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VISUAL REQUIREMENTS BASED ON MINIMUM OBSTACLE AVOIDANCE DISTANCE

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HAYES INTERNATIONAL CORPORATION
Missile and Space Support Division

For

NASA - GEORGE C. MARSHALL SPACE FLIGHT CENTER
Huntsville, Alabama

April 30, 1965

Technical Report H-MOL-32

VISUAL REQUIREMENTS BASED ON MINIMUM OBSTACLE AVOIDANCE DISTANCE

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ABSTRACT

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This report is the result of studies to determine the minimum time and distance necessary for a vehicle utilizing two-wheel Ackermann steering to assume a path perpendicular to the original direction of travel. This human factors study was performed in order to define the visual requirements of the operator of a lunar surface vehicle for adequate maneuvering capabilities.

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INTRODUCTION

This report is the result of studies to determine the minimum time and distance necessary for a vehicle utilizing two-wheel Ackermann steering geometry to assume a path perpendicular to the original direction of travel. This distance will be referred to in this report as the minimum obstacle avoidance distance (MOAD). This human factors study was performed in order to define the visual requirements of the operator of a lunar surface vehicle for adequate maneuvering capabilities.

DISCUSSION

Parameters affecting the minimum obstacle avoidance distance include wheelbase (B), rate of change of steering angle (ω), vehicle velocity (v), and the maximum angle the steering wheels may achieve with respect to the longitudinal vehicle axis (θ). In order to reduce the number of variables considered in this study, (θ) was fixed at 20°. This is compatible with previous studies of steering and stability considerations of lunar roving vehicles. The values of the remaining parameters considered were:

B = 85, 100, 115, 130 inches

ω = 4, 7, 10, 13 degrees/second

v = 4, 8, 12, 16 kilometers/hour

In preparing the analytical model of the vehicle path, it was assumed that true Ackermann steering existed thr ghout the vehicle velocity regime which was investigated (i.e., no eciable slip angles would be generated at any wheel), and that ve e velocity would remain constant throughout the maneuver. It is recognized that slip angles will exist at the wheels, particularly at higher velocities. For this reason, the MOAD may be greater with slip. However, since the magnitude of these slip angles will depend upon the coefficient of friction between the wheels and the lunar surface and upon wheel and suspension design as well as upon vehicle velocity, and because these factors, other than velocity, cannot be clearly defined at this time, it is assumed within this study that negligible slip angles exist.

Figures 1 through 4 are plots of the vehicle paths taken from the analog computer data with path plots of identical wheelbase presented with coincident origins to indicate the actual vehicle position and time relationships. Figures 5 through 8 indicate the relationship between the steering rate and the MOAD. It should be noted that this relationship is asymptotic as the MOAD approaches the vehicle minimum turning radius. Figures 9 through 12 indicate the relationship between the vehicle velocity and the MOAD. It can be seen from these figures that this relationship is linear and that the effect of wheel base variation is a constant.

CONCLUSIONS

Operator requirements for vehicle control will be greatly dependent on three factors inherent in the mobility system design. These are: wheelbase

(B), maximum steering angle (θ), and rate of change of steering angle (ω). Any study of the requirements for field of view, TV resolution and positioning or range must consider the relationship of these factors within the particular mobility concept. Within the range of values examined in this study, the rate of change of steering angle (ω) has the greatest effect on the minimum obstacle avoidance distance. If the lowest steering angle (4 degrees/sec) considered is eliminated as a design possibility, the MOAD variation within the remaining parameters drops to less than one half of its present figure. It therefore appears that for reduction in lag within the man-machine relationship, the steering rate should be greater than 4 degrees/second. In addition, although the MOAD decreases with increasing ω, since the relationship is asymptotic with respect to the minimum turning radius, high rates of ω may not be worthwhile due to extreme control sensitivity and increased structural and power requirements within the steering system.

For the values of the vehicle parameters under consideration here, the MOAD ranges from 6.9 to 20.5 meters. The visual range required under maximum conditions therefore would be approximately 21 to 25 meters to allow time for recognition and reaction by the operator.

Generalized minimum horizontal field-of-view requirements for operator vehicle control have not been fully determined. For operator confidence it would appear that the ability to see at least to the point where the vehicle will complete a turn 90° to the original direction would be of great benefit. For the variables under consideration here, it was found that this point ranged up to approximately 42 degrees from the origin of the turning action. There was surprisingly little angular variation within the ranges of ω and v under consideration, the greatest variation being approximately 14 degrees.

A vertical field of view which will include the minimum turning radius must allow approximately a 20 degree line-of-sight below horizontal.

This study indicates that vehicle wheelbase has little effect on the required horizontal or vertical fields of view.

From this study it can be seen that the visual requirements for control of a lunar surface vehicle are highly related to factors which may vary considerably with different vehicle design concepts. For this reason it is to be expected that locomotion simulation studies will be extremely beneficial in determining operator control and the optimum relationships between vehicle response, control sensitivity, and control method.

FIGURES

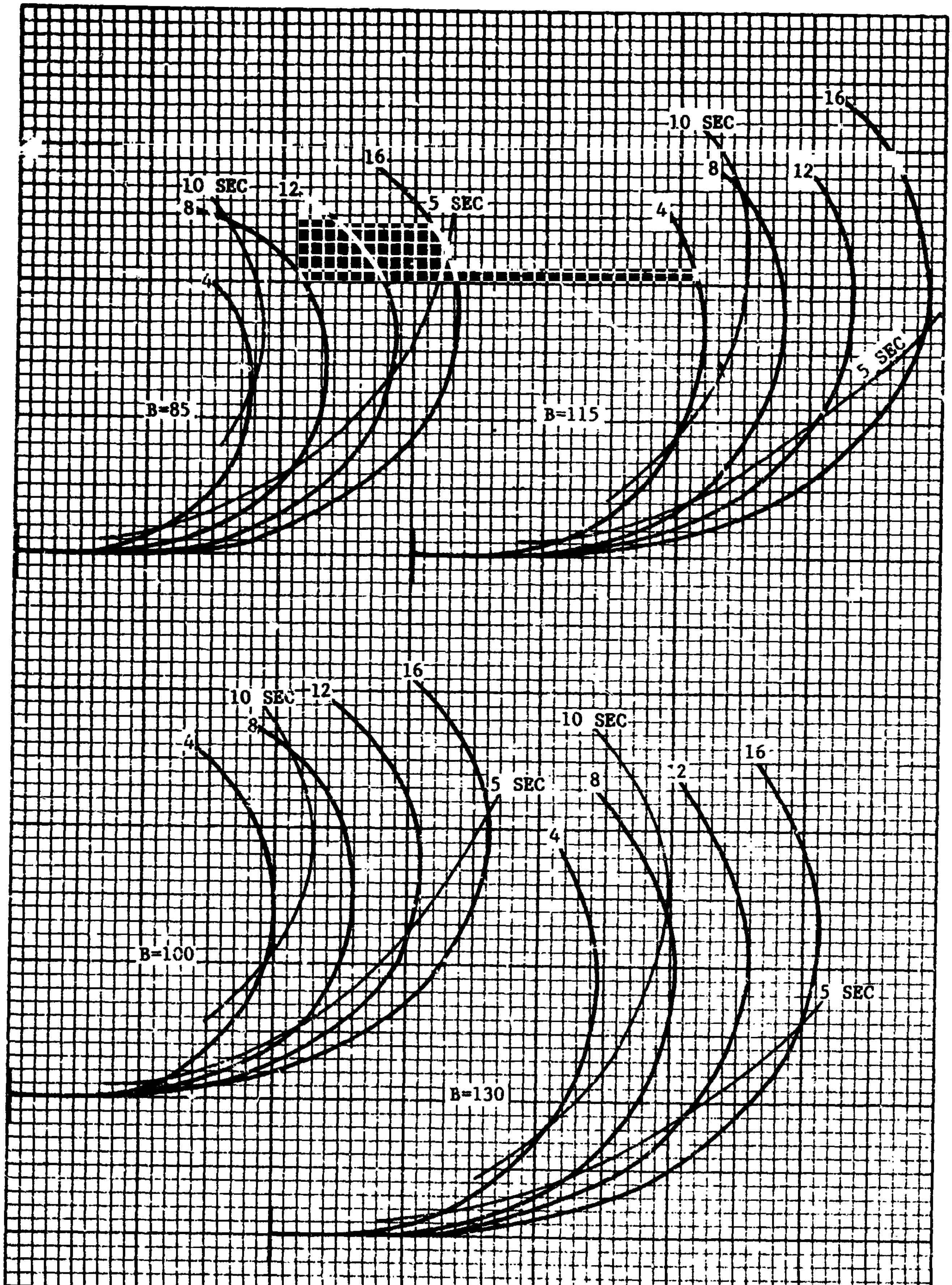


Fig 1 - Vehicle Paths for Various Wheelbase and Velocity Parameters. Steering Rate (ω) Constant at 4 Deg/Sec.

SCALE: 1 in = 5 meters

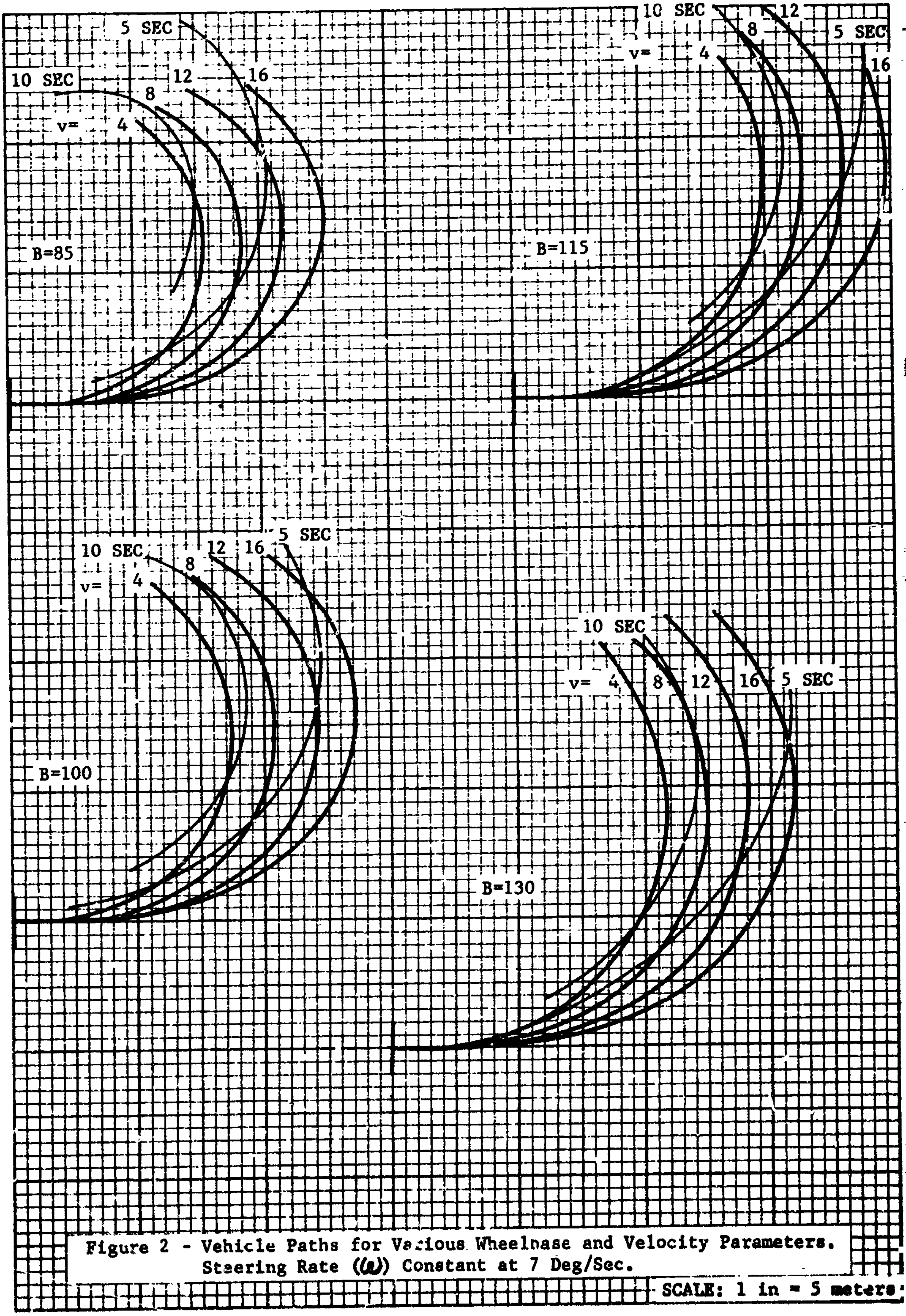


Figure 2 - Vehicle Paths for Various Wheelbase and Velocity Parameters. Steering Rate (ω) Constant at 7 Deg/Sec.

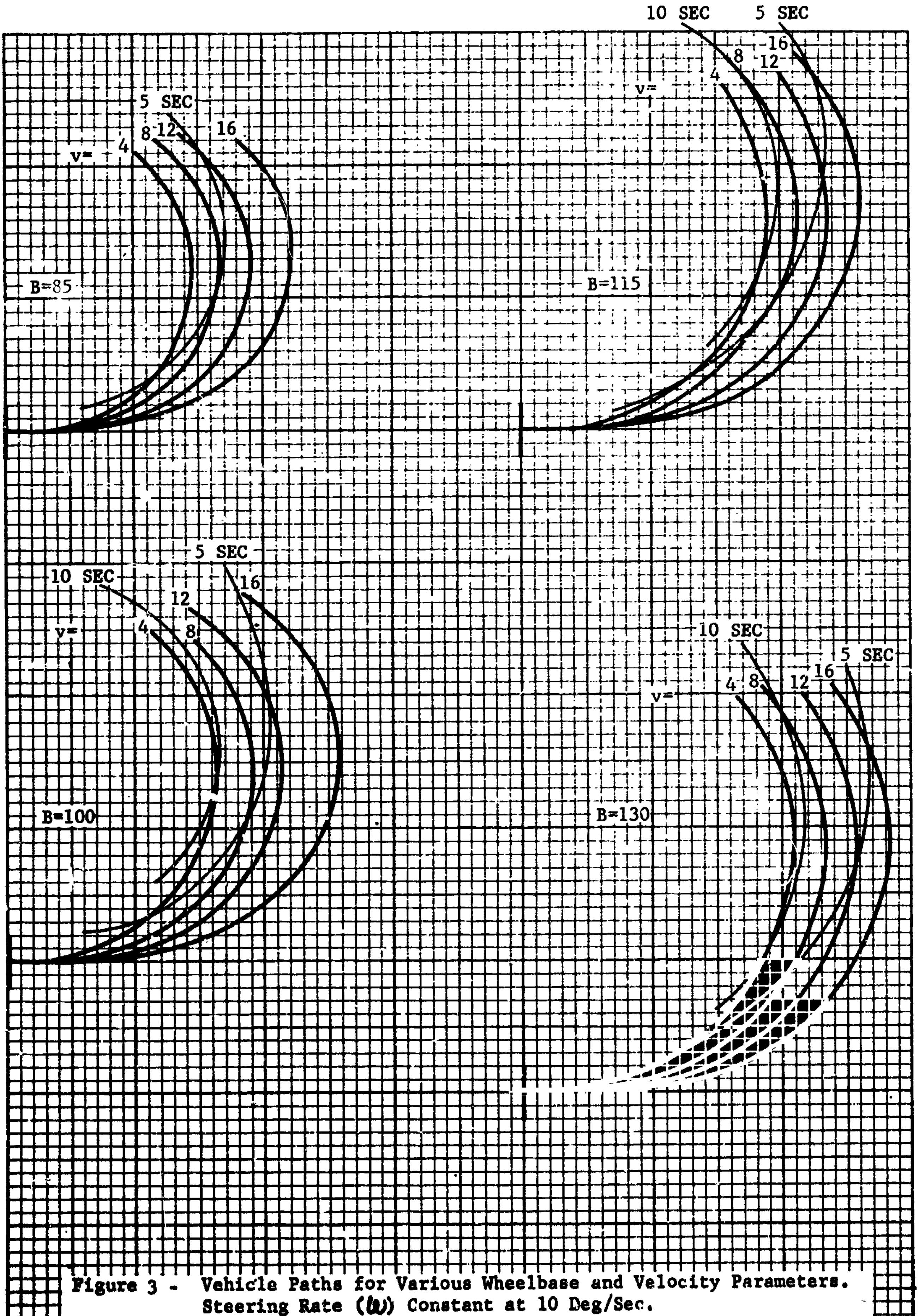


Figure 3 - Vehicle Paths for Various Wheelbase and Velocity Parameters. Steering Rate (ω) Constant at 10 Deg/Sec.

SCALE: 1 in = 5 meters

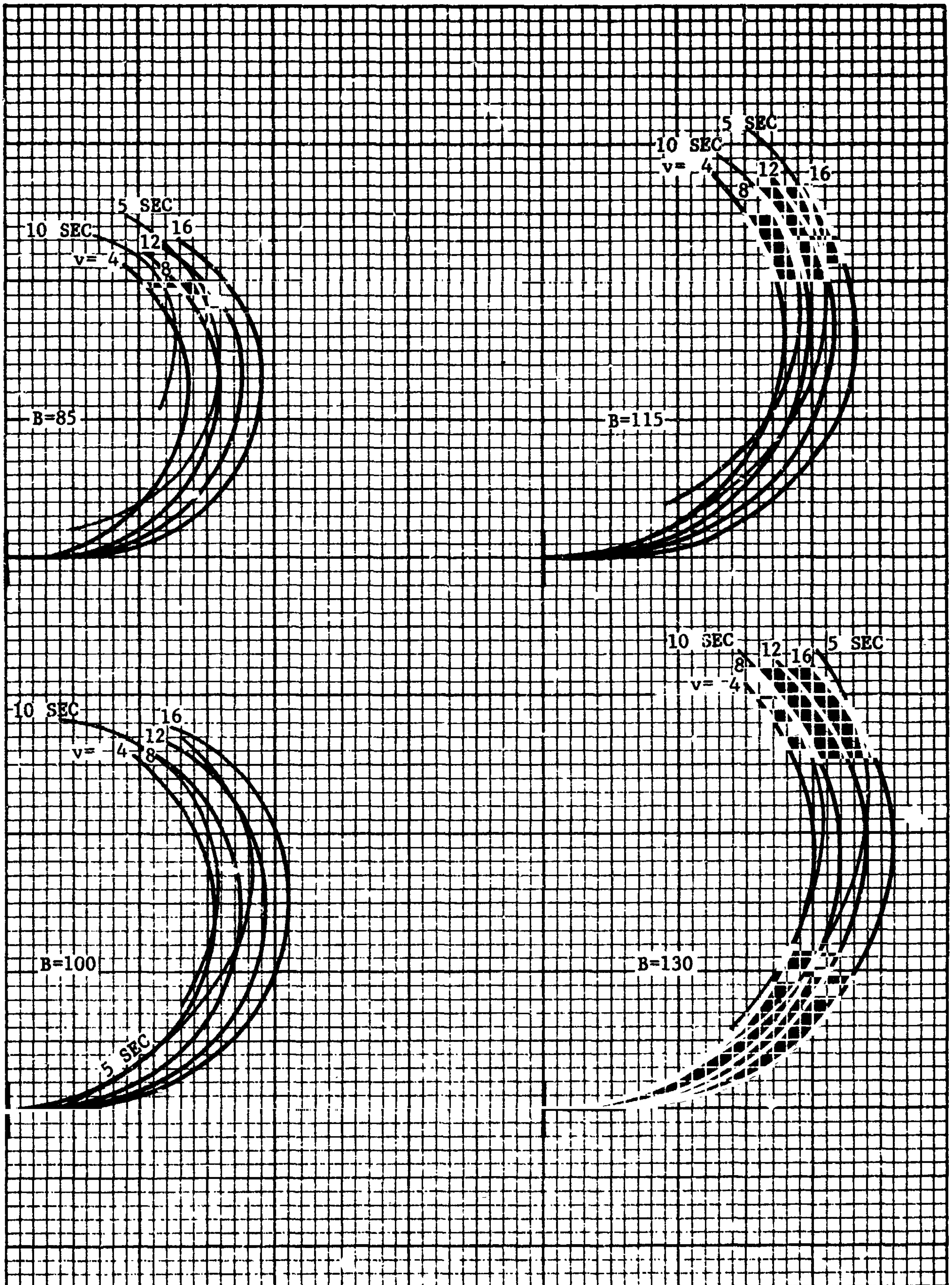


Figure 4 - Vehicle Paths for Various Wheelbase and Velocity Parameters. Steering Rate (ω) Constant at 13 Deg/Sec.

SCALE: 1 in = 5 meters

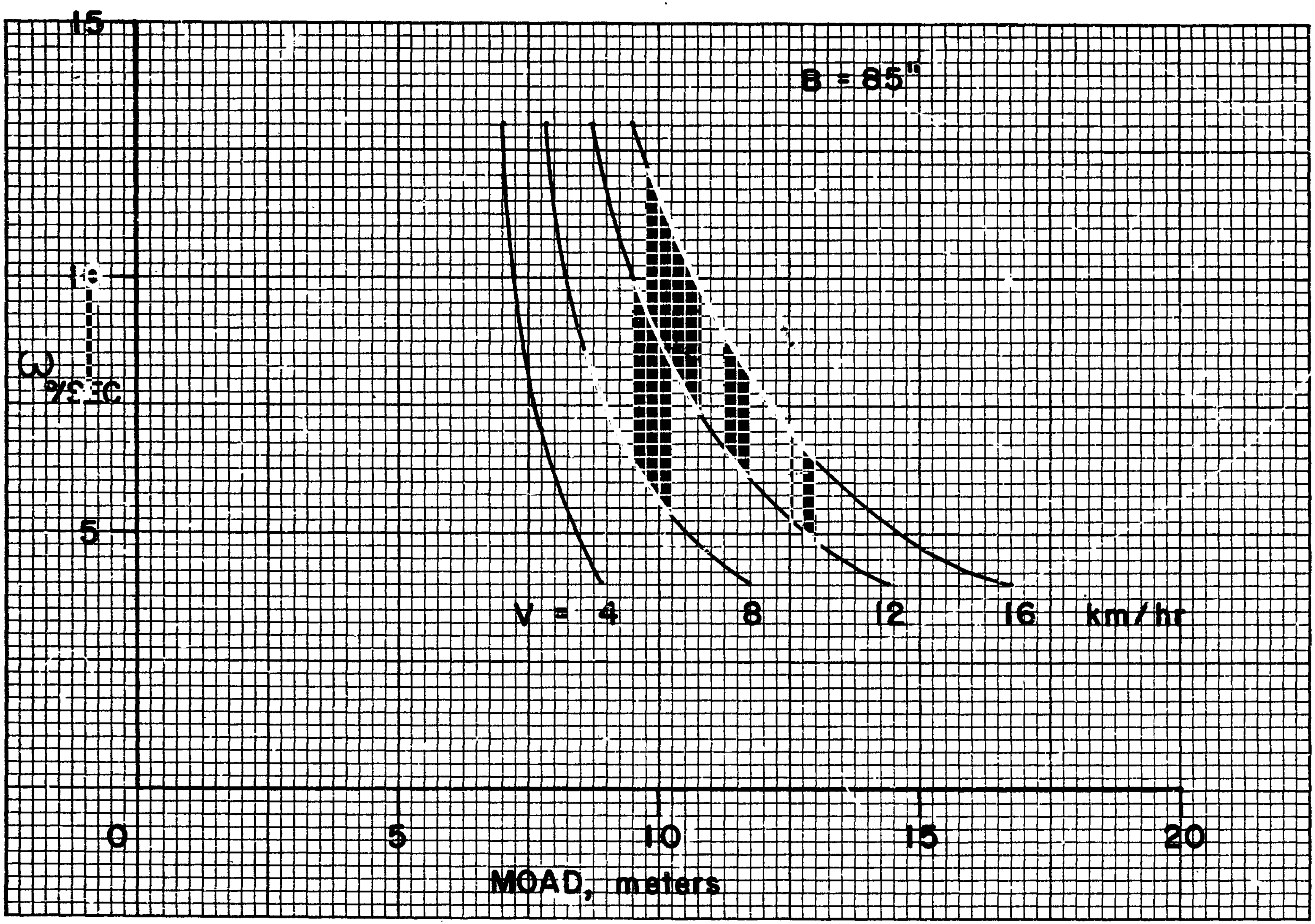


Figure 5

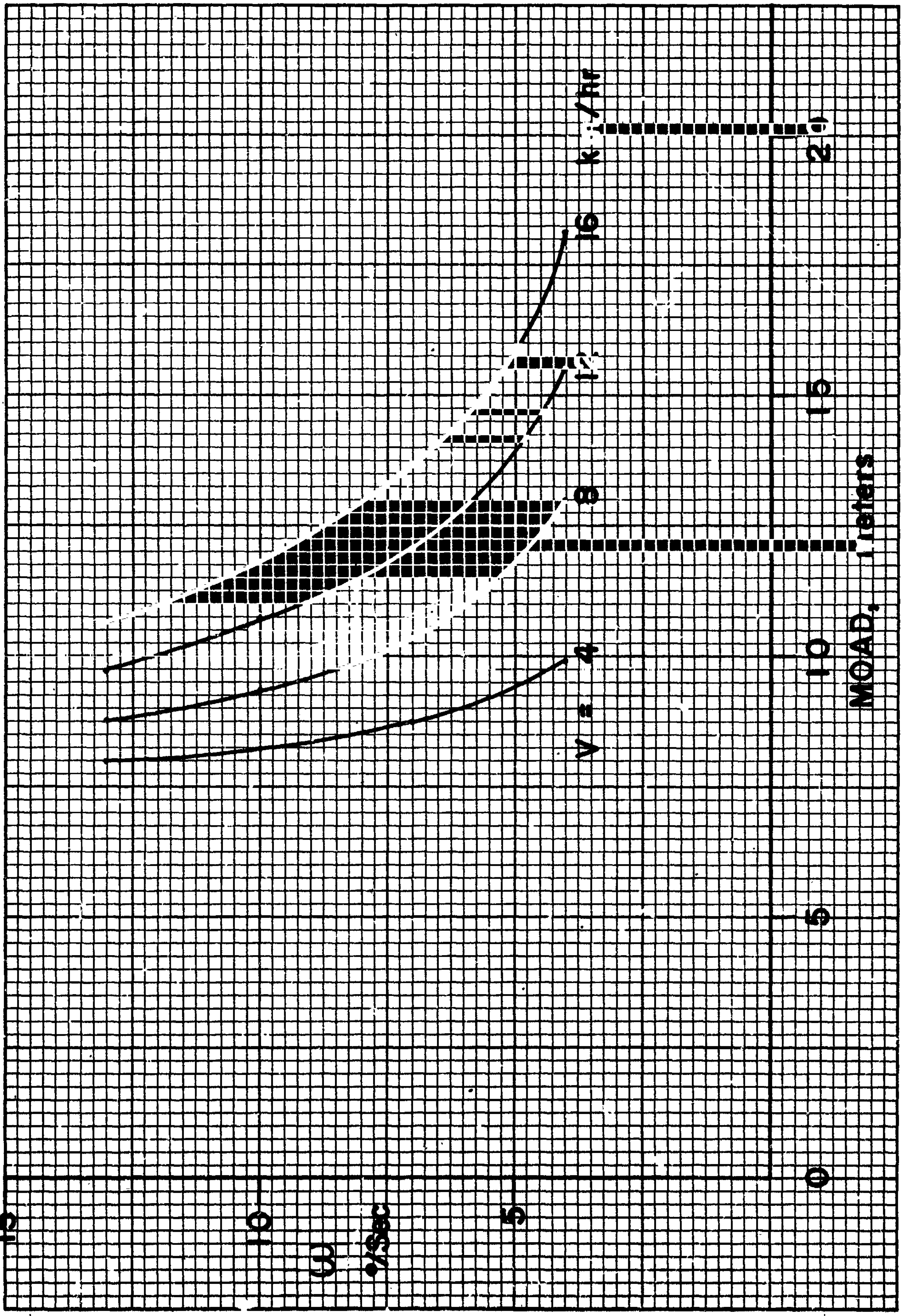


Figure 6

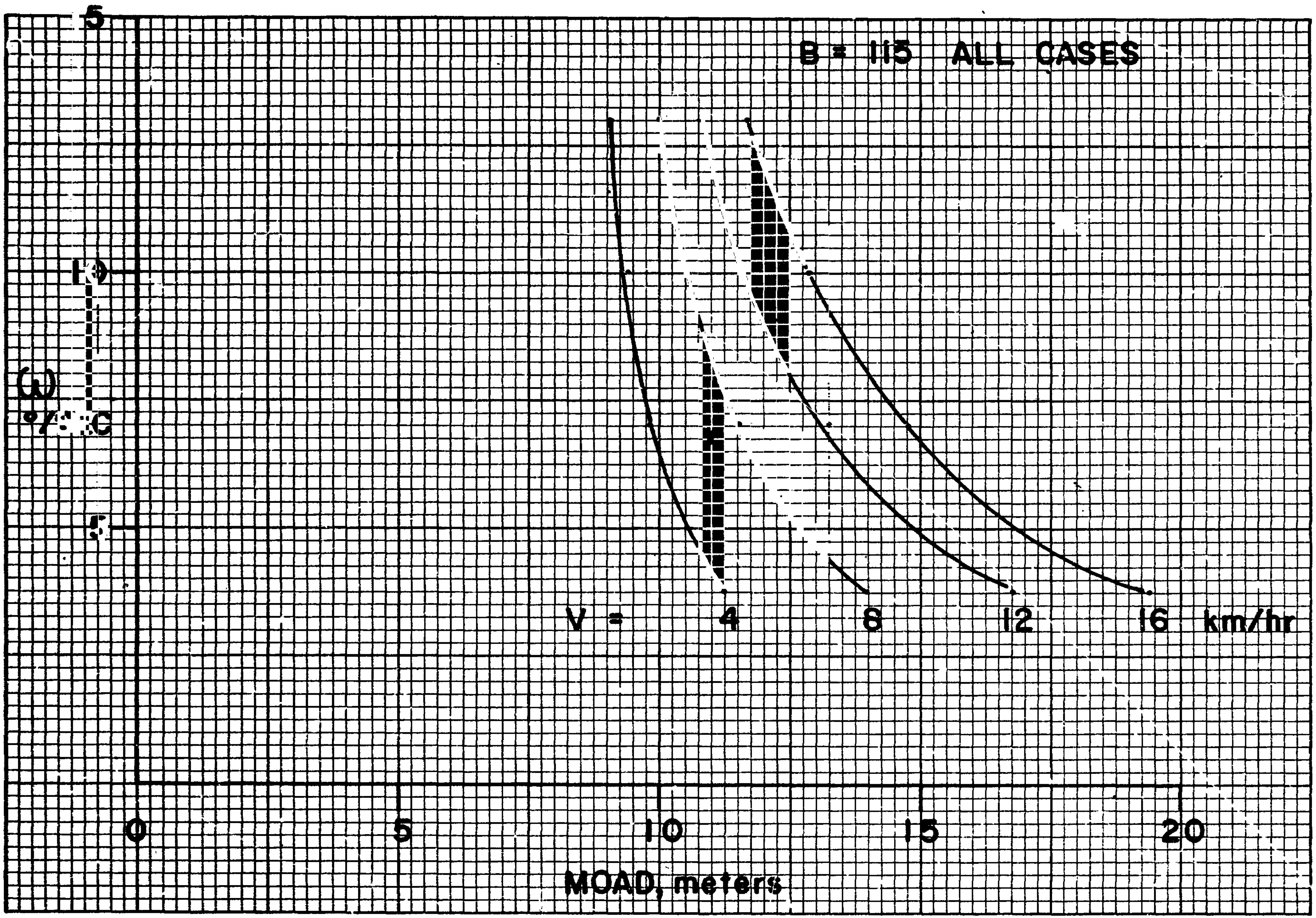


Figure 7

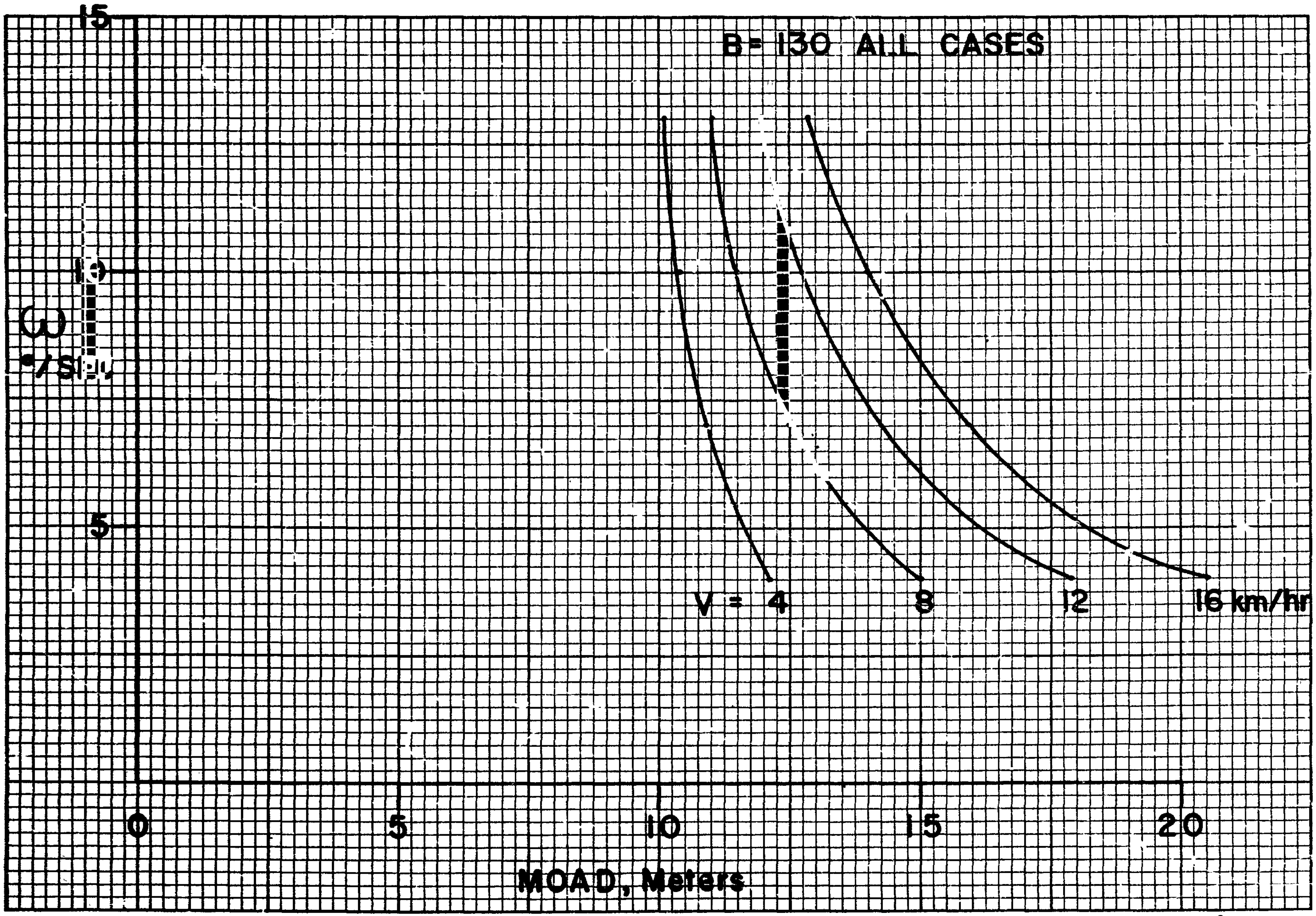
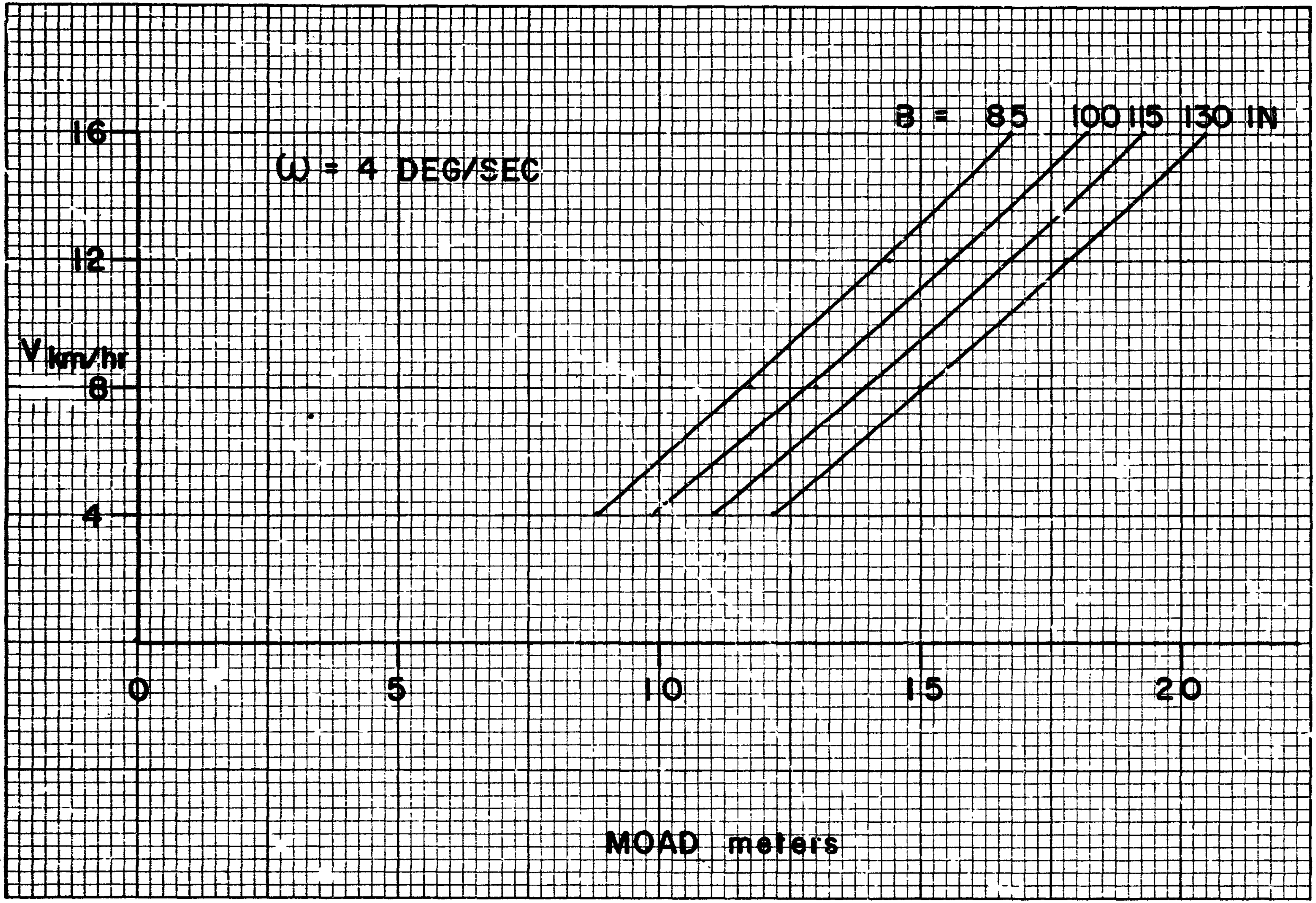


Figure 8



B = 85 100 115 130 IN
ω = 4 DEG/SEC
16
12
V km/hr
8
4
0
5
10
15
20
MOAD meters

Figure 9

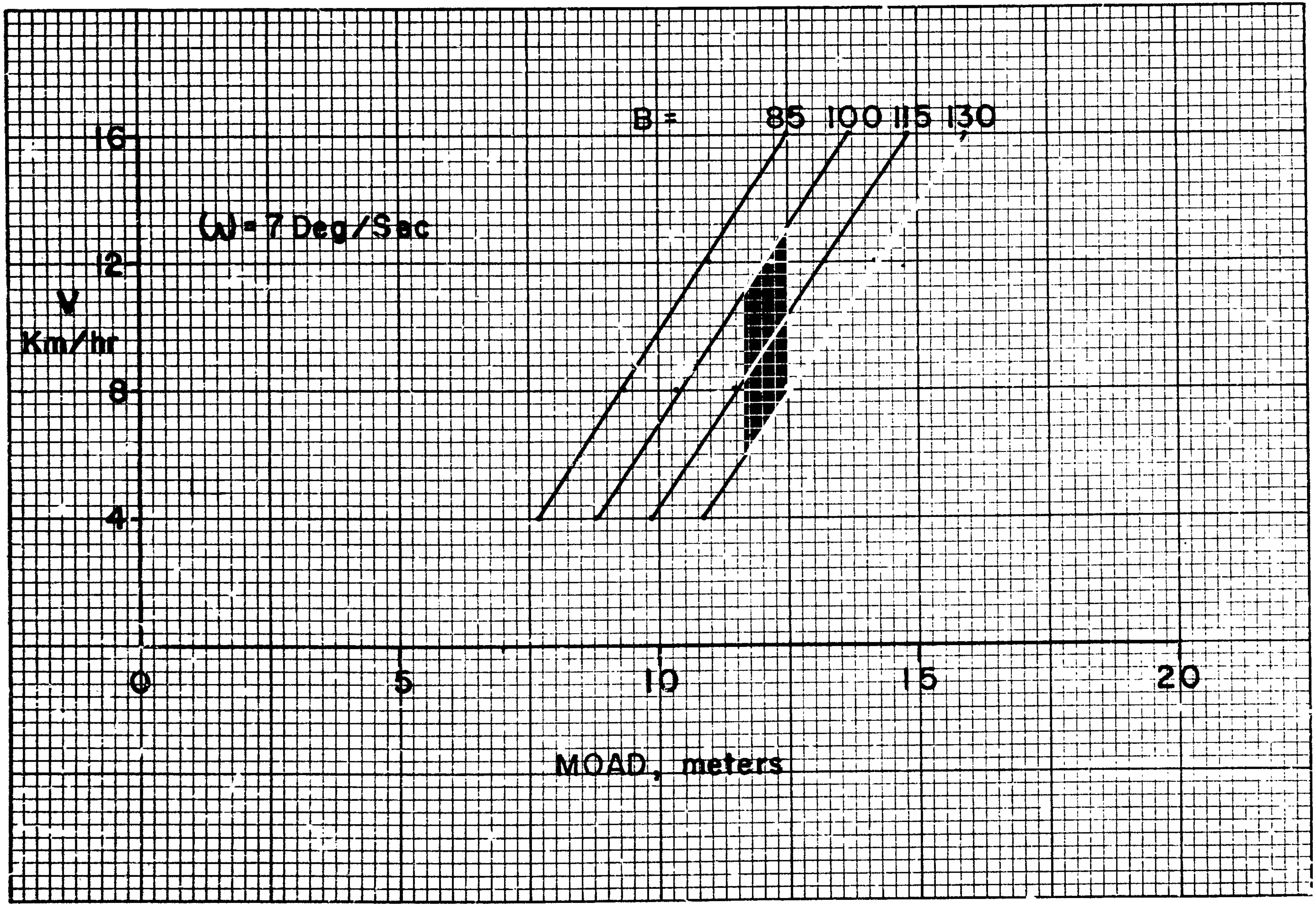


Figure 10

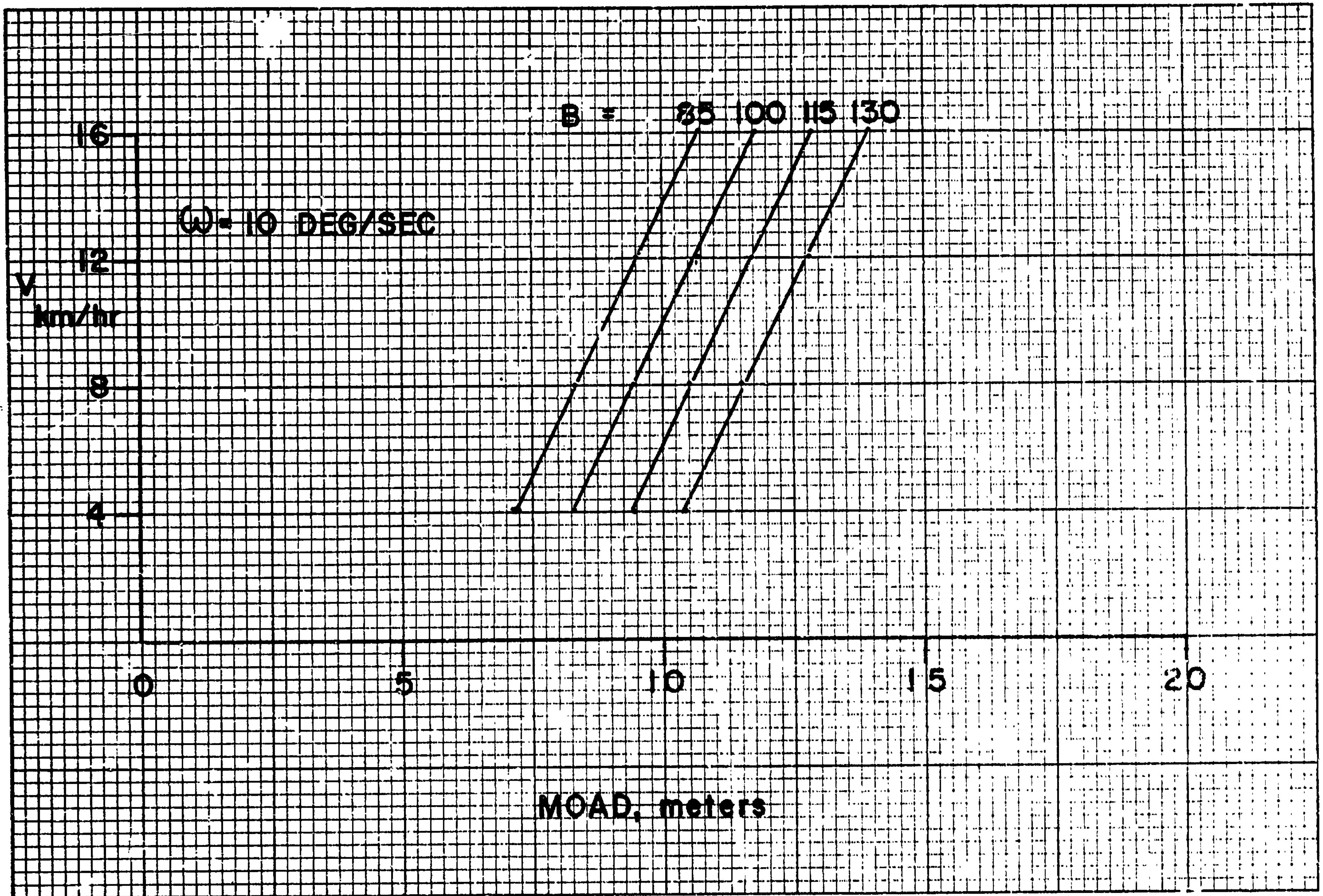
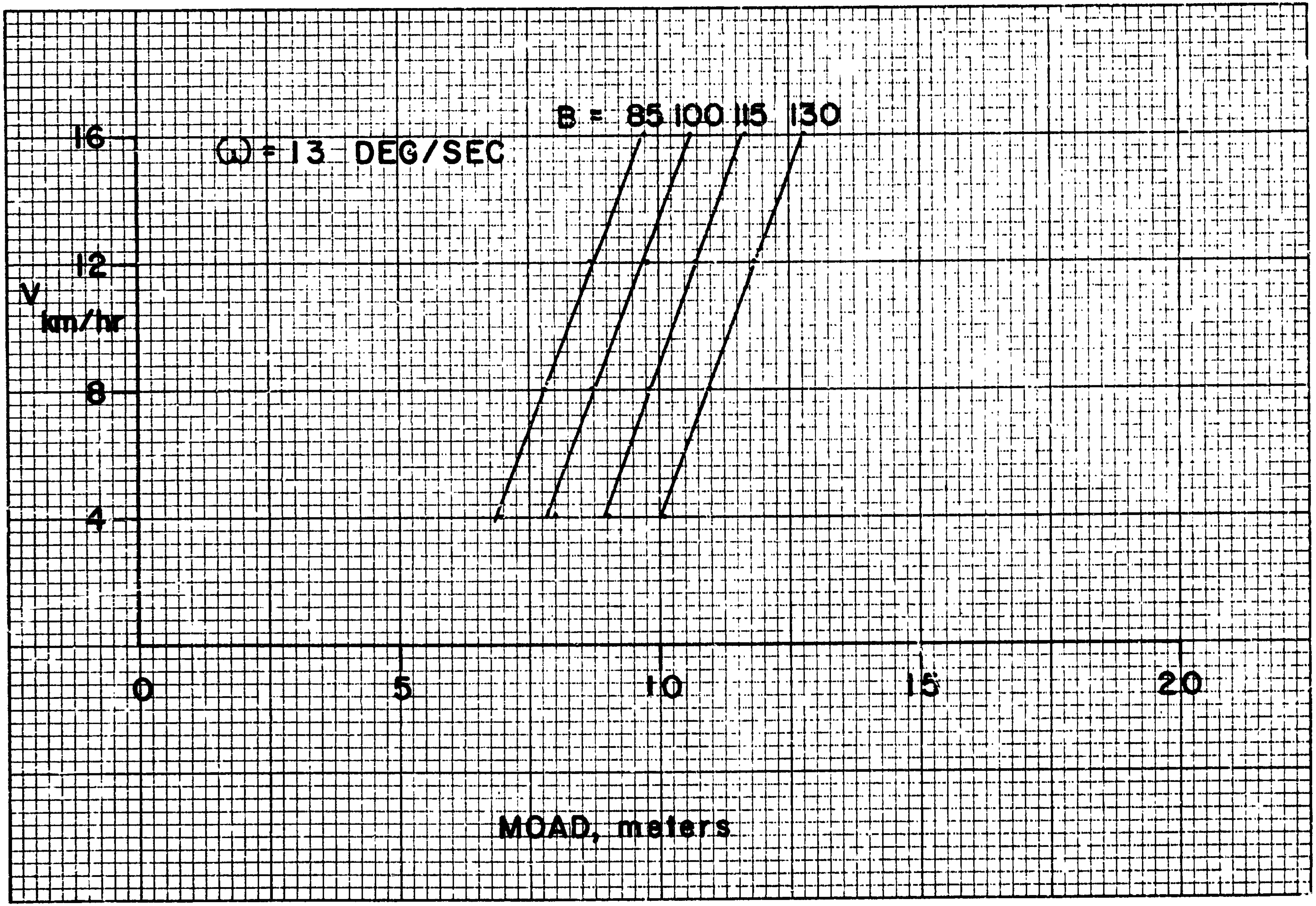

B = 85 100 115 130
ω = 10 DEG/SEC
V km/hr
16
12
8
4
0
5
10
15
20
MOAD, meters

Figure 11



ω = 13 DEG/SEC
B = 85 100 115 130
V km/hr
16
12
8
4
0
5
10
15
20
MOAD, meters

Figure 12

APPENDIX I

ANALYTICAL MODEL OF VEHICLE PATH

The transient portion of the vehicle path is described by equations:

For $0 \leq t \leq t_m$

$$X = V \int_0^t \cos\left[\left(\frac{V}{B\omega}\right)(\log \cos \omega t)\right] dt$$

$$Y = -V \int_0^t \sin\left[\left(\frac{V}{B\omega}\right)(\log \cos \omega t)\right] dt$$

For $t > t_m$, the vehicle describes a circle of radius:

$$R = \frac{B}{\tan \theta_m}$$

where

V = Vehicle velocity

B = Vehicle wheel base

ω = Rate of change of steering angle

$t_m = \dfrac{\theta_m}{\omega}$

θ_m = Maximum steering angle

The path thus described is that of the inside rear wheel. θ_m is measured at the inside front wheel.

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2. Cramblet, D. C. and W. Merritt, Preliminary Lunar Roving Vehicle Steering and Stability Considerations, TR-4-56-2-D, Kennedy Space Flight Center.