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MIDWEST RESEARCH INSTITUTE

ENGINEERING MECHANICS DIVISION

August 31, 1950

FINAL REPORT

Project No. R117E 65

DESIGN INFORMATION FOR CONSTRUCTION
OF LIGHT PERSONNEL ARMOR

Prepared for

Laboratory
Watertown Arsenal
Ordnance Department
Watertown, Massachusetts

Contract No. DA-23-072-ORD-3

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CONTENTS

	<u>Page</u>
I. Summary and Introduction	1
II. Description of Equipment	3
III. Discussion	7
A. Performance Prediction Method	7
B. Comparison of Materials at Normal Impact	7
C. Effects of Incidence Angle	11
D. Effects of Fragment Mass and Plate Thickness	13
E. Fragment Deformation and Hardness	13
F. Effects of Physical Properties of Materials	15
IV. Conclusions	19
Appendix A	
Index to Curves	
Performance Curves; Figures 1 through 87	
Appendix B	
Schematic Diagram; Figure 88	
Appendix C	
Photographs of Equipment; Figures 89 through 91	

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S T R E S S R E S E A R C H I N S T I T U T E

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I. SUMMARY AND INTRODUCTION

The Midwest Research Institute has conducted research under three successive contracts to the Ordnance Department on the resistance of light personnel armor materials to penetration by munition fragments. The general objectives of this work have been to determine the effects of each of the principal variables associated with penetration and to determine, if possible, what physical properties of light armor materials have the greatest influence on their resistance to penetration.

The work accomplished under the first two contracts was concerned with the type of failure induced by overmatching fragment simulators, i.e., those having a diameter greater than the thickness of the armor, as this was considered the most severe condition to which the armor would be exposed. It was then desired to complete the picture by showing the abilities of armor materials to resist penetration by undermatching fragments, which may be more representative of average combat conditions, considering that most of the fragments produced by random-fragmentation types of munitions are of relatively small size. Consequently, the research conducted under the present contract has been primarily concerned with armor behavior under impact by undermatching fragment simulators. The scope of the work has included the study of corollary conditions usually associated with undermatching fragments, viz., small fragment size, higher critical velocities (ballistic limits), and high striking velocities. In addition to these conditions, some of the effects of variations in fragment hardness have been studied.

It was found that the formula previously developed for predicting the performance of certain armor materials under impact by overmatching fragments does not hold for undermatching conditions, with the possible exception of nylon. The reason for this limitation is that several variables, including the nature and form of the armor materials, have appreciable effects on the resistance to impact by undermatching fragments. These effects tend to overshadow that of the simple shear type of failure generally encountered with overmatching fragments.

In view of this situation, it was decided that further investigation of the effects of physical properties should take precedence over the proposed investigation of variations in perimeter shape. The results of the latter would appear to be of little value, since they would apply to overmatching conditions only. Consequently, it was felt that the results would not be worth the time and cost of completing construction of the special items of equipment required for this phase of the program.

The data obtained under this contract, together with that obtained previously, are now sufficient to give good indications regarding

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the combination of physical properties desired in light armor materials and to enable the preparation of a personnel armor design manual to be started.

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II. DESCRIPTION OF EQUIPMENT

At the beginning of the work on this contract it became obvious that the magnetic screens used for residual velocity measurement under the preceding contract would be inadequate for the extremely small fragment simulators to be investigated. The small masses involved would not produce an adequate signal as the fragment passed between the pole pieces of each coil assembly. Up to that time other methods of measuring residual velocity had seemed impractical because of cap troubles, i.e., the cap or chips punched out of the armor plate would produce spurious time interval signals when other types of screens were used. This difficulty had precluded the use of other types of screens because the small space available in the original firing box had not allowed enough freedom in the placement of the screens. Consequently, the base line distance could not be changed appreciably, nor could the screens be moved sidewise as necessary to intercept the fragment but avoid the cap under various conditions of armor penetration. This difficulty had been aggravated by the comparatively large one-piece caps generally resulting from plate perforation by large diameter fragments.

In order to avoid, if possible, the construction of a new firing box, further refinements were made in the magnetic screen arrangement. A new screen assembly was designed to have increased sensitivity, extended frequency response and higher signal-to-noise ratio. The construction of this screen is shown in Fig. 89. Some comparative residual velocity measurements were made with the old and new magnetic screens, using

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1/4-in. diameter fragment simulators which were considerably heavier than the 3/32-in. diameter simulators contemplated for undermatching studies. The results indicated that the old screens would introduce appreciable errors, especially in the higher velocity range, if used with fragment simulators smaller than about 50 grains.

During the initial experiments with the 3/32-in. diameter fragments, it became apparent that the new magnetic screen would not provide the required accuracy at the higher residual velocities encountered. In addition to this, the increased divergence encountered with the small fragments, especially at high obliquities and low striking velocities, made it necessary to have a more spacious firing box. Consequently, a new box was constructed which had sufficient room for placing the screen in various locations. The construction of this box is shown in the photographs, Figs. 90 and 91. The increased room made it comparatively easy to avoid cap impingement on the final screen, and so enabled us to use a contact or short-circuiting type of screen at that station. This type had an additional advantage in that the voltage of the signal generated was sufficient to operate the chronographs directly, thereby avoiding possible errors from the inconsistent triggering experienced with the coil-amplifier-thyratron combination.

The arrangement finally adopted for the measurement of residual velocities consists of a fine copper wire mounted immediately behind the armor plate and a screen located at a convenient distance, varying from two to eight feet, beyond the wire. The breaking of the wire starts the

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chronograph and the short-circuiting of the screen stops it. The screen consists of alternate sheets of waxed paper and aluminum foil clamped in a frame, as shown in Fig. 91.

The measurement of striking velocity was accomplished by the breaking of two fine copper wires located in the fragment guide. This method was the same as that used in previous work, with the exception of a few refinements to permit accurate measurement of the velocity of very small fragment simulators. The method used to correct the residual velocity for the effects of wire breakage and air drag was as follows:

Chronograph measurements of striking and residual velocity were taken with no armor material in place. A piece of heavy paper, 0.008 in. thick, was used in place of the armor sample to stop pieces of wire, walling and unburned powder from short-circuiting the residual velocity screen. The velocity measurements were repeated at several values of residual velocity base line. The difference between striking and residual velocity was plotted as a function of base line distance for each size of fragment involved. The correction factor for the combined effects of wire breakage and air drag was then taken from this graph. The results obtained in this way were average values because of varying amounts of tumbling.

The fragment simulators were right circular cylinders made from drill rod (SAE 1095 steel). Most of the fragments were used in their unhardened state, measuring from 90 to 95 Rockwell B. In an effort to prevent "mushrooming" of the noses, some of the fragments were hardened

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and drawn to approximately 45 Rockwell C. Others, which had been hardened to approximately 60 Rockwell C and not drawn, were unsatisfactory because of their tendency to shatter, either on impact or before leaving the guide.

The fragment simulators were propelled by a Ramset Tool using a special barrel having a smaller bore and greater length than standard. This tool is an improved version of the Tempo Tool used in previous work. The smaller fragments required new guides which were similar to the previous ones except for the arrangement of gas escape slots and the two-piece construction which permits the guide to be opened for easy cleaning and removal of occasional jammed fragments.

A refinement was added to the equipment in the form of a panel of lights and switches for quickly checking the wires and screens for continuity and short circuits. This panel, which is visible at the top of the firing box in Figs. 90 and 91, proved to be a valuable time-saver. A schematic diagram of the test circuit is given in Fig. 88.

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III. DISCUSSION

A. Performance Prediction Method

During previous research on the resistance of body armor materials to fragment penetration, it was noted that the performance of a given material could be predicted with reasonable accuracy by a formula which involved plate thickness, fragment mass, and shear perimeter. This relation had been found to hold over the range of conditions in which overmatching fragments had been used, that is, fragments the diameter of which exceeded the plate thickness. During the course of work on the present contract, it was found that this relationship does not hold for matching and undermatching conditions with the possible exception of nylon. This relationship had been developed for overmatching conditions in which the principal mode of failure was shear. It is not surprising that the relationship does not hold for undermatching conditions wherein the failure of the armor material is influenced to a much greater degree by other mechanisms than shear.

It was noted that the curves shown in Figs. 75 and 79 correspond quite closely to the performance equation previously derived. However, since the only variable which was changed in making this comparison was the mass of the fragment, it cannot be said conclusively that nylon will conform to this equation under all conditions.

B. Comparison of Materials at Normal Impact

The performances of Hadfield steel, daron, and 24ST aluminum alloy have been plotted on the basis of equal weight per square foot in

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Figs. 1 and 2. The curves for Hadfield steel and doron were adjusted slightly from the experimental curves to put them on the same weight basis as the 24ST.

It will be observed from Fig. 1 that the order of merit of these materials at high impact velocities is the reverse of that at low velocities. This effect is apparently in agreement with the results obtained at Aberdeen Proving Ground using G2 fragment simulators. The main factors involved in this apparent paradox are probably the ductility and work-hardening effect of Hadfield steel which work to the best advantage in the low velocity region near the ballistic limit. Low velocity impacts allow time for a large area of the material immediately surrounding the point of impact to detrude or deform. The apparent result of this effect is to prolong the time of impact and extract a greater amount of energy from the fragment. The fundamental impact equation can be expressed as

$$m \Delta v = \int_0^t F dt$$

Since F is limited by the strength of the material, any increase in t will increase Δv . Consequently, the amount of energy extracted will also increase.

Observation of Hadfield steel plates penetrated at high impact velocities shows that only a small area of material is involved. This is believed to be due to the fact that the effect of the inertia of the material immediately surrounding the point of impact becomes appreciable at the higher impact velocities. The effect of high velocities would be

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to cause very high acceleration of the plate material at the point of impact. Because of the high acceleration, the force imposed on the plate would exceed its breaking strength in a very short time after impact. Thus the inertia of the material immediately surrounding the point of impact prevents this material from being detruded to any great extent. Therefore, we would conclude that the time of impact is comparatively short at high velocities and that the amount of energy extracted from a fragment is comparatively small, assuming that the amount of fragment deformation is approximately the same for low and high velocities. Visual observations indicate that the amount of fragment deformation upon impact with Hadfield steel did not vary greatly over the range of conditions studied.

In the case of the 24ST aluminum alloy, fragment deformation increased appreciably at higher impact velocities. Consequently, the amount of energy extracted by the 24ST could be expected to increase in the high velocity range, other factors being equal. The 24ST, being a fairly rigid material because of its thickness, does not exhibit a high degree of ductility even at the lower striking velocities. Except for the effects of increased fragment deformation at high velocities, the 24ST does not exhibit much change in mode of failure over the range of striking velocities. Thus, it is not surprising that the performance curves of 24ST and Hadfield steel cross each other. A possible explanation for the fact that the performance curve of doron lies between those of Hadfield steel and 24ST in the high velocity range may be found in the fact that the fragments suffer relatively little deformation upon impact with doron.

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The foregoing discussion offers at least a partial explanation for the different orders of merit of these armor materials according to the method of test. A summary report¹ on tests of armor materials conducted at Aberdeen Proving Ground indicates that the order of merit of some materials depends upon the type of test to which they are subjected. The first type of test discussed in this report was the so-called rectangular arrangement of boxes around a 20 mm HE shell or a controlled fragmentation shell. In this test the plate of material to be tested was 8 inches away from the center of the burst and was consequently exposed to fairly high impact velocities of the order of 2800 to 3200 feet per second. The second type of test involved the determination of ballistic limit under impact by G2 fragment simulators. In this case the striking velocity was relatively low, being approximately 800 ft/sec for 24ST aluminum, 1400 ft/sec for duron, and 1660 ft/sec for Hadfield steel.

The preceding conclusions agree very well with the results shown by Fig. 1. Since the properties of Hadfield steel are best realized at low striking velocities, it would be expected that this material would show superior resistance to penetration under these conditions. As the energy of the fragment decreases with distance, the resistance of the armor for Hadfield steel is also decreased. This is true for all armor materials. The curves for Hadfield steel are the highest of the other materials.

Now that the relative merits of the materials have been determined, fragment simulators can be used to determine the relative merits of the materials.

¹ APG Report
of Ballistic Tests

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The spread between the individual curves in this case is less than the experimental error encountered in the tests.

A comparison of nylon with other armor materials is given in Figs. 3 and 4 on the basis of equal weight per unit area. The apparently poor performance of nylon in this investigation is attributed to the small nose area of the fragment, as discussed in Section III F, entitled "Effects of Physical Properties of Materials". The especially poor performance of nylon under high impact velocities is further accentuated by the melting of the threads that was noticed under these conditions.

Under the conditions of Fig. 4, the performance of 75ST is slightly better than that of 24ST. However, no definite conclusions should be drawn from this because the amount of difference is comparable to the experimental error.

A comparison of nylon with doron is given in Figs. 86 and 87. As mentioned above, the conditions used were such as to minimize the effectiveness of nylon as an armor material.

C. Effects of Incidence Angle

As in previous reports, the term "incidence angle" refers to the angle between the path of an approaching fragment and the perpendicular to the plane of the armor material. In the final report on the previous contract it was stated that the performance prediction method could be modified to take into account the effect of angle of incidence of 1/4-in. diameter fragments against aluminum alloys and Hadfield steel. In

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the case of the former, the armor thickness was considered to be increased from that at 0° according to the secant of the angle of incidence, and the shear perimeter was also increased because of the elliptical rather than circular perforation.

These factors cannot be applied to most of the conditions studied under the present contract, for the reason that the small fragments tend to yaw during impact at oblique angles. Figure 7 shows that the curve for penetration of 0.102 in. 24ST by the 3/16-in. long fragments at 45° is considerably below the 0, 15 and 30° curves. Observation of the penetrations showed that the short fragments yawed considerably more during penetration at an incidence angle of 45° than at the smaller angles. This "broadsideing" tendency is believed responsible for the fact that considerably more energy was extracted from the fragment at 45° incidence angle. As would be expected, this effect is more pronounced with the short fragment, which has a small longitudinal moment of inertia, than with the long fragment.

In Fig. 8, which describes the behavior of 0.102 in. 24ST under impact by the long fragment, it is seen that only the low-velocity portion of the 45° curve is spread away from the 0, 15 and 30° curves. This is attributed to the assumption that the longer duration of impact at low striking velocities allows some yawing to occur, even though the long fragment has a comparatively large longitudinal moment of inertia. Conversely, it is assumed that the short duration of impact at high striking velocities, together with the large moment of inertia, does not permit appreciable yawing to occur.

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Trends similar to the foregoing can be observed in Figs. 6 and 9 through 12.

Figures 14 and 15 show that the performance of Hadfield steel at 15° angle of incidence is slightly inferior to that at 0°. Although this trend is opposite to the general trend shown by other materials, it substantiates the results of previous work with larger fragments conducted by other investigators as well as by the Midwest Research Institute.

D. Effects of Fragment Mass and Plate Thickness

Figures 20 through 26 show the effect of varying the mass or length of the fragment, and Figs. 27 through 29 show the effect of varying the plate thickness. As mentioned previously, it was found that these curves do not follow the relationship between fragment mass, plate thickness and shear perimeter which is applicable to overmatching fragments. Although time did not permit a search for another relationship which may apply to the undermatching conditions, this will be investigated in connection with the preparation of the armor design manual.

E. Fragment Deformation and Hardness

The greater portion of the experimental results were obtained with unhardened steel fragment simulators measuring from R_B 90 to 95. Practically no deformation of the fragment nose was perceptible after impact with unimpregnated nylon duck and relatively little with 280 aluminum. However, a moderate amount of "upsetting" of the fragment nose occurred upon impact with doron, the amount being greater at high

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impact velocities. 24ST and 75ST aluminum alloys induced a large amount of "upsetting" and "mushrooming" of the fragment noses, the amount also being greater at high impact velocities. Observation of partial penetrations indicated that the deformation of the fragment nose started immediately after the fragment struck the plate and that the deformation increased as the fragment nose progressed through the plate. This action accounts, at least in part, for the increased diameter of the hole at the exit side of the hard aluminum plates. Hadfield steel induced a large amount of "mushrooming" of the fragment nose at all striking velocities, and the amount of "upsetting" was greater at high velocities. There was some indication that the "mushroomed" edge was sheared off during penetration at intermediate and possibly at high velocities, also.

In general, the amount of fragment deformation experienced with the 3/32-in. diameter fragments against metallic materials was quite severe. No appreciable deformation had been encountered with the 1/4-in. and 1/2-in. diameter fragments used in previous work, even though the fragment hardness was approximately the same in all cases. The impact velocities of the small fragments were, in general, much higher than those of the larger fragments, but this does not seem to account entirely for the difference in deformation. There are indications that other factors, possibly fragment mass and time of impact, have a marked influence on fragment deformation. A few of the 2.47 grain fragments which had been hardened to approximately 60 R_C were successfully fired at Hadfield steel without shattering. In some cases, the noses of these fragments were

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upset appreciably, and color shadings progressing from dark blue to straw color were visible behind the nose, indicating that the temperature reached during impact had probably been high enough to soften the nose and thus contribute to the deformation. However, the data were not sufficient to warrant definite conclusions.

Because of the difficulties experienced with shattering of the fully hardened fragments, some of the 13.55 grain fragments were drawn to a hardness of about 45 R_C. These were fired at 0.035 in. Hadfield steel at normal impact and the results are given in Fig. 85. Although the fragment deformation was appreciably less than with unhardened fragments, no positive trend is apparent from Fig. 85. It was expected that the curve of results from the hardened fragments would lie above that for the unhardened ones, especially at the high velocity end of the curve. Apparently, other factors are involved which we cannot explain at this time. Consequently, it is planned to investigate further the question of fragment deformation and hardness during the preparation of the design manual.

F. Effects of Physical Properties of Materials

With the exception of some of the aluminum alloys, the armor materials tested under this contract were received from Aberdeen Proving Ground. The nylon used in this work was 2 x 2 basket weave weighing 13 ounces per square yard. No plastic impregnation or other special treatment was applied to it. The doron received had no markings or other indications as to which type it was. The sheets used were 21 ply, average thickness

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0.155 in. and average weight 22.5 ounces per square foot. The Hadfield steel used was 0.035 in. thick with the hardness varying from 70 to 90 R_B .

Observation of Figs. 1 through 4 shows that the high velocity performance of nylon is inferior to that of most of the other materials considered. A reason for this may be the thread melting effect associated with concentrating the impact energy in a very small area. This effect increases as the striking velocity is increased as observed by examinations of the fractures. Another property of nylon which has an adverse effect on its resistance to high-velocity impact is its softness. Because of the combination of softness and low melting point, there is no tendency to deform the nose of the fragment. Therefore, there is no opportunity to absorb the impact energy over a wider area. Consequently, it appears that nylon can be used to best advantage only when exposed to low velocity fragments. A composite armor using a combination of nylon and a suitable metal should have the nylon placed nearest the body if the construction will permit maintaining a proper space between the nylon and the body.²

Throughout the work on this contract, an attempt was made to determine which physical properties have the greatest effect on resistance to armor penetration. There appears to be no simple quantitative comparison between critical velocities and the common criteria such as tensile strength, shear strength, etc. It has been noted that, when the leading body armor materials are compared on an equal weight basis, their over-

² ACC MD Report No. 208, "The Effect of a Non-Perforating Missile on the Animal Body Protected by Nylon Armor" by Tillett, Banfield & Herget.

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all performances are nearly equal. Also, under most conditions, it appears that a superior physical property in any one material is offset by an inferior property which is inherent to the nature of the same material. No presently known material combines the most desirable properties of all the materials tested.

Although the quantitative effects of the desirable properties are yet unknown, the qualitative effects of various properties have become fairly clear. During the work with undermatching fragments on nylon duck, the condition existed where the fragment diameter was small enough to approach the diameter of one strand of the nylon. On all of these shots a cross effect was noted around the point of penetration. This was caused by the straining or pulling of one or two strands in both directions of the weave. This concentration of load on a small number of strands is probably responsible for the poor performance of nylon under these conditions. Work on previous contracts with large diameter flat-nosed fragments at normal impact showed nylon to have a much higher critical velocity than the other materials tested, viz., 24ST, 75ST, or Hadfield steel. This superiority of nylon did not hold true when the fragment nose shape was changed from flat to conical or when the incidence angle was increased to 45°.

The foregoing observations indicate that any woven or fabric material should have rip-stop weave, spot impregnation or a similar device to distribute the load over a larger area. Impregnated materials, such as doron, should have sufficient bond between fibers to equalize the load and

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prevent spreading them apart under impact by sharp-nosed fragments. A high melting point for any material is desirable to prevent the thread melting encountered with nylon under high-velocity impact. Any effective armor material should be of sufficient hardness to deform the fragment and thereby absorb the impact energy over as large an area as possible. Other properties which add to the penetration resistance of armor materials are ductility or stretch and flexibility. Ductility or stretch, as evidenced by Hadfield steel, and to a moderate extent by nylon, allows the material to detrude under impact. This condition increases the time interval of penetration, thereby allowing the material to absorb a greater amount of energy during penetration. Flexibility would have a similar effect to ductility in that it would result in a greater length of time during which penetration would occur. Flexibility would also allow the construction of one-piece armor suits or the use of larger plates in constructing body armor.^{3,4}

- 3 WAL Memorandum Report WAL 710/280, "Comparison of Resistance Characteristics of Flyer's Protective Armor, M1, and Experimental Armor Vest, T39, and the Effect of Component Plate Size", by J. F. Sullivan.
- 4 ACC MD Report No. 228, "The Effect of a Non-Perforating Missile on the Animal Body Protected by Steel Armor", by Tillett, Banfield & Herget.

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IV. CONCLUSIONS

A. On the basis of the experimental work described in this report it is concluded that the physical properties desired in an efficient body armor material include the following:

1. Ductility or stretch of metals or fabrics.
2. Sufficient hardness to deform fragment noses.
3. Flexibility, to prolong time of impact.
4. High melting point.
5. In the case of fibrous materials, a means for achieving equal radial distribution of forces around the point of impact.
6. In the case of fibrous materials, a means for preventing the separation of fibers under impact by sharp-nosed fragments.

B. The order of merit of most of the materials considered depends on the conditions under which they are tested. The order may be reversed by varying the impact velocity or fragment size.

C. The performance prediction method developed for overmatching fragments does not hold for undermatching fragments or for Hadfield steel under the conditions described in this report.

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APPENDIX A

Index to Curves
Performance Curves; Figs. 1 through 87

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INDEX TO CURVES

Figure

I. Comparative Performance of Materials at
Normal Impact

- A. 24ST Aluminum, Doron and Hadfield Steel 1, 2
- B. Nylon Duck and Aluminum Alloys 3, 4
- C. Nylon Duck and Doron 86, 87

II. Effects of Incidence Angle

- A. 24ST Aluminum 5 - 10
- B. 230 Aluminum 11, 12
- C. 75ST Aluminum 13
- D. Hadfield Steel 14, 15
- E. Nylon Duck 16, 17
- F. Doron 18, 19

III. Effects of Fragment Mass

- A. 24ST Aluminum 20 - 22
- B. 230 Aluminum 23
- C. Hadfield Steel 24
- D. Nylon Duck 25
- E. Doron 26

IV. Effects of Material Thickness

- A. 24ST Aluminum 27, 28
- B. 75ST Aluminum 29

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INDEX TO CURVES (Concluded)

Figure

V. Basic Experimental Data

A. 24ST Aluminum	30 - 53
B. 2SO Aluminum	53 - 61
C. 75ST Aluminum	62 - 66
D. Hadfield Steel	67 - 74
E. Nylon Duck	75 - 80
F. Doron	81 - 84

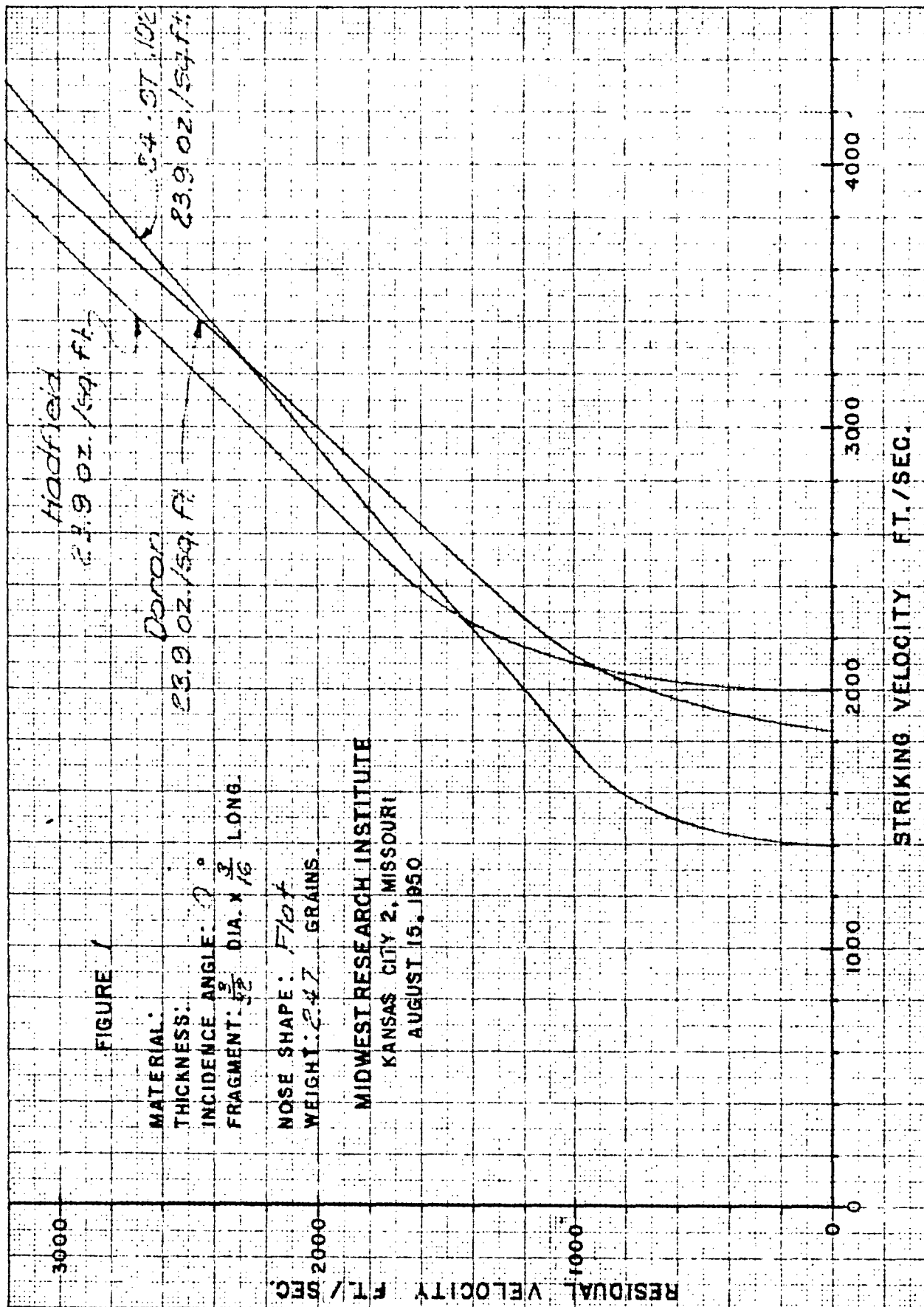
VI. Effects of Fragment Hardness	85
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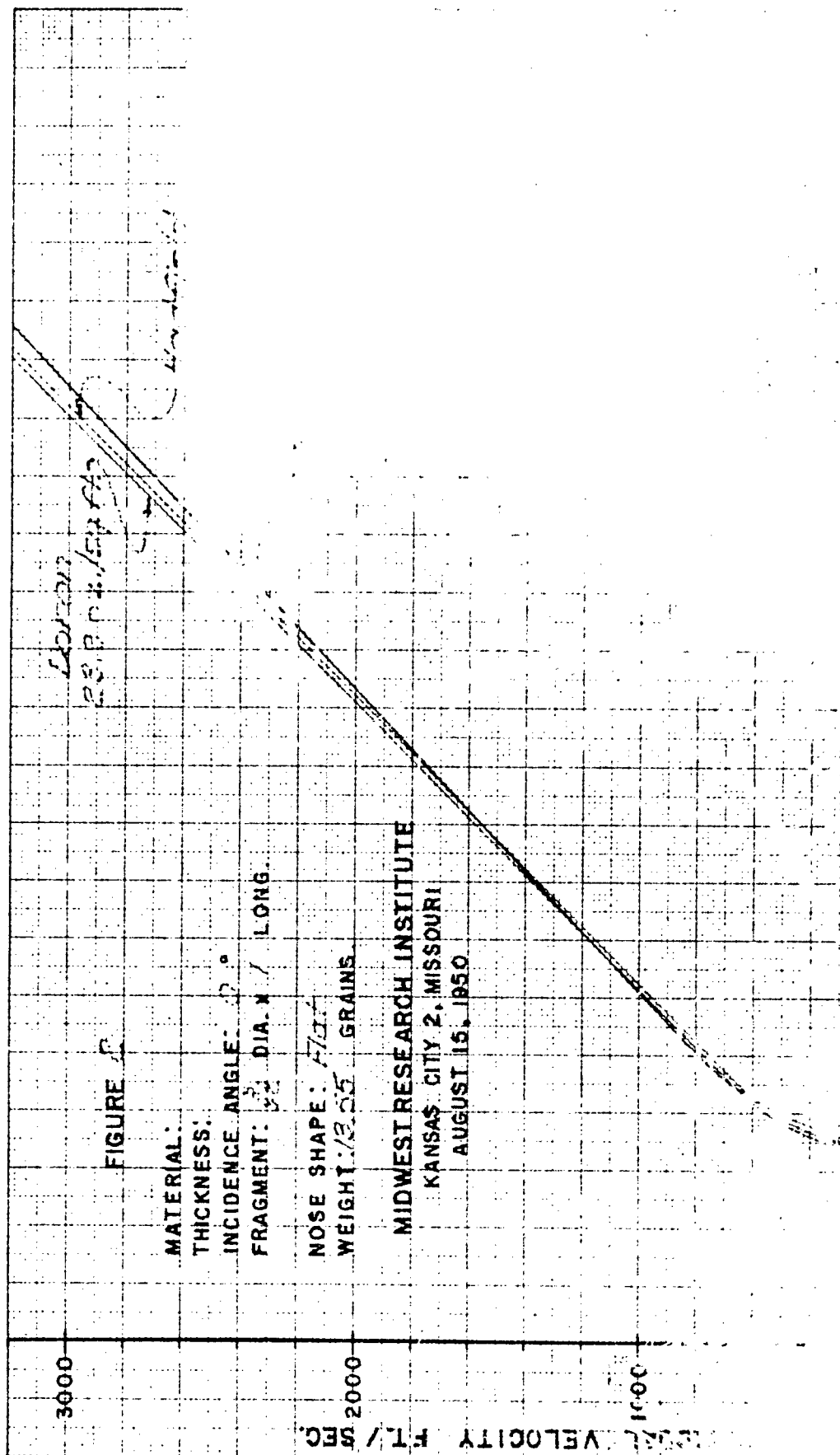
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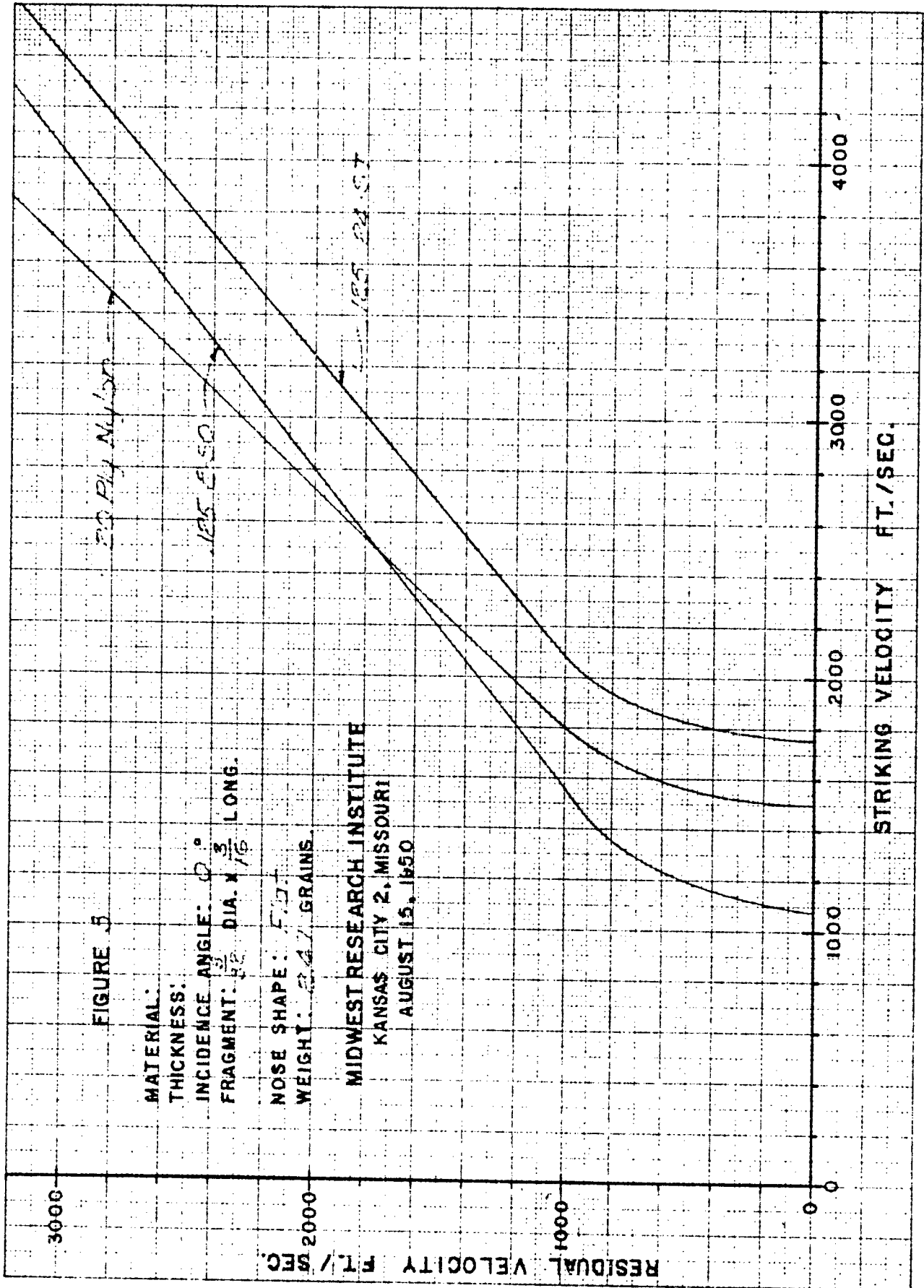


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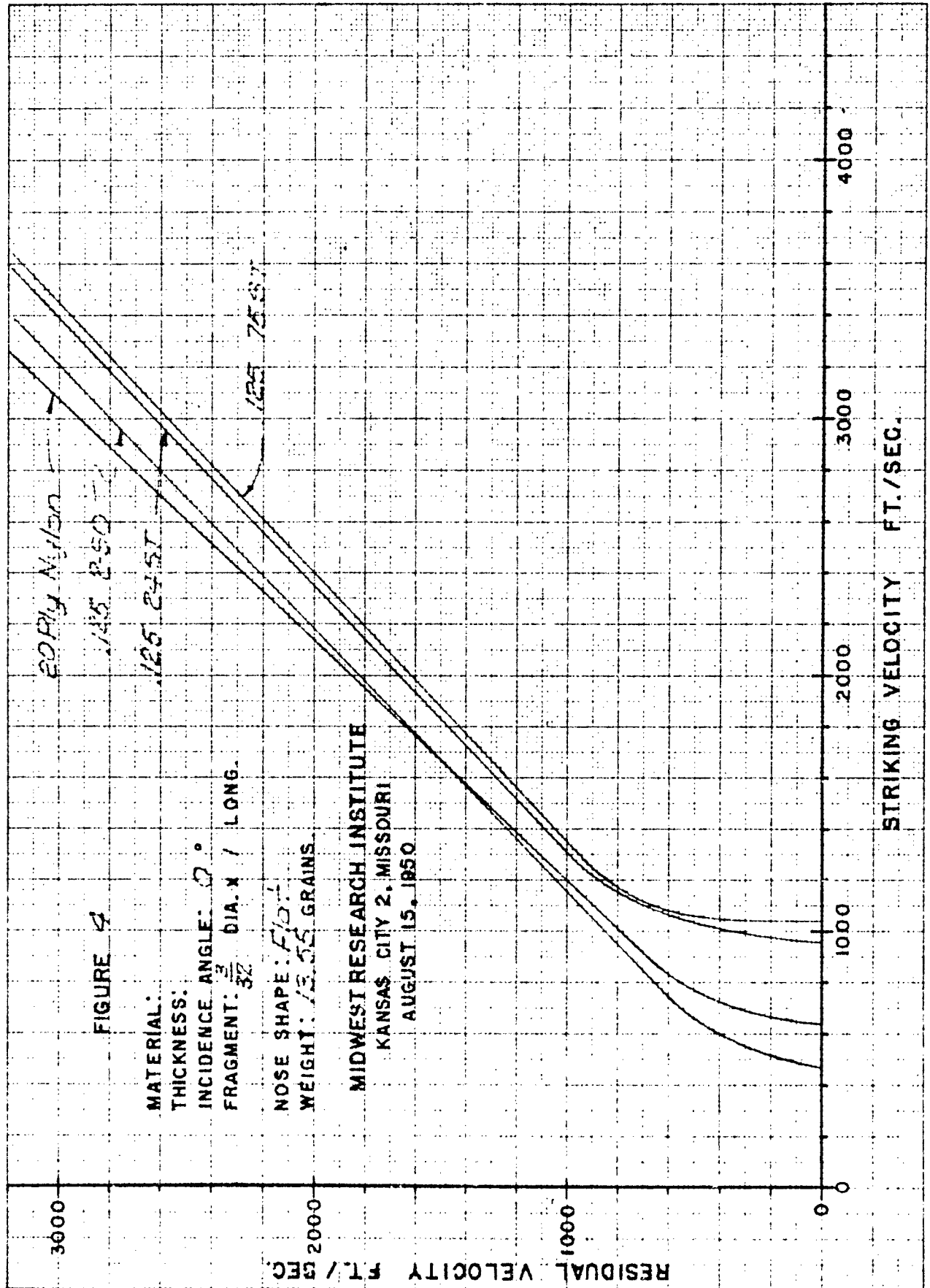
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FIGURE 5

MATERIAL: 245T

THICKNESS: .091

INCIDENCE ANGLE: 0°

FRAGMENT: $\frac{3}{32}$ DIA. x $\frac{3}{16}$ LONG.

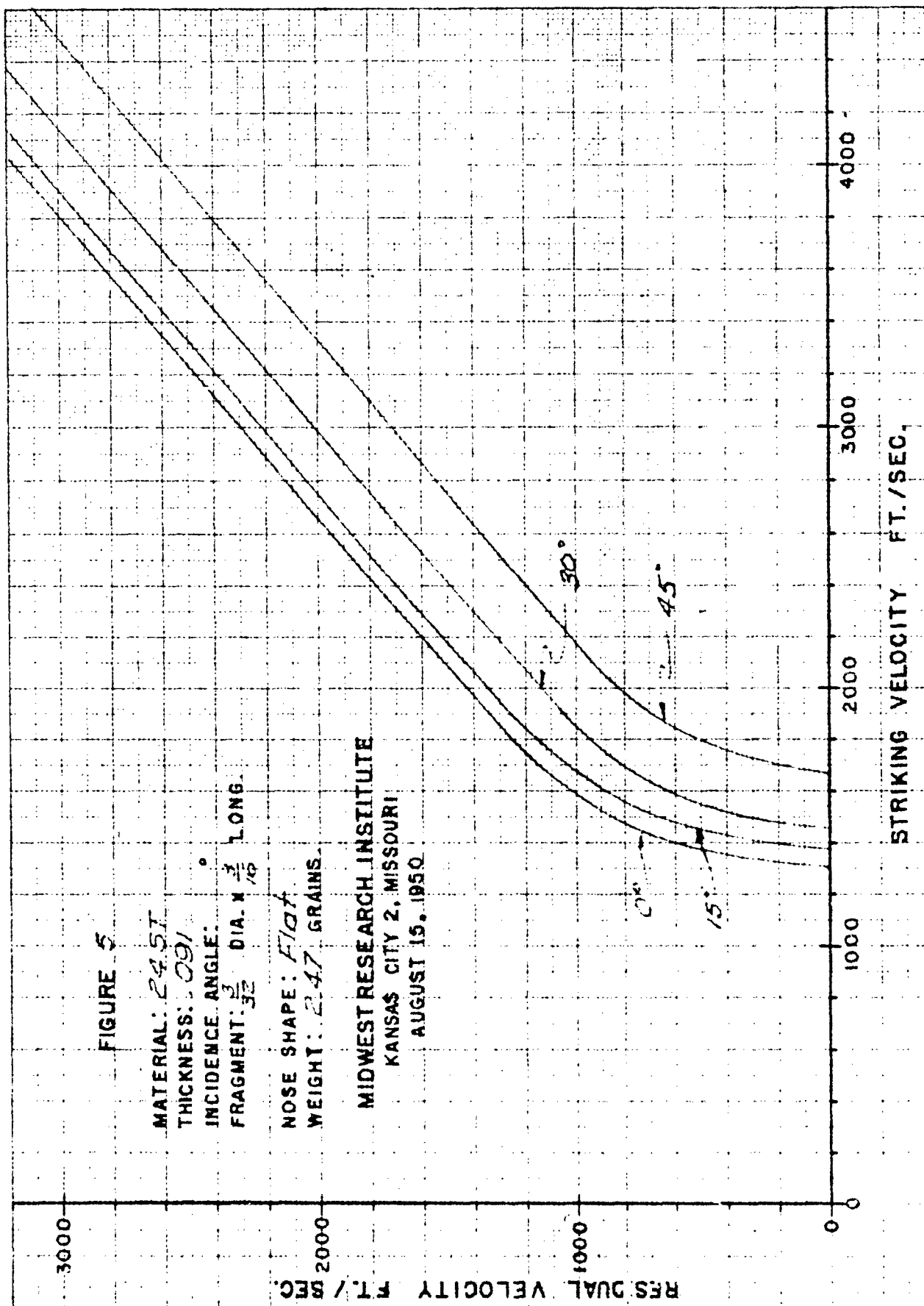
NOSE SHAPE: Flat

WEIGHT: 2.47 GRAINS.

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AUGUST 15, 1950



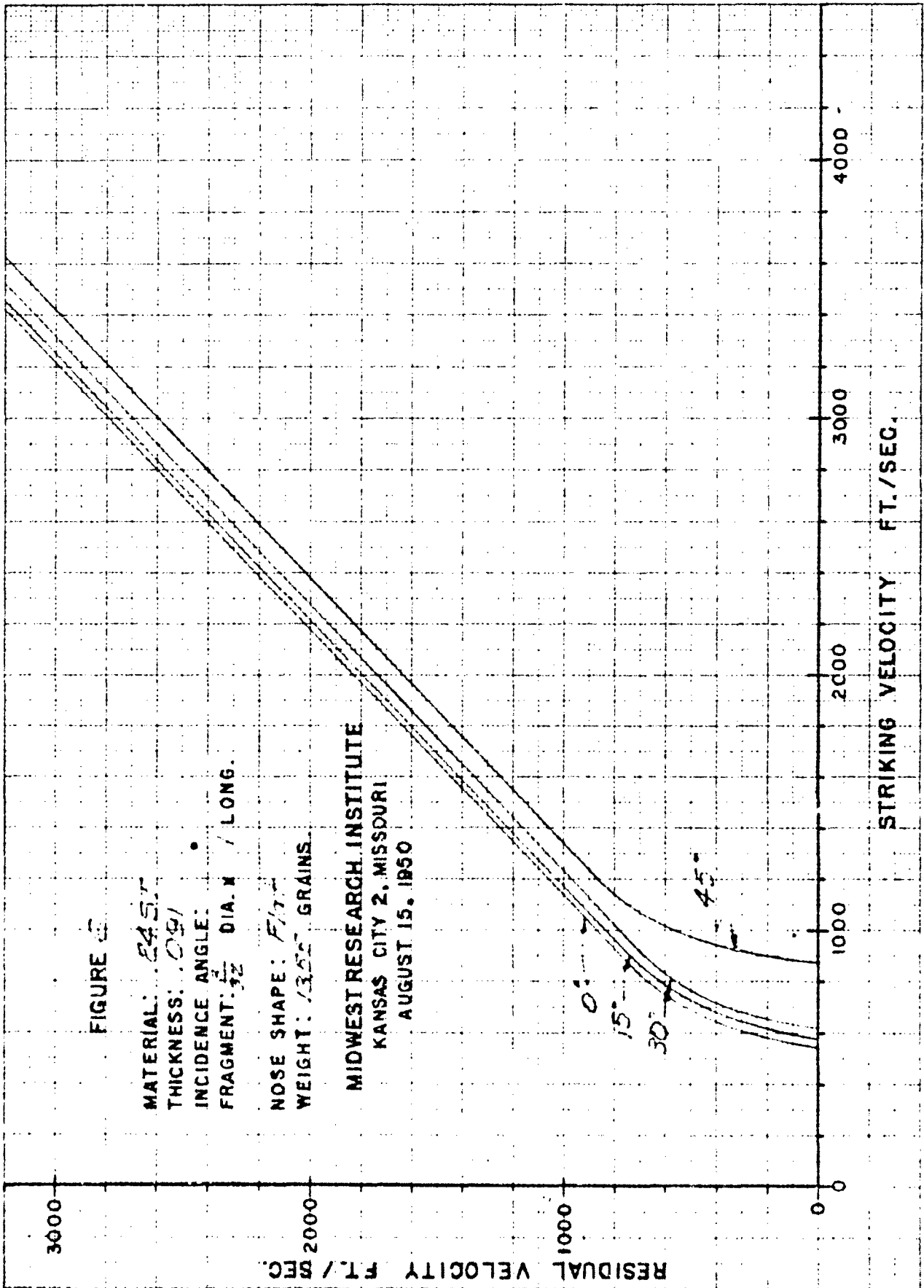
RESTRICTED

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DATA SHEETS

CHARLES BRUNNENSWERK, INC. NO. 70-10-10



RESTRICTED

MATERIAL: 24.57

THICKNESS: .02

INCIDENCE ANGLE:

FRAGMENT: $3\frac{3}{32}$ DIA. \times $3\frac{3}{16}$ LONG.

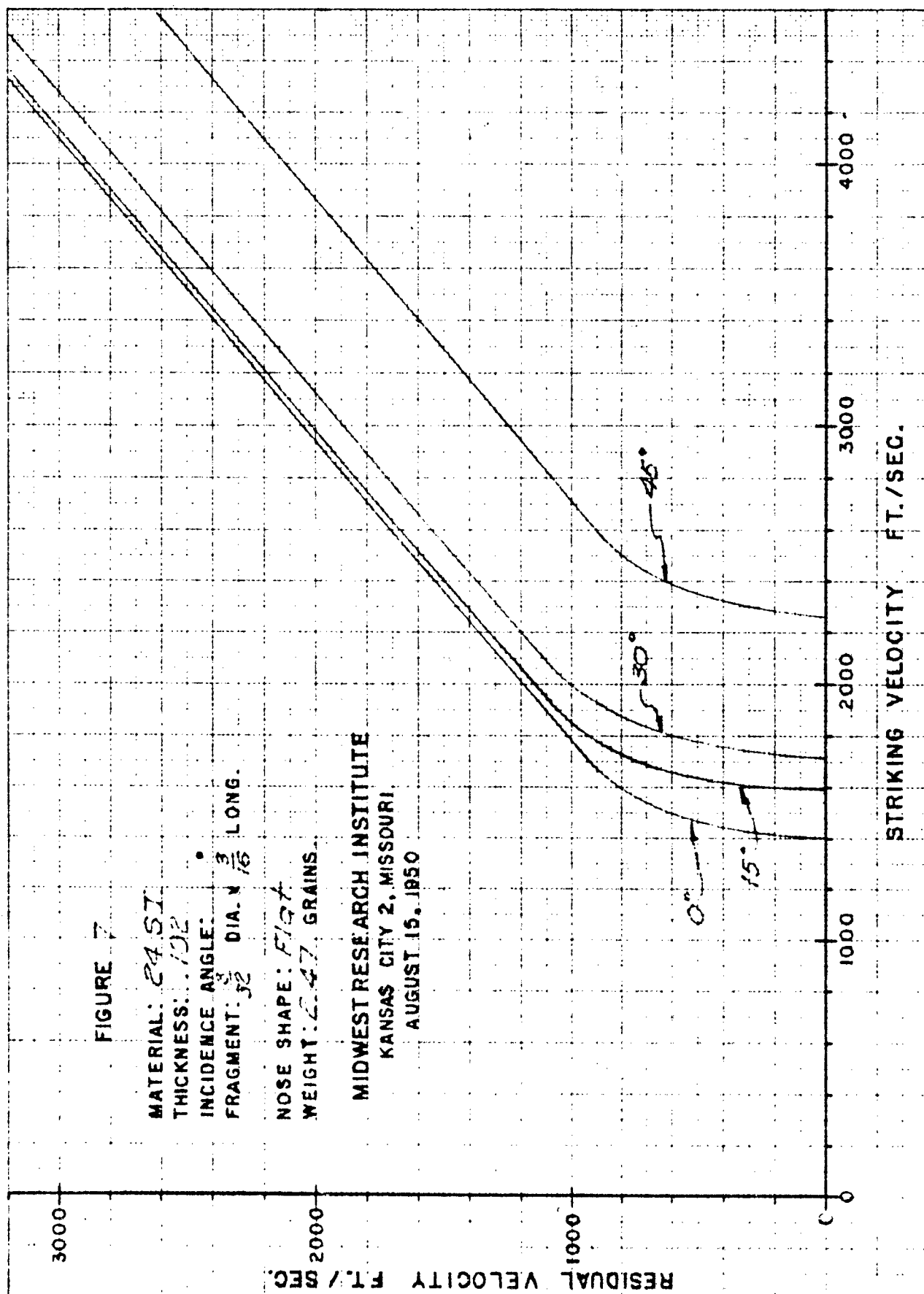
NOSE SHAPE: *FIG 4*

WEIGHT: 2.47 GRAMS.

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KANSAS CITY 2, MISSOURI.

AUGUST 15, 1950



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DATA SHEETS

CHARLES BULLINGTON COMPANY, INC. NO. 700-M

FIGURE 5

MATERIAL: 24 ST

THICKNESS: .102

INCIDENCE ANGLE: 0°

FRAGMENT: $\frac{3}{16}$ DIA. X 1 LONG.

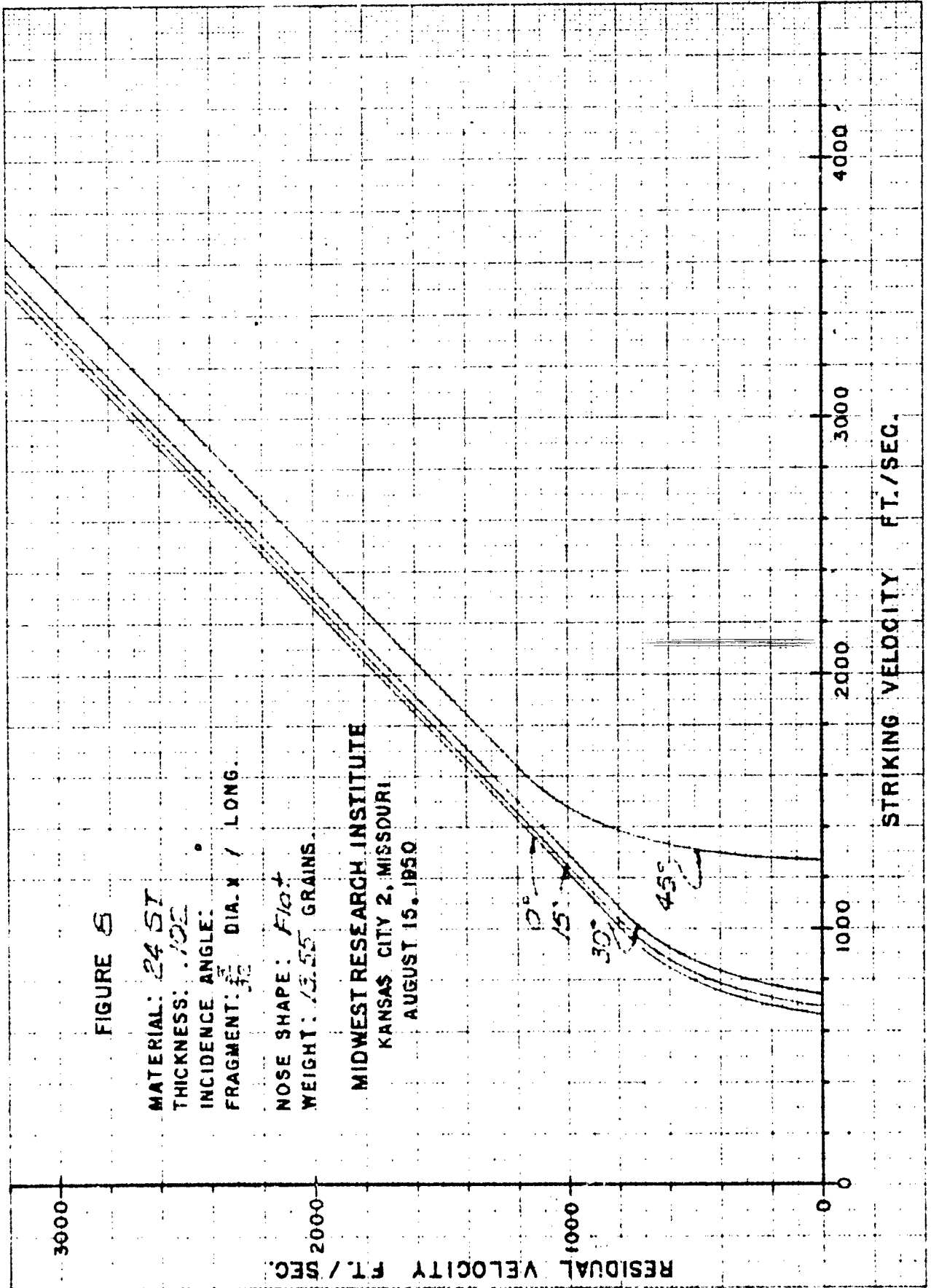
NOSE SHAPE: Flat

WEIGHT: 13.55 GRAINS.

MIDWEST RESEARCH INSTITUTE

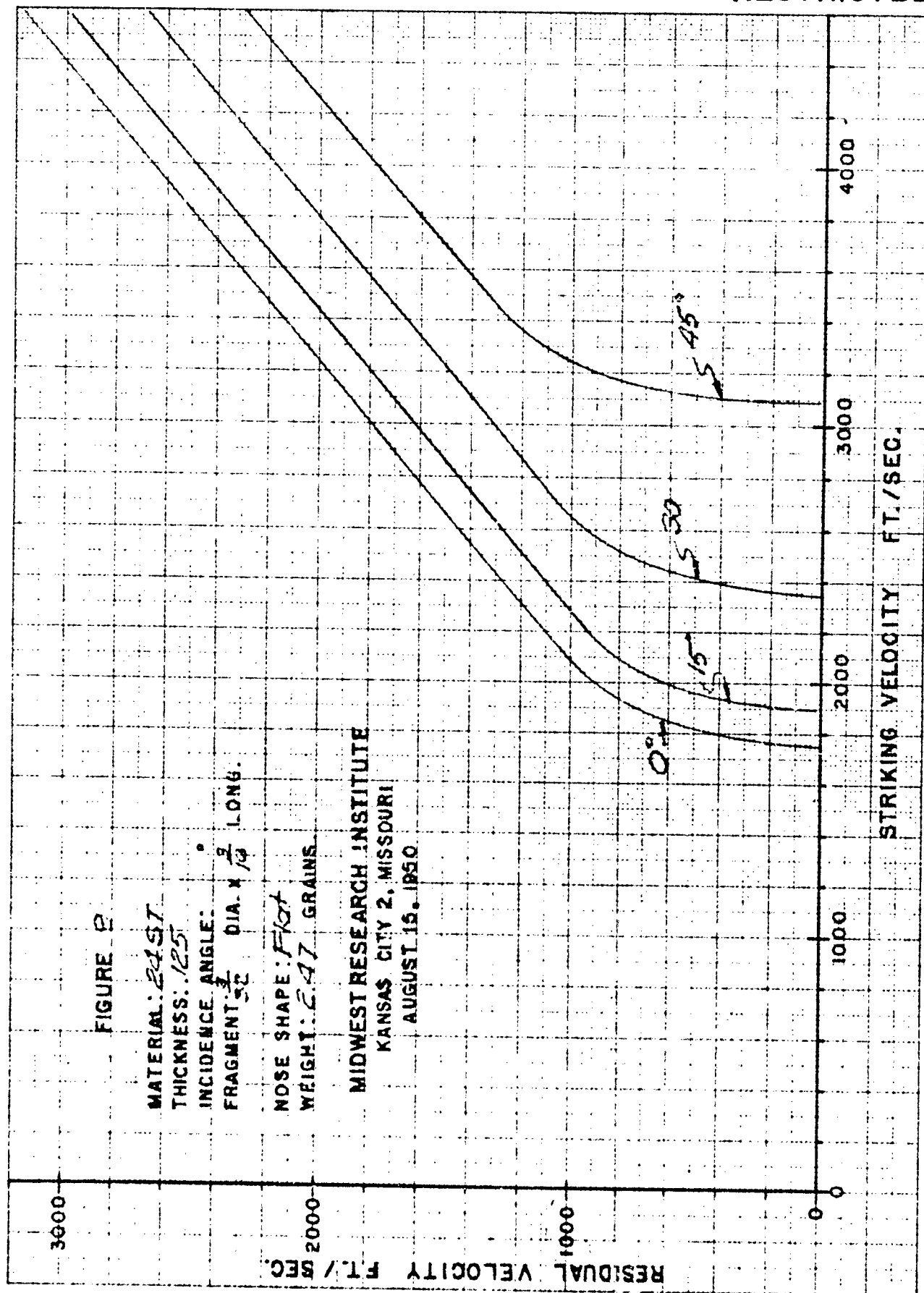
KANSAS CITY 2, MISSOURI

AUGUST 15, 1950

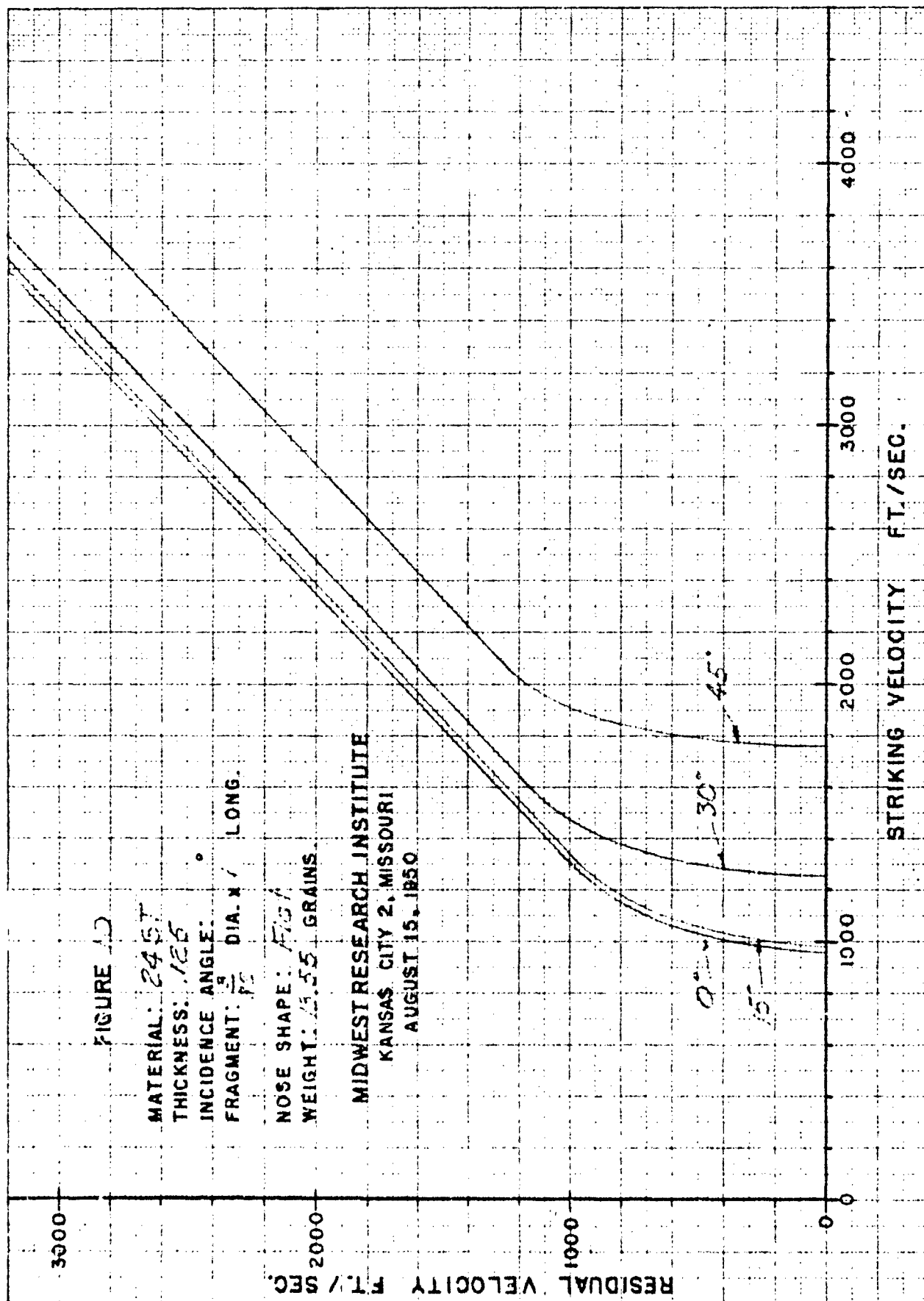


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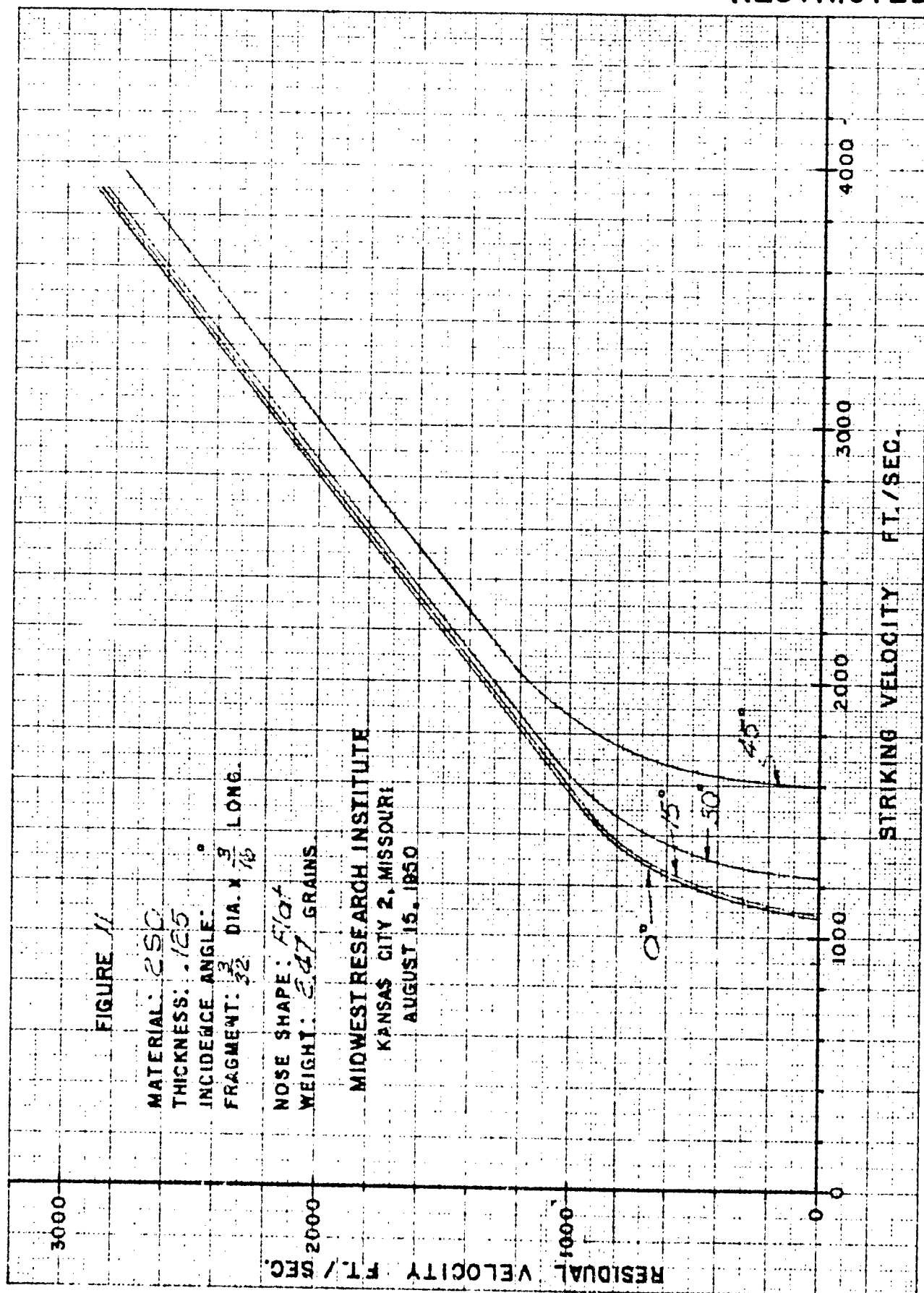


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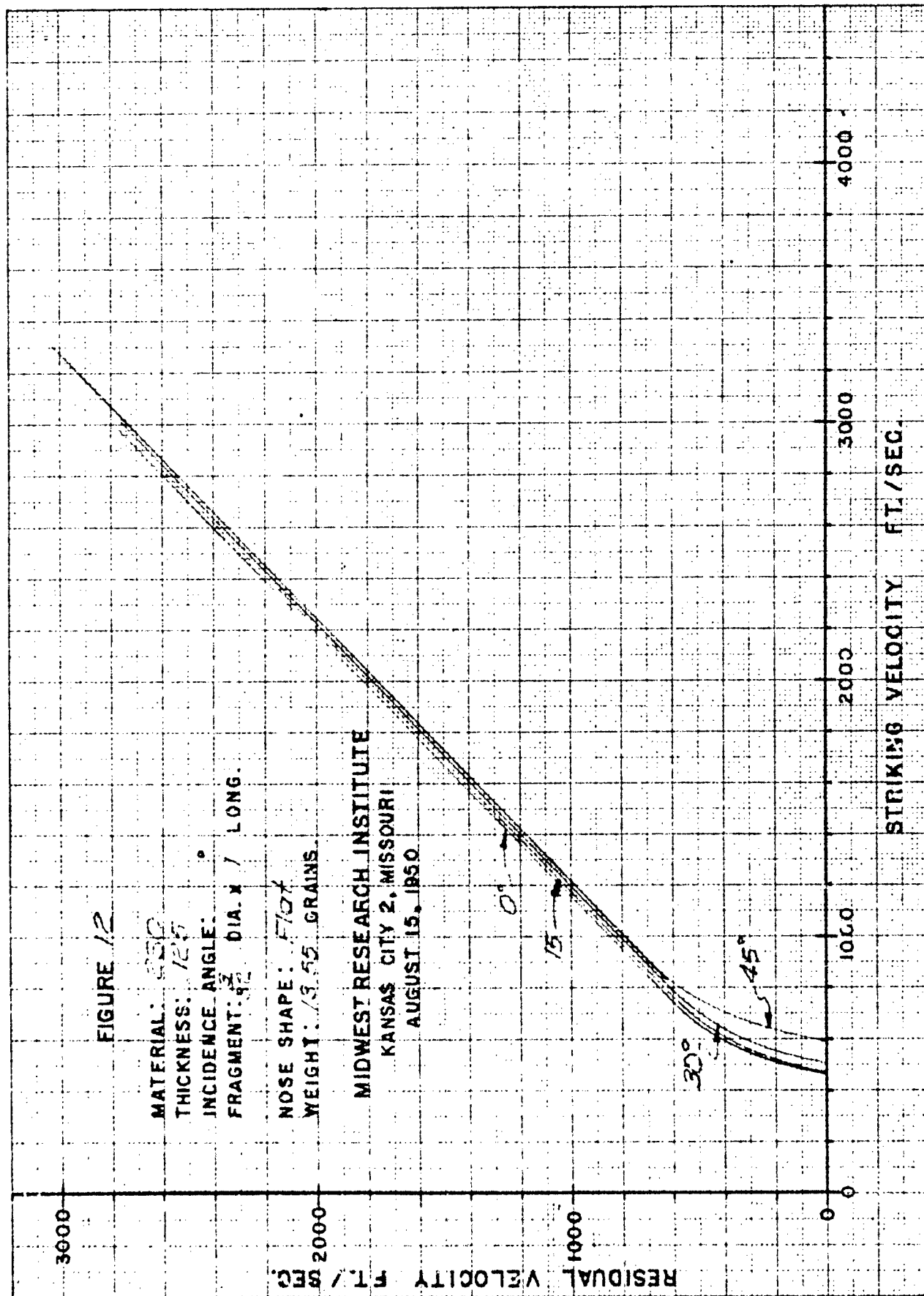
RESTRICTED

RESTRICTED



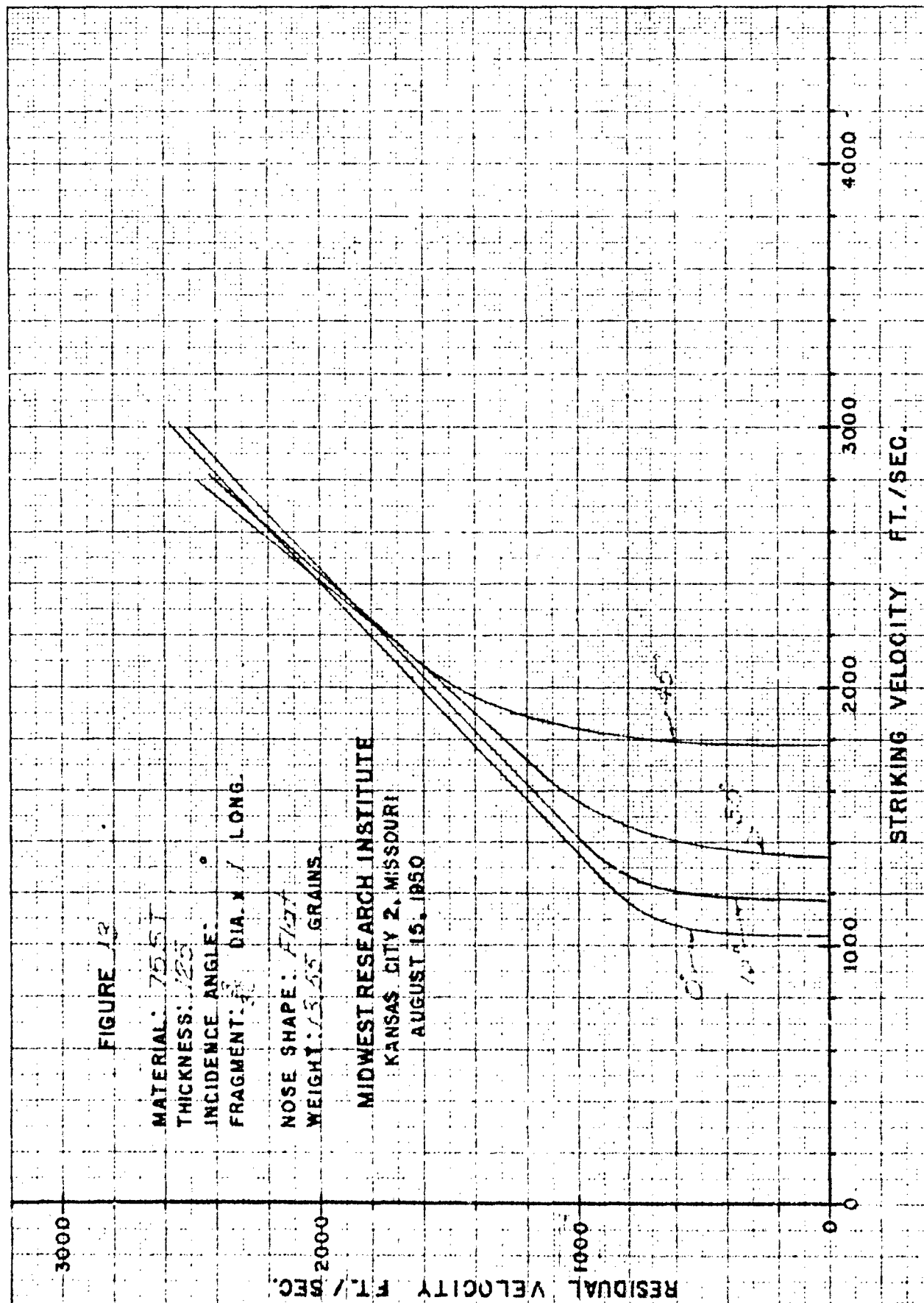
RESTRICTED

RESTRICTED

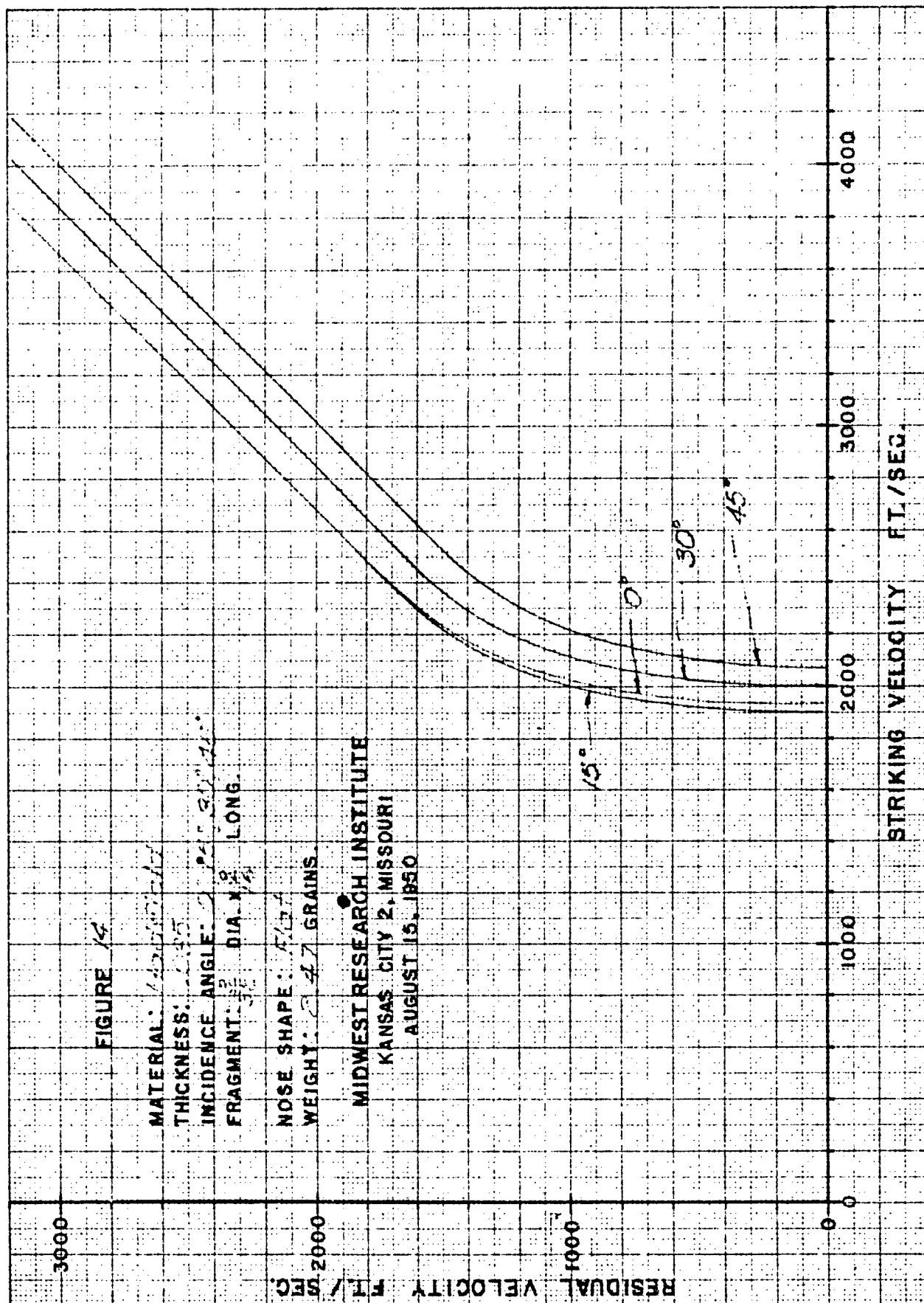


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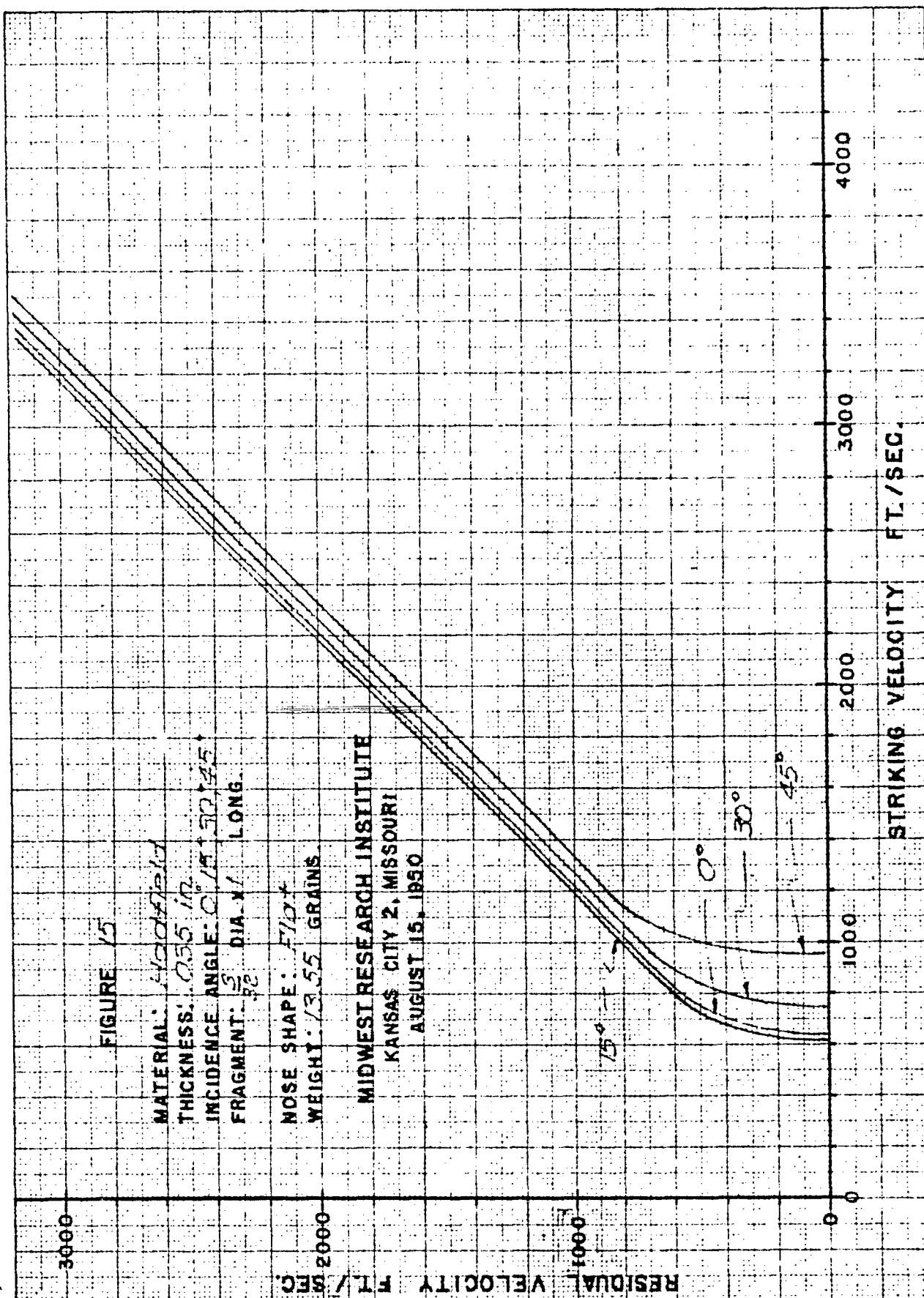
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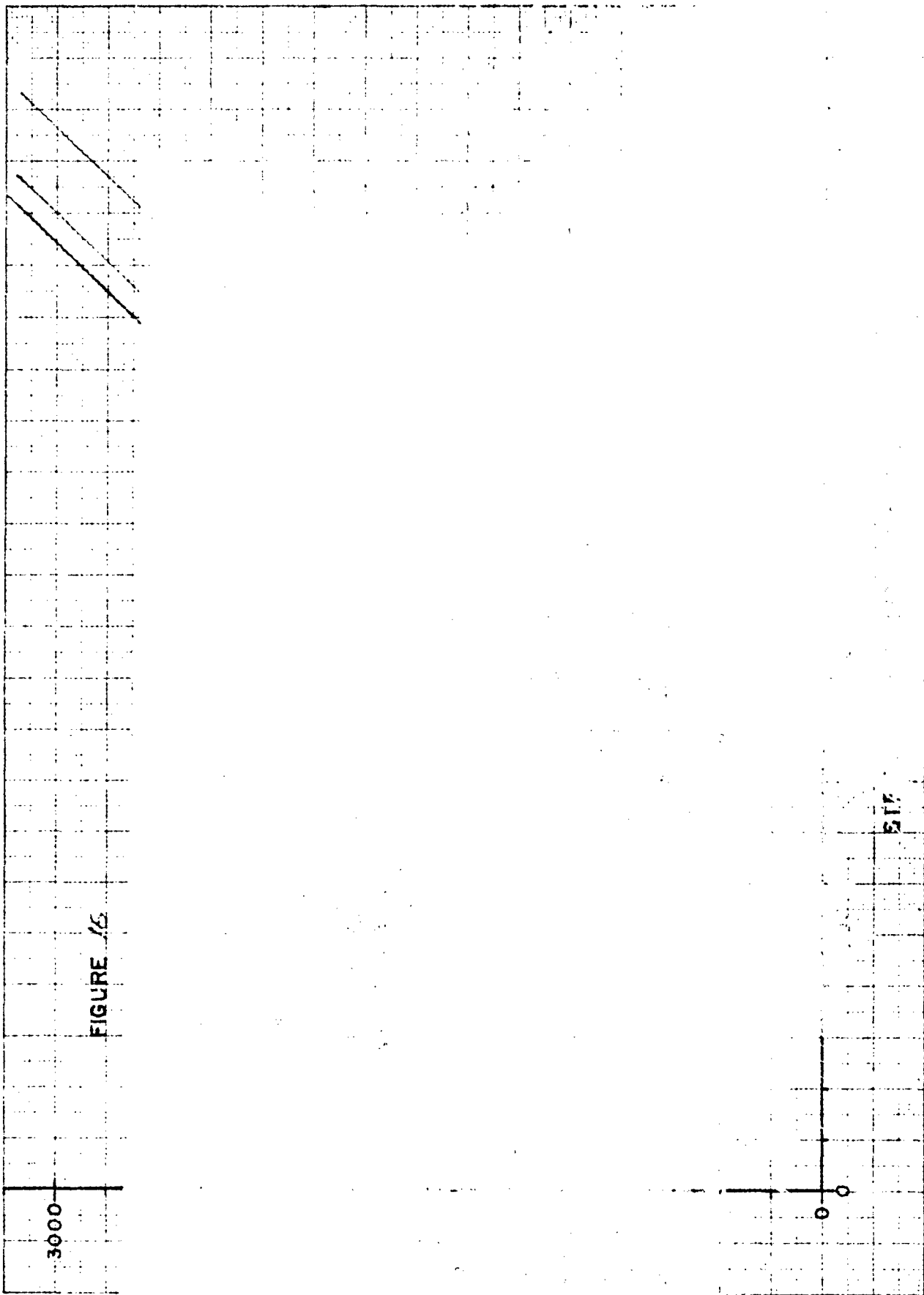
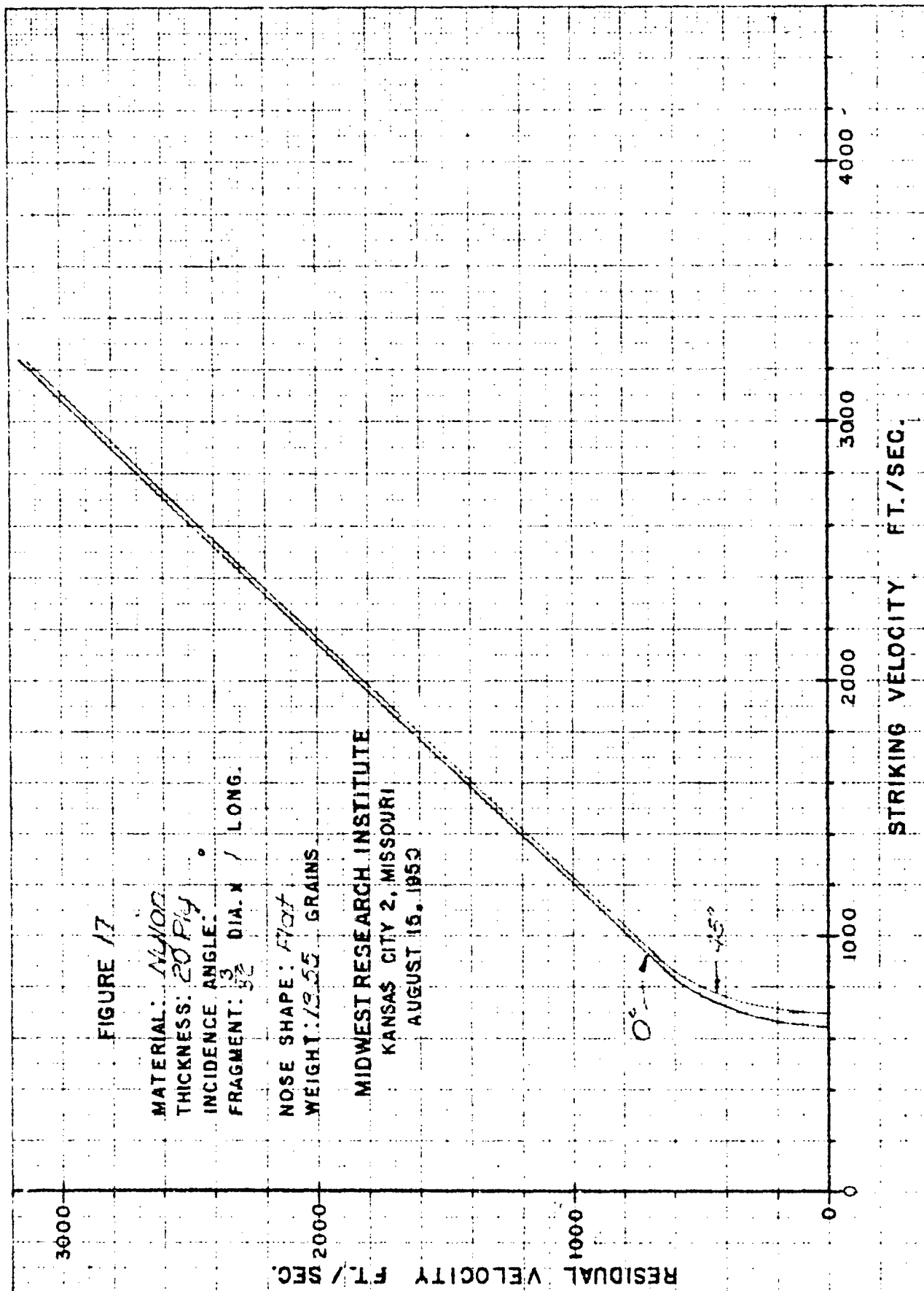


FIGURE 16

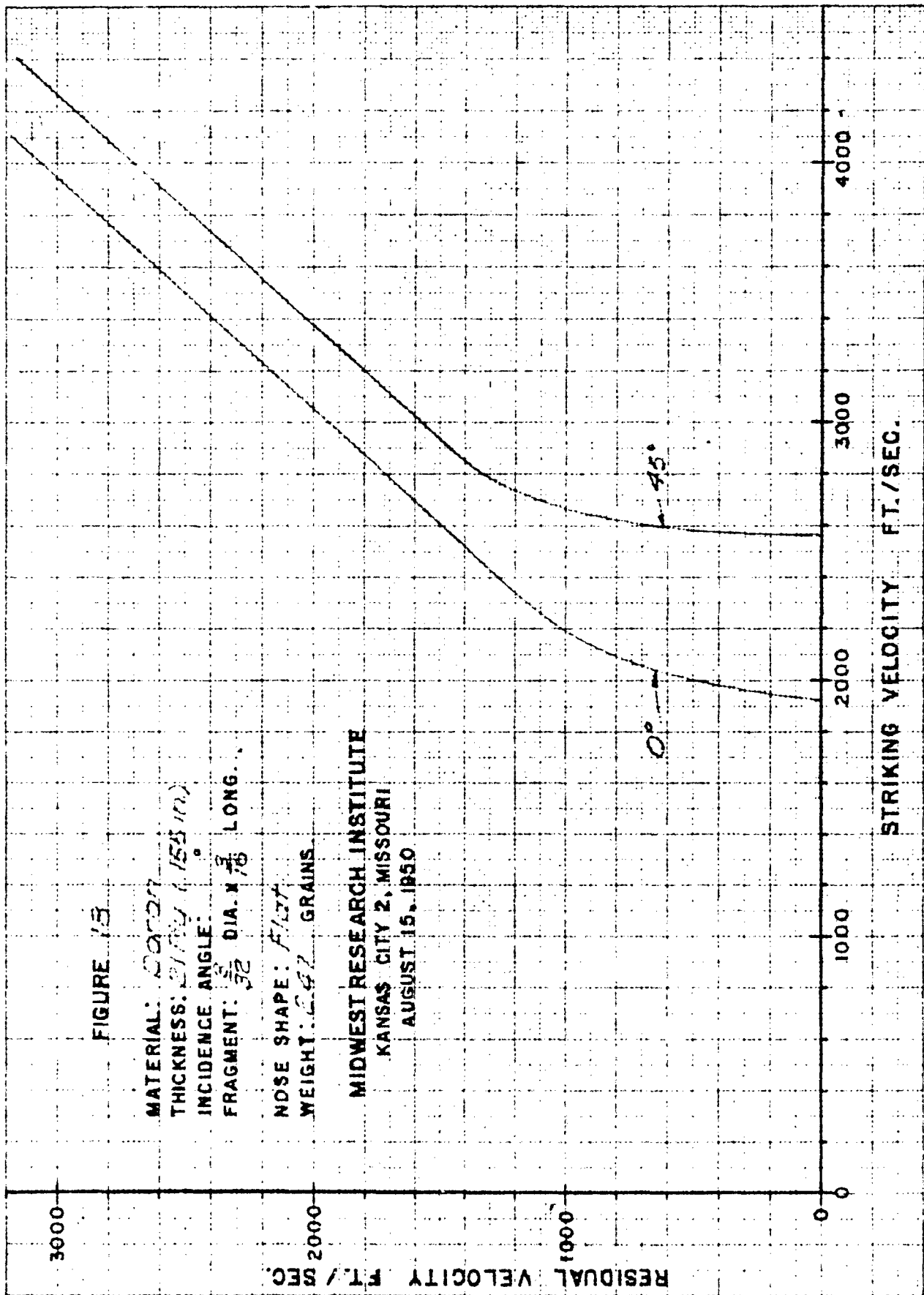
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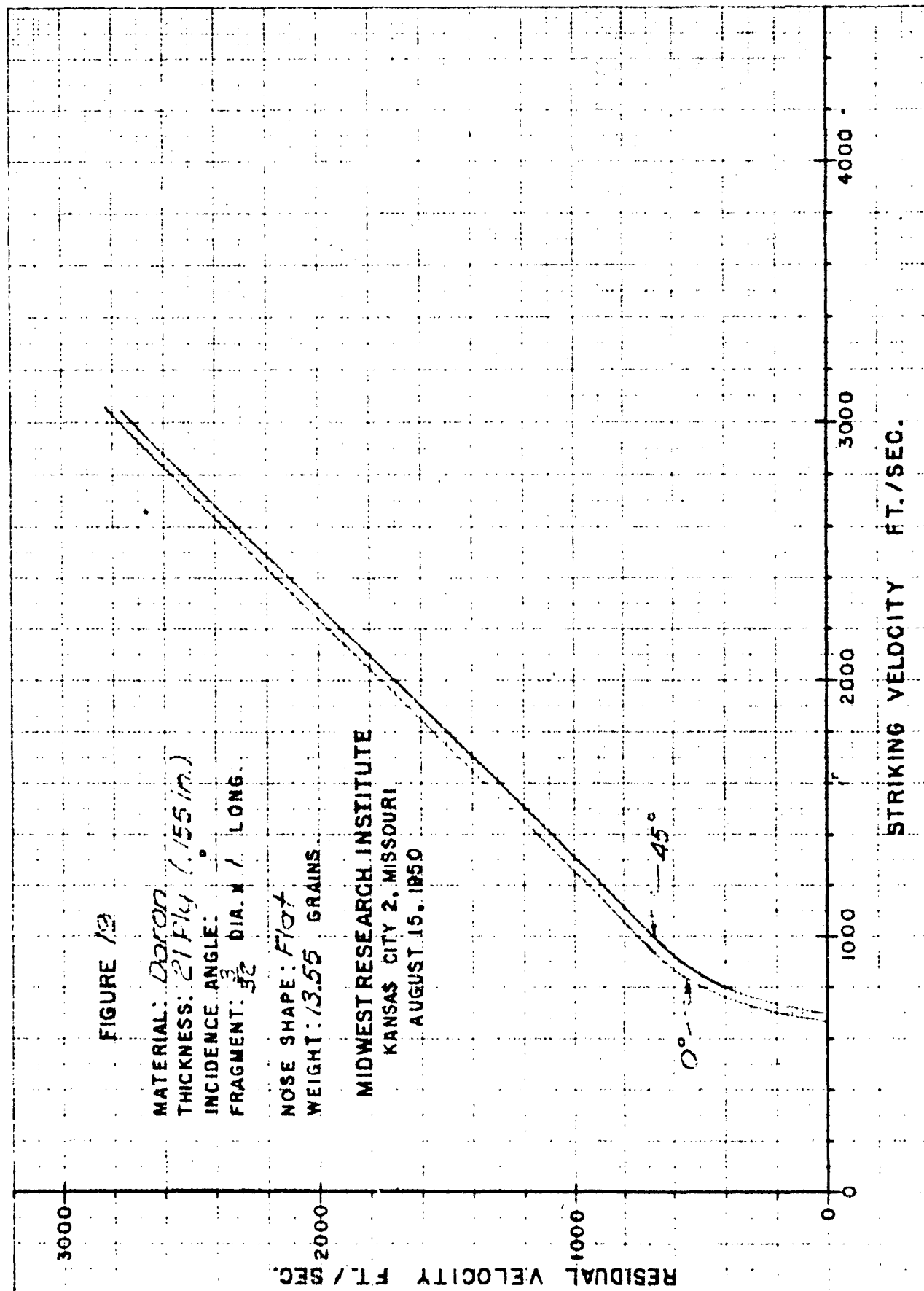
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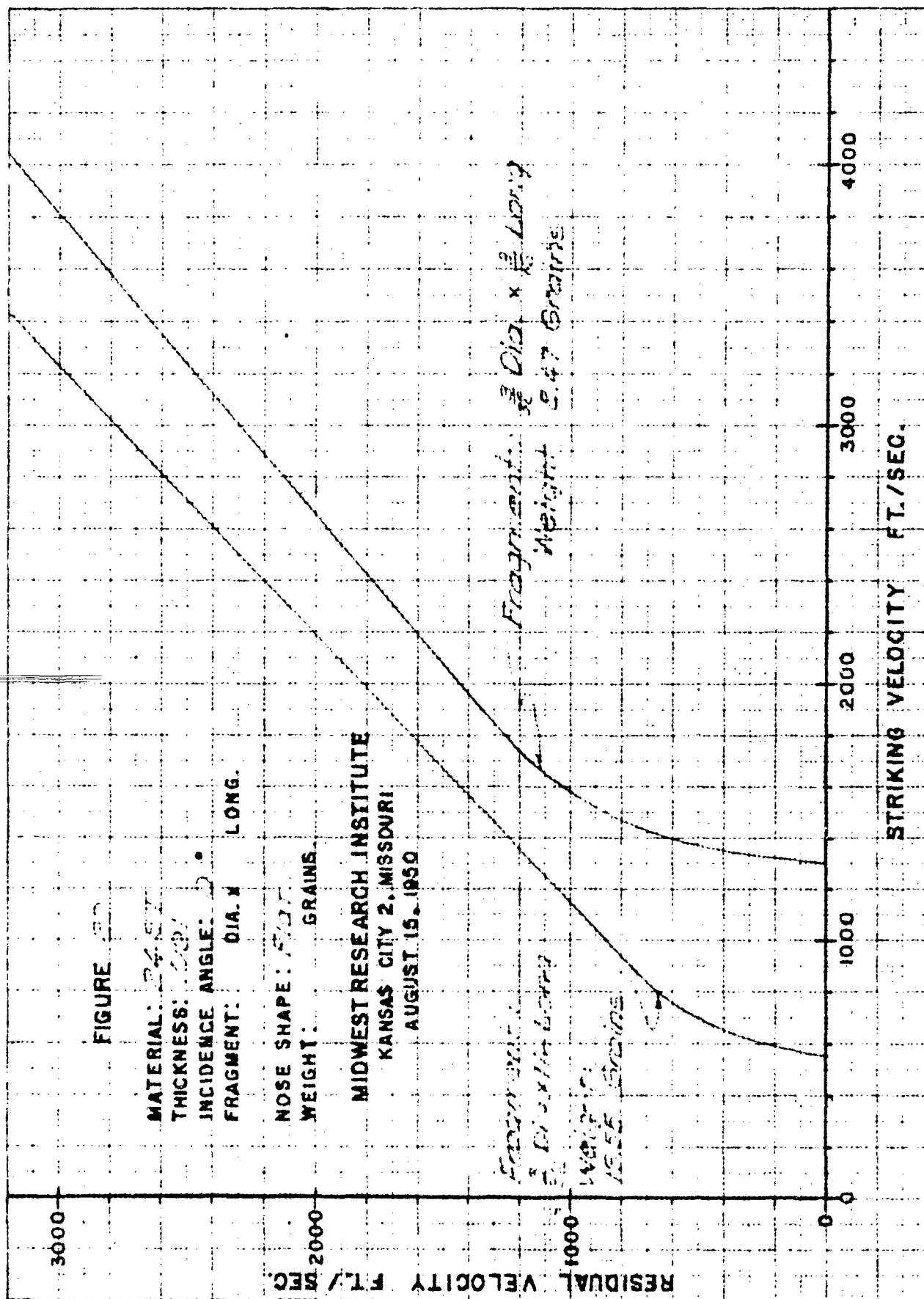




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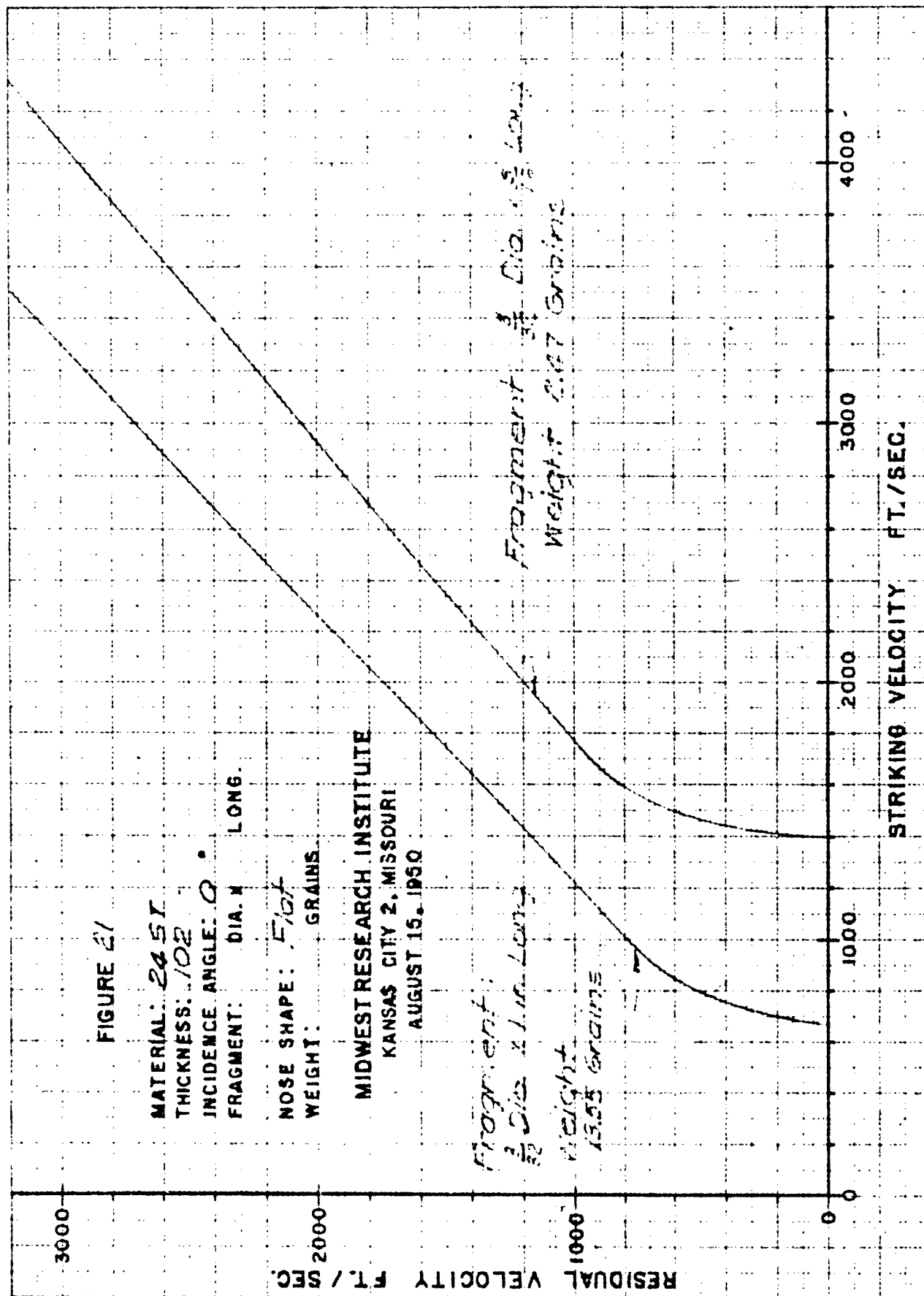
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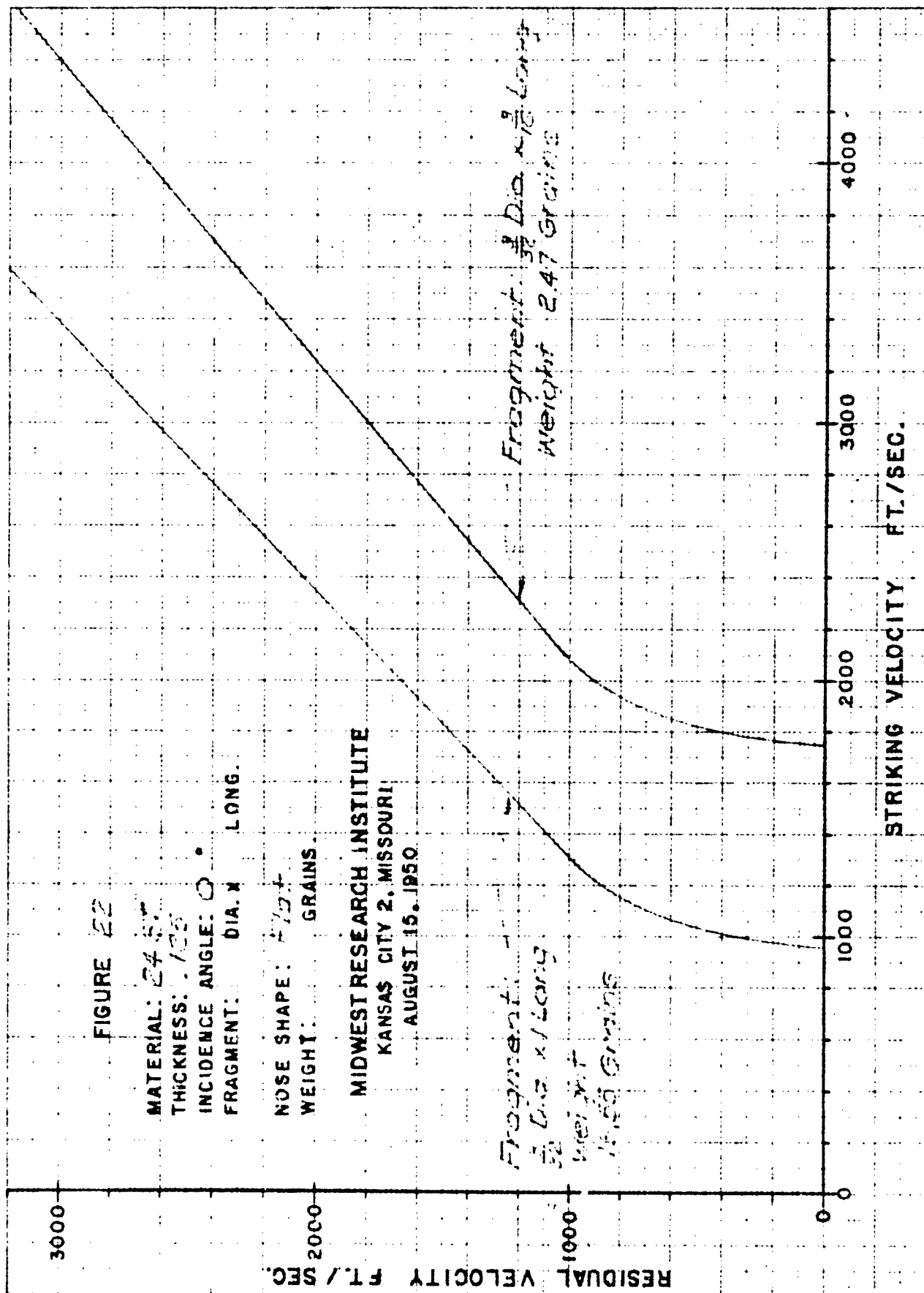
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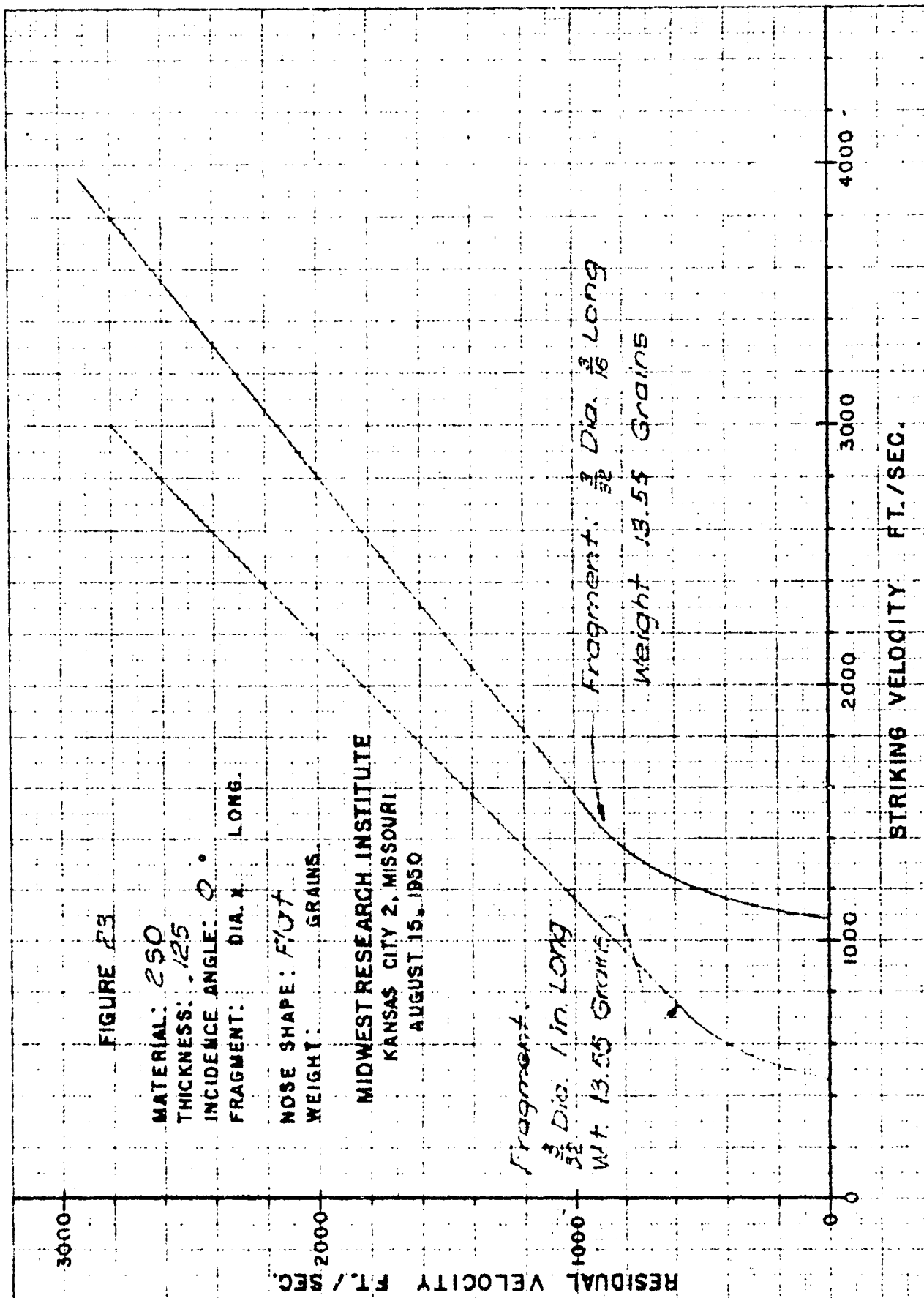
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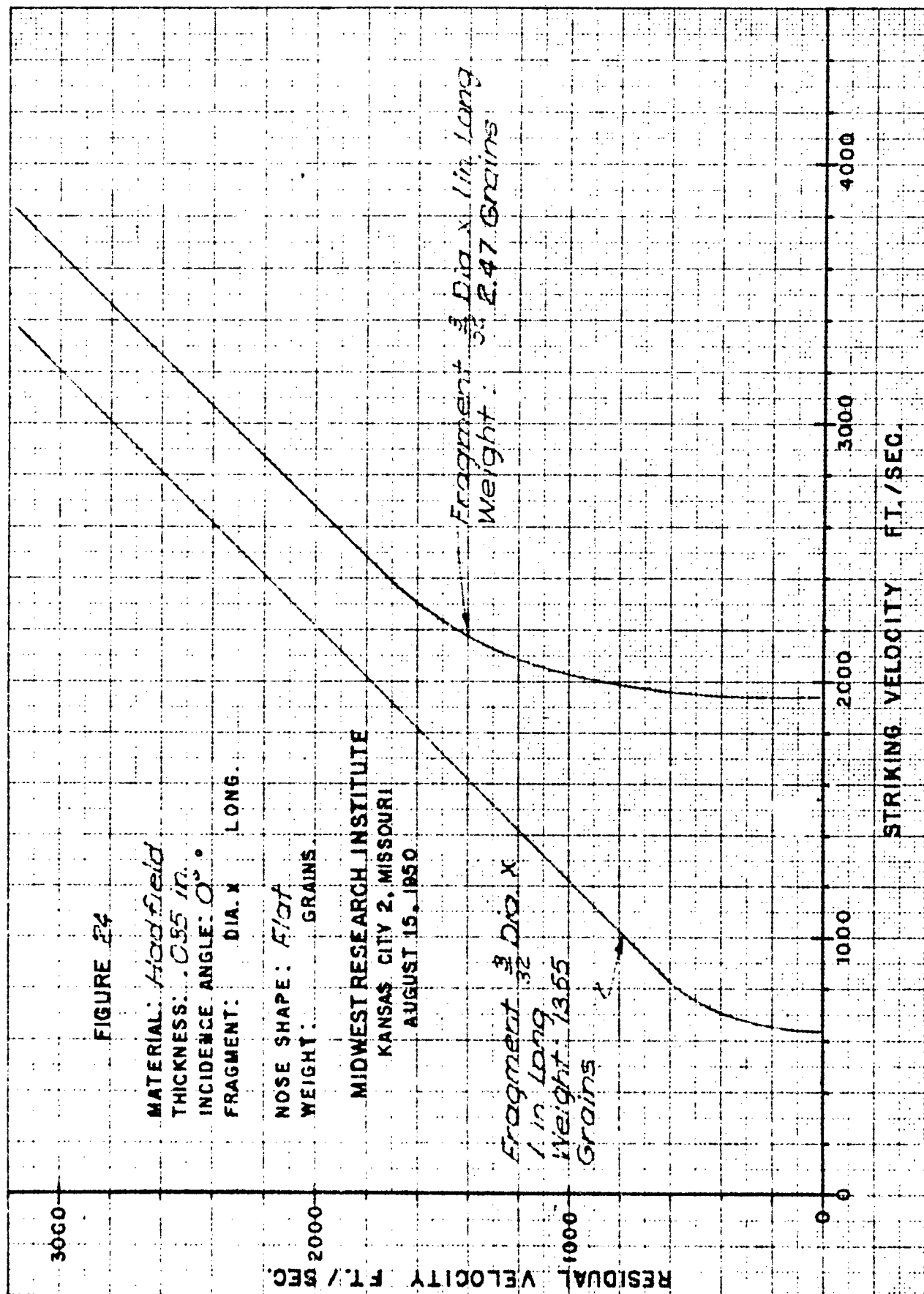
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RESTRICTED



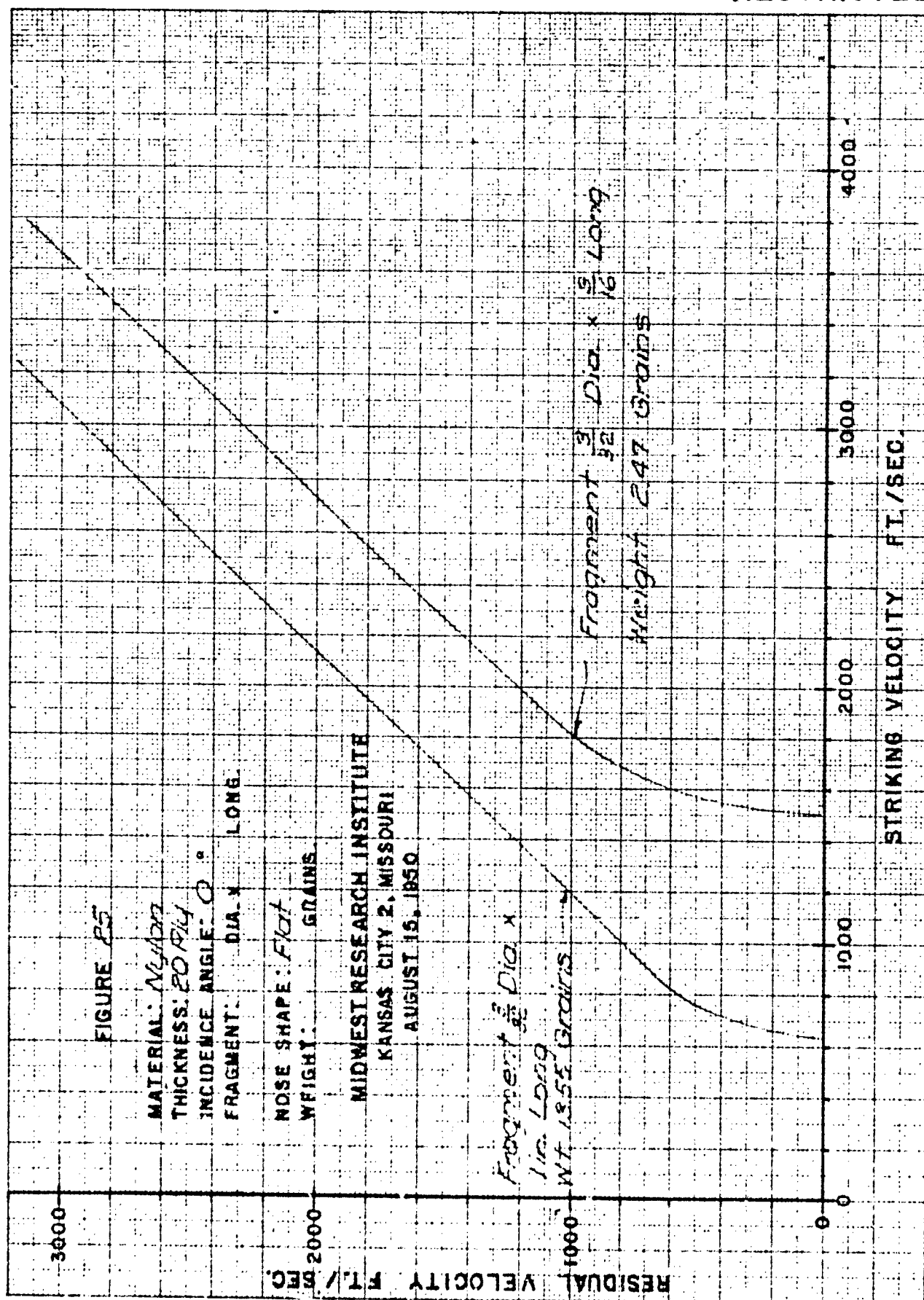
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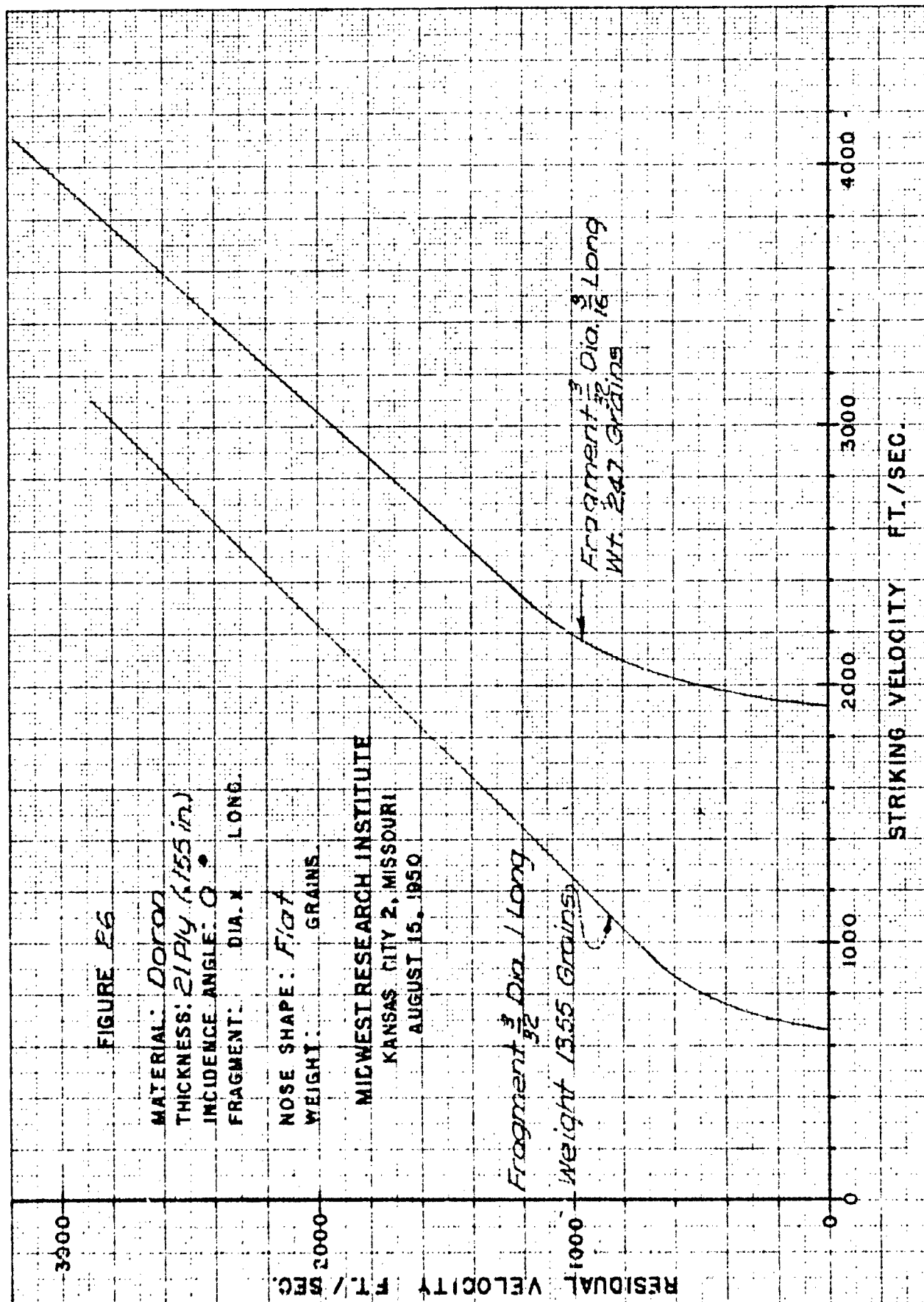
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RESTRICTED

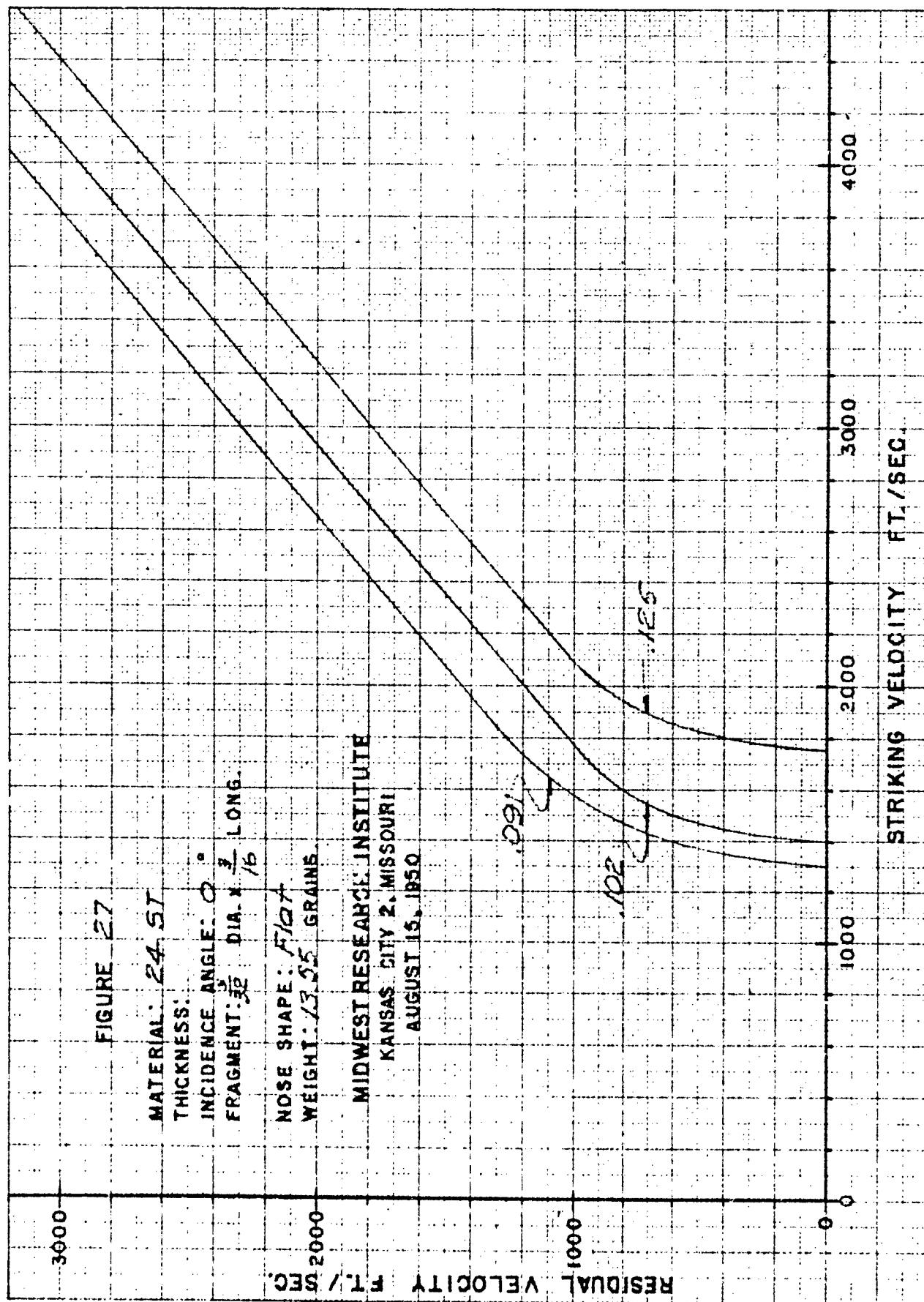


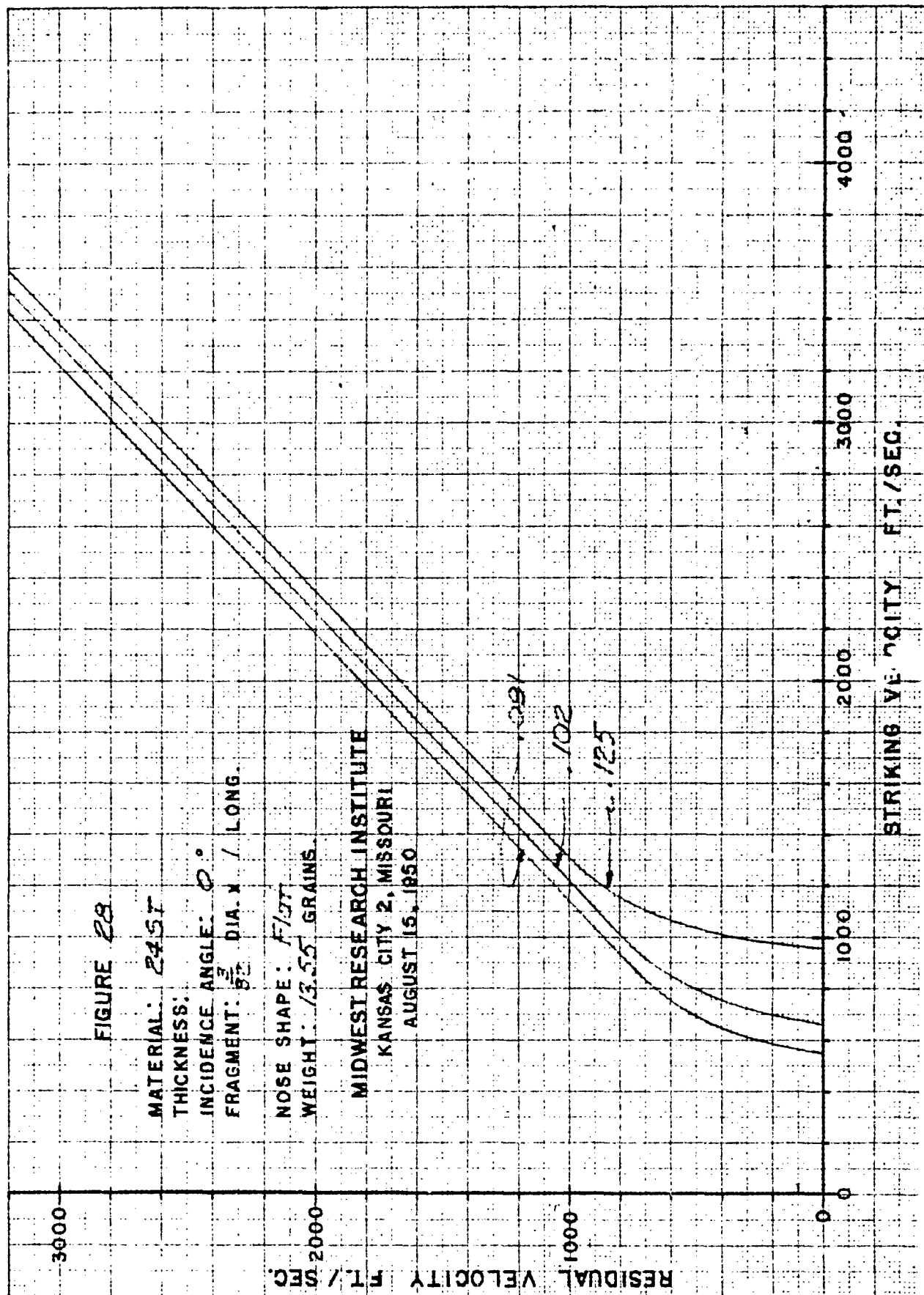
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RESTRICTED



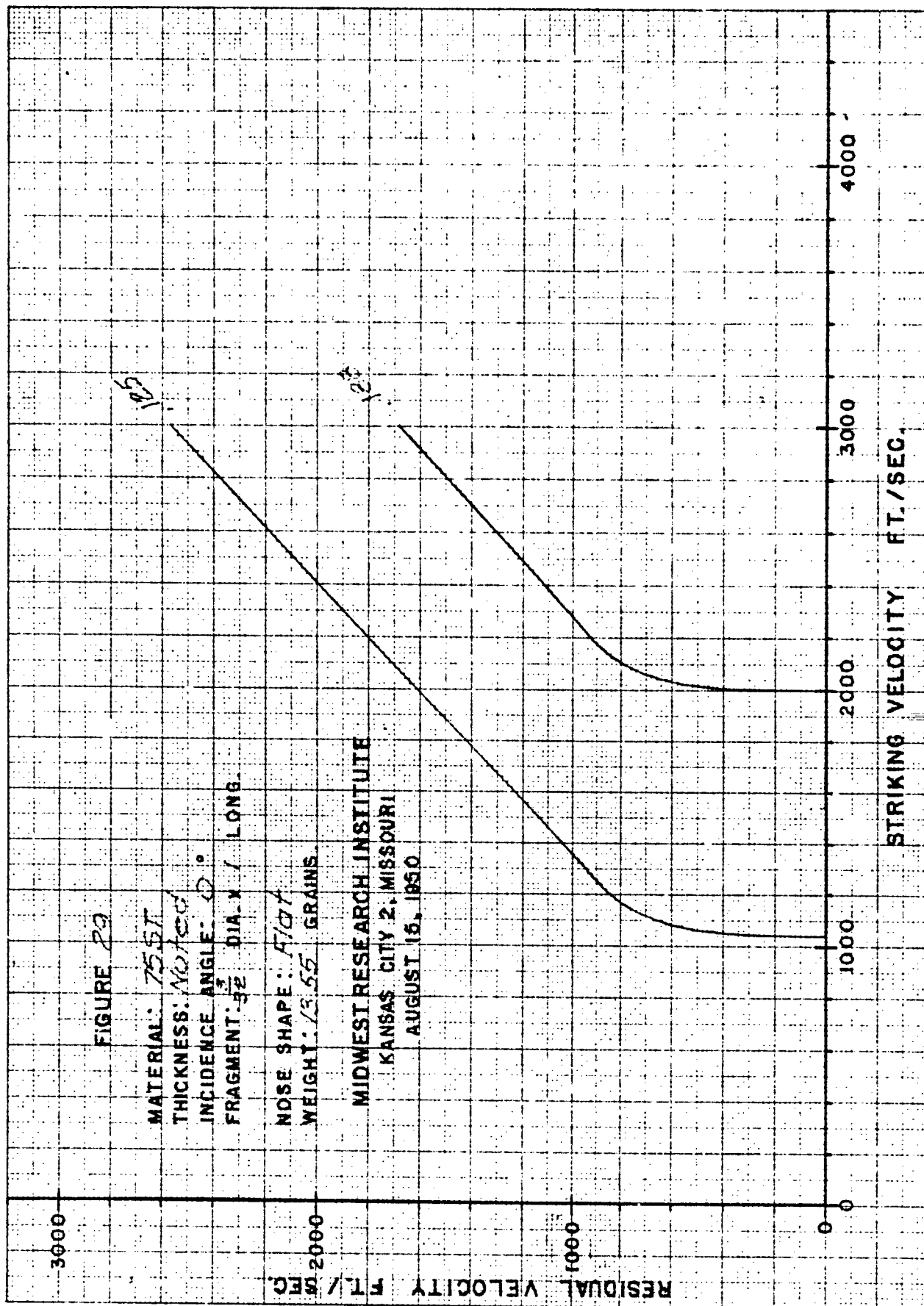
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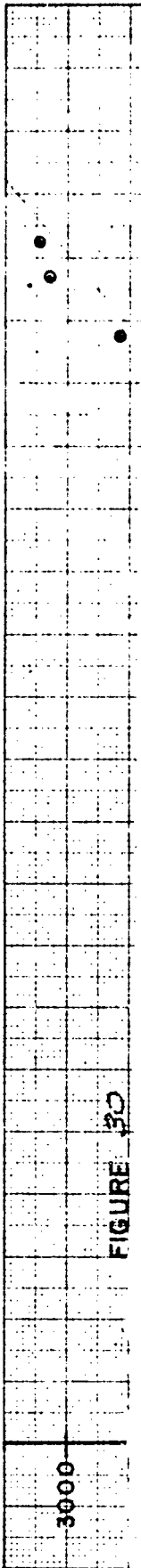


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DATA SHEETS

CHARLES BRUNING COMPANY, INC. NO. 700-M
Millimeter, 10th line heavy



RESIDUAL VELOC.

STRIKING VELOCITY FT./SEC.

4000

3000

2000

1000

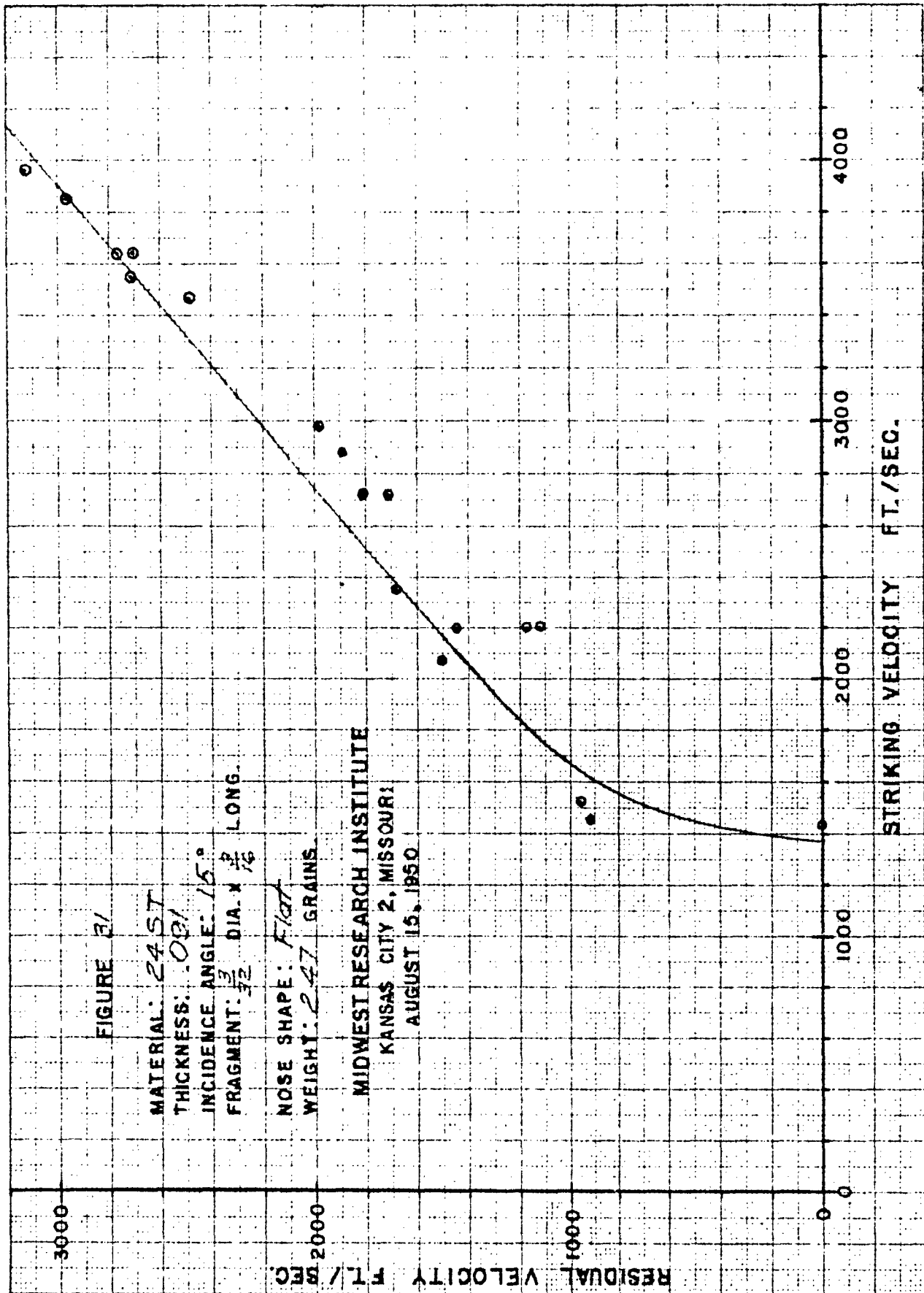
0

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DATA SHEETS

CHARLES BRUNING COMPANY, INC. NO. 7800-M
M. 1111-1111, 1111, 1111-1111

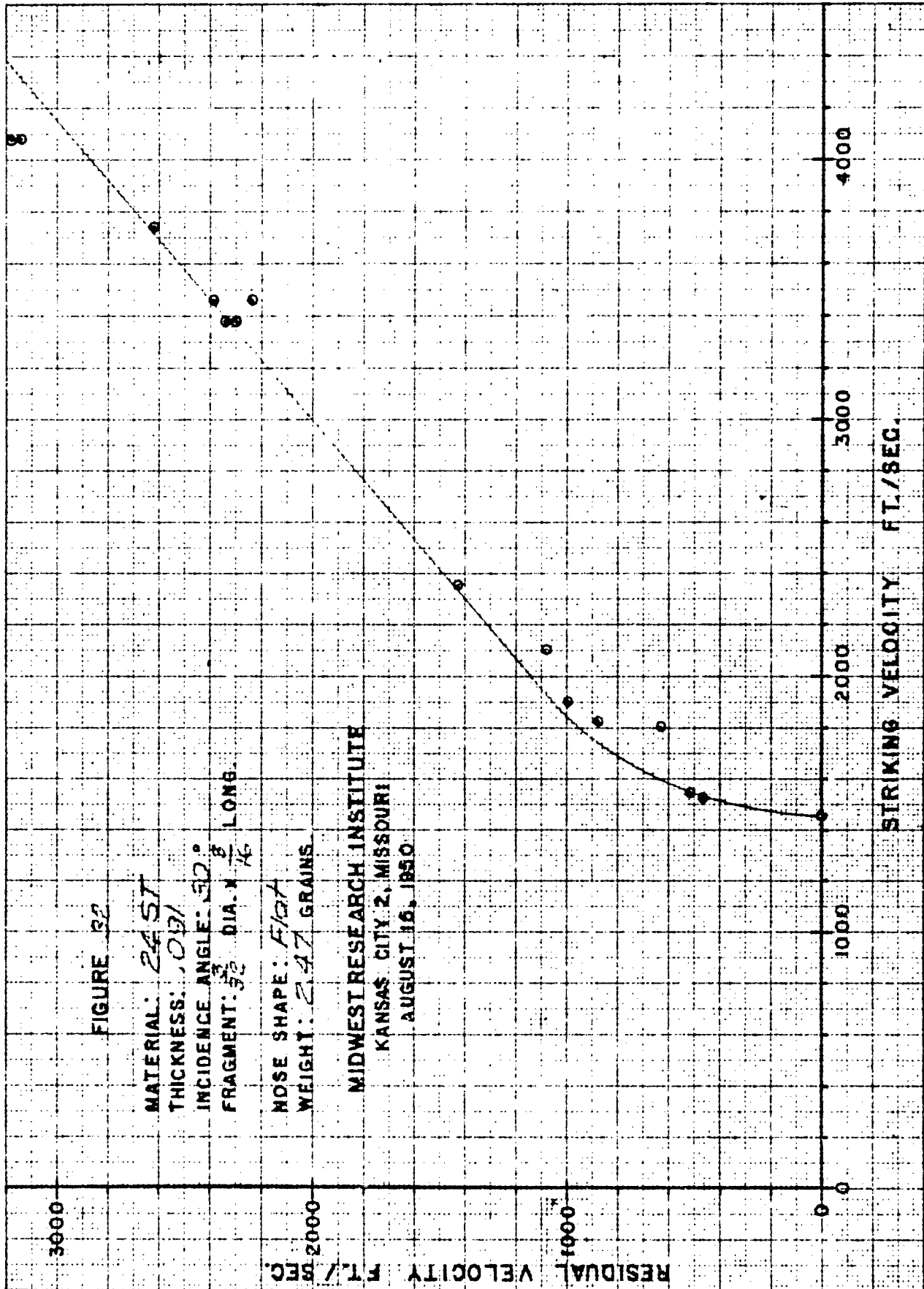


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RESTRICTED

DATA SHEETS

CHARLES BRUNING COMPANY, INC. NO. 700-M
Minutemen, 10th line heavy

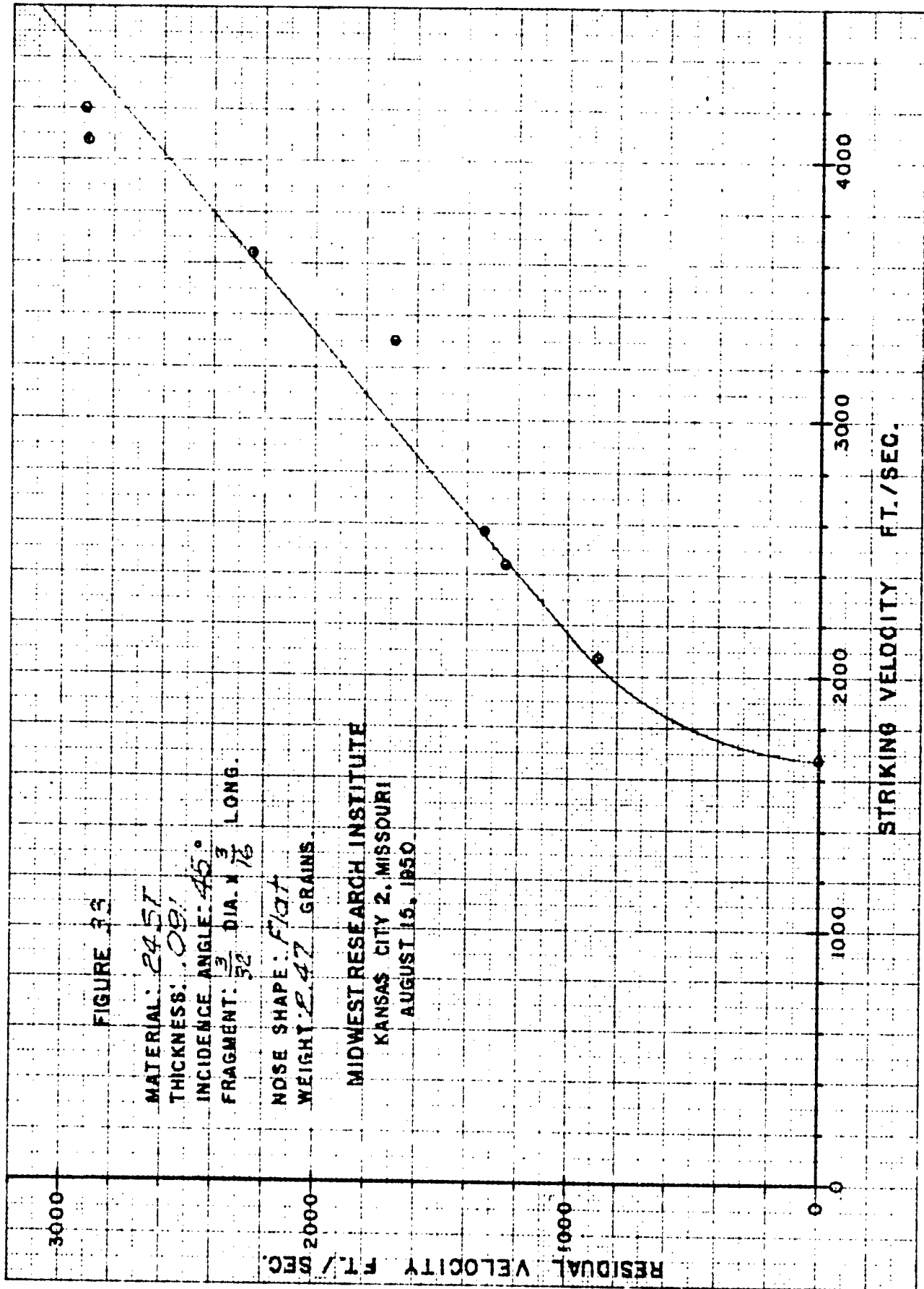


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RESTRICTED

DATA SHEETS

CHARLES BRUNING COMPANY, INC. NO. 700-M
MILWAUKEE, WISCONSIN



RESTRICTED

MATERIAL: 2457

THICKNESS: 0.091

INCIDENCE ANGLE: 0°

FRAGMENT: $\frac{3}{32}$ DIA. x $\frac{1}{32}$ LONG.

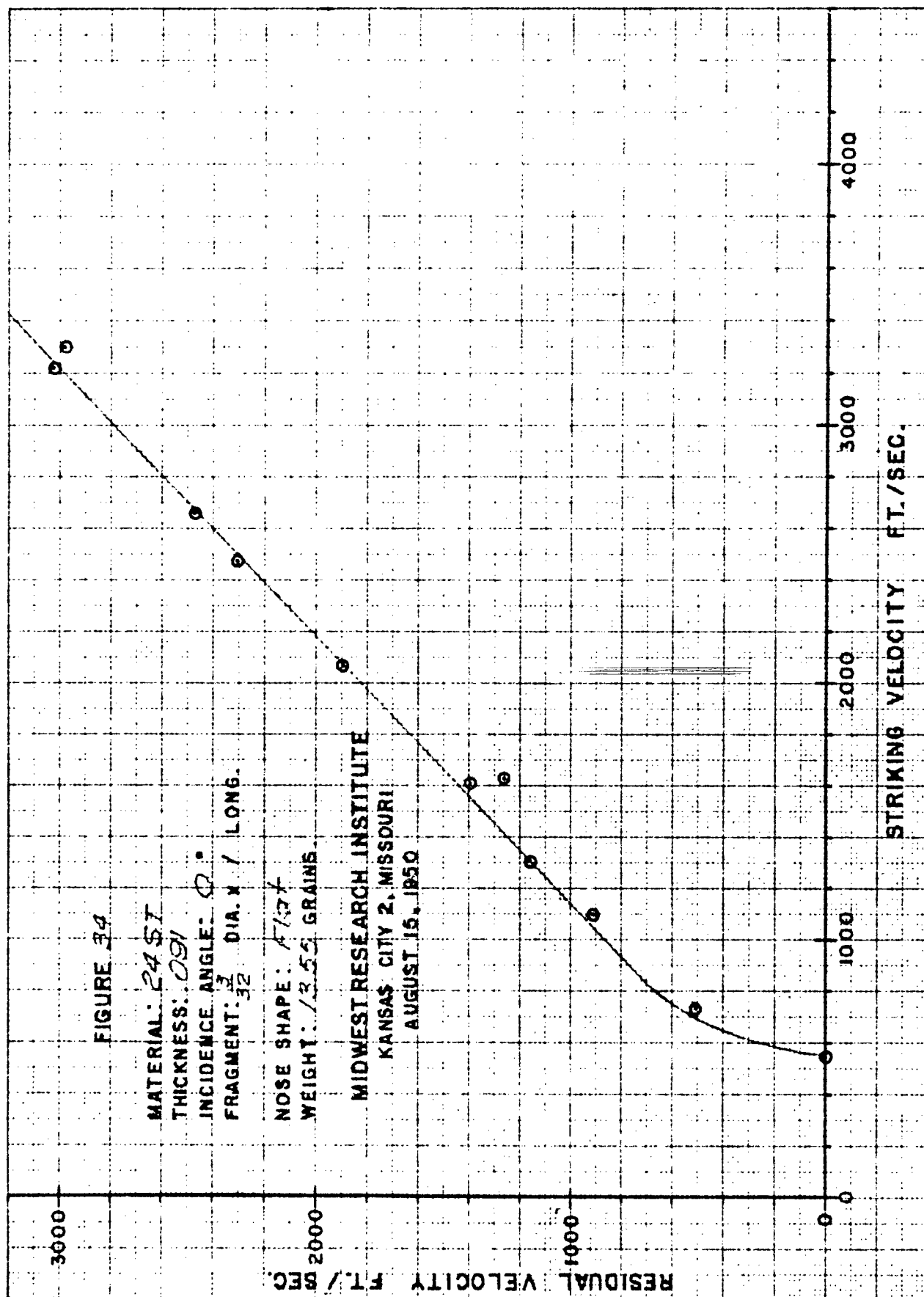
NOSE SHAPE: *F134*

WEIGHT: 255 GRAMS

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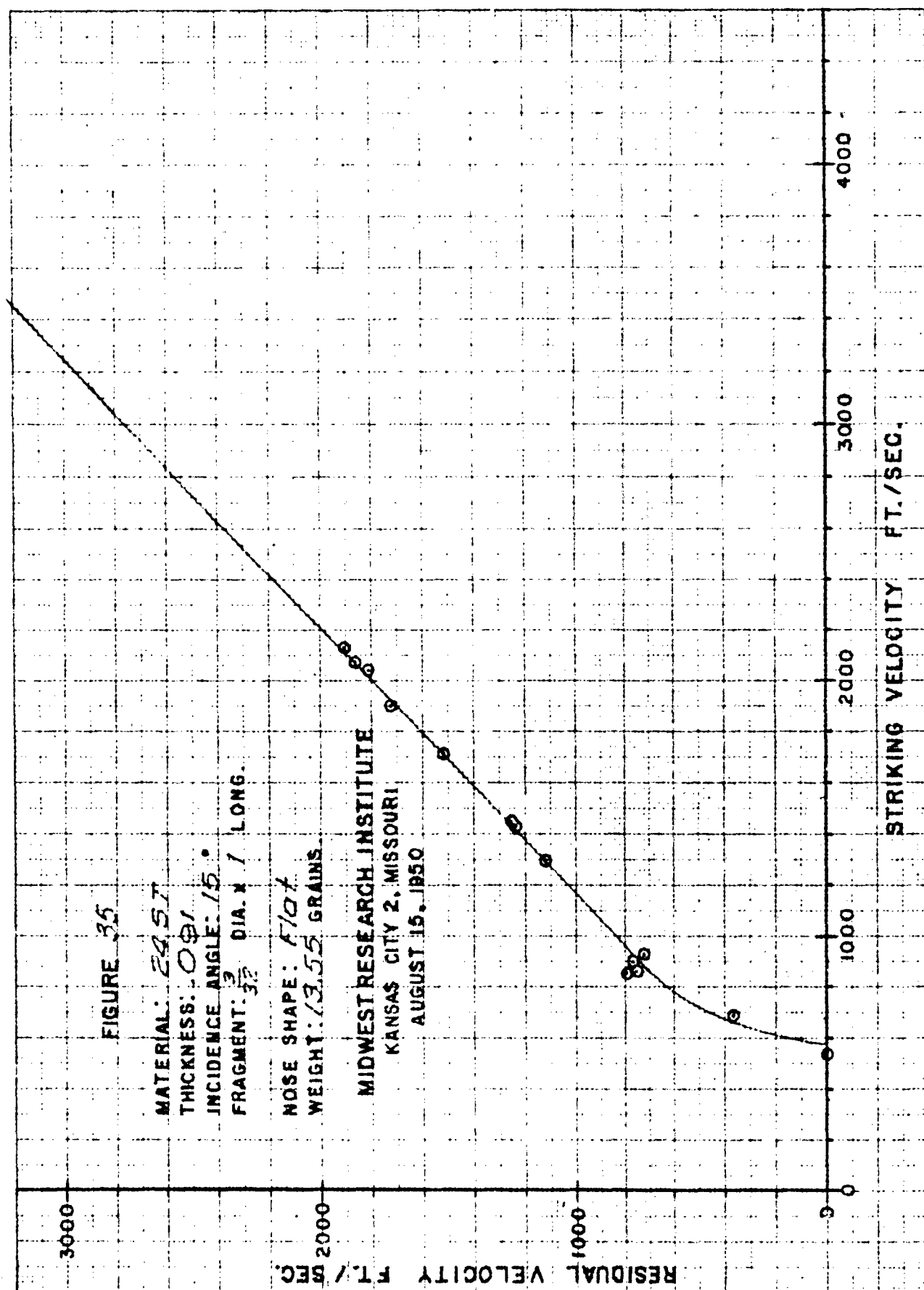
KANSAS CITY 2, MISSOURI

AUGUST 15, 1950



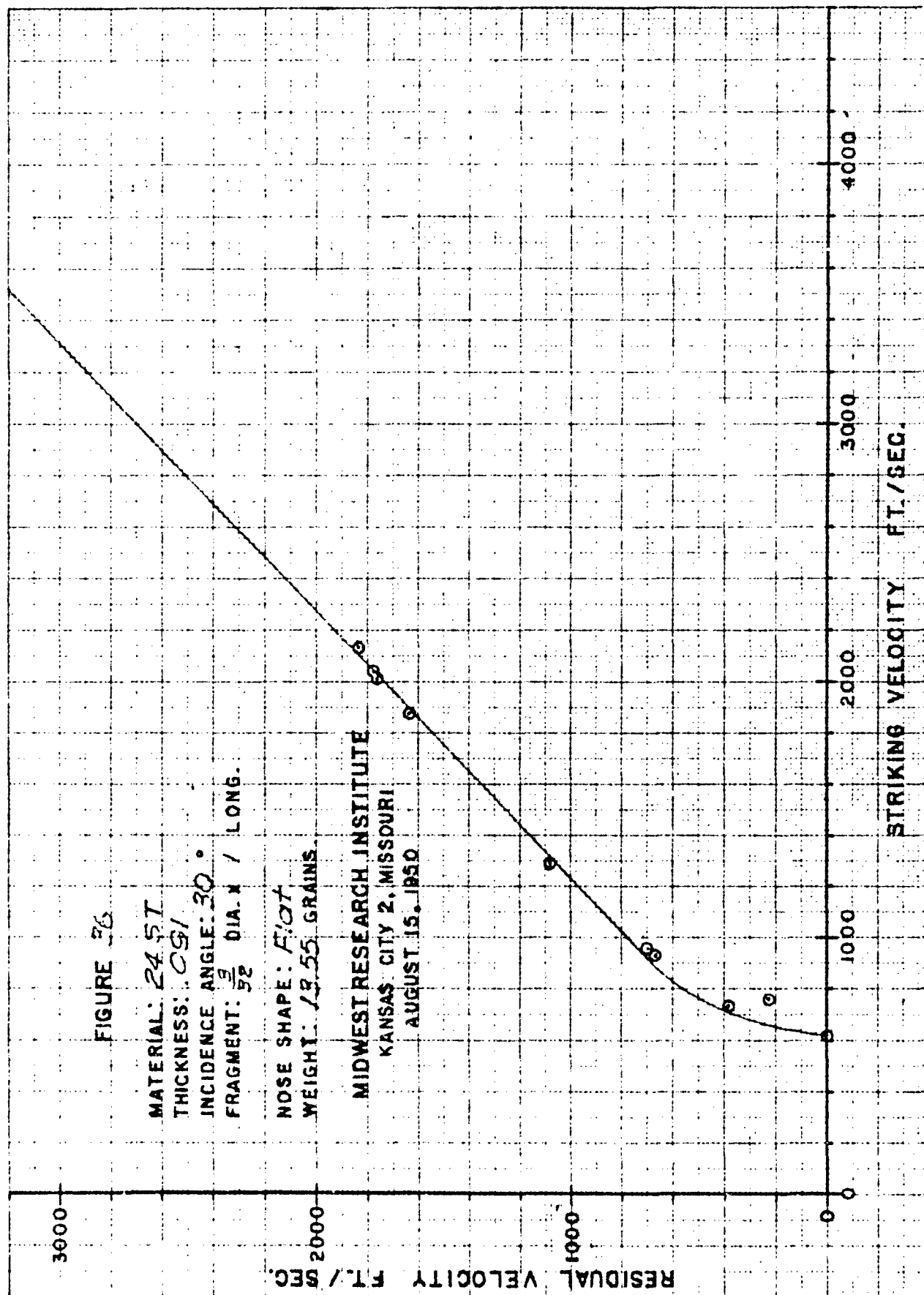
RESTRICTED

RESTRICTED



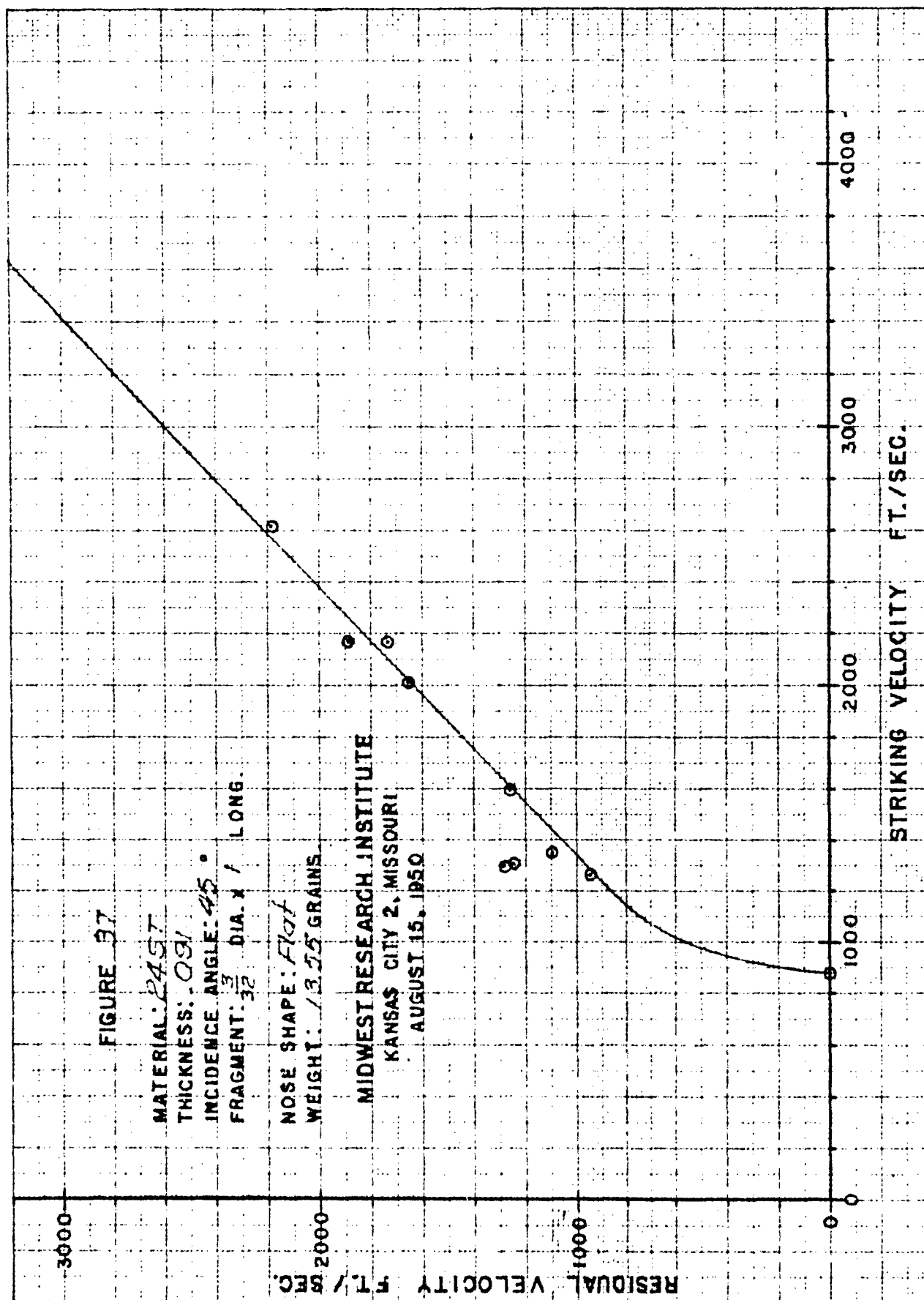
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RESTRICTED



RESTRICTED

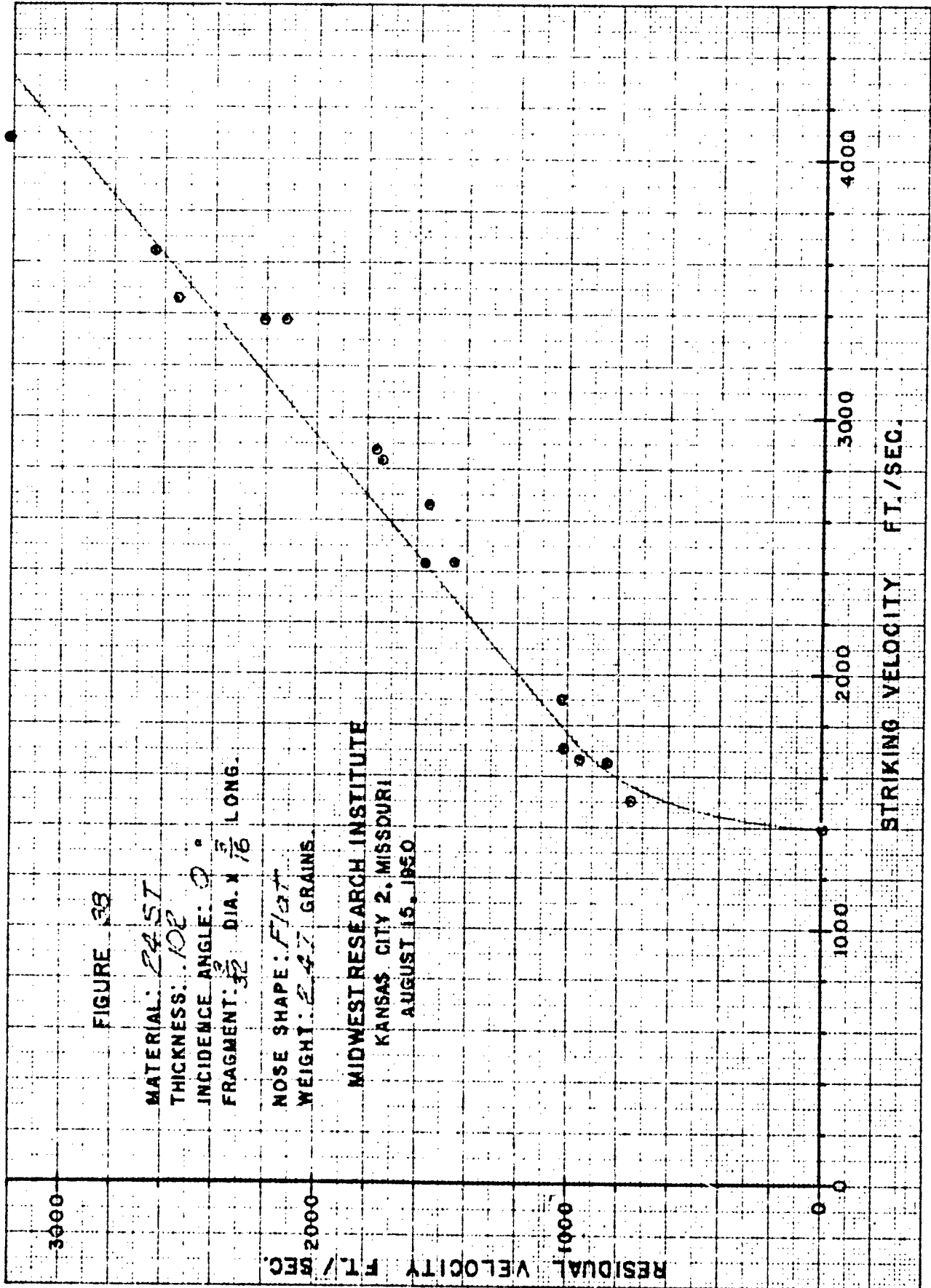
RESTRICTED



RESTRICTED

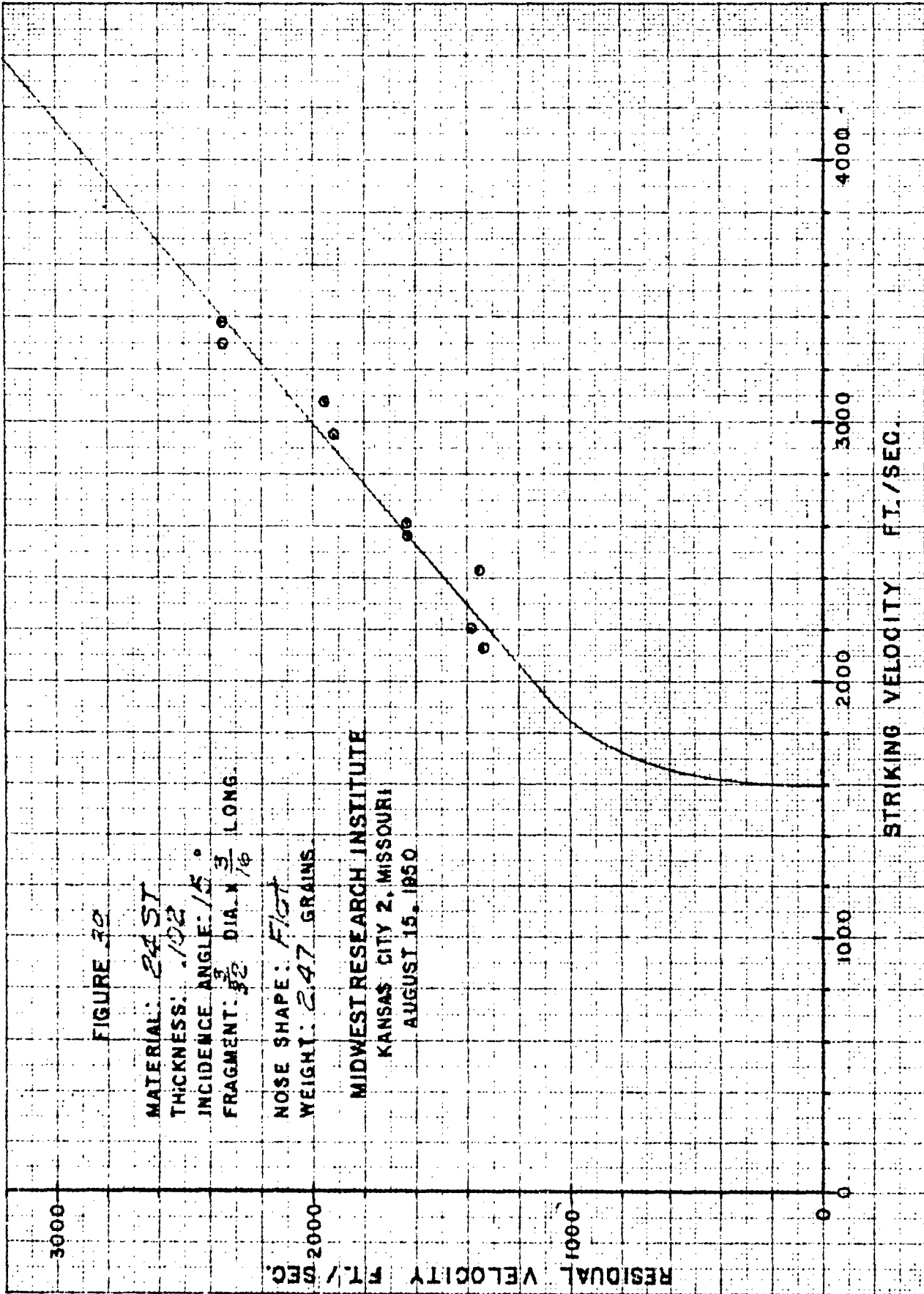
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RESTRICTED

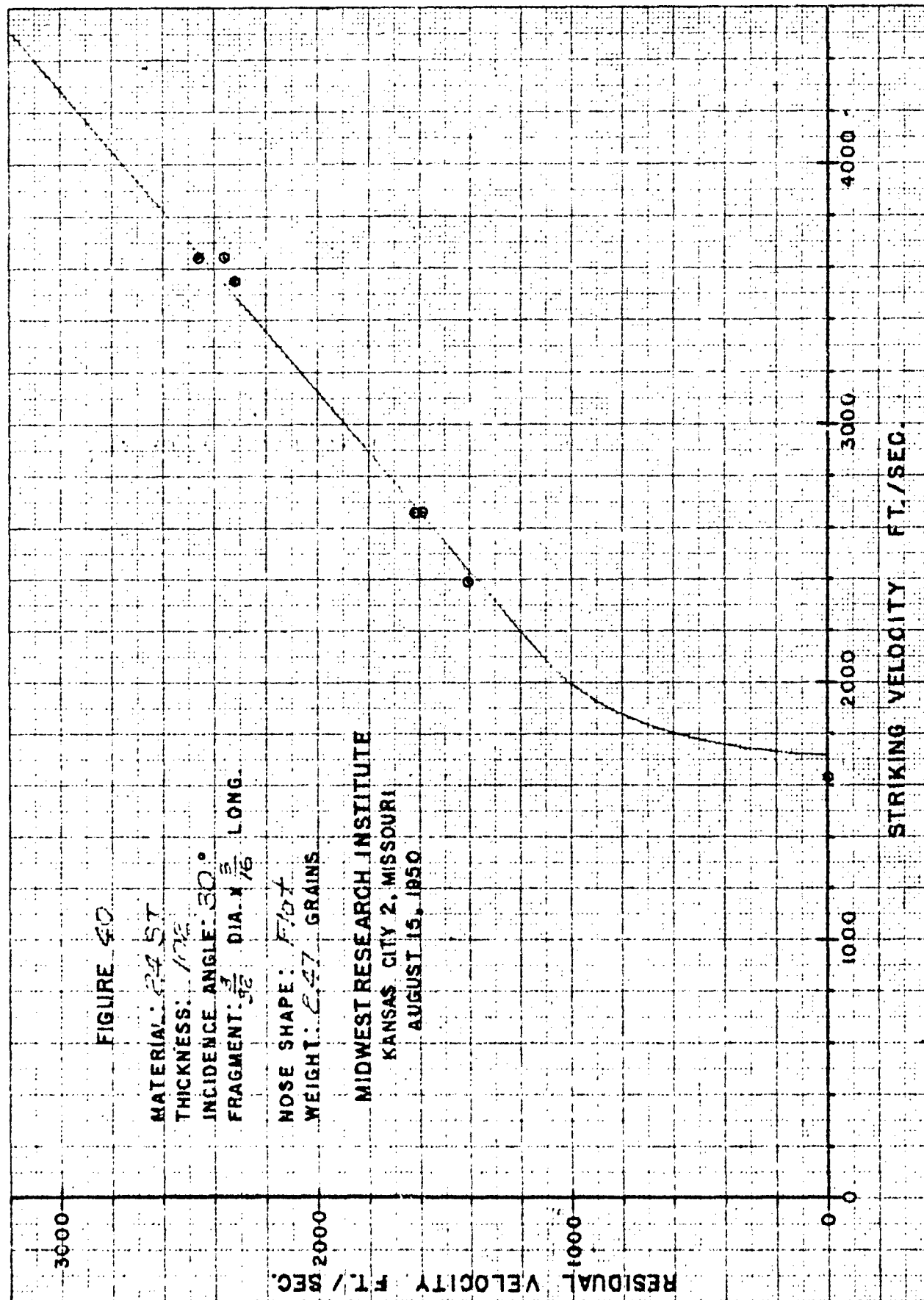


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RESTRICTED



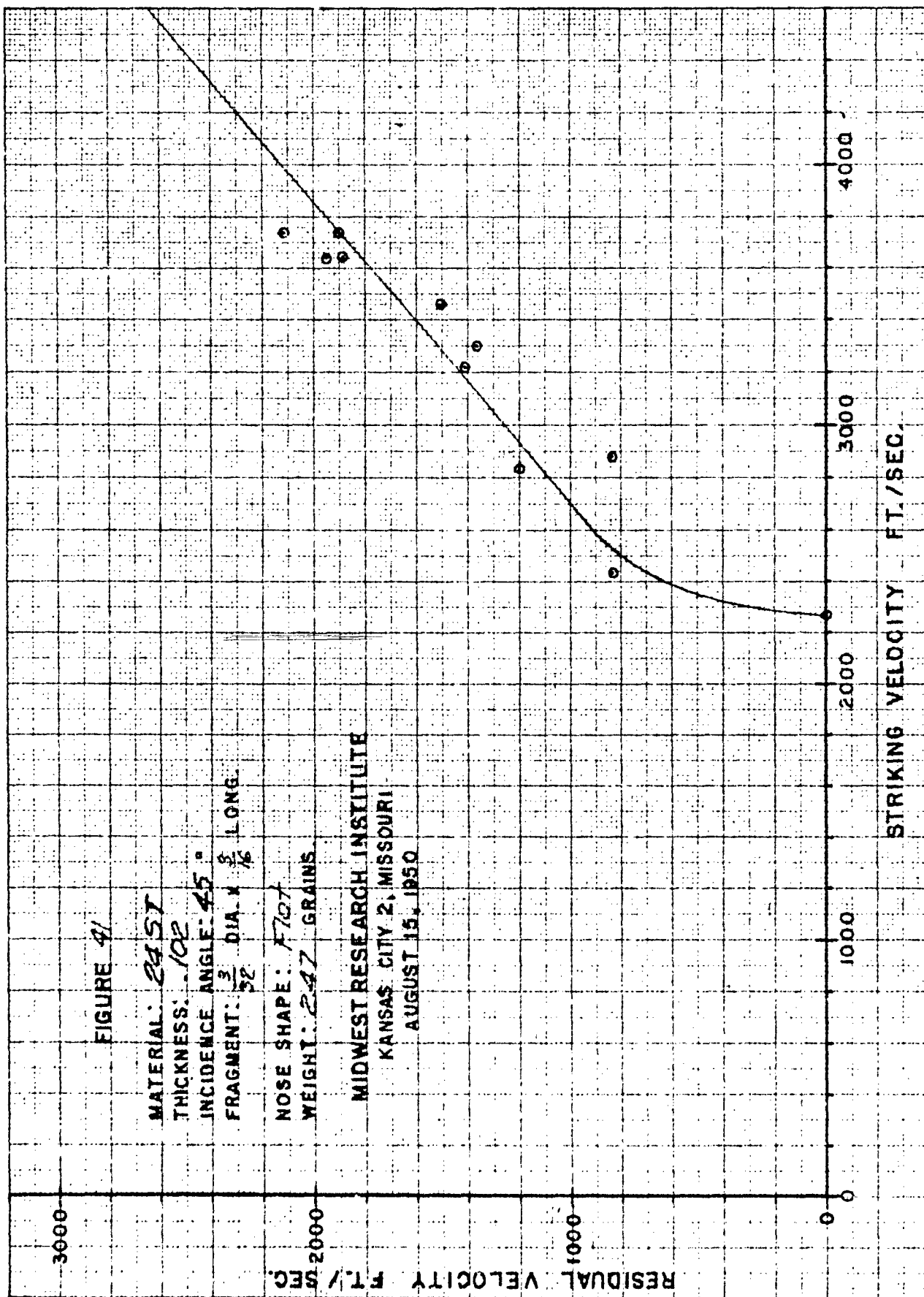
RESTRICTED



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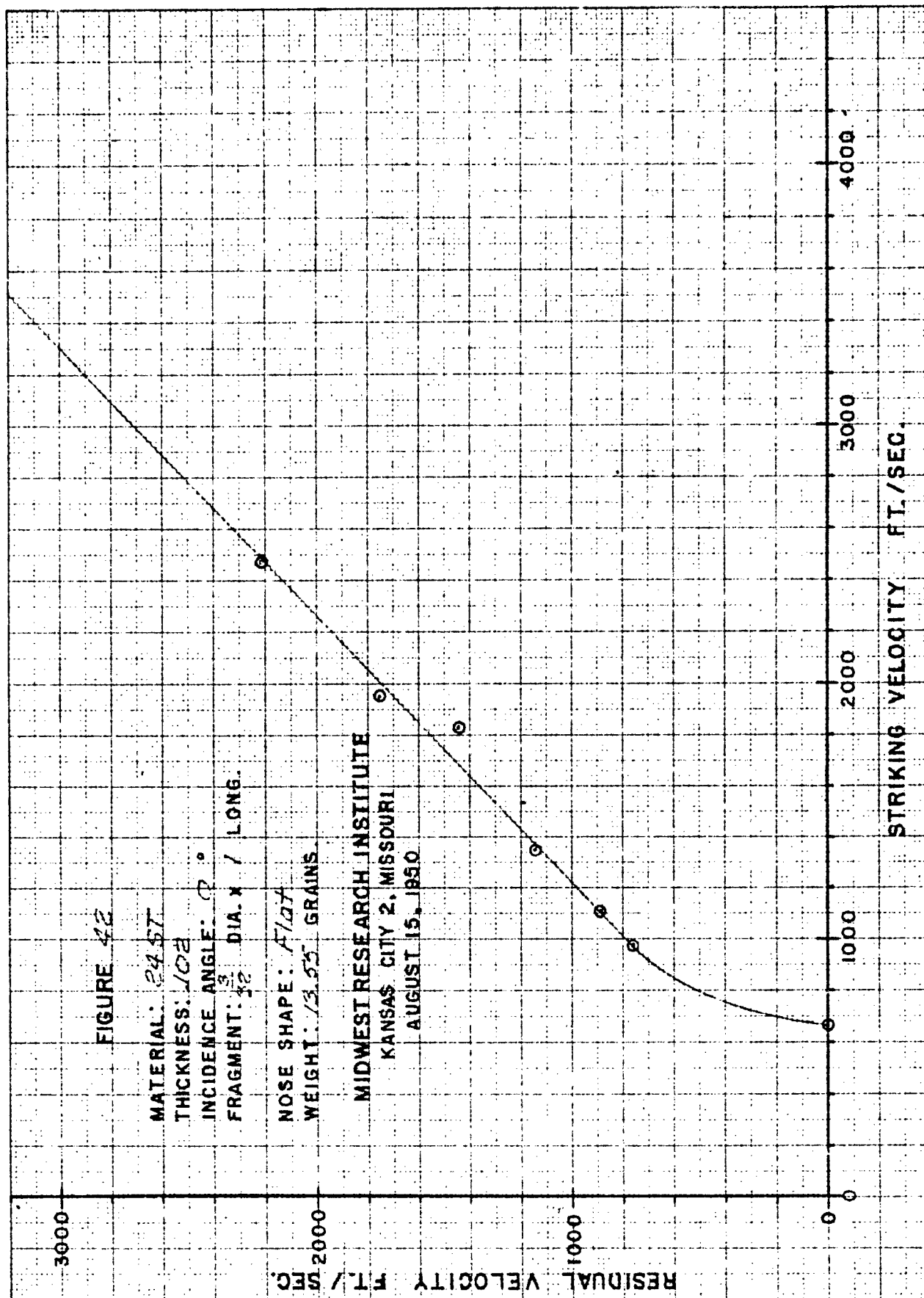


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DATA SHEETS

CHARLES BRUNING COMPANY, INC. NO. 700-M
Millwaukee, 19th St. & Heavy

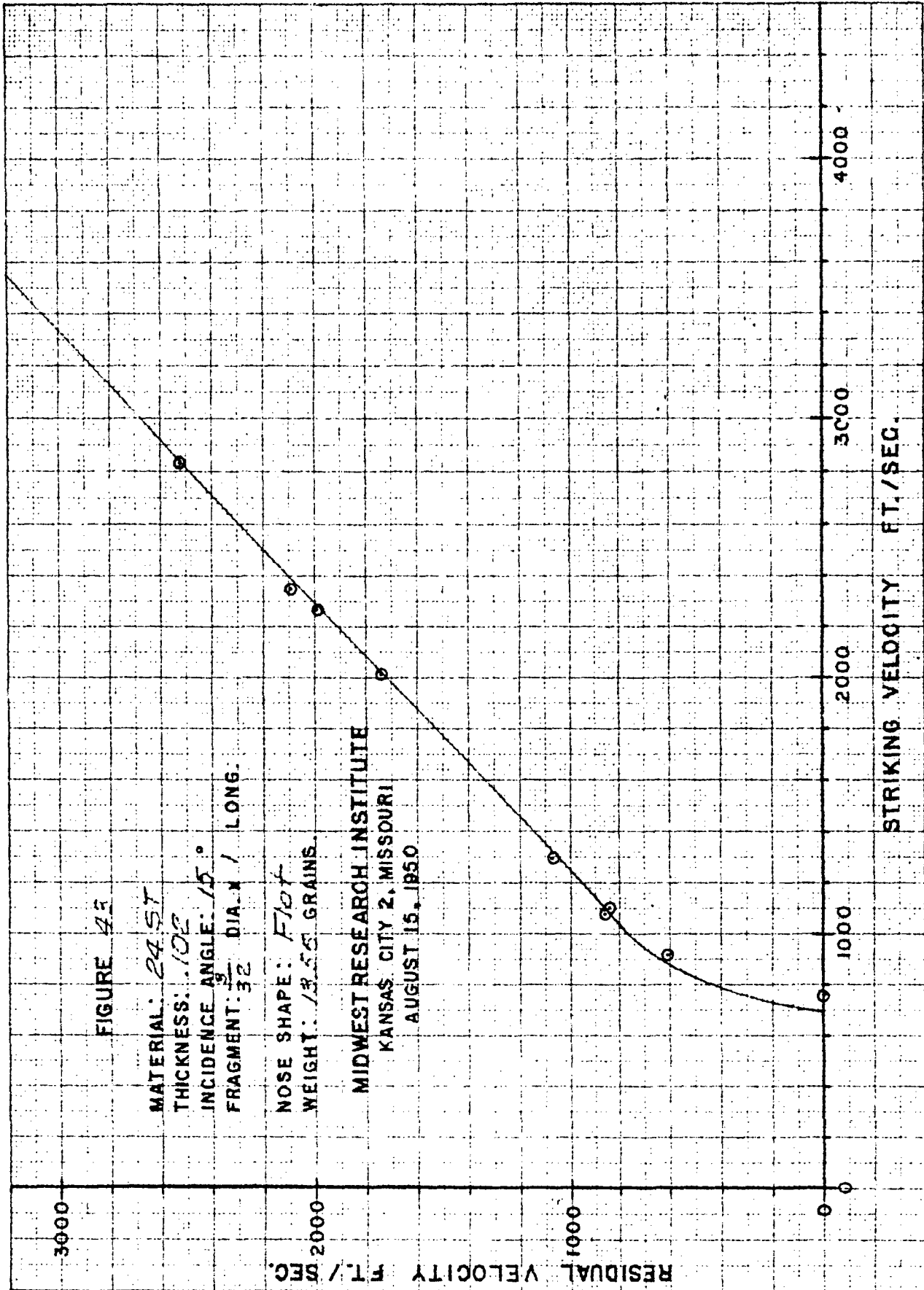


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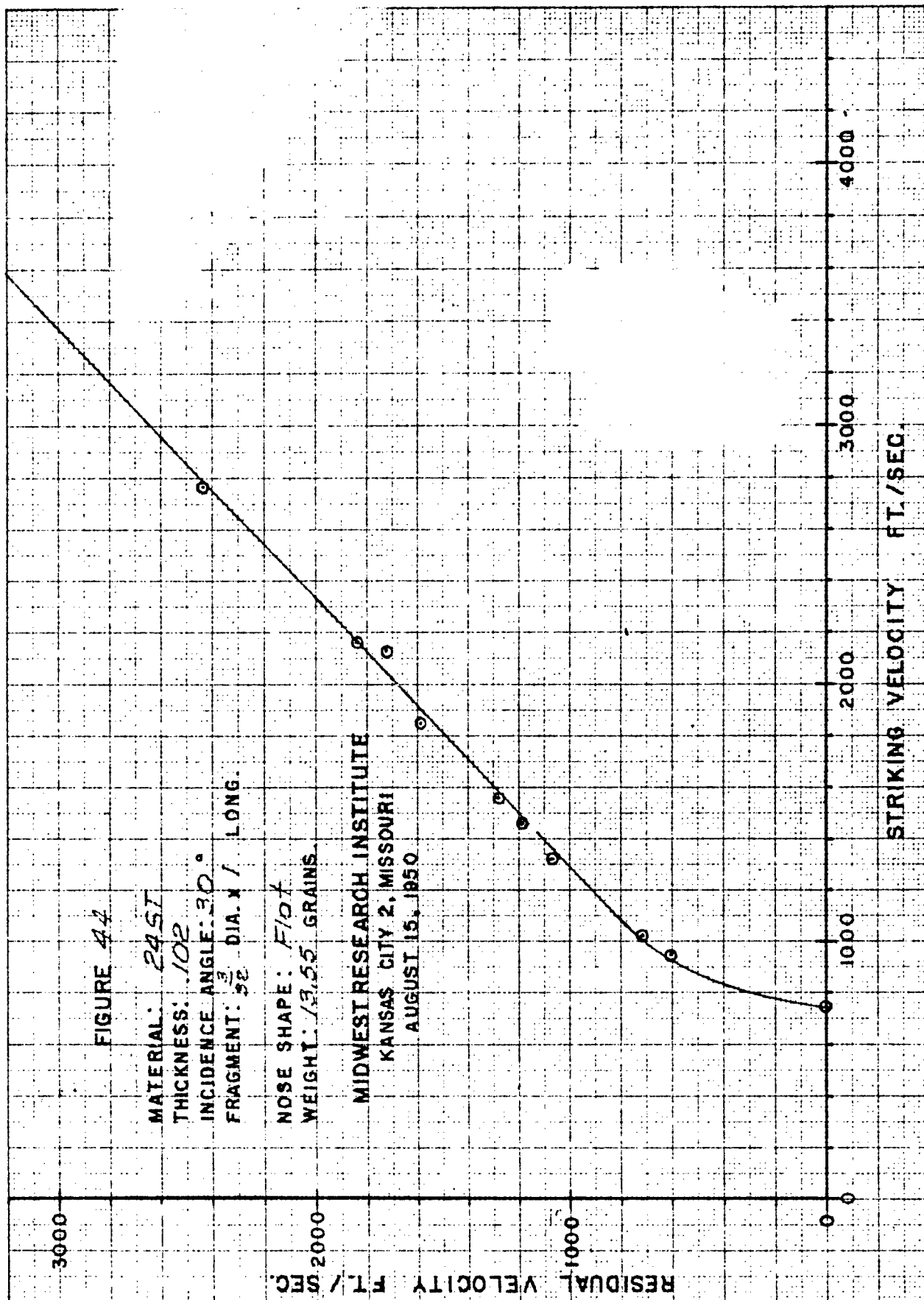
RESTRICTED

DATA SHEETS

CHARLES BRUNING COMPANY, INC. NO. 700-8
Millersville, Pa. 17340



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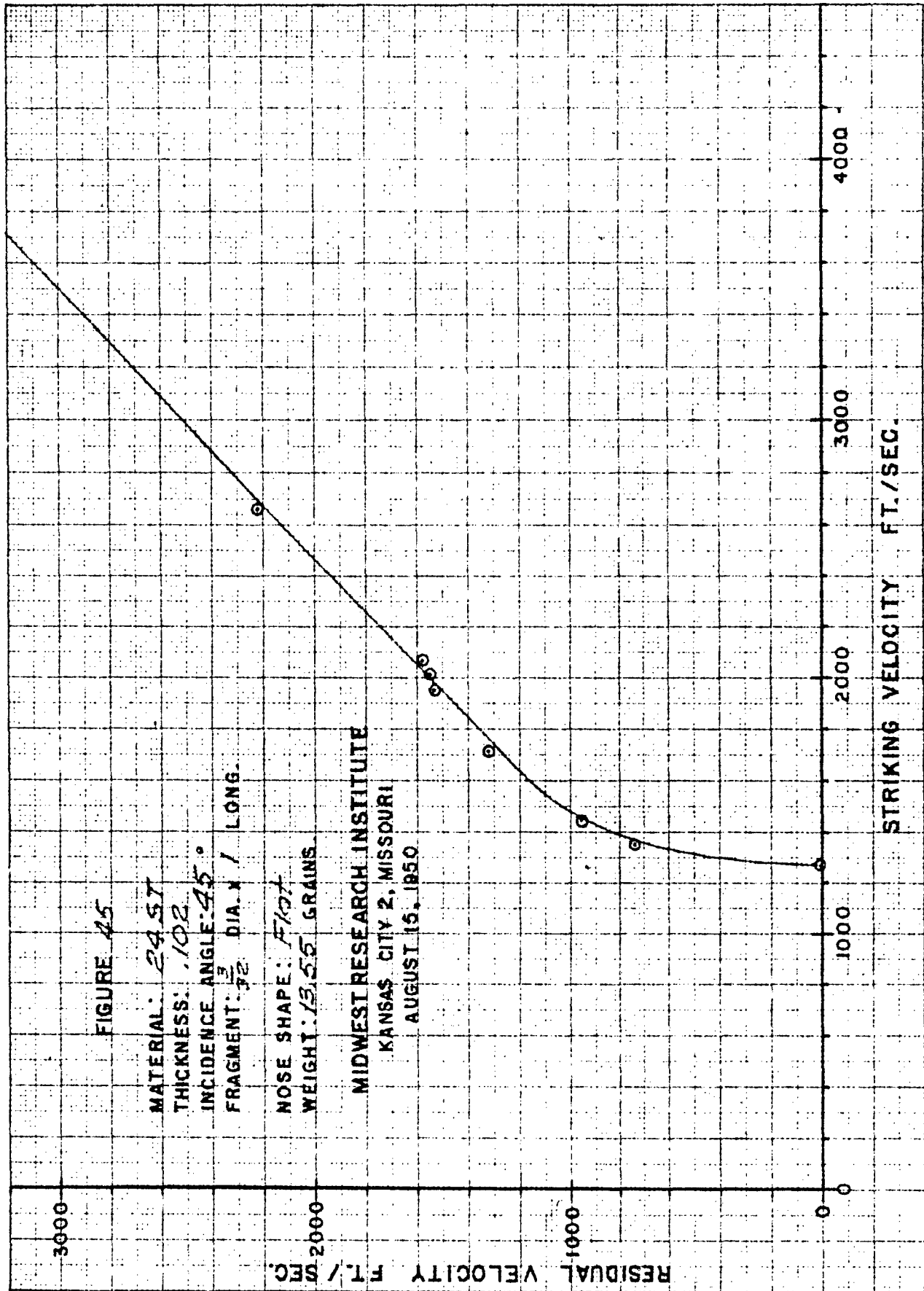
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RESTRICTED

DATA SHEETS

CHARLES BRUNING COMPANY, INC. NO. 700-M
Millimeters, 101t. Inks, heavy

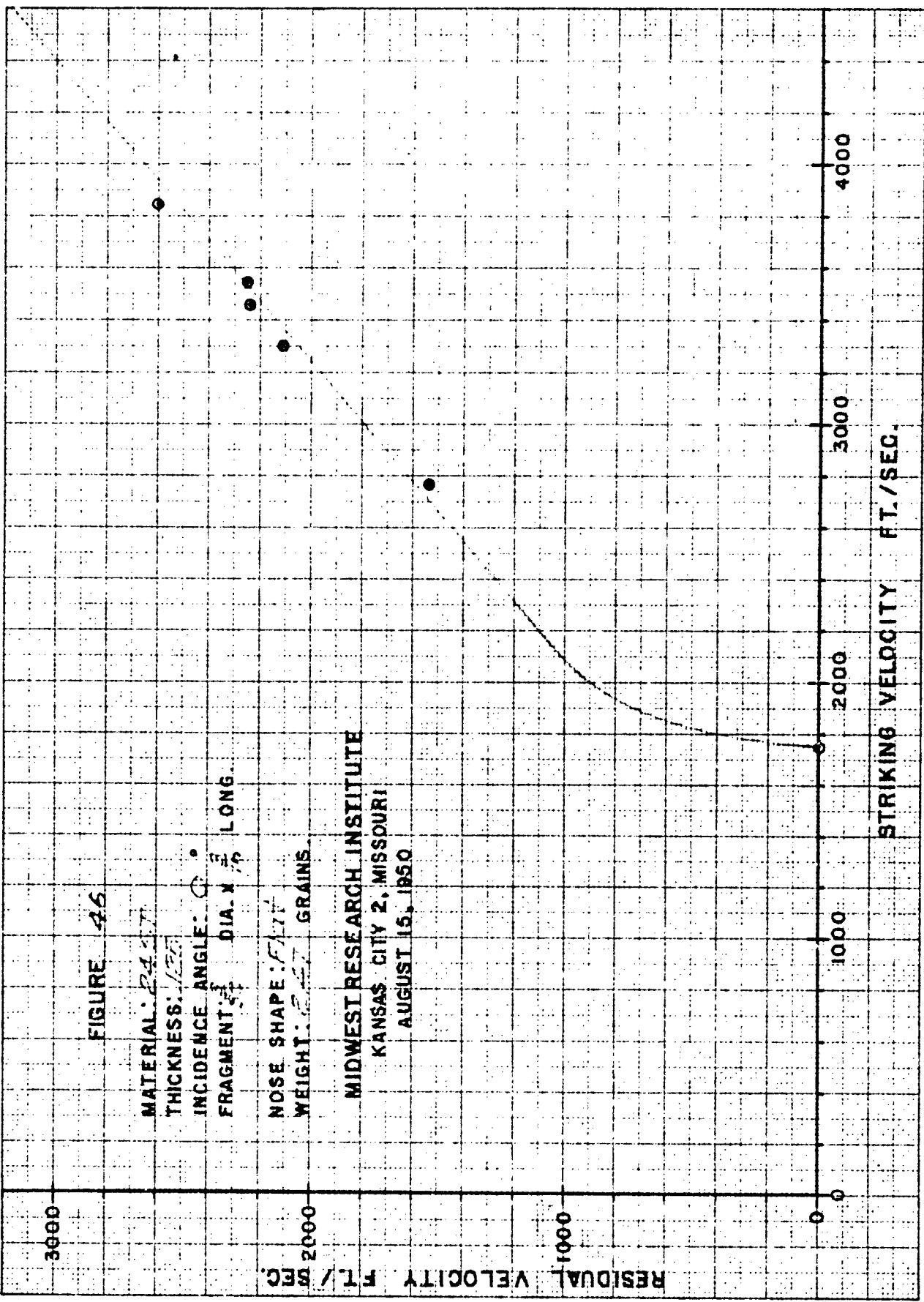


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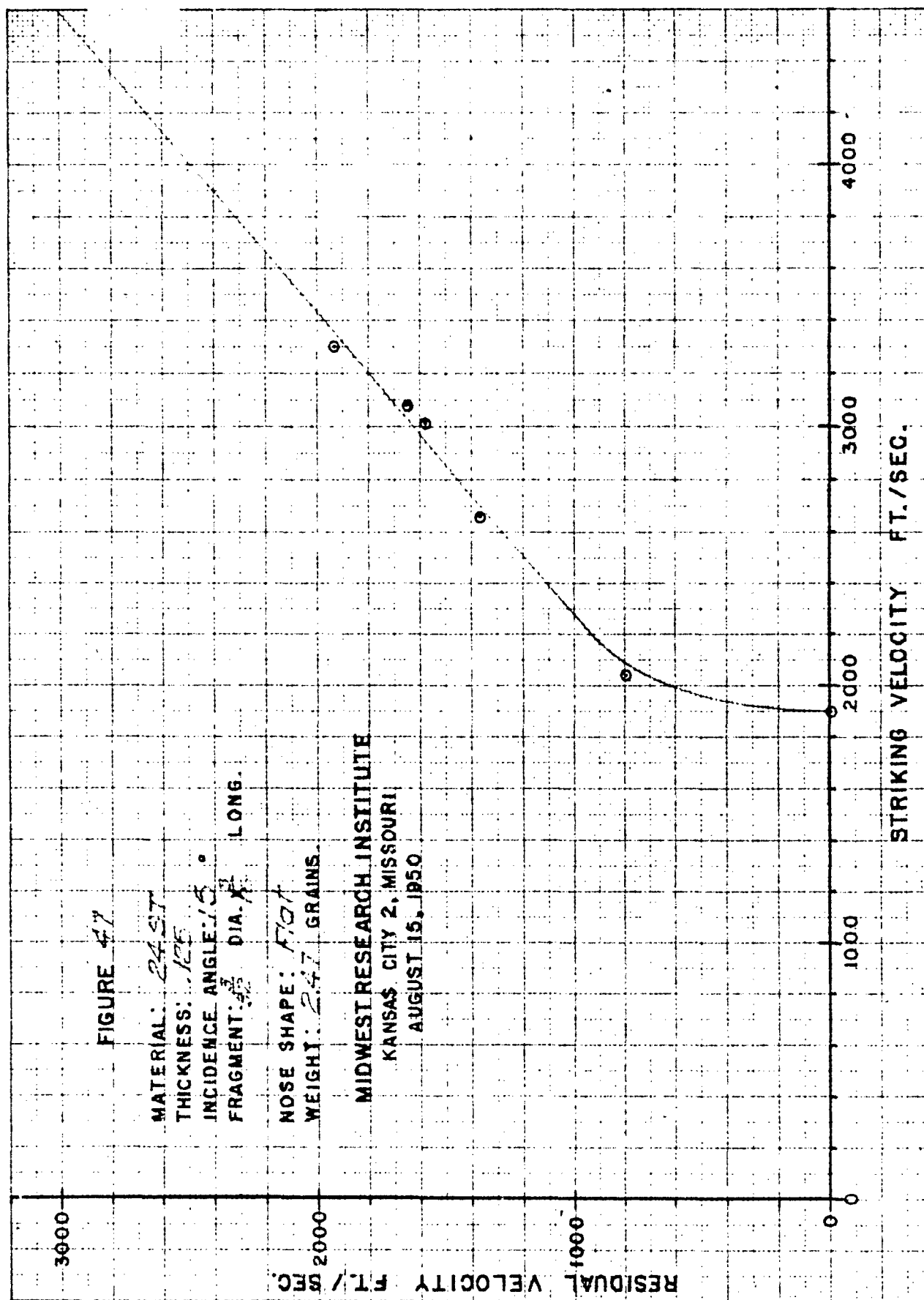
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DATA SHEETS

CHARLES BRUNING COMPANY, INC. NO. 700-M
Millersburg, Iowa



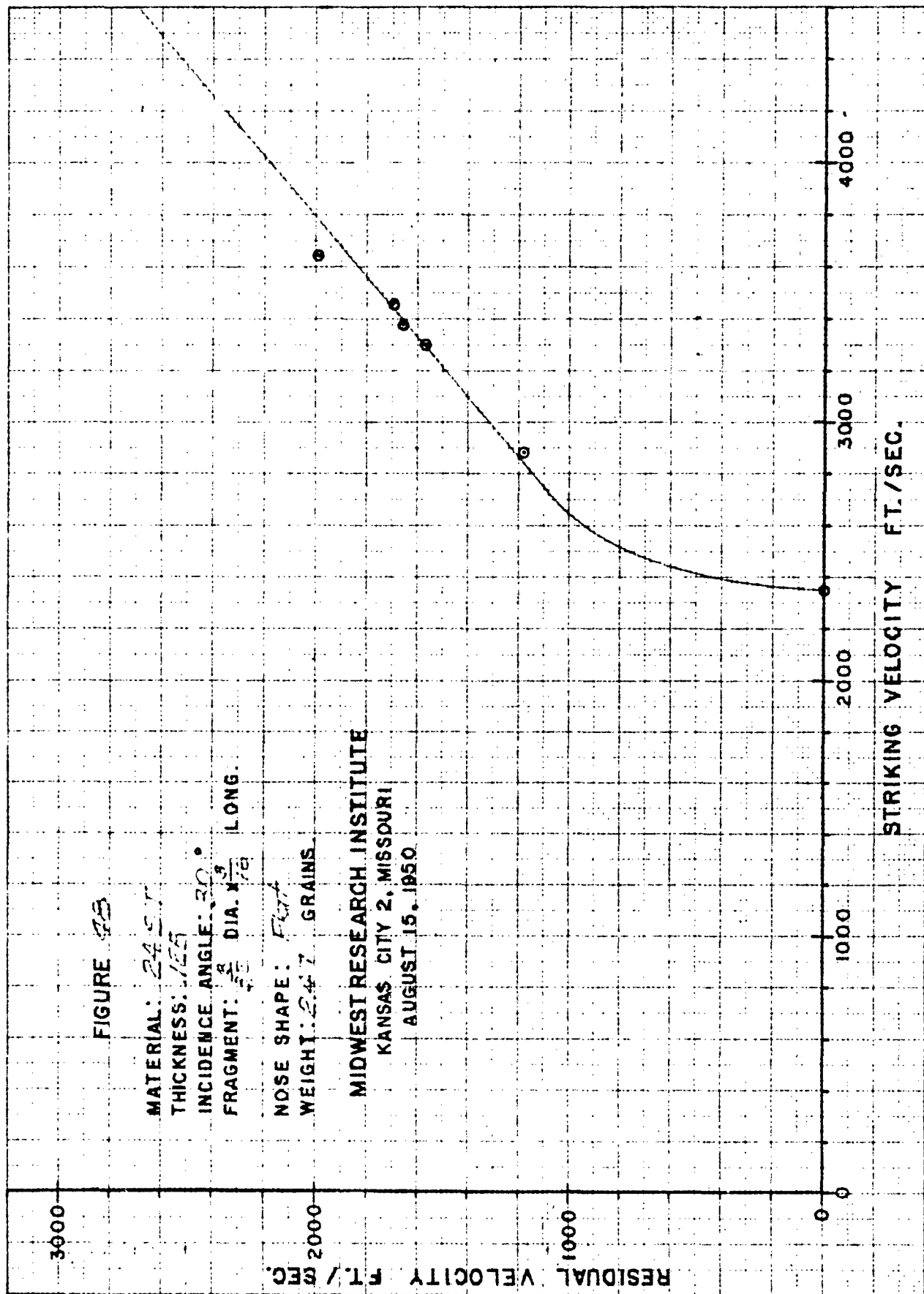
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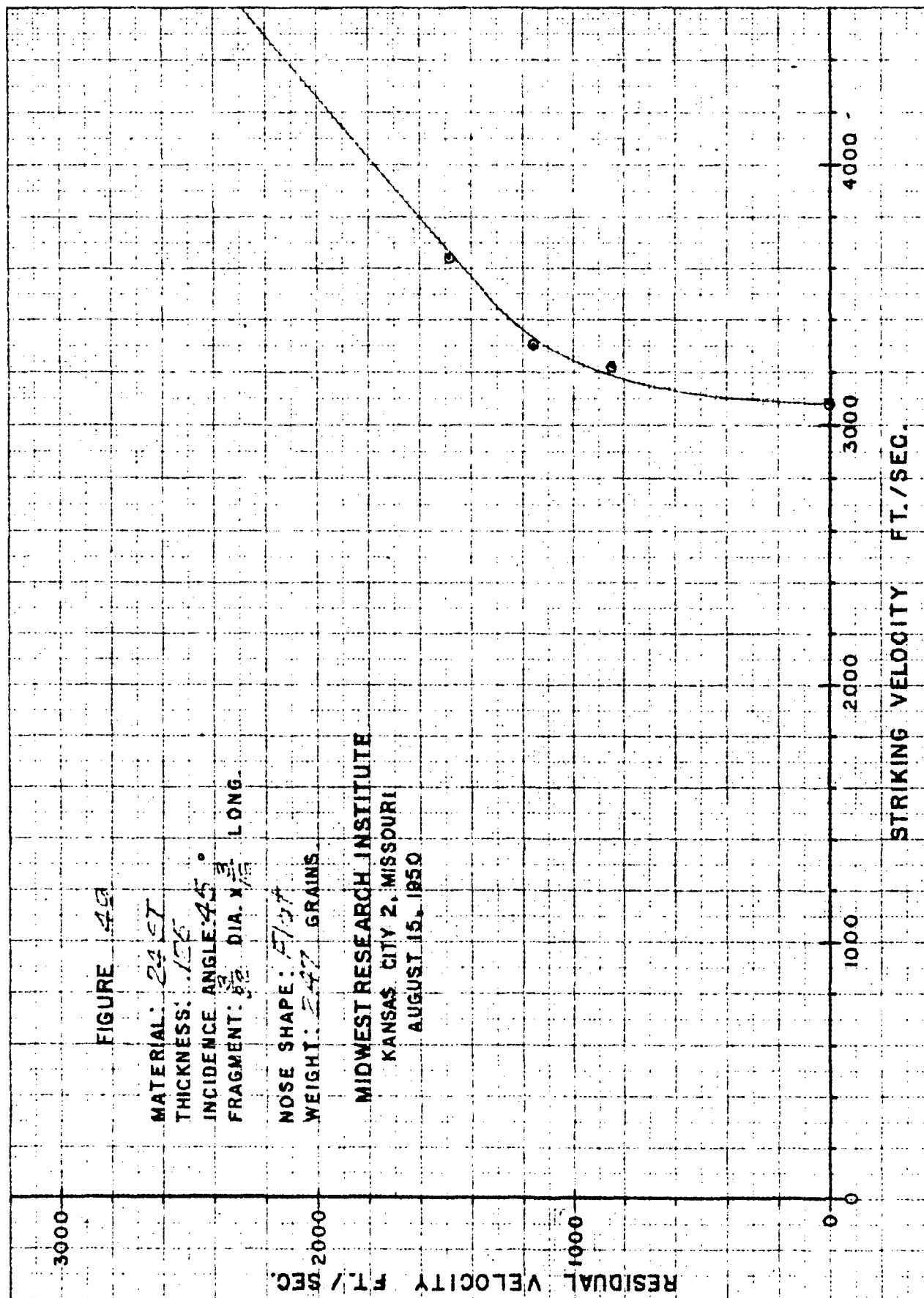
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AUGUST 15, 1950



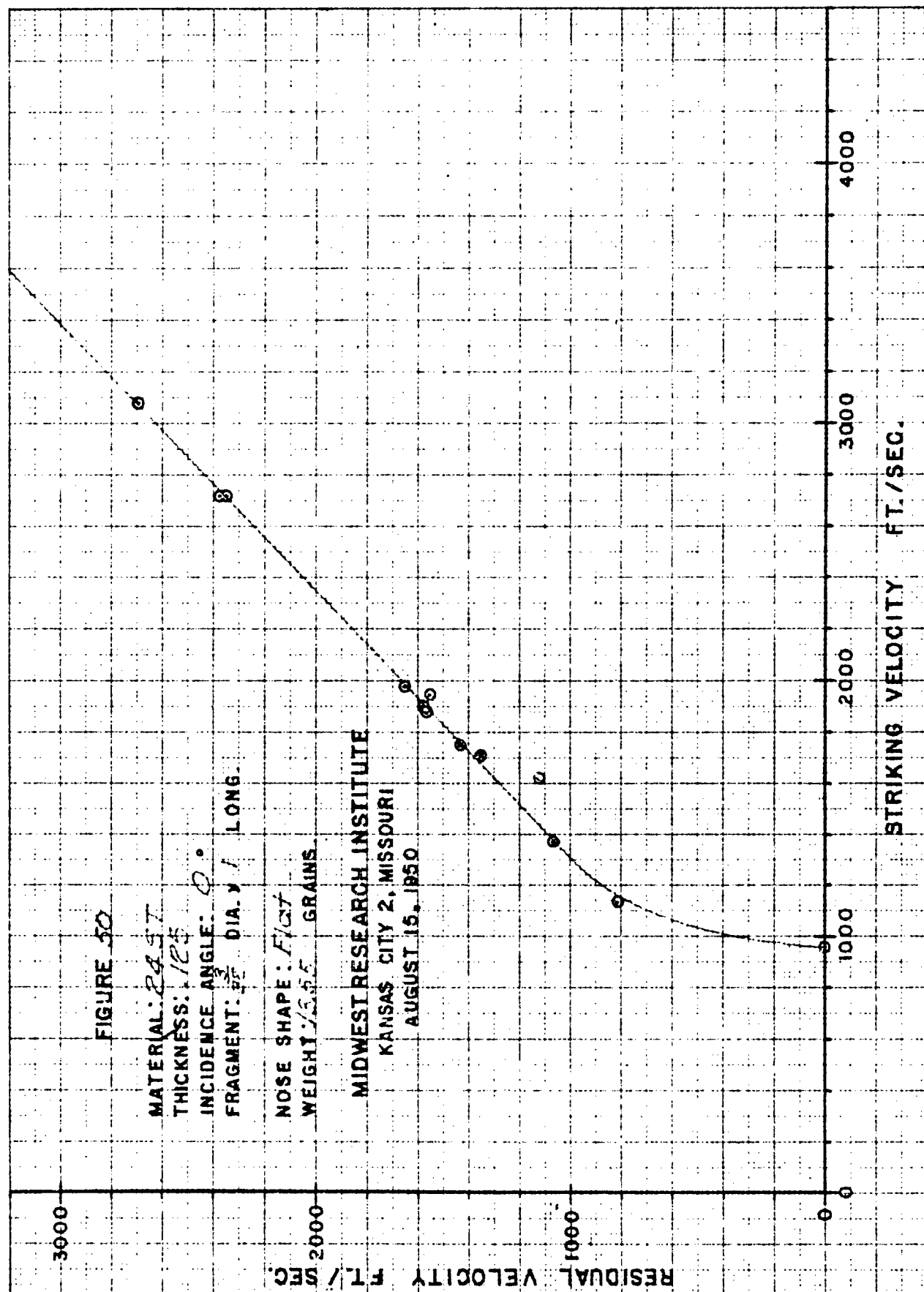
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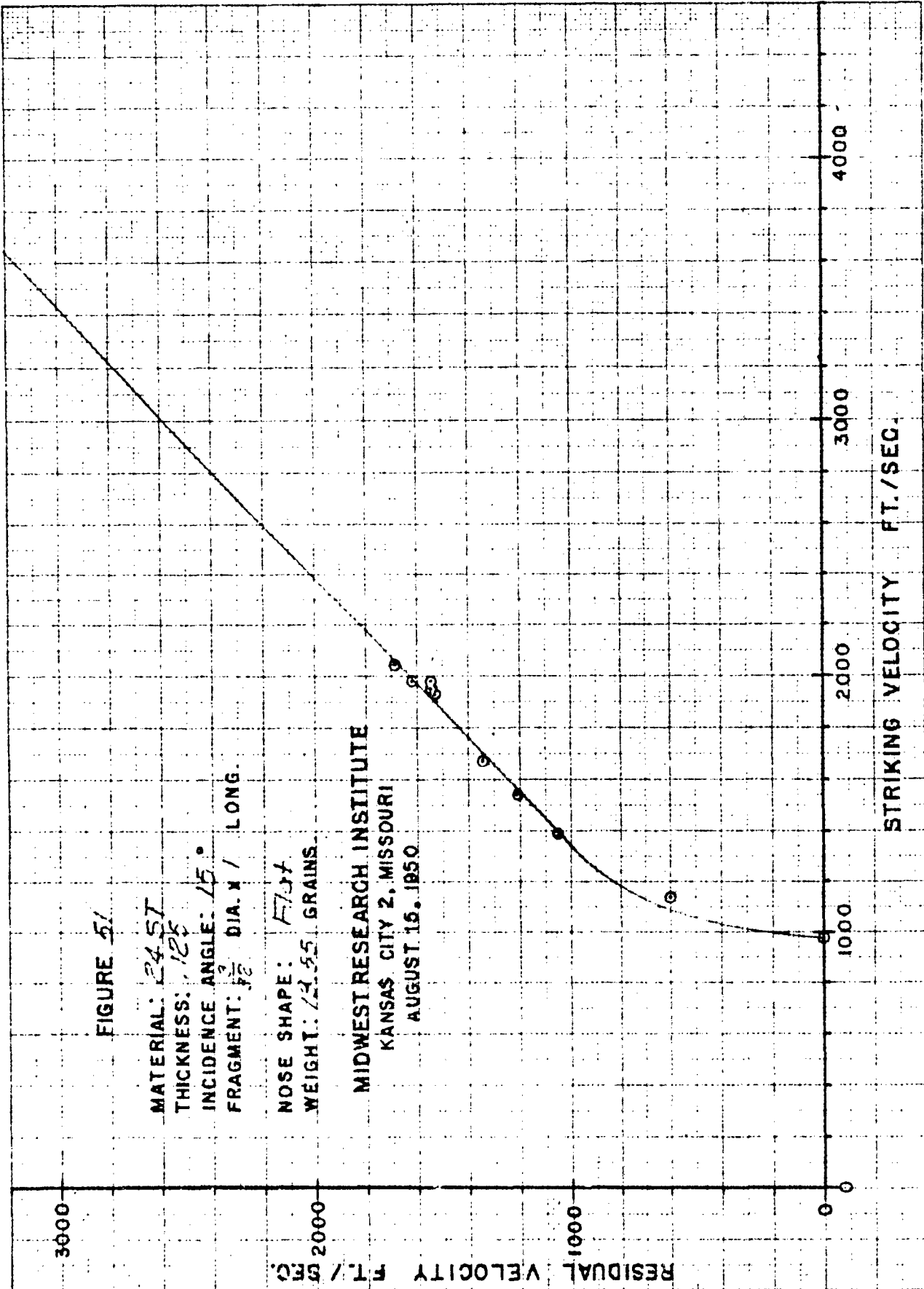
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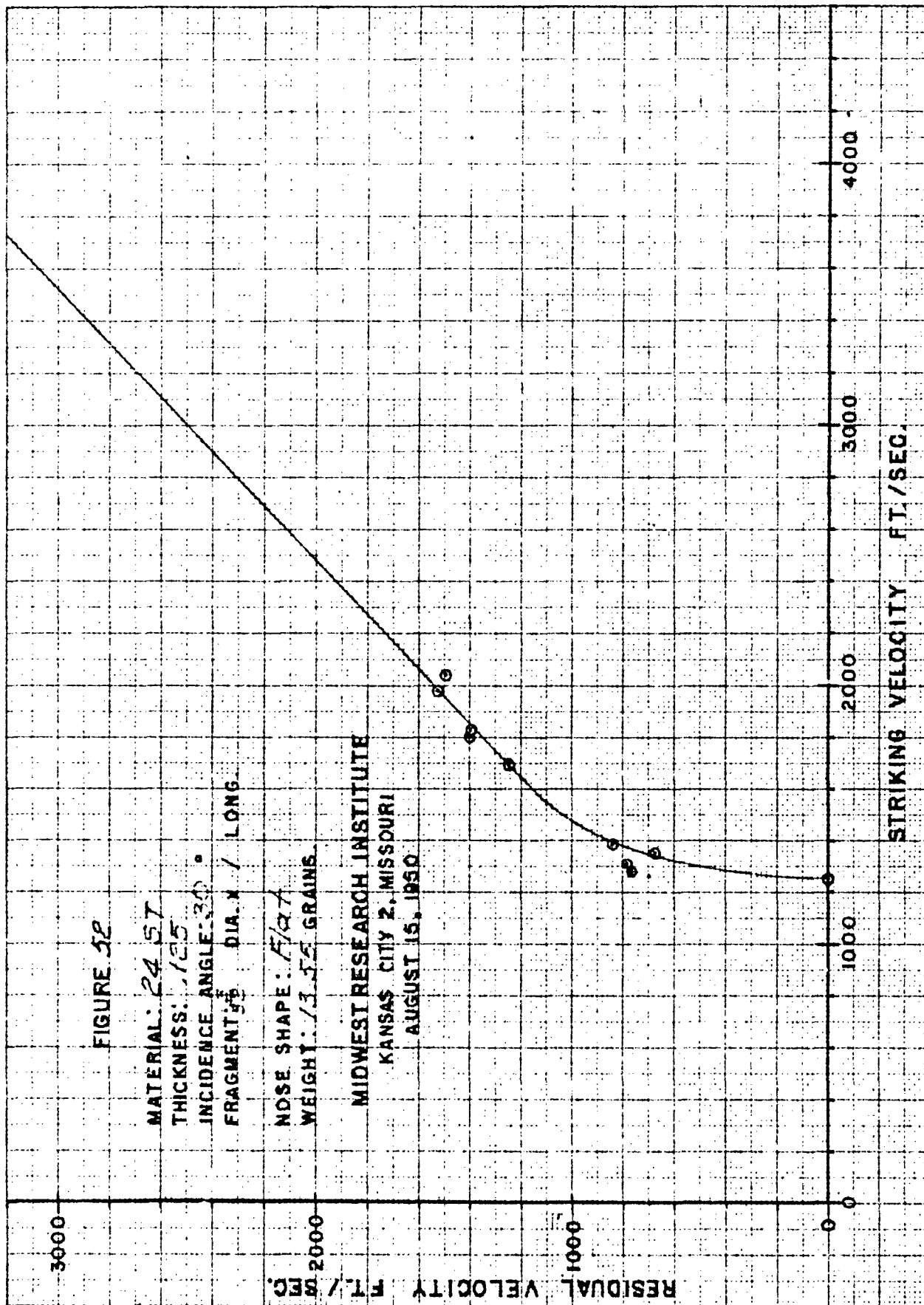
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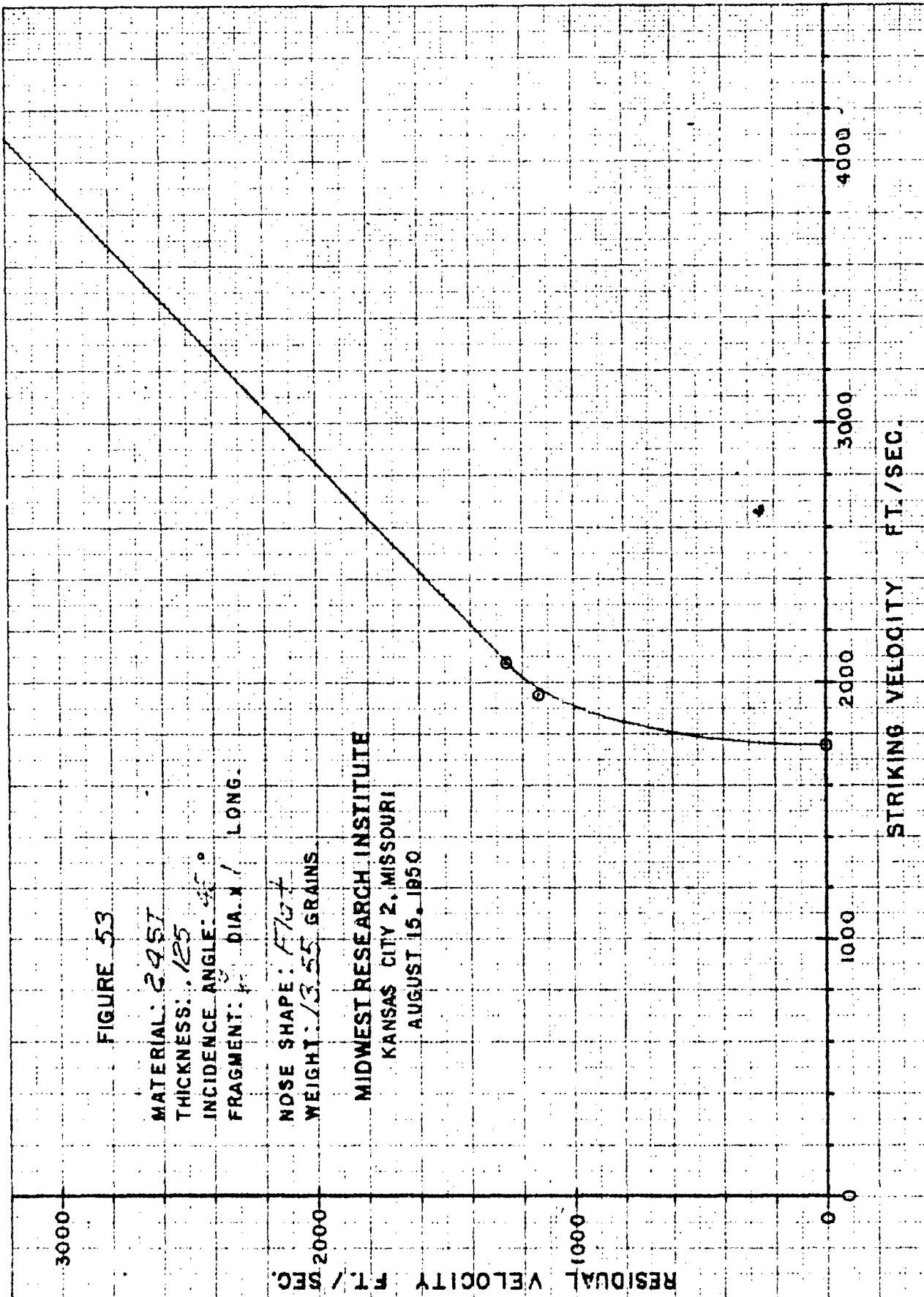
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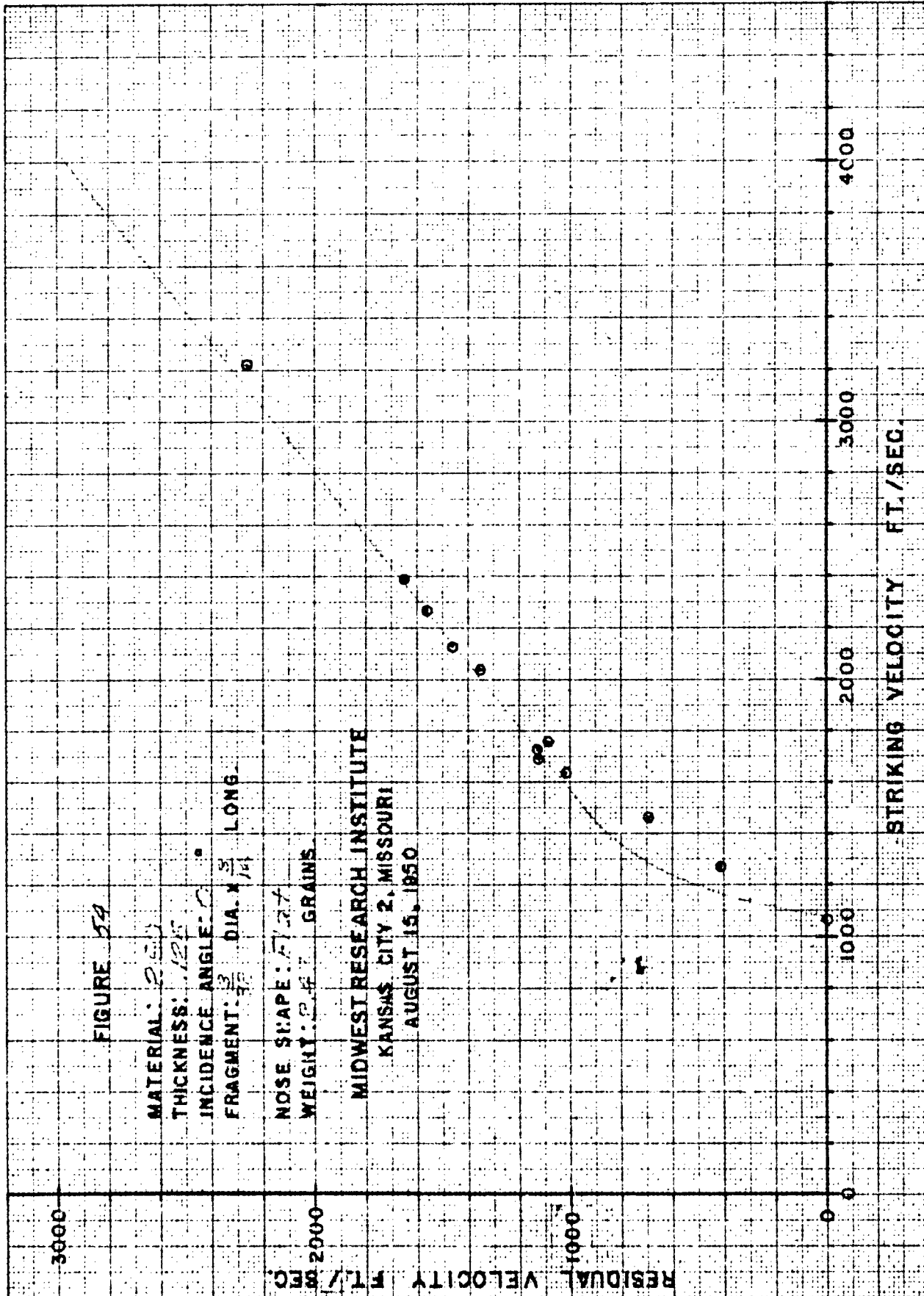
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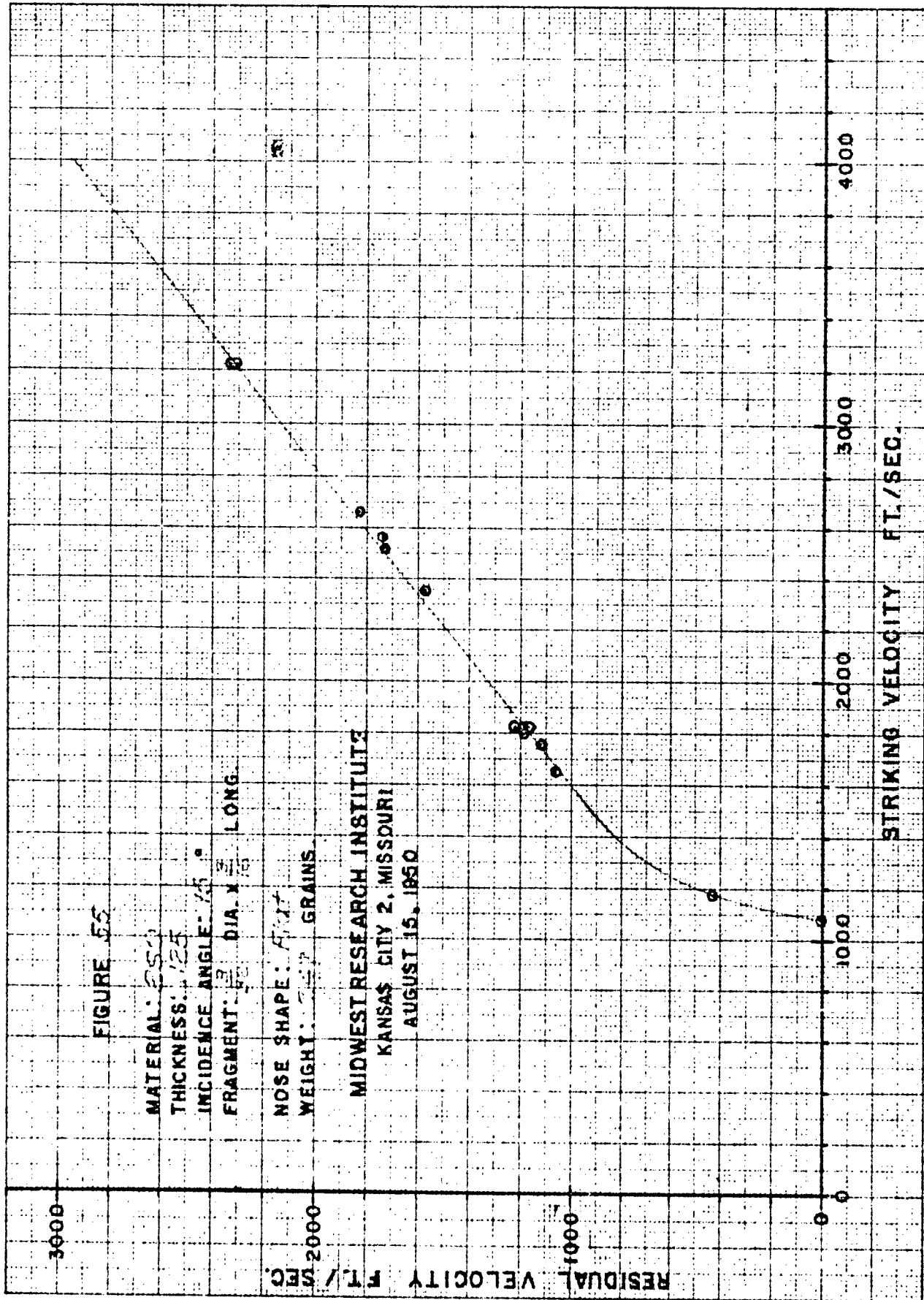
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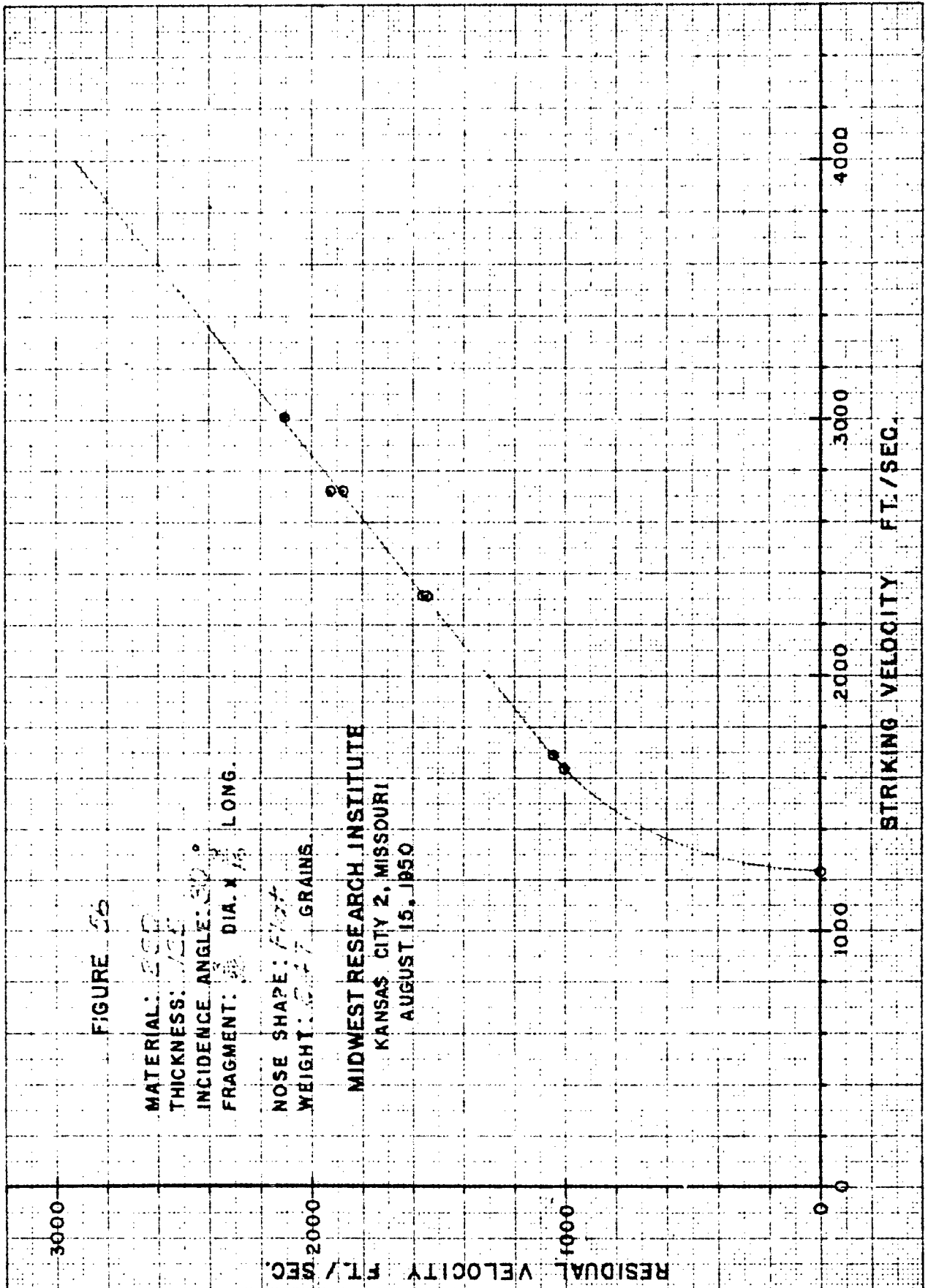
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DATA SHEETS

CHARLES BRUNING COMPANY, INC. NO. 700-M

St. Louis, Mo. U.S.A.

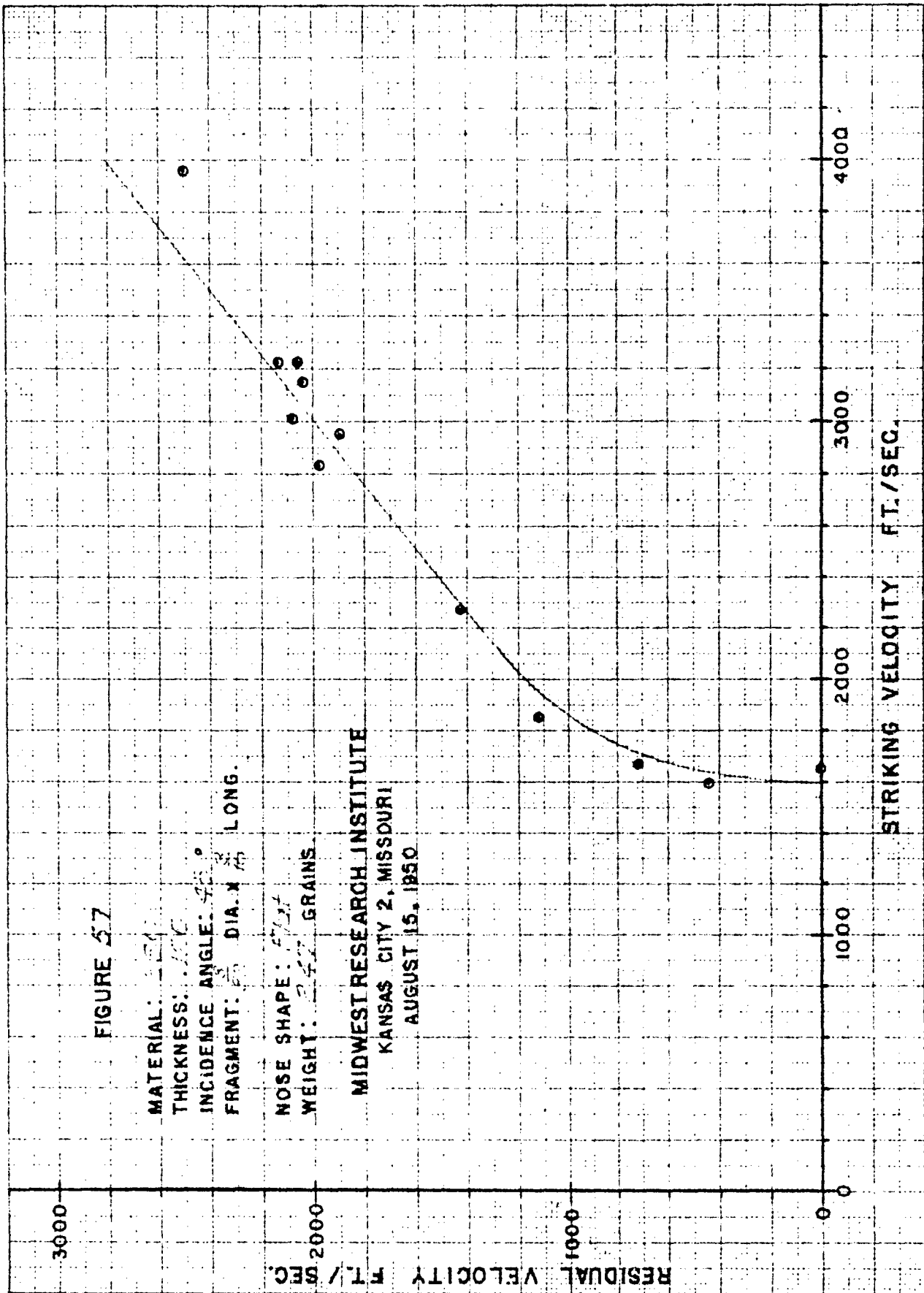


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DATA SHEETS

CHARLES BRIDGES COMPANY, INC. NO. 700-M
3100 North 10th Street, St. Louis, Mo.

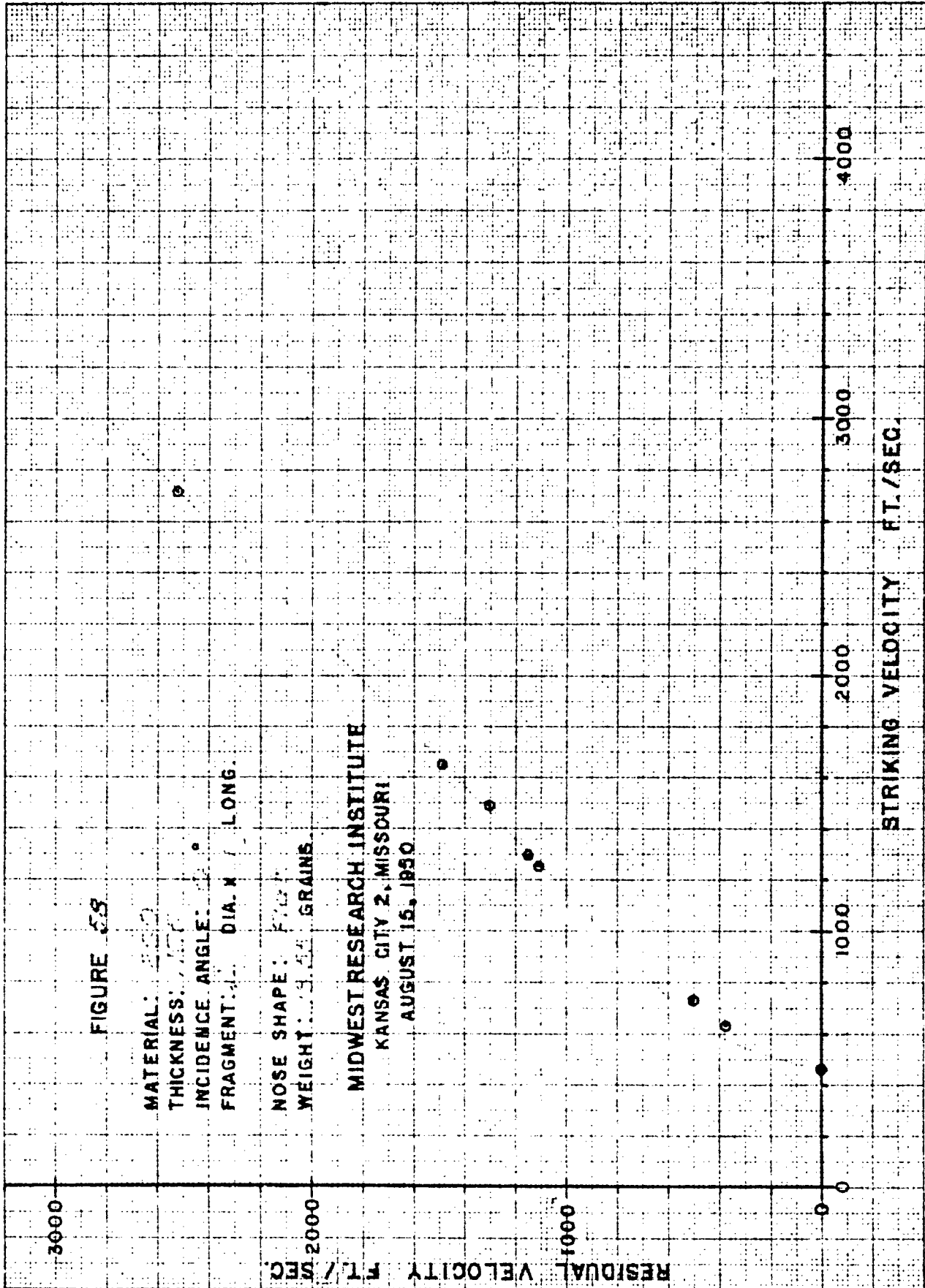


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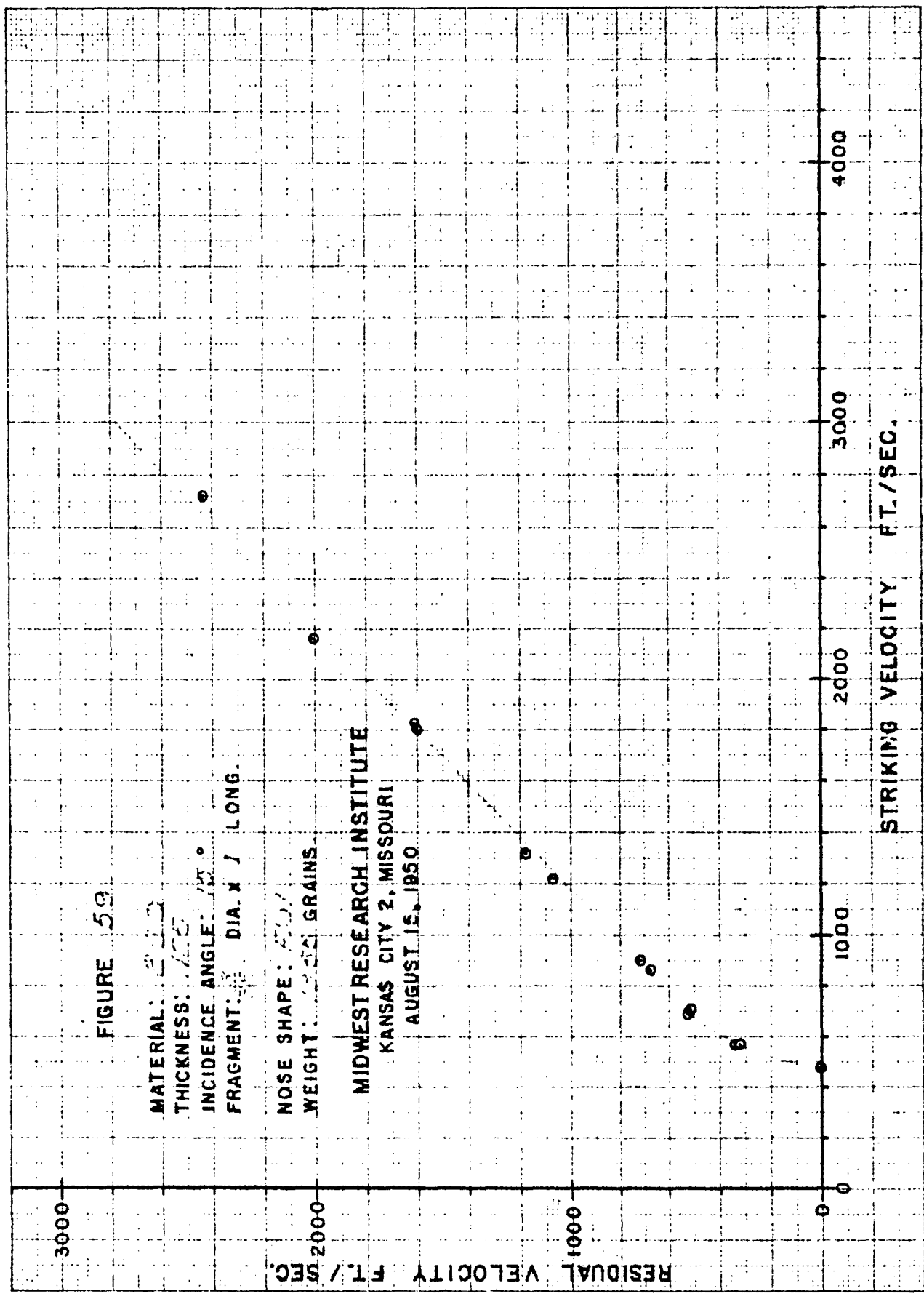
DATA SHEETS

CHARLES BRUNING COMPANY, INC. NO. 700-M
MILITARY DIVISION



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FIGURE 50

MATERIAL: 350

THICKNESS: 0.0015

INCIDENCE ANGLE: 30° .

FRAGMENT. DIA W/ LONG

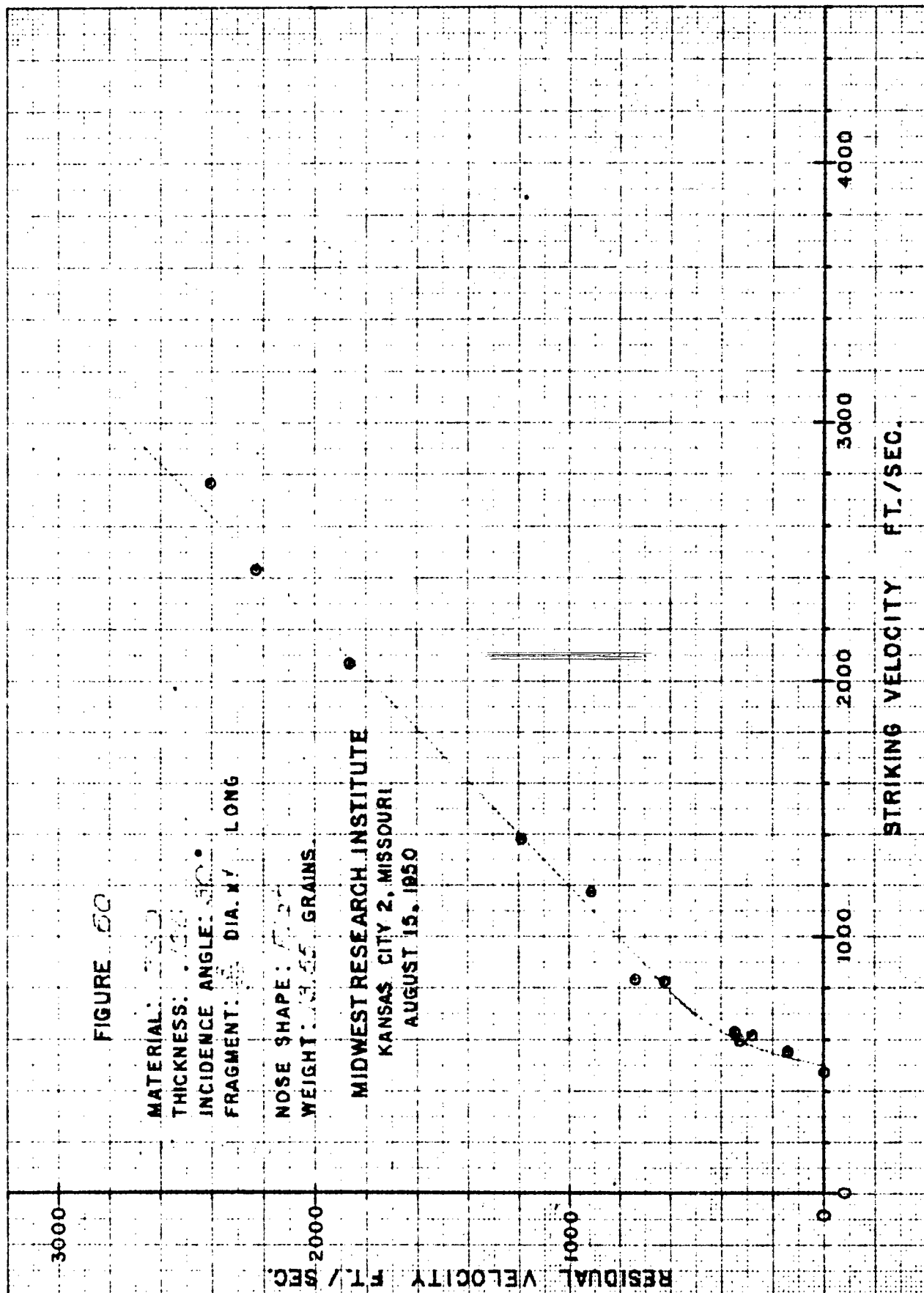
NOSE SHAPE: 7-1

WEIGHT: 13.55 GRAMS

MIDWEST RESEARCH INSTITUTE

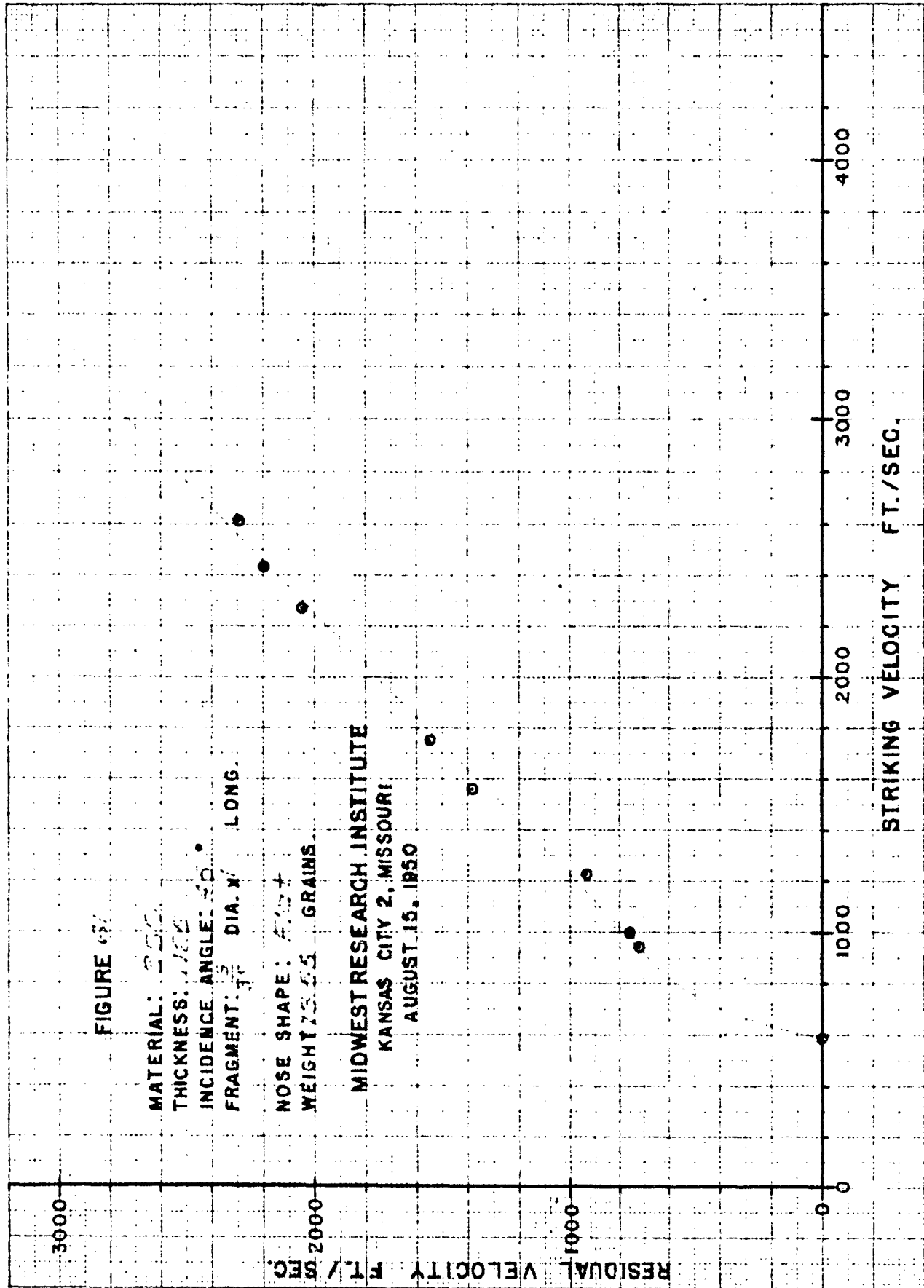
KANSAS CITY 2, MISSOURI.

AUGUST 15, 1959



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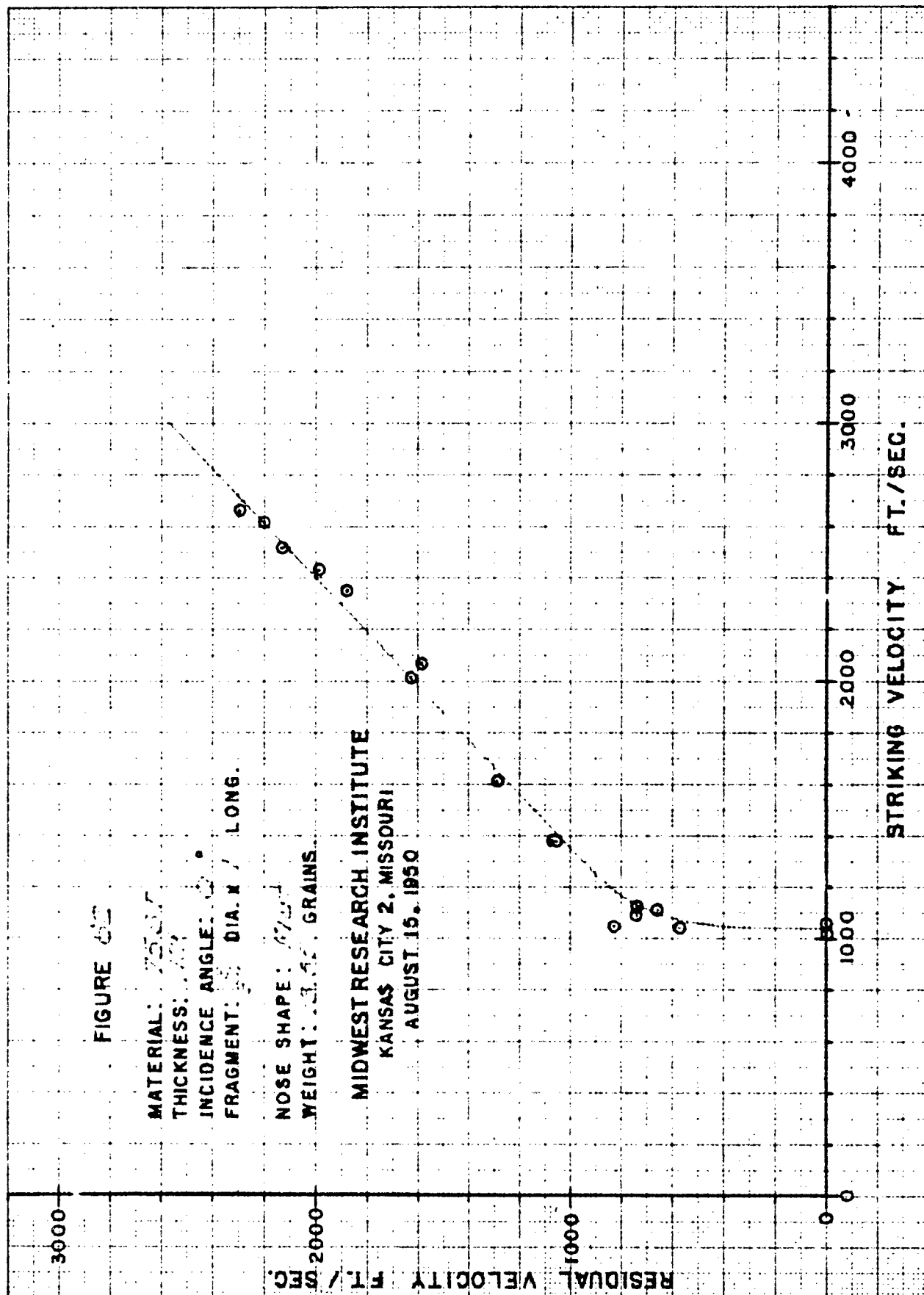
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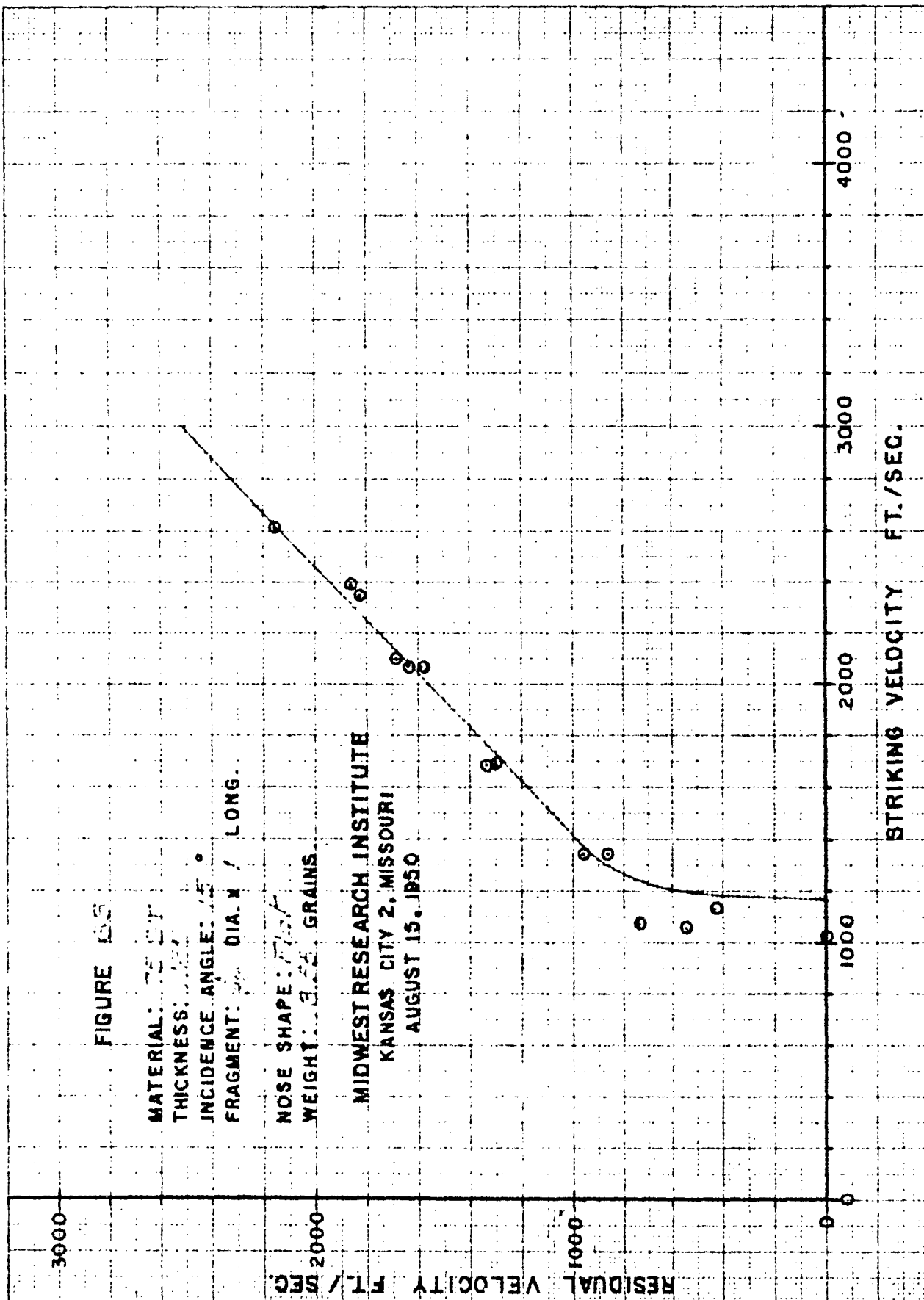
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RESTRICTED

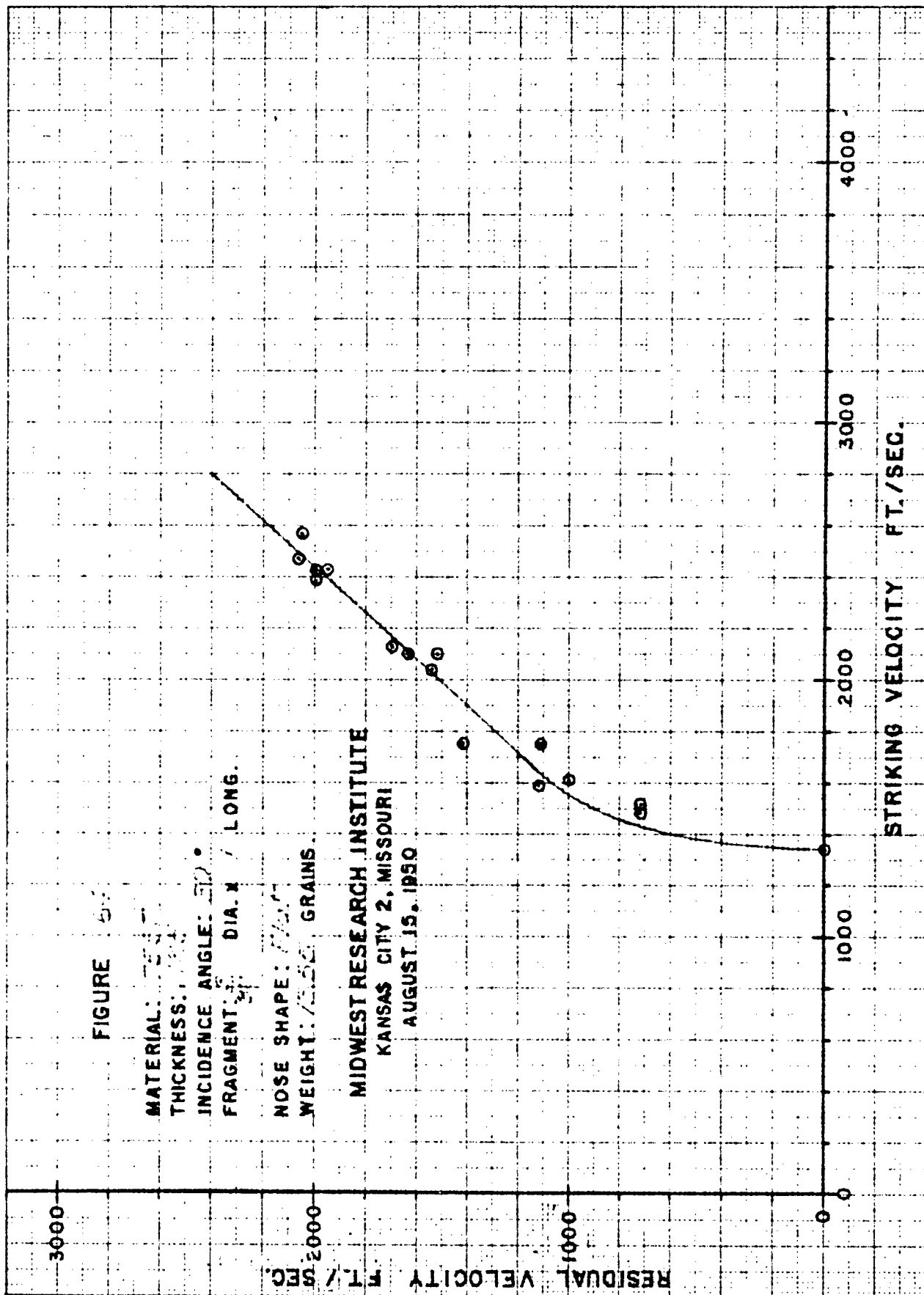
RESTRICTED



RESTRICTED



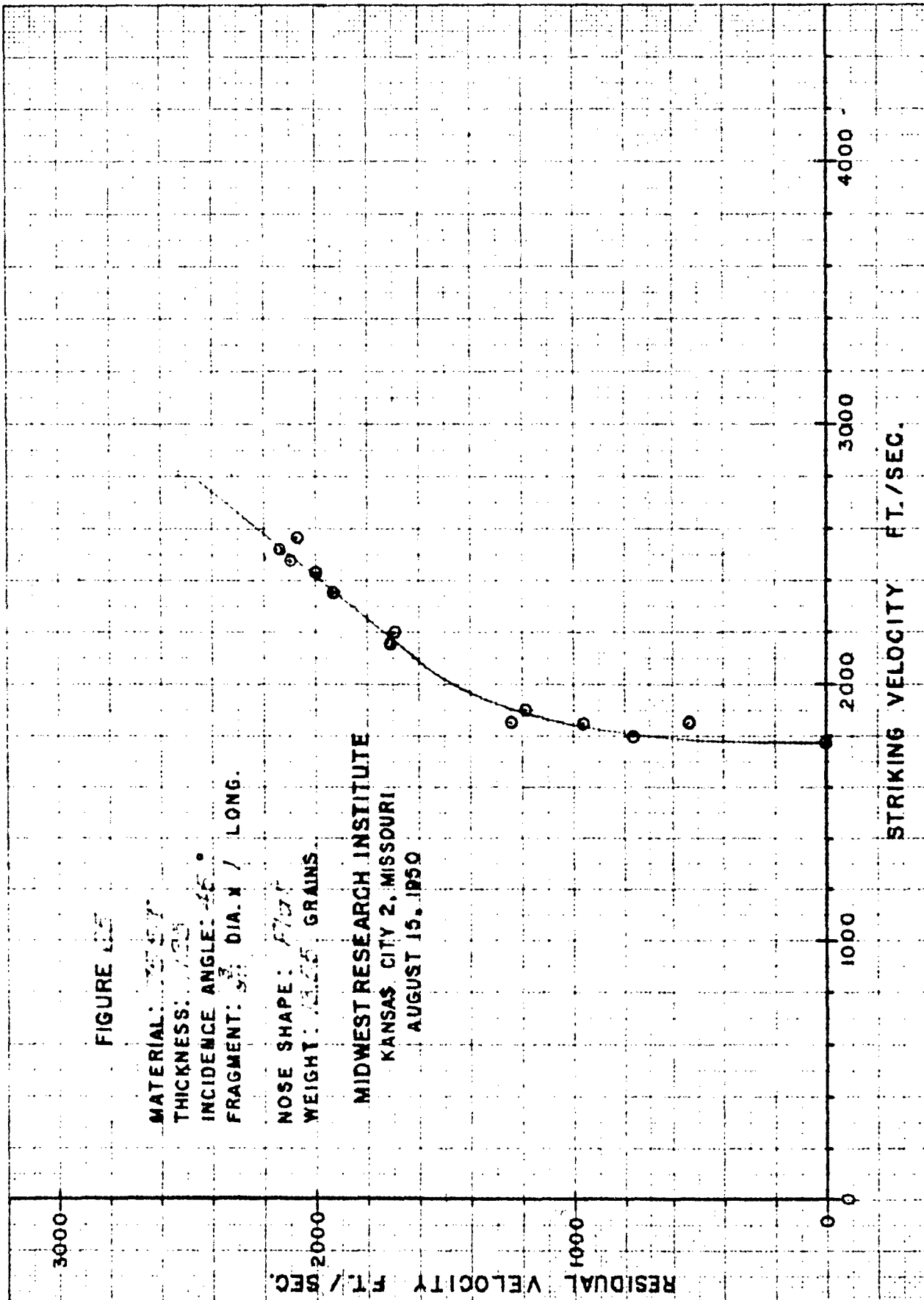
RESTRICTED



RESTRICTED

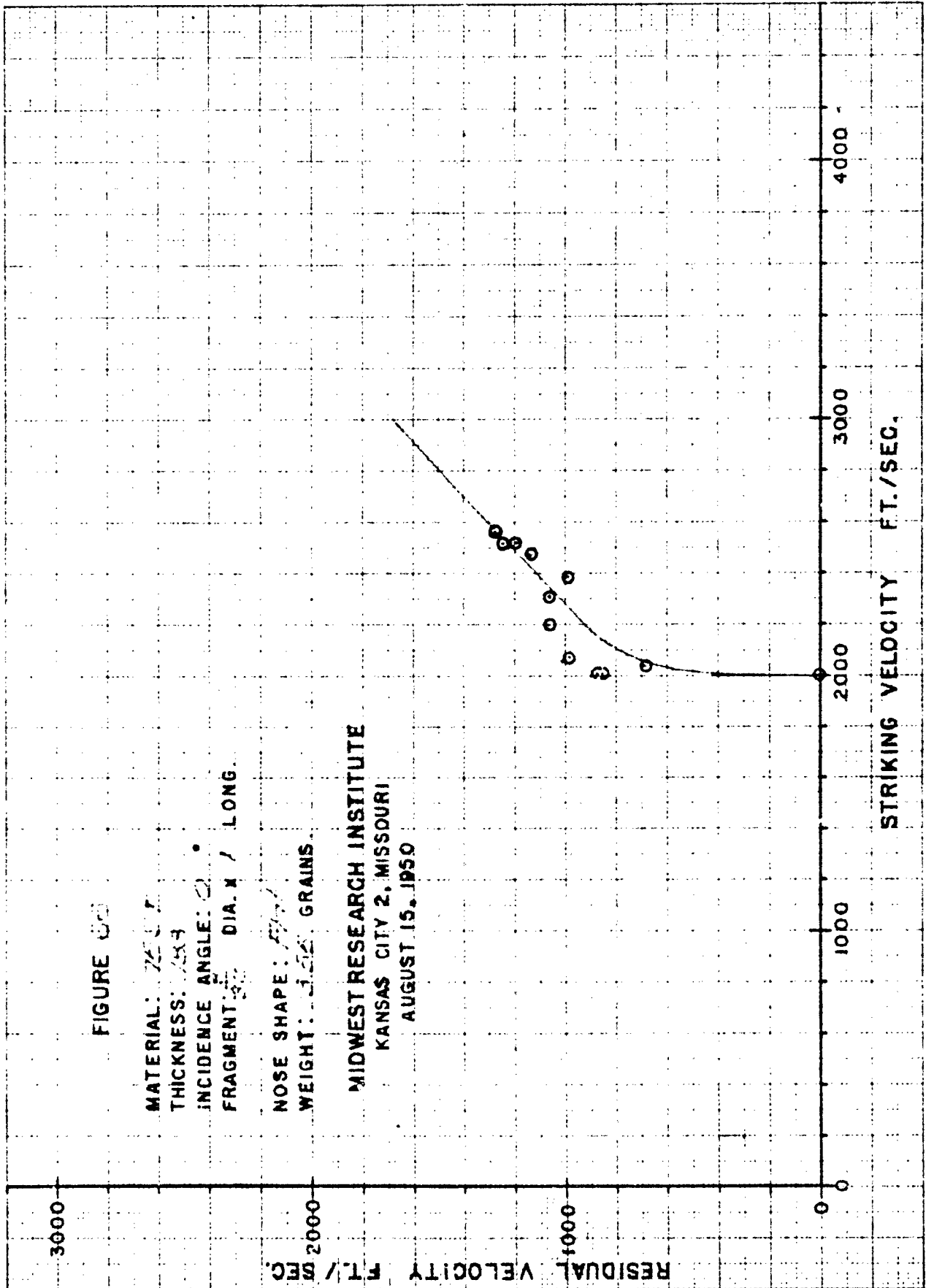
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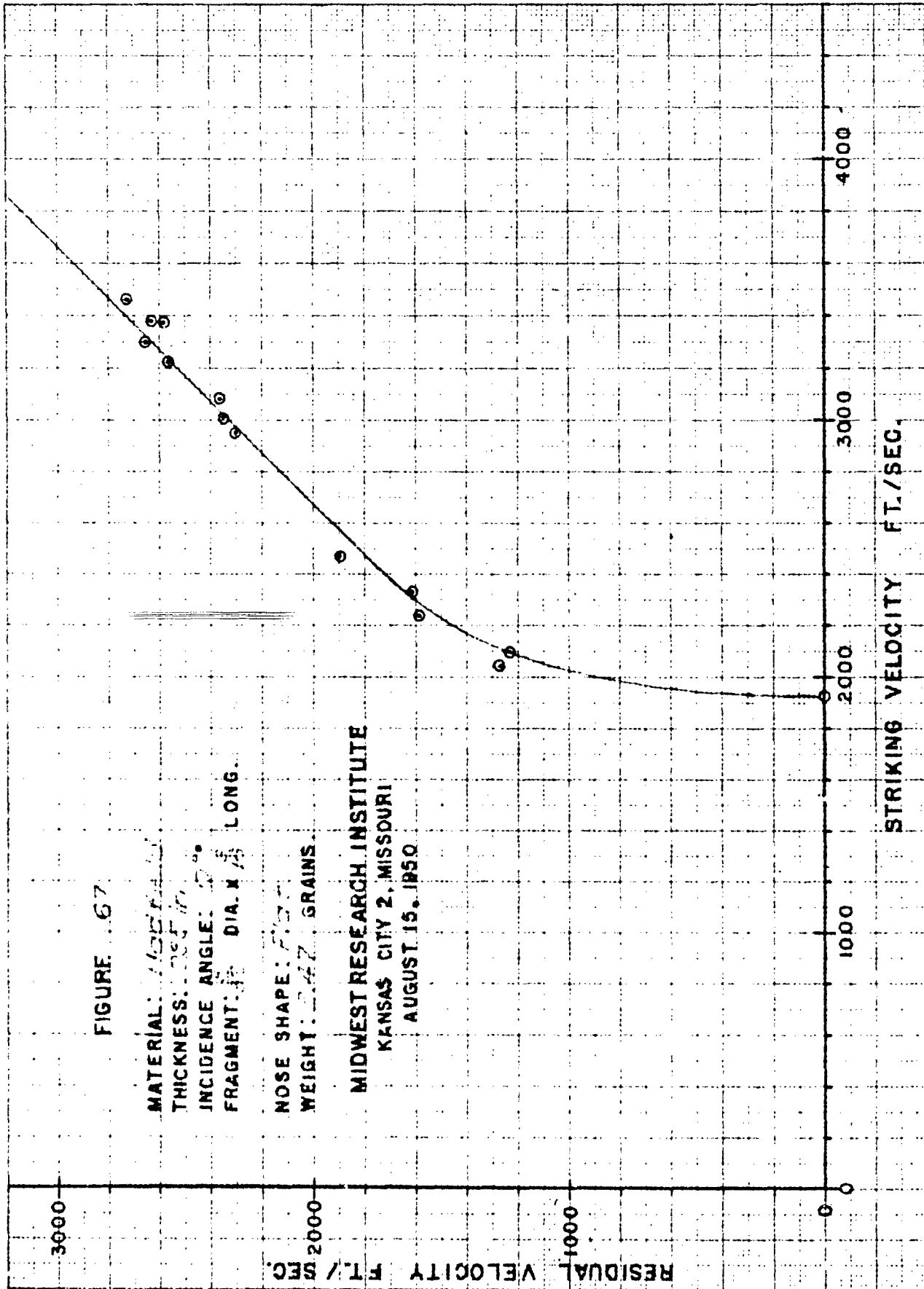
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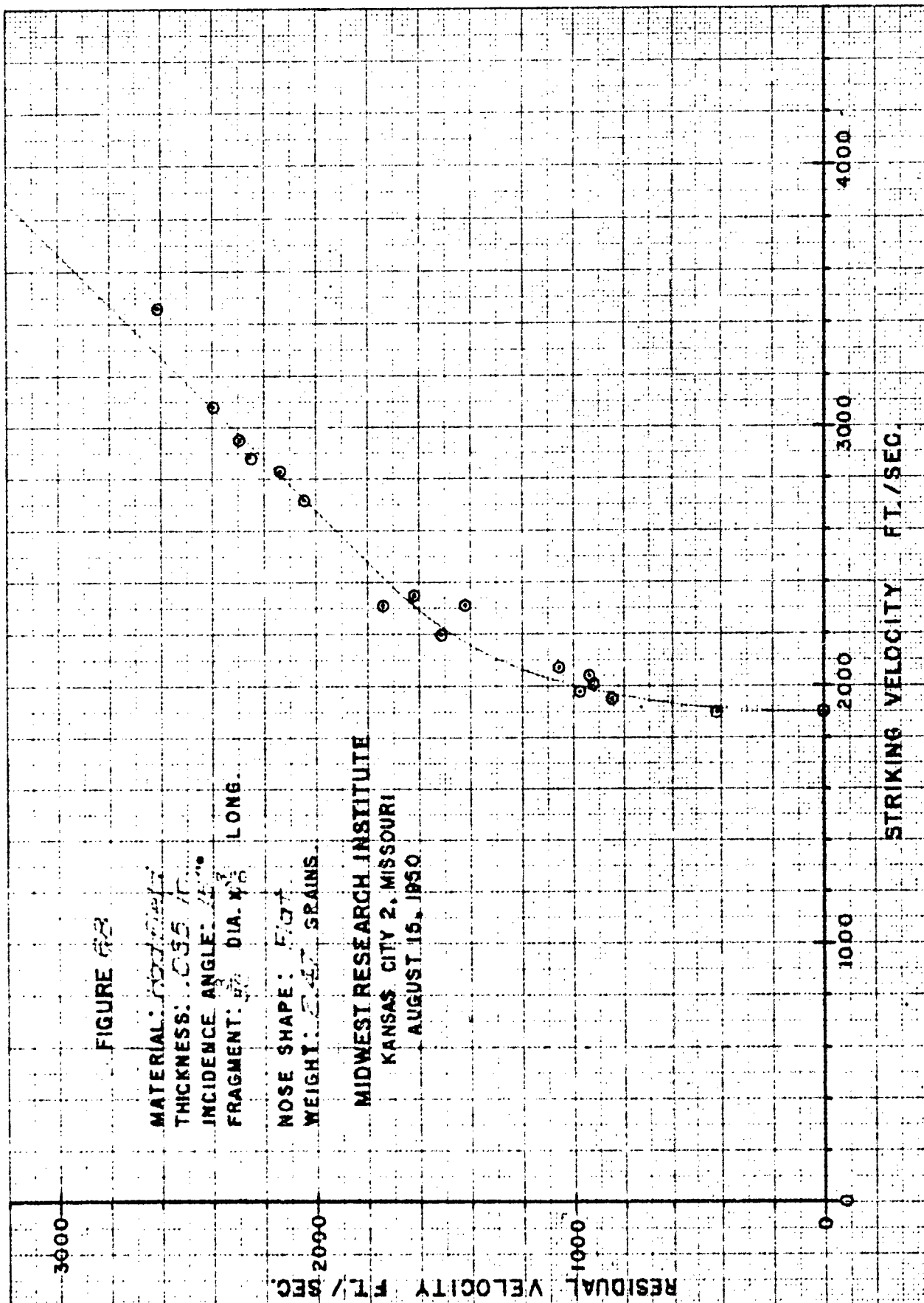
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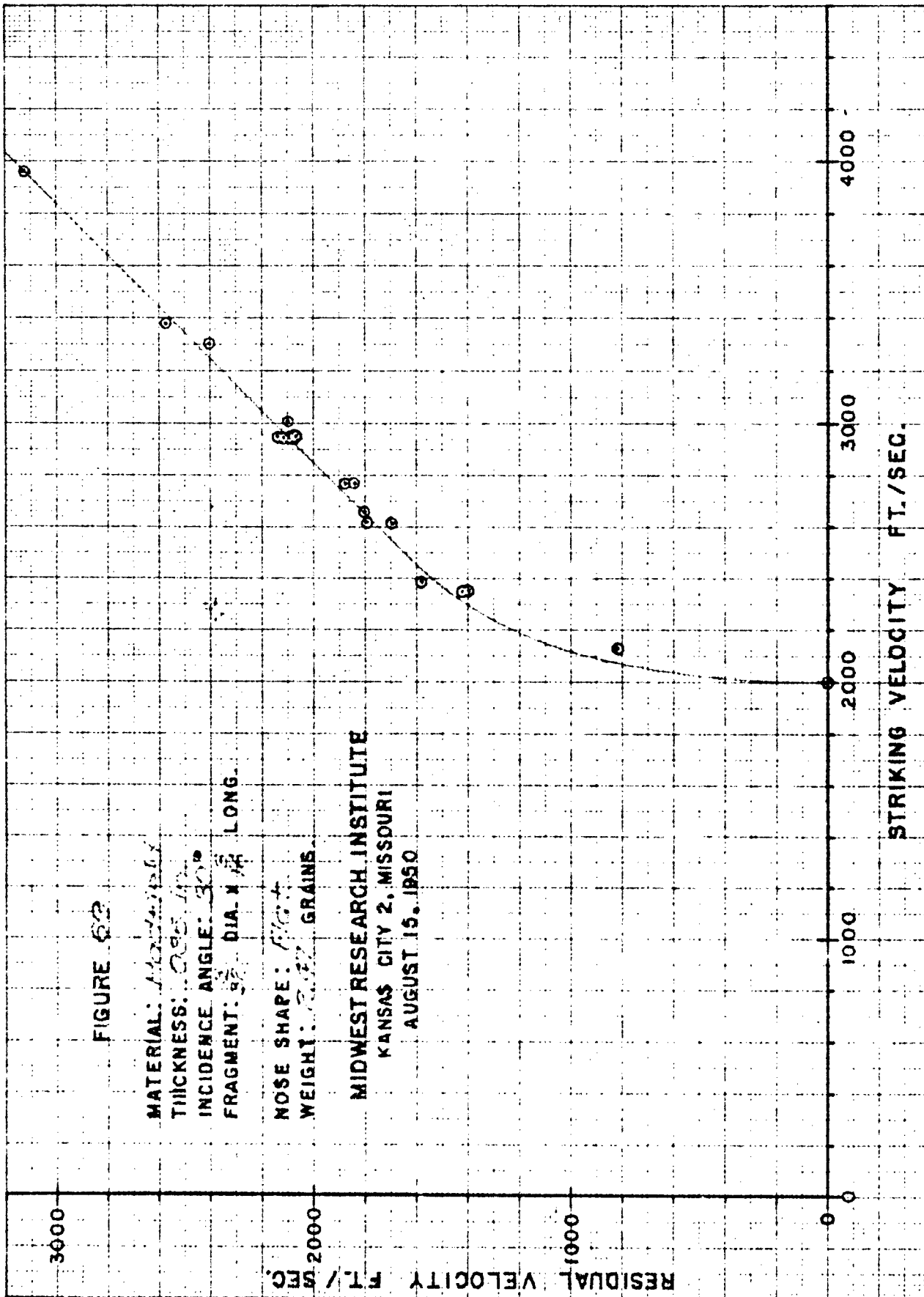
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DATA SHEET

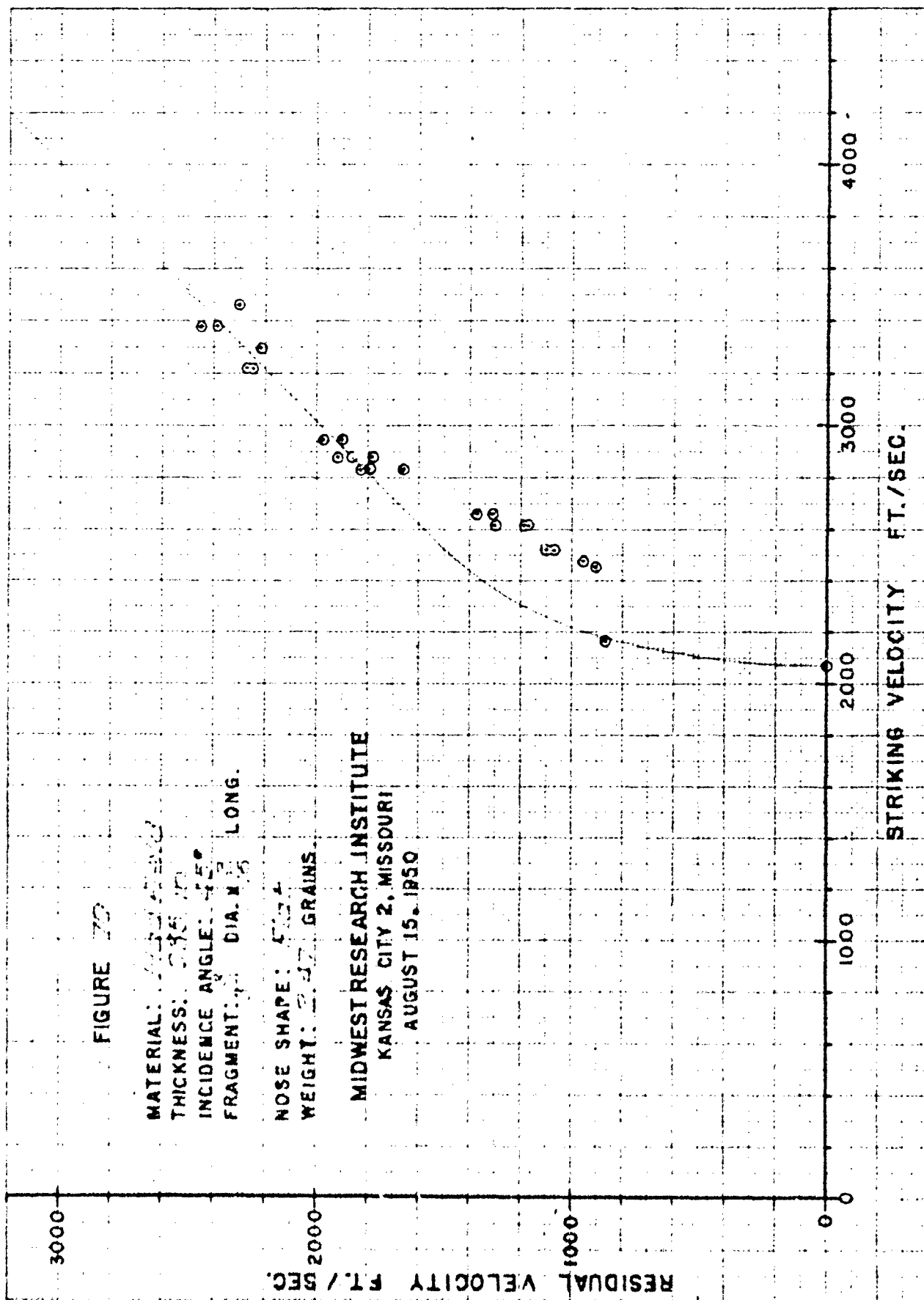
CHARACTERISTICS OF PROJECTILE AND TARGET

FIGURE 70

MATERIAL: 6061-T6 ALUMINUM
THICKNESS: 0.045 IN.
INCIDENCE ANGLE: 45°
FRAGMENT: 1/2 DIA. X 1/8 LONG.

NOSE SHAPE: FLAT
WEIGHT: 2.37 GRAINS

MIDWEST RESEARCH INSTITUTE
KANSAS CITY 2, MISSOURI
AUGUST 15, 1950

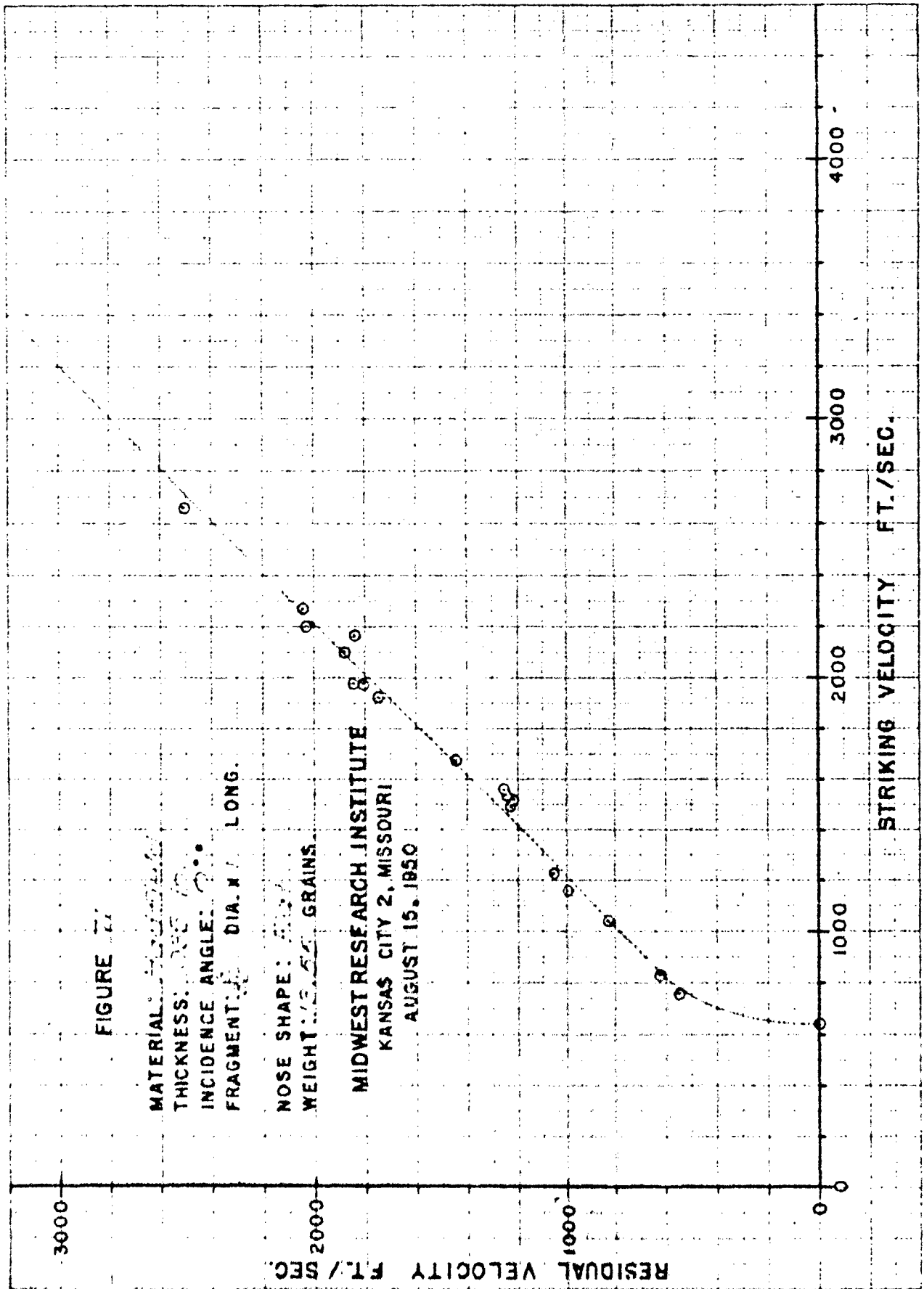


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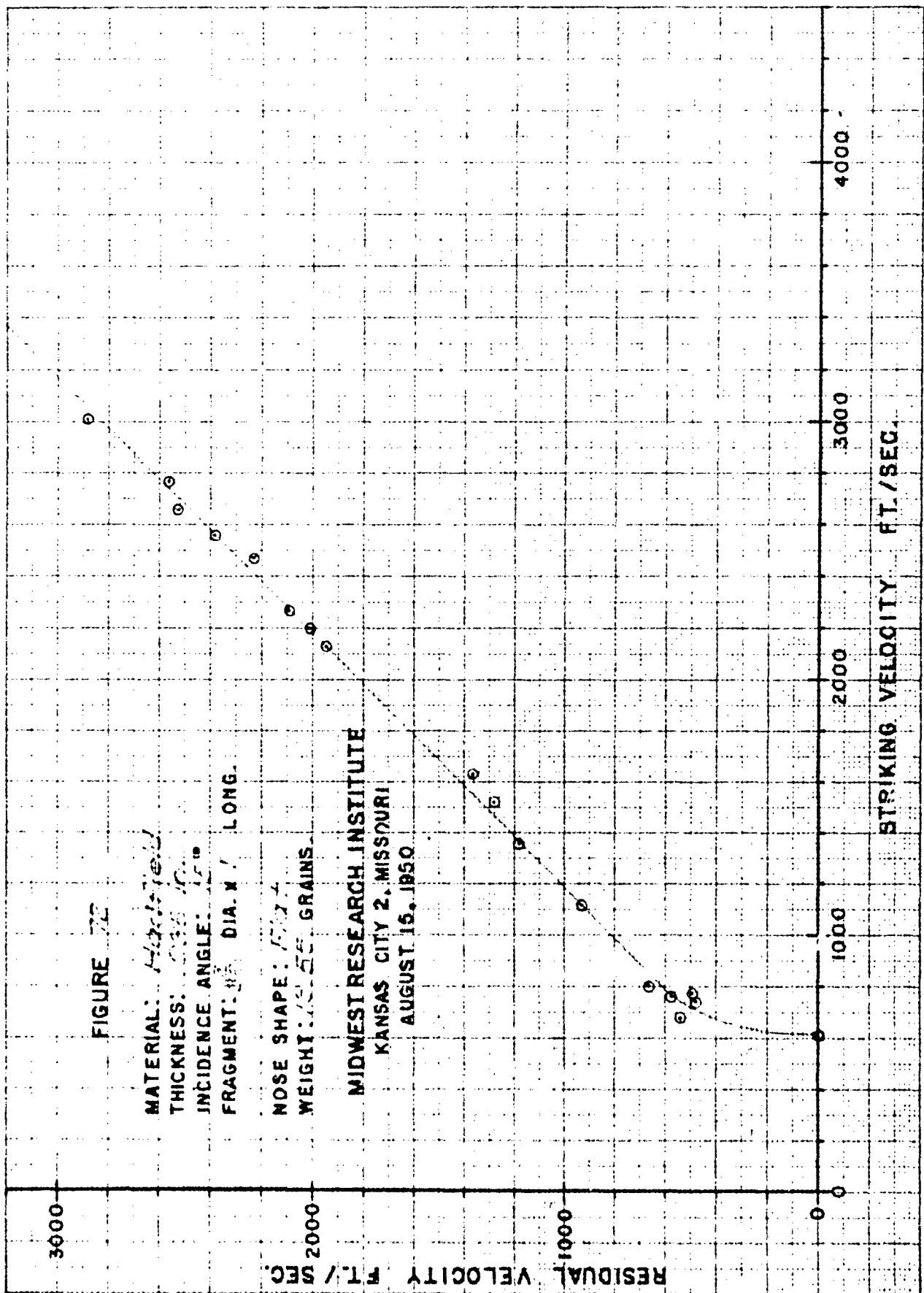
DATA SHEETS

CHARLES F. BROWN, JR. NO. 7000



RESTRICTED

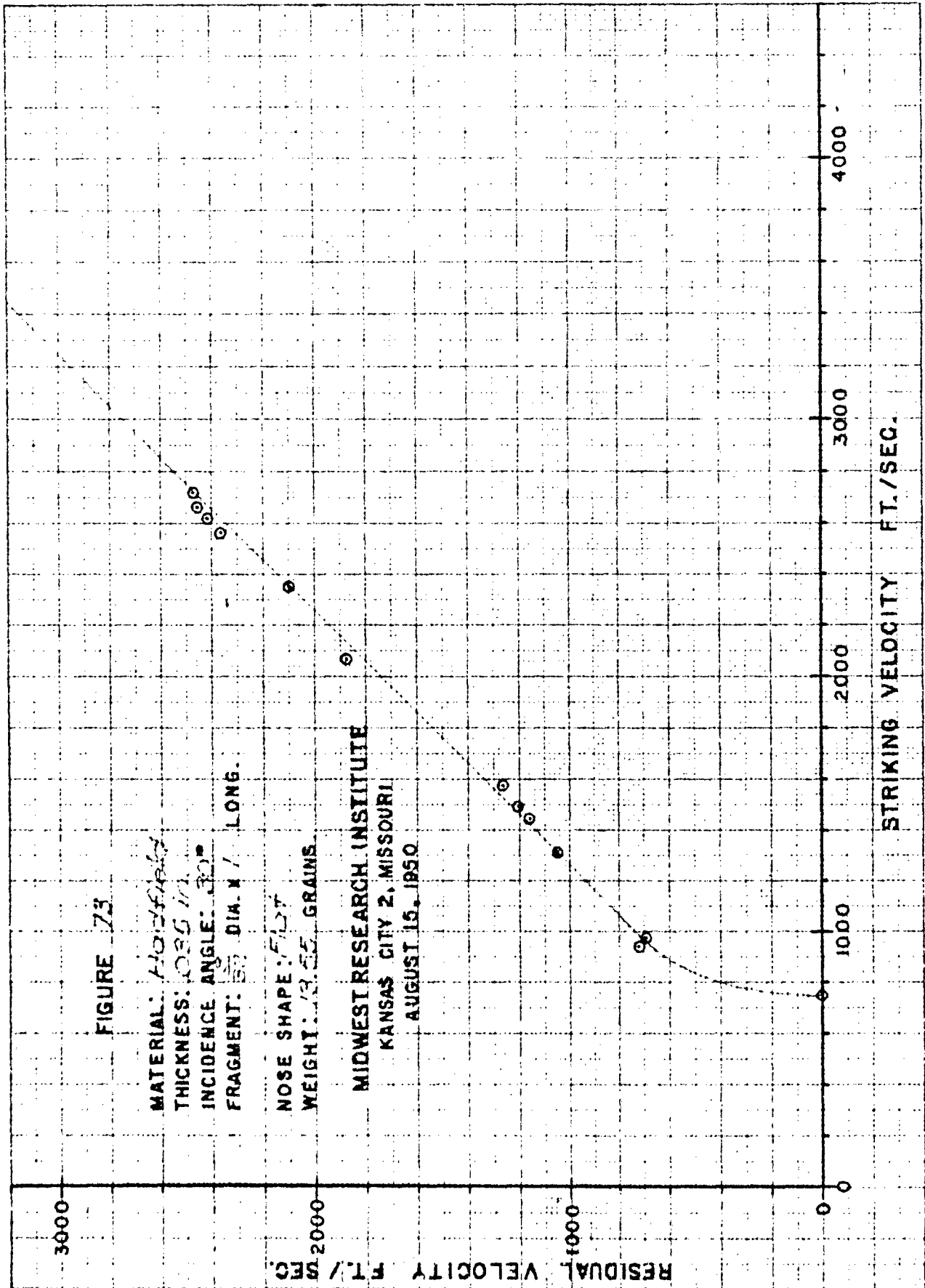
CHARLES BRUNNEN COMPANY, INC.
NEW YORK, N. Y.



RESTRICTED

DATA SHEETS

CHARLES BRUNN COMPANY, INC. NO 700-M
MILWAUKEE, WISCONSIN



RESTRICTED

RESTRICTED

DATA SHEETS

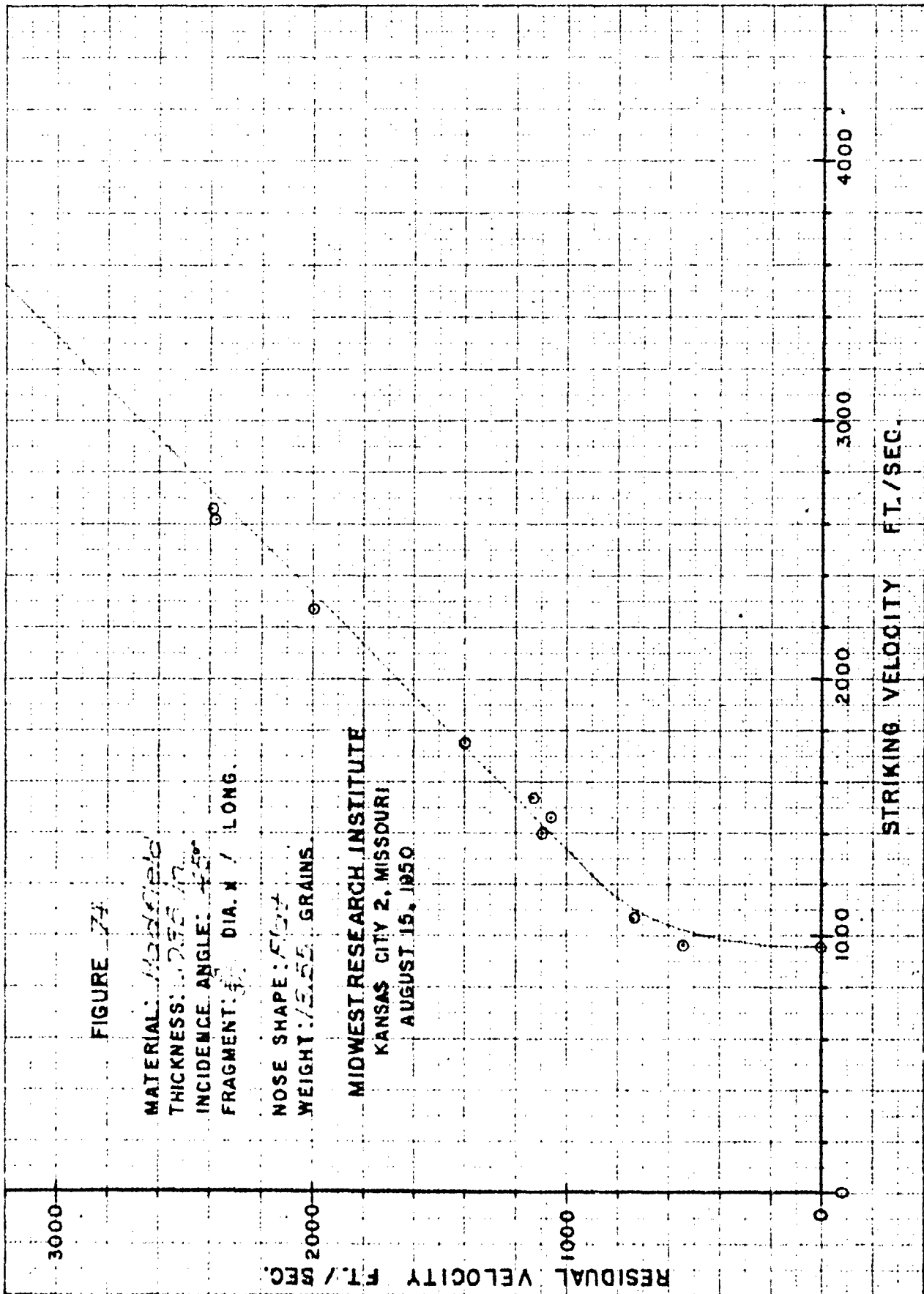
CHARLES BRUNN COMPANY, INC. NO. 7000-M
MIDWEST RESEARCH INSTITUTE

FIGURE 74

MATERIAL: *Mild Steel*
THICKNESS: *0.035 in.*
INCIDENCE ANGLE: *45°*
FRAGMENT: *1/4* DIA. *1* LONG.

NOSE SHAPE: *Flat*
WEIGHT: *0.555* GRAINS.

MIDWEST RESEARCH INSTITUTE
KANSAS CITY 2, MISSOURI
AUGUST 15, 1950

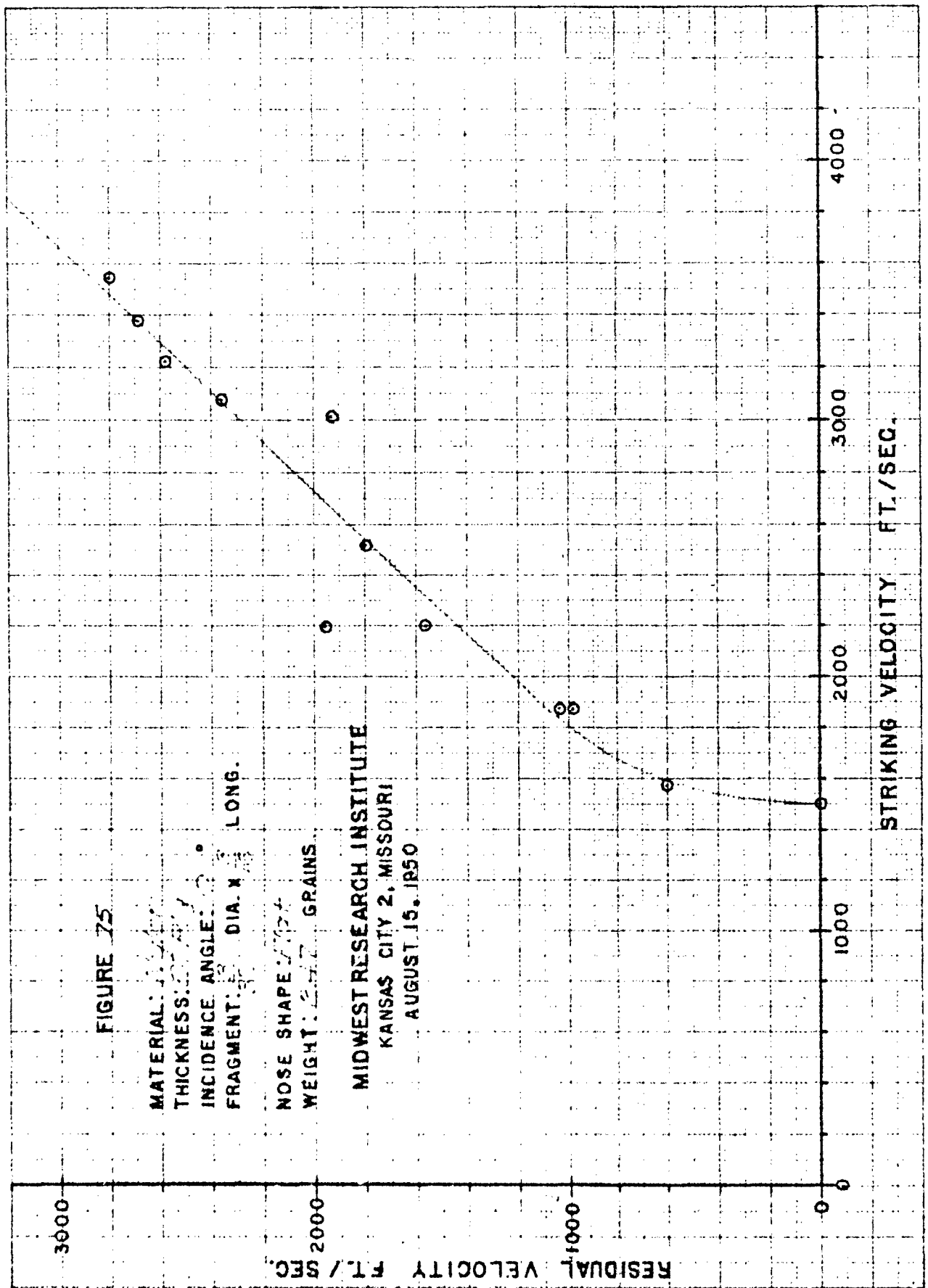


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RESTRICTED

DATA SHEETS

CHARLES BRUNN GUN MOUNTING, INC. NO. 700-M
NEW YORK, N. Y.

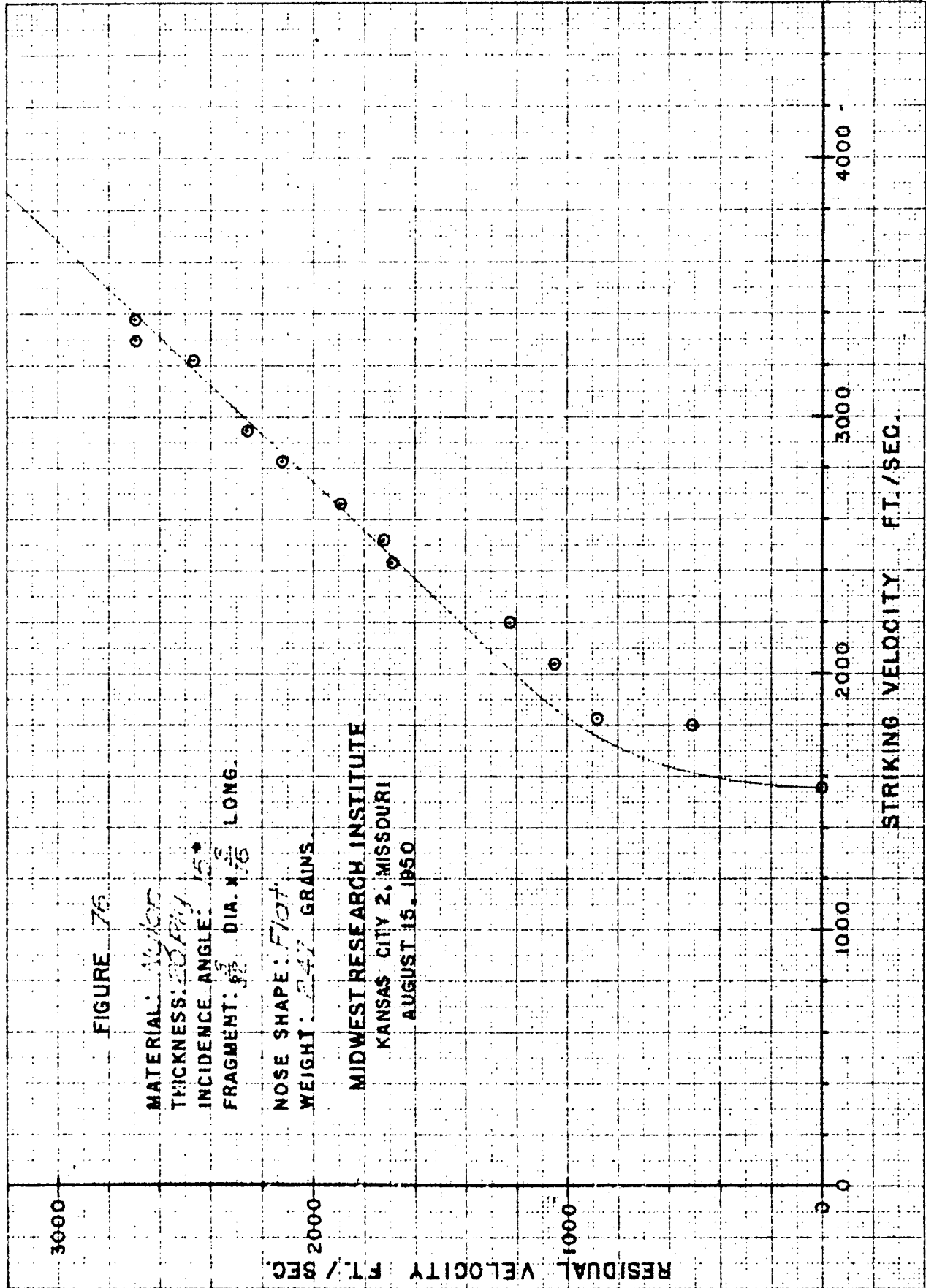


RESTRICTED

RESTRICTED

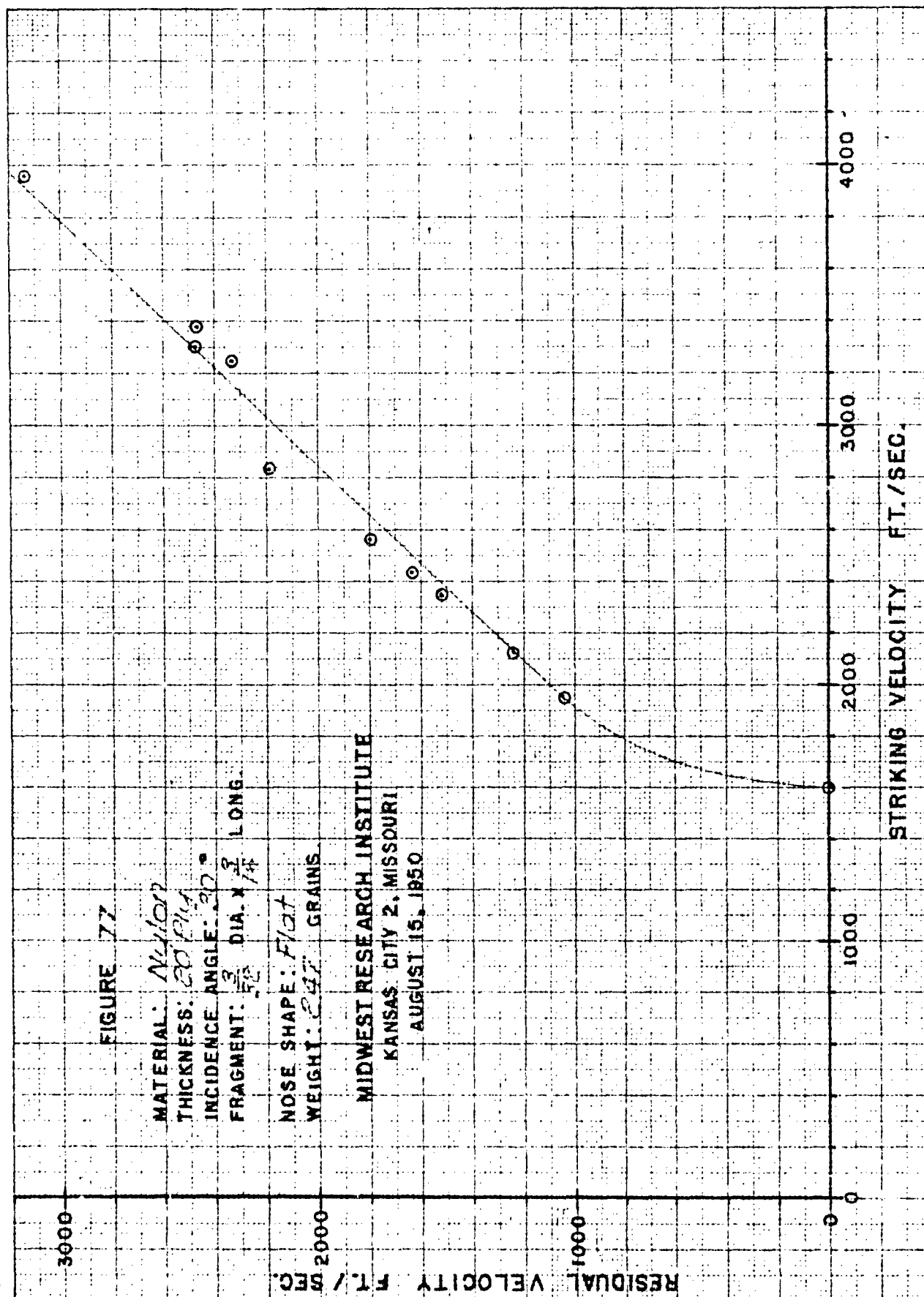
DATA SHEETS

CHARLES BREWING COMPANY, INC. NO. 700-M
MILWAUKEE, WISCONSIN 53217



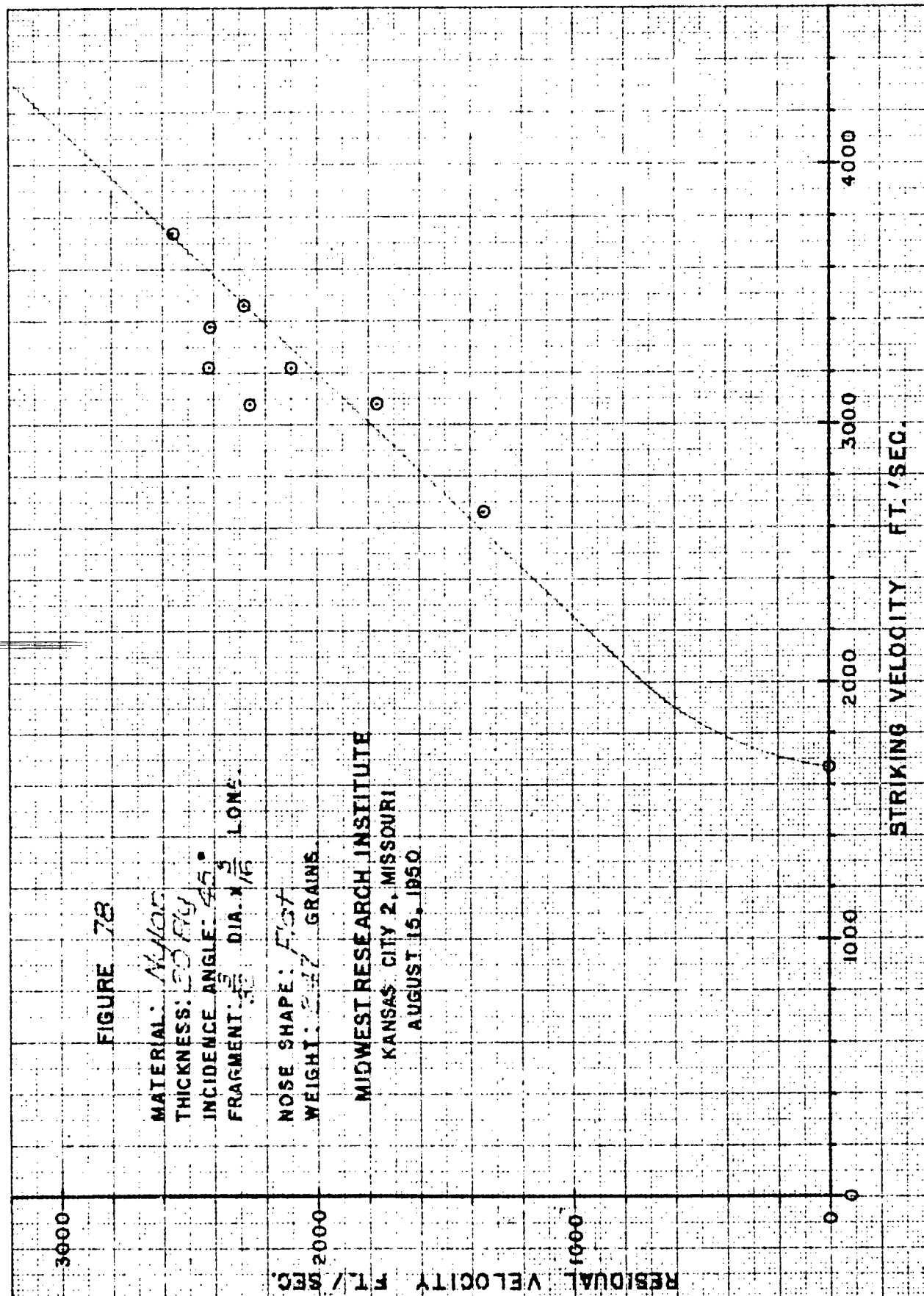
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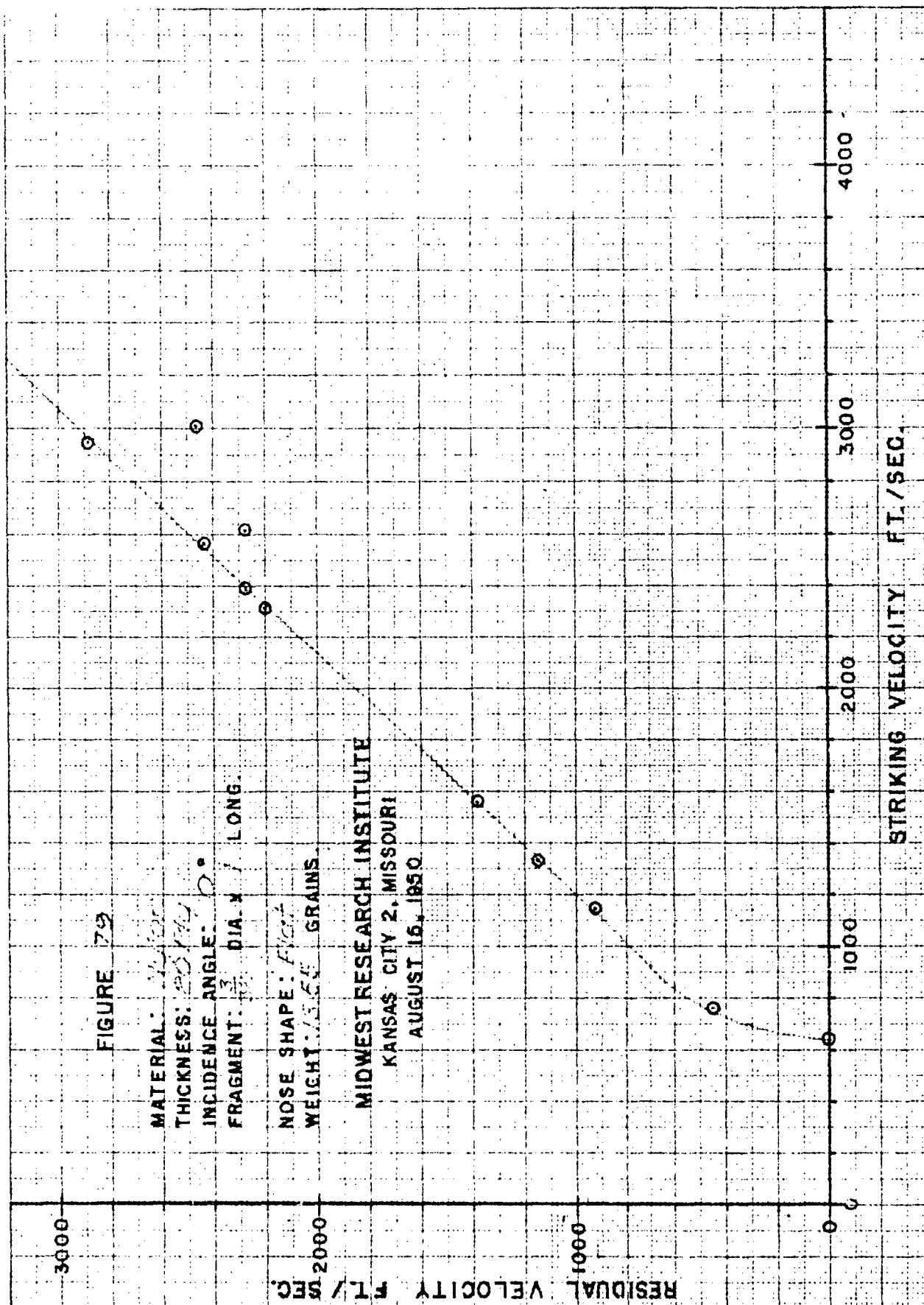
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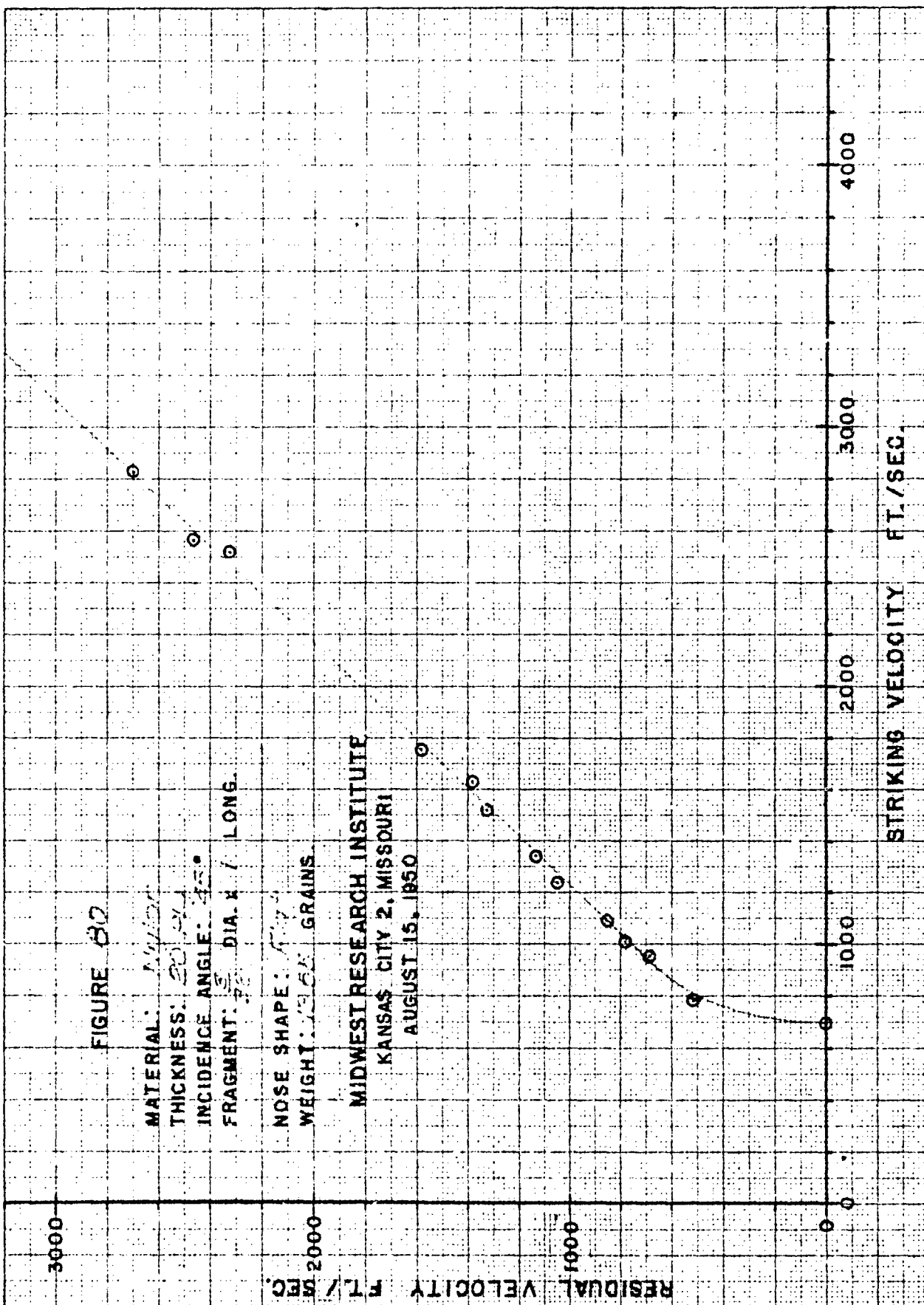
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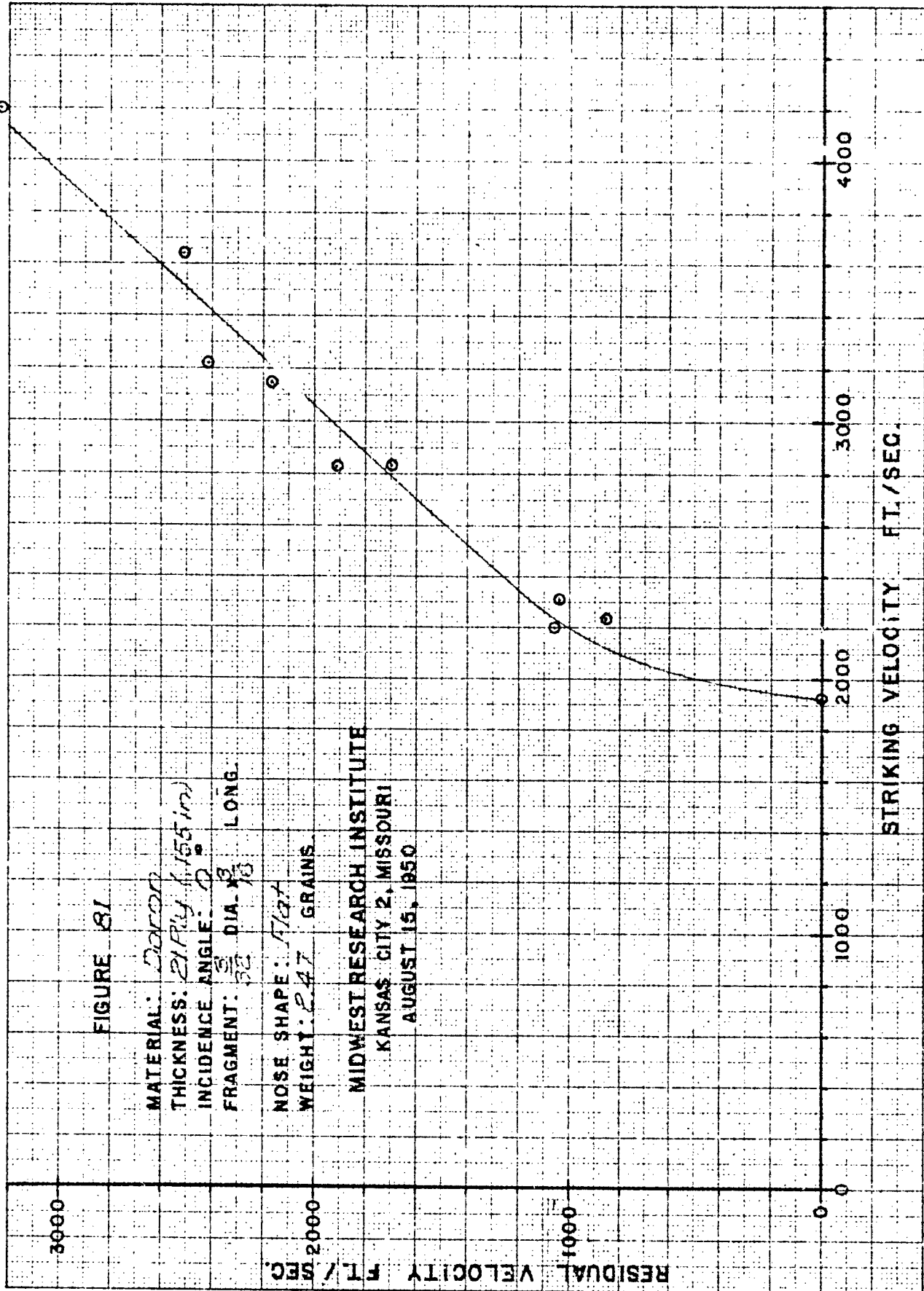
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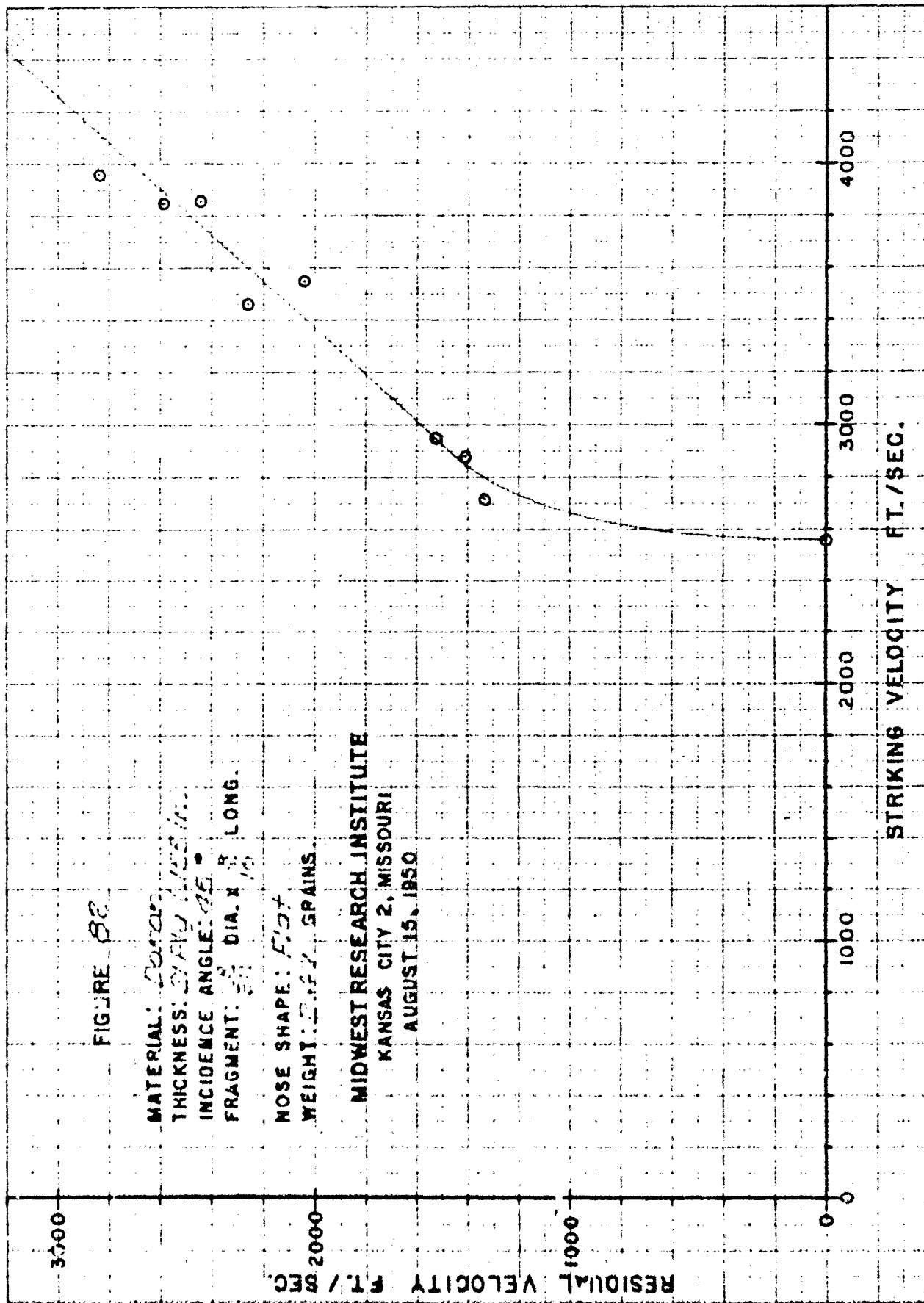


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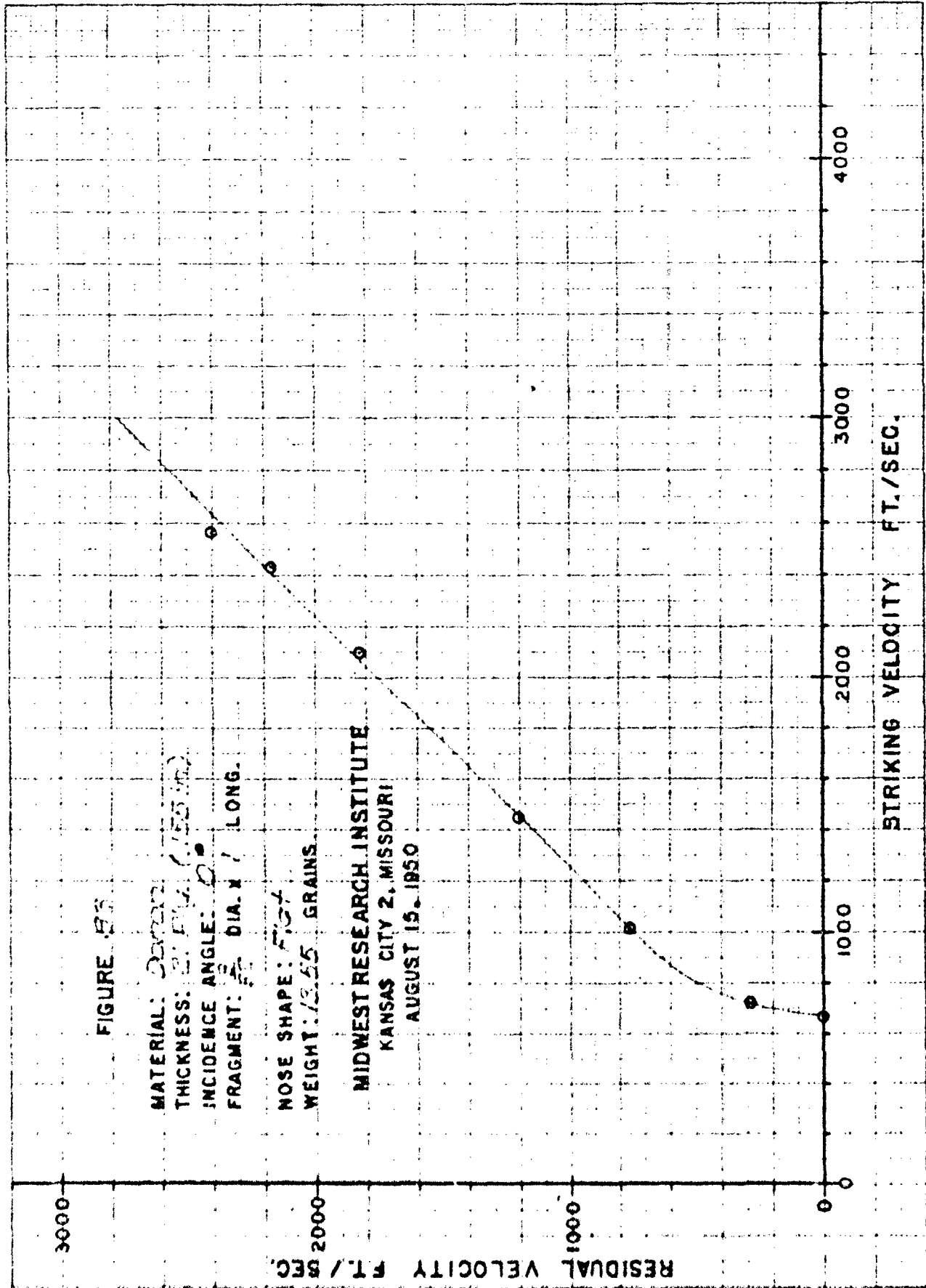


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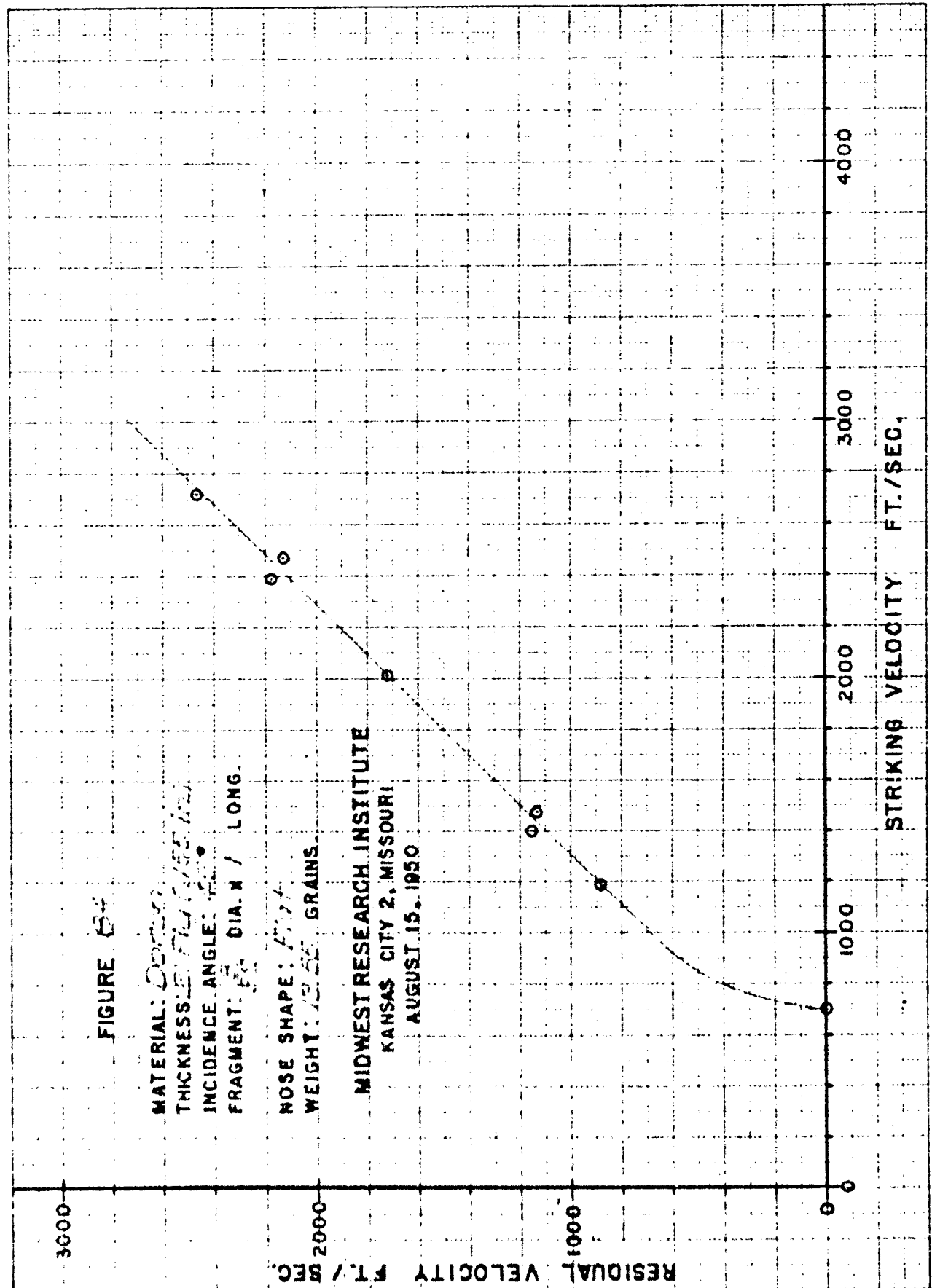
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MILWAUKEE, WISCONSIN

FIGURE B-

MATERIAL: *Ductile Iron*
THICKNESS: *2 1/2" (63.5 mm)*
INCIDENCE ANGLE: *25°*
FRAGMENT: *1/2" DIA. X 1" LONG.*

NOSE SHAPE: *Flat*
WEIGHT: *13.55 GRAMS.*

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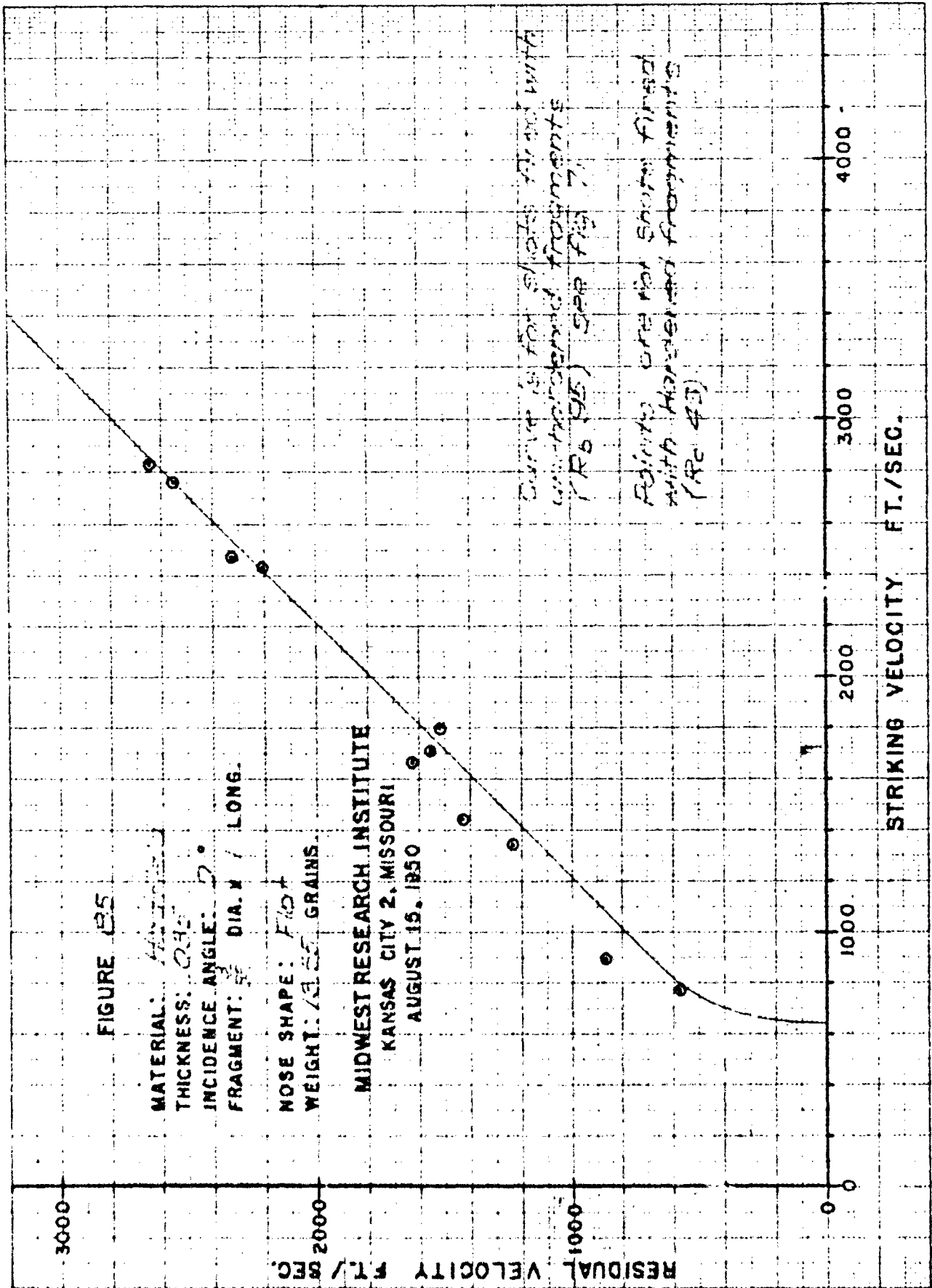


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M. J. WALKER



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FIGURE 55

MATERIAL:

THICKNESS:

INCIDENCE ANGLE: 0°

FRAGMENT: DIA. $\frac{1}{8}$ LONG.

NOSE SHAPE: F/27

WEIGHT: 242 GRAINS.

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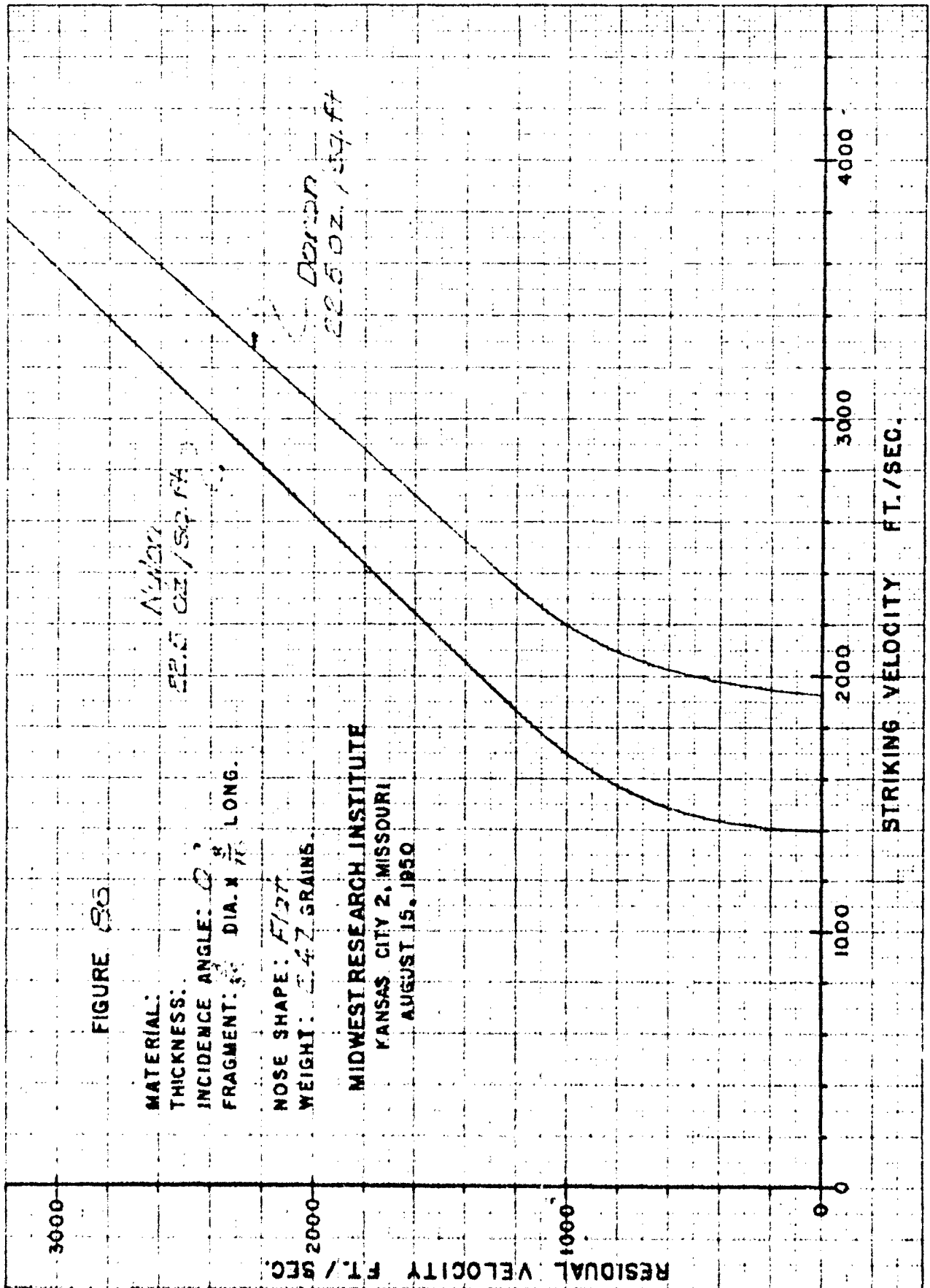
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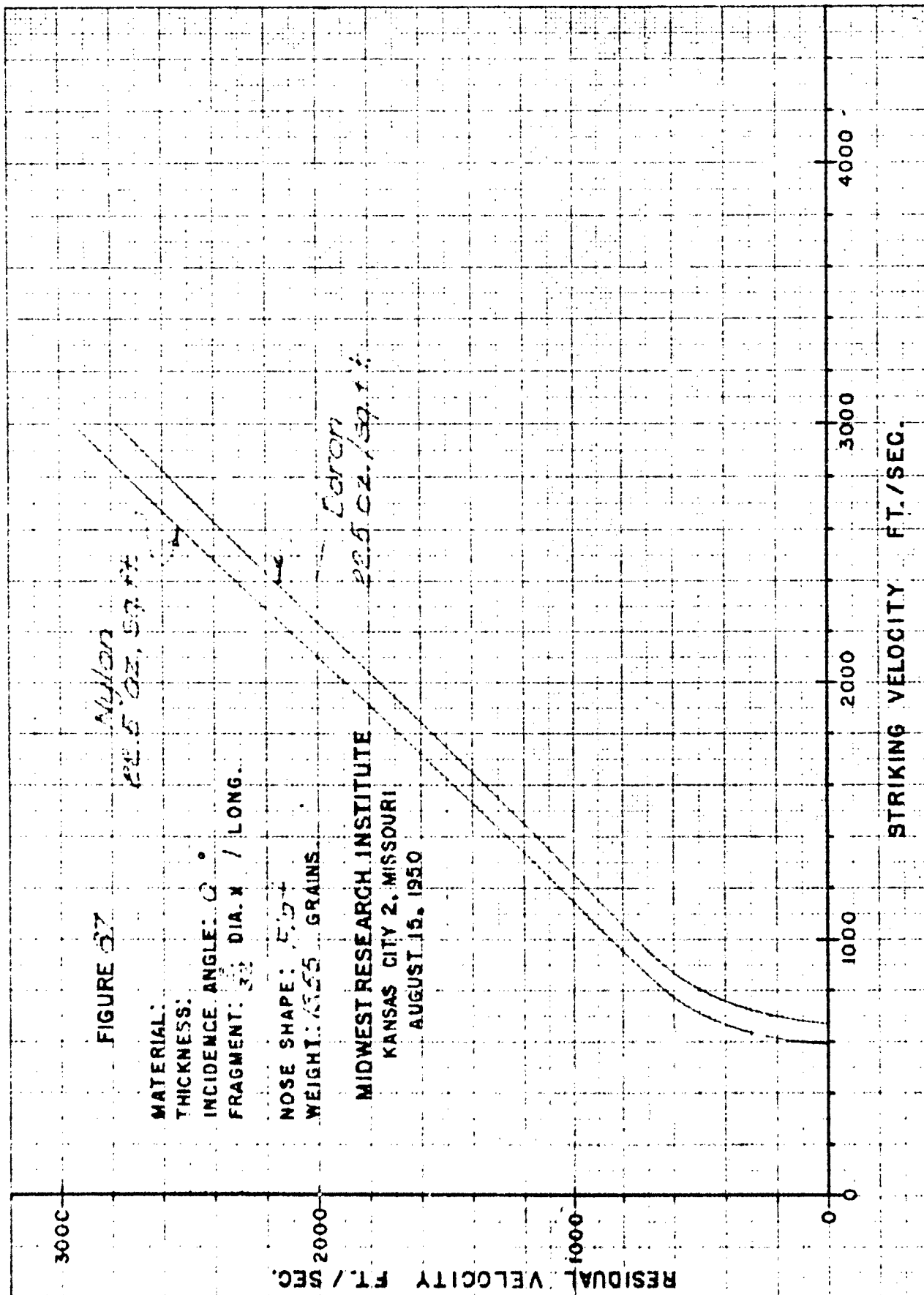
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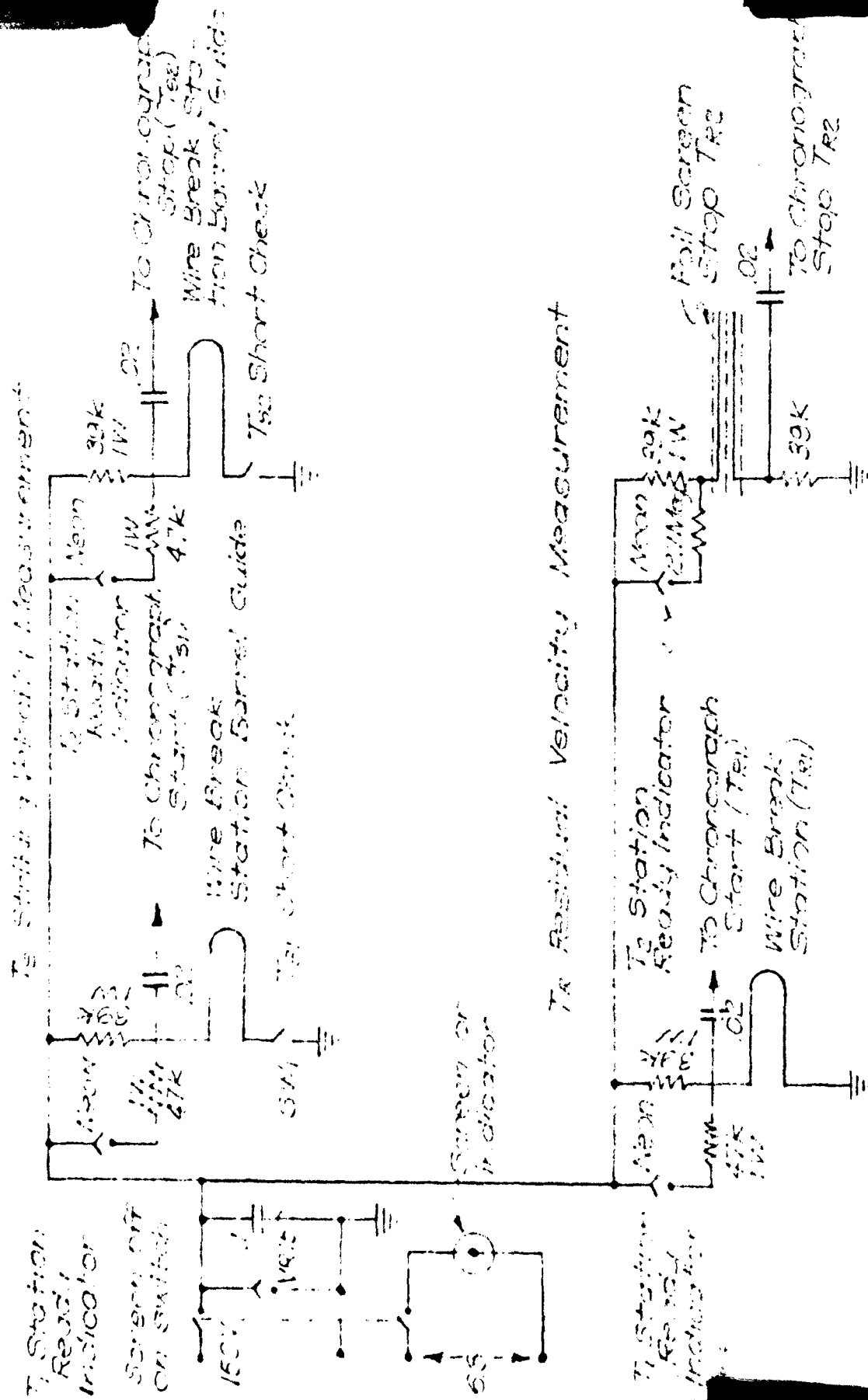
APPENDIX B

Schematic Diagram; Fig. 88

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APPENDIX C

Photographs of Equipment; Figs. 89 through 91

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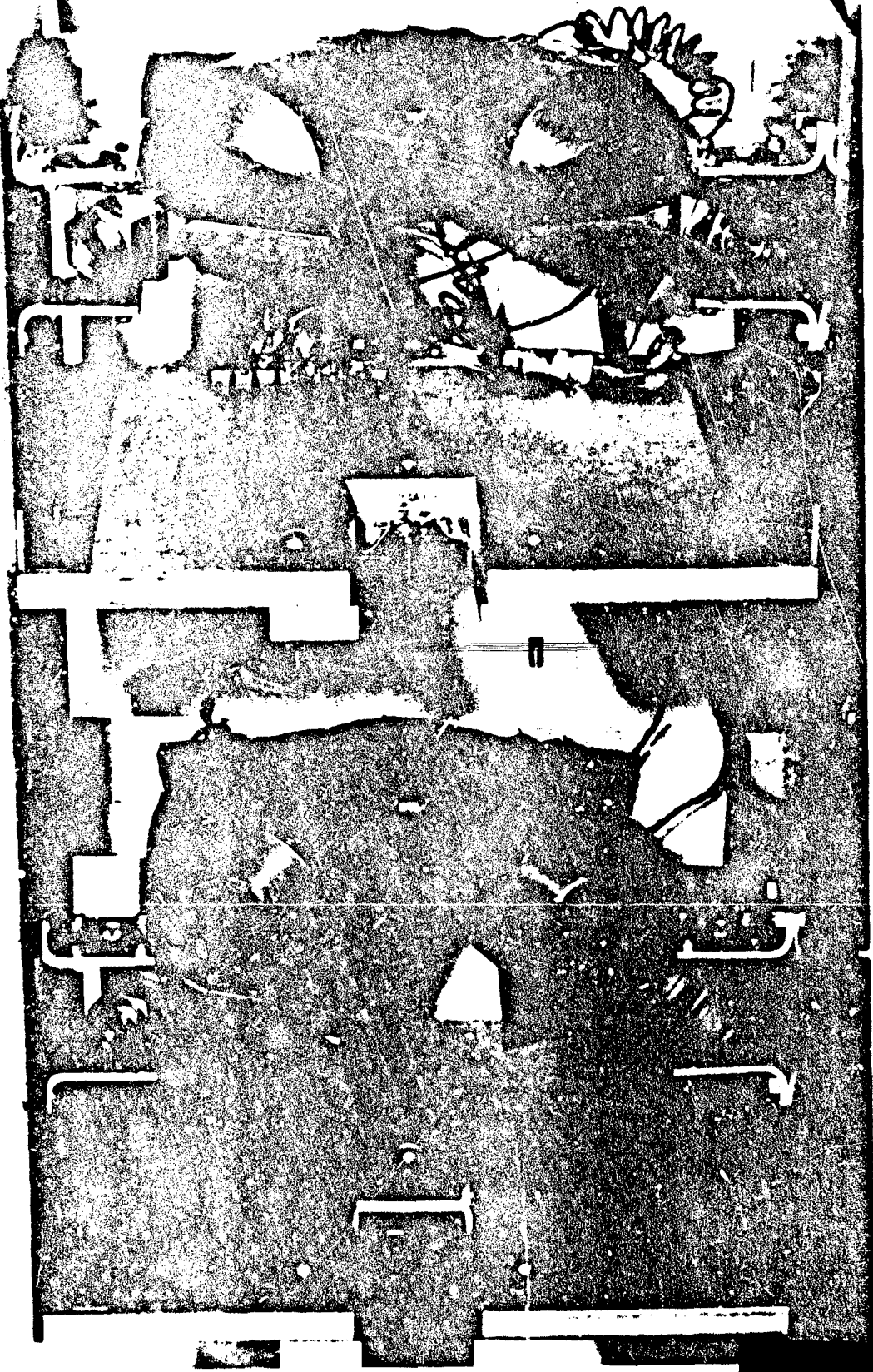


Fig. 89 - Magnetic Screen Assembly for Measuring Residual Velocity

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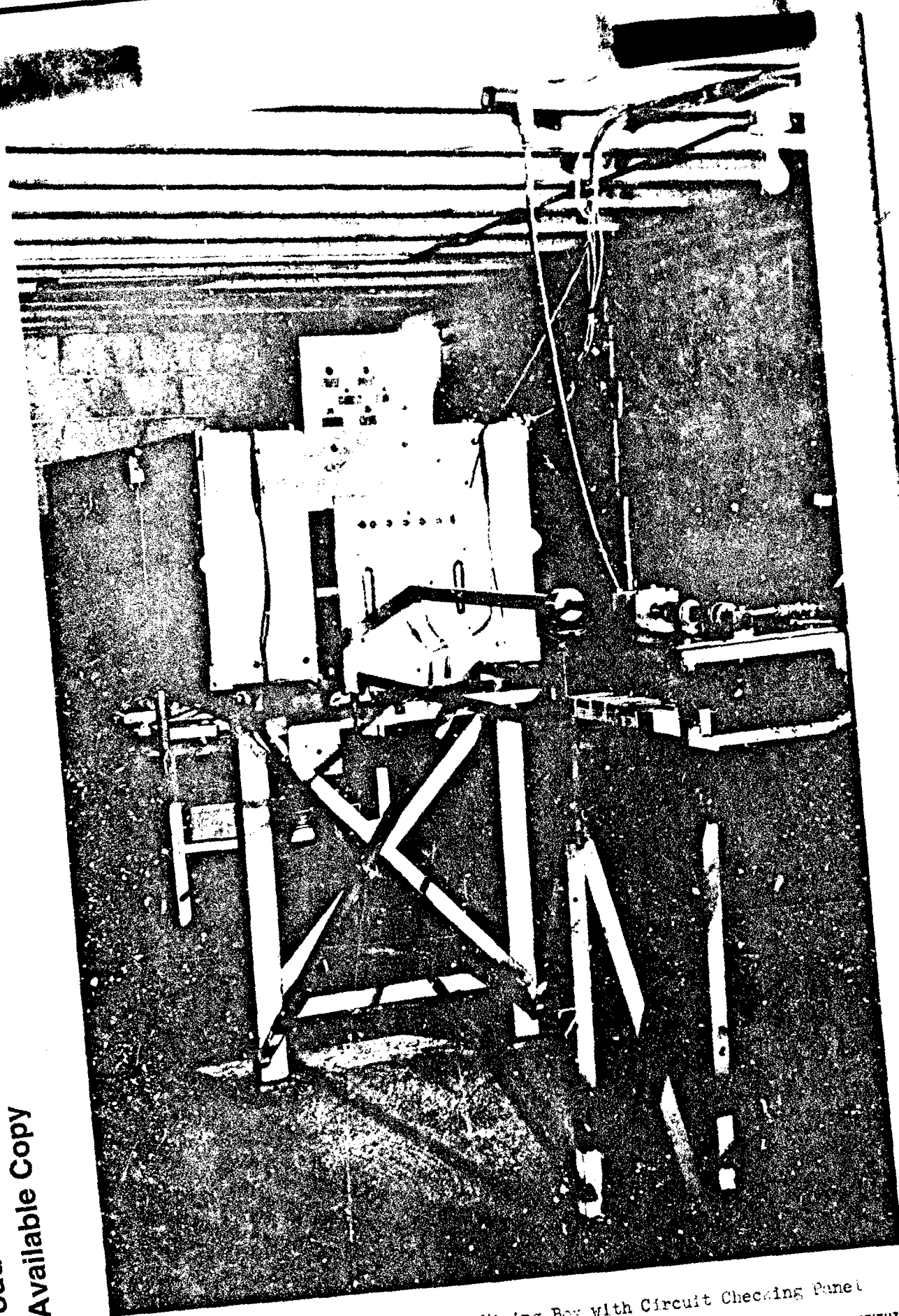


Fig. 1 - Gun, Fragment Guide and Firing Box with Circuit Checking Panel

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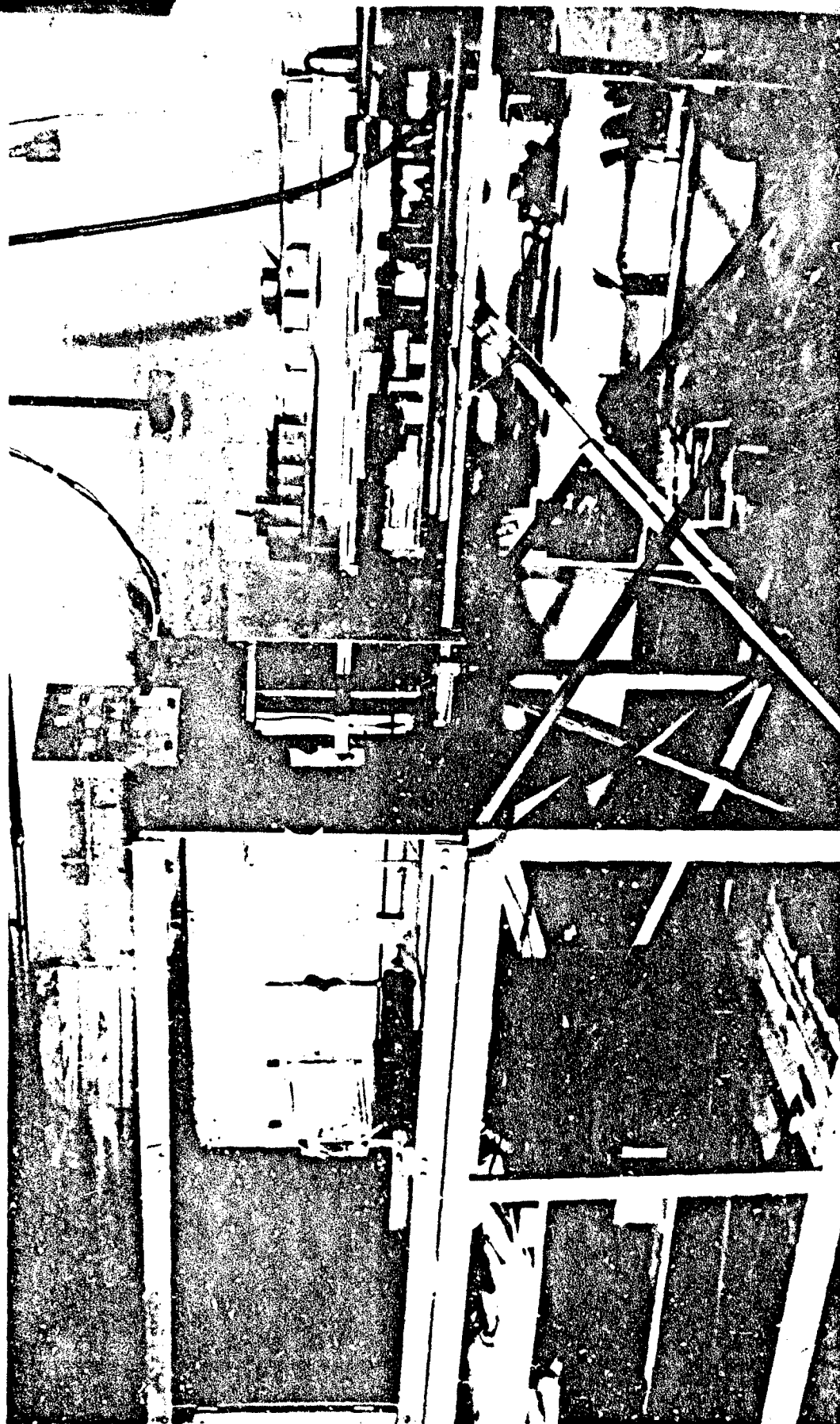


Fig. 91 - Firing Box with Foil Screen in Place

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