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Cutting Experiments with Plastic Edges

Stanley K. Wakamiya

Product Safety Technology Division
Center for Consumer Product Technology

June 1978

Report To:

Consumer Product Safety Commission
5401 Westbard Avenue
Bethesda, Maryland 20016

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U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, *Secretary*
Dr. Sidney Harman, *Under Secretary*
Jordan J. Baruch, *Assistant Secretary for Science and Technology*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

I. INTRODUCTION

In March 1977, NBS initiated a research program to provide technical support to the Consumer Product Safety Commission in developing a procedure to identify potentially hazardous plastic edges on toys and children's articles. A previous NBS program had been concerned with potentially hazardous steel edges.

Most of the effort in this program thus far has been directed towards obtaining quantitative experimental data on which a test procedure and safety criteria could be based. Since any test procedure and safety criteria that may be established for plastic edges should be equitable with those for metal edges, all experiments included tests using reference steel edges* so that the performance of plastic edges could be related to the performance of reference steel edges under the same test conditions. The following specific tasks were accomplished:

1. Characterization of typical plastic edges found on toys according to material, geometry, and hardness.

2. Preliminary cutting experiments on pig skin using replicas of the plastic edges characterized in task 1.

3. Cutting experiments to investigate the effect of velocity on cutting performance of plastic edges.

4. Experiments to assess the cutting ability of various types of plastic edges.

5. Ranking of the plastic edges tested in task 4.

II. CHARACTERIZATION OF PLASTIC EDGES

In order to identify the types of edges which may be hazardous and are likely to appear on toys, NBS assembled a sample of twelve plastic edges from thirty different toys, the edges of which were subjectively judged to be sharp. Two of these edges were taken from toys similar to those which were reported by CPSC to have caused laceration injuries. The remaining ten edges were selected to represent the thirty edges in terms of hardness of the plastic materials and the subjective sharpness of the edges. The edges were then characterized according to edge tip geometry, chemical composition and hardness.

A. Edge Geometry

The geometry of the edge tips were determined from photographs taken through a light sectioning microscope and a conventional optical microscope. Typical photomicrographs of the plastic edge tips are shown in

*The metal reference edges were sheared steel edges, judged "marginally safe" when tested according to the proposed Sharp Edge Test Method for metal and glass published in the Federal Register Vol. 43; No. 58; March 24, 1978.

figure 1. The tip radii of the edges observed through the light-sectioning microscope at 200X magnification ranged from 0.013 mm (0.0005 inch) to 0.102 mm (0.004 inch). The included angles of the edges were observed to range between 0 and 88 degrees. The side profiles of the edges were observed using an interference microscope. Side profiles of nine of the edges were observed to be devoid of any discernible peaks and valleys at 33X and at 78X magnifications. Three edges samples had minute serrations on the order of .02 mm to .09 mm (.001 to .004 in). The geometry of each of the 12 edges is listed in figure 2.

B. Edge Materials

The material composition of the plastic edges were identified through infrared spectroscopy. The twelve edges were found to be four each of styrene-butadiene, polypropylene and polyethylene.

There were two reasons for identifying the materials of the edges. The first reason was to insure that the materials of the edges selected for this investigation be representative of the plastic materials most commonly used in toys. The second reason was that knowledge of the edge materials would enable identification of some of the physical properties of such materials which may be related to the cutting mechanism.

C. Physical Properties

The tensile elastic modulus and hardness are two physical properties of materials which probably affect the cutting performance of edges. Both properties are measures of a material's resistance to deformation. The higher the tensile elastic modulus and hardness, the more resistant a material is to deformation. An edge made of a material which is more resistant to deformation would have less tendency to buckle, or flatten or become less sharp due to deformation when brought into contact with another object. Thus, if two edges have identical edge tip geometries the edge with higher tensile elastic modulus and hardness measurements should be more likely to lacerate skin.

The Shore D hardness measurements*, made according to ASTM D-1484 for some of the edges, are shown in figure 3. The range of tensile elastic moduli, obtained from the Modern Plastics Encyclopedia 1/, for the edge materials are shown in figure 4. These hardness values and tensile elastic moduli indicate that, in general, styrene-butadiene (a high impact polystyrene) is the most resistant to deformation, and polyethylene is the least resistant to deformation.

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*The ASTM test method requires flat test specimens. Some edges were taken from toys with no relatively flat surfaces. In such instances no hardness measures were taken.

III. PRELIMINARY CUTTING EXPERIMENTS

A. Test Edges

The test edges used in these experiments were epoxy replicas of the toy edges described in section II. Plastic edges on toys, being relatively soft and flexible, dull rapidly during cutting tests. Thus, the geometry of the edges can change drastically after only a few attempted cuts. In order to run repeated tests and to obtain consistent results, replicas of the original edges were needed. After investigating several techniques for producing replicas, a casting method, using an RTV mold and an epoxy plastic casting material was found to produce satisfactory results. Figure 5 shows photomicrographs of typical original and replica edges.

B. Skin Specimens

All tests described in this report were conducted using excised, defatted samples of pig skin for determining the skin cutting ability of edges. Pig skin was selected for these tests based on results of earlier experiments performed by Deck 2/ at the University of Virginia. Deck's test results show that excised, defatted pig skin reacts to laceration by edges in a similar way as does excised, defatted human skin: for a particular edge at some given force, similar injuries occur on human skin and pig skin.

The pig skin samples were procured from a local slaughterhouse. All samples were excised from the shoulder areas of freshly killed yearling pigs and were kept moist and refrigerated until shortly before the cutting experiments were conducted. The test specimens were defatted carefully to remove the subdermal fat, leaving the dermal and epidermal layers of the skin. The samples were trimmed into 2.5 cm X 5 cm (1 in X 2 in) test specimens, with an average thickness of approximately 2.5 mm (0.1 inch). The test samples were taken out of refrigeration and allowed to reach room temperature before testing.

C. Experimental Procedure and Apparatus

The set-up used in this cutting experiment is illustrated schematically in figure 6. The skin specimen was mounted on a specimen holder, a hardwood dowel 1.6 cm (5/8 in) in diameter by 3.2 cm (1 1/4 in) long, with the outermost layer of skin (epidermis) facing out. The specimen was held in place by means of steel prongs inserted in the dowel. The test edge was clamped firmly in a small clamp as shown in figure 6. The skin sample, mounted on the specimen holder at one end of a lever arm, was manually translated* along the edge of the test edge at approximately 5 cm/s

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*The translational cutting mode was used to minimize the effects of localized deformation of plastic edges during testing. By translating the skin sample, rather than rotating the sample at the fixed portion of the edge, the skin specimen was continuously brought into contact with undeformed portions of the test edge during a cutting attempt.

(2 in/s). The normal force was applied between the skin sample and the test edge by means of a constant force spring which exerted a moment about the pivot point of the lever arm. The normal force was adjusted by varying the length of the lever arm between the skin sample and the pivot point.

Several precautions were taken to minimize the inertial loading effects and end effects. First, before the start of a test run, the skin was initially brought into contact with the loading surface, rather than the test edge. Then, the skin specimen was translated smoothly along the loading surface and passed over the length of the edge to the unloading surface. Secondly, to minimize end effects, the test edge was critically positioned and clamped so that the ends of the cutting surface of the test edge were flush with the loading and unloading surfaces as shown in figure 6. Thus, initial contact and final separation between the pig skin and the test edge occurred at essentially constant force and velocity.

Skin cutting tests were conducted using the epoxy replicas of the original toy edges mentioned in section II at normal forces of 4.4 N (1 lb) 8.9 N (2 lb) and 13 N (3 lb).* At least three and a maximum of five cutting attempts were made on one skin specimen using one replica edge at 4.4 N (1 lb) normal force. This was repeated with two other replicas of the same edge at 8.9 N (2 lb) and 13 N (3 lb). This procedure was followed for replicas of all twelve edges mentioned in section II. Since skin samples were found to vary in resistance to laceration, each skin specimen was "calibrated" by making a test cut with a reference edge and recording the results. Results of test cuts produced by plastic edges were compared to the test cuts on the same skin specimen made by the reference edge.

D. Results and Discussion

The results of the cutting tests using the replica edges indicated that these edges were significantly less sharp than the reference steel edges. For purposes of this investigation, the depth of cut was assumed to be an adequate measure of the injury sustained by the skin. The reference steel edges caused abrasions of the epidermis (the outermost layer of skin) at 4.4 N (1 lb) force. At 8.9 N (2 lb) the reference edge produced cuts of 20 to 40 percent of the total thickness of the pig skin. The depth of cuts produced at 13 N (3 lb) ranged between 30 and 50 percent. In contrast, none of the replica edges produced even an abrasion of the epidermis at the highest test force, 13 N (3 lb).

If the original toy edges had been used in these tests, similar results would probably have been obtained. As shown in figure 3, the hardest toy edge measured 82 on the Shore D hardness test; most toy edges were considerably softer. The replica edges had an average Shore D

*The upper test force limit was set at 13 N, since this was the force at which the reference steel edge consistently cut pig skin to a depth of 30 to 40% of the skin specimen thickness.

hardness of 80, which is comparable to the reading for the hardest toy edges in the original samples. Comparisons of the photomicrographs of the replicas and the corresponding original edges showed that the edge tip radii were about 20 percent smaller on the replicas. Thus, since the replica edges were at least as hard as the original edges, and since the replicas were slightly sharper than the original, it appears reasonable to deduce that the replicas caused at least the same amount of cutting as the original edges would have caused.

IV. INVESTIGATION OF VELOCITY EFFECTS

The effect of velocity on cutting of human skin was reported to be minimal or non-existent by Sorrells and Berger 3/ for metal edges. However, since the cutting mechanism for plastic edges may differ from that for steel edges, an investigation of velocity effects on cutting of skin by plastic edges was judged necessary.

A. Test Procedure and Apparatus

Using the same experimental procedure and apparatus used in experiments discussed in the preceding section (III.C), tests were conducted on pig skin using plastic edges at edge velocities ranging from 5 cm/s (2 in/s) to 127 cm/s (50 in/s). Although the relative velocity between the edge and the skin sample was manually controlled, a photocell sensor connected to a digital time interval meter was used to measure the elapsed time over a premeasured distance on the edge during each test run. The average velocity of the edge relative to the skin was calculated from the elapsed time and the premeasured distance.

Two types of plastic edges were tested; scribed and broken acrylic edges, and functional serrated plastic knife edges. Several samples of both types of edges were used in the tests to minimize the dulling effects.

B. Measurement of Cut

In order to quantitatively assess the cutting ability of edges at different velocities, it was necessary to use an instrument for measuring the depth of a test cut. The instrument selected is essentially a depth gage with a dial indicator identical to the one used by Sorrells and Berger 3/ to measure the depth of cut in their human skin cutting experiments. As shown in figure 7, the depth gage consists of a special probe tip mechanically linked to a read-out dial. The wedge shaped tip is approximately 1.3 cm (1/2 in) long with an edge tip radius of 0.2 mm (8 mil inch) and an edge tip angle of 15 degrees. A piece of 1.3 cm (1/2 in) aluminum rod provided a reference surface on which to place the skin specimen after a test run to measure the depth of cut as shown in figure 7. The curved reference surface was chosen to facilitate measurement at the deepest part of the cut.

The depth of cut was measured immediately after each test cut. Two measurements were taken for each test cut. The thickness of the skin specimen immediately adjacent to the test cut was measured by placing the skin specimen between the probe tip of the depth gage and the skin specimen. This measurement was recorded as T_S. Then, the probe tip of the depth gage was inserted into the test cut. The position of the specimen was carefully adjusted to obtain the lowest reading on the dial to insure that the measurement was being made at the deepest part of the cut. This reading was recorded as T_F. The percent depth of cut, D, was calculated from these two measurements by:

$$D = \frac{T_S - T_F}{T_S} \times 100$$

C. Results and Discussion

The results of the tests are shown graphically in figures 8 and 9. In both of these graphs the percent depth of cut is plotted as a function of the velocity. Although the data in these figures show a slight trend toward decreased depth of cut at higher velocities, this trend is practically negligible considering the large scatter in the data. Furthermore, note that velocity was varied over a very wide range. For acrylic edges, for example, the average depth of cut decreased from 28% to 16% when the velocity was varied from 5 cm/s (2 in/s) to 127 cm/s (50 in/s). Thus a 25-fold increase in velocity is associated with a decrease in depth of cut by a factor of only 1.8. For the serrated plastic knife edges, the average depth of cut decreased from 36 to 28 percent when the velocity was increased from 25 cm/s* to 127 cm/s. Thus, the average percent depth of cut dropped by a factor of 1.3, when the velocity was increased by a factor of 5.

It is quite possible that the slight trend towards decreasing depth of cut at increasing velocities is due to other factors. For example, it might well stem from the differences in the length of time the edge was in contact with the skin specimen. Since all test edges were of the same length (4 cm), the time of contact between the skin and the edge decreased when the velocity was increased. Conceivable an edge in contact with the skin for a shorter period of time might not cut as deep.

A series of tests were conducted to compare the effect of force on cutting of skin with the velocity effect. As shown in figures 10 and 11, an increase in normal cutting force results in a proportional increase in depth of cut, i.e.; doubling the cutting force also approximately doubles the percent depth of cut.

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*The serrated edges could not be tested at velocities lower than 25 cm/s. The edge snagged the skin at lower velocities and made the data unreliable.

Since no appreciable velocity effect was noted in this investigation, it appears that velocity may be ignored as a significant factor. The normal cutting force has a much greater effect on the cutting performance of plastic edges.

V. CUTTING EXPERIMENTS FOR RANKING PLASTIC EDGES

Skin cutting experiments were conducted to rank various plastic edges from sharp to dull according to cutting performance. As previously described, the depth of cut is assumed to be an adequate measure of the degree of injury sustained by the skin, and hence the measure of the degree of sharpness of that edge.

If a set of edges could be ranked from sharp to dull and could be related in cutting performance to the reference steel edges, then this set of edges could serve as a basis for devising an inspection procedure and safety criteria for plastic edges.

A. Test Procedure and Apparatus

A photograph of the apparatus used in this investigation is shown in figure 12. The basic cutting action was similar to that shown in figure 6 in section III.C. The skin sample was translated along the length of the test edge which was clamped in the edge holder. The same precautions were taken as described in III.C to minimize inertial loading effects and end effects.

As shown in figure 12, the test edge was secured in the edge holder, and clamped in a vise, which was attached rigidly to the stationary frame of a metal turning lathe. The picture also shows the pig skin specimen mounted around the hardwood specimen holder at one end of a pivoted lever arm. The skin was held in place by steel prongs protruding from the specimen holder in a radial direction away from the test edge. A tension spring attached to the other end of the lever arm provided a means for adjusting the normal force. The lever arm and spring assembly was mounted on a plate, which was rigidly attached to the lathe carriage. Using the lead screw mechanism of the lathe, the skin sample was moved along the length of the test edge at a constant speed of 5 cm/s (2 in/s).

B. Test Edges

Twelve different types of edges were used in this investigation. Figure 13 describes the test edges and lists the material, method of fabrication, and hardness for each edge. In general the materials for the edges were selected for their brittleness. Brittle materials break relatively easily when dropped on hard surfaces and tend to form fragments with sharp edges. Thus, toys made of brittle materials may present a safety hazard.

It is recognized that edges, like AS, ASB and PB, made of very brittle plastics, such as general purpose acrylic and certain types of polyester are seldom used in toys. Similarly, plastic edges molded in certain configurations intended for cutting, such as edge B are unlikely to be found on toys. However, these edges were selected to represent worst case conditions: to include some of the sharpest edges which could conceivably occur on manufactured toys or on fragments of broken toys.

General purpose polystyrene was included as an edge material since it is sometimes used in toys. Two toys in a sample of thirty were found to be made of this plastic, although no subjectively sharp edges were found on these toys.

Edge EC was used as a test edge since it resembles many of the actual toy edges in geometry and has hardness approximately equivalent to that of the harder toy edges.

Styrene-butadiene, although relatively ductile, was included as an edge material since it is one of the most widely used plastics for toys today.

The two types of sheared steel edges were included as test edges to allow comparison between unfinished sheared metal edges which might be found on toys, and edges which might occur on plastic materials. Note that edge ER is the reference steel edge.

Most of the edges were fabricated by either shearing the material on a power shear or by scribing and breaking the material. These methods of fabricating edges were used because they produced edges with fairly consistent cutting characteristics. Furthermore, these methods produced edges similar to those found on fragments of broken plastics. Photomicrographs of the test edges are contained in the Appendix.

C. Measurement of Cut

The depth of cut was measured using the procedure described in IV.B. When testing the duller edges, it was found that the skin sample was sometimes crushed, forming a groove, rather than a cut. In such cases the depth of the groove was measured, but it was noted that no penetration of the epidermis occurred.

D. Results and Discussion

This investigation was carried out in two phases. In Phase I a series of cutting tests were conducted at a particular force to compare the cutting ability of edges at that force. In Phase II each type of edge was tested at various forces to investigate the effect of changes in normal force on the cutting performance of edges. Since no appreciable velocity effect on cutting of skin had been observed earlier, as described in section IV.D, all tests were conducted at 5 cm/s (2 in/s).

Several precautions were taken to minimize the variability in the data and to minimize bias of the results due to differences in cutting characteristics of the pig skin specimens. First, the skin specimens used in tests at one particular force level were prepared from a pig skin sample measuring 10 cm (4 in) by 20 cm (8 in) taken from the shoulder area of one pig. Secondly, all test cuts were made on the skin in the same direction, perpendicular to the backbone of the pig.

The results of the Phase I experiments are shown in figures 14 and 15. The percent depth of cut is plotted as a function of the edge type at 13 N and 22 N in these figures. In these figures the test edges are arranged in order of decreasing average percent depth of cut from left to right. Each data point represents a test cut produced by one test edge on a skin specimen. Filled in circles represent cases where cutting attempts produced grooves in the skin, but not true cuts.

As shown in figures 14 and 15, edge DS (the steel edge sheared on a dull shear) produced much deeper cuts than any other edge at both 13 N and 22N normal force. Five plastic edges, B, AS, PS, ASB and SS produced results similar to the reference steel edge, ER. All of these edges always penetrated the epidermis and cut partially into the dermal layer of the skin. Two of the plastic edges, SSB and EB, sometimes penetrated the epidermis; on other occasions, these edges left only a groove on the skin without cutting. Three plastic edges, EC, HSB and HSS never penetrated the epidermal layer of skin.

Thus, the results of the Phase I test suggest that the plastic edges tested can be grouped into three categories. Group I consists of edges ASB, B, AS, SS and PS which always produced cuts of approximately the same percentage depth of cut as the reference steel edge. These edges were considered about equal in cutting performance with the reference steel edges. Group II includes edges EB and SSB which sometimes cut skin. These edges were considered slightly less sharp than the reference steel edges. Group III consists of edges HSB, EC and HSS, which never produced cuts and, therefore, were judged much less sharp than the reference steel edges. The percent depths of cuts for the various edges at 13 N cannot be directly compared to the results at 22 N since different pig skin samples were used for these two tests. However, the relative ranking of the edges can be compared.

The Phase II tests were conducted to study the effect that changes in normal force has on the cutting of skin by plastic edges. Figures 16 and 17 summarize the results of these tests. One sample of each type of the twelve types of edges were tested at normal forces of 6.7 N (1.5 lb), 13 N (3 lb), 22 N (5 lb) and 31 N (7 lb). All of these tests were conducted on skin specimens prepared from the shoulder area of one pig. To insure that all the skin specimens for the test had similar cutting characteristics, each skin specimen was cut at 13 N force using the reference steel edge, ER. Only those specimens on which the depth of cut deviated no more than 5 percentage points from the mean percent depth of cut were selected as test specimens.

4. Ten plastic edges, most of which are harder than those normally found on plastic toys, were grouped into three categories according to their cutting ability relative to the reference steel edges. The three categories are: Group I, consisting of edges which are very similar in cutting ability to the reference steel edges; Group II, containing edges which appear to be slightly less sharp than the reference edges; and Group III, consisting of those which are significantly less sharp than the reference edges. No plastic edge was found to be appreciably sharper than the reference steel edges. (See section V.E.)

5. Although it would be extremely difficult to develop a test method which would distinguish among edges within any one of the Groups defined in item 4, it appears possible to develop a procedure and a test device which would discriminate among the three groups of edges.

Section View of
Edge 2-2, 200X

Profile of Edge 2-2
33X Magnification

Section View of
Edge 7-1, 100X

Profile of Edge 7-1
33X

Figure 1. Typical Plastic Edge Tips
Taken From Actual Toys

Figure 2. Geometry and Material of Plastic Toy Edges

Edge No.	Material	Section Profile		Side Profile
		Radius, mm (in)	Angle deg.	Avg. Roughness Height, mm(in)
EI-1	Styrene-Butadiene	.025 - .050) (.001 - .002)	27	.02 (.001)
EIV-1	Styrene-Butadiene	.050 (.002)	0	Smooth
E2-1	Polypropylene	.025 - .050 (.001 - .002)	0	Smooth
E2-2	Polypropylene	.050 - .100 (.002 - .004)	26	Smooth
NBS2-1	Polypropylene	.015 - .045 (.0005 - .002)	56	Smooth
NBS3-1	Polyethylene	*	60	.09 (.004)
NBS4-1	Polyethylene	.050 (.002)	67	Smooth
NBS5-1	Styrene-Butadiene	.025 - .050 (.001 - .002)	59	Smooth
NBS7-1	Polyethylene	.025 (.001)	74	.05 (.002)
NBS9-1	Polypropylene	.075 (.003)	62	Smooth
NBS10-1	Polyethylene	.030 - .070 (.001 - .003)	27	Smooth
NBS12-1	Styrene-Butadiene	.025 (.001)	88	Smooth

*Not observable due to irregular shape of the edge tip.

Figure 3. Hardness Measurements of Some Plastic Toy Edges

Edge	Material	Hardness, Shore D*
NBS-12	Styrene-Butadiene	79
NBS-5	Styrene-Butadiene	81
NBS-III	Styrene-Butadiene	62
E-2-1	Polypropylene	65
NBS-3	Polyethylene	46
NBS-7	Polyethylene	61
NBS-4	Polyethylene	62

*Hardness measurements were taken according to ASTM D1484 on 1" X 2" X 1/16" specimens. The results are averages of five readings for each edge. The standard deviations ranged from 0.5 to 2.1.

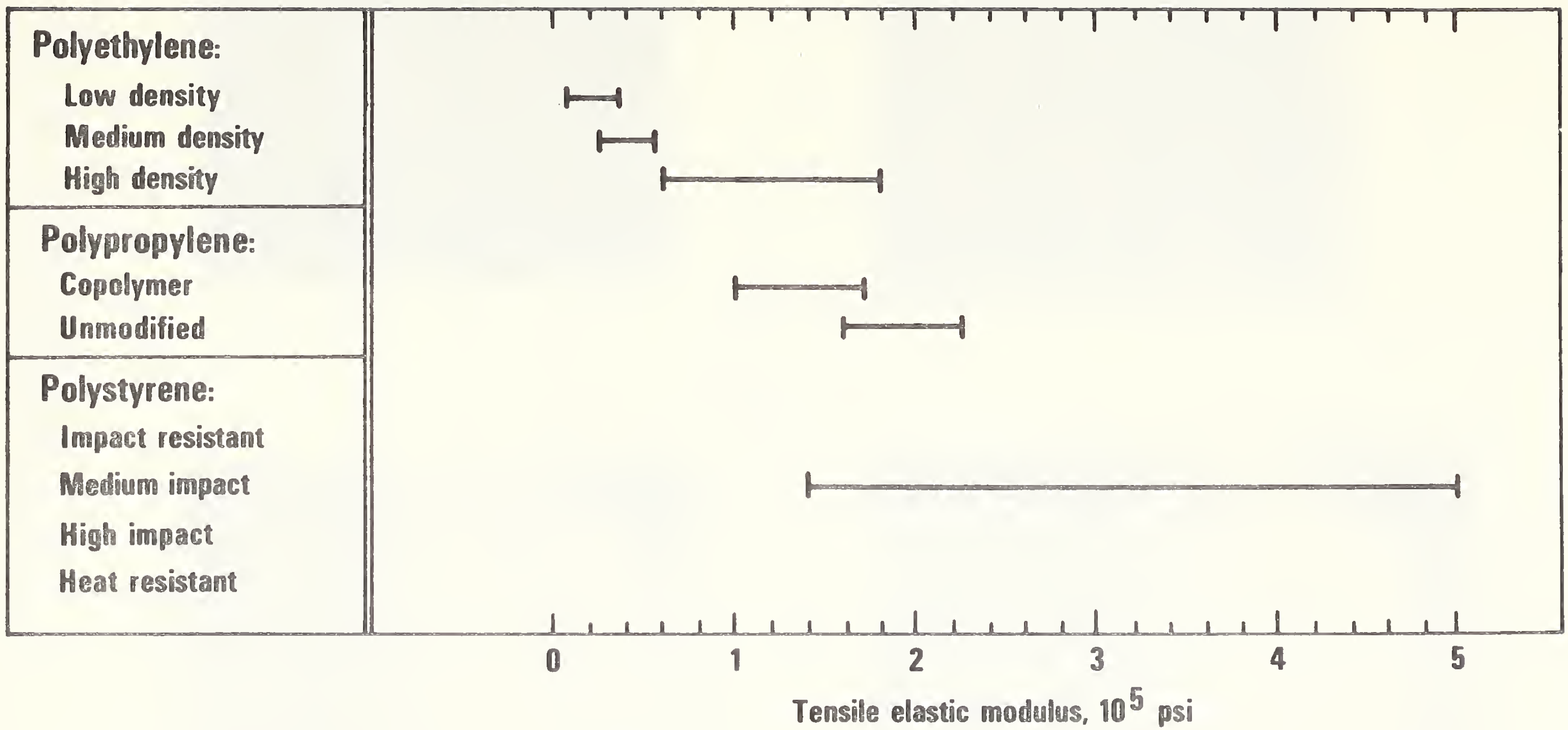

Figure 4. Range of Tensile Elastic Moduli for Plastics Commonly Used in Toys.

Section View, 100X

Profile of Edge, 33X

Actual Toy Edge

Section View, 100X

Profile of Edge 33X

Replica of the Actual Toy Edge

Figure 5. Photomicrographs of Actual and Replica Toy Edges

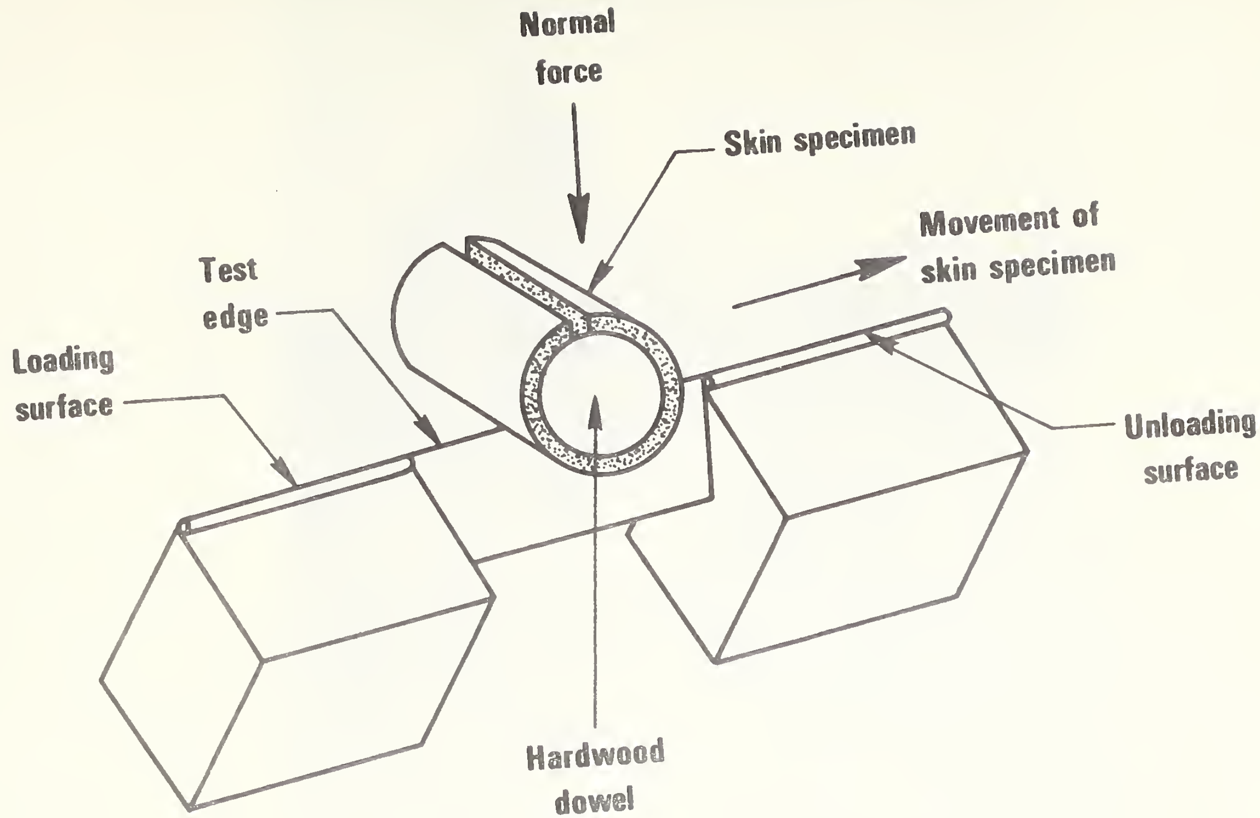

Figure 6. Schematic of Skin Cutting Experiment

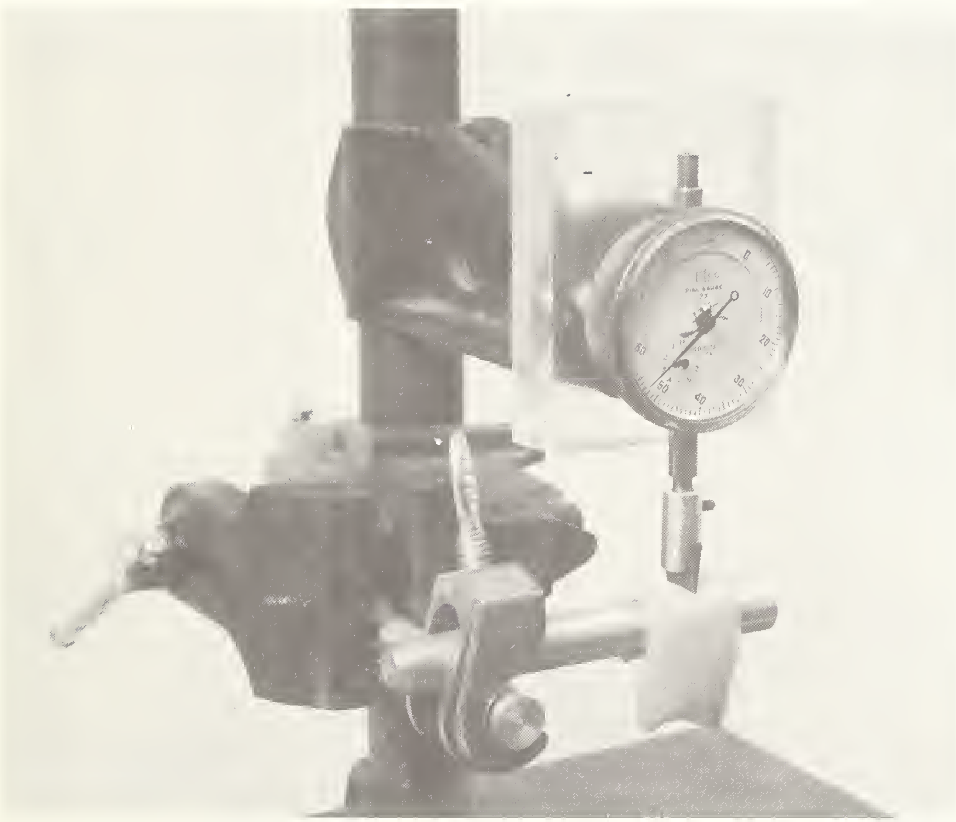

Figure 7. Cut Measurement Method

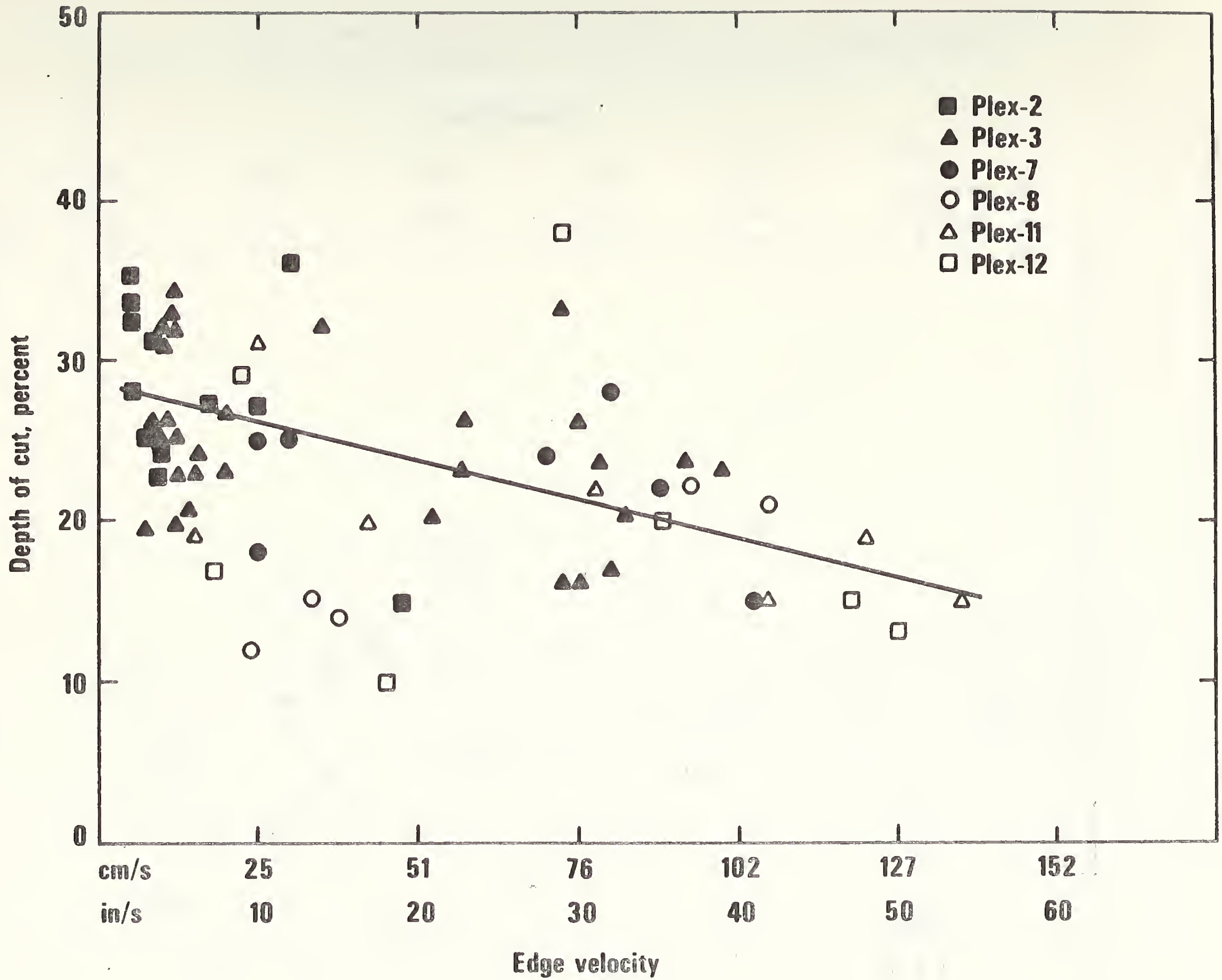

Figure 8. Plot of Edge Velocity vs. Depth of Cut for Acrylic Edges at 8.9 N (2 lb) Force

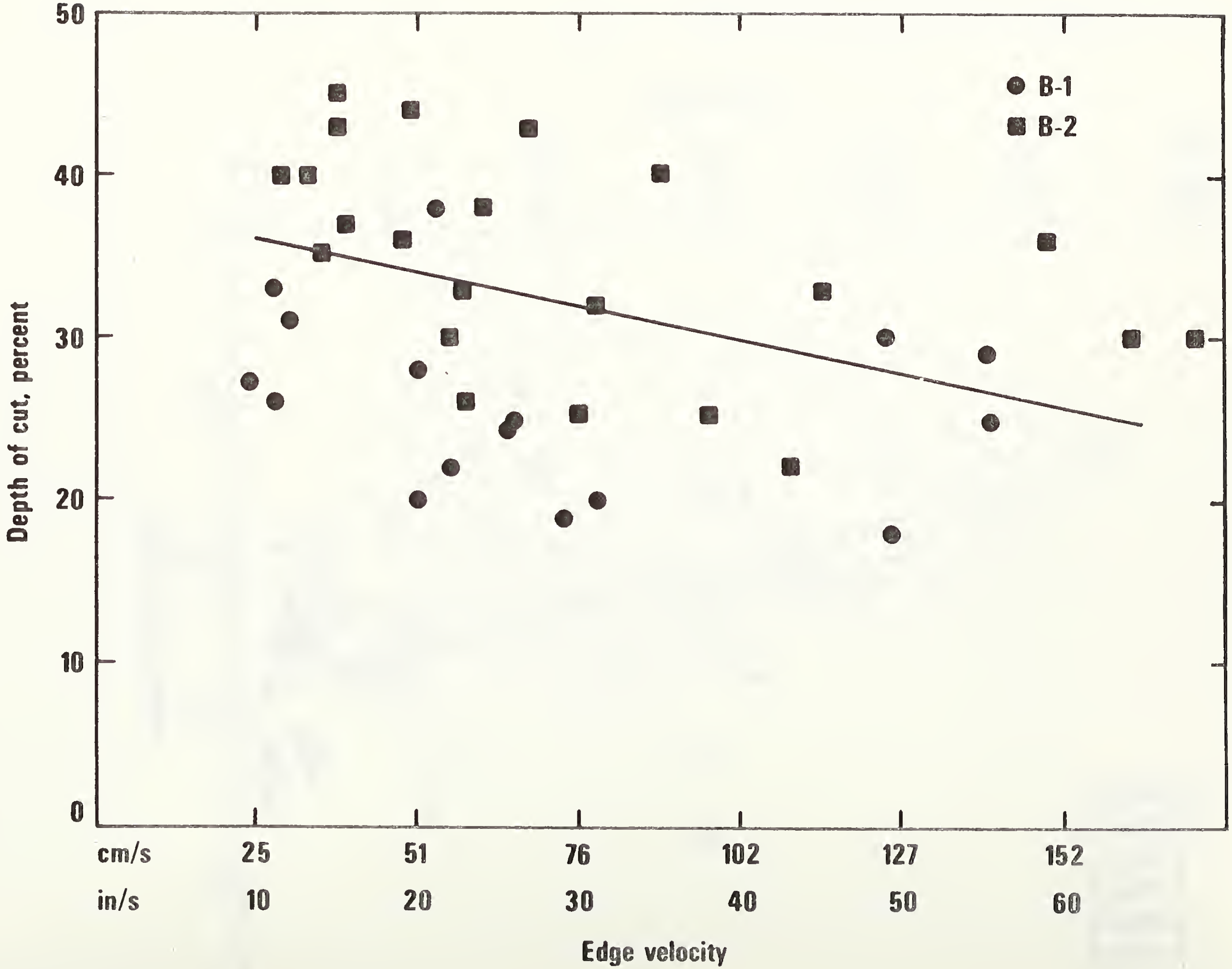

Figure 9. Plot of Edge Velocity vs. Depth of Cut for Serrated Plastic Knife Edges at 8.9 N (2 lb) Force.

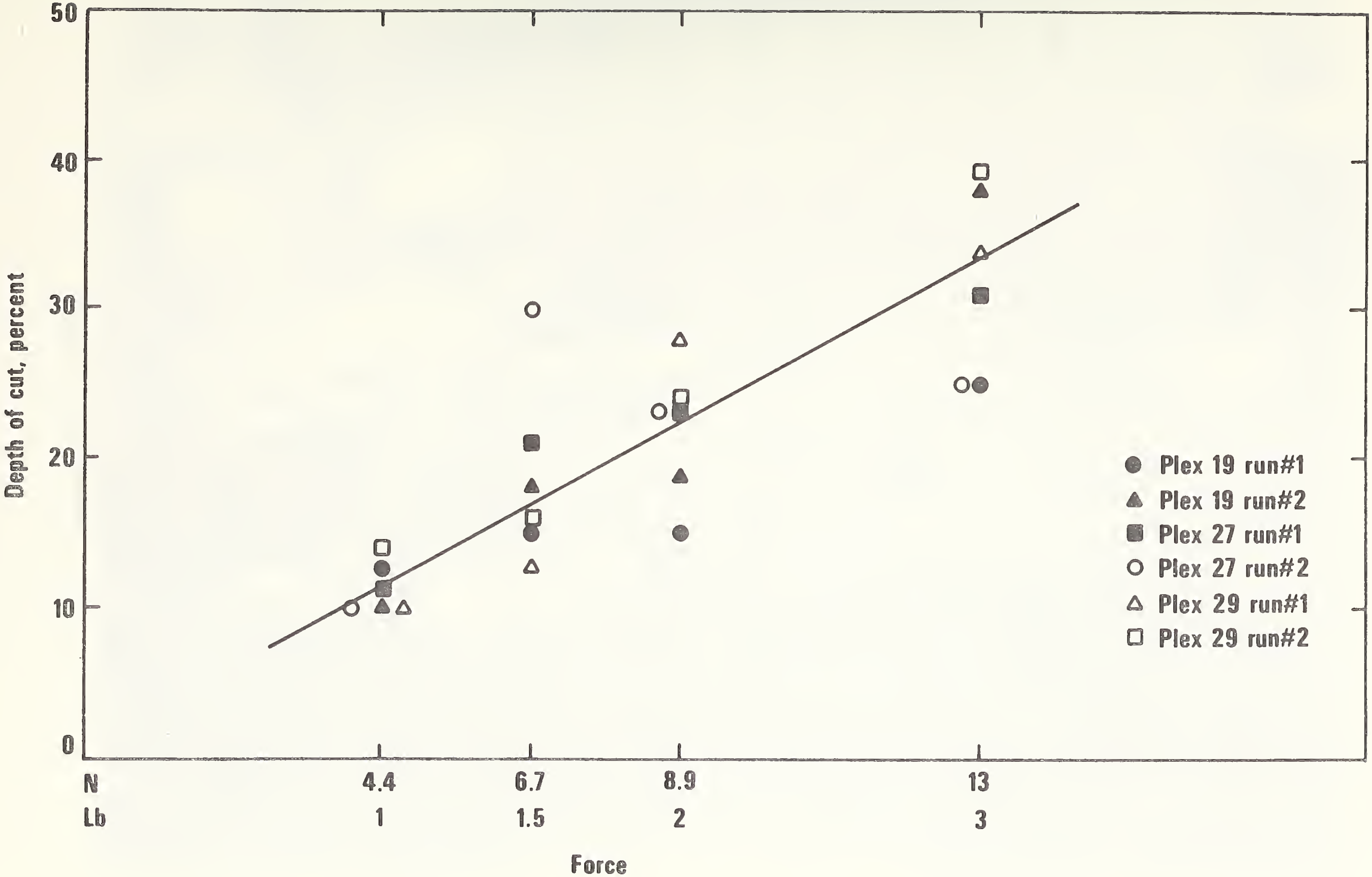

Figure 10. Plot of Depth of Cut vs. Cutting Force for Acrylic Edges.

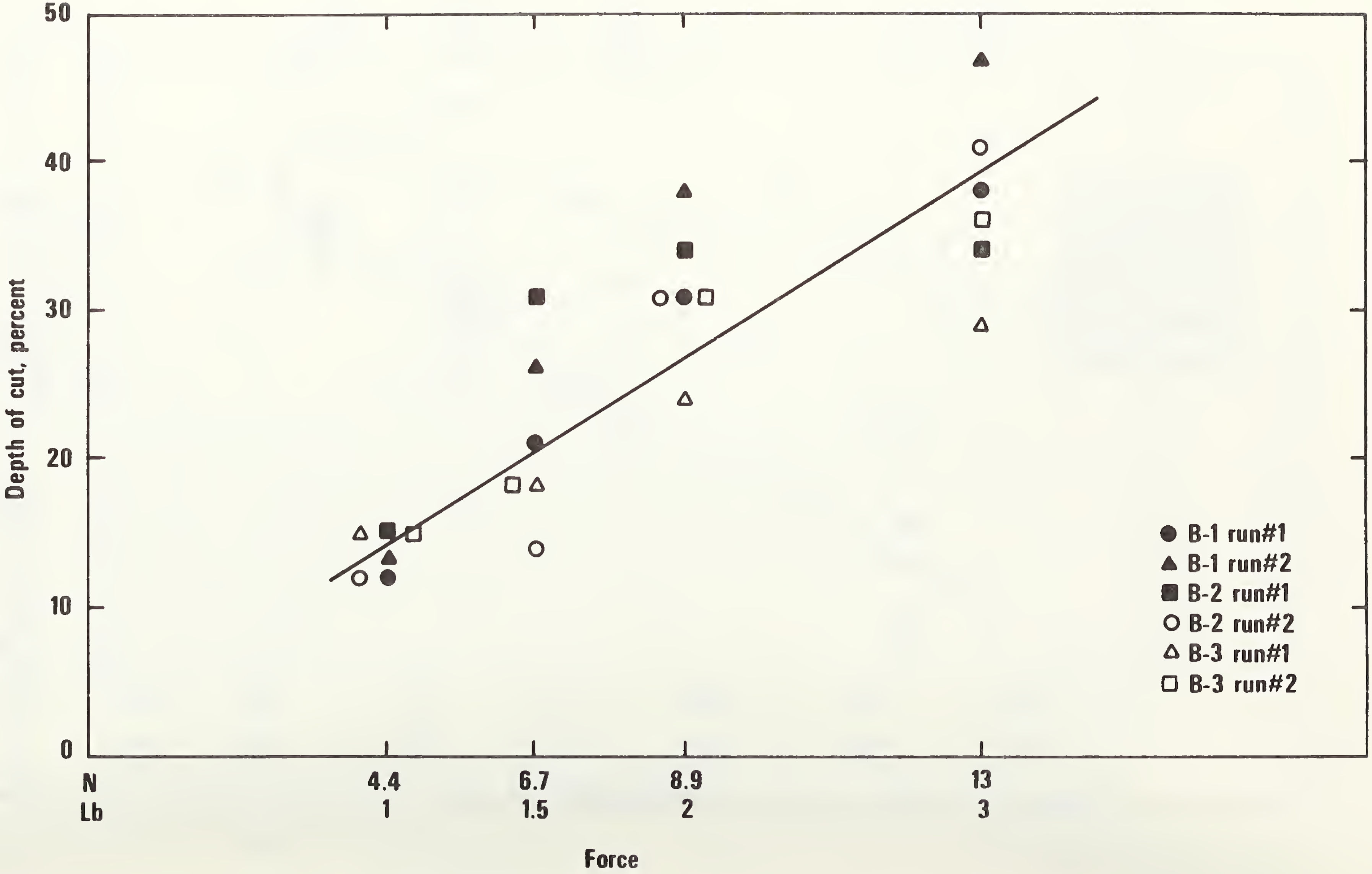

Figure 11. Plot of Depth of Cut vs. Cutting Force for Serrated Plastic Knife Edges

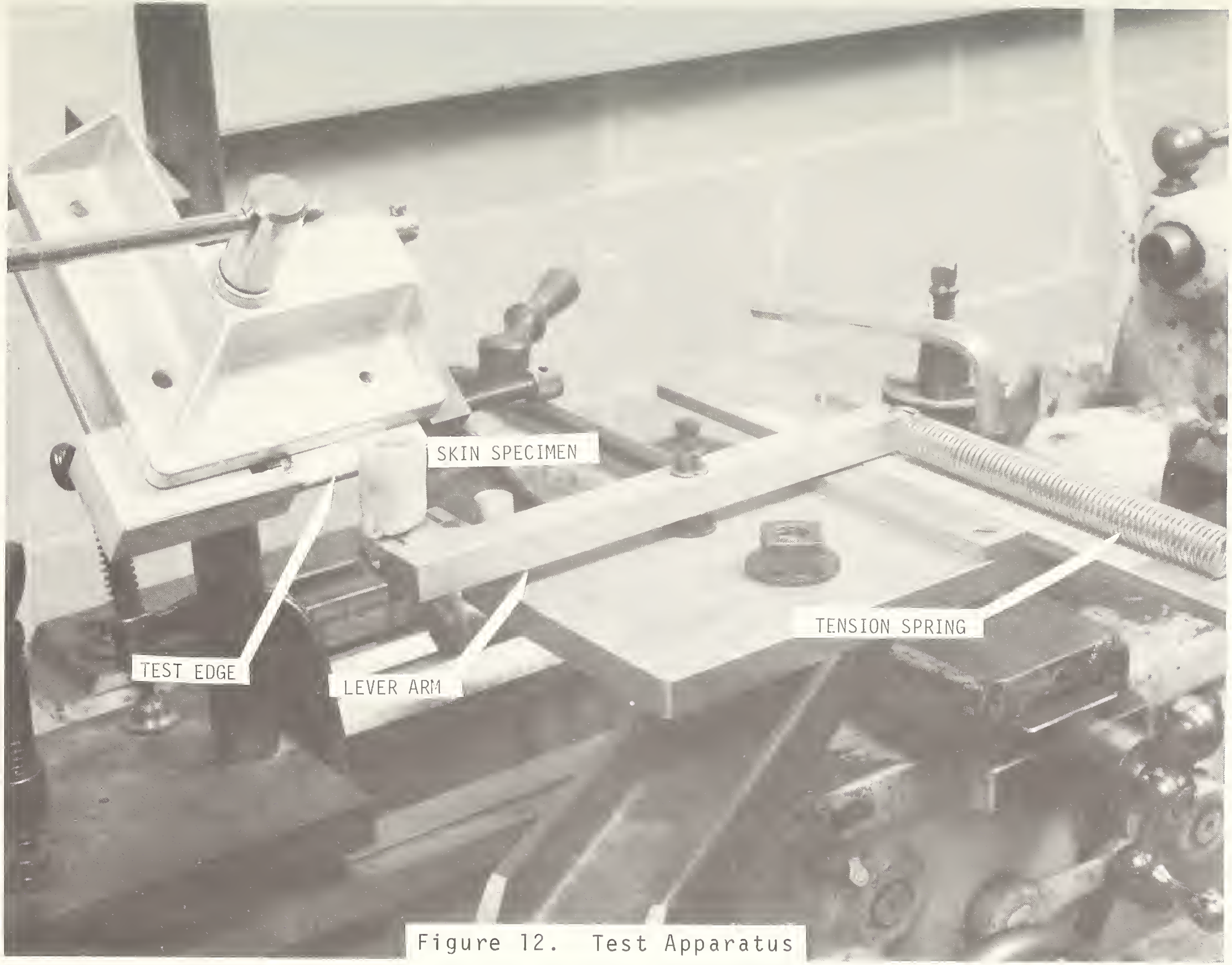

Figure 12. Test Apparatus

Figure 13. Description of the Test Edges

Edge	Material	Method of Fabrication
ER	0.5 mm thick galvanized steel	Sheared on a power shear with a sharp cutting edge.
DS	0.5 mm thick galvanized steel	Sheared on a power shear with dull cutting edges.
PS	3 mm thick sheet cast polyester	Sheared on a power shear with dull cutting edges.
AS	3 mm thick general purpose acrylic sheet	Sheared on a power shear with dull cutting edges.
SS	3 mm thick general purpose styrene sheet	Sheared on a power shear with dull cutting edges.
HSS	3 mm thick styrene-butadiene sheet	Sheared on a power shear with dull cutting edges.
ASB	3 mm thick general purpose acrylic sheet	Scribed and broken in a sheet metal bender.
SSB	3 mm thick general purpose styrene sheet	Scribed and broken in a sheet metal bender.
HSB	3 mm thick styrene-butadiene sheet	Scribed and broken in a sheet metal bender.
EB	3 mm thick cast epoxy resin sheet	Scribed and broken in a sheet metal bender.
EC	Epoxy resin	*
B	2 mm thick molded polystyrene	Injection molded. (A purchased serrated functional edge)

*Uncured epoxy resin was poured into a rectangular container. After the epoxy hardened, meniscus formed by the resin at the sides of the container was used as the test edge.

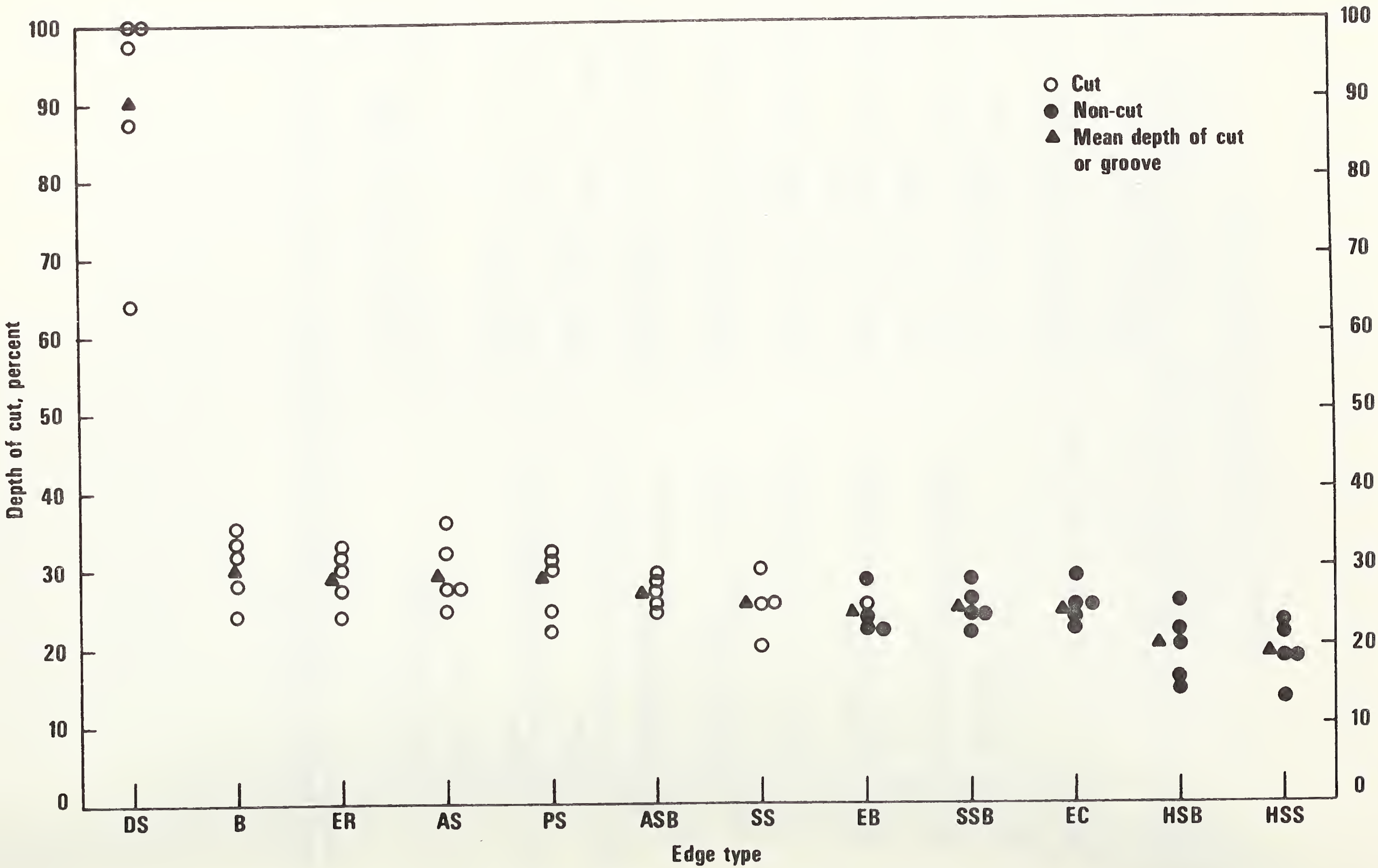

Figure 14. Graph of Depth of Cut vs. Edge Type
13N (3 lb) Force

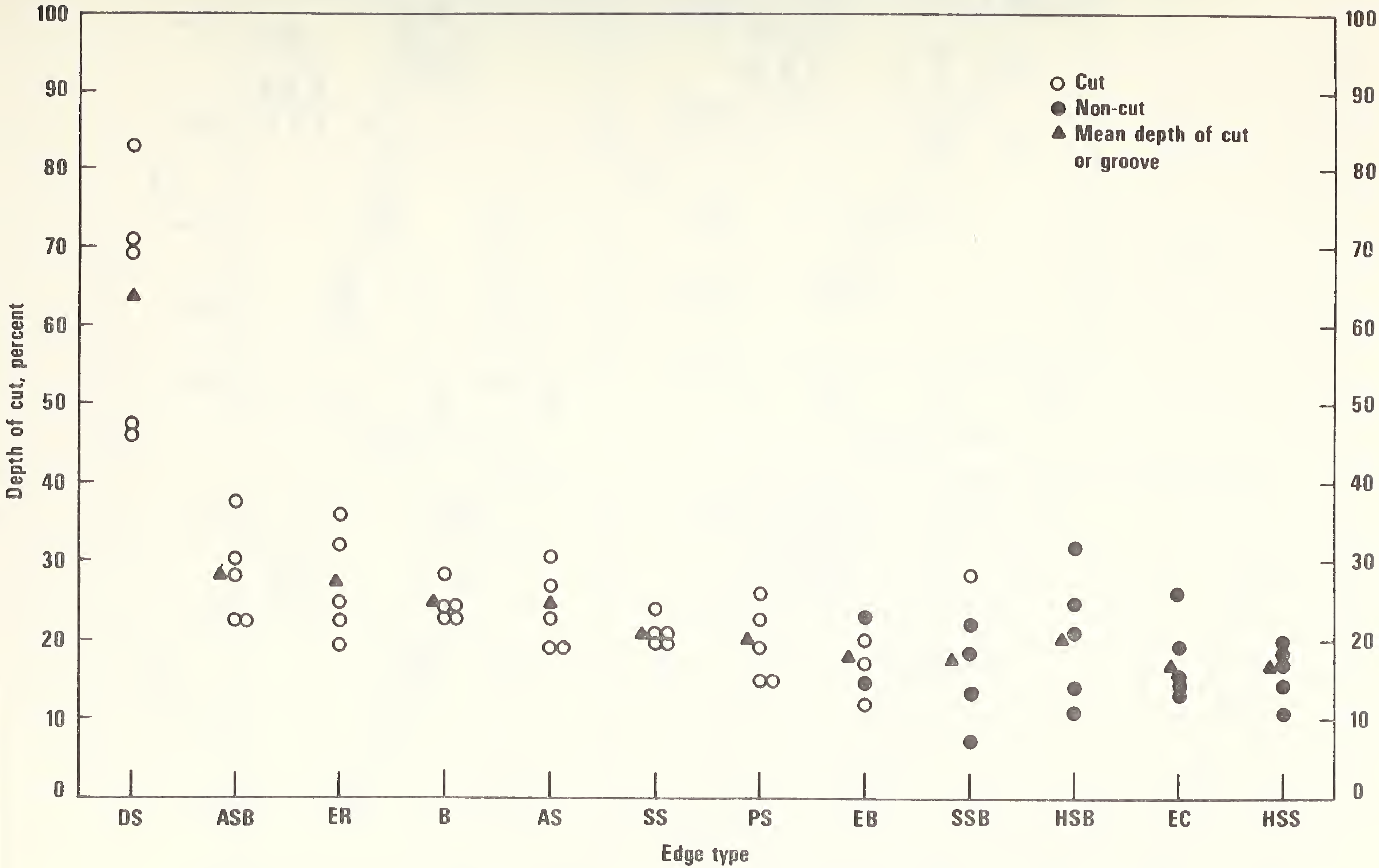

Figure 15. Graph of Depth of Cut vs. Edge Type
22N (5 lb) Force

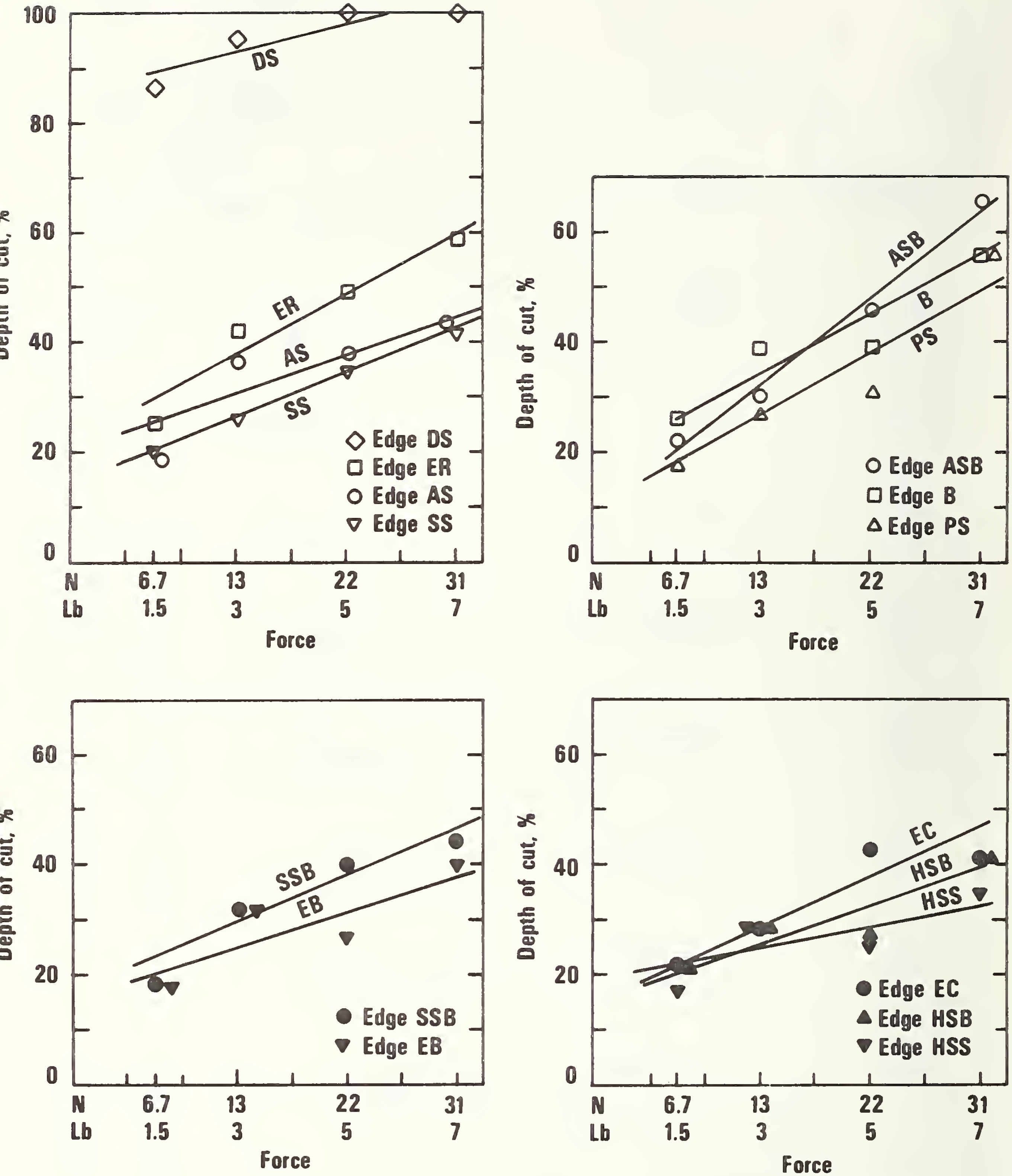

Figure 16. Graphs of Depth of Cut vs. Force

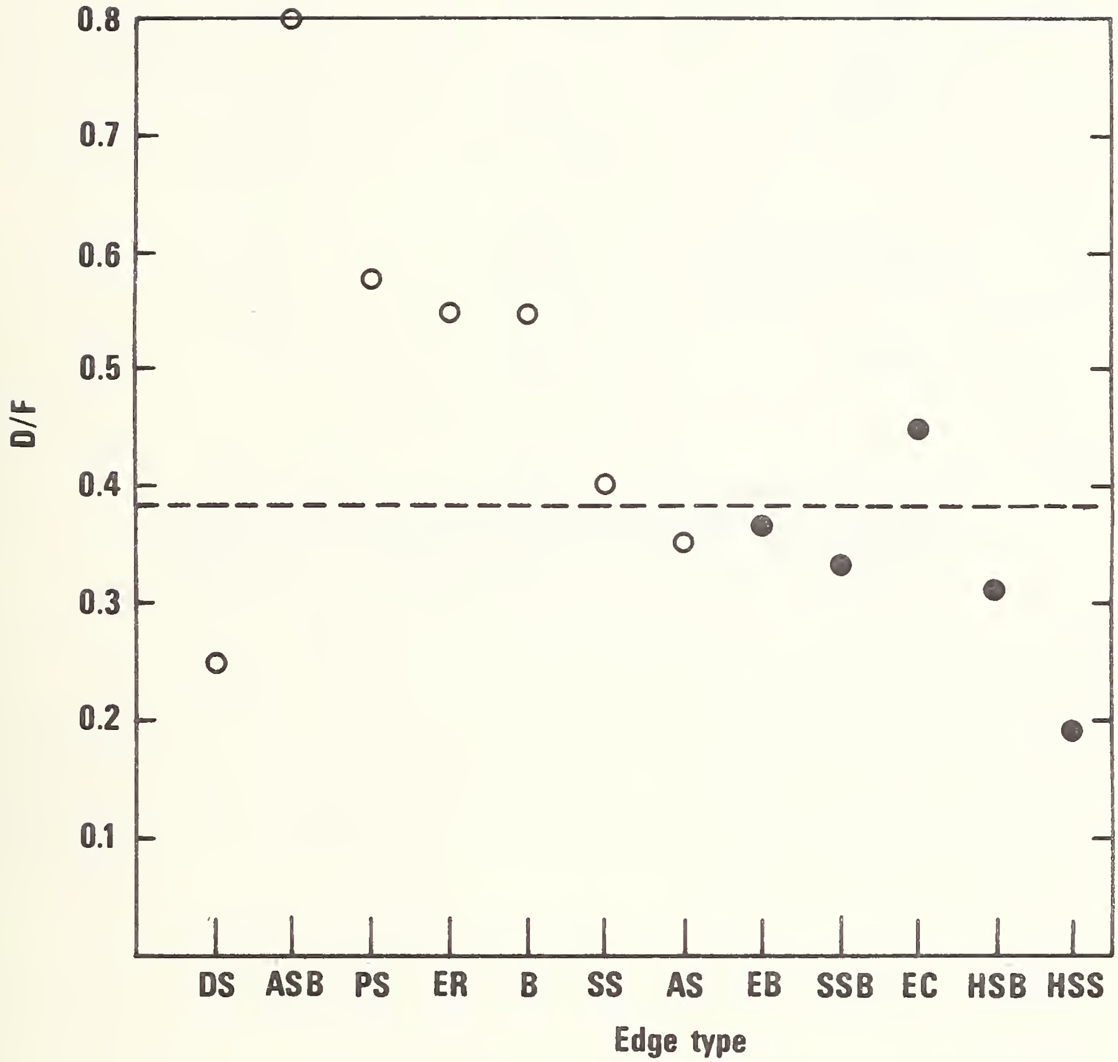

Figure 17. Graph of D/F vs. Edge Type

Figure 18. Hardness Measurements of Plastic Test Edges

Material	Edge Type	Hardness, Shore D*
Epoxy resin	EB EC	80
Styrene-butadiene	HSS HSB	80
Polyester Resin	PS	84
General Purpose Polystyrene	SSB SS, B	85
General Purpose Acrylic	AS ASB	90

*Hardness measurements were made per ASTM D1484. Results are shown as the average of five measurements made on 1" X 2" X 1/8" specimens. Standard deviations ranged from 0.5 to 1.7.

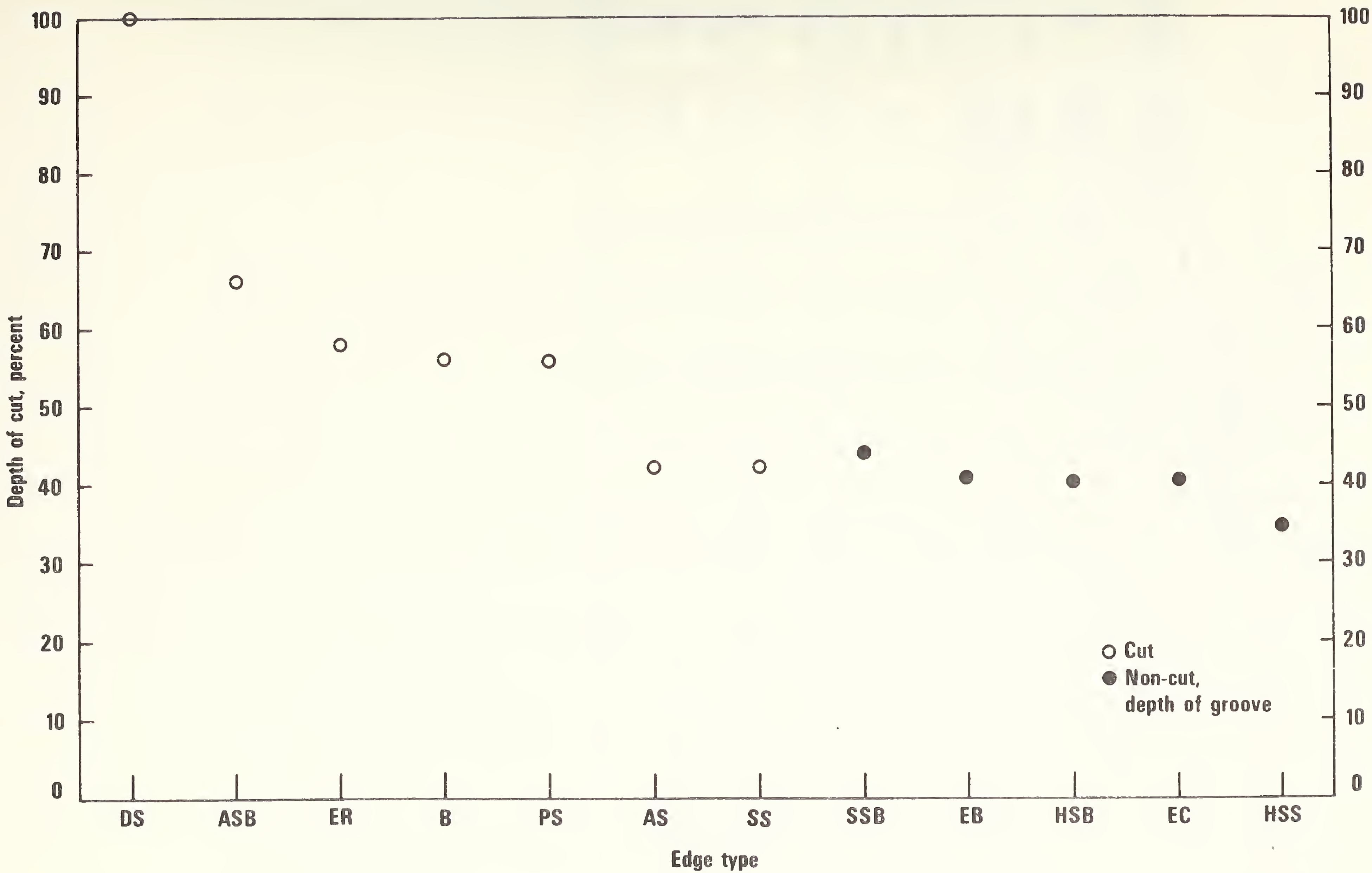

Figure 19. - Graph of Depth of Cut vs. Edge Type
31N (7 lb) Force

Figure 20. Ranking of Edges

Ranking of Edges in Order of Decreasing Sharpness						
	Rank #	At 13N (3 lb)	22N (5 lb)	31 N (7 lb)	D/F	Overall Ranking
Group I	1	B	ASB	ASB	ASB	ASB
	2	ER	ER	ER	PS	ER
	3	AS	B	B	ER	B
	4	PS	AS	PS	B	PS
	5	ASB	SS	AS	SS	AS
	6	SS	PS	SS	AS	SS
Group II	7	EB	EB	SSB	EB	EB
	8	SSB	SSB	EB	SSB	SSB
Group III	9	EC	HSB	HSB	EC	EC
	10	HSB	EC	EC	HSB	HSB
	11	HSS	HSS	HSS	HSS	HSS

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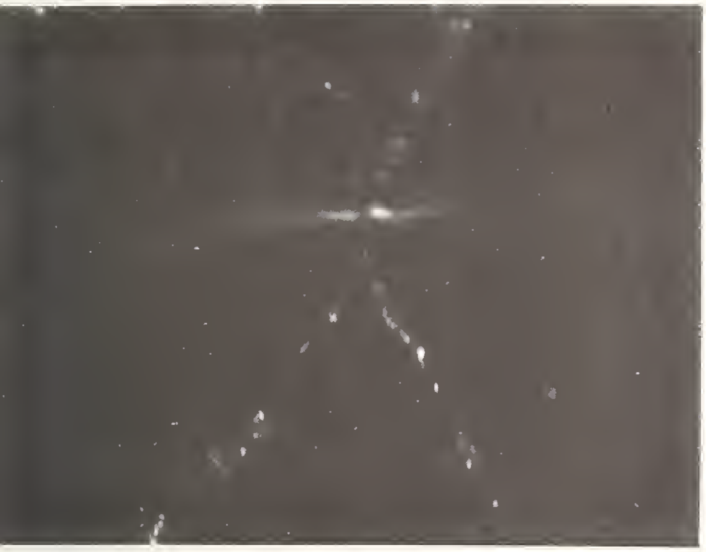
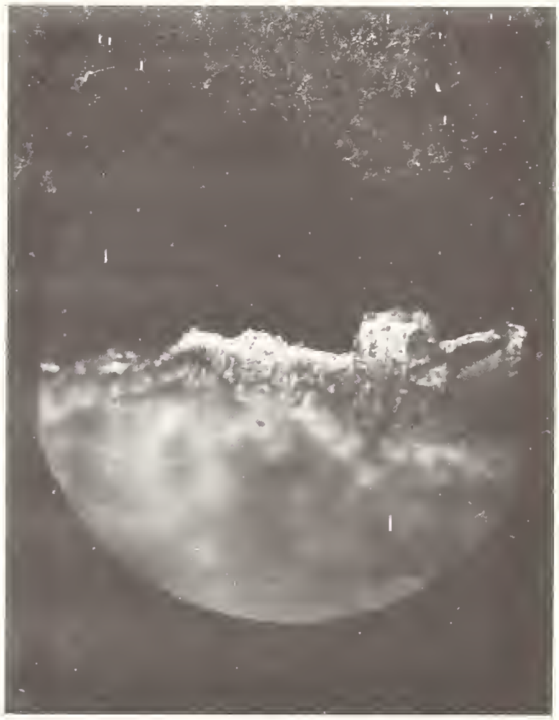
APPENDIX



Edge DS Section View
200X



Edge DS Profile, 78X

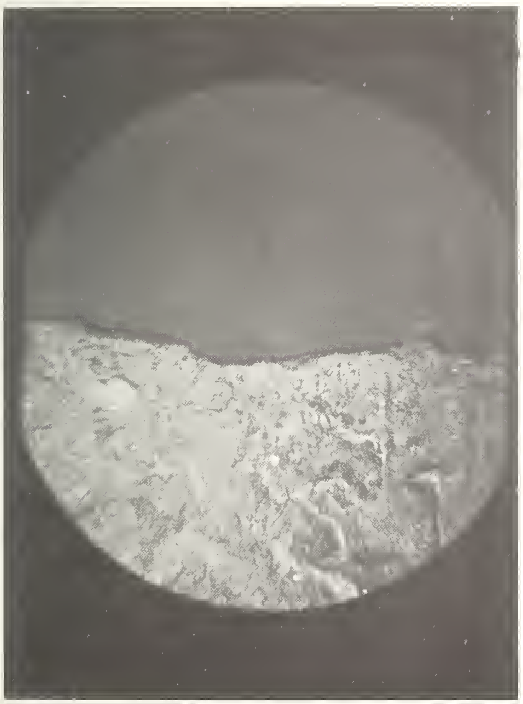
Edge ER (Reference Steel
Edge) Section View, 200X

Edge ER Profile, 78X

Photomicrographs of Steel Test Edges

Edge ASB Profile, 78X

Edge B Profile, 13X



Edge PS Profile, 78X

Edge AS Profile, 78X

Photomicrographs of Plastic Test Edges

Edge SS Profile, 78X

Edge EB Profile, 78X

Edge SSB Profile, 78X

Edge EC Profile, 78X

Photomicrographs of Plastic Test Edges

Edge HSB Profile, 78X

Edge HSS Profile, 78X

Photomicrographs of Plastic Test Edges

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15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

An investigation was conducted to determine the skin lacerating ability of plastic edges. The purpose of this study was to obtain quantitative experimental data on which to base a test procedure and a safety criteria for identifying potentially hazardous plastic edges found on toys and children's articles.

A variety of plastic edges including plastic replicas of edges taken from toys were used to cut excised, defatted pig skin. Cutting experiments were performed at various forces and velocities and the depth of the resulting cuts were measured.

Test results indicate that over the range 5 cm/s to 127 cm/s the relative velocity between the test edge and the skin sample apparently does not significantly affect the cutting of skin whereas the normal force exerted by the edge on the skin has a definite effect on the cutting performance of plastic edges.

The experimental data obtained in this study shows that there are some types of plastic materials, which when broken, form edges with lacerating abilities similar to that of the reference sheared steel edges, which were judged "marginally safe" when tested with the Consumer Product Safety Commission (CPSC) Metal Sharp Edge Test. However, the results of this study indicate that most plastic edges found on toys are less likely to cause laceration injuries than these reference steel edges.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Cut; edge; force; injury; pig skin; plastic; velocity

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