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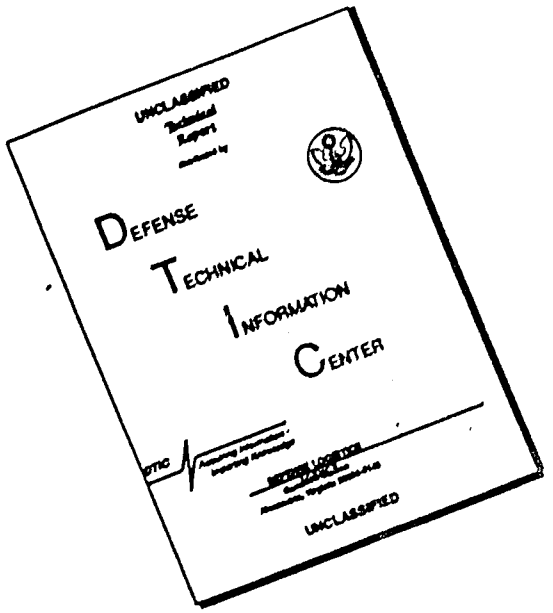

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ENGINEERING MECHANICS DIVISION

October 31, 1949

FINAL REPORT

Prepared for
Laboratory
Watertown Arsenal
Ordnance Department
Watertown, Massachusetts

Project No. 7-S99-E

STUDY OF THE BEHAVIOR OF LIGHT PERSONNEL ARMOR CONSISTING OF METALLIC, OR A COMBINATION OF FIBROUS AND METALLIC MATERIALS

Contract No. W23-072-ORD-2161

By:

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CONTENTS

SUMMARY

Under the present contract, the basic method for predicting the performance of light personnel armor previously developed under Contract No. W23-072-ORD-2123 has been extended to include other variables which enter the problem of armor design. The major portion of the work under the previous contract was limited to the study of flat-nosed fragments fired perpendicularly at plates using comparatively low striking velocities. This study has been extended to include the effects of various fragment nose shapes, angles of incidence, higher velocities and smaller fragments.

It was found that the previously developed formula for predicting light armor performance remains valid over the extended range of conditions for most of the materials studied. It is shown that the original formula can be modified to enable a designer to account for the effect of angle of incidence for metallic materials. Except in the case of fibrous materials, the effect of nose shape was found to be comparatively small for the range of shapes studied; hence, no shape factor was included in the formula.

I. INTRODUCTION

During the course of the preceding contract, the Midwest Research Institute developed a method for the evaluation of the resistance of certain materials to penetration by fragments having various masses and striking velocities. The final report for that contract presented data taken with cylindrical, flat-nosed fragments of 1/2-inch diameter which were projected perpendicularly against the armor materials.

One objective of the work under the present contract has been to explore an extended range of conditions to determine what limitations might be presented by this method of evaluation. Accordingly, studies have been made of the effects of: 1) various angles of incidence of the approaching fragment; 2) different fragment nose shapes; 3) different fragment perimeters; and 4) higher striking velocities.

It is a purpose of this report to present data which will extend the scope of the previously developed semi-empirical assessment method and to indicate the comparative reactions of different materials to various conditions of penetration.

II. DESCRIPTION OF EQUIPMENT

The equipment used for obtaining the data of this report is, with a few exceptions, the same as that used in the previous contract. For a complete description, including photographs and wiring diagrams, reference should be made to the final report of Contract No. [illegible]-ORD-2123.

Equipment changes include a new laboratory location, a new design of pick-up for the measurement of residual velocity, and special Tempo Tool barrels for higher striking velocities.

The laboratory location has greatly improved working conditions for both personnel and instruments. All the original safety features remain the same.

The new design of residual velocity pick-up provides a higher signal-to-noise ratio to enable velocity measurements of small fragments to be made at the wide divergence angles resulting from oblique impact. The signal-to-noise ratio was improved by providing a transverse magnetic field for the screens as contrasted to the axial field formerly used. The new arrangement minimizes screen coupling. Pole pieces having a width of 3 1/2 inches in the plane of the screen are provided. They are separated by an air gap of 3 inches, thus providing a sufficiently large screen area to accommodate the divergence angles resulting from most of the oblique impact conditions.

The pulses derived from the residual velocity magnetic screens are admitted to two amplifiers (see Appendix B) whose outputs are connected to the start and stop inputs, respectively, of the counter chronograph. These amplifiers are identical and are fairly simple in their design. The requirements are for high grain and relatively narrow band width. The tube line-up consists of a 6AU6 pentode input, followed by a 12AU7 twin triode cascade amplifier which feeds into the grid of a 2D21 thyratron. The output pulse from the thyratron cathode is used to operate the chronograph.

III. DESCRIPTION AND APPLICATION OF EVALUATION METHOD

A thorough description of the semi-empirical assessment method for the performance of armor materials is to be found in the final report of Contract No. W23-072-ORD-2123. Briefly, it consists of the following relationship for metals:

$$d = \frac{M_o}{M} \times \frac{P}{P_o} \times \frac{h}{h_o}$$

where M = mass of striking fragment

P = perimeter of fragment

h = thickness of plate

M_o = 10 x 10^{-4} slugs

P_o = 1.0 inches

h_o = 0.1 inches

and for fabric:

$$d_F = \frac{M_o}{M} \times \frac{P}{P_o} \times \frac{n}{n_o}$$

where M = mass of striking fragment

P = perimeter of fragment

n = number of layers of fabric

M_o = 10 x 10^{-4} slugs

P_o = 1.0 inches

n_o = 10 layers

It should be noted that the "d" relationship for fabric has been somewhat revised to account for the variation of fragment perimeter.

When using the evaluation method to determine the relative performance of various materials, one should avoid drawing general conclusions covering a wide range of "α" values. The "α" curves for various materials are sufficiently different in shape to indicate that the relative merits of the materials may even become reversed when the plate thickness, fragment perimeter or mass is changed sufficiently, Consequently, when making comparisons between materials under a given set of conditions, the recommended procedure is to determine the appropriate value of α for each material from the values of plate thickness, fragment perimeter, and mass. (When considering oblique impact, the values of plate thickness and fragment perimeter should be modified as outlined in Section IV-C.) Then a curve having the required value of α can be chosen from the family of "α" curves given in this report for the material in question. In cases of non-integral values of α, the desired curves can be constructed by interpolation. If the material is one the resistance of which is markedly affected by nose shape, this effect can be estimated by reference to a curve of data taken under similar conditions. Then the "α" curve, after being adjusted for nose shape, should predict the performance of the material under the stated conditions with a reasonable degree of accuracy.

IV. DISCUSSION

A. Performance Curves and "α" Relations

Figures 62 through 167 in Appendix A represent all the data obtained during the term of this contract. Experimental points are indicated by plus marks and their average loci by solid lines. The dashed curves are values of α corresponding to the experimental data in each case. The values of α are taken from the families of "α" curves shown in Figures 1 through 4.

These families of "α" curves have been derived as suggested in the previous contract with the exception that they are based on data taken from the middle of the range of "α" values covered in the present investigation. This modification provides better agreement for data having high α values without detrimental effect on those of low α values.

Hadfield Steel has not conformed in general with the "α" method of evaluation. Further investigation may reveal some such relationship within specified limits. Figures 60 and 61 suggest this possibility wherein the limiting condition would be constant fragment perimeter. At the present time, no comparison can be made between the relative performance of different thicknesses of Hadfield Steel. The reason is that the two thicknesses investigated, i.e., .036-inch and .048-inch, were supplied in different degrees of hardness. The average hardness of the .036-inch sheet, as measured on the Rockwell B scale was 58 and that of the .048-inch sheet was 69.

B. Comparative Curves for Various Materials

Figure 5 compares 2S0, 24ST, and 75ST aluminum alloys with nylon duck having a weight per ply of 13 ounces per square yard. The curves are taken from their respective "α" families and have values of α which give approximately equal weight per unit area.

The curves of Figure 6, which are taken directly from experimental data, are included for purposes of comparison with Figure 5. For additional comparison, the experimental curve of .048-inch Hadfield Steel has been included. Figures 6 through 9 each contain curves for different armor materials when subjected to the same conditions of impact. Because of the variables involved, these curves were taken directly from experimental data. They furnish some measurement of the relative merits of the different materials under specific conditions. It will be noted from Figures 6 and 7 that the behaviors of the metallic materials do not differ greatly one from another under some of the conditions shown. It is difficult to draw accurate conclusions regarding the relative critical velocities of the metallic materials in cases where these velocities were nearly equal to each other. The reason for this is that critical velocity varies considerably from one test to another, using specimens of a given material. By mutual agreement with the sponsor, it was decided that the extensive effort required to get accurate determination of critical velocities was not warranted in this investigation.

Figure 6 indicates that nylon duck has a comparatively high critical velocity when exposed to normal impact by flat-nosed fragments. However, this critical velocity was greatly reduced by oblique impact of flat-nosed fragments and still further reduced by conical-nosed fragments. These trends are observed in Figures 11, 12, 31 and 32.

Figures 8 and 9 indicate that the performance of 2S0 aluminum alloy is appreciably inferior to that of 24ST under 45° impact by either flat- or conical-nosed fragments. Figures 6 and 7 indicate that 2S0 has approximately the same performance as that of 24ST under normal impact by either flat- or conical-nosed fragments. These comparisons may apply only for an "α" value of approximately 2.3. When the value of α is increased to 7.0, Figures 100 and 138 show by comparison that the performance of 2S0 is greatly inferior to that of 24ST under normal impact by flat-nosed fragments.

C. Incidence Angle

Angle of incidence as defined in this report is the angle formed between the path of an approaching fragment and the perpendicular to the plane of the armor material.

Figures 10 through 39 illustrate the effects on fragments of certain nose shapes produced by varying the incidence angle of the armor materials. The nose shapes studied were flat, horizontal, and conical (90° apex angle).

To predict the approximate effect of varying the angle of incidence for metals, allowance must be made for the effective change in plate thickness and perimeter of the cap punched out during impact. The new values of thickness and perimeter thus obtained can then be substituted in the "α" equation and a suitable value obtained for α.

In the case of aluminum, it is observed that the mode of failure remains that of a simple shear over the entire elliptical perimeter. The new perimeter, therefore, is that of the ellipse produced by the oblique angle of penetration. The new effective plate thickness is measured through the hole in a direction parallel to the approach of the bullet. This may be determined by multiplying the actual plate thickness "h" by the secant of the angle of incidence.

In the case of Hadfield Steel, it is noted that the manner of failure is somewhat different. Under normal impact, the fragment produces a uniform type of failure around the entire perimeter of the cap punched out of the plate. At incidence angles of 15° and more, the nature of failure is uniform around part of the perimeter while the balance fails in a combined tearing and bending action.

In the studies to date, this latter action occurs over approximately one-fourth or one-fifth of the elliptical perimeter. The apparent ease of this type of failure is occasionally indicated when the portion of the cap initially punched out of the plate swings around, as if on a hinge, with sufficient velocity to dent the reverse side of the plate. If it may

be assumed the energy absorbed in the latter portion of the failure is small compared to that absorbed by the initial and uniform type failure, then a factor is apparent which may be used to modify the elliptical perimeter. Thus far, it appears to be 3/4 to 4/5.

The modified plate thickness is obtained as in the case of aluminum by multiplying the actual plate thickness by the secant of the angle of incidence.

For aluminum, the modified λ values have been computed and their corresponding curves appear as dashed lines on each related graph. In the case of Hadfield Steel, this has not been done because of the limitations for "α" evaluation discussed in Section IV-A of this report.

D. Nose Shape

Figures 40 through 59 compare for a given material the respective performances of fragments having different nose shapes, viz., flat, hemispherical, and conical. Comparisons are given at incidence angles of 0° and 45°.

It does not appear feasible to attempt to draw detailed conclusions regarding the relative effects of the various nose shapes because of the inconsistent behavior noted in Figures 43 through 50. It is believed that these inconsistencies are due to two factors: (1) the variation in performance of different specimens of a given material under supposedly identical impact conditions; and, (2) the errors involved in measuring both striking and residual velocities. The velocity-measuring errors are due primarily

to the short base lines used. In the case of striking velocity, a short base line is necessitated by the need for guiding the fragment up to the plate. In the case of residual velocity measurement, the short base line is necessitated by the wide angles of divergence encountered under oblique impact conditions.

Curves which are believed to represent the approximate extremes of combined errors and material variations are shown in Figures 47 and 49.

E. Fabric

Curves 10, 11, 12, 31 and 32 show that the performance of nylon duck is not appreciably affected by varying the incidence angle. However, when a large number of plies is used, certain nose shapes have a pronounced effect. Figures 41 and 42 show that when there is a large number of plies the conical nose fragment penetrates much more readily than the flat nose fragment; however, when a small number of plies is used, the difference in nose shape has a negligible effect, as illustrated in Figure 40.

F. Multiple Laminations of Metal

The investigation of the performance of multiple laminations of metal was limited to the study of four contiguous layers of .032-inch 24ST-3 aluminum alloy. The results of the study indicate that, for the conditions tested, the performance of the laminated material is slightly inferior to that of an equivalent thickness of solid material. A comparison of the two can be obtained by referring to Figures 167 and 137.

The dashed curve on Figure 167 was determined by applying the evaluation method successively to four separate plies. The method was to take a given striking velocity and, using a value of α equal to 1.18 (obtained by interpolation from the "α" curves given in Figure 3), determine the residual velocity of the fragment as it leaves the first ply. This residual velocity was then considered to be the striking velocity for the second ply. By using the same value of α again, the residual velocity of the second ply was determined. This procedure was repeated for the third and fourth plies. The entire procedure was then repeated for other values of initial striking velocity. The curve was then constructed by plotting residual velocity versus striking velocity. It will be noted that the evaluation method applied above to multiple laminations is the same as that described in the final report of Contract No. W23-072-ORD-2123, with the exception that the mass of the penetrating fragment was considered to be constant throughout.

In the previous contract, the mass of the fragment when striking each successive layer was considered to be increased by the mass of the cap torn from the preceding layer. This was based on the assumption that the cap was broken away from the surrounding material before the full extent of permanent deformation had been reached. The study of time of impact made with the six-channel oscillograph, together with observations of partial penetration of laminated plates, indicates that all or a large portion of the permanent deformation occurs before the fracture is complete.

This indicates that, in the case of laminated constructions consisting of contiguous layers of stiff materials, the force of penetration begins to be transmitted to successive layers before the failure of the first layer is complete. Thus, it would seem logical to consider the mass of the penetrating fragment as being constant throughout the penetration process.

Upon reviewing the data of the previous contract, it was found that closer agreement between experimental curves and those predicted by the evaluation method could be obtained when the mass of the penetrating fragment was considered constant.

G. Metal and Fabric

Figures 164 through 166 indicate that the "α" relation can be used to predict the performance of composite materials with a fair degree of accuracy. For these figures, the "α" curves were constructed in a manner similar to that described in Section F. In this case, it is probable that the mass of the penetrating fragment should be considered to be increased by the mass of the aluminum cap before it contacts the succeeding layers of nylon for the reason that fracture of the aluminum is probably completed before the succeeding layers of nylon are fully loaded. However, it was felt that the position of the "α" curve would not be appreciably affected by the small mass of the .064-inch cap and, for the sake of simplicity, the fragment mass was considered constant.

It will be noted from Figure 25 that the penetration resistance of the composite armor at 45° incidence angle is appreciably greater than at 0° in the lower velocity range. Figure 10 shows that a construction consisting of four plies of nylon does not exhibit any appreciable difference in penetration resistance between 0° and 45°. The same is true of thin sheets of aluminum alloy. Accordingly, if no other factors were present, it would be expected that a combination of thin aluminum and a few plies of nylon at 45° would show practically no improvement in resistance over that at 0°. Observation of plate fractures at 45° indicates that there is a tendency to turn the fragment during penetration, especially at low velocities. It is possible that the fragment is turned as it leaves the aluminum plate so that it presents a more nearly broadside surface to the nylon, thereby bringing more threads into action.

The foregoing may explain why a combination of nylon and aluminum exhibits better performance at 45° than would be expected by taking the 45° curves of nylon and aluminum into account separately.

V. CONCLUSIONS

The following general conclusions can be drawn from the curves presented in this report:

1. The critical design condition for each of the aluminum alloys studied is that of normal impact by flat-nosed fragments.

2. Of the various conditions studied, those which are critical for nylon duck are normal impact by conical-nosed fragments and 45° impact by flat-nosed fragments.

3. The critical condition for Hadfield Steel is oblique impact at approximately 15°.

4. Solid aluminum apparently has a slightly greater penetration resistance than an equivalent thickness of laminated aluminum under normal impact by 1/4-inch diameter, flat-nosed fragments.

5. Aluminum alloys and nylon duck conform to the "α" relation, at least for the range of conditions studied. This relation permits one to construct a family of curves for a given material from one basic curve determined experimentally. This family of curves can then be used to predict the performance of various thicknesses or numbers of layers of a given material for normal impact by flat-nosed, cylindrical fragments of different masses and diameters over a range of striking velocities. Hadfield Steel does not appear to conform to this relation.

6. For conditions of oblique impact by flat-nosed fragments, the performance of aluminum alloys can be predicted with reasonable accuracy from a family of

"a" curves by modifying the values of plate thickness and fragment perimeters to correspond to the angle in question.

7. For most of the conditions studied, the penetration resistance of aluminum alloys and Hadfield Steel is not affected by fragments of various nose shapes in a sufficiently consistent manner to permit the formulation of a rule to predict the performance accurately.

8. Comparing the tested materials on the basis of equal weight per unit area, only one of these materials, viz., 2S0 aluminum alloy, has shown consistently inferior performance over most of the range of test conditions. Nylon duck shows a remarkably superior critical velocity under impact by flat-nosed fragments. The other materials, viz., Hadfield Steel, 24ST, and 75ST aluminum alloys, are roughly equal in over-all performance.

9. It may be possible to utilize the advantages of some materials under certain conditions provided that some special types of armor construction or other means can be found to avoid exposing the material in question to other conditions for which it is not well suited. Examples of these situations follow:

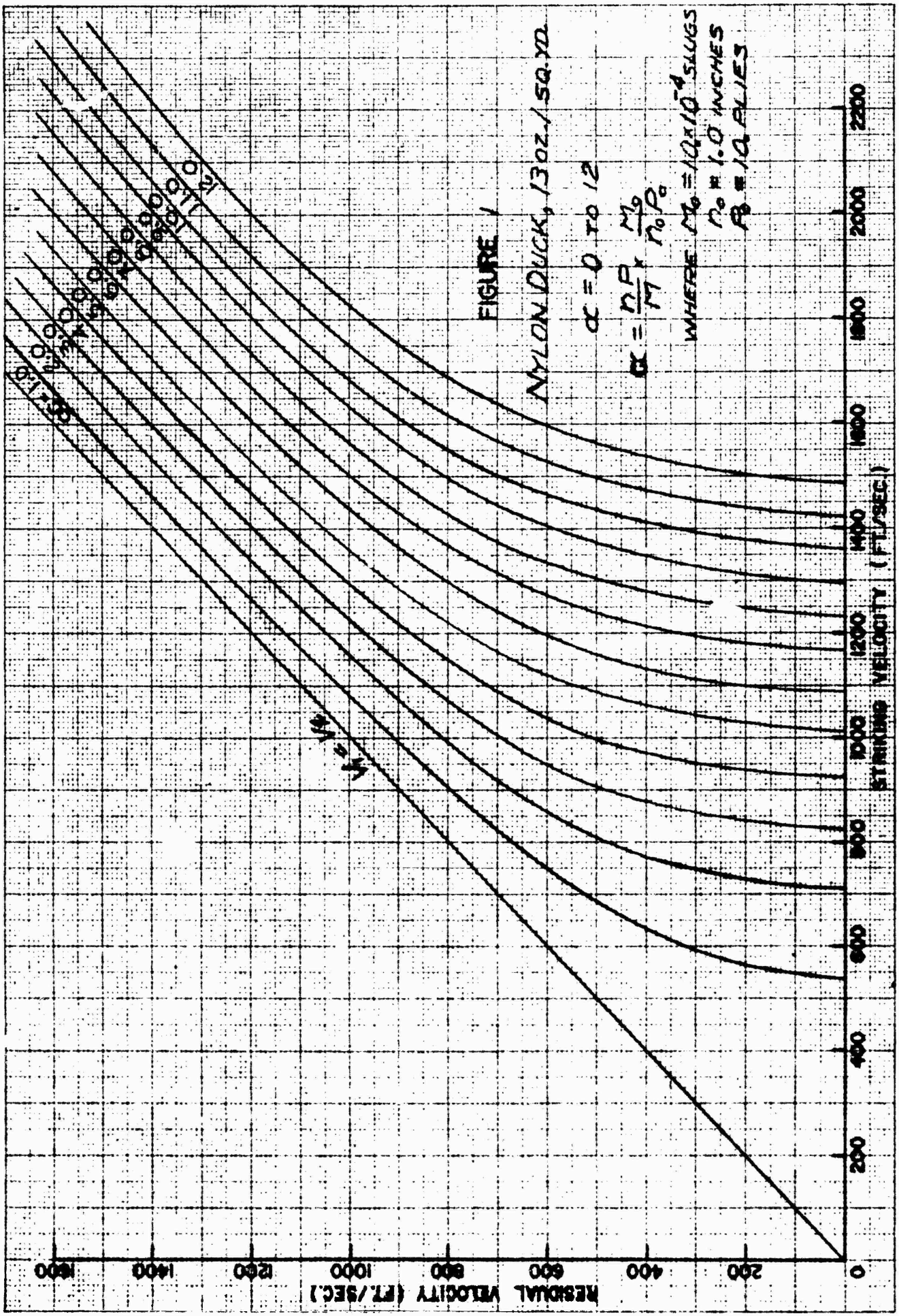
a. The characteristic of nylon, whereby this material exhibits a high critical velocity under normal impact by flat-nosed fragments, indicates that it may possibly be used as the interior material in composite armor, provided that a form of construction can be found which will circumvent the disadvantage of excessive detrusion under impact. However, the advantage of high critical velocity would not be realized under impact by conical-nosed fragments unless the cap from the outside material (presumably metal) is sufficiently flat to make the cap and fragment act as a flat-nosed fragment when the cap contacts the nylon.

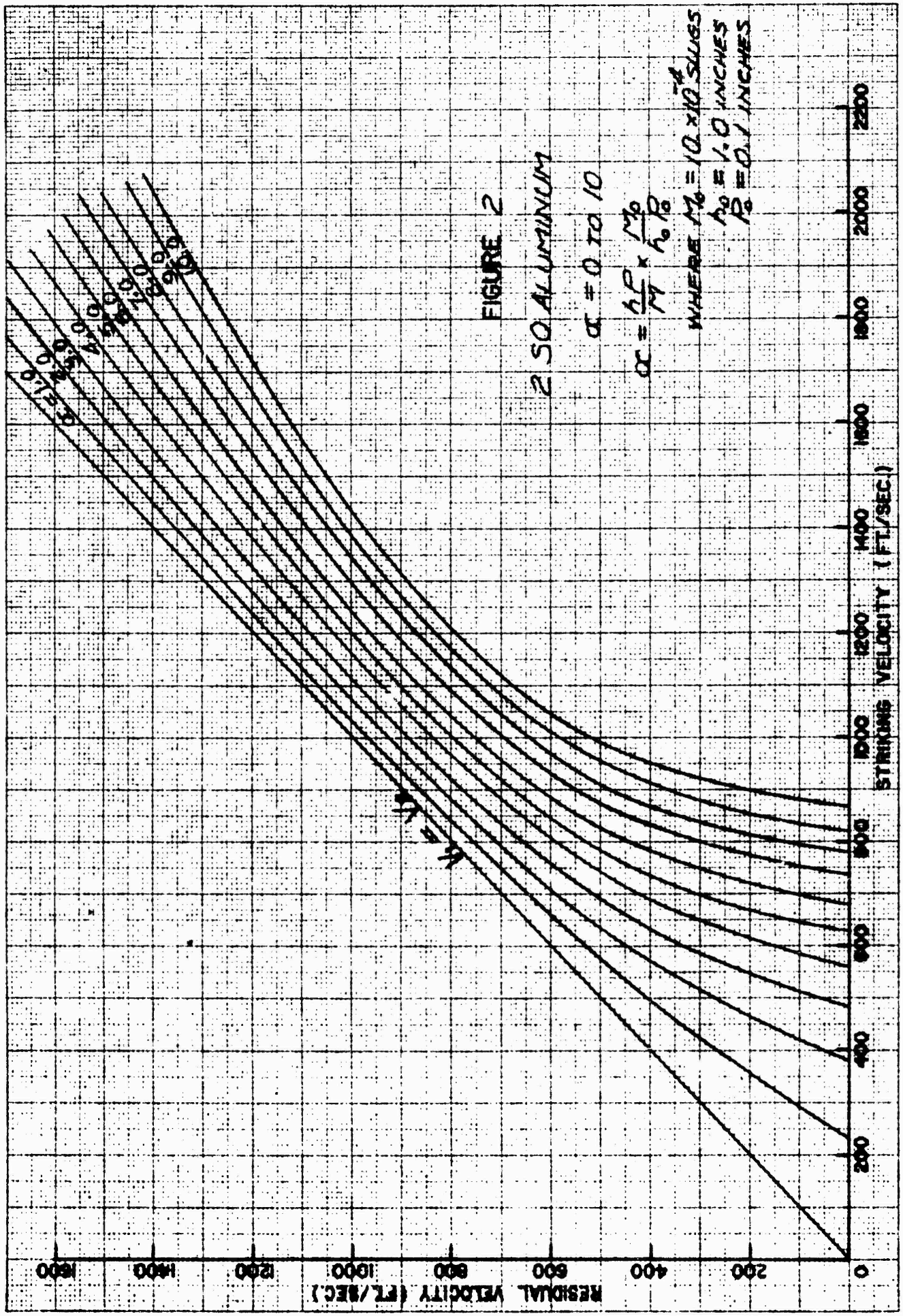
b. The reduced resistance of Hadfield Steel under 15° and 30° impact may conceivably be improved if it can be backed up with a material which will force the steel to fail uniformly around the entire perimeter of the cap. However, it is probable that a suitable material, that is, one having adequate stiffness for this purpose, would be too heavy to use in conjunction with Hadfield Steel.

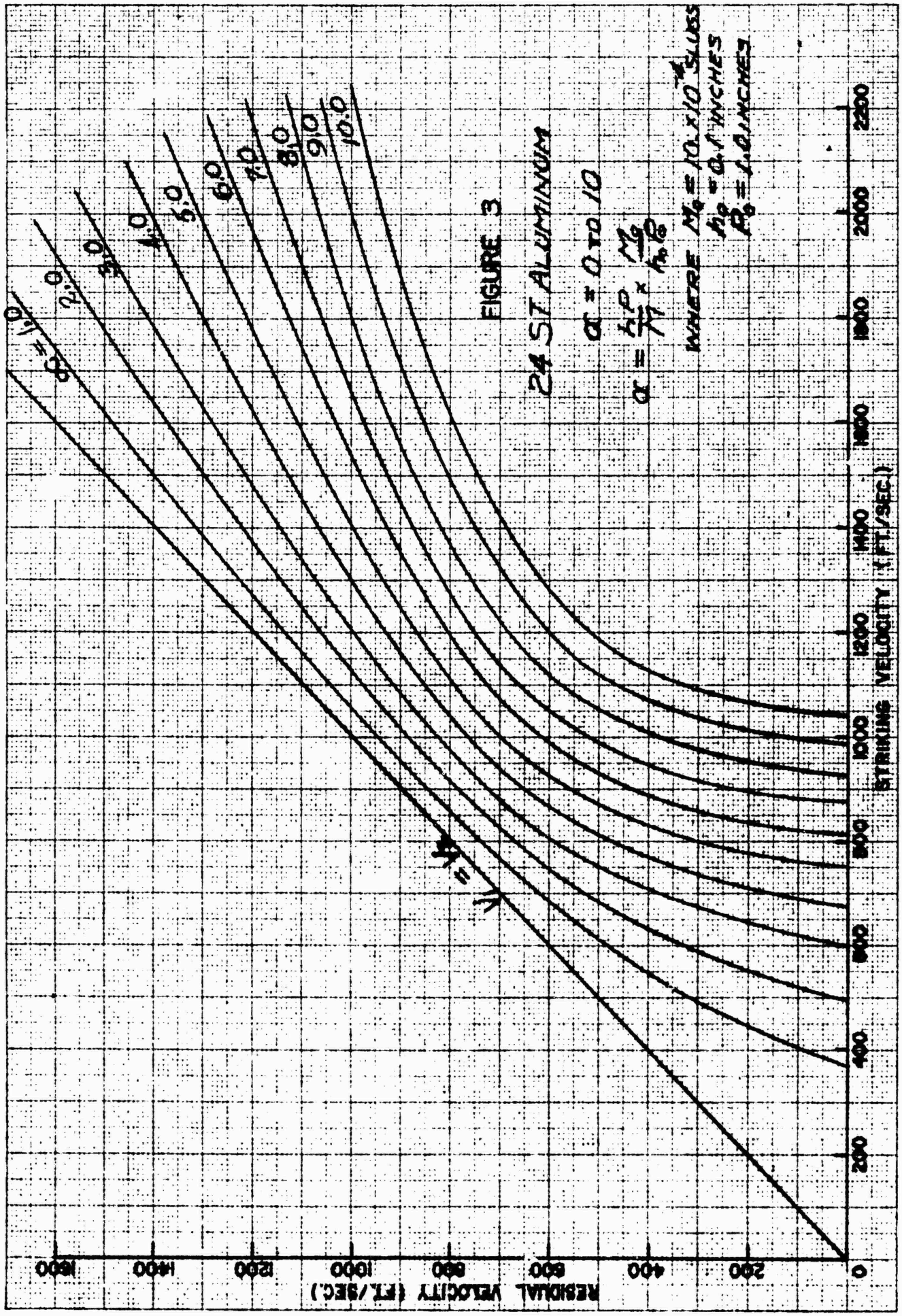
APPENDIX A

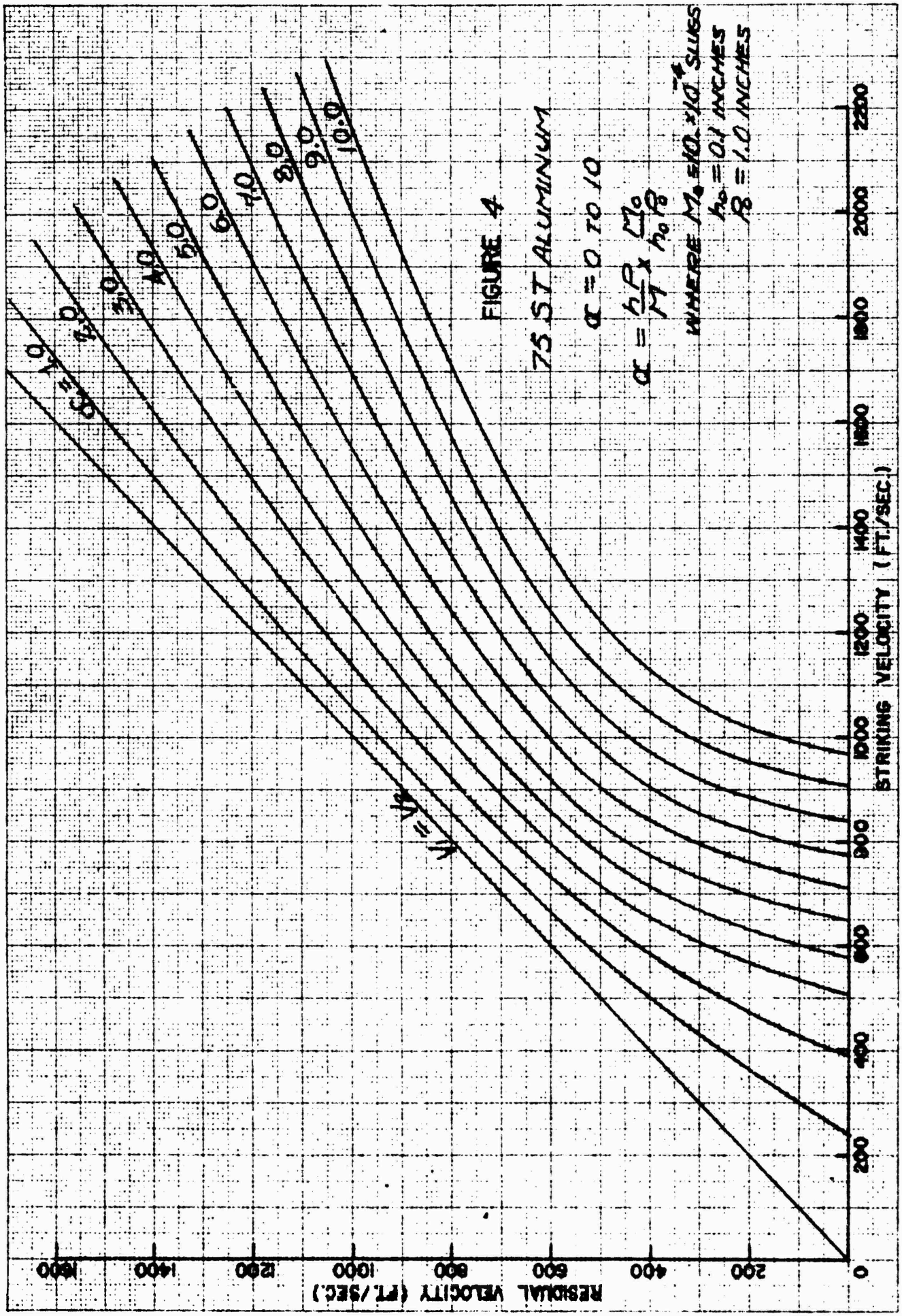
INDEX TO CURVES

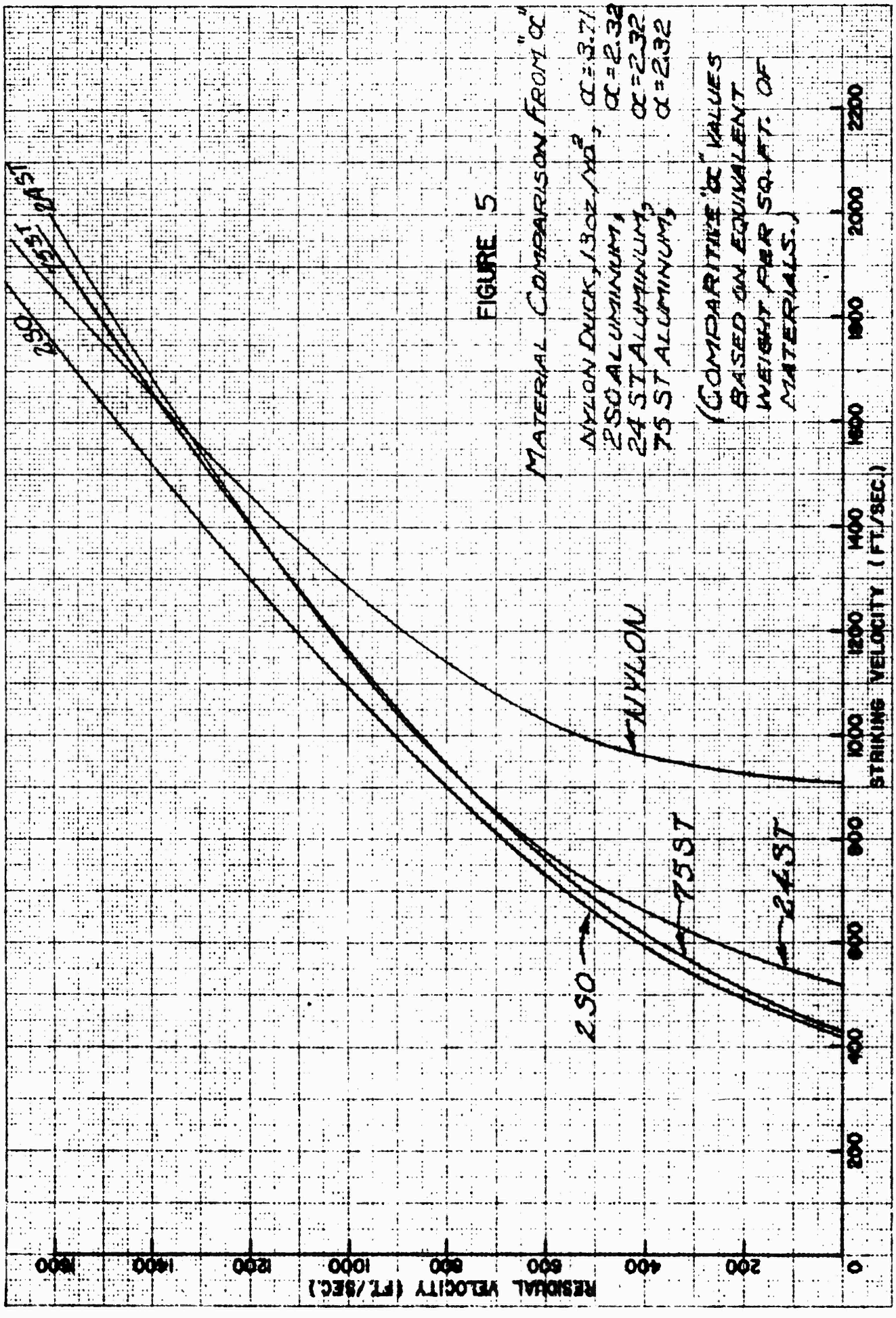
INDEX TO CURVES (Concluded)











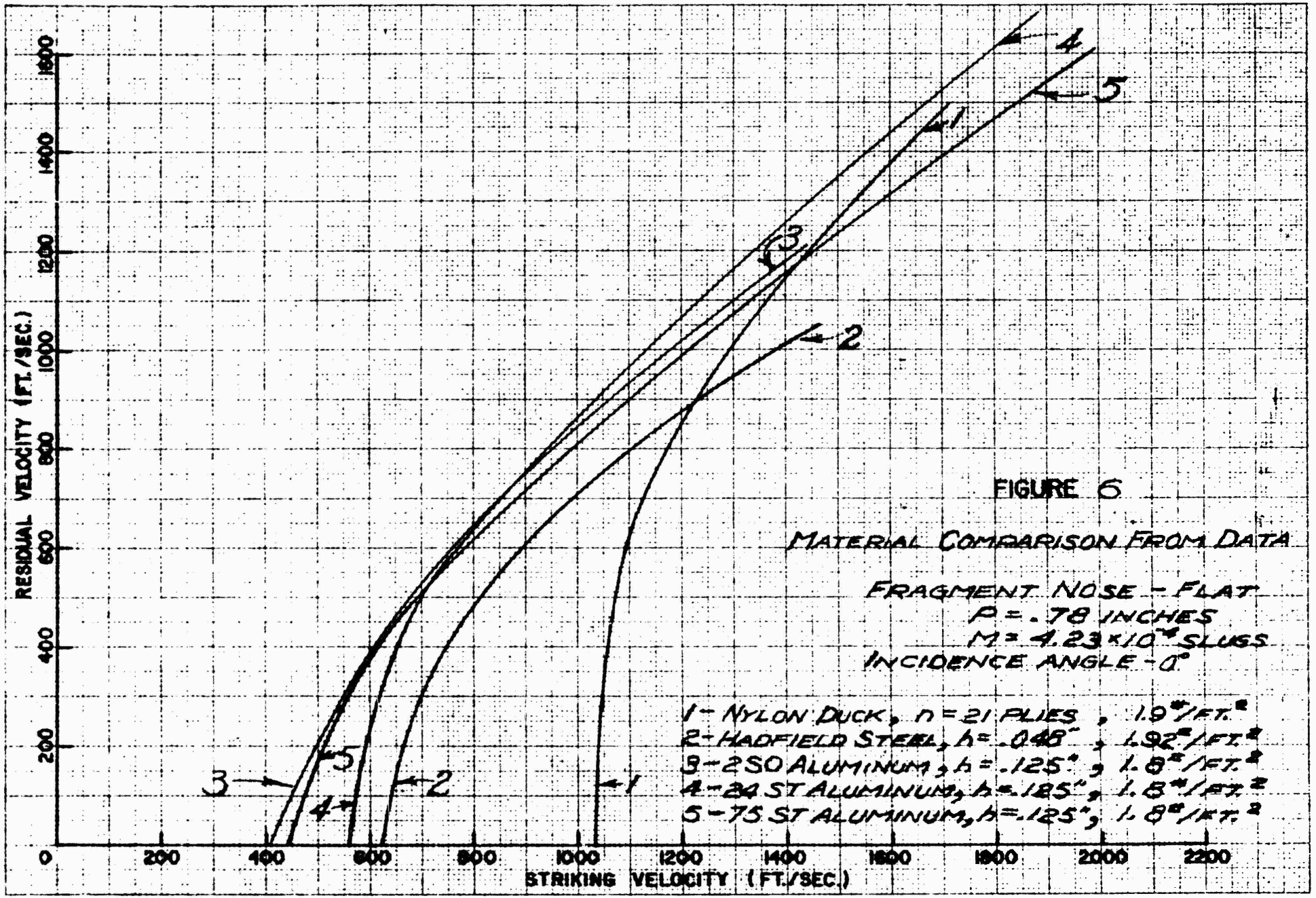


FIGURE 6

MATERIAL COMPARISON FROM DATA

FRAGMENT NOSE - FLAT
P = .78 INCHES
M = 4.23 x 10⁻⁴ SLUGS
INCIDENCE ANGLE - 0°

RESTRICTED

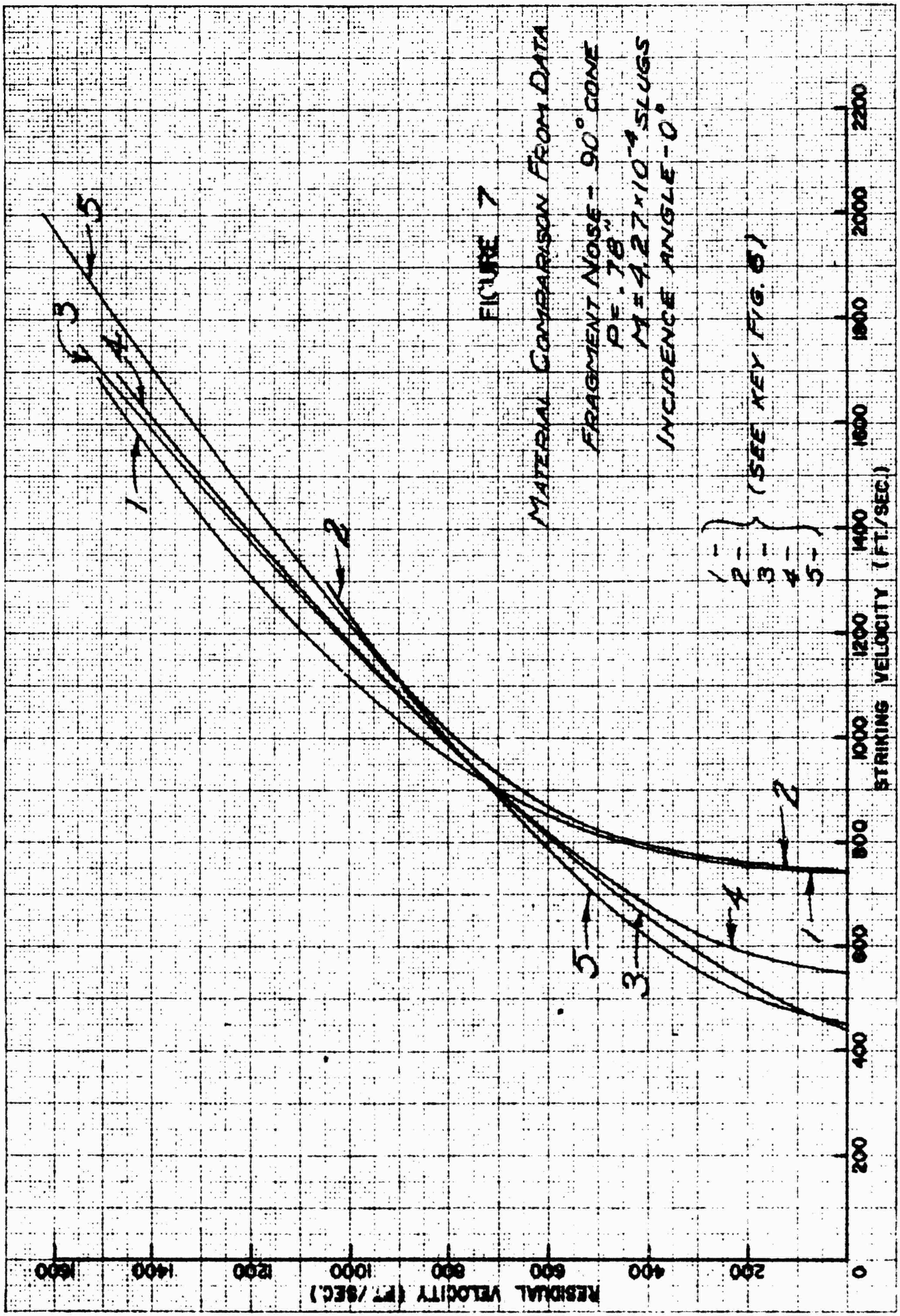

MATERIAL COMPARISON FROM DATA
FRAGMENT NOSE - 90° CONE
De = .78"
M = 4.27 x 10⁻⁴ SLUGS
INCIDENCE ANGLE - 0°
1 - 2 - 3 - 4 - 5 - (SEE KEY FIG. 6)
STRIKING VELOCITY (FT./SEC.)
RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

FIGURE 7

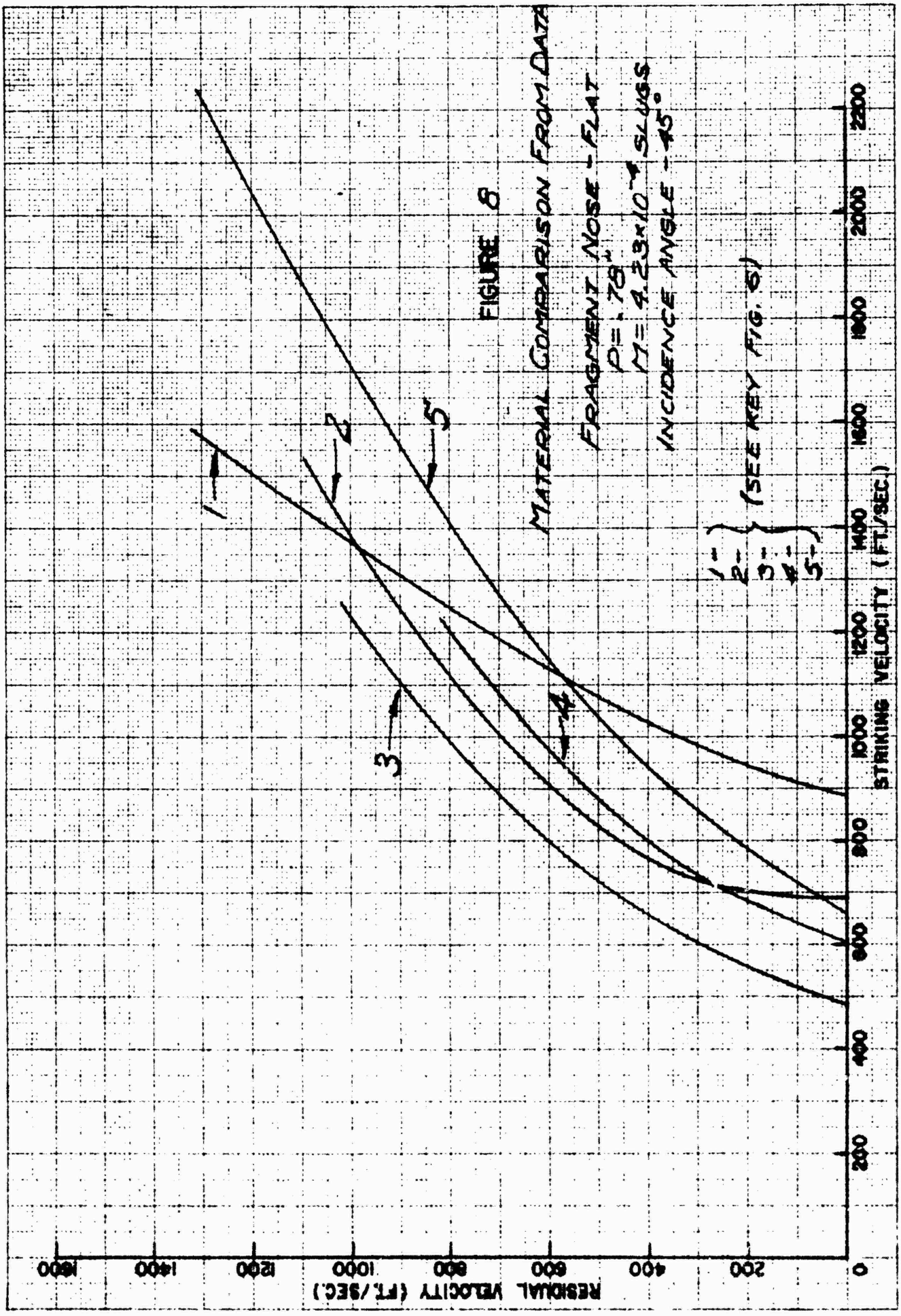


FIGURE 8
MATERIAL COMPARISON FROM DATA
FRAGMENT NOSE - FLAT
D = .75"
M = 4.23 x 10⁻⁴ SLUGS
INCIDENCE ANGLE - 45°
1 - 2 - 3 - 4 - 5 - (SEE KEY FIG. 5)
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

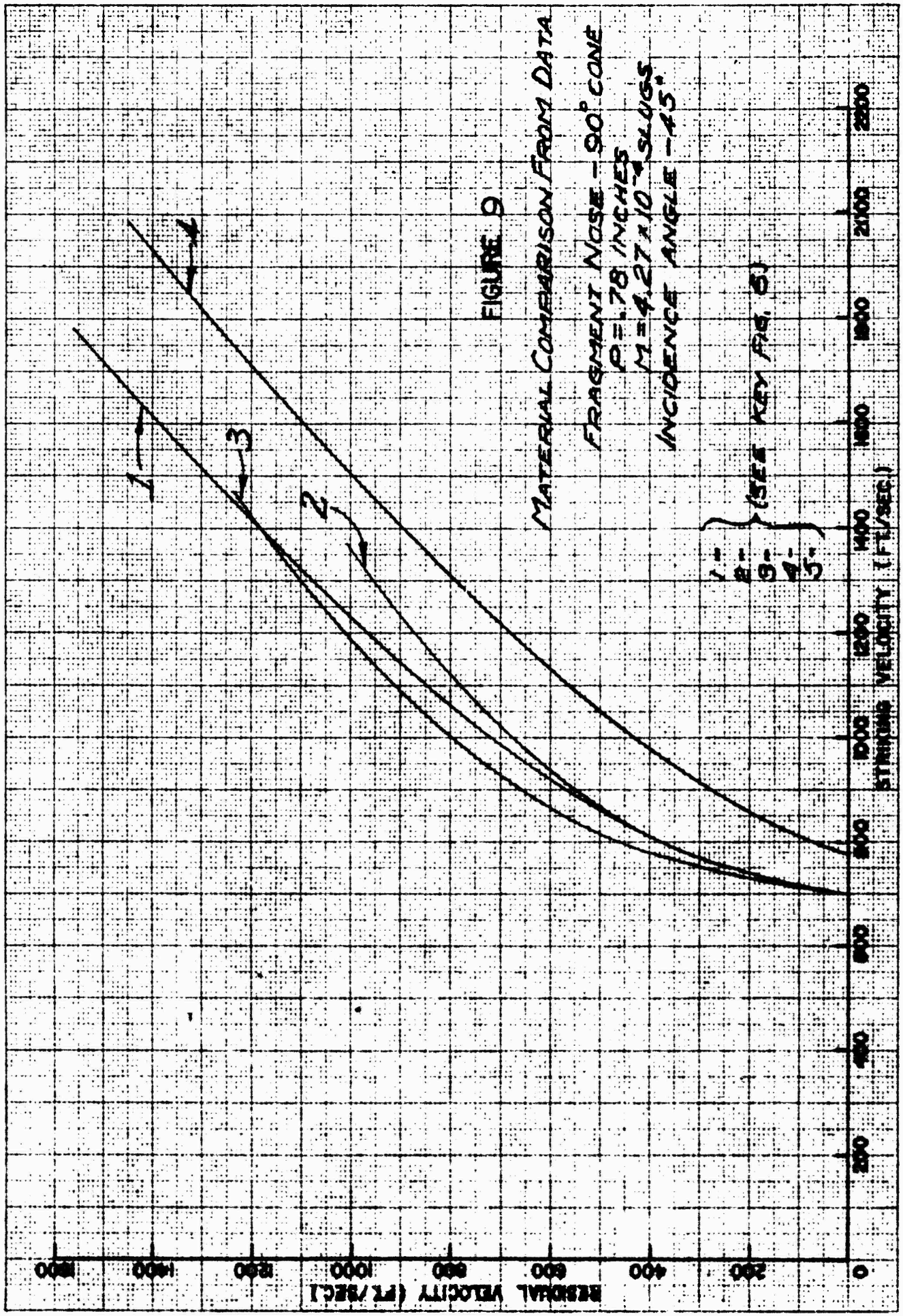


FIGURE 9
MATERIAL COMPARISON FROM DATA
FRAGMENT NOSE - 90° CONE
ρ = 1.78 INCHES
M = 4.27 x 10⁻⁴ SLUGS
INCIDENCE ANGLE - 45°
1 - (SEE KEY FIG. 6)
2 -
3 -
4 -
5 -
1
2
3
4
5
RESIDUAL VELOCITY (FT/SEC.)
STRIKING VELOCITY (FT/SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

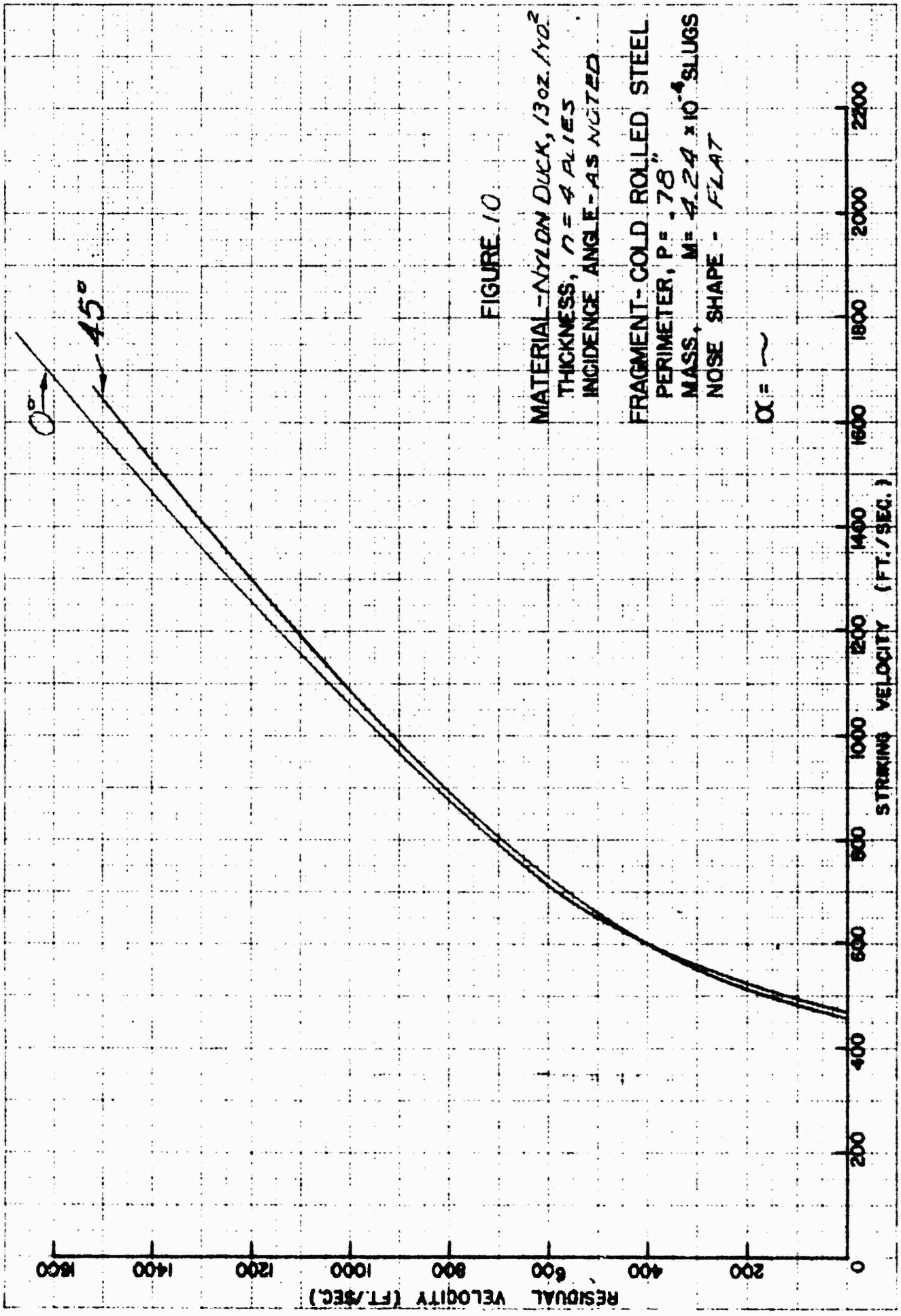

MATERIAL-NYLON DUCK, 13 oz./YD.²
THICKNESS, n = 4 PLIES
INCIDENCE ANGLE-AS NOTED
FRAGMENT-COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.24 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = ~
0°
45°
STRIKING VELOCITY (FT./SEC.)
RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

FIGURE 10

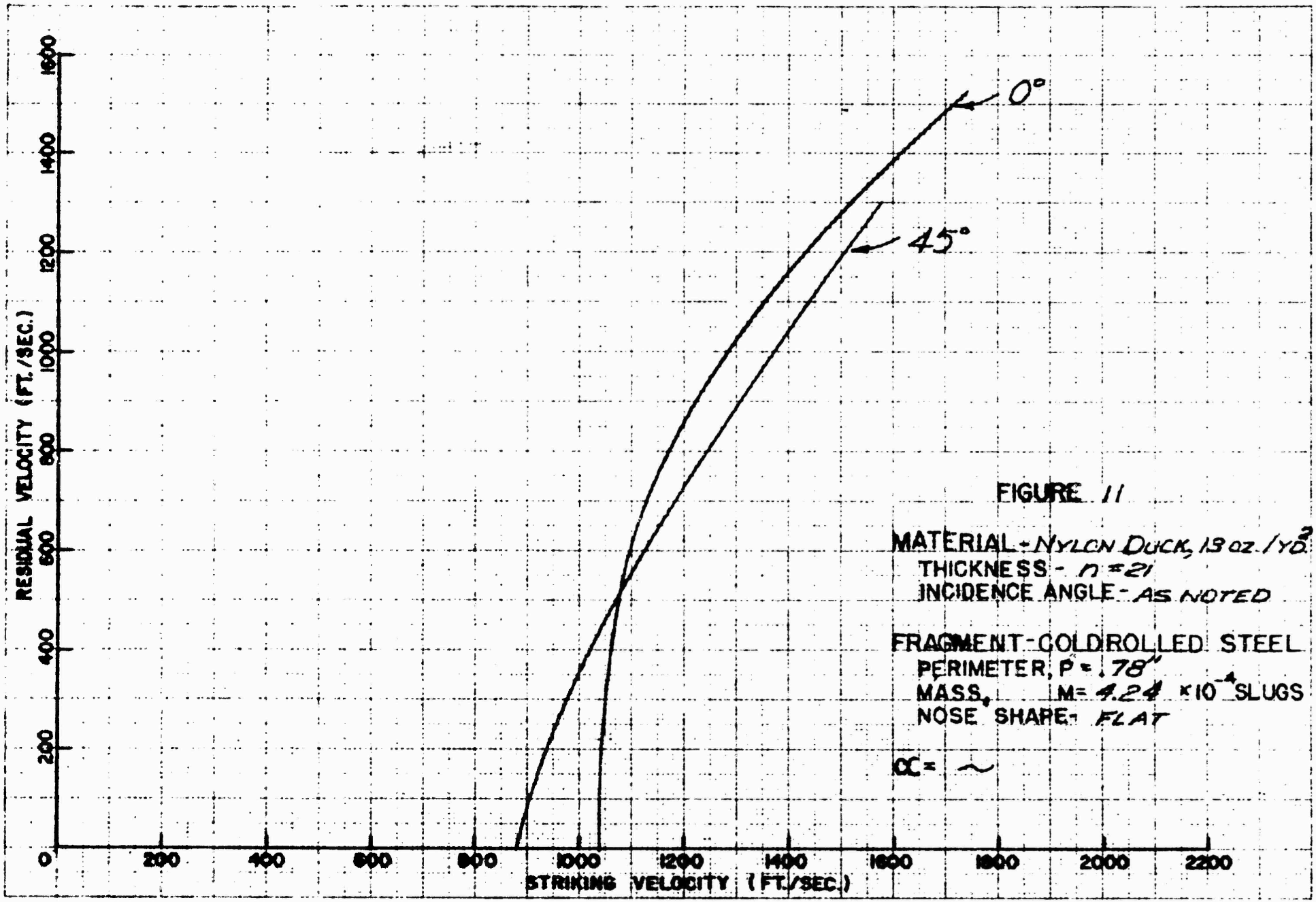


FIGURE 11

MATERIAL - NYLON DUCK, 13 oz./YD.^{2}
THICKNESS - n = 21
INCIDENCE ANGLE - AS NOTED

FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.24 $\times 10^{-4}$ SLUGS
NOSE SHAPE - FLAT

OC = ~

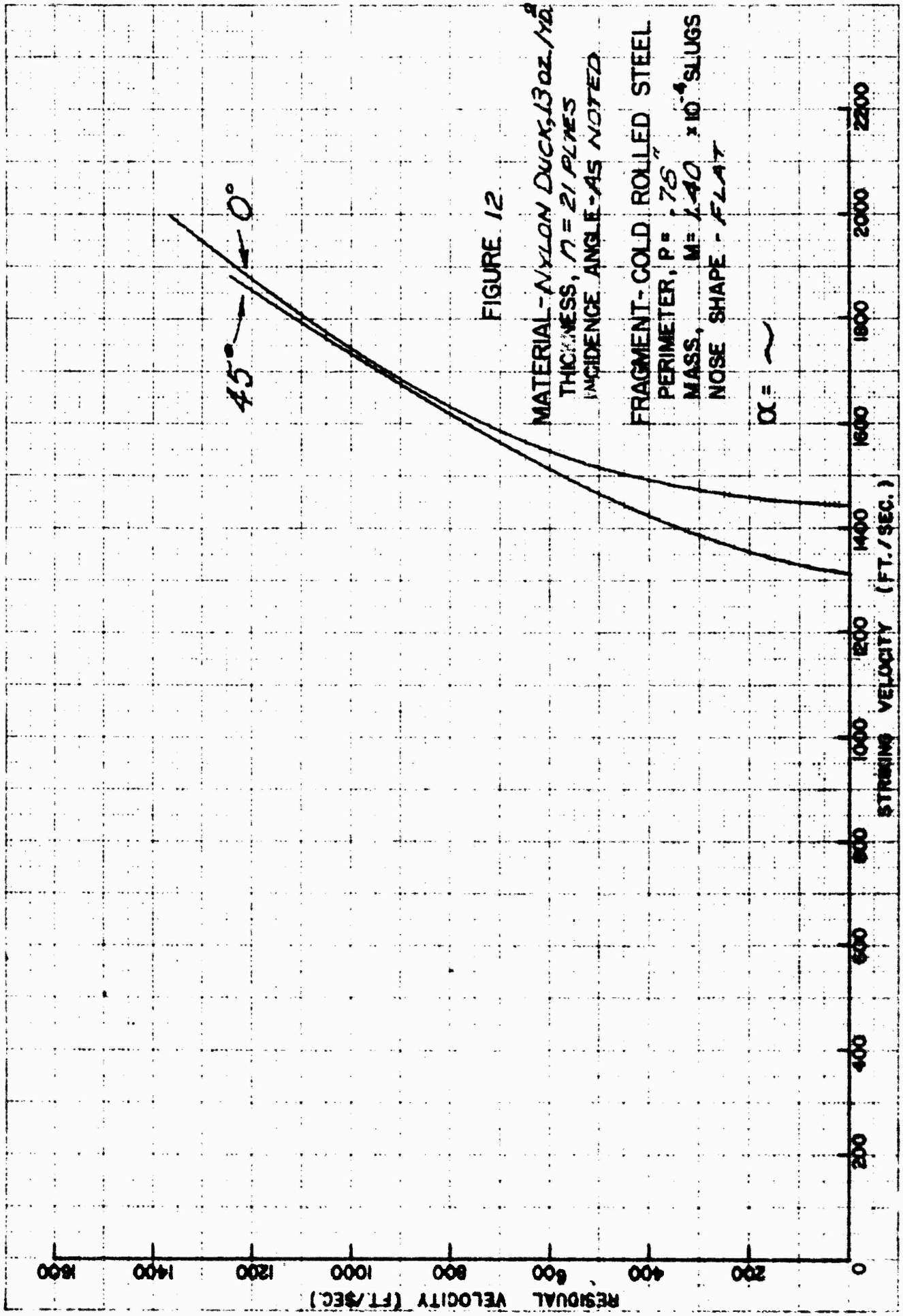
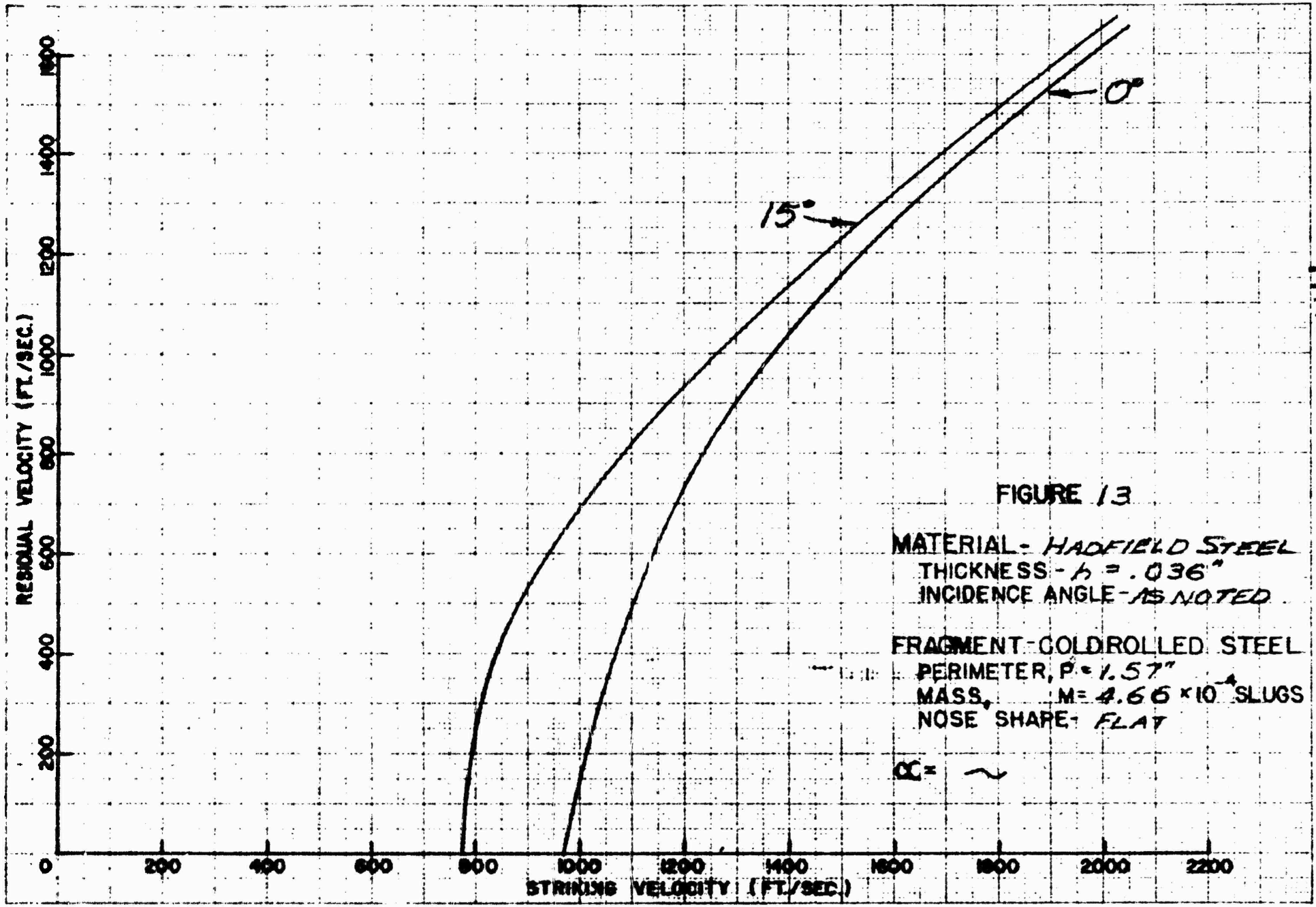
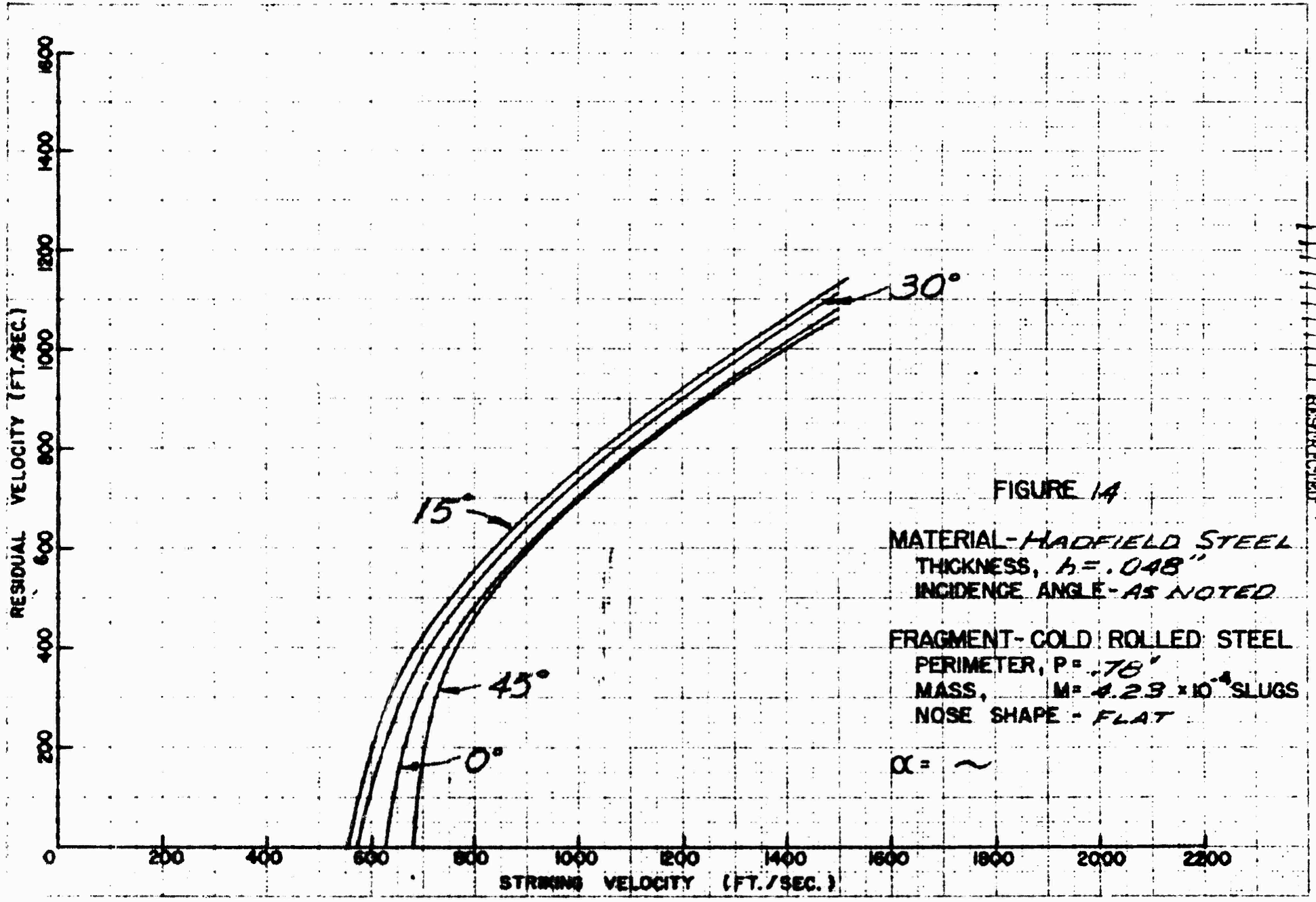


FIGURE 12
MATERIAL - NYLON DUCK, 13 OZ./YD.²
THICKNESS, n = 21 PLIES
INCIDENCE ANGLE AS NOTED
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .75"
MASS, M = .140 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = ~
45° — 0°
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
0°
15°
FIGURE 13
MATERIAL - HADFIELD STEEL
THICKNESS - h = .036"
INCIDENCE ANGLE - AS NOTED
FRAGMENT - COLDROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 4.66 × 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
CC = ~


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
30°
15°
45°
0°
FIGURE 14
MATERIAL - HADFIELD STEEL
THICKNESS, h = .048"
INCIDENCE ANGLE - AS NOTED
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 × 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = ~

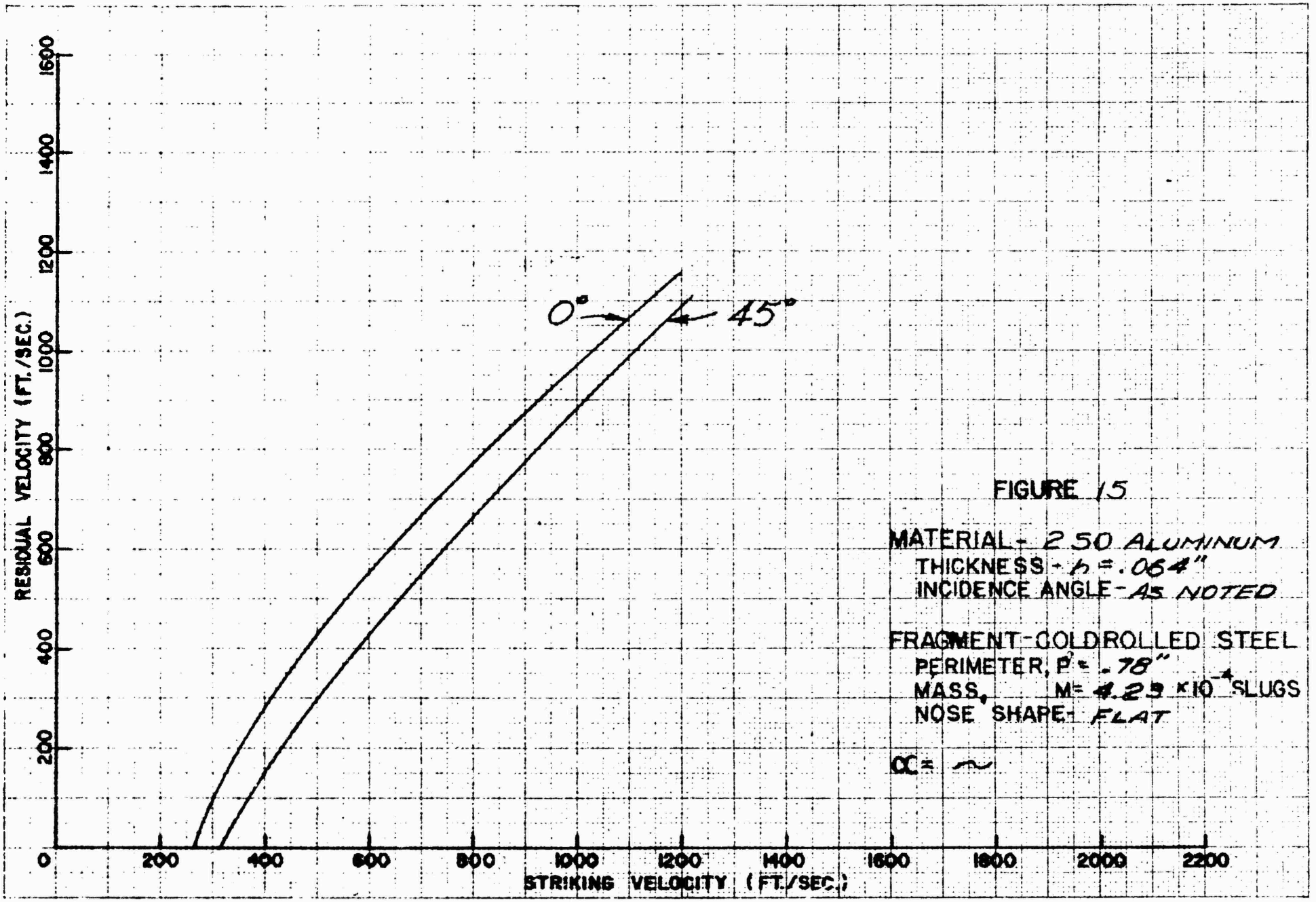


FIGURE 15

MATERIAL - 2S0 ALUMINUM
THICKNESS - $h = .064''$
INCIDENCE ANGLE - AS NOTED

FRAGMENT - COLDROLLED STEEL
PERIMETER, $P = .78''$
MASS, $M = 4.23 \times 10^{-4}$ SLUGS
NOSE SHAPE - FLAT

CC = ~

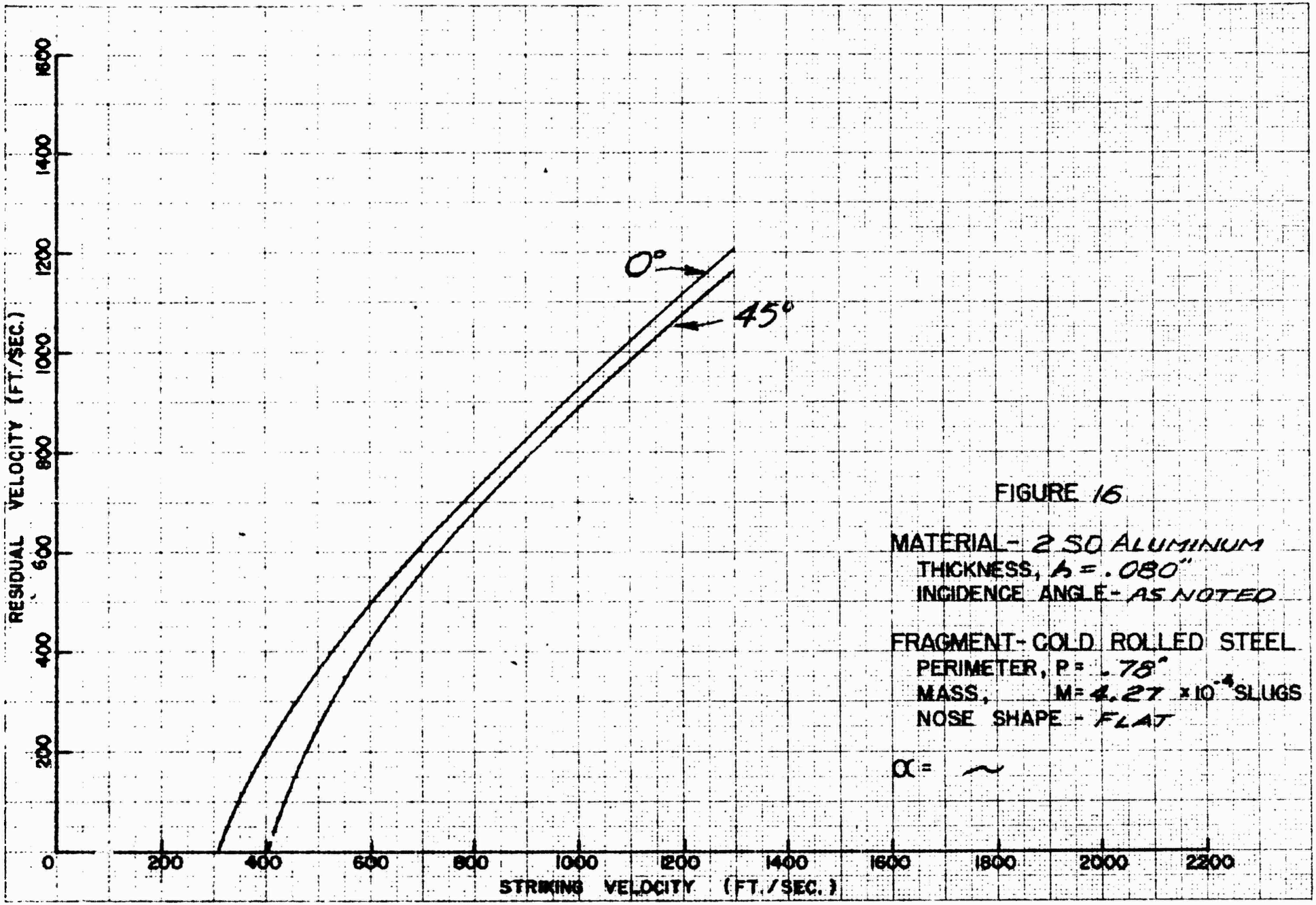


FIGURE 16

MATERIAL - 2S0 ALUMINUM
THICKNESS, h = .080"
INCIDENCE ANGLE - AS NOTED

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.27×10^{-4} SLUGS
NOSE SHAPE - FLAT

α = ~

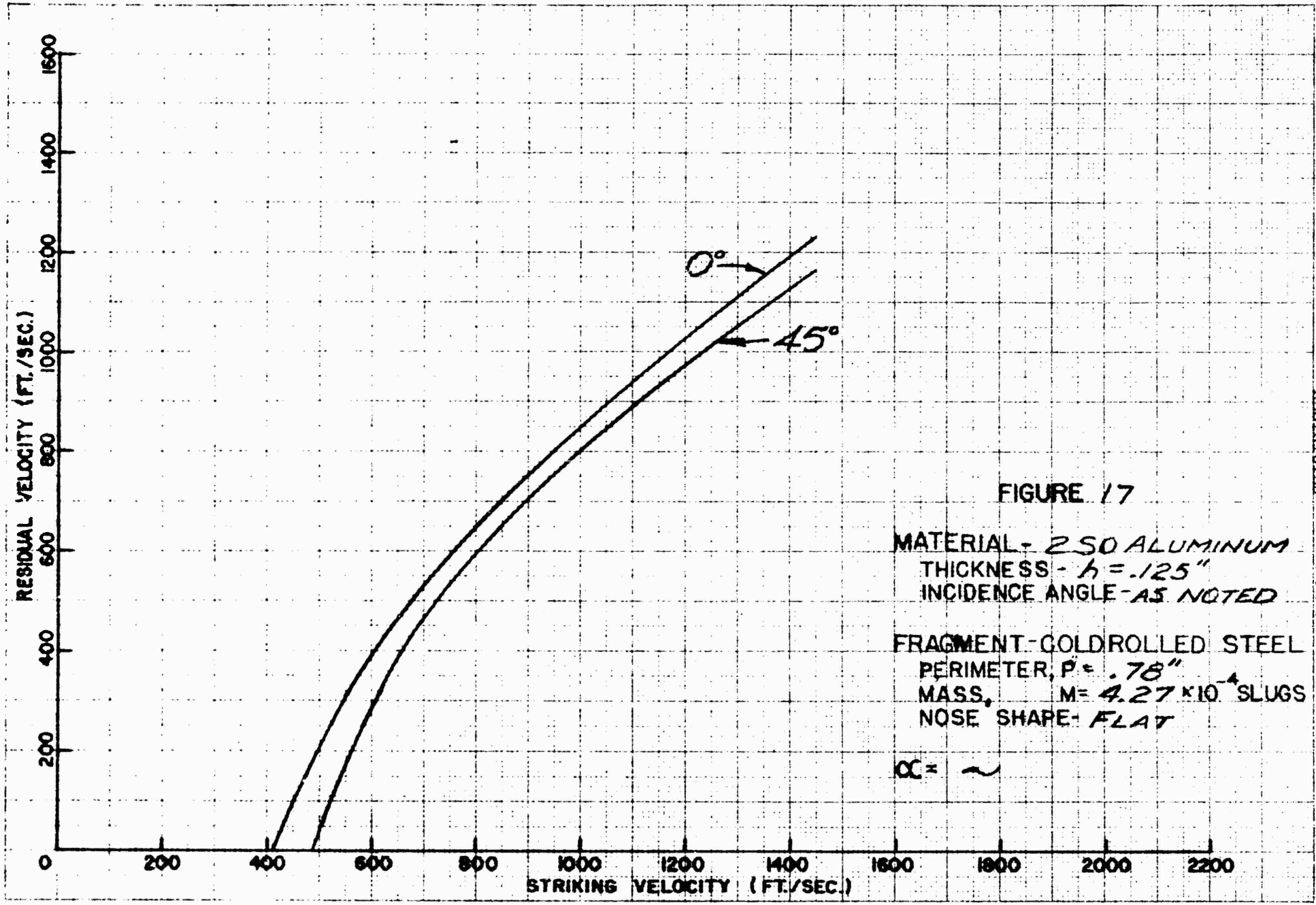


FIGURE 17

MATERIAL - 2S0 ALUMINUM
THICKNESS - $h = .125"$
INCIDENCE ANGLE - AS NOTED

FRAGMENT - COLD ROLLED STEEL
PERIMETER, $P = .78"$
MASS, $M = 4.27 \times 10^{-4}$ SLUGS
NOSE SHAPE - FLAT

$\alpha = \sim$

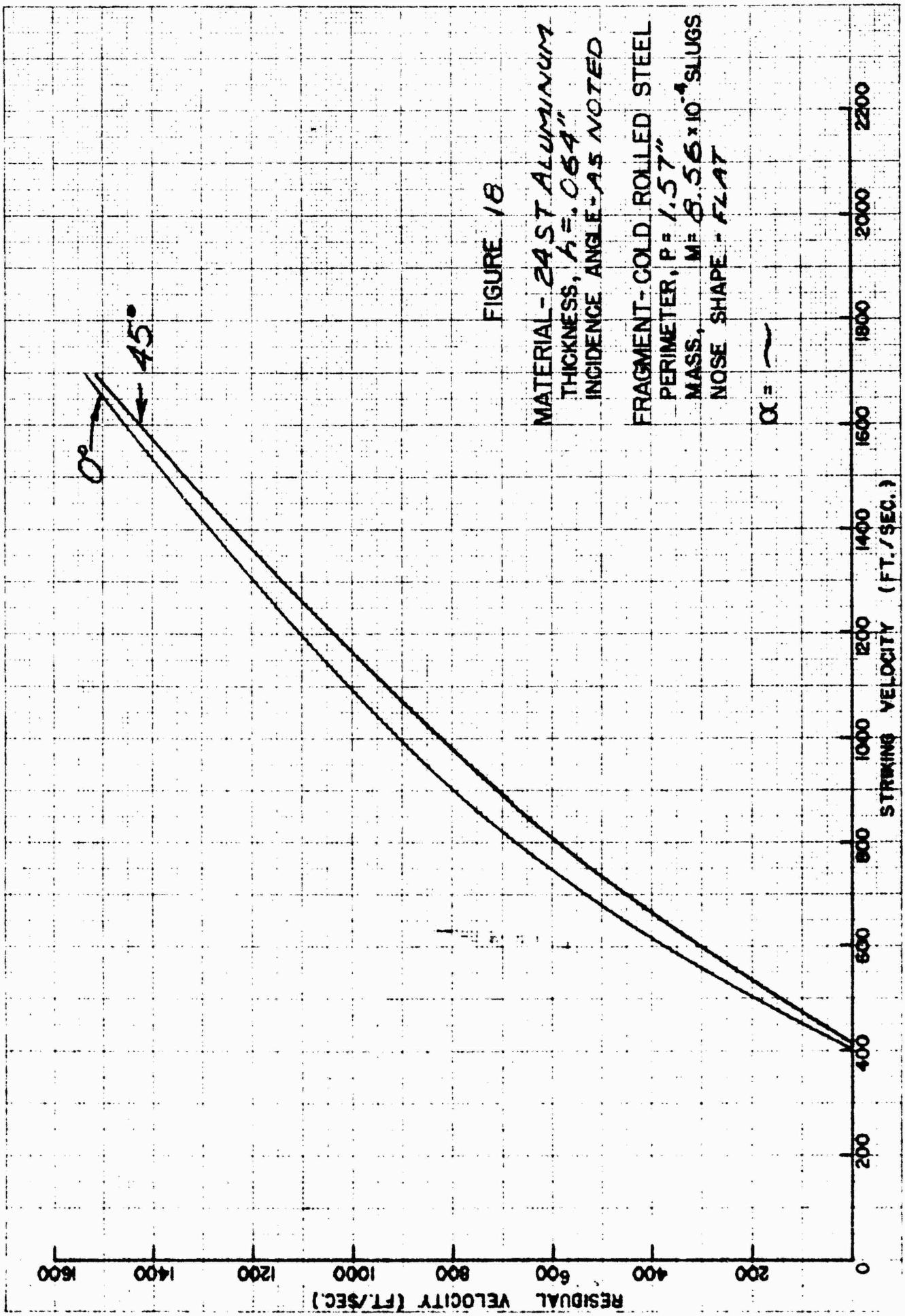


FIGURE 18
MATERIAL - 24ST ALUMINUM
THICKNESS, h = .064"
INCIDENCE ANGLE - AS NOTED
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 8.56 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = ~
0°
45°
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

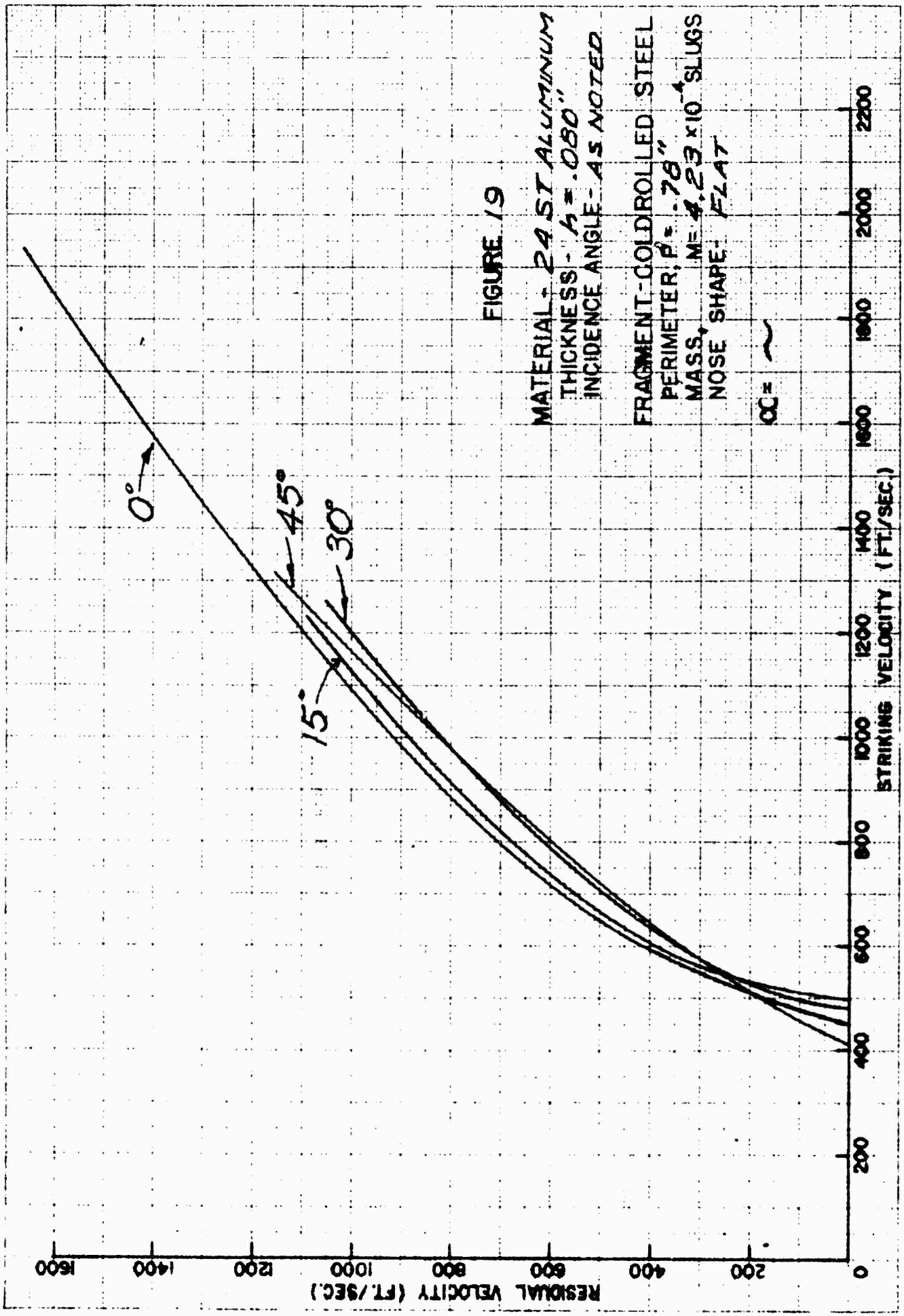

MATERIAL - 24 ST ALUMINUM
THICKNESS - h = .050"
INCIDENCE ANGLE - AS NOTED
FRAGMENT - COLDROLLED STEEL
PERIMETER, p = .78"
MASS, M = 4.23 x 10⁻⁴ SLUGS
NOSE SHAPE: FLAT
α = ~
0°
15°
30°
45°
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

FIGURE 19

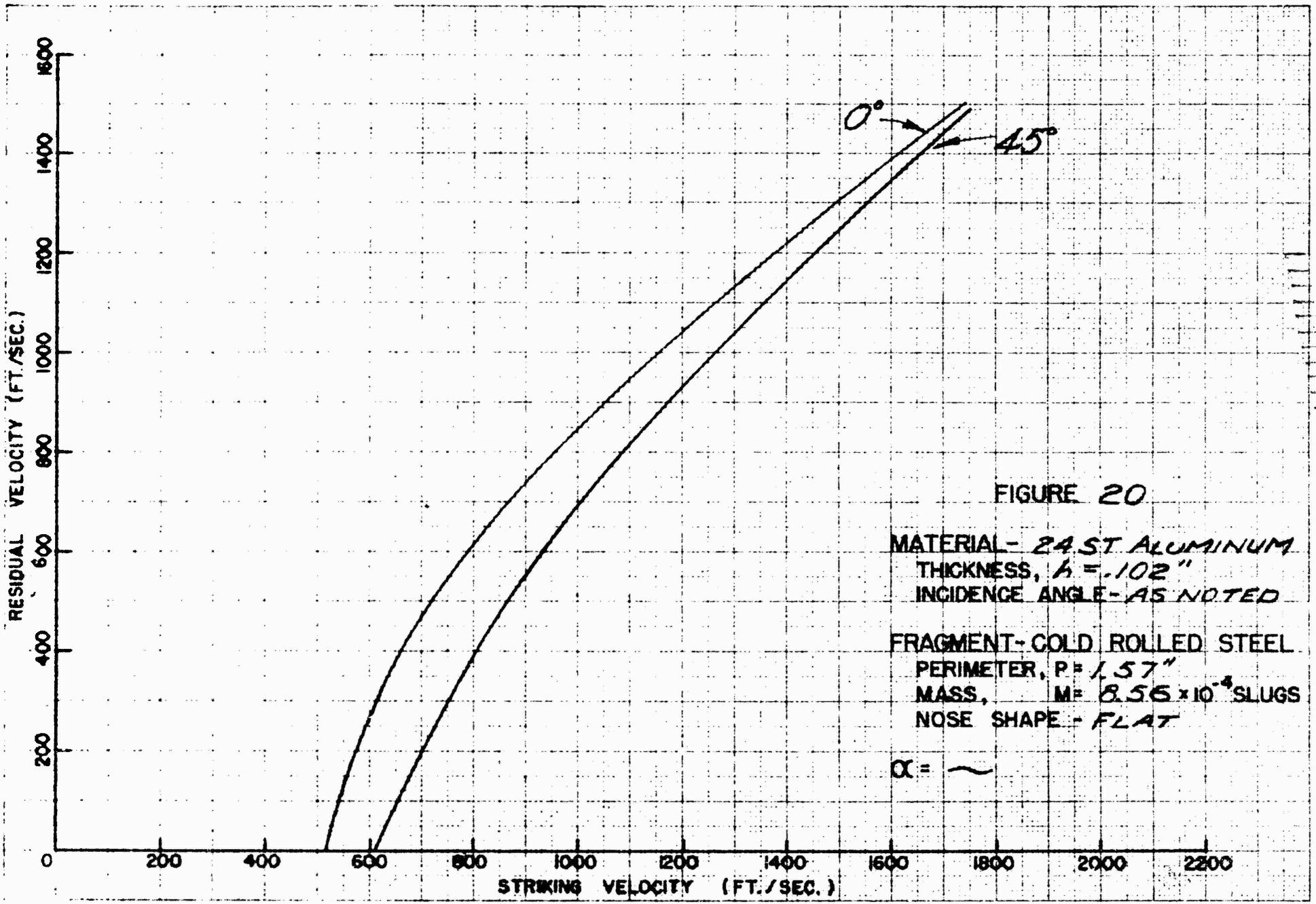


FIGURE 20

MATERIAL - 24ST ALUMINUM
THICKNESS, h = .102"
INCIDENCE ANGLE - AS NOTED

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 8.56 x 10^{-4} SLUGS
NOSE SHAPE - FLAT

α = ~

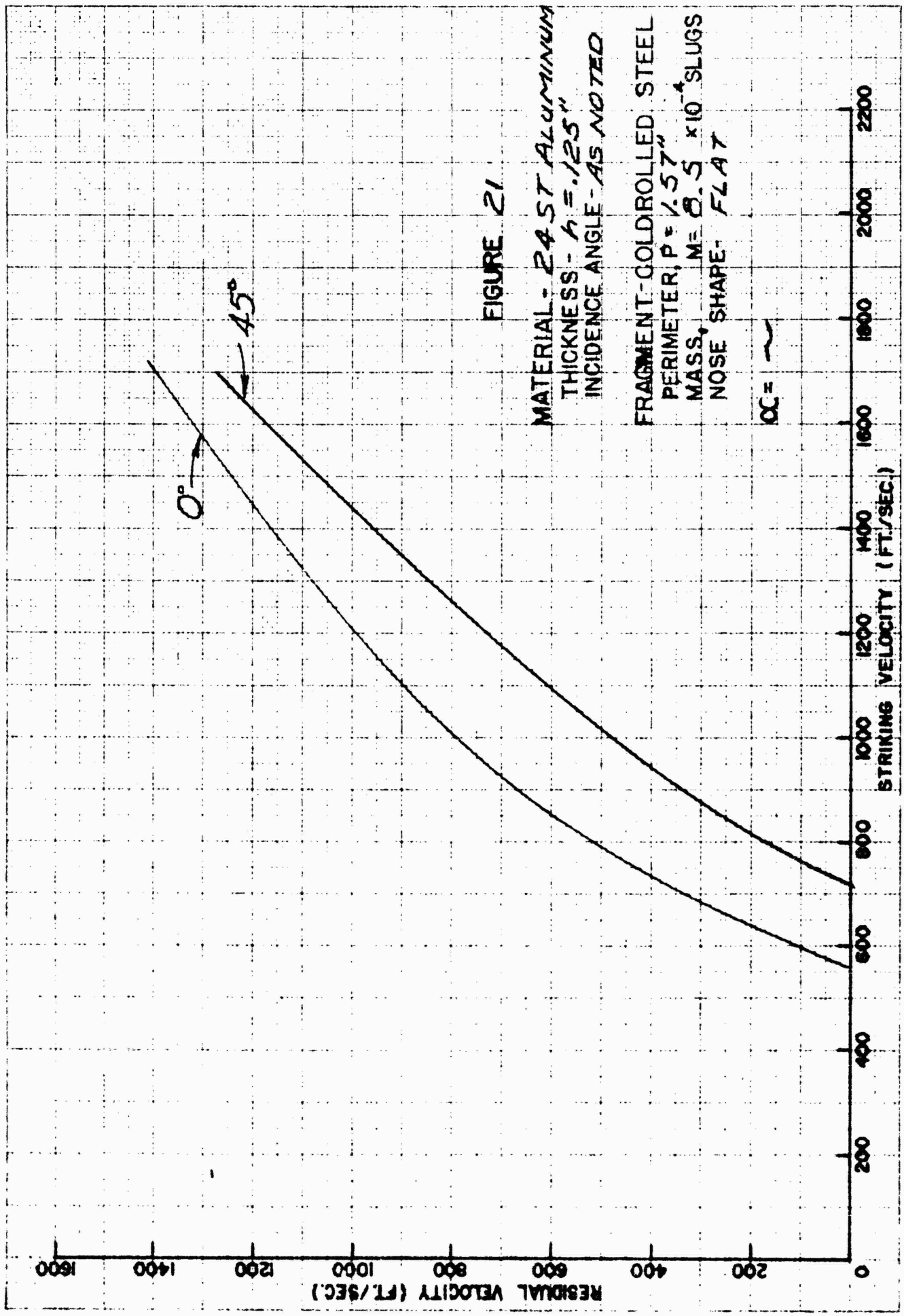
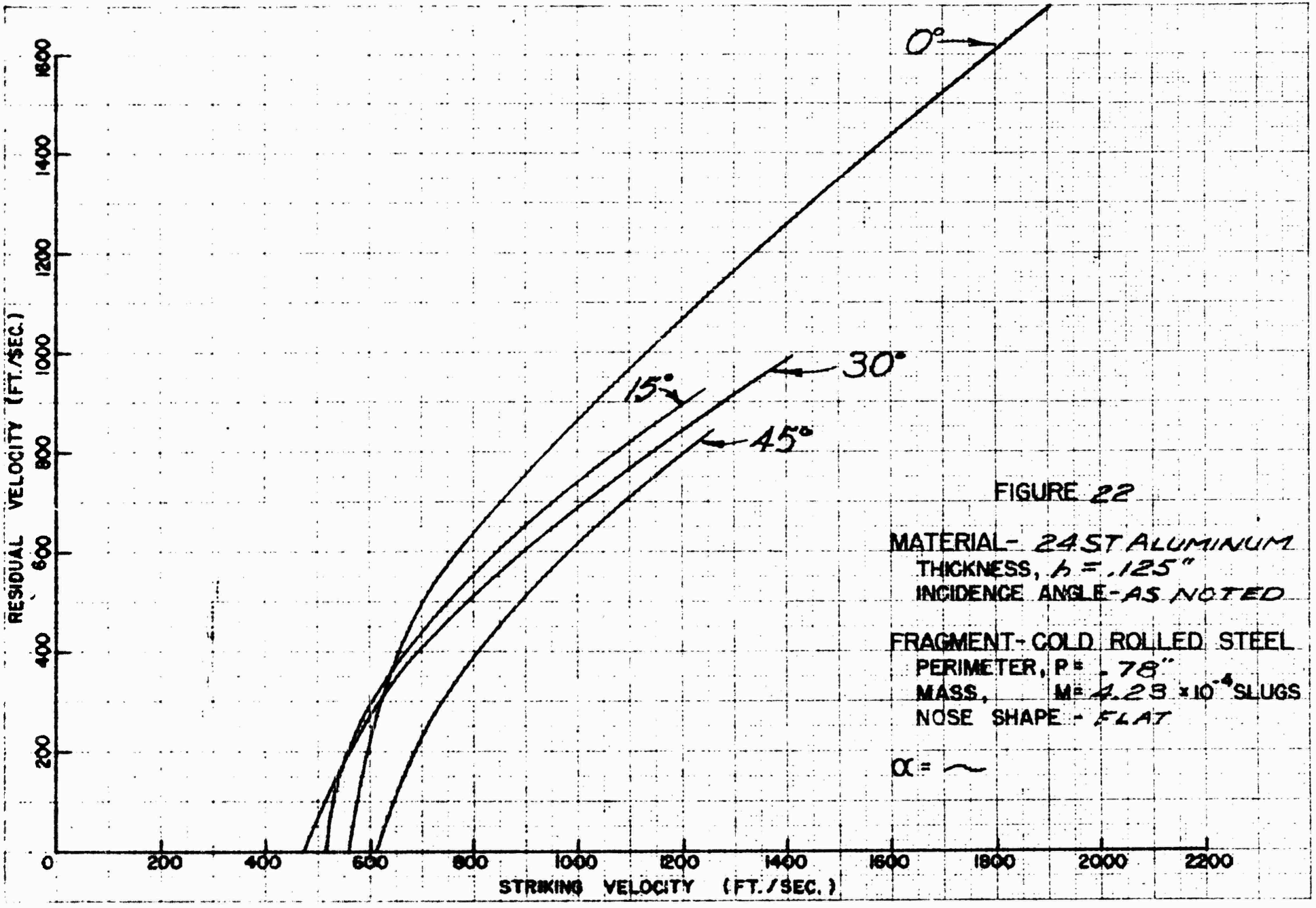
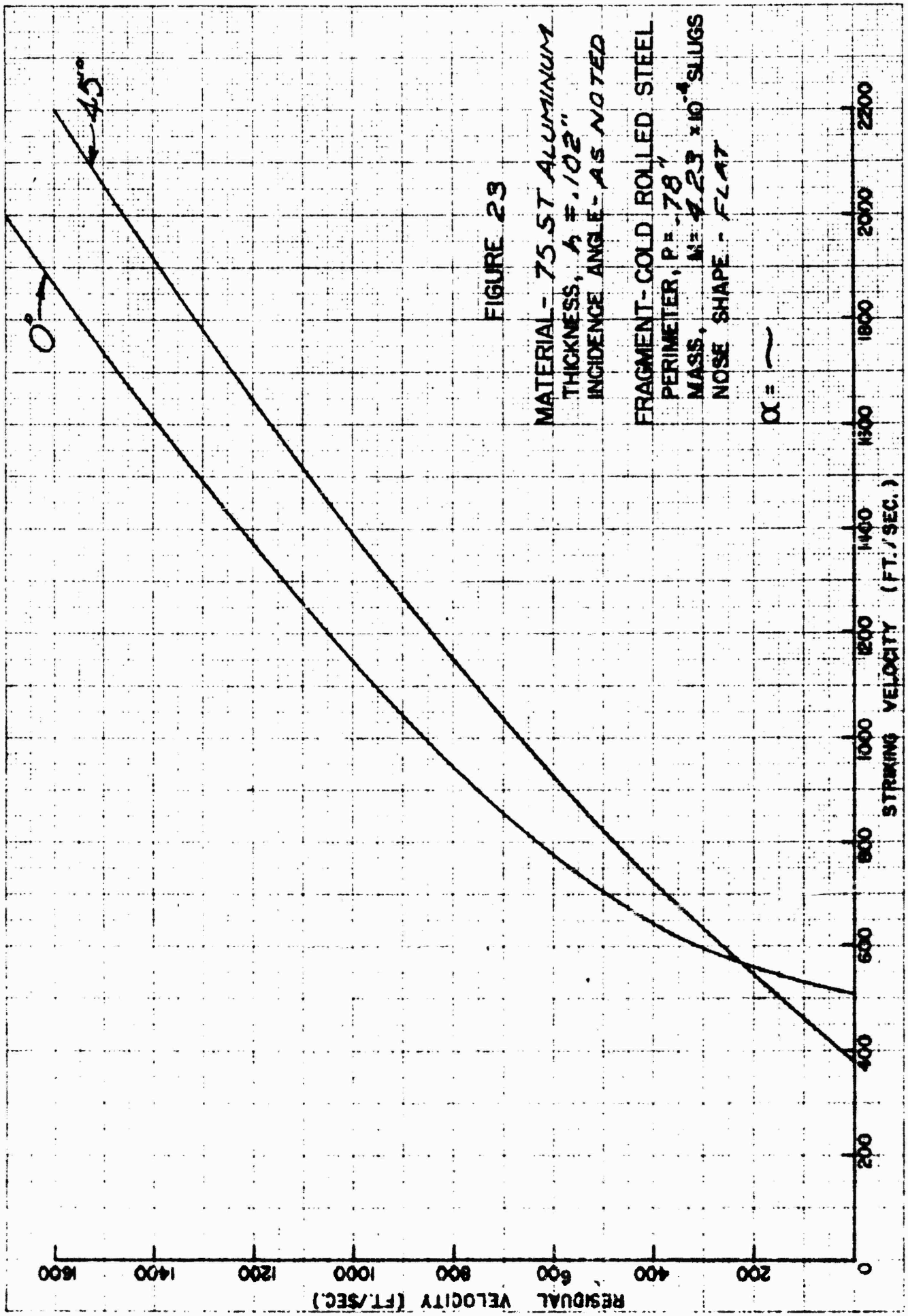
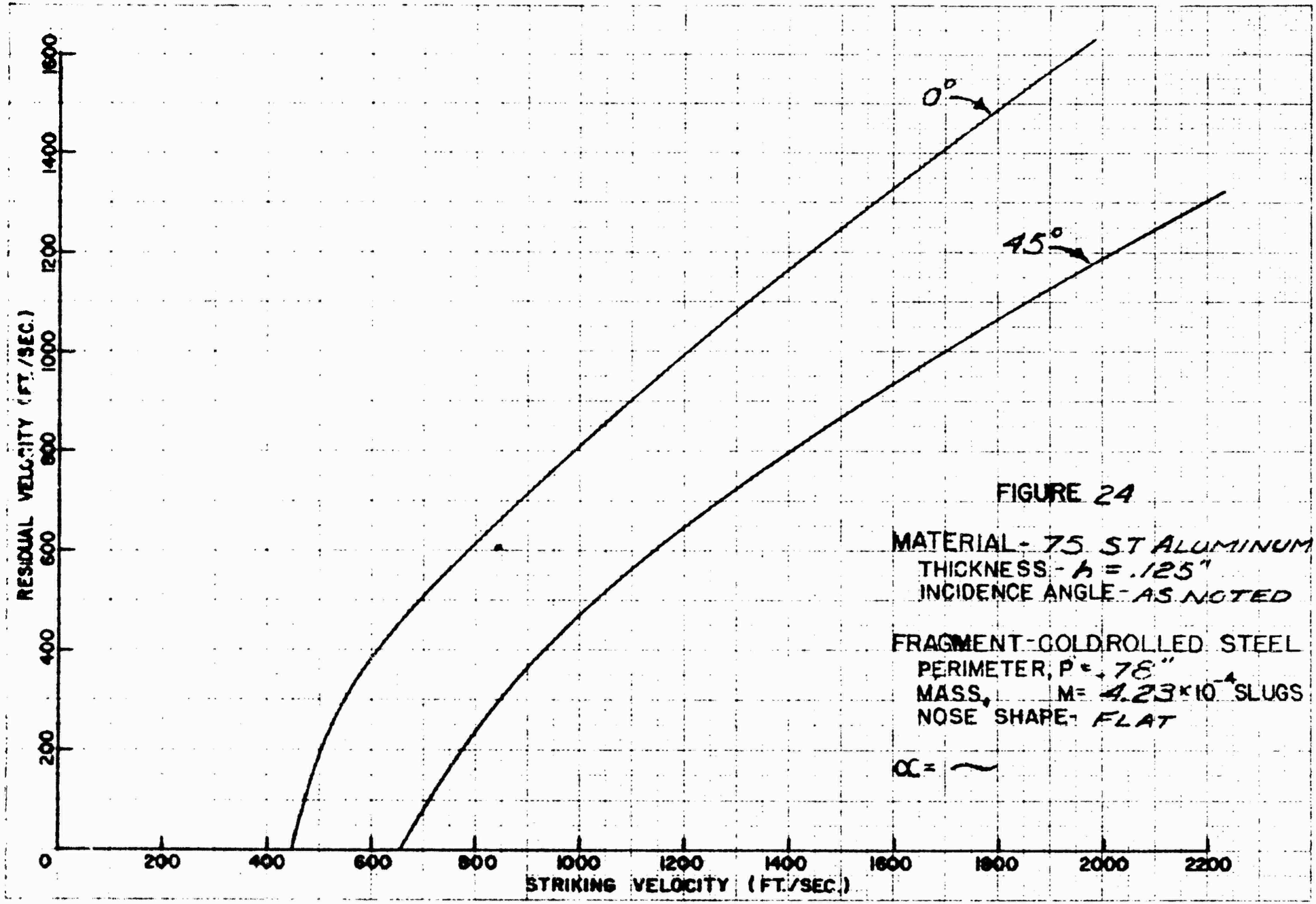


FIGURE 21
MATERIAL - 24ST ALUMINUM
THICKNESS - h = .125"
INCIDENCE ANGLE - AS NOTED
FRAGMENT - COLDROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 8.5 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = ~
0°
45°
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
0°
15°
30°
45°
FIGURE 22
MATERIAL- 24ST ALUMINUM
THICKNESS, h = .125"
INCIDENCE ANGLE- AS NOTED
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = ~


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
45°
0°
FIGURE 23
MATERIAL- 75-ST ALUMINUM
THICKNESS, h = .102"
INCIDENCE ANGLE- AS NOTED
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = ~


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
0°
45°
FIGURE 24
MATERIAL - 75 ST ALUMINUM
THICKNESS - h = .125"
INCIDENCE ANGLE - AS NOTED
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 × 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = ~

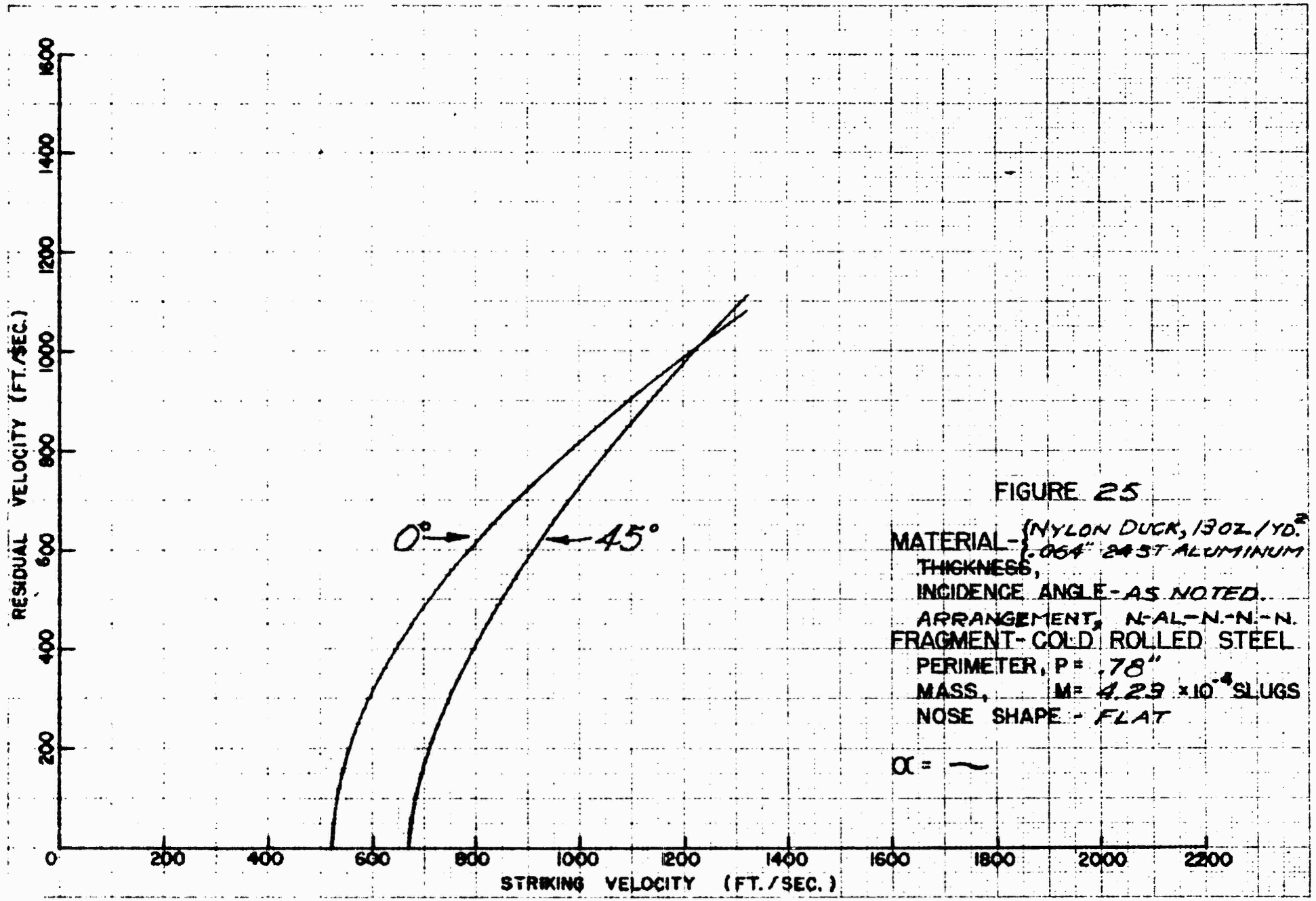


FIGURE 25

MATERIAL - {NYLON DUCK, 13 OZ./YD.²
.064" 24ST ALUMINUM
THICKNESS,
INCIDENCE ANGLE - AS NOTED.
ARRANGEMENT, N-AL-N.-N.-N.
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.29 x 10^{-4} SLUGS
NOSE SHAPE - FLAT

α = —

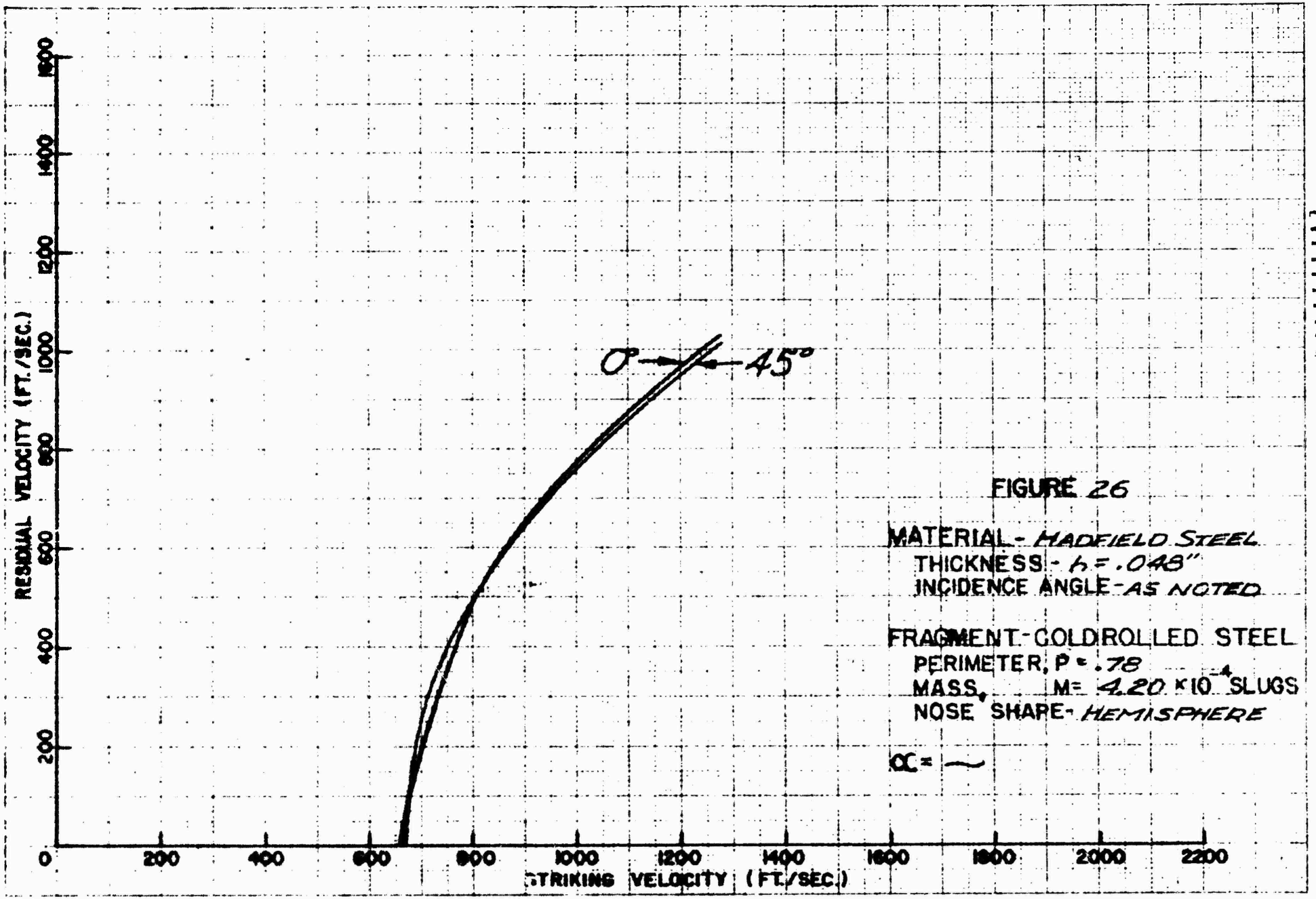


FIGURE 26

MATERIAL - HADFIELD STEEL
THICKNESS - $h = .048''$
INCIDENCE ANGLE - AS NOTED

FRAGMENT - COLD ROLLED STEEL
PERIMETER, $P = .78$
MASS, $M = 4.20 \times 10^{-4}$ SLUGS
NOSE SHAPE - HEMISPHERE

$\alpha =$ —

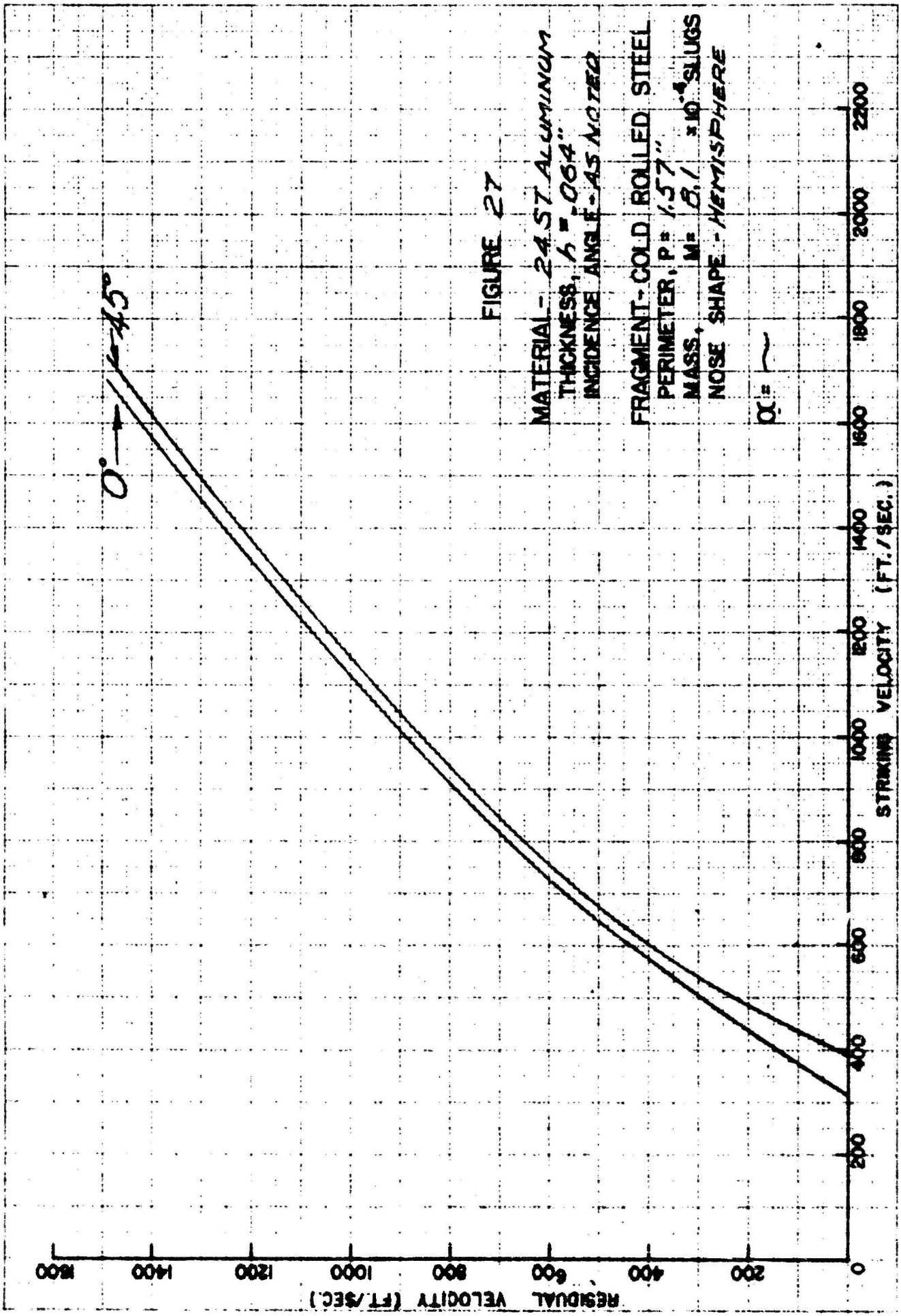


FIGURE 27
MATERIAL - 24ST ALUMINUM
THICKNESS, h = .064"
INCIDENCE ANGLE - AS NOTED
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 8.1 x 10⁻⁴ SLUGS
NOSE SHAPE - HEMISPHERE
α = ~
α = 0°
α = 45°
RESIDUAL VELOCITY (FT/SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

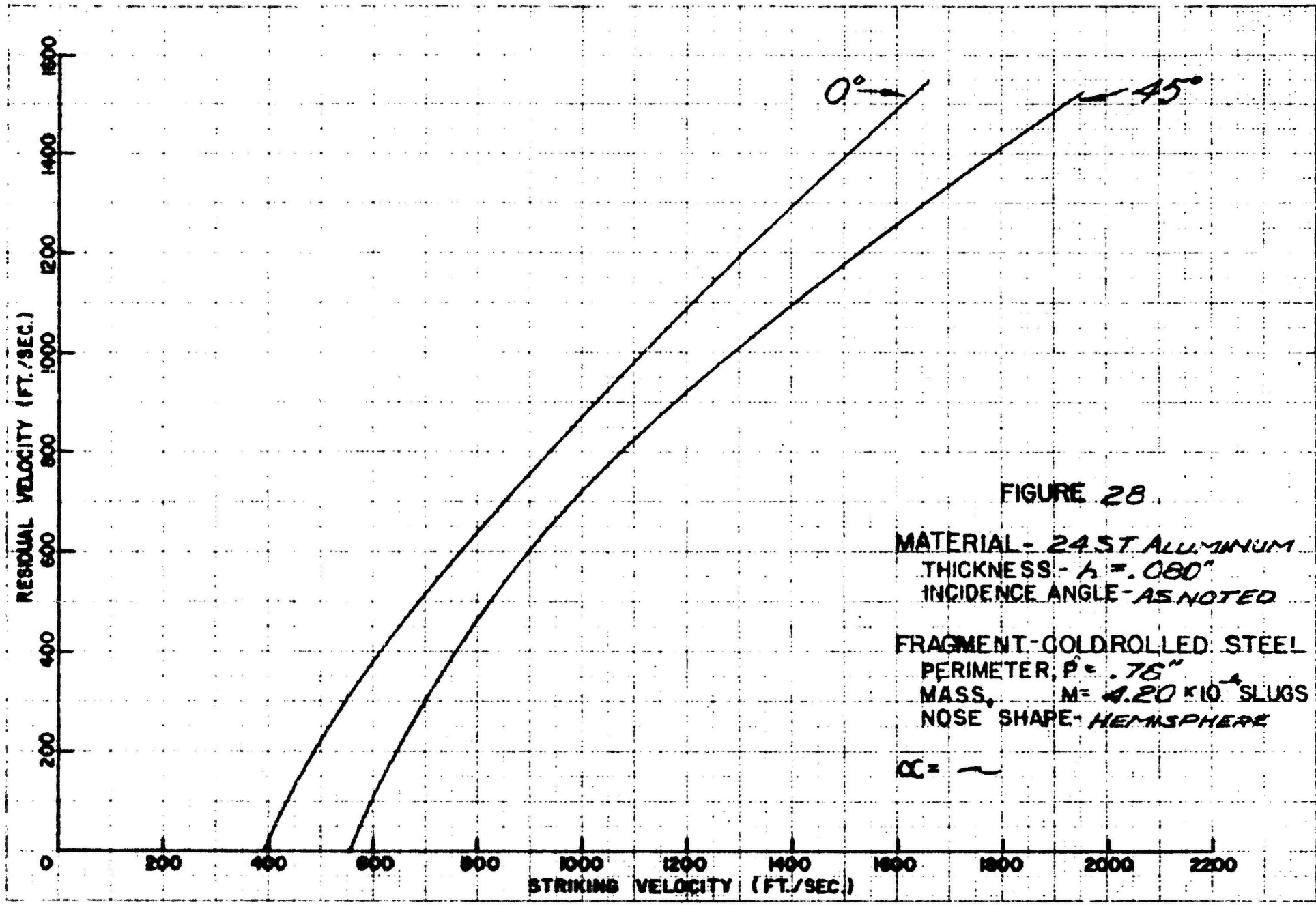


FIGURE 28

MATERIAL - 24ST ALUMINUM
THICKNESS - h = .080"
INCIDENCE ANGLE - AS NOTED

FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .76"
MASS, M = 4.20 × 10⁻⁴ SLUGS
NOSE SHAPE - HEMISPHERE

α = ~

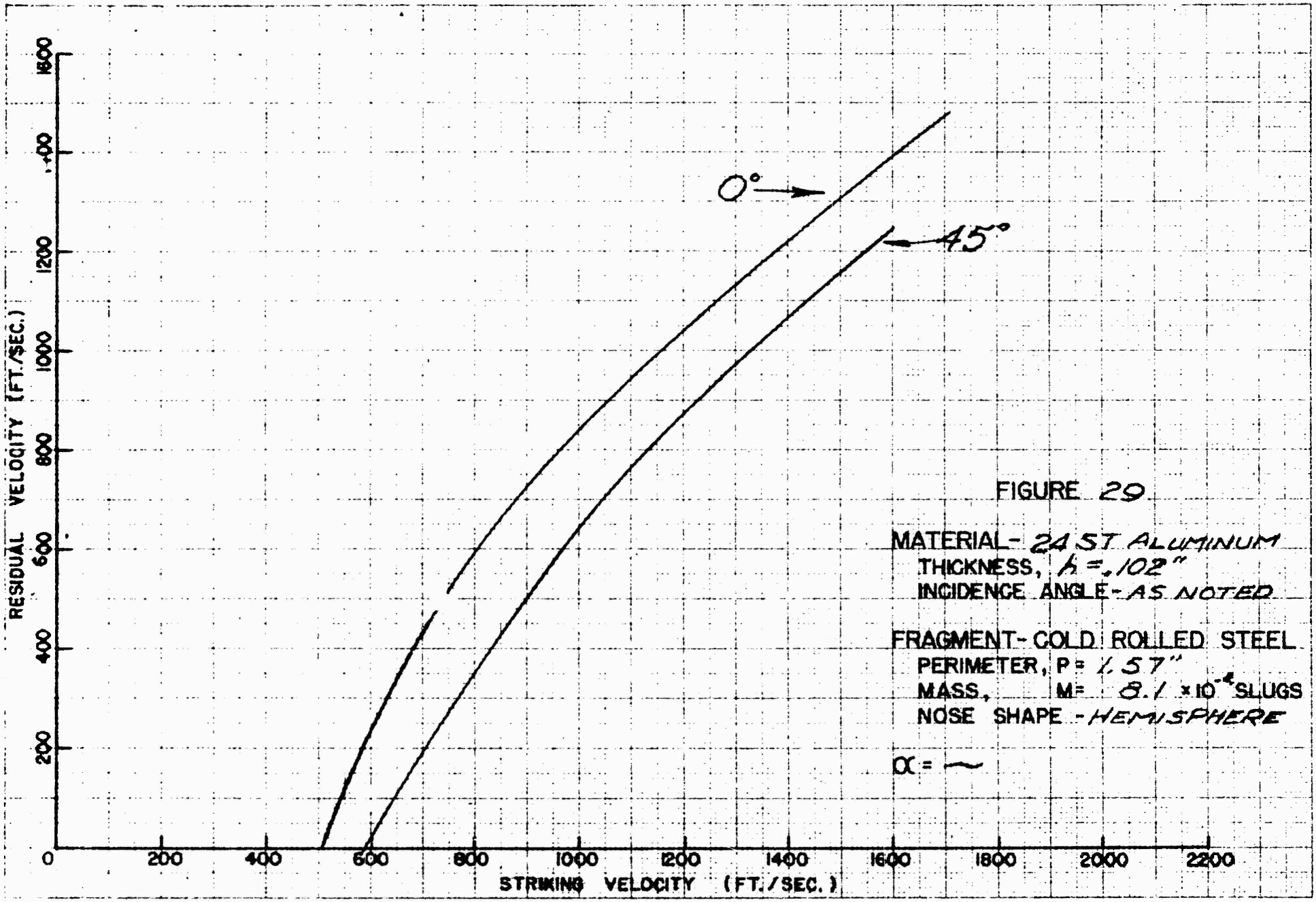


FIGURE 29

MATERIAL- 24 ST ALUMINUM
THICKNESS, h = .102"
INCIDENCE ANGLE- AS NOTED

FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 8.1 × 10^{-4} SLUGS
NOSE SHAPE - HEMISPHERE

α = ~

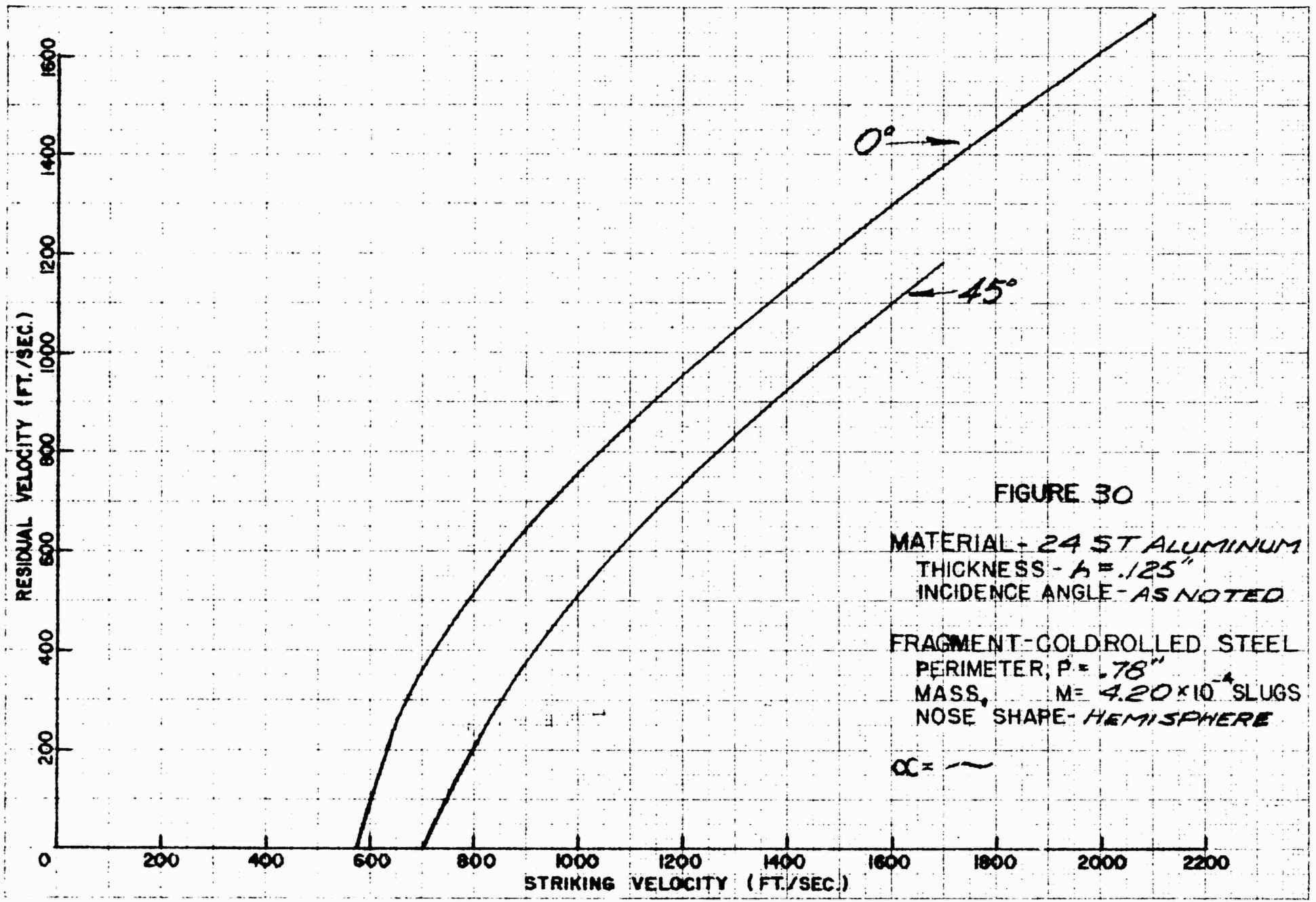


FIGURE 30

MATERIAL - 24 ST ALUMINUM
THICKNESS - h = .125"
INCIDENCE ANGLE - AS NOTED

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.20×10^{-4} SLUGS
NOSE SHAPE - HEMISPHERE

OC = ~

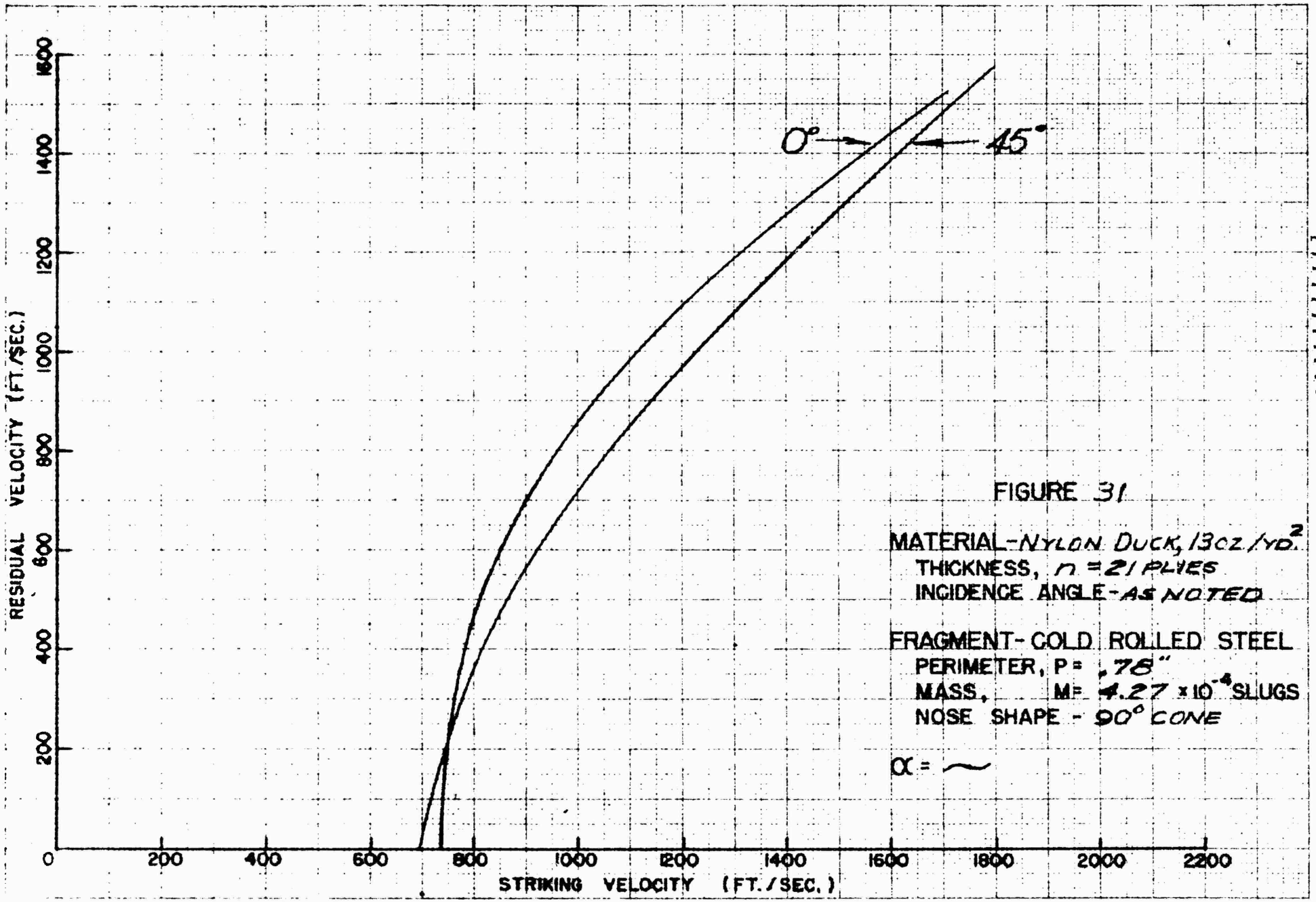


FIGURE 31

MATERIAL - NYLON DUCK, 13 OZ./YD.^{2}
THICKNESS, n = 21 PLIES
INCIDENCE ANGLE - AS NOTED

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.27×10^{-4} SLUGS
NOSE SHAPE - 90° CONE

α = ~

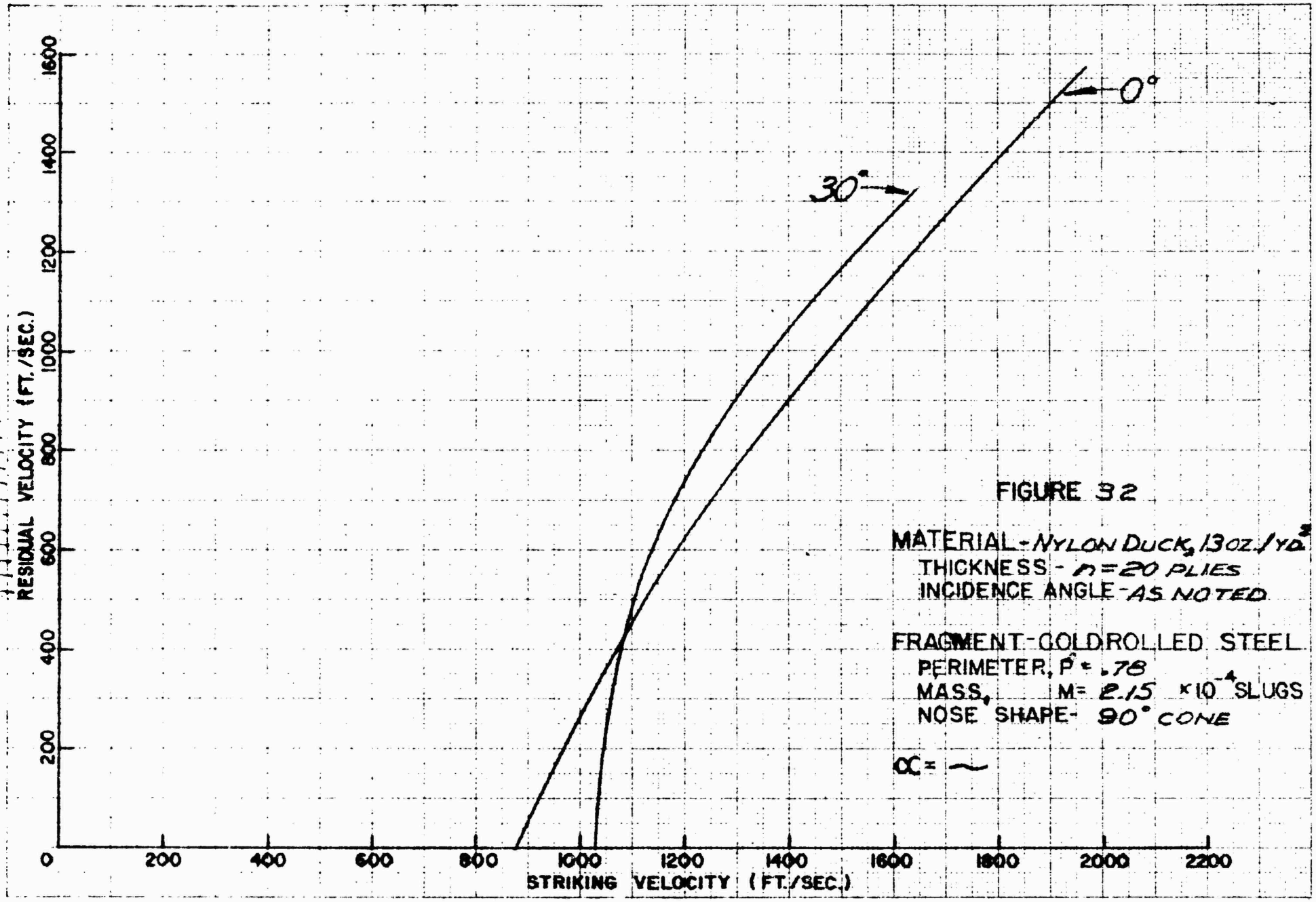


FIGURE 32

MATERIAL - NYLON DUCK, 13 OZ./YD.²
THICKNESS - n = 20 PLIES
INCIDENCE ANGLE - AS NOTED

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78
MASS, M = 2.15 $\times 10^{-4}$ SLUGS
NOSE SHAPE - 90° CONE

α = ~

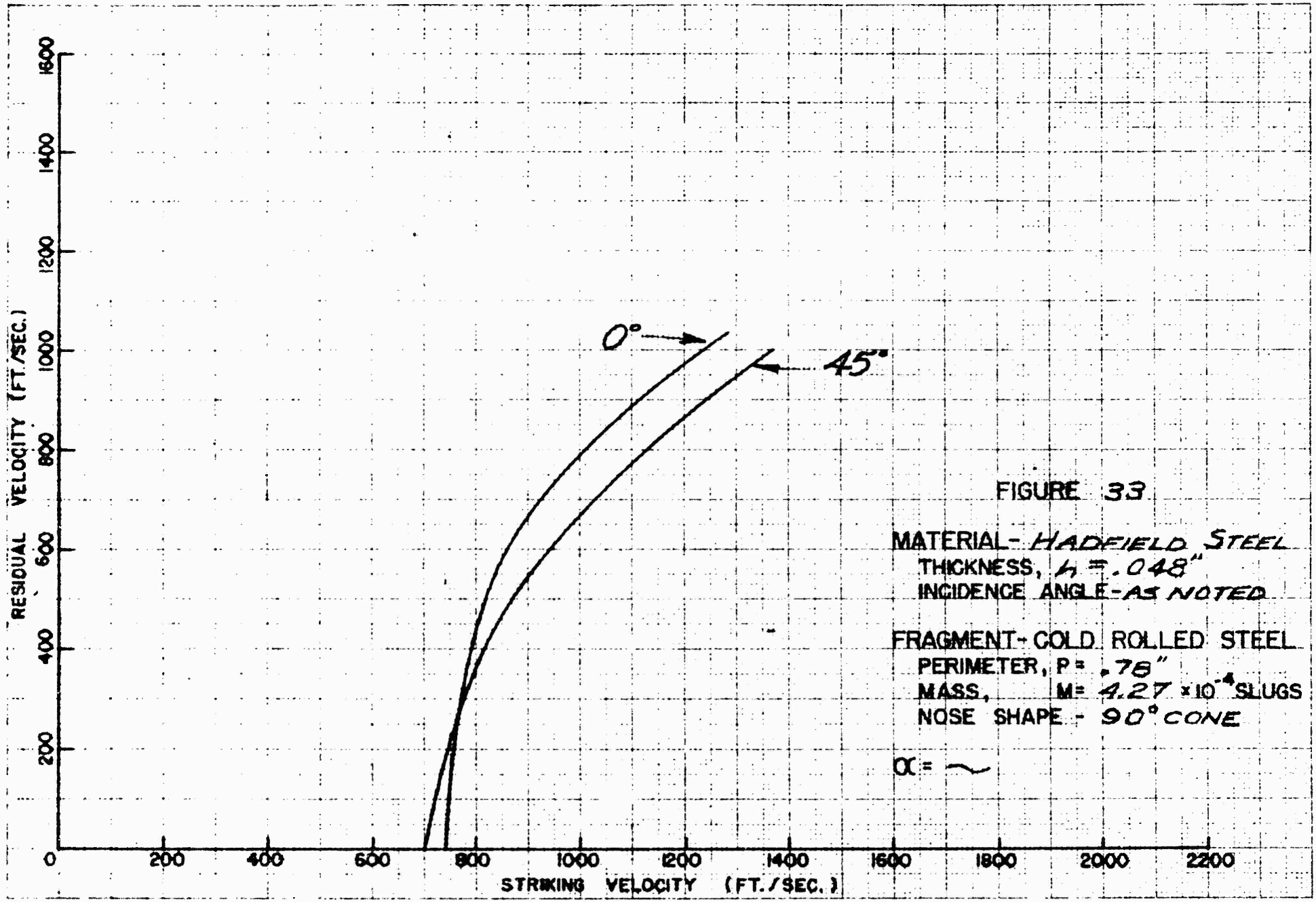


FIGURE 33

MATERIAL - HADFIELD STEEL
THICKNESS, h = .048"
INCIDENCE ANGLE - AS NOTED

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.27×10^{-4} SLUGS
NOSE SHAPE - 90° CONE

α = ~

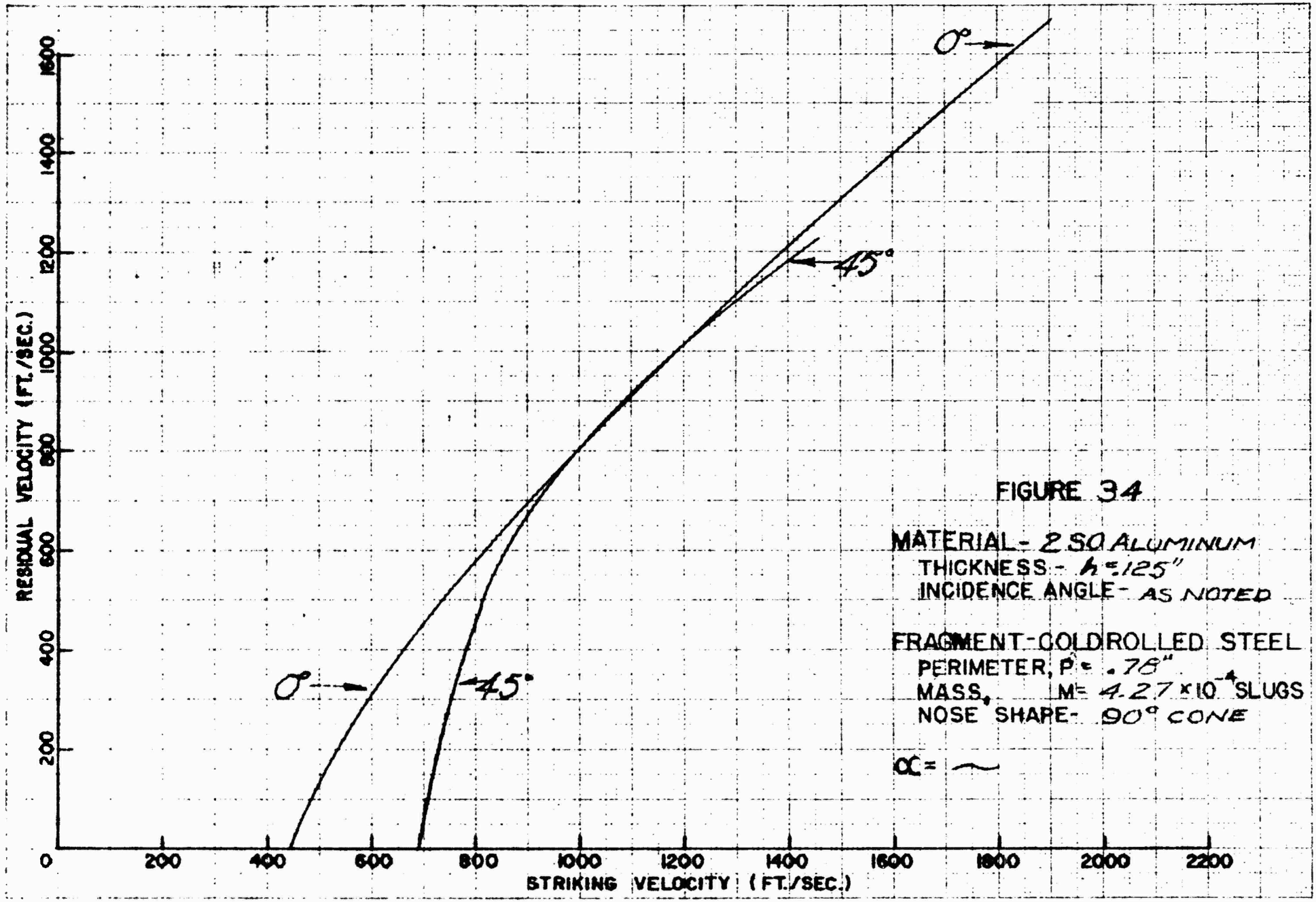


FIGURE 34

MATERIAL - 2S0 ALUMINUM
THICKNESS - $h = .125"$
INCIDENCE ANGLE - AS NOTED

FRAGMENT - COLDROLLED STEEL
PERIMETER, $P = .78"$
MASS, $M = 4.27 \times 10^{-4}$ SLUGS
NOSE SHAPE - 90° CONE

$OC = \sim$

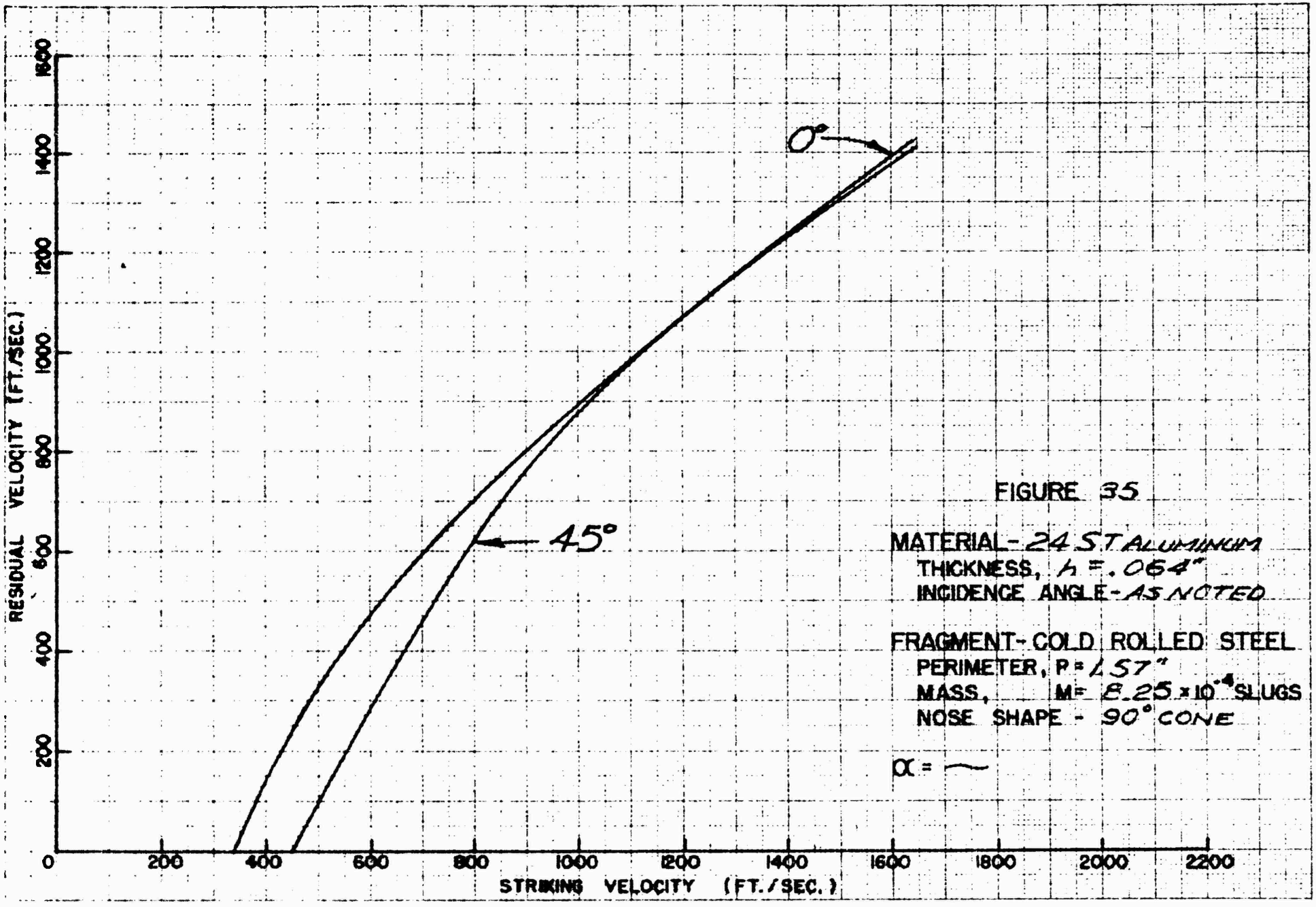


FIGURE 35

MATERIAL - 24 ST ALUMINUM
THICKNESS, h = .064"
INCIDENCE ANGLE - AS NOTED

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 8.25 x 10^{-4} SLUGS
NOSE SHAPE - 90° CONE

α = —

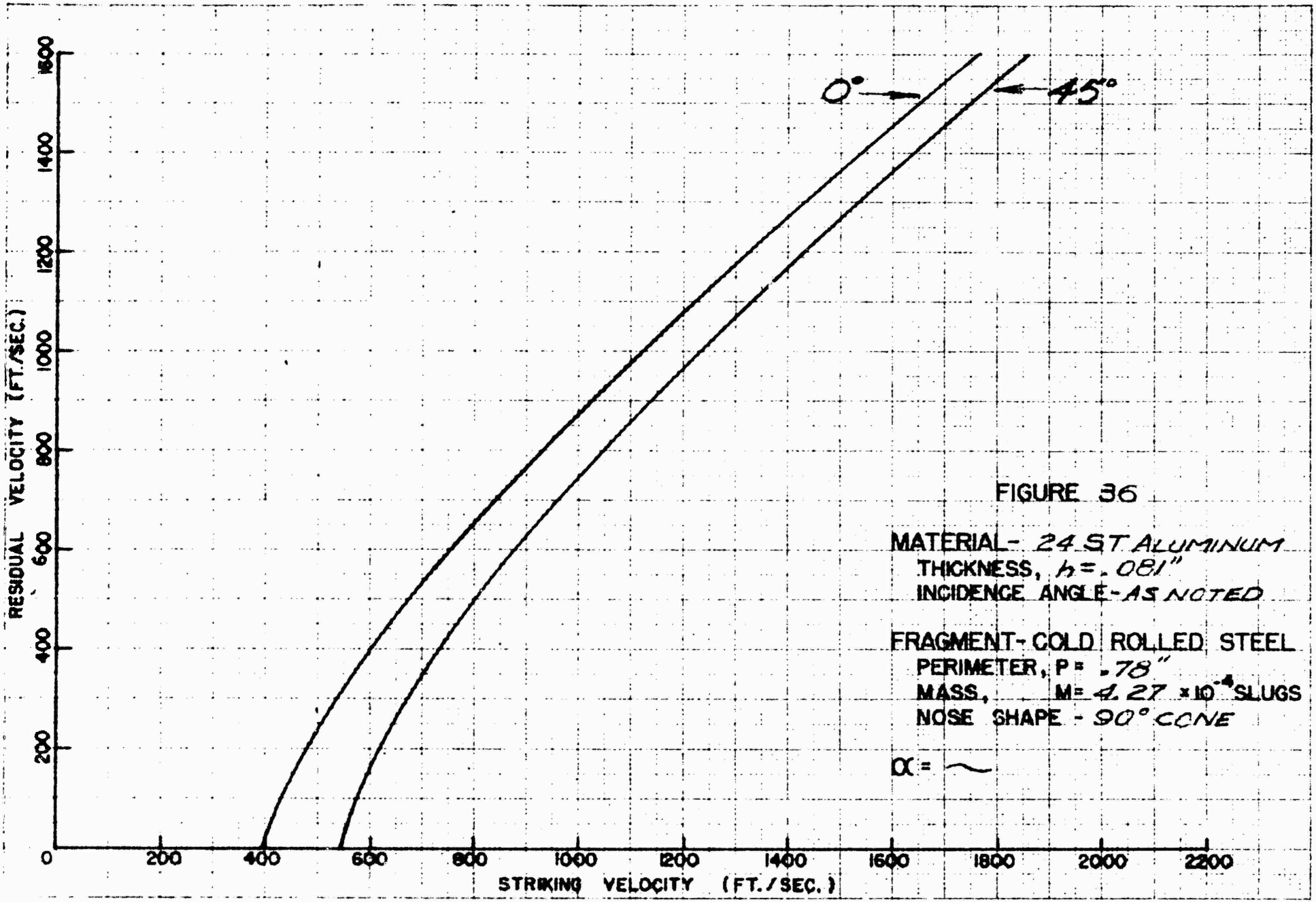


FIGURE 36

MATERIAL- 24ST ALUMINUM
THICKNESS, $h = .081"$
INCIDENCE ANGLE- AS NOTED

FRAGMENT- COLD ROLLED STEEL
PERIMETER, $P = .78"$
MASS, $M = 4.27 \times 10^{-4}$ SLUGS
NOSE SHAPE - 90° CONE

α = ~

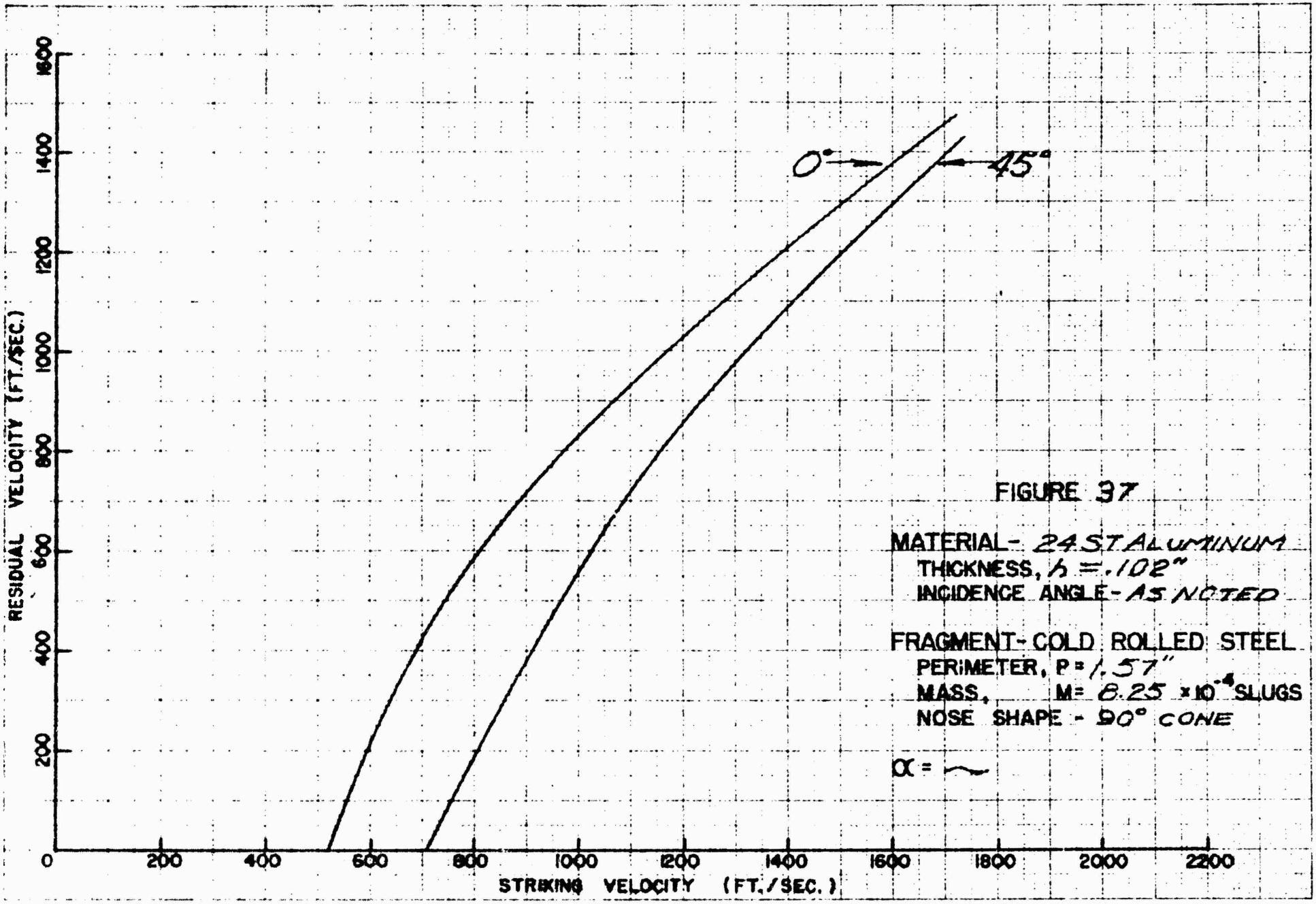


FIGURE 37

MATERIAL - 24ST ALUMINUM
THICKNESS, $h = .102"$
INCIDENCE ANGLE - AS NOTED

FRAGMENT - COLD ROLLED STEEL
PERIMETER, $P = 1.57"$
MASS, $M = 8.25 \times 10^{-4}$ SLUGS
NOSE SHAPE - 90° CONE

$\alpha =$ ~

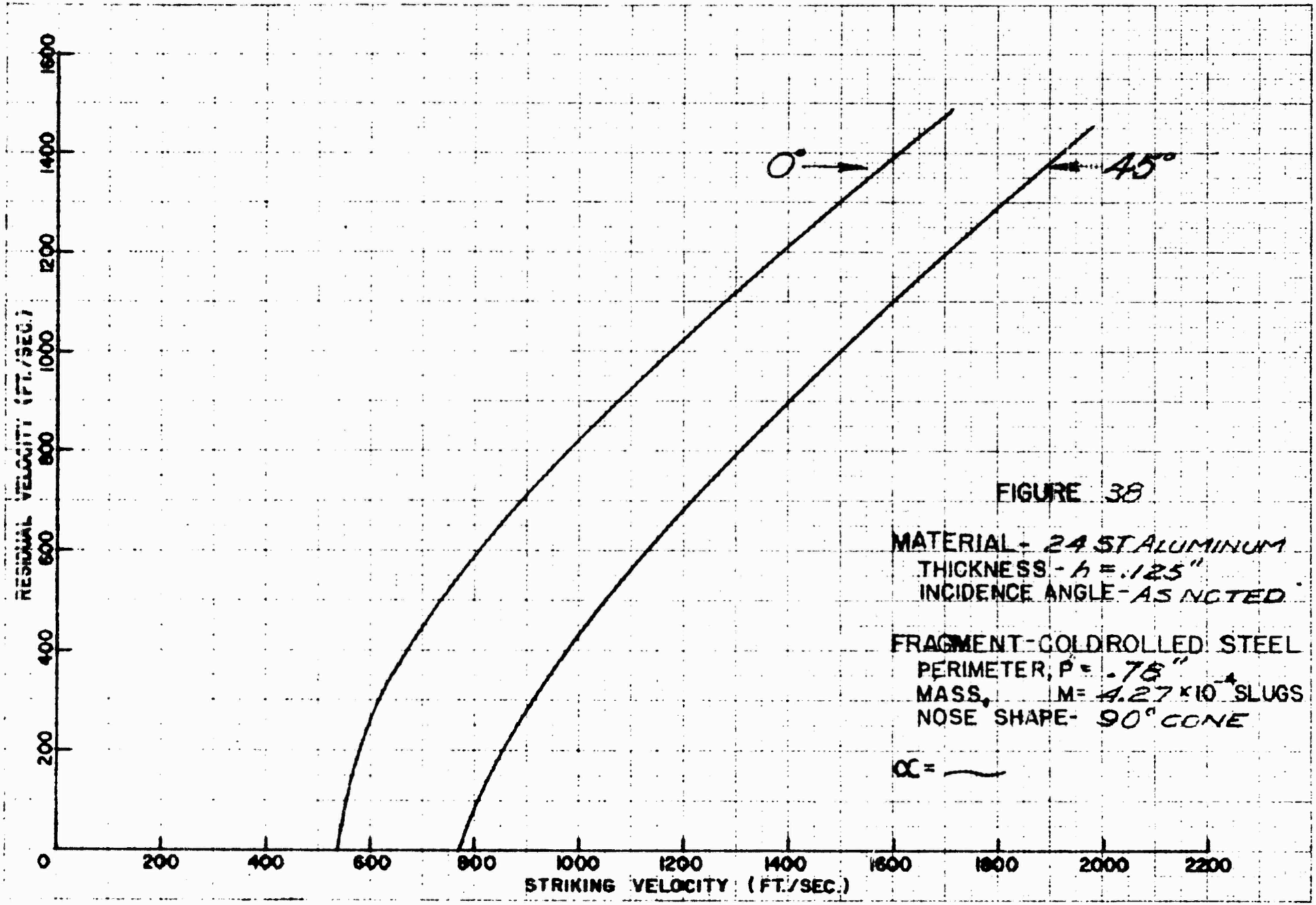


FIGURE 38

MATERIAL - 24ST ALUMINUM
THICKNESS - $h = .125''$
INCIDENCE ANGLE - AS NOTED

FRAGMENT - COLD ROLLED STEEL
PERIMETER, $P = .78''$
MASS, $M = 4.27 \times 10^{-4}$ SLUGS
NOSE SHAPE - 90° CONE

$\alpha =$ ——

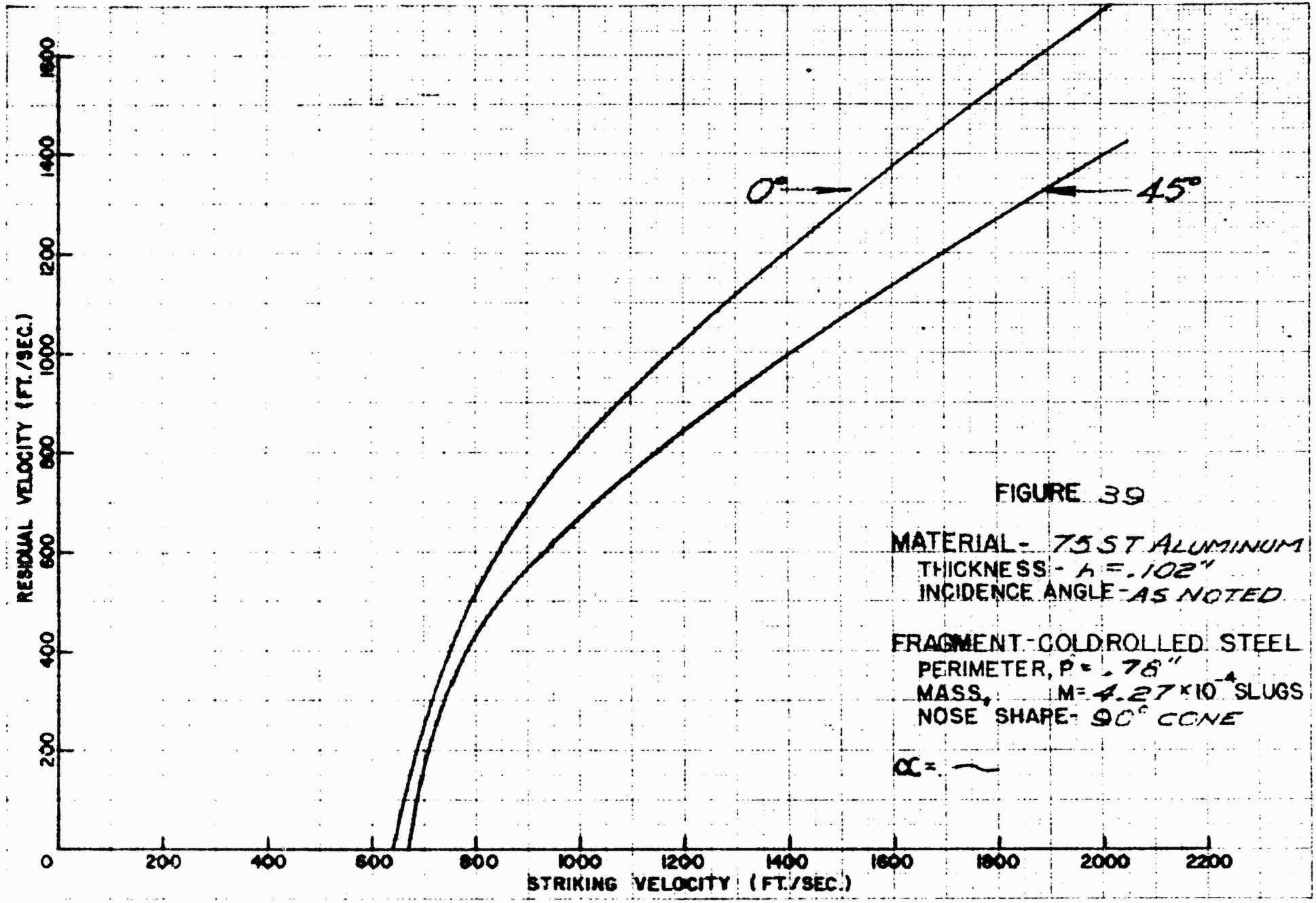


FIGURE 39

MATERIAL - 75ST ALUMINUM
THICKNESS - h = .102"
INCIDENCE ANGLE - AS NOTED

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.27×10^{-4} SLUGS
NOSE SHAPE - 90° CONE

α = .~

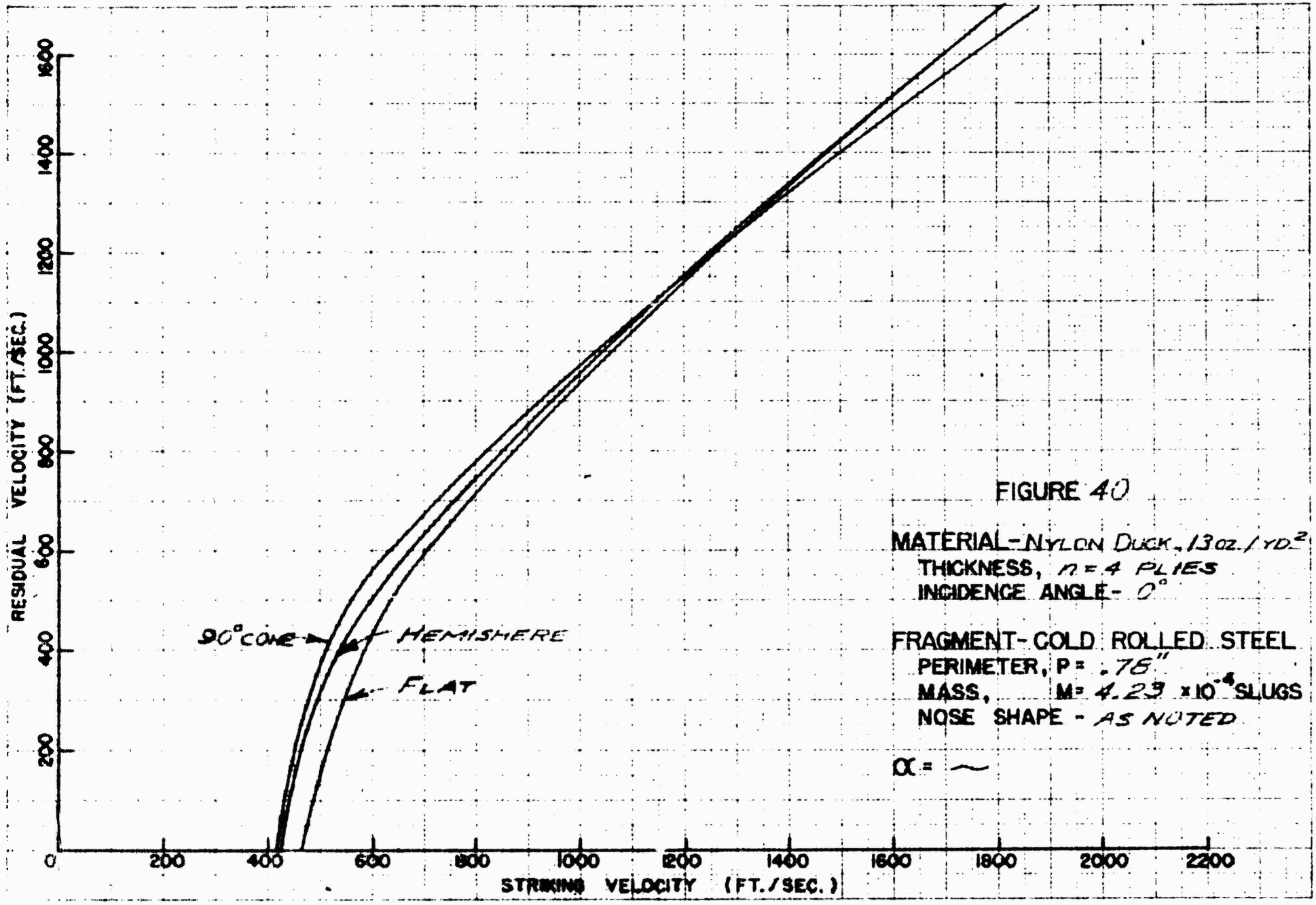


FIGURE 40

MATERIAL - NYLON DUCK, 13 oz./YD.^{2}
THICKNESS, n = 4 PLIES
INCIDENCE ANGLE - 0°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 x 10^{-4} SLUGS
NOSE SHAPE - AS NOTED

α = ~

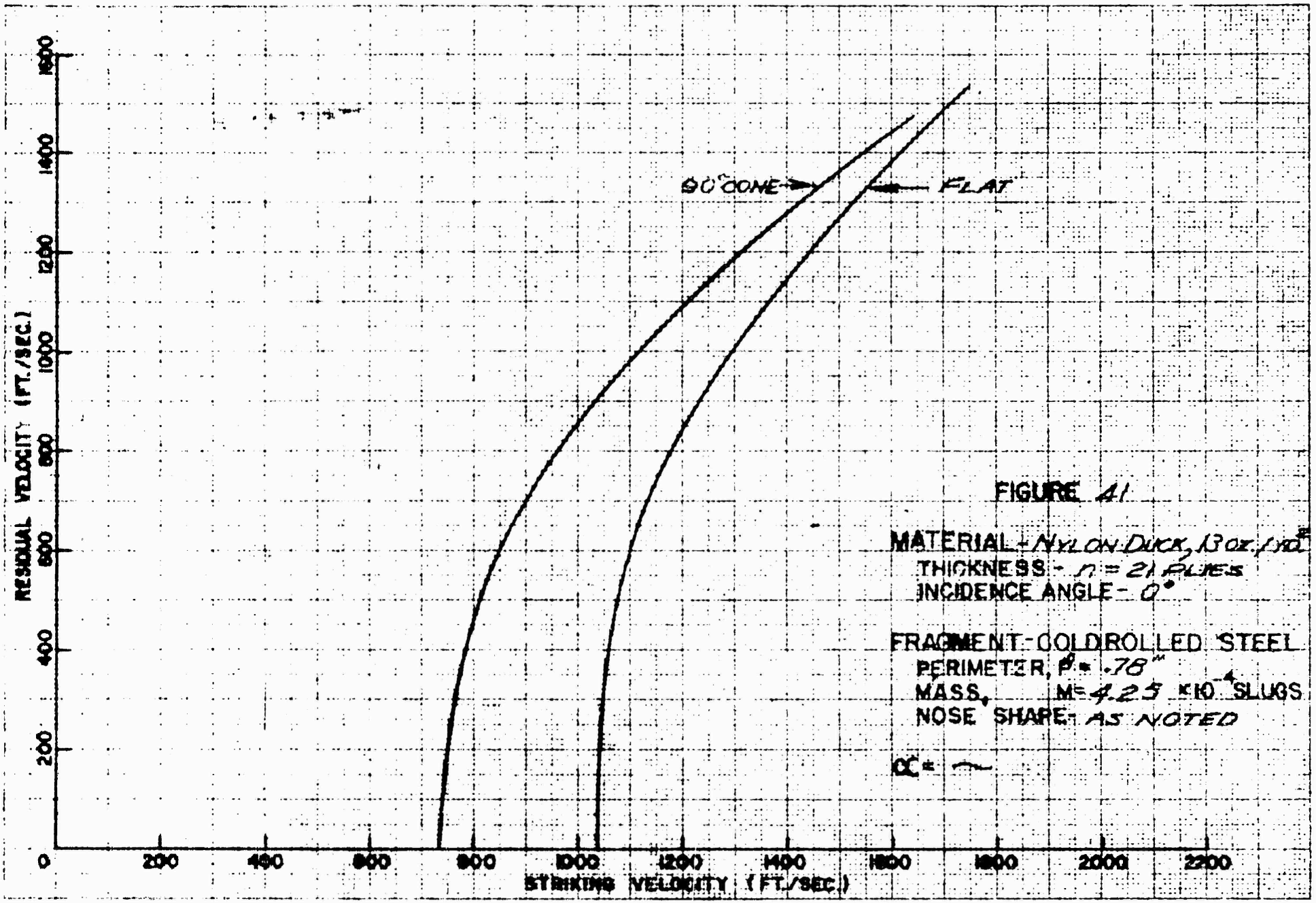
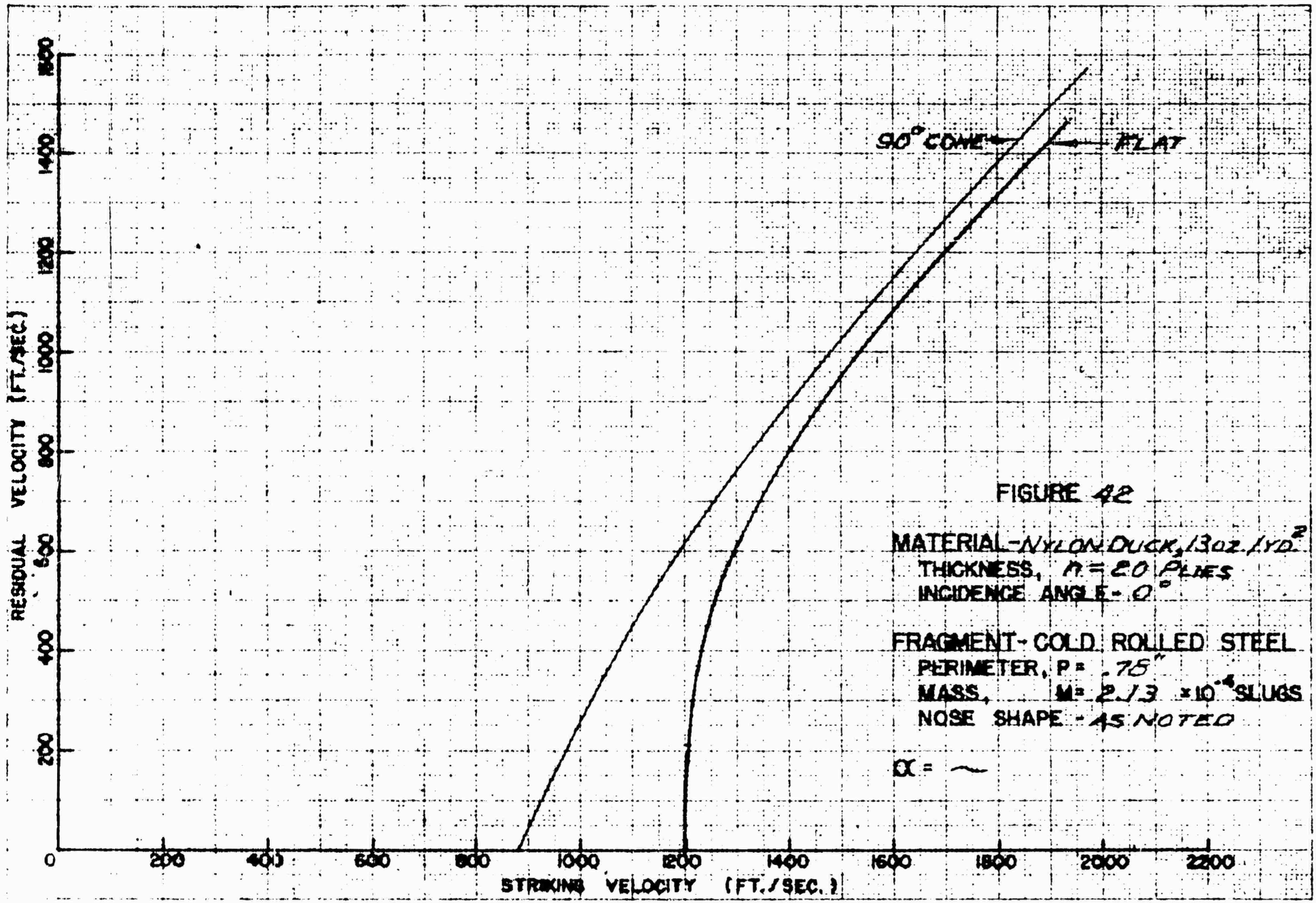


FIGURE 41

MATERIAL - NYLON DUCK, 13 oz./yd²
THICKNESS - n = 21 PLIES
INCIDENCE ANGLE - 0°

FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.25 x 10⁻⁴ SLUGS
NOSE SHAPE - AS NOTED

CC = ~


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
90° CONE
FLAT
FIGURE 42
MATERIAL - NYLON DUCK, 13 oz./YD.²
THICKNESS, n = 20 PLIES
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .75"
MASS, M = 2.13 x 10⁻⁴ SLUGS
NOSE SHAPE - AS NOTED
α = ~

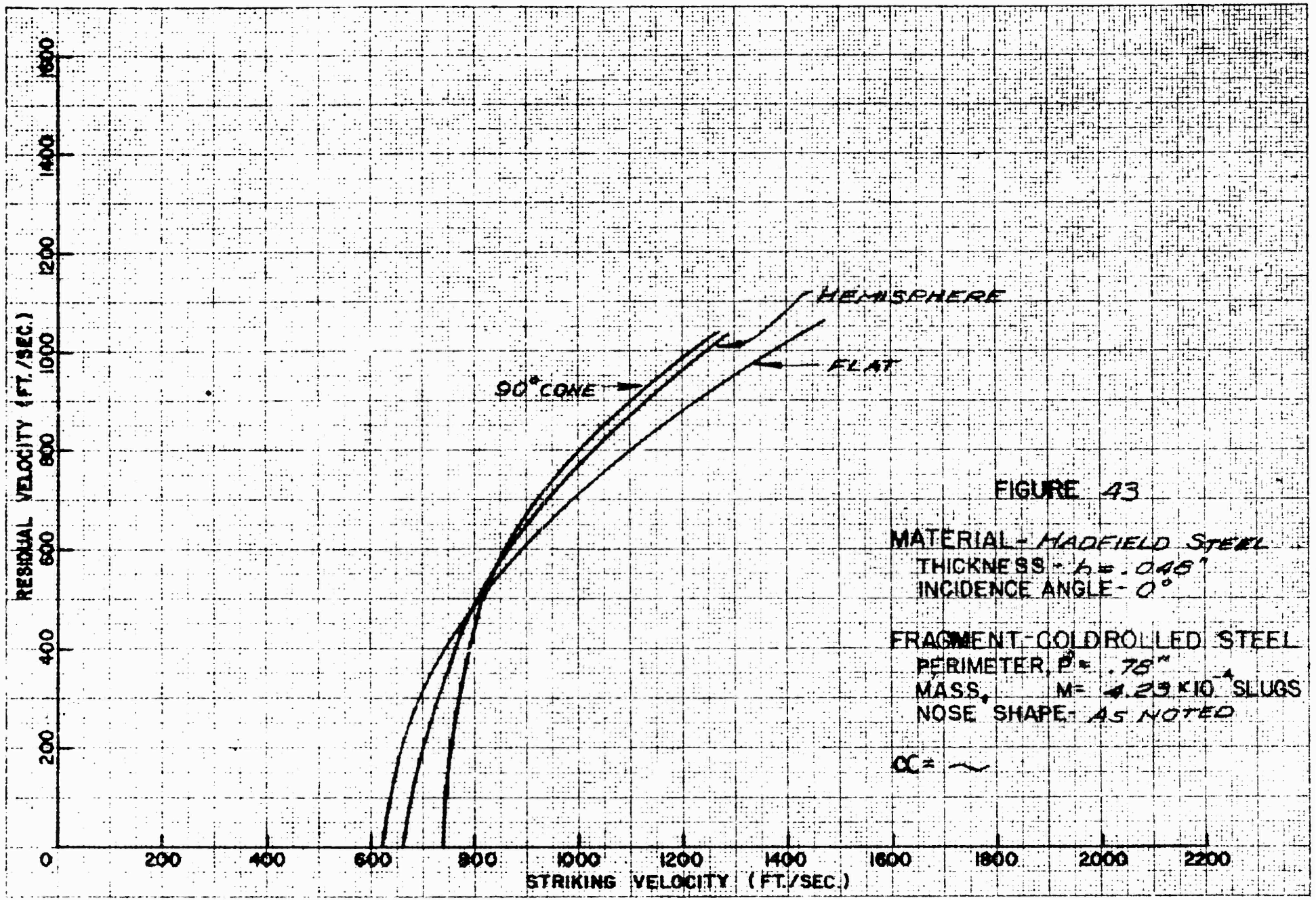
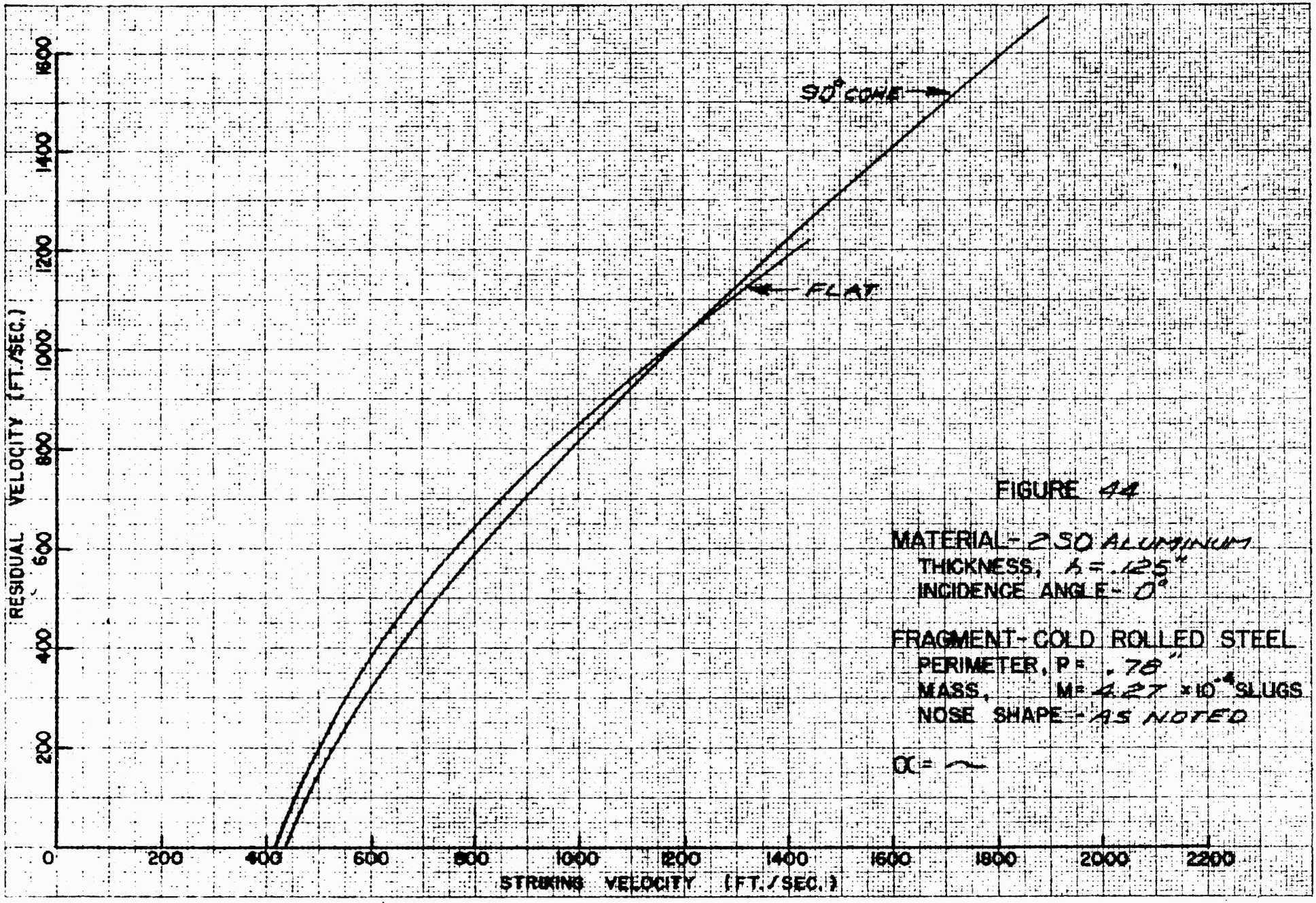


FIGURE 43

MATERIAL - HADFIELD STEEL
THICKNESS - h = .046"
INCIDENCE ANGLE - 0°

FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 x 10^{-4} SLUGS
NOSE SHAPE - AS NOTED

OC = ~


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
90° COVE
FLAT
FIGURE 44
MATERIAL - 2S0 ALUMINUM
THICKNESS, h = .125"
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.27 x 10⁻⁴ SLUGS
NOSE SHAPE - AS NOTED
α = ~

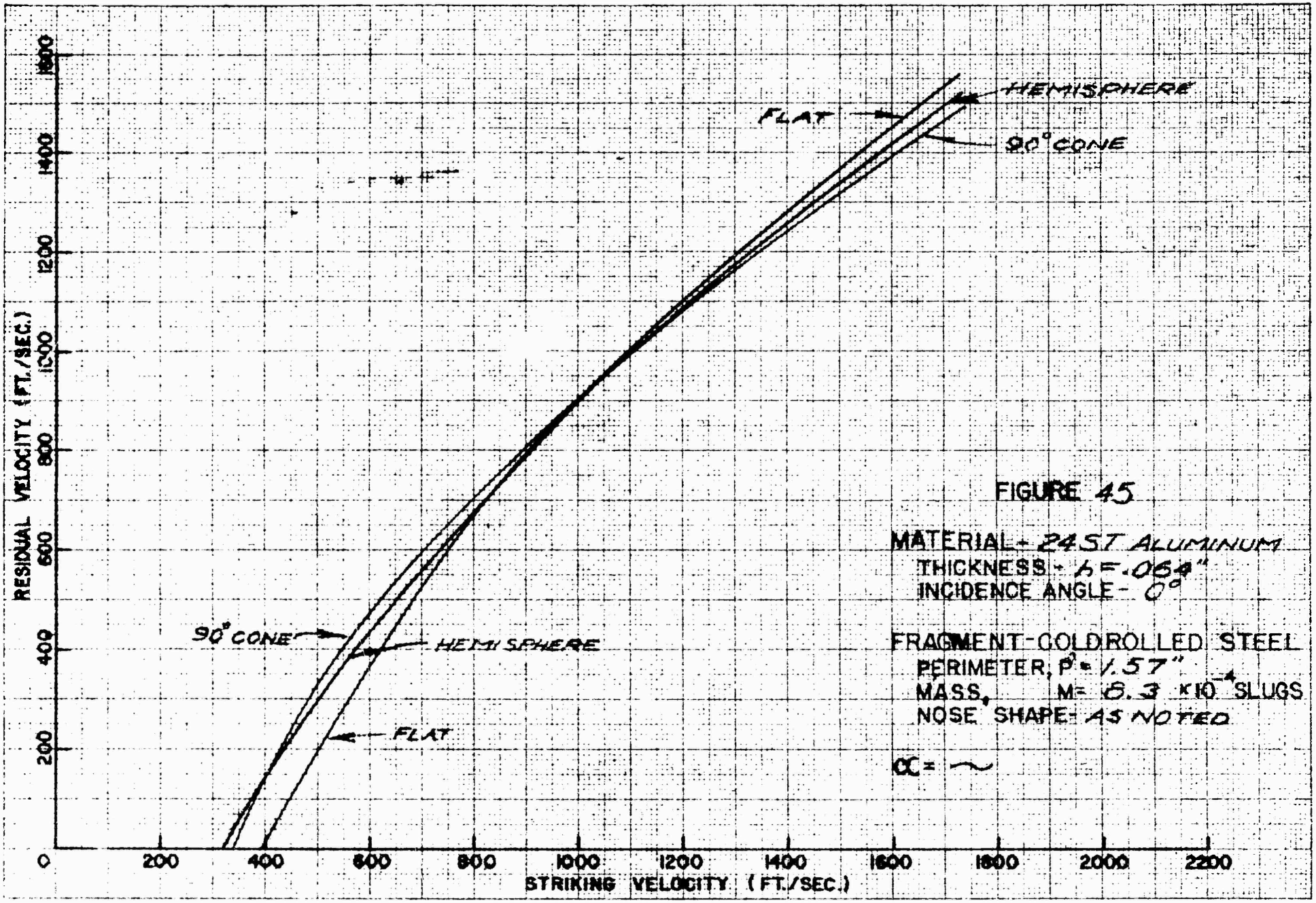
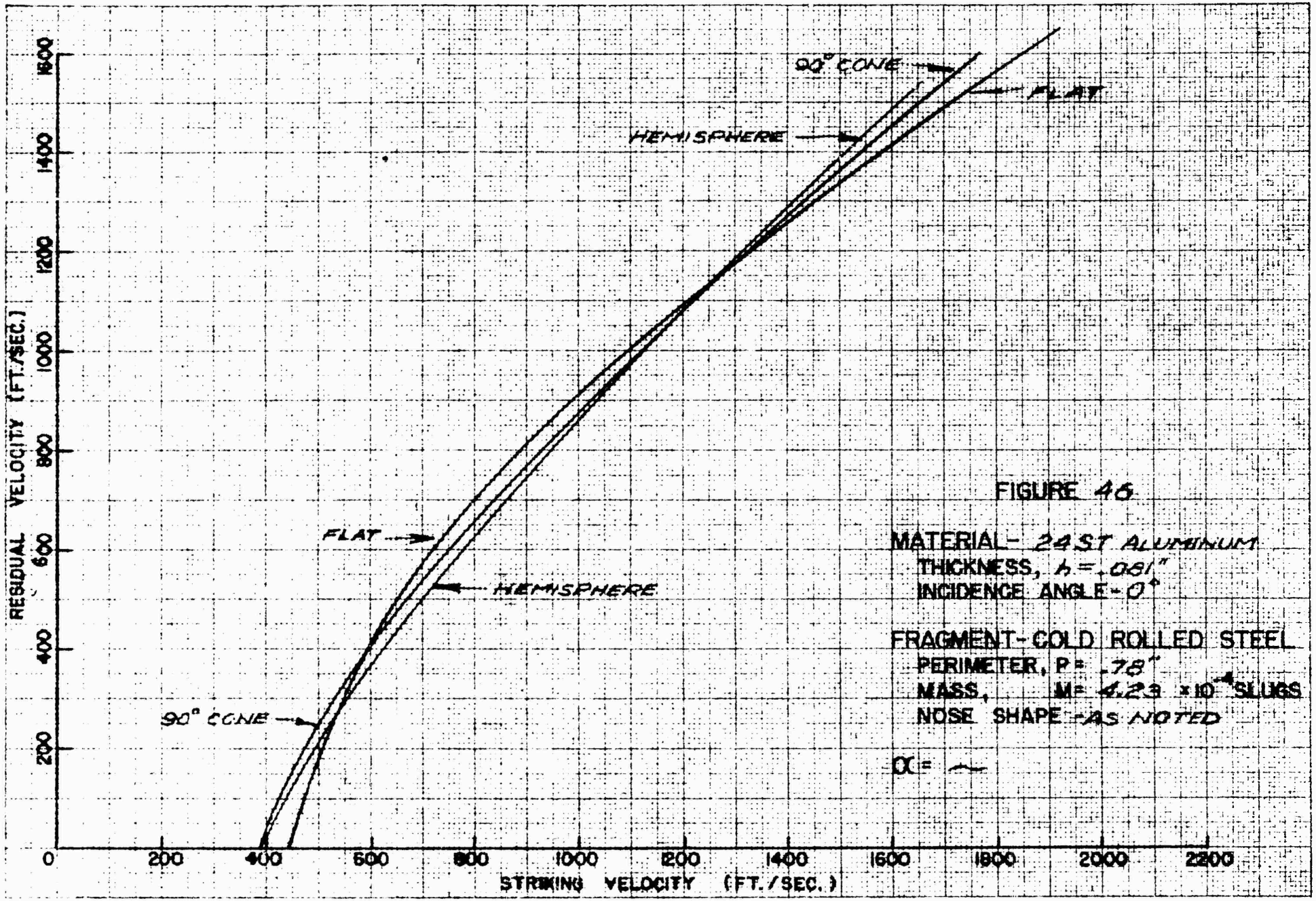


FIGURE 45

MATERIAL - 24ST ALUMINUM
THICKNESS - .064"
INCIDENCE ANGLE - 0°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 6.3 $\times 10^{-4}$ SLUGS
NOSE SHAPE - AS NOTED

OC = ~



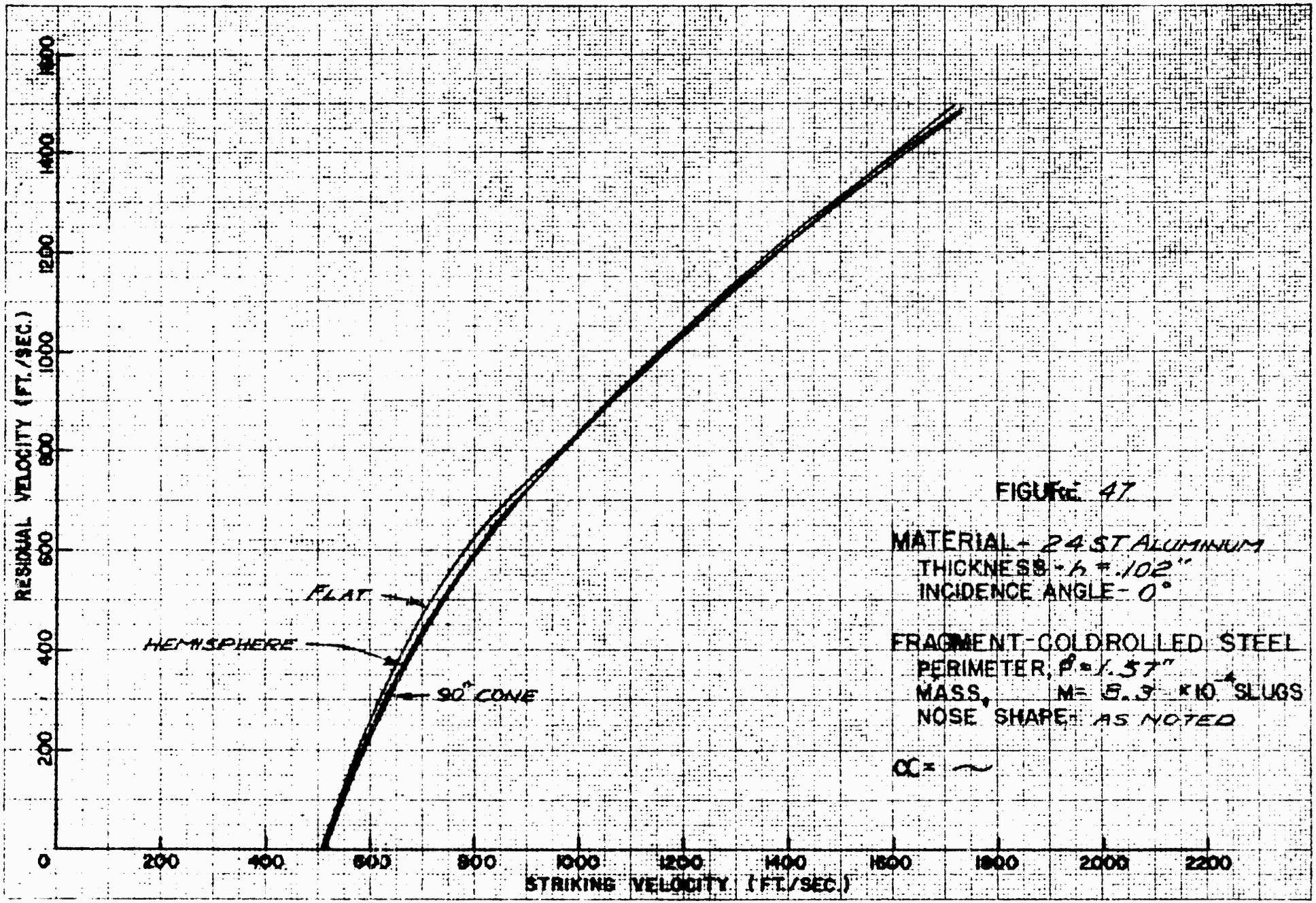


FIGURE 47

MATERIAL - 24ST ALUMINUM
THICKNESS - h = .102"
INCIDENCE ANGLE - 0°

FRAGMENT - COLDROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 5.3 × 10⁻⁴ SLUGS
NOSE SHAPE - AS NOTED

CC = ~

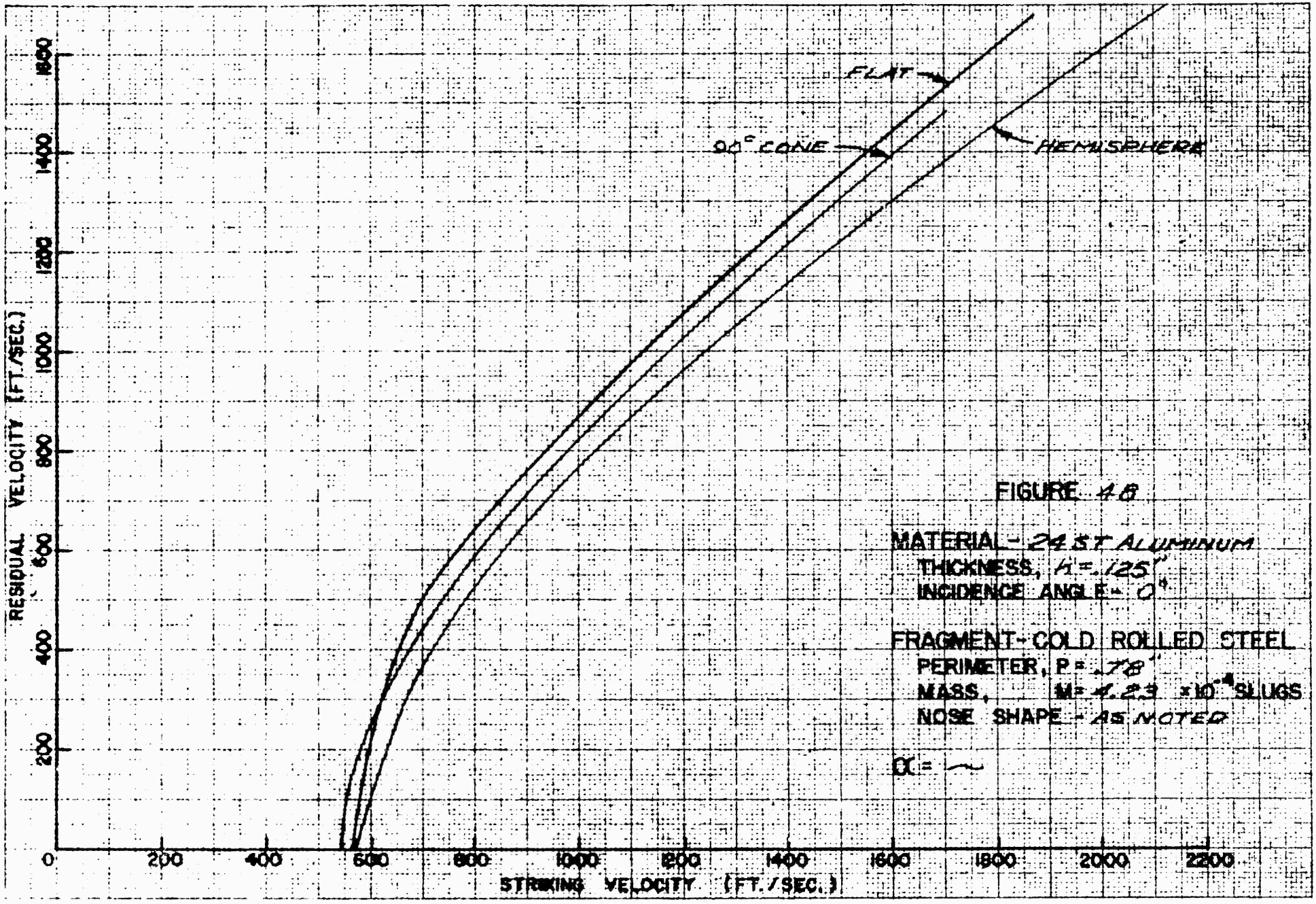


FIGURE 48

MATERIAL - 24ST ALUMINUM
THICKNESS, h = .125"
INCIDENCE ANGLE = 0°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 x 10^{-4} SLUGS
NOSE SHAPE - AS NOTED

α = ~

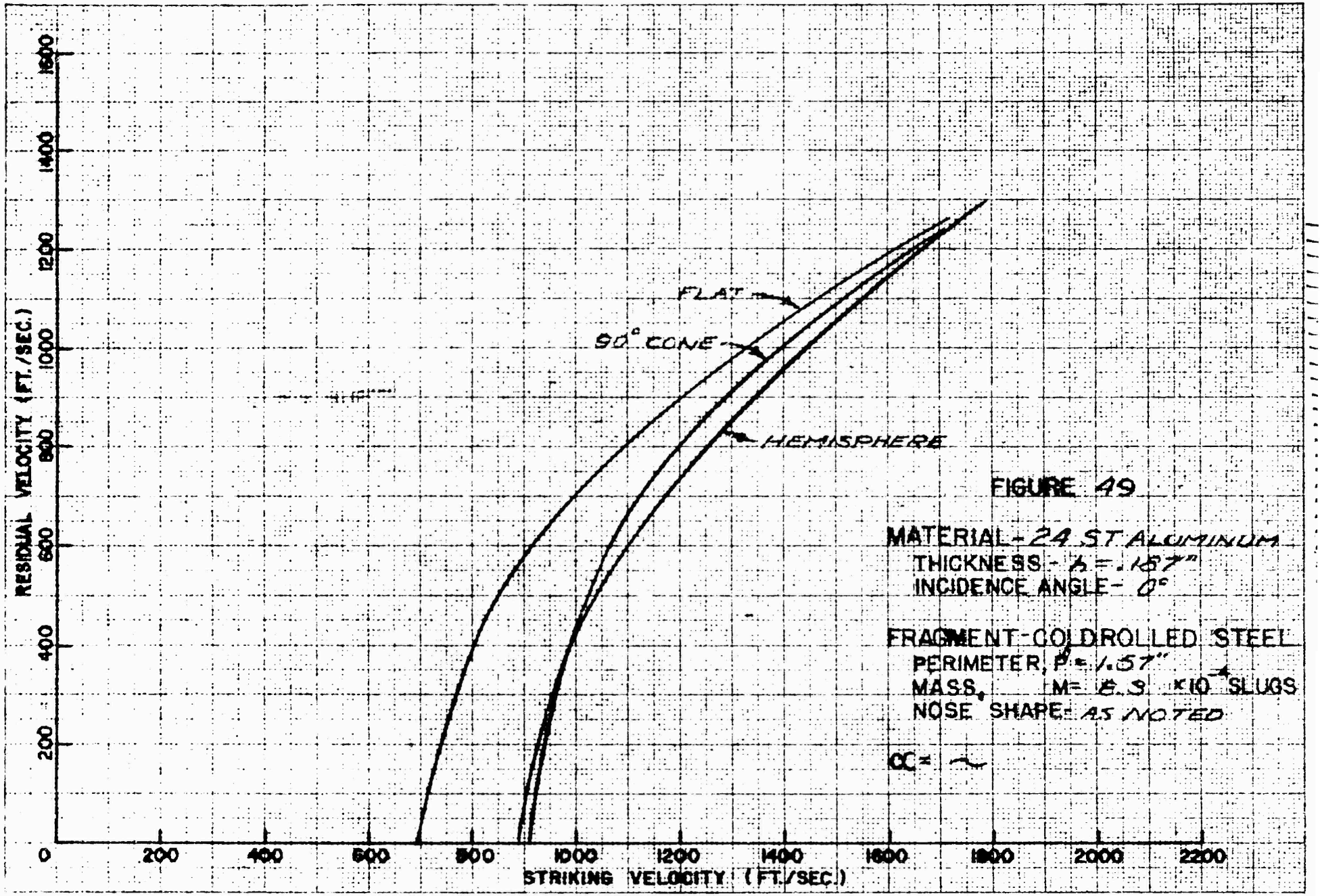


FIGURE 49

MATERIAL - 24 ST ALUMINUM
THICKNESS - $h = .157''$
INCIDENCE ANGLE - $0°$

FRAGMENT - COLDROLLED STEEL
PERIMETER, $P = 1.57''$
MASS, $M = 8.3 \times 10^{-4}$ SLUGS
NOSE SHAPE - AS NOTED

CC = ~

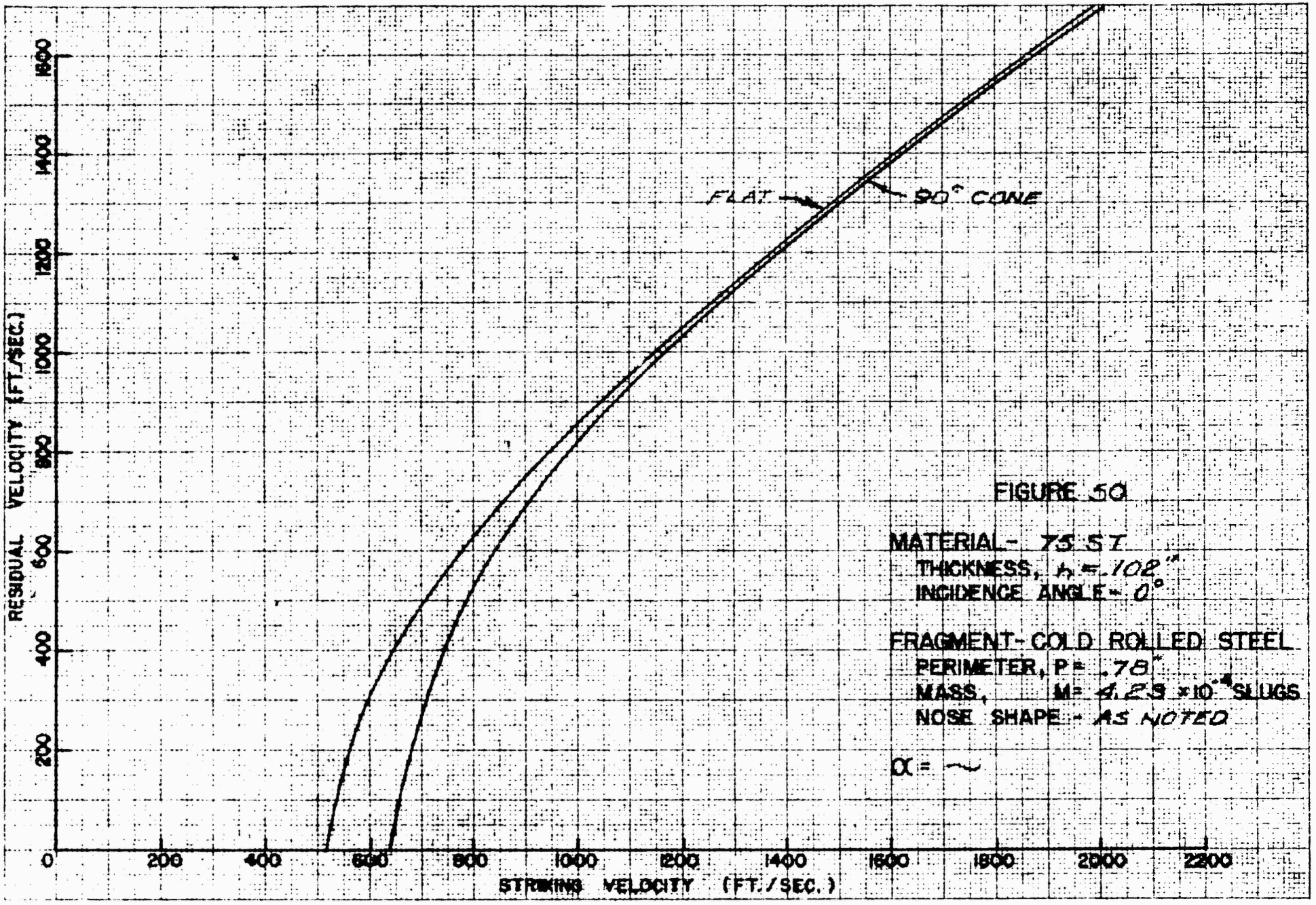


FIGURE 50

MATERIAL - 75 ST
THICKNESS, h = .102"
INCIDENCE ANGLE = 0°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23×10^{-4} SLUGS
NOSE SHAPE - AS NOTED

α = ~

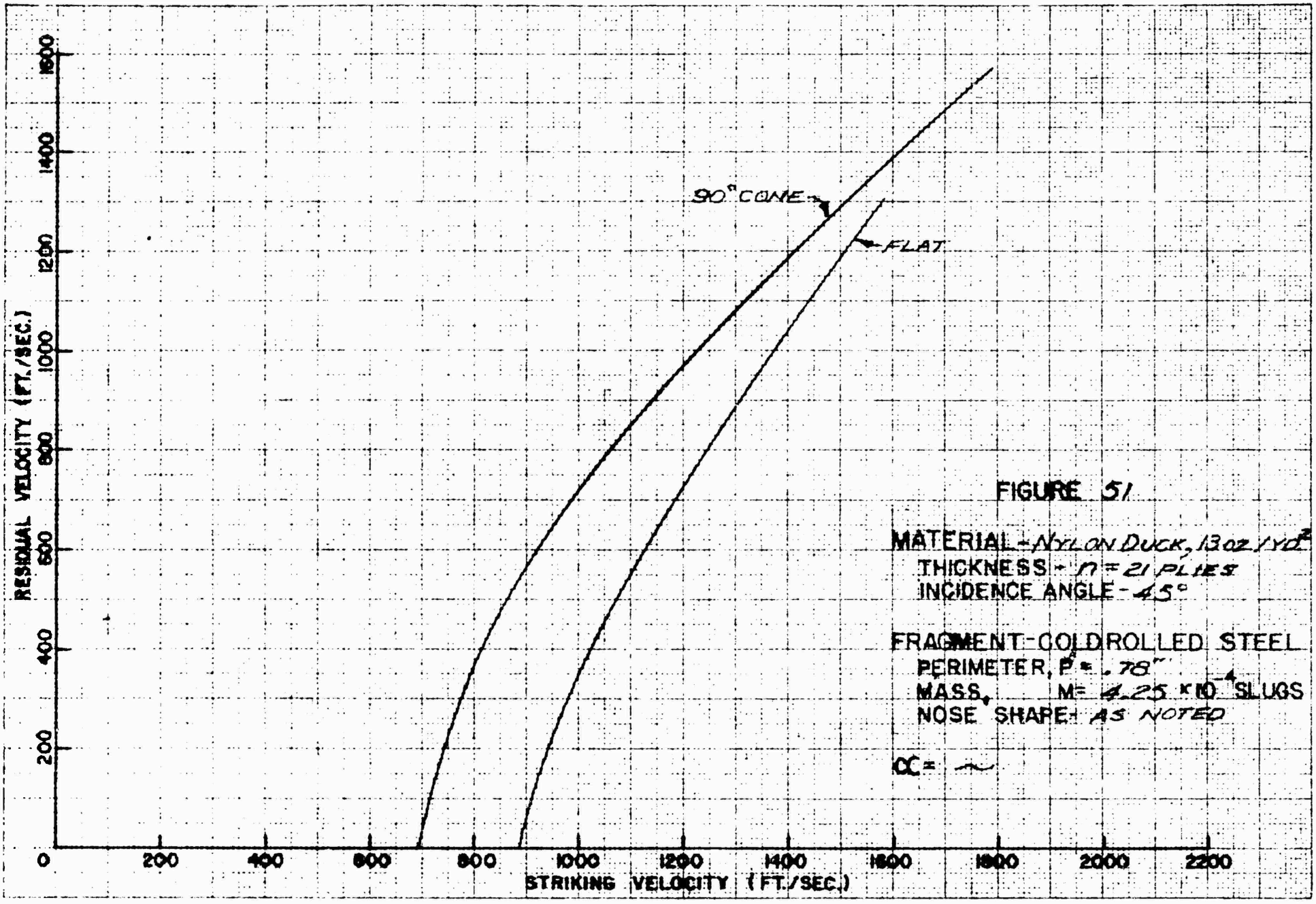


FIGURE 51

MATERIAL - NYLON DUCK, 13 OZ/YD²
THICKNESS - n = 21 PLIES
INCIDENCE ANGLE - 45°

FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.25 × 10⁻⁴ SLUGS
NOSE SHAPE - AS NOTED

CC = ~

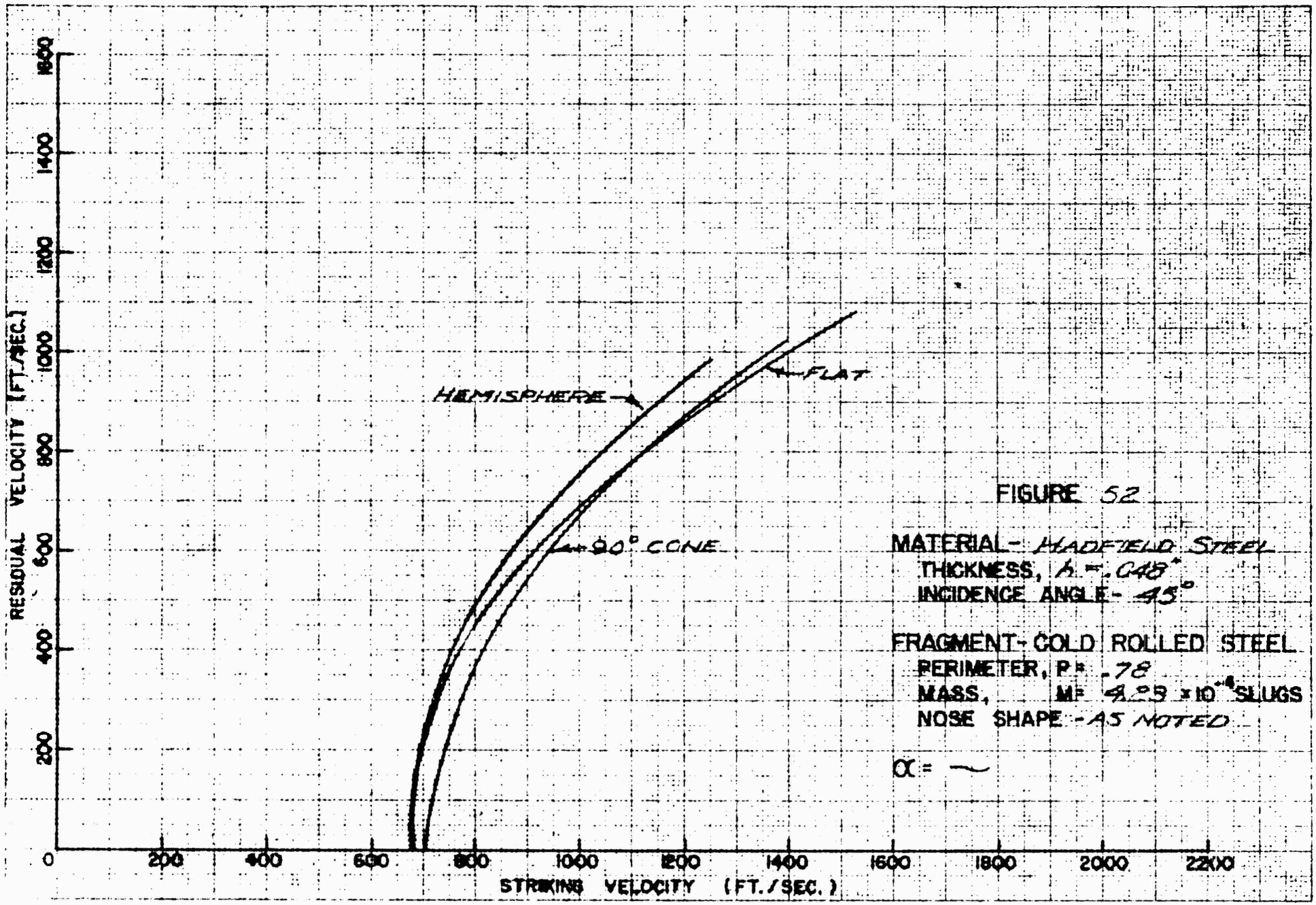


FIGURE 52

MATERIAL - HADFIELD STEEL
THICKNESS, h = .048"
INCIDENCE ANGLE - 45°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78
MASS, M = 9.09 x 10^{-6} SLUGS
NOSE SHAPE - AS NOTED

α = —

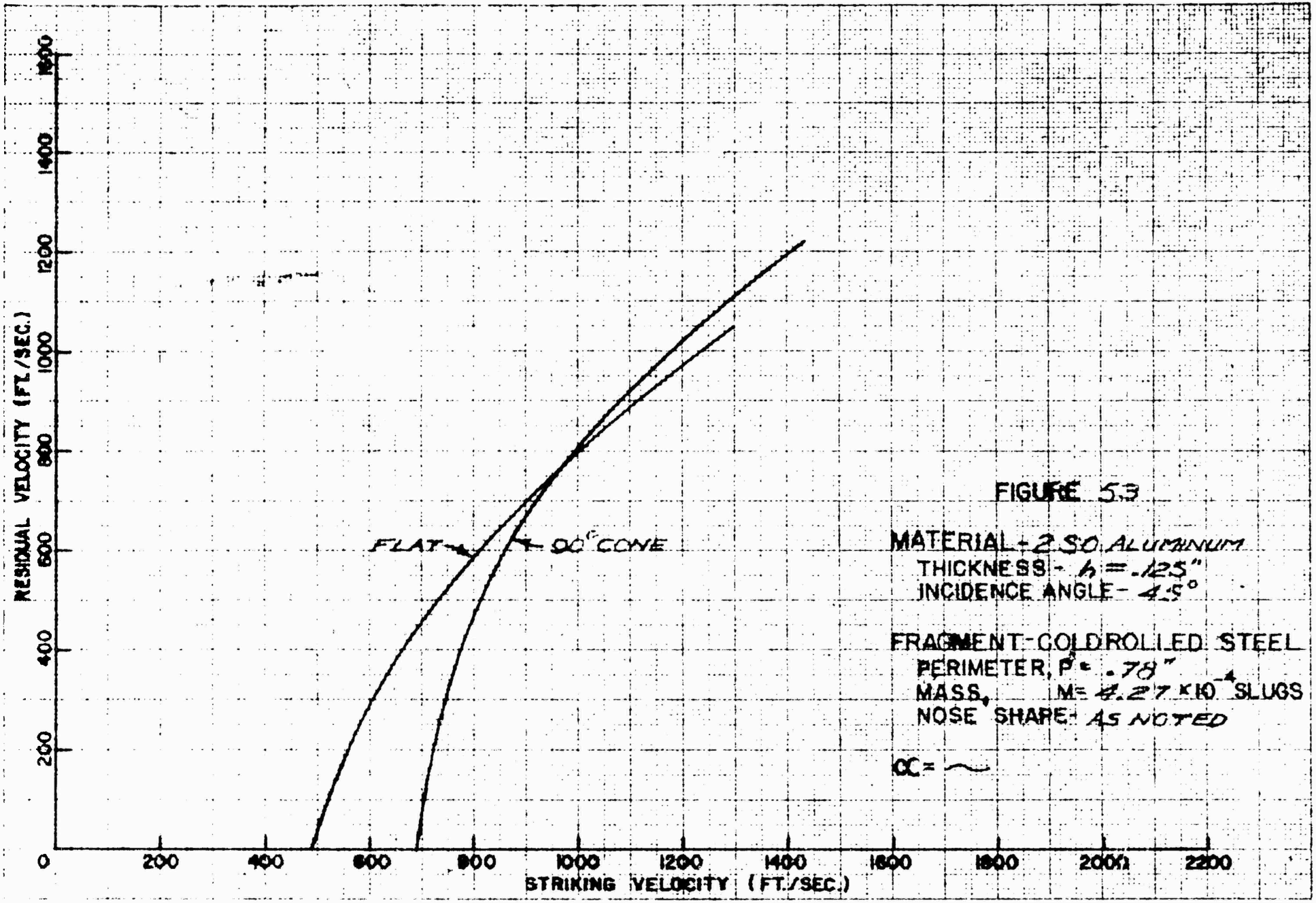

RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
STRIKING VELOCITY (FT./SEC.)
FLAT
90° CONE
MATERIAL - 2 S O. ALUMINUM
THICKNESS - h = .125"
INCIDENCE ANGLE - 45°
FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.27 x 10⁻⁴ SLUGS
NOSE SHAPE - AS NOTED
OC = ~

FIGURE 5.3

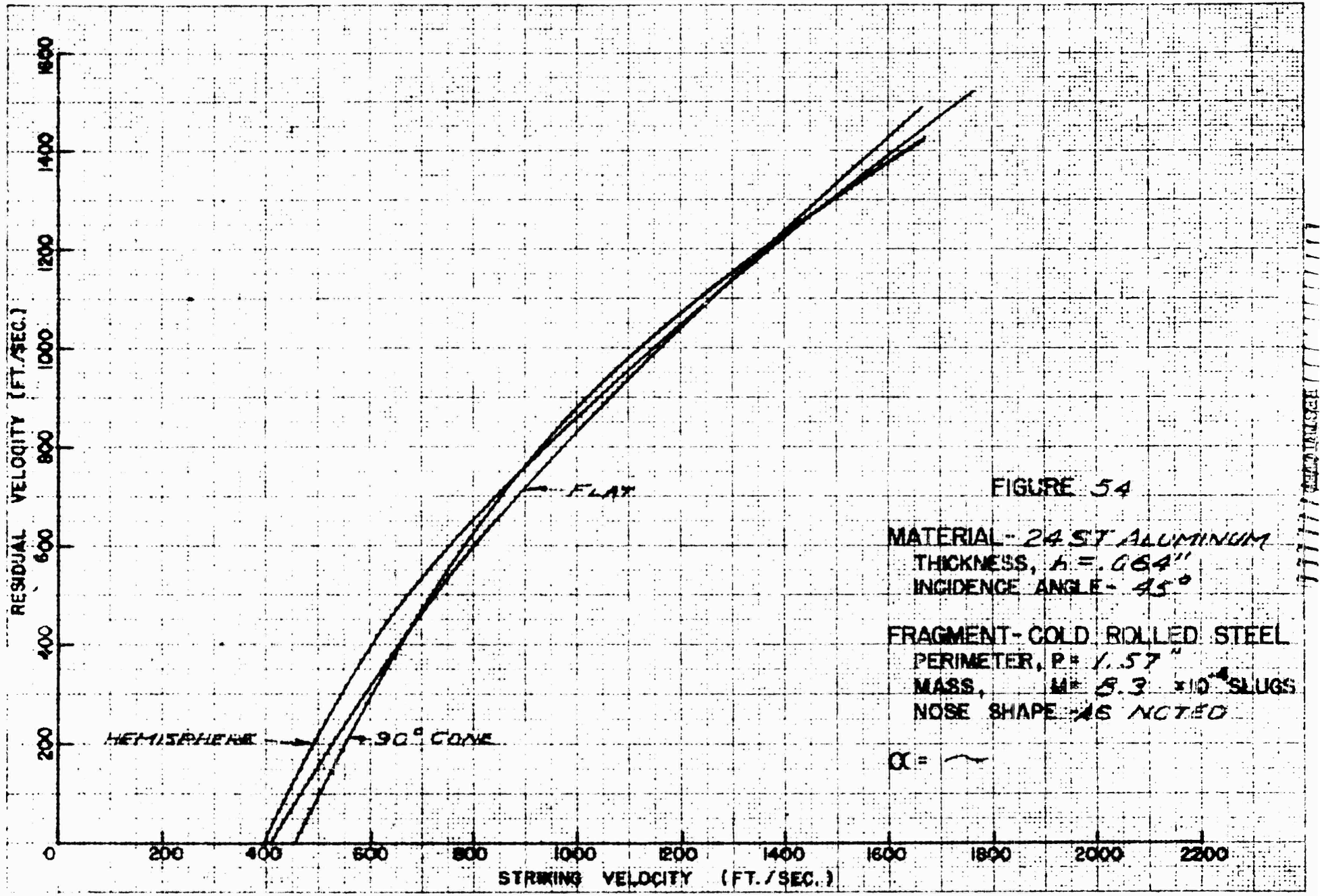
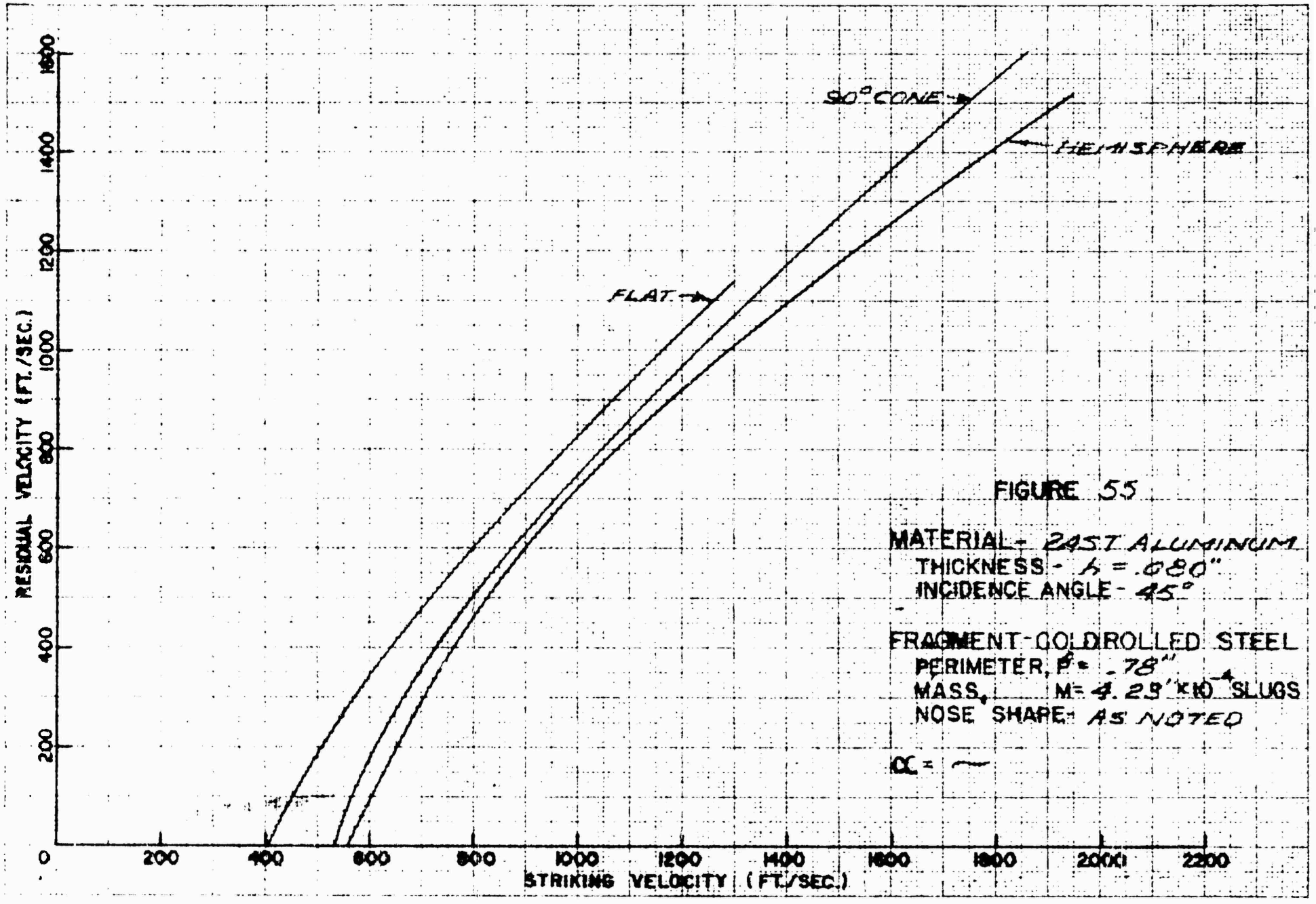


FIGURE 54

MATERIAL - 24ST ALUMINUM
THICKNESS, h = .064"
INCIDENCE ANGLE - 45°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 5.3 x 10⁻⁴ SLUGS
NOSE SHAPE - AS NOTED

α = ~


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
90° CONE
HEMISPHERE
FLAT
FIGURE 55
MATERIAL - 24ST ALUMINUM
THICKNESS - h = .080"
INCIDENCE ANGLE - 45°
FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.25 x 10⁻⁴ SLUGS
NOSE SHAPE - AS NOTED
CC = —

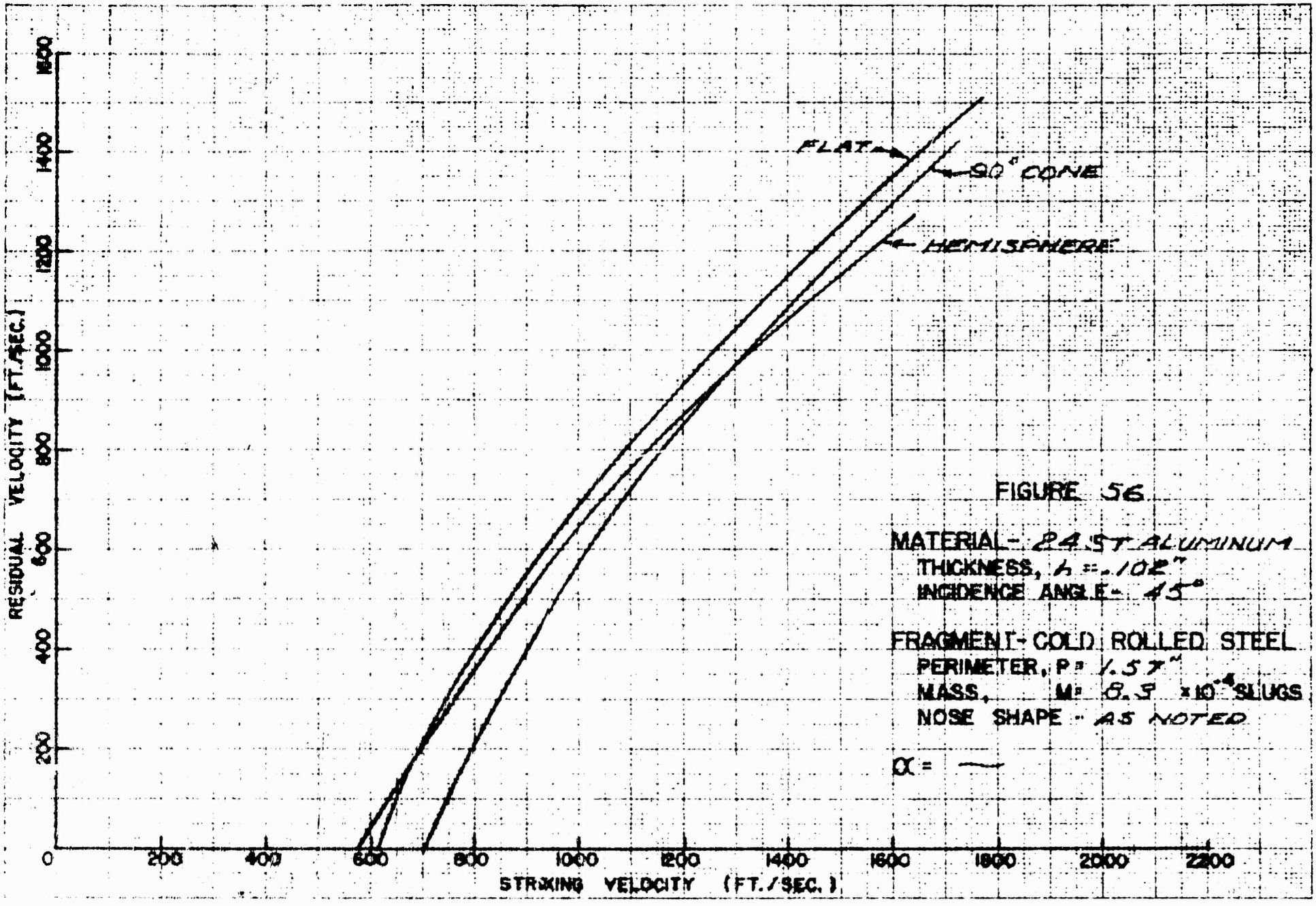


FIGURE 56

MATERIAL - 24ST ALUMINUM
THICKNESS, h = .102"
INCIDENCE ANGLE - 45°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 8.5 $\times 10^{-4}$ SLUGS
NOSE SHAPE - AS NOTED

α = —

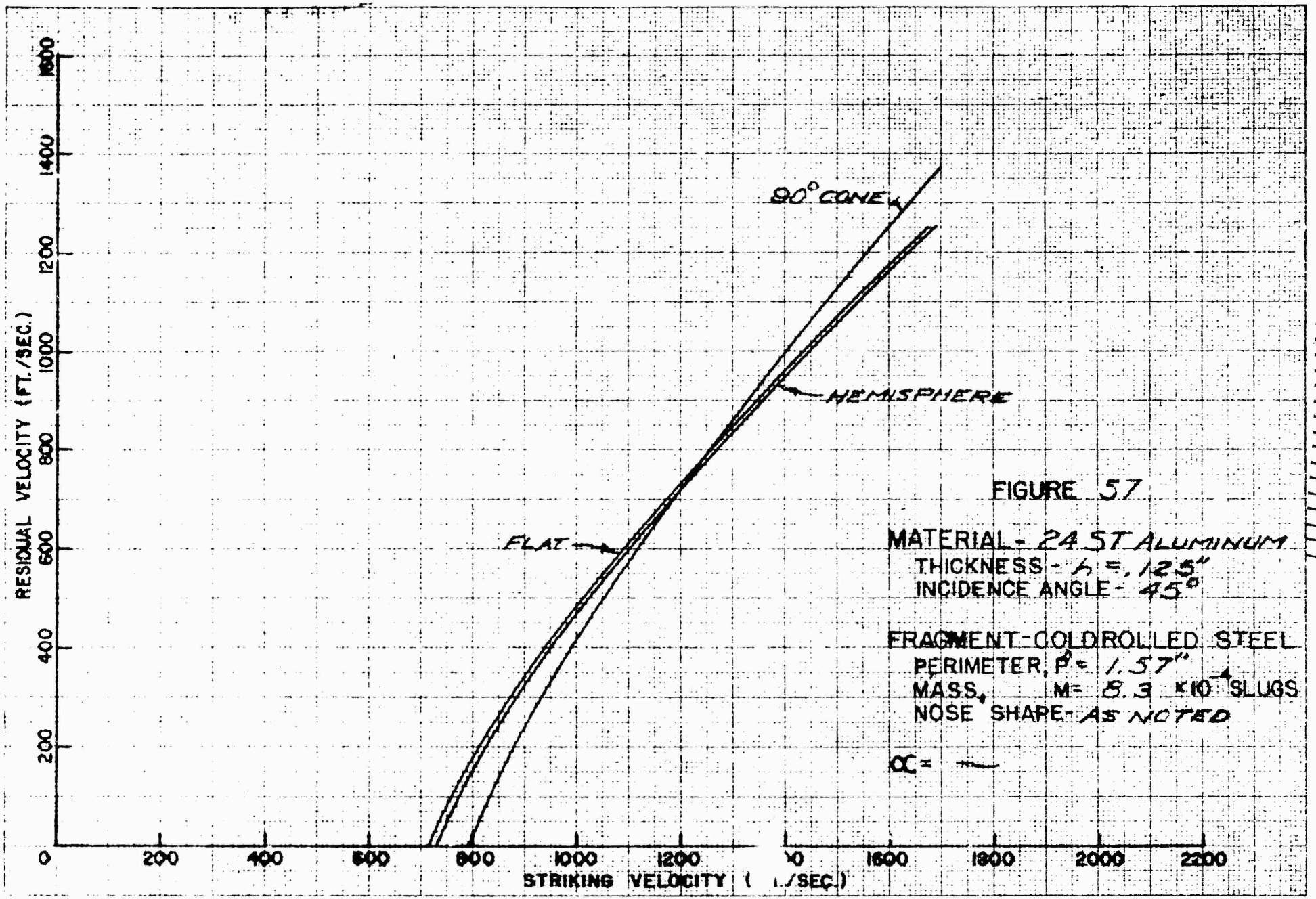


FIGURE 57

MATERIAL - 24 ST ALUMINUM
THICKNESS - h = .125"
INCIDENCE ANGLE - 45°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 8.3 $\times 10^{-4}$ SLUGS
NOSE SHAPE - AS NOTED

OC =

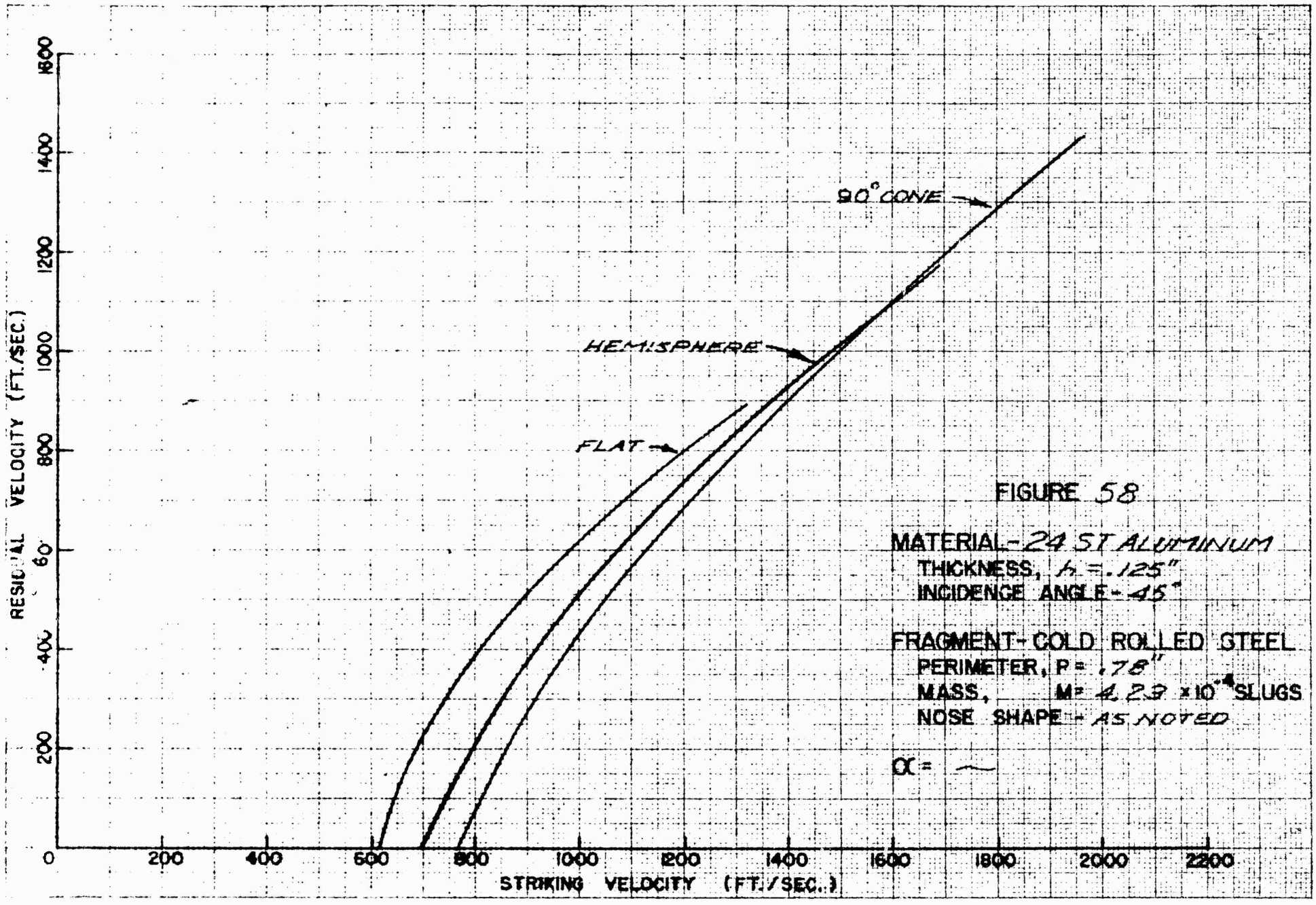


FIGURE 58

MATERIAL - 24 ST ALUMINUM
THICKNESS, $h = .125"$
INCIDENCE ANGLE - 45°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, $P = .78"$
MASS, $M = 4.23 \times 10^{-4}$ SLUGS
NOSE SHAPE - AS NOTED

$\alpha =$ ~

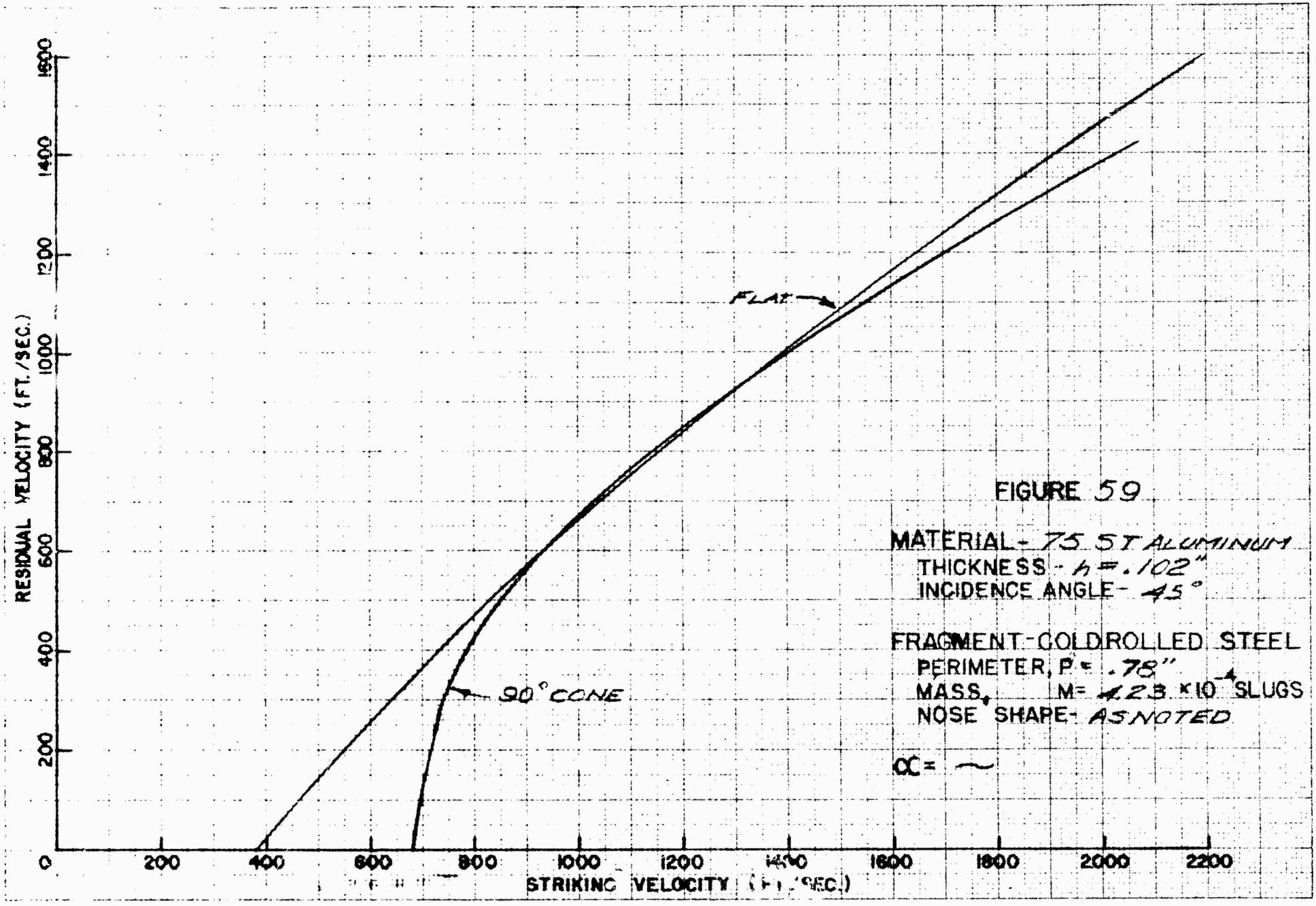


FIGURE 59

MATERIAL - 75 ST ALUMINUM
THICKNESS - $h = .102''$
INCIDENCE ANGLE - 45°

FRAGMENT - COLDROLLED STEEL
PERIMETER, $P = .78''$
MASS, $M = 4.23 \times 10^{-4}$ SLUGS
NOSE SHAPE - AS NOTED

$\alpha =$ ~

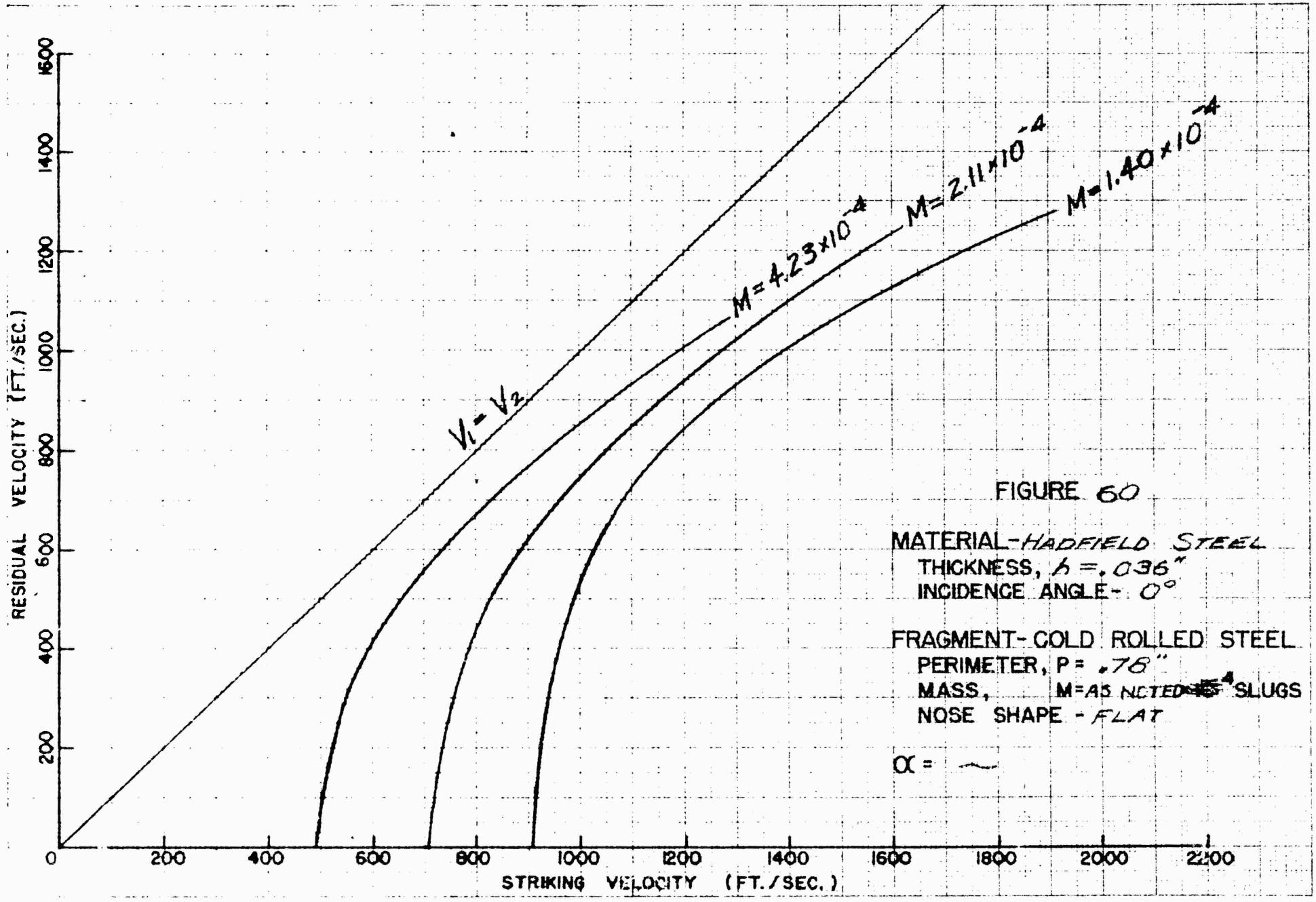


FIGURE 60

MATERIAL - HADFIELD STEEL
THICKNESS, $h = .036"$
INCIDENCE ANGLE - $0°$

FRAGMENT - COLD ROLLED STEEL
PERIMETER, $P = .78"$
MASS, M=AS NOTED SLUGS
NOSE SHAPE - FLAT

$\alpha =$ ~

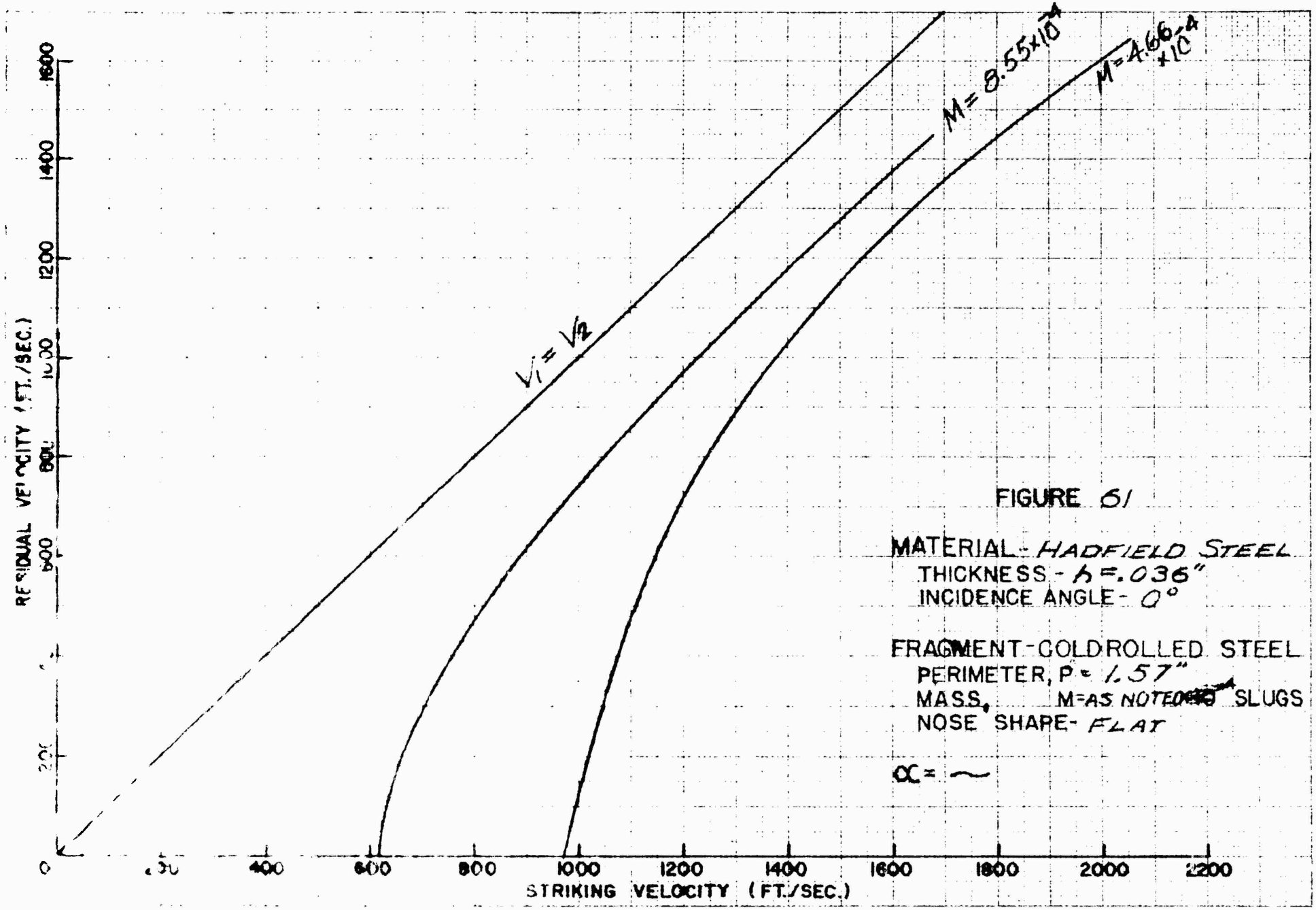


FIGURE 61

MATERIAL - HADFIELD STEEL
THICKNESS - $h = .036"$
INCIDENCE ANGLE - $0°$

FRAGMENT - COLDROLLED STEEL
PERIMETER, $P = 1.57"$
MASS, M=AS NOTED SLUGS
NOSE SHAPE - FLAT

$\alpha = \sim$

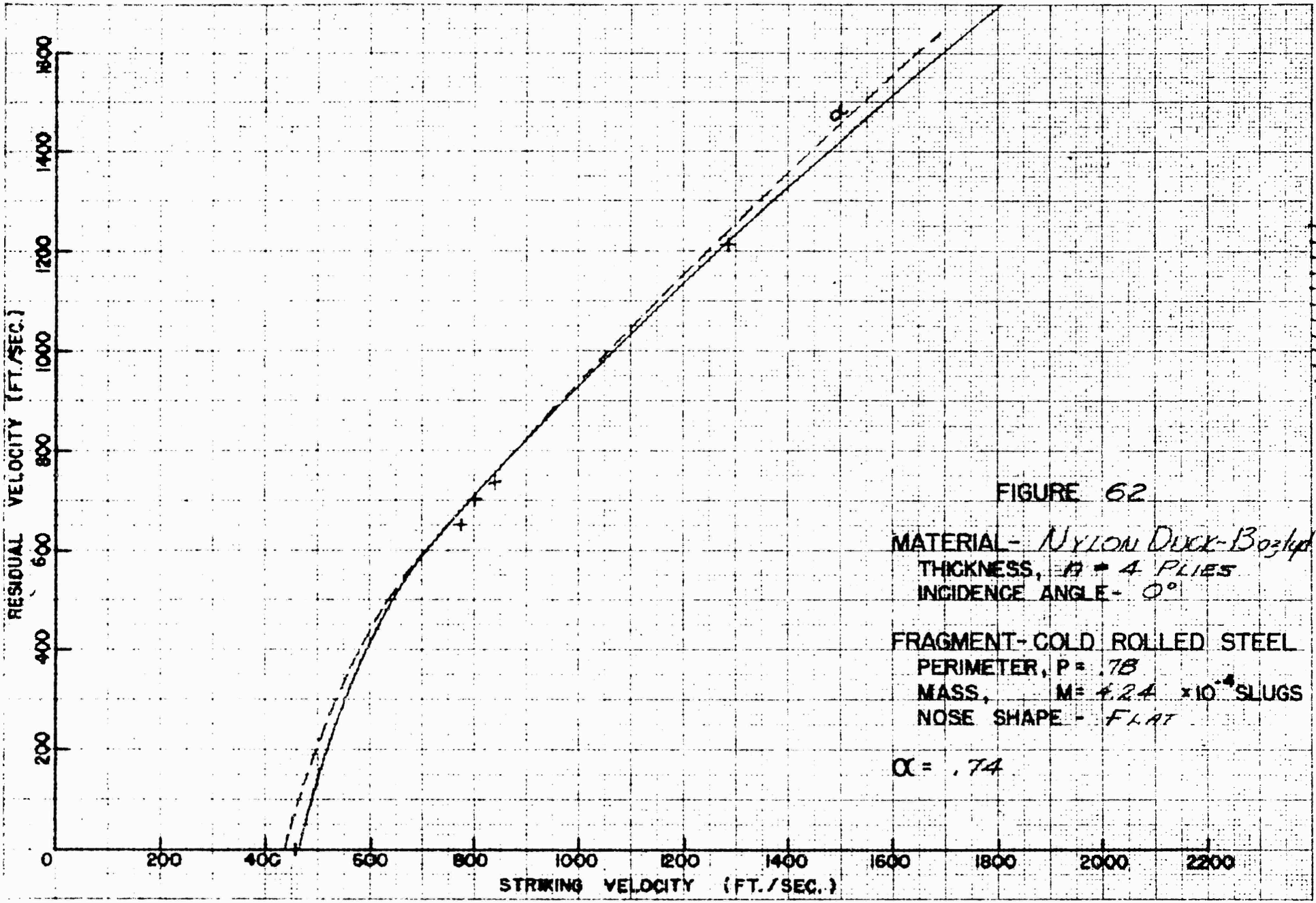
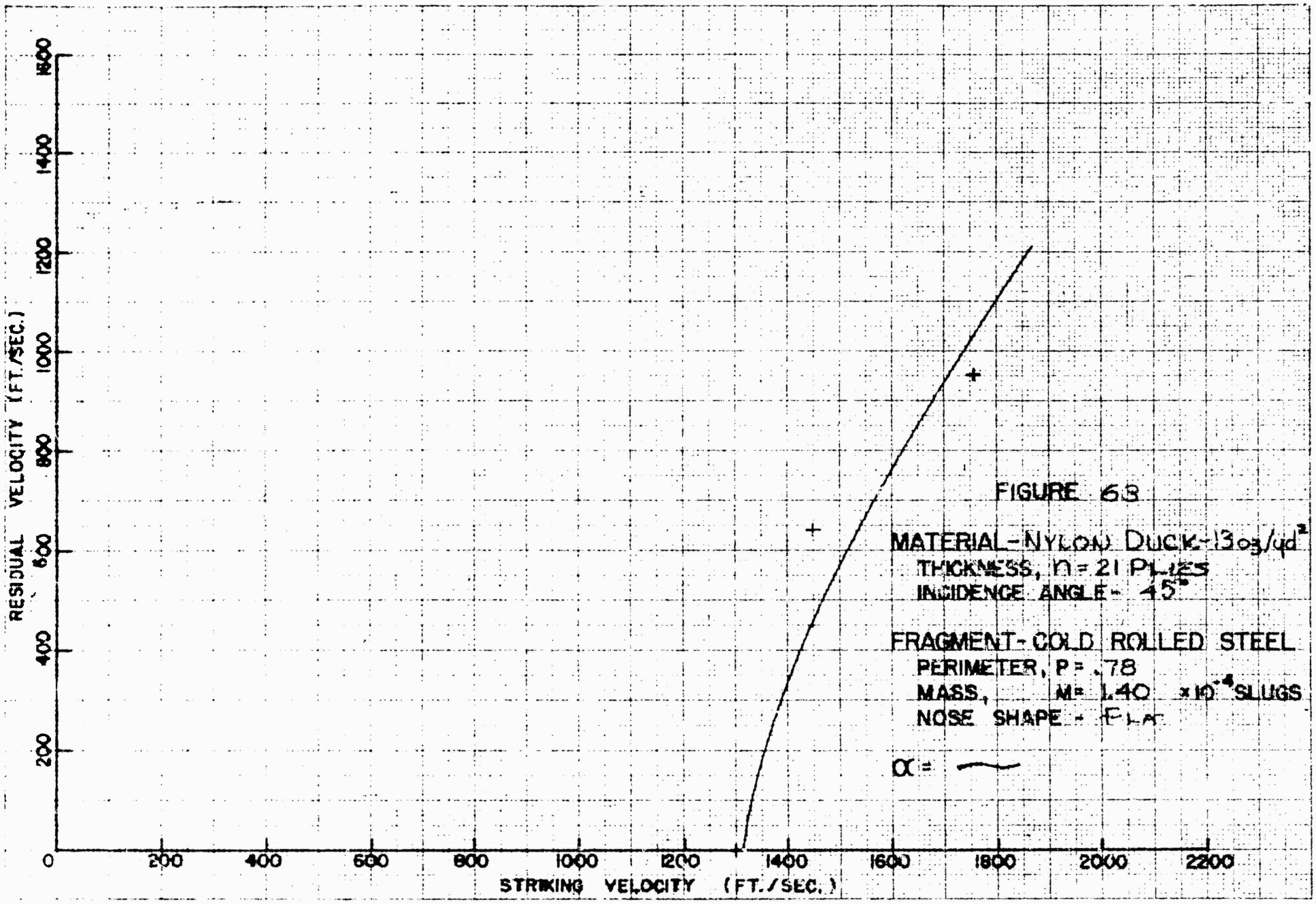


FIGURE 62

MATERIAL- NYLON DUCK-B03kp
THICKNESS, n = 4 PLIES
INCIDENCE ANGLE- 0°

FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = .78
MASS, M = 4.24 $\times 10^{-4}$ SLUGS
NOSE SHAPE - FLAT

α = .74


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 63
MATERIAL - NYLON DUCK - 13 oz/yd²
THICKNESS, n = 21 PLIES
INCIDENCE ANGLE - 45°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78
MASS, M = 1.40 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α =

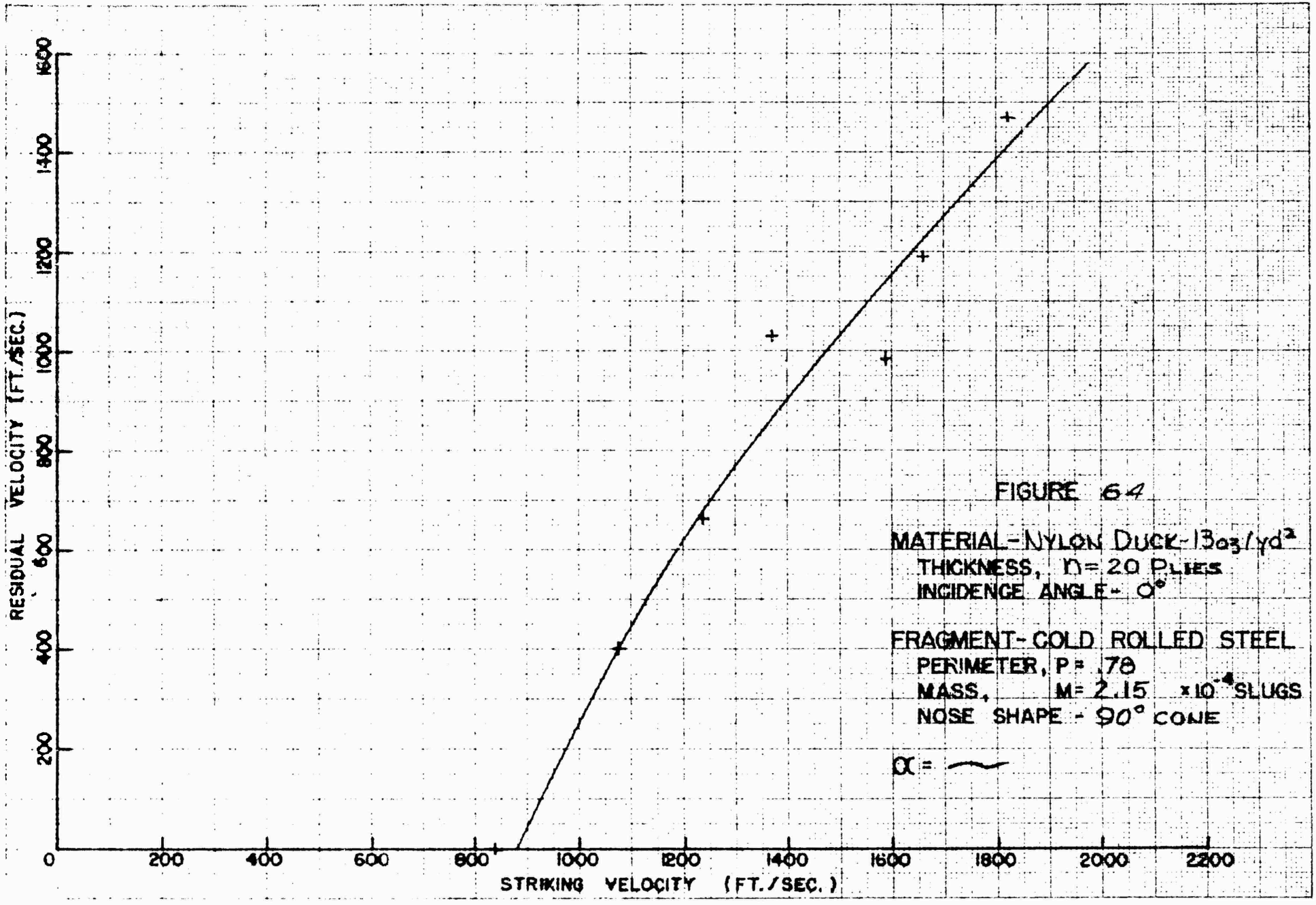
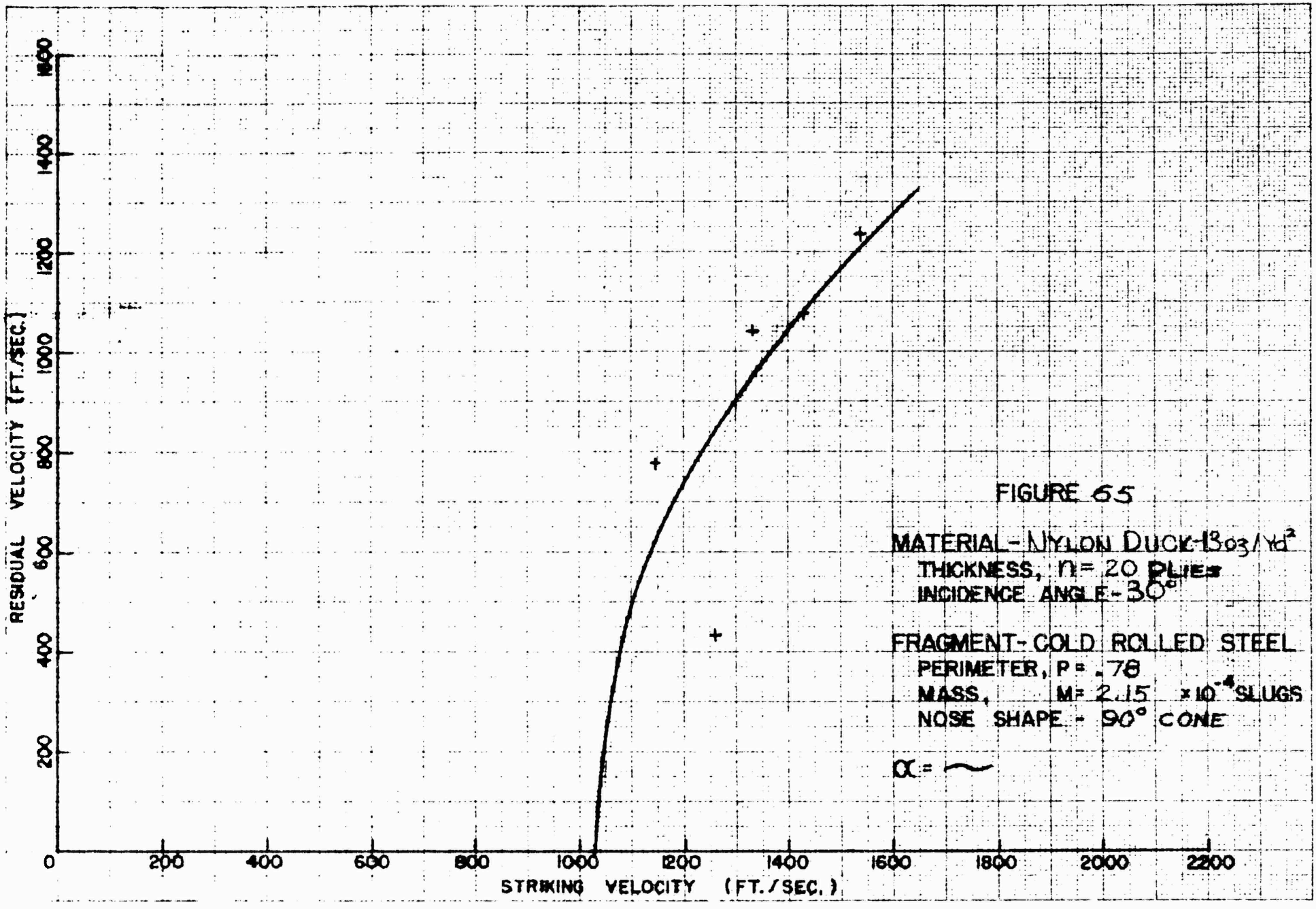


FIGURE 64

MATERIAL - NYLON DUCK - 13oz/yd²
THICKNESS, n = 20 PLIES
INCIDENCE ANGLE = 0°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78
MASS, M = 2.15 x 10^{-4} SLUGS
NOSE SHAPE - 90° CONE

α = ~


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
STRIKING VELOCITY (FT./SEC.)
FIGURE 65
MATERIAL - NYLON DUCK 13oz/Yd²
THICKNESS, n = 20 PLIES
INCIDENCE ANGLE - 30°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78
MASS, M = 2.15 x10⁻⁴ SLUGS
NOSE SHAPE - 90° CONE
α = ~

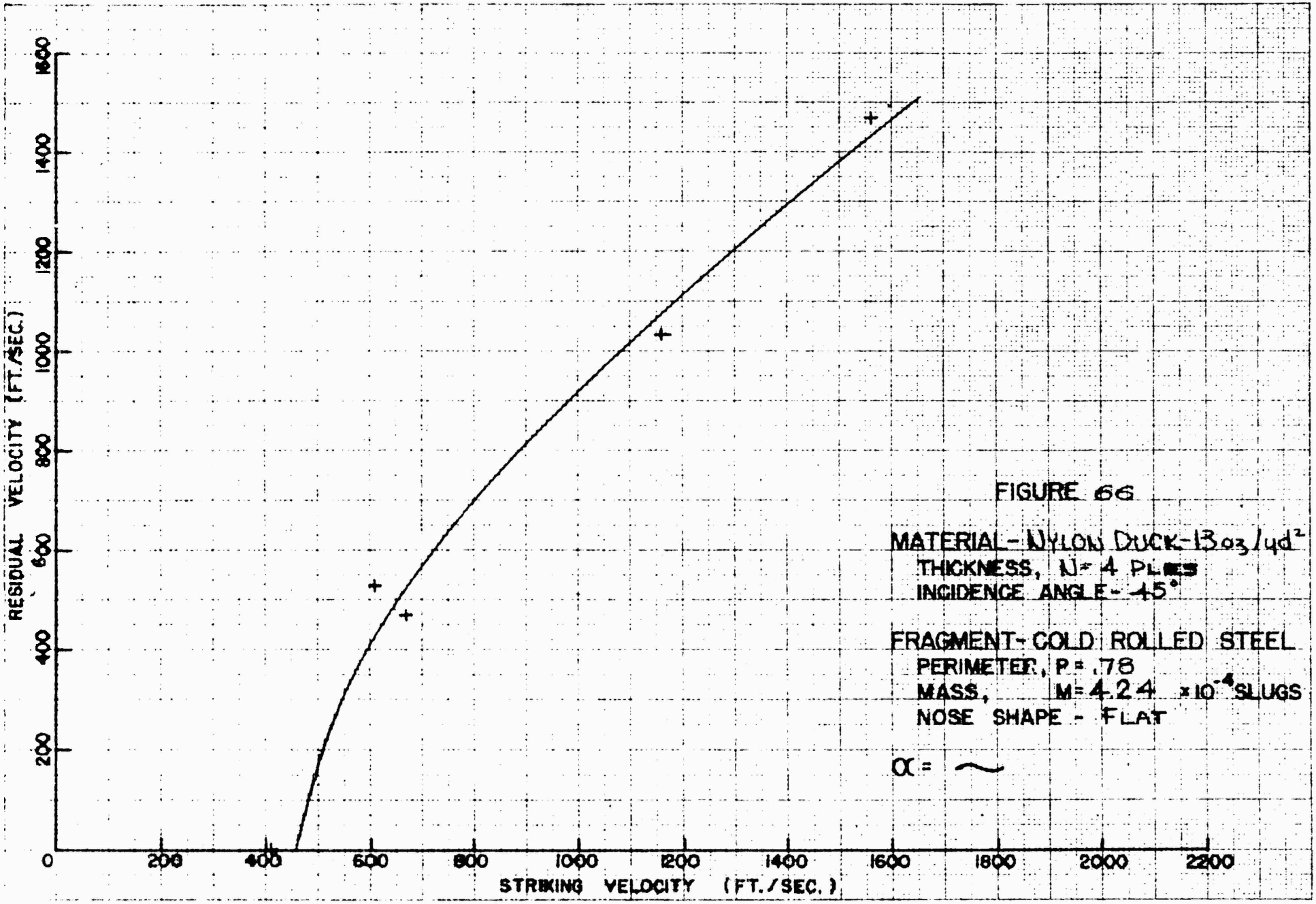


FIGURE 66

MATERIAL - NYLON DUCK-13oz/yd²
THICKNESS, N = 4 PLIES
INCIDENCE ANGLE - 45°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78
MASS, M = 4.24 x 10^{-4} SLUGS
NOSE SHAPE - FLAT

α = ~

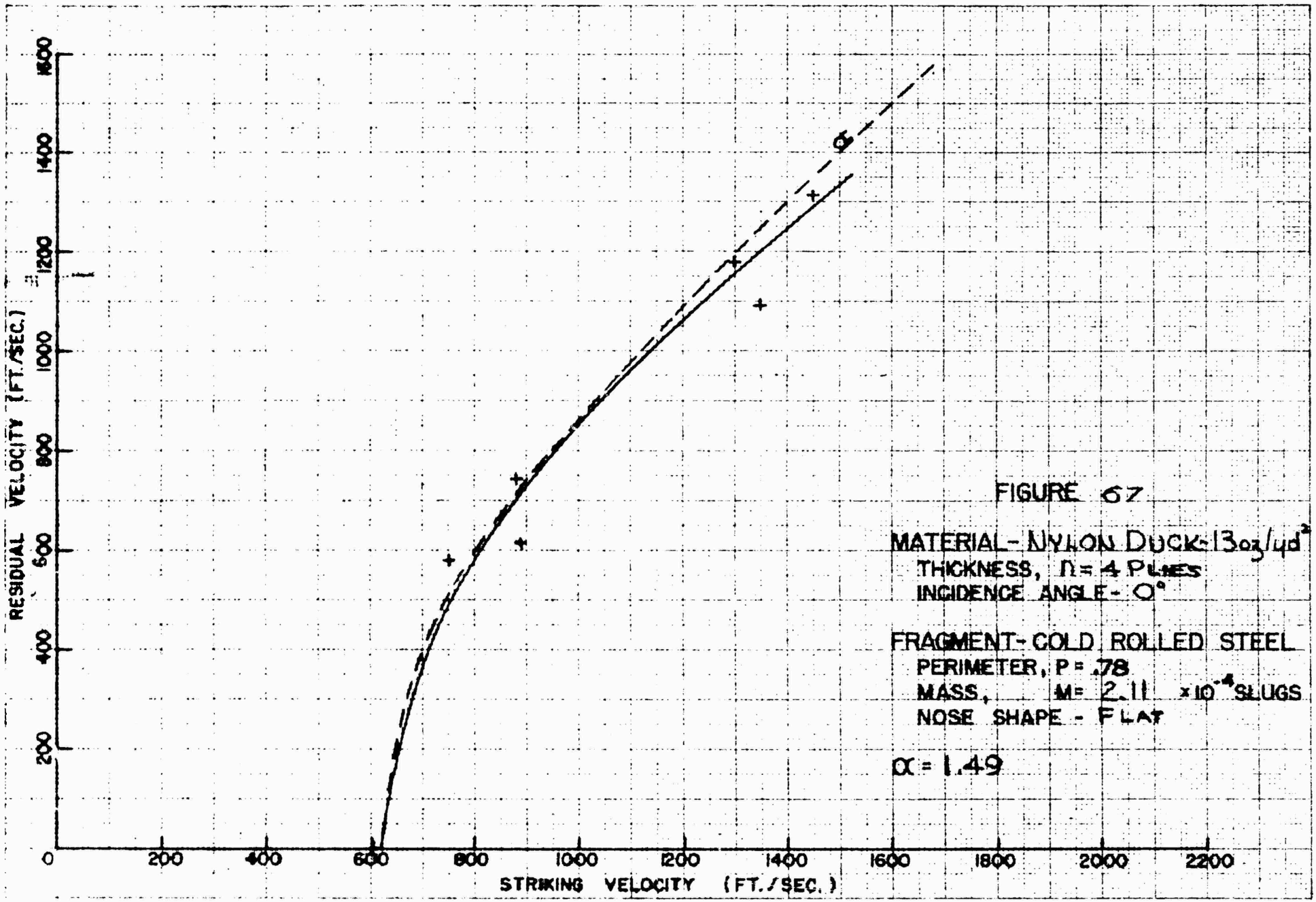
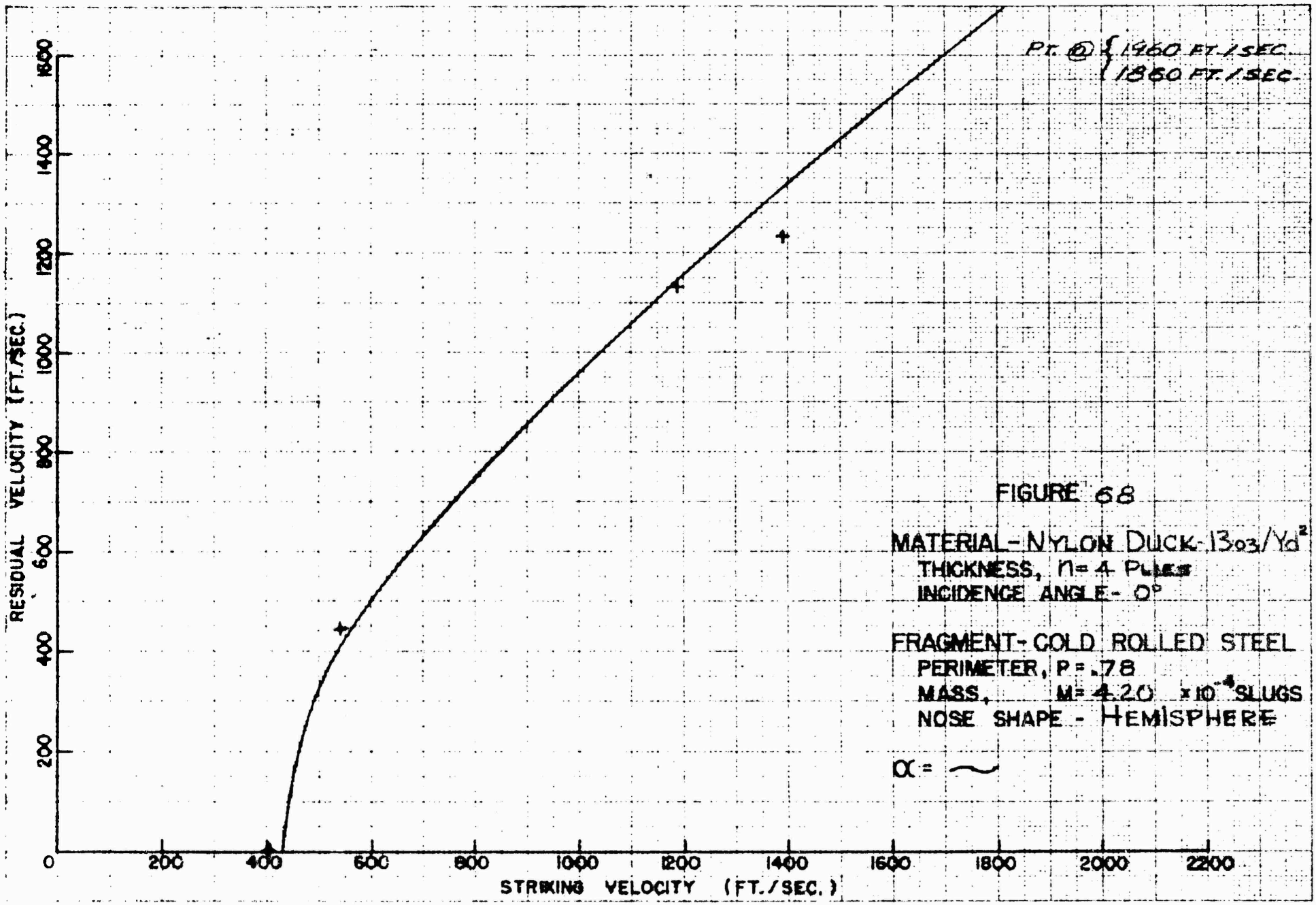


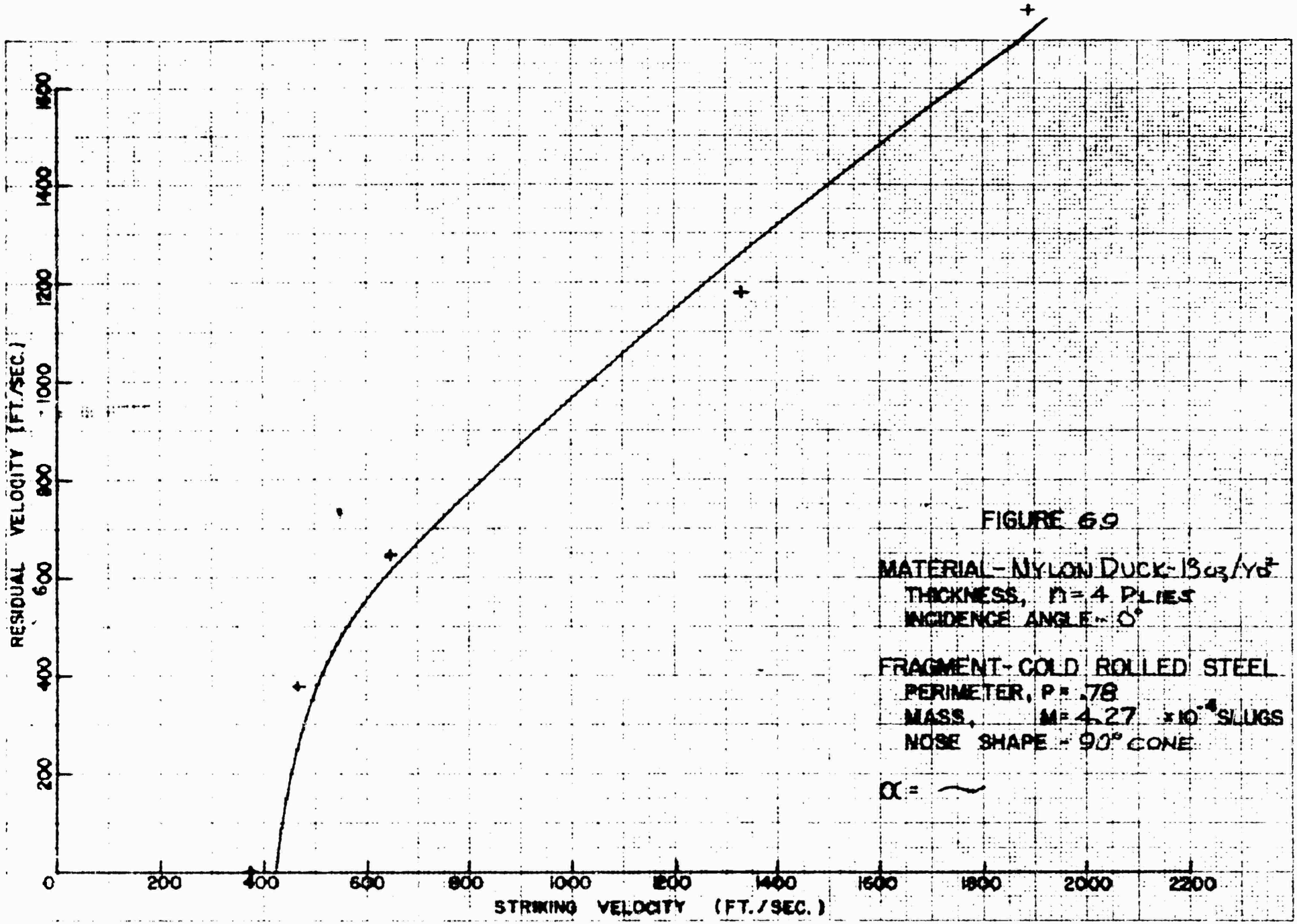
FIGURE 67

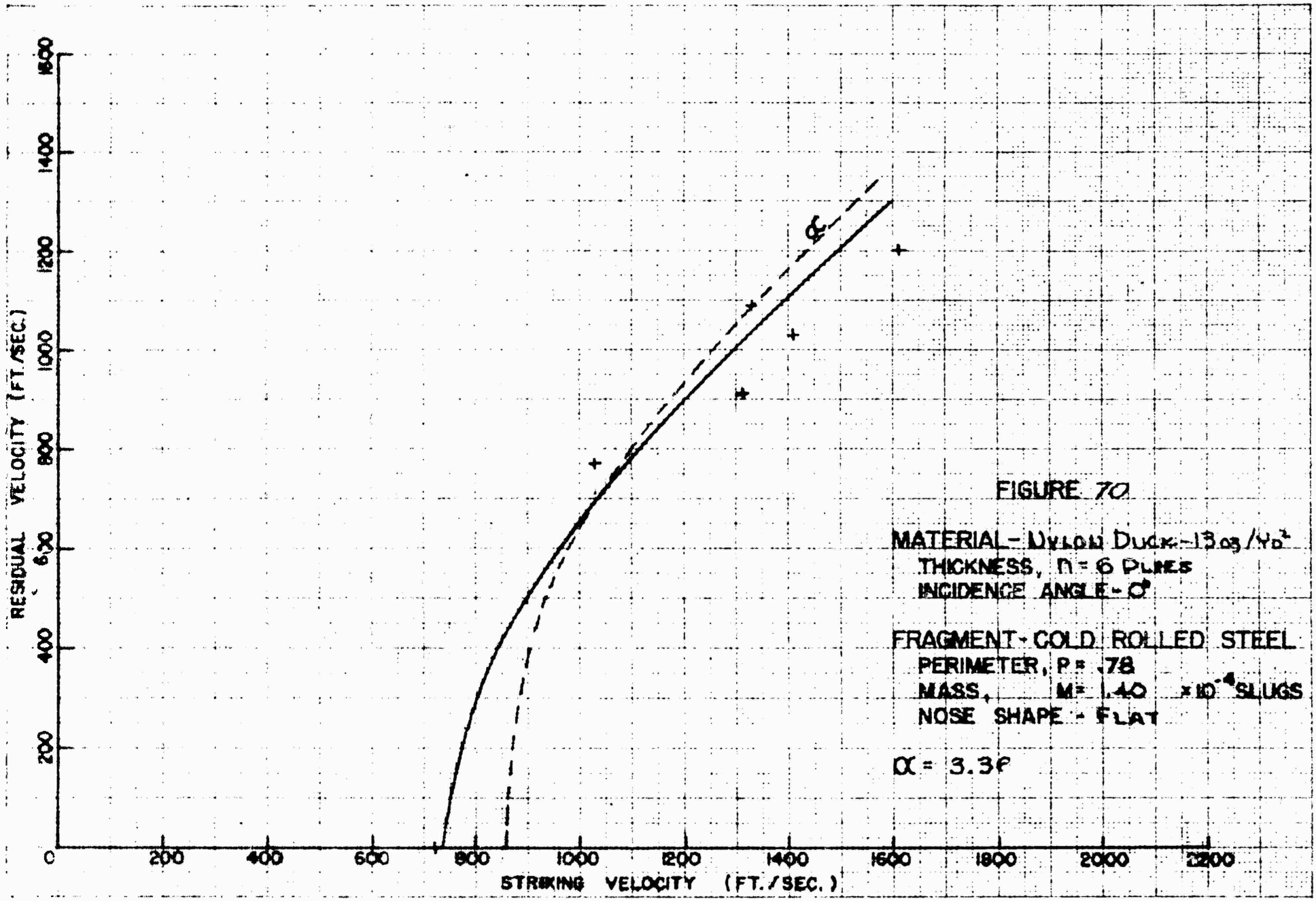
MATERIAL - NYLON DUCK - 13 oz/yd²
THICKNESS, n = 4 PLIES
INCIDENCE ANGLE - 0°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78
MASS, M = 2.11 $\times 10^{-4}$ SLUGS
NOSE SHAPE - FLAT

$\alpha = 1.49$


Pt. @ { 1460 FT./SEC.
1860 FT./SEC.
RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
STRIKING VELOCITY (FT./SEC.)
FIGURE 68
MATERIAL - NYLON DUCK 13 oz/Yd²
THICKNESS, n = 4 PLIES
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78
MASS, M = 4.20 x 10⁻⁴ SLUGS
NOSE SHAPE - HEMISPHERE
α = ~


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 69
MATERIAL - NYLON DUCK - 13 oz/Yd²
THICKNESS, n = 4 PLIES
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78
MASS, M = 4.27 x10⁻⁴ SLUGS
NOSE SHAPE - 90° CONE
α = ~


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 70
MATERIAL - Nylon Duck - 13 oz/Yd²
THICKNESS, n = 6 Plies
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78
MASS, M = 1.40 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 3.3P

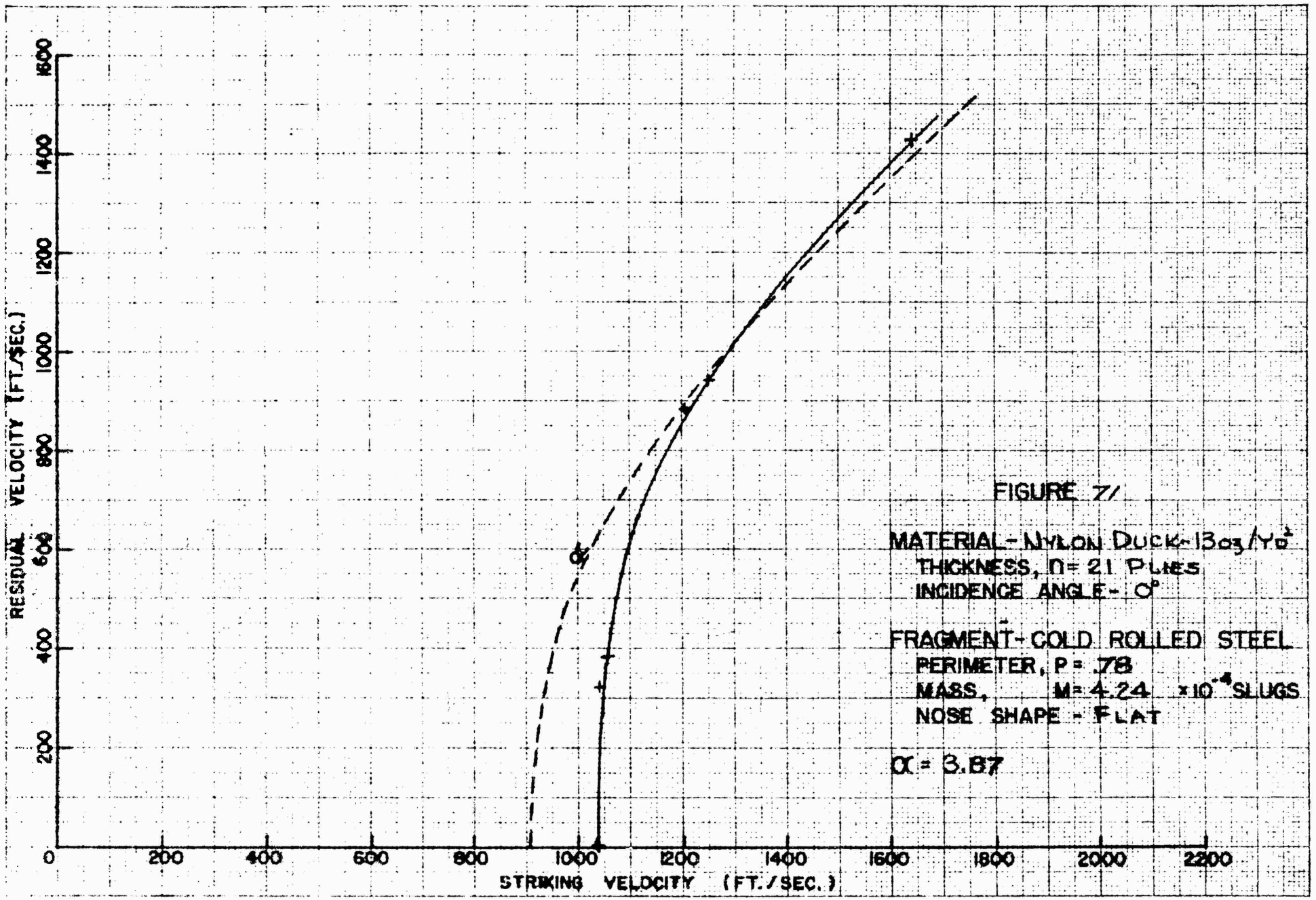


FIGURE 71

MATERIAL - NYLON DUCK - 13 oz/YD²
THICKNESS, n = 21 PLIES
INCIDENCE ANGLE - 0°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78
MASS, M = 4.24 $\times 10^{-4}$ SLUGS
NOSE SHAPE - FLAT

α = 3.87

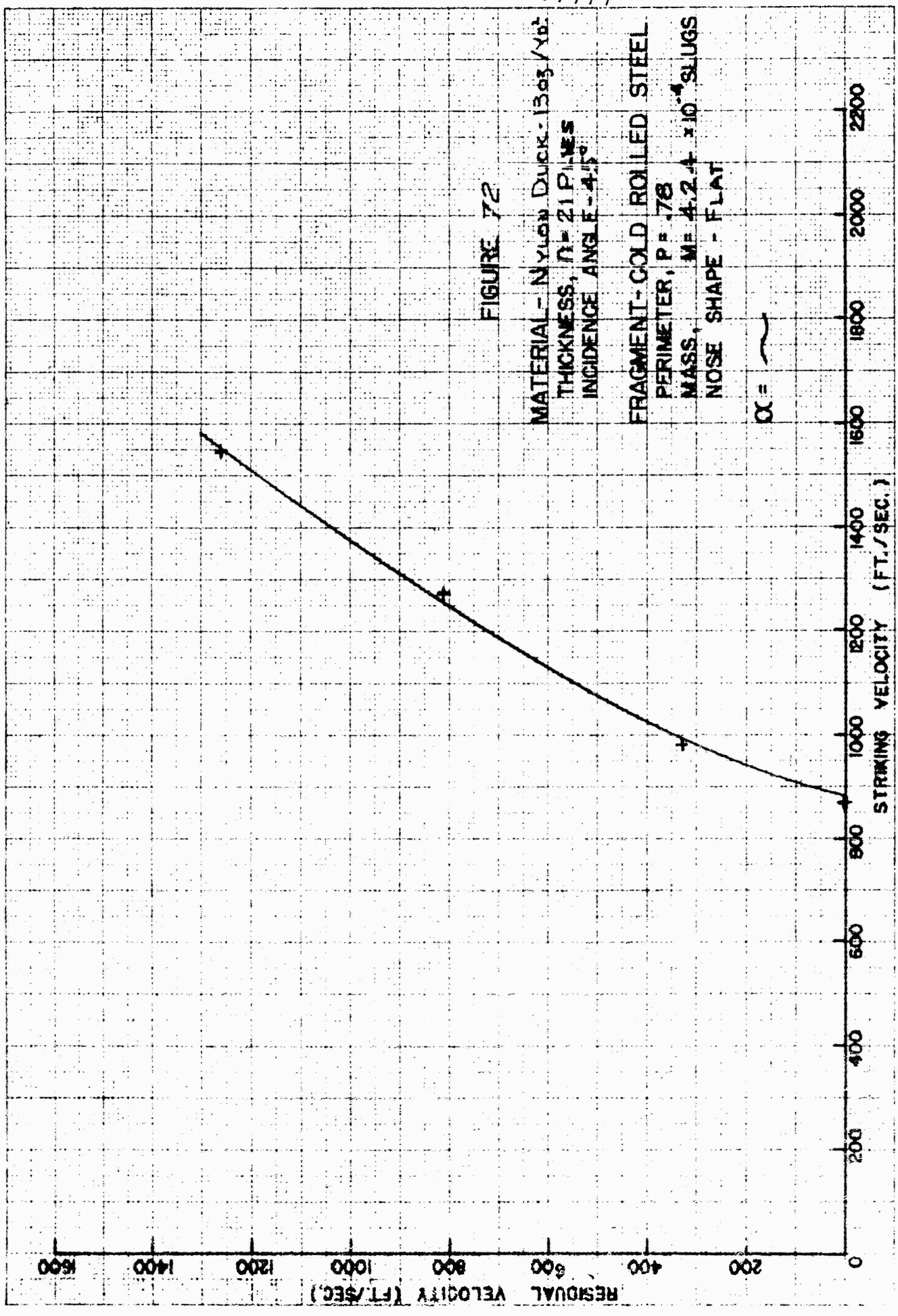
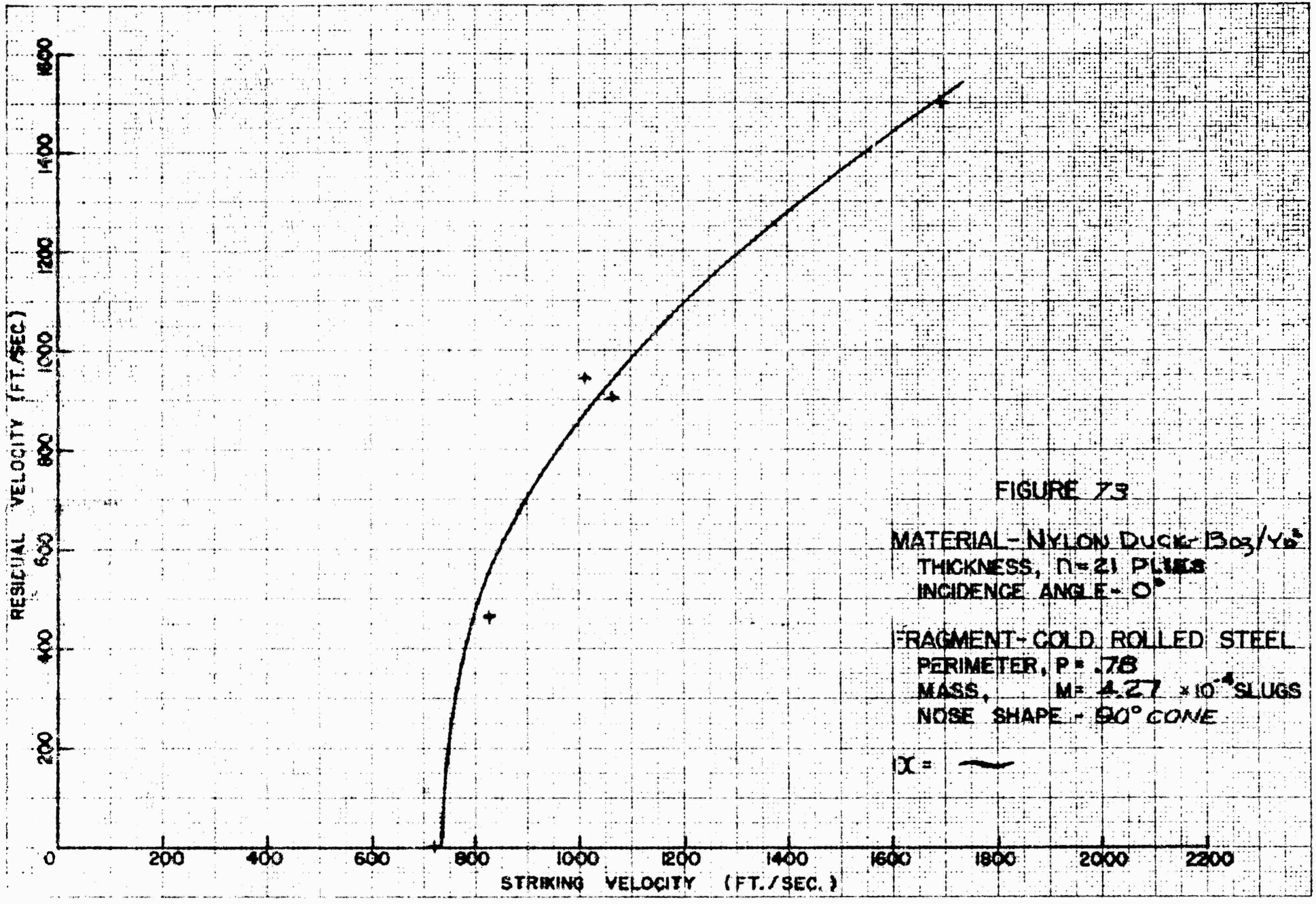
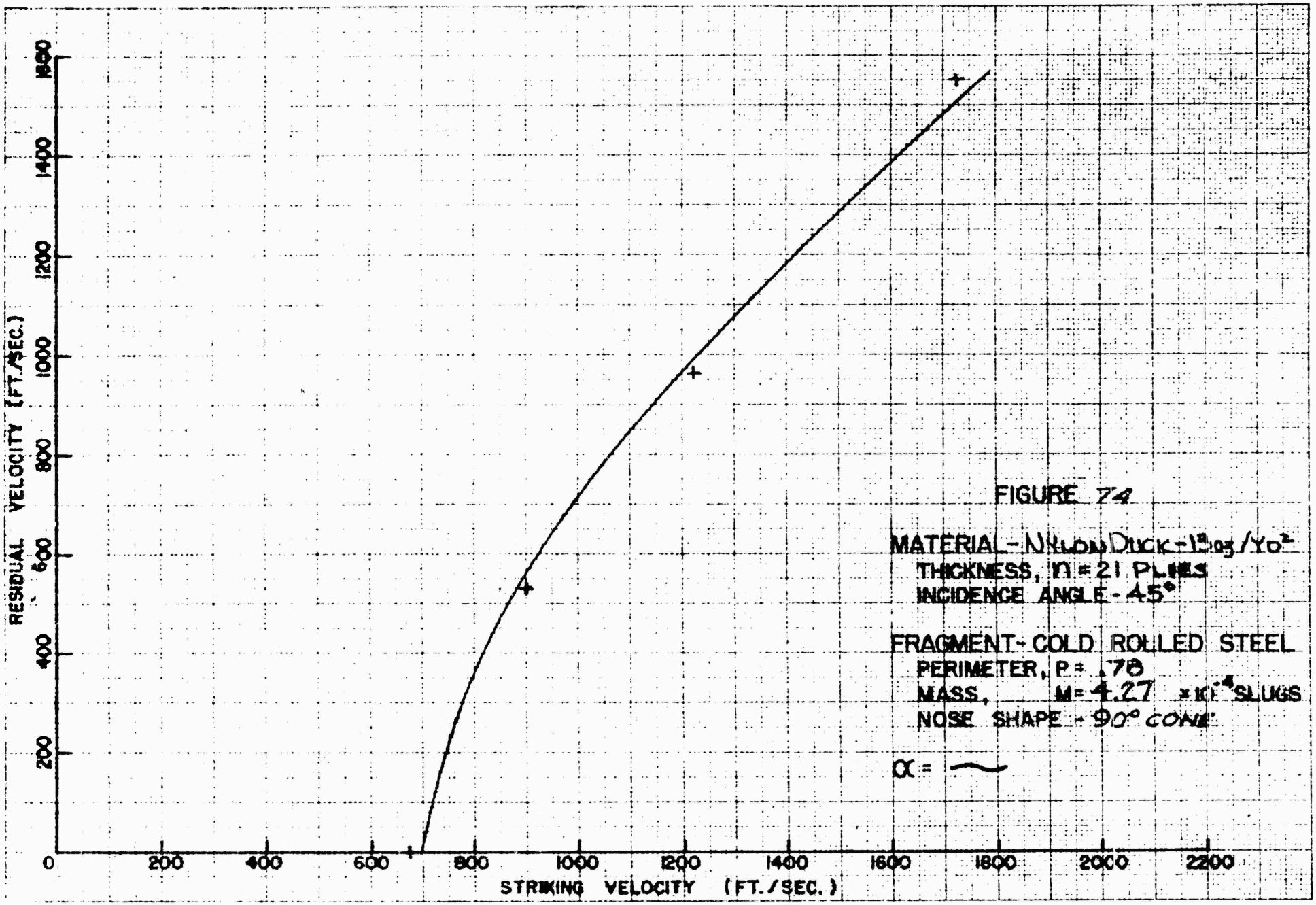
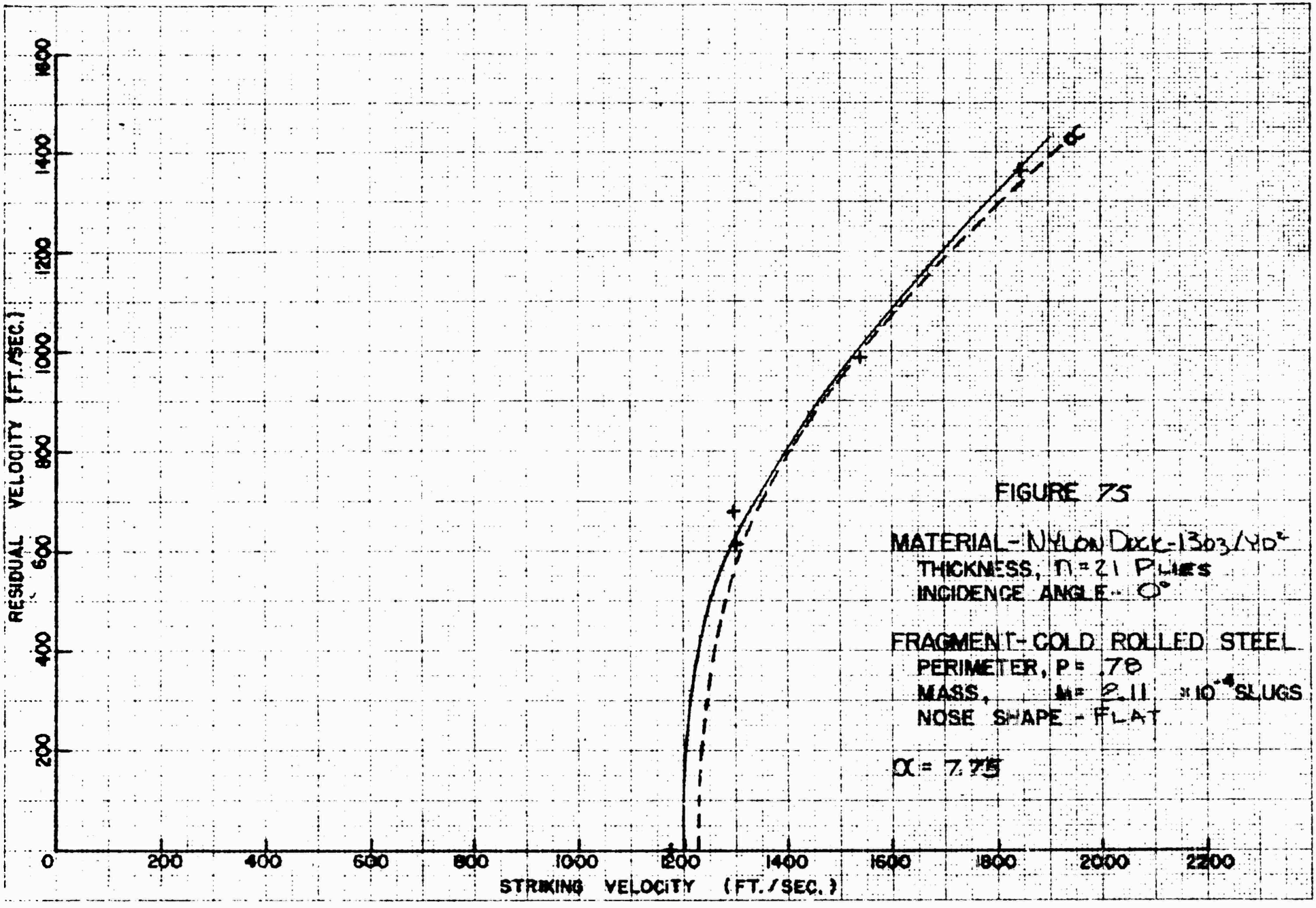
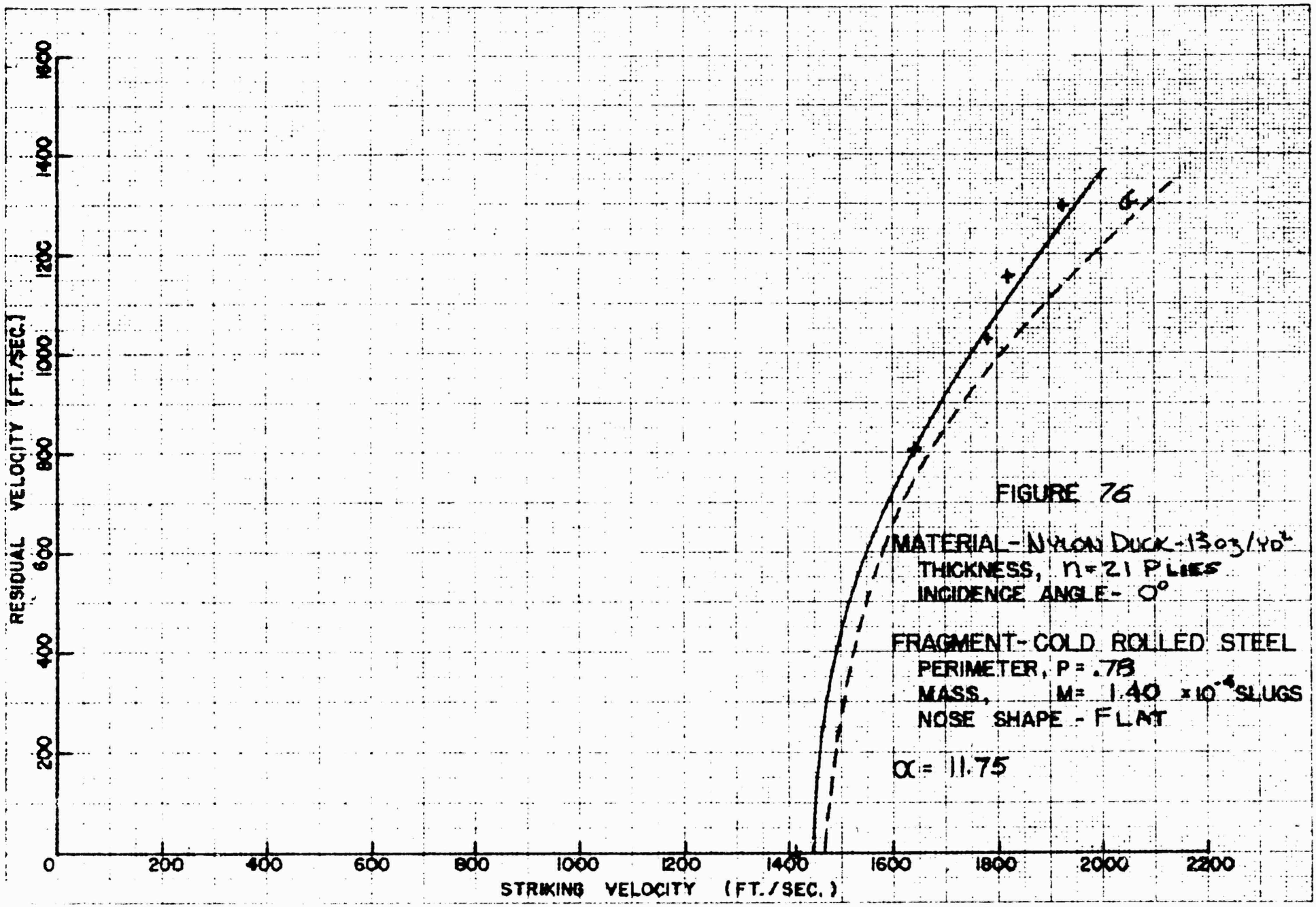


FIGURE 72
MATERIAL - NYLON DUCK - 13 oz/Yd²
THICKNESS, n = 21 PLIES
INCIDENCE ANGLE - 45°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78
MASS, M = 4.24 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = ~
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 73
MATERIAL - NYLON DUCK B03/Y6
THICKNESS, n = 21 PLIES
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78
MASS, M = 4.27 x 10⁻⁴ SLUGS
NOSE SHAPE - 90° CONE
X =


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 74
MATERIAL - NYLON DUCK - 13 oz/Yd²
THICKNESS, n = 21 PLIES
INCIDENCE ANGLE - 45°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78
MASS, M = 4.27 x 10⁻⁴ SLUGS
NOSE SHAPE - 90° CONE
α = ~


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
1800
2000
2200
FIGURE 75
MATERIAL - NYLON DOCK-1303/40°
THICKNESS, T = 21 PLIES
INCIDENCE ANGLE = 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78
MASS, M = 2.11 ×10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 7.75


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 76
MATERIAL - NYLON DUCK - 13.03/YD²
THICKNESS, n = 21 PLIES
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78
MASS, M = 1.40 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 11.75

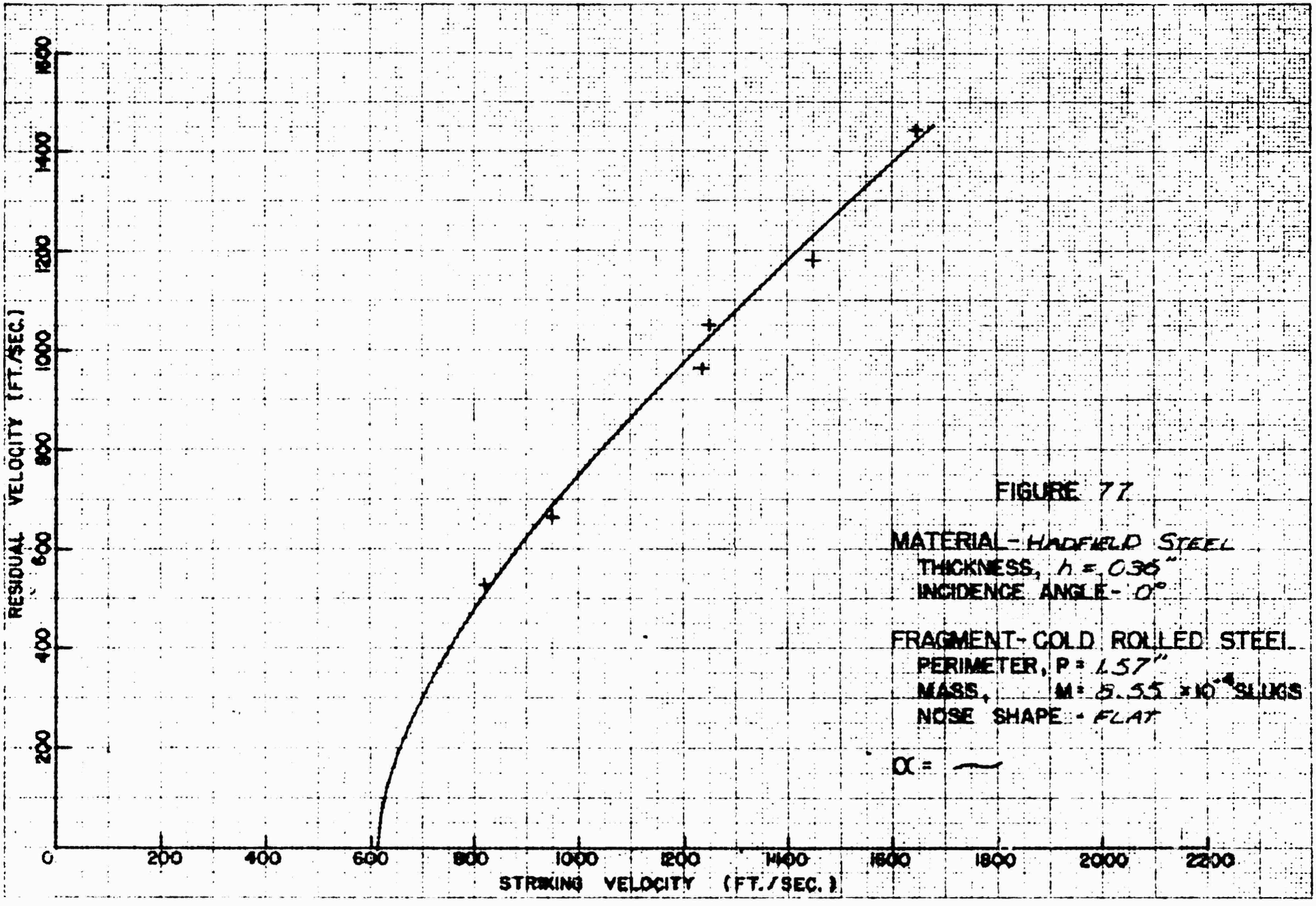
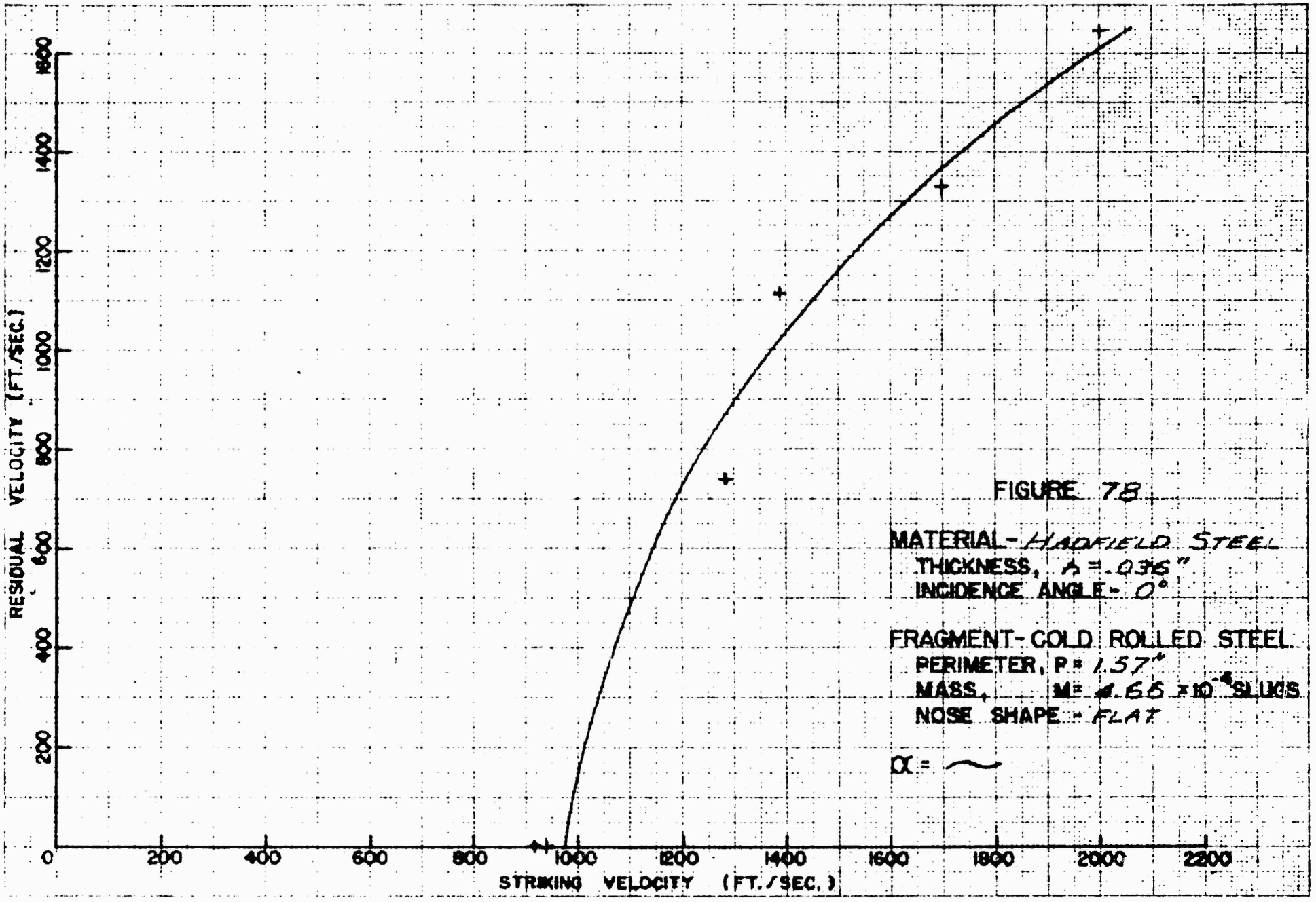


FIGURE 77

MATERIAL - HADFIELD STEEL
THICKNESS, $h = .036"$
INCIDENCE ANGLE - 0°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, $P = .157"$
MASS, $M = 5.55 \times 10^{-4}$ SLUGS
NOSE SHAPE - FLAT

$\alpha =$ —


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
1000
1200
1400
1600
1800
2000
2200
FIGURE 78
MATERIAL - HADFIELD STEEL
THICKNESS, h = .036"
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 4.66 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = ~

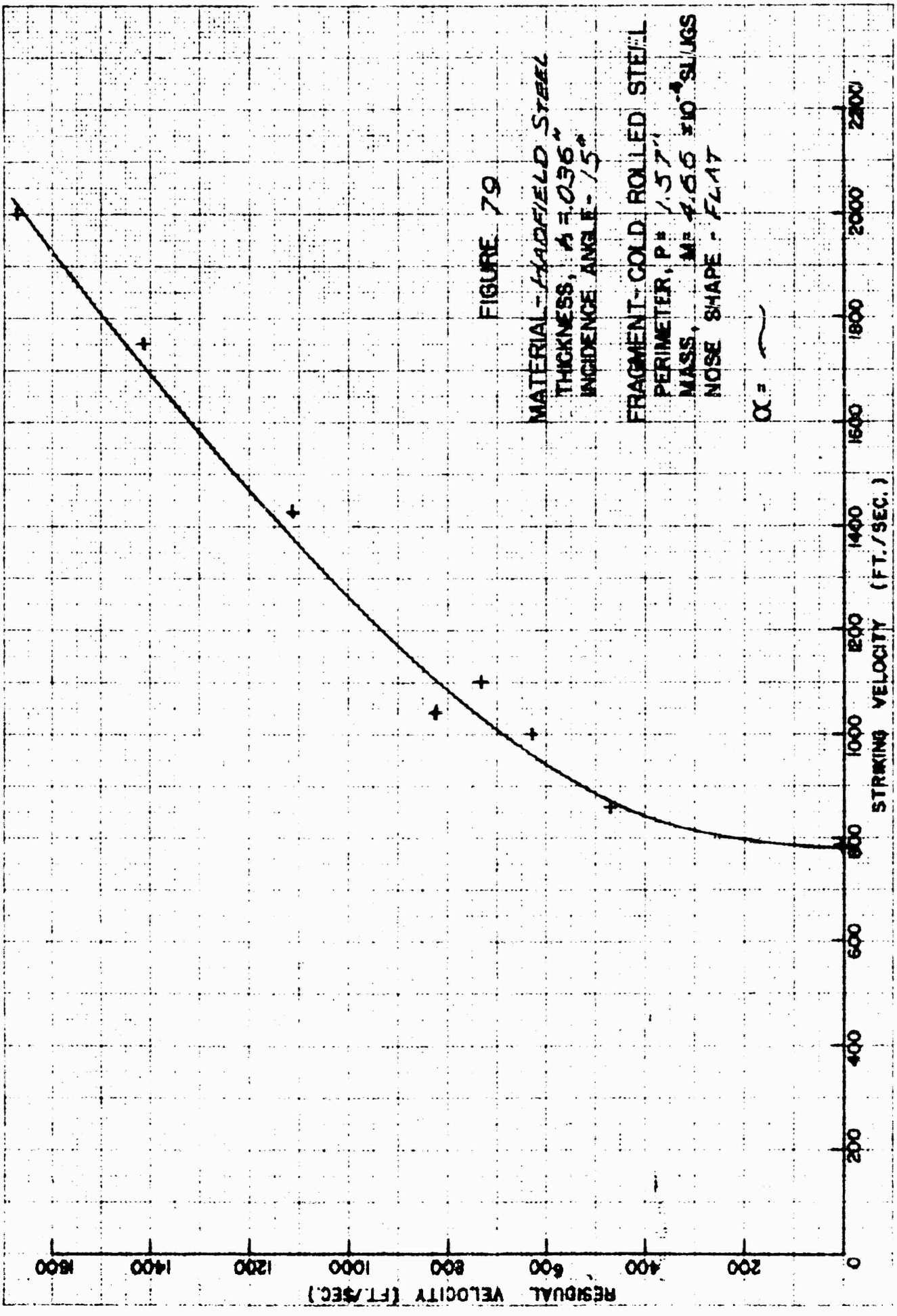


FIGURE 79
MATERIAL - SHIELD STEEL
THICKNESS, h = 0.036"
INCIDENCE ANGLE - 15°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 4.66 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = ~
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

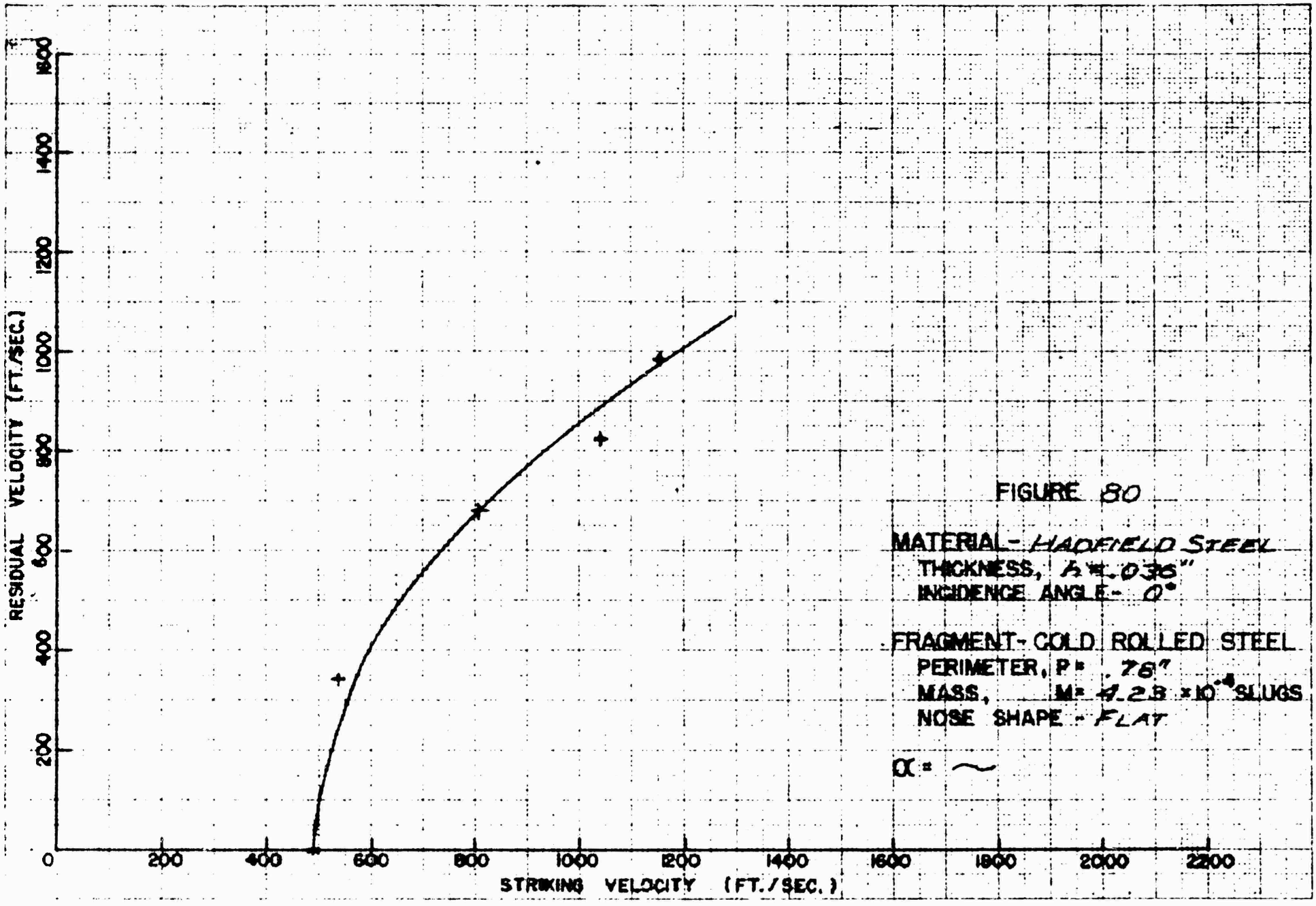


FIGURE 80

MATERIAL - HADFIELD STEEL
THICKNESS, h = .036"
INCIDENCE ANGLE - 0°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .76"
MASS, M = 4.28 × 10^{-4} SLUGS
NOSE SHAPE - FLAT

α = ~

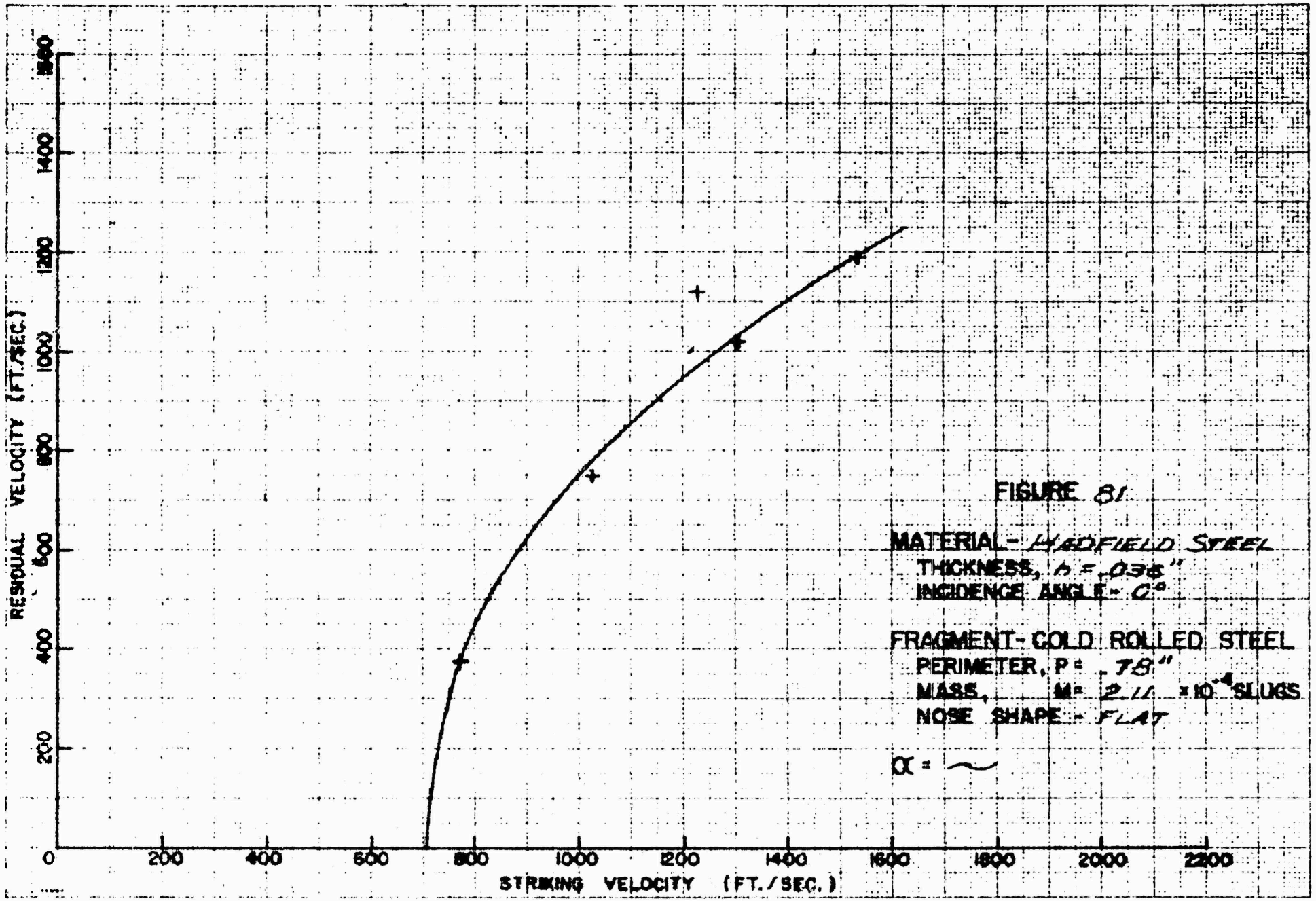
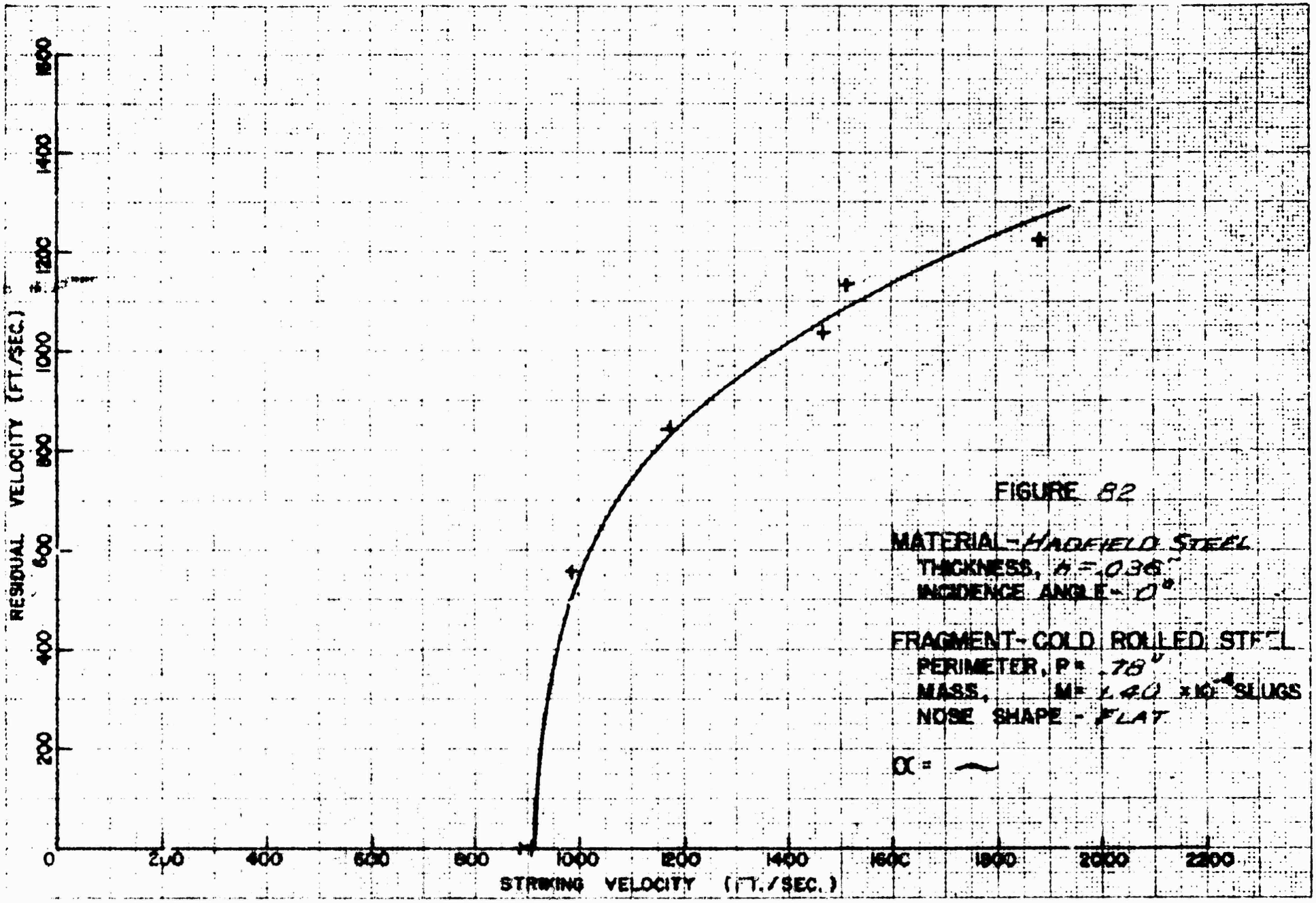


FIGURE 81

MATERIAL - HADFIELD STEEL
THICKNESS, h = .036"
INCIDENCE ANGLE = 0°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 2.11 x 10^{-4} SLUGS
NOSE SHAPE - FLAT

α = ~


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 82
MATERIAL - HADFIELD STEEL
THICKNESS, h = .036"
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 1.40 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = ~

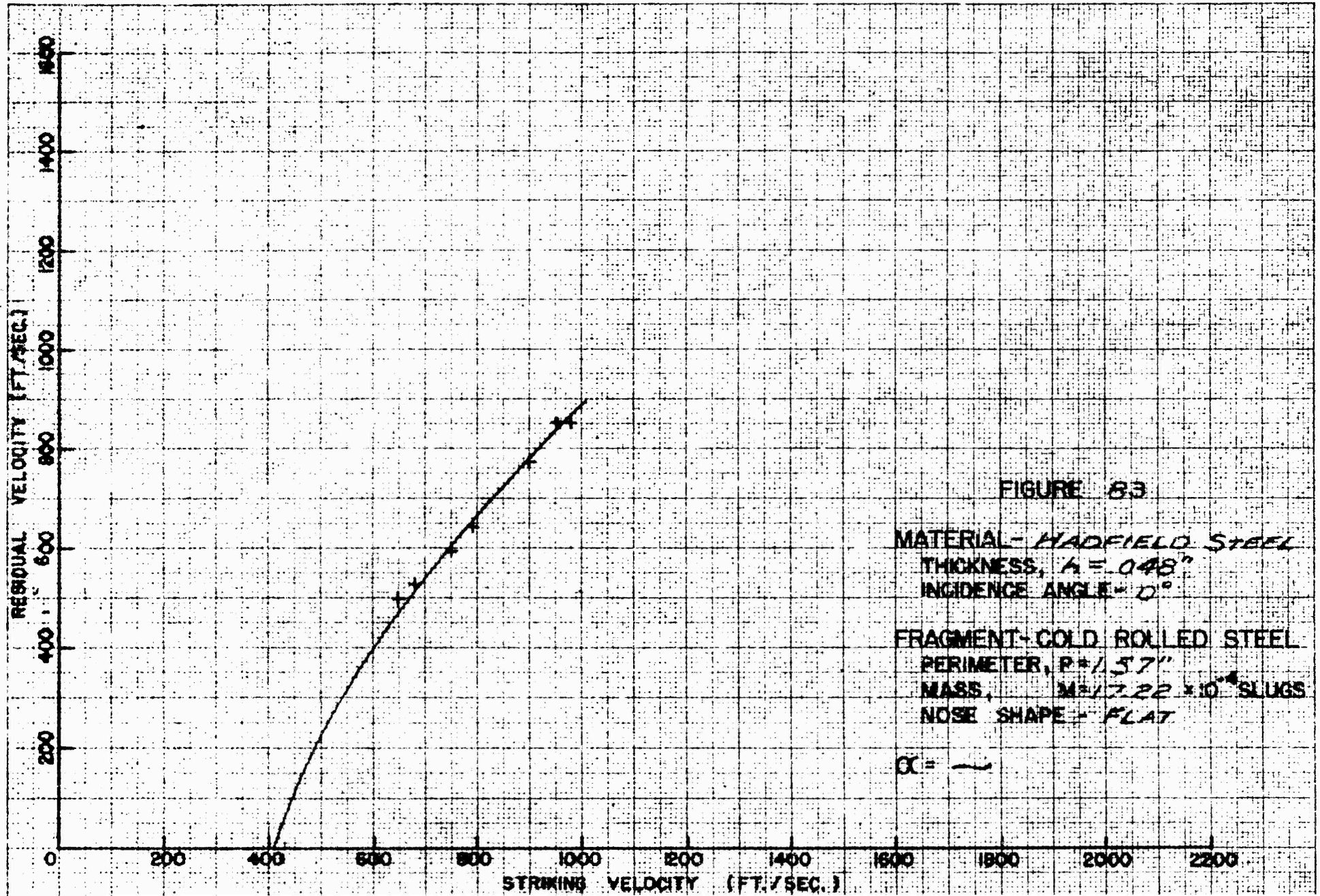
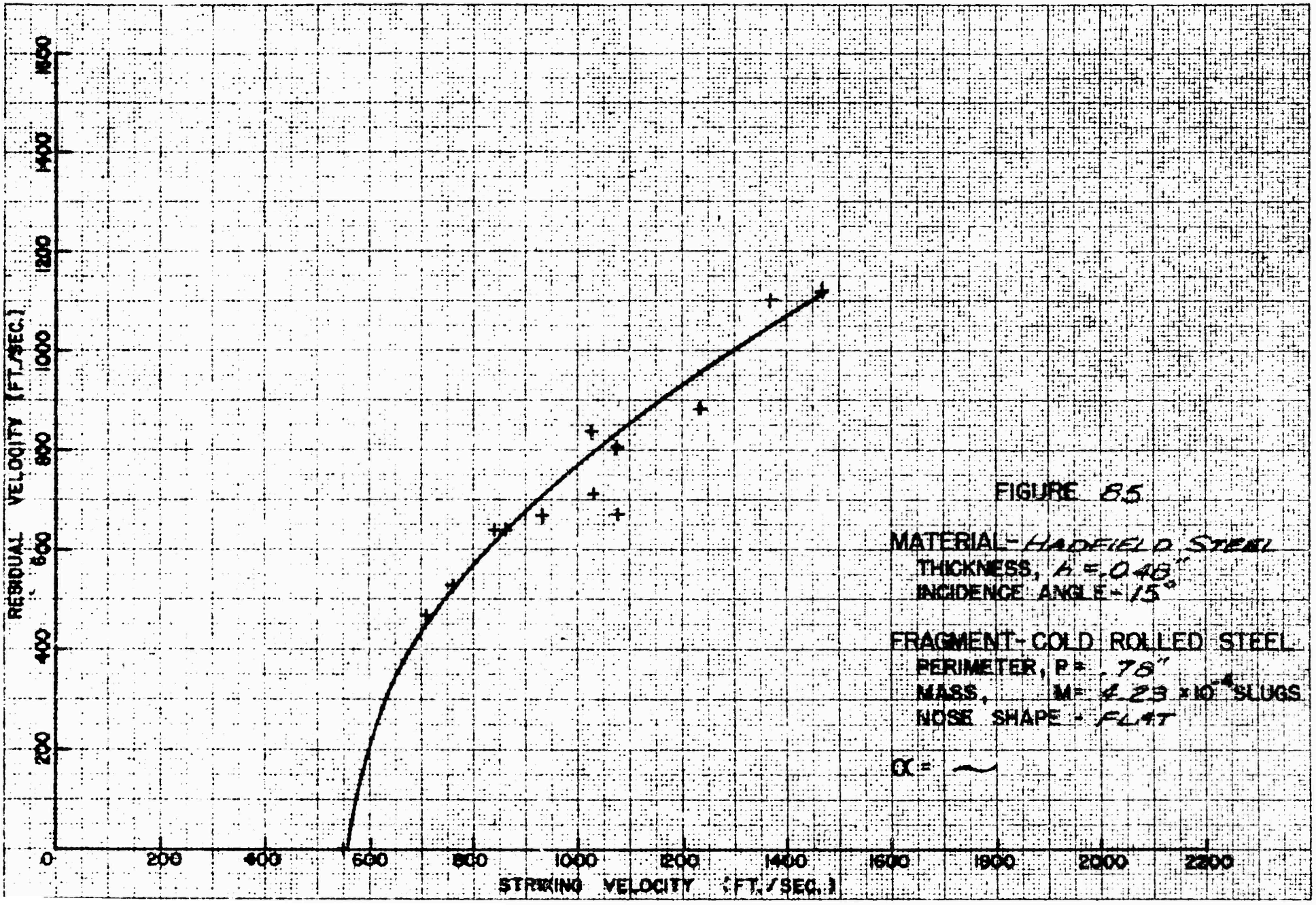

RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 83
MATERIAL- HADFIELD STEEL
THICKNESS, h = .048"
INCIDENCE ANGLE = 0°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 1.22 × 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = —

FIGURE 84
MATERIAL - HADFIELD STEEL
THICKNESS, h = .048"
INCIDENCE ANGLE = 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .75"
MASS, M = 4.23 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
OC = —
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
1800
2000
2200
FIGURE 85
MATERIAL - HADFIELD STEEL
THICKNESS, h = .048"
INCIDENCE ANGLE = 15°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = ~

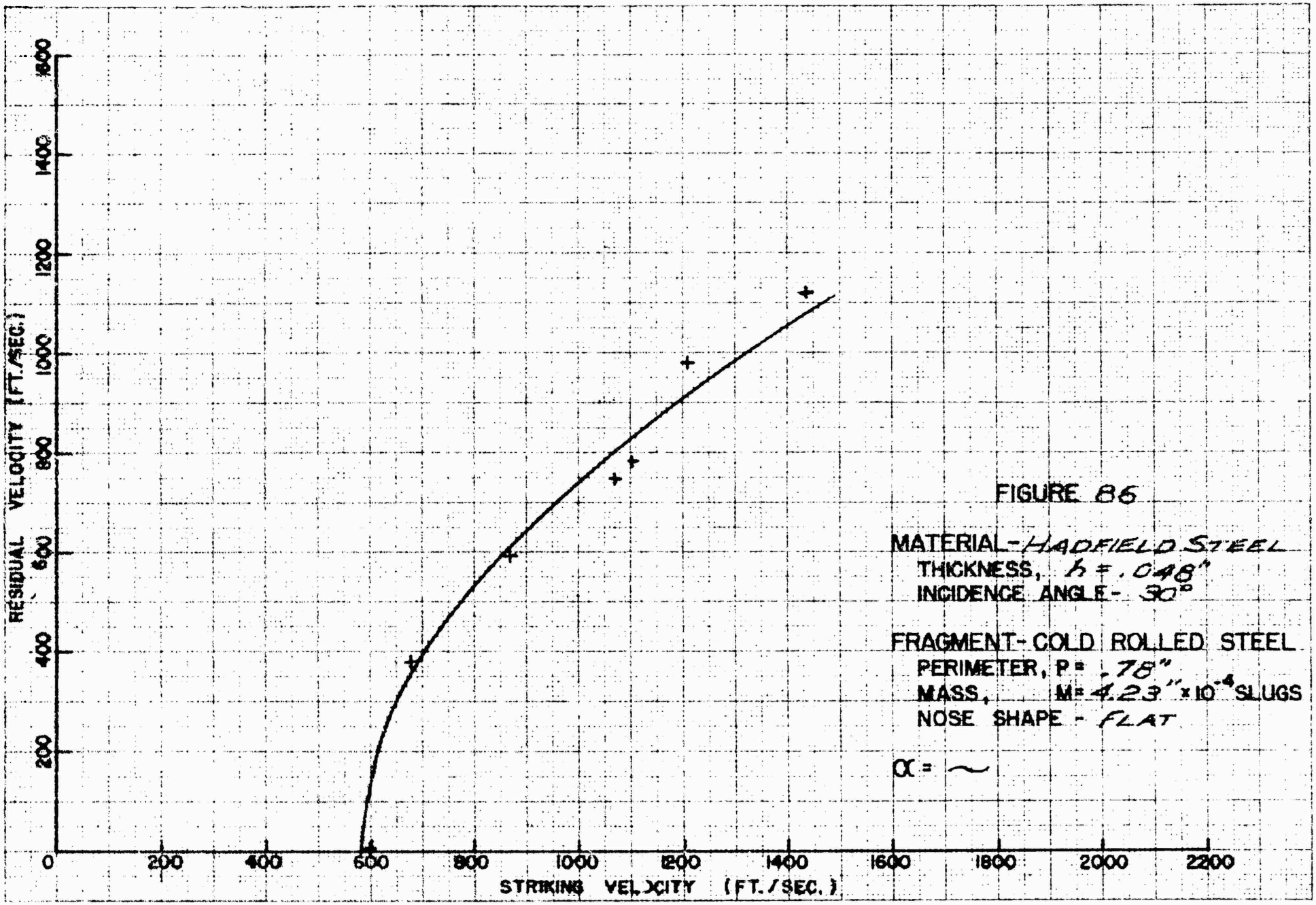


FIGURE 86

MATERIAL - HADFIELD STEEL
THICKNESS, $h = .048"$
INCIDENCE ANGLE - 30°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, $P = .78"$
MASS, $M = 4.23" \times 10^{-4}$ SLUGS
NOSE SHAPE - FLAT

$\alpha = \sim$

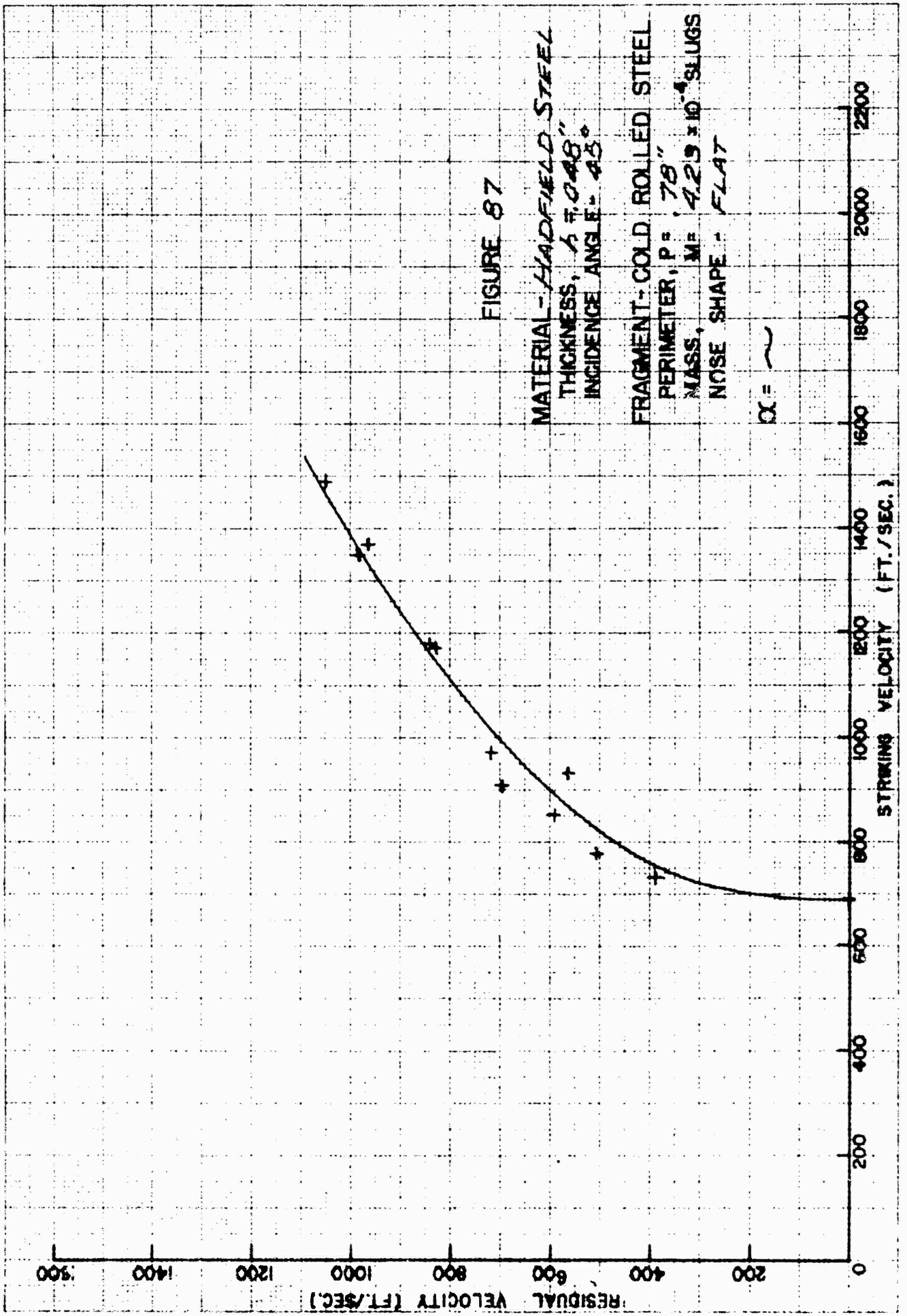


FIGURE 87
MATERIAL - HADFIELD STEEL
THICKNESS, h = .048"
INCIDENCE ANGLE = 45°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.29 x 10⁻⁴ SLUGS
NOSE SHAPE = FLAT
α = ~
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

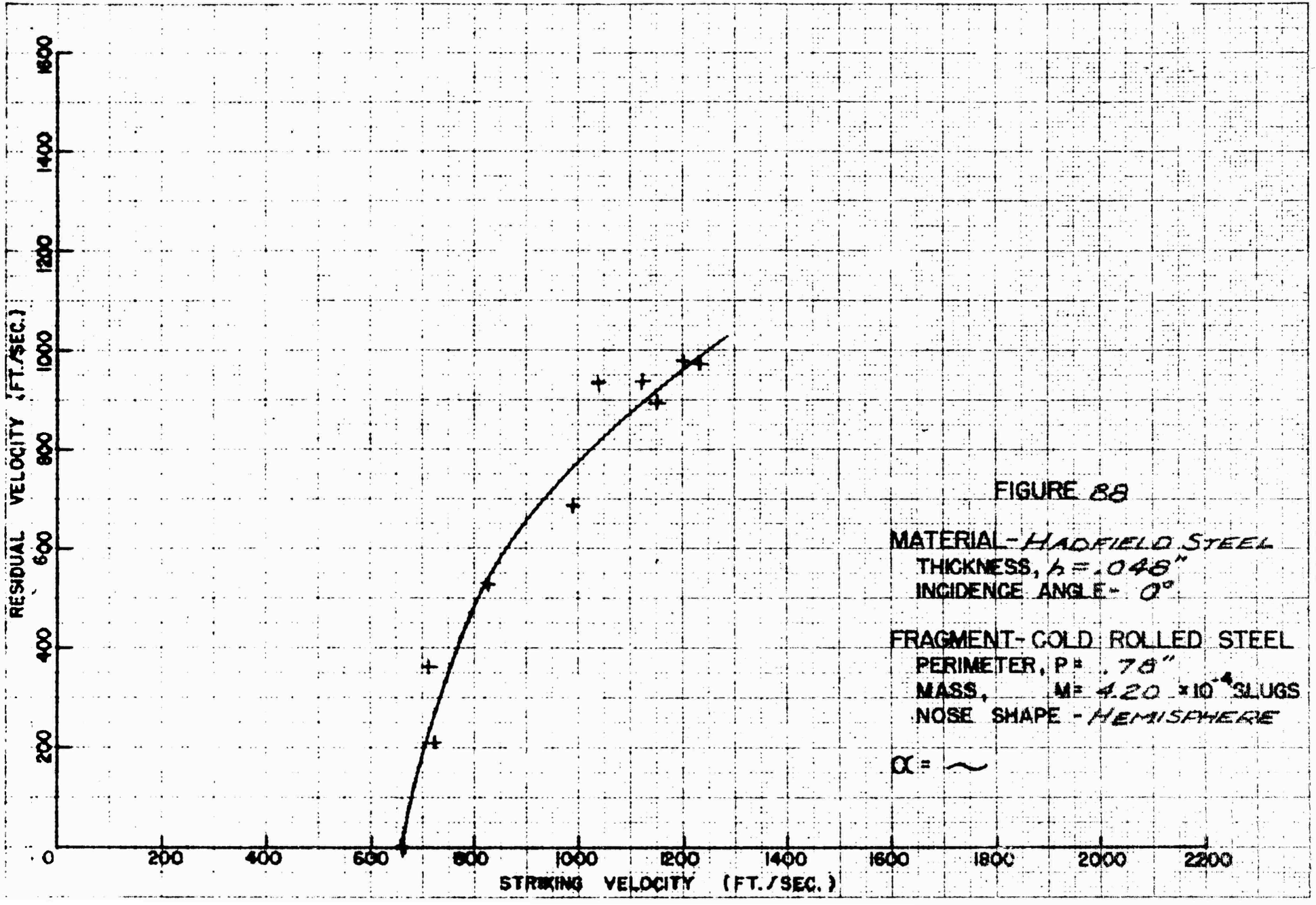


FIGURE 88

MATERIAL - HADFIELD STEEL
THICKNESS, $h = .048''$
INCIDENCE ANGLE - 0°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, $P = .78''$
MASS, $M = 4.20 \times 10^{-4}$ SLUGS
NOSE SHAPE - HEMISPHERE

$\alpha = \sim$

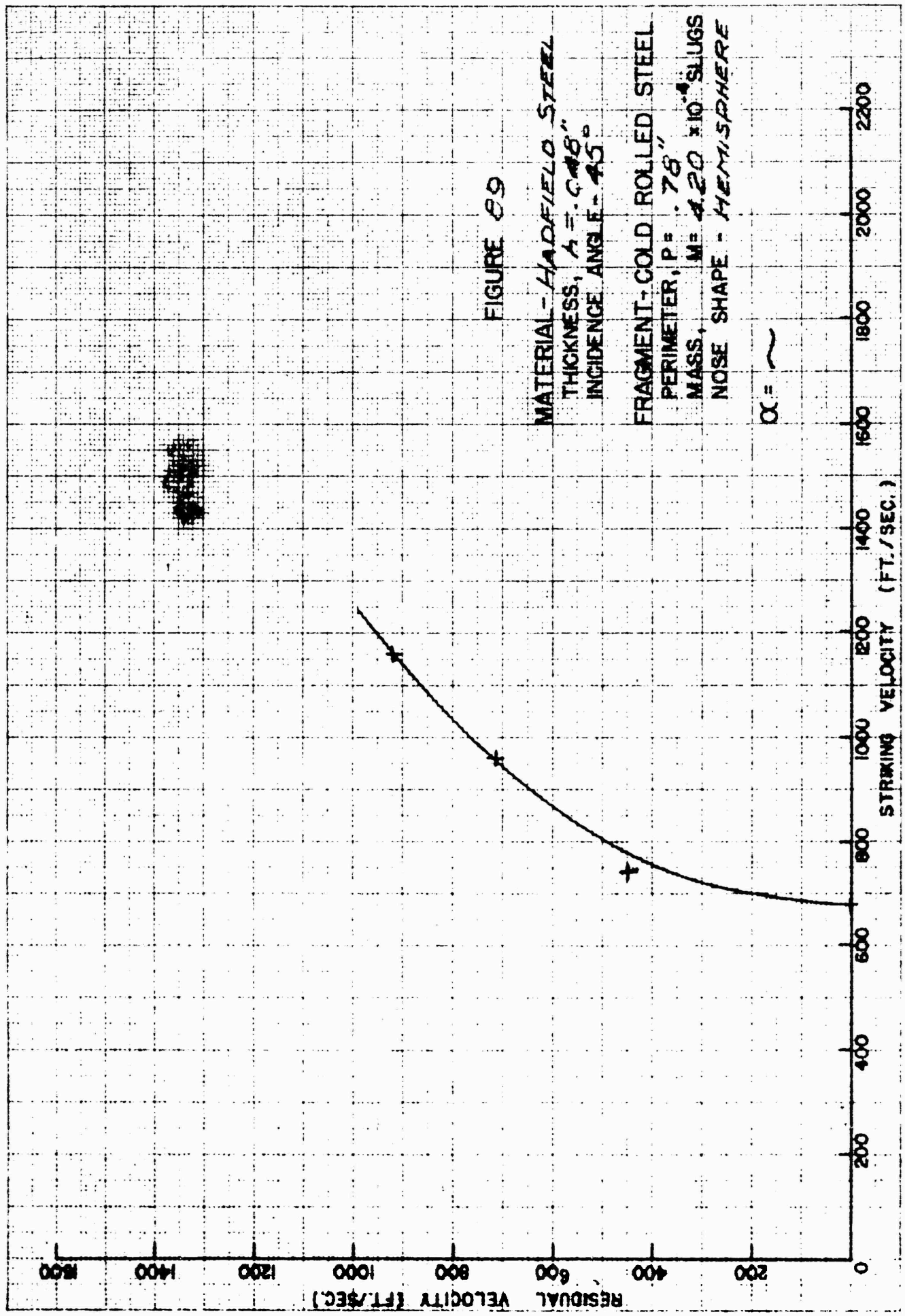


FIGURE 89
MATERIAL - HADFIELD STEEL
THICKNESS, h = .048"
INCIDENCE ANGLE - 45°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.20 x 10⁻⁴ SLUGS
NOSE SHAPE - HEMISPHERE
α = ~
STRIKING VELOCITY (FT./SEC.)
RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

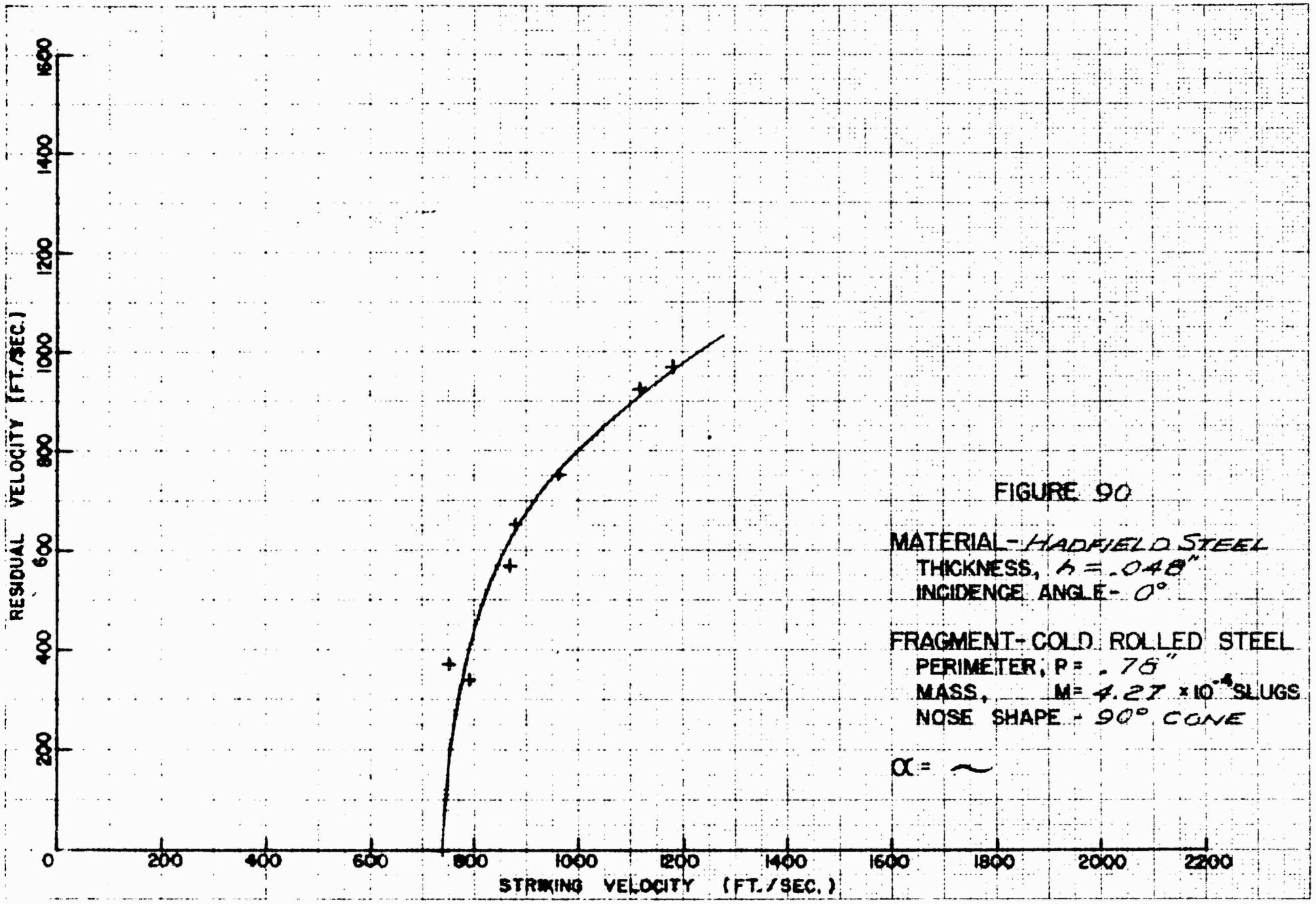


FIGURE 90

MATERIAL - HADFIELD STEEL
THICKNESS, $h = .048"$
INCIDENCE ANGLE - 0°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, $P = .76"$
MASS, $M = 4.27 \times 10^{-4}$ SLUGS
NOSE SHAPE - 90° CONE

$\alpha = \sim$

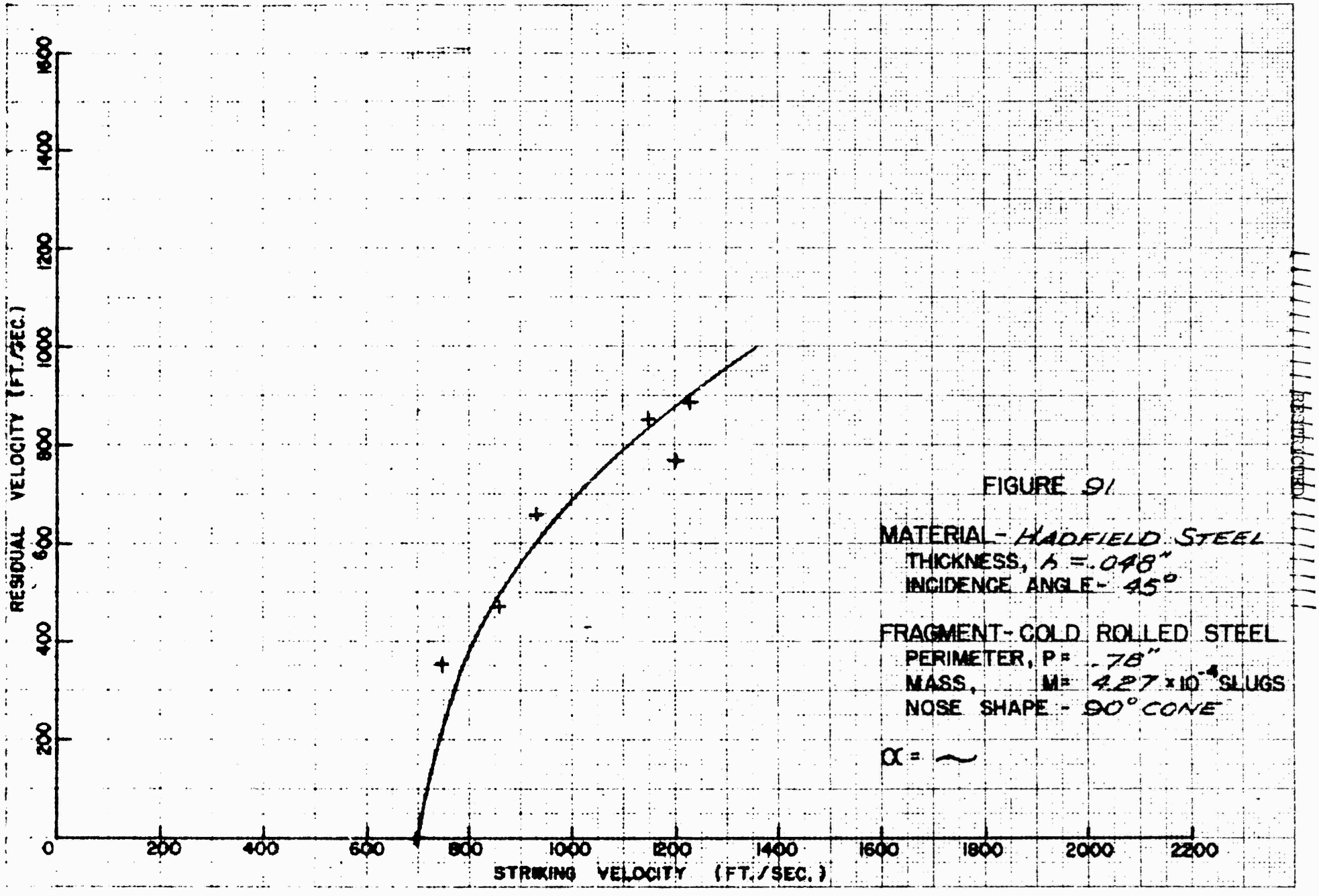


FIGURE 91

MATERIAL - HADFIELD STEEL
THICKNESS, h = .048"
INCIDENCE ANGLE - 45°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.27×10^{-4} SLUGS
NOSE SHAPE - 90° CONE

α = ~

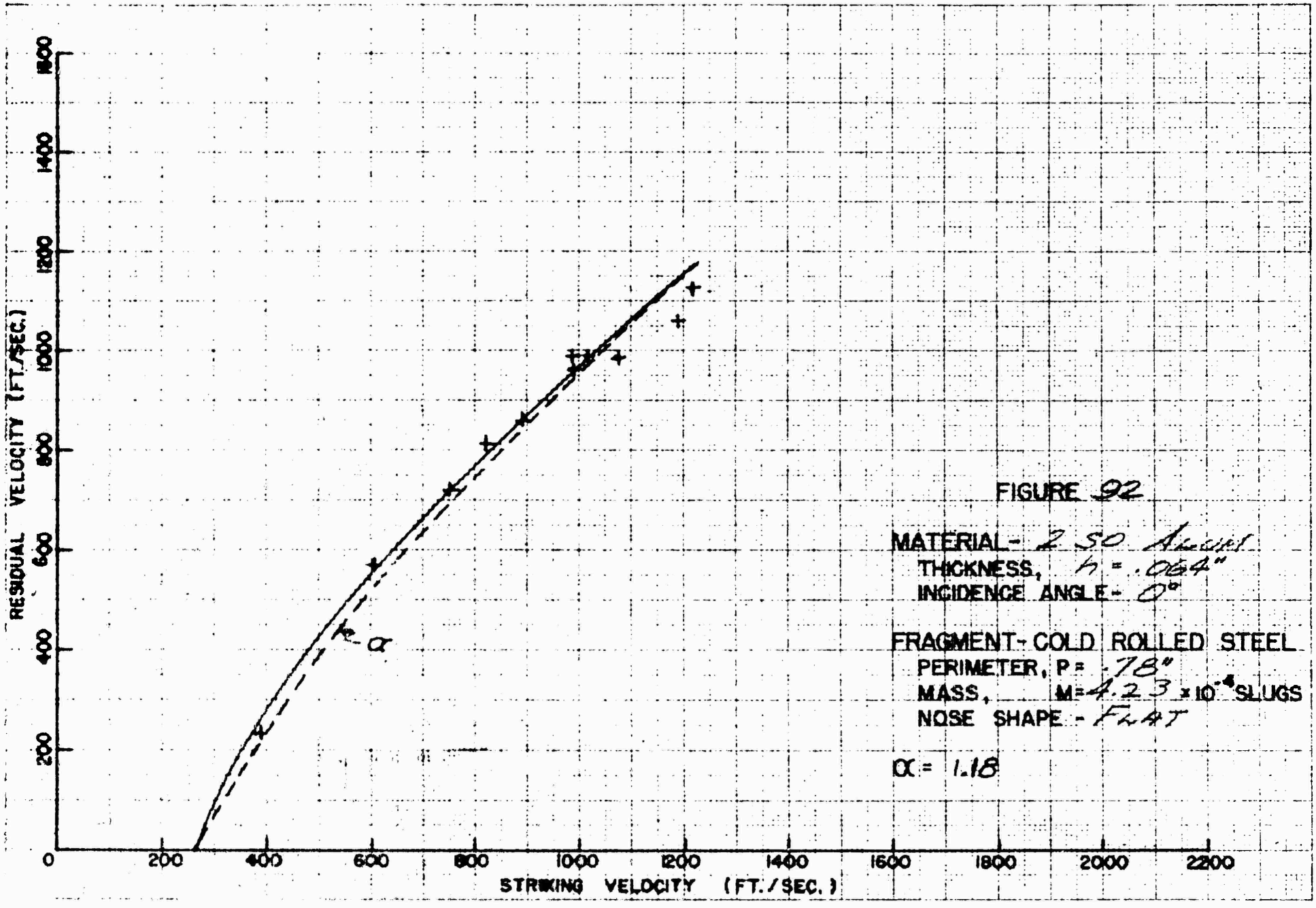


FIGURE 92

MATERIAL - 2 S0 Aluminum
THICKNESS, h = .064"
INCIDENCE ANGLE - 0°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 x 10^{-4} SLUGS
NOSE SHAPE - Flat

α = 1.18

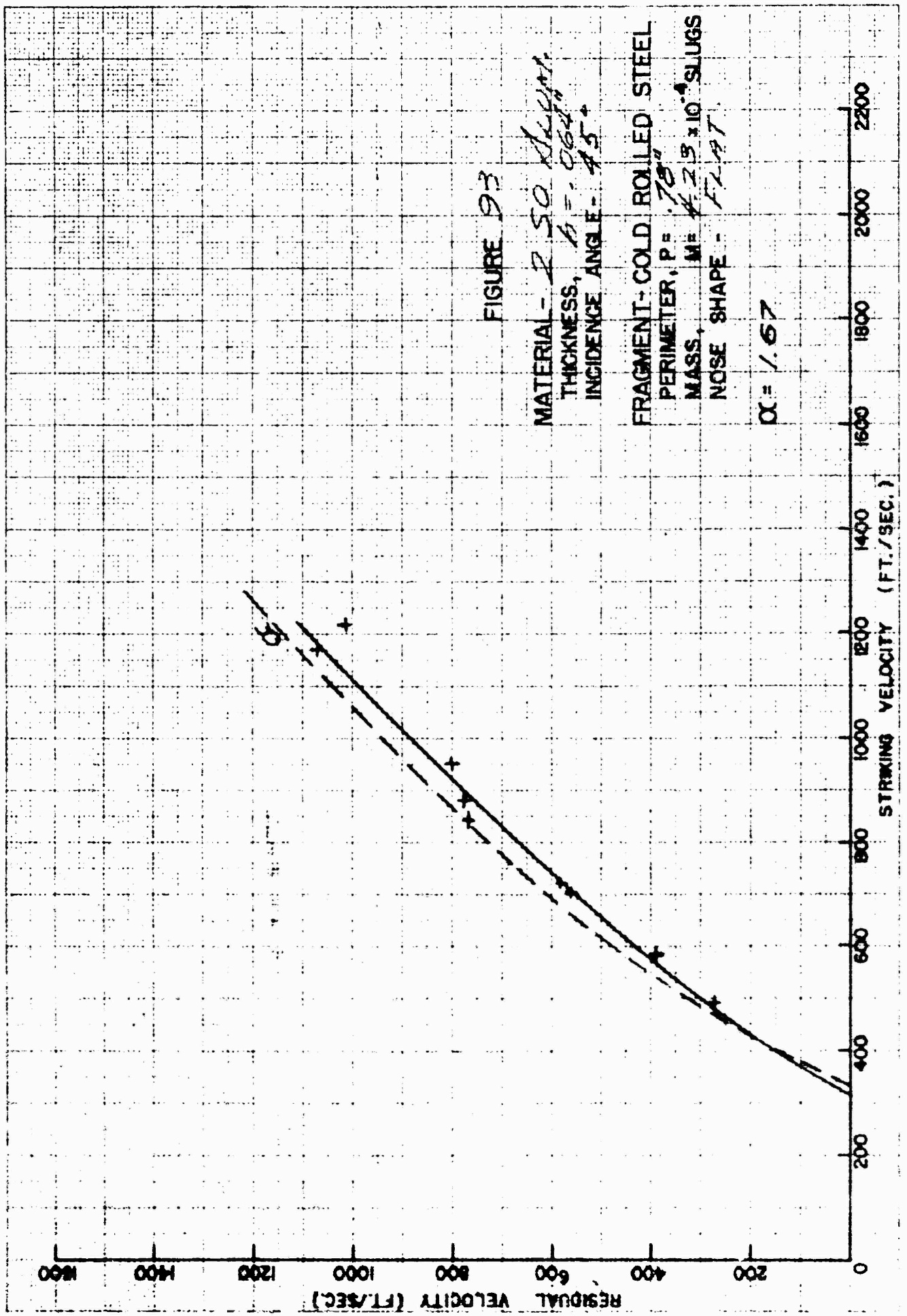
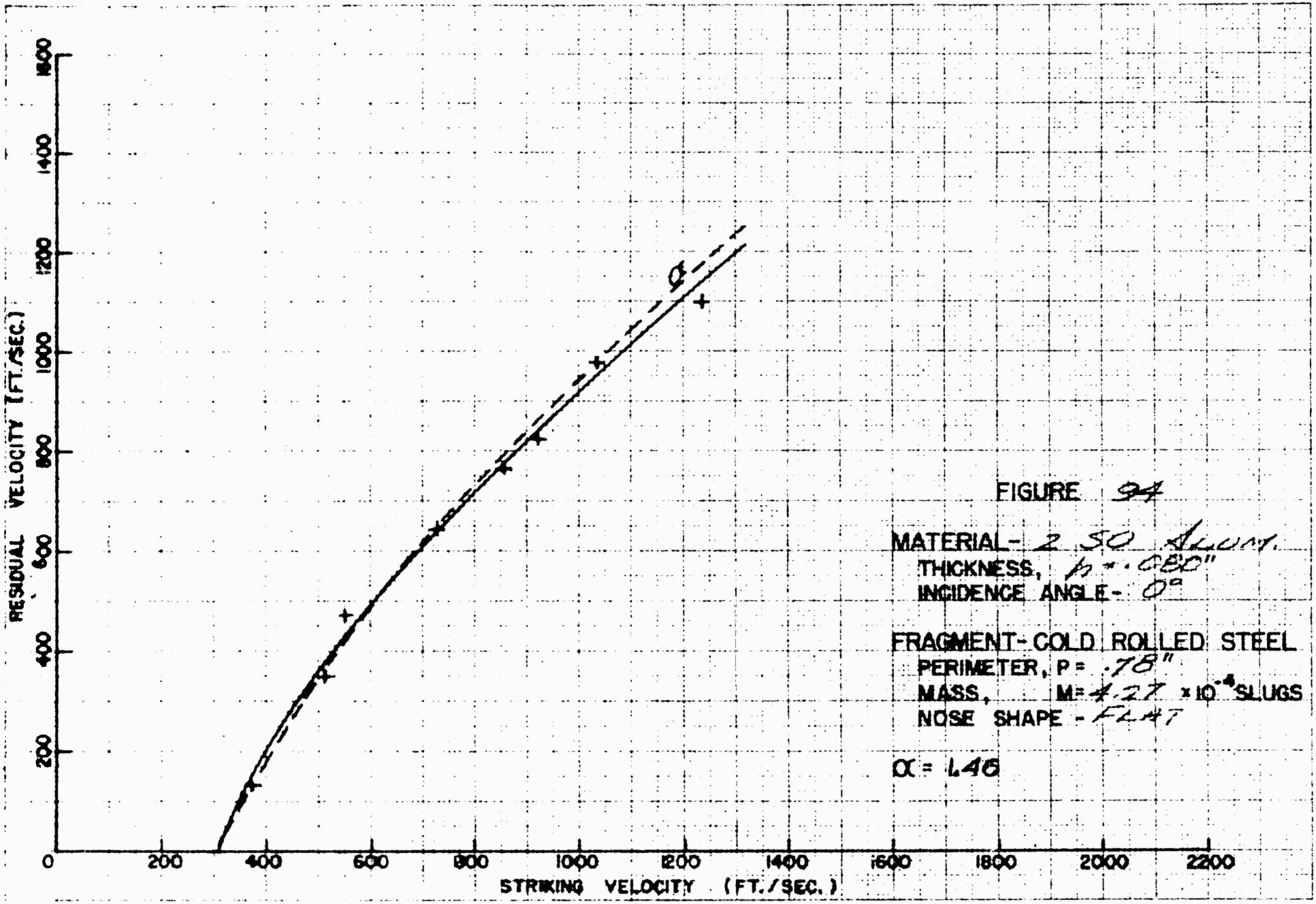


FIGURE 93
MATERIAL - 2 S0 Aluminum
THICKNESS, h = .064"
INCIDENCE ANGLE - 45°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 x 10⁻⁴ SLUGS
NOSE SHAPE - Flat
α = 1.67
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 94
MATERIAL- 2 S0 Alum.
THICKNESS, h= .080"
INCIDENCE ANGLE- 0°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P= .78"
MASS, M= 4.27 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 1.46

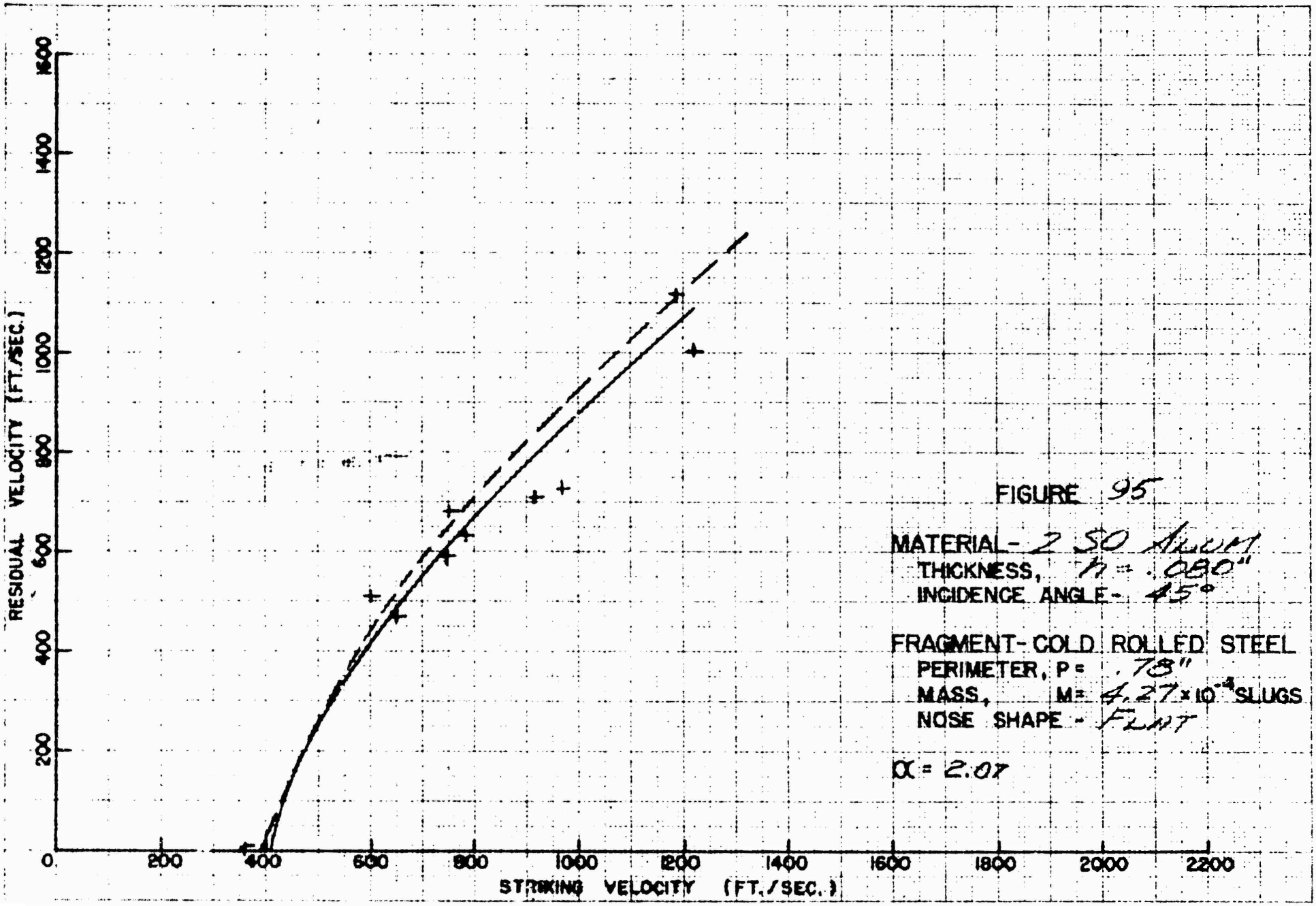


FIGURE 95

MATERIAL - 2 S0 ALCLAD
THICKNESS, h = .090"
INCIDENCE ANGLE - 45°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.27 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT

α = 2.07

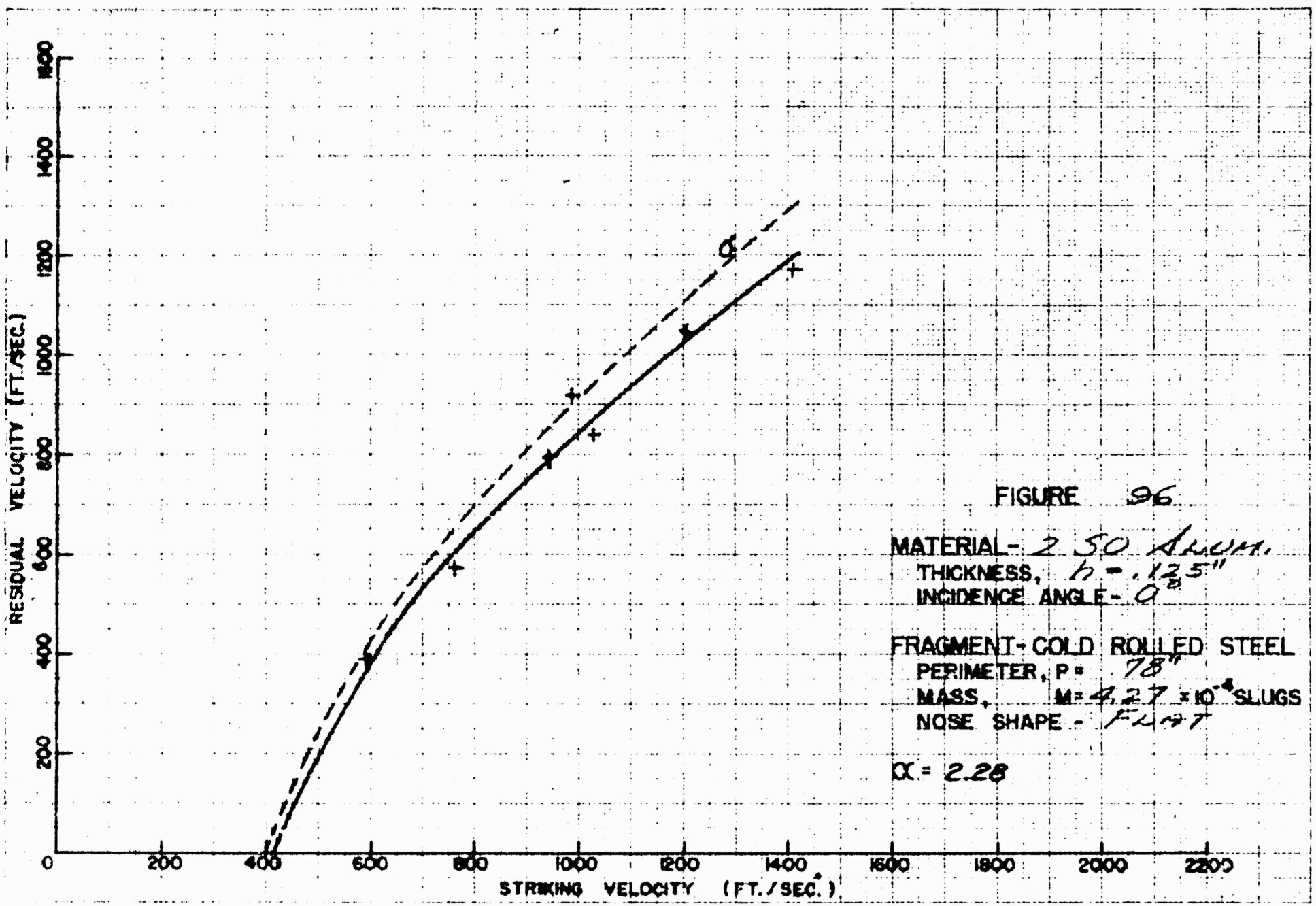


FIGURE 96

MATERIAL - 2 S O Alum.
THICKNESS, h = .125"
INCIDENCE ANGLE - 0

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.27 x 10^{-4} SLUGS
NOSE SHAPE - Flat

α = 2.28

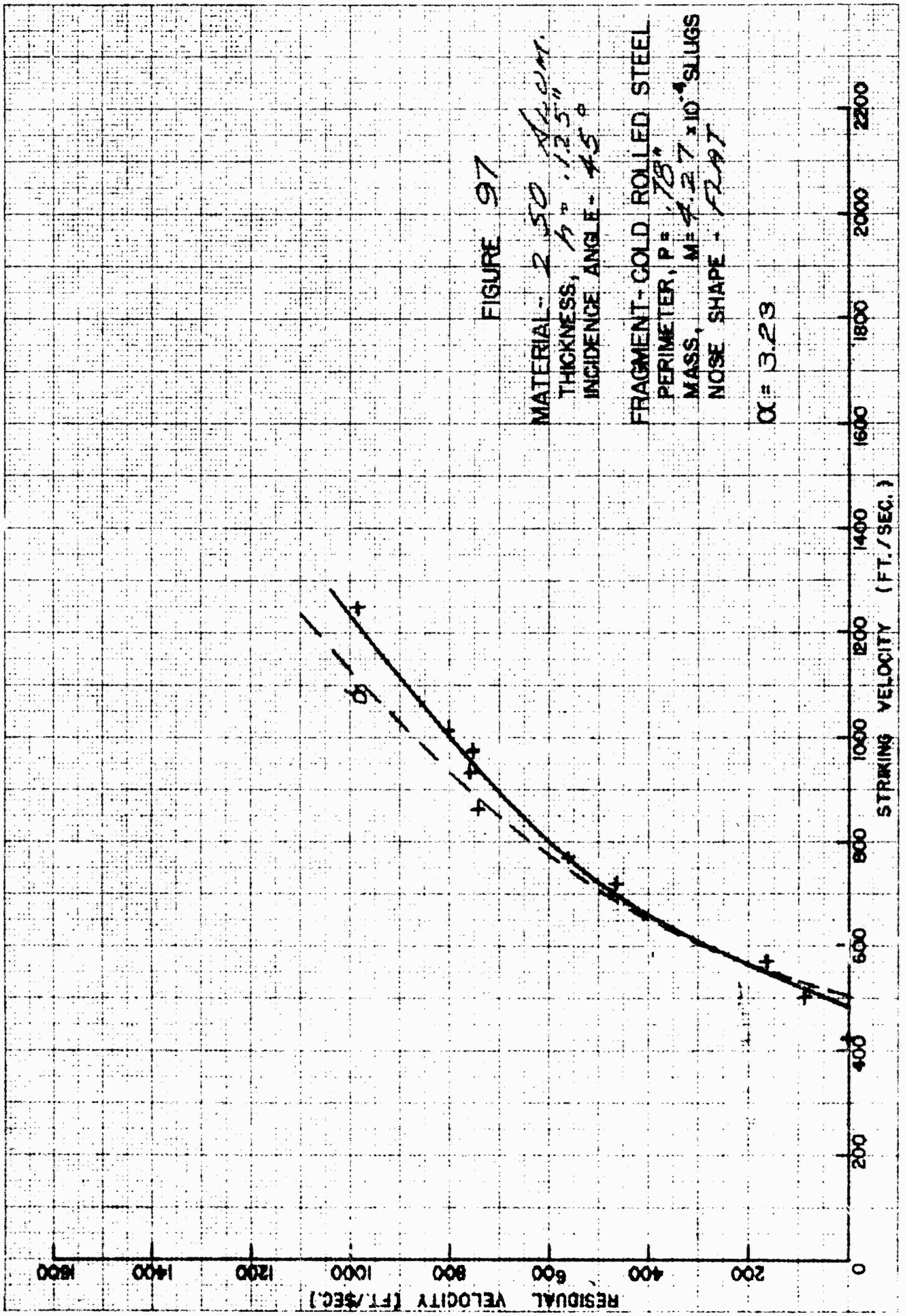


FIGURE 97
MATERIAL- 2.50 Rc cast
THICKNESS, h = .125"
INCIDENCE ANGLE = 45°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.27 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 3.23
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

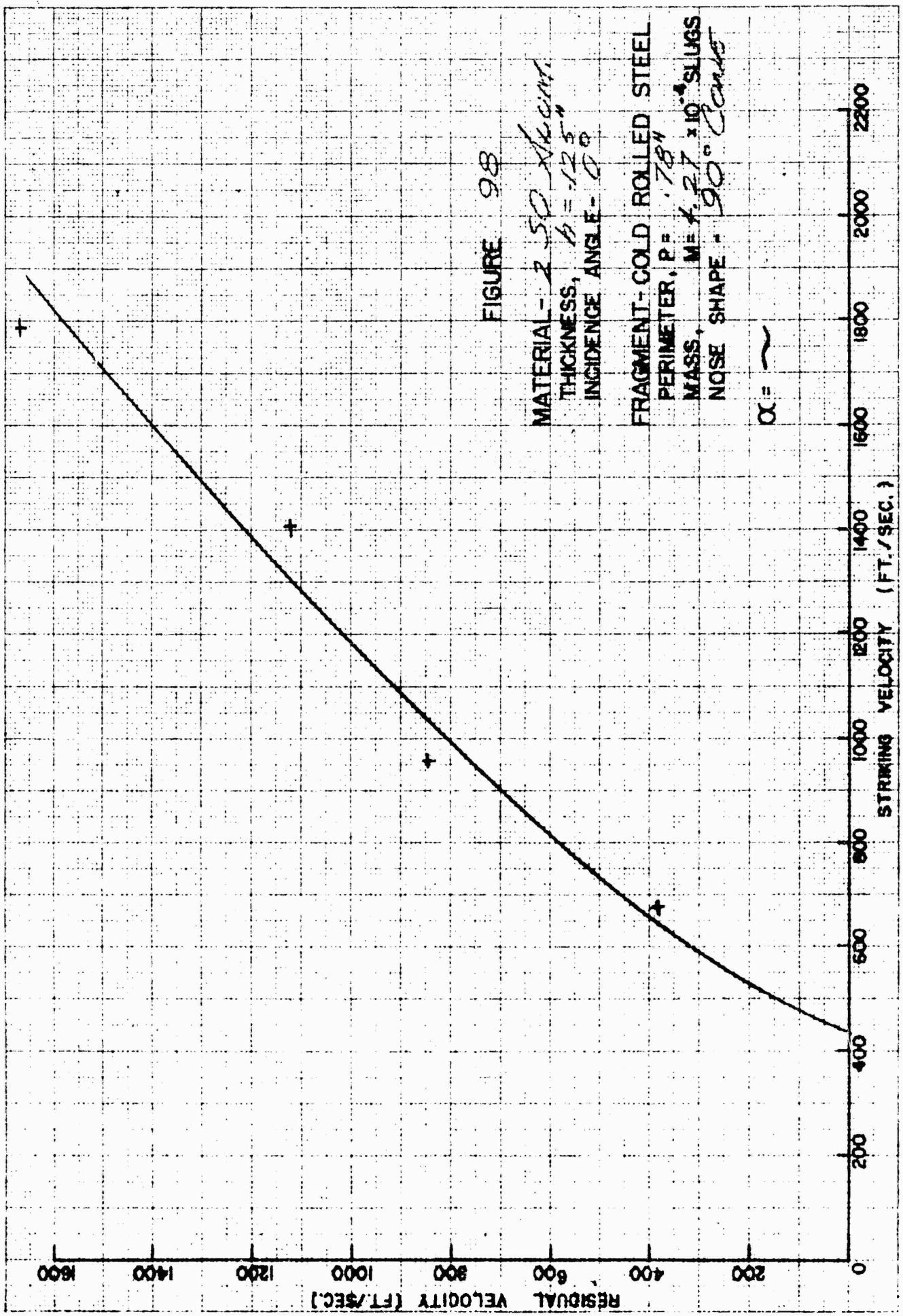


FIGURE 98
MATERIAL - 2 S0 Aluminum
THICKNESS, t = .125"
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.27 x 10⁻⁴ SLUGS
NOSE SHAPE - 90° Cone
α = ~
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

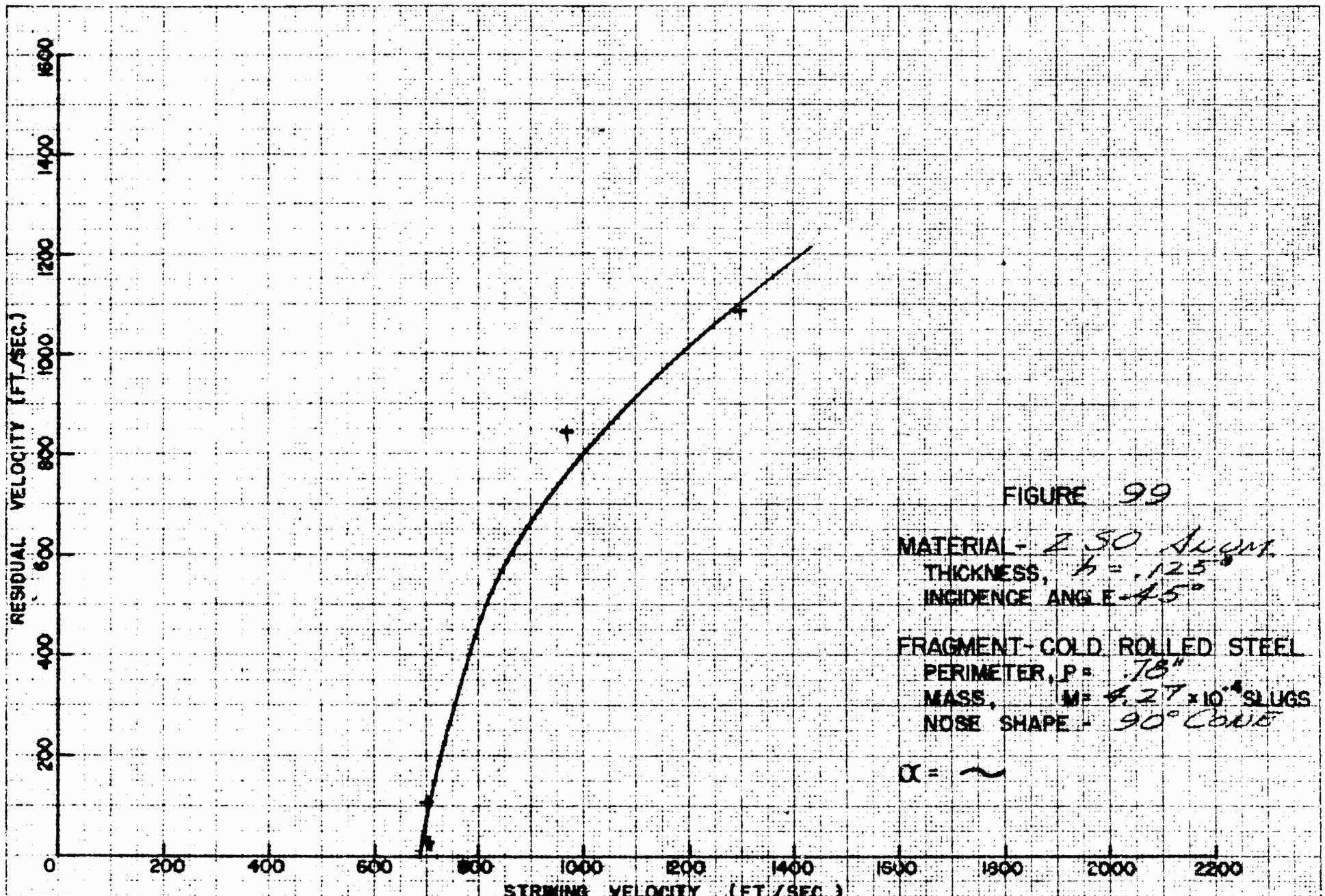


FIGURE 99

MATERIAL - 2 S O Aluminum
THICKNESS, h = .125"
INCIDENCE ANGLE - 45°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.27 x 10^{-4} SLUGS
NOSE SHAPE - 90° Cone

α = ~

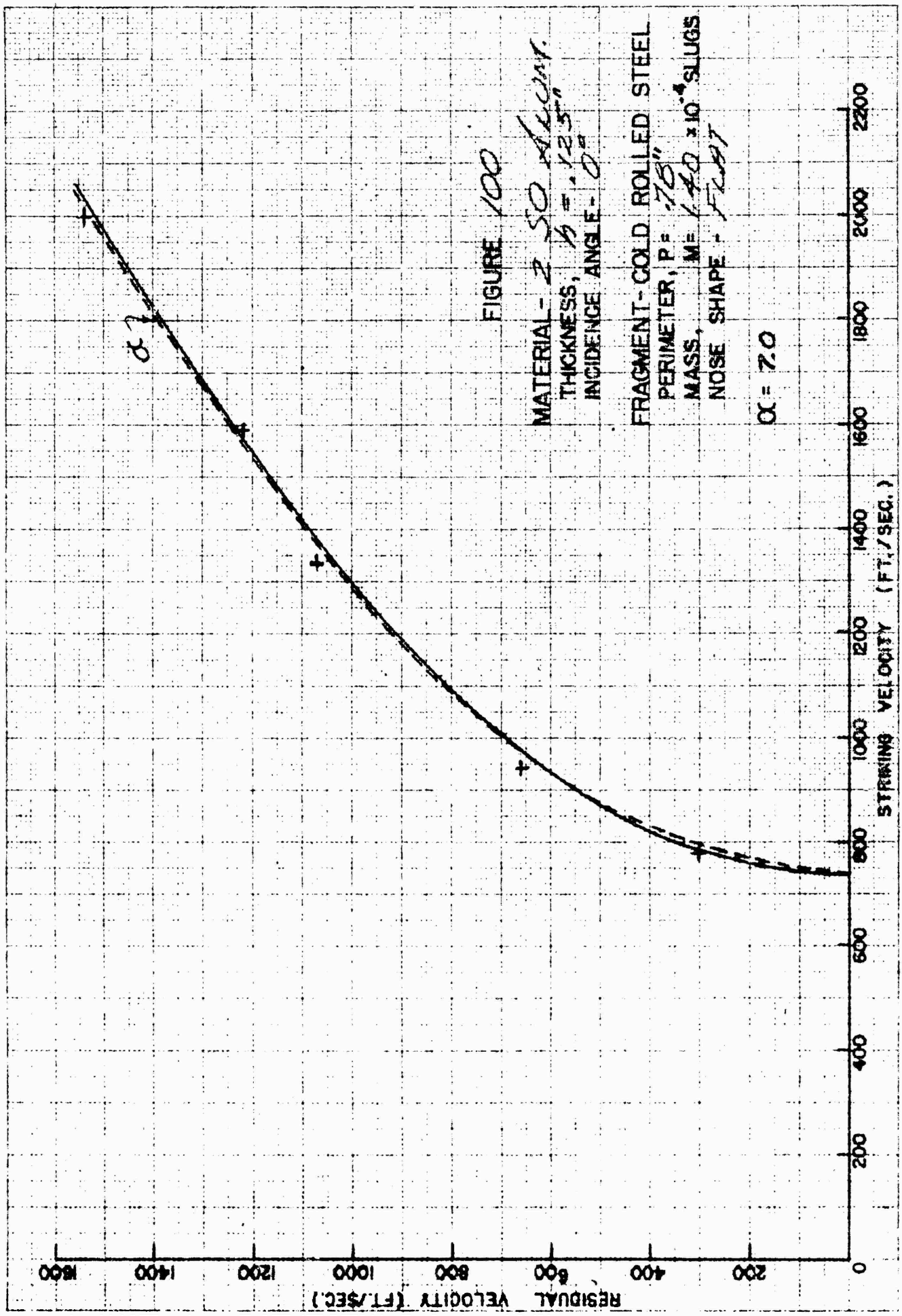


FIGURE 100
MATERIAL - 2 SO ALCLAD
THICKNESS, h = .125"
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .76"
MASS, M = 1.40 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 7.0
α = 7
STRIKING VELOCITY (FT./SEC.)
RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

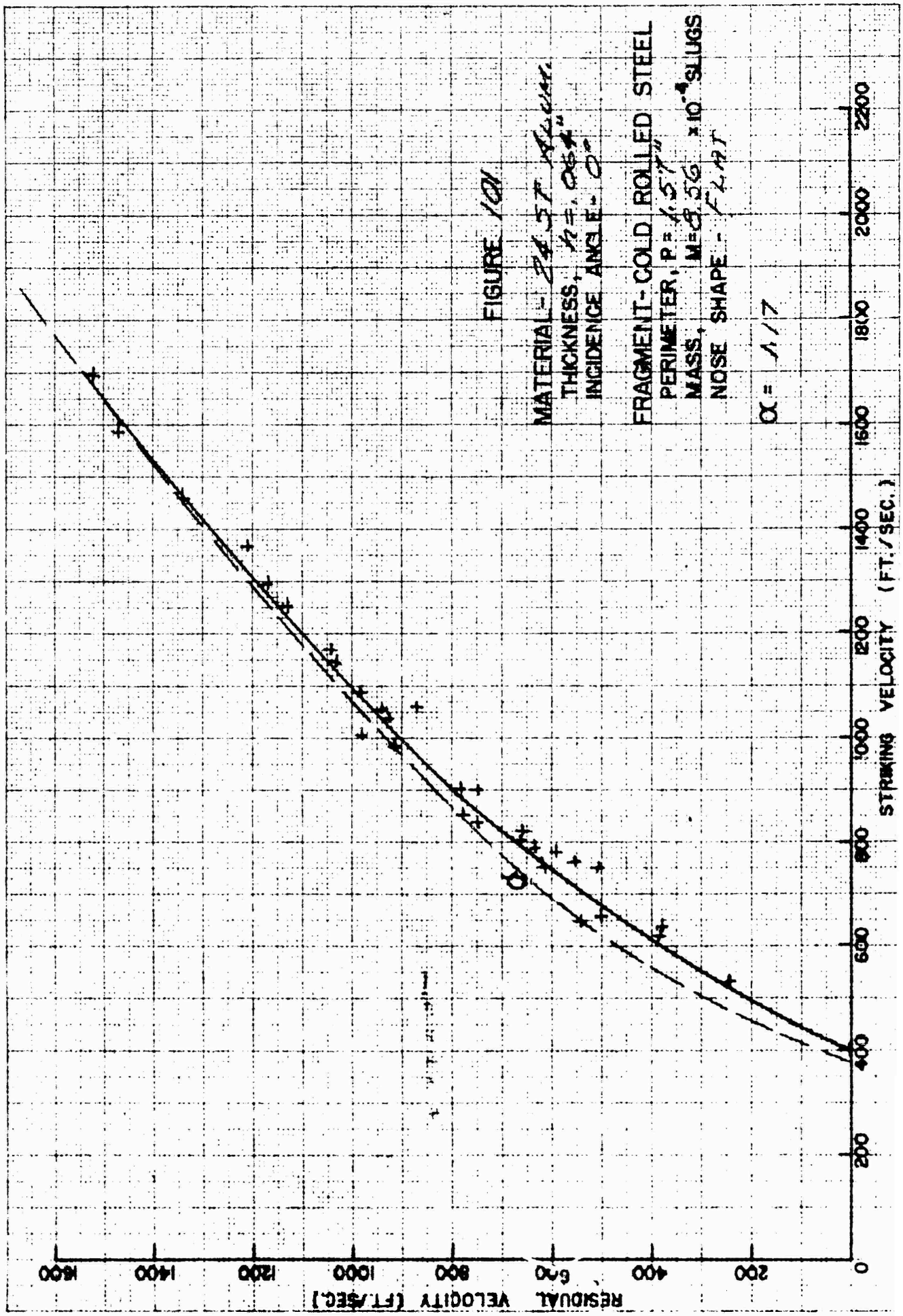


FIGURE 101
MATERIAL - 24 ST Aluminum
THICKNESS, t = .064"
INCIDENCE ANGLE = 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 4.56 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 1.17
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

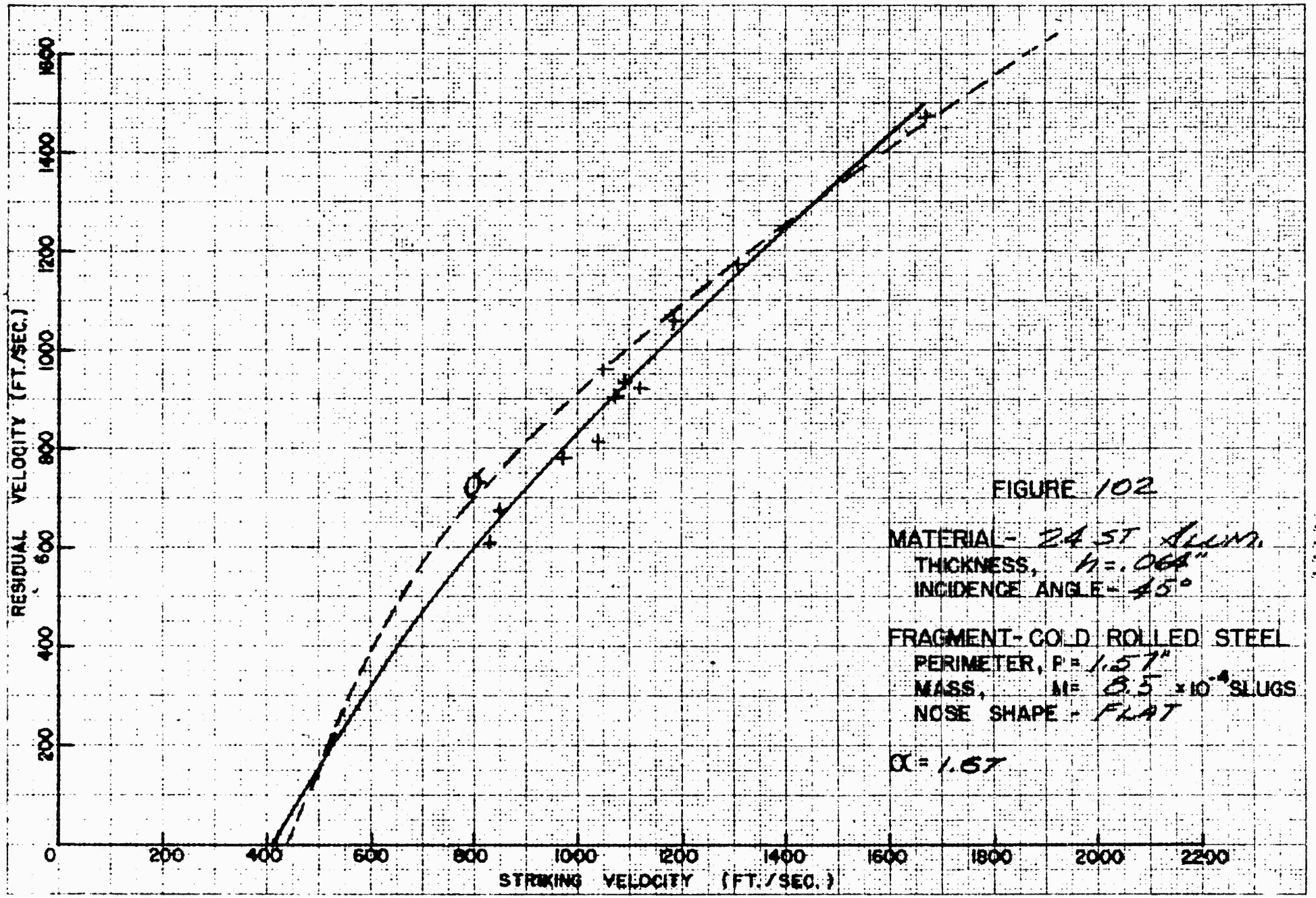


FIGURE 102

MATERIAL - 24ST Alum.
THICKNESS, h = .064"
INCIDENCE ANGLE - 45°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 8.5 $\times 10^{-4}$ SLUGS
NOSE SHAPE - FLAT

$\alpha = 1.67$

RESTRICTED

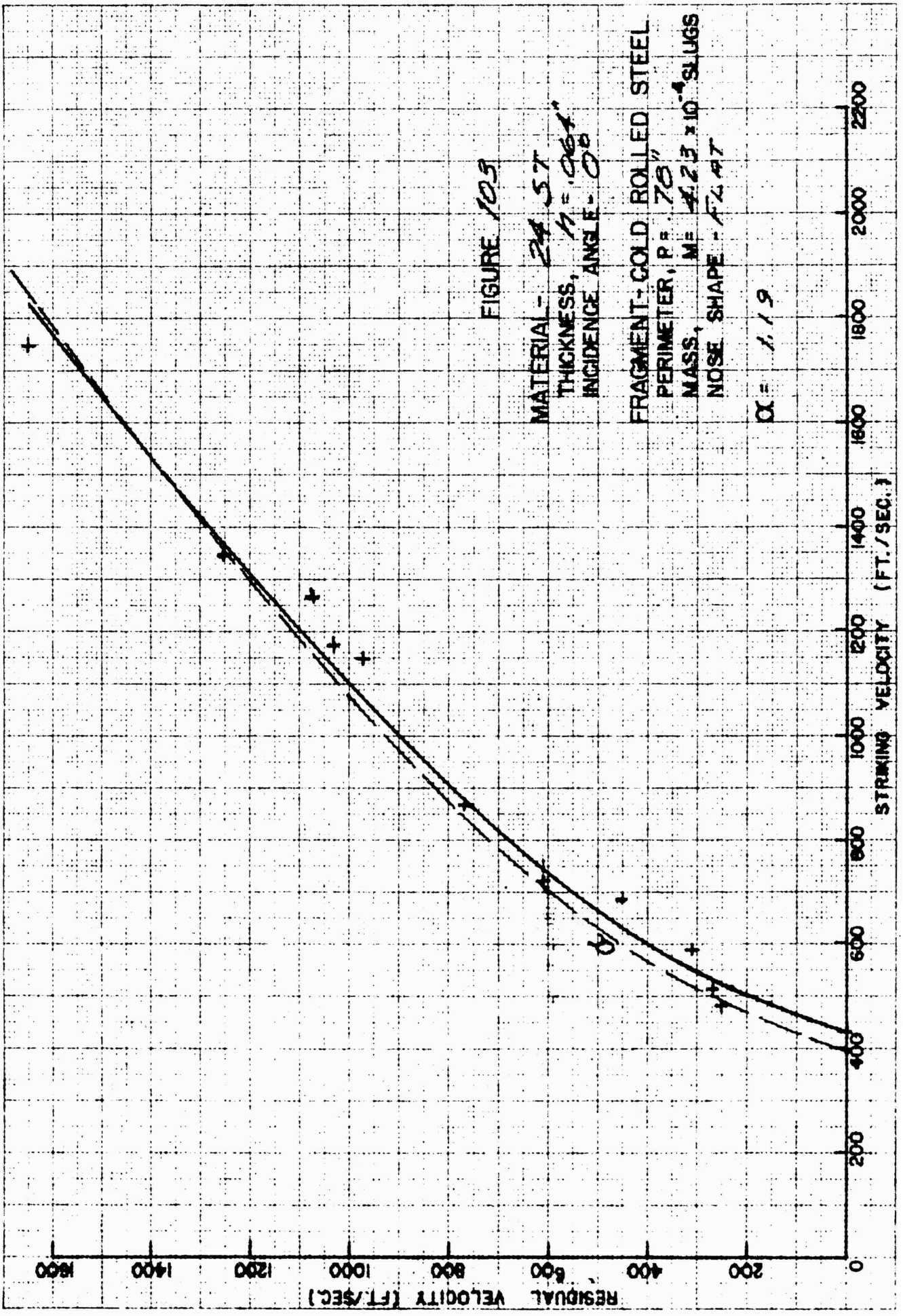


FIGURE 103
MATERIAL - 24 ST
THICKNESS, h = .064"
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = .423 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 1.19
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

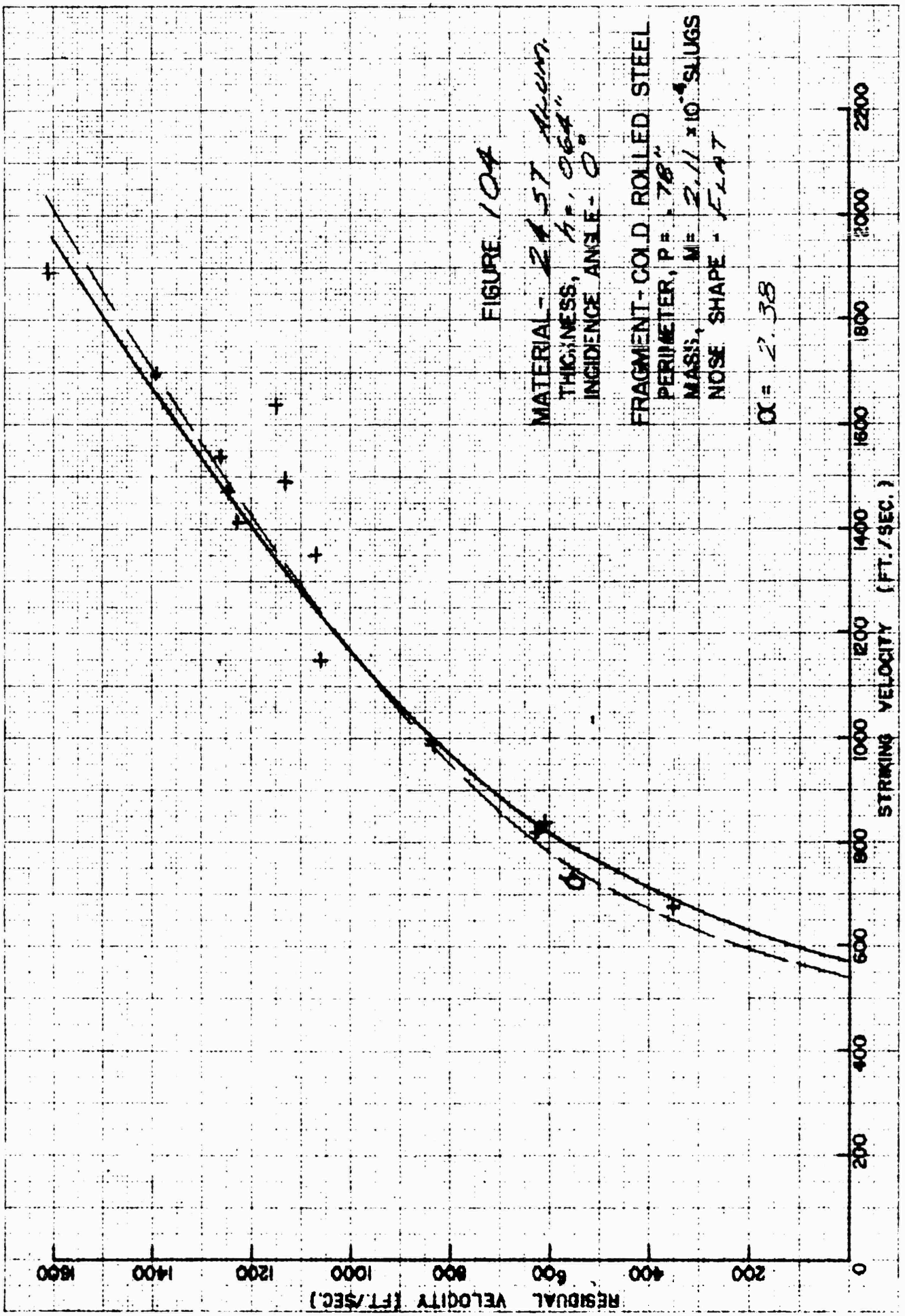


FIGURE 104
MATERIAL - 24 ST Aluminum
THICKNESS, t = .064"
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 2.11 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 2.38
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

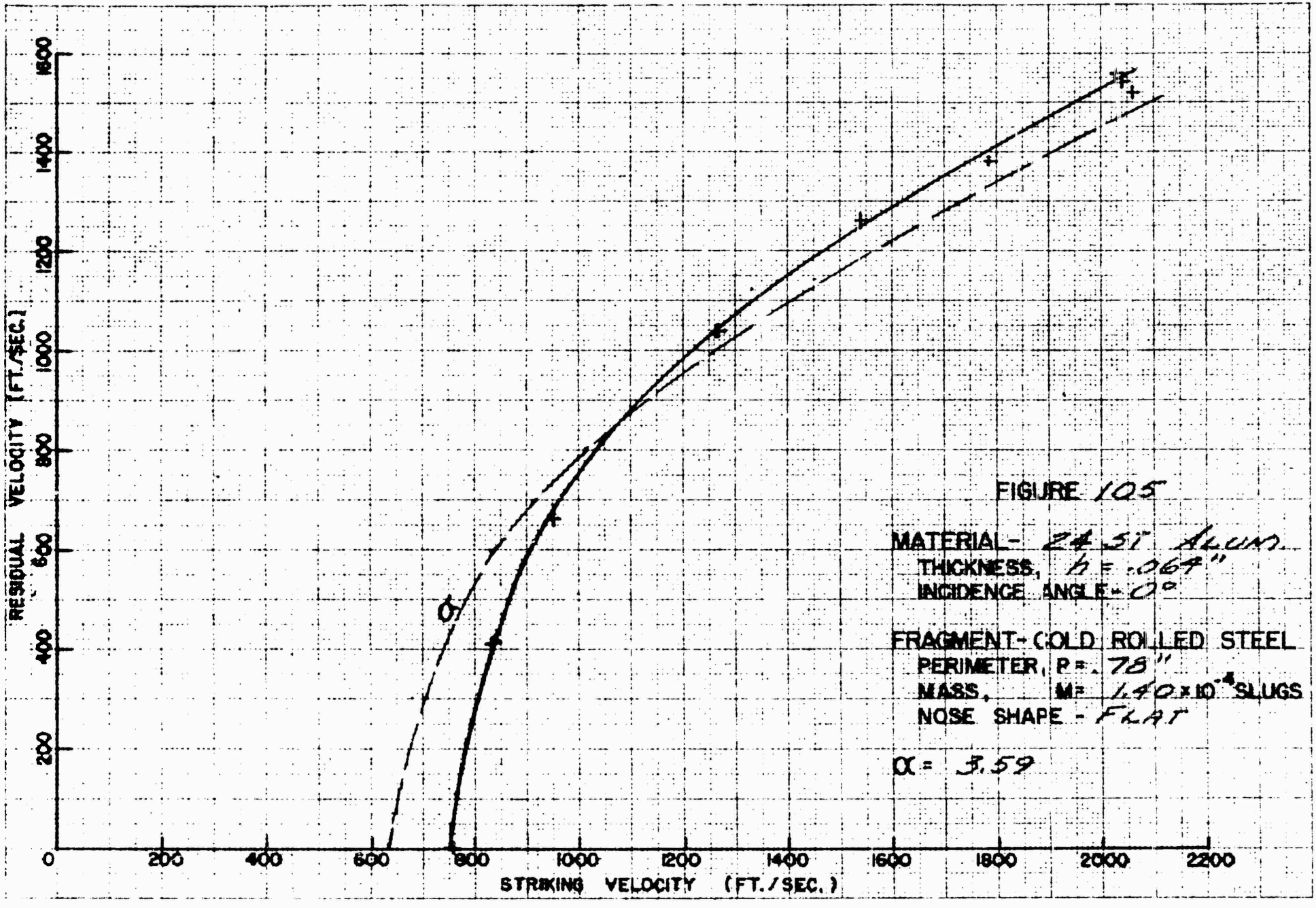


FIGURE 105

MATERIAL - 24ST Alum.
THICKNESS, h = .064"
INCIDENCE ANGLE - 0°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 1.40 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT

α = 3.59

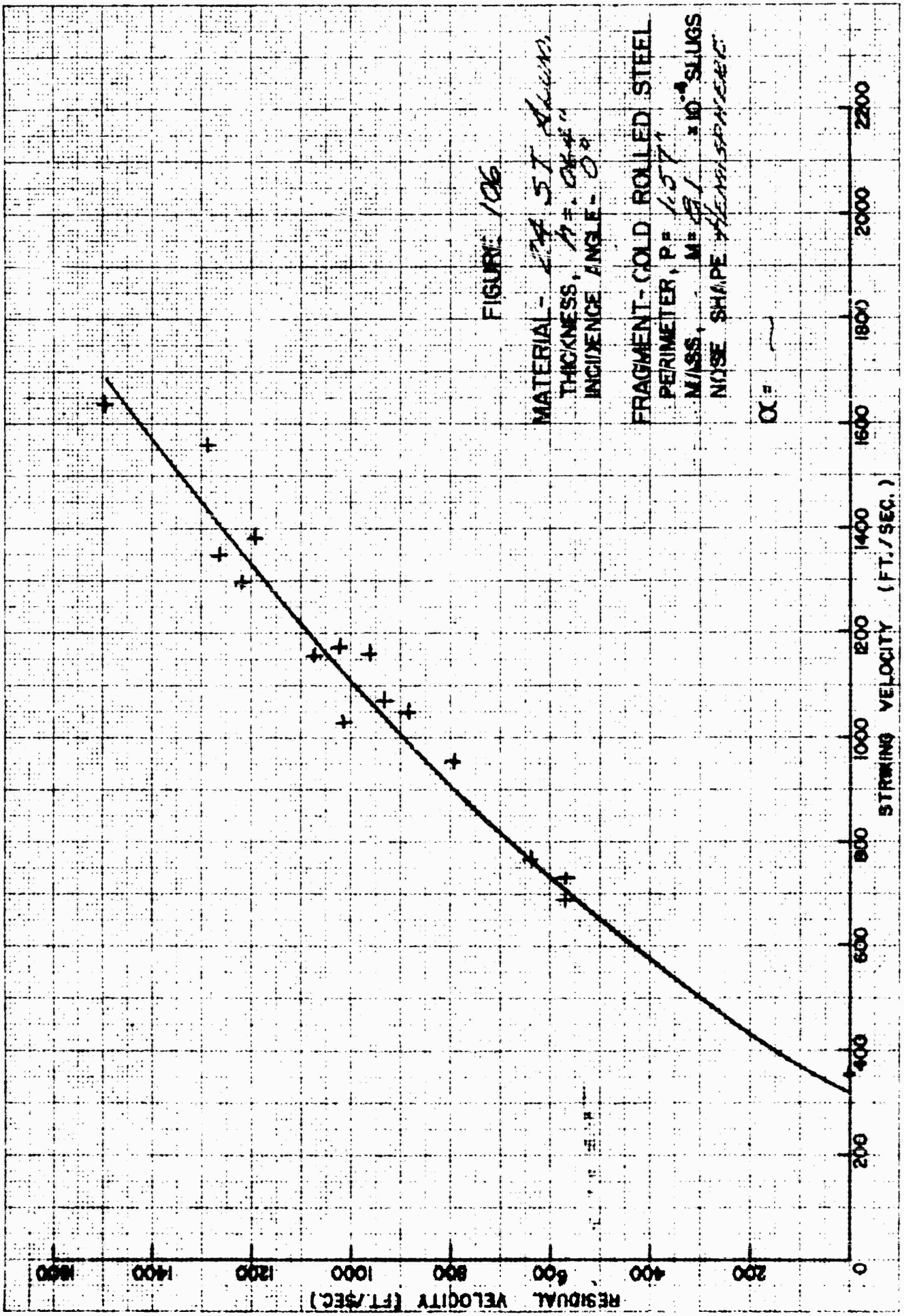


FIGURE 106
MATERIAL - 24ST ALUMINUM
THICKNESS, h = .064"
INCIDENCE ANGLE = 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = .051 x 10⁻³ SLUGS
NOSE SHAPE = 90° INCLUDED CONE
α = ~
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

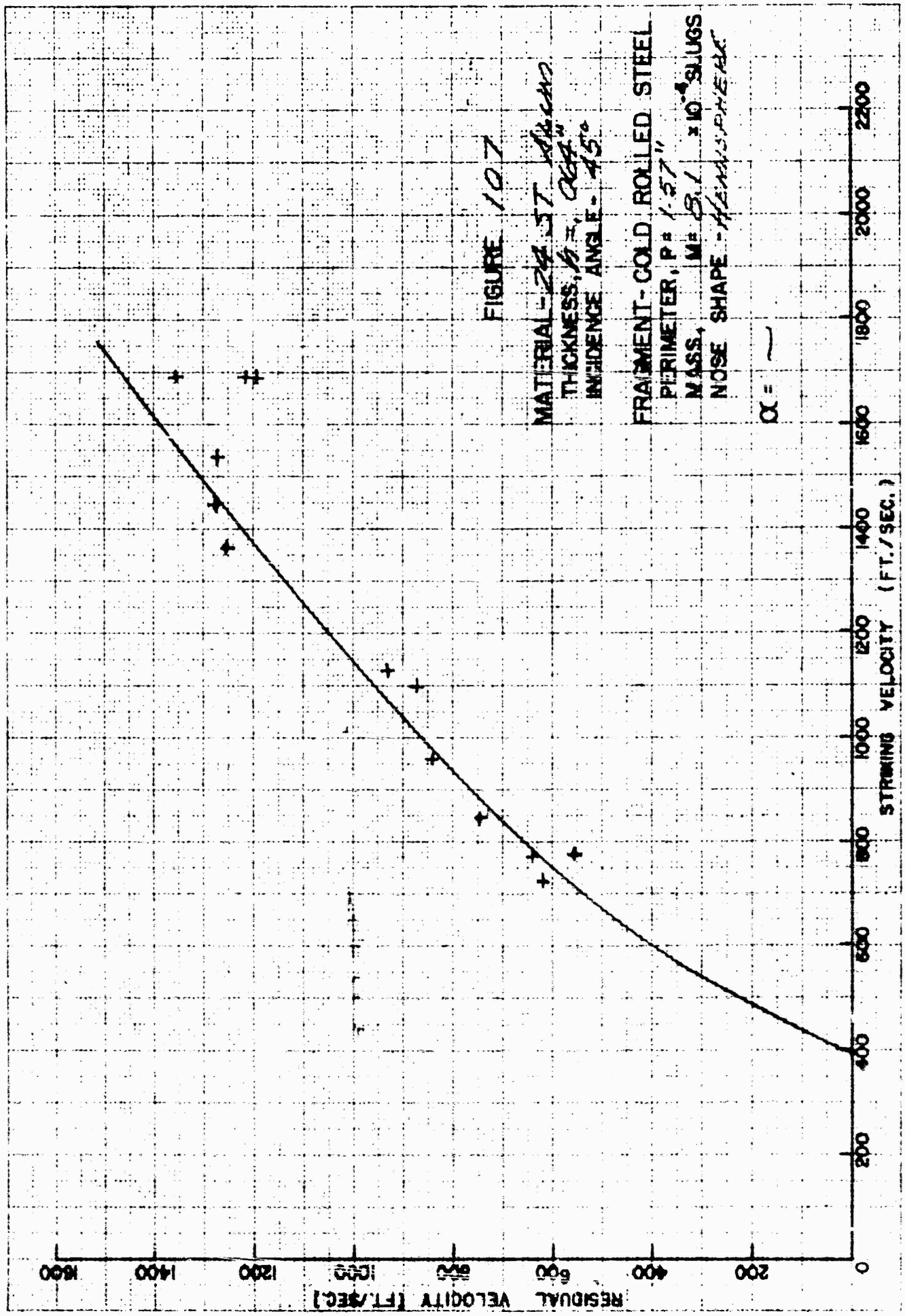


FIGURE 107
MATERIAL - 24 ST Alclad
THICKNESS, h = .064"
INCIDENCE ANGLE - 45°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 8.1 x 10⁻⁴ SLUGS
NOSE SHAPE - Hemispherical
α = ~
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

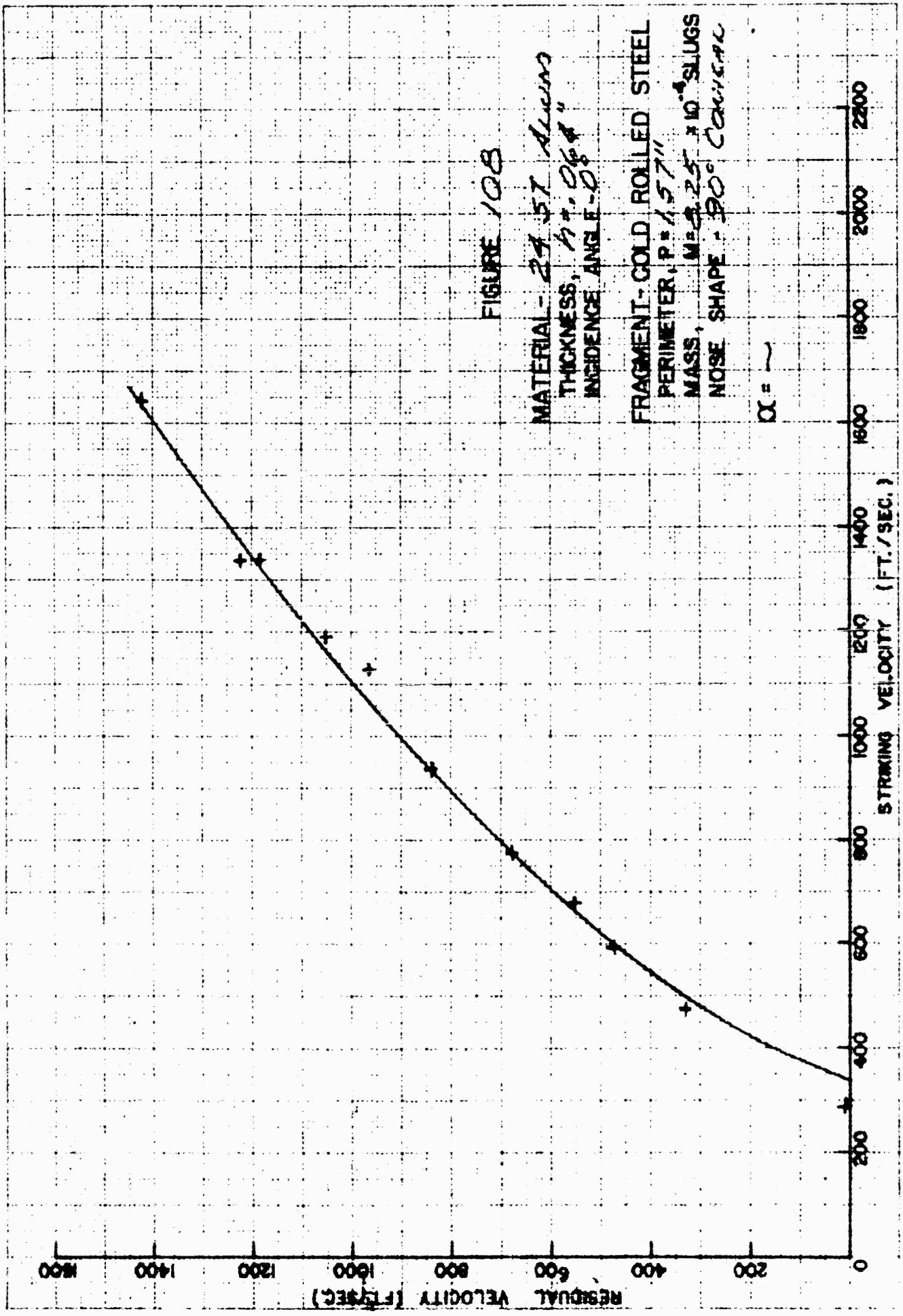
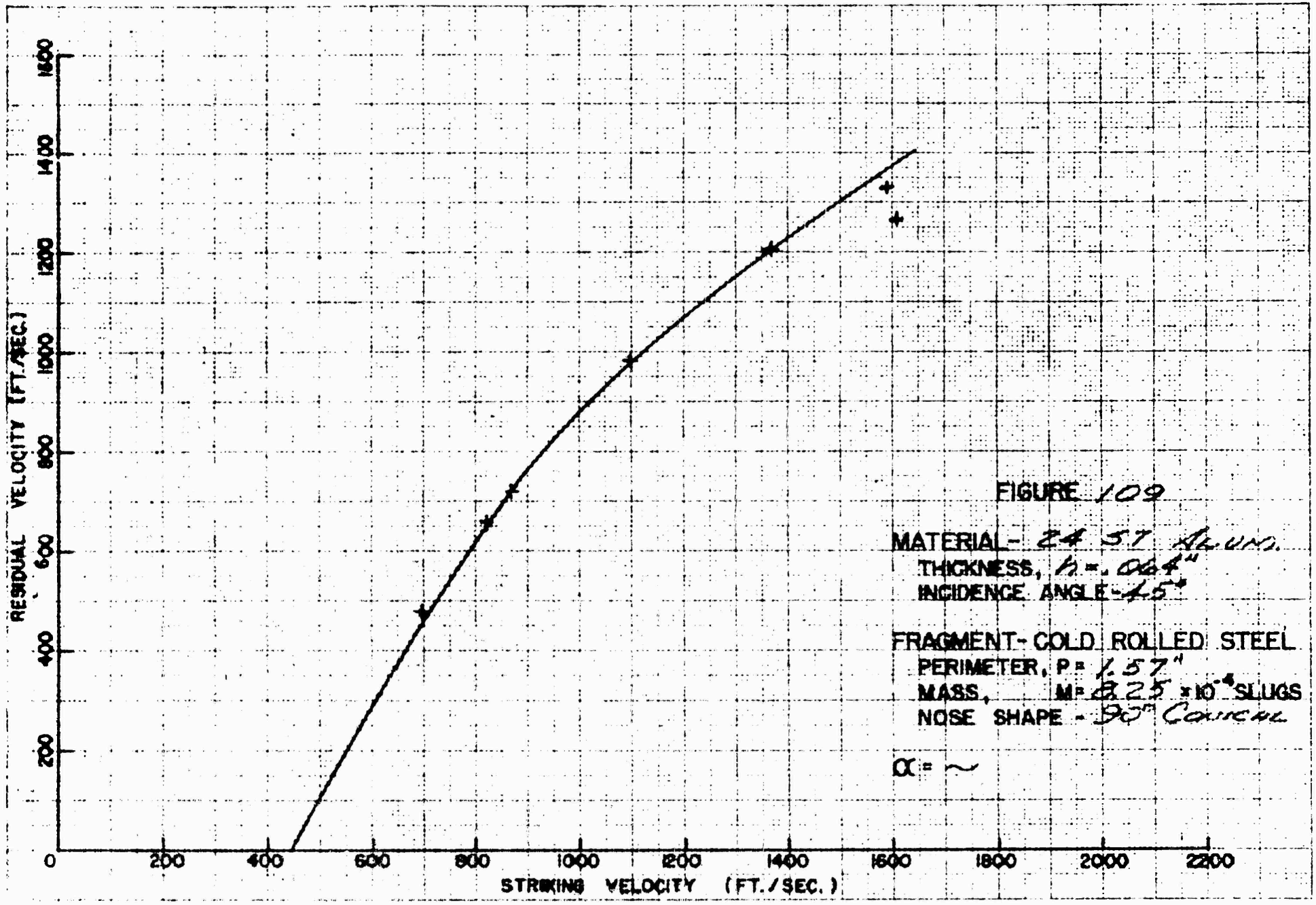


FIGURE 108
MATERIAL - 24 ST Alclad
THICKNESS, h = .064"
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 2.25 x 10⁻⁴ SLUGS
NOSE SHAPE - 90° Conical
α = ~
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 109
MATERIAL - 24 ST Alclad
THICKNESS, h = .064"
INCIDENCE ANGLE - 45°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 8.25 x 10⁻⁴ SLUGS
NOSE SHAPE - 90° Conical
α = ~

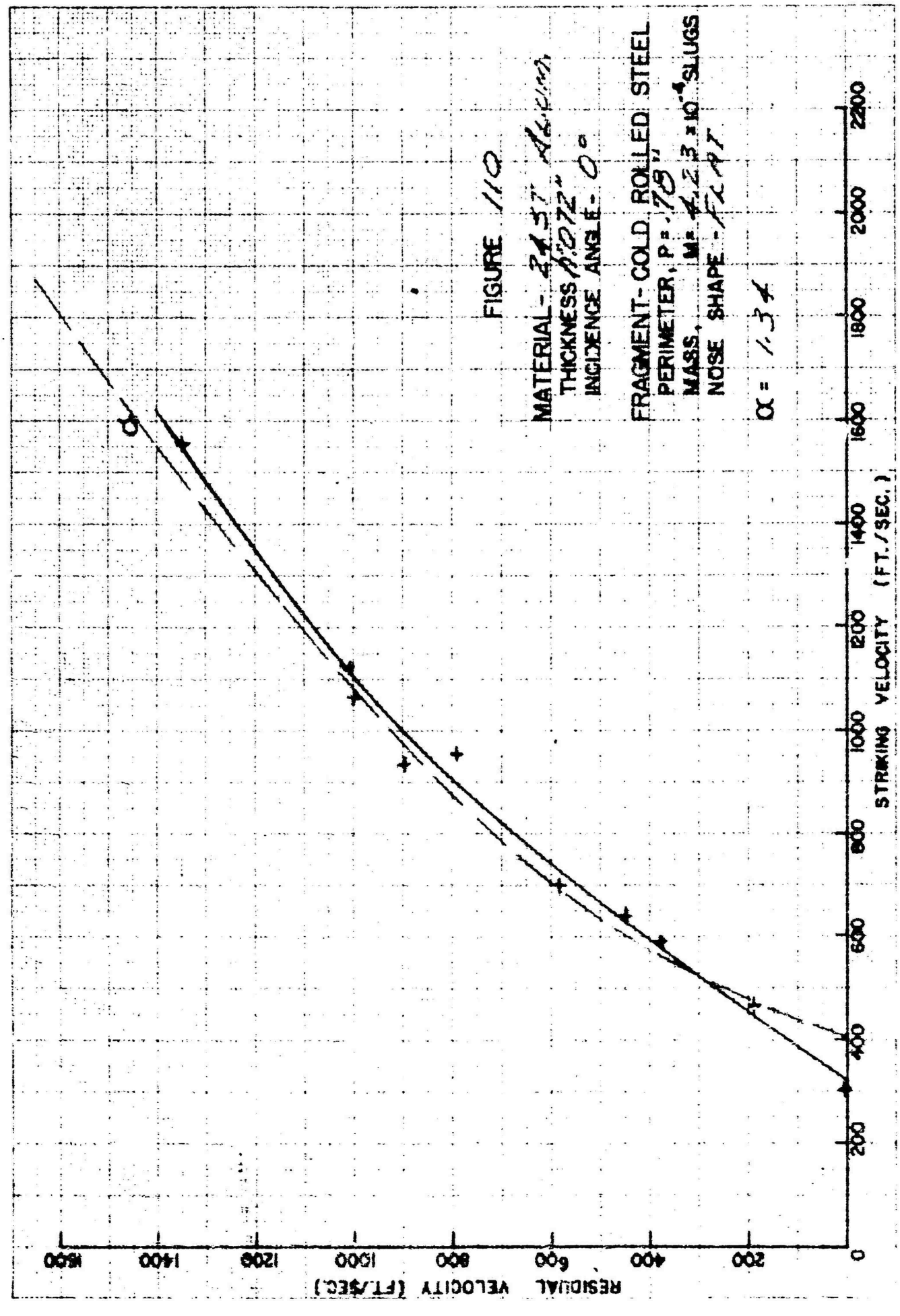
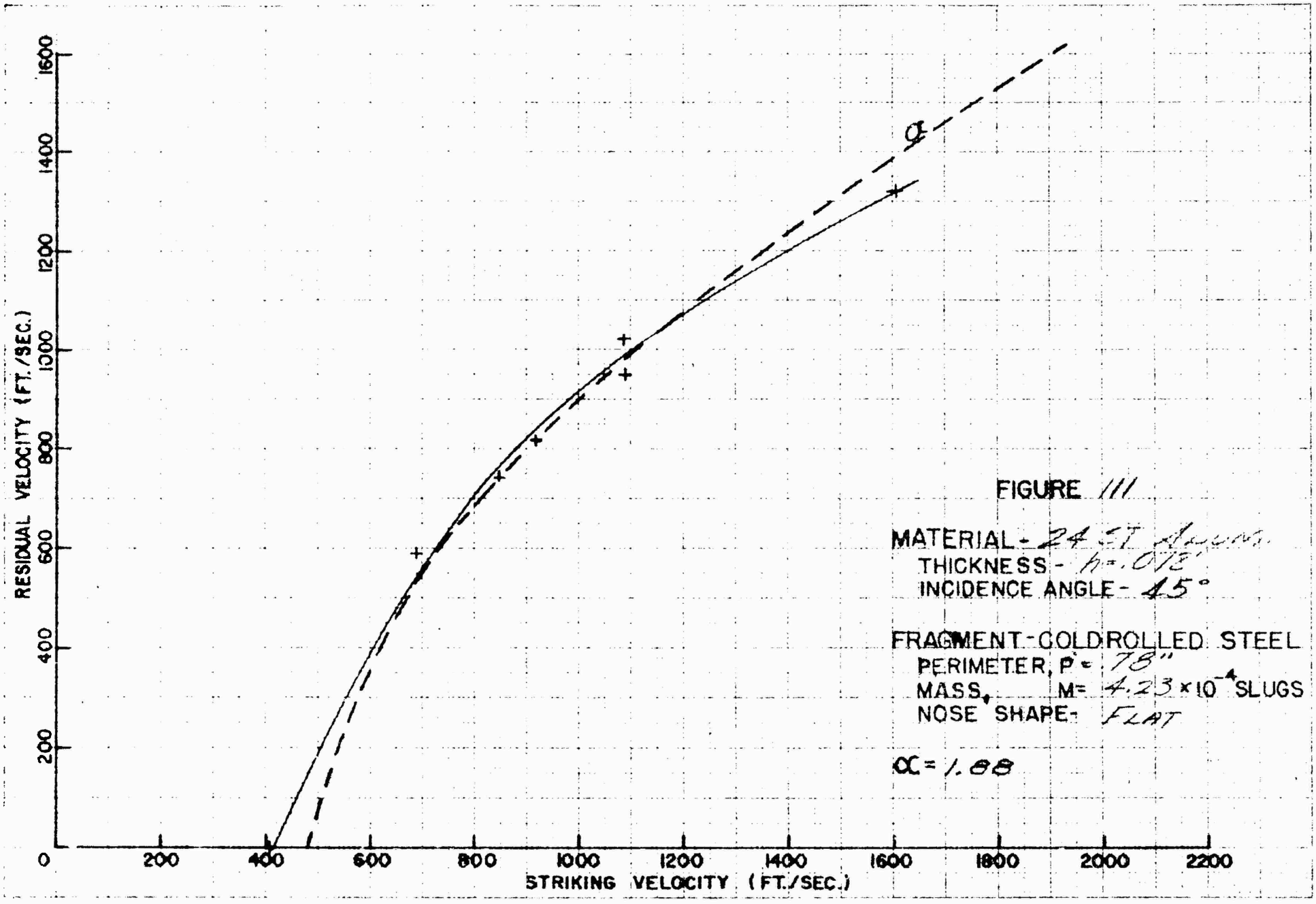
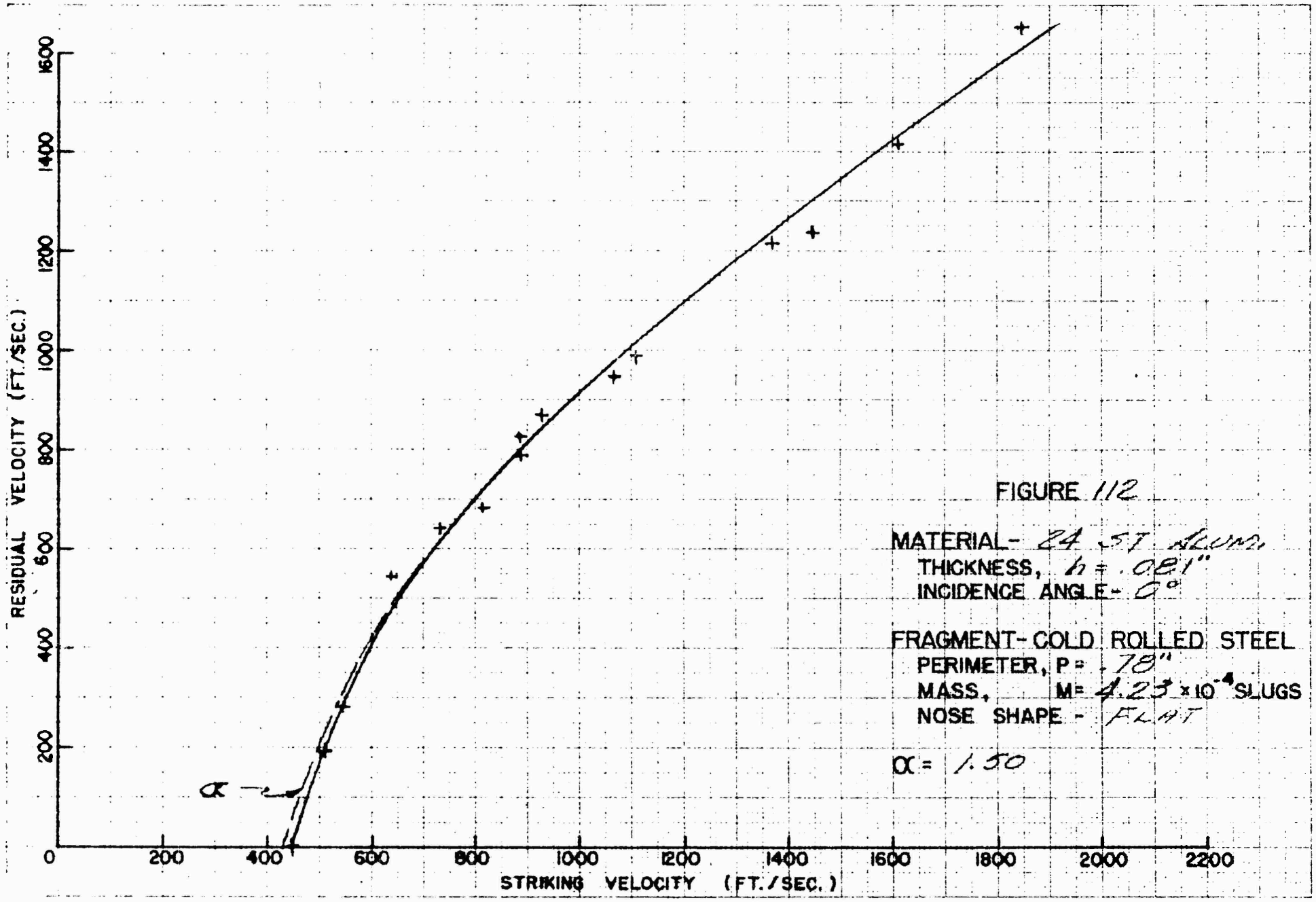
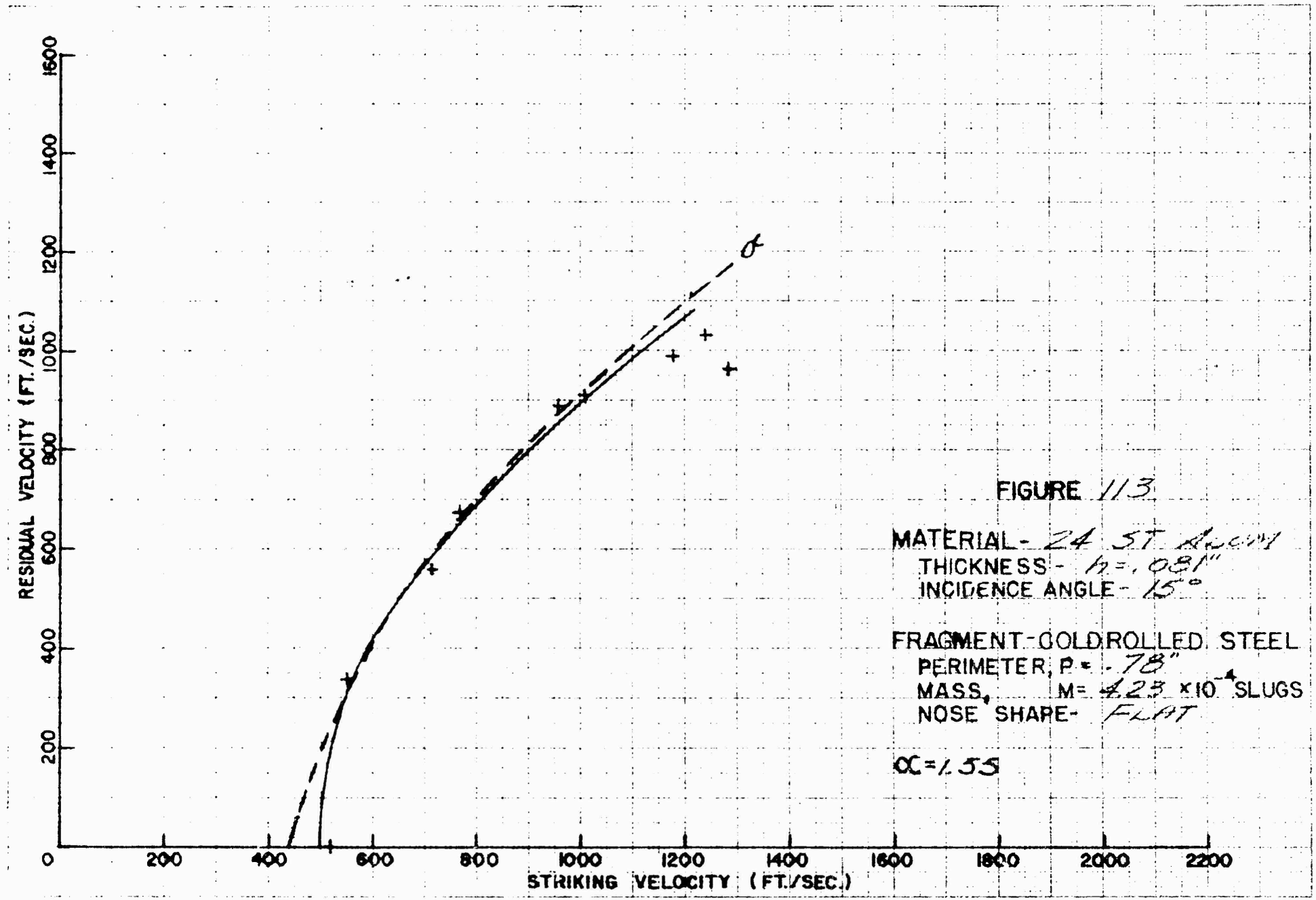
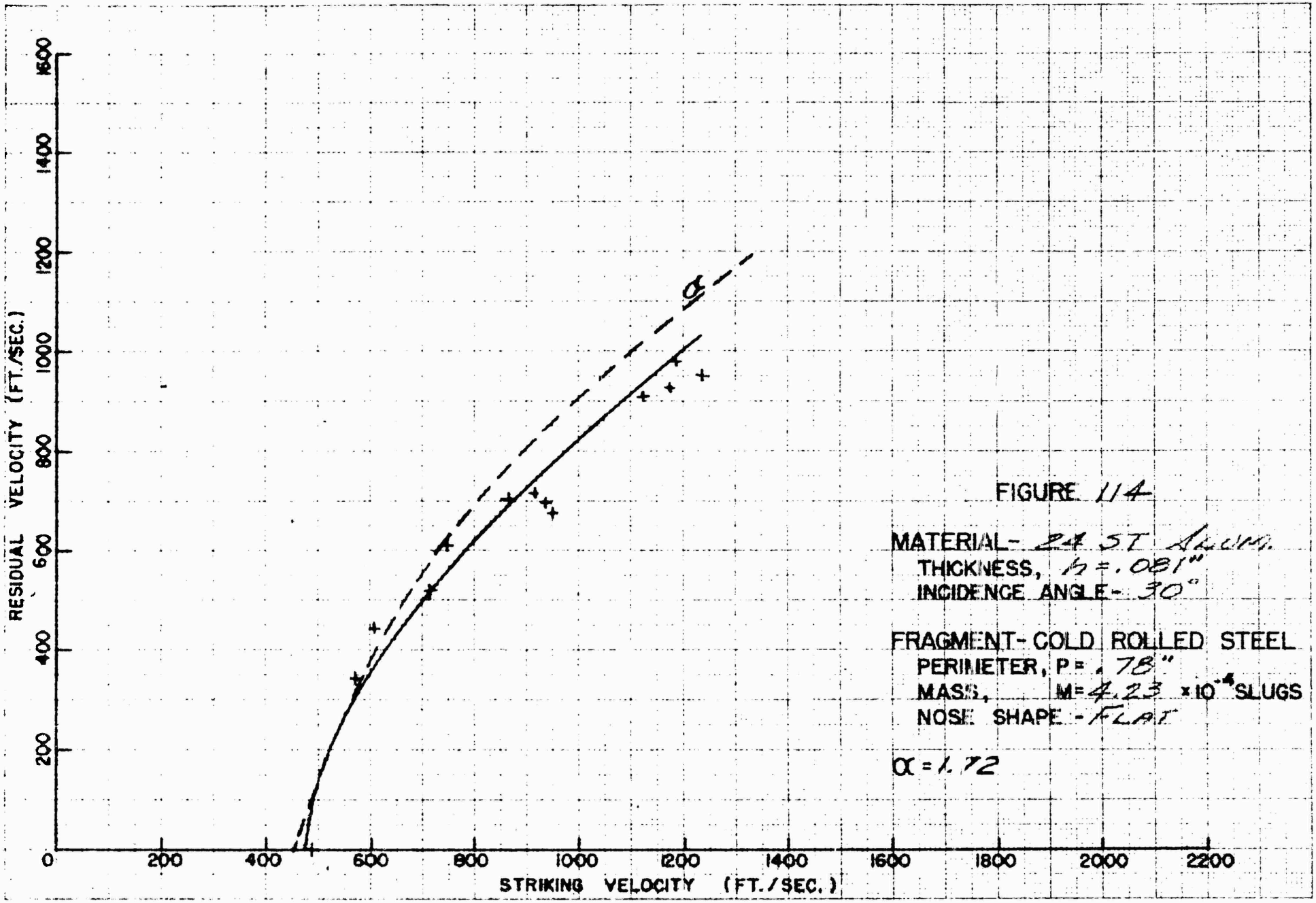


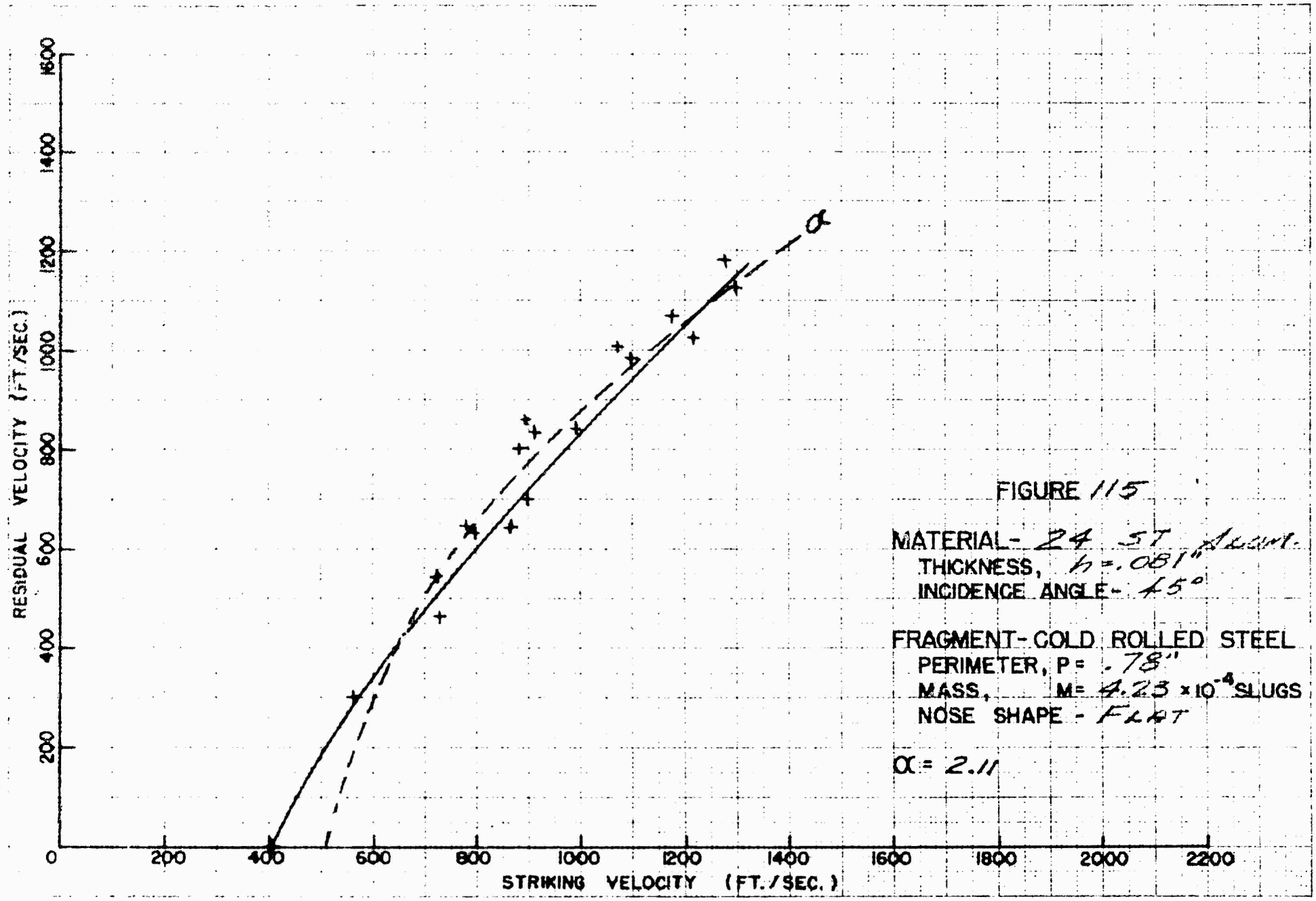
FIGURE 110
MATERIAL - 24ST Aluminum
THICKNESS .0072"
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 1.34
RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

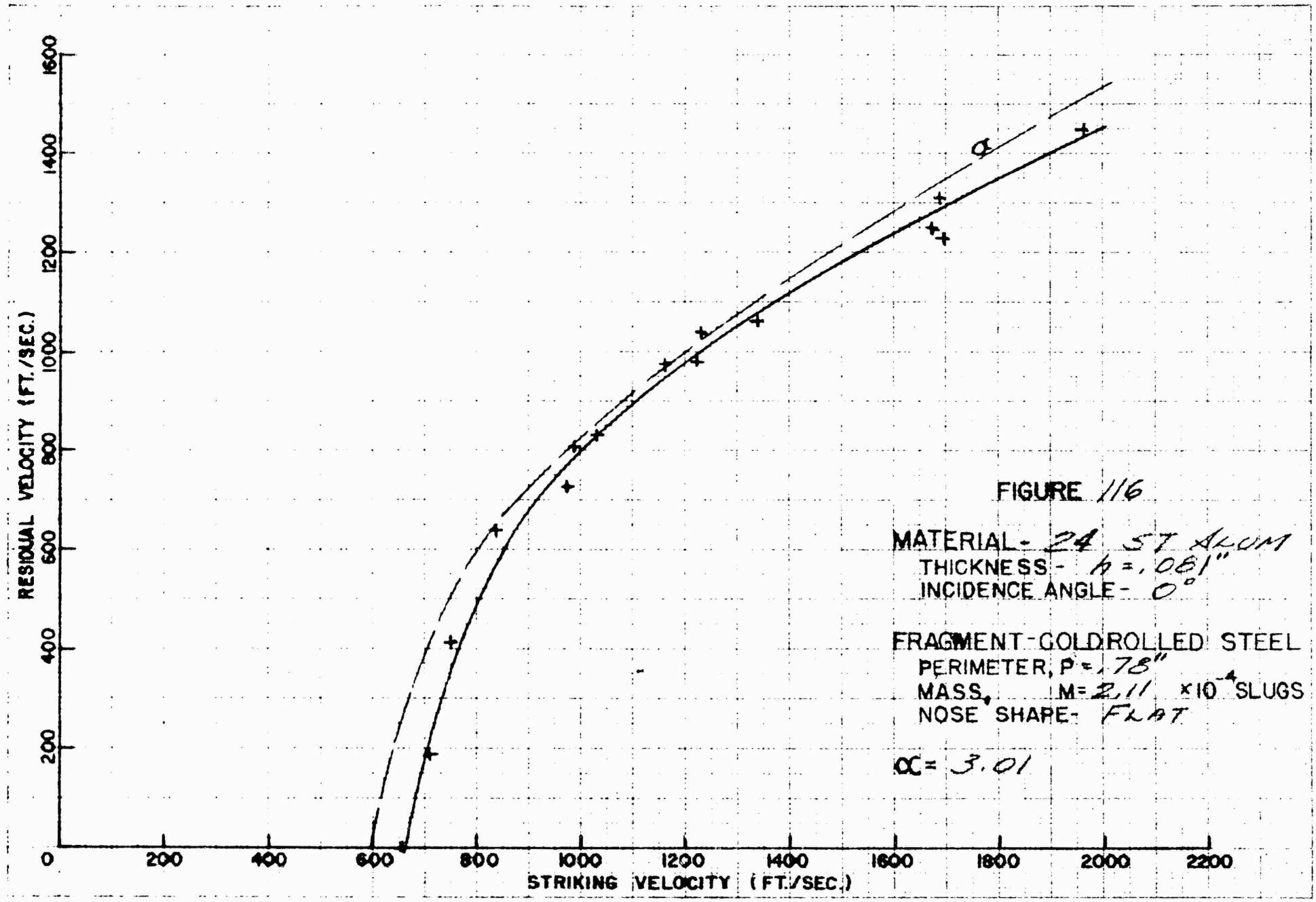

RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE III
MATERIAL - 24 ST Alum.
THICKNESS - h=.016"
INCIDENCE ANGLE - 45°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 × 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 1.88

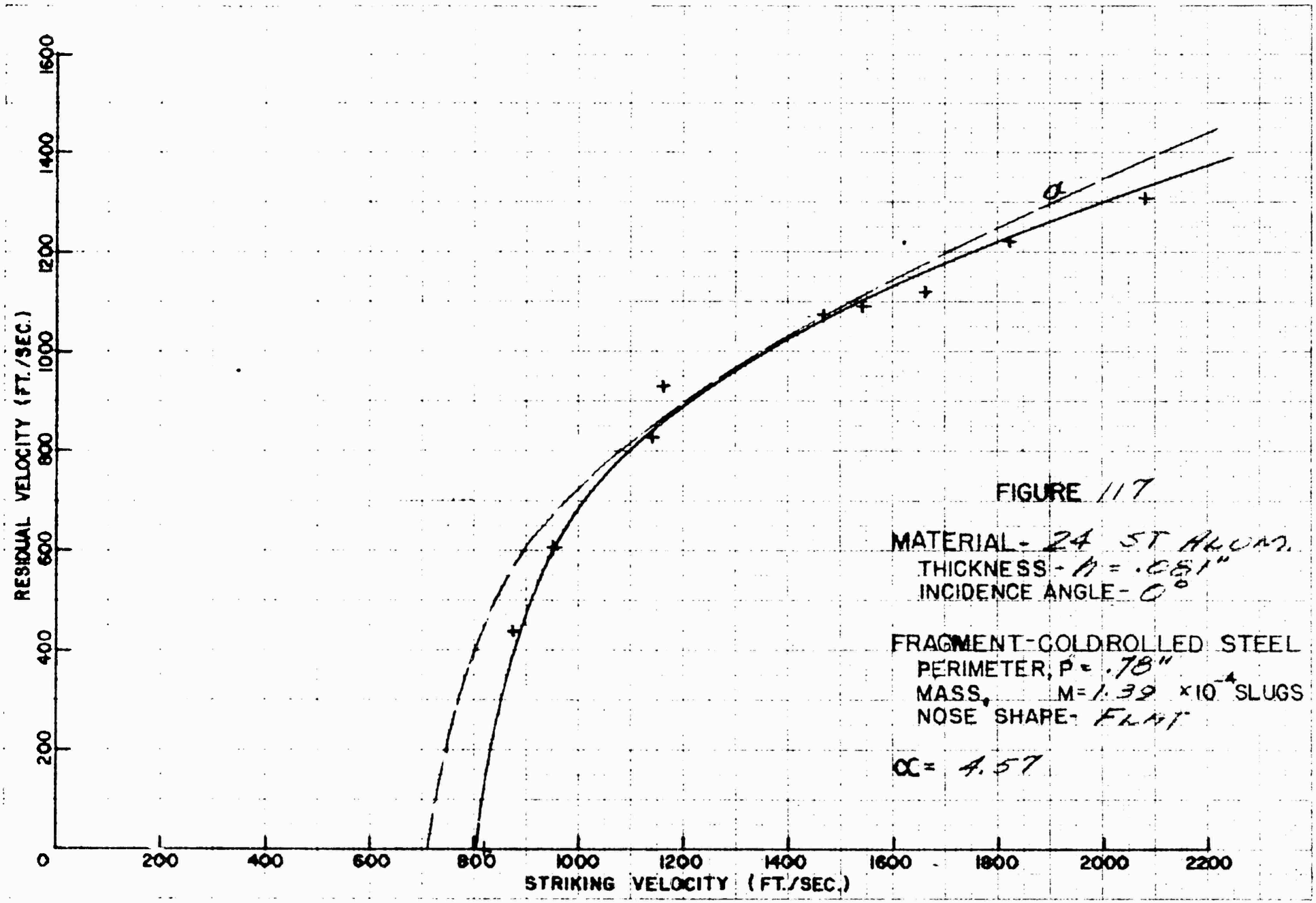

RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
α
FIGURE 112
MATERIAL- 24 ST ALUM.
THICKNESS, h = .081"
INCIDENCE ANGLE- 0°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M= 4.23 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 1.50


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 113
MATERIAL - 24 ST Alcoa
THICKNESS - h = .091"
INCIDENCE ANGLE - 15°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 x 10⁻⁴ SLUGS
NOSE SHARE - FLAT
CC = 1.55


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
α
FIGURE 114
MATERIAL- 24 ST ALCLAD
THICKNESS, h = .081"
INCIDENCE ANGLE- 30°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 1.72


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
STRIKING VELOCITY (FT./SEC.)
FIGURE 115
MATERIAL- 24 ST Alcad.
THICKNESS, h = .081"
INCIDENCE ANGLE- 45°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 x 10⁻⁴ SLUGS
NOSE SHAPE - Flat
α = 2.11


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 116
MATERIAL - 24 ST ALUM
THICKNESS - h = .081"
INCIDENCE ANGLE - 0°
FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 2.11 ×10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 3.01


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
a
FIGURE 117
MATERIAL- 24 ST ALCAD.
THICKNESS - h = .051"
INCIDENCE ANGLE - 0°
FRAGMENT-COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 1.39 ×10⁻⁴ SLUGS
NOSE SHAPE- FLAT
CC = 4.57

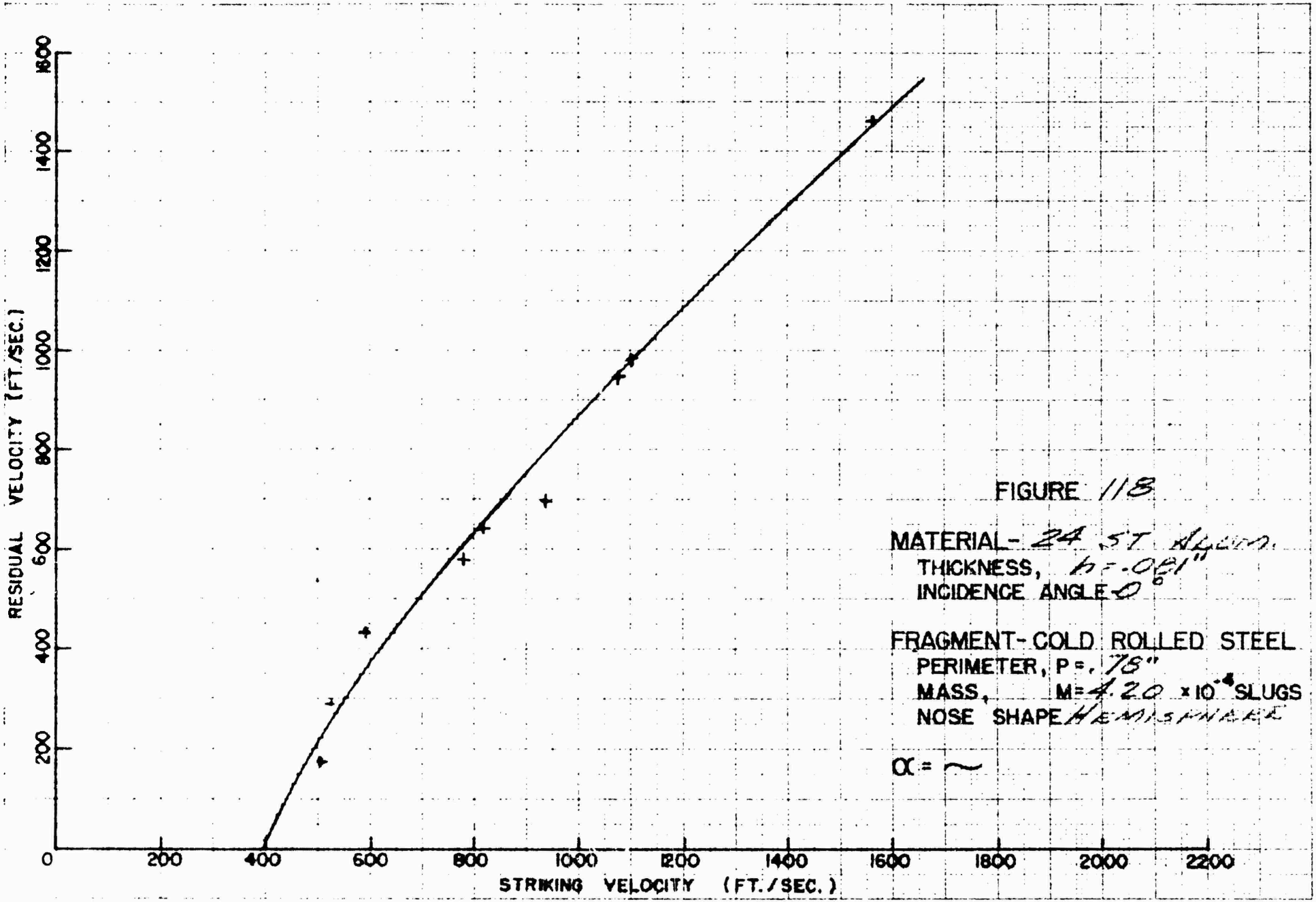


FIGURE 118

MATERIAL- 24 ST Alcm.
THICKNESS, h=.061"
INCIDENCE ANGLE 0°

FRAGMENT- COLD ROLLED STEEL
PERIMETER, P=.78"
MASS, M=4.20 x 10^{-4} SLUGS
NOSE SHAPE HEMISPHERE

α = ~

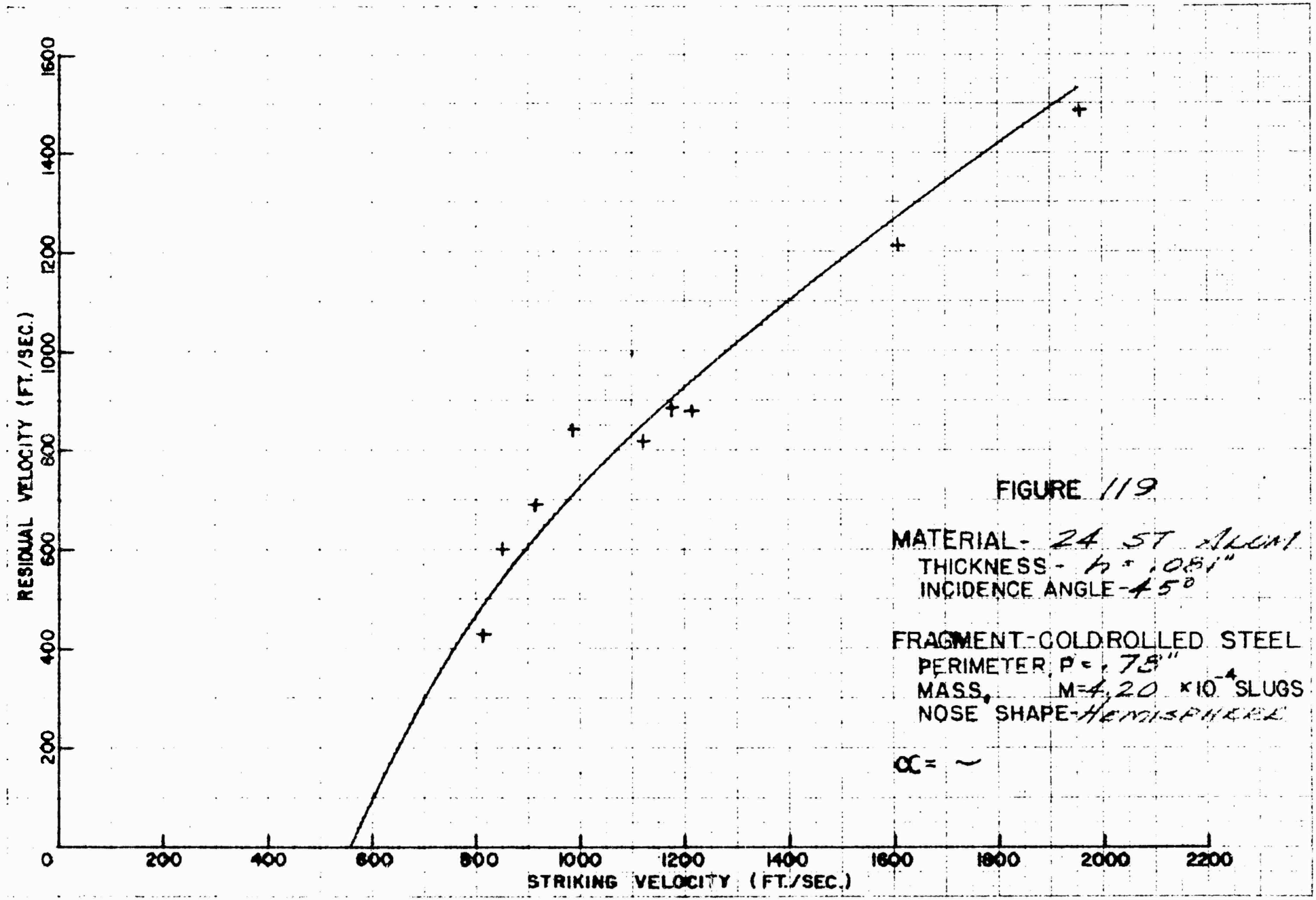
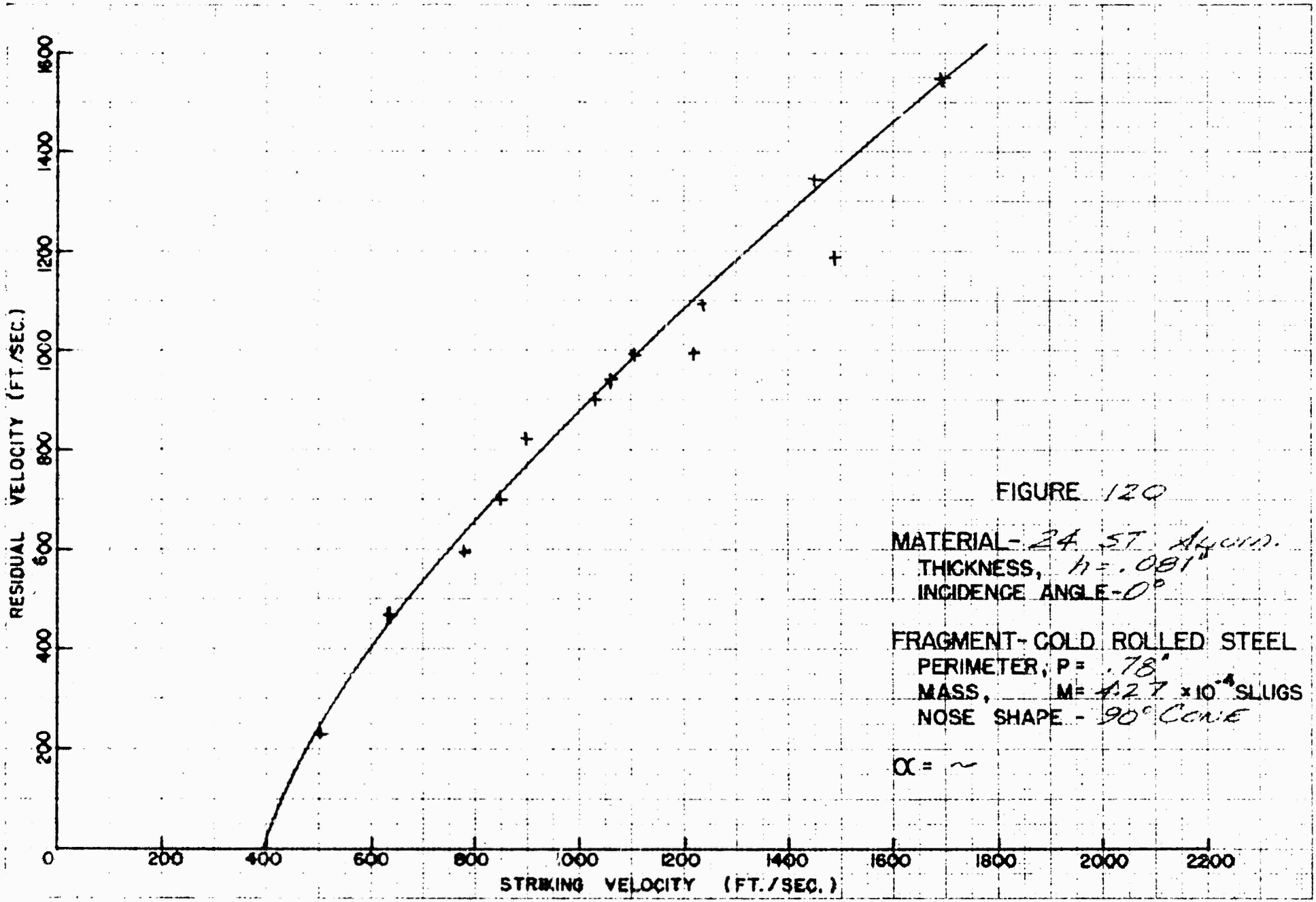


FIGURE 119

MATERIAL- 24 ST ALCLAD
THICKNESS - h = .051"
INCIDENCE ANGLE - 45°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .79"
MASS, M = 4.20 × 10^{-4} SLUGS
NOSE SHAPE - HEMISPHERICAL

OC = ~


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
STRIKING VELOCITY (FT./SEC.)
FIGURE 120
MATERIAL - 24 ST Alcad.
THICKNESS, h = .081"
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.27 x 10⁻⁴ SLUGS
NOSE SHAPE - 90° Cone
α = ~

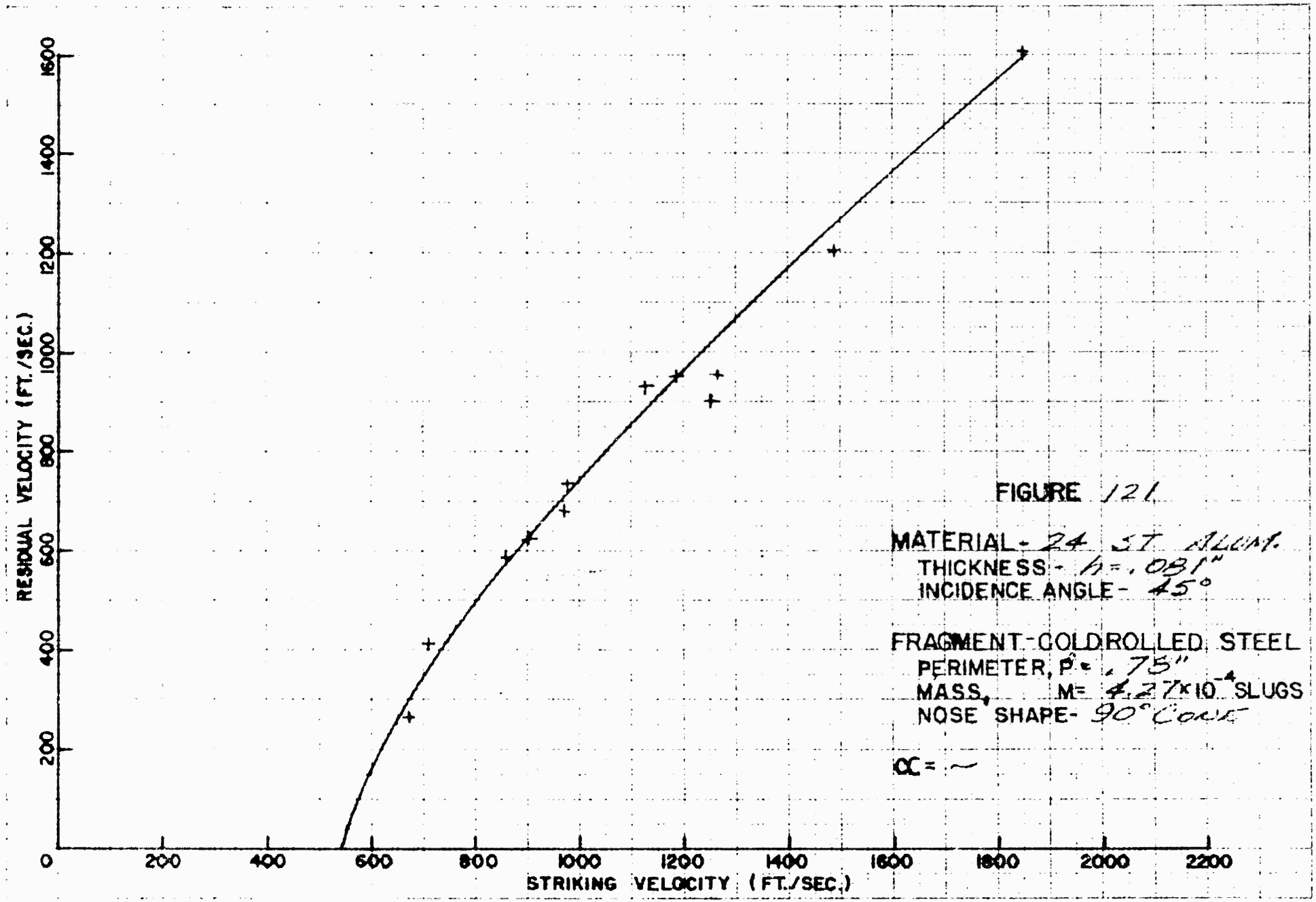
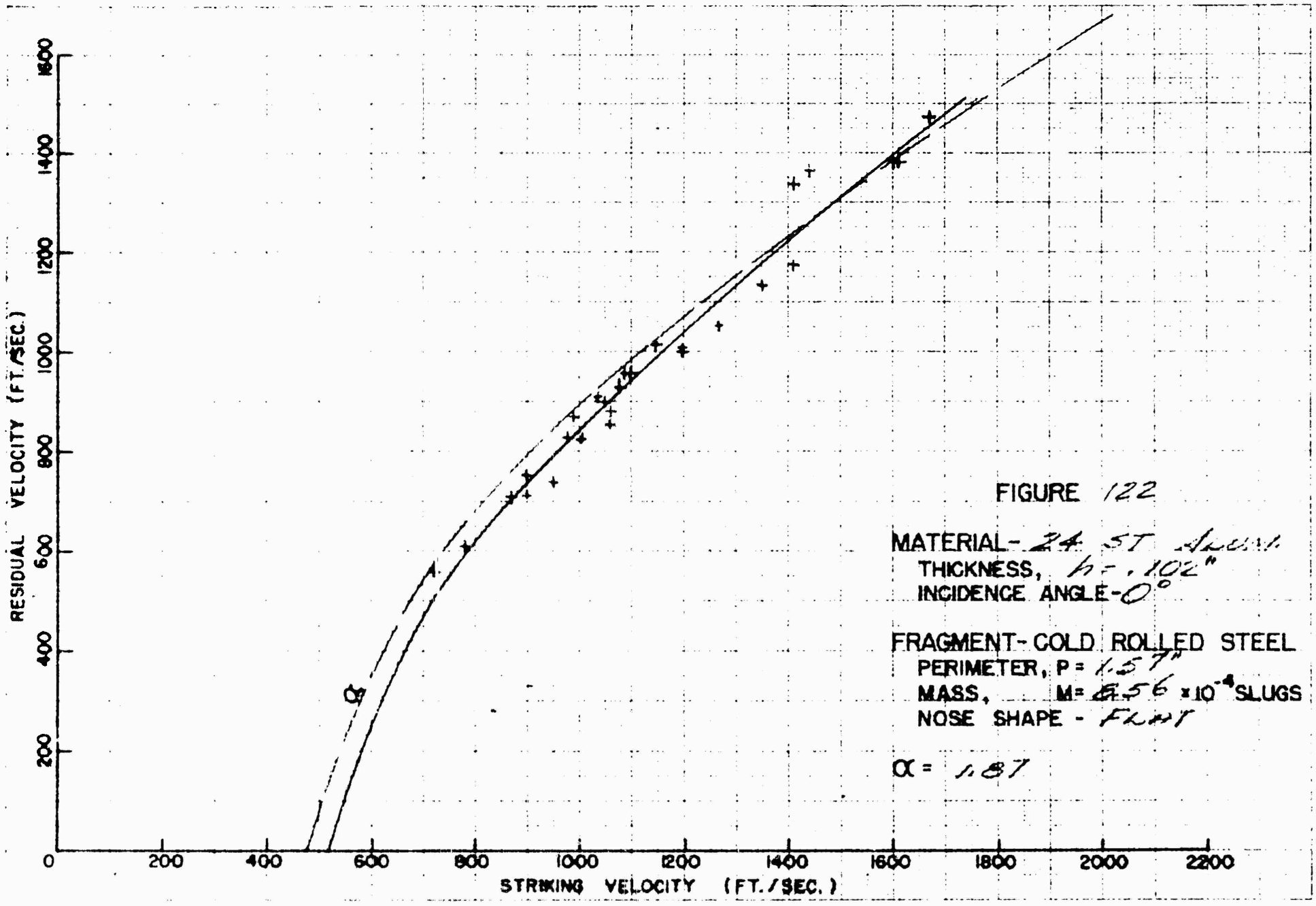


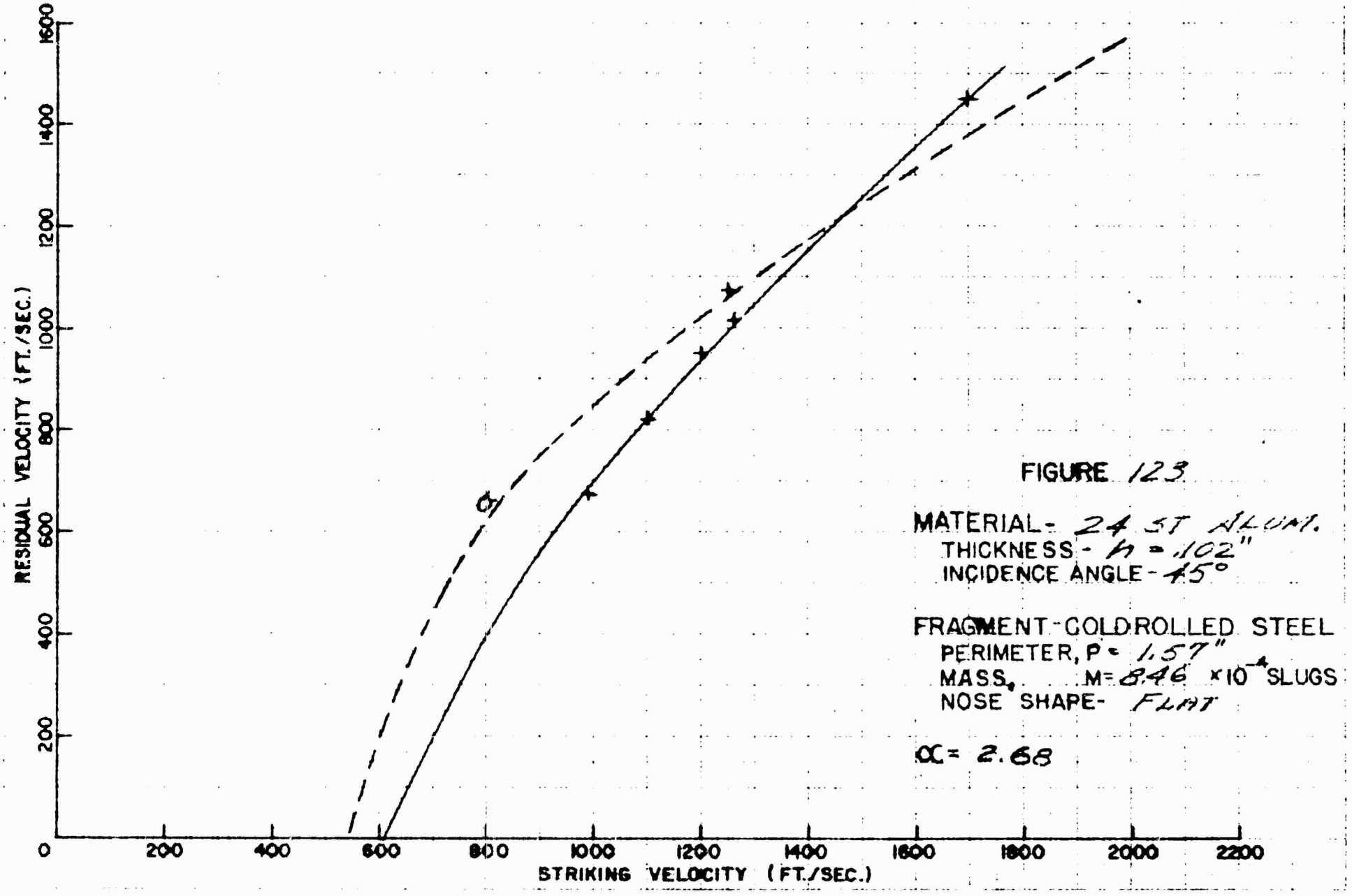
FIGURE 121

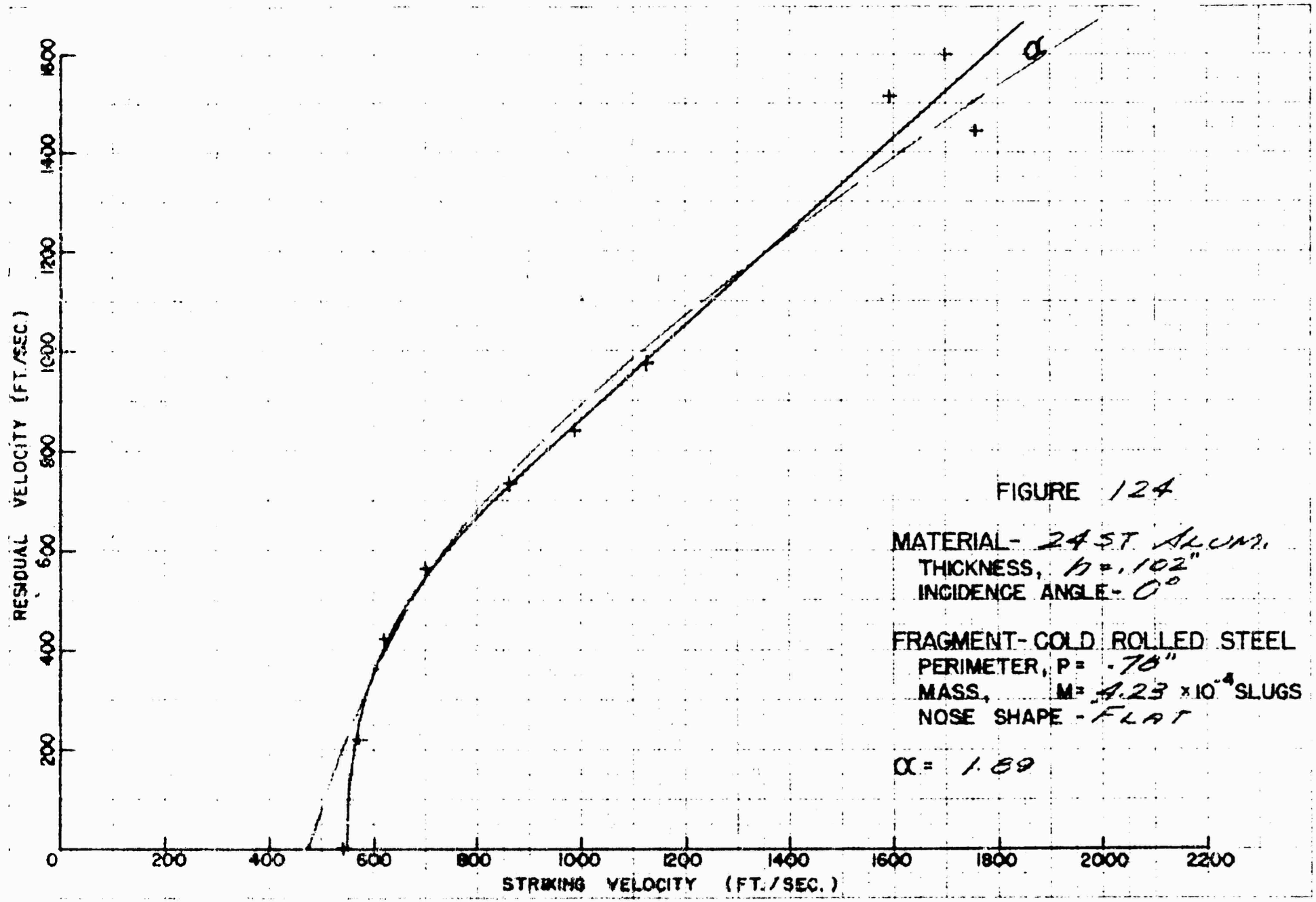
MATERIAL - 24 ST ALUM.
THICKNESS - h = .081"
INCIDENCE ANGLE - 45°

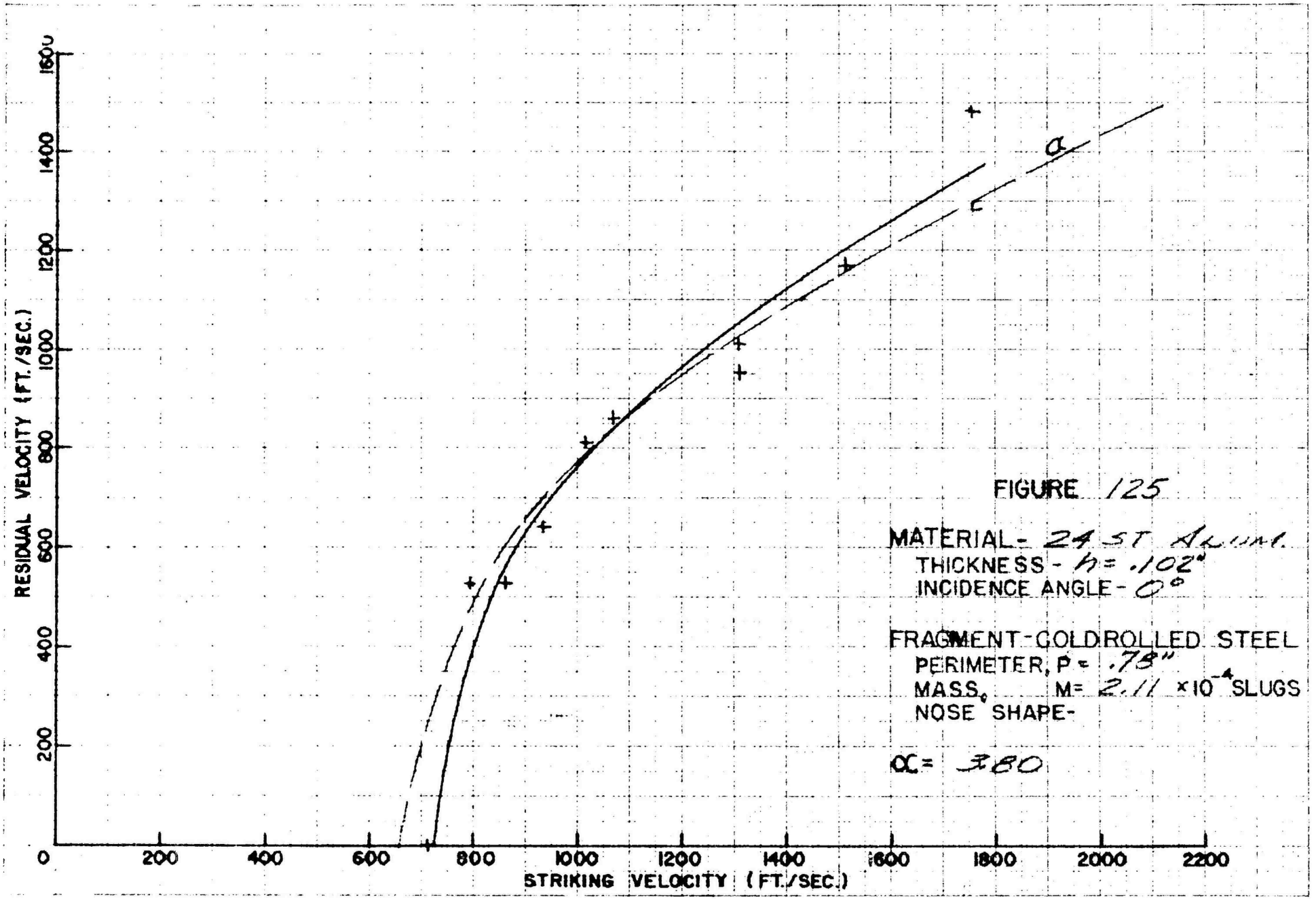
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .75"
MASS, M = 4.27×10^{-4} SLUGS
NOSE SHAPE - 90° Cone

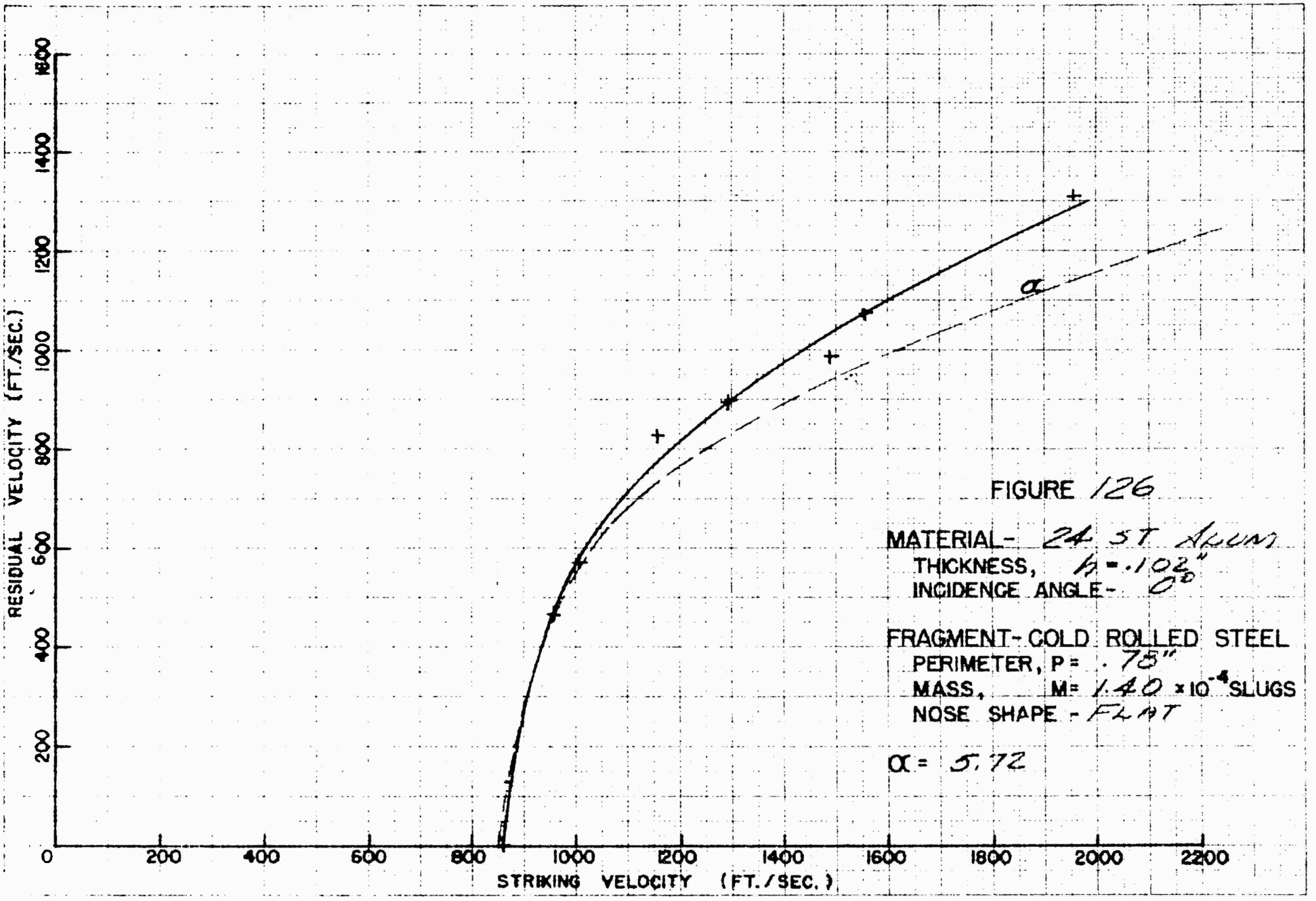
OC = ~


RESIDUAL VELOCITY (FT./SEC.)
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 122
MATERIAL- 24 ST ALCLAD
THICKNESS, h = .102"
INCIDENCE ANGLE- 0°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 6.56 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 1.87


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 123
MATERIAL- 24 ST ALUM.
THICKNESS - h = .102"
INCIDENCE ANGLE - 45°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 846 x 10⁻⁴ SLUGS
NOSE SHAPE- FLAT
α = 2.68


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
STRIKING VELOCITY (FT./SEC.)
α
FIGURE 124
MATERIAL- 24ST ALUM.
THICKNESS, h = .102"
INCIDENCE ANGLE- 0°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = .70"
MASS, M = 4.23 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 1.69


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
STRIKING VELOCITY (FT./SEC.)
a
c
FIGURE 125
MATERIAL- 24ST Alum.
THICKNESS - h = .102"
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .75"
MASS, M = 2.11 x 10⁻⁴ SLUGS
NOSE SHAPE-
α = 180


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
STRIKING VELOCITY (FT./SEC.)
α
FIGURE 126
MATERIAL- 24 ST ALUM
THICKNESS, h = .102"
INCIDENCE ANGLE- 0°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = .75"
MASS, M = 1.40 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 5.72

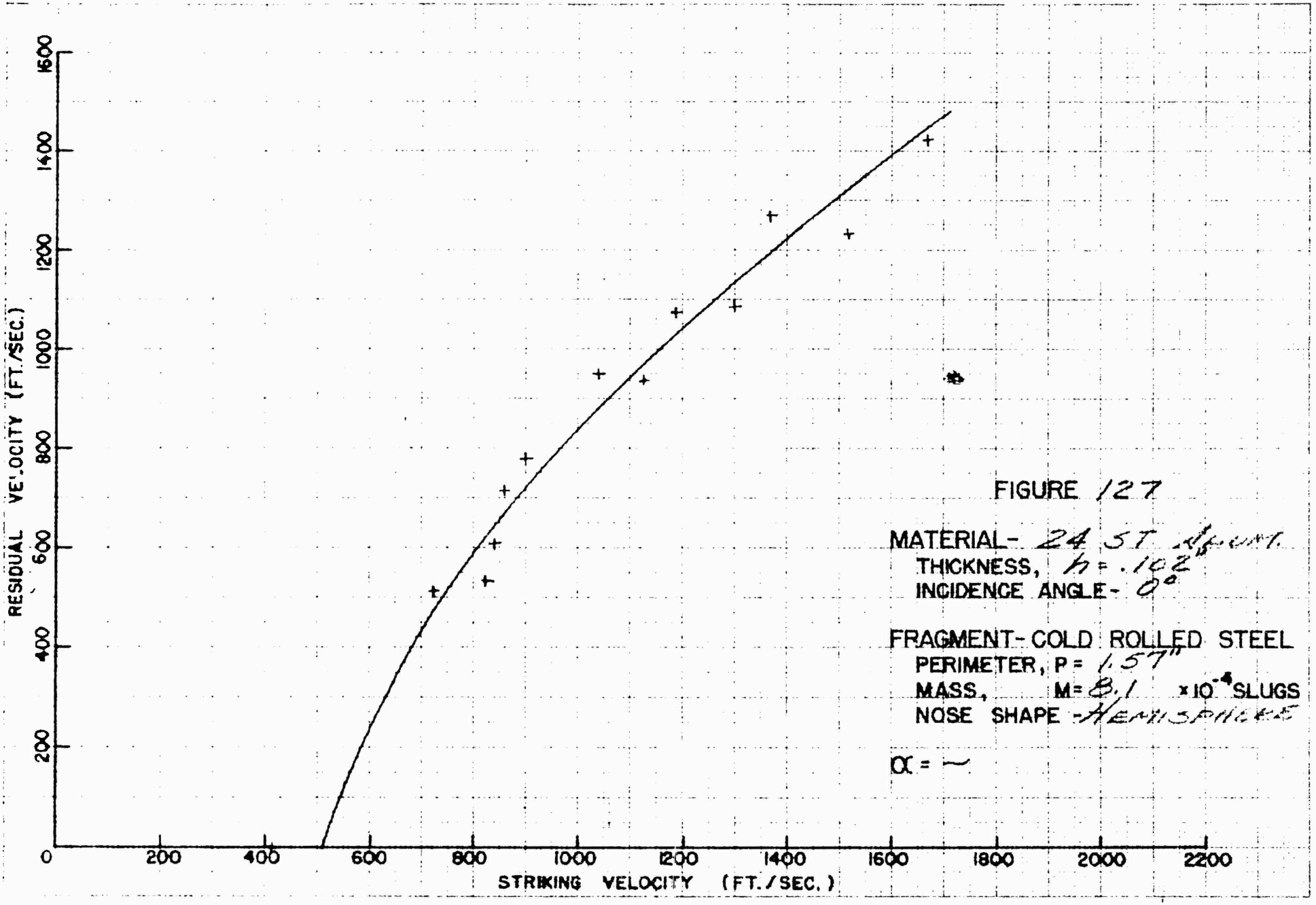


FIGURE 127

MATERIAL- 24 ST Alum.
THICKNESS, h = .102"
INCIDENCE ANGLE- 0°

FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 8.1 $\times 10^{-4}$ SLUGS
NOSE SHAPE - HEMISPHERE

α = ~

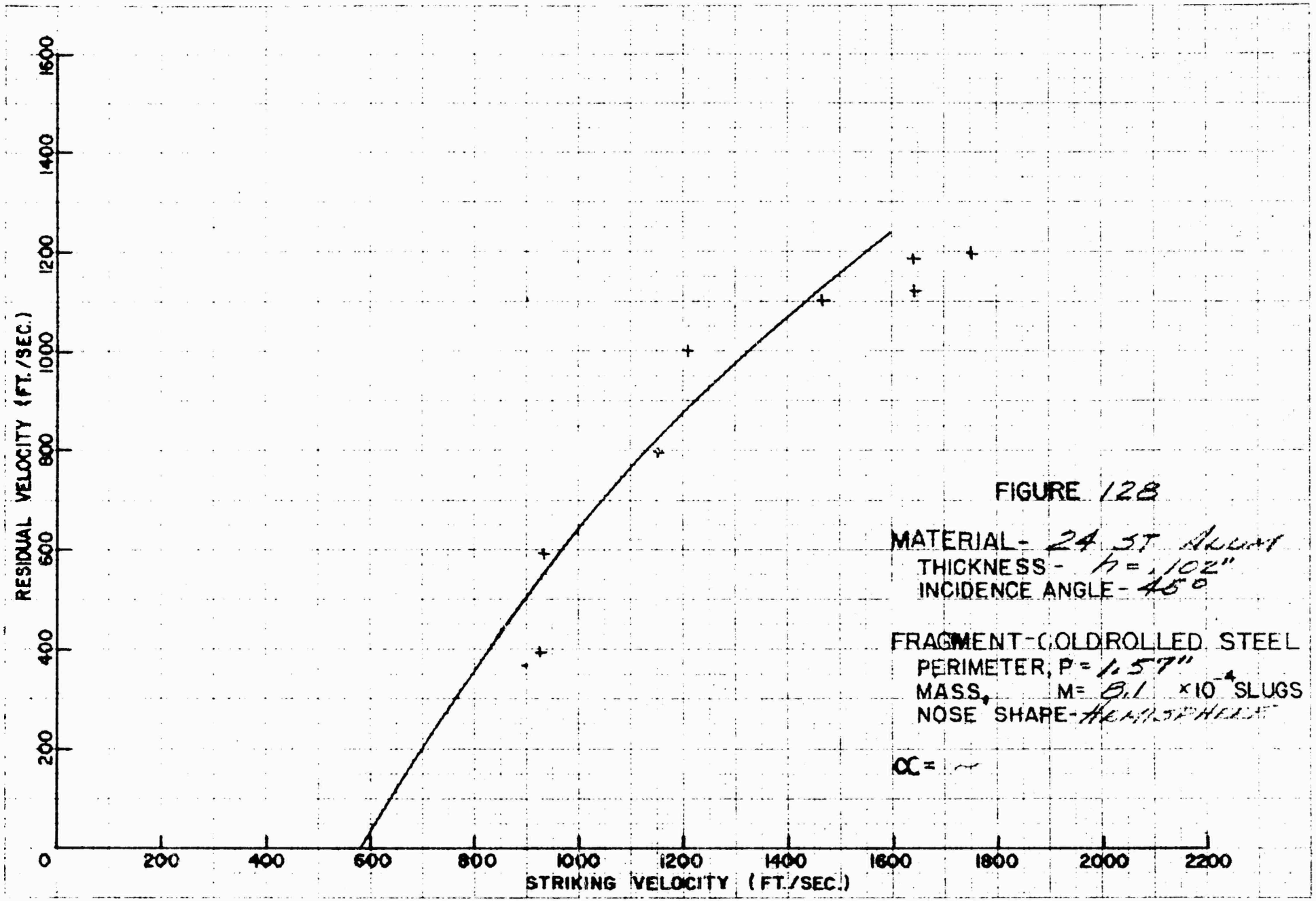
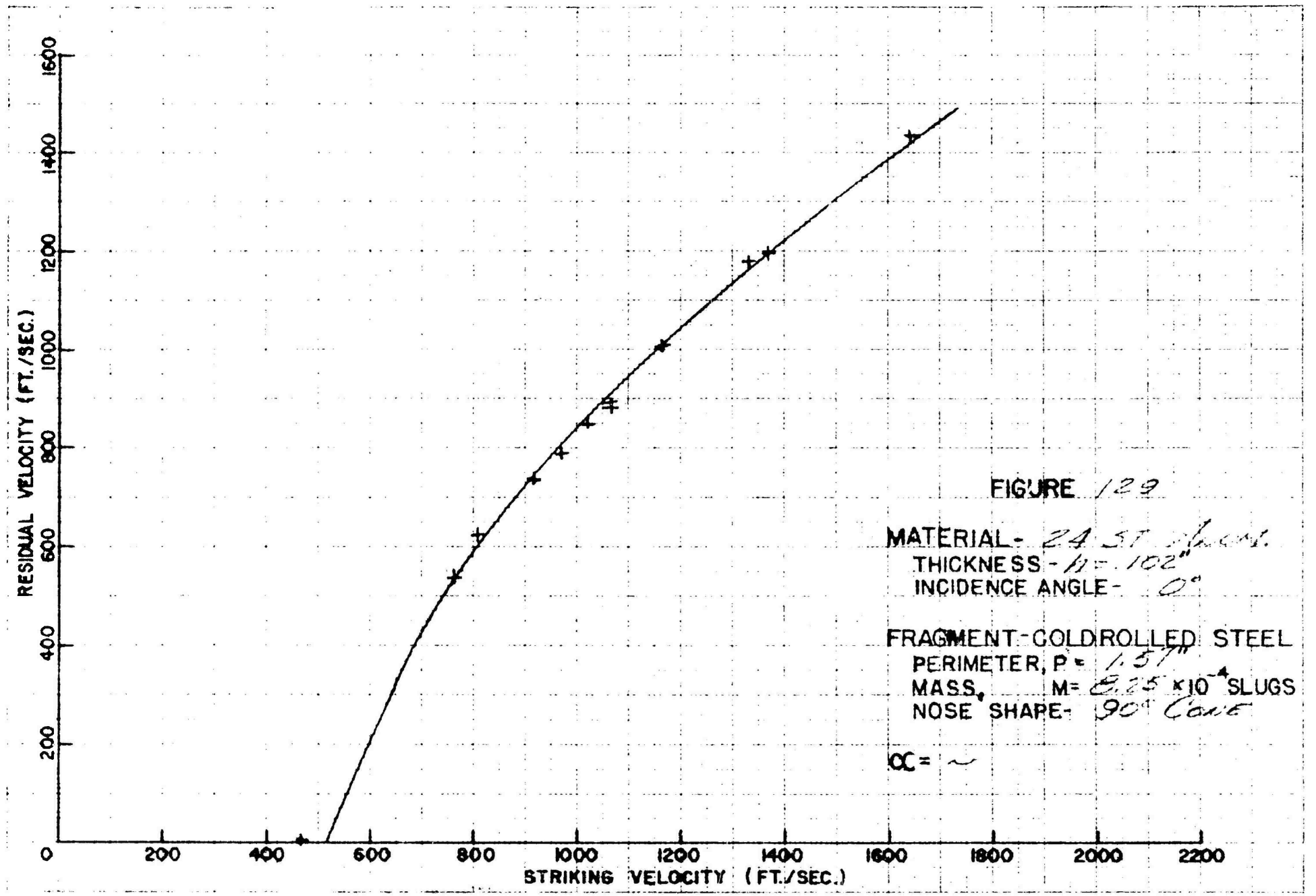


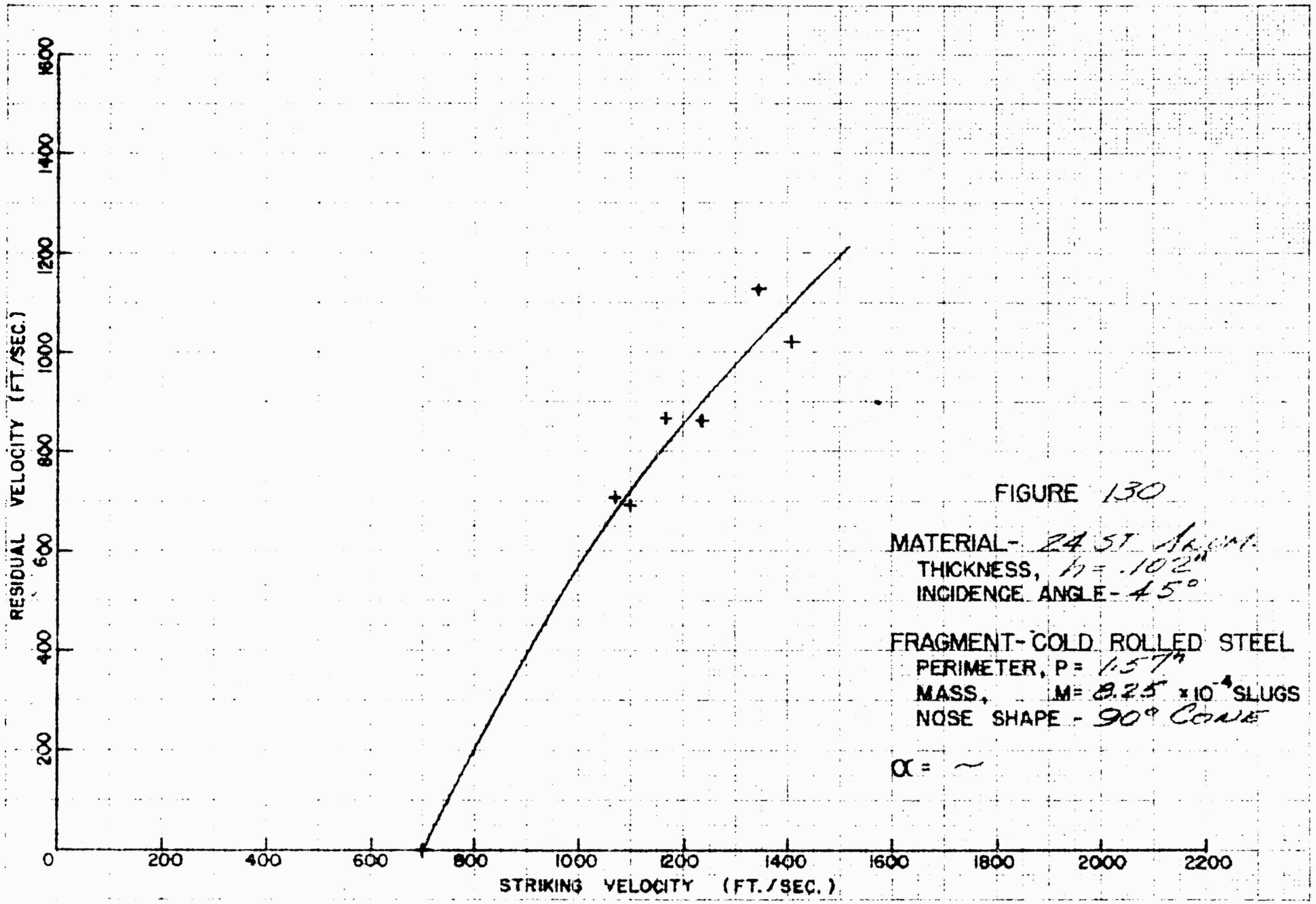
FIGURE 128

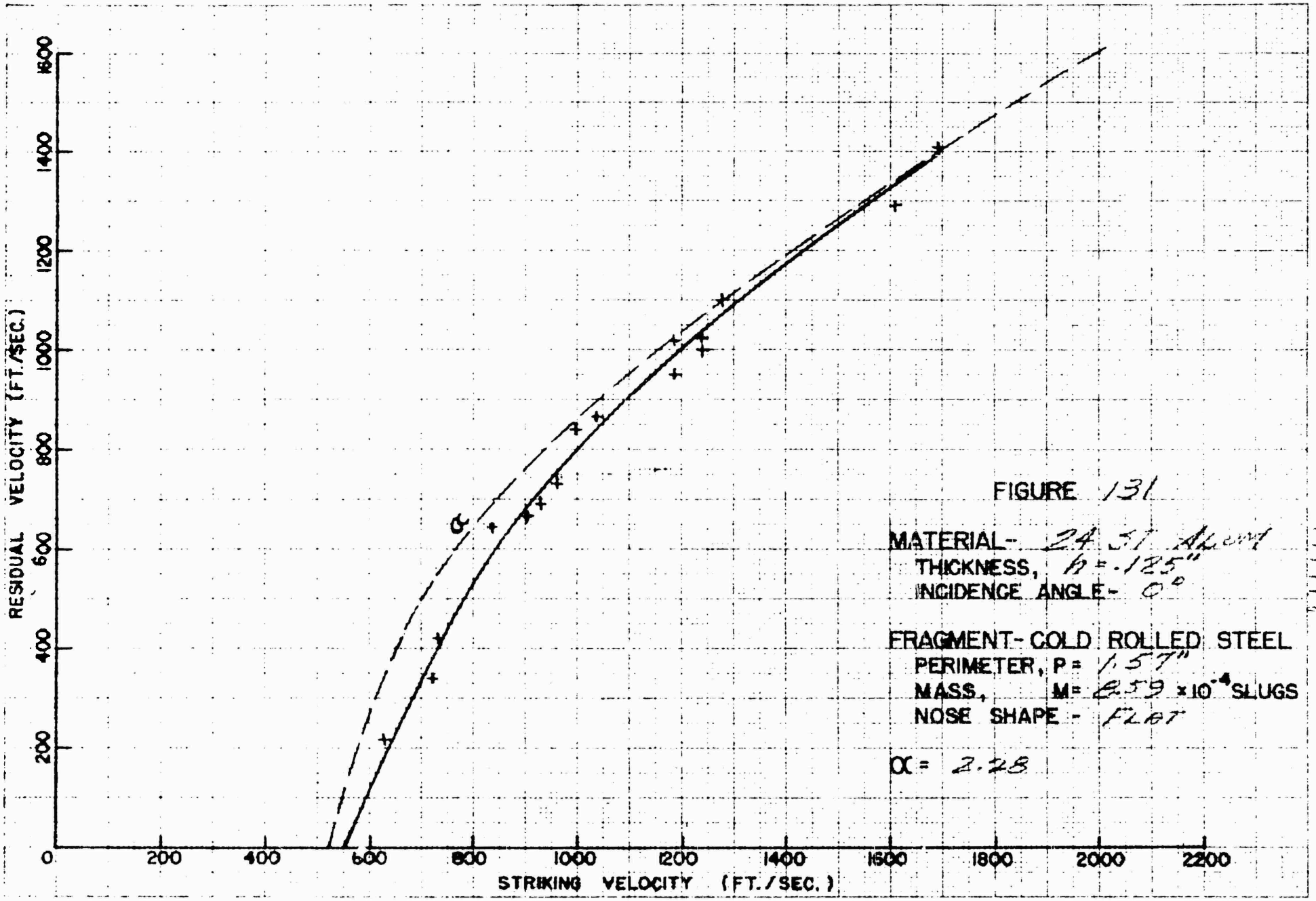
MATERIAL - 24 ST ALCLAD
THICKNESS - h = .102"
INCIDENCE ANGLE - 45°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 8.1 $\times 10^{-4}$ SLUGS
NOSE SHAPE - HEMISPHERICAL

OC = ~


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 129
MATERIAL- 24 ST Alcad.
THICKNESS - h = .102"
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.51"
MASS, M = 6.25 x 10⁻⁴ SLUGS
NOSE SHAPE - 90° Cone
OC = ~


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
STRIKING VELOCITY (FT./SEC.)
FIGURE 130
MATERIAL- 24ST Alclad
THICKNESS, h = .102"
INCIDENCE ANGLE- 45°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 8.25 x 10⁻⁴ SLUGS
NOSE SHAPE - 90° Cone
α = ~


RESIDUAL VELOCITY (FT./SEC.)
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STRIKING VELOCITY (FT./SEC.)
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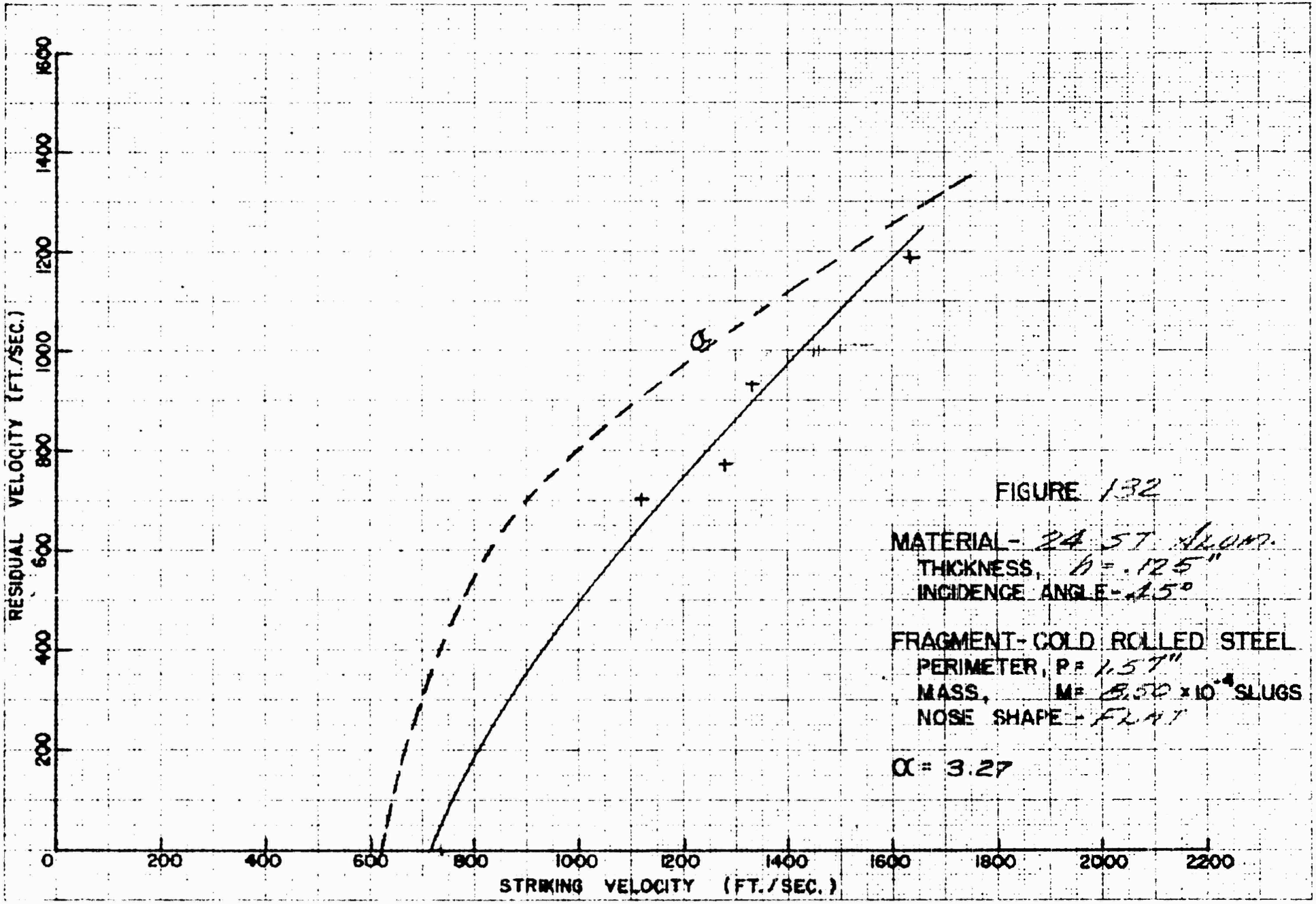
1000
1200
1400
1600
1800
2000
2200
α
FIGURE 131
MATERIAL- 24ST Alcad
THICKNESS, h = .125"
INCIDENCE ANGLE- 0°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 2.59 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 2.25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STRIKING VELOCITY (FT./SEC.)
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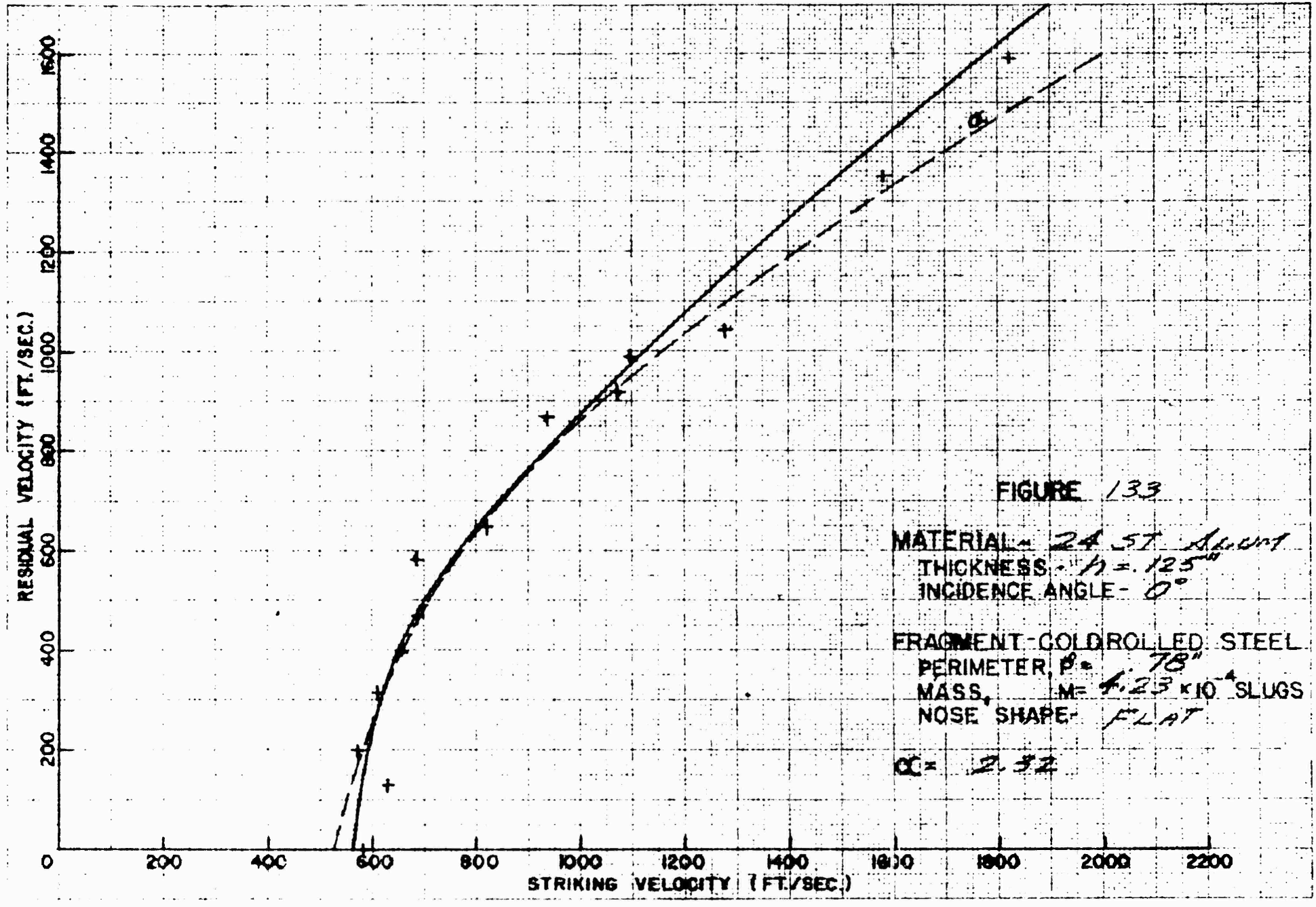
2200
FIGURE 132
MATERIAL- 24 ST Alcad.
THICKNESS, t = .125"
INCIDENCE ANGLE- 45°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 5.50 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 3.27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STRIKING VELOCITY (FT./SEC.)
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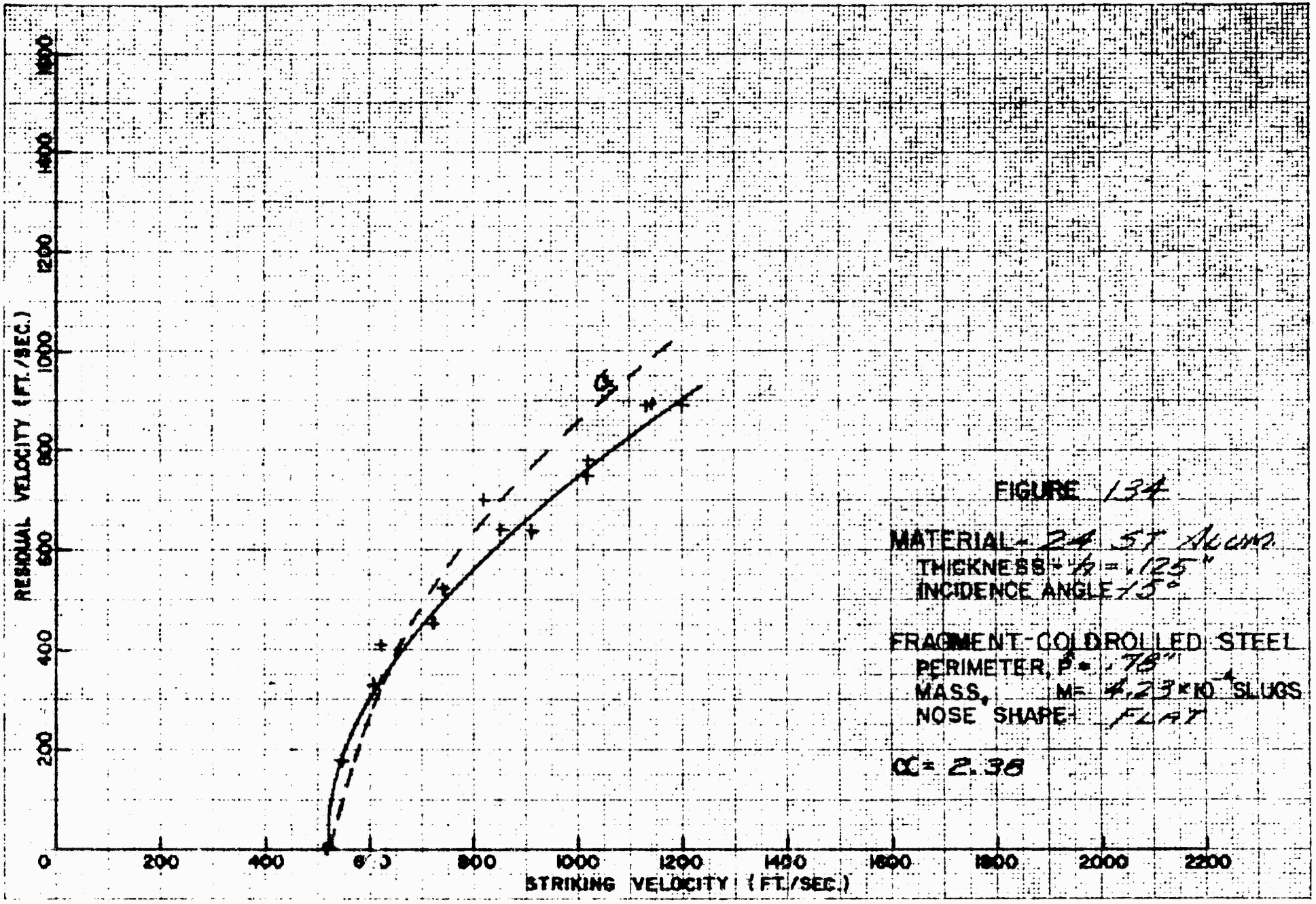
FIGURE 133
MATERIAL - 24 ST Alcad
THICKNESS - h = .125"
INCIDENCE ANGLE - 0°
FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 1.23 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
CC = 2.32


RESIDUAL VELOCITY (FT./SEC.)
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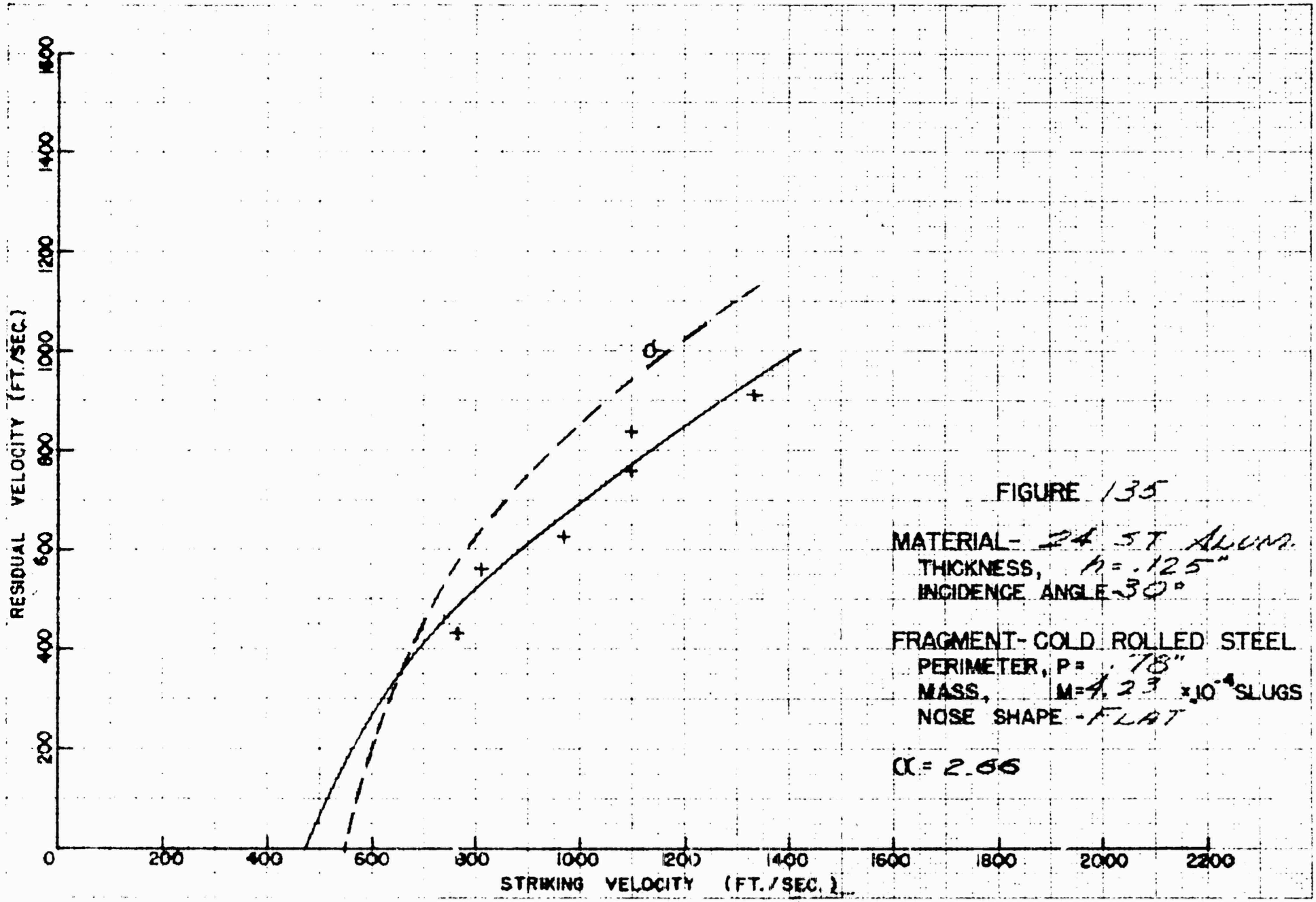
2200
STRIKING VELOCITY (FT./SEC.)
FIGURE 134
MATERIAL - 24 ST Alcad
THICKNESS - 1/8 = .125"
INCIDENCE ANGLE 45°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .75"
MASS, M = 4.23 * 10^-4 SLUGS
NOSE SHAPE - FLAT
CC = 2.38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STRIKING VELOCITY (FT./SEC.)
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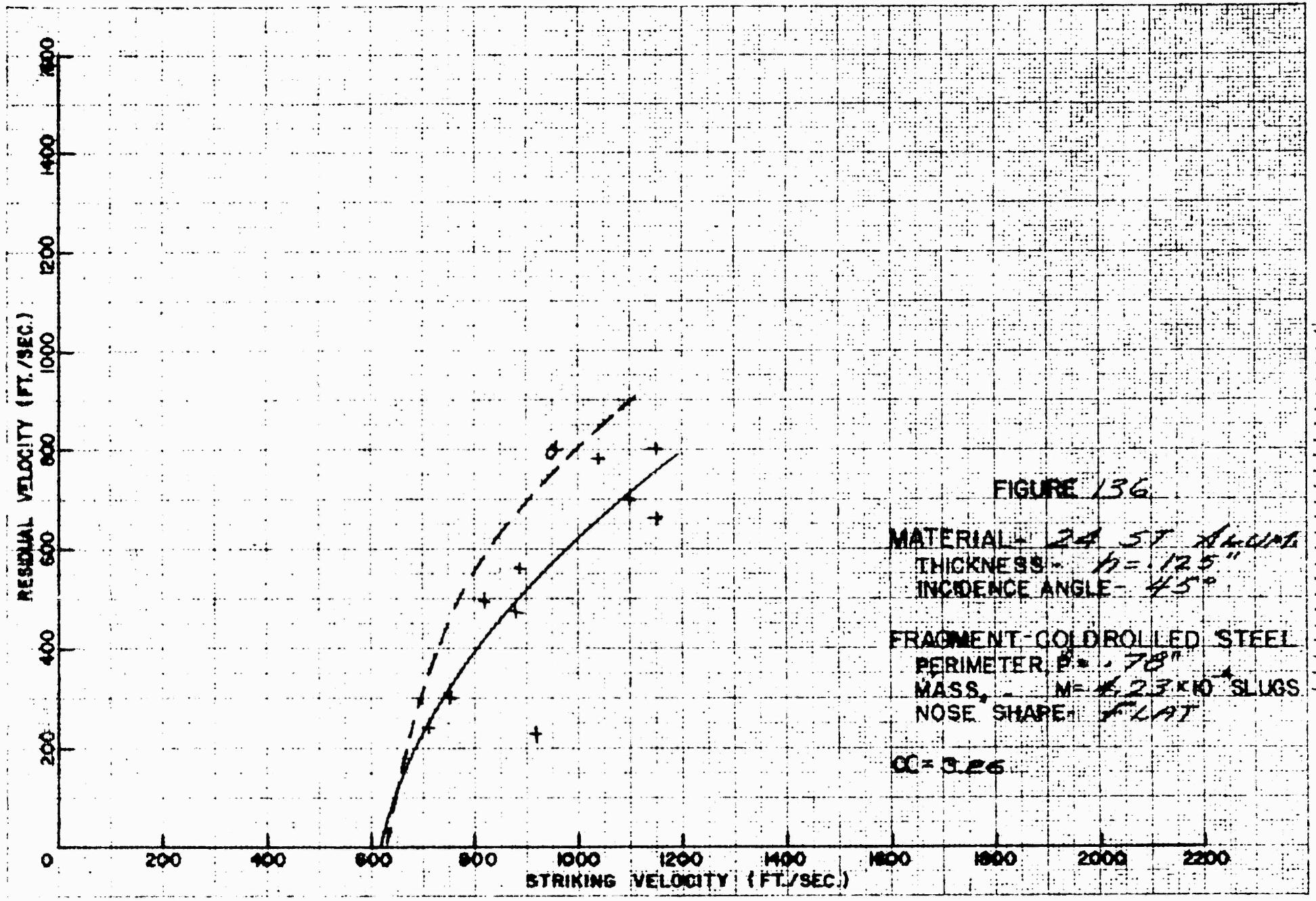
FIGURE 135
MATERIAL- 24 ST ALUM.
THICKNESS, h = .125"
INCIDENCE ANGLE-30°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M=1.23 x10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 2.66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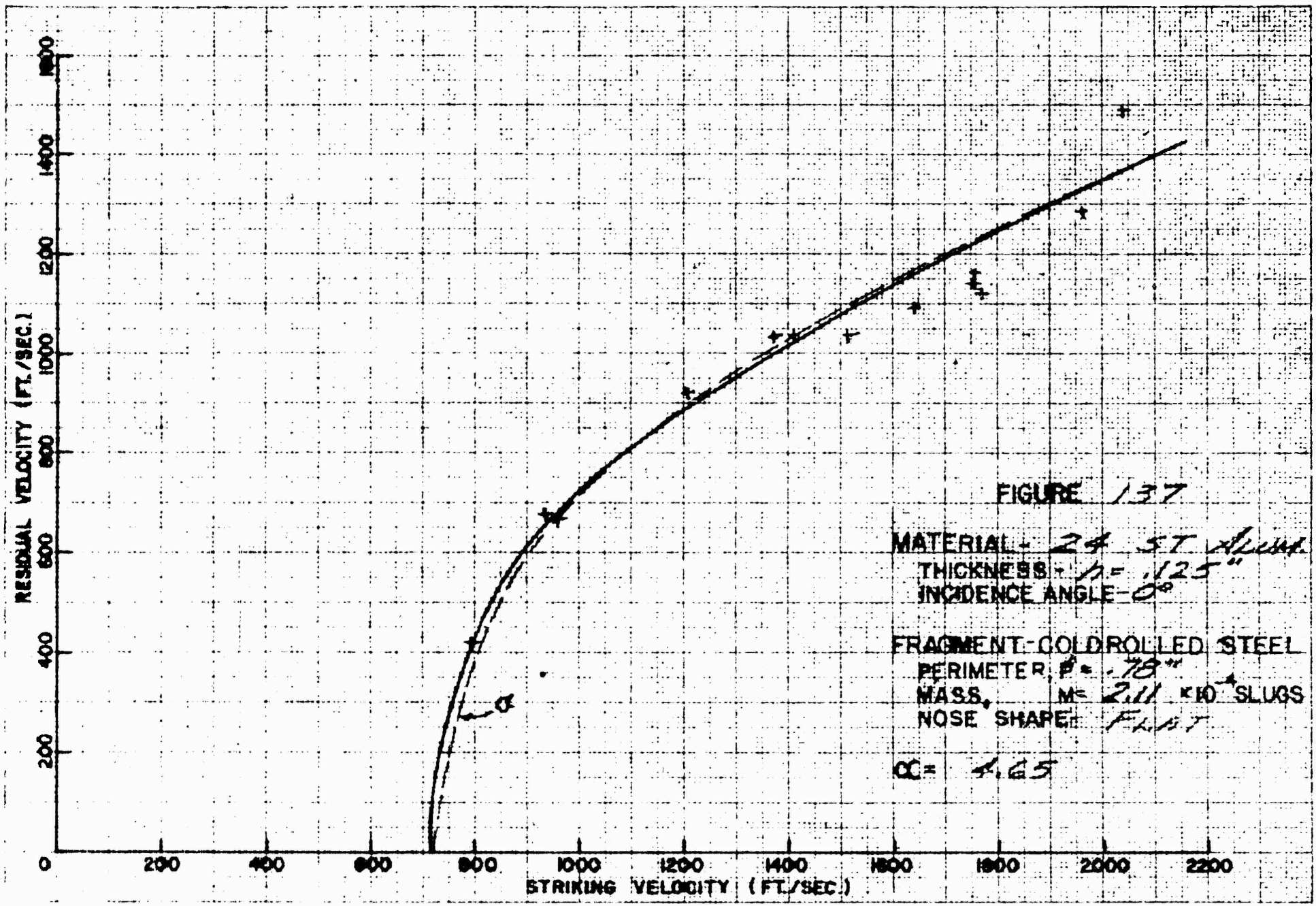
1400
1600
STRIKING VELOCITY (FT./SEC.)
1800
2000
2200
FIGURE 136
MATERIAL- 24 ST ALCLAD
THICKNESS- h=.125"
INCIDENCE ANGLE- 45°
FRAGMENT-COLDROLLED STEEL
PERIMETER, P= .78"
MASS, M= 4.23*10⁻⁴ SLUGS
NOSE SHAPE- FLAT
CC= 3.26


RESIDUAL VELOCITY (FT./SEC.)
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200
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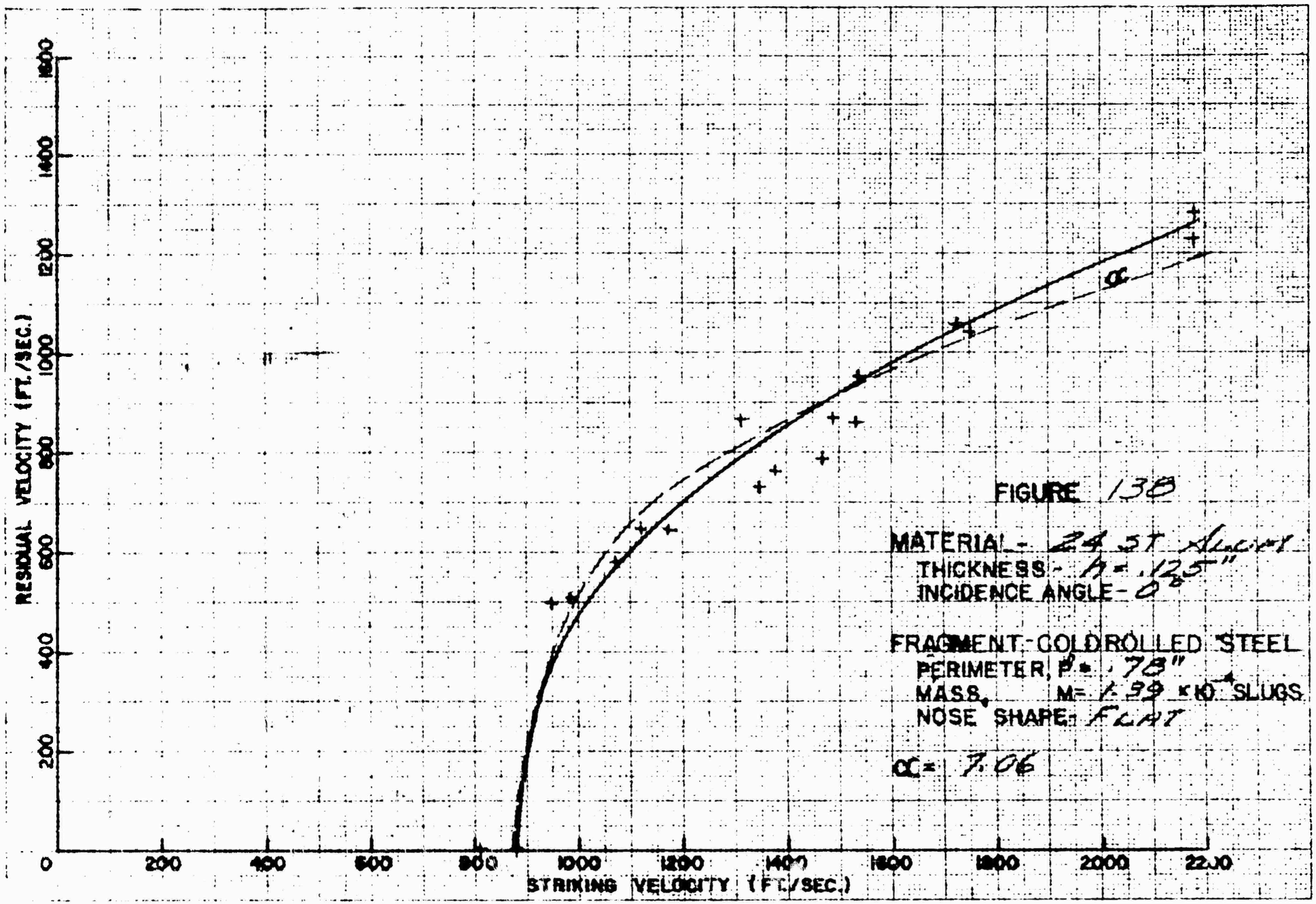
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
1800
2000
2200
FIGURE 137
MATERIAL - 24 ST Alclad
THICKNESS - h = .125"
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 2.11 ×10⁻⁴ SLUGS
NOSE SHAPE - FLAT
CC = 4.65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1600
STRIKING VELOCITY (FT./SEC.)
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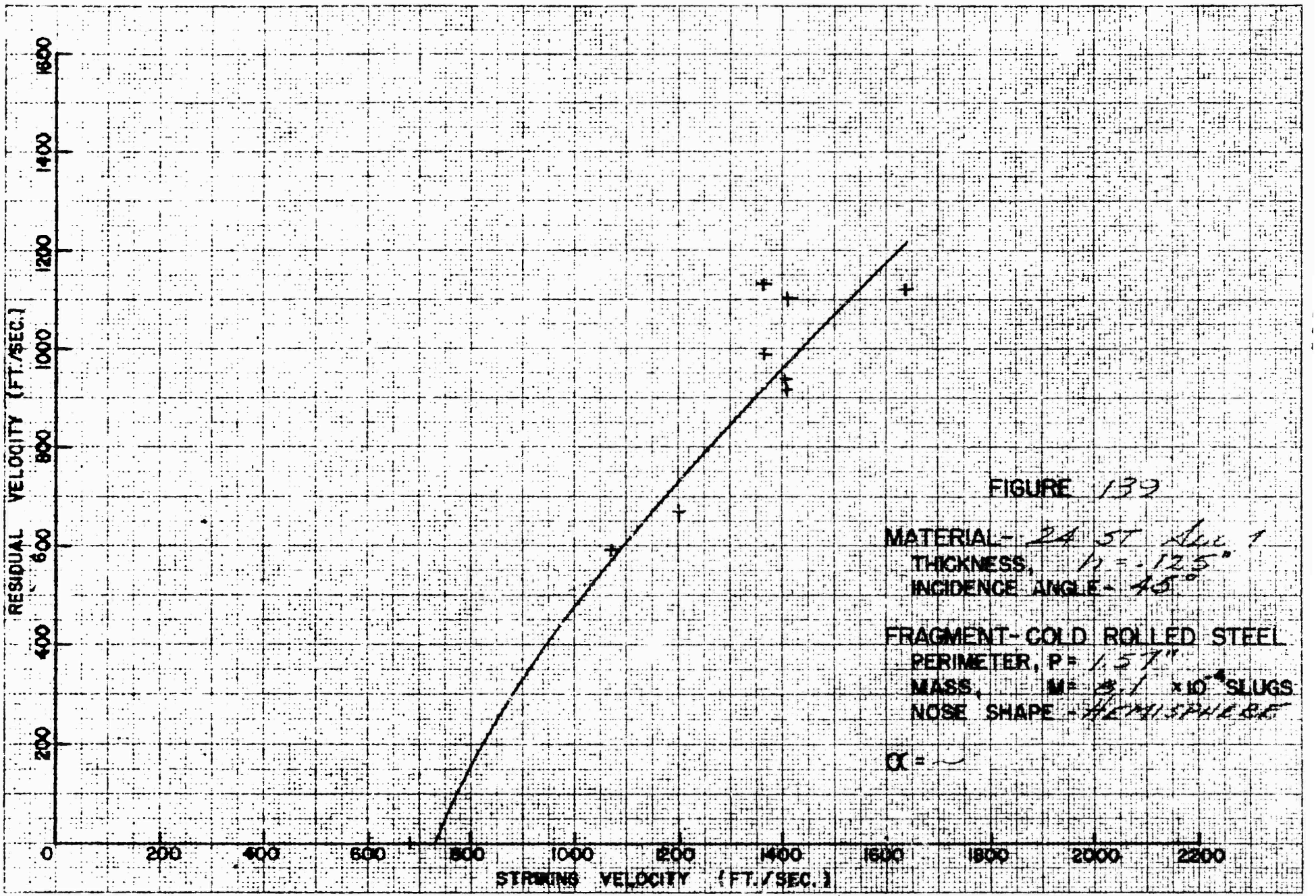
2200
FIGURE 138
MATERIAL - 24ST Alclad
THICKNESS - h = .125"
INCIDENCE ANGLE - 0°
FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 1.99 x 10⁻⁴ SLUGS
NOSE SHAPE: FLAT
α = 7.06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STRIKING VELOCITY (FT./SEC.)
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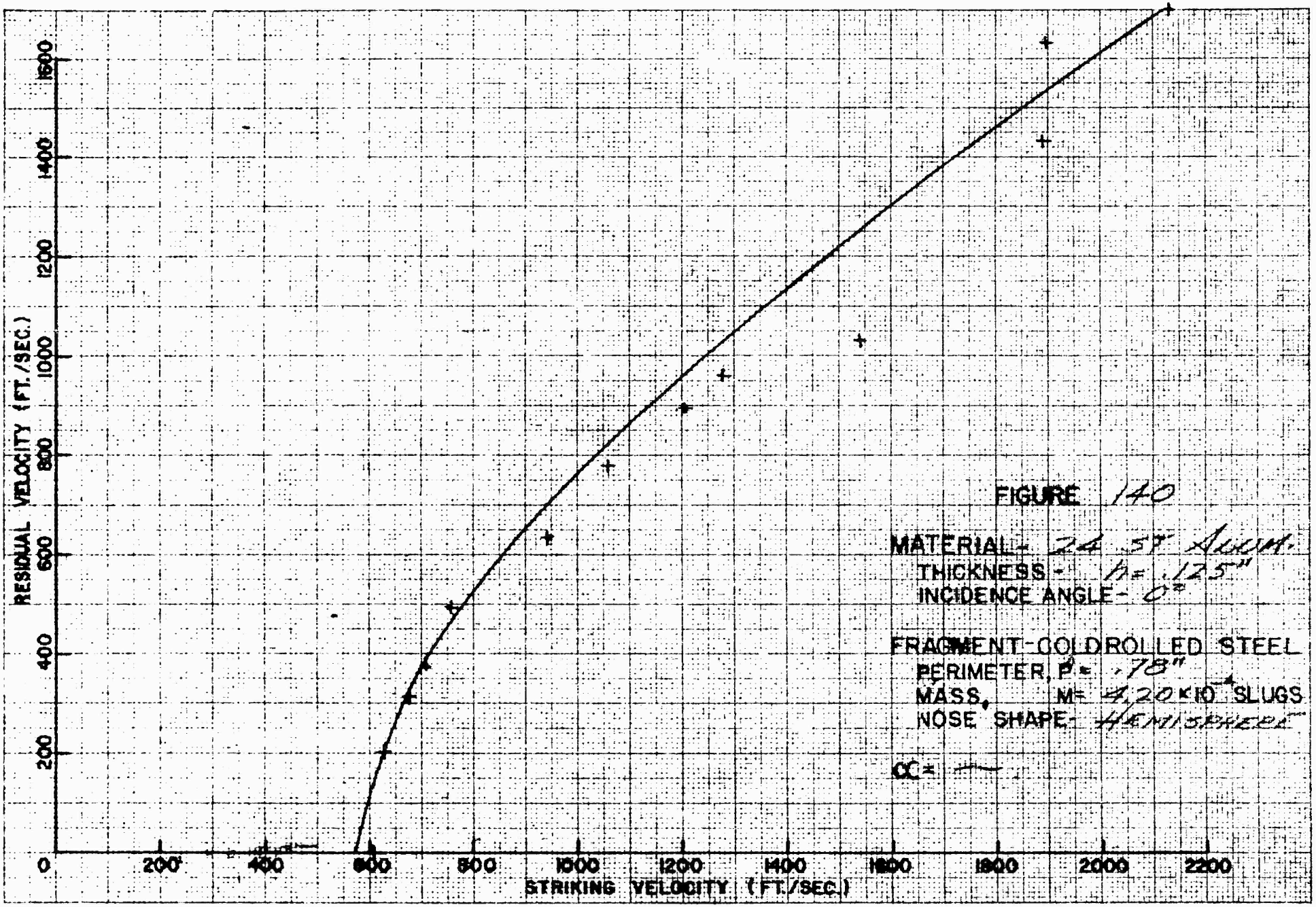
FIGURE 139
MATERIAL- 24 ST Alc. 1
THICKNESS, h = .125"
INCIDENCE ANGLE- 45°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 8.1 x 10⁻⁴ SLUGS
NOSE SHAPE - HEMISPHERICAL
α = —

RESTRICTED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1400
1600
STRIKING VELOCITY (FT./SEC.)
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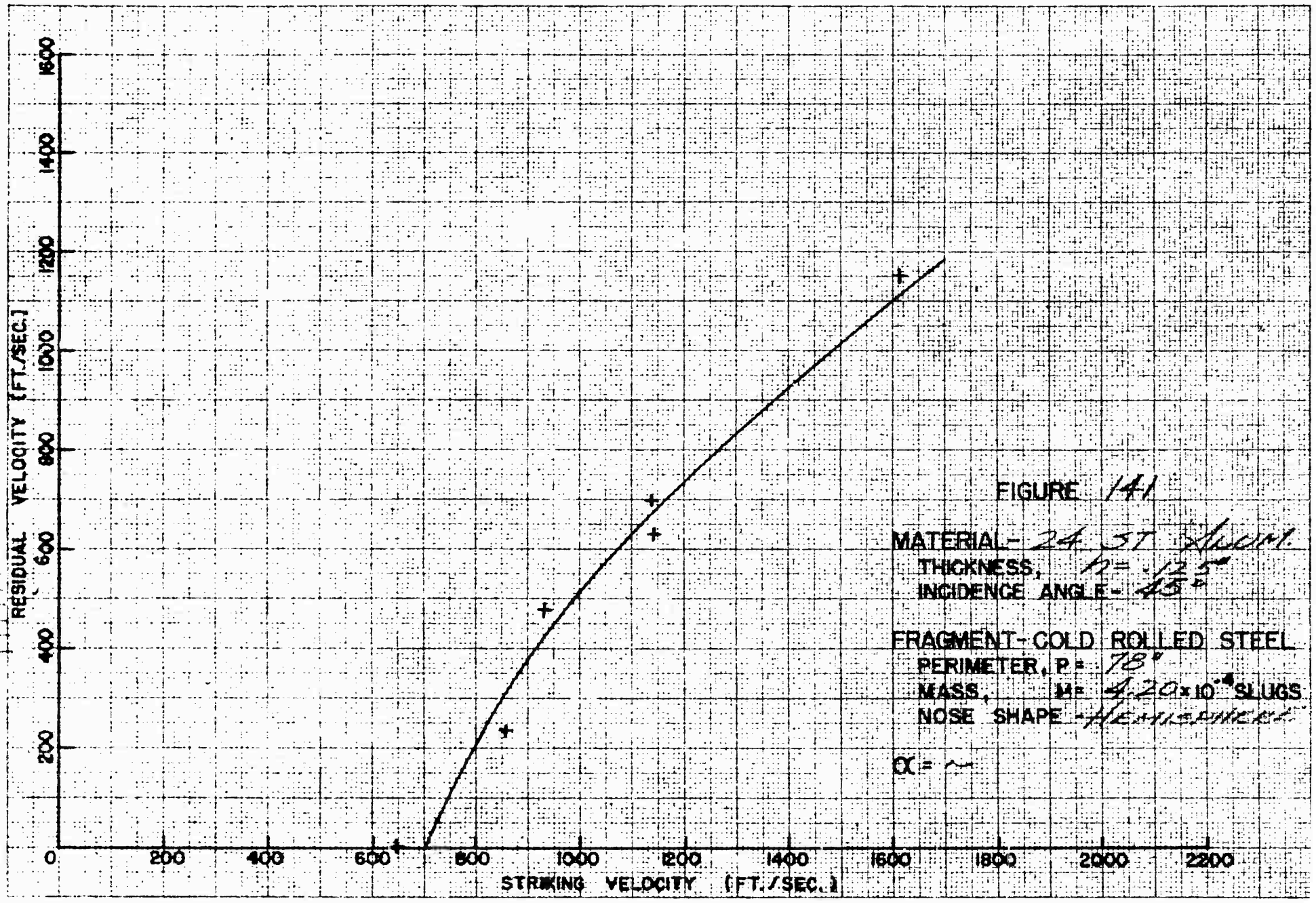
2200
FIGURE 140
MATERIAL- 24 ST ALUM.
THICKNESS - h= .125"
INCIDENCE ANGLE- 0°
FRAGMENT-COLDROLLED STEEL
PERIMETER, P= .78"
MASS, M= 4.20 x 10⁻⁴ SLUGS
NOSE SHAPE- HEMISPHERE
CC=


RESIDUAL VELOCITY (FT./SEC.)
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1600
STRIKING VELOCITY (FT./SEC.)
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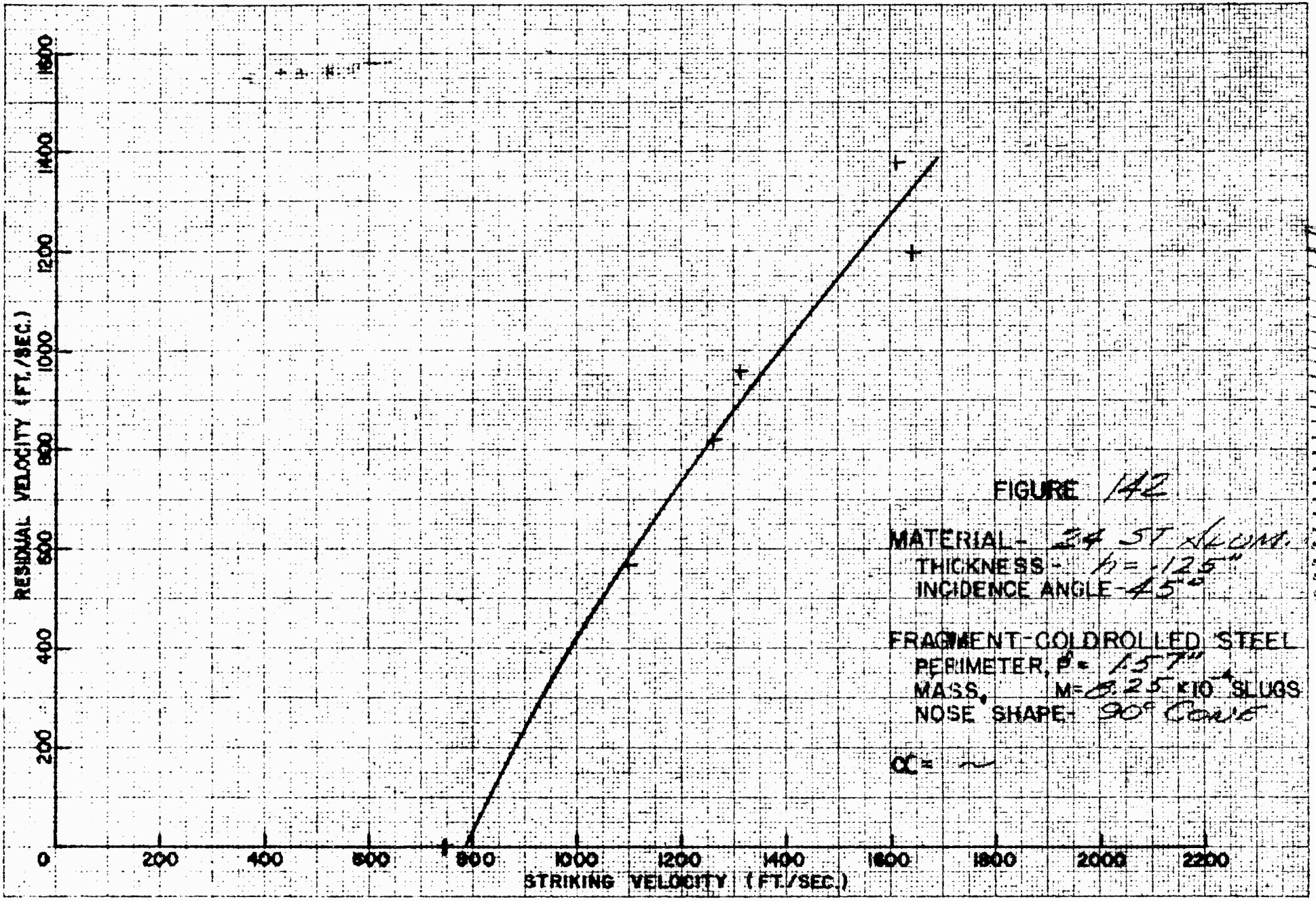
FIGURE 141
MATERIAL- 24 ST Alclad
THICKNESS, h= .125"
INCIDENCE ANGLE= 45°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P= .78"
MASS, M= 4.20x10⁻⁴ SLUGS
NOSE SHAPE- HEMISPHERICAL
α = ~


RESIDUAL VELOCITY (FT./SEC.)
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STRIKING VELOCITY (FT./SEC.)
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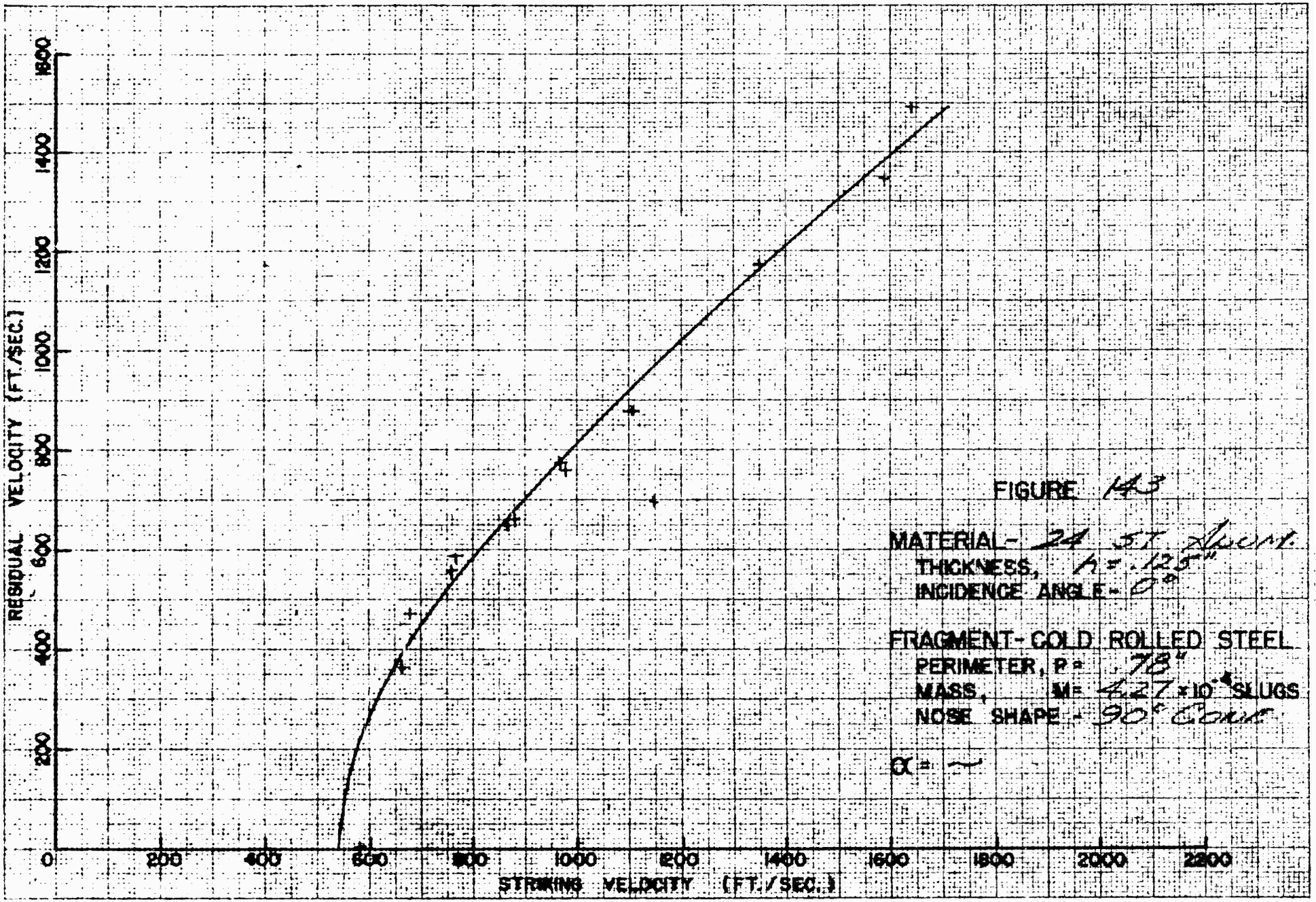
2200
FIGURE 142
MATERIAL- 24 ST Alcad.
THICKNESS - h = .125"
INCIDENCE ANGLE - 45°
FRAGMENT-COLDROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 6.25 x 10⁻⁴ SLUGS
NOSE SHAPE- 90° Cone
α = ~


RESIDUAL VELOCITY (FT./SEC.)
0
200
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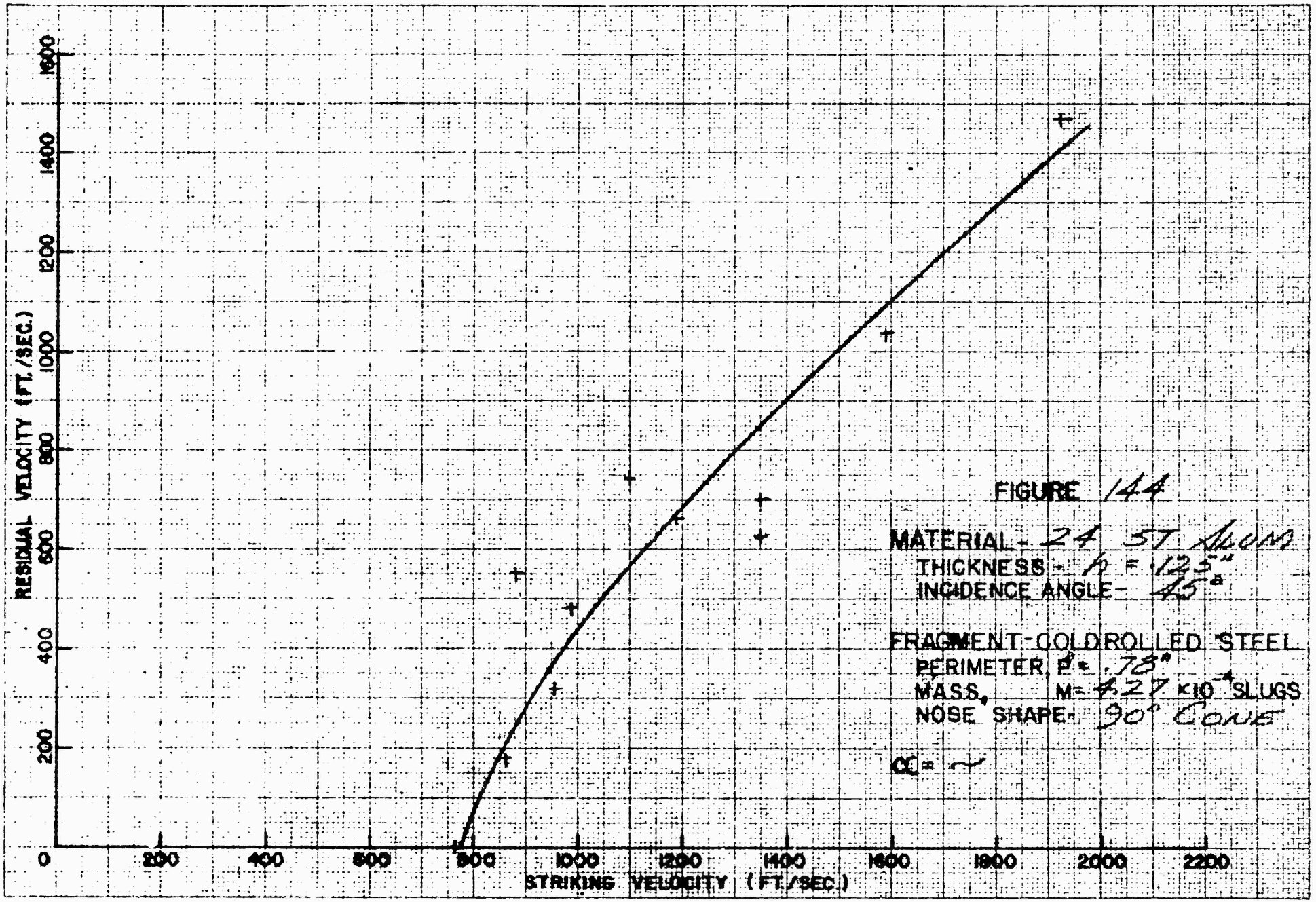
2200
STRIKING VELOCITY (FT./SEC.)
FIGURE 143
MATERIAL - 24 S.T. Alcad.
THICKNESS, h = .125"
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.27 x 10⁻⁴ SLUGS
NOSE SHAPE - 90° Cone
α = ~


RESIDUAL VELOCITY (FT./SEC.)
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1600
STRIKING VELOCITY (FT./SEC.)
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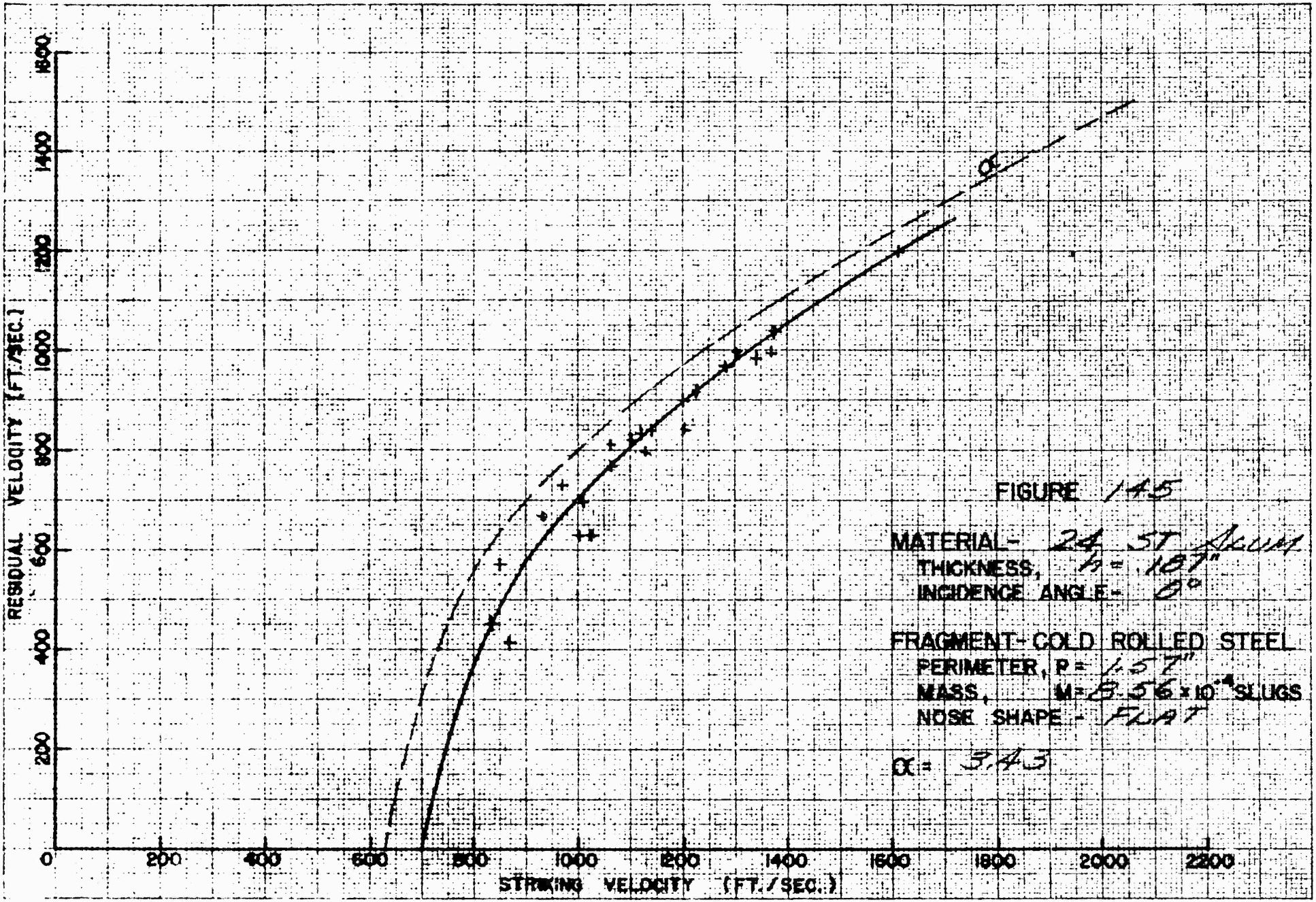
2200
FIGURE 144
MATERIAL - 24 ST Alum
THICKNESS - 1/2 & 1/4"
INCIDENCE ANGLE - 45°
FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.27 x10⁻⁴ SLUGS
NOSE SHAPE - 90° Cone
OE = +


RESIDUAL VELOCITY (FT./SEC.)
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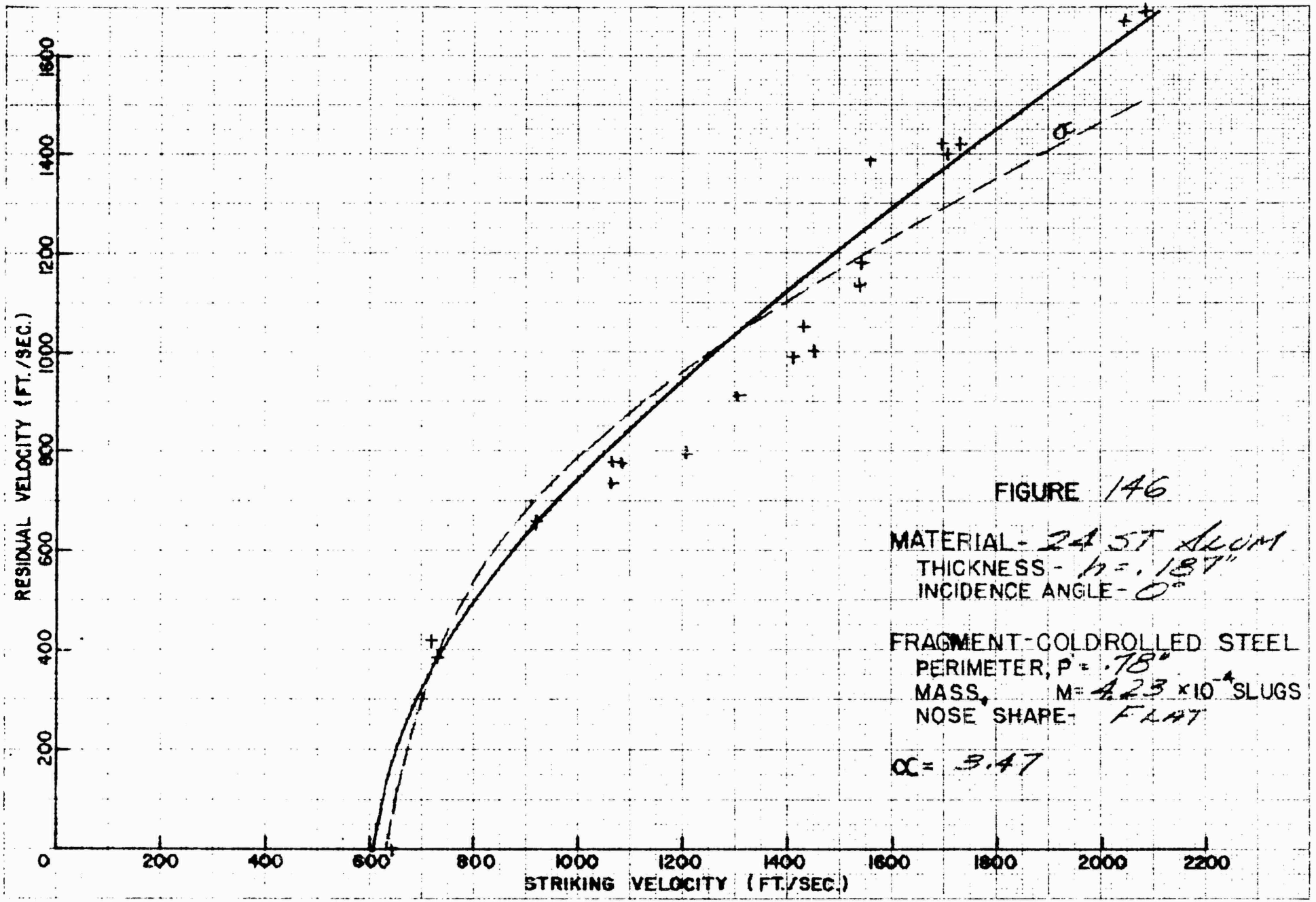
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
1800
2000
2200
FIGURE 145
MATERIAL - 24 ST Alclad
THICKNESS, h = .187"
INCIDENCE ANGLE - 0°
FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = 1.57"
MASS, M = 5.56 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 3.43


RESIDUAL VELOCITY (FT./SEC.)
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1600
STRIKING VELOCITY (FT./SEC.)
0
200
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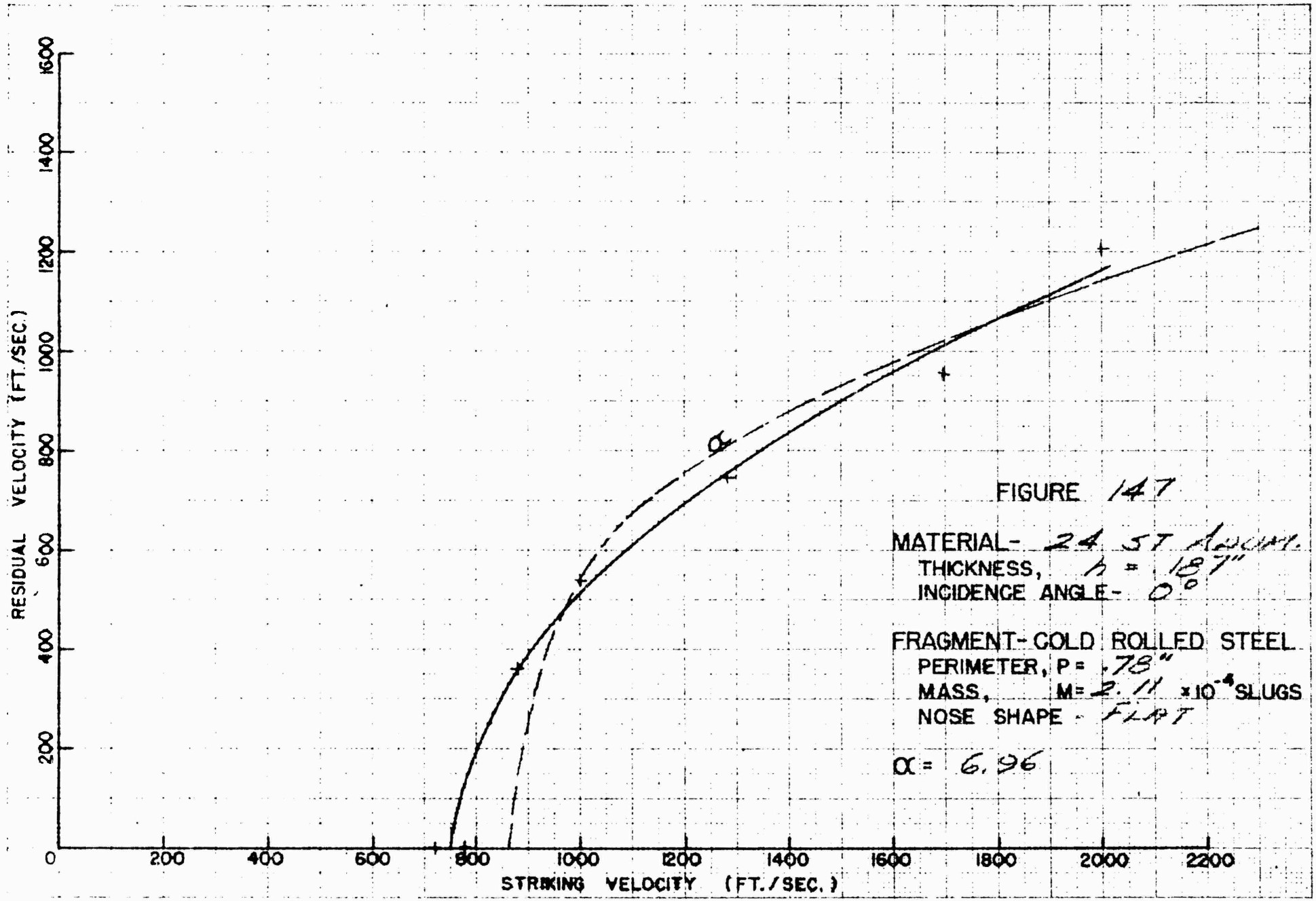
2000
2200
FIGURE 146
MATERIAL- 24 ST ALCLAD
THICKNESS - h = .187"
INCIDENCE ANGLE - 0°
FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
OC = 3.47


RESIDUAL VELOCITY (FT./SEC.)
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1600
STRIKING VELOCITY (FT./SEC.)
200
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600
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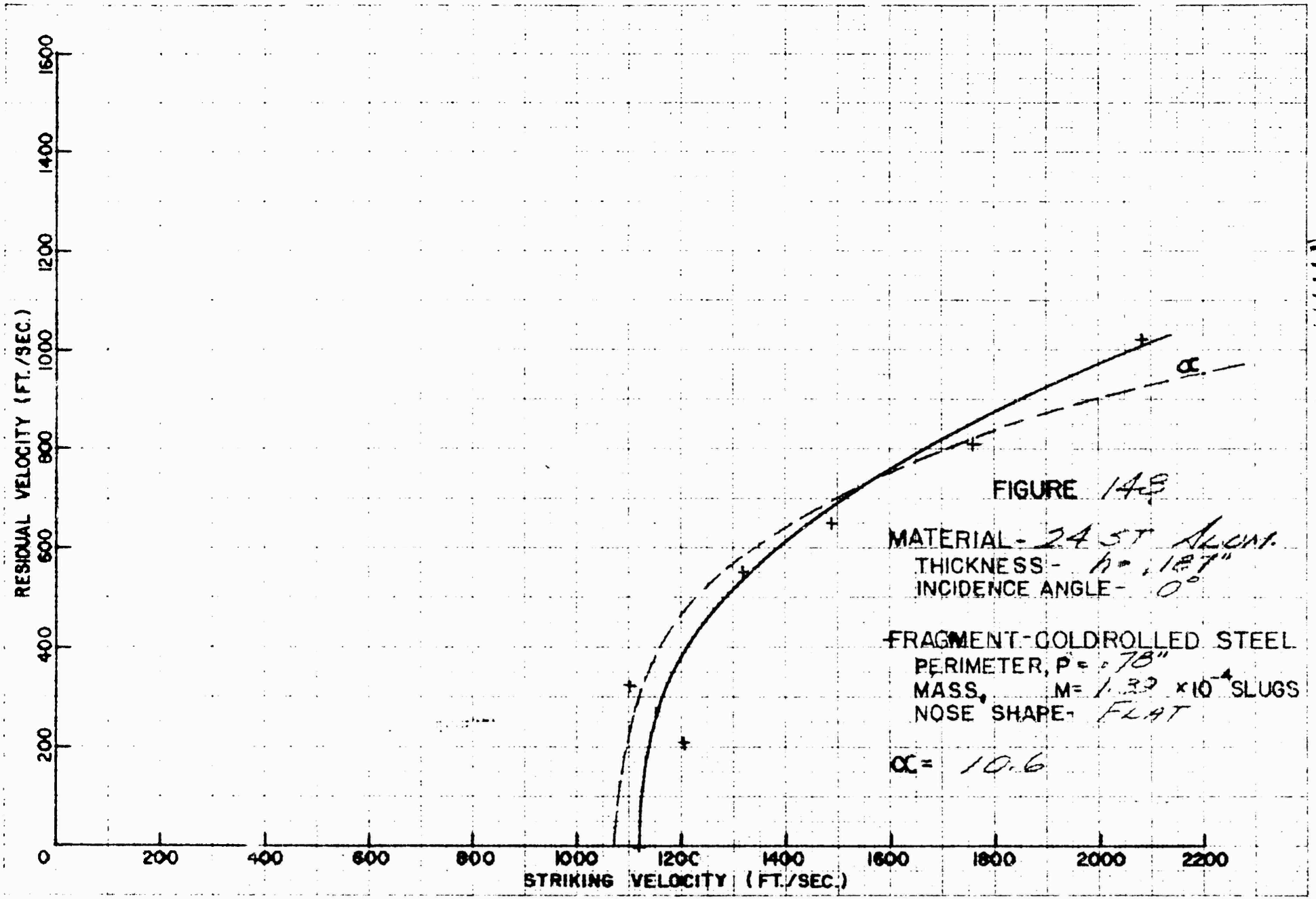
1200
1400
1600
1800
2000
2200
FIGURE 147
MATERIAL- 24 ST ALCLAD
THICKNESS, h = .187"
INCIDENCE ANGLE- 0°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 2.11 x10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 6.96


RESIDUAL VELOCITY (FT./SEC.)
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1400
1600
STRIKING VELOCITY (FT./SEC.)
200
400
600
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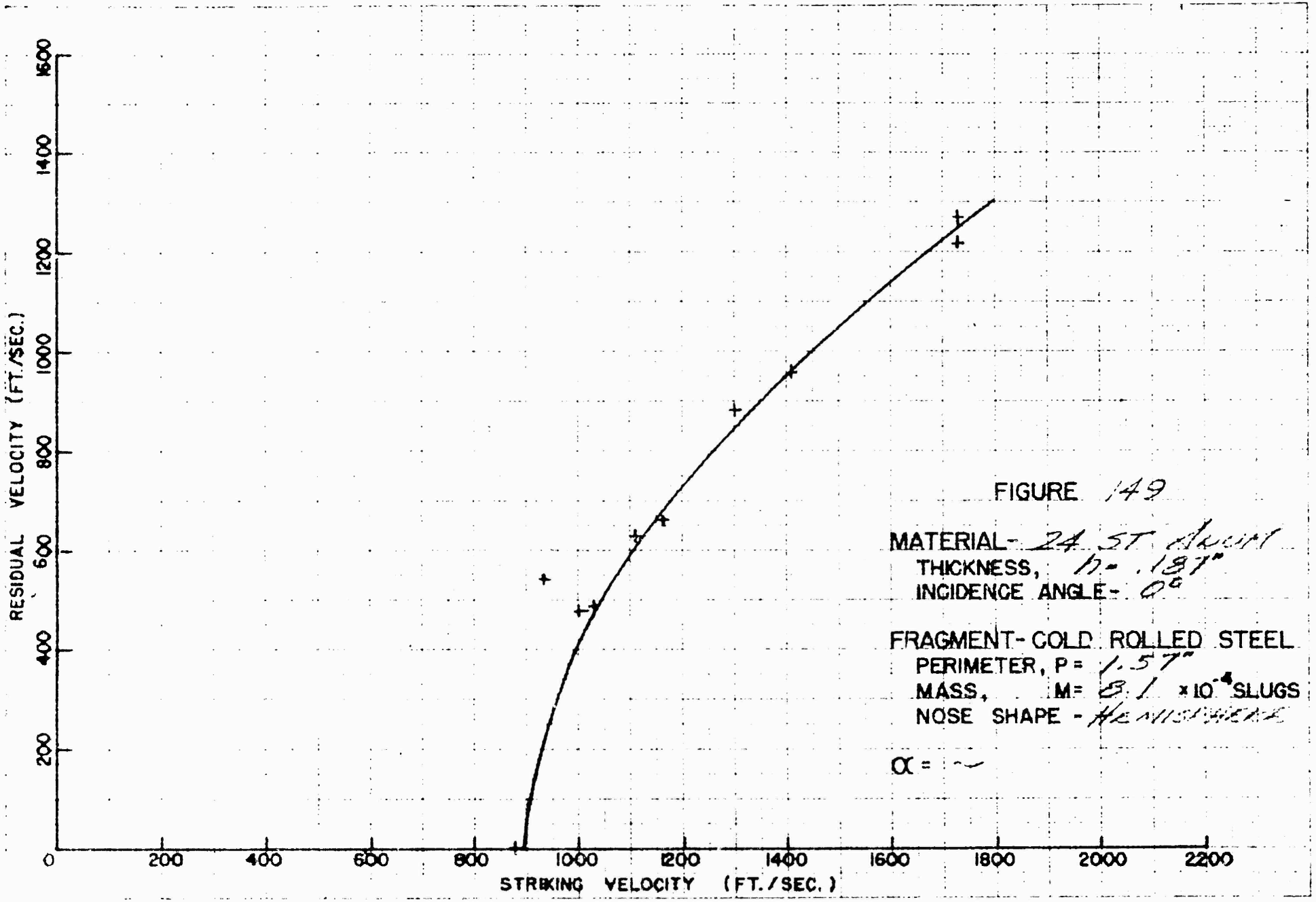
1000
1200
1400
1600
1800
2000
2200
α_c
FIGURE 145
MATERIAL - 24ST ALCLAD
THICKNESS - h = .187"
INCIDENCE ANGLE - 0°
FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 1.33 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α_c = 10.6


RESIDUAL VELOCITY (FT./SEC.)
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1400
1600
STRIKING VELOCITY (FT./SEC.)
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400
600
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1000
1200
1400
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2200
FIGURE 149
MATERIAL- 24 ST ALCLAD
THICKNESS, h= .191"
INCIDENCE ANGLE- 0°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P= 1.57"
MASS, M= 8.1 x10⁻⁴ SLUGS
NOSE SHAPE - HEMISPHERE
α = ~

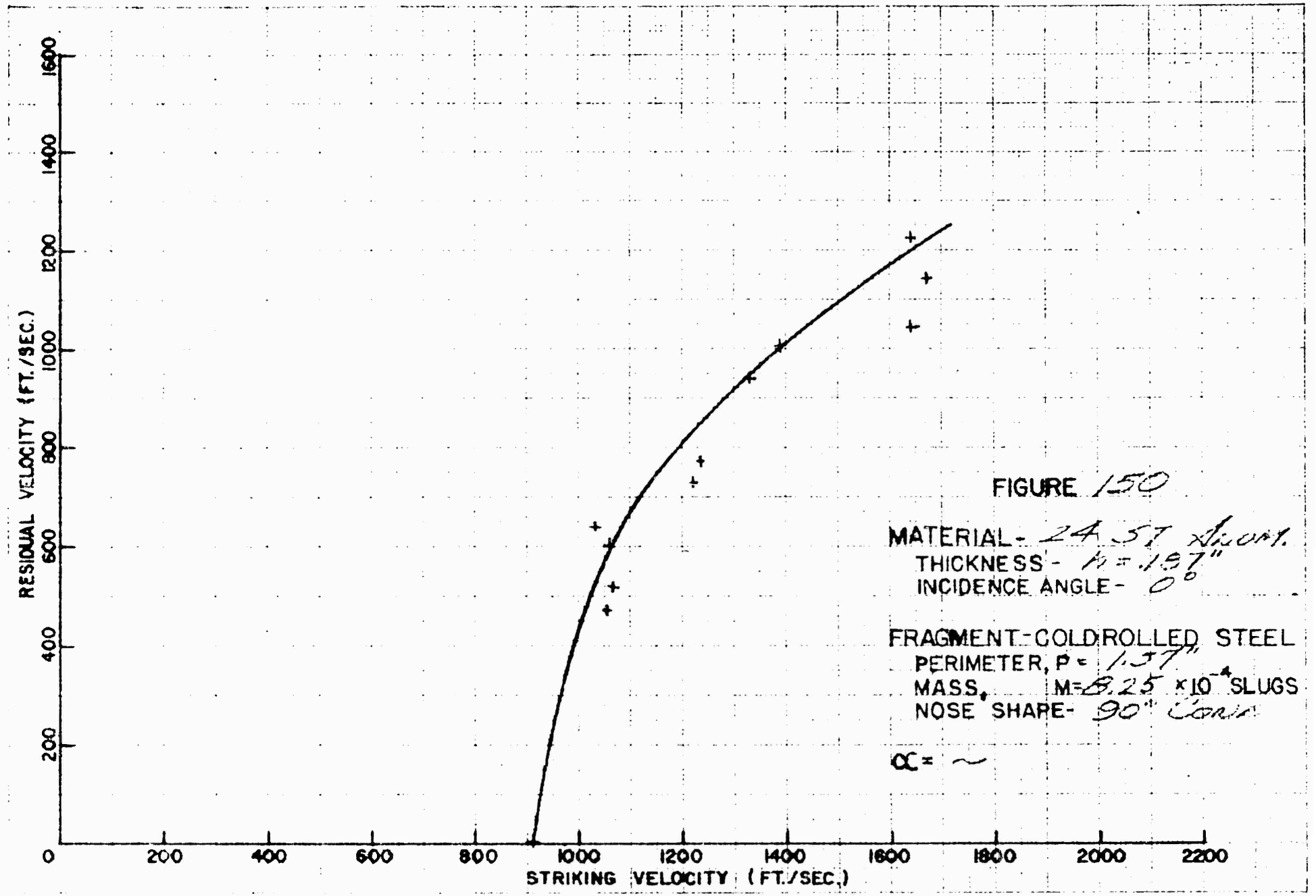


FIGURE 150

MATERIAL- 24ST Aluminum
THICKNESS- h = .197"
INCIDENCE ANGLE- 0°

FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = 1.37"
MASS, M = 8.25 × 10^{-4} SLUGS
NOSE SHAPE- 90° Cone

CC = ~

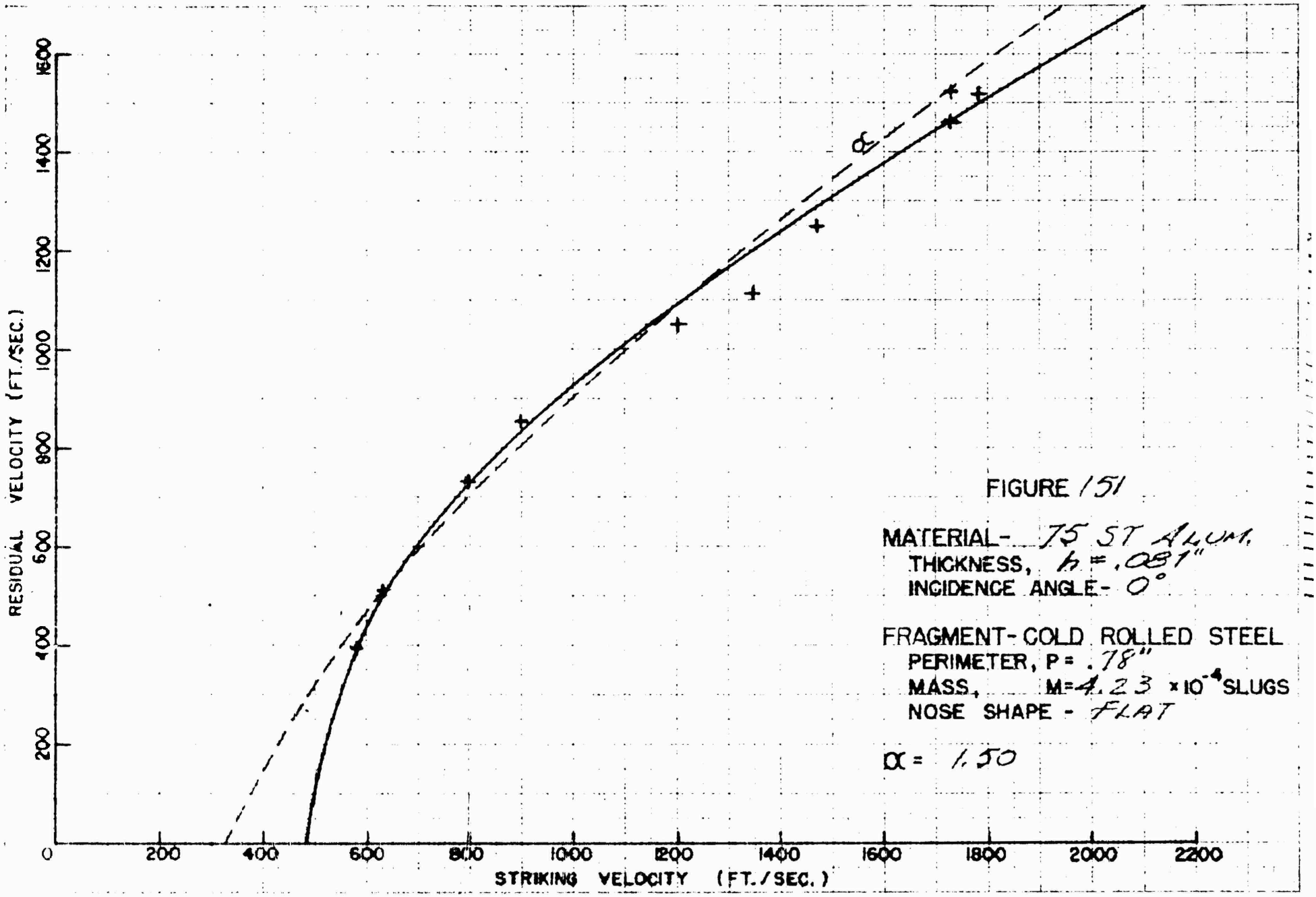


FIGURE 151

MATERIAL- 75 ST ALUM.
THICKNESS, $h = .081"$
INCIDENCE ANGLE- 0°

FRAGMENT- COLD ROLLED STEEL
PERIMETER, $P = .78"$
MASS, $M = 4.23 \times 10^{-4}$ SLUGS
NOSE SHAPE - FLAT

$\alpha = 1.50$

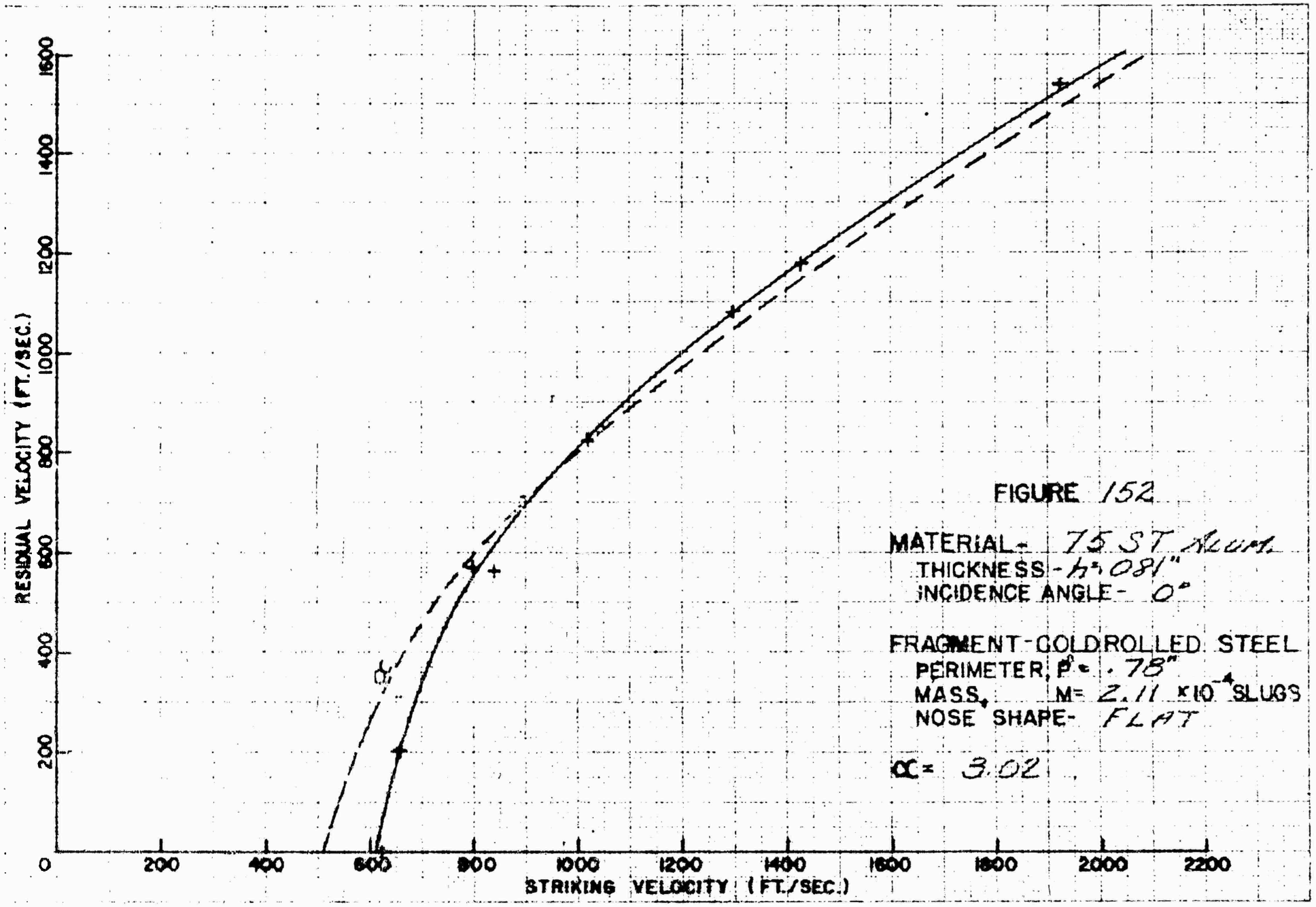
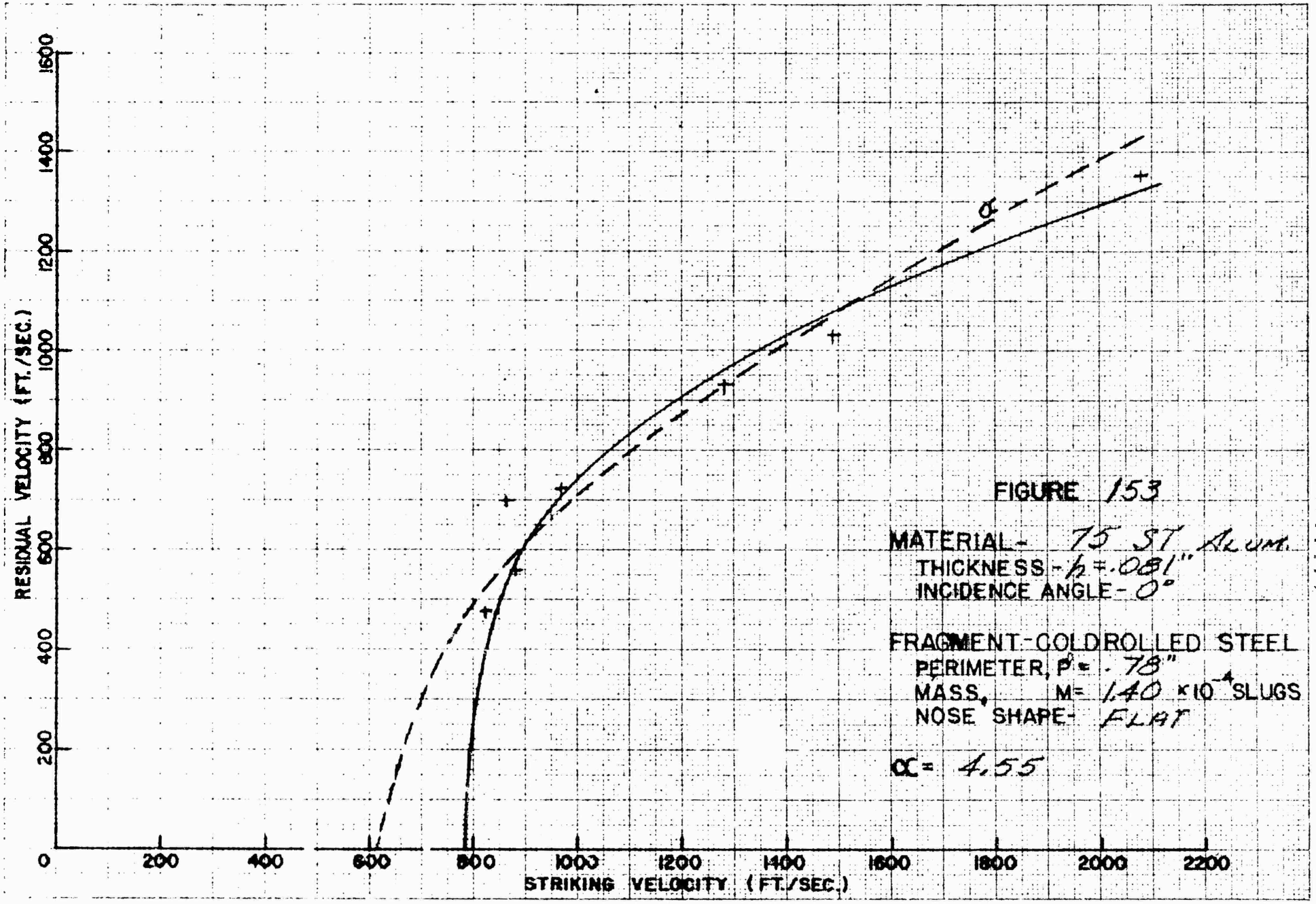


FIGURE 152

MATERIAL- 75ST Alum.
THICKNESS- h=.081"
INCIDENCE ANGLE- 0°

FRAGMENT- COLD ROLLED STEEL
PERIMETER, P= .78"
MASS, M= 2.11 $\times 10^{-4}$ SLUGS
NOSE SHAPE- FLAT

CC= 3.02


RESIDUAL VELOCITY (FT./SEC.)
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600
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1400
1600
STRIKING VELOCITY (FT./SEC.)
0
200
400
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1000
1200
1400
1600
1800
2000
2200
FIGURE 153
MATERIAL - 75 ST Alum.
THICKNESS - h = .081"
INCIDENCE ANGLE - 0°
FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 1.40 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 4.55

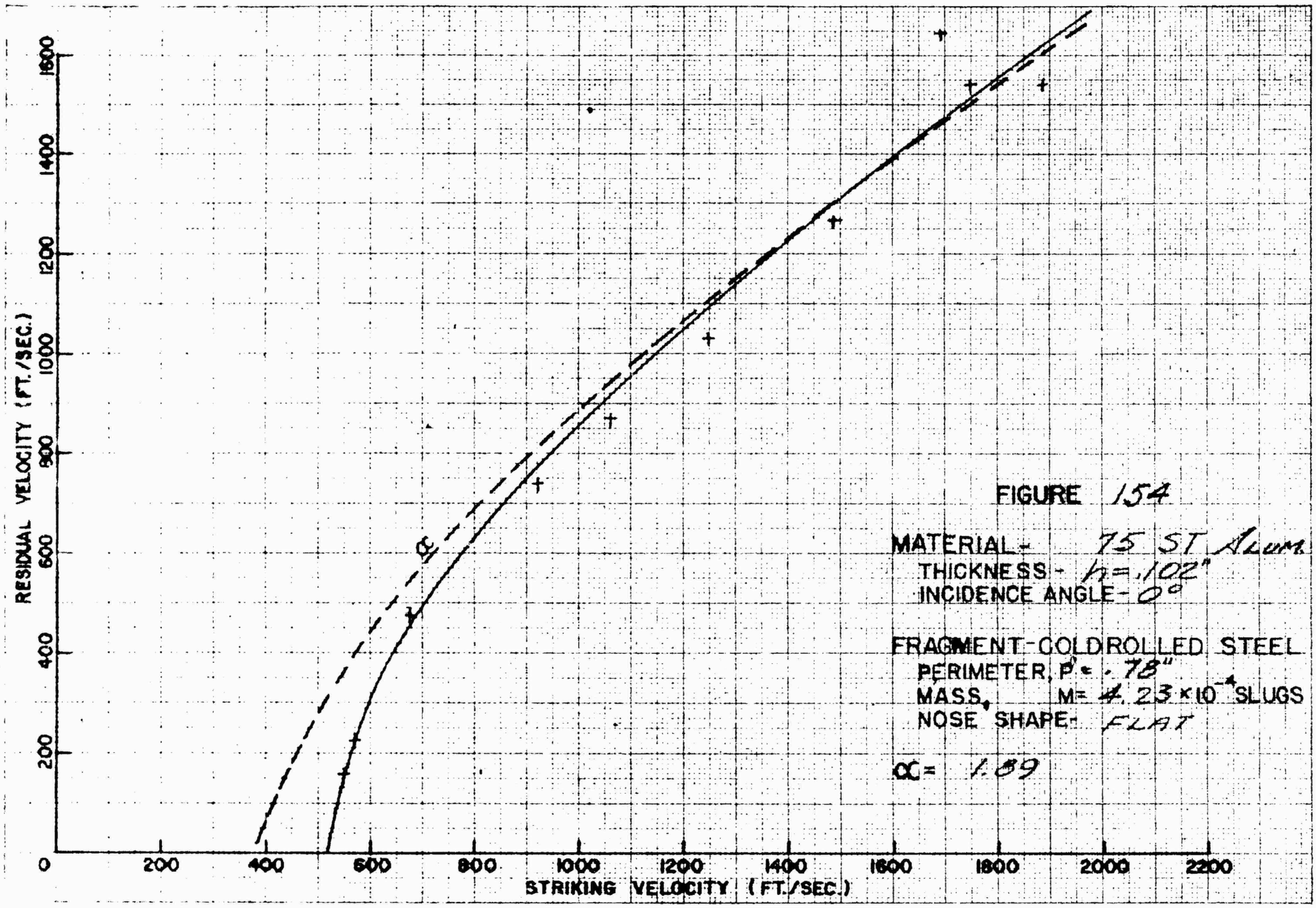
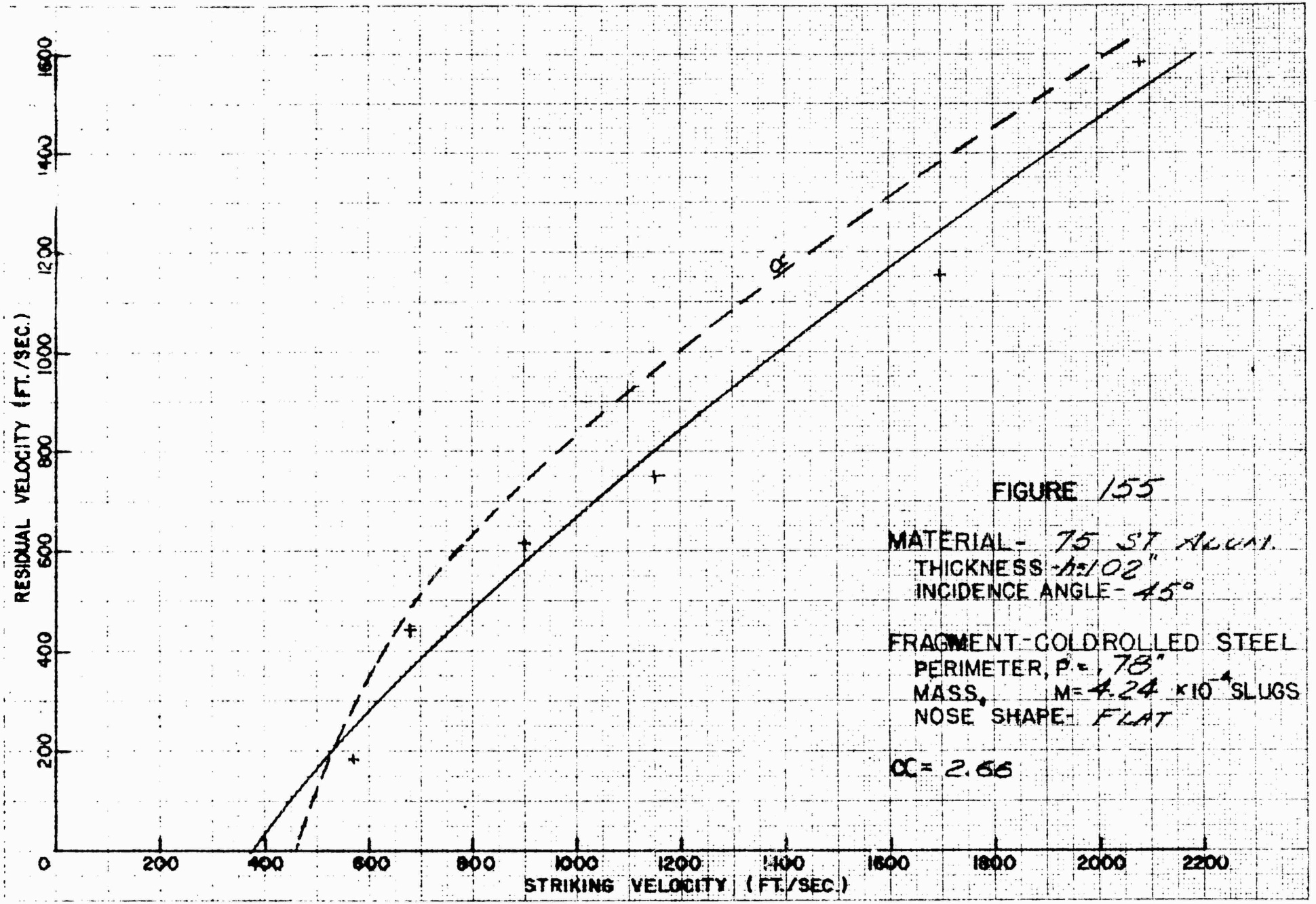


FIGURE 154

MATERIAL - 75 ST Alum.
THICKNESS - h=.102"
INCIDENCE ANGLE - 0°

FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 × 10⁻⁴ SLUGS
NOSE SHAPE - FLAT

α = 1.09


RESIDUAL VELOCITY (FT./SEC.)
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1400
1600
STRIKING VELOCITY (FT./SEC.)
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200
400
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2200
FIGURE 155
MATERIAL- 75 ST ALCLAD
THICKNESS- .102"
INCIDENCE ANGLE- 45°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P= .78"
MASS, M= 4.24 x10⁻⁴ SLUGS
NOSE SHAPE- FLAT
CC= 2.66

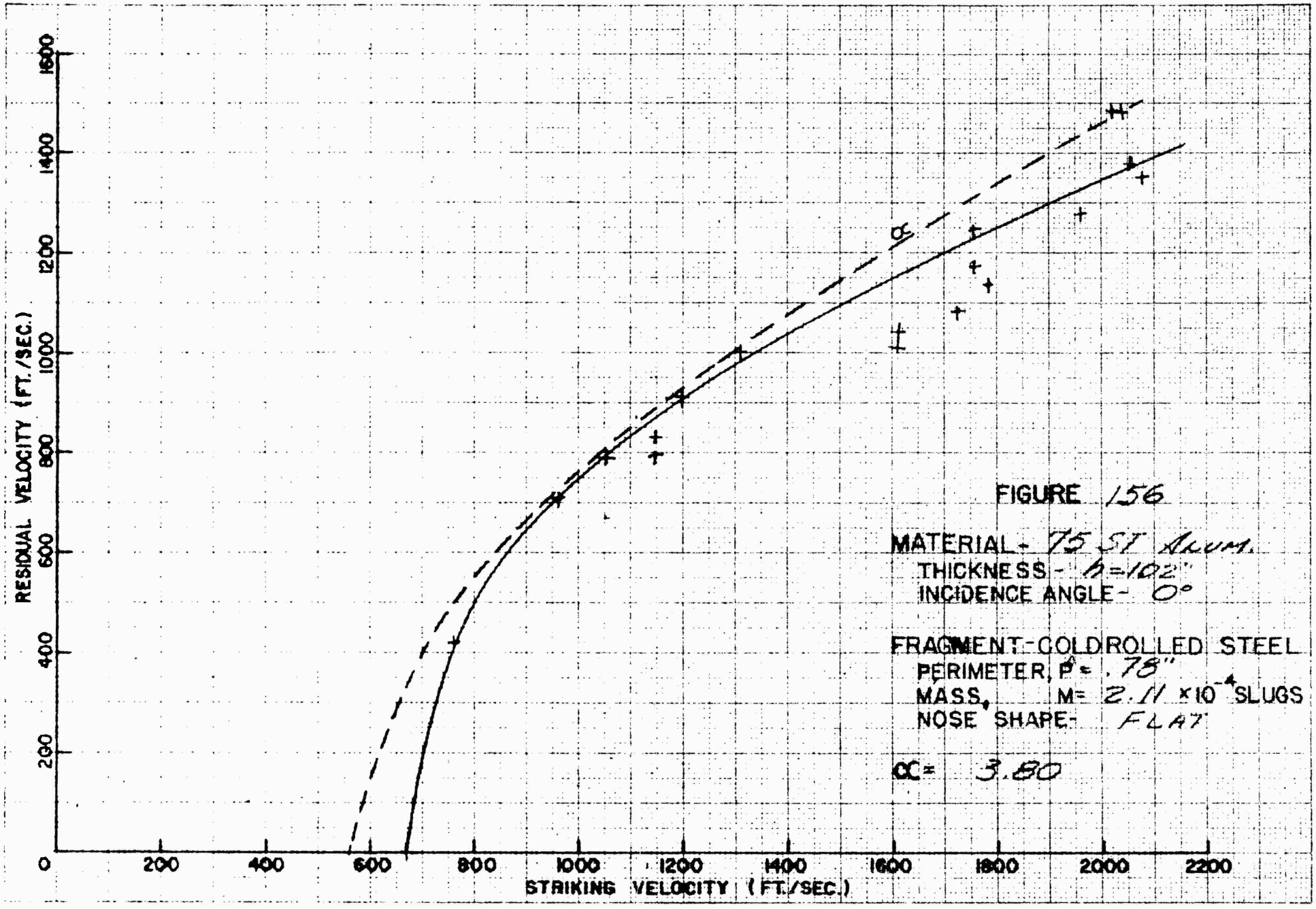


FIGURE 156

MATERIAL - 75 ST Alum.
THICKNESS - h = .102"
INCIDENCE ANGLE - 0°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .75"
MASS, M = 2.11 × 10⁻⁴ SLUGS
NOSE SHAPE - FLAT

α = 3.80

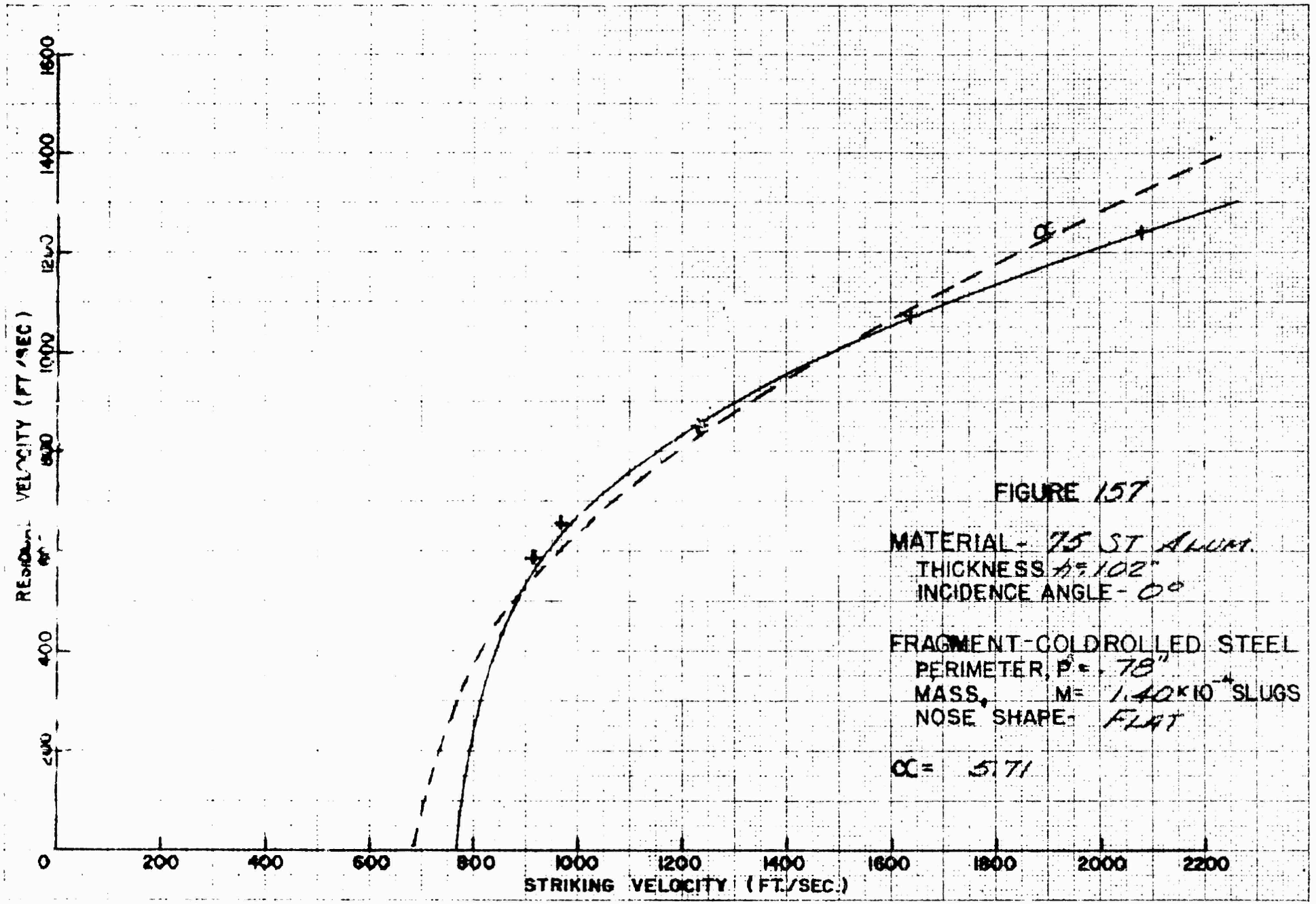


FIGURE 157

MATERIAL - 75 ST Alum.
THICKNESS h = .102"
INCIDENCE ANGLE - 0°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 1.40 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT

CC = 5.71

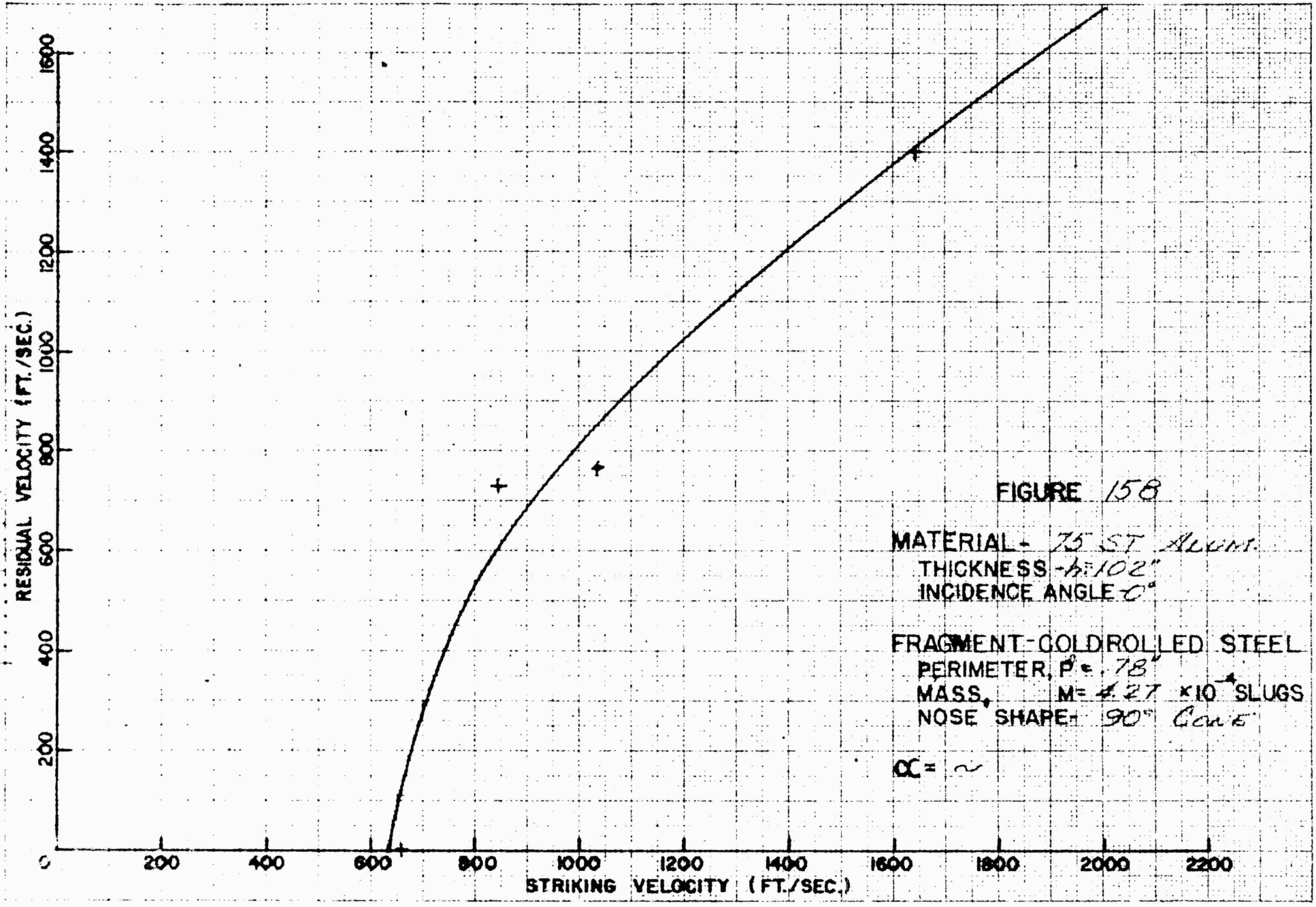


FIGURE 158

MATERIAL - 75 ST Alum.
THICKNESS - h=.102"
INCIDENCE ANGLE 0°

FRAGMENT - COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.27 x 10⁻⁴ SLUGS
NOSE SHAPE - 90° Cone

OC = ~

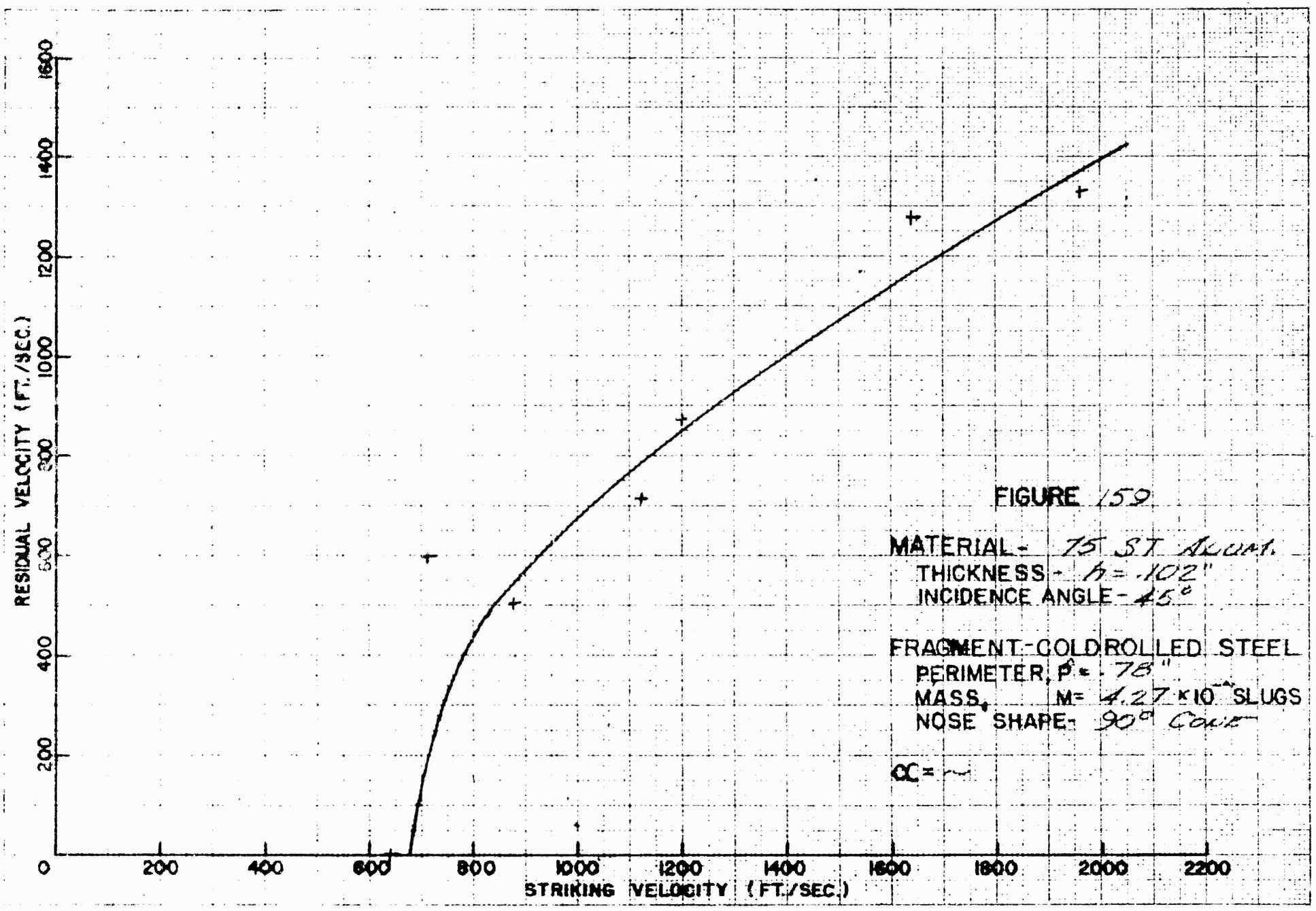
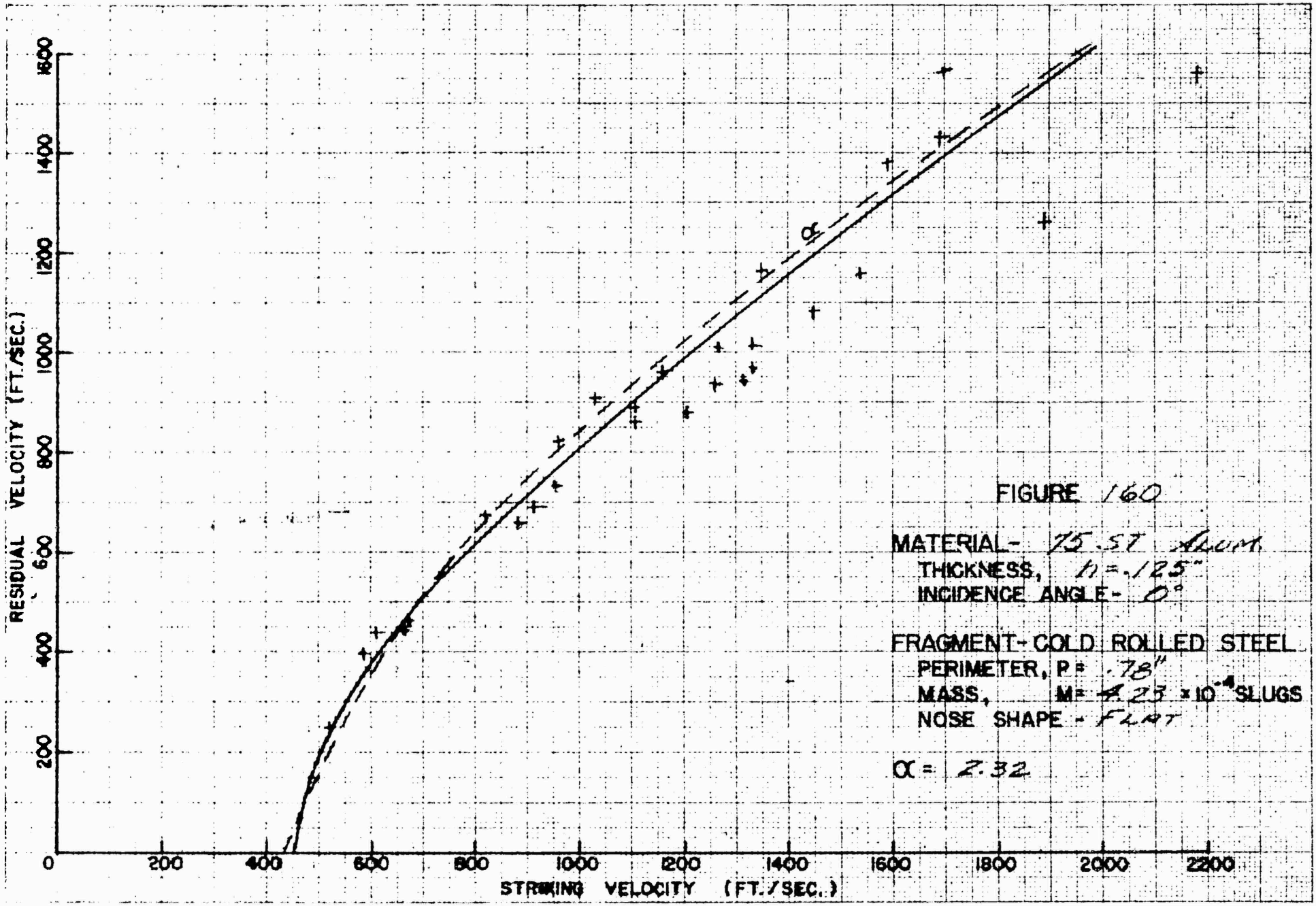


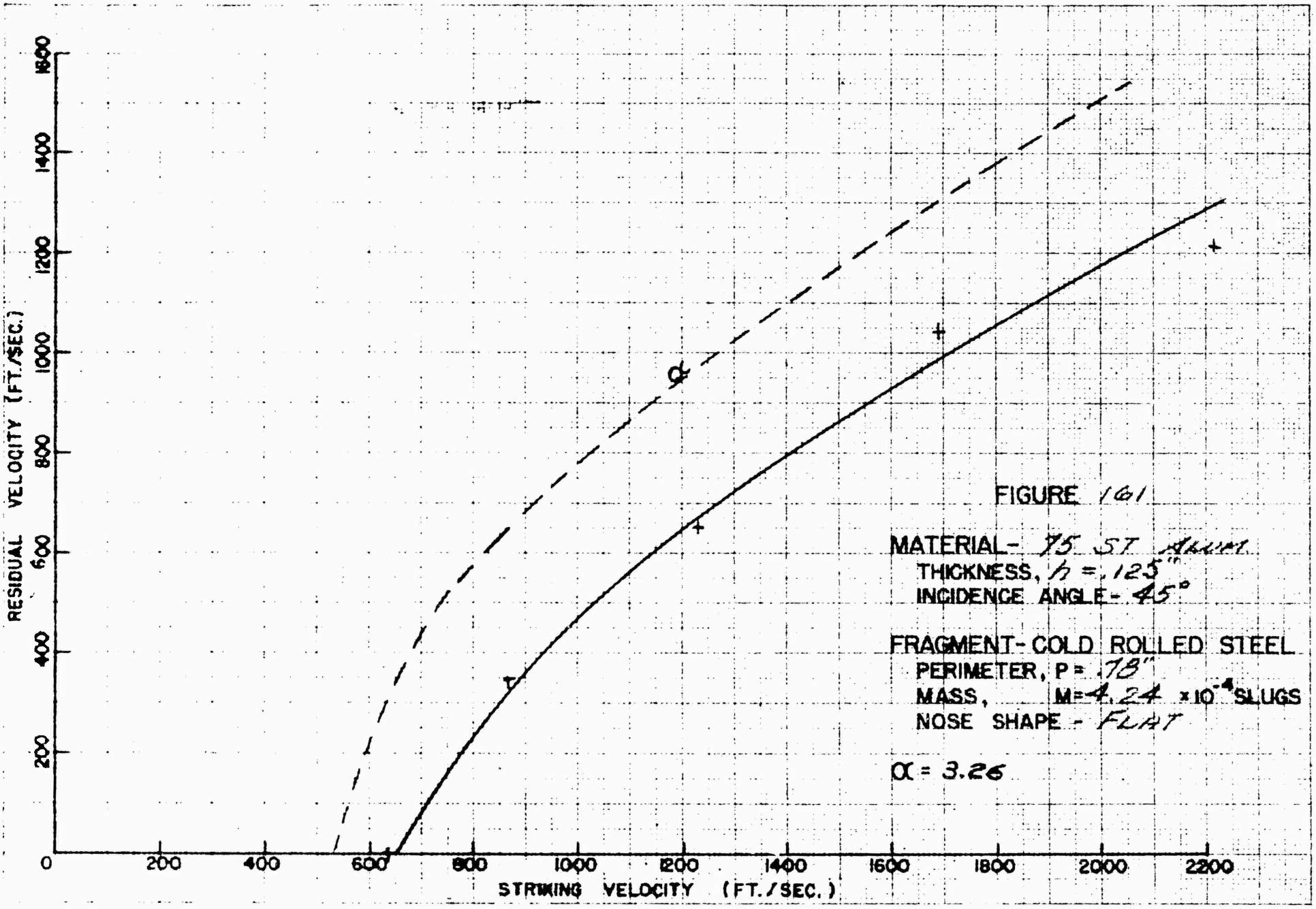
FIGURE 159

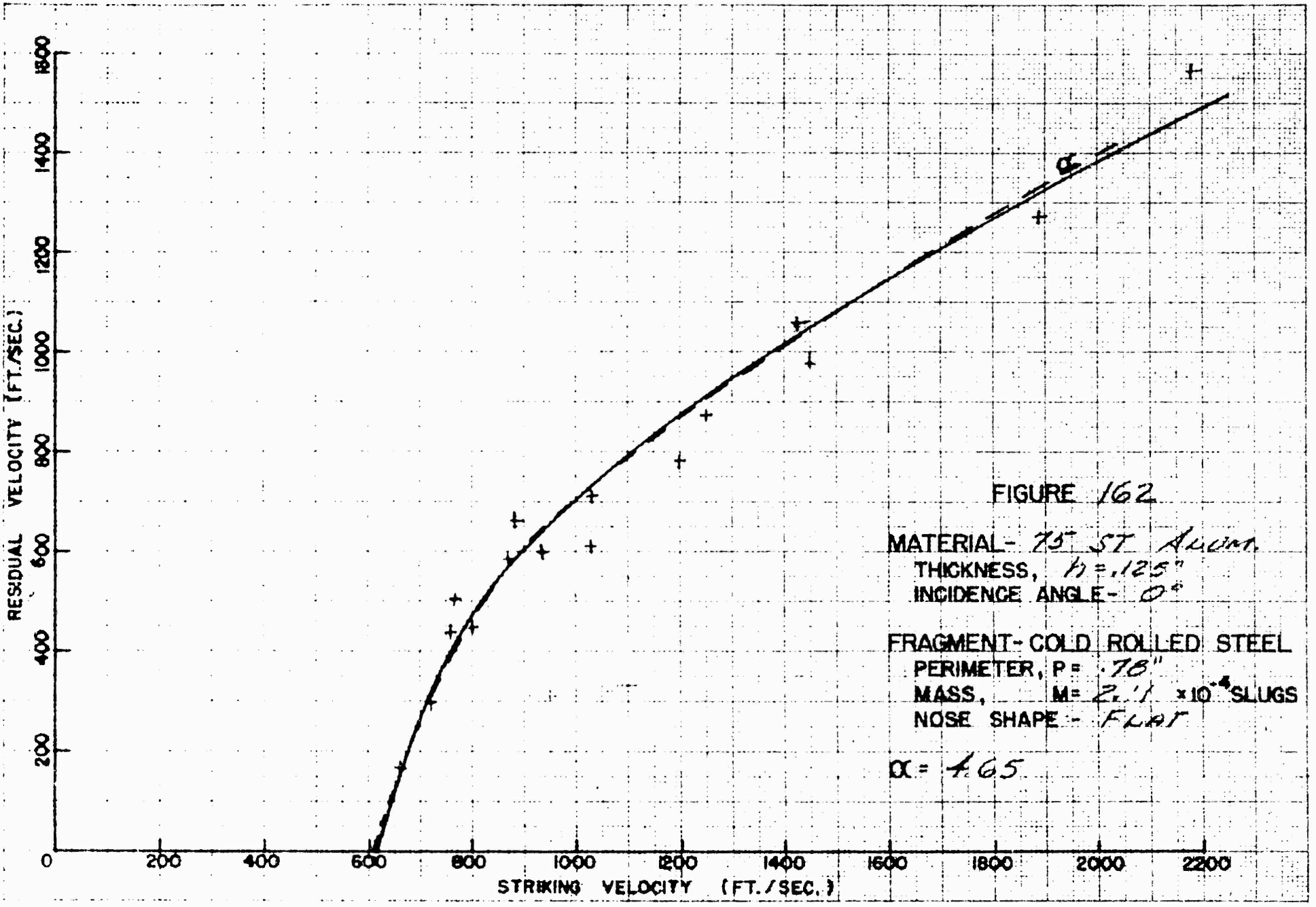
MATERIAL - 75 ST Alcan.
THICKNESS - h = .102"
INCIDENCE ANGLE - 45°

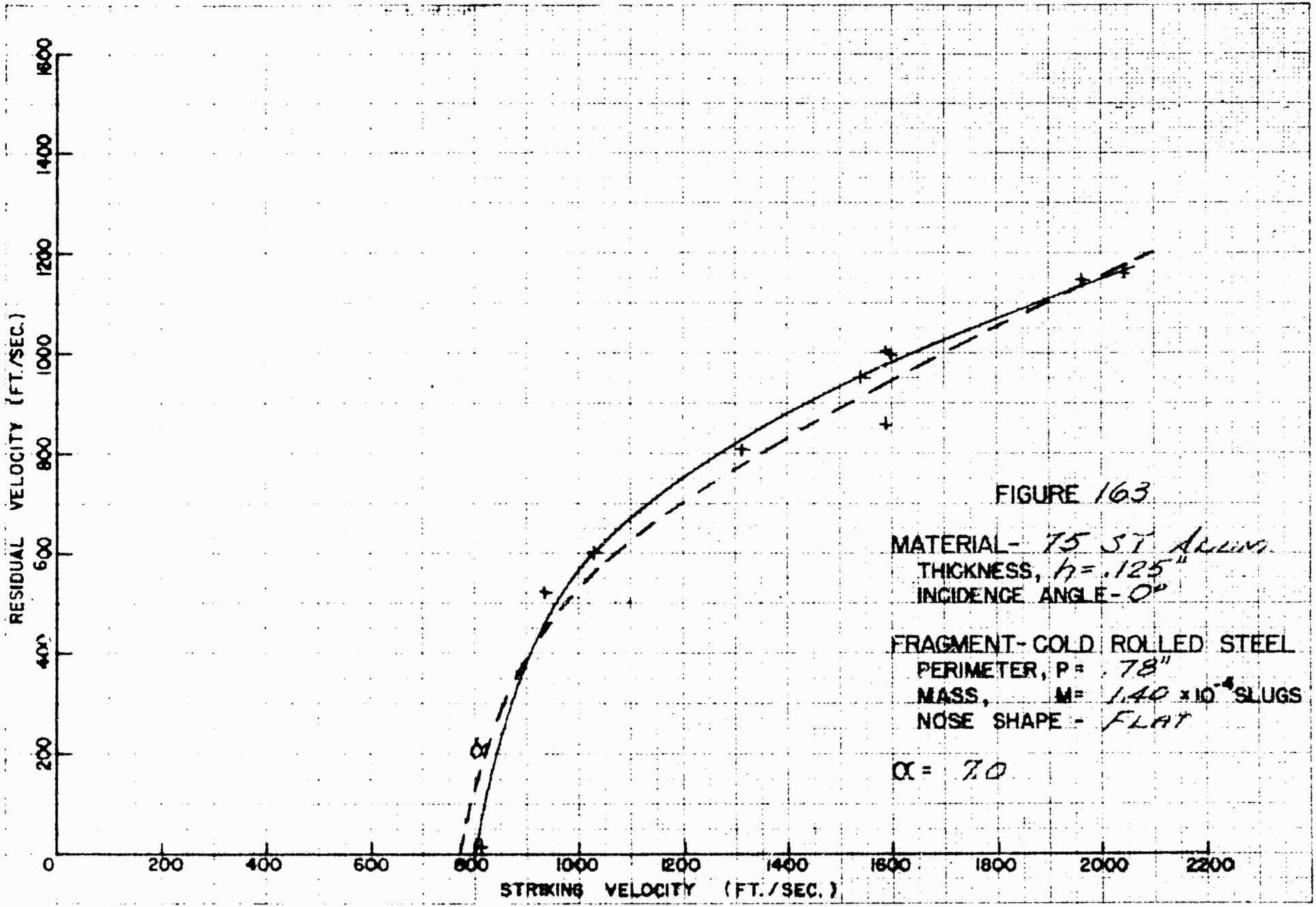
FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.27 × 10⁻⁴ SLUGS
NOSE SHAPE - 90° Cone

CC = ~


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 160
MATERIAL- 75.ST Alum.
THICKNESS, h = .125"
INCIDENCE ANGLE- 0°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 2.32


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 161
MATERIAL- 75 ST Alum.
THICKNESS, h = .125"
INCIDENCE ANGLE- 45°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.24 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 3.26


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
α
FIGURE 162
MATERIAL- 75ST ST Alum.
THICKNESS, h = .125"
INCIDENCE ANGLE- 0°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 2.1 ×10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 465


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
FIGURE 163
MATERIAL- 75 ST Alum.
THICKNESS, h = .125"
INCIDENCE ANGLE- 0°
FRAGMENT- COLD ROLLED STEEL
PERIMETER, P = .78"
MASS, M = 1.40 x 10⁻⁴ SLUGS
NOSE SHAPE - FLAT
α = 7.0

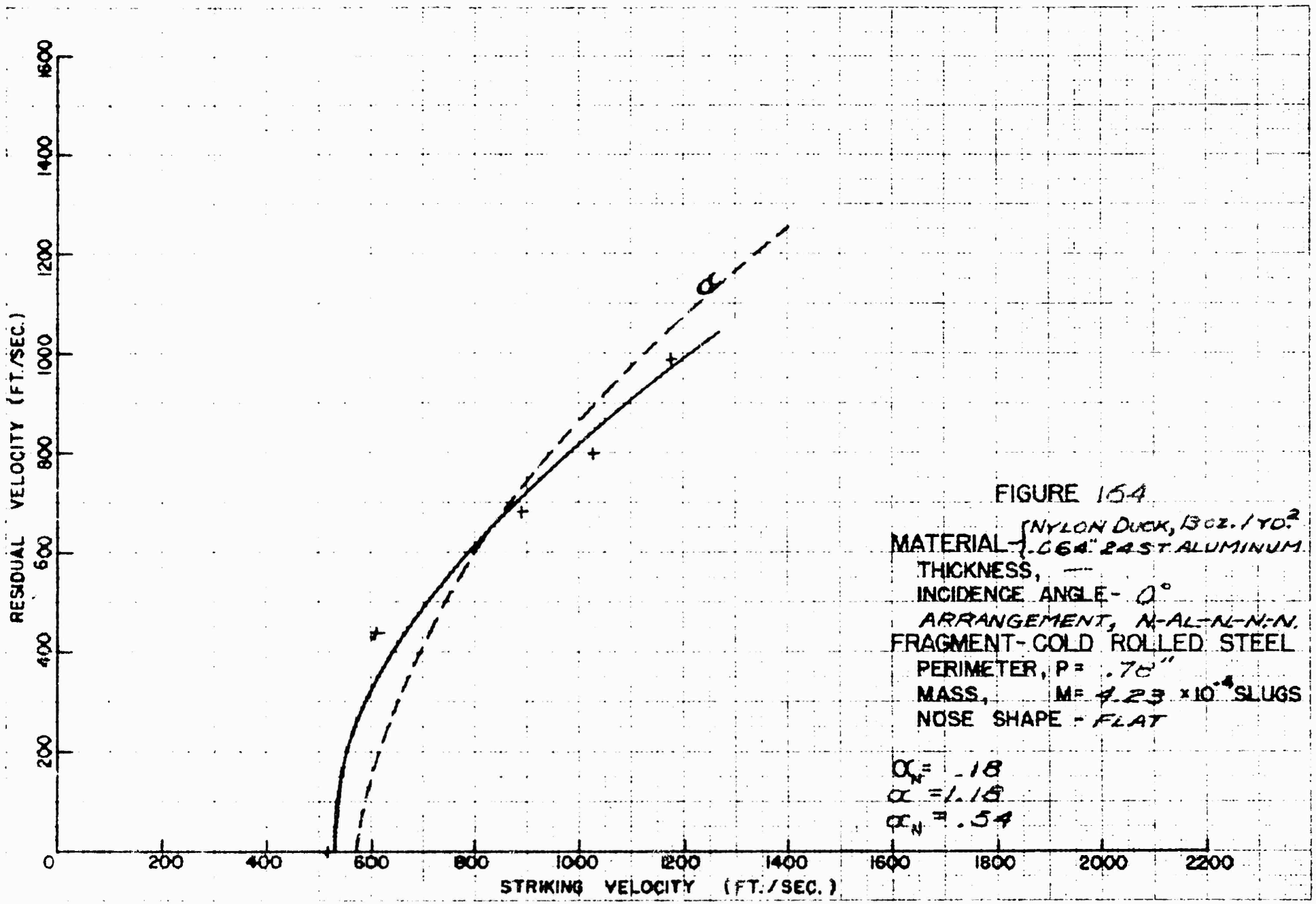


FIGURE 164

MATERIAL - { NYLON DUCK, 13 oz./YD.²
.064" 24ST ALUMINUM

THICKNESS, —

INCIDENCE ANGLE - 0°

ARRANGEMENT, N-AL-N-N-N.

FRAGMENT - COLD ROLLED STEEL

PERIMETER, P = .78"

MASS, M = 4.23 x 10^{-4} SLUGS

NOSE SHAPE - FLAT

α_N = .18

α = 1.18

α_N = .54

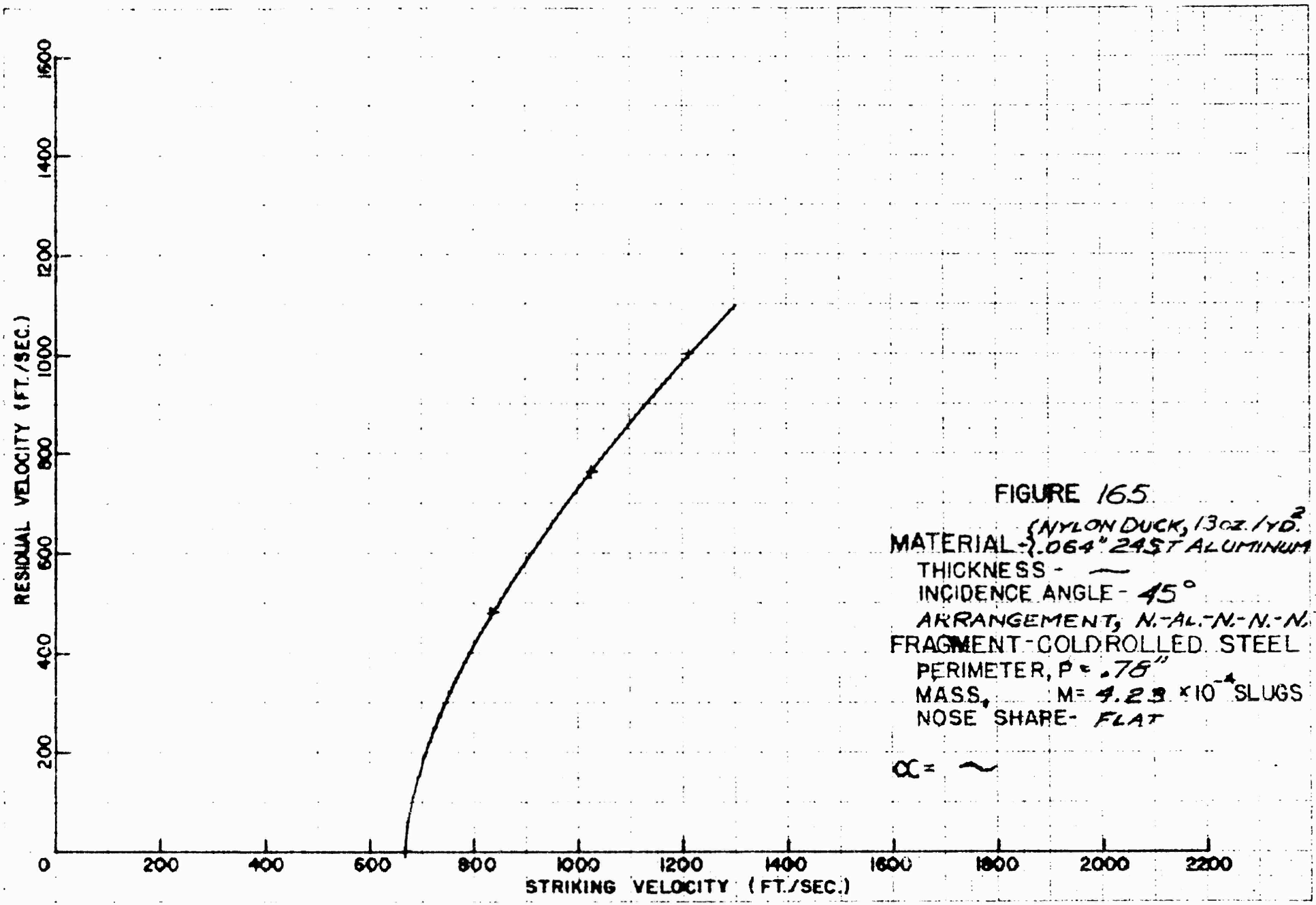


FIGURE 165

MATERIAL - {NYLON DUCK, 13 oz./yd.² .064" 24ST ALUMINUM
THICKNESS - —
INCIDENCE ANGLE - 45°
ARRANGEMENT, N.-AL.-N.-N.-N.
FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 4.23 × 10⁻⁴ SLUGS
NOSE SHARE - FLAT

α = ~

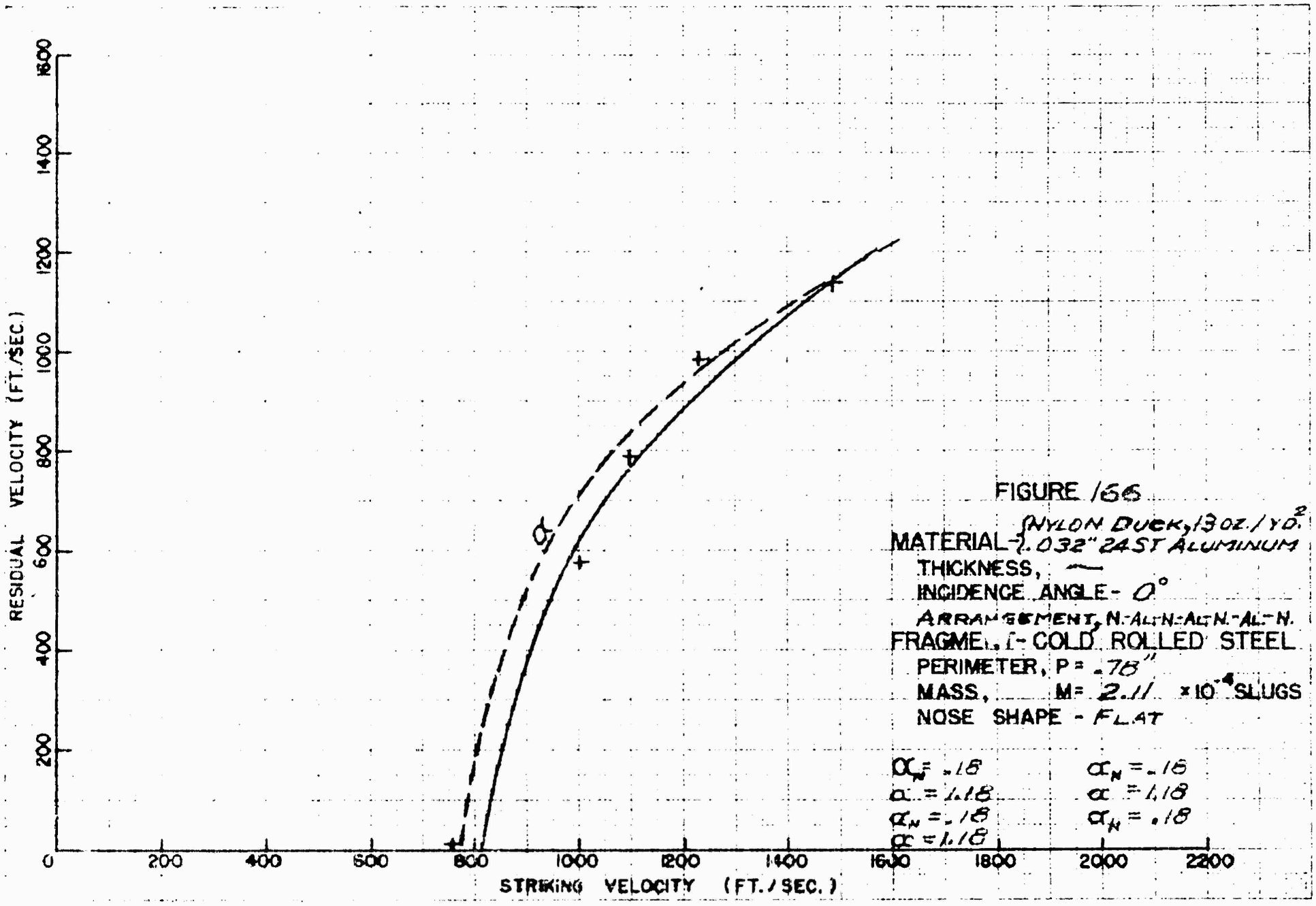


FIGURE 166

MATERIAL - {NYLON DUCK, 13 OZ./YD.^{2} / .032" 24ST ALUMINUM

THICKNESS, —

INCIDENCE ANGLE - 0°

ARRANGEMENT, N-AL-N-AL-N-AL-N.

FRAGMENT - COLD ROLLED STEEL

PERIMETER, P = .78"

MASS, M = 2.11 $\times 10^{-4}$ SLUGS

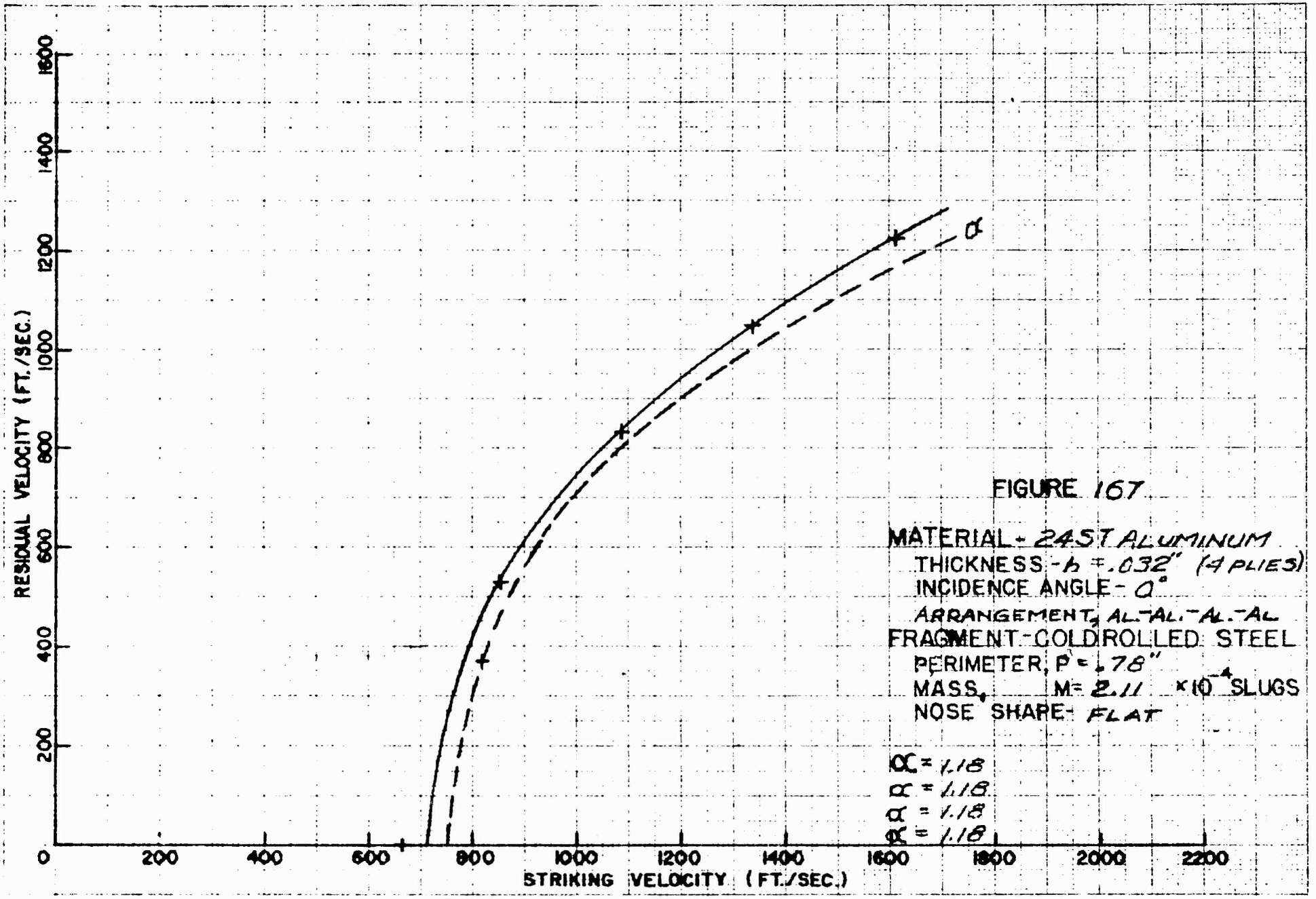
NOSE SHAPE - FLAT

$\alpha_N = .16$ $\alpha_N = .16$

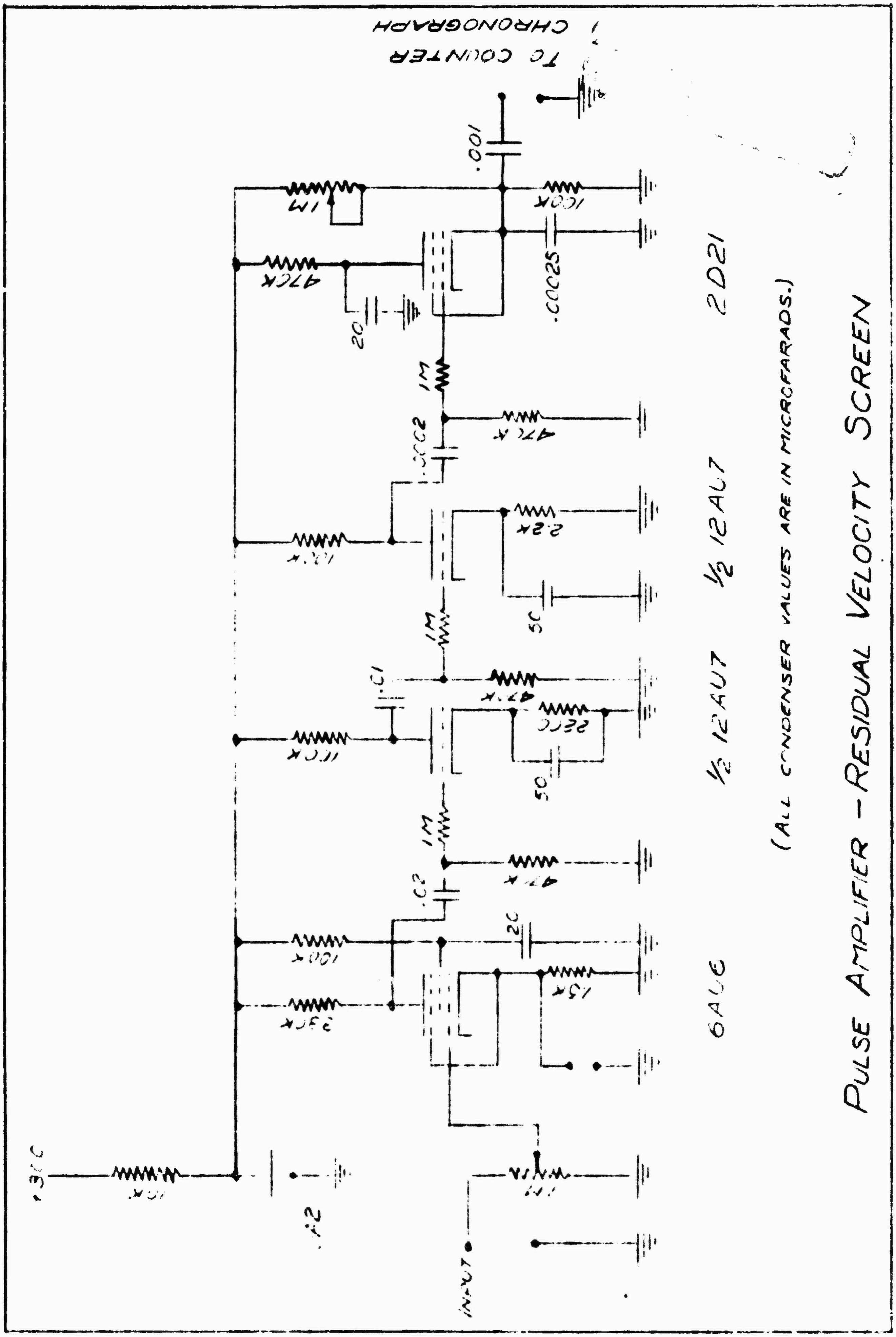
$\alpha = 1.18$ $\alpha = 1.18$

$\alpha_N = .18$ $\alpha_N = .18$

$\alpha = 1.18$


RESIDUAL VELOCITY (FT./SEC.)
0
200
400
600
800
1000
1200
1400
1600
STRIKING VELOCITY (FT./SEC.)
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
α
FIGURE 167
MATERIAL - 24ST ALUMINUM
THICKNESS - h = .032" (4 PLIES)
INCIDENCE ANGLE - 0°
ARRANGEMENT, AL.-AL.-AL.-AL
FRAGMENT - COLDROLLED STEEL
PERIMETER, P = .78"
MASS, M = 2.11 ×10⁻⁴ SLUGS
NOSE SHAPE - FLAT
= 1.18
= 1.18
= 1.18
= 1.18

APPENDIX B


TO COUNTER
CHRONOGRAPH
.001
1M
100K
47K
20
.00025
2D21
1M
.002
47K
2.2K
100K
50
½ 12AU7
1M
.01
47K
220
100K
50
½ 12AU7
1M
.02
47K
20
100K
15K
33K
6AU6
+300
10K
.2
1M
INPUT
(ALL CONDENSER VALUES ARE IN MICROFARADS.)
PULSE AMPLIFIER – RESIDUAL VELOCITY SCREEN