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A COMPARISON OF THE ZERO LIFT PEAK PROFILE DRAG COEFFICIENT AS PREDICTED BY AN EMPIRICAL AREA RULE METHOD AND WIND TUNNEL DATA ON AN F8U-1 AIRPLANE CARRYING WING PYLON-MOUNTED EXTERNAL STORES

Arnold L. Ducoffe*

ABSTRACT

Zero lift peak profile drag coefficients are calculated for an F8U-1 carrying wing pylon-mounted external stores. The analytical data are compared with experimental data and the resulting agreement is shown to be poor.

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Case No. 409.04

October 18, 1955

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A COMPARISON OF THE ZERO LIFT PEAK PROFILE DRAG COEFFICIENT AS PREDICTED BY AN EMPIRICAL AREA RULE METHOD AND WIND TUNNEL DATA ON AN F8U-1 AIRPLANE CARRYING WING PYLON-MOUNTED EXTERNAL STORES

SUMMARY

This paper presents a comparison of an empirical area rule method for predicting zero lift peak profile drag coefficient with experimental data. An F8U-1 airplane carrying wing pylon-mounted external stores of 25-, 30-, and 35-inch diameter and fineness ratios of 6, 7-1/2 and 9 for each diameter is analysed by the area rule method. The resulting prediction of the zero lift peak profile drag coefficients is compared with wind tunnel data.

The results indicate that the area rule method is not adequate for predicting the clean airplane peak profile drag coefficient. Also shown is the inadequacy of the method when large external stores are carried on the wing.

INTRODUCTION

The prediction of the zero lift transonic profile drag* coefficient for airplanes using available techniques is at best qualitative. One method, called the "area rule", has been devised by the NACA and holds promise for predictions of a quantitative nature. The problem of estimating the drag coefficient in the transonic speed range at zero lift for airplanes carrying large external stores is further complicated by

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* Profile drag is herein defined as total drag less skin friction drag and is synonymous with pressure drag.

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large interference effects. It is the purpose of the paper to present a comparison of transonic wind tunnel peak profile drag data on the Chance Vought Aircraft (F8U-1) carrying large external stores and transonic area rule estimates of the peak profile drag for the same airplane configurations. A list of references on the area rule is presented in reference 1.

DISCUSSION

Transonic wind tunnel aerodynamic data[2] have been obtained at the Cornell Aeronautical Laboratory for the Chance Vought F8U-1 airplane (0.042 scale model). The tests included the measurement of aerodynamic forces for various wing pylon-mounted store configurations. These store configurations were composed of three diameters, namely, 25", 30", and 35" with fineness ratios of 6, 7-1/2, and 9 for each store diameter. The stores were mounted on the wing so that the store center of gravity was located at 26% of the mean aerodynamic chord and the spanwise location of the stores was at 80.3 inches. Aerodynamic force coefficients were measured between Mach numbers of 0.7 and 1.2.

A method for predicting peak profile drag coefficient at zero lift for clean airplanes has been presented in reference 3. The zero lift peak profile drag coefficient is defined as the difference between the maximum zero lift drag coefficient in the transonic speed range (usually occurs around Mach numbers of 1.1) and the essentially constant zero lift subsonic drag coefficient. The manner in which this peak profile drag coefficient is estimated is summarized briefly below.

The method is essentially that of applying the transonic area rule to a given airplane configuration and then using an empirical curve[3] for estimating the peak profile drag coefficient. In order to apply this method the longitudinal area distribution (forming an equivalent body of revolution) using area slices cut by planes parallel to the yz plane must be obtained. The yz plane is defined as the plane

lying perpendicular to the longitudinal (x axis) of the airplane. Area slices cut by the yz plane are defined as "Mach one" area slices. Since the peak profile drag coefficient usually occurs at Mach numbers greater than unity the area slices should be taken parallel to the Mach lines which are inclined at the Mach angle ($\sin^{-1}\frac{1}{M}$). However, it is the writer's impression that the method suggested in reference 3 implies that Mach one slices can be used since the peak pressure drag Mach number is usually close to unity. The prediction of the peak profile drag coefficient is found by evaluating a shape parameter which we shall term Z and is given by the relationship:

$$Z = \frac{f - 2\,(1 - d_b/d_{max})}{l/d_{max}}$$

where

d_b is the diameter of the equivalent circular area formed by the Mach one area slices at the base (aft end of the fuselage) of the model.

d_{max} is the diameter of the maximum equivalent circular area formed by the Mach one area slices.

l is the length of the airplane (usually the distance between the nose of the fuzelage and the aft end of the fuselage).

f is a parameter which is given by the relationship:

$$f = \int_0^l \left(\frac{dS}{dx}\right)^2 dx$$

where

S is the area cut by the Mach one slices at each longitudinal station.

x is the longitudinal coordinate being measured from the nose of the fuselage.

The evaluation of the parameter f is usually obtained by computer methods. For this analysis an analog computer was used. The Mach one area slices for the F8U-1 were supplied by the Chance Vought Aircraft Corporation and are presented as Figure 1. The broken line between stations 0 and 32 represents an assumed fairing since the discontinuity in area at station 32 would give infinite values for the parameter f. In order to evaluate the shape parameter Z for the F8U-1 with external stores the area distribution of the stores (area slices in planes normal to the store longitudinal axis) was added at the appropriate longitudinal (airplane) stations. A typical plot of the area distribution for the F8U-1 plus a 25-inch diameter store of fineness ratio 6 is shown in Figure 2.

With the shape parameter Z evaluated the peak profile drag coefficient is obtained from Figure 3 which has been derived from reference 3.

RESULTS

The zero lift peak profile drag coefficient based on wing area for the F8U-1 airplane is estimated at 0.0137 by the method of reference 3. Wind tunnel data indicate that the zero lift peak profile drag coefficient is 0.0185. In addition the wind tunnel data show that the zero lift profile drag coefficient at M = 1 is 0.0120. Thus it is seen that the area rule method of reference 3 gives better agreement with the zero lift Mach one profile drag coefficient than the zero lift peak profile drag coefficient. It should be remembered that the method of reference 3 uses Mach one area slices whereas the zero lift peak profile drag coefficient occurs at Mach numbers slightly higher than unity. What the effect of oblique slices would be is unknown to the writer at this time.

The effect of adding wing pylon-mounted external stores on the zero lift peak profile drag coefficient is shown in Figure 4. The

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solid lines represent data calculated using the area rule method of reference 3 and the broken lines represent wind tunnel data taken from reference 2.

The data in Figure 4 indicate that the agreement between the empirical data of reference 3 and wind tunnel data of reference 4 is not good. The wind tunnel data indicate essentially a linear drop-off of peak profile drag coefficient with increasing fineness ratio whereas the area rule data shows very little change with fineness ratio. This would appear to indicate that the area rule method is apparently not applicable for cases where interference drag becomes large as is the case where a large store is pylon-mounted on the wing of an airplane. It should be noted that the authors of reference 3 only claim good agreement for zero lift peak profile drag coefficient predictions for a clean airplane.

CONCLUSIONS

The area rule method of reference 3 does not give satisfactory agreement for the zero lift peak profile drag coefficient for airplanes with large external stores which are wing pylon-mounted. It is felt that the method fails because of the large interference effects between the wing and the stores. Some question also exists as to the applicability of this empirical method to clean airplanes since the agreement between the area rule and experimental data for the clean F8U-1 airplane is poor.

It is recommended that an empirical curve of the form of Figure 3 presented herein should be derived for airplanes carrying wing pylon-mounted external stores. In this way the large interference effects would be included.

ARNOLD L. DUCOFFE - 5141

Case No. 409.04
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LIST OF SYMBOLS

d_b	diameter of the equivalent circular area formed by the Mach one area slices at the base (aft end of the fuselage) of the model
d_{max}	diameter of the maximum equivalent circular area formed by the Mach one area slices
f	parameter
l	length of the airplane
l/d_{max}	fineness ratio of equivalent body of revolution formed by Mach one area slices
x	longitudinal coordinate measured from nose of fuselage
D	store diameter
L	store length
L/D	store fineness ratio
M	Mach number
S	area cut by Mach one area slices
Z	shape parameter

REFERENCES

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3. Nelson, Robert L., and Storey, William E., Jr., "Pressure Drag of Bodies at Mach Numbers up to 2.0", NACA Conference on Aerodynamics of High Speed Aircraft, Ames Aeronautical Laboratory, July 8-10, 1953.

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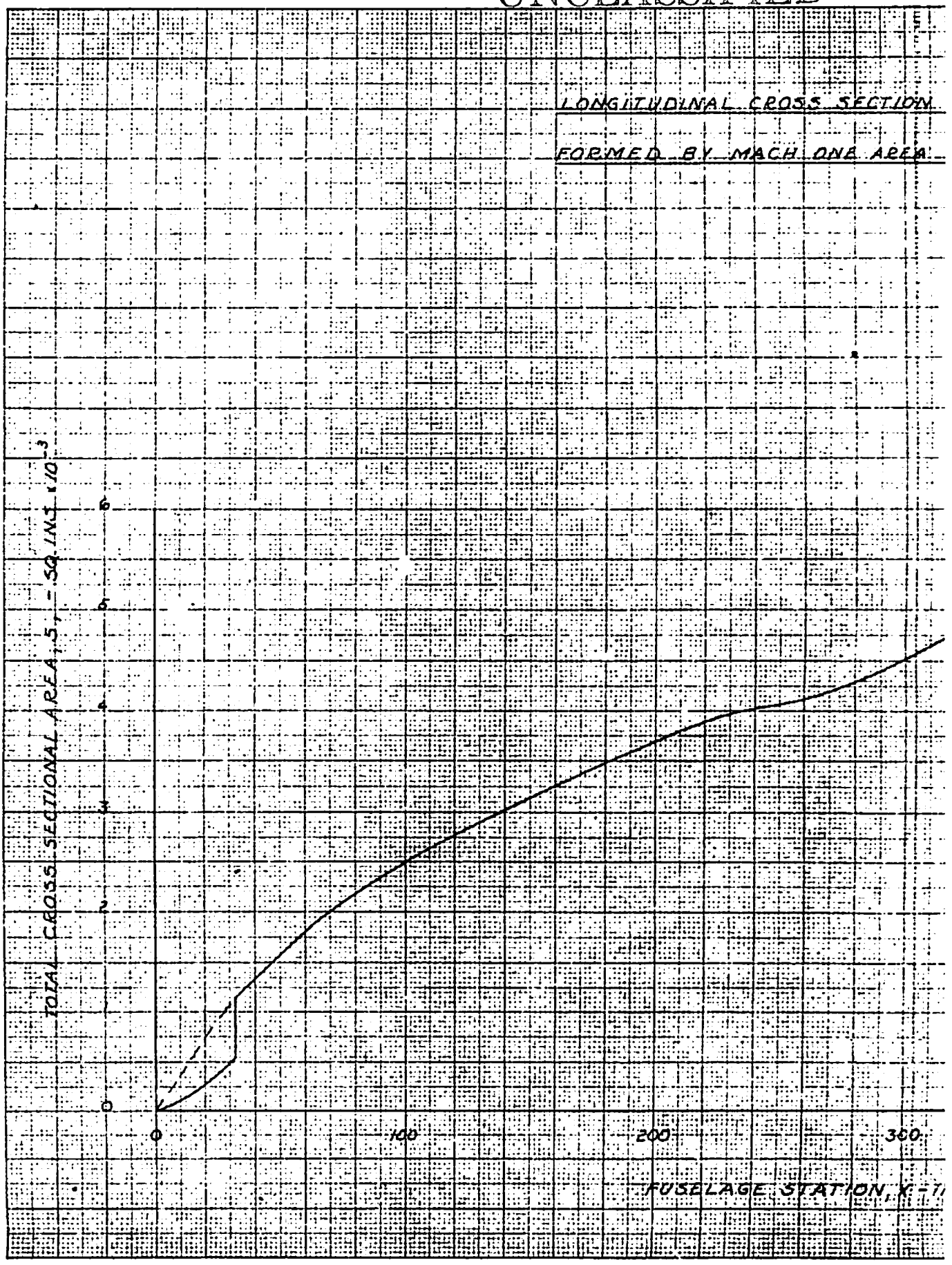

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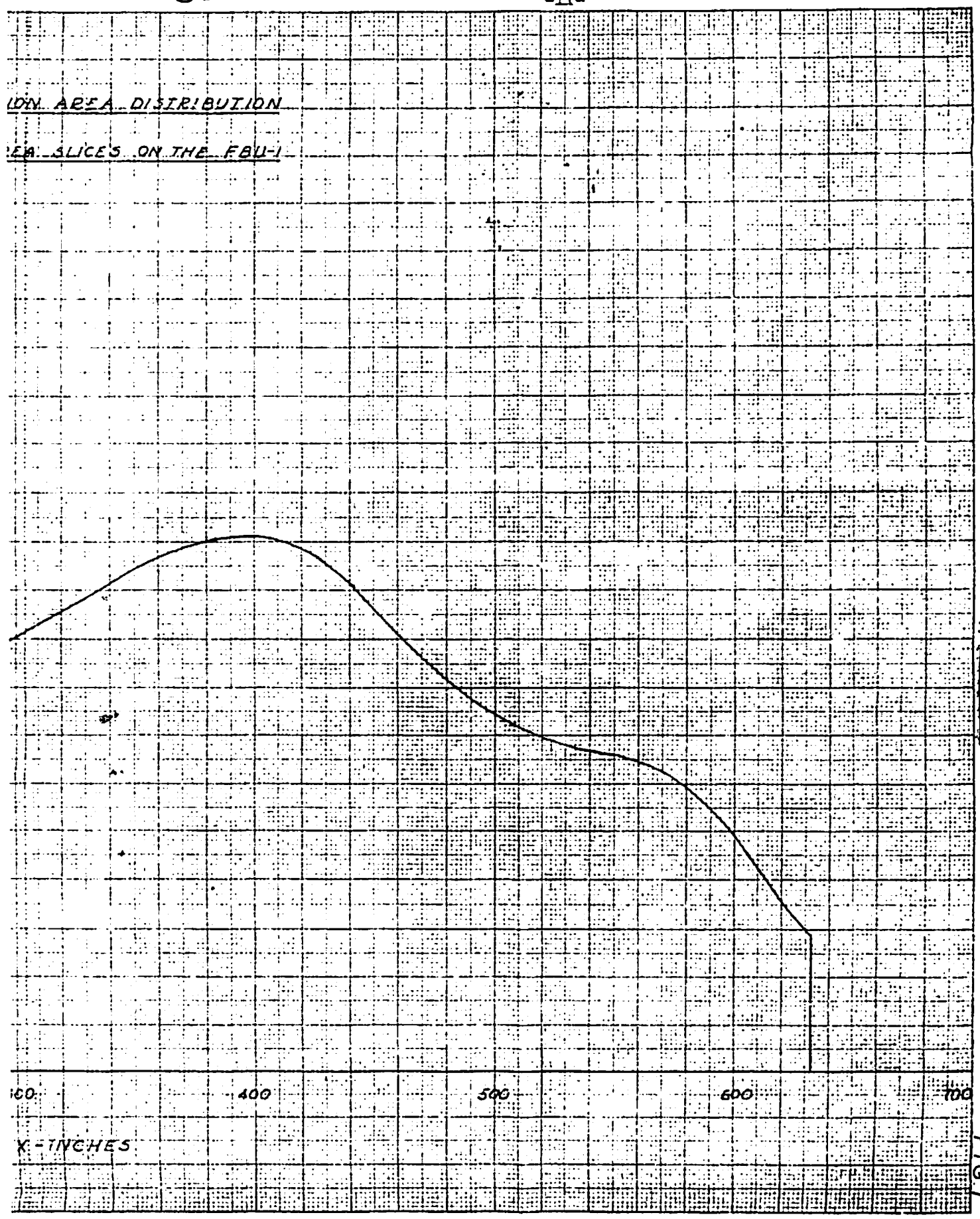

FIG. 1

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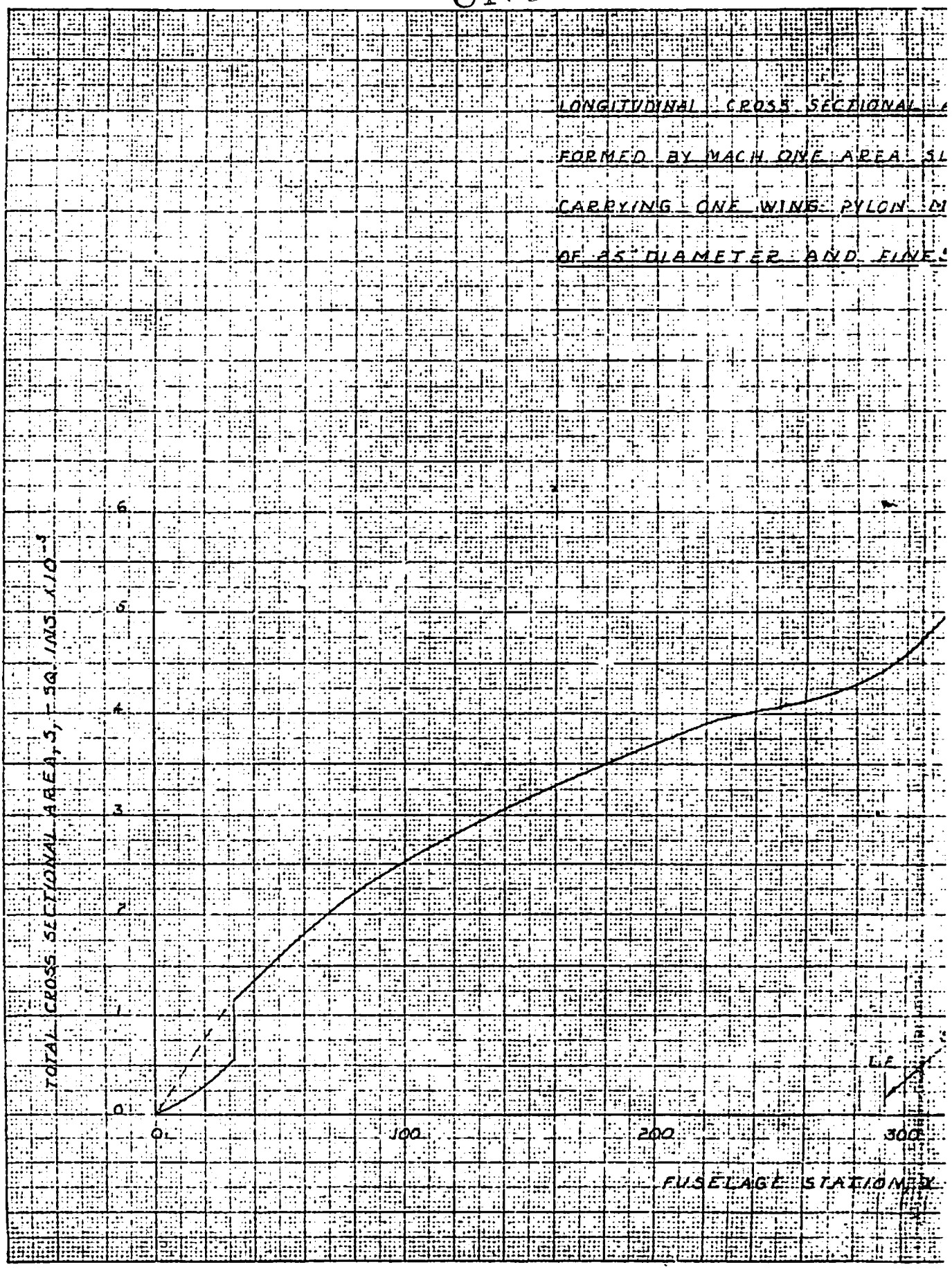

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FIG. 2

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REA SLICES ON THE FOUR

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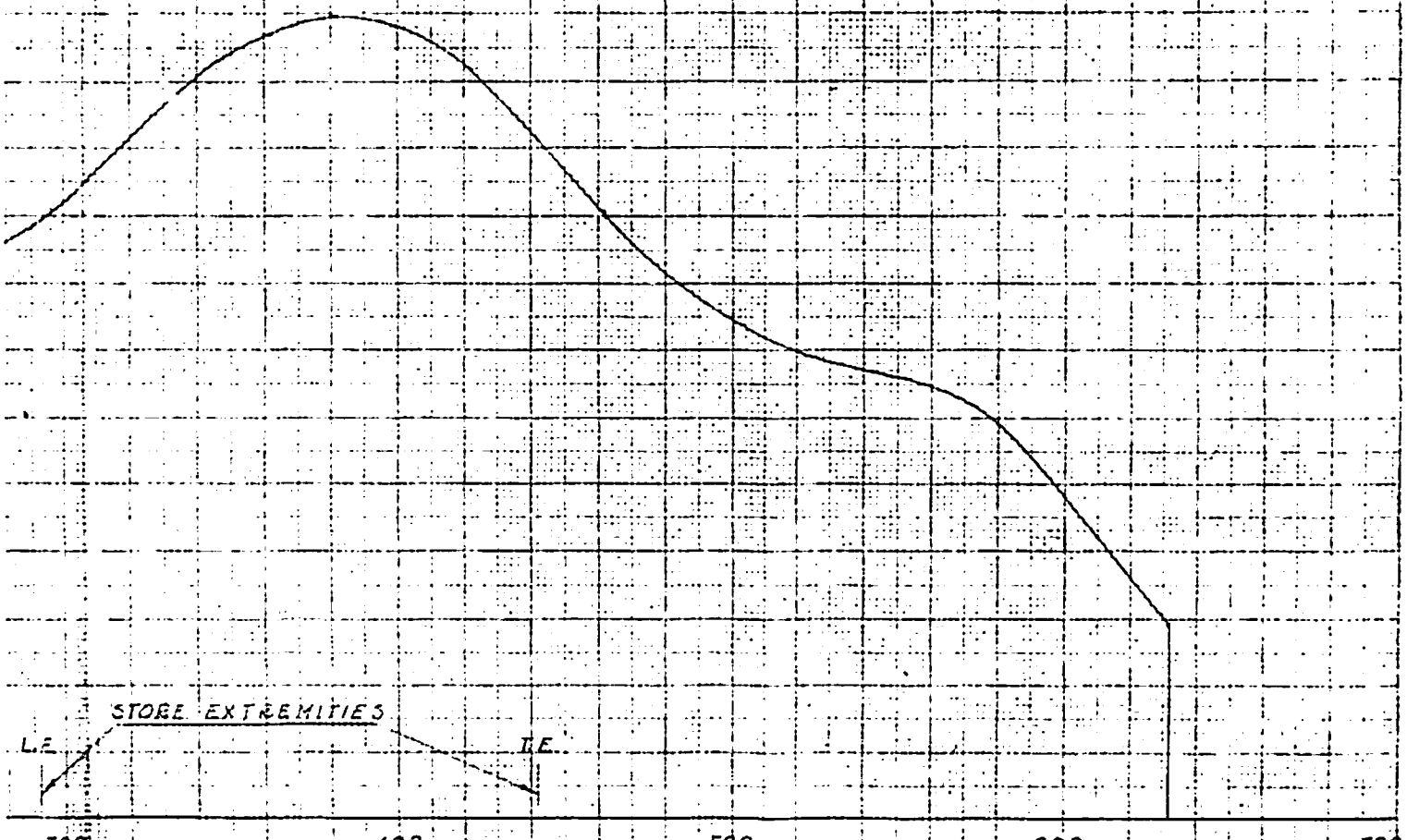

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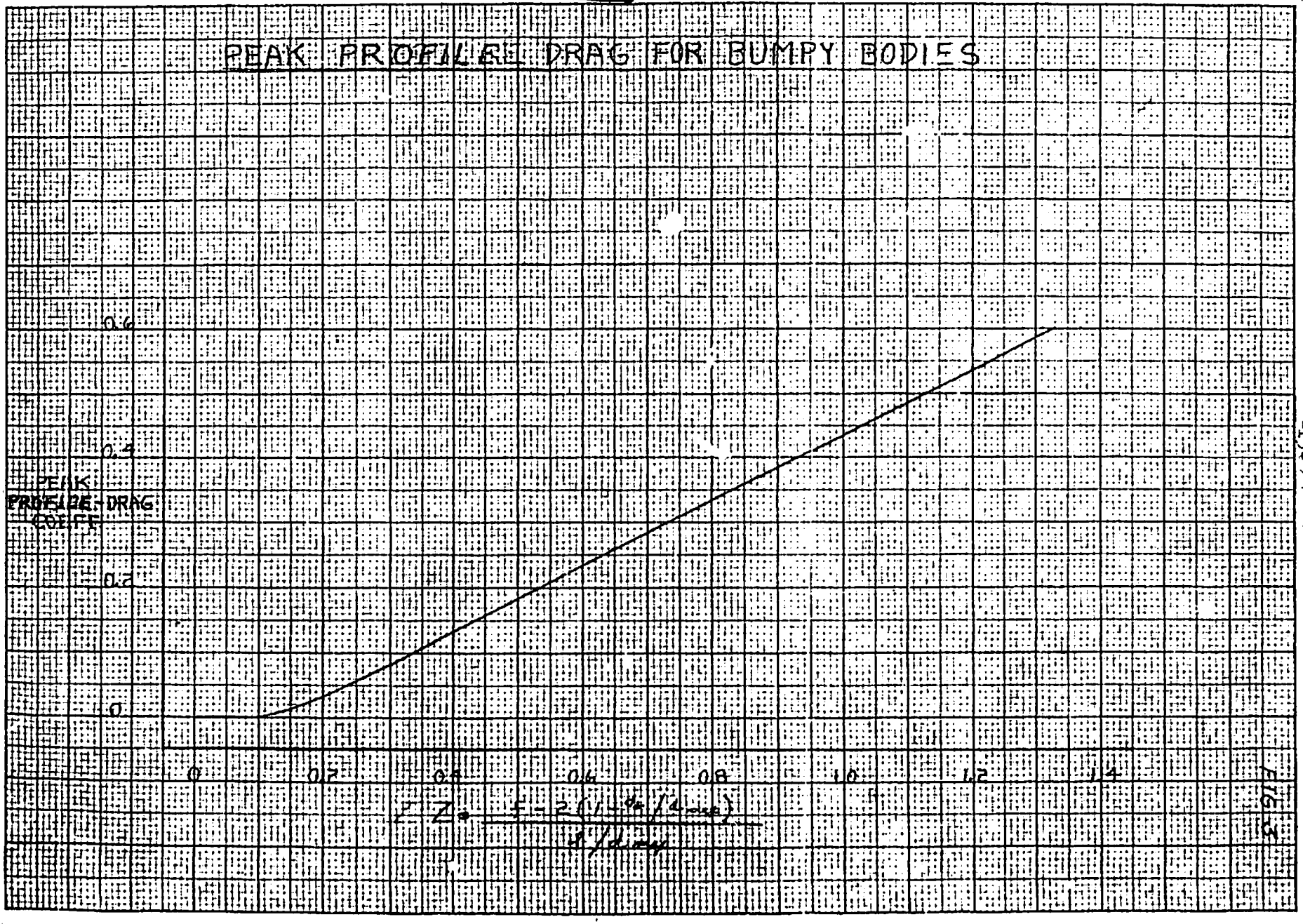

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FIG 3

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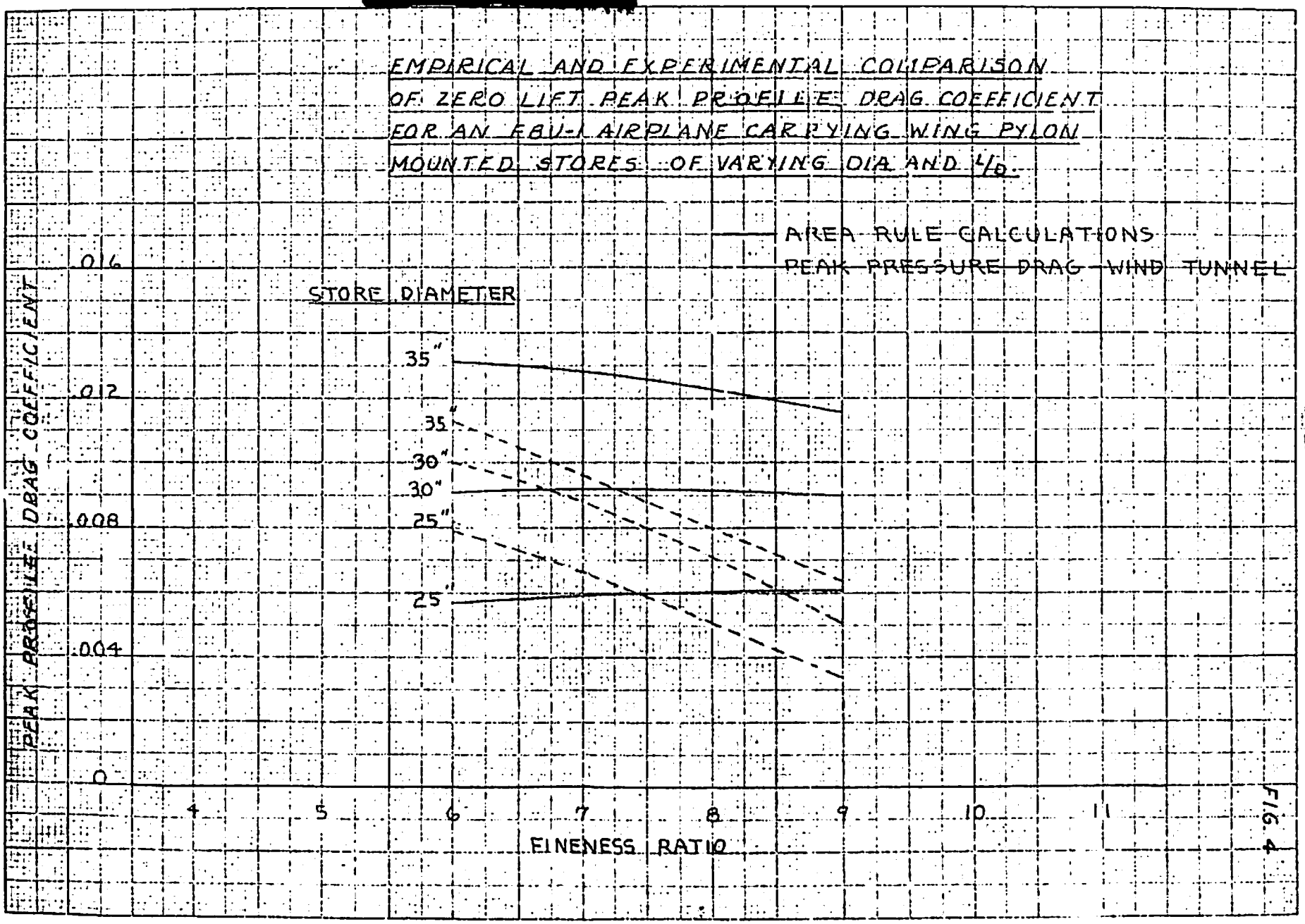

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FIG. 4

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