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MARS 3: ESTIMATE OF PARAMETERS OF THE ATMOSPHERE AT THE LANDING POINT OF THE SPACECRAFT

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MARS 3 ESTIMATE OF PARAMETERS OF THE ATMOSPHERE AT THE LANDING POINT OF THE SPACECRAFT

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1. Introduction /2

The landing of the descent module of the Mars 3 automatic interplanetary station and the reception of video signals from the surface of the planet made it possible to estimate the parameters of the atmosphere of Mars at the point of landing of the Mars 3 spacecraft, in spite of the absence of any other information during the descent.

This estimate was based on the time interval from the moment the descent module entered the atmosphere at the arbitrary altitude H = 100 km from the mean surface level (H = 0 where R = 3400 km) until the moment of appearance of the video signal.

The analysis utilized the aerodynamic characteristics of the parachute-descent module [DM] system, considering the logic of operation of the system and landing apparatus of the DM. The initial materials used to estimate the parameters of the atmosphere were models encompassing the possible range of values of characteristics of the Martian atmosphere. The calculation of the time of appearance of the video signal, performed for various models of the atmosphere and levels of the surface of Mars, allows us to indicate the atmospheric model and surface level most fully agreeing with the actual descent time of the module and correspondingly estimate the atmospheric pressure at the landing point of the Mars 3 DM.

2. Basic Initial Data /3

Time of entry into atmosphere[1]

$$t_{en} = 16^h\ 43^m\ 50.7^s$$

2 December 1971.

Arbitrary altitude of entry point (above mean surface level H_0 where R = 3400 km):

$$H_{en} = 100 \text{ km.}$$

Nominal coordinates of landing point

$$\phi = 45°30' \text{ s. lat.}$$
$$\lambda = 158°\ 25' \text{ w. long.}$$

Nominal trajectory angle of entry

$$\theta_{en} = -14.5°$$

Nominal entry velocity

$$V_{en} = 5736 \text{ m/sec.}$$

Time of appearance of video signals from surface of planet

$$T_{init.\ pan.} = 16^h\ 50^m\ 35.5^s$$

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[1]Here and throughout the paper we use Moscow time.

TABLE 1 /4

Parameters of the Atmosphere at the Nominal Surface Level

Parameter Nos.	1	2	3	4	5
Pressure at Surface P[mb]	5.0	5.5	6.0	6.5	9.0
Temperature at Surface T_0[°K]	200	256	230	210	256
Mass Composition [%] - CO_2	100		88	100	90
Ar	-		12	-	10% Ne
Molecular Weight kg/(kg·mol)	44	-	43.5	44	41.6
Universal Gas Constant τ/°K(kg·mol)	8314	8314	8314	8314	8314

Altitude characteristics of these atmospheric models presented in Tables on pages 6-10.

3. Analysis of Results

In order to estimate the conditions most fully satisfying /5 the results of descent of the Mars 3 DM, we performed calculations to determine the probable characteristics of motion of the DM, assuming the deviation of the parameters from their nominal values to be normal.

The conditions were estimated by comparing the actual time of appearance of the video signal with the calculated time. Using the method of statistical linearization, we produced values of the mathematical expectation and dispersion of the calculated time of appearance of the video signal ($T_{init.\ pan.}$) for discrete levels of the surface (see Figures 1, 2, 3, 4).

On Figure 5, the solid line (1) shows the altitude levels corresponding to the measured time of appearance of the signal for the models of the atmosphere with otherwise nominal conditions. The corresponding dotted lines (2) and (3) correspond to the same condition considering deviations in nominal parameters with altitude up to 3 b.

The lower dotted curve (2) corresponds to deviations of parameters (for example, angles of entry into the atmosphere greater than nominal) which lead (with a fixed descent time) to higher pressures at the surface of the planet or lower surface levels.

The upper dotted curve (3) corresponds to deviations of parameters (for example, angle of entry into the atmosphere lower than nominal) which lead to lower pressures at the nominal /6
surface of the planet or higher surface level.

As we can see from this graph (Figure 5), solid curve (1), corresponding to the nominal entry parameters, shows that the pressure at the surface at the landing point is between 9.2 and 9.8 mb. The extreme estimates are 11.8-12.2 mb and 5.6-6.6 mb.

If we keep in mind the available materials on the parameters of the atmosphere of Mars, it is apparent that the extreme high estimate is improbable.

Thus, the possible pressure at the surface of Mars at the landing point of the Mars 3 descent module can be estimated as 5.6-9.8 mb.

In conclusion we must note that these estimates are preliminary in nature and will be refined in the future.

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Minimum Model

P_0 = 5 mb

T_0 = 200°K

$a = 15.7\sqrt{T}$

$\rho_0 = 1.36 \cdot 10^{-3}$ kg·sec²/M⁴

	N km	T°K	ρ kg·sec²/M⁴
1.	-6	230	$1.79 \cdot 10^{-3}$
2.	-4	220	1.66
3.	-2	210	1.47
4.	0	200	$1.36 \cdot 10^{-3}$
5.	2	190	1.17
6.	4	180	1.0
7.	6	170	$8.6 \cdot 10^{-4}$
8.	8	160	7.2
9.	10	150	5.88
10.	12	140	4.77
11.	14	140	3.64
12.	16	"	2.74
13.	18	"	2.055
14.	20	"	$1.55 \cdot 10^{-4}$
15.	22	"	1.17
16.	24	"	$8.88 \cdot 10^{-5}$
17.	26	"	6.73
18.	28	"	5.1
19.	30	"	3.8
20.	32	"	2.9
21.	34	"	2.27
22.	36	"	1.75
23.	38	"	1.32
24.	40	"	$9.33 \cdot 10^{-6}$
25.	50	"	2.29
26.	60	"	$5.56 \cdot 10^{-7}$
27.	70		1.38
28.	80	"	$3.35 \cdot 10^{-8}$
29.	90	"	$8.22 \cdot 10^{-9}$
30.	100	"	$2.04 \cdot 10^{-9}$
31.	-8	240	
32.	-10	250	

Model 2 /8

$P_0 = 5.5$ mb $T_0 - 256°$ $\rho_0 = 1.12 \cdot 10^{-3}$ kg·sec/M^4

	N km	T°K	ρ mb	ρ kg·sec^2/M^4
1.	-6	286	8.8	$1.63 \cdot 10^{-3}$
2.	-3	270	7.0	1.43
3.	0	256	5.5	1.12
4.	3	247	4.4	$9.475 \cdot 10^{-4}$
5.	6	241	3.5	7.75
6.	9	237	2.8	6.32
7.	10	236	2.6	5.69
8.	12	234	2.2	5.0
9.	14	231	1.84	4.3
10.	15	230	1.70	3.98
11.	16	228	1.56	3.66
12.	18	227	1.30	3.06
13.	20	224.5	1.1	2.54
14.	21	224	1.0	2.35
15.	22	223	$9.25 \cdot 10^{-1}$	2.2
16.	24	221	8.0	1.94
17.	26	218	6.53	1.66
18.	27	216	6.0	1.53
19.	28	214.5	5.45	1.38
20.	30	212	4.5	1.12
21.	32	210.5	3.8	$9.8 \cdot 10^{-5}$
22.	34	209.5	3.4	8.6
23.	35	209	3.2	8.15
24.	36	208.5	2.95	7.55
25.	38	207.5	2.6	6.6
26.	40	207	2.2	5.71
27.	45	206	1.5	3.875
28.	50	"	$7.0 \cdot 10^{-2}$	1.835
29.	55	"	5.0	1.325
30.	60	"	2.0	$5.2 \cdot 10^{-6}$
31.	65	"	$4.0 \cdot 10^{-3}$	1.02
32.	70	"	2.5	$6.52 \cdot 10^{-7}$
33.	80	"	$3.2 \cdot 10^{-4}$	$8.35 \cdot 10^{-8}$
34.	90	"	$4.2 \cdot 10^{-5}$	1.10
35.	100	"	$5.2 \cdot 10^{-6}$	$1.36 \cdot 10^{-9}$

Model 3

$M = 43.5$ $CO_2 - 88\%$ $Ar - 12\%$

$P_0 = 6$ mb $T_0 = 230°K$ $a = 15.9\sqrt{T}$

N km	T°K	ρ kg·sec²/M⁴
-4	256	$1.785 \cdot 10^{-3}$
12	243	1.615
0	230	1.45
2	217	1.26
4	214	1.10
6	211	$9.23 \cdot 10^{-4}$
8	208	7.47
10	205	6.02
12	202	4.93
14	199	4.08
16	195	3.43
18	192	2.89
20	189	2.44
22	186	2.07
24	183	1.74
26	179	1.45
28	176	1.21
30	173	1.02
32	170	$8.50 \cdot 10^{-5}$
34	167	7.20
36	164	6.00
38	161	4.90
40	158	2.00
45	150	1.02
50	150	$1.02 \cdot 10^{-6}$
68.5	150	$1.02 \cdot 10^{-7}$
86.5	174	$2.48 \cdot 10^{-8}$
100	225	

Model 4

P_0 = 6.5 mb

100% CO_2 T_0 = 210°K

M = 44

	N kg	T°K	P mb	ρ kg·sec²/M⁴
1.	-6	228	11.4	$2.68\cdot10^{-3}$
2.	-4	222	9.17	$2.3\cdot10^{-3}$
3.	-2	216	7.73	$1.97\cdot10^{-3}$
4.	0	210	6.5	$1.68\cdot10^{-3}$
5.	2	204	5.36	1.43
6.	4	198	4.44	1.22
7.	6	192	3.64	1.03
8.	8	186	2.92.	$8.61\cdot10^{-4}$
9.	10	180	2.38	7.2
10.	12	174	1.91	5.97
11.	14	168	1.51	4.9
12.	16	162	1.20	4.01
13.	18	156	$9.32\cdot10^{-1}$	3.24
14.	20	150	7.2	2.61
15.	22			
16.	24			
17.	26			
18.	28			
19.	30	128	$1.6\cdot10^{-1}$	$6.81\cdot10^{-5}$
20.	32			
21.	34			
22.	36			
23.	38			
24.	40	119	$3.36\cdot10^{-2}$	$1.53\cdot10^{-5}$
25.	50	110	$6.32\cdot10^{-3}$	$3.12\cdot10^{-6}$
26.	60	122	1.3	$5.79\cdot10^{-7}$
27.	70	135	$2.74\cdot10^{-4}$	1.1
28.	80	135	$6.81\cdot10^{-5}$	$2.73\cdot10^{-8}$
29.	90	135	1.69	$6.79\cdot10^{-9}$
30.	100	135	$4.2\cdot10^{-6}$	1.68

Model 5

P_0 = 9 mb

T_0 = 256°K $\rho_0 = 1.8 \cdot 10^{-3}$ kg·sec²/M⁴

	N km	T°K	P mb	ρ kg·sec^2/M^4
1.	-7	291	14.7	$2.58 \cdot 10^{-3}$
2.	-6	286	13.8	2.46
3.	-3	271	11.25	2.12
4.	0	256	9.0	1.8
5.	1	251	8.46	1.72
6.	2	246	7.71	1.6
7.	3	241	7.17	1.52
8.	4	236	6.61	1.43
9.	5	231	6.06	1.34
10.	7	221	5.10	1.18
11.	10	205	3.91	$9.72 \cdot 10^{-4}$
12.	12	195	3.14	8.22
13.	14	185	2.54	7.0
14.	16	"	1.87	6.10
15.	18	"	1.58	5.15
16.	20	"	1.39	3.85
17.	22	"	1.19	2.96
18.	24	"	1.01	2.36
19.	26	"	$8.15 \cdot 10^{-1}$	1.94
20.	28	"	6.43	1.61
21.	30	"	4.90	1.35
22.	32	"	3.75	1.11
23.	34	"	2.75	$9.2 \cdot 10^{-5}$
24.	36	"	2.15	7.5
25.	38	"	1.80	6.10
26.	40	"	1.76	4.85
27.	50	"	$6.18 \cdot 10^{-2}$	1.70
28.	60	"	2.18	$6.02 \cdot 10^{-6}$
29.	70	"	$8.0 \cdot 10^{-3}$	2.2
30.	80	"	3.04	$8.32 \cdot 10^{-7}$
31.	90	"	1.13	3.1
32.	100	"	$4.2 \cdot 10^{-4}$	1.15

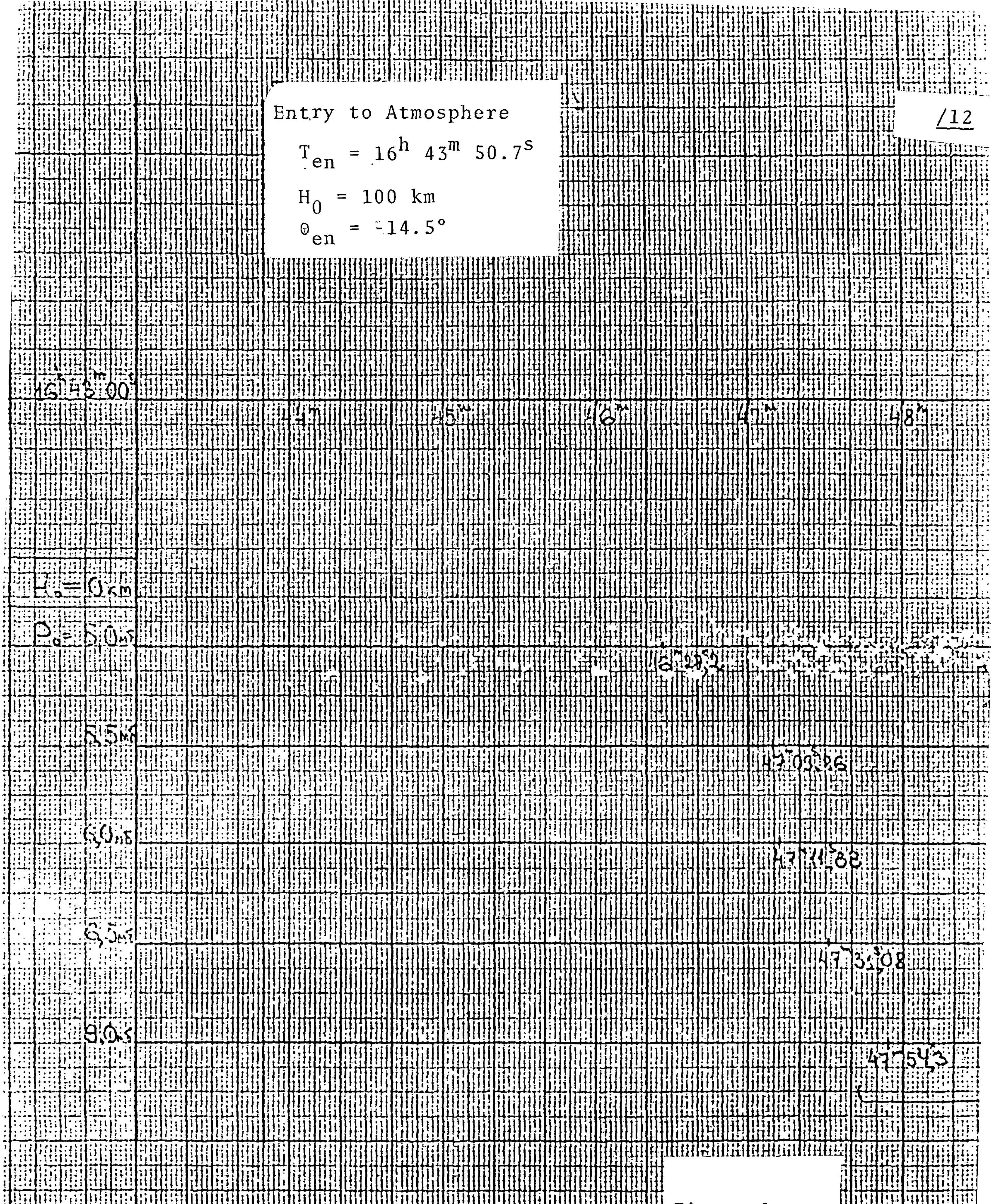
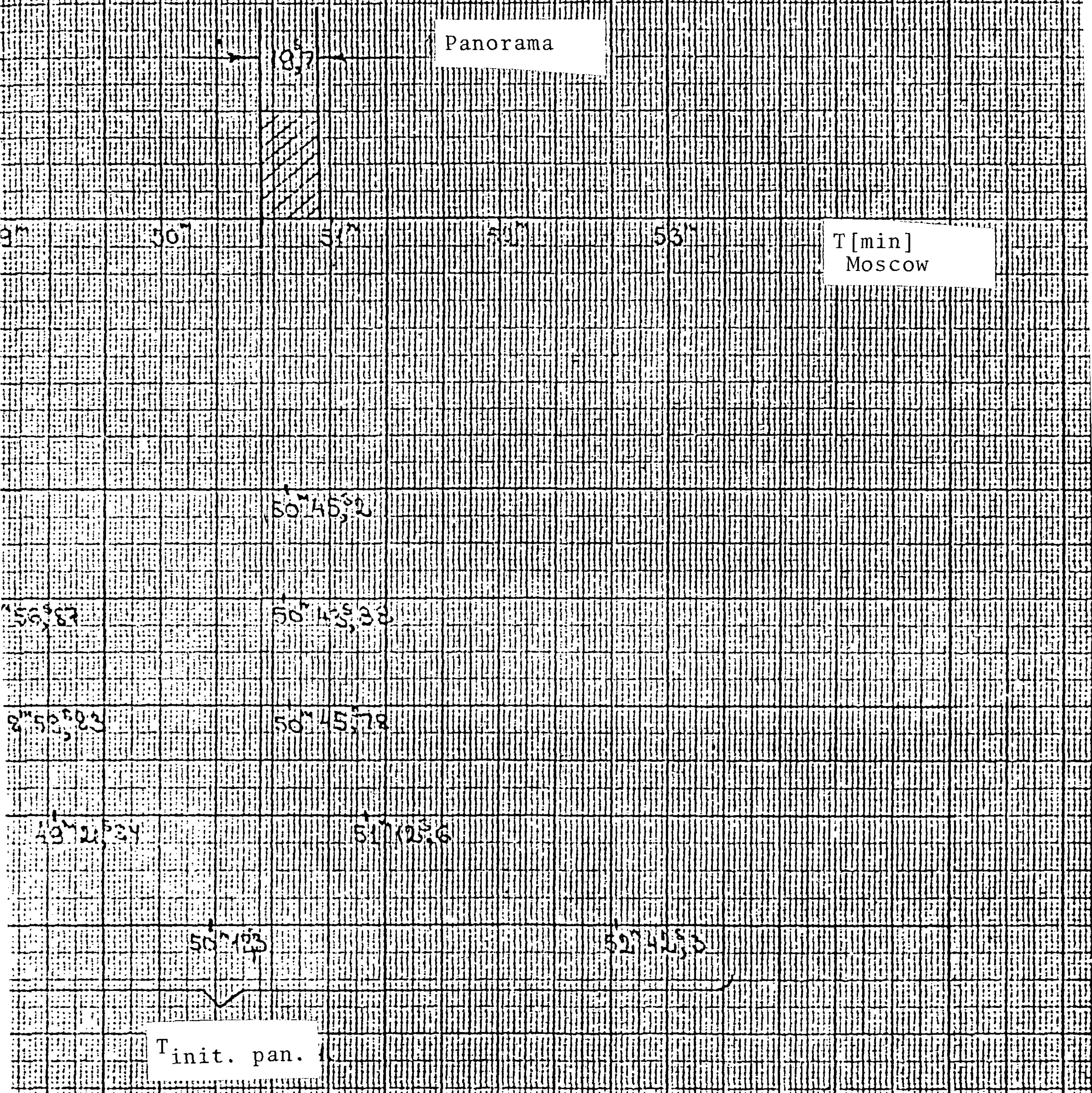
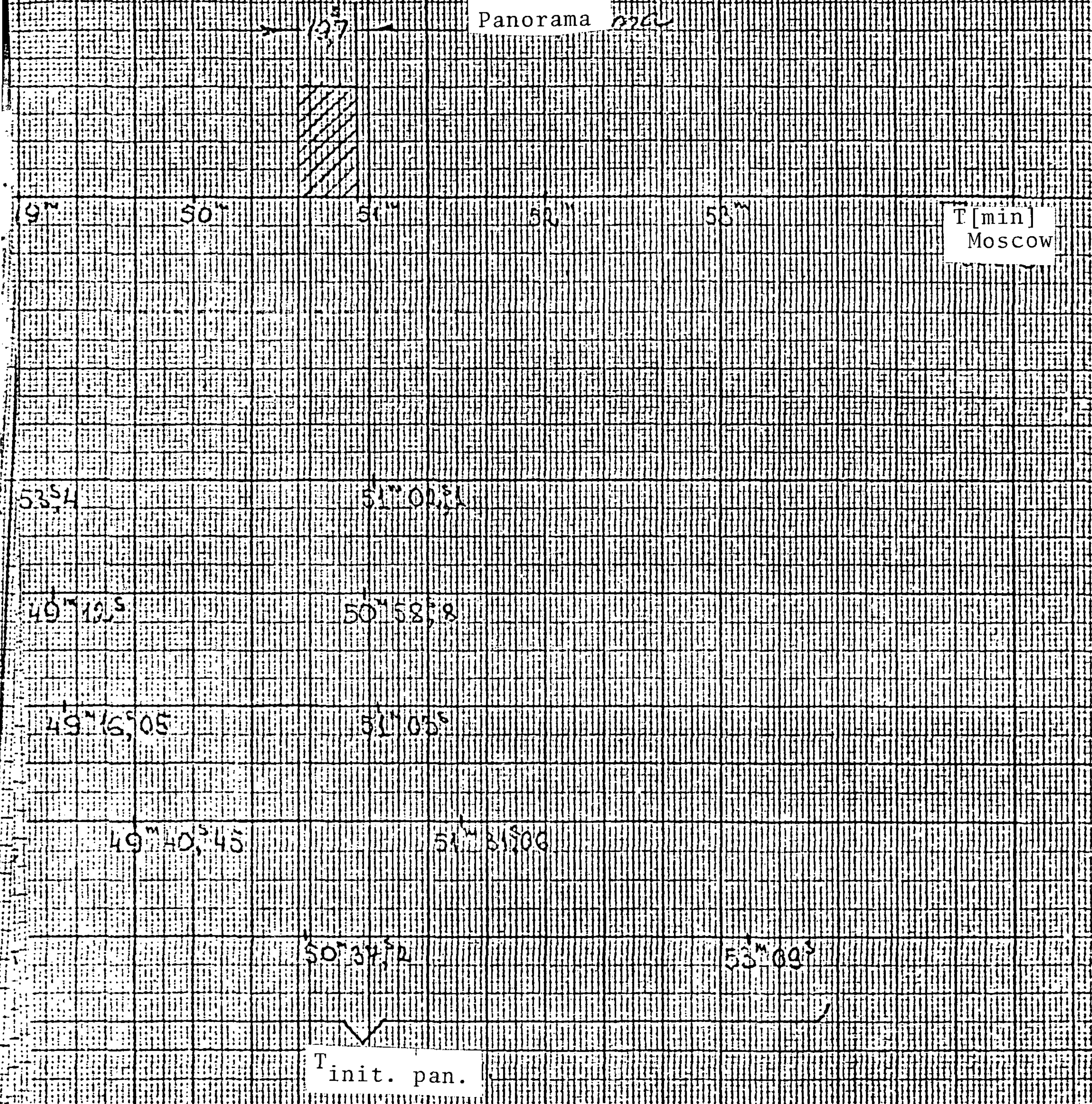

Entry to Atmosphere
$T_{en} = 16^h\ 43^m\ 50.7^s$
$H_0 = 100$ km
$\Theta_{en} = -14.5°$
44m
45m
46m
47m
48m

Figure 1

/13




Panorama
T[min]
Moscow
$T_{init. pan.}$

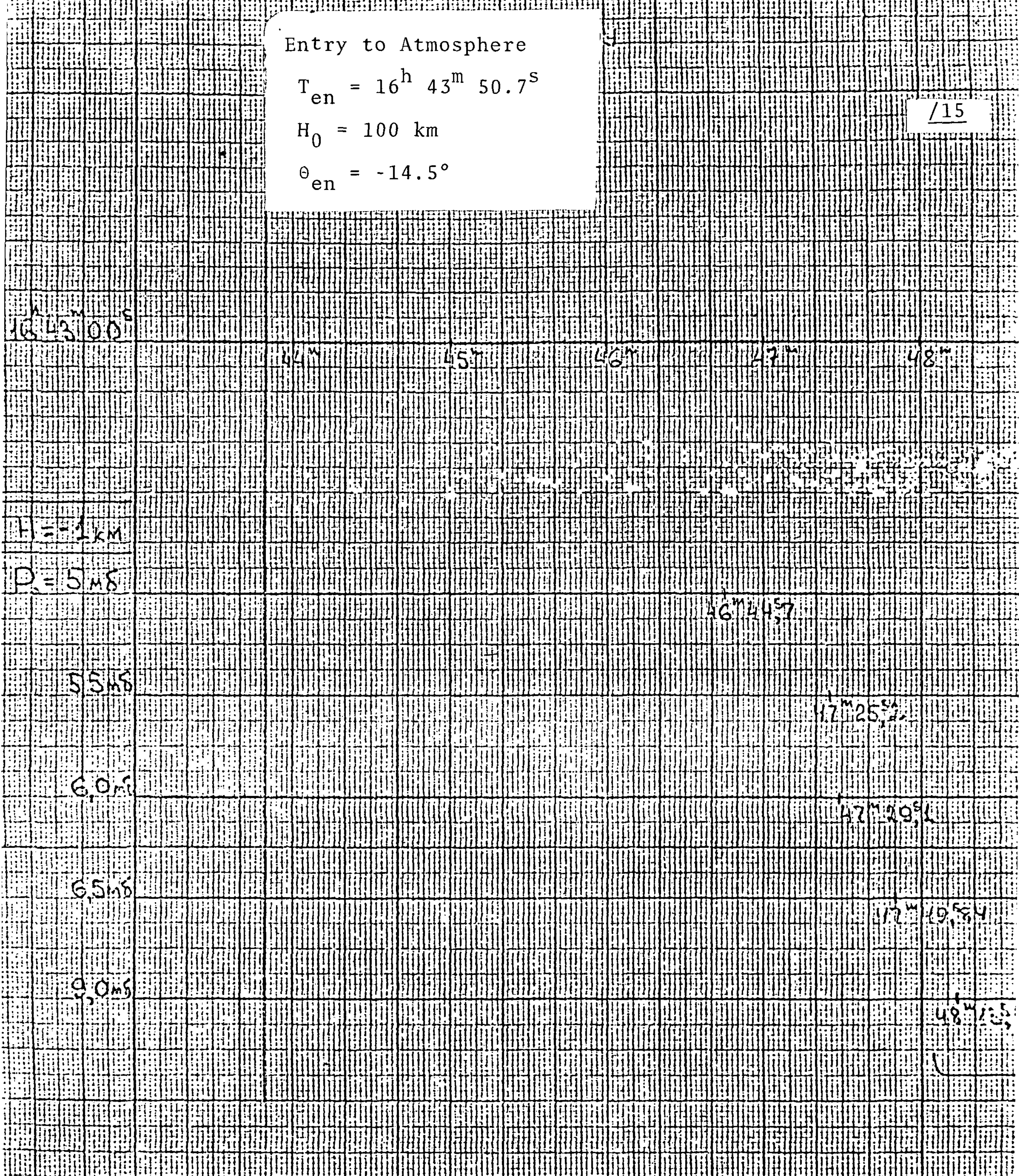

Entry to Atmosphere
T_en = 16^h 43^m 50.7^s
H_0 = 100 km
Θ_en = -14.5°
16^h 43^m 00^s
44^m
45^m
46^m
47^m
48^m
H = -1 км
D = 5 мб
5,5 мб
6,0 мб
6,5 мб
9,0 мб
46^m 44,7^s
47^m 29,4

Figure 2

2 December 1971

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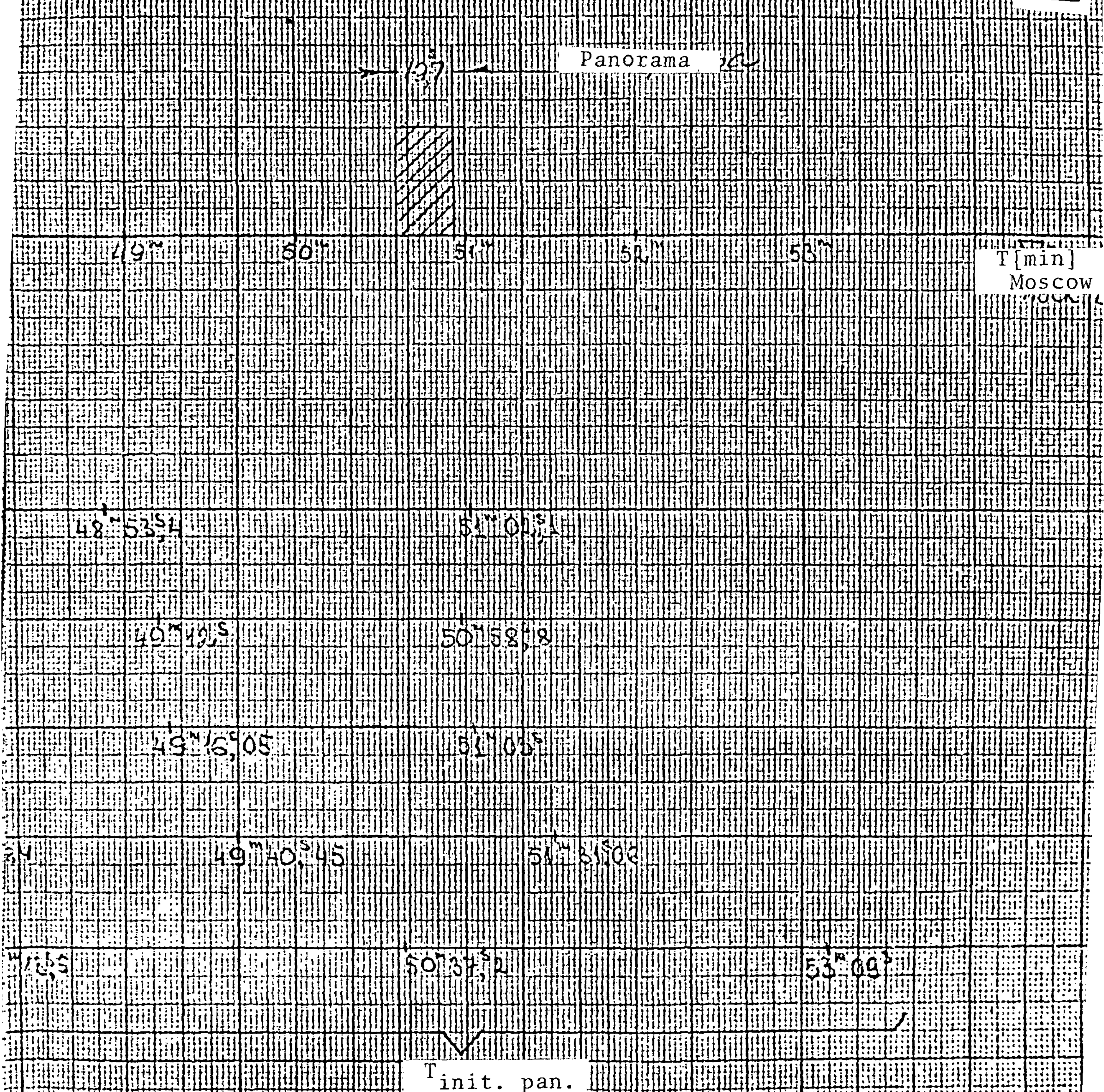

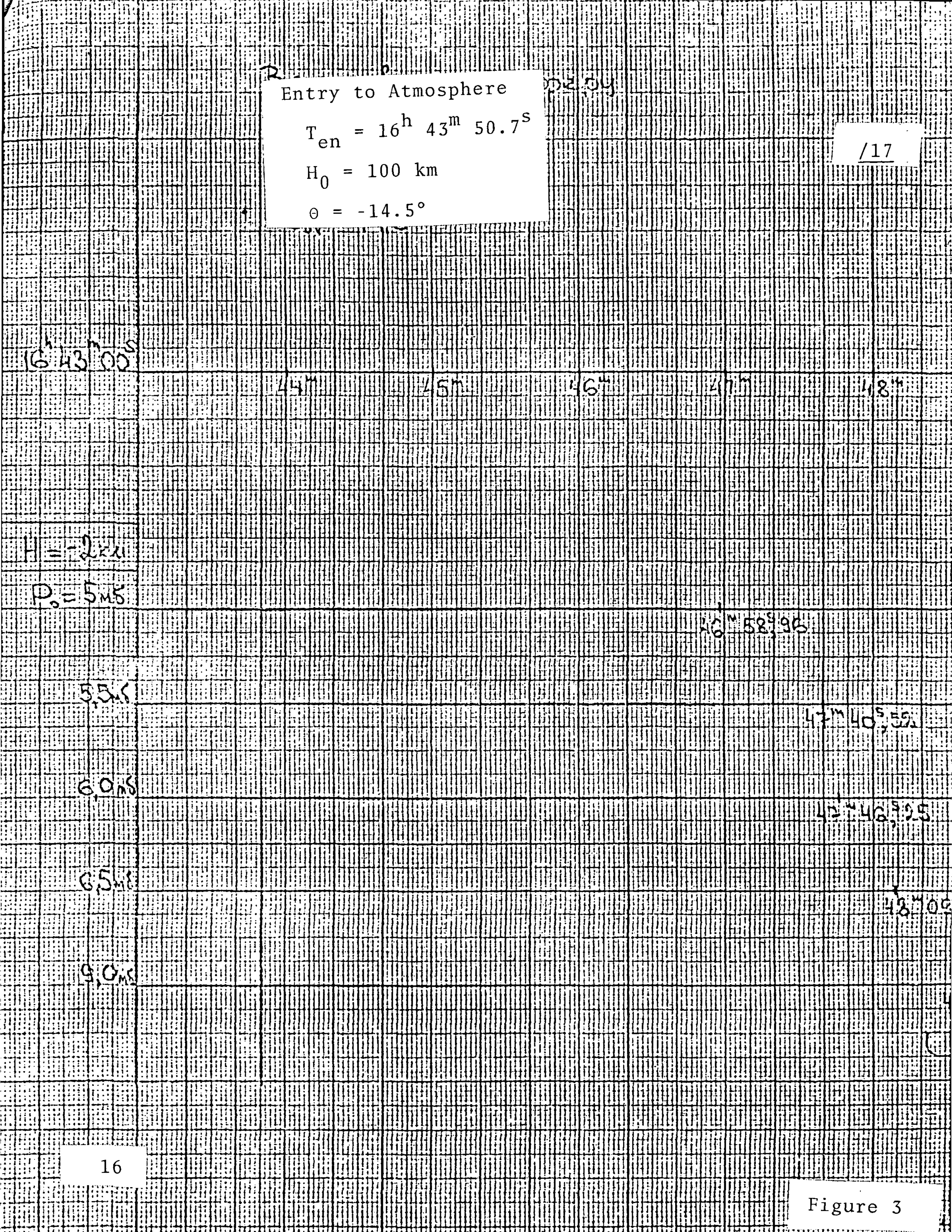
Entry to Atmosphere
T_{en} = 16h 43m 50.7s
H_0 = 100 km
Θ = -14.5°
16h 43m 00s
44m
45m
46m
47m
48m

Figure 3

2 December 1971

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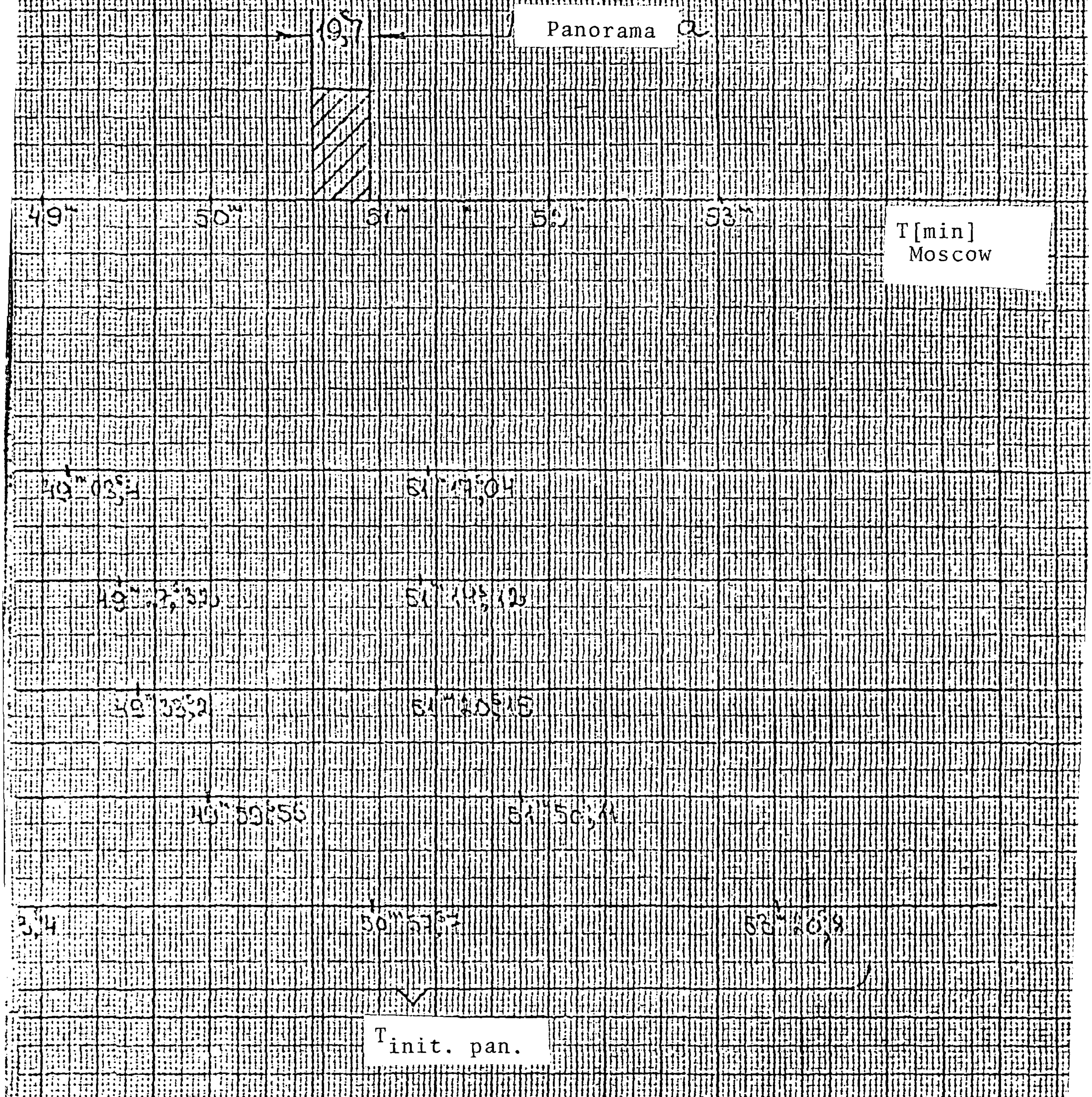


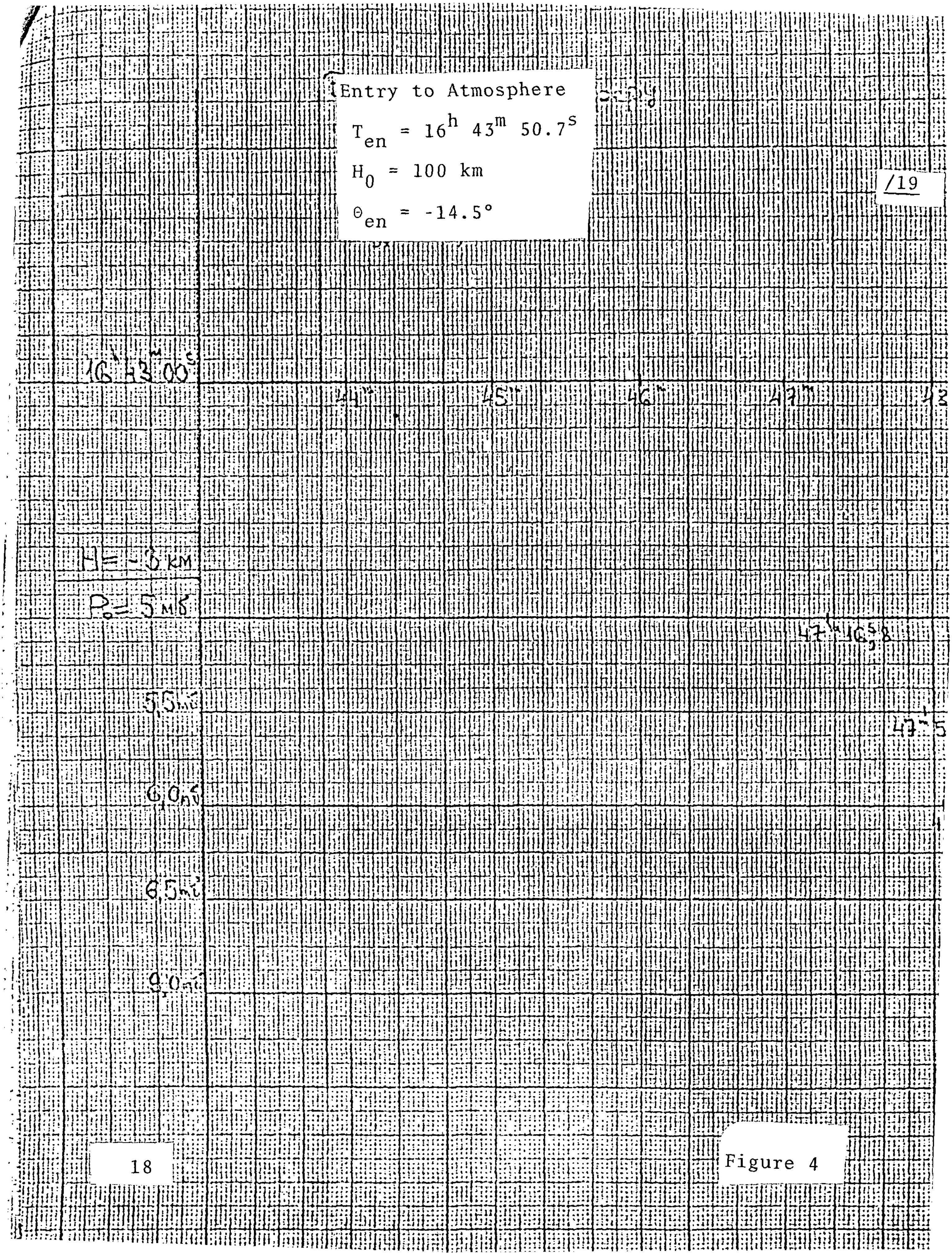
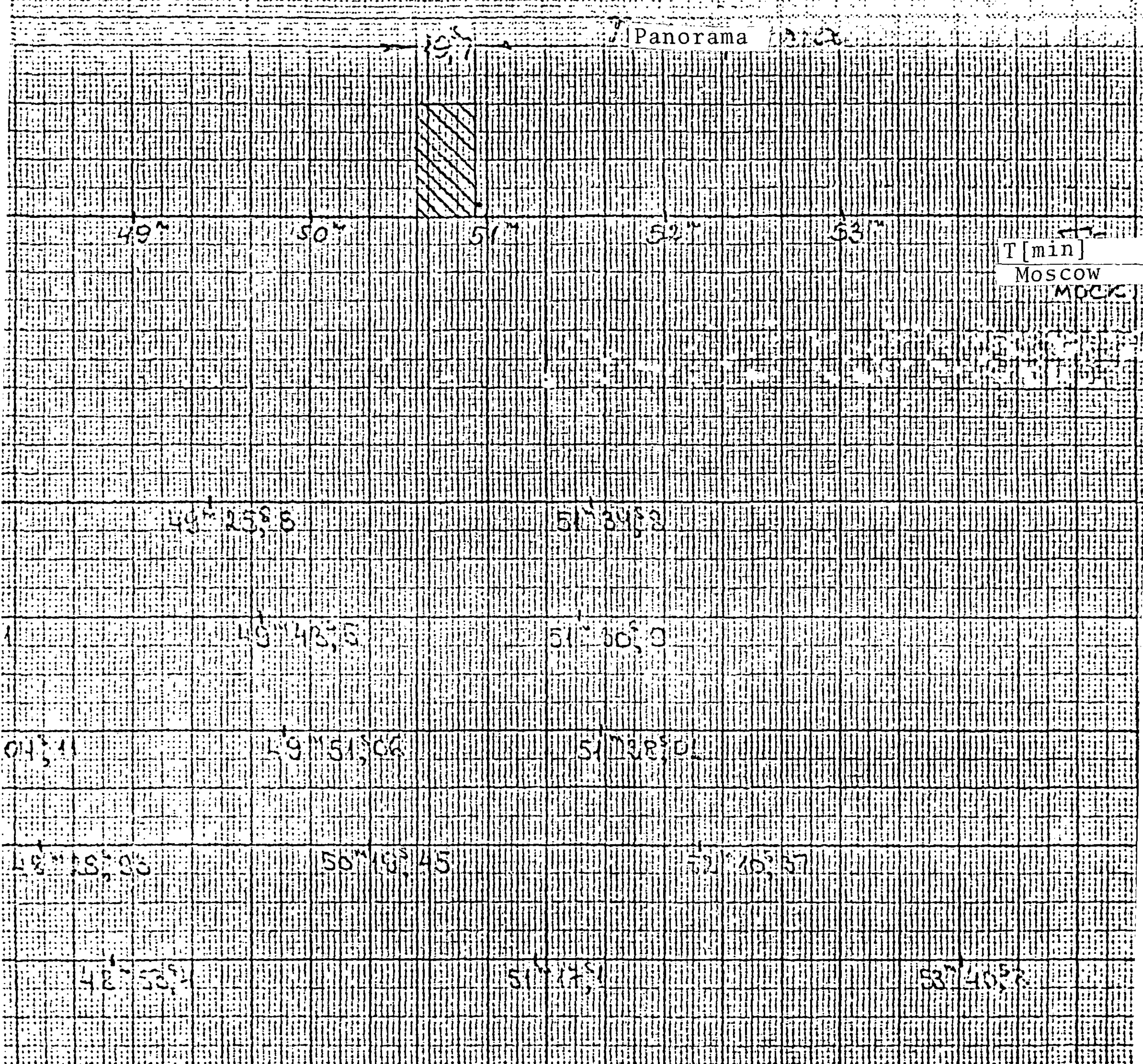

Entry to Atmosphere
T_{en} = 16^h 43^m 50.7^s
H_0 = 100 km
Θ_{en} = -14.5°
16h 43m 00s
44m
45m
46m
47m
P0 = 5 мб
47m 16,8s
5,5 мб
6,0 мб
6,5 мб

Figure 4

/20



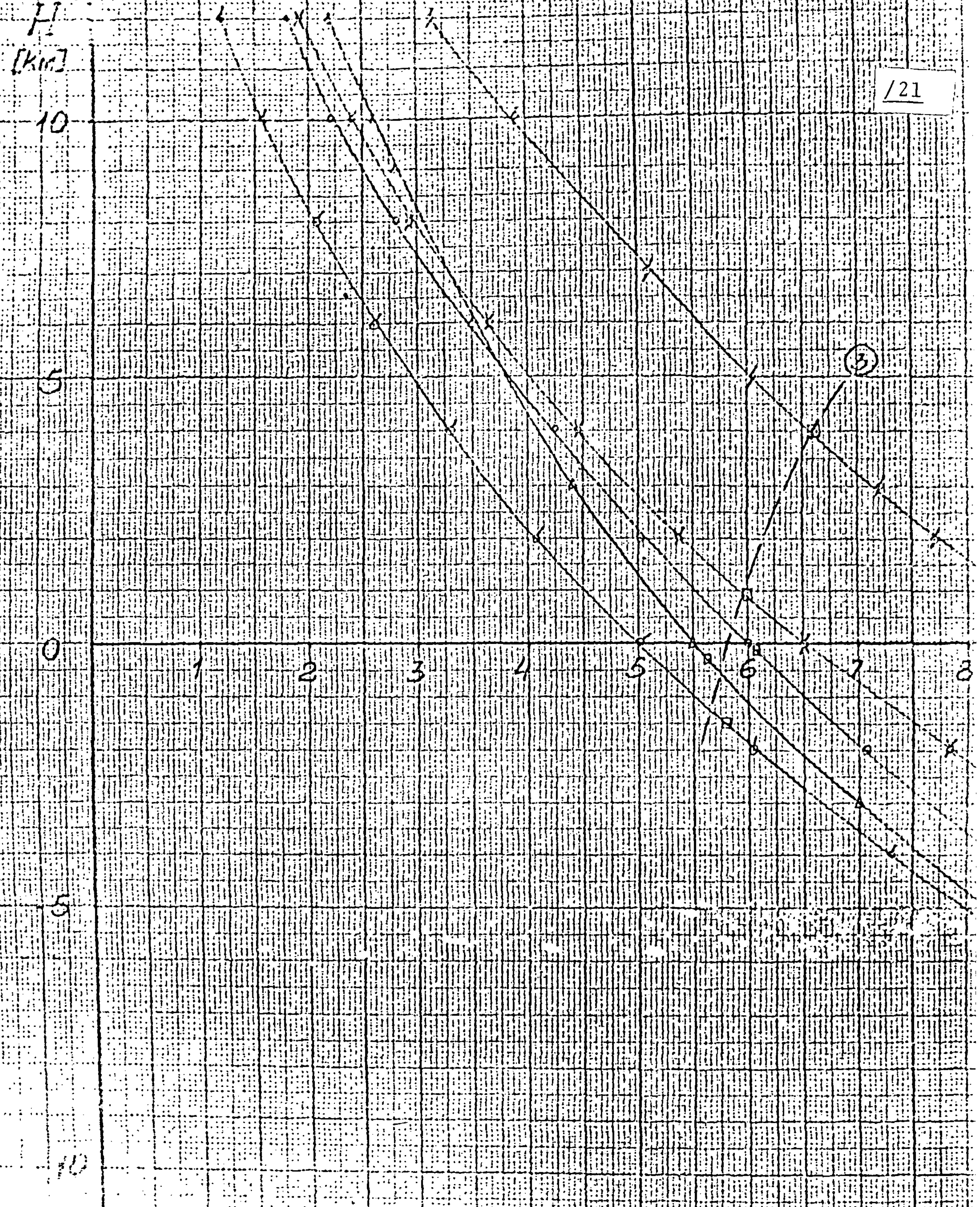
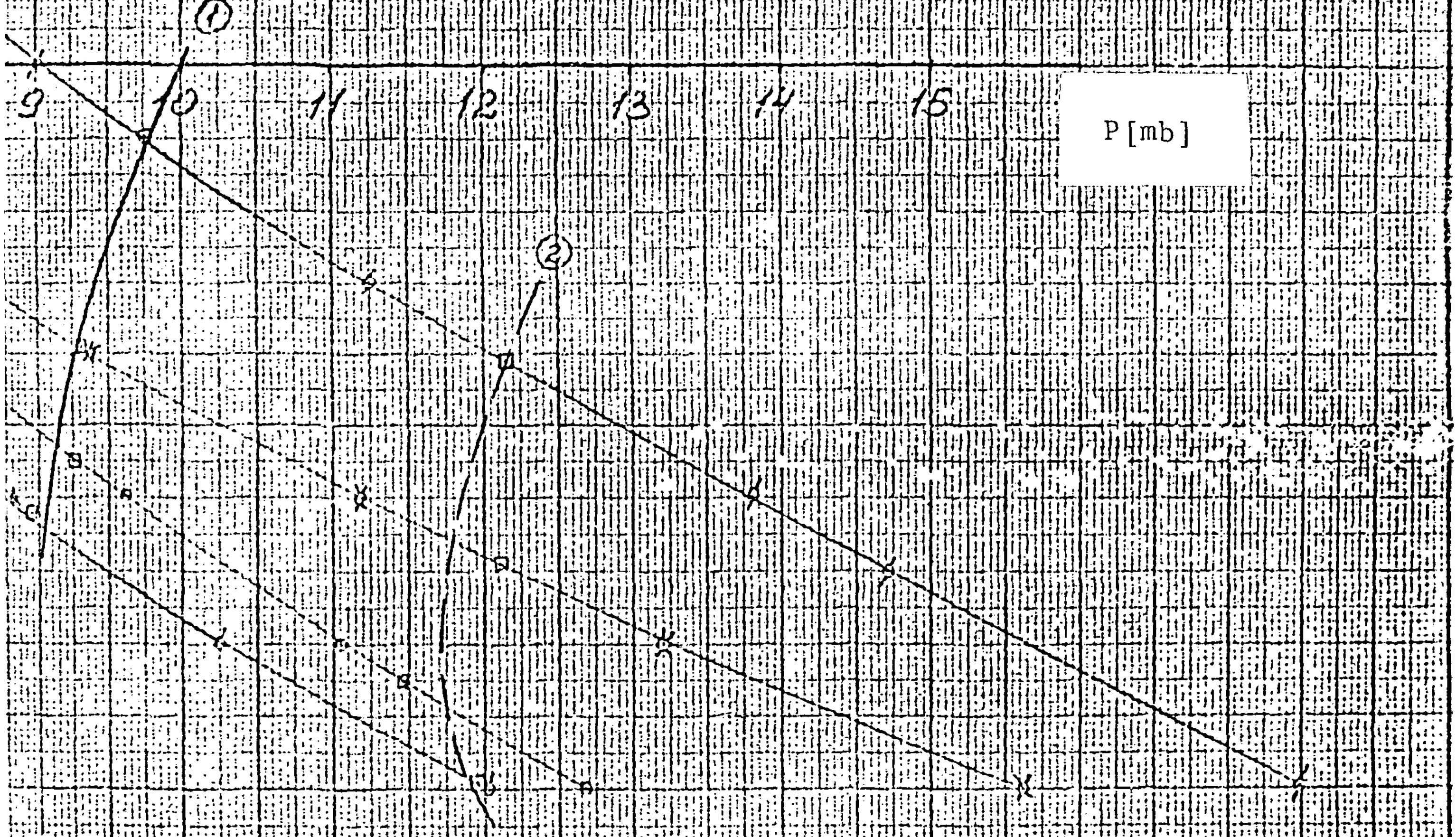


Figure 5.



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9
10
11
12
13
14
15
P[mb]
②