Reflecting balloons for radar evaluation

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REFLECTING BALLOONS FOR RADAR EVALUATION

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OTTAWA
APRIL 1965

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ABSTRACT

Field tests of balloons to be used in determining radar sensitivity and position-measuring accuracy are described. The merits of this type of radar evaluation are discussed.

REFLECTING BALLOONS FOR RADAR EVALUATION

- J. Akeroyd -

INTRODUCTION

In order to evaluate over-all performance of radars, a target of known reflecting area is desirable. Aircraft are used for this, but they have several disadvantages: the aspect is not constant with position changes, aircraft are not always available when needed, and the cost is high. Balloons present a constant aspect to the radar, they can be released at any time,and the cost is low. Since balloons are slow-moving, there is time to make radar adjustments and check relative position readings between adjacent radars. Balloons can be tracked optically for a short distance (approximately 25 miles) which makes them specially useful in checking tracking radars. The main disadvantage of balloons is that their heading and altitude cannot be varied. This should not be too big a disadvantage except where there are exceptional local propagation problems.

Level flight is necessary as it indicates the balloon is maintaining its size, and therefore it sphericity. Also, level predictable height is needed to check radar antenna coverage, particularly if no height finder is available.

Since a balloon is fully inflated only at its ceiling altitude [1], the purpose of the tests was mainly to determine the length of time of level flight. Ten hours was chosen as a design goal.

Balloon altitude is determined by the weight and size of the balloon [1]. A 4-foot-diameter 1-mil Mylar spherical balloon floats at about 40,000 feet. In order to obtain a higher altitude, a large non-reflecting balloon must be used to lift the 4-foot reflecting balloon. The use of a large reflecting balloon is not advised, as this would give too large a radar reflection. If too large a reflector is used it is lost owing to sweep length limit rather than before the signal fades.

BALLOON TYPES TESTED

Some rubber balloons with conducting Mylar mesh covers were tested. Owing to inconsistent results, tests were discontinued when Mylar balloons became available.

The Mylar reflecting balloons were 4 feet in diameter, 1 mil thick, and aluminized, giving an echoing area of 1.1 square meters [1]. They were supplied by two manufacturers. Some had pressure-relief valves supplied and installed by the manufacturer. Others were supplied with a neck into which we installed valves of NRC design.

The lifting balloons for high altitudes were 25-foot-diameter spheres supplied with pressure-relief valves and 42-foot-altitude tetrahedrons supplied with a neck into which we installed NRC-designed pressure-relief valves. All these balloons were made of 1-mil clear Mylar.

TESTS

The first field trials of Mylar balloons were held in October 1963; only 4-foot balloons were tested. The second and third trials were carried out in May and November, 1964. In these trials, 4-foot balloons and assemblies of 4-foot and 25-foot-diameter spheres or 42-foot-altitude tetrahedrons were tested.

The balloons were tracked continuously by search radars, and heights were measured at approximately 5-minute intervals. Tracking was maintained until the balloons faded from the radar owing either to balloon failure or to the balloon leaving the radar coverage.

RESULTS

Detailed results of rubber balloon tests are not given as balloon life was short, approximately four hours. The rubber deteriorated quickly at altitude owing to ultraviolet light. Attempts were made to have balloons resistant to ultraviolet light manufactured, but without success. The NRC pressure-relief valve was developed during testing of rubber balloons.

Tables I to III give details of all balloon configurations tried and a brief summary of results. The detailed results of flights are shown in Figs. 1 to 44; these are plots of altitude against elapsed time after launch with mileage shown at the last plot.

In Tables I to III the column headings are:

- Balloon number
- Reflecting balloon manufacturer (A or B) and size
- Reflecting balloon pressure-relief valve, NRC or manufacturer B, and pressure setting (inches of water)
- Lifting balloon manufacturer and size
- Lifting balloon pressure-relief valve, NRC or manufacturer B, and pressure setting (inches of water)

Track length in hours and minutes

Track length in nautical miles

Loss of track owing to radar fade or balloon failure

Height at loss,in feet (the last height measured before radar fade)

Predicted height,in feet

Measured height of level flight, in feet

During the trials in October 1963 (Table I) sixteen 4-foot-diameter balloons were released. Various valve pressure settings were used to try to determine the superpressure necessary to allow for evening cooling. There was no definite indication in the results that the pressure was critical. However, the only balloon that lost altitude before radar fade did have low pressure (no. 15, pressure 6.1"). It was, therefore, decided to use approximately 18" pressure for the remaining tests. This pressure gives a good safety factor below the bursting pressure and is adequate to allow for night cooling.

Of these 16 balloon launches, all were successful but no. 12 which was not tracked. It is likely that this balloon burst shortly after launch, as it was released during a heavy rain shower. Balloons 8 - 11 have height readings well above those predicted; this was caused by height finder trouble. Balloon 16 was not tracked satisfactorily owing to radar breakdown.

Balloon 13 was returned from a point 300 miles from the release point. The person finding the balloon reported that it was still partly inflated. Tests after the balloon was returned showed slow leaks at the seams. In spite of these leaks, the balloon maintained level flight for 208 miles or 3 hours 8 minutes after launch.

During the trials in May and November, 1964, twelve 4-foot-diameter balloons were launched (Table II). All these gave good results, except balloons nos. 22 and 23 which seem to have had slow leaks, possibly at the valve. Some irregularities in height readings appear, most noticeably in the curves for balloons nos. 19, 24, 26 and 29. These are due to discrepancies in height measurement, as the height was measured from a number of radars.

During the May and November 1964 trials, 17 high-altitude balloons were launched (Table III). None of these seemed to attain level flight at the predicted altitude, nor acted as predicted.

It is possible that balloons 30, 33 and 35 did attain level flight but were not tracked by radar. These may have gone above the radar cover, been lost, and not tracked on descent. No reasonable explanation for the inconsistent results with large balloons has been found although some laboratory tests were made [1].

During all the tests, unusual weather was experienced. This accounts for the wide variation in balloon speeds. The winds were often stronger than usual and varied widely with altitude. During the early May tests (balloons 1, 2 and 13) there was a record heat wave with unusual winds and temperature inversion; near the end of May there was a record cold wave with strong winds, rain, freezing rain, and snow.

CONCLUSIONS

The results indicate that reflecting balloons are useful for evaluating radar performance. Ten hours of level flight was chosen as a design goal, but this was not attained. Experience in these tests indicates that so high a figure was not necessary since the balloons would be carried beyond the coverage of most radars in less than ten hours.

Small balloons (3 - 4 feet) could be used to evaluate radar performance, even at sites where no height finder is available. Good results should be obtained, as most balloons of this size float close to the predicted altitude. The procedure is to predict the height of level flight, and then use the radar coverage diagram to predict the maximum range to which the balloon should be tracked. If a large discrepancy in tracking range is found, it could be caused by balloon trouble, and another balloon should be launched. Balloon failure rate is so low that a second release should not often be required.

If a height finder is available, a check of balloon altitude should be maintained and the predicted range altered to suit the actual altitude.

The high-altitude balloons are not suitable for general use in radar evaluation. They could be useful where height finders are available to check the vertical coverage of search radars. These balloons will rise to a high altitude and descend again within the range of the radar. By knowing the range and height, the upper part of the radar beam could be checked. Maximum altitude of the balloon can be preselected by choosing a suitable size of lifting balloon.

The tetrahedron-shaped balloon is not recommended as it is difficult to launch. The 25-foot spheres can be launched with surface winds up to 25 miles per hour, but the tetrahedrons are difficult to launch in any wind. The tetrahedrons were tried because they are slightly lower in cost than spheres.

Although rubber balloons have a short life they may be of some use. The only advantage over plastic balloons is lower cost: a rubber balloon with conducting Mylar mesh cover can be launched for about $25; a Mylar balloon can be launched for about $80. Rubber balloons tested weighed either 200 grams or 350 grams, the heavier one having longer life because of extra thickness. The 200-gram balloon reached an altitude of about 35,000 feet, the 350-gram balloon about 28,000 feet. Since rubber balloons are affected by sunlight, they could best be used after dark. They could also be used in daylight if there were upper winds of over 30 miles per hour, or if a short-range radar were being tested, in which case the balloon would be out of range before it deteriorated and came down.

ACKNOWLEDGMENTS

The author wishes to express his appreciation for the advice and assistance of Mr. S.H.G. Connock of the Division of Mechanical Engineering and Mr. A. Hendry of the Radio and Electrical Engineering Division, and to Mr. L.J.E. McEwan of the Radio and Electrical Engineering Division for assistance in the field trials.

REFERENCE

1. A. Hendry and J. Akeroyd, "Free Floating Metallized Plastic Balloons for Use as Radar Targets", NRC Report ERB-703, April 1965

TABLE I — SUMMARY OF RESULTS, 4-FOOT BALLOONS, OCTOBER 9-11, 1963

BALLOON NUMBER	REFLECTING BALLOON	VALVE AND PRESSURE (IN. WATER)	LIFTING BALLOON	VALVE AND PRESSURE (IN. WATER)	TRACK LENGTH		LOSS		HEIGHT AT LOSS	PREDICTED HEIGHT	MEASURED HEIGHT
					HRS. MIN.	MILES	RADAR FADE	BALL. DOWN			
1	A 4'	NRC 19"			2:44	114	x		38,600	38,500	39,000
2	A 4'	NRC 19"			3:13	132	x		39,500	39,000	39,500
3	A 4'	NRC 14"			3:50	160	x		39,000	38,500	39,500
4	A 4'	NRC 19"			3:28	129	x		41,000	38,500	41,000
5	A 4'	NRC 8"			3:09	120	x		43,500	44,400	44,000
6	A 4'	NRC 8"			2:48	110	x		39,700	37,500	39,700
7	A 4'	NRC 19"			3:14	129	x		39,700	39,000	40,500
8	A 4'	NRC 14"			5:21	215	x		42,000	38,000	41,000
9	A 4'	NRC 5"			3:48	208	x		45,000	37,500	45,000
10	A 4'	NRC 19"			3:03	162	x		44,900	37,500	44,900
11	A 4'	NRC 14"			3:56	176	x		41,000	37,400	43,800
12	A 4'	NRC 19"			NOT TRACKED						
13	A 4'	NRC 5.4"			3:08	208	x		40,200	37,600	40,200
14	A 4'	NRC 14"			4:33	290	x		37,500	37,700	40,000
15	A 4'	NRC 6.1"			5:00	266	x		23,500	38,000	40,000
16	A 4'	NRC 14"			1:25	104	x		39,000	37,600	39,000

TABLE II — SUMMARY OF RESULTS, LOW ALTITUDE, MAY 1964, NOVEMBER 1964

BALLOON NUMBER	REFLECTING BALLOON	VALVE AND PRESSURE (IN. WATER)	LIFTING BALLOON	VALVE AND PRESSURE (IN. WATER)	TRACK LENGTH		LOSS		HEIGHT AT LOSS	PREDICTED HEIGHT	MEASURED HEIGHT
					HRS. MIN.	MILES	RADAR FADE	BALL. DOWN			
17	B 4'	B 18"			4:40	250	x		39,500		39,500
18	B 4'	B 18"			4:25	220	x		39,500		39,500
19	A 4'	NRC 16"			8:00	720	x		20,000		40,000
20	B 4'	B 18"			7:00	250	x		39,000		39,000
21	B 4'	B 18"			6:30	500		x	8,000		40,000
22	A 4'	NRC 16"			7:25	540	x		24,000		40,000
23	A 4'	NRC 16"			4:25	365	x		19,000		40,000
24	A 4'	NRC 16"			4:30	295	x		30,000		40,000
25	A 4'	NRC 17"			5:50	730	x		40,000		40,000
26	A 4'	NRC 16"			3:40	320	x				
27	B 4'	NRC 16"			5:15	380	x		38,000		39,000
28	A 4'	NRC 16"			5:20	445	x		39,500		39,500

TABLE III — SUMMARY OF RESULTS, HIGH ALTITUDE, MAY 1964, NOVEMBER 1964

BALLOON NUMBER	REFLECTING BALLOON	VALVE AND PRESSURE (IN WATER)	LIFTING BALLOON	VALVE AND PRESSURE (IN WATER)	TRACK LENGTH		LOSS		HEIGHT AT LOSS	PREDICTED HEIGHT	MEASURED HEIGHT
					HRS. MIN.	MILES	RADAR FADE	BALL. DOWN			
29	A 4'	NRC 16"	A 42' TET.	NRC 2.5"	3:15	240	x		55,000	90,000	55,000
30	B 4'	NRC 16"	B 25'	B 2.25"	3:00	85	x		80,000	85,500	80,000
31	B 4'	NRC 16"	A 42' TET.	NRC 2.5"	1:21	60	x		45,000	90,000	80,000
32	A 4'	NRC 16"	B 25'	B 2.0"	1:21	80	x		20,000	85,500	20,000
33	A 4'	NRC 16"	A 42' TET.	NRC 3.2"	0:48	80	x		79,000 CLIMBING	90,000	79,000 CLIMBING
34	A 4'	NRC 16"	B 25'	B 2.25"	2:18	100	x		20,000	85,500	65,500
35	B 4'	B 18"	B 25'	B 2.25"	4:09	222	x		82,000	85,500	82,000
36	A 4'	NRC 16"	A 42' TET.	NRC 3.0"	2:18	70		x	10,000	90,000	88,000
37	B 4'	B 18"	B 25'	B 2.25"	3:15	95	x		46,000	85,500	46,000
38	B 4'	NRC 16"	B 25'	B 2.25"	4:30	195	x		18,500	85,500	80,000
39	A 4'	NRC 16"	A 42' TET.	NRC 2.5"	3:20	160	x		30,000	90,000	70,000
40	B 4'	NRC 16"	B 25'	B 2.25"	4:00	180		x	14,000	85,500	55,000
41	B 4'	B 18"	A 42' TET.	NRC 2.5"	4:00	165	x		59,500	90,000	76,000
42	B 4'	NRC 16"	A 42' TET.	NRC 2.6"	1:05	95	x		33,000	90,000	33,000
43	B 4'	NRC 16"	A 25'	B 2.25"	3:20	155	x		12,000	85,500	80,000
44	B 4'	NRC 16"	A 42' TET.	NRC 2.4"	7:20	340	x		18,500	90,000	80,500
45	B 4'	B 18"	B 25'	B 2.25"	3:30	220	x		39,500	85,500	39,500

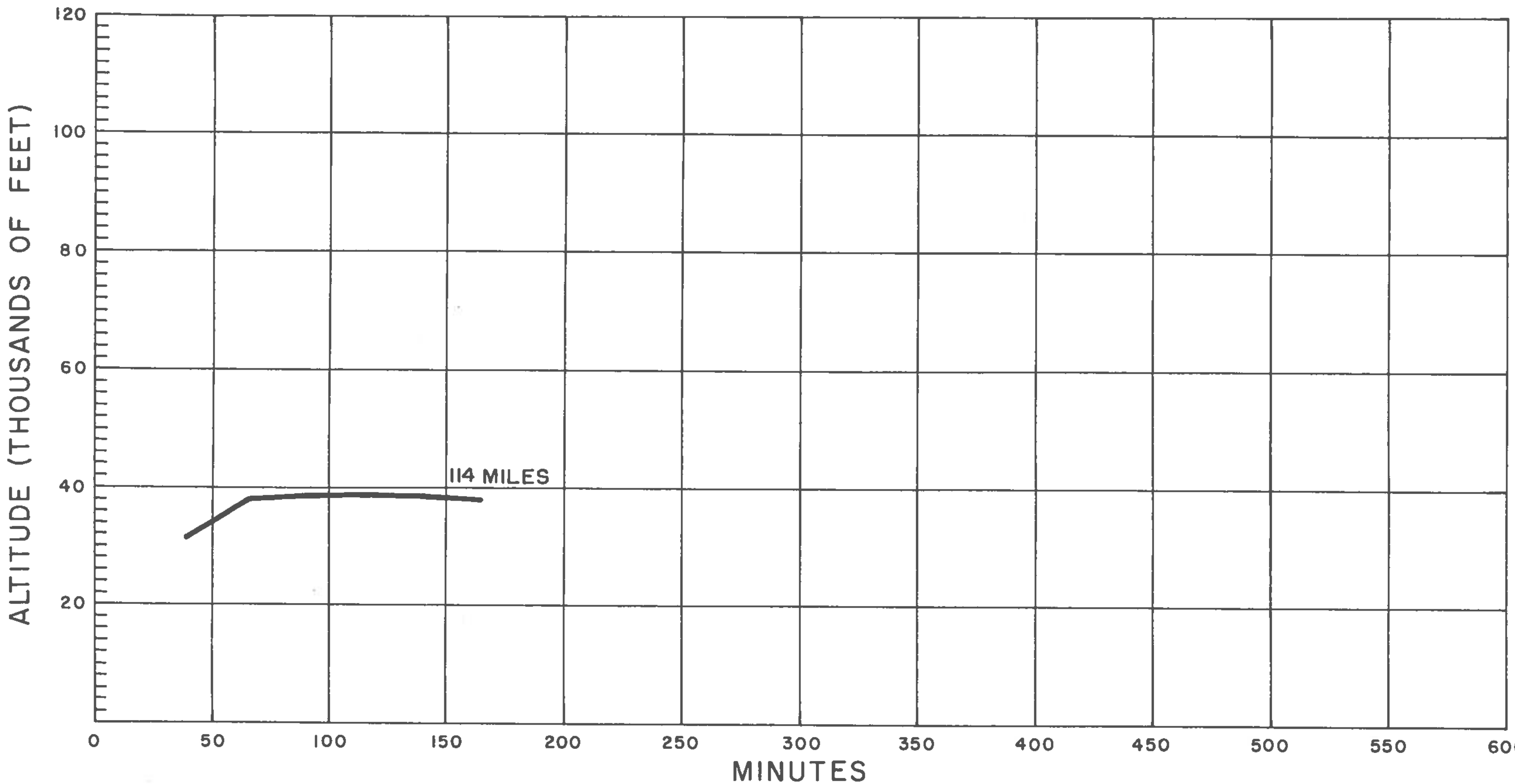


FIG. 1, BALLOON No. 1

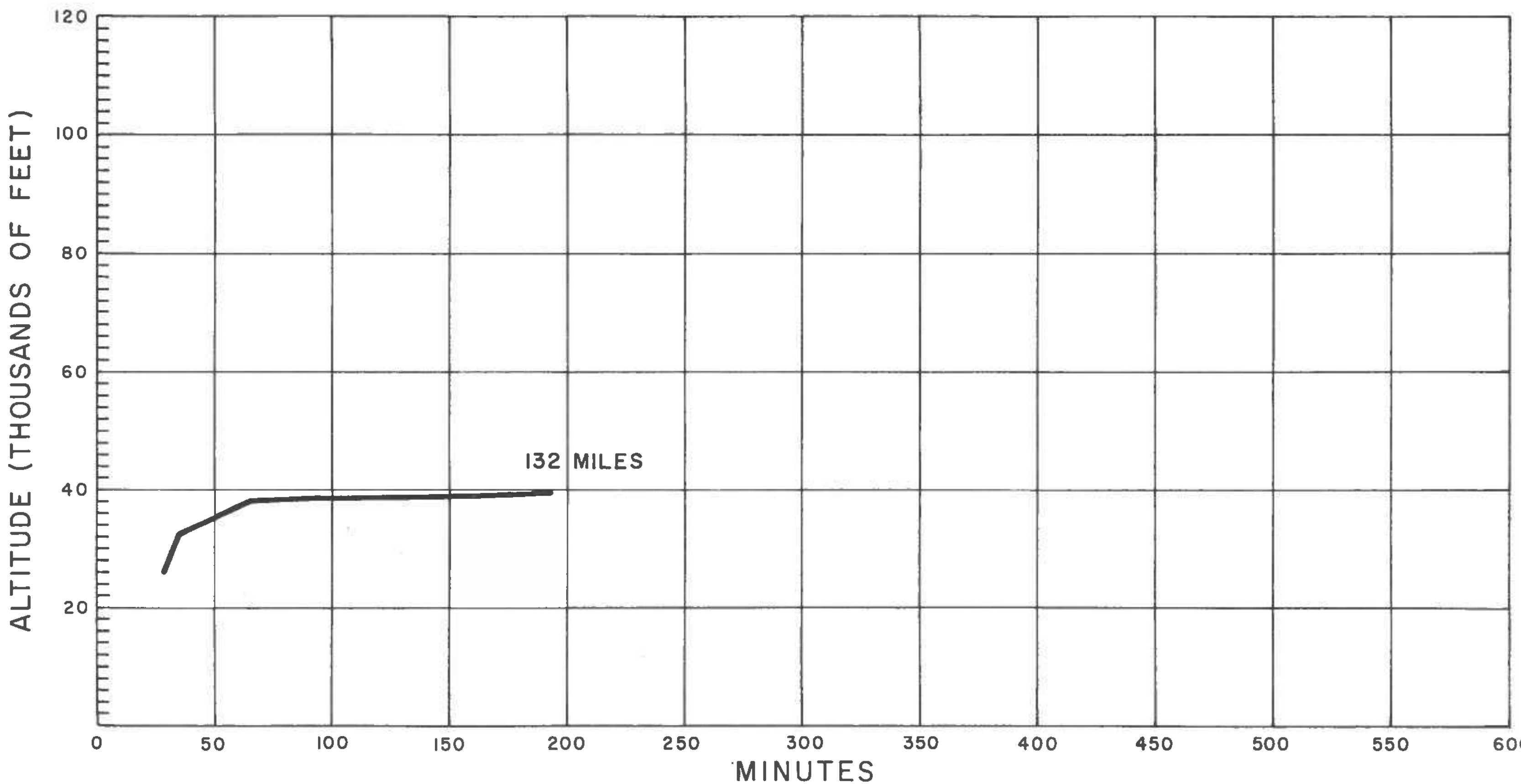
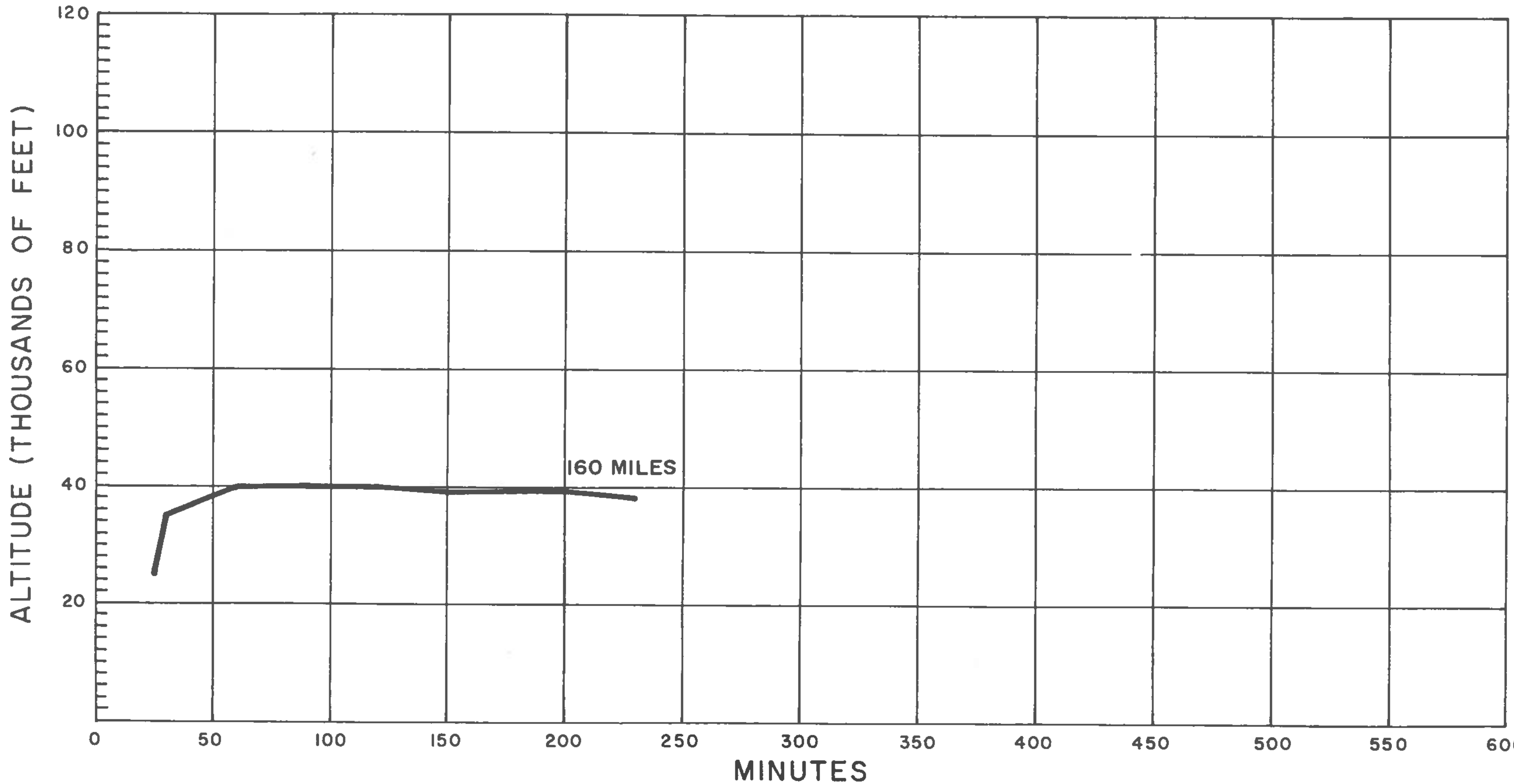


FIG. 2, BALLOON No. 2



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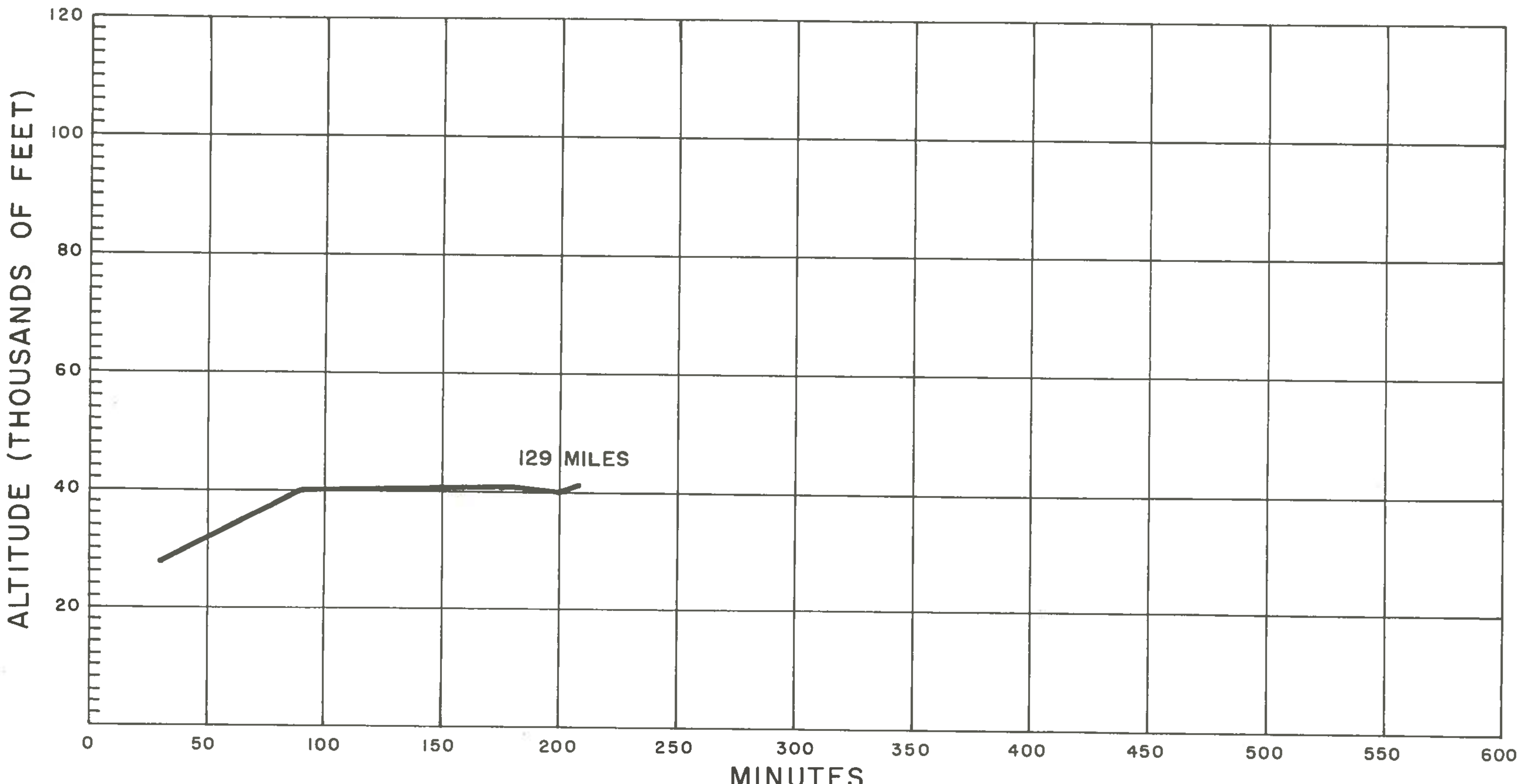
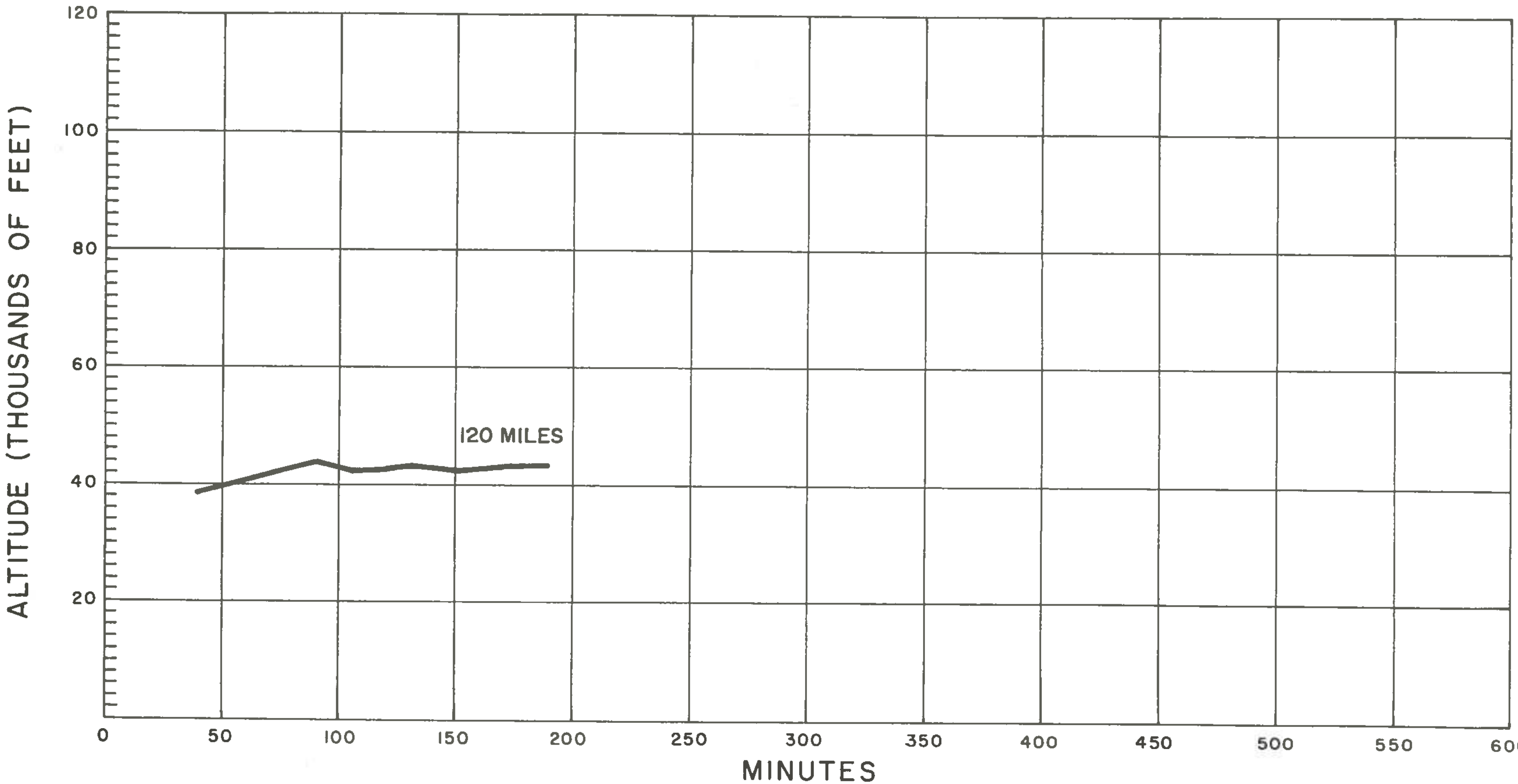


FIG. 4, BALLOON No. 4



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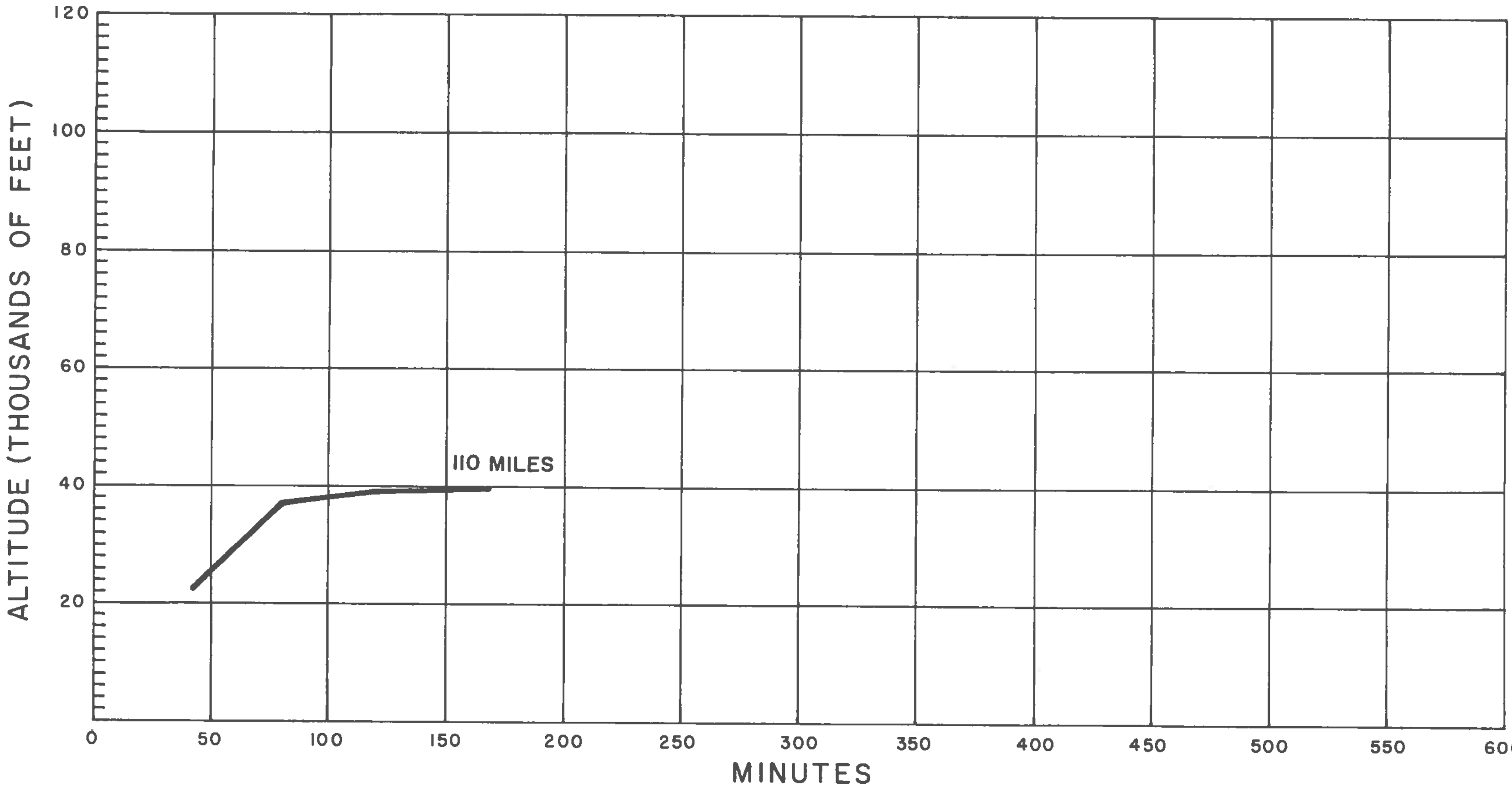

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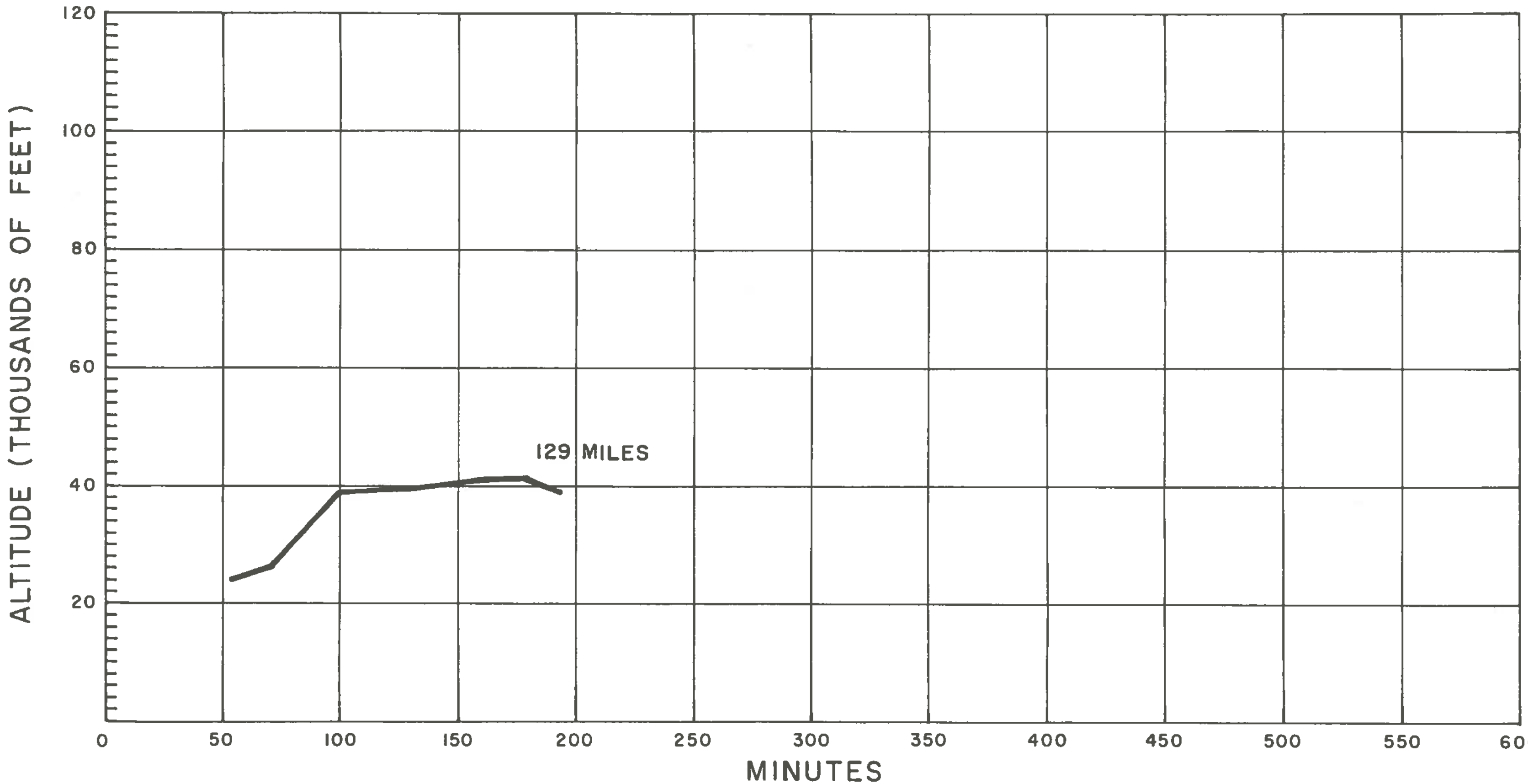

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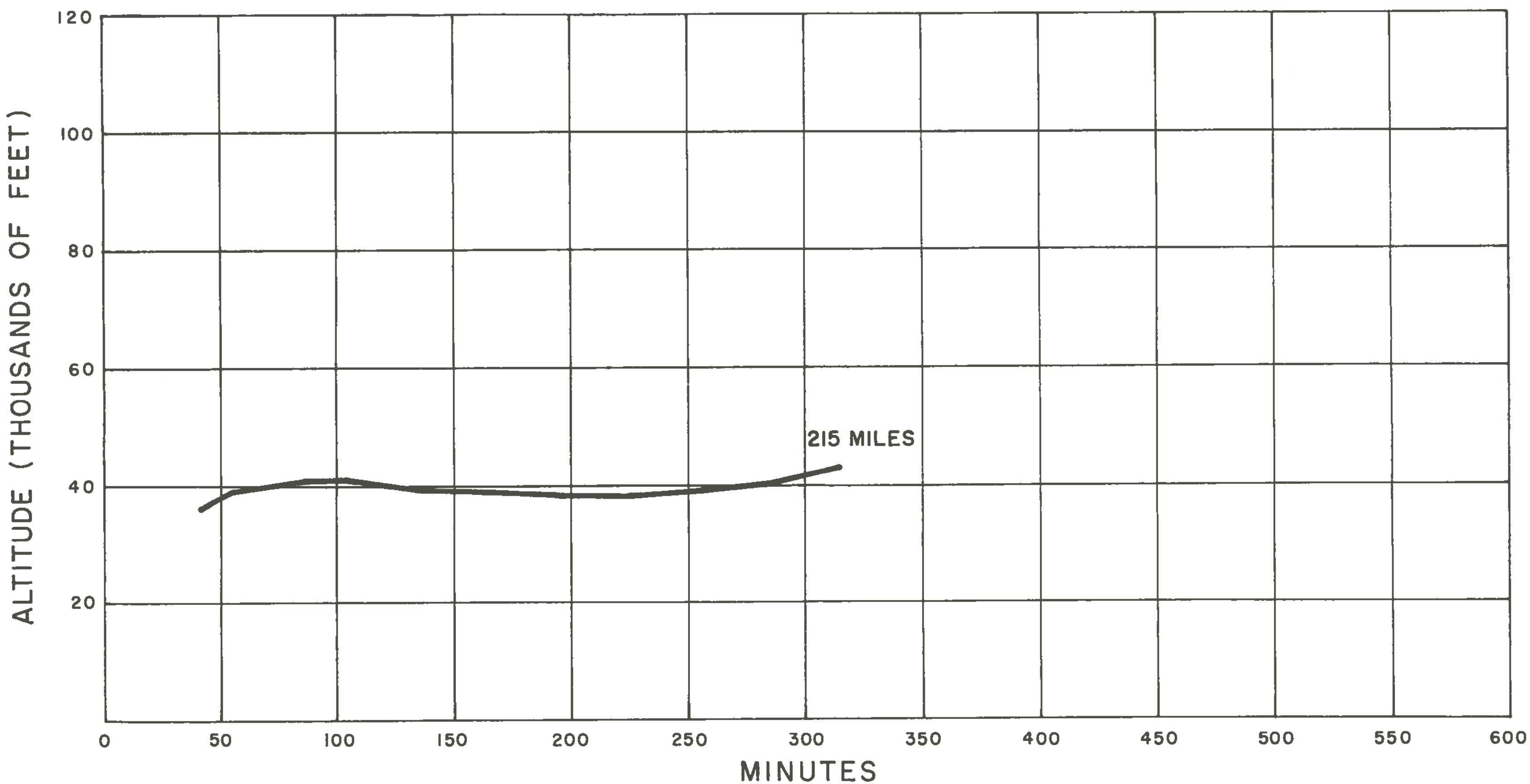

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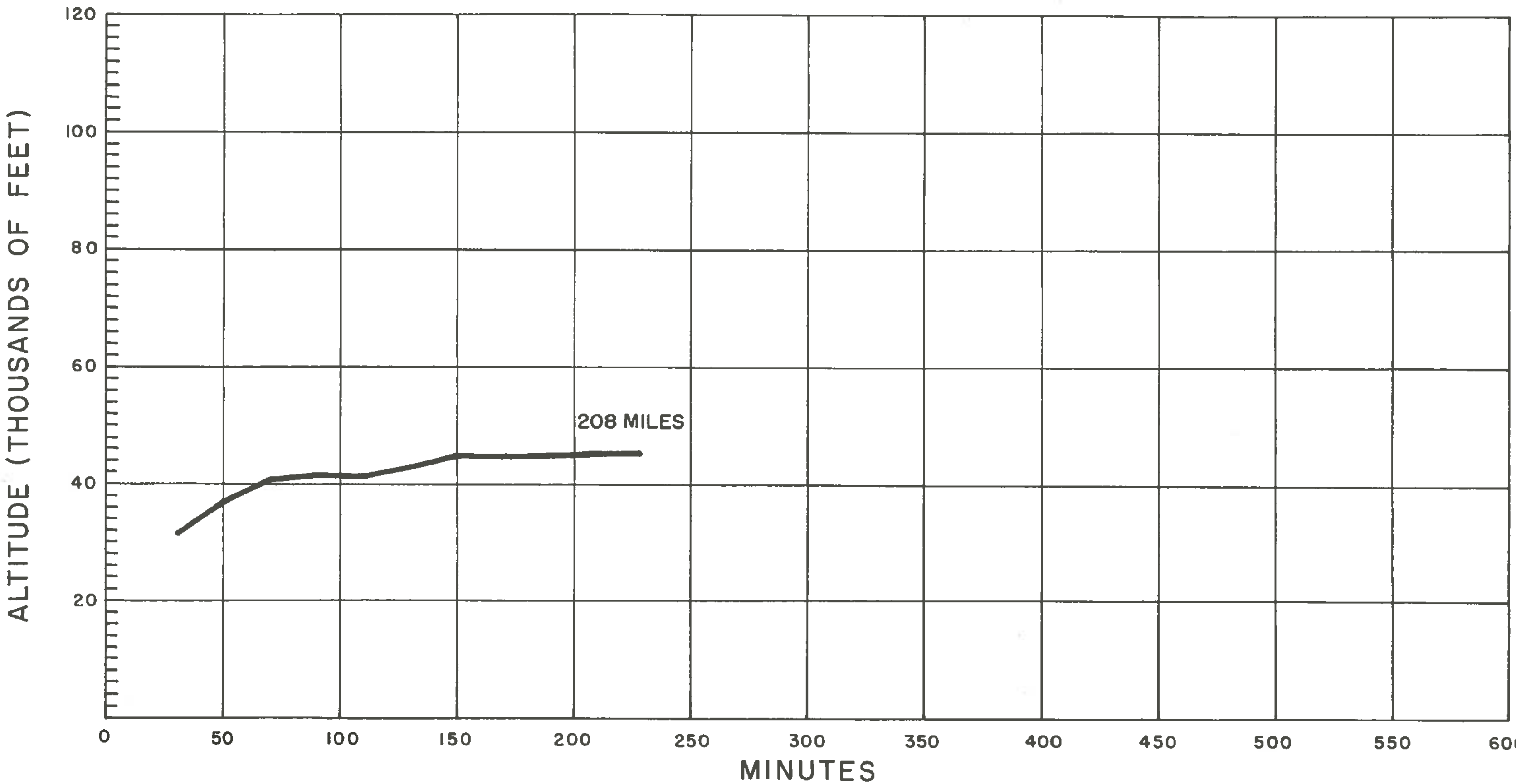

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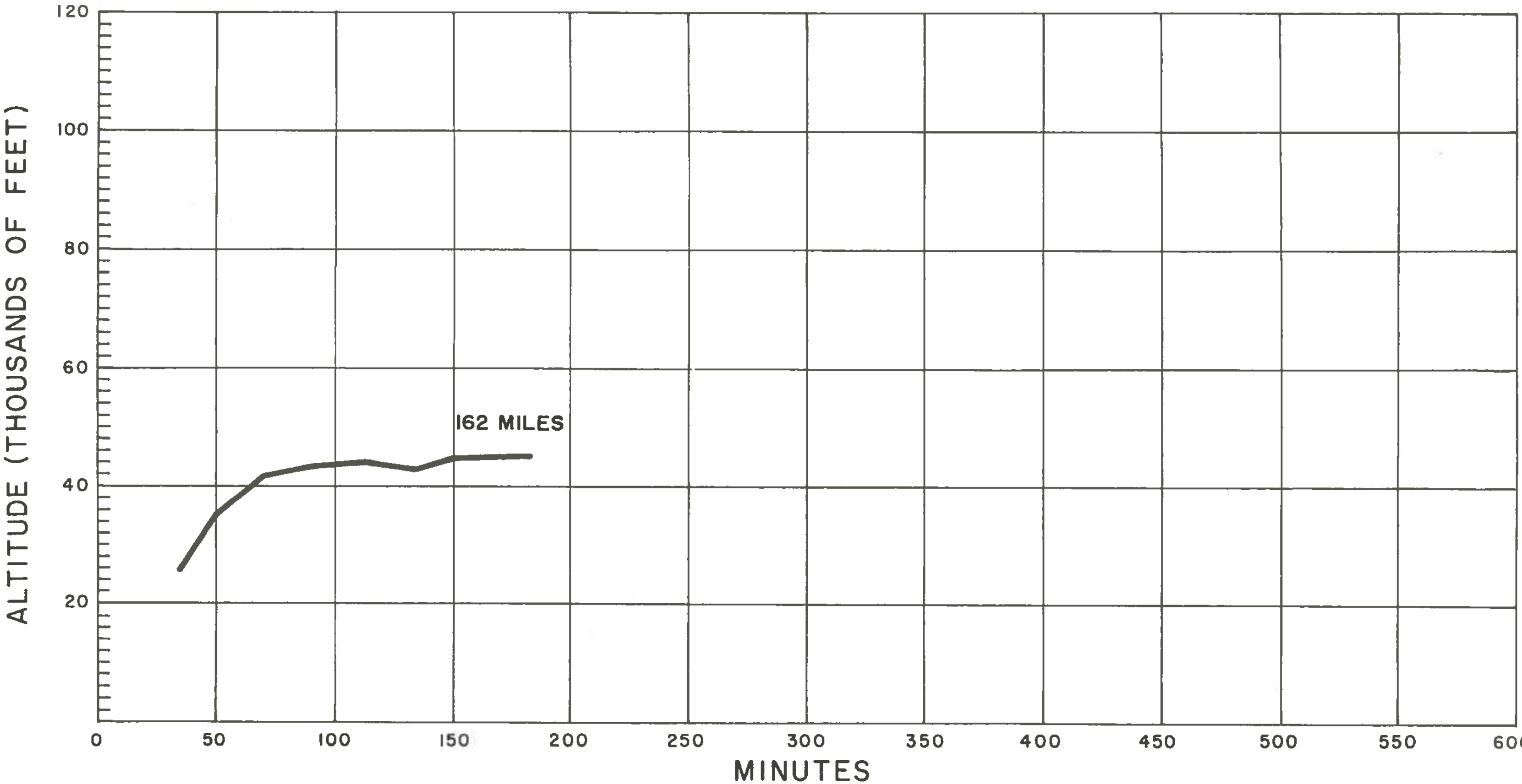

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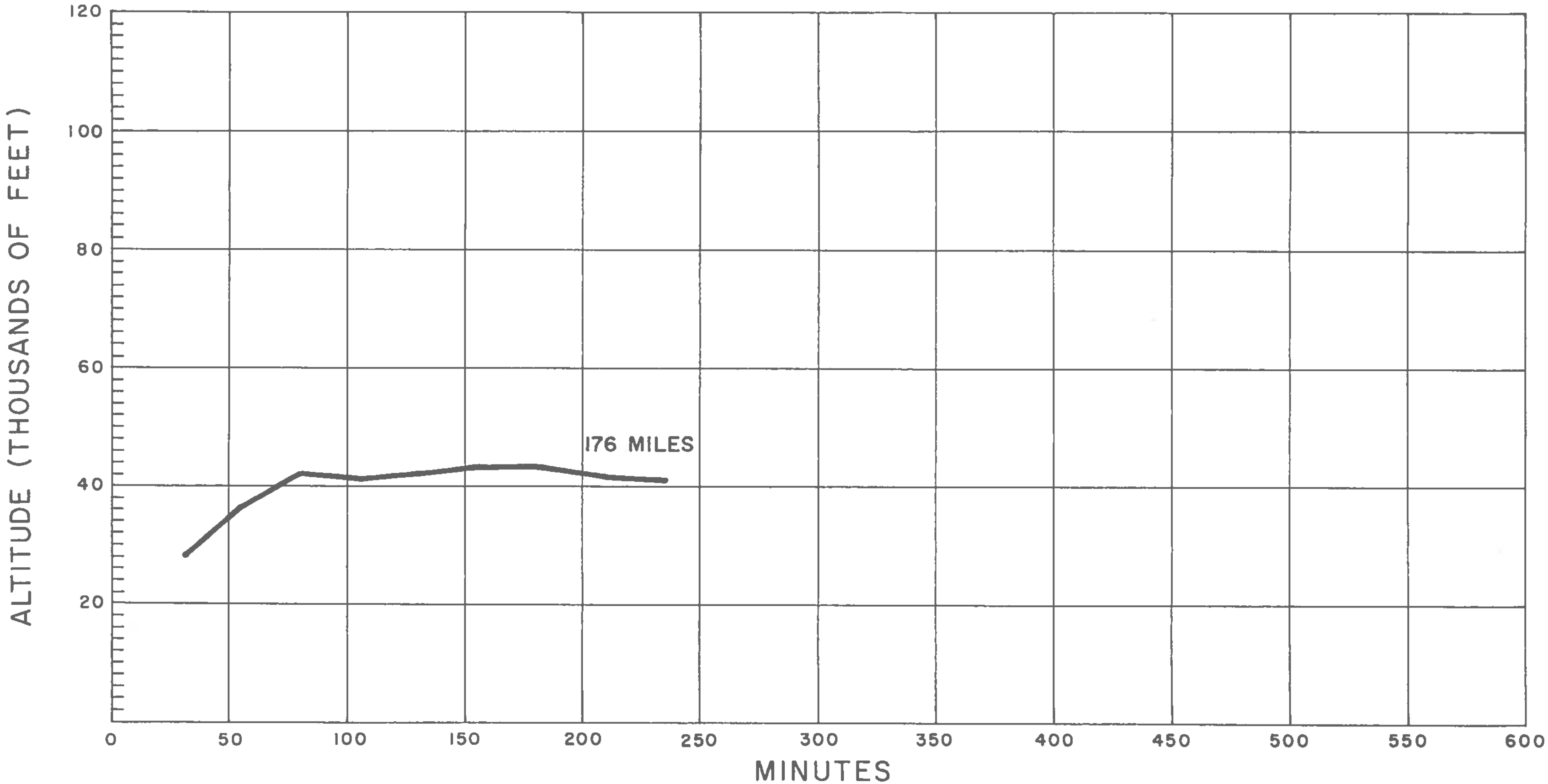

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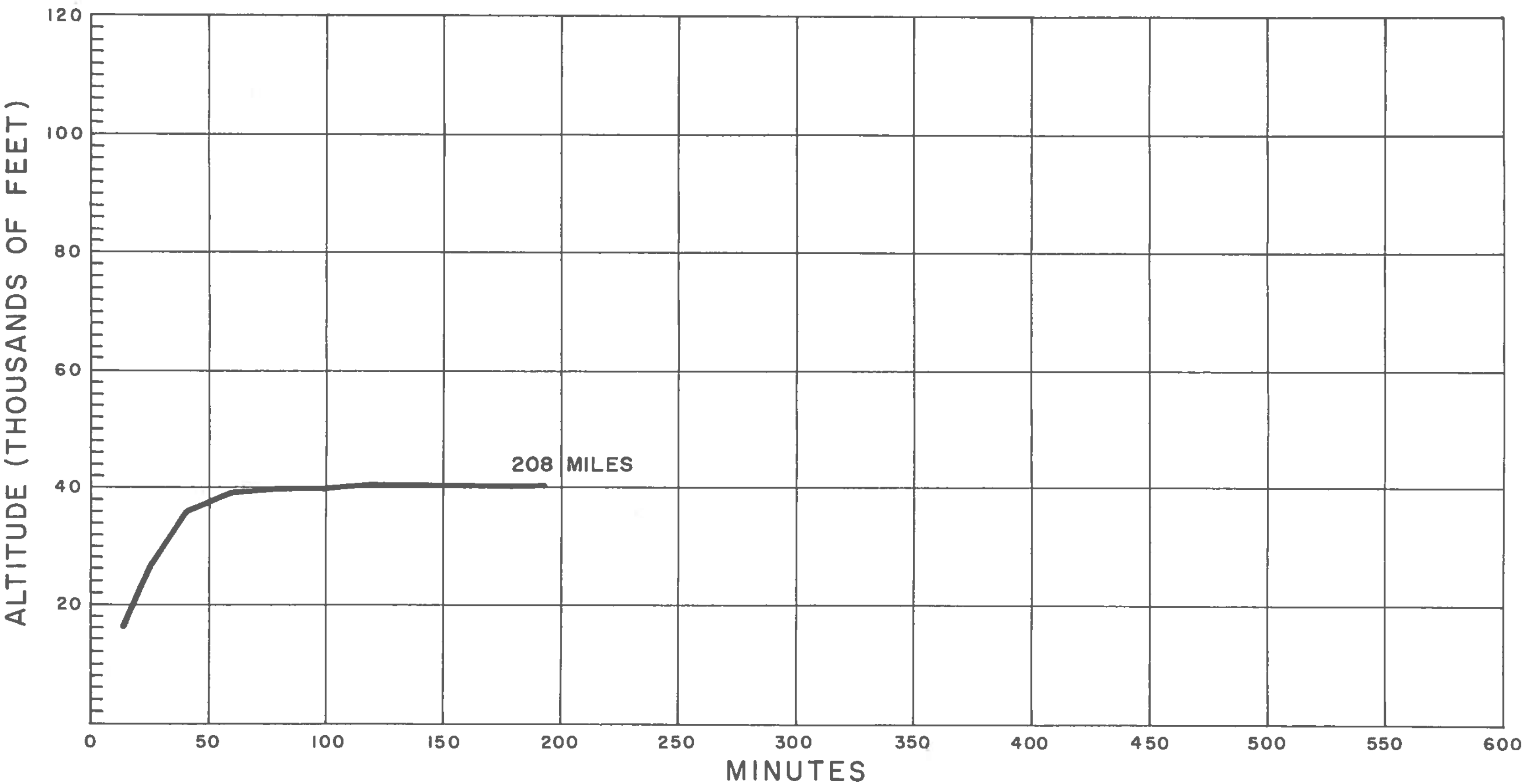

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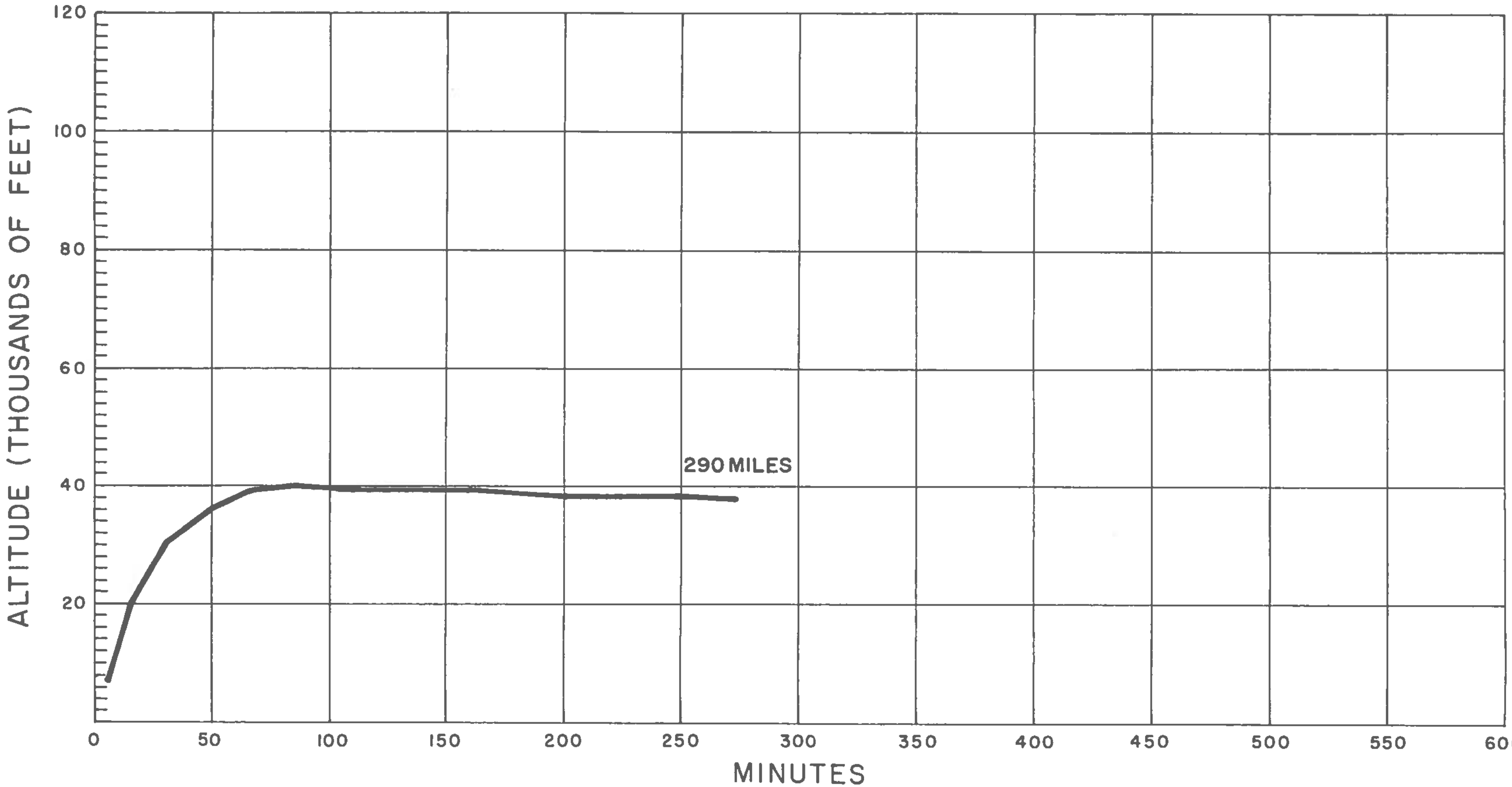

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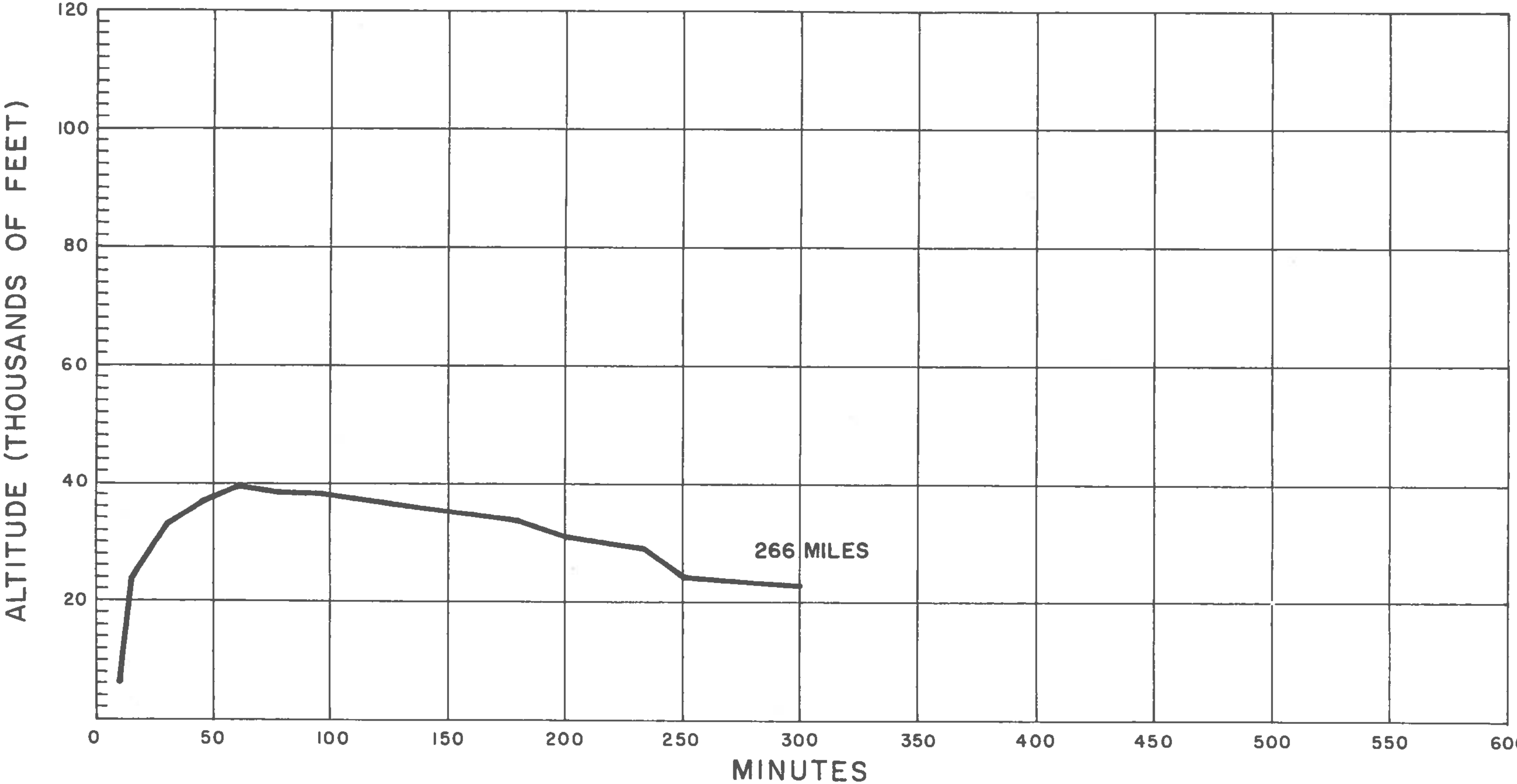

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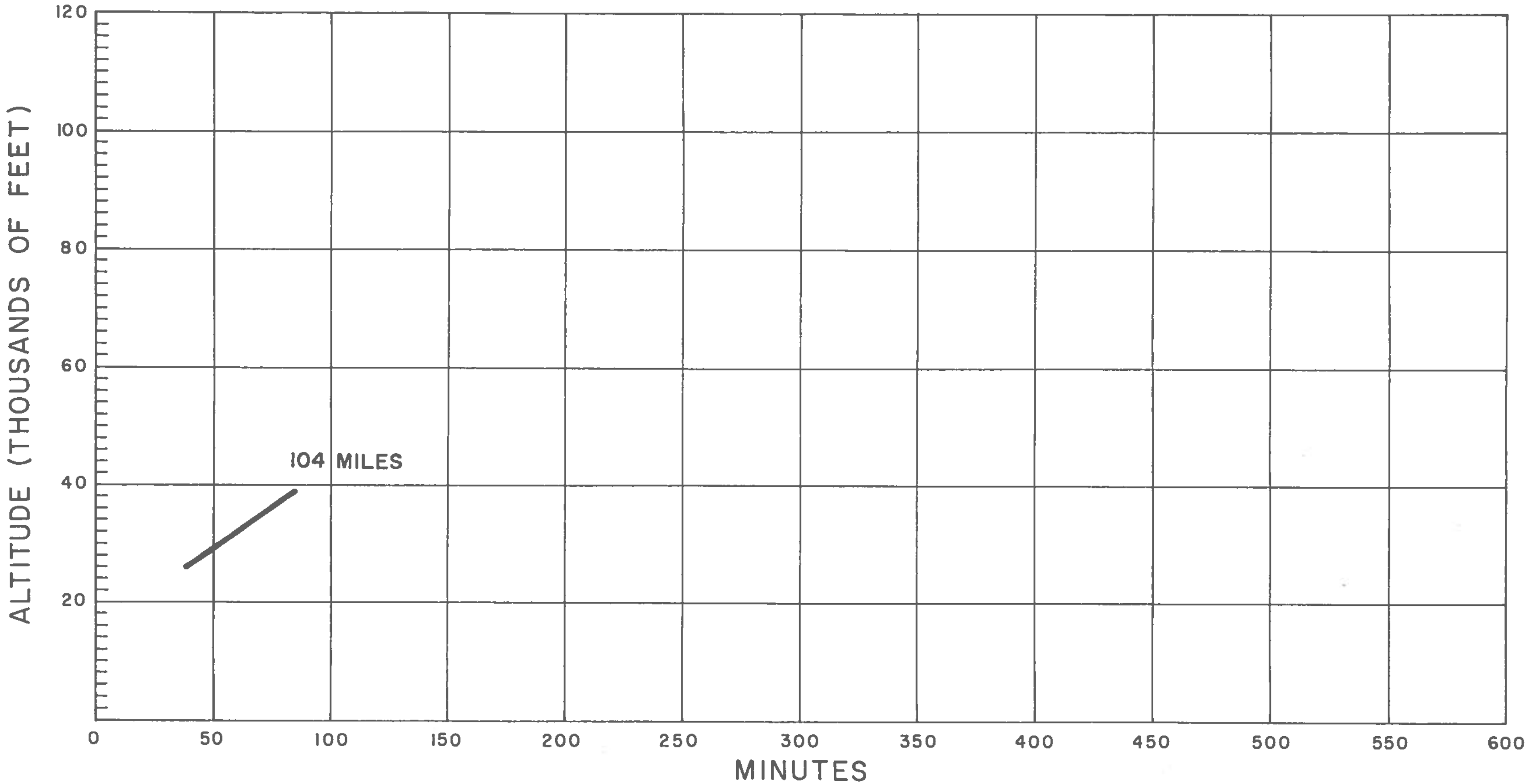

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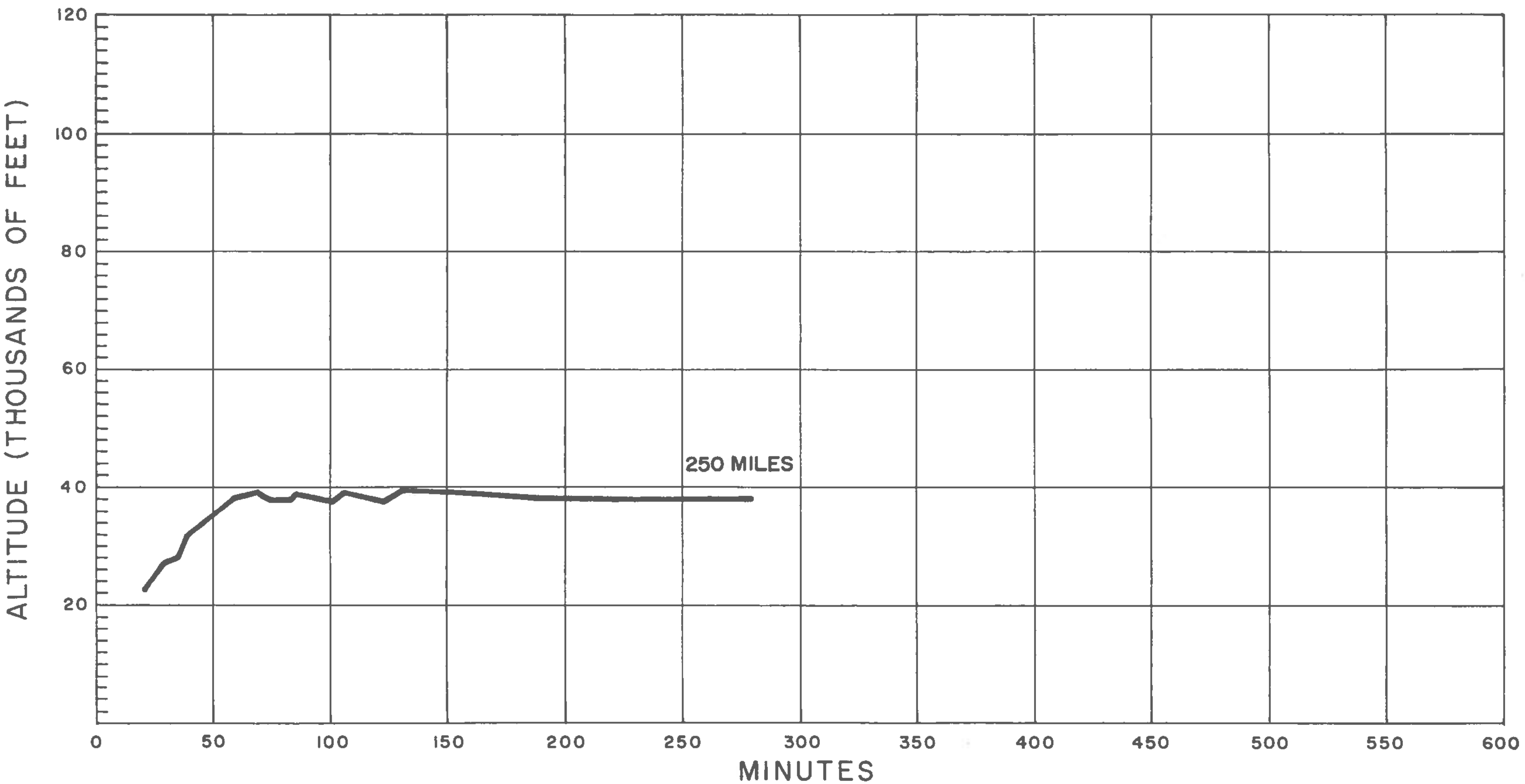

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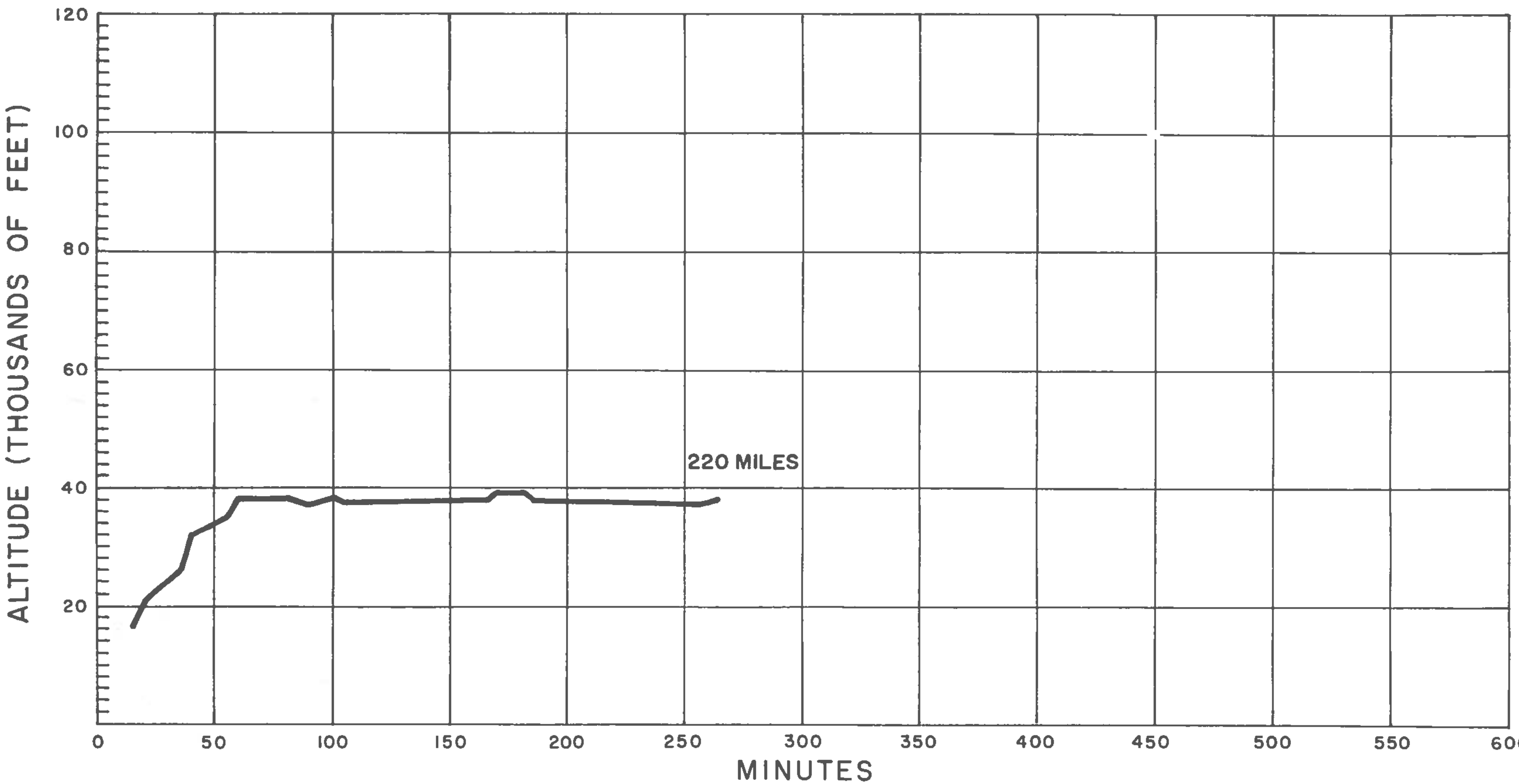

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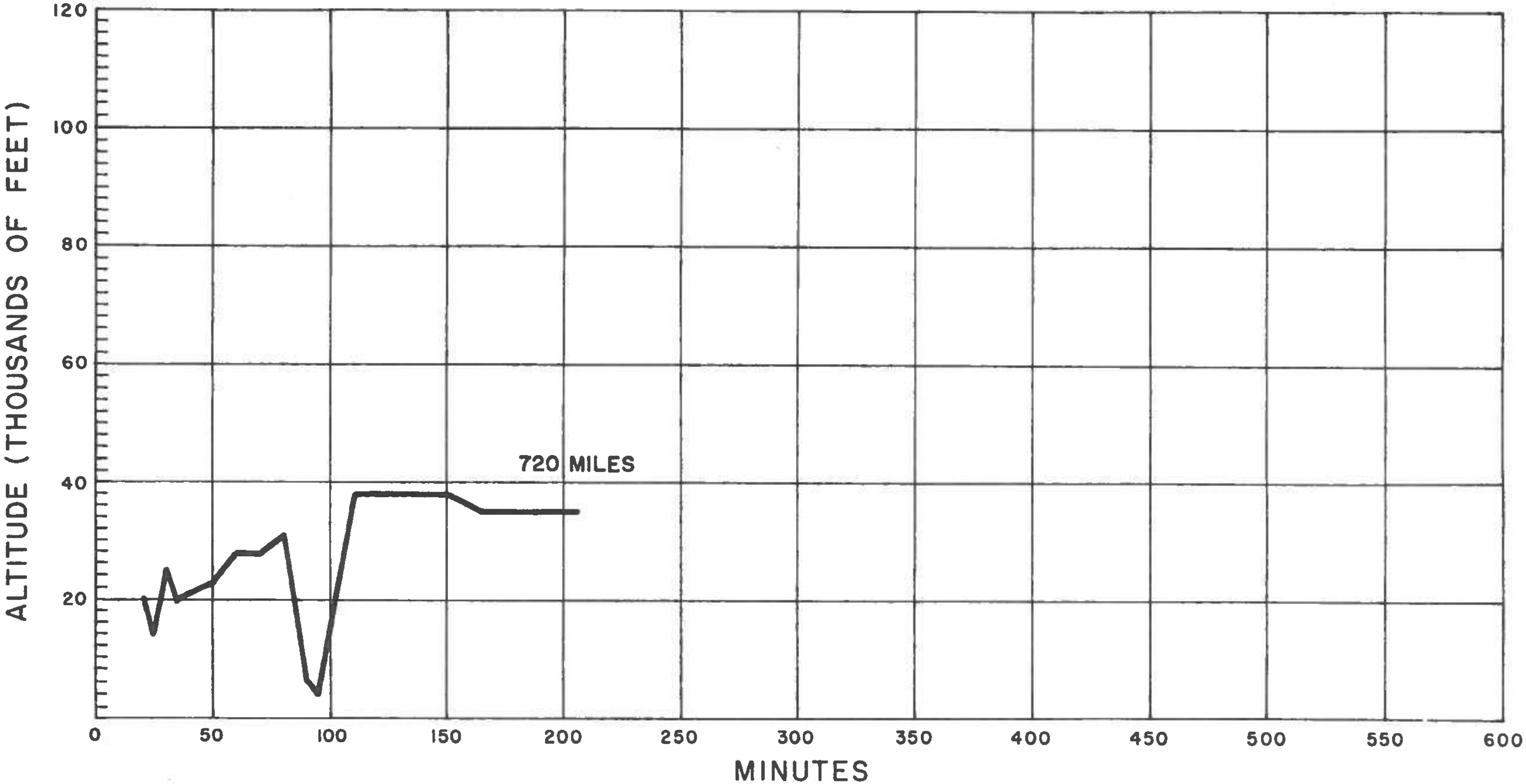

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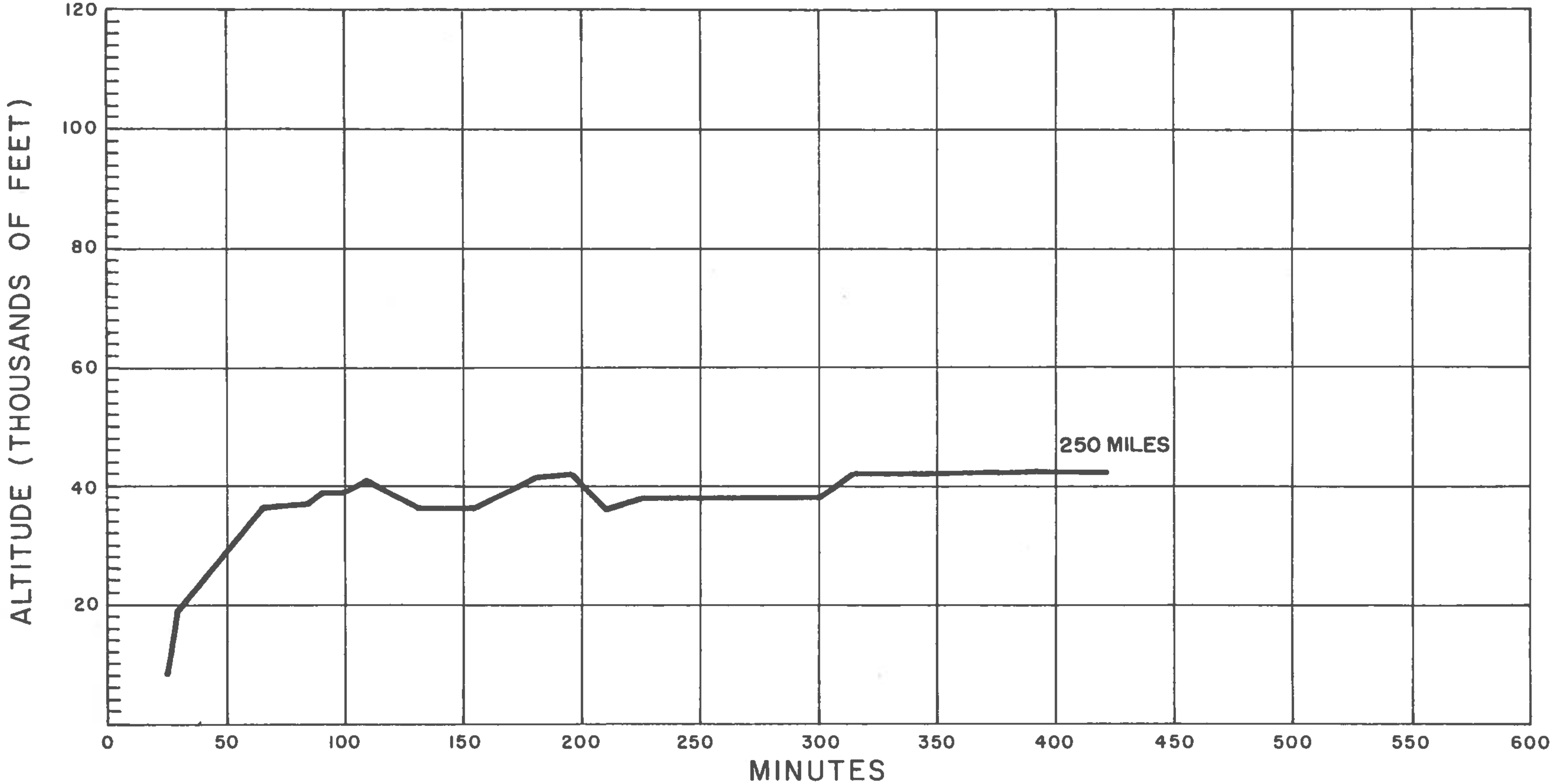

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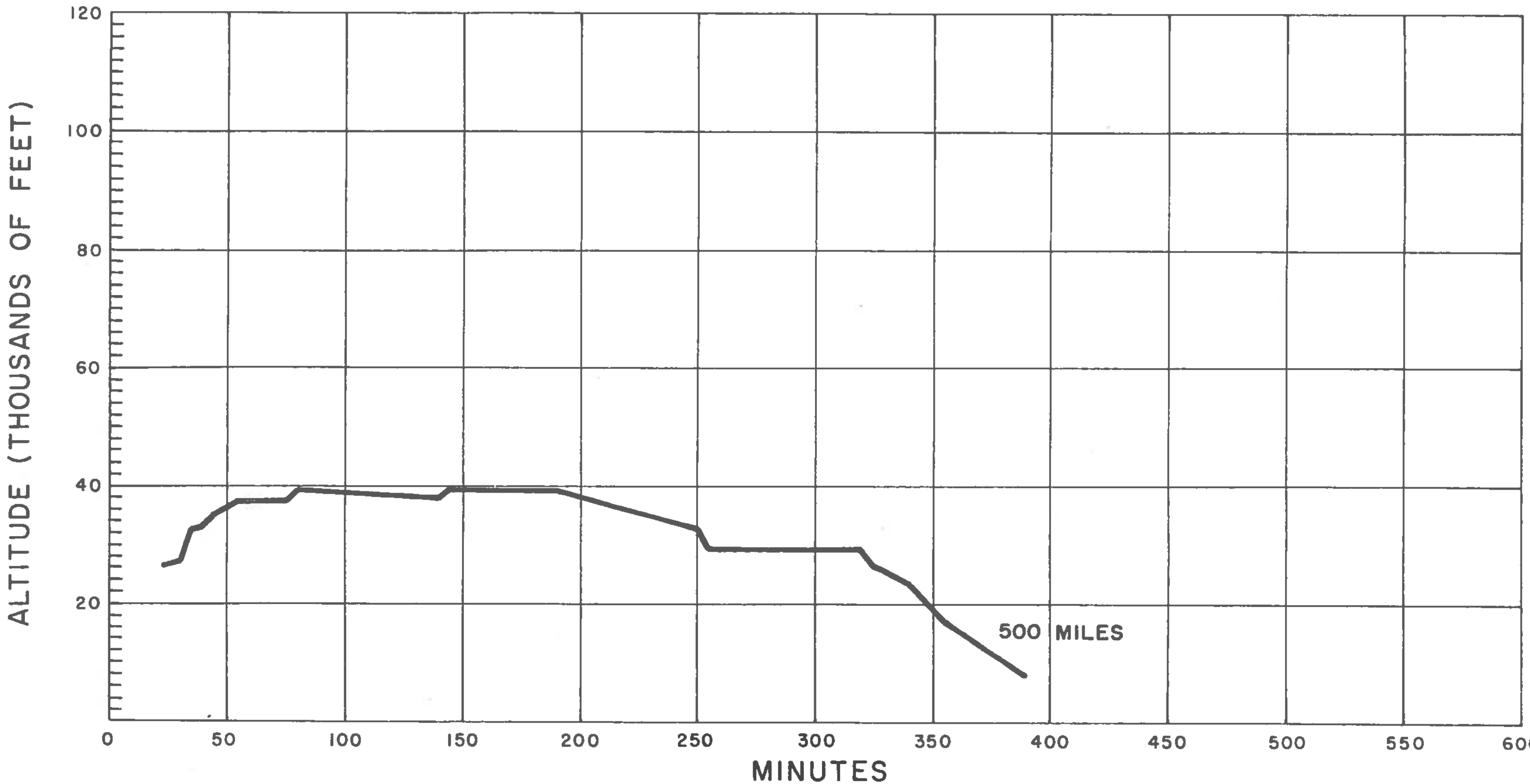

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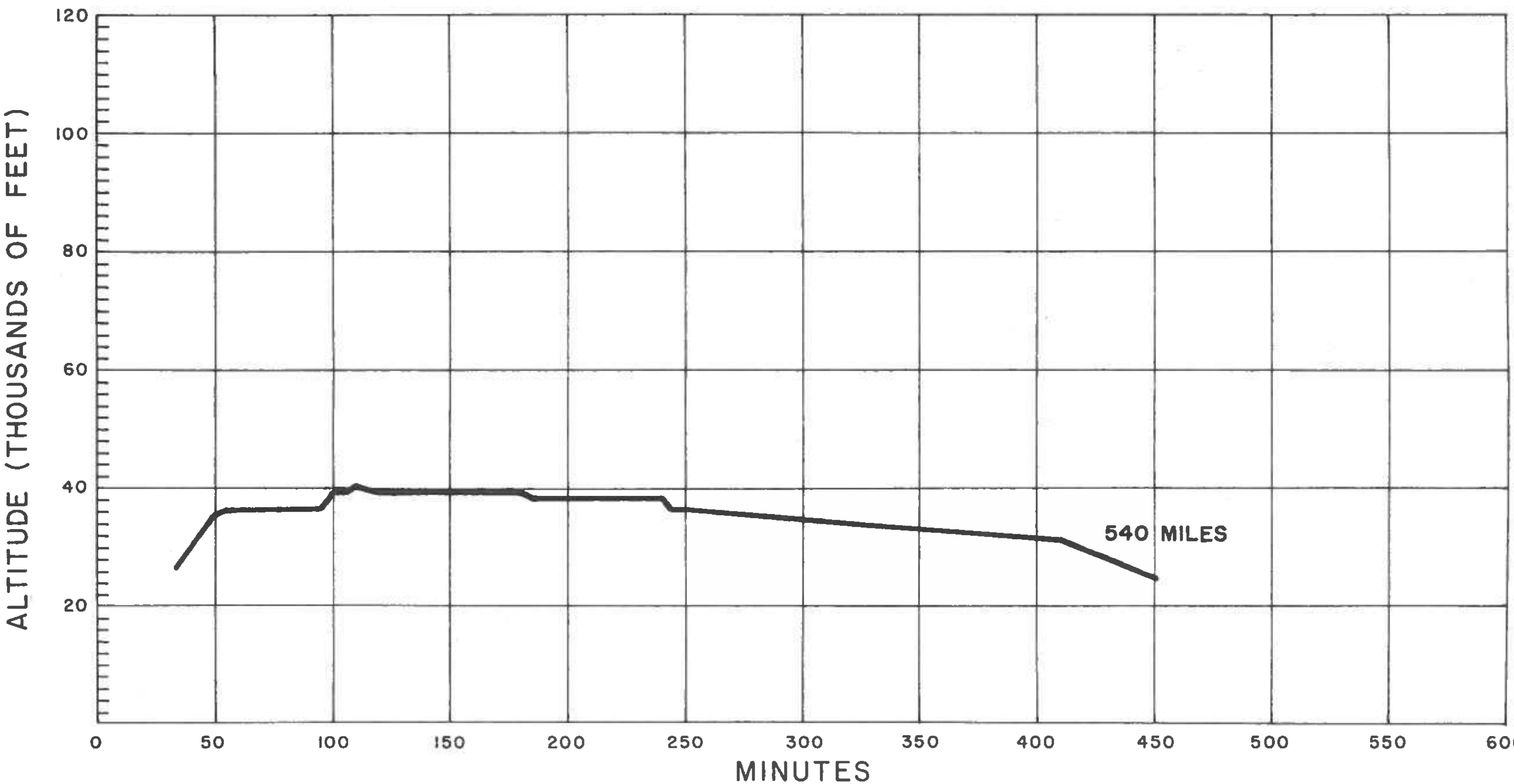

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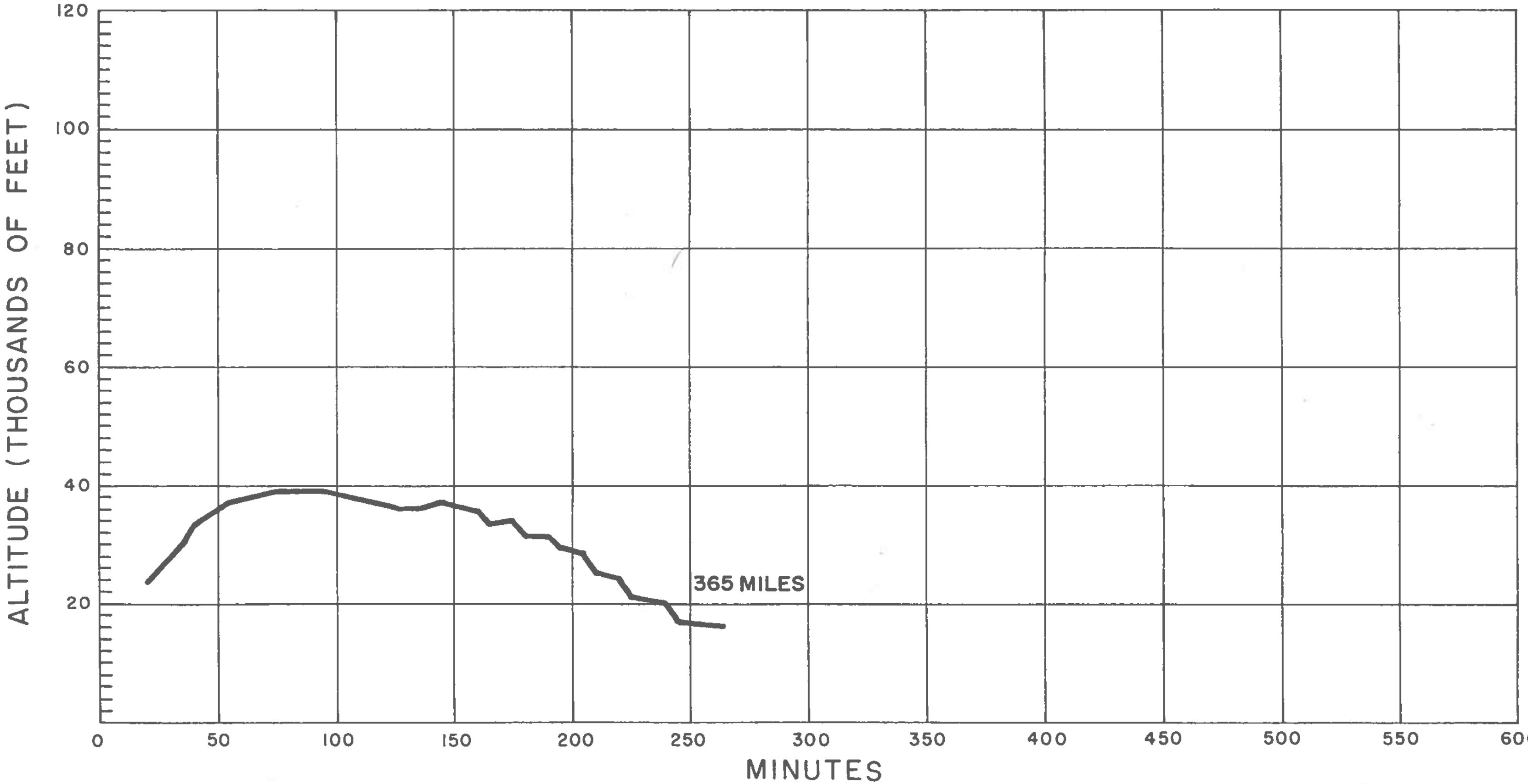

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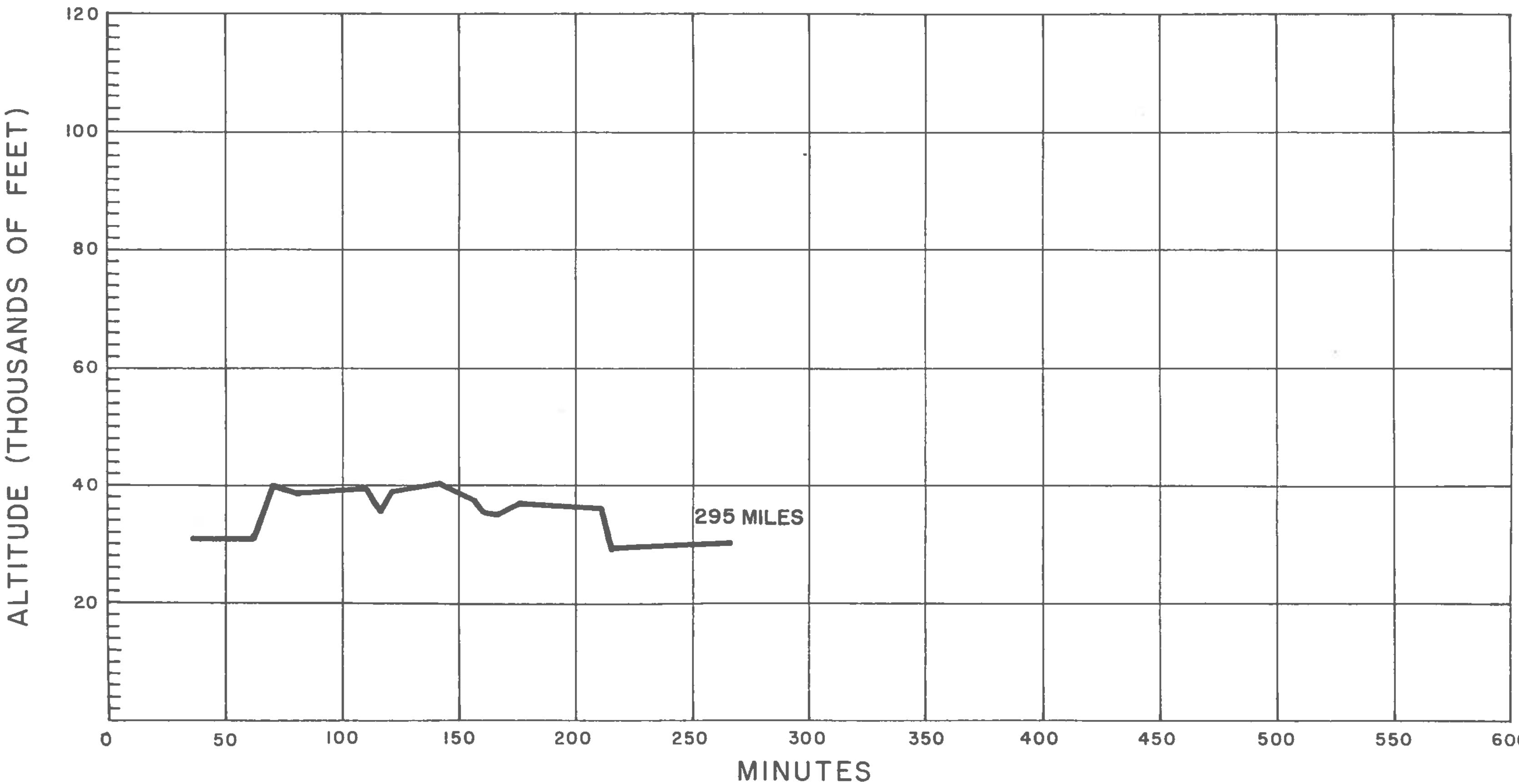

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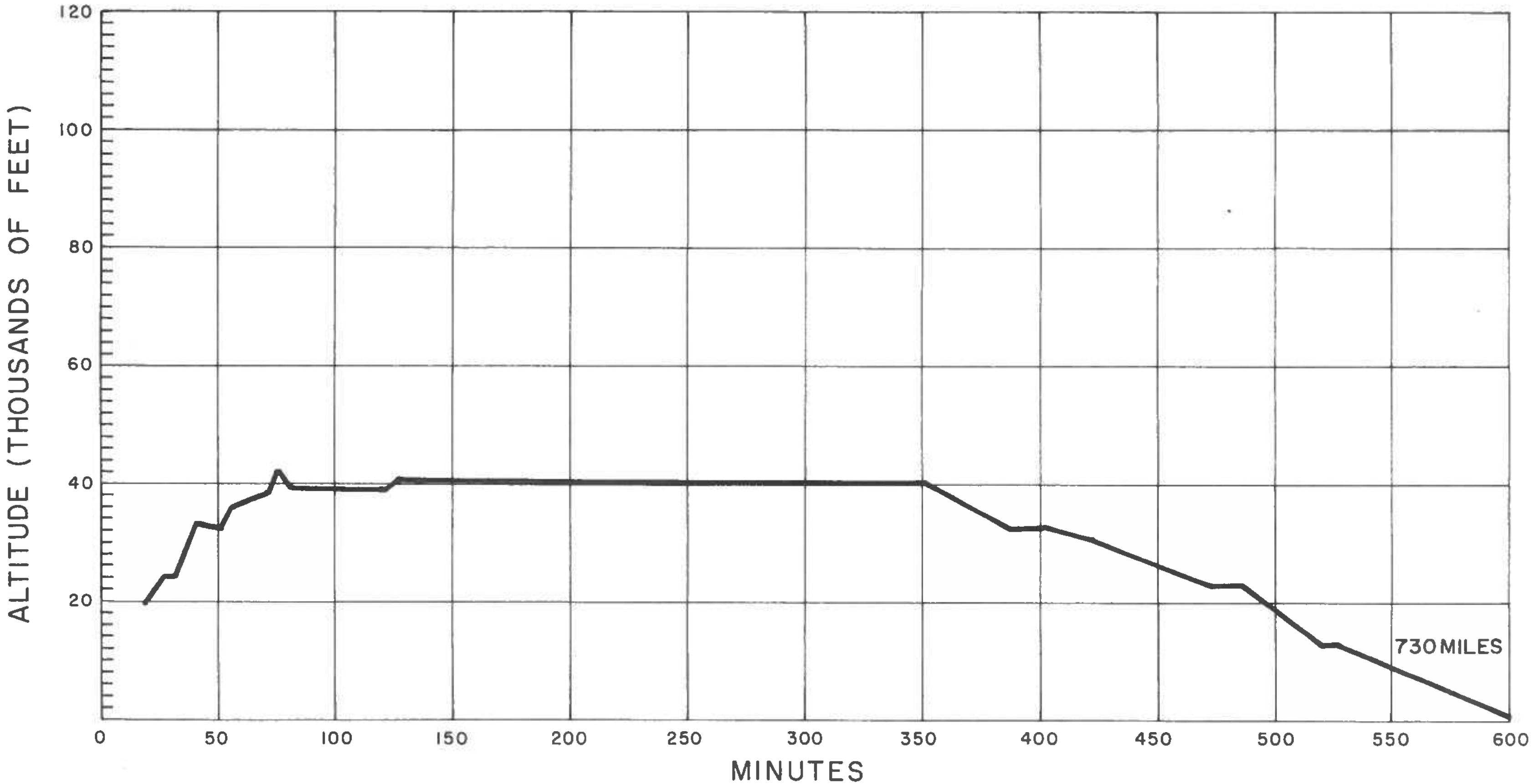

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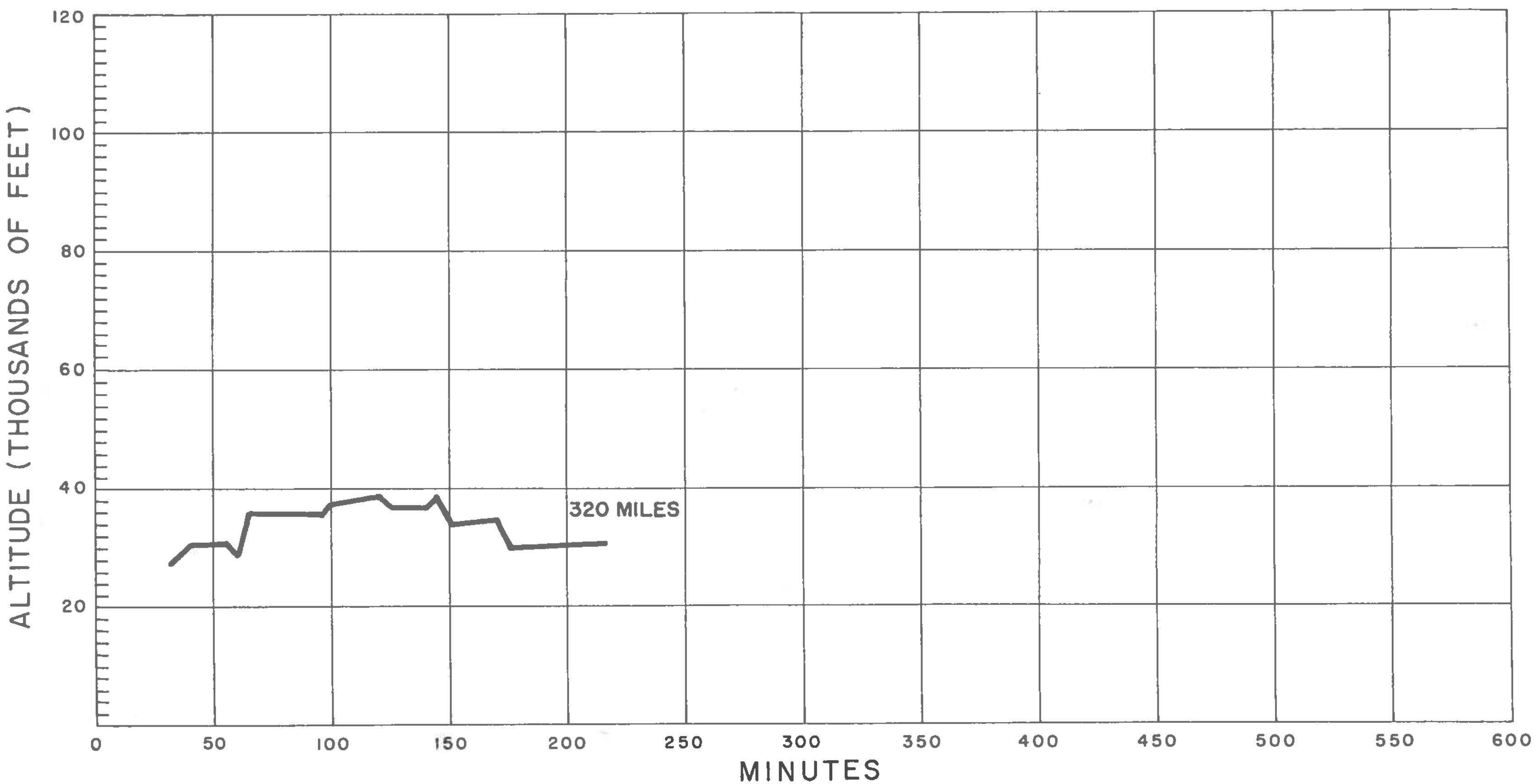

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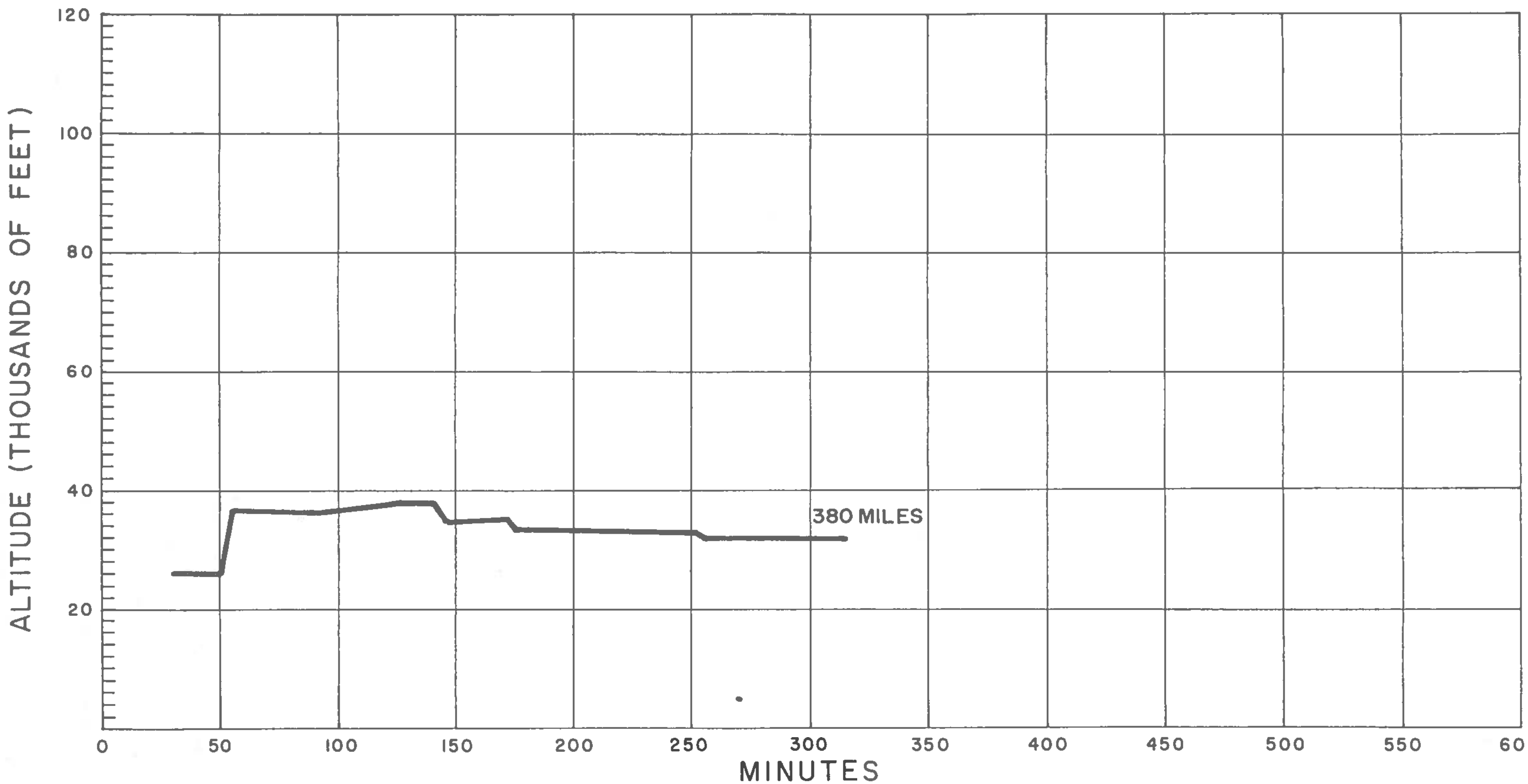

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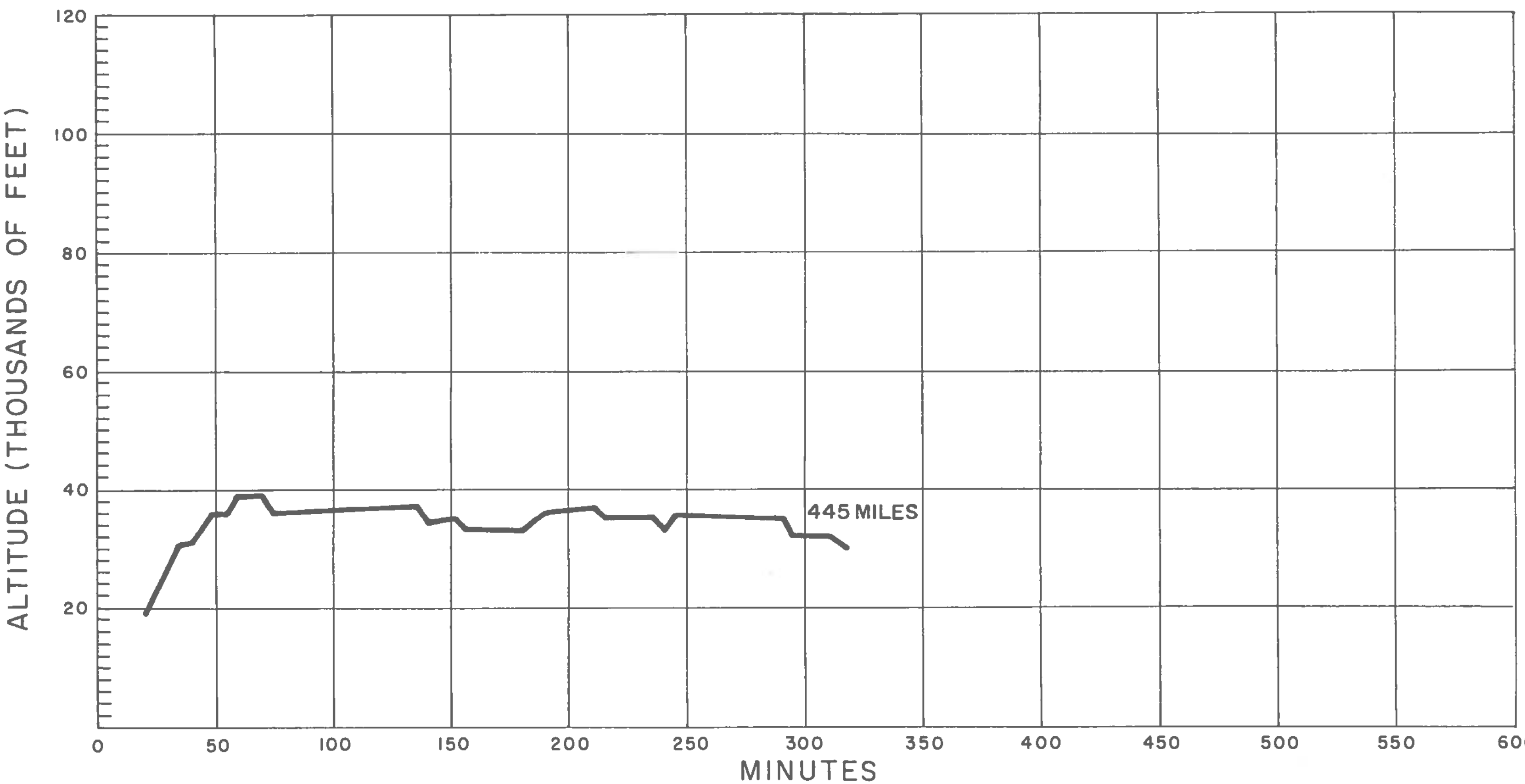

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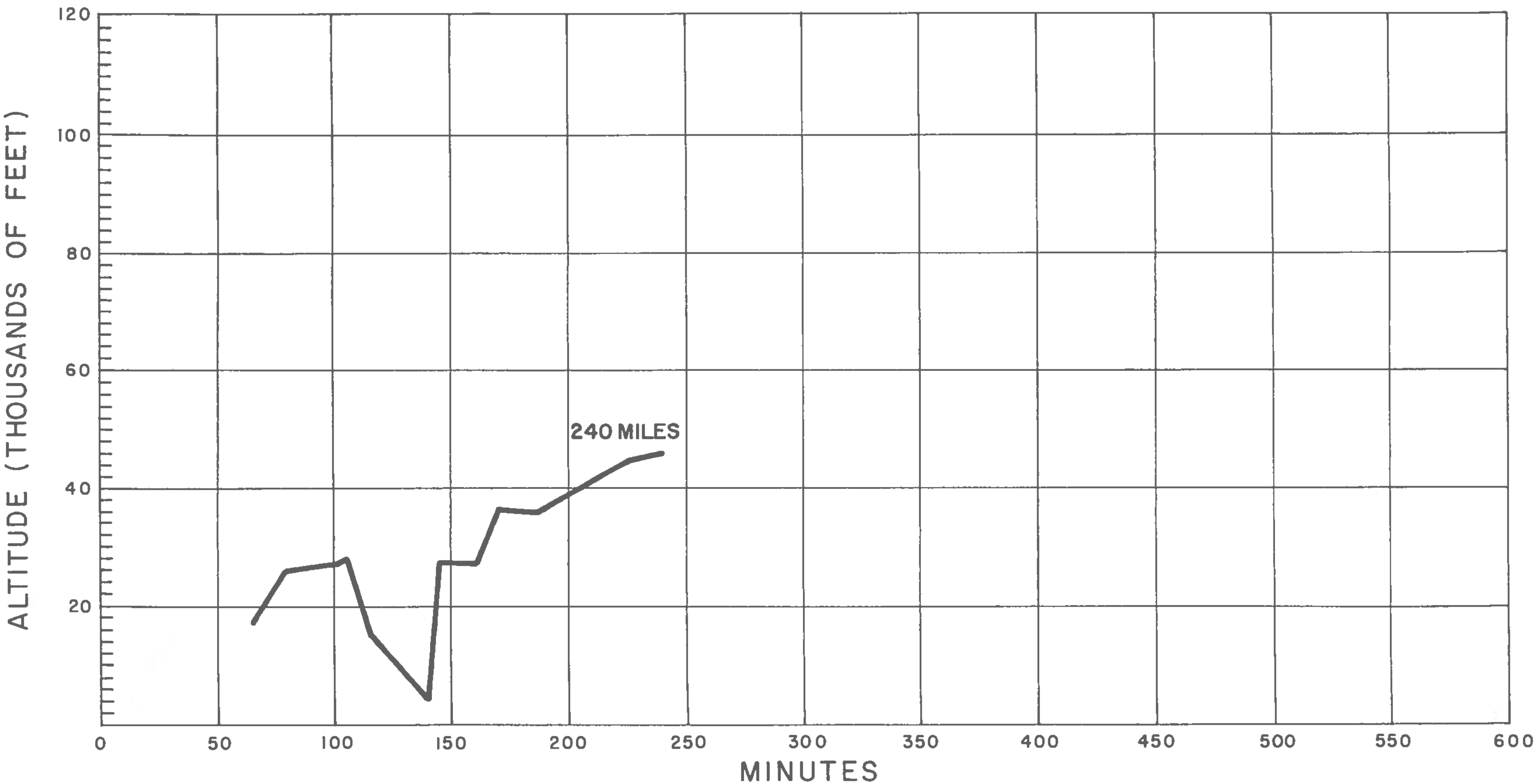

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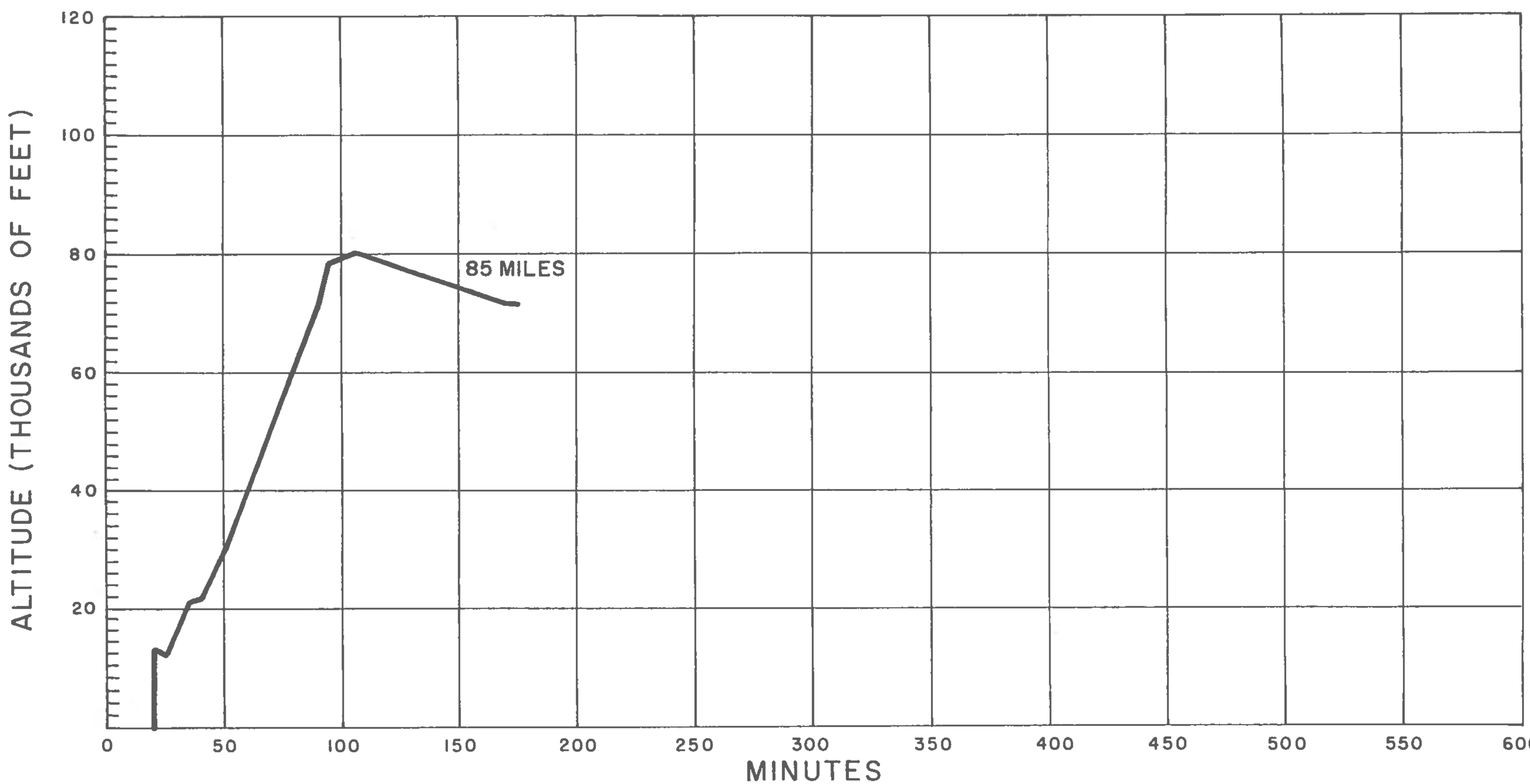


FIG. 29, BALLOON No. 30

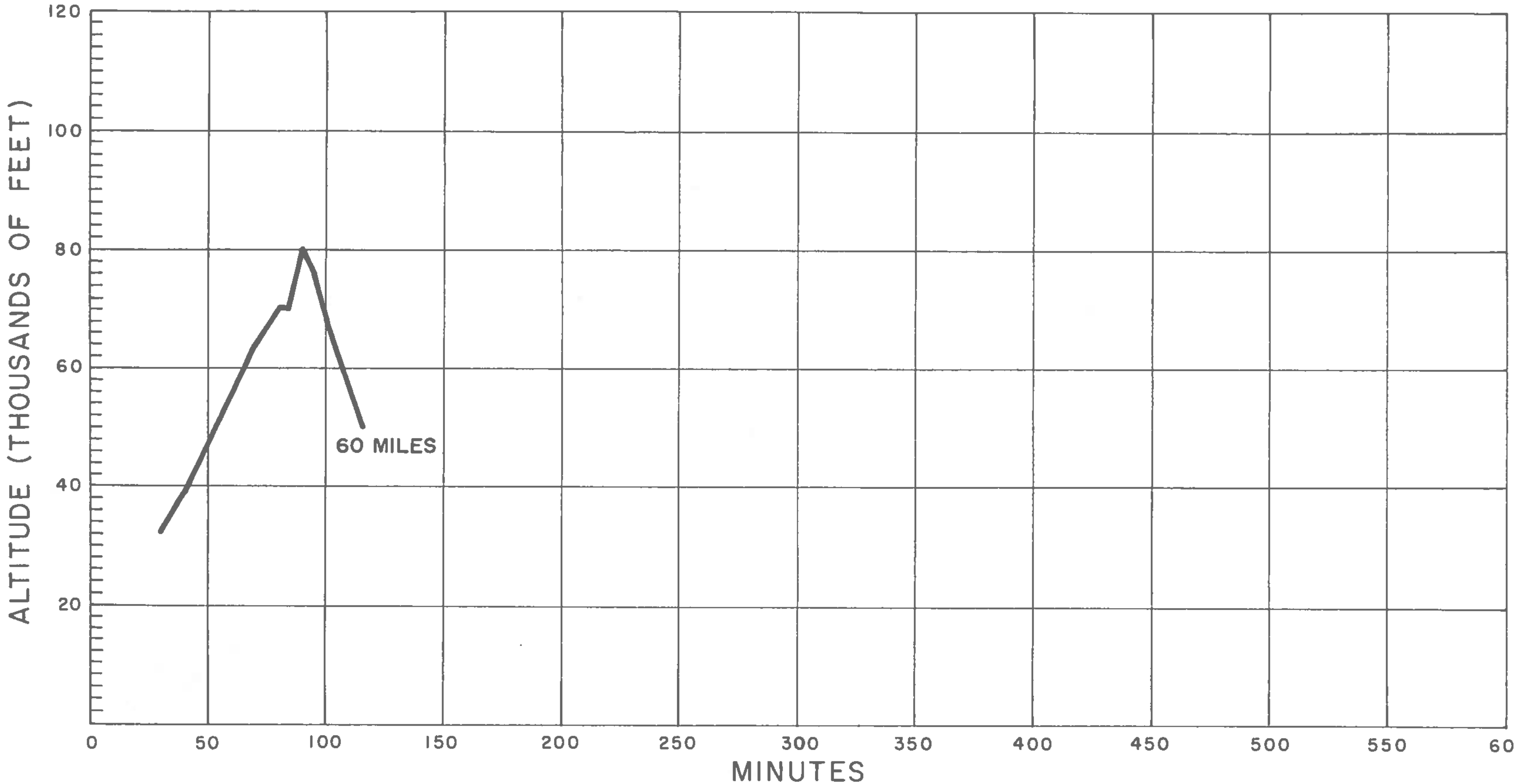
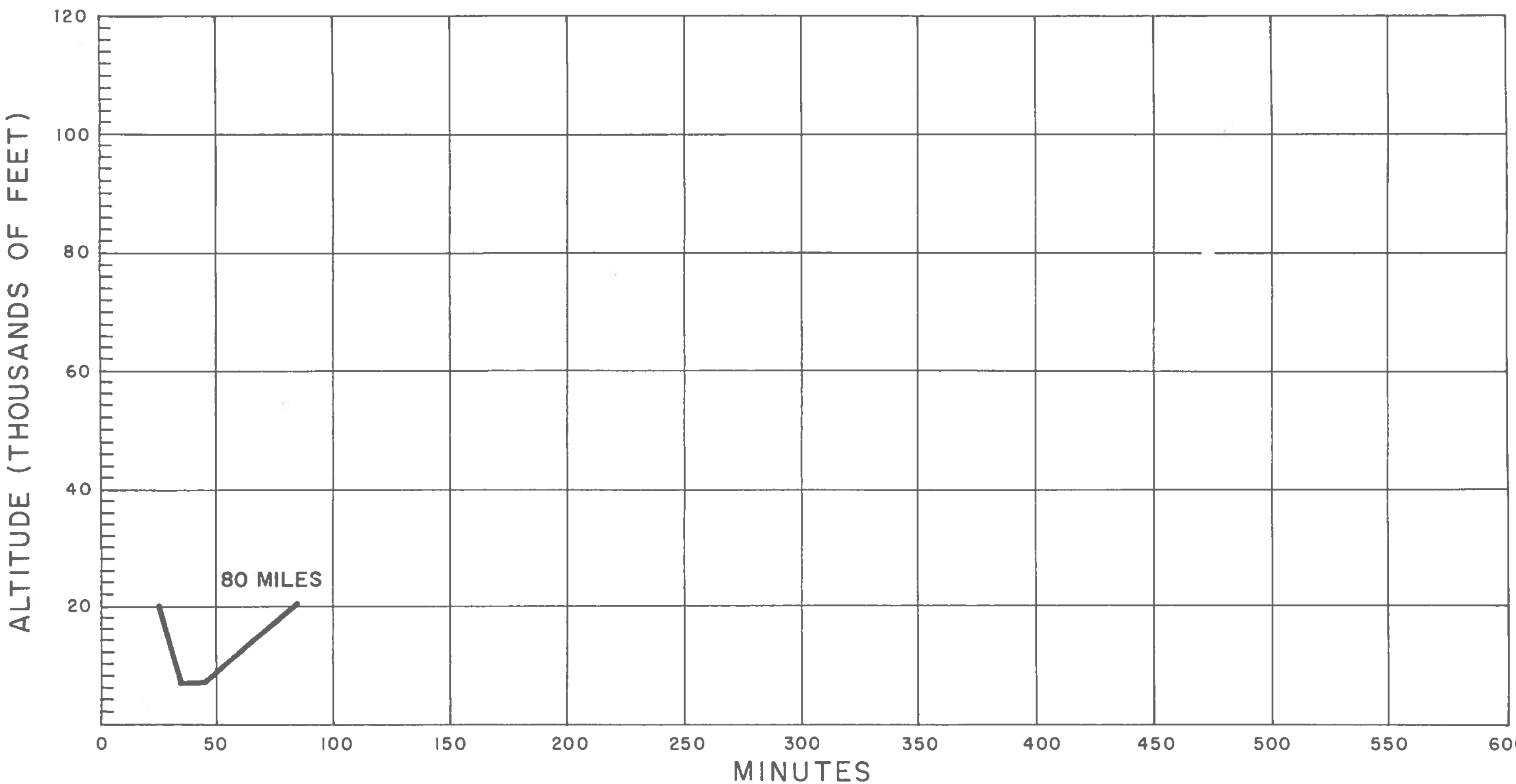


FIG. 30, BALLOON No. 31



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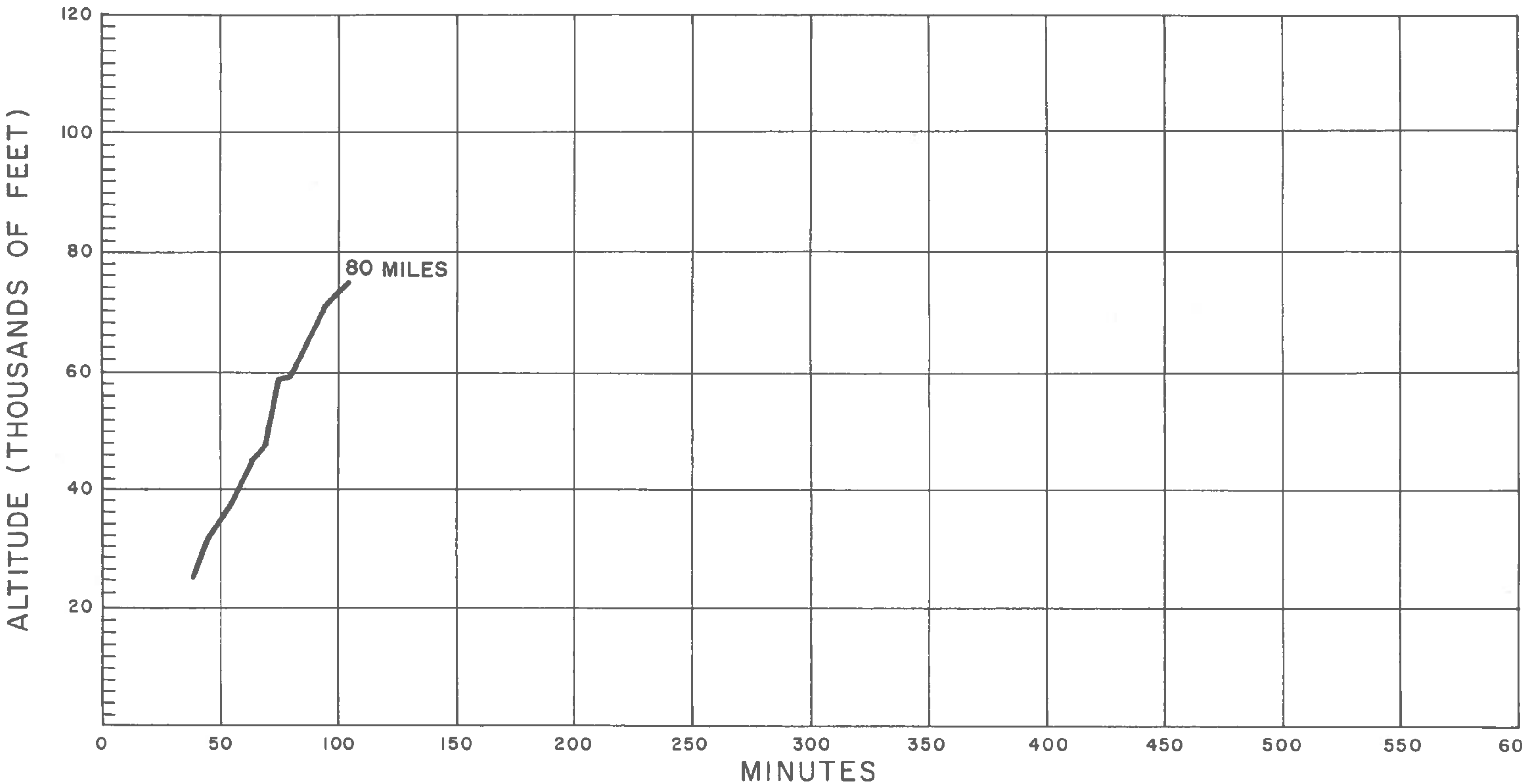

FIG 32, BALLOON No. 33

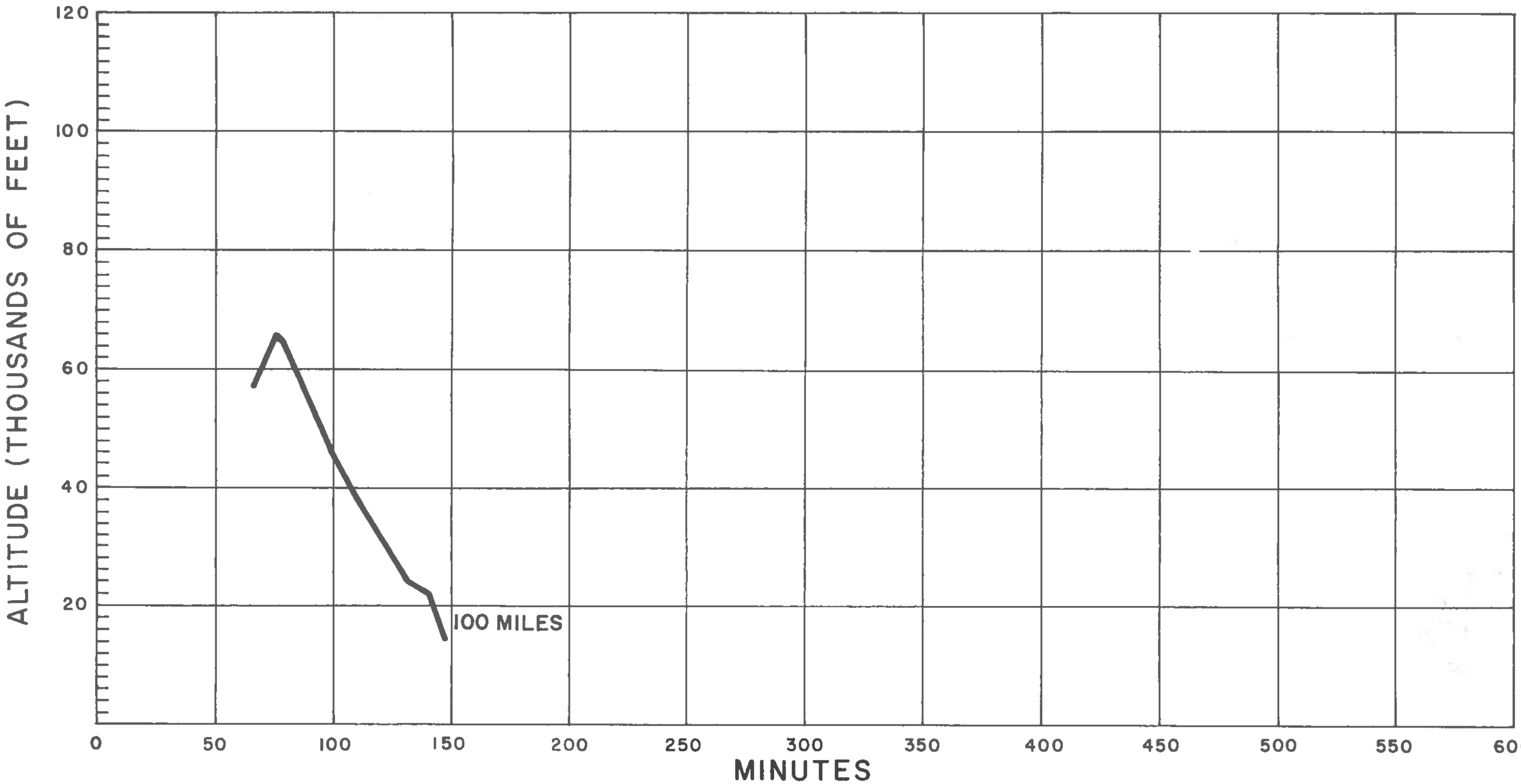

FIG. 33, BALLOON No. 34

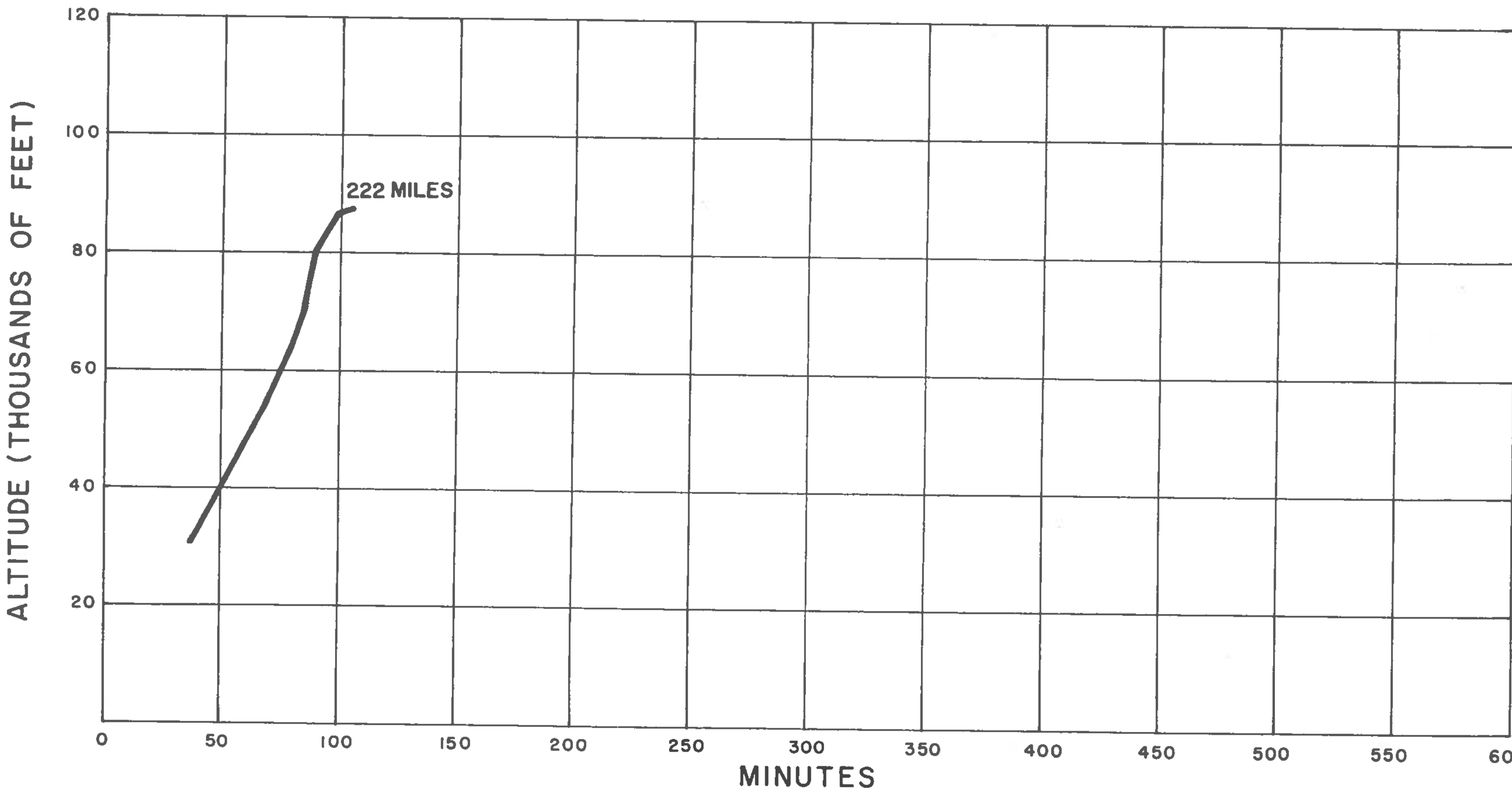

FIG. 34, BALLOON No. 35

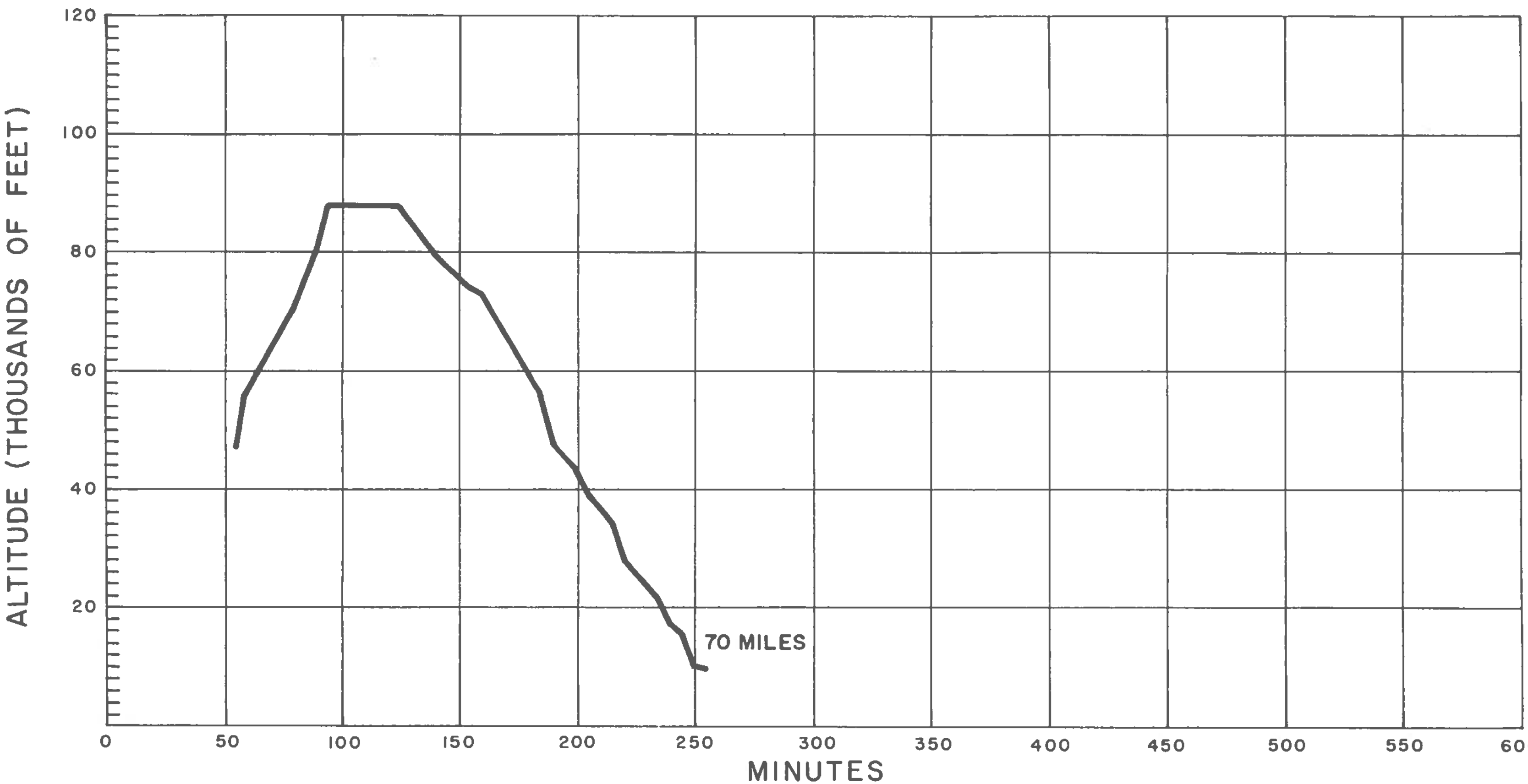

FIG. 35, BALLOON No. 36

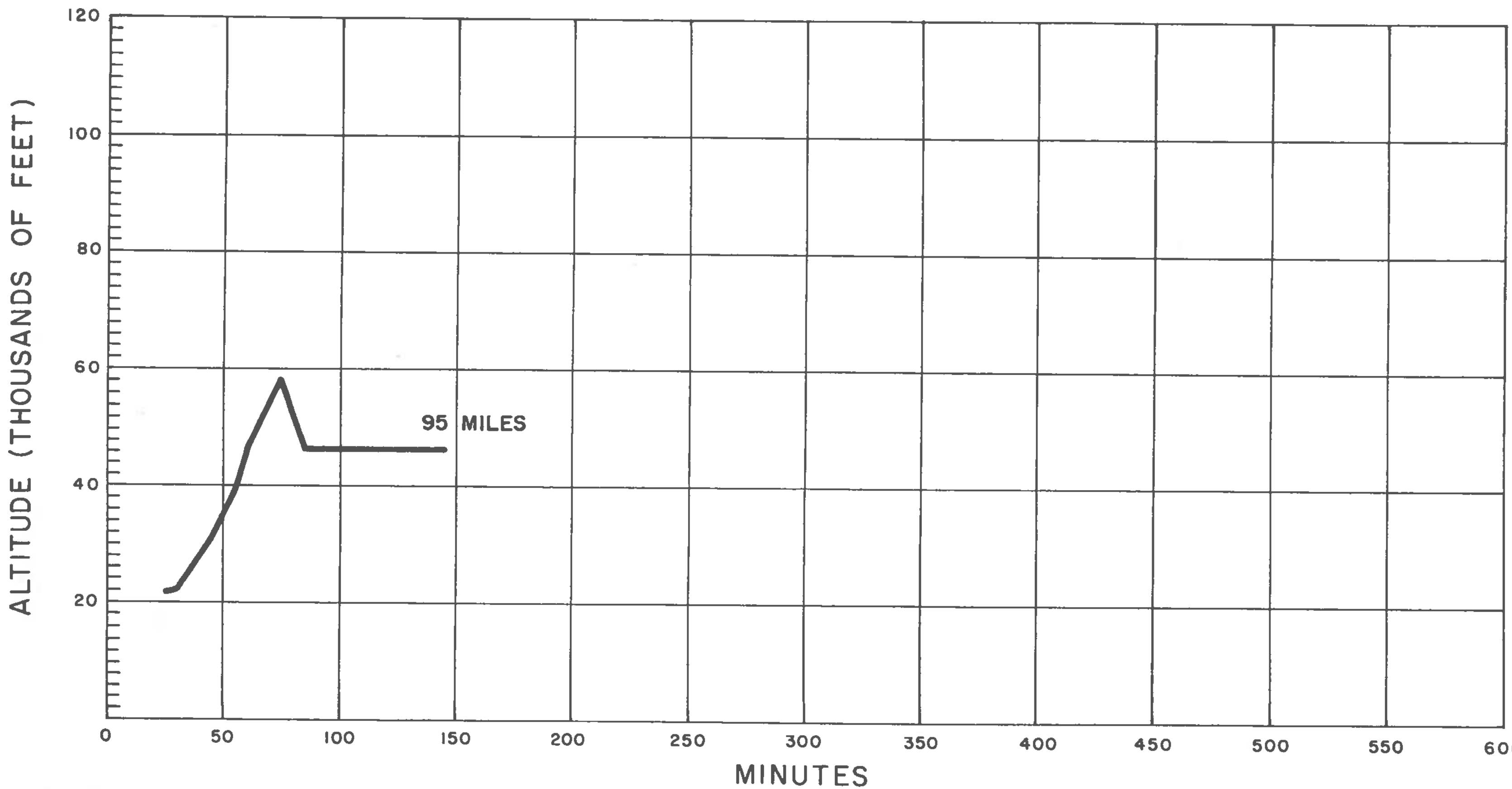

FIG. 36, BALLOON No. 37

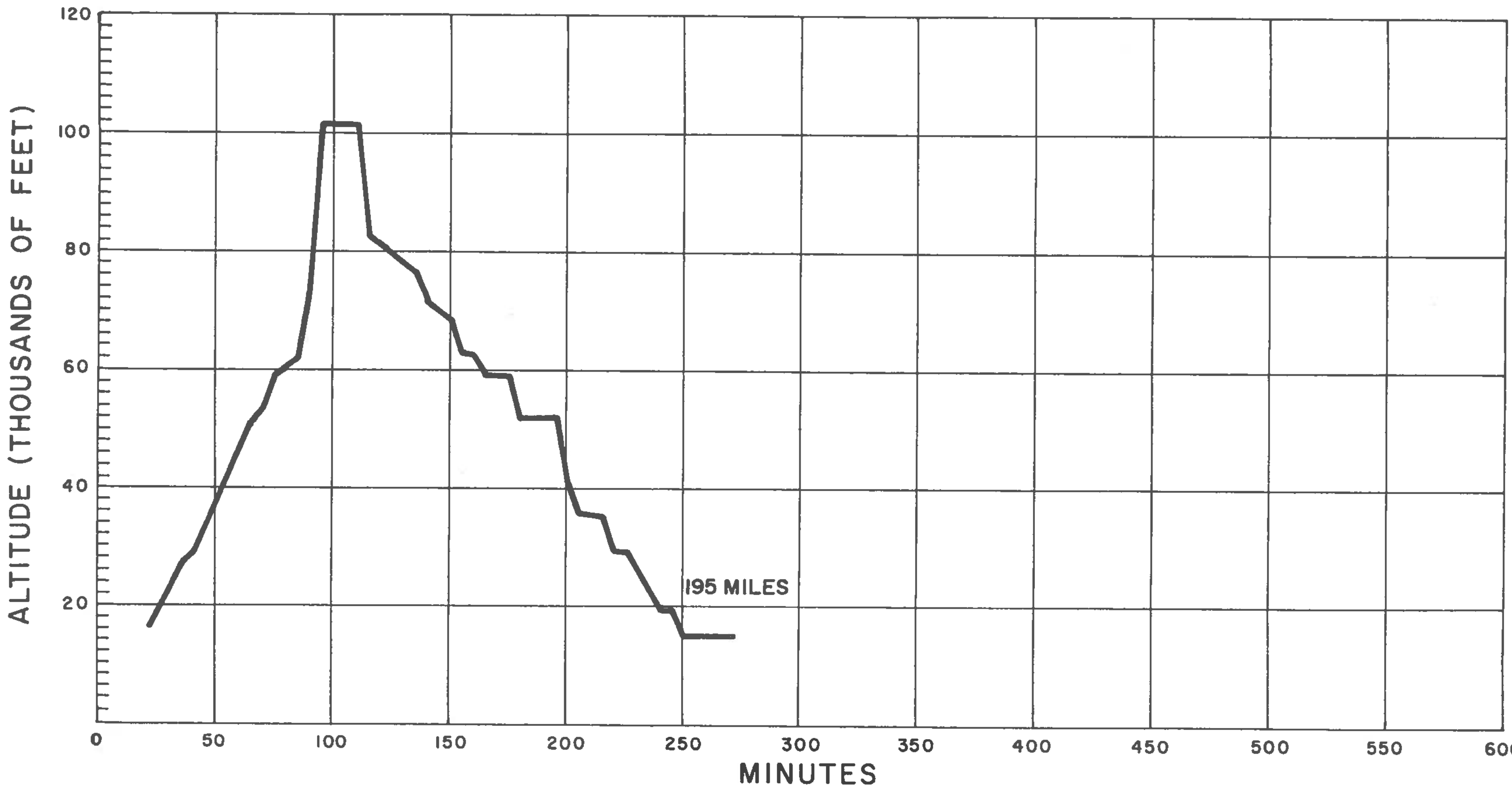

FIG. 37, BALLOON No. 38

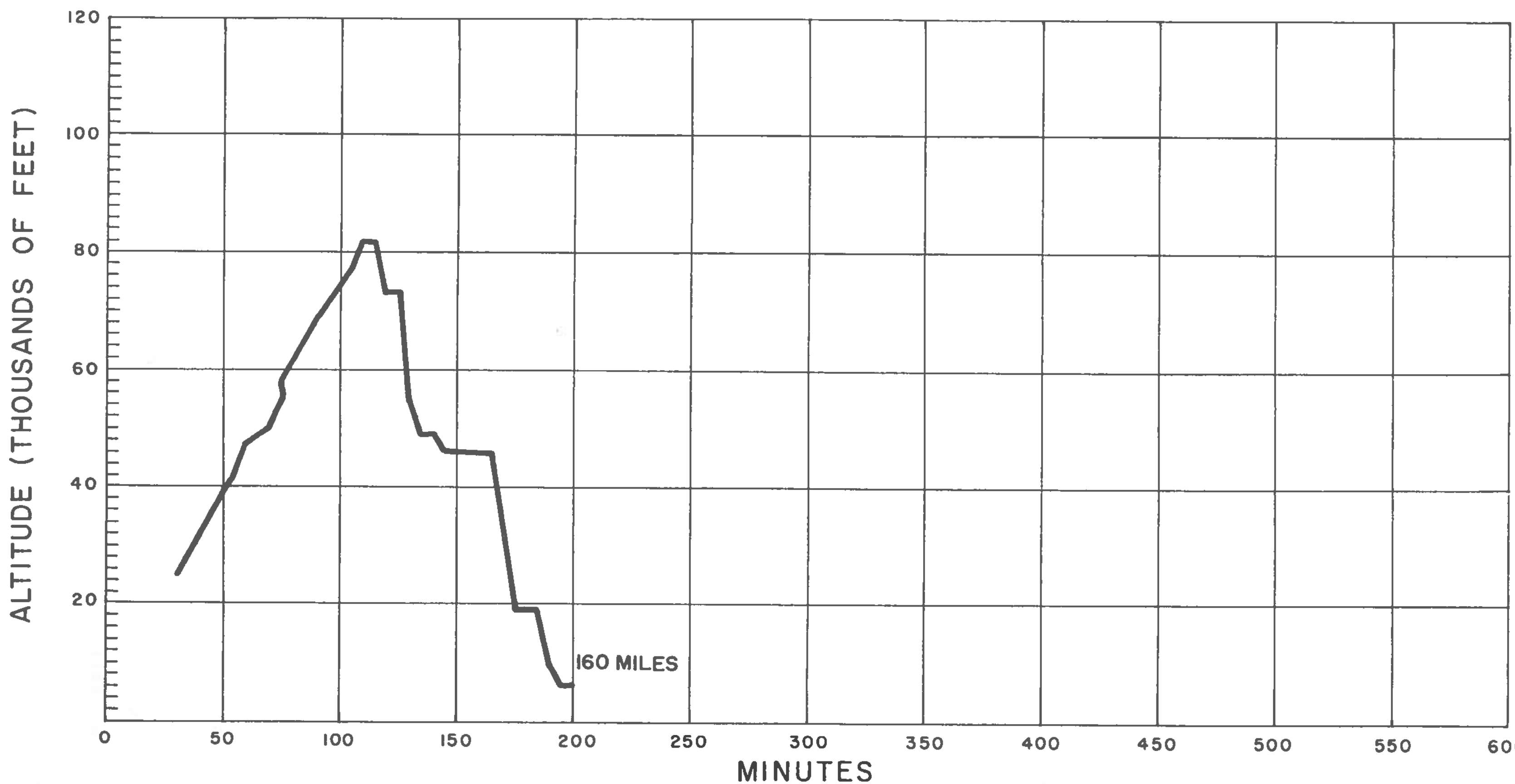

FIG. 38, BALLOON No. 39

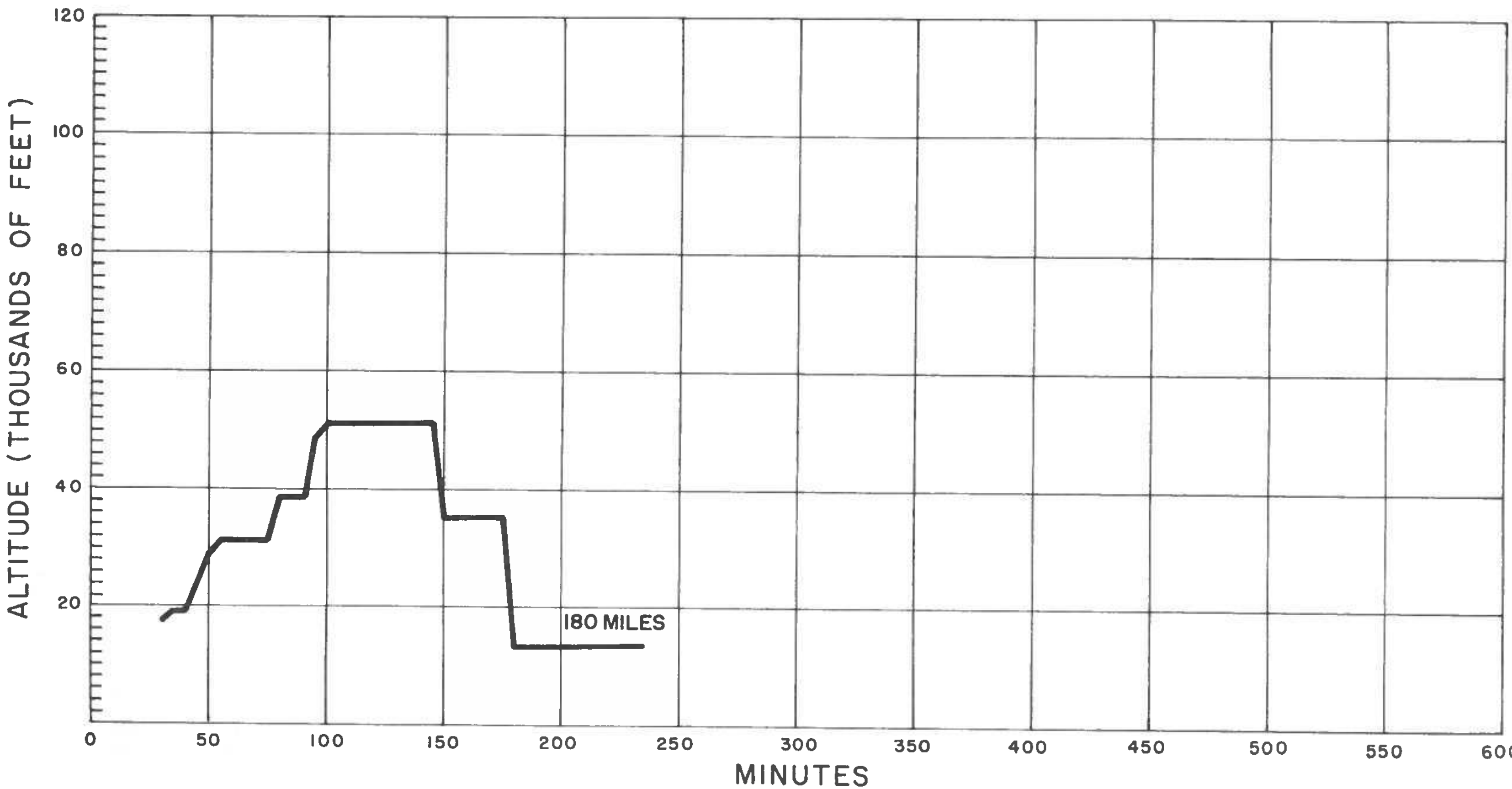

FIG. 39, BALLOON No. 40

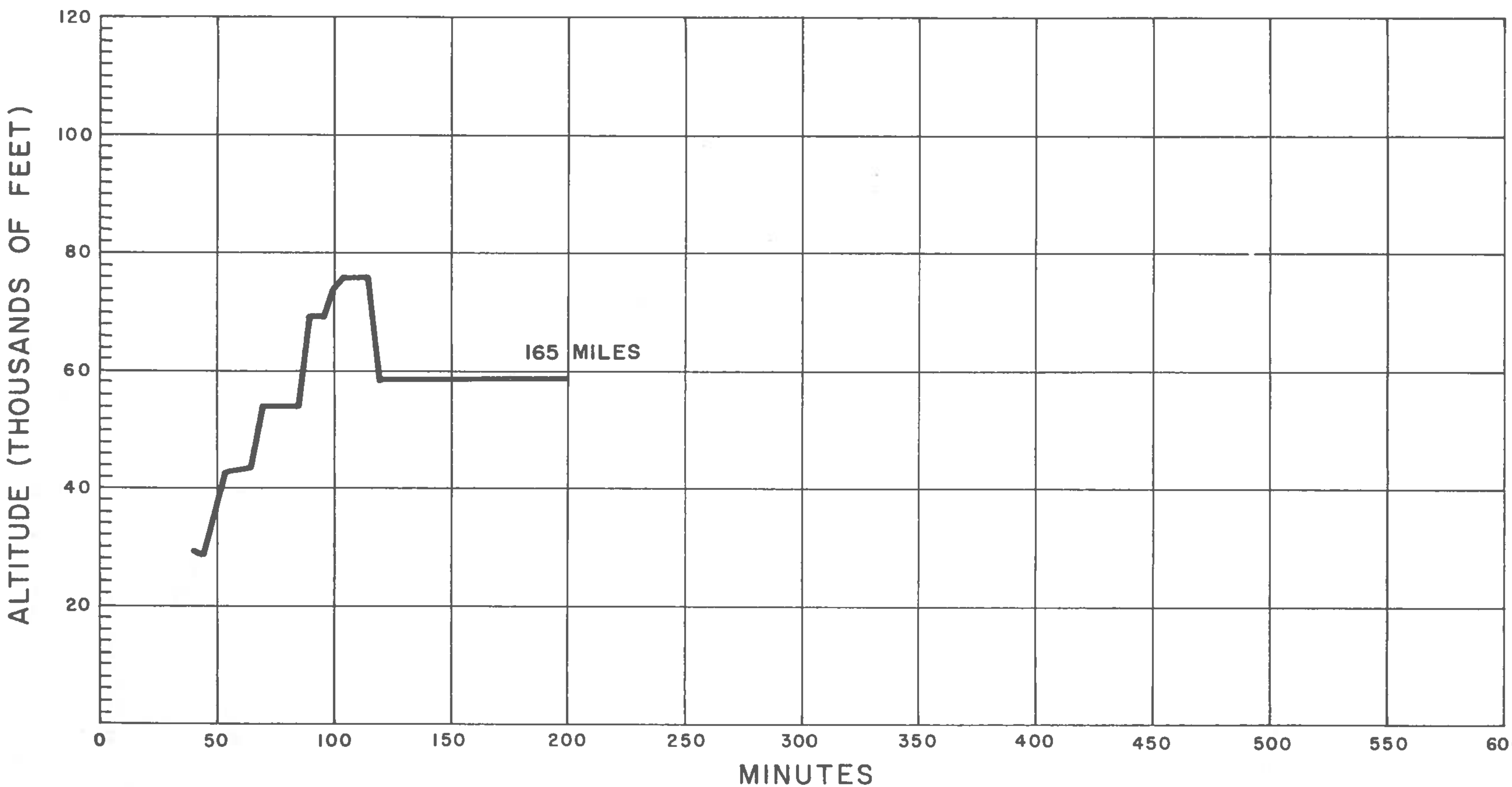

FIG. 40, BALLOON No. 41

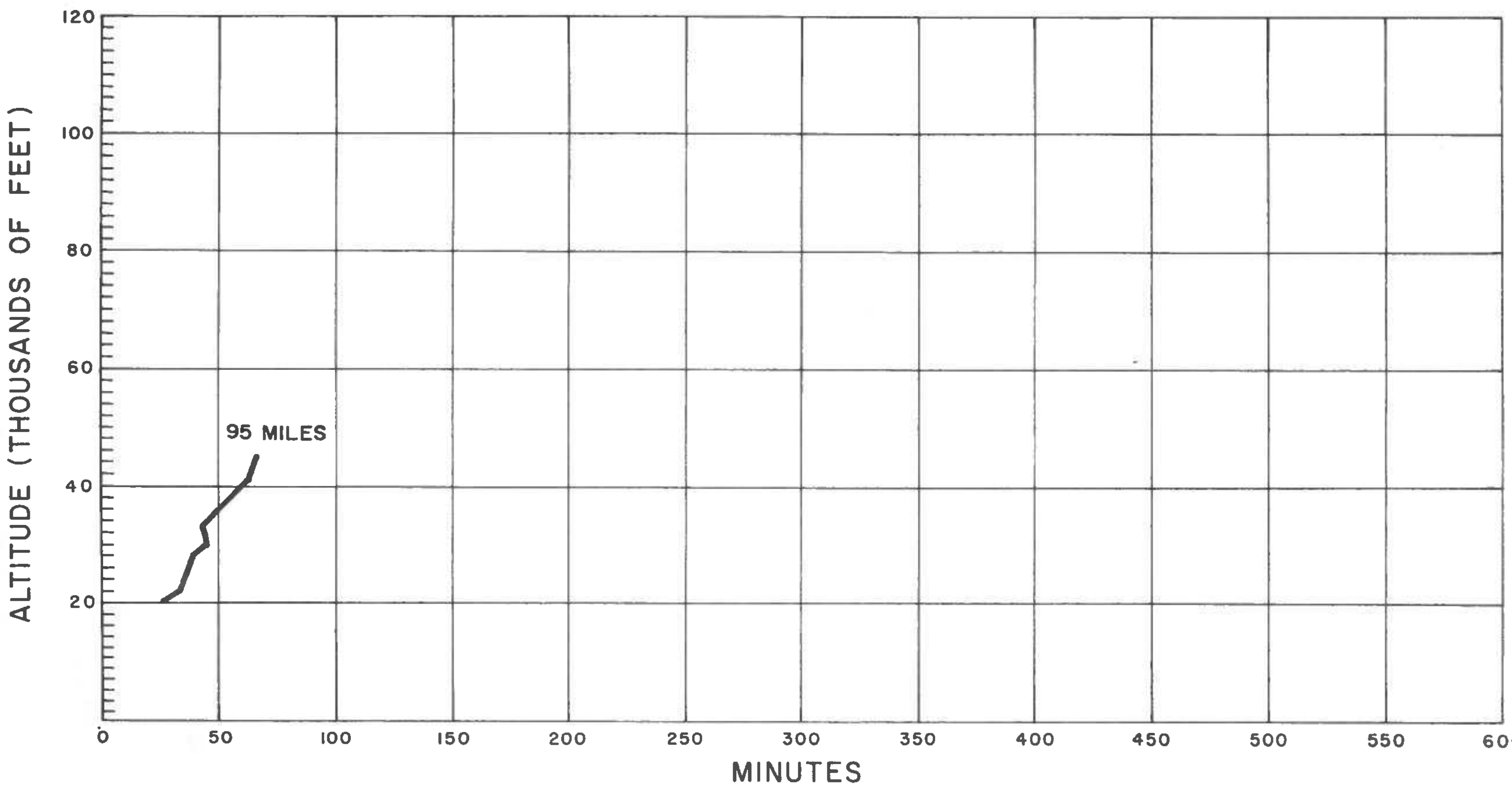

FIG. 41, BALLOON No. 42

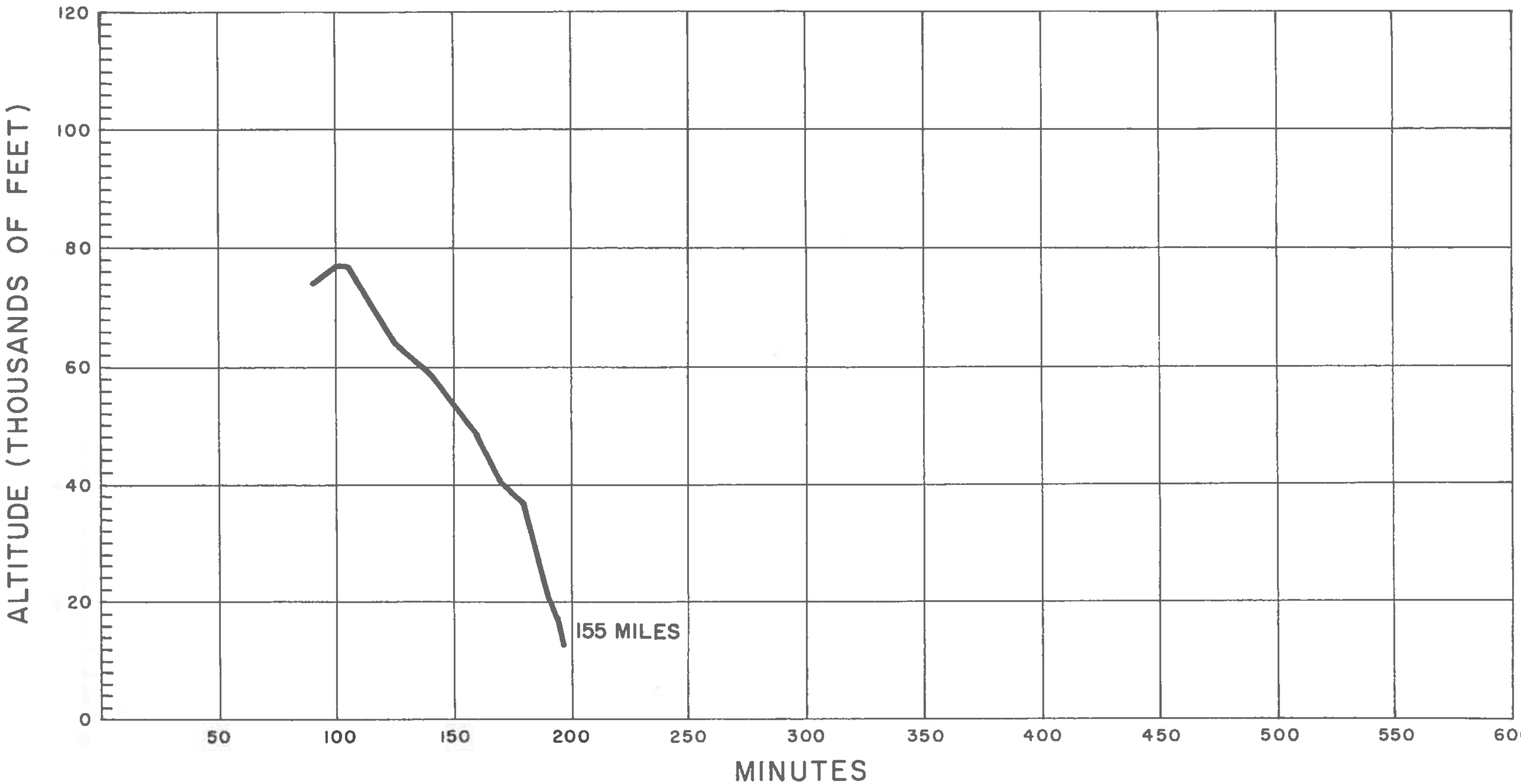

FIG. 42, BALLOON No. 43

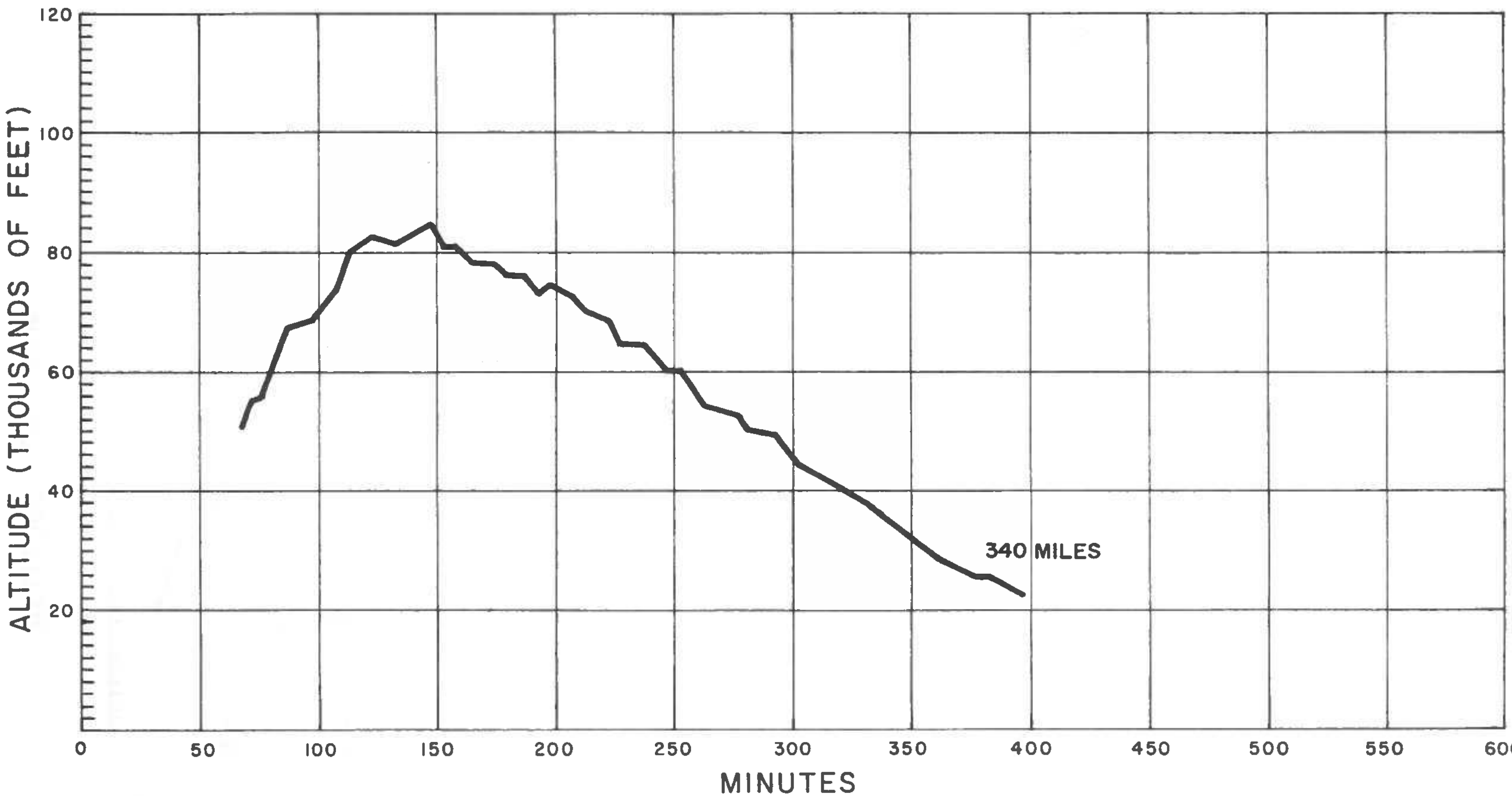

FIG. 43, BALLOON No. 44

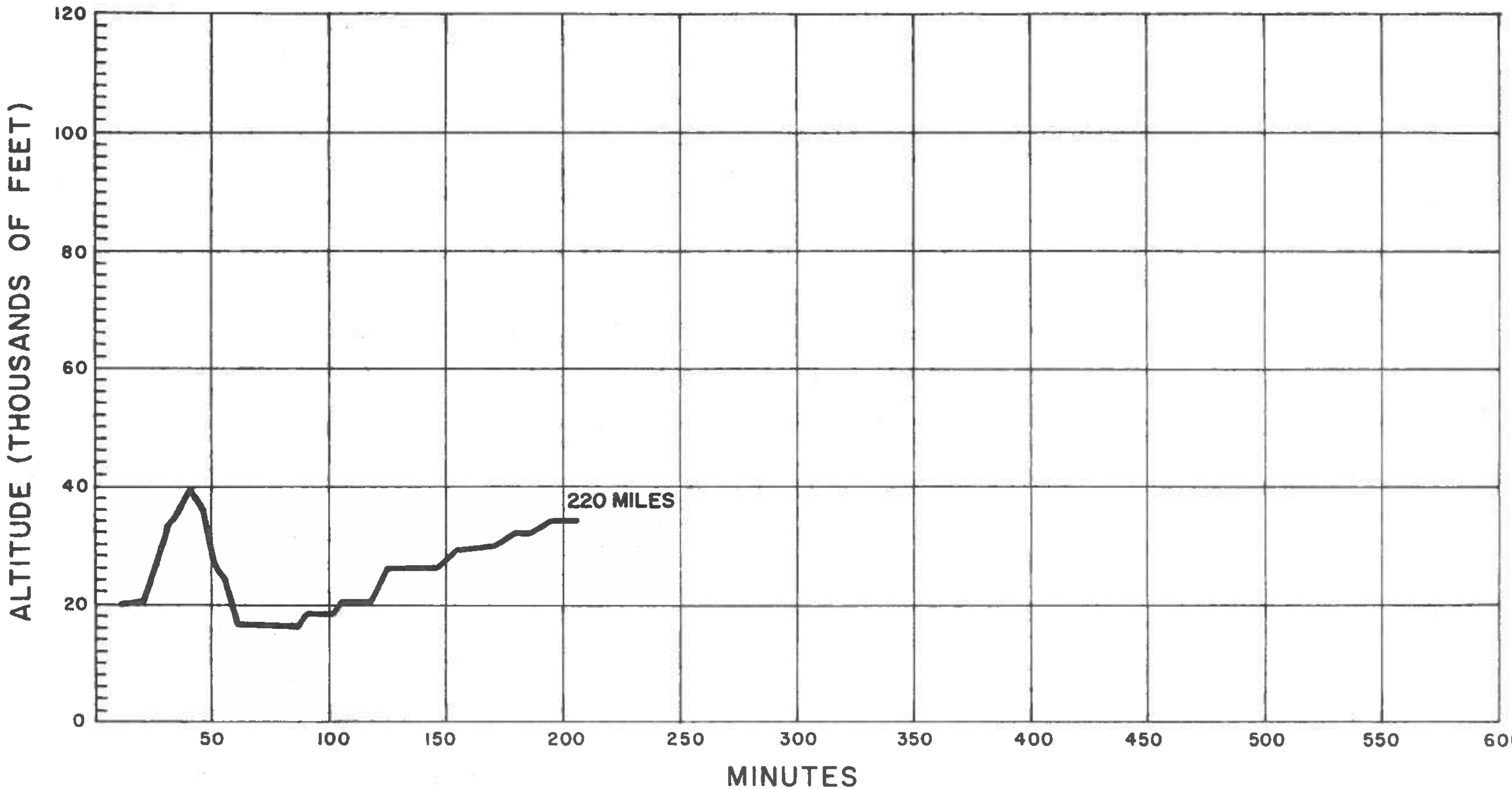

FIG. 44, BALLOON No. 45