To: [redacted] March 7, 1958 25X1

From: [redacted]

Subject: Report on Meeting with [redacted] on February 4, 1958 - Informal Discussion of LTA Aerodynamic Considerations 25X1

SUMMARY

The concepts proposed [redacted] in Proposal 11510-B for powered plastic balloons were discussed with the [redacted] people in an informal table discussion. Because of the rather radical departure from the existing blimp technology and because of the possible startling gains in performance which would be possible, [redacted] felt it would be well to have an interchange of thoughts and opinions between [redacted] The meeting would give [redacted] a chance to ask questions regarding present and planned airship programs and airship requirements. The meeting would also allow [redacted] to discuss accomplishments in the free and captive plastic balloon field and to discuss pertinent parts of the design problem, including materials, fabrication techniques, performance capabilities, power plants, control techniques, configuration, etc. 25X1 25X1 25X1 25X1 25X1

BuAer's interest appeared principally in two areas:

(1) To increase airship speed to 90-95 knots

(2) 20,000 ft altitude capability for an AEW ship.

It was pointed out how the boundary layer concept of aerodynamics allows an insight into the mechanism of air flow about airships and considerable gain in both speed and duration will be possible through the use of flow separation prevention techniques. To achieve these gains, an aerodynamic research program such as the one proposed is necessary. [redacted] experience would indicate the feasibility of the plastic material in increasing the altitude capability and for carrying the loads, but the weathering qualities of the material are not known now and need to be investigated. 25X1

BuAer acknowledged that the program as presented for the first year appeared technically feasible; the funding for the program is to be done by ONR and should be expanded to include materials research.

I. Participants

[redacted] 25X1

[redacted] 25X1

[redacted] 25X1

II. Introduction

The introduction was made by [redacted] on the purpose of the meeting, and he was most generous in telling about the company capabilities as well as the historical and current association of the [redacted] people (present at the meeting) with the stratosphere balloon programs. 25X1 25X1

He then presented [redacted] who first outlined and then went into greater detail on why we have submitted proposals for powered lighter-than-aircraft, what our experience has been in the this area, what we hope to accomplish by our suggested program; and, finally, he solicited guidance from the [redacted] airship people on what they felt would be the future trend in LTA programs and whether what we have proposed and would present (at the meeting)actually made sense. 25X1 25X1

He acknowledged that we were experienced mainly in free balloons which, however, were capable of carrying tremendous loads to extreme altitudes. We have extended the principles learned here to captive balloons, which are also capable of carrying considerable loads to lower altitudes (in the order of 5,000 ft), however, capable of withstanding winds of fairly high velocity (in the order of 50 knots). We have, in a logical extension of free balloon work, made a low cost study [redacted] in which the feasibility and application of powered plastic balloons were considered. The approach taken was a fundamental one, at the recommendation of the sponsor and with the concurrence of the project people. As a result of this study, and of additional later work, it appears that the powering of a plastic balloon is feasible and that, by a rather modest program, a significant break-through could be made in the LTA concept. 25X1

For example, by the use of boundary layer control (here defined as the prevention of flow separation and the extension of the laminar region), it will be possible to reduce the fineness ratio from the 4.17:1 to a much lower ratio, perhaps 1.5:1. In so doing, the volume to weight ratio is improved and the configuration is such that it will be less cross wind dependent.

The problem of flow separation will be solved by suction, ring stabilization and stern propulsion. Combining the ring stabilizer with the propeller would, in effect, be a ducted propeller with increased efficiency. Since the static thrust of a ducted propeller is almost double that of an unshrouded propeller, low speed controllability would be greatly improved. Then, combined with the use of the more efficient materials now available, the size ship required for a given task is greatly reduced and performance is appreciably improved.

These, then, were the concepts upon which our proposals were based.

Since we had the background experience as noted earlier, and since we had the company support, capable people in the necessary fields of interest (materials research, manufacturing, quality control, government inspection and specifications, structures, aerodynamics and field operations), we felt it would not be out of order to suggest changes in the state of the art, changes with definite advantages and based on sound fundamental principles. However, since [redacted] 25X1
has the experience in LTA and would be a possible future user, we wanted to ask [redacted] Do these ideas make sense? Or, conversely, what i[redacted] looking 25X1
for in an airship?

[redacted] was the spokesman for the [redacted] group and indicated that the 25X1
position of the LTA field was as follows: For some years the question of high altitude capability has been the subject of [redacted] discussions. As long as the 25X1
main objectives have been in the ASW area, a requirement for low altitude capability only has existed. However, now, when AEW work is being considered, the altitude limitations of present LTA is a real problem. Other people in the Navy might have requirements for extreme altitudes; however, he did not now have such a requirement - but he could immediately use a LTA having a 20,000 ft altitude capability.

Such a LTA should have certain capabilities, especially insofar as wind capabilities are concerned. For example, present blimps have a 60 knot limitation on speed - and many times winds of 50 knots are encountered over the ocean. A new airship should have a 90 knot capability, since speed and maneuverability are especially critical in ASW warfare. At the present time, the ZPG-2 airship is a good ASW vehicle and there is no need for the development of a new one. [redacted] substantiated the remarks made by [redacted] and added some remarks 25X1
about the present altitude capabilities (which are rather low).

[redacted] made some comments on a long range wind tunnel program to study 25X1
the blimp aerodynamics, as well as a continuing program on the study of new fabrics and design techniques. The ASW airship should include many of the improvements resulting from these programs. The mounting of the engine on the fins, stern or in the wake has been studied - the stern mounting scheme, in addition to aerodynamic advantages, offers the distinct advantage of physical separation from the instrumentation (important in sonar problems).

[redacted] discussed the "Aerocap" captive balloon capabilities and sizes. 25X1
The present sizes being designed are up to 40 ft length (134,000 ft^3), with

a lifting capability of 5,000 lb to 2,000 ft above the surface. The above balloon is being developed on an AEC program and will be delivered in May. The load capability will be extended to 20,000 lb, with first deliveries to be made by the end of the year.

The concepts in these captive balloons will be to utilize the plastic materials to their best advantage. Because of this efficient use of material, the size of balloon required will be smaller (and therefore more economical); and, because of the above, the weight of the balloon system will be reduced conservatively by a factor of 2 or 3 over standard construction methods.

Pneumatic (inflated) fins will be used for heading control, since these balloons are unpowered; however, it is felt that the principles shown can be extended to powered airships.

[redacted] discussed in some detail the various aspects of power require- 25X1
ments for the powered balloons, including some comments on the discrepancy between the theoretical and the actual requirements (the latter being much greater than predicted). In considering possible means for reducing the power requirements, the work of Prandtl, and the later compilation of Schlicting, on boundary layer control is valid (and among the better reference sources).

These references conclude that blunt bodies (vs. pointed, streamlined bodies) are not necessarily disadvantageous as long as the flow along the body is controlled. The greatest drag occurs when the flow separates from the after body (imparting unrecoverable turbulent energy to the wake); thus, if this is prevented, the drag will result mainly from the surface friction. Then, since a blunt body has less surface area than a streamlined body, there is an additional reduction in drag. Also, a properly designed stern propeller can recover a portion of the longitudinal wake energy caused by skin friction. Keeping the flow entirely laminar would be highly desirable but probably not attainable; however, any gain in area of laminar flow would be an advantage over the existing situation, and the proposed "fatter" body has a much larger favorable pressure gradient than a streamlined body in its forward regions.

Present airships use about a 4.17:1 fineness ratio, which has apparently proven satisfactory; but, for the design proposed, the fineness ratio would be somewhere between the present fineness ratio and a sphere. The design would depend on the results of the investigation, but it would include the results of the study of the aerodynamics, structures, propulsion and control.

The aerodynamic problems would be attacked in full scale (tethered) balloons through the measurement of boundary layer profiles. It is felt that the extrapolation of data from small scale wind tunnel models will not give the quantitative data necessary (mainly because tunnel turbulence masks the phenomena being investigated). The similarity concepts of Reynolds number have to be very carefully considered. For example, in consideration of the equation $R_N = \frac{\rho VL}{\mu}$, the L term, if considered as a diameter, is no longer appropriate. The momentum thickness, θ, or the displacement thickness, δ, should be used (Prof. Hazen suggests that it be based on the length of run).

Maintenance of laminar flow along the forward body will be improved because of the favorable pressure gradient. Turbulent separation will be prevented by stern propellers, ring tails, and/or boundary layer suction and will be the major gain.

The structure considered will consider plastic materials of types shown most suitable. The support of the engine in a stern mounting is shown possible from the consideration of the equation for a pneumatic beam, $F = \frac{\Delta P R^3}{2L}$. A considerable advantage is gained through the use of a low fineness ratio, since the influence of the radius of the base of the beam (R) varies as the cube and, inversely, as the length of the beam (L).

A stern drive is being considered using a ducted propeller. The propeller assembly would be moveable or the flow deflected to provide the control, thus the fins would be eliminated. Such a scheme would provide a means of abetting the flow maintenance and would provide a positive control without having fins extending beyond the diameter of the blimp. The reduced exposed area would then make the gust loadings less, and low speed controllability would be greatly improved.

Mayer asked whether an inflated ring (propeller duct) had been considered. The answer given was that it had been considered but that it is believed to be less clean aerodynamically in an area where the aerodynamics are very important.

A question on whether we considered the limiting R_N for laminar flow as critical was answered to the affirmative. Some work at the David Taylor Model Basin on 18 inch diameter sphere in both water tank and wind tunnel has shown a correlation with the work of Fage. This work shows the stability occurring up to R_N of 6 million; the airship we propose would have a R_N of 16 million (based on ship length).

Hollenberg questioned the length of laminar flow. He said that laminar flows have been maintained to R_N of 6-8 million but that the airship industry (with all their experience) has been unable to extend the laminar flow beyond this. Any irregularity in the surface trips the flow, including dust particles, but it is especially sensitive to waviness.

Froehlich agreed that this was true, but bodies with the very strong favorable pressure gradients have not heretofore been investigated at large body Reynolds numbers. Theory indicates that the area of laminar flow is larger for bodies with very strong favorable pressure gradients (ref. Schlicting, p. 344).

[redacted] noted that various types of boundary layer control could be used, including suction, venting, ejection of flow, etc. 25X1

[redacted] pointed out that the program (which studied the feasibility) had been mainly concerned with the progress made in the last 10 years in free balloons and how the knowledge gained might be utilized for a vehicle having greater maneuvering (powered) capability. The study had looked at the fundamental problems which would have to be solved to arrive at an optimum vehicle. Since a study of the boundary layer profile would be a necessary part of the investigation, it appears that the captive type balloon would give meaningful data if it were high enough to get above the earth's boundary layer or ground effect. Possibly, a better technique would be one of selecting a calm day and towing the balloon through an essentially calm atmosphere. [redacted] has made full scale flight boundary layer profile measurements on gliders. He has shown that atmospheric motion is essentially of a laminar nature, as compared to wind tunnels where the motion is turbulent to varying degrees. Since the nature of the air has a large influence on the growth of the boundary layer, it is essential that tests be conducted in as near a laminar flow as possible. 25X1 25X1

[redacted] talked about the work done by the Bureau of Aeronautics in making wake surveys (using a pitot rake) of the NACA work on profile measurements, and of the current work of [redacted] on the full scale measurements of flow characteristics (using an operational blimp). He acknowledged that very little was known about the boundary layer (and boundary layer control) on bodies of this size and that much remained to be done. 25X1 25X1

[redacted] then discussed the very high altitude powered balloons, in which a limited amount of lateral control might be used to maintain position, traverse a latitude line, or maintain a flight vector different from the free wind. If one considers what might be done today, utilizing only available (and proven equipment), a modest capability appears possible. Considering, for example, electric propulsion with silver cell batteries as the source of power, a Class "C" shaped balloon (of the volumes noted) would give the performance shown in Figure 1. The battery weights were taken as 15% of the gross weight and the efficiencies of the component parts were taken as follows: electric motor, 75%; gearing, 95%; propeller, 75%. 25X1

An interesting attribute shown in this curve is the independence of the performance (shown) on the altitude. A drag coefficient of 0.05 was assumed. This value represents a conservative figure for conventional design with flow separation control.

Figure 2 shows a very interesting plot of the gross weight vs. the volume for various altitudes. By plotting the weight of a 2 mil balloon (as shown), the net weight carried can be immediately seen.

For the very modest speeds being considered, power requirements at the higher altitudes might be as low as 3-1/2 H.P. Because of the choice of electric power, intermittent operation is possible (and probably desirable).

Operationally, such a balloon might be associated with a ship. It could be packed into a small volume and then launched at the appropriate time. Wind effects could be negated by steaming downwind; and/or, a launching platform could be used in the same way free balloons are now launched.

In reply to a question from [redacted] the program envisioned by [redacted] 25X1
[redacted] was outlined into the two basic areas, as follows: 25X1

I. Aerodynamics of Airship

A. Theoretical:

Carry out the necessary theoretical work associated with laminar and turbulent boundary layers and solve the dynamic stability equations associated with the airship shapes under consideration.

B. Experimental:

Field verification, with full size models, of the theoretical work.

C. Document results in a report which will be applicable to future airship designs.

II. Altitude Expansion

Demonstrate the feasibility of propelled stratospheric vehicles with an electrically-propelled balloon of modest capability.

[redacted] then pointed out the need for continuing improvements - the Navy 25X1
needs the 1959 models now. He also pointed out some of the operational problems which they face - with the wind and the low altitude capabilities of the present blimps being the worst problems.

He then commented further that our present proposals appeared to break down into two main areas of endeavor: (1) a small blimp with stern propulsion and improved aerodynamic characteristics and (2) a very high altitude balloon having propulsion as an auxiliary feature for some mobility.

In answer to a question of definition of low altitude, he defined 7,000 ft as low altitude. [redacted] then said that he wanted an airship that would be 25X1
useful up to 20,000 ft. Therefore, as a definition of terms, 0-20,000 was

defined as the low altitude (which would be immediately useful to [redacted], 25X1
and above this would be the high altitude (which at this time would be mainly of academic interest). The 0-20,000 altitude would satisfy both ASW and AEW requirements at this time. [redacted] pointed out that, conservatively, a 25X1
2 to 4 time improvement in duration and reduction in drag is possible with the program suggested; and the performance required certainly appears feasible.

[redacted] asked what we proposed for materials which could give a blimp 25X1
which could be taken out of the hangar at 7°F into a 35 knot wind which slams it into the hangar without damaging the balloon.

[redacted] said that the low altitude balloons (0-20,000 ft) could utilize present 25X1
Mylar (stronger than the polyethylene films) but of thicker gauge. Also, a new "weatherable" Mylar, having a weathering life of at least a year, has been recently tested in Florida. An even more recent development is the Type "R" film which will have an expected life of 10 years. The schemes can also be used for increasing the weathering life. For example, metalizing surface treatment might yield an increase in weathering life by a factor of 4 or 5. Pigmenting would be another means for increasing the life. Other combinations of materials (i.e., Fortisan and Dacron) might be used to supplement properties. Whitnah showed samples of a "scrim" material, used in some of our work, which was made of Fortisan and polyethylene. The strength figures associated with this material agreed with the Goodyear work, according to Mr. Marcellino.

We have not used the Dow materials, since the early Saran materials were rather difficult to work with, requiring an oil surface coating to prevent "blocking", having a tendency for tears to propagate, and being very critical in being heat-sealed. We have not had contact with Dr. Grebe of the Styrofoam Division of Dow Chemical, who is reportedly interested in blimps.

[redacted] mentioned that we have had an active balloon materials research 25X1
program in progress for over two years. Since balloons pass through the troposphere, it was necessary to consider in great detal the effects of low temperature and that much of this research has concerned itself with this aspect.

[redacted] said that up to six years ago [redacted] was pretty much in the dark 25X1
on materials. However, with the program started then, they have learned much about the properties of materials and how they should be handled. For example, material crease (strength) was a problem which was investigated thoroughly, and which resulted in a MIL specification for the testing of materials generally and creases specifically. This specification covers the use of Dacron material, which fits into practical aircraft experience.

The present construction technique, using a multiplicity of panels seamed together, was admittedly a disadvantage; a technique which would eliminate the seams would be welcome. The reason for the use of multiple panels was somewhat hazy, but it appears to have been done for two reasons - the first, as a means for rip-stopping and, the second, for prevention of rotation of the blimp body. (Note: diagonal strength is important in bodies of high fineness ratio - this is one of the requirements we hope to reduce with our lower fineness ratios.)

With regard to life of the blimp materials, [redacted] pointed out that the present envelopes have been used as long as 8-10 years; certainly, 6 years is not too long. Ideally, the airships should be moored outside continuously - this is now being done [redacted] but not at [redacted] (where there are adequate hangaring facilities). [redacted] pointed out that the life is a rough function of fatigue characteristics of the material rather than the weathering characteristics. 25X1 25X1 25X1

[redacted] showed some curves on the relative sizes of a balloon of 1.5:1 ratio (Figure 3) as compared to 4.17:1 for equal volumes. The comparison was quite striking - the probable ease of maneuvering, especially in and out of hangars, was obvious. [redacted] mentioned that we had given some thought to the design of a small airship to be used in conjunction with the submarine hunter-killer mission of aircraft carriers. He stated that several ships could be carried deflated in crates aboard a ship. Rapid inflation equipment could be designed to reduce operational difficulties, and the proposed shorter shape in a size of 50,000 cu ft should not be difficult to handle. Perhaps the stern propulsion unit, along with a gondola, could be attached to a gas bag considered to be more or less expendable. 25X1 25X1

[redacted] personnel mentioned that inflation in 30-40 knot wind would be necessary, along with a 95 knot speed and a duration of 15-18 hours. Helicopters are now liked because of their readiness factors, but they do have noise, fatigue, and vibration problems. Helium storage aboard ships is a difficult problem to cope with. 25X1

The program we suggested was rather light on the materials aspects; Capt. [redacted] suggested that the program we outlined was good but that it should include more on the study of materials. Also, he suggested that the first program be completed and reviewed before getting into the development models to assure that the gains will be worthwhile. 25X1

[redacted] asked a question about the objectives of the program we proposed. These were listed as follows: 25X1

1. Payload - 400 lb
2. Altitude - 7,000 ft
3. Free ballooning capability - 2 hours
4. Cruise range - 100 miles (at Vmax)
5. Vmax - 50 knots
6. Operational capabilities - field inflatable in 15 knot wind; volume approximately 25,000 cu ft.

It was pointed out that this was a specific task requiring modest performance. Therefore, it does not give a true picture of the capabilities possible with a plastic balloon utilizing the advanced techniques.

[redacted] pointed out that there has been disinterest in vehicles at high altitudes if they have slow velocities since, as a correlarly, their maneuverability would be low. He did comment on the difficulties of enemy counter actions above the 40,000 ft altitudes. 25X1

[redacted] mentioned that a solar powered stratospheric ship would be an eventual goal to aim for and that three conditions were in favor of such a development: 25X1

1. Large areas for the collection of the sun's energy were available

2. At stratospheric heights there would be a minimum of weather to content with; studies indicate that winds are light in the 60,000-80,000 ft altitude

3. Decreased temperature and increased radiation allow a solar battery to operate much more efficiently; (Demorest has flown a solar battery on a stratospheric balloon to demonstrate this effect).

A logical first step in this direction would be the carrying out of the program entitled "Electrically Propelled Balloon", as previously described. Research on the use of solar energy for this purpose should be initiated.

Ultimately large airships, perhaps carrying infrared detection equipment on an operational basis could be designed. A study was made of the horsepower required to maintain a station in the Mediterranean area during the months of July and January for a family of airship sizes from 10,000 lb gross weight to 50,000 lb gross weight. January is expected to be the worst month and July the best. Figures 4, 5 and 6 indicate optimum altitudes and the following maximum power requirements for the family of sizes considered:

	Optimum Altitude	Maximum Power Requirement Range
July	60,000 ft	60 - 190 H.P.
January	75,000 ft	60 - 360 H.P.

It was questioned whether [redacted] could construct a balloon as described within a year, and it was pointed out that the techniques used in plastic balloon work differed from the standard blimp construction techniques and the ability to move fast was one of the desirable features. Also, it was pointed out 25X1 that, from the cost standpoint, the technique [redacted] uses permits economical construction from temporary and easily changed tooling. 25X1

The meeting was adjourned, with general technical approval from [redacted] on the first year of the proposed program. Financial support of the program was to be discussed later by [redacted]. 25X1 25X1

In the afternoon session, the participants were:

[redacted] 25X1

The conversation was limited to engineering discussions, mainly on materials, design and fabrication techniques.

[redacted] personnel showed a chart of the weight-strength characteristics of materials, stating that the plastics appeared equal to coated synthetic cloths. Whitnah stated that a combination of nylon and polyethylene (7 oz nylon, 2 oz polyethylene) has a strength of 400 lb/in., a value much higher than those on the BuAer chart. 25X1

Sealing of plastic materials was discussed with regard to the different methods required for different plastics. Polyethylene, for example, is very easy to seal because it has a fairly large tolerance in the range of sealing temperatures; whereas, materials such as Saran are very touchy in this respect. Generally, there is a reduction in the strength at the heat seal because of the degradation (and loss of molecular alignment) due to the melting. Special methods are available whereby these effects are minimized by rapid heating and cooling while the films are physically held in juxta position.

Permeability or diffusion can be controlled through the use of a suitable film and through proper sealing techniques. The occurrence of holes in the film can be governed by the use of inspection techniques or, better yet, through the use of laminated films. As an aside, the leakage problems at altitude are less severe for the same hole area than at sea level because the mean free path of the molecules is longer and, consequently, fewer gas molecules escape from the balloon. This factor would certainly be important for long duration flights.

The heavy loads can be carried by balloons through the utilization of the "Natural Shape". This is the scheme promoted by Professor Upson, the University of Minnesota, and [redacted], in which the shape is so made 25X1 that the lateral stresses are minimized (theoretically going to zero) and all the loads are taken in the longitudinal direction.

Gust velocities of 30-35 ft/sec must be considered in the design.

Reference was made to a report by a [redacted] (formerly with Goodyear, now with North American Aviation) on the ballonet design. The designs considered in this report apparently were based strictly on the differential pressure between the gas and the atmosphere (say 3/4 in. of water); and they did not take into account the other perturbing factors which might be considered. Also, a factor of safety of about 2 or 3 was applied (by Goodyear) to assure complete safety. This apparently is a standard practice with Goodyear. 25X1

Since stresses and strains are a function of both the loading and the time, a means of establishing a working stress is to take the "quick-break" strength of the fabric as 100% and then working at the 25% level as a working stress. Actually, experience is at about 1/2 of the 25% level. For material testing purposes, Goodyear uses a cylinder of material approximately 10 inches in diameter, which is then inflated to failure.

The use of Dacron versus cotton materials was discussed. Recent tests were made on cylinders (made of the above materials) of approximately 4 ft diameter and 10 or 15 ft long for bending and torsional stresses. As a measure of the elongation, the cotton material (at 19% of the ultimate stress) had 1/3 of the elongation of the Dacron (at 17% of the ultimate stress). This was true on some 2,000 test cycles. At 20% of the ultimate stress, the elongations tend to become closer. [redacted] now has a program to get data at the 35% level; however, no results are yet available. They are expected to become available in about six months. 25X1

In answer to a question regarding the use of many individual segments of materials in the construction of present blimps, it was indicated that if they were all in the same direction it would give a twist to the balloon. The application is therefore not for rip-stop purposes. It was once proposed that a balloon be made of a single sleeve of material; however, a special loom would be required and this was not economically feasible.

The measurement of stresses in plastic structures are to be measured (in a current program at [redacted]) using a vibrating mass system to give material tension. 25X1

The penumatic beam technique can be used in the empennage of plastic balloons. The equation used to determine the strength of the cantilever beam is given as:

$$F\ell = K \Delta P \, W_B \, A_B \, \frac{y}{\ell}$$

where: the factor K is a function (of the tangent) of the angle of deflection, θ. This function shows a light decrease of K with increase in θ. W_B is the width of the base, A_B is the area of the base, and $\frac{y}{\ell}$ is the deflection term.

A Goodyear study on the wrinkling of balloons in flight showed that approximately 1-1/2 times the stress at the start of wrinkling is required to reach the ultimate (critical).

Mayer's earlier work in the blimp program apparently involves a study of the deflection equations, and he indicated that there was a gain in strength inversely as the 4/3's power of the fineness ratio.

The final discussion was on how we would control the balloon. The proposal was indefinite on this point and had therefore raised questions in the minds of the BuAer people. They were particularly interested in the mechanisms whereby we proposed to do the controlling and also on what our basic design criteria was. This, it was pointed out by [redacted] people, would come out of the study program. Several methods were mentioned, one of which will probably be used in the preliminary design.

Copies to: [redacted]

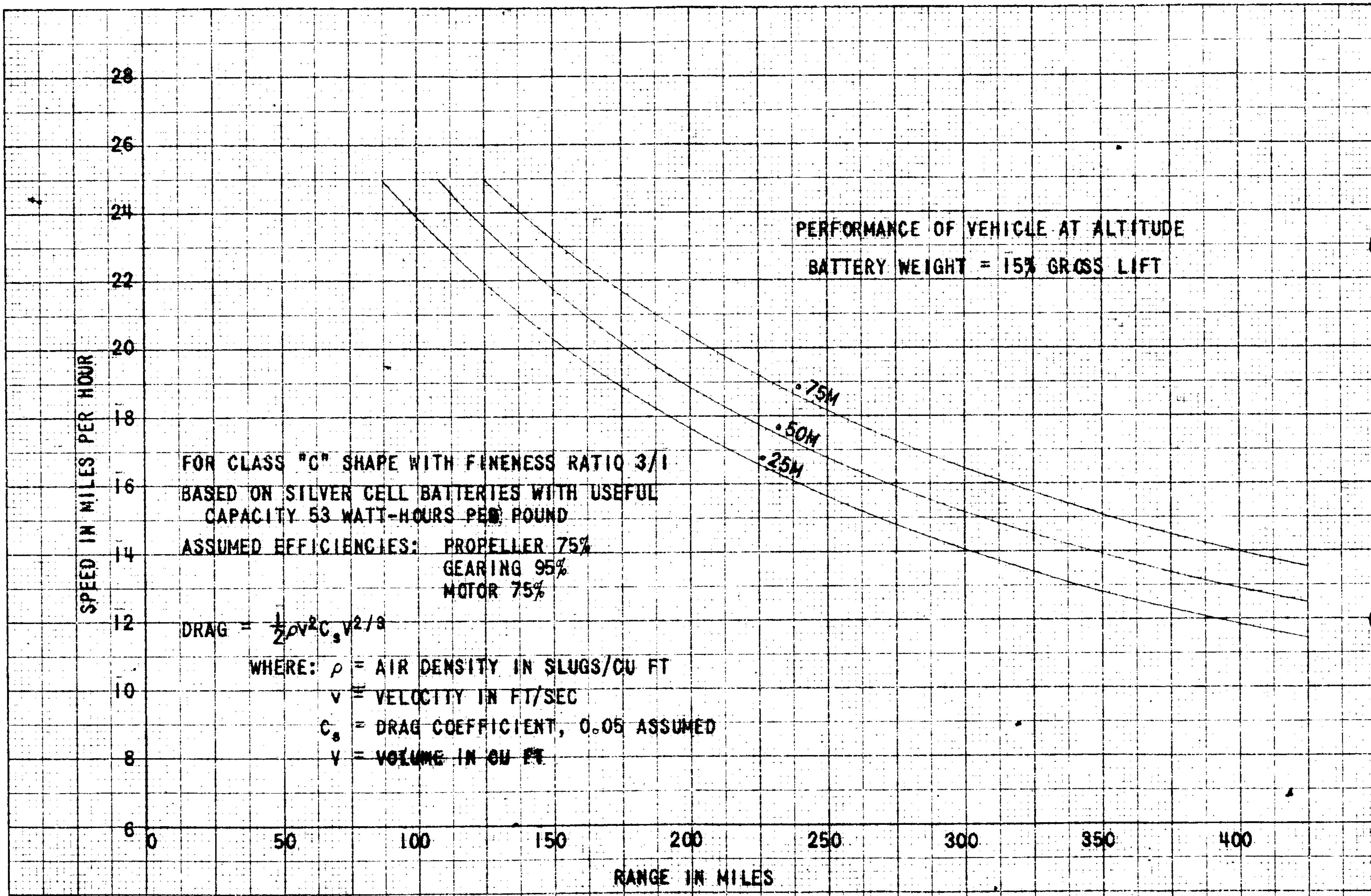

FIGURE 1

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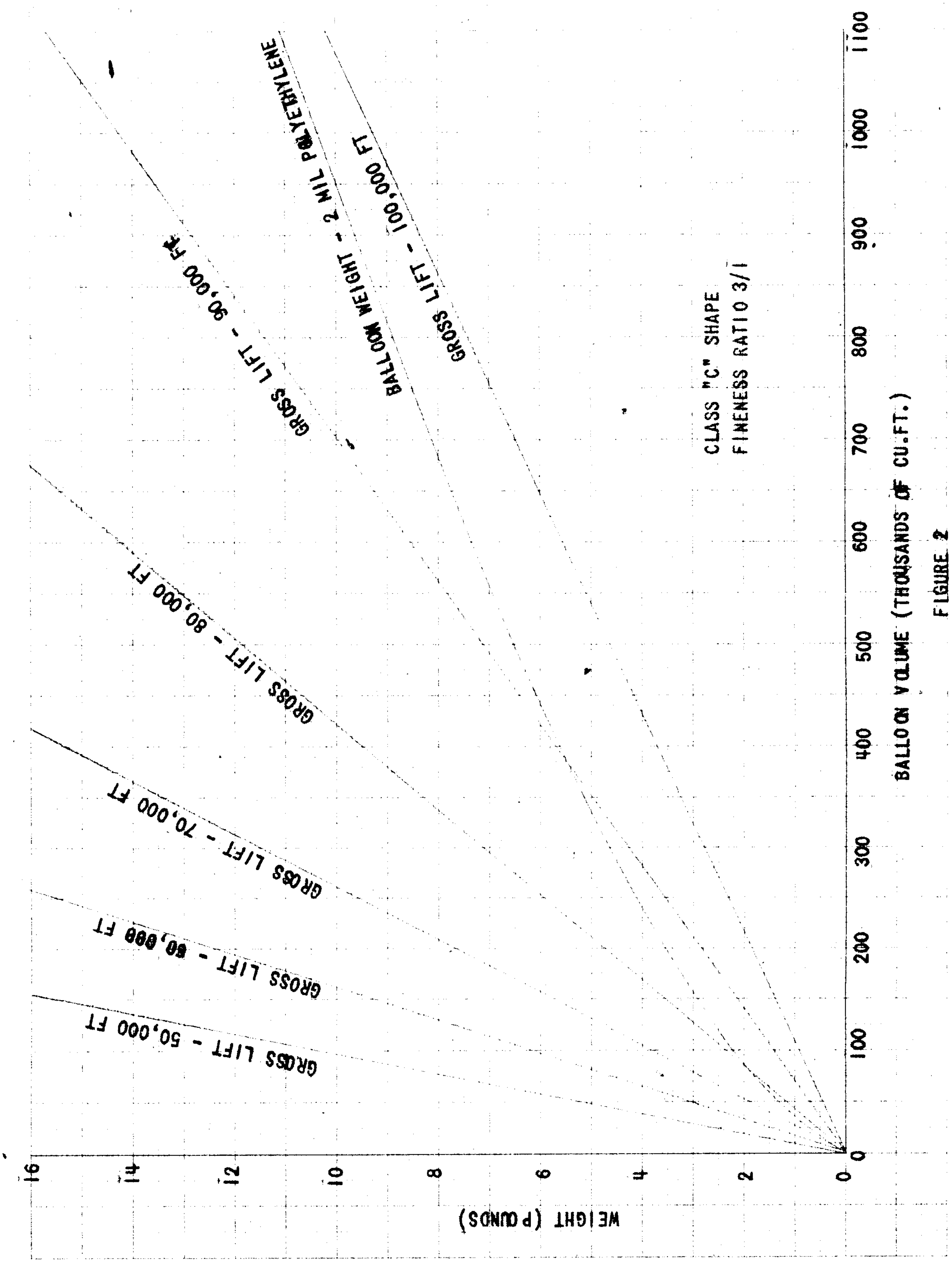
GROSS LIFT - 50,000 FT
GROSS LIFT - 60,000 FT
GROSS LIFT - 70,000 FT
GROSS LIFT - 80,000 FT
GROSS LIFT - 90,000 FT
BALLOON WEIGHT - 2 MIL POLYETHYLENE
GROSS LIFT - 100,000 FT
CLASS "C" SHAPE
FINENESS RATIO 3/1
WEIGHT (POUNDS)
0
2
4
6
8
10
12
14
16
BALLOON VOLUME (THOUSANDS OF CU.FT.)
0
100
200
300
400
500
600
700
800
900
1000
1100

FIGURE 2

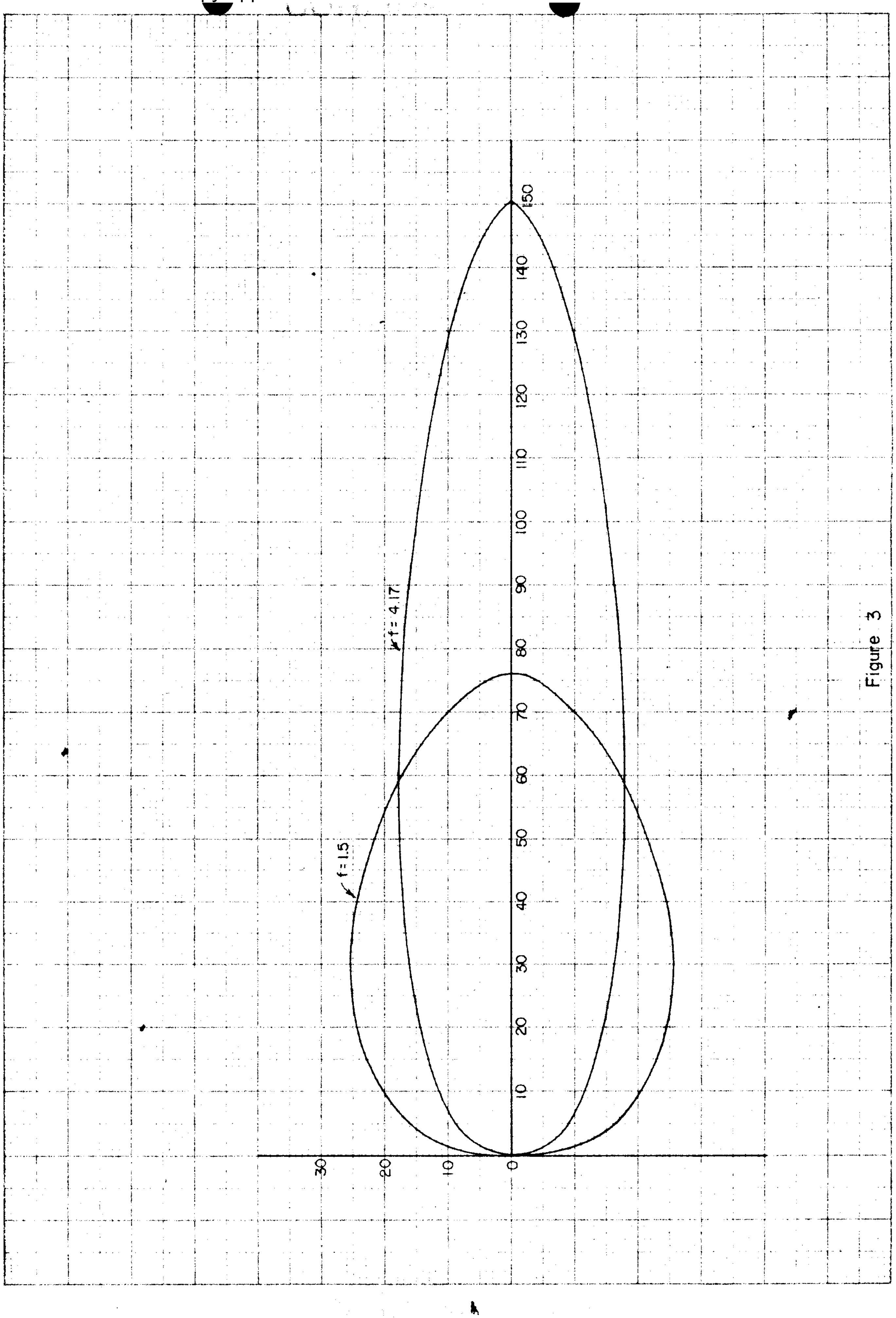

Figure 3

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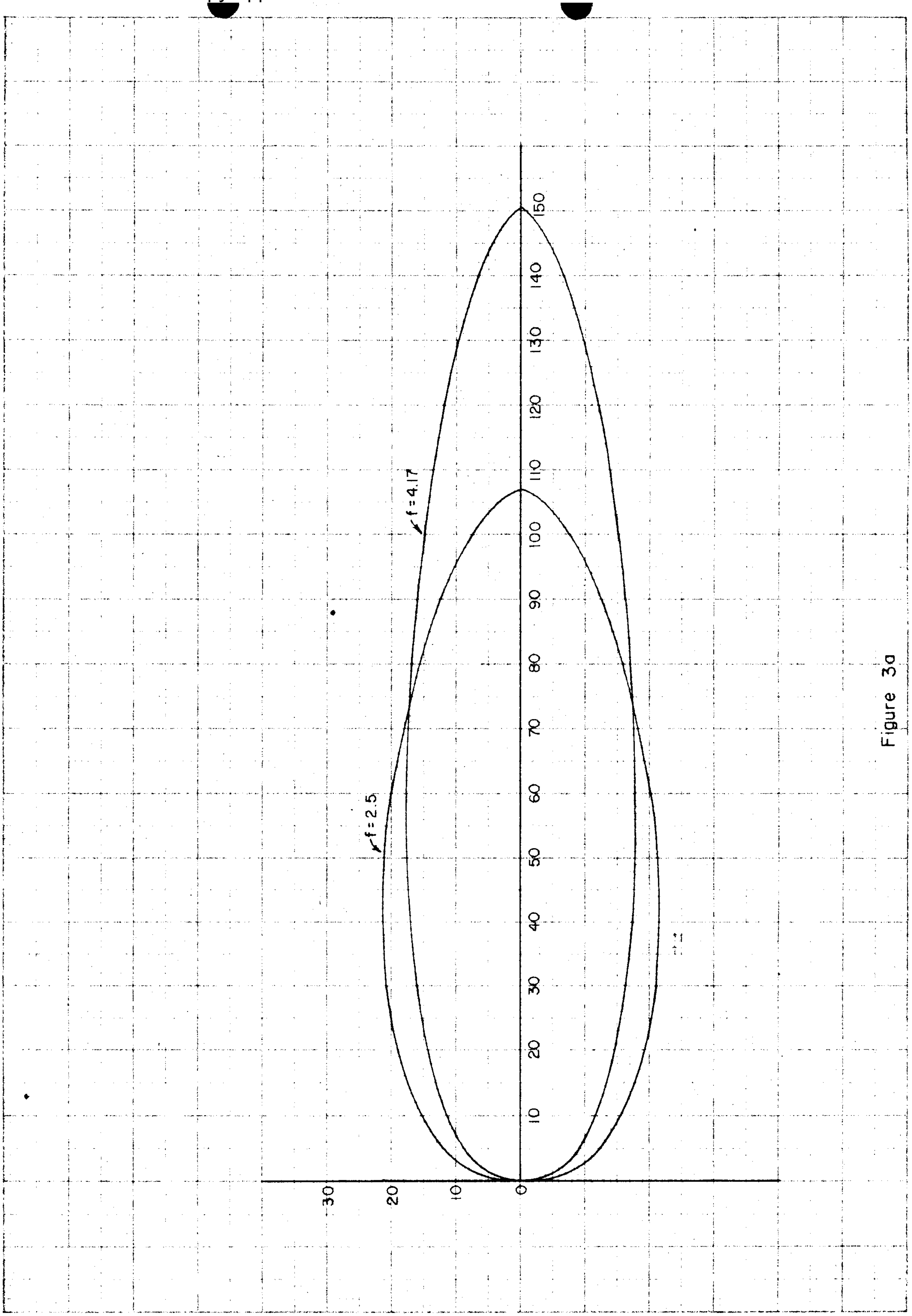
f = 4.17
f = 2.5
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
30
20
10
0

Figure 3a

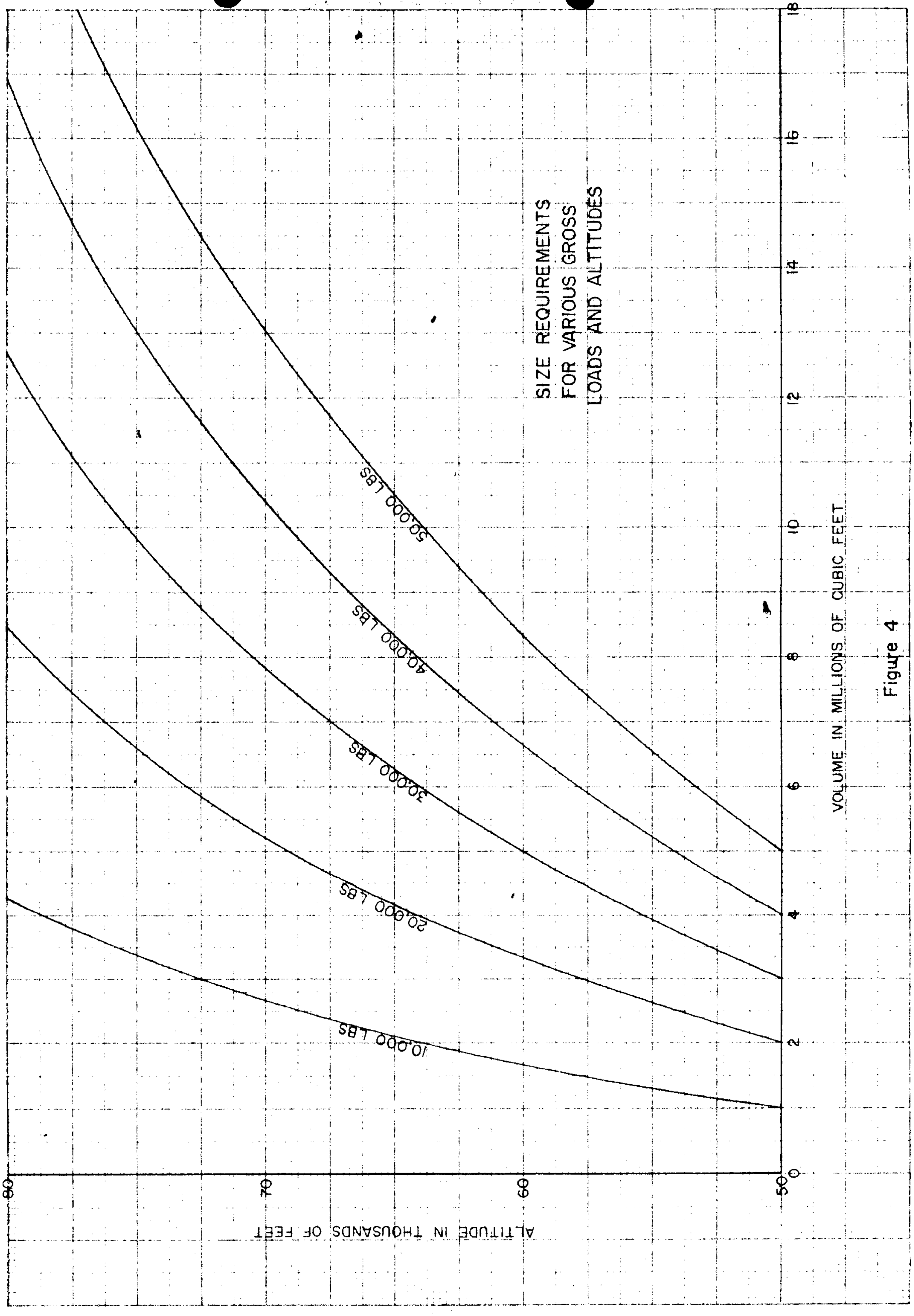
SIZE REQUIREMENTS
FOR VARIOUS GROSS
LOADS AND ALTITUDES
50,000 LBS
40,000 LBS
30,000 LBS
20,000 LBS
10,000 LBS
VOLUME IN MILLIONS OF CUBIC FEET
ALTITUDE IN THOUSANDS OF FEET
0
2
4
6
8
10
12
14
16
18
50
60
70
80

Figure 4

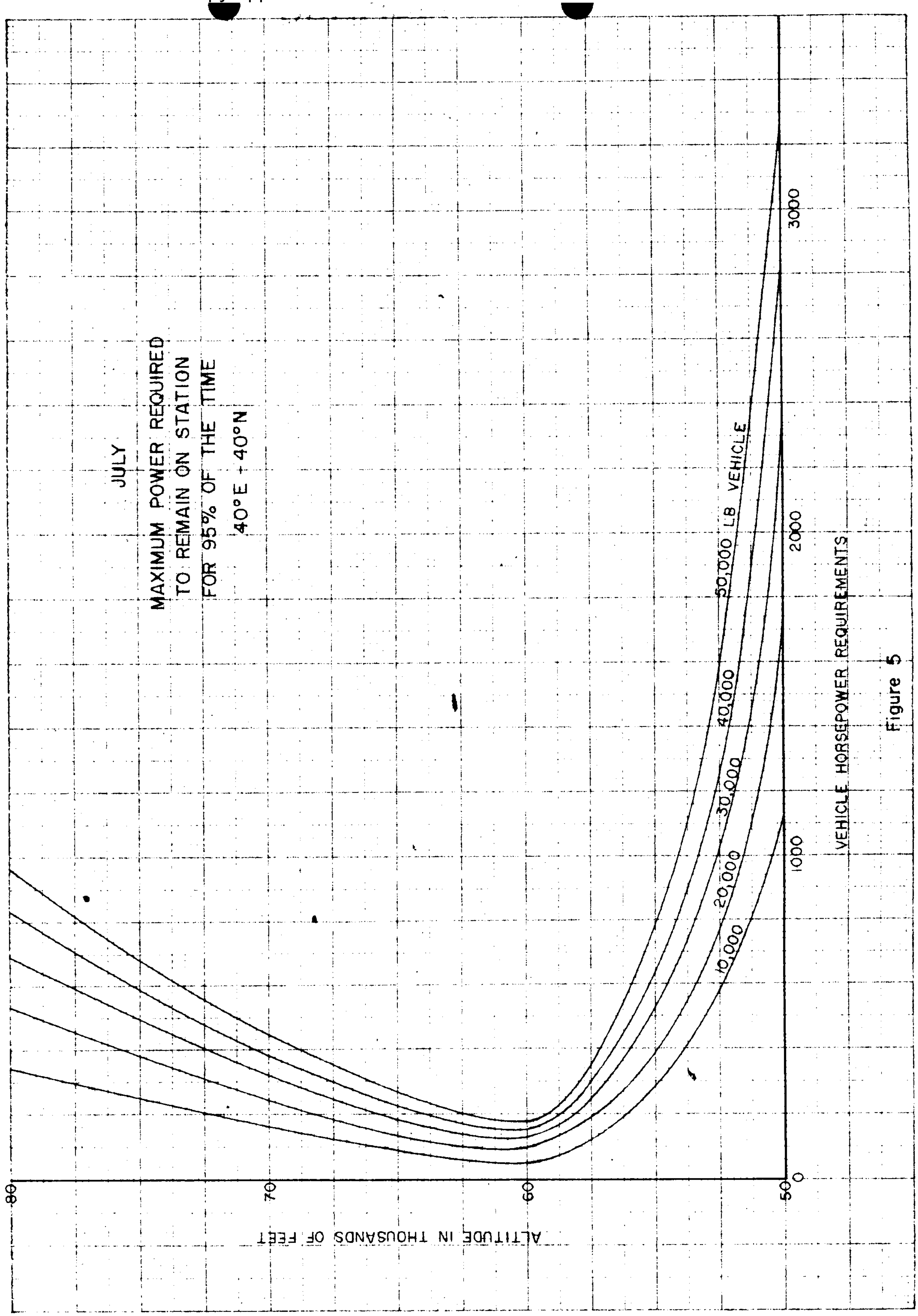
JULY
MAXIMUM POWER REQUIRED
TO REMAIN ON STATION
FOR 95% OF THE TIME
40°E - 40°N
50,000 LB VEHICLE
40,000
30,000
20,000
10,000
0
1000
2000
3000
VEHICLE HORSEPOWER REQUIREMENTS
80
70
60
50
ALTITUDE IN THOUSANDS OF FEET

Figure 5

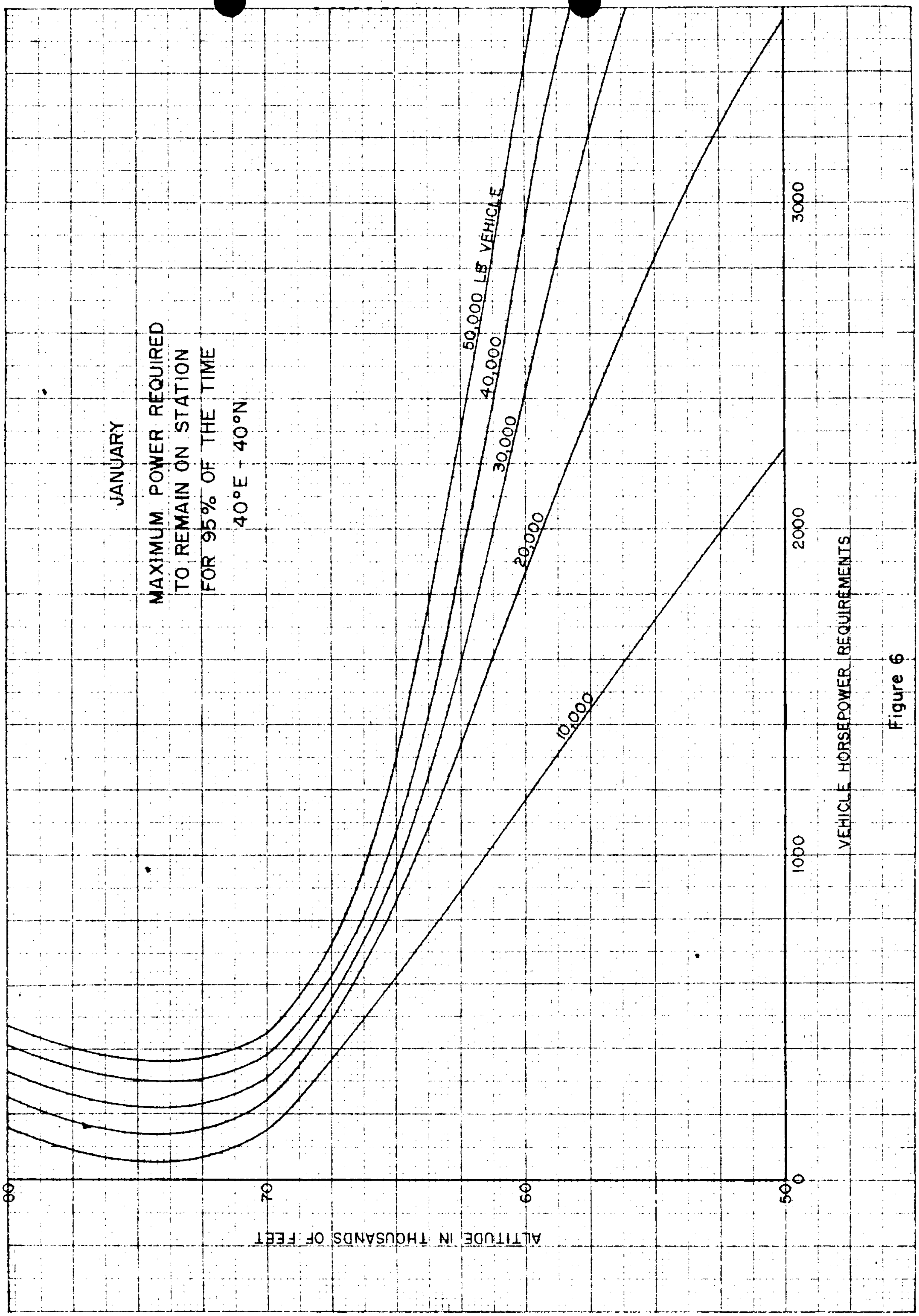
JANUARY
MAXIMUM POWER REQUIRED
TO REMAIN ON STATION
FOR 95% OF THE TIME
40°E - 40°N
50,000 LB VEHICLE
40,000
30,000
20,000
10,000
VEHICLE HORSEPOWER REQUIREMENTS
0
1000
2000
3000
ALTITUDE IN THOUSANDS OF FEET
80
70
60
50

Figure 6