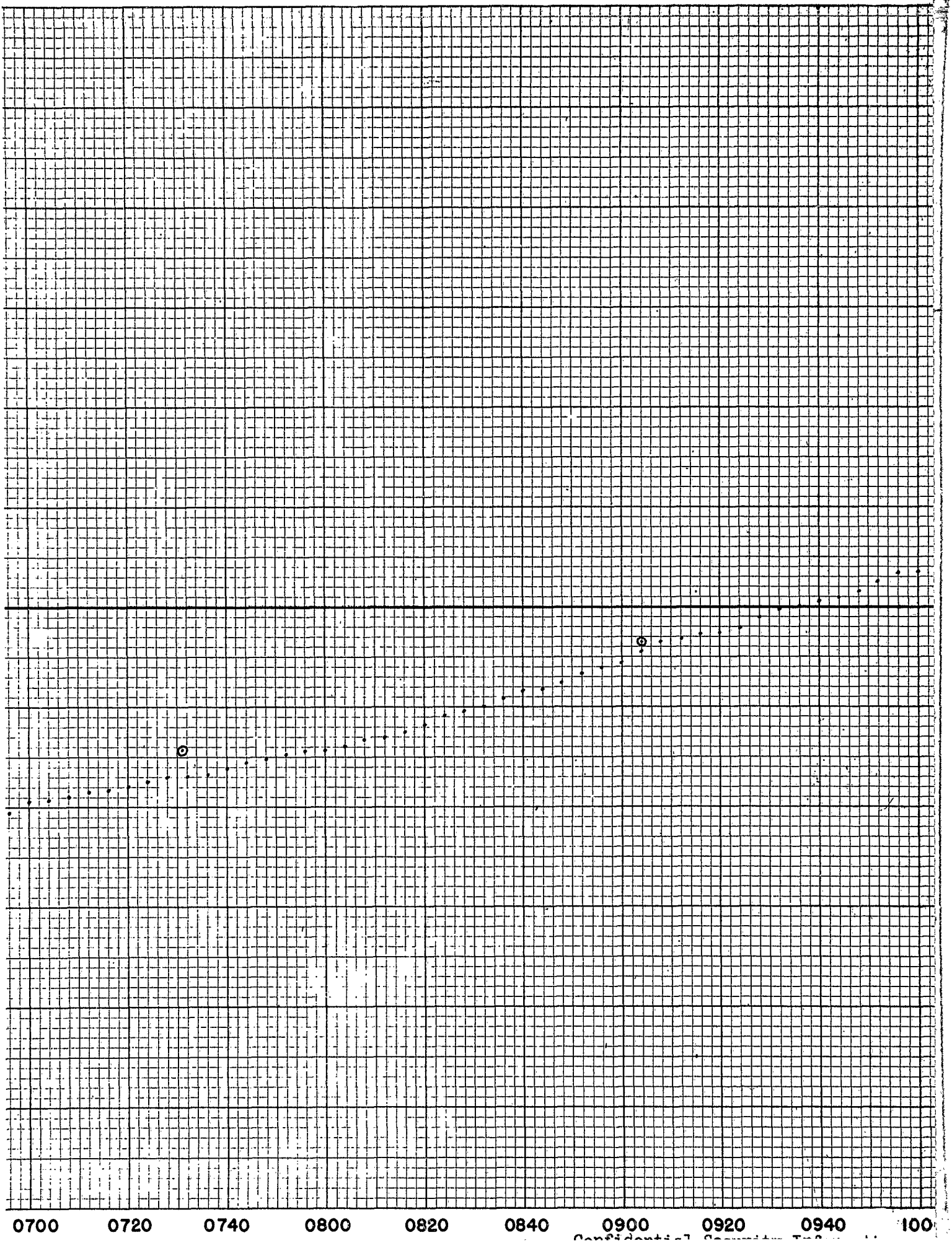

TIME — TEMPERATURE
FLIGHT NO.24
8 a 9 JULY, 1952
DATA FROM THERMOGRAPH RECORD
FIRST READING
RECHECK
1620
1640
1700
1720
1740
1800
1820
1840
1900
CENTRAL STANDARD TIME

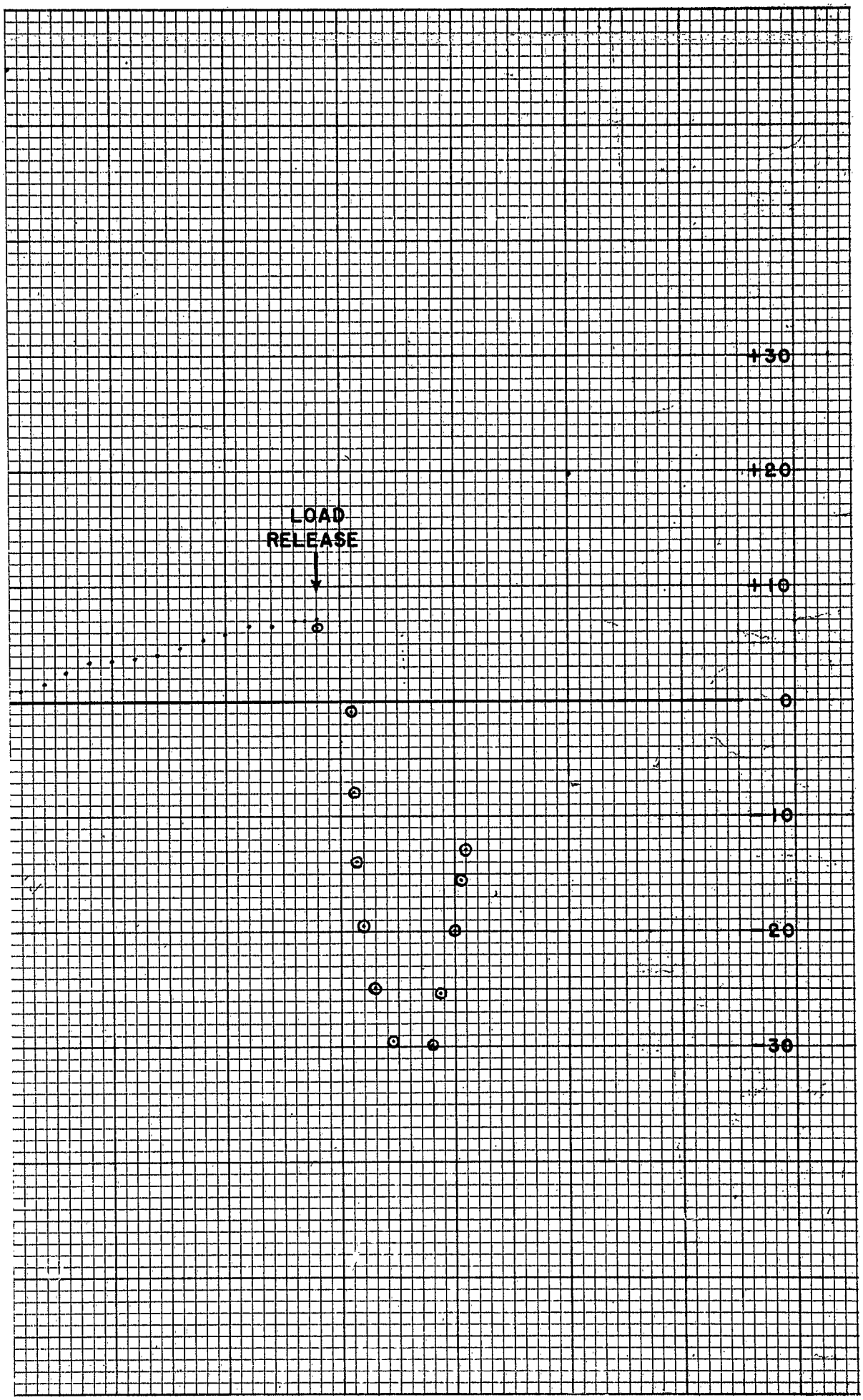

GROUND
SUNSET
BALLOON
SUNSET
Observed
Theoretical
)0
1920
1940
2000
2020
2040
2100
2120
2140
2200

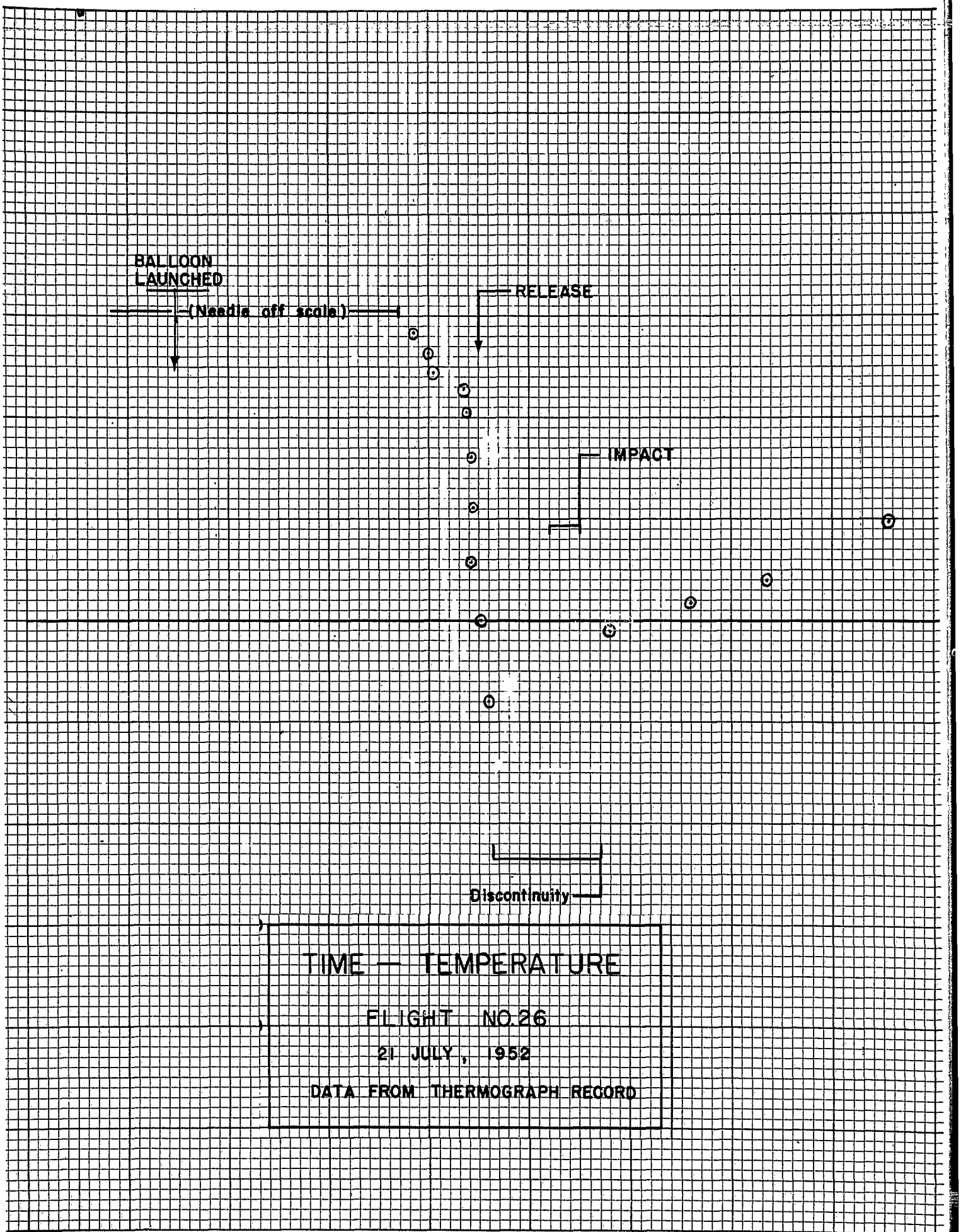

0
2220
2240
2300
2320
2340
2400
0020
0040
0100

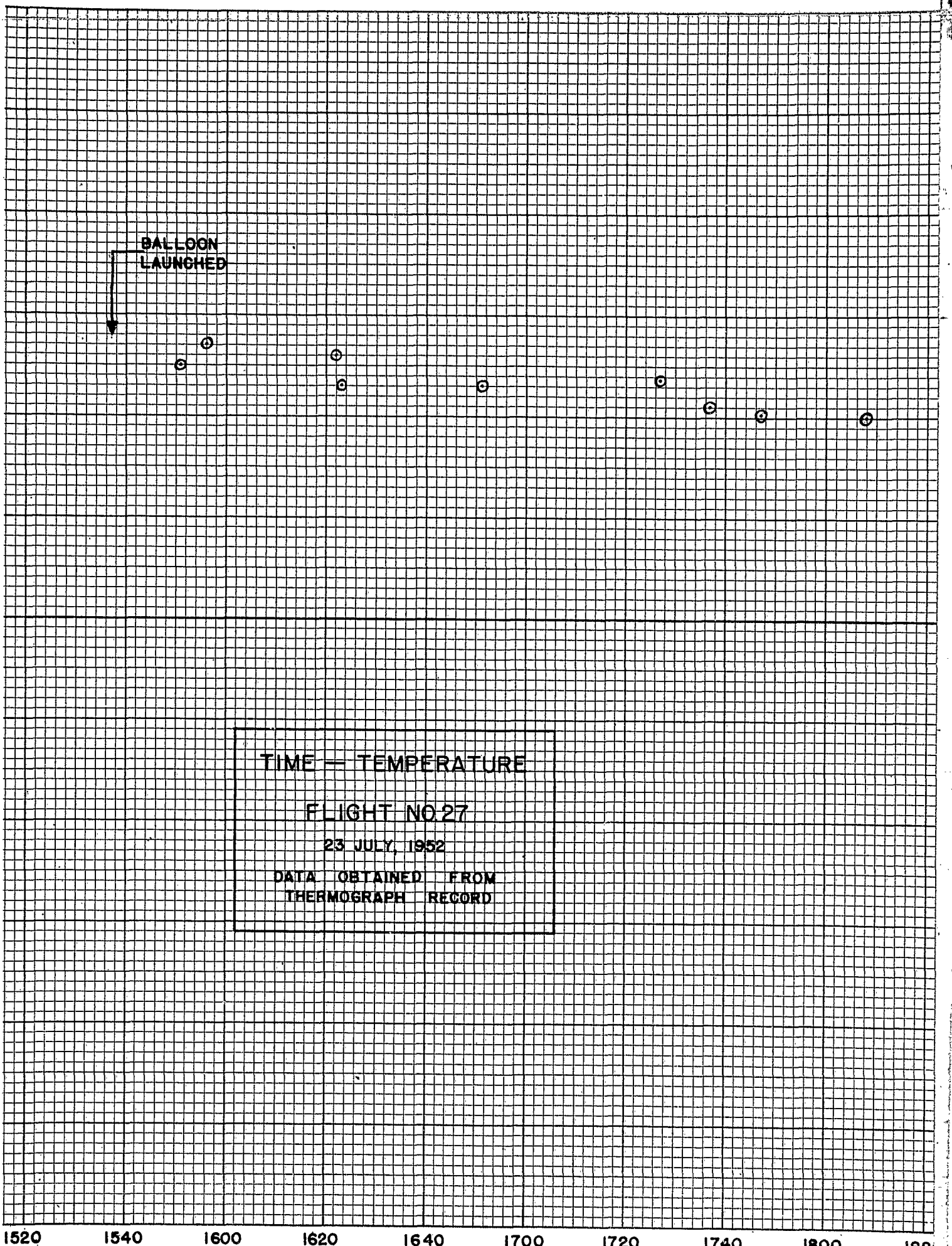

0
-10
-20
-30
)0
0120
0140
0200
0220
0240
0300
0320
0340
0400

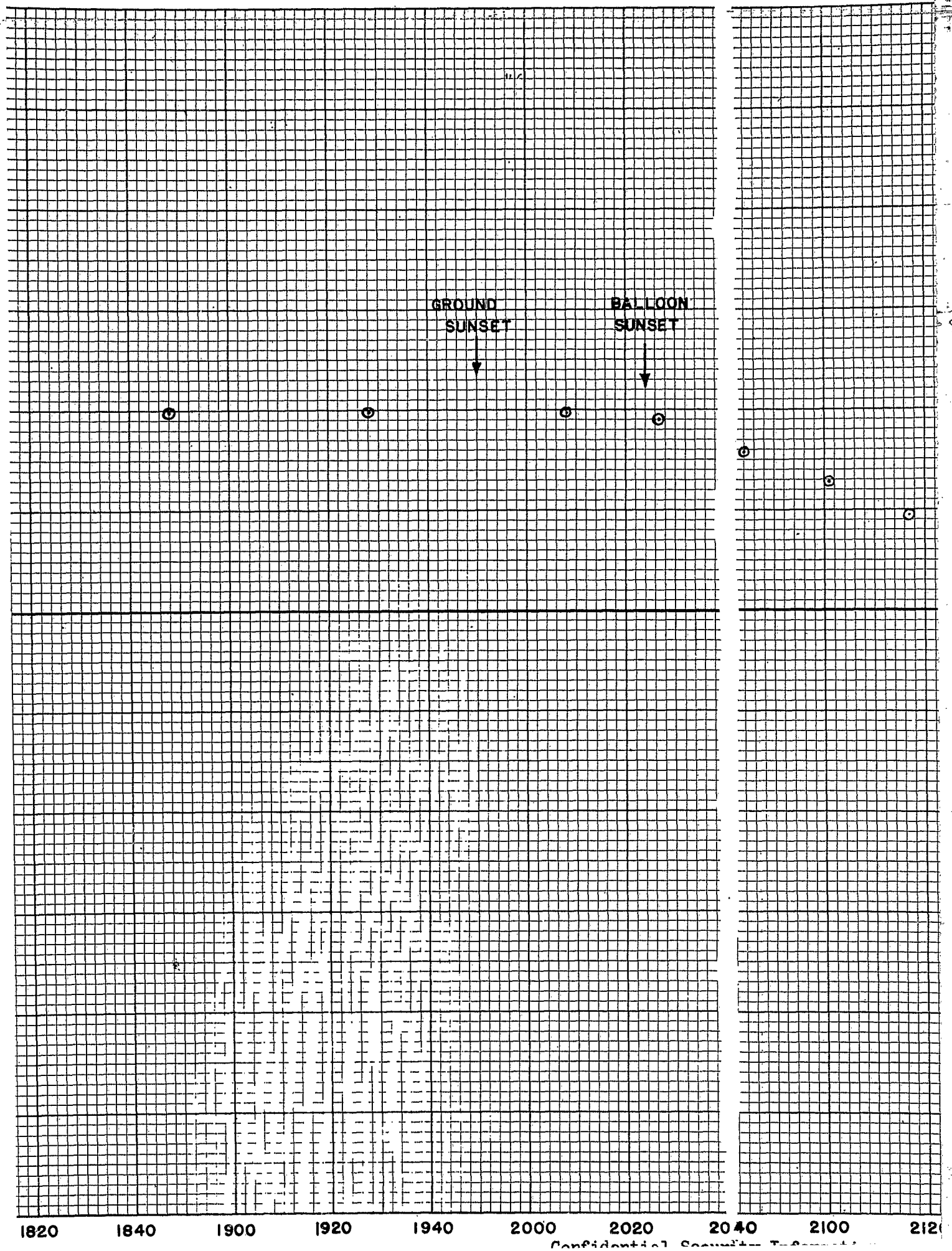

BALLOON
SUNRISE
GROUND
SUNRISE
400
0420
0440
0500
0520
0540
0600
0620
0640
0700

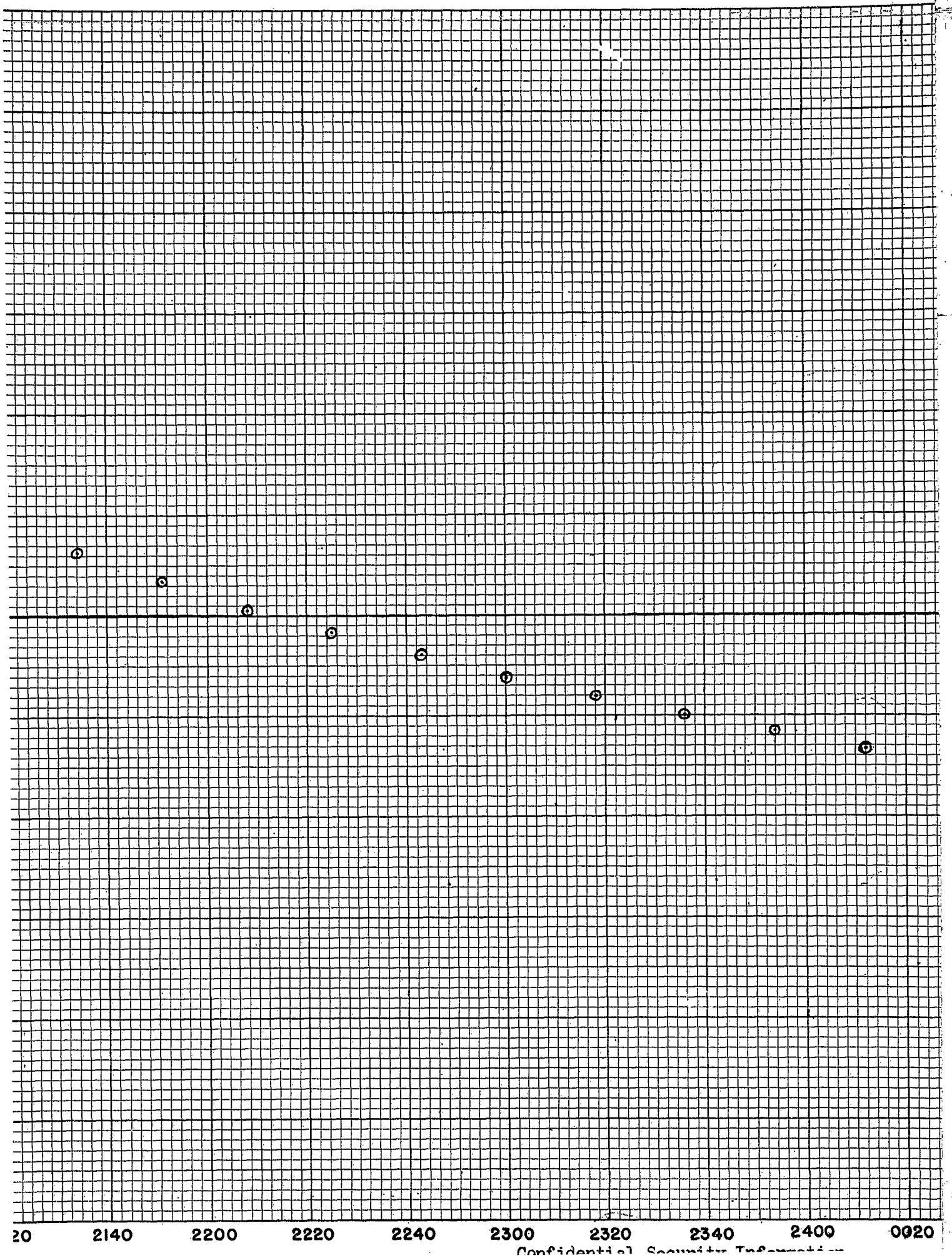

0700
0720
0740
0800
0820
0840
0900
0920
0940
100

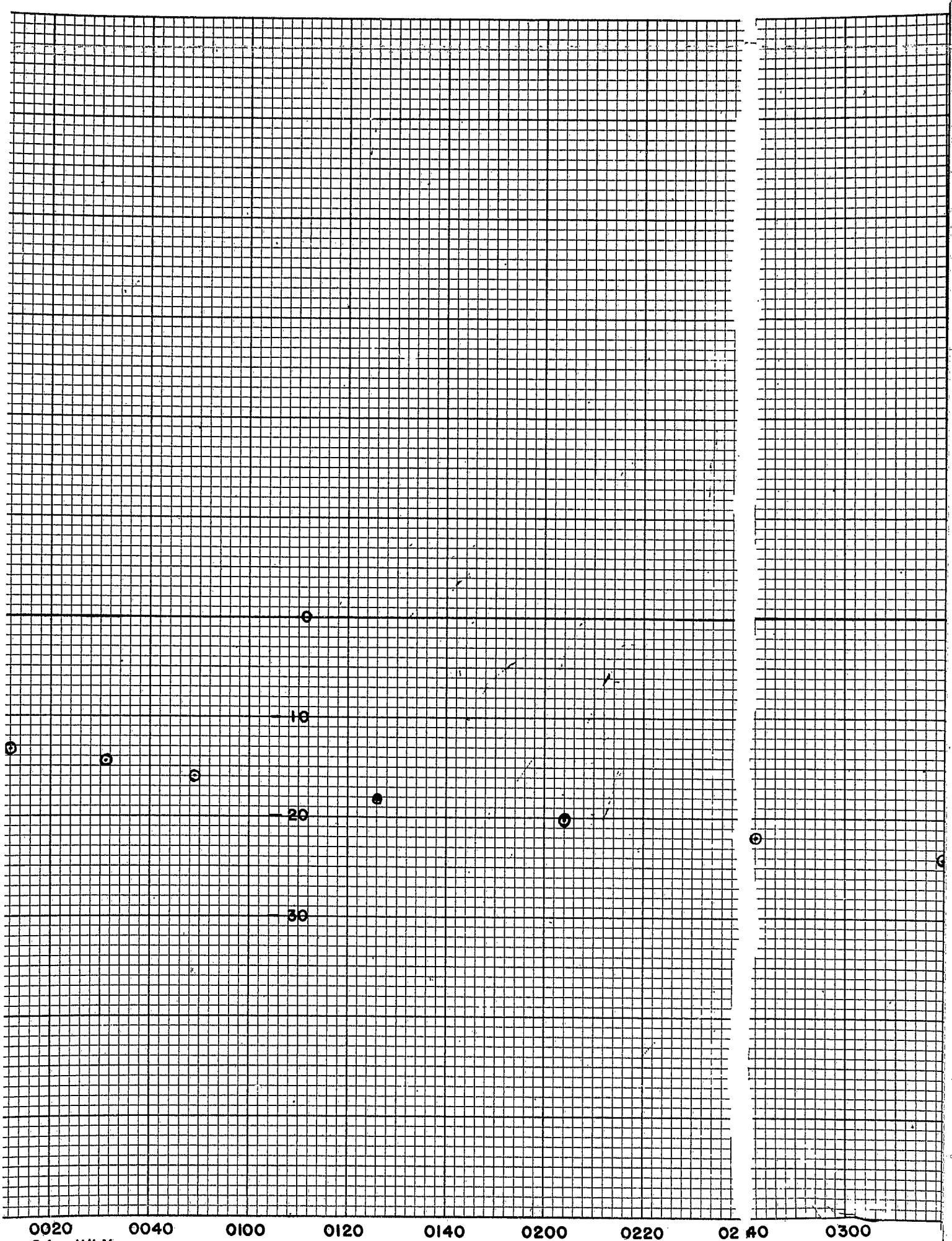

LOAD
RELEASE
+30
+20
+10
0
-10
-20
-30
1000
1020
1040
1100
1120
1140

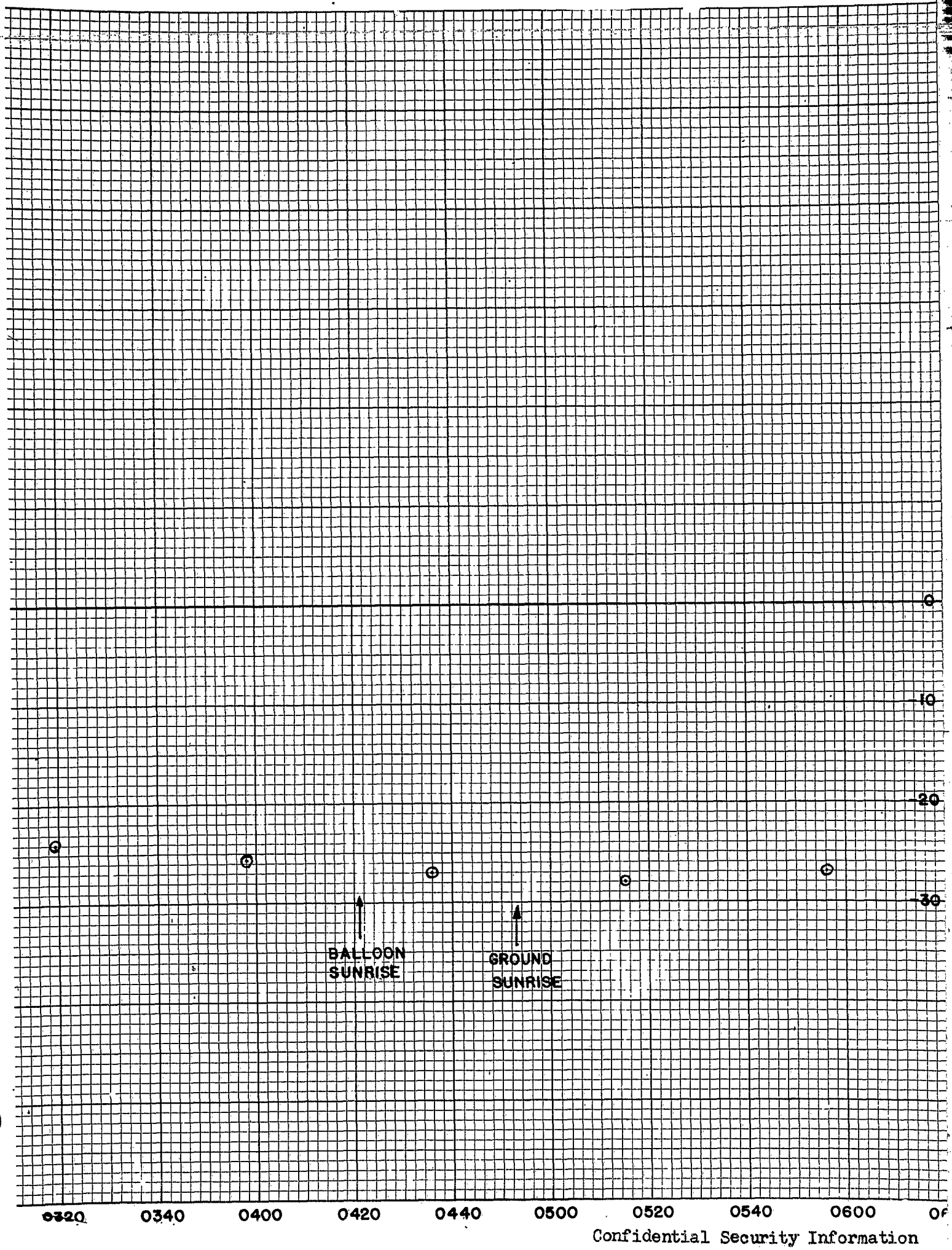

BALLOON LAUNCHED
(Needle off scale)
RELEASE
IMPACT
Discontinuity
TIME — TEMPERATURE
FLIGHT NO. 26
21 JULY, 1952
DATA FROM THERMOGRAPH RECORD
1440
1500
1520
1540
1600
1620
1640
1700
172
CENTRAL STANDARD TIME

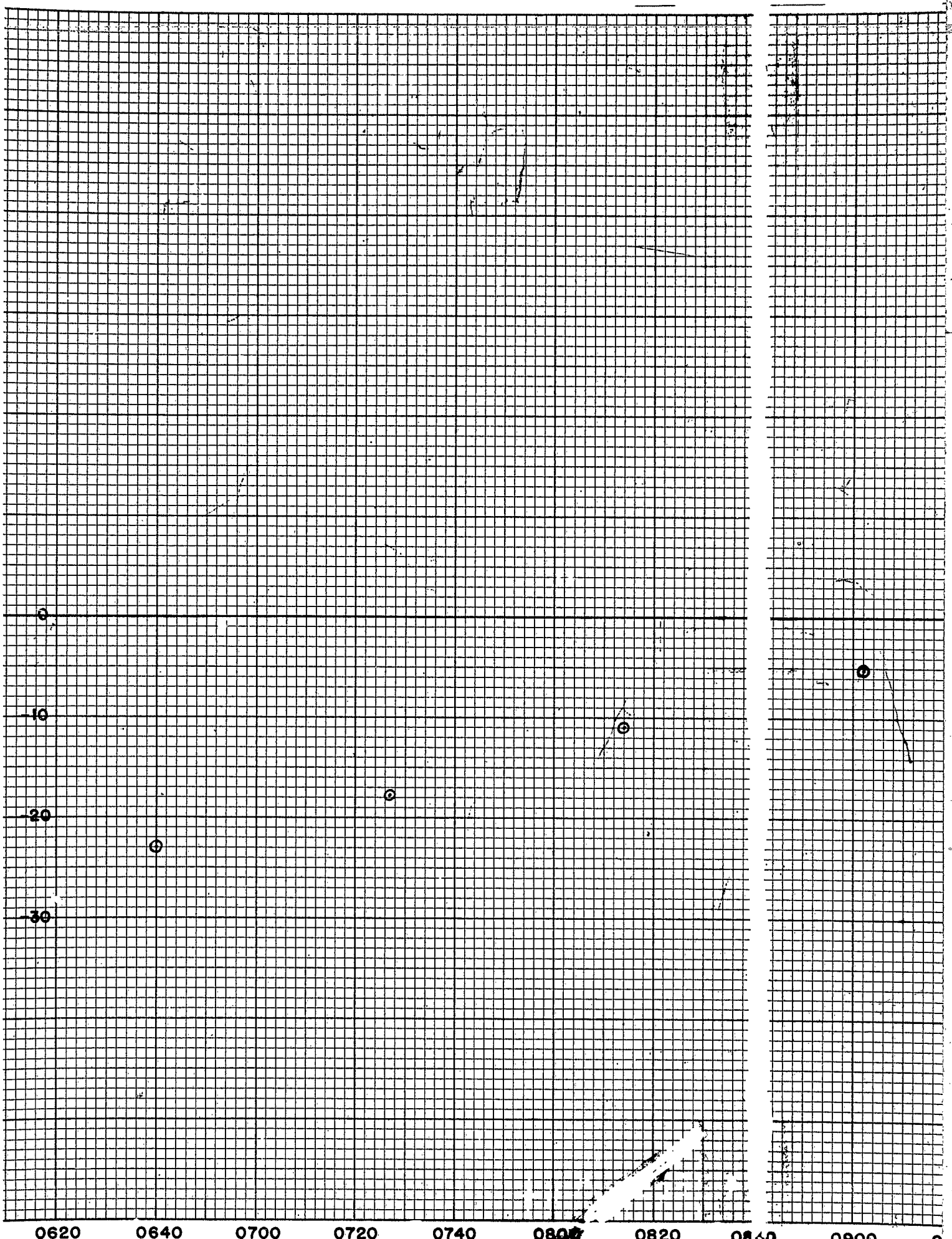

BALLOON
LAUNCHED
TIME — TEMPERATURE
FLIGHT NO.27
23 JULY, 1952
DATA OBTAINED FROM
THERMOGRAPH RECORD
1520
1540
1600
1620
1640
1700
1720
1740
1800

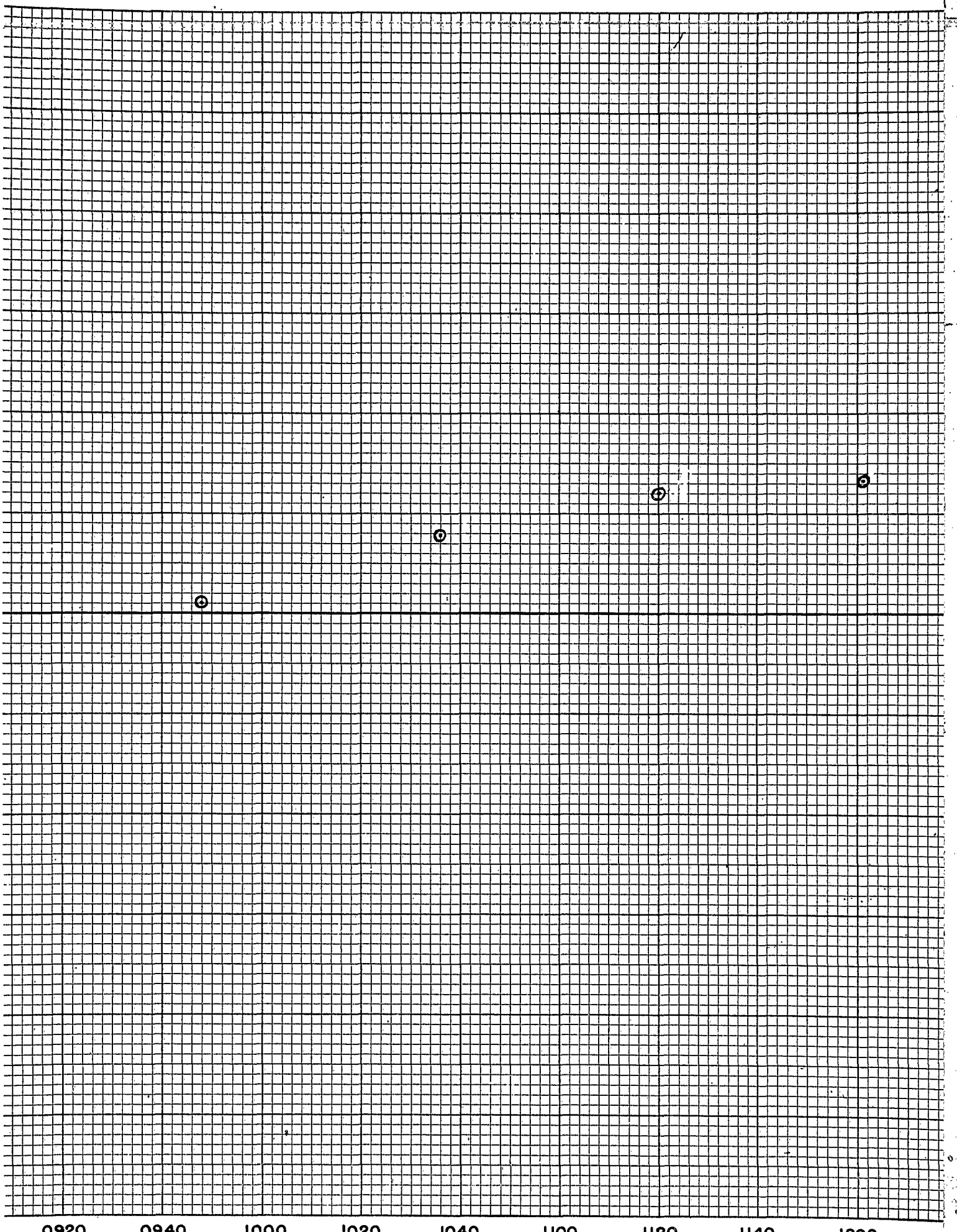

GROUND
SUNSET
BALLOON
SUNSET
1820
1840
1900
1920
1940
2000
2020
2040
2100
212

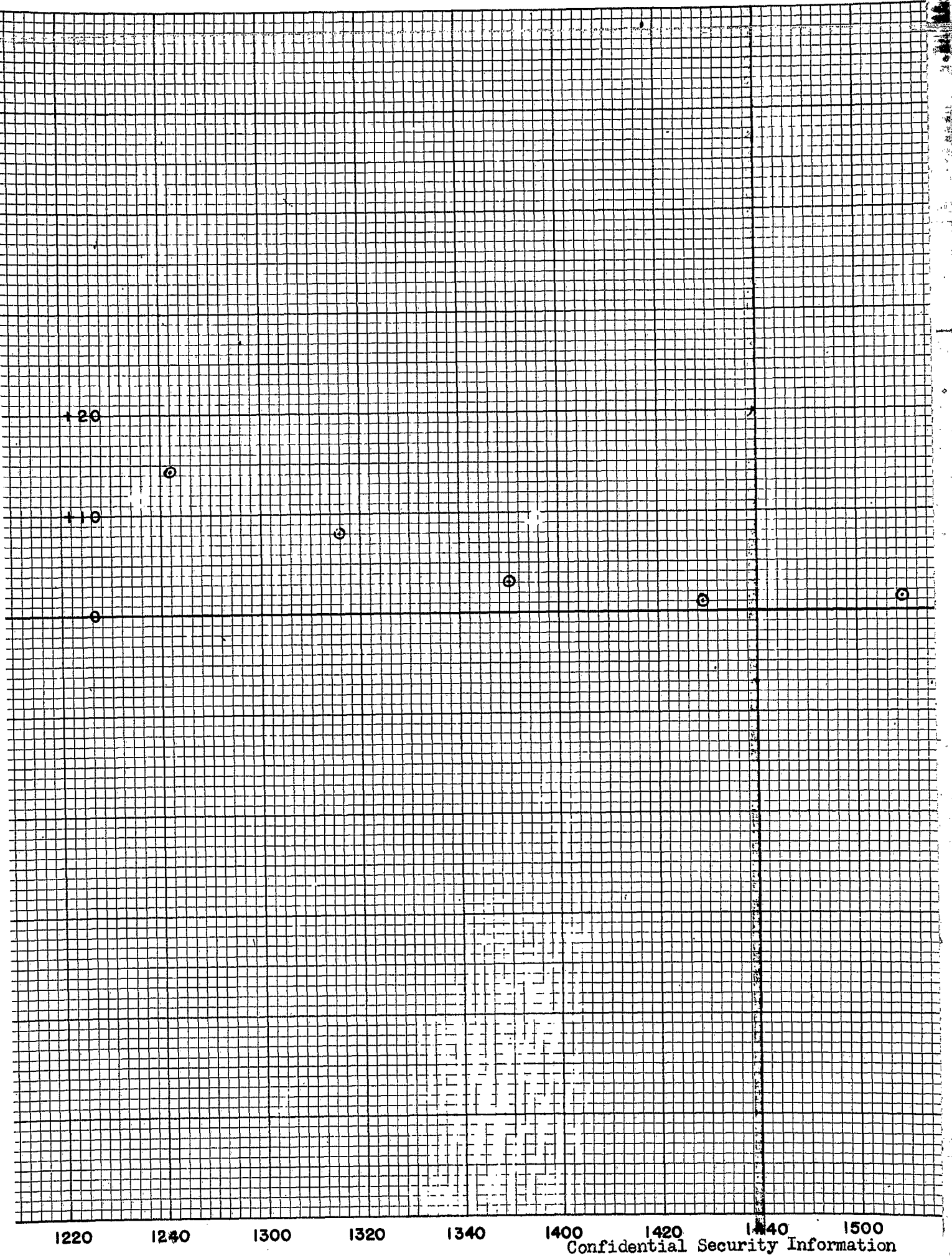

20
2140
2200
2220
2240
2300
2320
2340
2400
0920

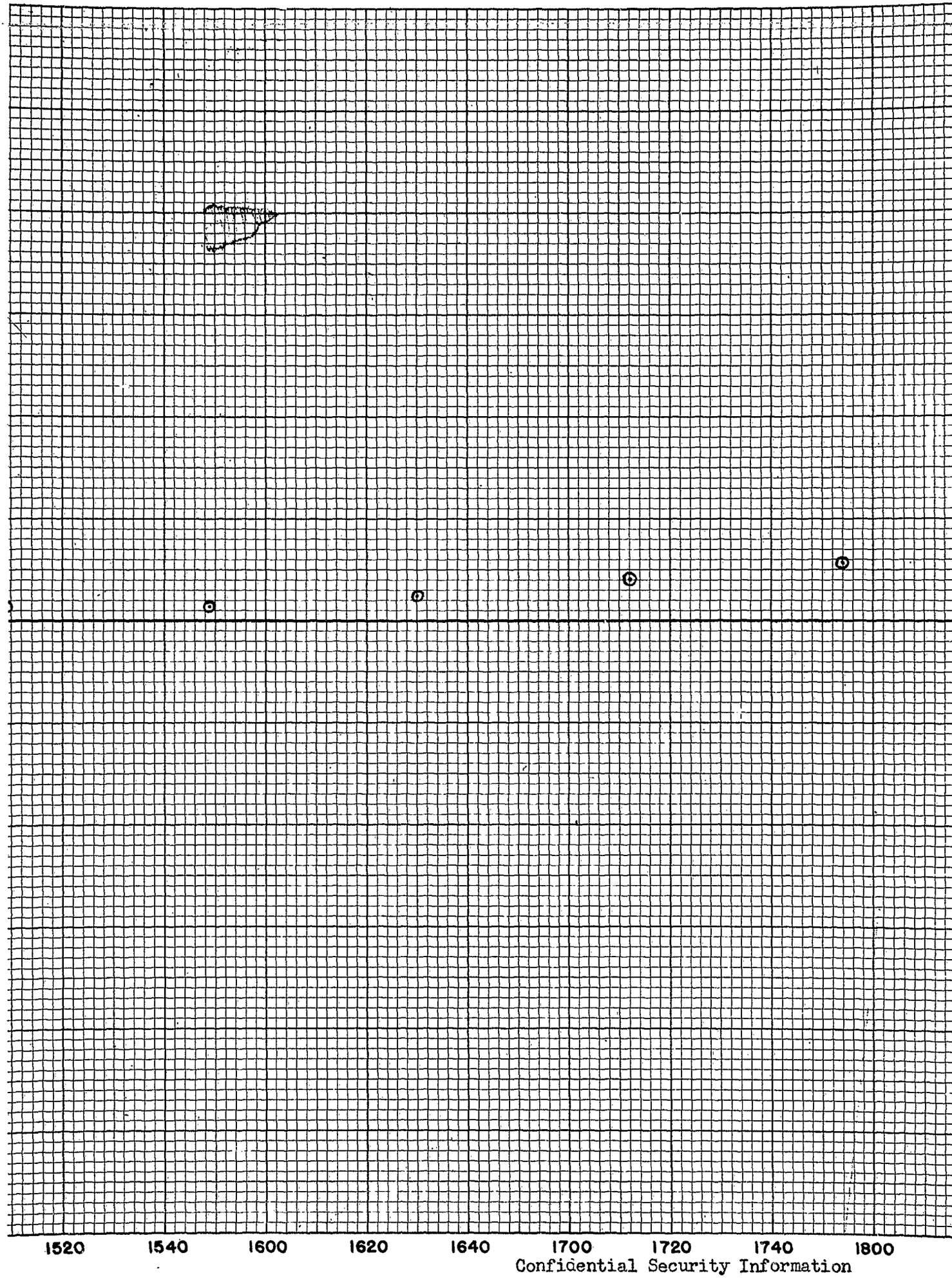

0
10
20
30
0020
0040
0100
0120
0140
0200
0220
0240
0300
24 JULY

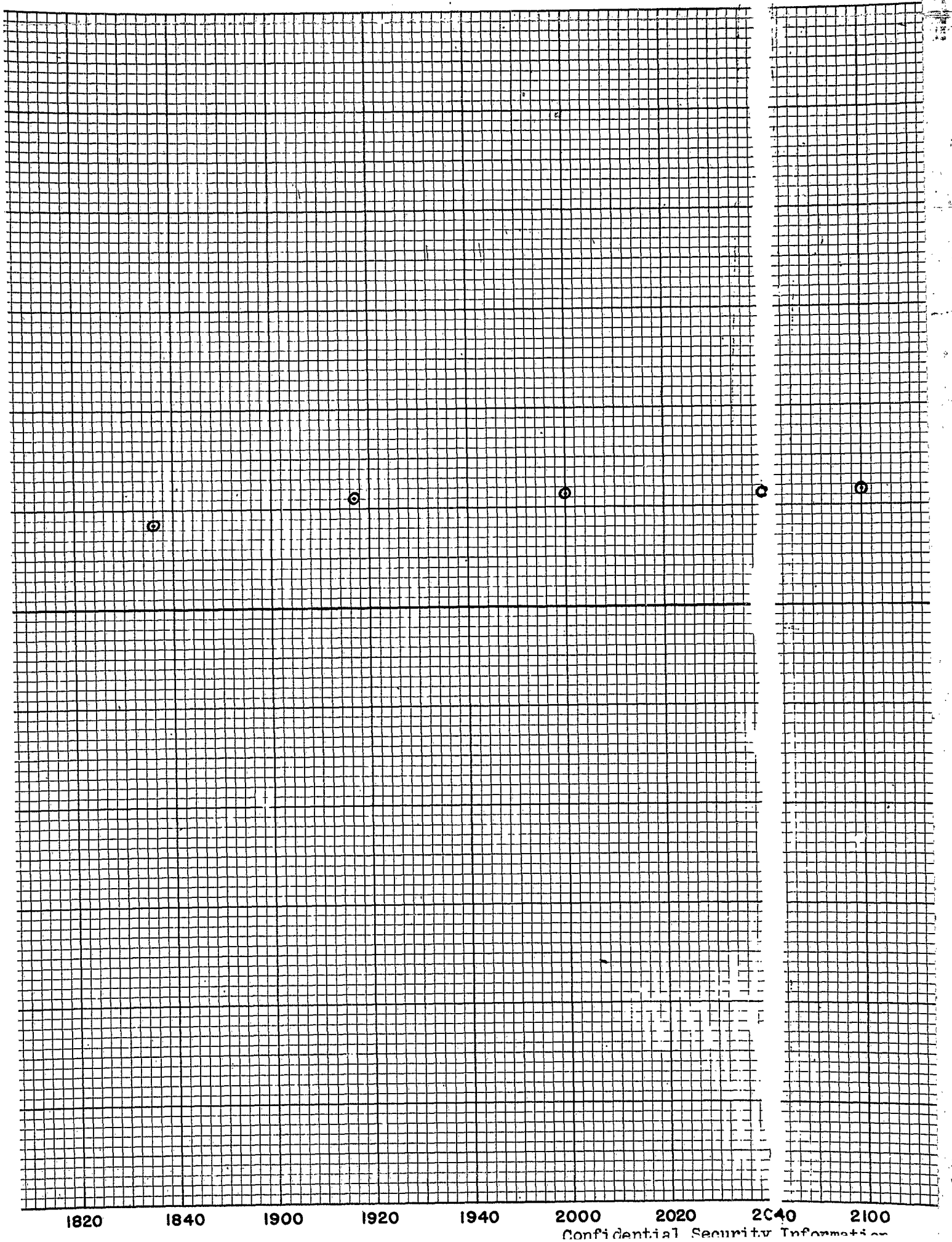

0
-10
-20
-30
BALLOON SUNRISE
GROUND SUNRISE
0320
0340
0400
0420
0440
0500
0520
0540
0600

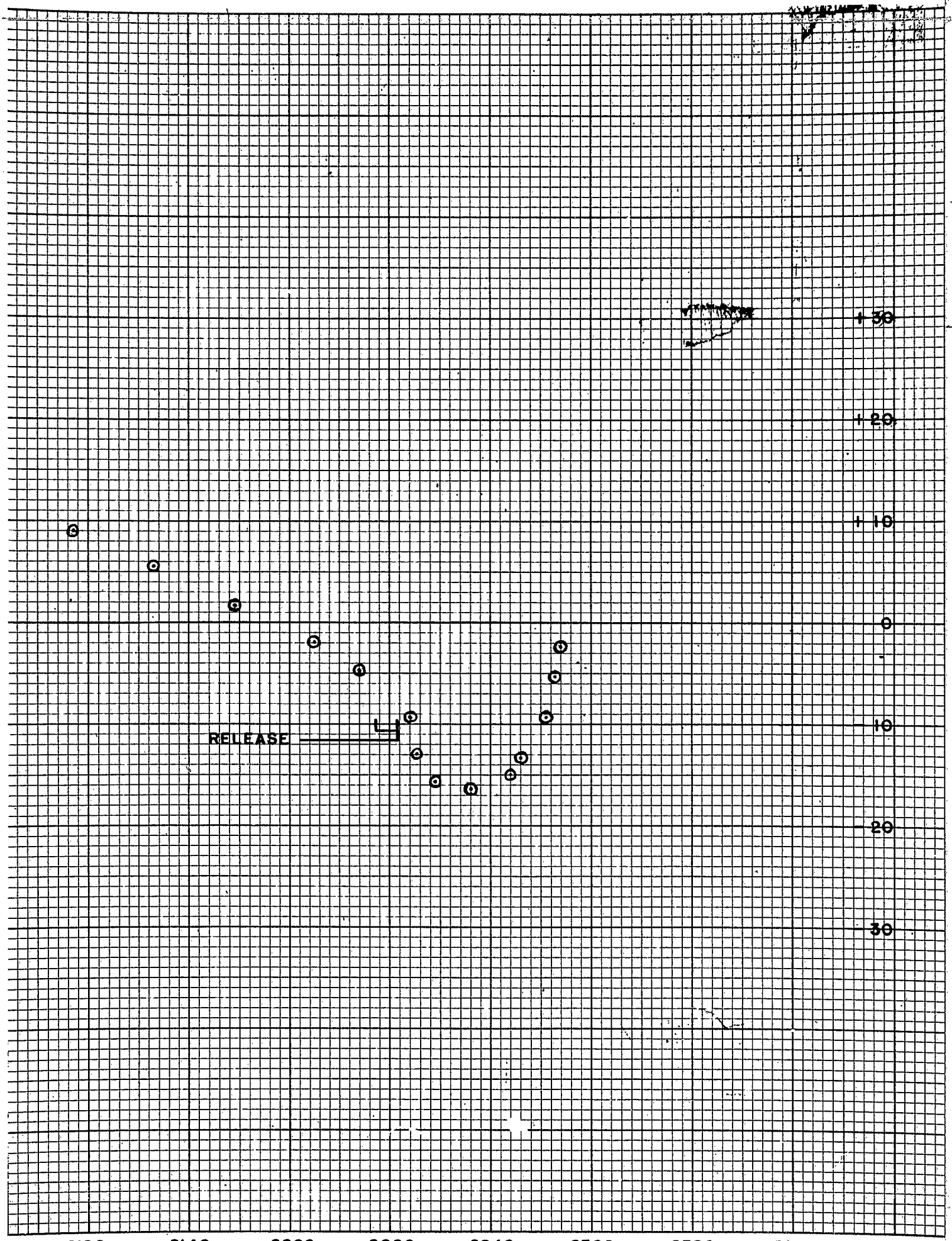

0
-10
-20
-30
0620
0640
0700
0720
0740
0820
0900

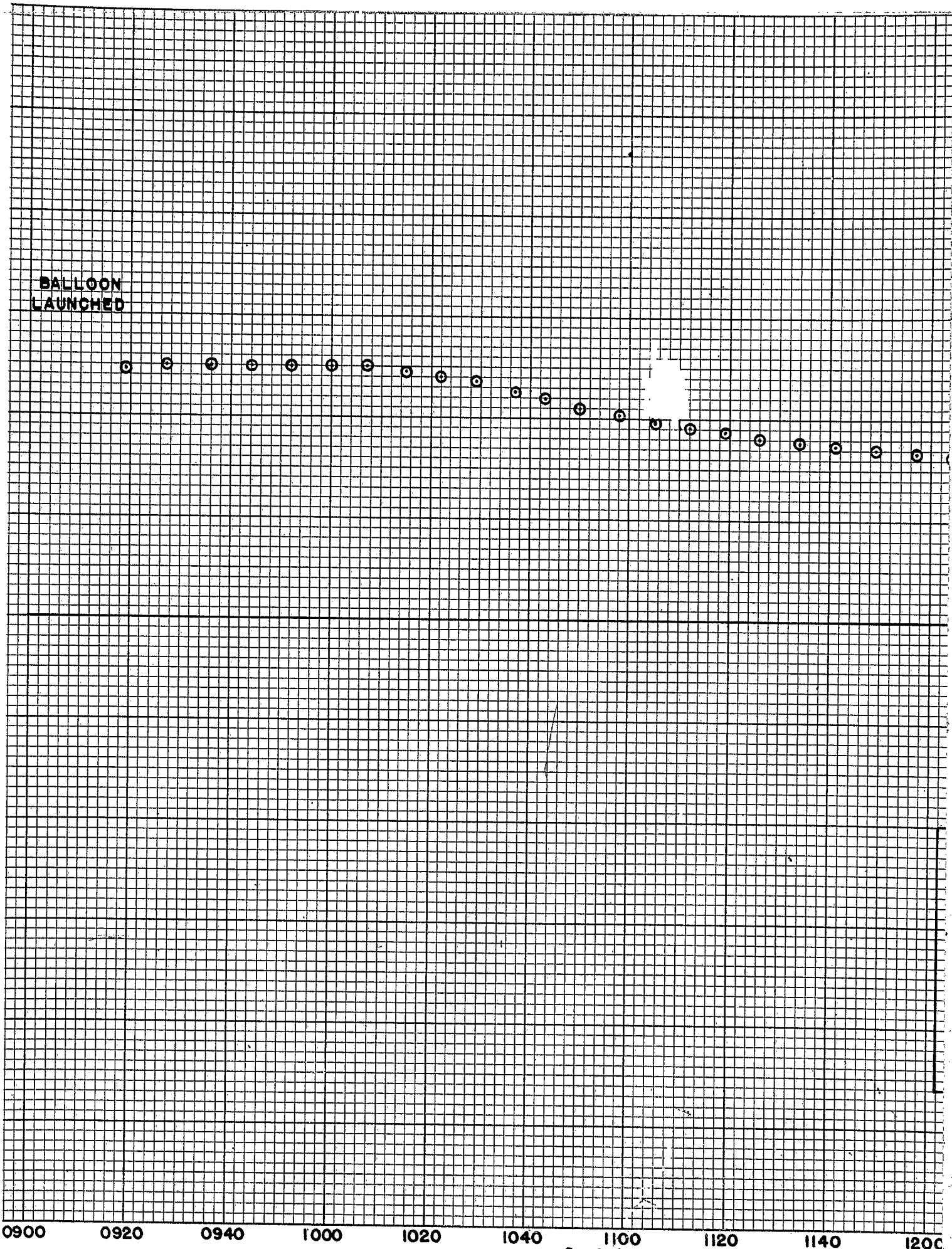

0920
0940
1000
1020
1040
1100
1120
1140
1200

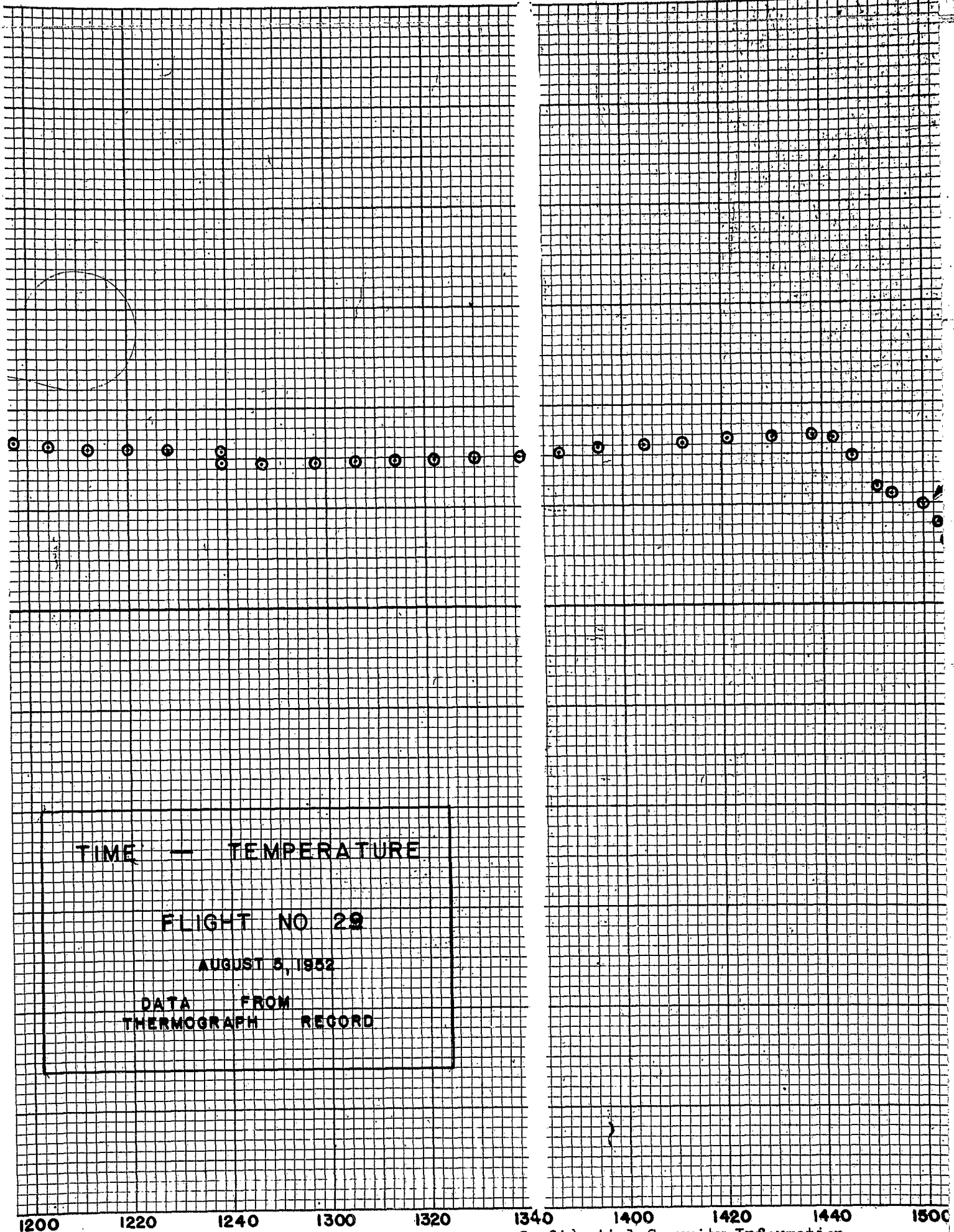

+20
+10
0
1220
1240
1300
1320
1340
1400
1420
1440
1500

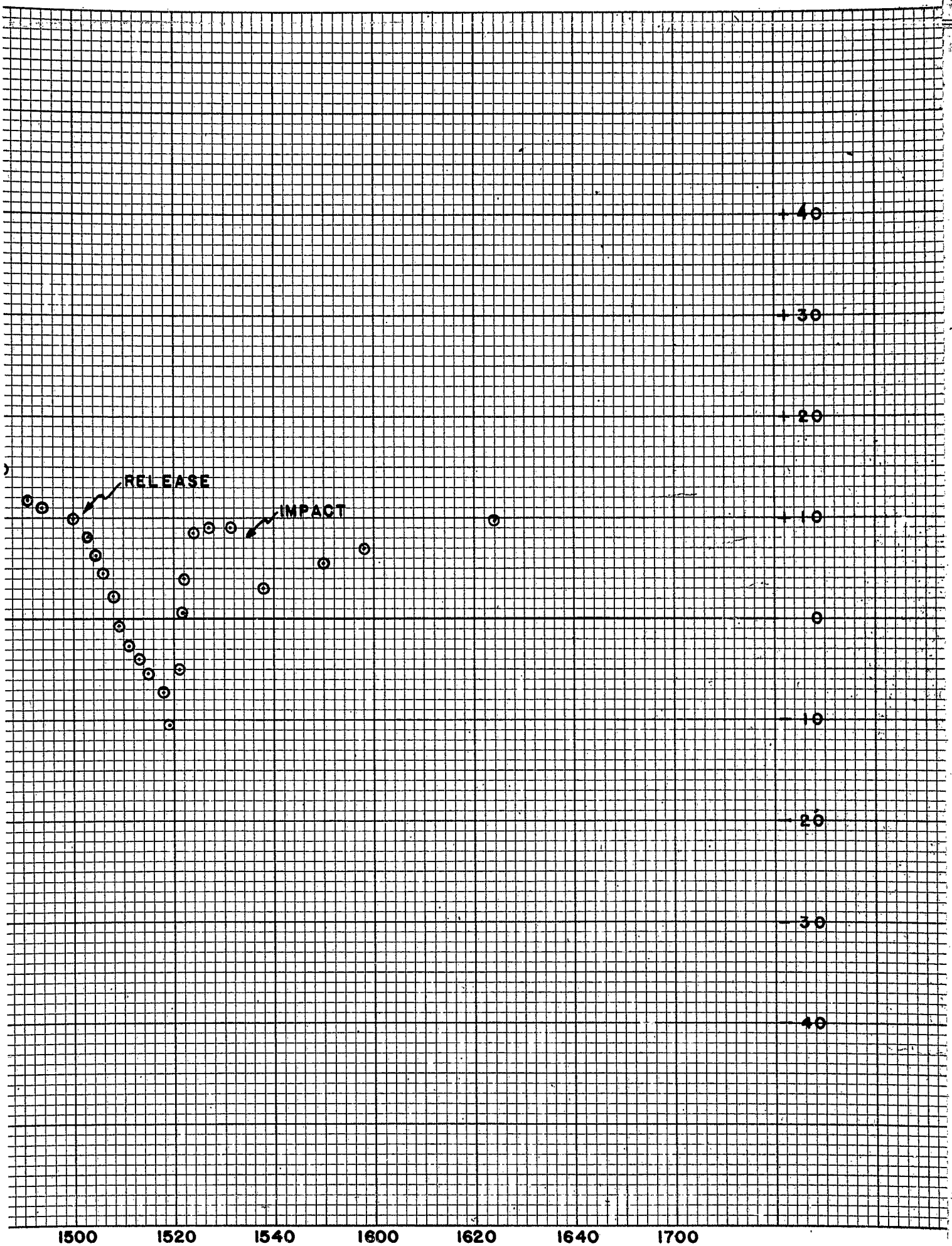

1520
1540
1600
1620
1640
1700
1720
1740
1800

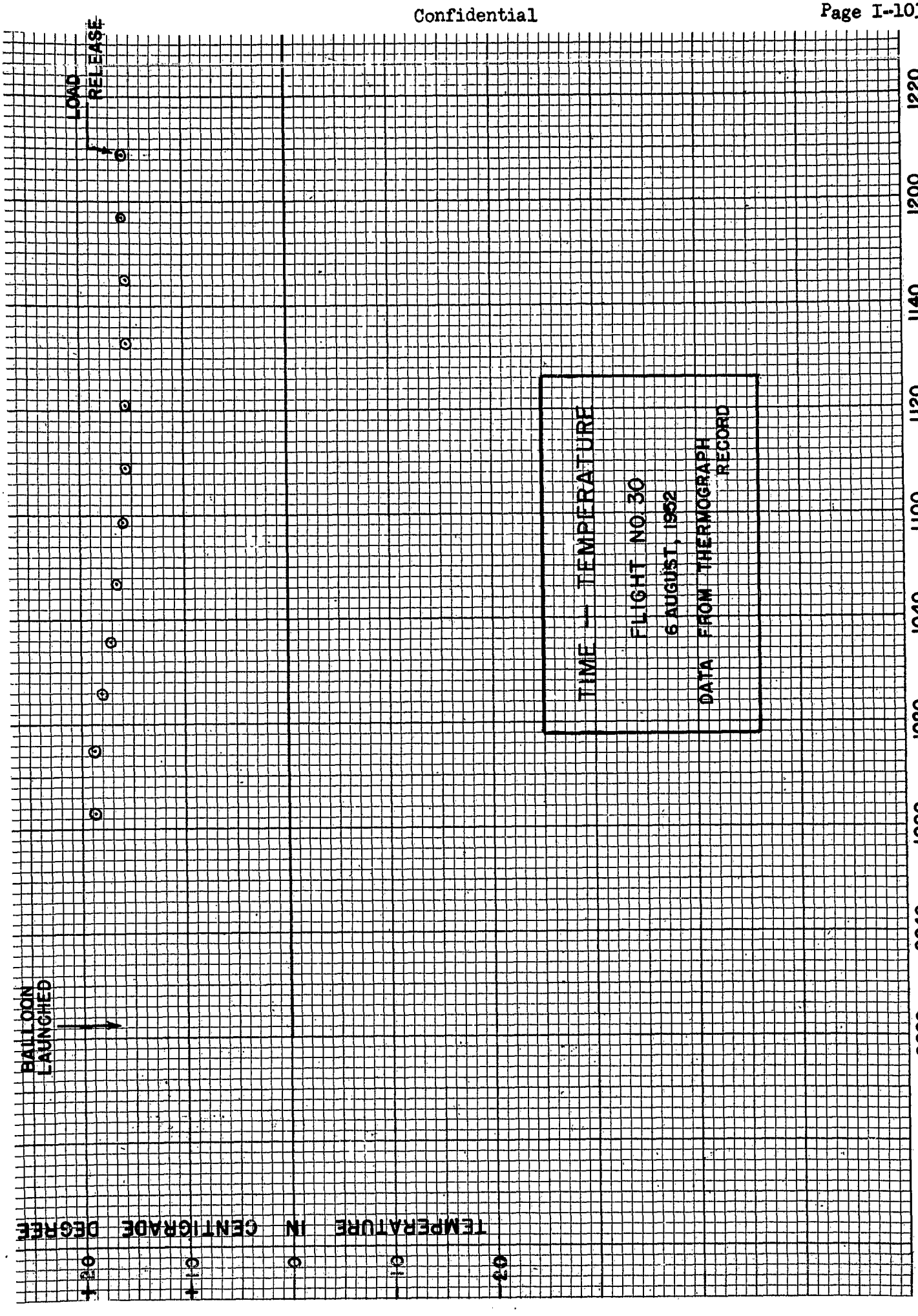

1820
1840
1900
1920
1940
2000
2020
2040
2100

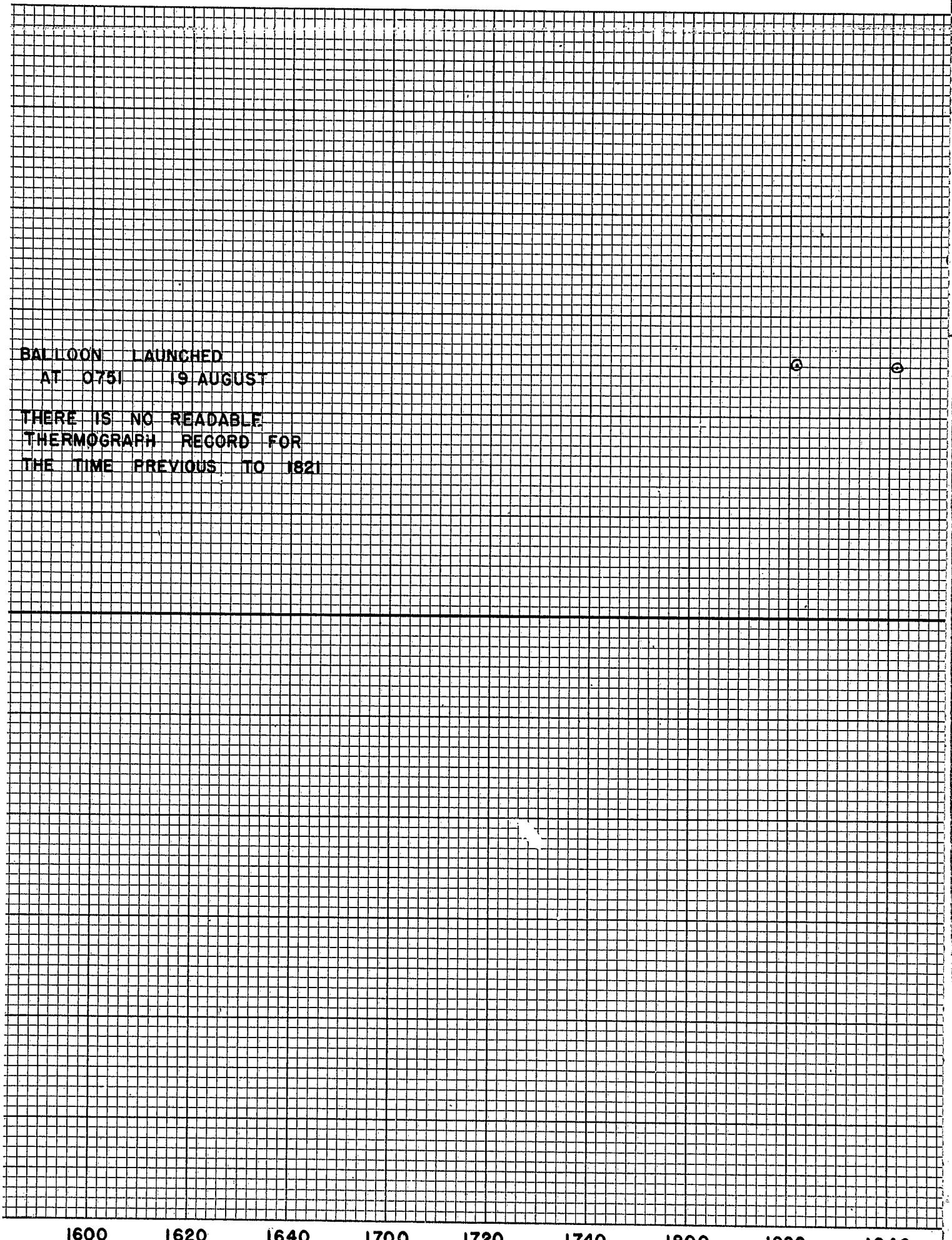

+30
+20
+10
0
-10
-20
-30
RELEASE
2120
2140
2200
2220
2240
2300
2320
2340

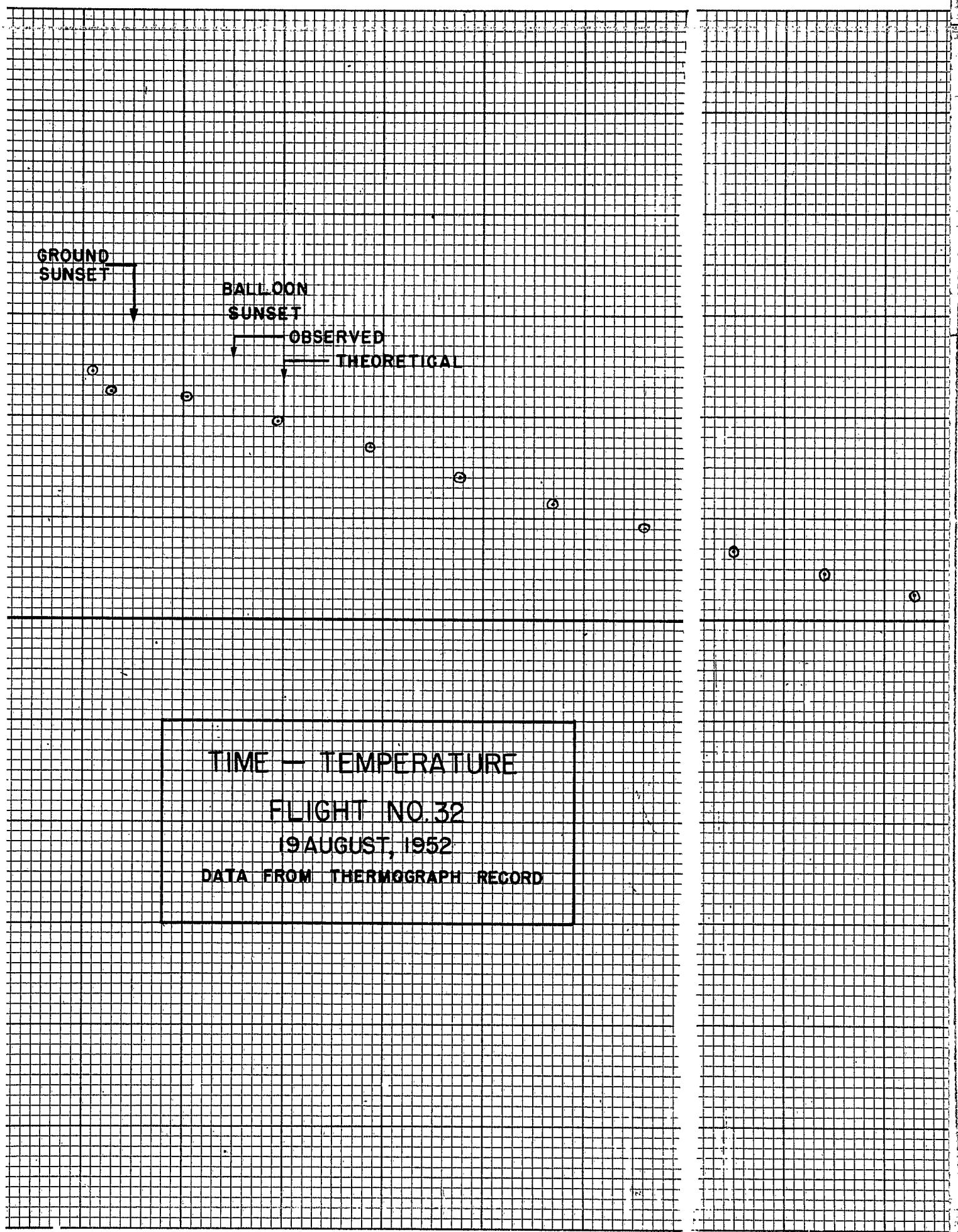

BALLOON
LAUNCHED
0900
0920
0940
1000
1020
1040
1100
1120
1140
1200

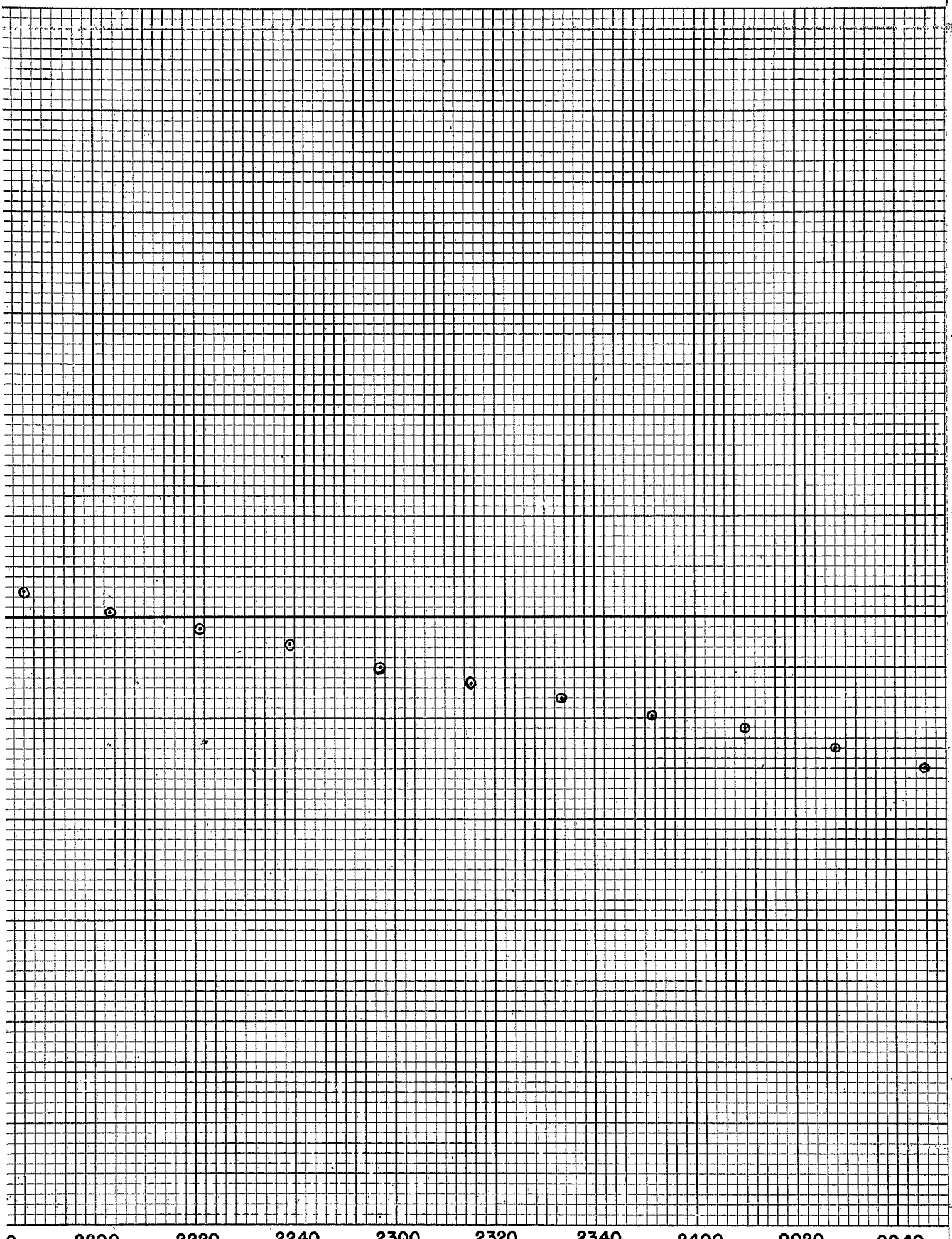

TIME — TEMPERATURE
FLIGHT NO 29
AUGUST 5, 1952
DATA FROM
THERMOGRAPH RECORD
1200
1220
1240
1300
1320
1340
1400
1420
1440
1500
CENTRAL STANDARD TIME

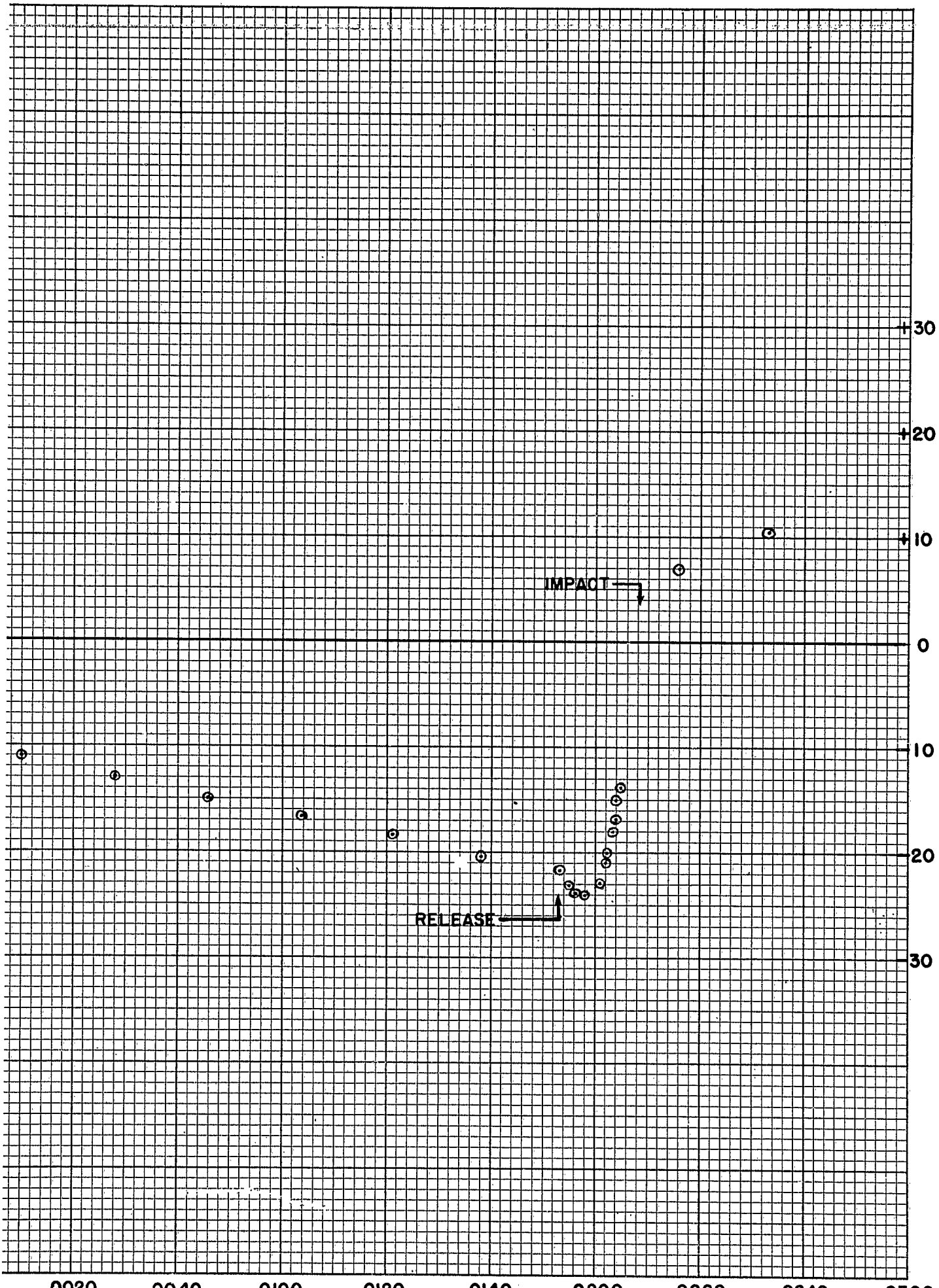

RELEASE
IMPACT
+40
+30
+20
+10
0
-10
-20
-30
-40
1500
1520
1540
1600
1620
1640
1700


TIME — TEMPERATURE
FLIGHT NO 30
6 AUGUST, 1952
DATA FROM THERMOGRAPH RECORD
CENTRAL STANDARD TIME
0920
0940
1000
1020
1040
1100
1120
1140
1200
1220
TEMPERATURE IN CENTIGRADE DEGREE
+20
+10
0
-10
-20
BALLOON LAUNCHED
LOAD RELEASE


BALLOON LAUNCHED
AT 0751 19 AUGUST
THERE IS NO READABLE
THERMOGRAPH RECORD FOR
THE TIME PREVIOUS TO 1821
1600
1620
1640
1700
1720
1740
1800
1820
1840


GROUND SUNSET
BALLOON SUNSET
OBSERVED
THEORETICAL
TIME — TEMPERATURE
FLIGHT NO. 32
19 AUGUST, 1952
DATA FROM THERMOGRAPH RECORD
1900
1920
1940
2000
2020
2040
2100
2120
2140
CENTRAL STANDARD TIME


0
2200
2220
2240
2300
2320
2340
2400
0020
0040


+30
+20
+10
0
-10
-20
-30
IMPACT
RELEASE
0020
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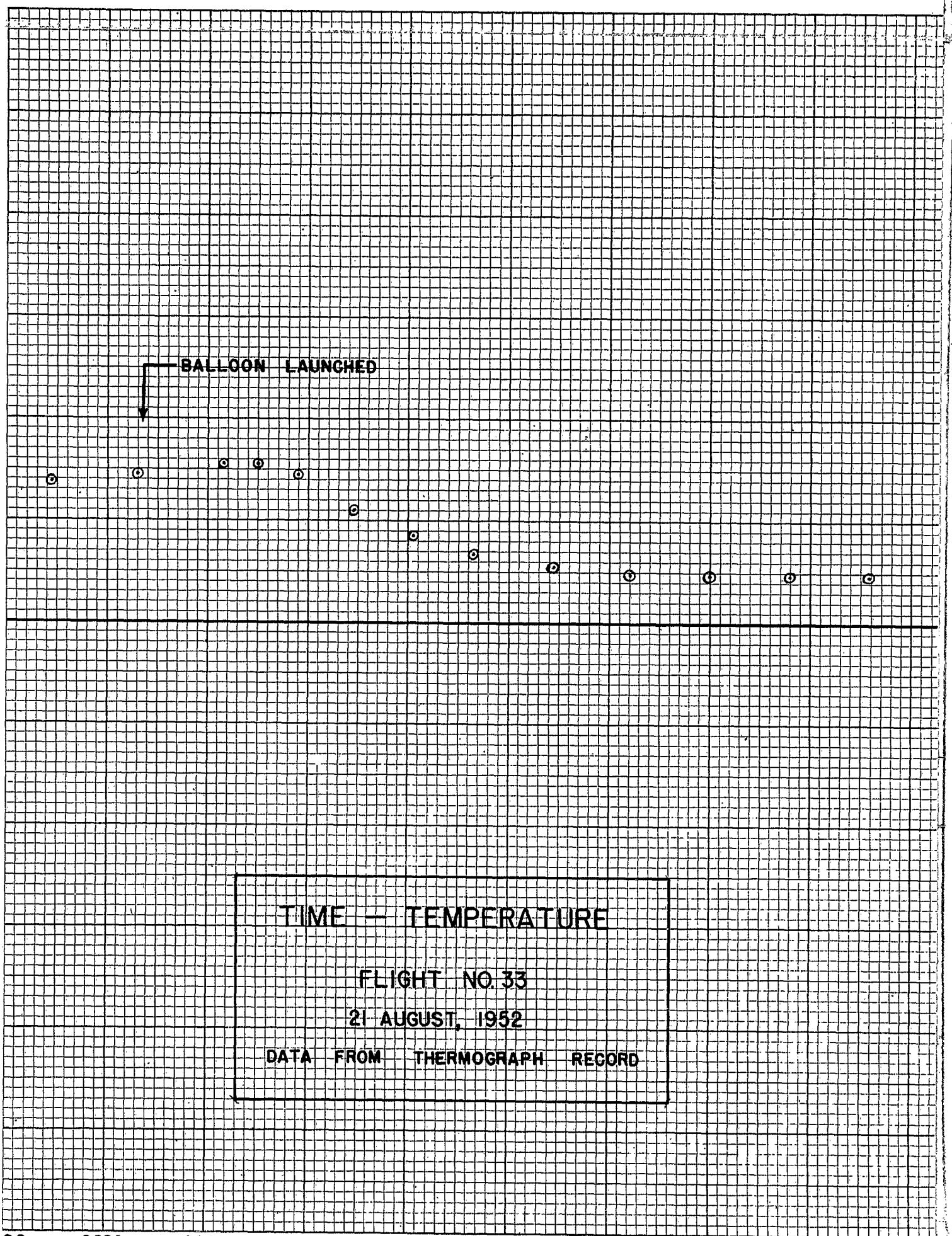
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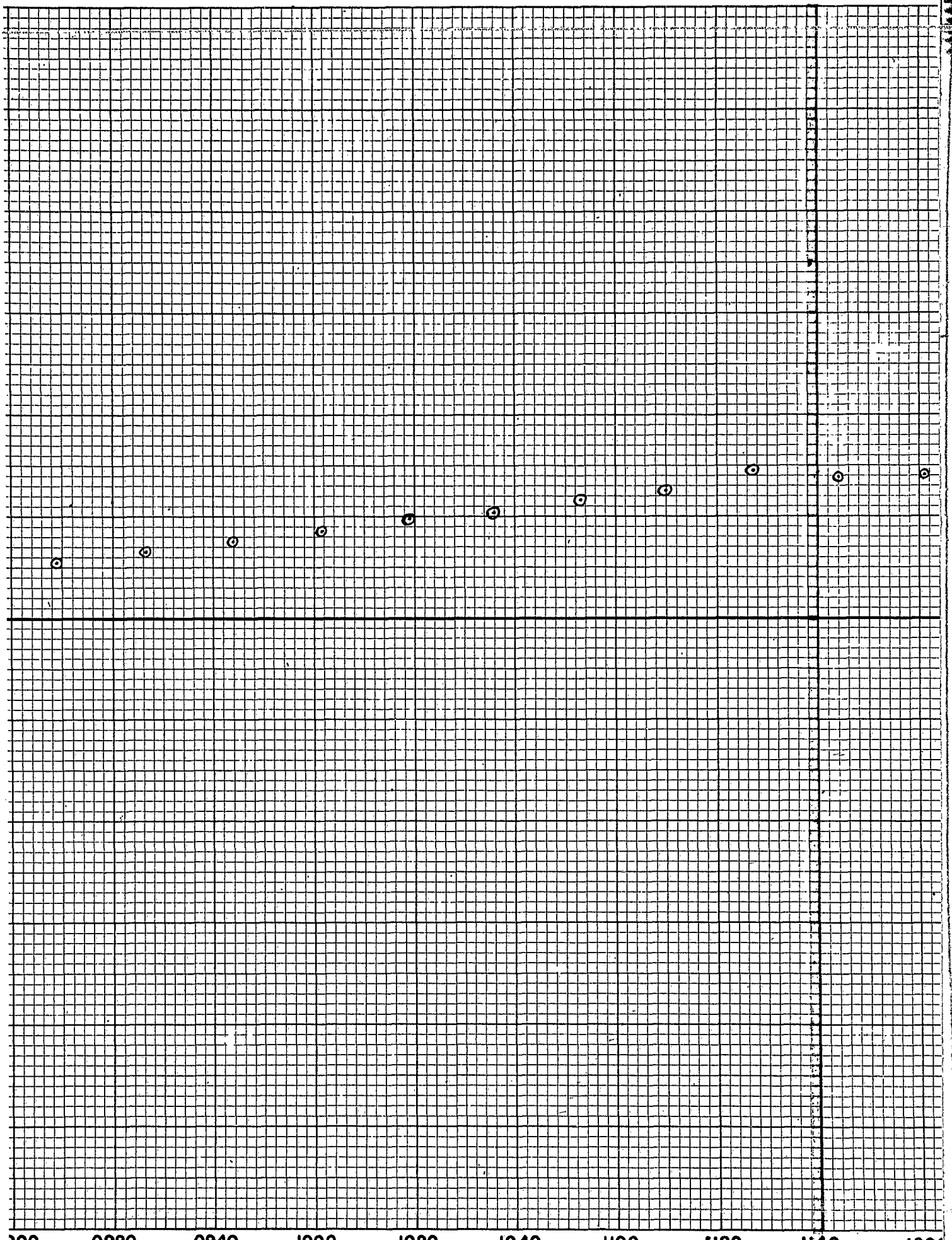
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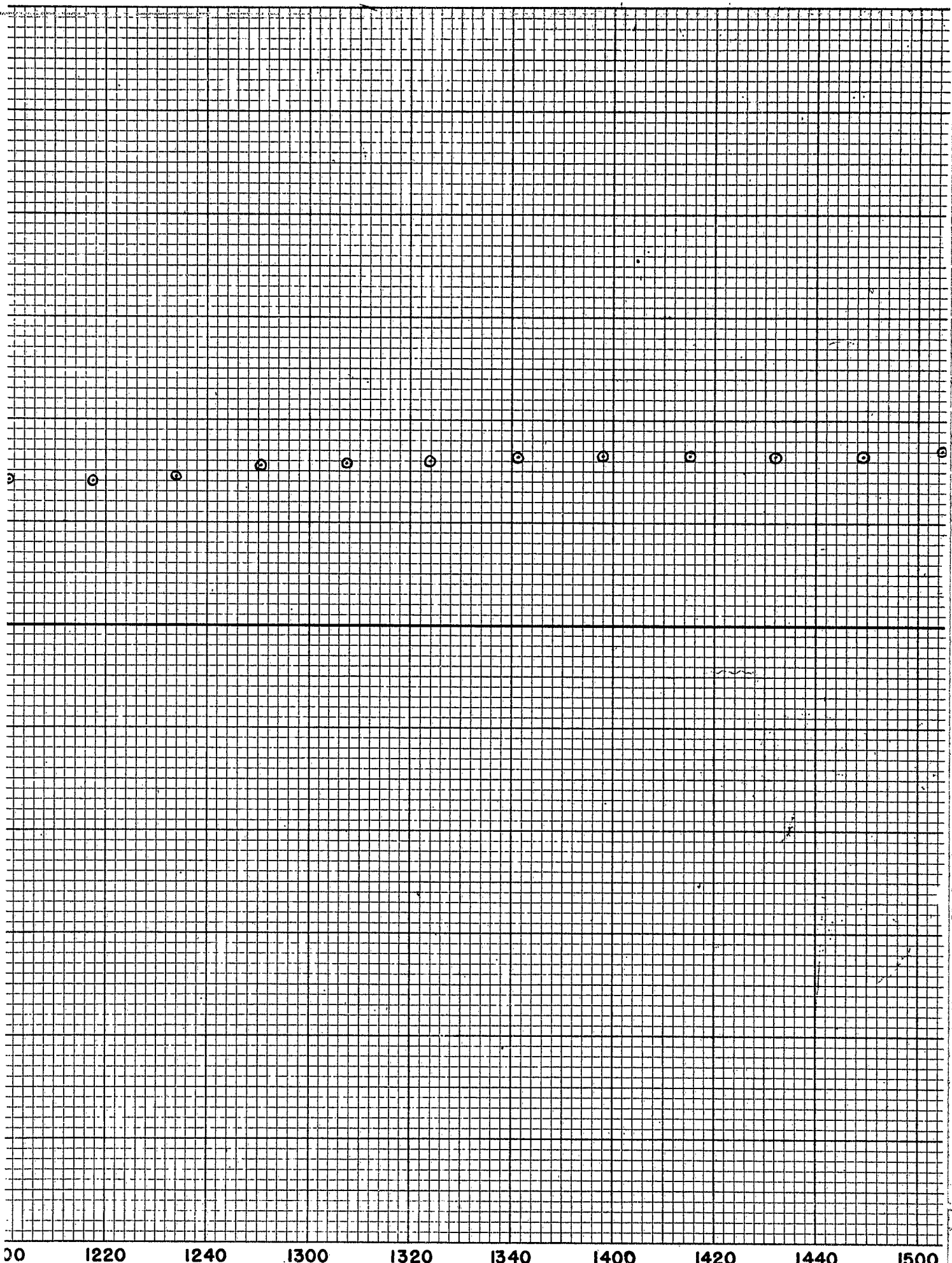
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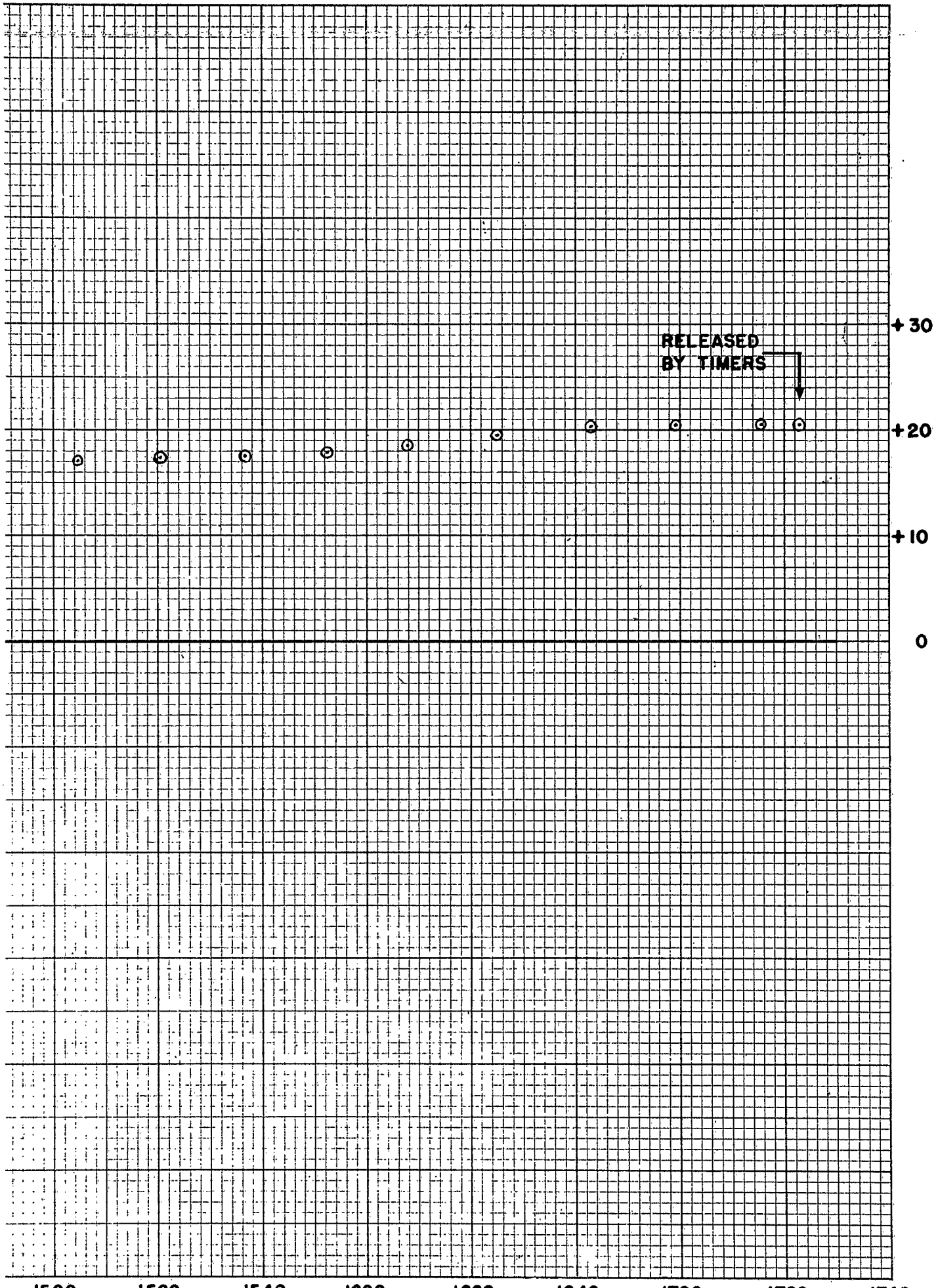
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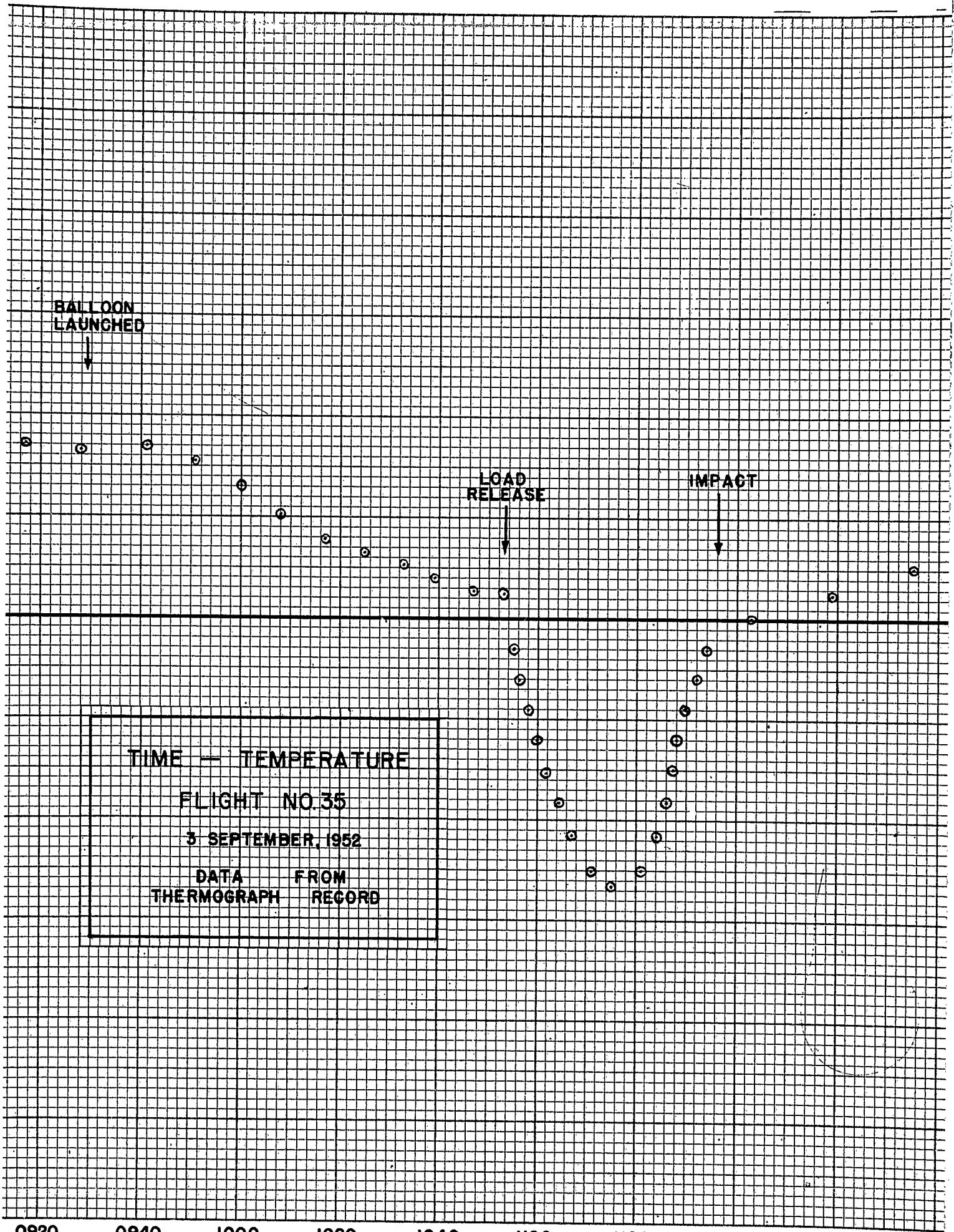
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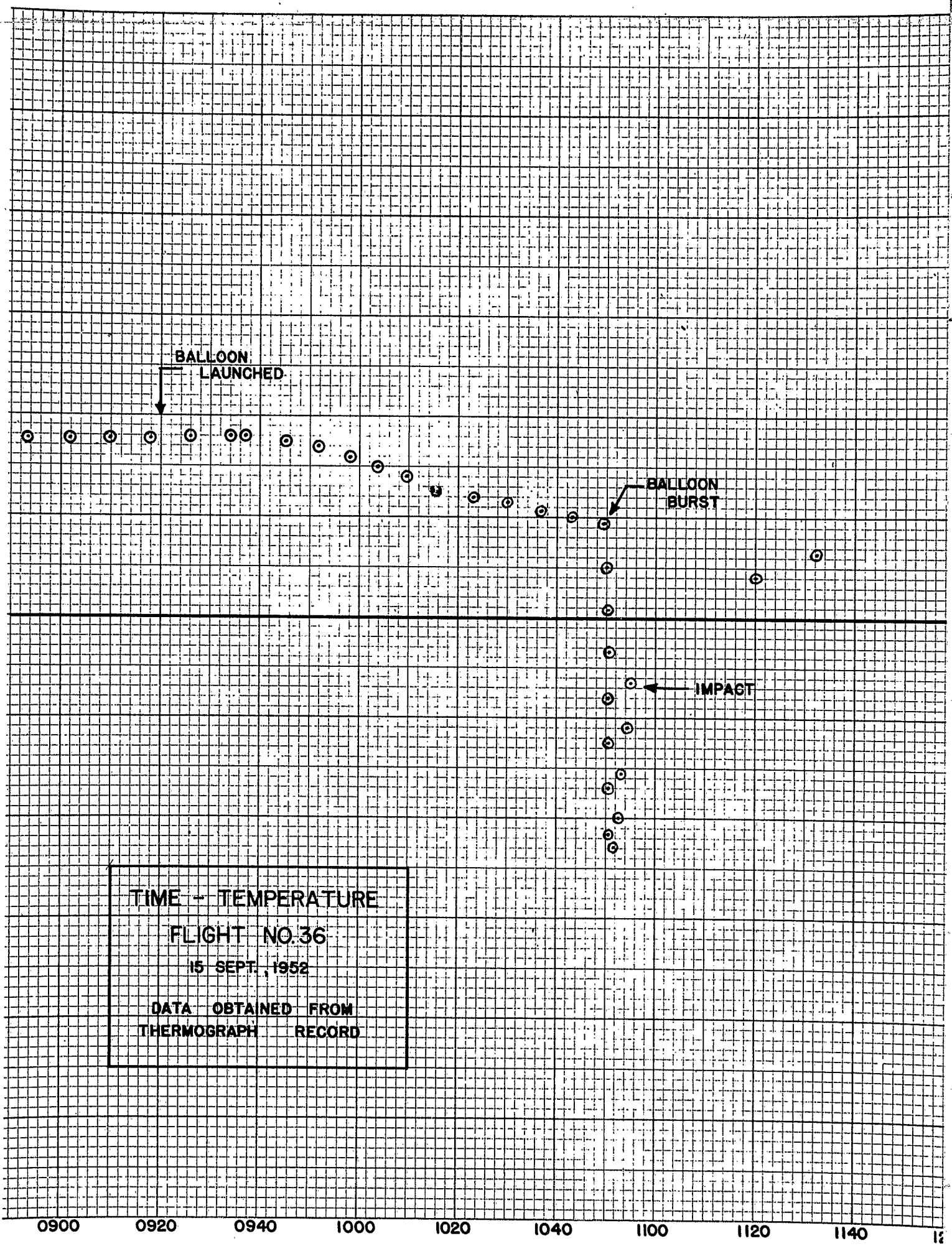
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BALLOON BURST
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TIME - TEMPERATURE
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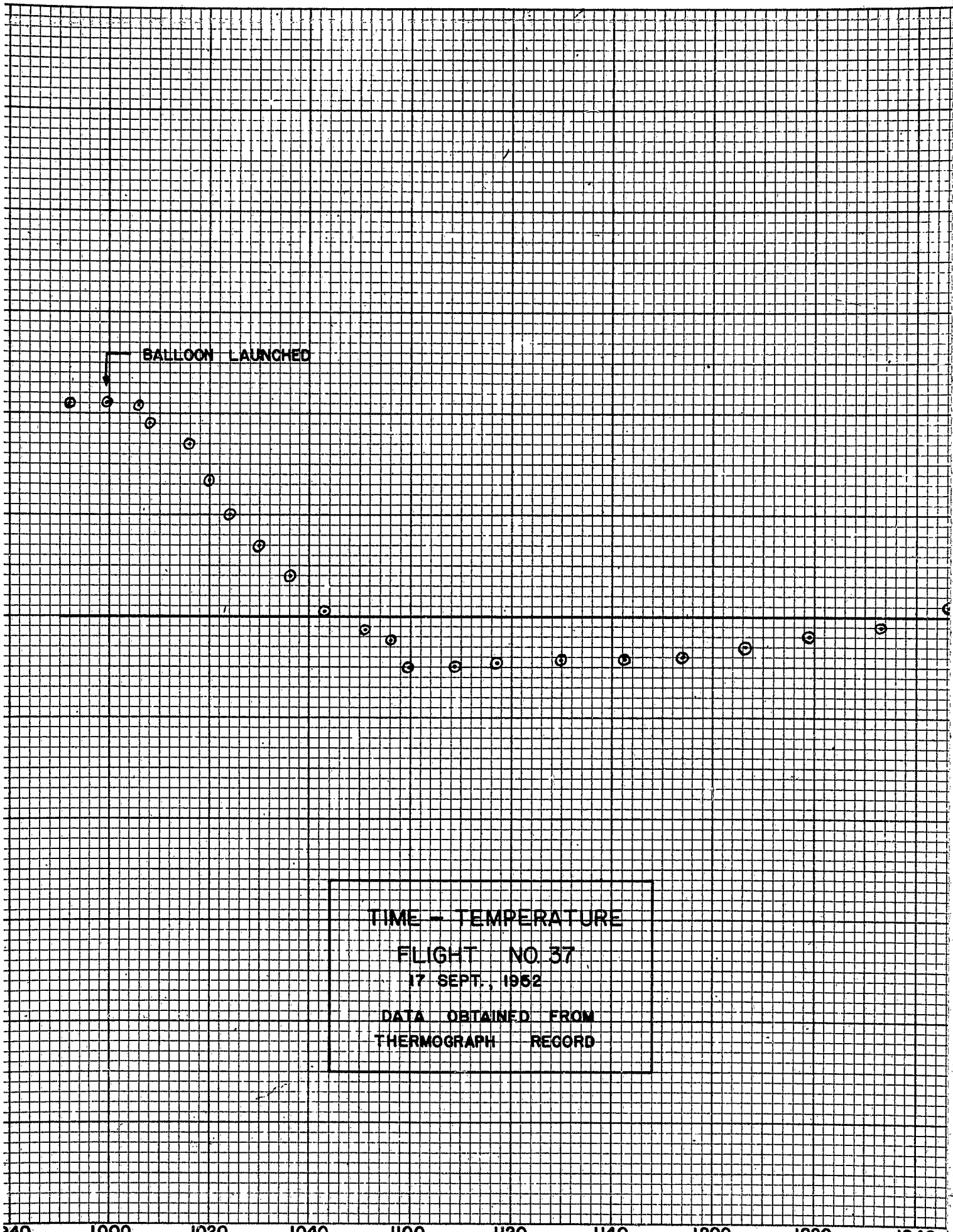
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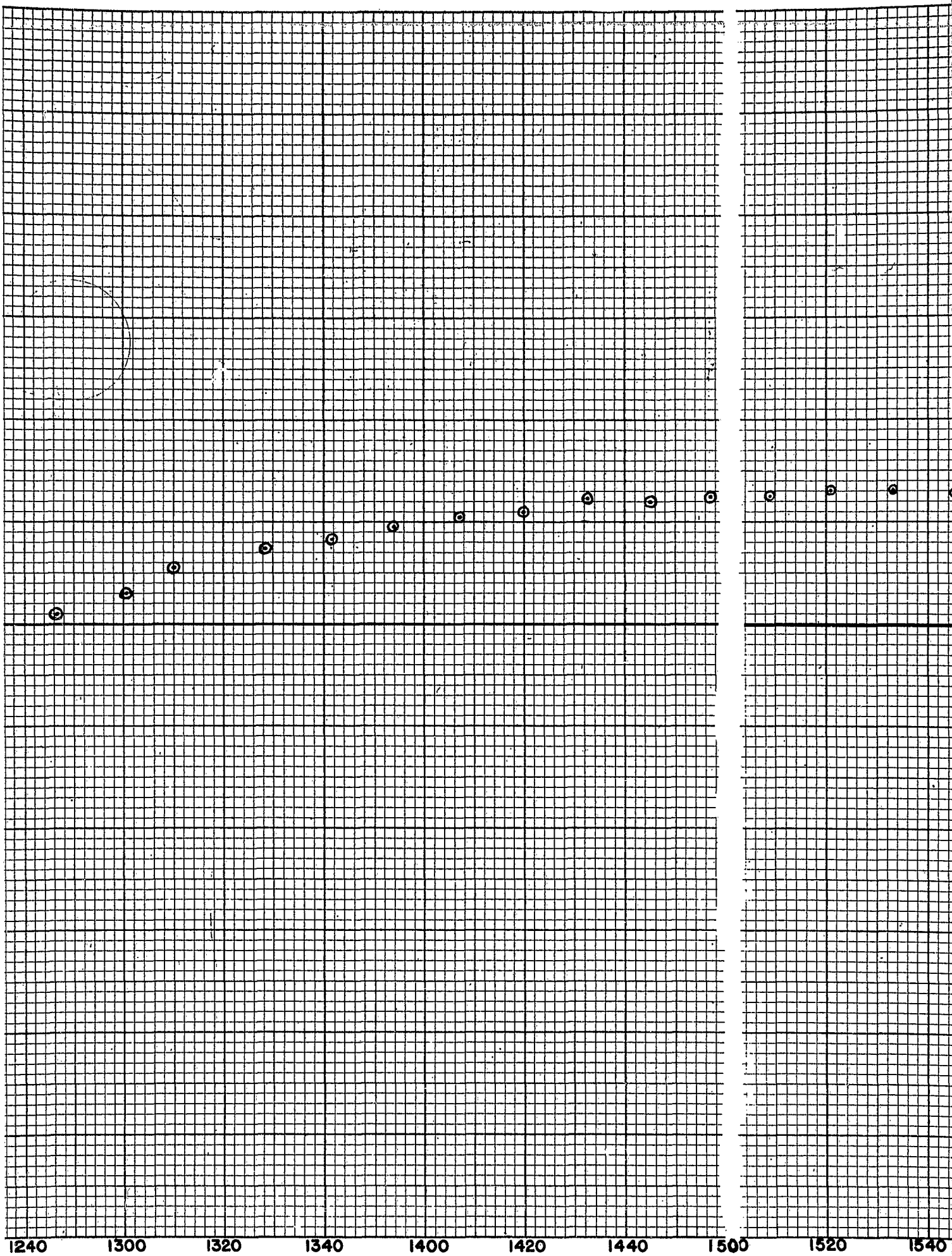
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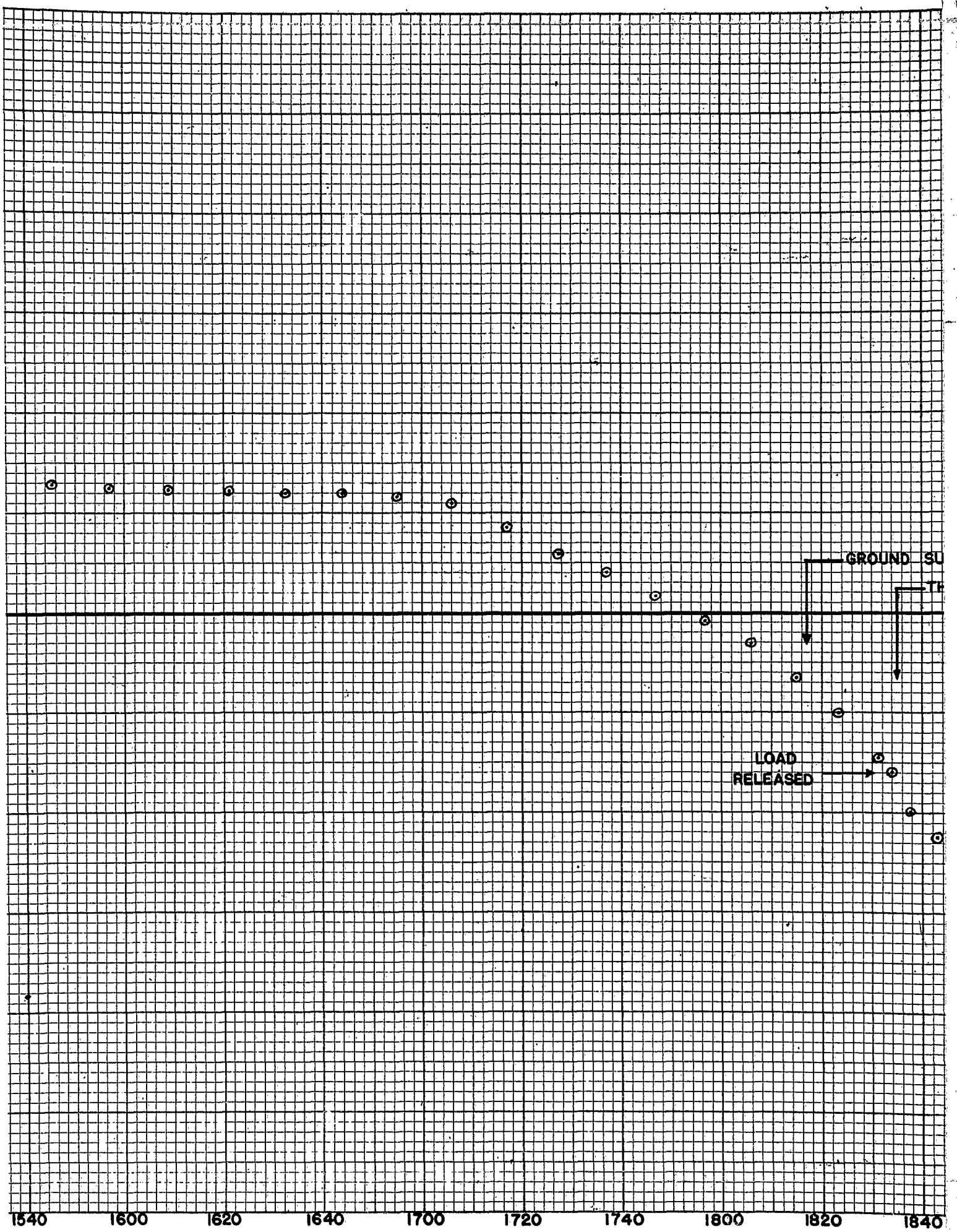
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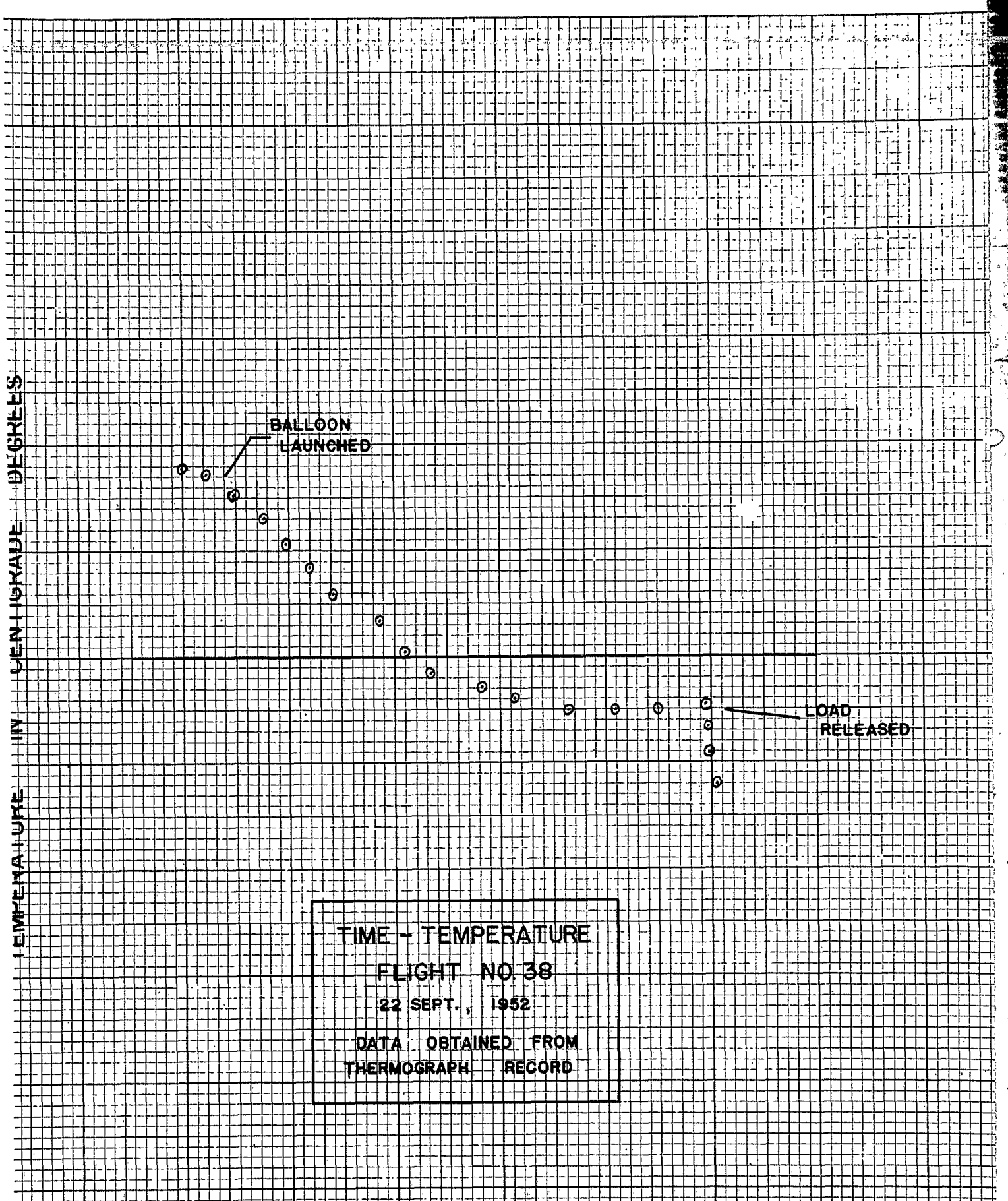
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TIME - TEMPERATURE
FLIGHT NO. 38
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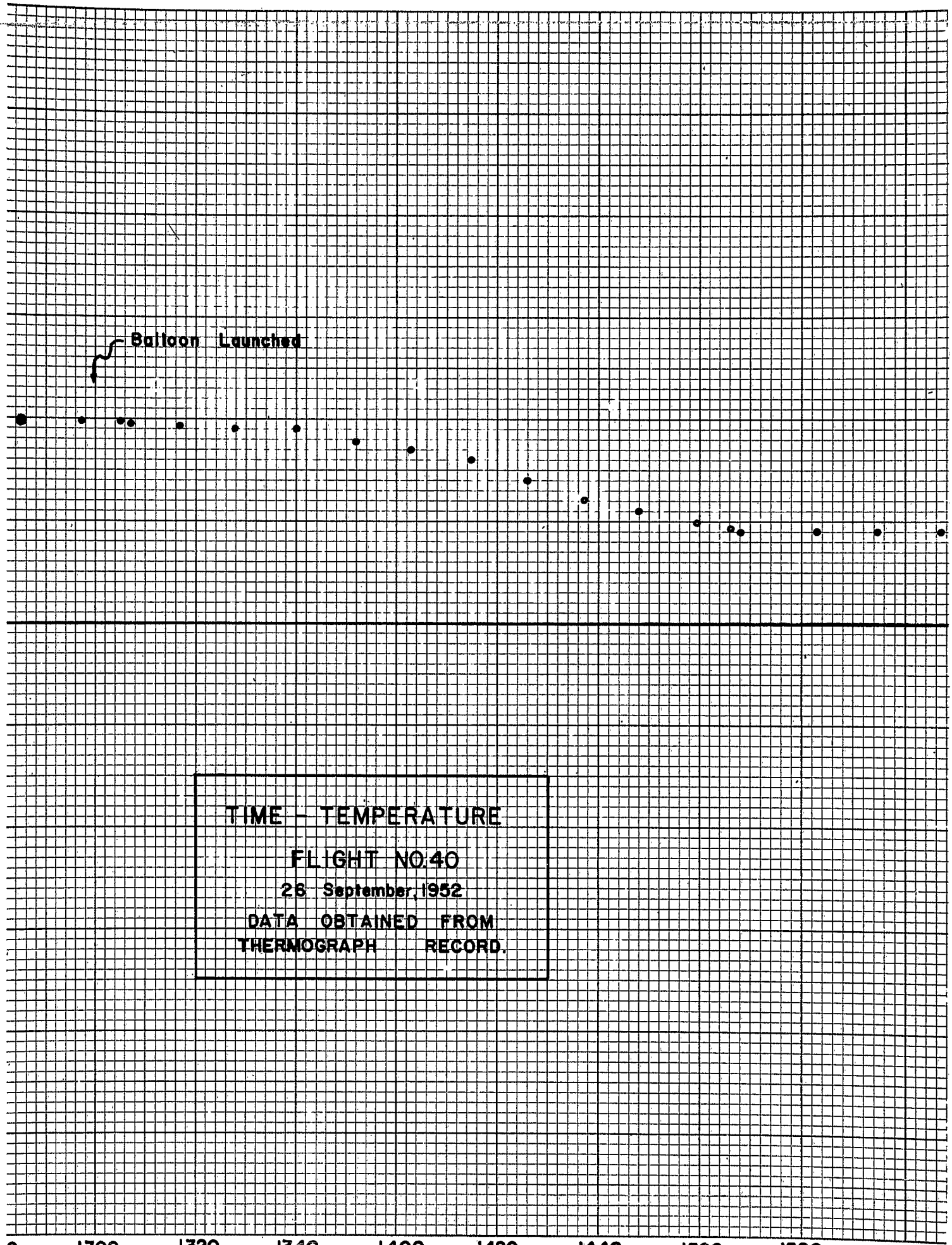
Balloon Launched
TIME - TEMPERATURE
FLIGHT NO.40
26 September, 1952
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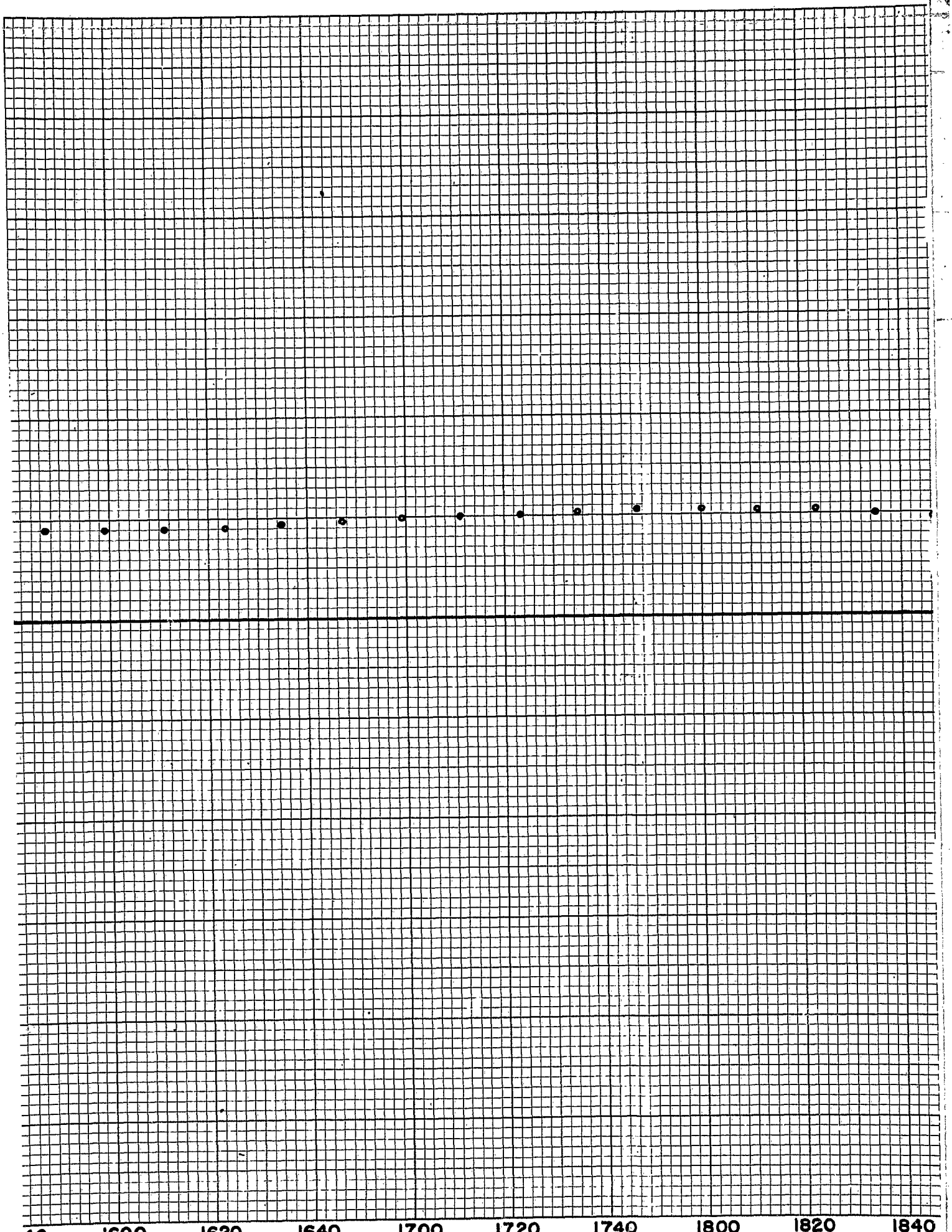
CENTRAL STANDARD TIME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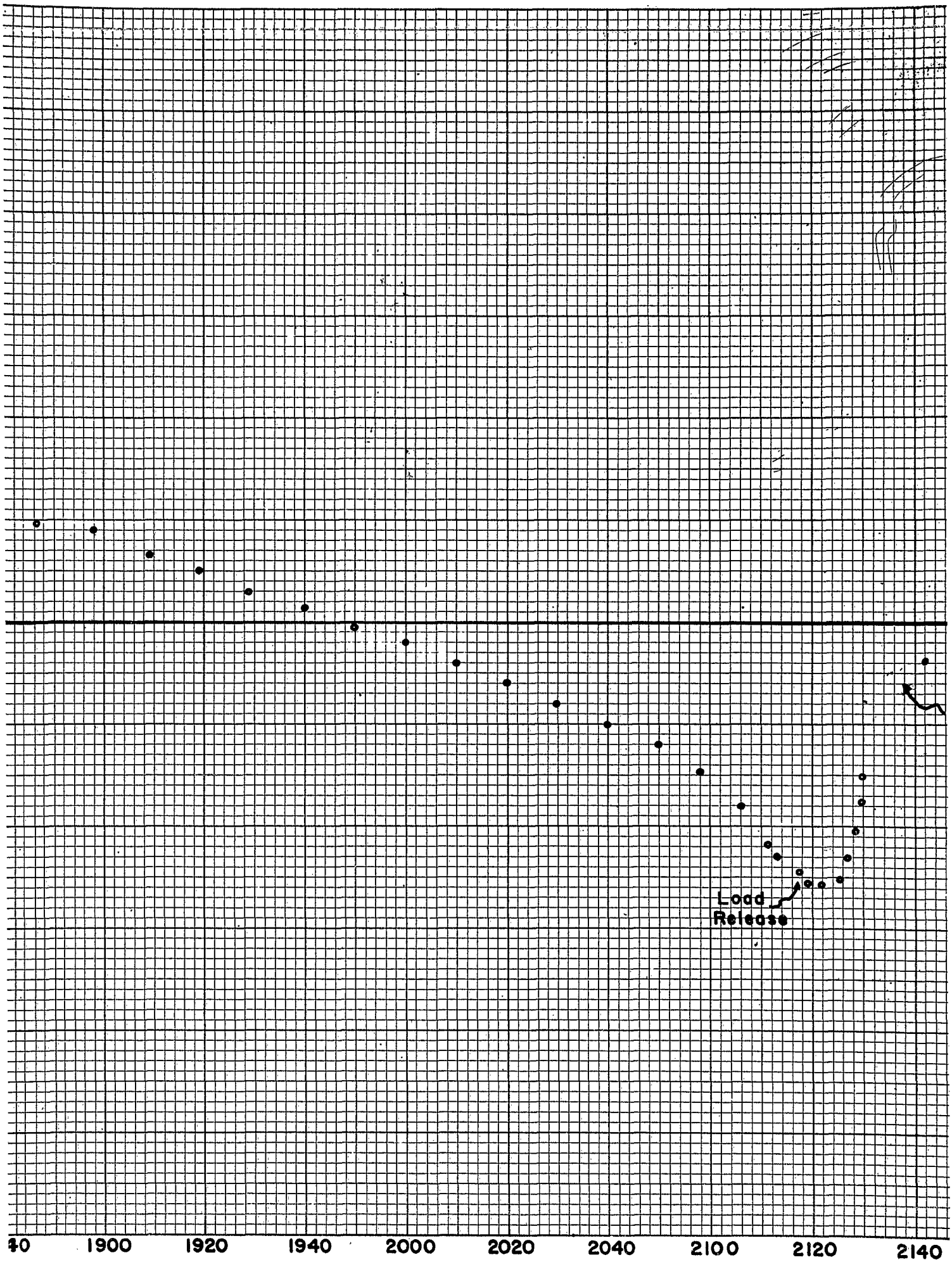
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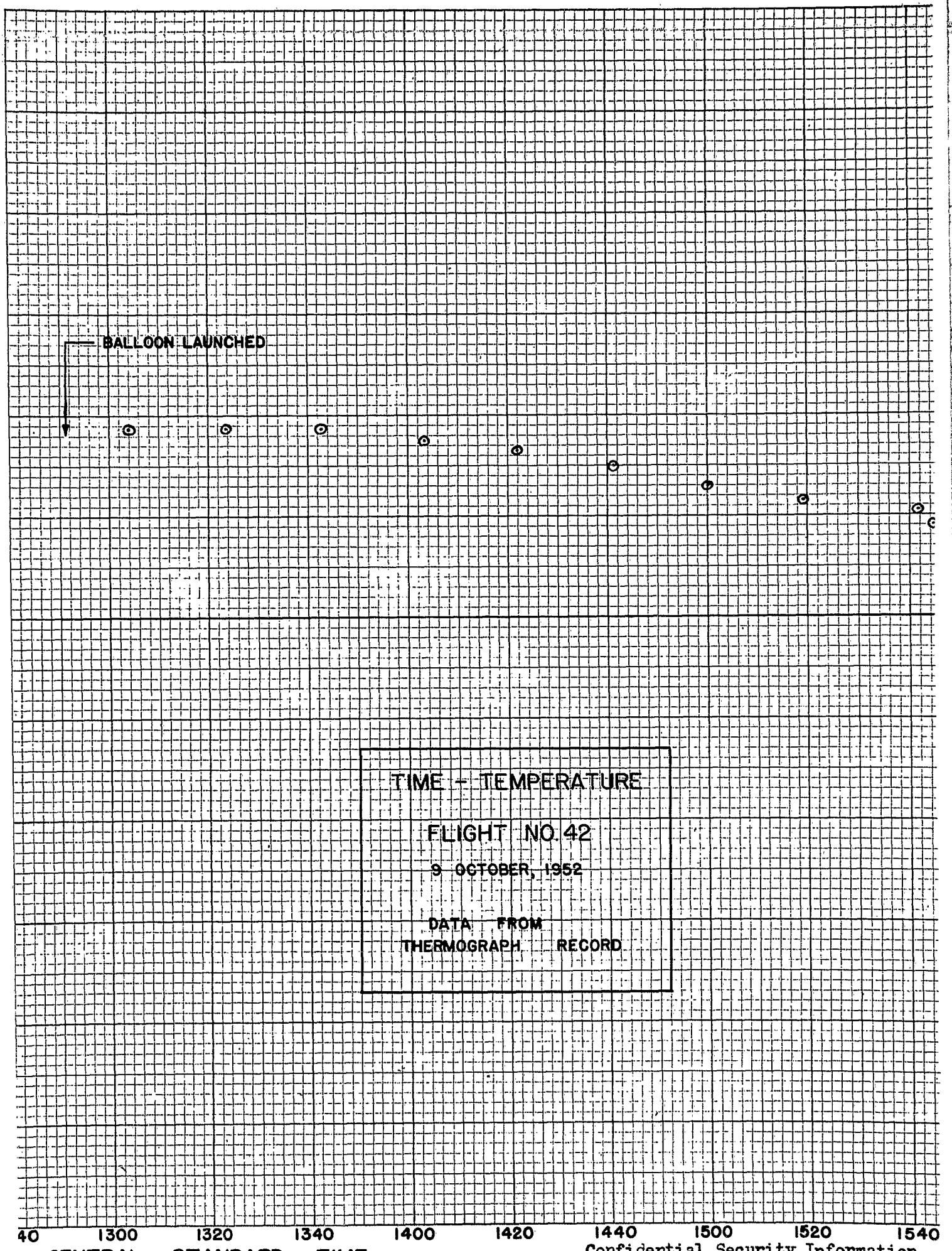
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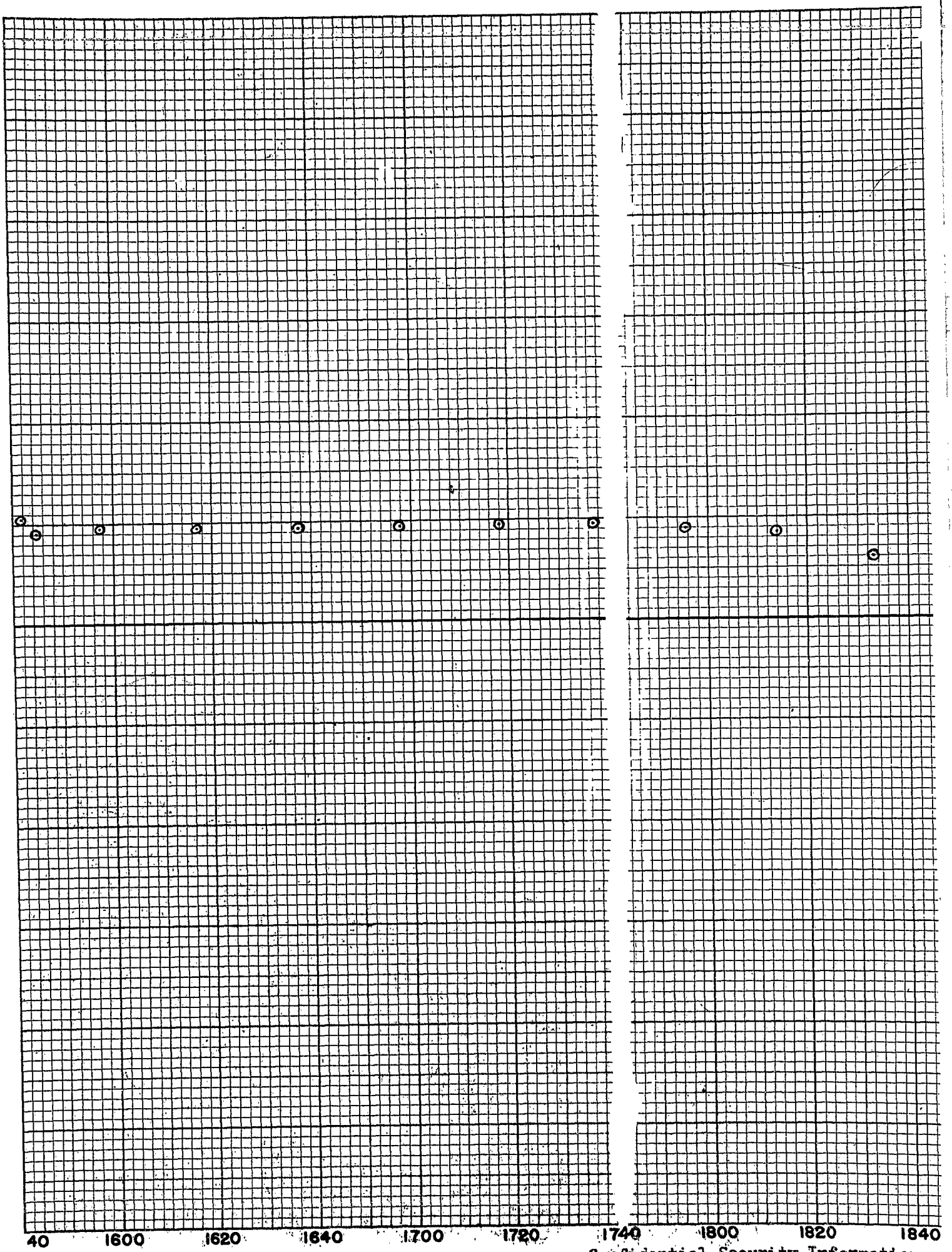
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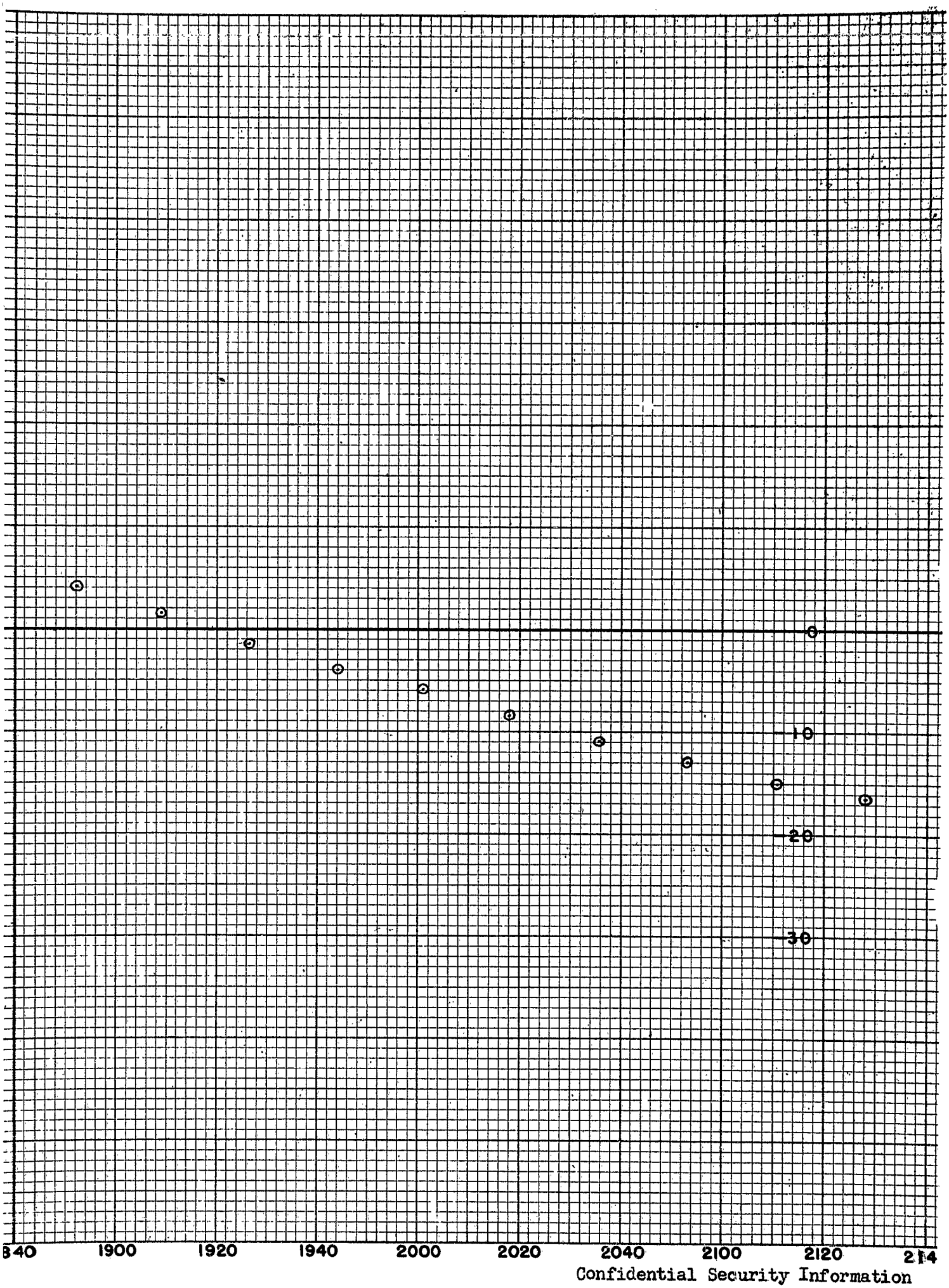
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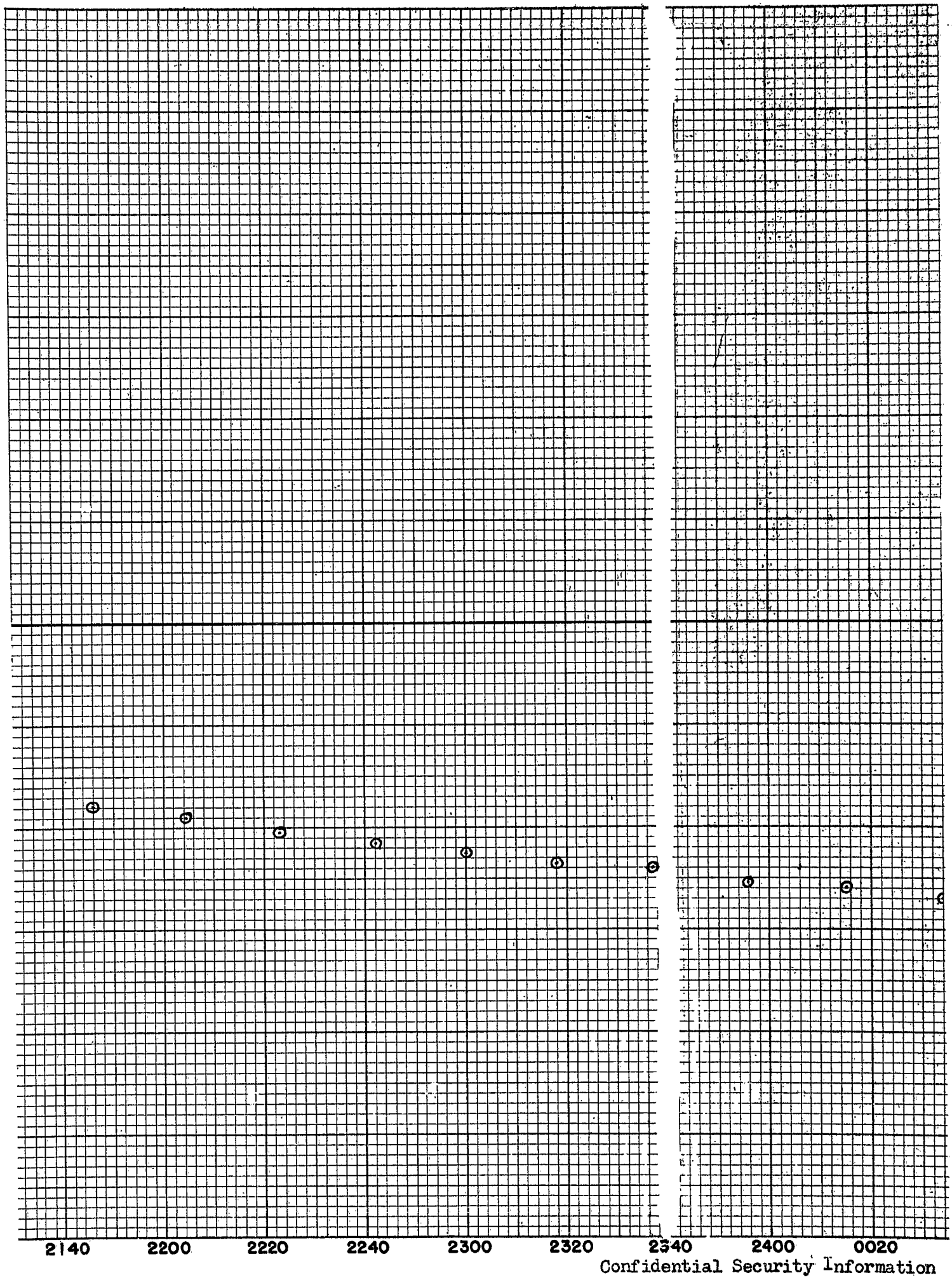
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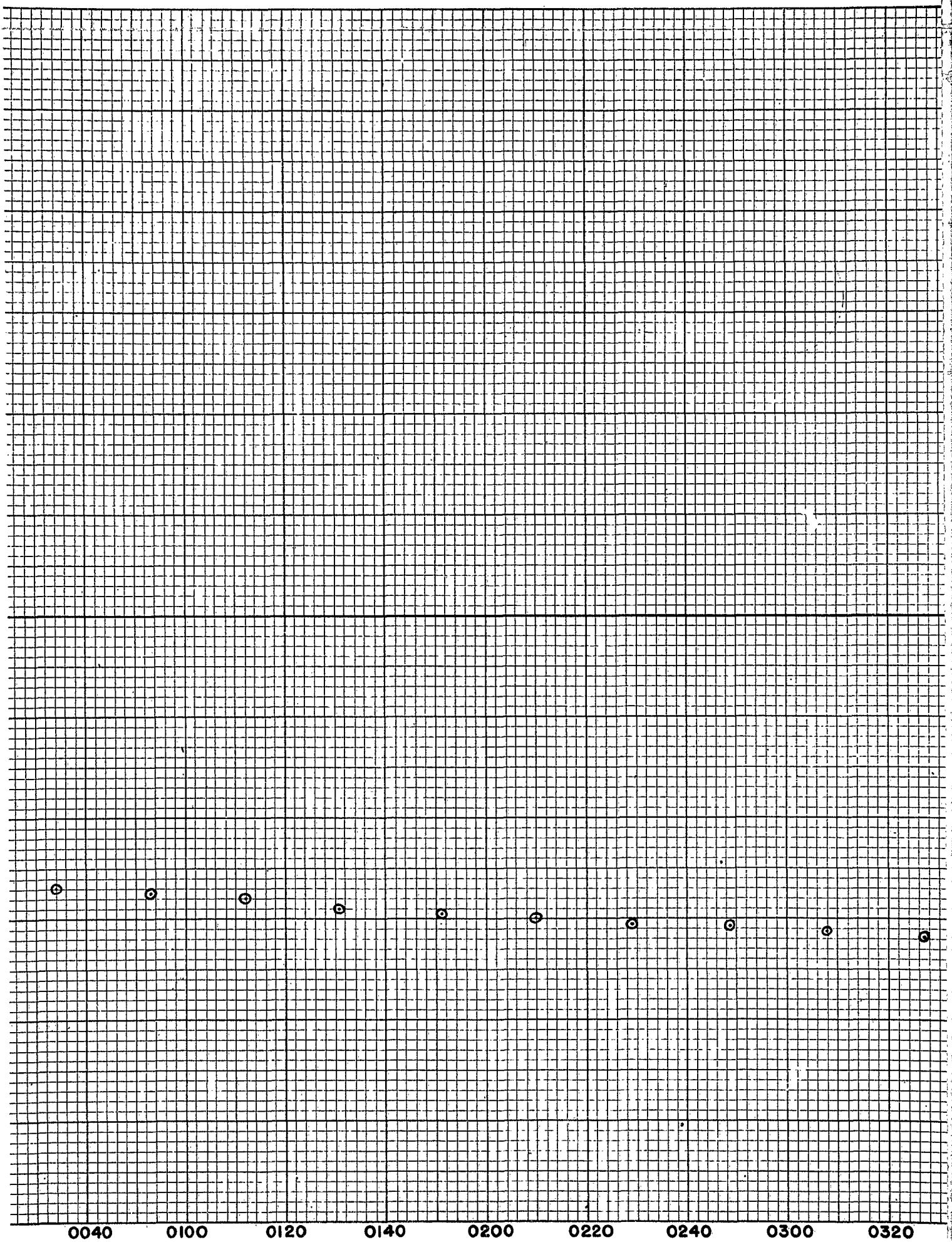
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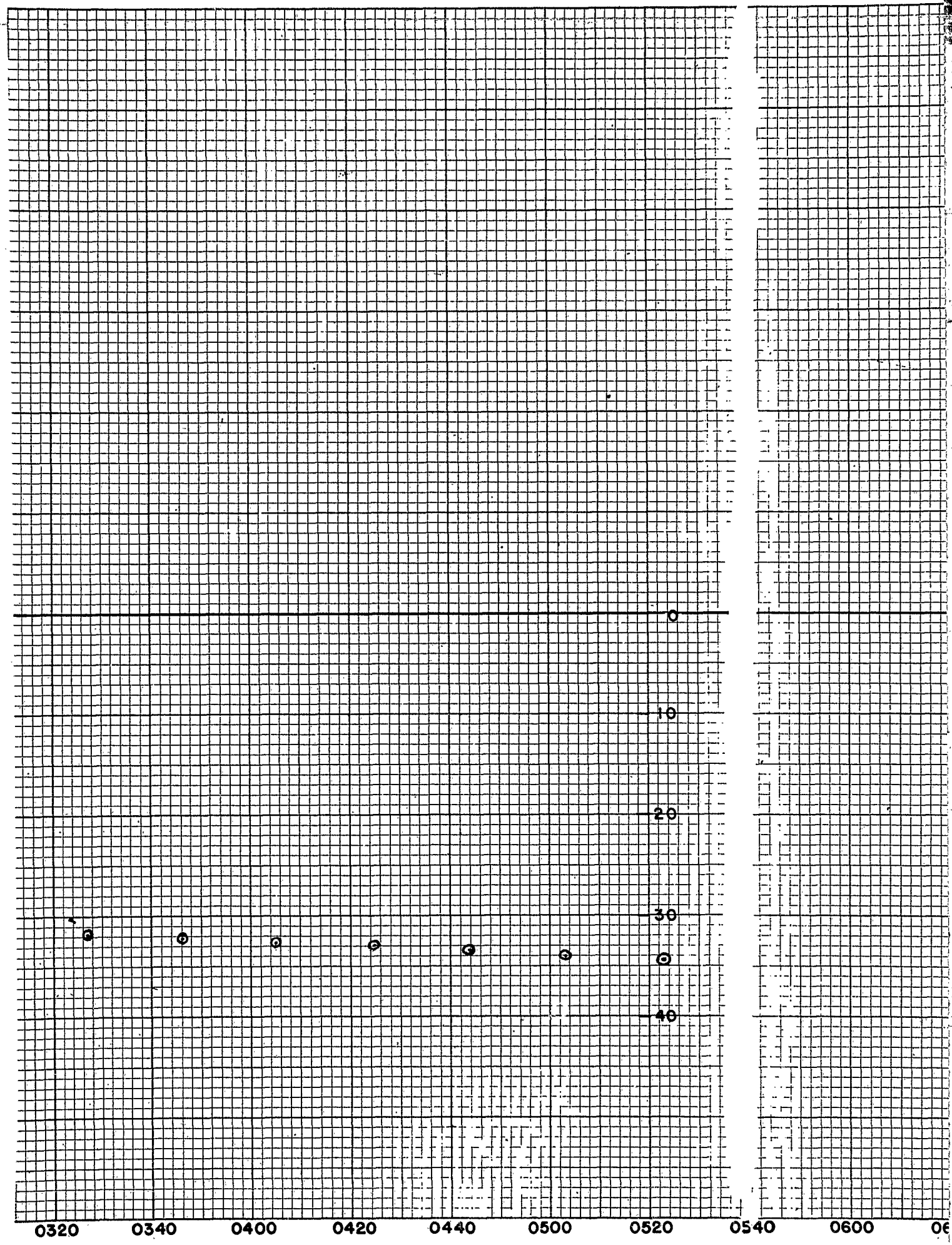
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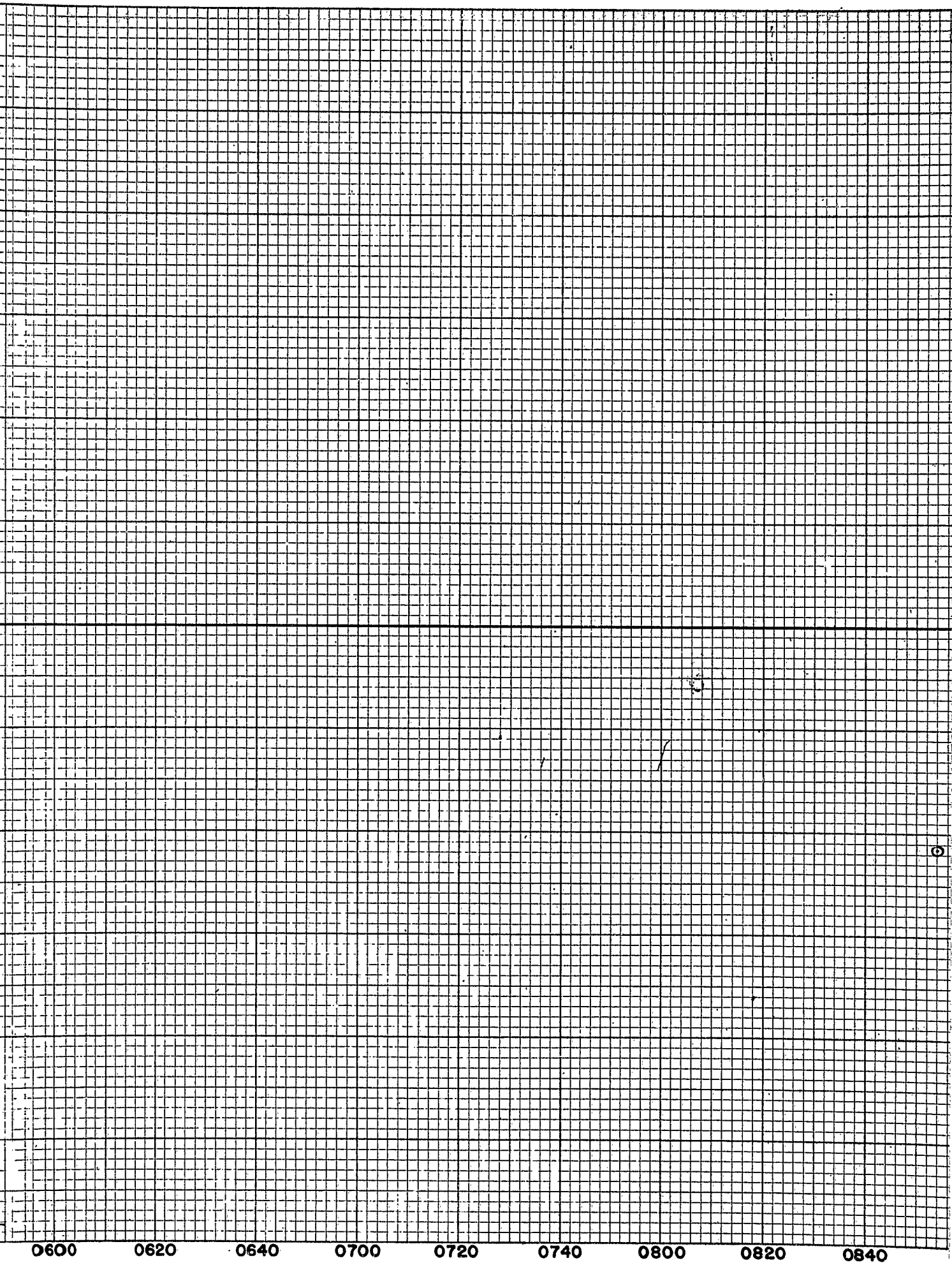
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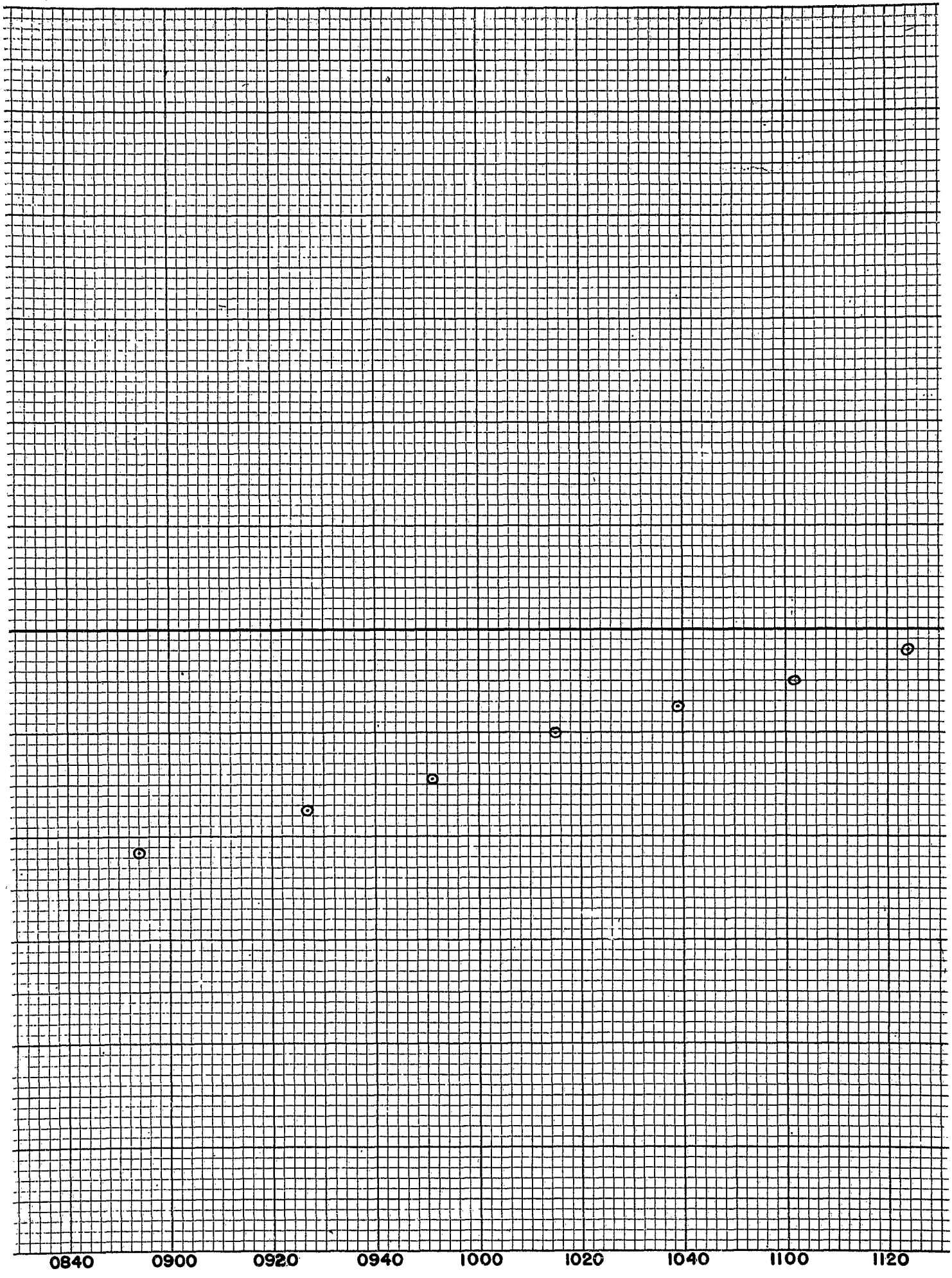
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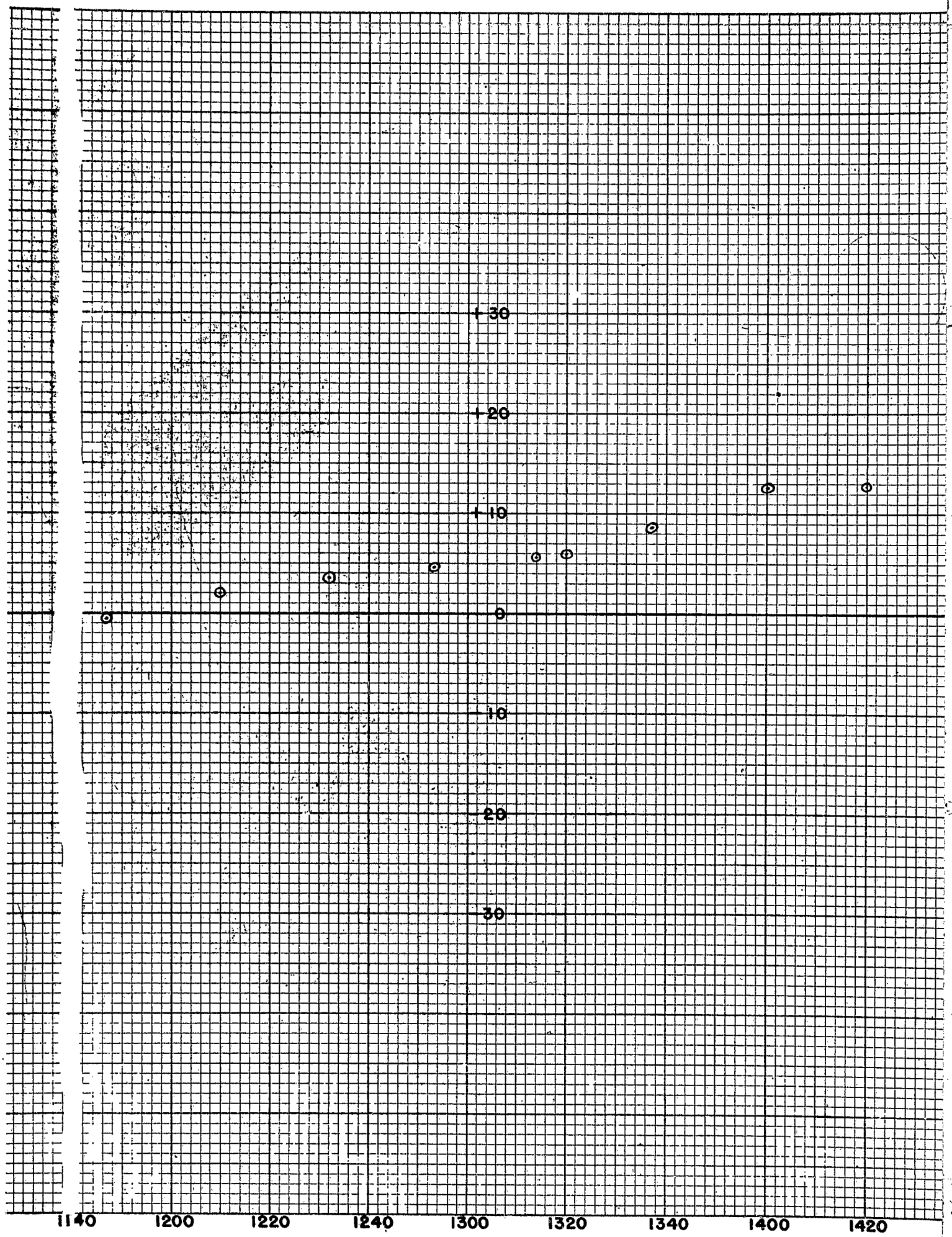
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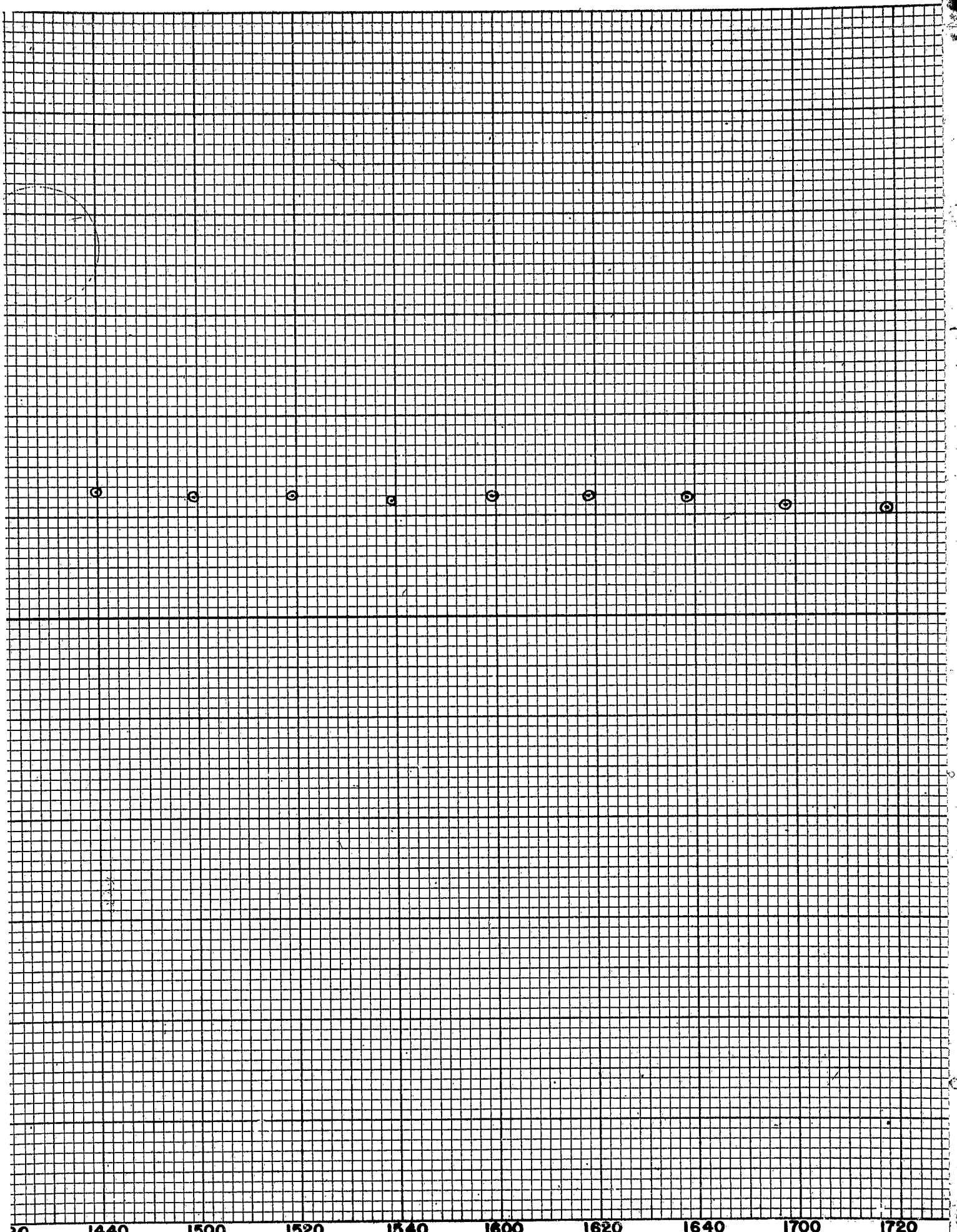
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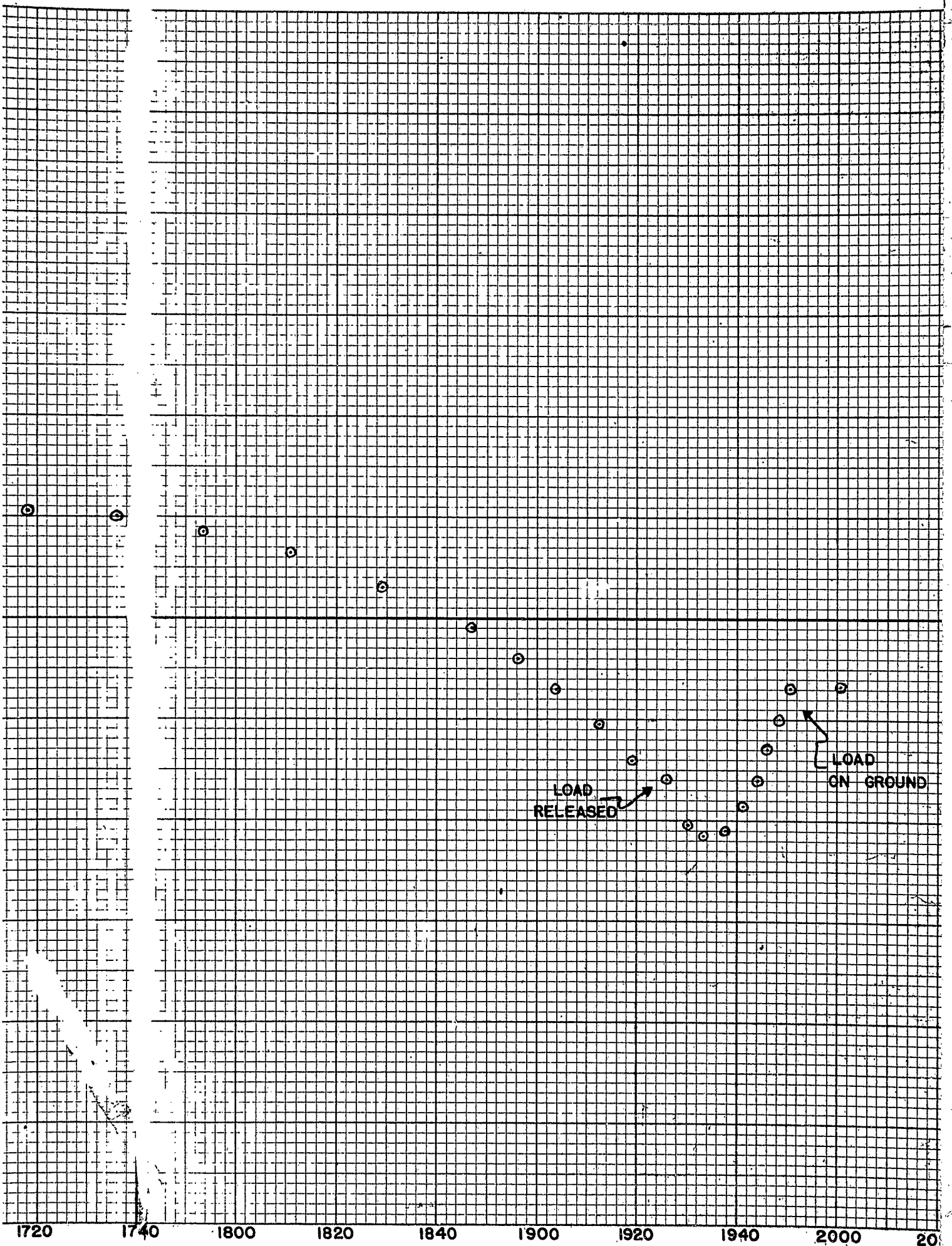
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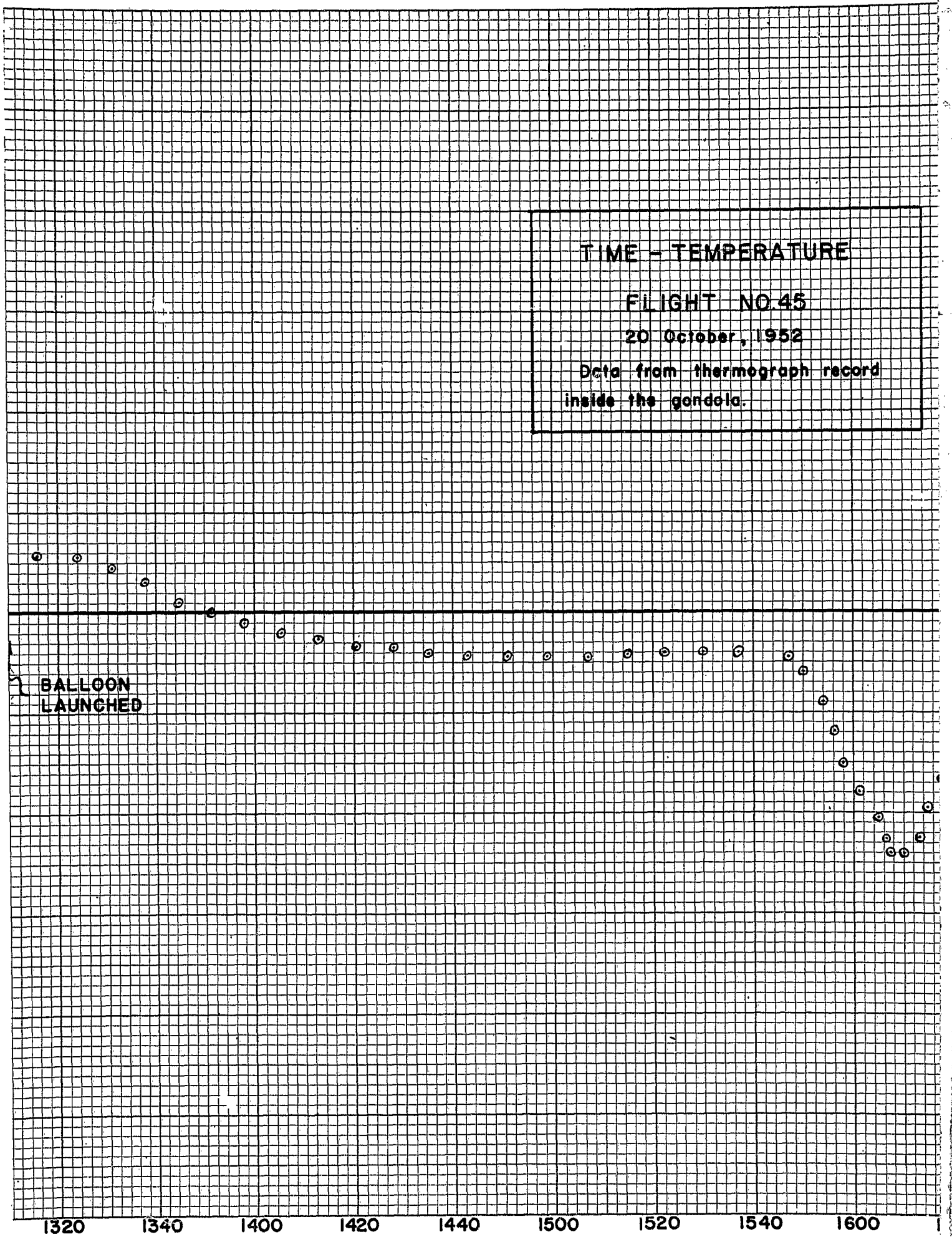
TIME - TEMPERATURE
FLIGHT NO.45
20 October, 1952
Data from thermograph record inside the gondola.
BALLOON LAUNCHED
1320
1340
1400
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1500
1520
1540
1600
CENTRAL STANDARD TIME

SECTION II - THEORETICAL METEOROLOGICAL ANALYSIS

A. CHARACTERISTICS OF STRATOSPHERIC FLOW

Contents

I. General considerations

1. Purpose
2. Review of previous work on tropospheric motion
3. Data

II. Method of analysis

4. Approach
5. Effect of small-scale motion on the computation of larger scale motion
6. Limitations introduced by the linear assumption for the large-scale motion and the interpretation of the observed velocity deviation
7. Effect of observation errors

III. Results of the analysis

8. Example of the analysis, flight #24
9. Results of all cases

IV. Conclusions

10. The scale of stratospheric motions
11. Forecasting implications

References

Figure II-1. Form of assumed velocity fluctuation

Figure II-2. The maximum error of the computed large-scale acceleration as a percentage of the small scale acceleration α, plotted as a fraction of the ratio of observation interval to wave period, τ/T

Figure II-3. Example of the trajectory obtained by a best fitting linear function of the velocity, if the observation interval is comparable to the wave period.

Figure II-4. Observed trajectory flight #24, broken line, and trajectory computed from a linear velocity trend, solid line. The sections of the trajectory selected for a second linear approximation are marked A and B.

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Table III. Analysis of the north-south component of flight #24.

Table IV. Analysis of east winds.

Table V. Analysis of west winds.

B. WINDS IN THE UPPER TROPOSPHERE AND LOWER STRATOSPHERE

I. Introduction

II. A summary of the winds in the lower stratosphere

III. Some features of the wind maximum at the tropopause

IV. Extension of the methods of analysis to the stratosphere

Figure II-5. Average wind velocities (m sec^{-1}) in the lower stratosphere observed for the balloon flights, April through November, 1952. The vertical lines give the vertical range of each observation. The circle denotes the level above which the flow becomes easterly.

Figure II-6. Hodograph for flight #35. The location of the nearby Radiosonde stations with respect to Minneapolis are also indicated.

Figure II-7. Radiosonde observation made at stations located along a line perpendicular to the shear vector of flight #35, see Figure 6. The highest temperatures in the lower stratosphere are observed to the right of the shear vector.

Table VI. Distribution of maximum wind speeds (m sec^{-1}) in the sixteen cases of high winds.

I. General Considerations

1. Purpose

The greatest portion of the flight of the plastic stratosphere balloons is usually spent floating on a constant pressure surface. The flight trajectories during this period describe the stratospheric flow in considerable detail but the number of flights, by meteorological standards constitute an extremely small sample. This description of the atmospheric flow is unusual for the conventional meteorological upper air reports consist of successive observations of the motion at fixed points while the balloon trajectory might be termed a quasi-Lagrangian[1] system, describing the motion of a particle in time. While Lagrangian systems are frequently employed in atmospheric hydrodynamical analysis, this type of observation is sufficiently new to warrant some discussion before comparing the present observations of the stratospheric flow with the better known characteristics of the flow in the troposphere.

It is the purpose of this study to gain an insight of the nature of the stratospheric flow by summarizing certain of its physical characteristics, the amplitudes and periods of the velocity fluctuations of the horizontal component of the flow. It is hoped that some of the limitations imposed by a restricted sample will not be so great for a summarization of physical characteristics as they may be for a climatological summary. The type of summary undertaken has some advantages also in providing a quantitative basis for comparison with the flow in the troposphere.

This investigation was also motivated by a direct requirement of the balloon program, that of the prediction of the future course of the balloon. Extrapolation will be a fundamental part of any system of prediction and the

[1] In the sense that the flow is quasi-isobaric, if this extension of the terminology of Starr, Journal of Meteorology, 1945, is permissable.

"representativeness" for this purpose, of a velocity observation will obviously depend upon the length of the period of observation and the periods of the velocity fluctuations. It is also possible that information on the different scales of stratospheric motion may be useful in studies of diffusion.

2. Review of previous work on tropospheric motion

Actually more observations of trajectories of constant altitude balloons have been made in the stratosphere than in the troposphere so that an entirely equivalent description of the tropospheric flow is not available. Some of the value of the stratospheric data, therefore, cannot be realized because it is necessary to rely on different sources using more indirect observations to provide the tropospheric comparison.

The weather systems and associated motions with which the meteorologist is usually concerned, are frequently termed large-scale. In the upper air, for example, the pressure disturbances and streamline patterns are tracked without difficulty in a network of observations spaced at intervals of several hundreds of miles. While the trajectories do not in general coincide with the streamlines, the available tropospheric balloon trajectories[2] at least establish that similar amplitudes are quite common. It is also recognized that velocity fluctuations of smaller period and amplitude exist in the troposphere although this motion is not detectable from the present network of observations. A number of investigators have made special measurements of the smaller scale motions by tracing smoke puffs and constant altitude balloons (Durst, 1948; Durst and Gilbert, 1950) and by making a series of closely-spaced pilot balloon runs (Brooks, 1947; Rapp, 1952). The reported small-scale velocity fluctuations

[2]Trajectories of constant altitude balloons at 300 mb are given in Report 1072, General Mills Aeronautical Research Laboratories, 21 March 1952.

are as large as 2.5 m sec^{-1} with periods of at least one hour, and for periods of 5 to 15 minutes fluctuations of 2 m sec^{-1} have been observed. The accelerations implied by these values are considerably larger than the accelerations of the large-scale motion, and it is necessary to perform some sort of averaging or filtering process, in order to observe these fundamental quantities in the hydrodynamical equations for the large-scale motion.

The large-scale accelerations have been obtained by averaging the motion of constant altitude balloons over relatively long time intervals (Durst and Gilbert, 1950; Mantis, 1952). Besides the order of magnitude the most important fact that emerged from these measurements is that the component of the acceleration perpendicular to the trajectory is frequently greater than the component tangential to the flow[3]. Estimates of the magnitude of the tangential component of the accelerations are fairly consistent; from the rms value for the acceleration of 2.9 X 10^{-2} cm sec^{-2} (Mantis) the amplitude of a representative 24 hour velocity fluctuation will be at least 10 m sec^{-1}. The centrifugal acceleration has a very unusual distribution and a representative value is difficult to estimate. However, values of acceleration as large as 10 X 10^{-2}cm sec^{-2} are frequently observed.

The investigations of Durst and Rapp have provided a large portion of the data for the tropospheric comparison and some of the same methods of analysis are used in the present study.

3. Data

The data available for this analysis consisted of 12 flights made by the University of Minnesota and two by the General Mills Laboratories. The floating elevation and periods of observation are rather variable; the range of elevation of all flights was from 79 to 94 thousand feet and the time interval ranged

[3]This is implied by the proponents of the gradient wind relationships but observational evidence was lacking until recently, Neiburger, M. et.al, 1948; Godson, 1950.

from twenty five minutes to five hours. The majority of these flights were made in the summer season of easterly stratospheric winds. Some cases of westerly flow are also included but no soundings were available in mid-winter and the few cases of light variable winds of the transition season were not analyzed.

The balloon's trajectory was determined from theodolite observations at five minute intervals; the elevation above the surface has been determined from the measurement of pressure and the assumption of the standard atmosphere. In a few cases double theodolite observations were also made and in most university flights, trajectories were also determined by photographing the earth from the balloon. Except for the most recent flights, the timing of the photographs was inaccurate and the principal value of the double theodolite and camera track has been in verifying the single theodolite plot.

II. Method of Analysis

4. Approach

The different time-scales of stratospheric motion are to be separated by a statistical procedure. The observed trajectory consists of a set of position points at equal time intervals. Each "leg" of the trajectory, therefore, represents the mean velocity vector in the time interval between position fixes. This set of vectors comprising the trajectory will be a function of time: $\vec{V}_i = \vec{V}_i(t)$ where $\vec{V}_i$ is the mean velocity vector in the ith leg.

Now it will be assumed that the east-west and north-south components of the $\vec{V}_i$ can be adequately represented by linear functions of time; for each component there will be a function:

$$V_i = \bar{V} + a t_i \qquad i = 1, 2, \cdots n \qquad (1)$$

where V_i = the component of the large scale motion in the ith leg

t_i = the time measured from the midpoint of the trajectory to the midpoint of the ith leg

n = the total number of legs being given by $n = \tau/\varepsilon$

τ and ε = the observation and leg intervals respectively

The constants $\bar{V}$ and a are determined for a given observation interval by the method of least squares. We should like to ascribe the observed departures of the velocities from the linear function to the effects of motion of small-scale and possibly also to error.

The proposed method does not, of course, provide an absolute separation of different scales of motion. The capabilities and limitations of the method were briefly explored by analyzing simple model velocity waves or fluctuations. These tests were designed to provide information on several questions of interpretation of the analysis: (1) The error introduced by small-scale motion into the computation of the function for the large-scale motion; (2) The limitation on the linear assumption as a description of the large-scale flow, and the related question of the significance of the deviations from the linear function.

5. Effect of small-scale motion on the computation of larger-scale motion

The error produced by small-scale motion in the computation of the linear functions will be discussed by considering the effect upon the value of the large-scale acceleration, the quantity a in equation (1). We shall naturally expect that the error will decrease as the observation interval, τ, becomes large with respect to the period of the fluctuation, T. The leg interval may also affect the computation but in no systematic fashion, it was found, so long as the leg interval is small compared to the period, $\varepsilon << T$. In any given computation the phase displacement of the wave with respect to the origin of the computation will be important since the computed acceleration may be zero for a symmetrical wave. Such a fortuitous cancelling of the effect of the small scale motion cannot be expected in practice so that the upper limit of the error, the maximum error for a given ratio τ/T was investigated. For this

purpose a simple velocity fluctuation of saw-tooth shape was chosen in which the velocity fluctuation consists of half periods of constant acceleration α with alternate sign:

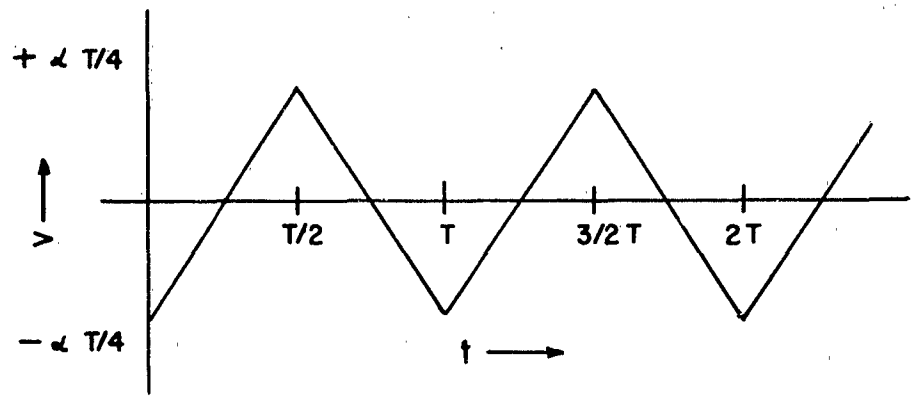

Fig. II-1. Form of assumed velocity fluctuation.

It will simplify the discussion if we assume the origin of the computation to be centered in the observation interval and the total number of legs to be even, $2k = \tau/\varepsilon$. By definition, the large-scale acceleration in equation (1) will be given by the expression:

$$a = \frac{\sum_{i=1}^{k} v_i t_i + \sum_{i=-1}^{-k} v_i t_i}{2\sum_{i=1}^{k} t_i^2} \qquad (2)$$

Where t_i is the time measured from the origin to the center of the ith leg. It was then established for the limiting case where $\varepsilon \to 0$, the contributions of like sign to the partial sum $\sum_{i}^{i+n} v_i t_i$, $n = T/2\varepsilon$ over any time interval $T/2$ will be a maximum only if the entire half wave with constant sign of v_i is included. Hence, the total contribution of the two partial sums over a half period at either end of the trajectory (which will be the greatest since t_i is largest) must be equal or less than the case for the complete half wave at the end of the trajectory, i.e.:

$$\leq \alpha \tfrac{3}{8} (T/4)^3 \left(2\frac{\tau}{T} - 1\right)$$

The total acceleration must be smaller than this quantity since the next larger partial sum $\sum_{i}^{i+p} v_i t_i$ will be of opposite sign. The case where $\frac{\tau}{T}$ is an integer is readily computed:

$$\left| a \right| = \propto \frac{3}{8}\left(\frac{T}{\tau}\right)^3 \left| \sum_{n=1}^{\frac{\tau}{T}} (2n-1)(-1)^n \right| = \propto \frac{3}{8}\left(\frac{T}{\tau}\right)^2$$

The residual errors in the computed acceleration expressed as a fraction of the small-scale acceleration $a/\propto$ are plotted against the ratio of observation interval to period in Figure 2.

6. Limitations introduced by the linear assumption for the large-scale motion and the interpretation of the observed velocity deviation

The acceleration computed by the linear assumption cannot yield representative values of the large-scale acceleration if the observation interval includes too large a fraction of the period of the fluctuation. Several tests were made with sinusoidal velocity fluctuations to study the extent of this limitation. A velocity oscillation:

$$v_i = v_0 + v_a \sin \frac{2\pi}{T} i\varepsilon \qquad (3)$$

was chosen in which the maximum acceleration will be $2\pi/T\, v_a$. An observation interval of 1/5 the period of the wave was used in this computation, $\tau = T/5$. The quantity a in equation (1) was then computed for different phase angles. All values of the acceleration from zero to $2\pi/T\, v_a$ were found with the representative rms value of 0.71 $2\pi/T\, v_a$ for all cases. Hence it would seem that a linear function will yield representative accelerations, at least if:

$$\tau \leq T/5$$

The case of intermediate values of the ratio τ/T will be discussed by a further example. The same type of velocity fluctuation was used but with a longer observation interval $\tau = 1.8T$. The leg interval in this case was $\varepsilon = T/15$.

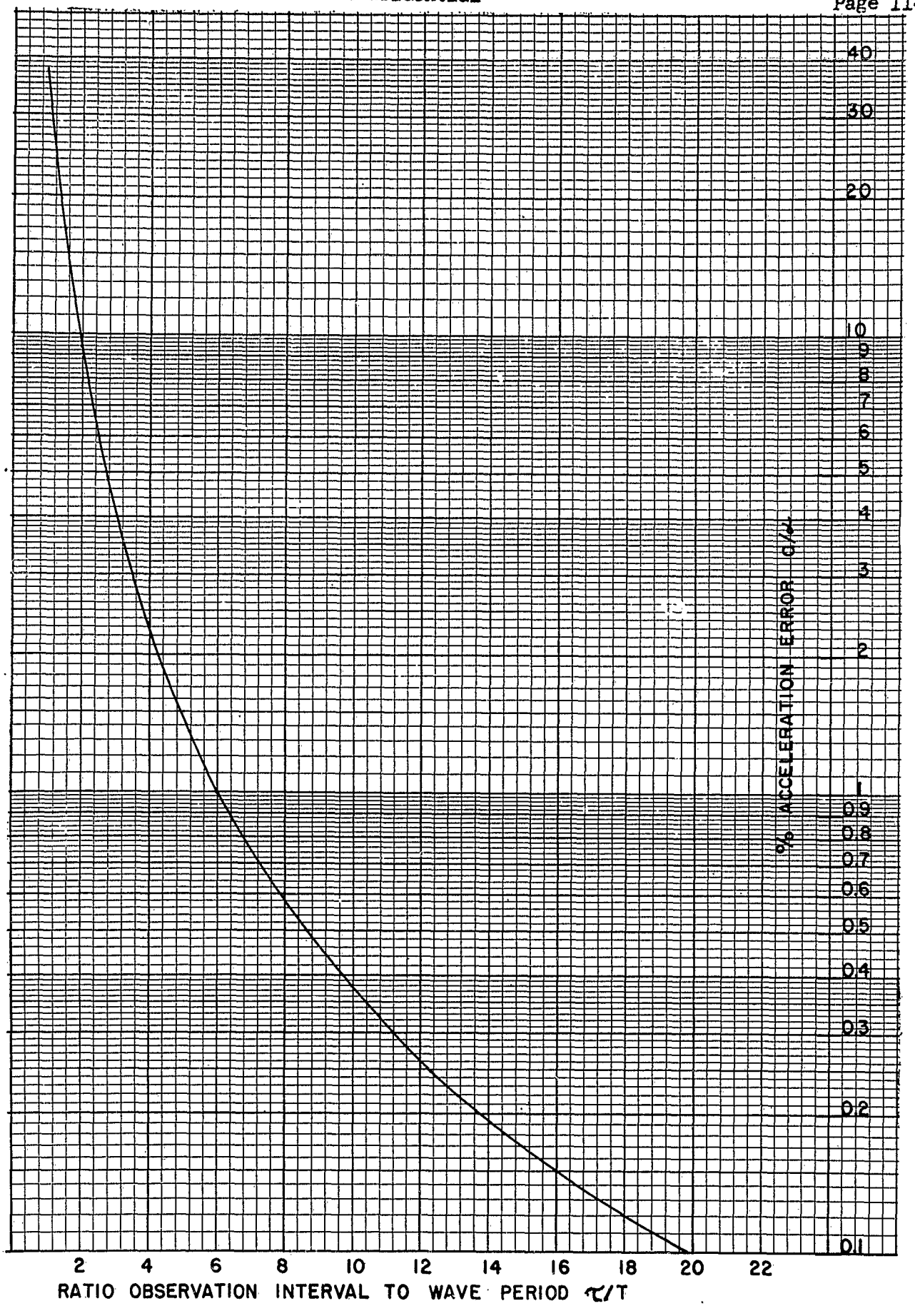

Fig. II-2. The maximum error of the computed large-scale acceleration as a percentage of the small scale acceleration α, plotted as a fraction of the ratio of observation interval to wave period, τ/T.

The wave and the computed linear trend are illustrated in Figure 3.

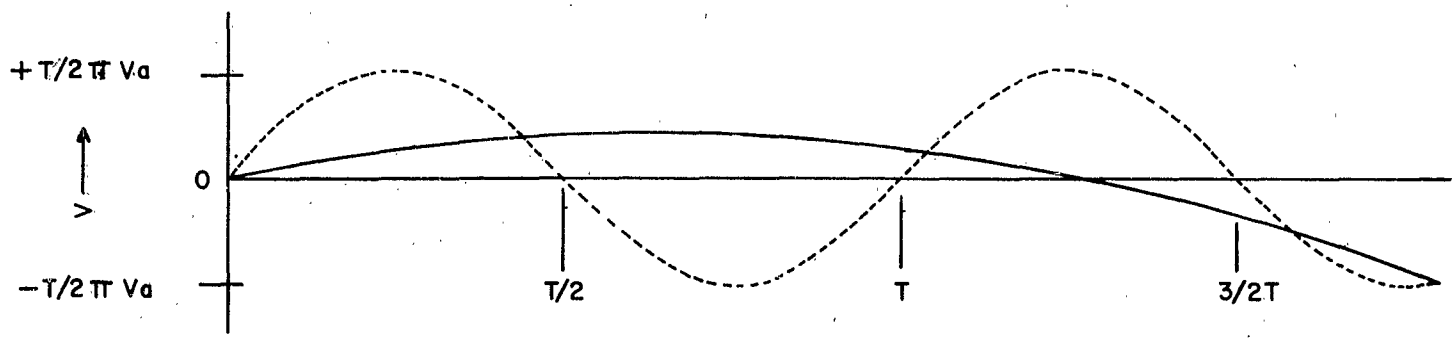

Fig. II-3. Example of the trajectory obtained by a best fitting linear function of the velocity, if the observation interval is comparable to the wave period; $\tau = 1.8T$ in this instance.

The large-scale acceleration was found to be 5% of the maximum acceleration, $= 0.05(\frac{2\pi V_a}{T})$, a reasonable residual value for the case where the observation spans almost two periods (See Figure 2).

The velocity wave appears principally as the deviations from the linear trend. The rms velocity deviation of the legs from the linear function was 0.67 Va. The approximate half period of the fluctuation is shown by the sequence or runs of like sign of the deviations of the legs of the trajectory from the computed linear trend. The major runs average 7.7 legs and we compare this time to a half period: $\frac{I}{2} = \frac{15.6}{2} \sim 7.7$ ℓ

If these were actual observations there always remains the possibility that a given run of like sign might occur simply by chance. For the above example the probability of such a sequence as observed occurring by chance will be computed to be 0.02 (Hoel, 1947, Page 177-182).

Representative accelerations of the smaller scale motion can be obtained by fitting the run of deviations of like sign by a second linear regression. In the two longest runs the accelerations were computed to be $0.74 V_a 2\pi/T$ and $-0.73 V_a 2\pi/T$ The deviations of the velocity in the individual legs, however, must be ascribed to the limitation of the linear assumption for an interval as long as a half period. The rms velocity deviations of the legs were $0.17 V_a$ and $0.10 V_a$, roughly 15% of the amplitude of the half wave being fitted.

The effect of leg interval was not pronounced in any of the computations unless the leg interval spans a large fraction of the wave period. To illustrate some of the difficulties, the same wave was fitted using a leg interval four times larger, $\varepsilon = 4/15\, T$ and $\tau = 2.4T$. The average number of runs of like sign is 2 and again this is very nearly a half period, $2\varepsilon = 8/15 T \sim T/2$. However, the probability of such an observed distribution of signs occurring by chance is very high, 0.29.

7. Effect of observation errors

In the analysis of observed trajectories a further restriction on the interpretation of the velocity fluctuations is determined by the accuracy of the observations. The various elements of an observation of position were reviewed in order to assess the order of magnitude of the error. The observations consist of measurement of time, of elevation and azimuth angles and an altitude determined by a pressure measurement. The computation of the distance away from the observation point for trajectory lengths encountered, requires a correction for atmospheric refraction and earth curvature. This correction is most conveniently made graphically and the error introduced at this point is quite large. The error in the distance computed from the graph is rather independent of distance out and the rms deviation from the mean of a set of independent readings of the graph was found to be of the order of 0.2 mile.

Some examples of observational errors which are equivalent to a position error of 0.2 mile for a balloon 80 miles away at an elevation of 80,000 feet

are given in Table I.

Table I

Observational errors equivalent to a position error of 0.2 mile for a balloon at 80,000 feet, 80 miles away.

Elevation angle = 0.03°

Azimuth angle = 0.15°

Altitude = 200 feet

Since the relative altitude not the absolute altitude is important in the computation of velocity it would seem that only in measurement of the elevation angle could errors of comparable magnitude be introduced. The fact that the greatest error will be made in the computation of the distance out has some further importance in the analysis because the error will depend upon the orientation of the trajectory and the greatest error will be made in the direction along rather than across the line of sight.

The effect of the error upon the computation of the large-scale acceleration may be determined in very much the same way as the effect of small-scale motion. If, despite the above discussion, the error is independent of the trajectory a given observation fix must lie within a circle of radius r, the maximum error in position. Then as before, the maximum contribution to the computed acceleration will be made by the end legs of the trajectory and the maximum velocity deviation in each end leg will be $V = 2r/\varepsilon$. For the case that the number of legs is $2k+1 = \tau/\varepsilon$, the maximum error in the computation of the acceleration, produced by a position error r, will be:

$$\Delta a = \frac{2Vk\varepsilon}{2\sum_{i=1}^{k}(i\varepsilon)^2} = \frac{(2r/\varepsilon)k\varepsilon}{\varepsilon^2\sum_{i=1}^{k}(i)^2} \qquad (4)$$

$$= \frac{12r(2k+1)}{\tau^2(k+1)} \sim \frac{24r}{\tau^2} \quad \text{where } k \text{ is large.}$$

If we take the absolute maximum error = 0.4 miles (smaller values will be expected for distances out less than 30 miles) the maximum errors in the computation of the acceleration as a function of the observation interval

may be determined from equation (4).

Table II

Maximum error in the computation of acceleration in units 10^{-2}cm sec^{-2} for an error in position of 0.4 mile*.

Observation interval, minutes	5	10	20	40	80	160	240	320
Acceleration error, cm sec^{-2} X 10^{-2}	16 X 10^2	420	104	26	3.2	1.6	0.72	0.40

*For comparison note that values of acceleration for 150 minute observation intervals are frequently larger than 10 X 10^{-2} while for 300 minutes, values of 3 X 10^{-2} are observed.

The probability of the occurrence of the maximum velocity deviation with opposite sign at each end leg is very small. On the assumption that the distribution of acceleration error is a multivariate normal function of uncorrelated position fix errors, the standard deviation of acceleration error is no more than one sixth the indicated maximum error.

III. Results of the Analysis

8. Example of the analysis, flight #24

As an aid in the interpretation of the results of the analysis of the flights reported in the following section, one trajectory analysis is presented here in detail. This flight, #24, which happens to be the longest observation in the group, was made from Minneapolis, 18 July 1952. The constant altitude portion of the flight began some 21 miles from the observation point and ended 320 minutes later at a distance 155 miles to the west. The pressure altitude during this interval varied by approximately ±200 feet from the mean elevation of 83,000 feet. The computation was based on position fixes at ten minute observation intervals.

The large scale motion was determined by fitting the linear function to the velocity components as discussed above. The comparison between the observed trajectory and the linear function for the large scale motion is shown in Figure 4 and the data and the results of the computations for the north-south component

of the motion are listed in Table III. In column B are tabulated the values of t_i, the time measured from the mid-point of the observation interval to the mid-point of the leg interval. Column C lists the observed average north-south component of the velocity in each 10 minute leg, determined graphically from a plot of the trajectory. The large-scale velocity in each leg, computed from the linear relation, equation (1) is given in column D. The mean north-south velocity $\overline{V} = -1.82$ m sec^{-1} and the large scale acceleration $a = 2.51 \times 10^{-2}$ sec^{-1}.

The deviations of the observed velocity from the computed large-scale velocity are tabulated in Column E, labled ΔV_i where $\Delta V_i \equiv V_{0i} - V_i$. These deviations may be interpreted as motion of smaller scale, observation error, or simply the result of the limitation of a linear description for the motion. This latter possibility cannot be excluded immediately if only because the rms $\Delta V_i = 1.34$ m sec^{-1} is almost as large as the mean velocity.

The effect of observational error is difficult to estimate because of the wide range in balloon distance and hence in probable error. The circle of maximum error, following the discussion in section 7, varies in radius from 0.05 miles at the beginning to 0.65 miles at the end of the trajectory. The rms value of the radius of maximum error for this trajectory was 0.45 miles which corresponds to a maximum velocity error of 2.4 m sec^{-1} in a ten minute leg. It will be observed that a number of the values of ΔV_i, therefore are too large to be explained by error alone. Actually if the error is at all reasonably distributed the rms deviation due to error would perhaps be no greater than one-third of the maximum value. This estimate is based upon the assumptions that the maximum displacements of the end points of a velocity vector correspond to twice the standard deviation of the position fix error and that the distribution of the velocity error is a joint normal distribution function of the two uncorrelated end point errors.

Table III. Analysis of the north-south component of flight 24

Obs no. i	Obs time t_i 10^2 sec	Obs vel $V_{o,i}$ m·sec^{-1}	Trend vel V_i m·sec^{-1}	Dev from trend ΔV_i m·sec^{-1}	Accum dev d_i m·sec^{-1}	Int wave obs time t' 10^2 sec	Trend vel V' m·sec^{-1}	Dev from trend $\Delta V'$ m·sec^{-1}
A	B	C	D	E	F	G	H	I
1	-93	-3.9	-4.2	.3	.3			
2	-87	-4.4	-4.0	-.4	-.1			
3	-81	-4.4	-3.9	-.5	-.6			
4	-75	-3.9	-3.7	-.2	-.8			
5	-69	-3.6	-3.6	0	-.8			
6	-63	-4.1	-3.4	-.7	-1.5			
7	-57	-2.7	-3.3	.6	- .9			
8	-51	-4.1	-3.1	-1.0	-1.9			
9	-45	-4.2	-3.0	-1.2	-3.1			
10	-39	-2.9	-2.8	- .1	-3.2			
11	-33	-2.8	-2.7	- .1	-3.3			
12	-27	-2.4	-2.5	.1	-3.2			
13	-21	-2.9	-2.4	- .5	-3.7	-15	-1.0	.5
14	-15	-3.7	-2.2	-1.5	-5.2	- 9	- .5	-1.0
15	- 9	-1.8	-2.0	.2	-5.0	- 3	.1	.1
16	- 3	-1.1	-1.9	.8	-4.2	3	.6	.2
17	3	0	-1.7	1.7	-2.5	9	1.1	.6
18	9	- .4	-1.6	1.2	-1.3	15	1.6	- .4
19	15	1.4	-1.4	2.8	1.5	-18	3.7	- .9
20	21	.7	-1.3	2.0	3.5	-12	2.7	-.7
21	27	3.7	-1.1	4.8	8.3	- 6	1.7	3.1
22	33	-1.0	-1.0	0	8.3	0	.7	- .7
23	39	-1.8	- .8	-1.0	7.3	6	- .4	- .6
24	45	-2.4	- .7	-1.7	5.6	12	-1.4	- .3
25	51	-2.8	- .5	-2.3	3.3	18	-2.4	.1
26	57	- .7	- .4	- .3	3.0			
27	63	-1.4	- .2	-1.2	1.8			
28	69	- .4	- .1	- .3	1.5			
29	75	.2	.1	- .1	1.6			
30	81	-2.4	.3	-2.7	-1.1			
31	87	.5	.4	.1	-1.0			
32	93	1.4	.6	.8				

A major cause of the observed velocity deviation is immediately suggested by the comparison of the trajectory for the large scale motion and the observed trajectory, Figure 4. The almost regular oscillation about the smooth curve makes it appear that these are velocity fluctuations of shorter period than the observation interval. This possibility is investigated quantitatively by determining the accumulated deviations, d_i listed in column F. (The displacement of an observation fix from the linear trend is given by the product Σd_i). The rms d_i = 3.51 m sec^{-1} considerably larger than the rms ΔV_i, indicating runs of the deviations of like sign. Further confirmation is found by investigating the distribution of algebraic sign of the values in column F. The probability that this distribution would occur by chance is less than 0.025.

The intermediate waves will not necessarily appear as changes in sign of the d_i unless the amplitudes of the waves are uniform. The half-period of the intermediate waves are best selected by the cases of increasing and then decreasing sign of the d_i. From the total number of cases the average period is found to be 130 minutes and the half periods of greatest amplitude chosen for further analysis are indicated as A and B in Figure 4. The north-south accelerations in these segments were computed by fitting a second linear regression and the values obtained were 8.9 X 10^{-2} and -17.0 X 10^{2}cm sec^{-2}. The corresponding quantities of the second regression computations are distinguished by using the prime symbol and the values are tabulated in columns G, H and I.

It is now possible to decide that the intermediate accelerations do not appreciably affect the computation of the large-scale acceleration. From Figure 2 it may be determined that the maximum contribution of a small-scale acceleration is 6% for this observation interval and wave period. The maximum contribution of the largest small-scale acceleration is therefore 1 X 10^{-2} which may be compared with the observed large-scale value of 2.5 X 10^{-2} cm sec^{-2}.

Velocity fluctuations of even smaller scale should appear as deviations from the second linear regression. The rms of these deviations $\Delta V'$=0.92m sec^{-1},

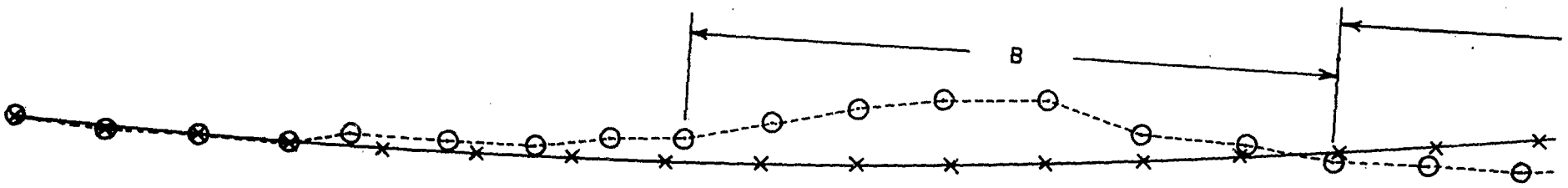

Fig. II-4. Observed trajectory flight 24, broken line, a
from a linear velocity trend, solid line. The sections of th
for a second linear approximation are marked A and B.

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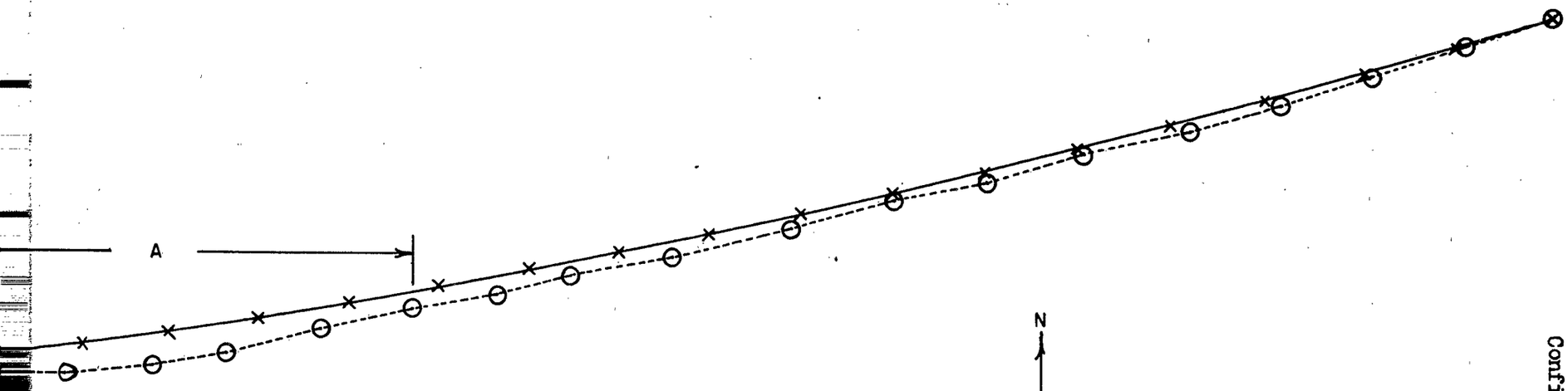

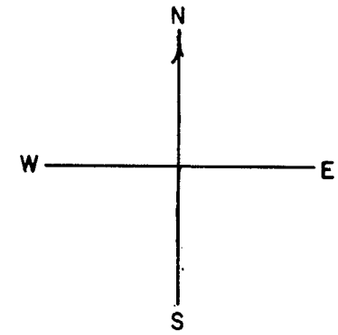

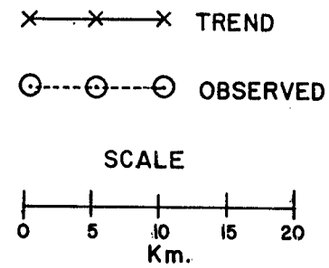

ine, and trajectory computed
of the trajectory selected

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which is smaller than our estimate of maximum error. Again some of the values of $\Delta V'$ are too large to be explained by error, but in general these fluctuations are so small as not to be distinguishable from the possible error.

In summary flight #24 exhibits three scales of atmospheric motion:

(1) The acceleration measured for the large-scale component which apparently has a period greater than 10 hours is 2.5×10^{-2} cm sec^{-2}.

(2) An intermediate fluctuation of average period of about 2 hours with accelerations of as large as 17×10^{-2} cm sec^{-2}, and

(3) Some evidence for waves with a period shorter than one hour but with amplitudes smaller than 1 m sec^{-1}.

9. Results of all cases

The results of the analysis of the 14 observations are given in Table IV for the cases of easterly flow and in Table V for west winds. Most of the column headings are self explanatory with notation following conventions described in the body of the report. Where applicable, the north-south and east-west components of a measurement are indicated after the column number. Distance out, column 5, refers to the average horizontal distance between the balloon and the observation point. In order to estimate more representative values of the large-scale acceleration, the maximum effect of the intermediate acceleration was computed using the diagram in Figure 2, and this value subtracted from the large-scale accelerations. The residuals which represent a minimum value of the large-scale acceleration are listed in column 11. Columns 12, 14 and 19 give the error estimates based on the possible displacement of the position fix. The error in the acceleration or overall trend (column 12) are the estimated standard errors computed from the error in position fix and the observation interval; these values are to be compared with the quantities in column 8. The estimated standard error in velocity (column 14) is computed from the error in position fix and the leg interval and may be compared with the values in columns 13, 16 and 18. The

Table IV. Analysis of east winds

Flt	τ	ϵ	Alt	Dist out	Mean vel mag	Mean vel dir	Overall trend		Interm trend		Interm wave period		Adjusted overall trend		Overall trend error	RMS vel dev from mean		Stnd error vel	RMS vel flux of long wave		RMS vel dev from long wave		RMS vel flux of int wave		RMS vel dev from int wave		Max fix error	RMS dev position fix-d$_i$		Prob. of dist. of d$_i$ signs	
	min	min	10^3 ft	mi	m·s^{-1}	deg	10^{-2}cm·s^{-2}		10^{-2}cm·s^{-2}		min	min	10^{-2}cm·s^{-2}		10^{-2}cm·s^{-2}	m·s^{-1}		m·s^{-1}	m·s^{-1}		m·s^{-1}		m·s^{-1}		m·s^{-1}		mi	mi			
1	2	3	4	5	6	7	8-N	8-E	9-N	9-E	10-N	10-E	11-N	11-E	12	13-N	13-E	14	15-N **	15-E **	16-N	16-E	17-N ***	17-E ***	18-N	18-E	19	20-N	20-E	21-N	21-E
16	25	5	81	55	5	87	-3.4	-0.4	—	—	—	—	—	—	10	.78	2.77	1.3	.13	0	.77	2.77	—	—	.77	2.77	.38	.43	.37	—	—
20-1	60	5	86	30	11	59	10.4*	15.0	38	16	>60	>60	0	5	.45	2.16	2.56	.32	1.07	1.57	1.88	2.03	1.70	.81	.81	1.86	.09	.28	.11	.025	.025
20-2	75	5	78	38	6	100	13.5*	16.7	12	4	>70	80	10.0*	15.7	.32	2.67	2.34	.36	1.74	2.16	2.03	.88	1.45	.71	1.42	.52	.10	.58	.16	.025	.032
24	320	10	83	90	13	82	2.5	0.9	13	10	130	120	1.5	0	.08	2.00	2.02	.80	1.50	.55	1.34	1.94	.95	1.38	.92	.92	.45	1.32	1.35	.025	.025
27-1	140	10	84	45	9	96	1.0	-3.6	13	—	100	—	0	-3.6	.25	1.18	1.69	.50	.22	.88	1.16	1.44	1.02	0	.55	1.44	.28	.55	.45	.040	.025
27-2	200	20	79	120	10	112	3.6	3.0	—	—	—	—	3.6	3.0	.20	1.72	2.09	140	1.16	1.73	1.27	1.17	0	0	1.27	1.17	.45	.82	.75	.19	.30
33	60	5	84	30	7	96	-8.0*	0.3	—	25	—	>60	-8.0	0	.45	1.63	1.39	.36	.67	0	1.49	1.39	0	1.20	1.49	.69	.09	.25	.41	.15	.025
491	105	5	83	20	6	104	0.9	5.2	10	4	70	80	0	4.5	.11	1.26	1.42	.25	.53	.89	1.14	1.11	.53	.21	1.01	1.09	307	.24	.17	.014	.07
462	160	10	79	50	4	116	2.1	1.4	13	5	100	140	0.3	0	.22	1.57	.77	.53	.59	.24	1.46	.73	1.23	.56	.78	.47	.30	1.64	1.16	.008	.008

Table V. Analysis of west winds

1	2	3	4	5	6	7	8-N	8-E	9-N	9-E	10-N	10-E	11-N	11-E	12	13-N	13-E	14	15-N	15-E	16-N	16-E	17-N	17-E	18-N	18-E	19	20-N	20-E	21-N	21-E
8	140	10	82	100	7	251	-6.6	2.7	18	—	>130	—	-3.6	2.7	.40	1.87	1.59	.80	1.58	.66	.99	1.45	.94	0	.30	1.45	.45	.76	.36	.001	.22
9	140	10	87	28	3	280	-3.9	1.6	8	—	>110	—	1.3	1.6	.08	1.39	.79	.15	.95	.38	1.01	.69	.85	0	.55	.69	.09	.59	.21	.035	.17
10	100	10	94	40	10	296	2.9	-7.3	13	—	>90	—	0	-7.3	.18	1.53	1.59	.18	.52	1.25	1.44	.98	1.12	0	.90	.98	.10	.67	.21	.016	.24
40	100	10	86	100	11	302	5.9	-3.7	—	—	—	—	5.9	-3.7	.80	1.57	1.37	.80	1.01	.62	1.20	1.22	0	0	1.20	1.22	.45	.34	.31	.056	.19
42	80	10	85	70	11	271	-11.4	.8	—	—	—	—	-11.4	.8	1.25	1.99	1.10	.80	1.57	.16	1.23	1.09	0	0	1.23	1.09	.45	.40	.32	.056	.14

* These large values of the acceleration have been determined for an observation interval which is too short to eliminate waves of intermediate period.

** Col 15 is obtained: (Col 15)^2 = (Col 13)^2 - (Col 16)^2

*** Col 17 is obtained: (Col 17)^2 = (Col 16)^2 - (Col 18)^2

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position fix errors are maximum estimates so that roughly half of these values should be comparable to the rms values of the observed trajectory displacement (column 20). Column 21 lists the results of the analysis of the sign sequences of position displacements. For example, a sign probability of 0.025 indicates that, assuming random error distribution about a long period wave, the probability that the observed sign sequence is due to error alone is less than 2.5%.

The results listed in the table indicate the existence of three general scales of motion. Long period waves are suggested by the overall trend and judging by the appearance of the trajectories the period in all cases is greater than twice the observation interval, i.e. greater than 5 hours for flights #8, #9, #24 and #27. The remaining overall trend values give evidence of either long period fluctuations or of waves of intermediate period - from 1 to 5 hours. The intermediate scale of motion is also indicated by the sign sequence analyses. The evidence of shorter waves, - 1 hour or less - is suggested by the part of the velocity deviations which cannot be accounted for as error in observation or as deviations inherent in the linear trend method.

The magnitudes of the accelerations obtained may be arranged according to the period of the fluctuation. The acceleration in the fluctuations of the largest scale range from 0 to 4×10^{-2} cm sec^{-2}. In the fluctuations of intermediate period accelerations as large as 15×10^{-2} cm. sec^{-2} are observed; while for fluctuation with periods less than an hour the deviations are not entirely distinguishable from the error it seems likely that the values of 50×10^{-2} cm sec^{-2} must occur.

The amplitude of these velocity fluctuations in these three scales of motion may also be estimated. If we assume the velocity fluctuations in each scale to be independent and normally distributed the variance of the observed velocity deviations σ_0^2 will be equal to the sum of the variance due to each scale of motion and to error:

$$\sigma_0^2 = \sigma_1^2 + \sigma_2^2 + \sigma_3^2 + \sigma_e^2 \qquad (5)$$

where the subscripts 1, 2, 3 and e denote the variance due to large-scale, intermediate scale, and small-scale motion and to error, respectively. For an observation of several hours the large-scale motion is determined by the linear function and the variance about this function σ_1^2 is assumed to be due to smaller scale motion and to error hence:

$$\sigma_1^2 = \sigma_2^2 + \sigma_3^2 + \sigma_e^2 \qquad (6)$$

The variance due to the largest scale of motion will, therefore, be determined as the difference of the total variance (5), and the variance about the linear trend (6). The square root of the variance due to the largest scale motion is listed in column 15; the corresponding values for the total observed fluctuations and the deviations from the trend are in columns 13 and 16.

The operation can be repeated to determine the variance due to the motion of smaller scale although the error due to limitations of the method and assumptions will increase after successive differences. These figures for the amplitude of smaller scale motion listed in column 17 and the remaining deviations of column 18 must be viewed as rough estimates.

IV. Conclusions

10. The scale of stratospheric motions

It has been found that, subject to limitations due to the length and accuracy of the observations, it is possible to distinguish motion over a rather wide range of periods. As noted in the preceeding section, the method of analysis seems to distinguish three general groups of periods. The characteristics of the motion in each group are summarized in Table VI.

Table VI

Characteristics of stratospheric motions of different periods

Period, hours	5-15	1-3	½
Accelerations $\times 10^{-2}$ cm sec^{-2}	0-4	10-15	~ 50

Table VI (continued)

Characteristics of stratospheric motions of different periods

Amplitude of velocity fluctuation, m sec^{-1}	1.5	1.0 - 1.5	$\sim$ 1.0
Amplitude of trajectory fluctuation miles	25*	1 - 2	$\sim$ 0.5

*Estimated to be consistent with the amplitude of the velocity fluctuation and the estimated period.

While the data is separated into three groups of motions according to the period it should not be assumed that it shows any discontinuities in the spectrum of the stratospheric motion. The rather surprising fact that the velocity amplitude is almost independent of period suggests that there is no different in the type of flow in the range of periods investigated.

These results may be compared with the motion observed in the troposphere. The motion termed large scale in the troposphere is of somewhat longer period than observed here and the velocity amplitude is much greater. In contrast with the above results for the stratosphere, the large scale tropospheric flow is quite distinct from the smaller scale motion. The intermediate and small-scale stratospheric motions are very nearly comparable to the troposphere, although again the velocity amplitudes of the smallest scale stratospheric motions seems to be smaller.

11. Forecasting implications

The problem of the extrapolation of the course of the balloon may now be considered in the light of the derived characteristics of the flow. The motion is seen to consist of velocity fluctuations with a wide range of periods but with similar amplitudes. As a first approximation it would seem obvious that the best or most representative wind measurement for extrapolition will be obtained by using an observation interval of a length comparable to the forecast interval.

For periods of a few hours it would be possible to extrapolate only the large scale motion of the flow with an expected accuracy of the trajectory amplitude of the intermediate small-scale flow (several miles). In forecasts for

a period of a day and with suitable observation length, the errors would be comparable to the amplitude of the large scale trajectory fluctuations (25 miles).

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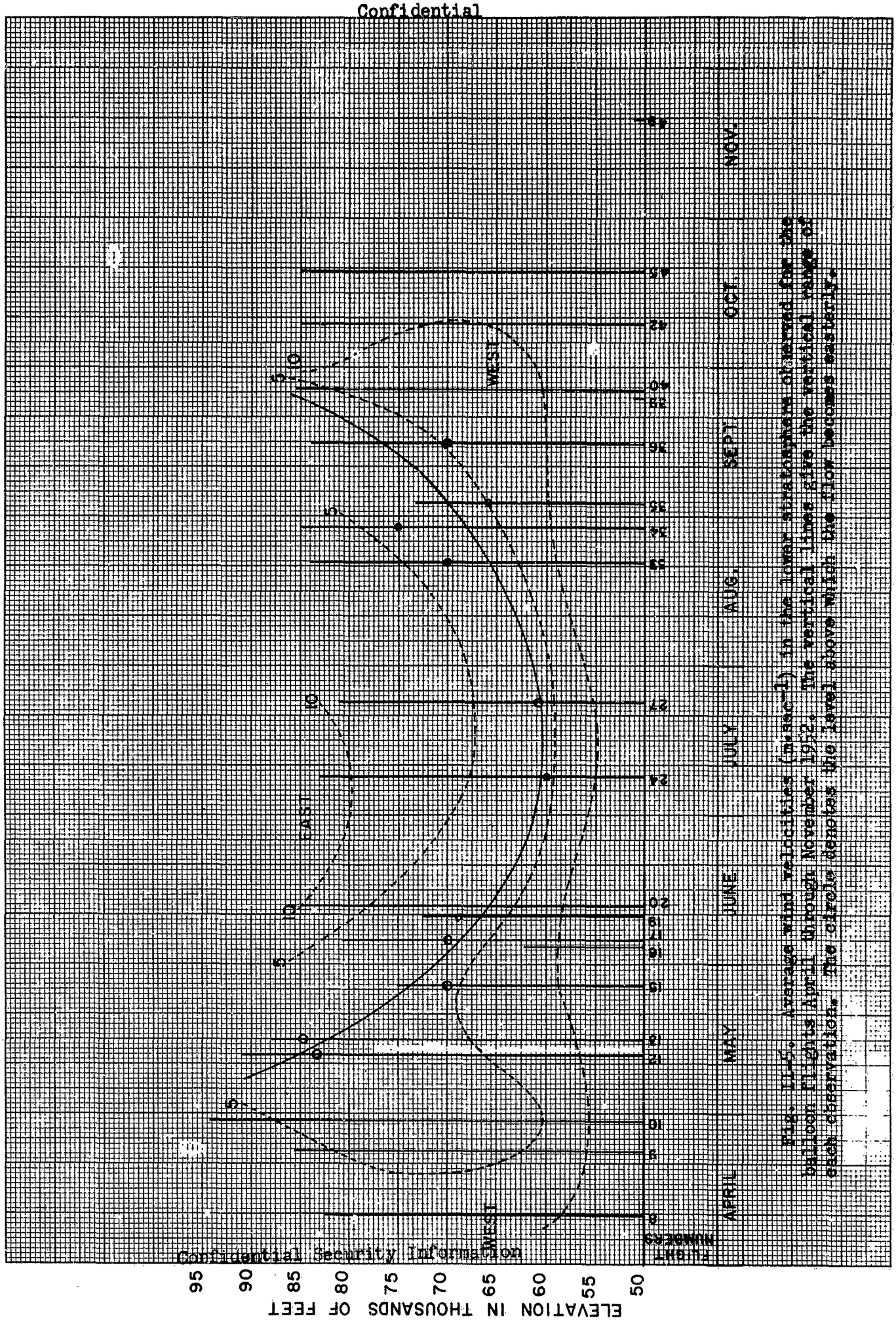

Fig. II-5. Average wind velocities (m/sec-1) in the lower stratosphere observed for the 0130 flights April through November 1952. The vertical lines give the vertical range of each observation. The circle denotes the level above which the flow becomes easterly.

FLIGHT NO. 35 9-3-52
TIME 0929 U. OF M.

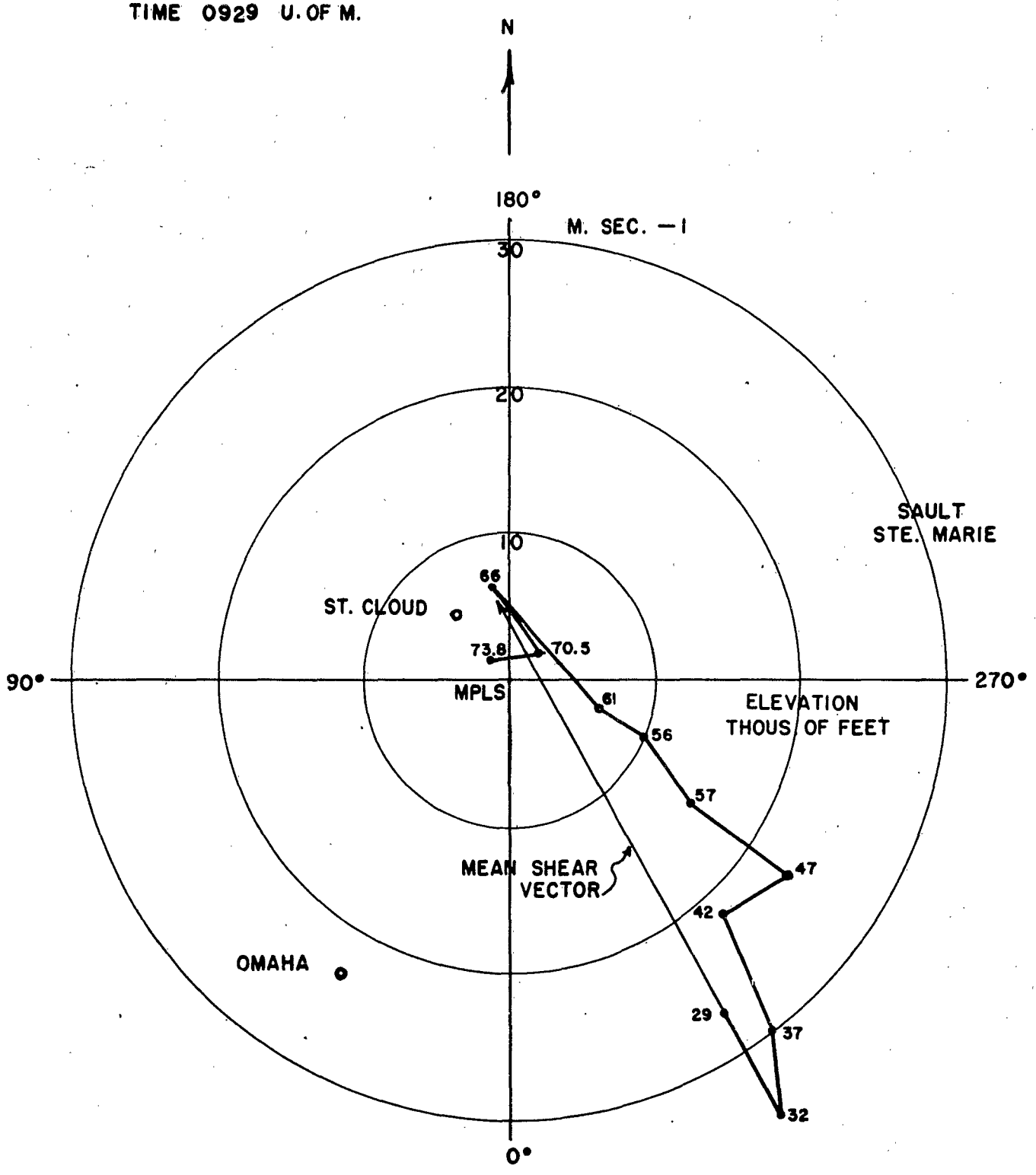

Fig. II-6. Hodograph for flight #35. The location of the nearby Radiosonde stations with respect to Minneapolis are also indicated.

some seasonal trend; the lowest elevation of reversal occurs in mid July in about the middle of the period of easterly flow. A slight tendency for the easterly flow to increase with elevation is also observed.

3. Some features of the wind maximum at the tropopause

The balloon ascents show several interesting details of the wind maximum which so frequently is found at the base of the stratosphere. In sixteen ascents winds in excess of 30 m sec^{-1} were observed. The distribution of the maximum observed wind speeds in these 16 flights is shown in Table VI.

Table VI

Maximum wind speeds m sec^{-1} observed in sixteen ascents during high winds.

	Range of maximum wind speeds, m sec^{-1}					
	30-34.9	35-39.9	40-44.9	45-49.9	50-54.9	55-59.9
No. of cases	6	3	3	2	1	1

The elevation of the wind maximum is very closely related to the height of the tropopause. The average elevation of the wind maximum for these 16 cases was 37,600 feet, which is just 2000 feet below the average tropopause height. The standard deviation of both tropopause height and elevation of the wind maximum was 5400 feet. The correlation coefficient of the elevation of the wind maximum to the tropopause height in these 16 cases was 0.83. Because of fair weather bias almost all of these ascents were made in northwesterly flow and this relationship, if representative at all, may be limited to this type of weather situation.

Another characteristic of these wind profiles was the noticeably greater wind shear in the layer above the wind maximum than below. The average vertical wind shear just below the maximum was $2.89 \times 10^{-3} sec^{-1}$ (2.0 mph per thousand feet) and above the maximum, the average shear was $-7.6 \times 10^{-3} sec^{-1}$ (5.2 mph per thousand feet).

B. WINDS IN THE UPPER TROPOSPHERE AND LOWER STRATOSPHERE

1. Introduction

The wind measurements made during the ascent of the plastic balloons frequently provide information in the upper atmosphere unavailable by conventional radio wind measurement. Because of the size and rate of ascent of the balloon no observations were lost during ascent solely because of too great a range. The tracking methods, both camera and theodolite, are essentially fair weather systems and the data will therefore suffer this bias.

A total of twenty-three ascents with wind measurements were made from Minneapolis, Minnesota, or Pierre, South Dakota, in the period April through November, 1952. The information obtained from these wind measurements will be reviewed in this report. The data will be discussed under three headings in the following sections: (1) A summary of the winds in the lower stratosphere; (2) Some features of the wind velocity maximum in the vicinity of the tropopause; and (3) The extension of meteorological analysis to the stratosphere.

2. A summary of the winds in the lower stratosphere

The broad features of the observed stratospheric winds are shown in Figure 1 which gives the variation of the vertical wind profile with season. The location and vertical extent of each observation is shown by the vertical lines. Isopleths of average velocity, which have been smoothed rather arbitrarily are given in m sec^{-1}. The location of the shift from westerly to easterly flow is noted by a circle for each observation and the smoothed average limit of easterly flow is given by the solid curve.

Perhaps the most important features of Figure 5 are the details of the period of easterly flow. Both the onset of easterly winds in the spring and the termination in the fall are very abrupt. The elevation of the boundary between easterly and westerly flow varies from day to day but does exhibit

4. Extension of the methods of analysis to the stratosphere

The observed winds were also reviewed with the thought of extending the methods of analysis to the lower stratosphere. The methods of extrapolating the wind and pressure field in regions of sparse data are essentially based upon the use of the thermal wind relationship in an effort to make the analysis of pressure, wind and temperature mutually consistent. The thermal wind vector or shear vector in the stratosphere was therefore investigated by plotting hodographs for all the ascents and in addition for all the available SKYHOOK ascents.

The hodographs in cases of strong tropospheric flow were quite similar, again possibly because these are all similar weather situations. A typical case is illustrated by the hodograph for flight #35, Figure 6. The flow is from the northwest just below the tropopause. From the shear vector it appears that the horizontal temperature distribution is quite constant in the layer from 32 to 66,000 feet, and that there is a slight cold air advection in this deep layer. The actual temperature distribution is substantially verified by the plot of the Radiosonde data observed along a line perpendicular to the shear vector, Figure 7.

A deep layer extending from the base of the stratosphere to as high as 75,000 feet, in which the orientation of the shear vector and sign of the advection is constant, is typical of a large number of the hodographs with strong flow. Above this layer a completely different horizontal temperature distribution is found which seems to be highly dependent upon season with no obvious relationship to the tropospheric weather system. The suggestion is rather strong therefore that the level 65,000 to 75,000 feet marks the upper extent of the tropospheric weather systems. In this respect the consistency of the sign of the advection is particularly significant because of the high correlation between advection and the sign of the vertical motion[1].

[1]Fleagle, R.G., 1948, Journal of Meteorology, p. 290.

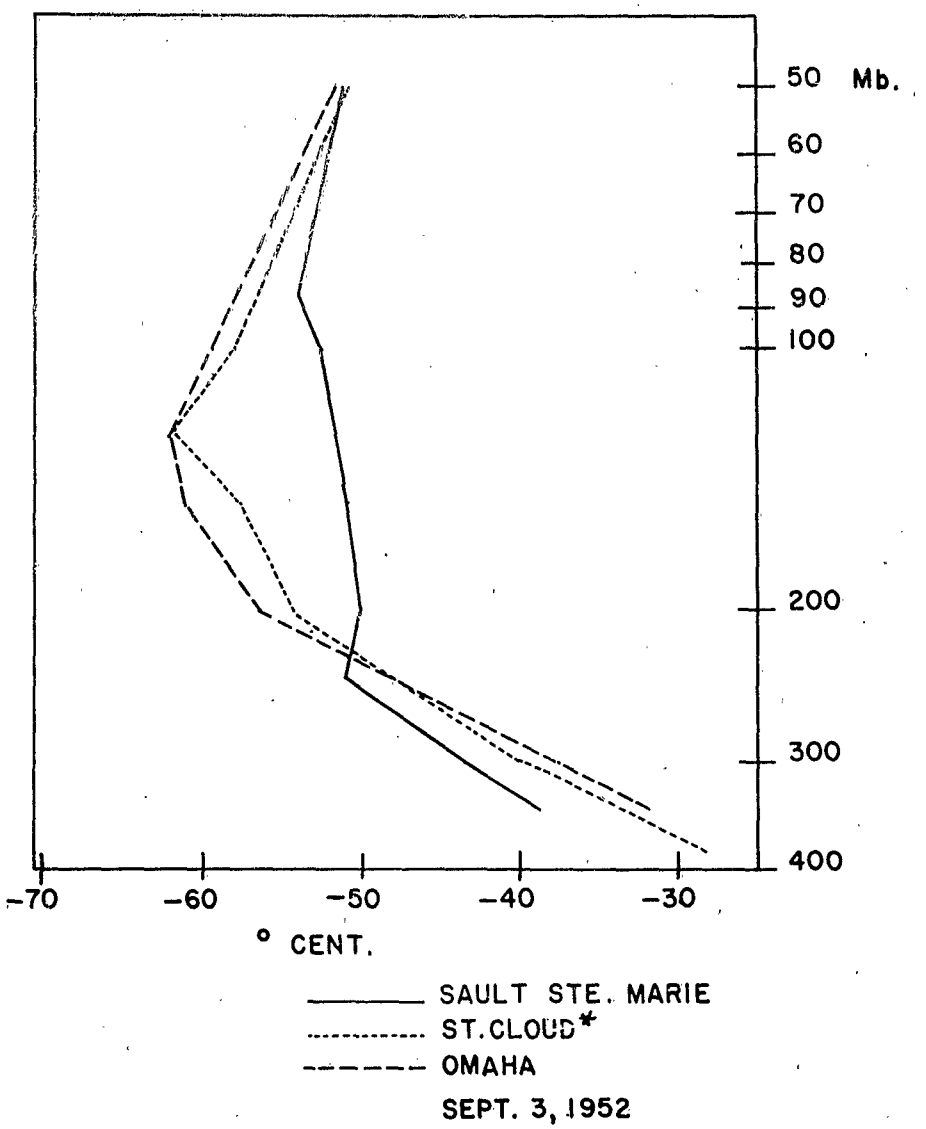

Fig. II-7. Radiosonde observation made at stations located along a line perpendicular to the shear vector of flight #35, see Figure 6. The highest temperatures in the lower stratosphere are observed to the right of the shear vector.

* St. Cloud sounding for 4 September 03 Z substituted for missing data.

Several of these observations are pertinent to the question of extrapolating the methods of analysis. The temperature and wind observations are consistent so that the usual methods for extending the analysis to upper levels should be valid to perhaps 65,000 feet. However, it also strongly suggests that flow patterns at this elevation will be as complicated as the isotherm pattern just above the tropopause. In this case it would seem that a rather dense network of upper air observations would be required to construct a weather map which would depict the flow at these elevations.

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