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Recommendations for a Safety Standard for Home Playground Equipment - Swing Sets

Bal M. Mahajan

Consumer Product Systems Section
Measurement Engineering Division

Interim Report

12/73 to 6/74

Prepared for
Consumer Product Safety Commission
5401 Westbard Avenue
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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

Recommendations for a
Safety Standard For Home Playground Equipment -- Swing Sets

Introduction

Injury data gathered by the National Electronic Injury Surveillance System (NEISS) indicate that more than 800,000 injuries occur each year that involve playground equipment and require emergency-room treatment. Approximately 57% of these injuries involve home playground equipment [1] and [3]. These statistics strongly suggest the need for safety standards for home equipment.

The objective of this study was to develop quality criteria and test methods useful in formulating safety standards for home equipment. The data in Tables 1 and 2 indicate that the highest incident of mishaps (at least 64%) involved swing sets, and the second highest incidence (approximately 16%) of mishaps involved slides. Swing sets were therefore given priority attention over other items, and this report deals mainly with them.

The study program was divided into the following five parts: (1) Hazard identification. Probable hazards associated with swing sets were identified, and categorized where feasible. (2) Loading conditions representing child-hazard interactions. These conditions were estimated. (3) Data acquisition. Available anthropometric and injury threshold data were obtained from the literature. Tests were conducted to determine relative degree of hazard of certain functionally similar components having different constructions, and the magnitudes of loads applied to certain components of swing sets were calculated. (4) Quality criteria and test methods. Insofar as the data gathered in parts 1 and 2 permit, criteria and test methods for establishing safety standards for swing sets are suggested. (5) Additional studies. Studies are suggested to provide the basis for establishing more effective safety standards.

Hazard Identification

For the purpose of this study a hazard is defined as any component or characteristic of a product which directly or indirectly presents a risk of injury during normal use or reasonably foreseeable abuse or misuse of the product. For example, an exposed sharp point presents a direct risk of injury, because a person coming in contact with a sharp point during normal use of the product may receive a skin injury; the accessibility of high frame members, such as the cross bar of an A-frame or top bar of a swing set, presents an indirect risk of injury because a child playing on the cross bar or top bar may fall and be injured.

The hazards associated with swing sets may be placed in three categories: Category A, the hazards which can be directly attributed to any design and construction defects; Category B, the hazards which may result from improper installation and maintenance; and Category C, the hazards which are associated with functional components; the mishaps involving these components are thought to result from human error rather than a product defect.

In order to identify the hazards specifically, the summaries of swing-set-related accident investigations reported in references [2] and [3] were carefully studied. In addition, proposed standards for children's home playground equipment [4] and safety standards for children's toys [5] and [6] were also reviewed.

Swing-set related mishaps, from reference [2], are presented in Table 3 by specific hazard, along with the hazard category. The brief description of swing-set related accidents obtained from reference [3] are given in Table 4 along with the responsible hazard and hazard category.

The data presented in Tables 3 and 4 represent too small a sample to draw any statistically meaningful conclusions. These data do indicate, however, that nearly half of the investigated cases of mishaps involved Category A hazards, the other half resulting from Category B and C hazards.

Description and categorization of some of the identifiable hazards are given below.

Pinch Points are defined as any intersection of two components moving relative to one another and having such clearance as to permit pinching or entrapping children's fingers or toes. For example, these would include chain links, a vertical tube or bar holder and the hinged tube or bar of a glider or lawn swing (Figures 1 and 2), and the juncture where the horizontal and vertical tubes of glider swings are hinged together (Figure 1). Pinch points are placed in hazard Category A.

Holes and Slots present in any component of the swing set with such dimensions as to permit entrapment of children's fingers or toes would be considered hazardous (Figure 3). Holes and slots are Category A hazards.

Protrusions are defined as: (1) any component protruding from the main structure that presents a direct risk of injury when contacted by someone. These include exposed bolts, nuts, pipes, edges, points, open s-hooks, wire ends of chain links, and sharp corners; (2) any component protruding from the main structure which may not present a direct risk of injury when contacted, but presents an indirect risk of injury by catching some part of a child's clothing or shoes, for example, capped protruding bolts (Figure 4). Protrusions are placed in hazard Category A.

Swing Seats. Glider and single-occupancy swing seats, due to their design and the material used in their construction, present risk of injury when impacting a child. Impacts between moving swings and children in the swing's path cannot be prevented. However, the trauma resulting from these impacts can be mitigated by changing the construction of the swing seats. Poorly designed rigid seats are Category A hazards.

The swing seat presents a risk of fall; the individual falling from the seat may be injured by striking the ground below the swing set or by being hit by the moving swing. However, with the exception of a baby falling from a baby swing without proper restraints, falls may be attributed primarily to human error. Falls from seats are assigned to hazard Category C.

Inadequate Spacing. (1) Horizontal. Swings situated too close to each other or to the frame of the swing set present a risk of collision between the hard metal frame and swing occupant or between the occupants of the two adjacent swings. The problem is worsened by the multi-direction mobility of the swings. Inadequate horizontal spacing is placed in hazard Category A.

(2) Vertical. A swing seat that is too low presents the risk of a child's feet or legs being caught between the swing seat and the ground. A swing seat that is too high presents the risk of falls, especially for a smaller child, when the child attempts to mount or dismount the swing. The wide variations in ages and sizes of children using swings makes it difficult to standardize the vertical clearance. The lack of standard installation procedures adds to the difficulty. Inadequate clearance is a Category B hazard.

Poor Strength. Poor strength of load-carrying components of the swing set presents the risk of traumatic mishap, because the component with inadequate strength will fail when the applied load exceeds the component's capacity. Some load carrying components of the swing sets are bolts, nuts, chains, hinges, seats, frame, top bar, and various connecting tubes. Deterioration of components that originally may have had adequate strength when put in service often leaves them with inadequate strength. In all accidents involving failure of some load-carrying component the equipment was old and had deteriorated. New equipment having poor strength presents a Category A hazard; strength inadequacy resulting from improper maintenance of the equipment is a Category B hazard.

Instability presents a risk of the swing set tipping over and injuring children playing on it or near it. Instability often results from inadequate anchoring. Proper anchoring is left entirely to the consumer because, in most cases, anchoring devices are sold as accessories and are not included with the equipment. Therefore, instability is placed in hazard Category A.

Accessibility of High Frame Members. The cross bar of the A-frame and the top bar present indirect risks of injury during reasonably foreseeable misuse of the product. Use of the cross bar and top bar by children for climbing or gymnastics can lead to traumatic falls.

The top bar is a necessary support for the swings in a conventional set. A cross bar may be considered by some as a design defect: first, because it probably encourages children to use the cross bar for climbing, for gymnastics, and as a step for climbing onto the top bar; second, because the cross bar adds very little to the strength, stability, or durability of the swing set if the set is properly anchored. Others may consider the cross bar an essential part of the equipment intended for elementary exercises, such as chin-ups, for building arm muscles and for improving muscular coordination. Furthermore, the cross bar is needed when the swing set is not permanently anchored. Both the cross bar and top bar are placed in hazard Category C.

Trapeze Bar presents a risk of traumatic fall when the user loses his grip. The trapeze bar, however, is a functional component of the product, and the risk of fall is thought to be due to human error. The trapeze bar is placed in hazard Category C.

Swing Set Frame. The frame presents a risk of injury when someone falls against it or runs into it, but it is a necessity in a conventional swing set. The frame is placed in hazard Category C.

Loading Conditions Representing Child-Hazard Interactions

Loading conditions which are of particular interest for this study include child-hazard interactions (that is, a child's interaction with a hazardous component) and the magnitudes of loads involved.

The several possible ways in whch children can interact with a given hazard make it difficult to determine the appropriate loading conditions. The problem is further complicated by variations in the children's ages and by the variations in physical size and strength capabilities among children of the same age group. Rough estimates of these conditions, however, would be adequate for this study.

Many child hazard interactions can be roughly represented by the following two: (a) casual handling and (b) impact.

Casual handling conditions represent interactions involving two types of loading mechanisms: (1) Interactions in which the applied load is a single force acting in a direction perpendicular to the area of contact between the interacting object and the child's skin. Examples: situations where a finger or toe is caught in a pinch point, and situations where the child is pushing, gripping, sitting on, or stepping on a protrusion. (2) Interactions in which the applied load has two factors, a normal force between the skin tissue and the interacting protrusion and the relative velocity between the skin and the protrusion in a direction perpendicular to the force. Examples: a child rubbing some part of his body against a protrusion, and a child trying to free his finger caught in a pinch point or entrapped in a slot.

The loads involved in casual handling can be estimated from children's strength capability data. Such data, especially the forces that children are capable of exerting when pulling, pushing and gripping, are given in Table 5, and were obtained from references [14] and [15]. Forces involved in casual handling may vary from 5 to 296 newtons* for children of 2 to 6 years. However, to determine whether or not an exposed edge would cut the skin under casual handling conditions, a force of 89 Newtons (20 lb) was used by Sorrells and Burger [13].

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*SI Units are used throughout this report, however, for the convenience of the readers the conversion factors from SI to customery units are given in Table 4A, and the suggested criteria are given in both units.

Impact loading occurs in situations where a child hits a component or where the child is hit by a moving component, such as a swing seat. In impact loading the resulting impulse, the peak value of impulsive force and contact area are the important factors [12] (also see Table 8). The impulse and the peak impulsive force primarily depend upon the striking momentum, rigidity of the hazardous object, thickness and resilience of the skin tissue, and properties of the backing material of the skin such as bone, muscle, abdominal cavity, etc.

The impulse or peak impulsive force, being dependent on so many factors, are difficult to determine. In impacts where the child hits the hazardous object, the data required for determining even the striking momentum are almost non-existent; therefore, the treatment of these impacts is postponed until the required data become available. Impacts in which the moving swing seat hits a child, however, were treated on a relative basis. The relative magnitudes of peak impulsive forces to which a child may be subjected when hit by differently constructed swing seats were measured. The results of such measurements are given later.

Data Acquisition

This part of the study deals with the information necessary to develop quality criteria and test methods for establishing safety standards for swing sets, or for playground equipment in general. Anthropometric data for children and injury threshold data were obtained from the literature. Tests were conducted to determine the relative degree of hazard of certain functionally similar components having different constructions. Magnitudes of probable loads applied to certain swing set components were calculated.

Anthropometric Data. The literature was searched to obtain available data on physical measurements of children. The measurements of particular interest include sizes of fingers and toes, arm length, popliteal height, and weight. Some such data may be found in references [7], [8], [9] and [10]. However, data for three-year-old and younger children, and data on sizes of toes for children of all ages are almost non-existent.

Reference [7] gives sizes of children's fingers in terms of penetration of fingers in slots and holes. Some data from reference [7] are presented in Table 6. The data concerning the weight, arm length and popliteal height of children of various ages, obtained mostly from reference [8], are presented in Table 7.

Injury Threshold Data. Data obtained from references [11] and [12], for injuries such as contusion, skin laceration and puncture, and skull and zygomatic bone fracture are given in Table 8.

Most of the injury threshold data present in the literature, having been derived from clinical reports of accidents and from laboratory experiments with animals and cadavers, may be questionable. Furthermore, very few of these data were derived specifically for injuries to children. The available data, however, must suffice until our knowledge of injury mechanisms and properties of human tissue is greatly improved.

Relative Hazardousness of Functionally Similar Components Having Different Constructions. The construction (design, geometry and material) of certain hazardous components used in swing sets, even to perform the same or similar functions, differs from set to set as well as within the same set. These functionally similar components include most of the Category A hazards, such as bolts, nuts, hinged joints, swing seats, etc. They would present different degrees of hazards in identical child hazard interactions. This is so because, for given loading conditions, the hazardousness (injury potential*) of an object is critically influenced by its construction [11].

Some of the Category A hazards were tested to determine their hazardousness and/or relative hazardousness. Test procedures and results of the tests are given below.

Protrusions. Any exposed protrusion that would cut the skin under casual handling conditions is considered sharp. The criteria, test procedure, and the test device described by Sorrells and Burger [13] for detecting exposed sharp edges were considered adequate for determining whether or not an exposed protrusion is sharp. Using the procedure and device of reference [13], tests were conducted to determine if the protrusions found on swing sets are sharp. The protrusions included exposed bolts, nuts, pipes, and wire ends in chain links. The results are presented in Table 9. It should be pointed out, however, that protrusions which are not sharp under casual handling conditions may present a risk of injury under other loading conditions.

Swing Seats. Hazardousness of a swing seat impacting a person is related to the peak impulsive force and the contact area. The factors affecting the impulse or the peak impulsive force were discussed earlier. The contact area is dependent upon seat thickness (Figure 5), the part of the child's body impacted, the angle of impact and impact velocity.

The relative peak impulsive forces to which a child may be subjected when hit by differently constructed seats were measured. The seat to be tested was swung through a specified swing angle, θ_o , and made to impact a force transducer fixed in the apparatus** shown in Figure 6. The resulting impulse was fed to an oscilloscope and the trace was photographed. Typical oscillograms for various impacts are presented in Figures 7 through 12. Peak impulsive forces were read from the photographs.

*The injury potential of a hazardous object is defined as the type and severity of injury the object is capable of inflicting on the human body for any loading conditions [11].

**This particular apparatus was made available by the courtesy of Mr. N. J. Calvano of NBS. A brief description of the apparatus is given in Appendix A. The apparatus has been designed and used for testing the effectiveness of face shields which are part of helmets used by law enforcement officers. Any similar apparatus however, would have been adequate for this purpose.

The two glider seats which were tested are shown in Figures 13 and 14, one made of sheet metal material and the other of plastic. Four different single-occupancy swing seats were tested: (1) a seat made of wood; (2) a seat made of sheet metal; (3) a plastic seat just as it came from the manufacturer (Figure 15); and (4) the plastic seat modified by cutting some of the ribs out to make it less rigid without altering the seat's appearance or its functional capabilities (Figure 16). Tests were performed with empty seats using a swing angle of 20 degrees for glider seats, 30 degrees for single-occupancy swing seats, and with the force transducer so located that at the time of impact the swing had maximum velocity.

The seat thickness was measured and recorded. Seat thickness and peak impulsive force are given in Table 10. These data indicate that the plastic glider seat is less hazardous than the metallic glider seat, and that the modified plastic swing seat is the least hazardous of the four swing seats tested.

However, the impacts used in the above tests are far from real child-swing impacts, and these tests cannot measure the impulse or the peak impulsive force to which a child would be subjected when impacted by a swing seat. Nevertheless, these tests or other similar tests can be used to measure the relative hazardousness of those variously constructed seats. Furthermore, a swing seat that is least hazardous by these tests would probably be least hazardous when hitting a child in real situations. Therefore, su^h testing procedures would be adequate for establishing safety standards. Further studies are needed for developing an apparatus that would be suitable for testing the relative hazardousness of seats and that could specified in safety standards.

<u>Loads Applied to Certain Swing Set Components</u>. The components meant for carrying loads are seats, chains or tubes connecting swing sets to the top bar, supports at the top bar and at the seats such as s-hooks, bolts, and hinges, and the cross bar and the bolts connecting the cross bar to the frame. Probable loads carried by some of these components are calculated below.

The effective load carried by a moving swing depends upon the weight of the child occupying the swing and the swing angle; this is given by (assuming that the swing is a simple pendulum):

$$F = Mg_n (3 \cos\theta - 2 \cos\theta_o) \text{ newtons (N)}, \quad (1)$$

where M = weight of an occupant in kilograms (kg) (for simplicity weight of seat is neglected)

g_n = 9.80665 metres per second squared (m/s^2),

θ = angular deflection of the swing from the vertical,

θ_o = maximum angular deflection of the swing (or swing angle).

The effective load F is maximum when $\theta = 0$, and is given by

$$F_{max} = Mg_n (3 - 2 \cos\theta_o) \text{ newtons} \qquad (2)$$

F_{max} is also the load to which top bar is subjected because of one moving swing.

The maximum value of tension in each chain of a single-occupancy swing (see Figure 1 for single occupancy swing) and the load applied to each of the chain supports at the top bar is approximately one-half of F_{max}.

The maximum load to which the cross bar may be subjected occurs when two or more children use it for various activities. The effective load acting on any component due to shock, when a child jumps on the component, can be much greater than the weight of the child.

The strength of load-carrying components may be tested statically by loading the swing seats with static loads ($F_{st} = Mg_n$) equal to F_{max} multiplied by a safety factor. The single-occupancy seats are often occupied by two children, but the multiple occupancy swing (i.e. glider or lawn swing) is less apt to be occupied by more children than the number for which it is designed. Therefore, it is suggested that a safety factor between 1.25 and 2 should be used for determining the static test loads of single occupancy swing, and a safety factor between 1.25 and 1.5 for multiple occupancy swing. Sample calculations of static test loads are given below.

For single occupancy swings, let us assume:

$\theta_o = 90°$

M = 30 kg (weight of an average 9-year-old)

Then, from equation 2, $F_{max} = (90)g_n = 882$ newtons

and,

$1103 \leq F_{st} \leq 1765$ newtons

$$\text{or } 112.5 \text{ kg} \leq M_{st} \leq 180 \text{ kg} \qquad (3)$$

And for multiple occupancy swings, let us assume:

$\theta_o = 45°$

$M = 30$ kg per occupant

Therefore, $F_{max} = (48)g_n = 471$ newtons per occupant

and $588 \leq F_{st}$/occupant ≤ 706 newtons

or 60 kg $\leq M_{st}$/occupant ≤ 72 kg (4)

Assuming that the swing is a simple pendulum, the tipping moment (T) acting on the swing set due to one single occupancy swing is given by

$$T = F\ L \sin(\theta - \alpha)$$

where L is the projected length of the A-frame leg, and is one-half the projected A-frame angle, both projections being in a plane perpendicular to the top bar (Figure 17).

From equation 1,

$$T = Mg_n\ L\ (3\cos\theta - 2\cos\theta_o)\ \sin(\theta - \alpha) \qquad (5)$$

$$\text{or } T = Mg_n\ LK \qquad (6)$$

$$\text{where, } K = (3\cos\theta - 2\cos\theta_o)\ \sin(\theta - \alpha) \qquad (7)$$

For given values of M and L, T will be maximum when K is maximum (eqn. 6). For given values of θ_o and α, the maximum value of K and instantaneous position θ_m at which this maximum occurs can be calculated.

For example,

Let $\theta_o = 90°$. (The assumption of $\theta_o = 90°$ would serve as a safety factor for stability consideration although this swing angle is probably not attainable by the riders of gliders and lawn swings.) Then equation (7) becomes

$$K = 3\cos\theta \sin(\theta - \alpha)$$

which has two extremes in θ, of which the pertinent maximum is for $\theta > \alpha$ now,

$$dK/d\theta = 3\cos(2\theta - \alpha)$$

at $\theta = \theta_m$, $dK/d\theta = 0$, $\theta > \alpha$. Then $\theta_m = (\pi/4) + (\alpha/2)$,

$\theta_m - \alpha = (\pi/4) - (\alpha/2)$, and

$$K_{max} = 3 \cos \theta_m \sin(\theta_m - \alpha)$$
$$= (3/2)(1 - \sin \alpha)$$

and the maximum tipping moment due to a single occupancy swing or due to one occupant of glider or lawn swing, is

$$T_{max} = Mg_n L\,(3/2)\,(1 - \sin\alpha) \quad (8)$$

The maximum tipping moment to which the swing set may be subjected occurs when all the swinging units are in phase. This tipping moment is counteracted by the moment of the weight of the swing set and the reactions at the anchors, if the set is anchored. When the tipping moment is larger in magnitude than the counteracting moment, the swing set will tip over.

If the frame is not to tip, then the restraining moment T_r must exceed the tipping moment. For an unanchored set,

$$T_r = M_f\, g_n\, L \sin \alpha \geq Mg_n L\,(3/2)\,(1 - \sin \alpha)s$$

where M_f is the mass of the frame, and s is the number of occupants for which the set is designed.

Or $M_f/(Ms) = (3/2)(1 - \sin\alpha)/\sin \alpha$ (9)

is the minimum necessary ratio of frame mass to mass of swings and occupants.

The stability of anchored as well as unanchored swing sets can be tested by loading the top bar of the swing set with a single force P acting in a direction perpendicular to the top bar and parallel to the ground, applied at a point in the vicinity of the middle point of the top bar. The magnitude of the force P can be calculated as follows:

force p_1, for representing one single occupancy swing, trapeze bar, or for representing one occupant of glider or lawn swing.

$$p_1 = (Mg_n\, L\, K_{max})/y \quad = Mg_n\,(K_{max}) \sec \alpha \quad (10)$$

where y is the perpendicular distance from the top bar to the ground (Figure 17).

For determining the value of p_1, it is suggested that the value of K_{max} used in equation 10 should be based upon $\theta_o = 90°$ and $\alpha = 25°$ (this value of α is usually found on most of the sets). Using the suggested values of K_{max}, $\alpha = 25°$ and $M = 30$ kg, equation 10 may be rewritten as:

$$p_1 = 281 \text{ newtons} \qquad (11)$$

The magnitude of force P to be used for testing the stability is given by

$$P = Ap_1 + Bp_1 + NCp_1 + NDp_1 = sp_1. \qquad (12)$$

where A = number of single occupancy swings in the set,

B = number of trapeze bars in the set,

C = number of gliders in the set,

D = number of lawn swings in the set,

n = number of occupants for which the glider or the lawn-swing seat is designed, and

s = (A+B+Dn+Dn) = number of occupants for which the set is designed.

Suggested Quality Criteria and Test Methods

Based upon the information presented in the previous section the quality criteria and test methods, where needed, for some of the Category A hazards are suggested below. It must be pointed out, however, that the suggested criteria may be debatable, primarily because subjective factors must be included in the decisions. Furthermore, because of the limited nature of the needed information, these criteria do not cover all of the possible hazards associated with swing sets. Nevertheless, an interim safety standard based upon these criteria can be established, and to the extent that it is utilized would either reduce the number of mishaps resulting from Category A hazards or mitigate the trauma resulting from those mishaps which do occur.

Pinch Points. (a) The juncture of two hinged components moving relative to one another shall have clearance such as not to admit a rod with a diameter equal to or greater than 4 mm (0.16 inch). (b) Chain links shall be so designed that a 5 mm (0.20 inch) diameter rod cannot be inserted into the gap between the links when the chain is unloaded, and when the chain is loaded if a 5 mm (0.20 inch) diameter rod can be inserted through a link, then the link shall also admit a 15 mm (0.60 inch) diameter rod inserted separately.

Holes and Slots. The holes and slots shall be so designed that if a 5 mm (0.20 inch) diameter rod can be inserted in them, then they shall also admit a 15 mm (0.60 inch) diameter rod inserted separately.

Protrusions. (a) Protrusions such as exposed bolts, nuts, pipe ends, s-hooks, edges, corners, wire ends of chain links, etc, shall not be sharp according to the test and criteria of reference [13]. (b) The protrusions shall be so designed that they will not catch the clothing or shoes of children. (c) All exposed bolt ends and tubes or pipes shall be capped or plugged without creating a clothing or shoe catching hazard. The plugs and caps shall not be removable by a pulling force of 178 N (40 lb_f). (Data in Table 5 show that a six year old child when attempting to pull apart objects can exert a force of 100 N; the older children probably can exert considerably larger force than 100 N).

Swing Seats. (a) All surfaces of swing seats shall be free from protrusions, and all corners of seats shall be rounded. (b) Seat thickness shall be 25 mm (1.0 inch) or greater. (c) Glider seats under impact conditions described in the previous section (unloaded, swing angle 20°, and impacting the apparatus with maximum velocity) shall not produce a peak impulsive force greater than 900 N (200 lb_f). (d) Single-occupancy swing seats under impact conditions described earlier (i.e. unloaded, swing angle of 30°, and impacting with maximum velocity), shall not produce peak impulsive forces in excess of 900 N (200 lb_f).

Criteria (c) and (d) for the glider and single occupancy swing seats given above are based upon very limited data. More data are needed to design the apparatus for impact testing and for specifying the criteria (peak impulsive force and seat thickness), since the peak impulsive force depends upon the effective mass of the impacted object.

Other criteria that can be used for swing seats instead of criteria (c) and (d) above, are specification of mass, rigidity and thickness of seats.

Horizontal Spacing. Behavioral data, concerning children's behavior as associated with swing sets, is needed for specifying the spacing limits. However, the following criteria are suggested; (a) the separation between the swing set frame and any swing or between any two swings shall be at least 0.36 metres (14 inches).

Strength. Strength of the load-carrying components of swing sets may be tested as follows. The suggested test loads are based upon the average weight of a nine year old, which is approximately 30 kilograms (66 lb_m).

(a) Individual Swings. Individual swings shall be tested one at a time by loading the swings for 10 minutes with a load equal to the maximum value of M_{st} obtained from equations 3 or 4, whichever is applicable, without evidence of structural failure of the swing seat and its supporting system. For example, for a single-occupancy swing and for a trapeze bar the test load should be 180 kilograms (396 lb_m), and for glider and multiple occupancy swings the test load should be 72 kilograms (158 lb_m) per occupant.

(b) Top bar and frame. The top bar and frame of any multiple suspended swing set shall be tested by simultaneously loading each position, which may be normally occupied, for ten minutes with loads equal to the minimum value of M obtained from equations 3 and 4, whichever is applicable, without any evidence of structural failure of the top bar or of the frame. For example, the test loads for single occupancy swings and trapeze bar should be 112 kilograms (247 lb_m) per occupant and for multiple occupancy swings the test load should be 60 kilograms (132 lb_m) per occupant.

(c) Cross Bar of the A-frame. The cross bar of the A-frame shall be loaded for ten minutes with a single load of 180 kilograms (396 lb_m), equally distributed over a distance of 80 mm (3.1 inch) at the center of the cross bar, with no evidence of failure of the cross bar at any location.

The above mentioned procedures are thought to be adequate for testing the strength of various components of new swing sets. The strength can be tested by applying dead loads as indicated above, or by applying the equivalent forces mechanically. The strength inadequacy resulting from the deterioration of the product could be equally hazardous. At present, however, no practical methods are available to check for this hazard, other than by educating consumers to perform periodic inspections.

Stability. With the swing set installed in accordance with the written instructions provided by the manufacturer, the top bar of the swing set shall be loaded with a force P acting in a direction perpendicular to the top bar and parallel to the ground, and applied at a point in the vicinity of the middle point of the top bar; the magnitude of the force P shall be obtained from equation 12; when so loaded for 10 minutes the swing set shall not tip over.

Additional Studies

The information needed to establish safety standards for home playground equipment is either not available or very limited in scope. Studies to obtain the needed information and to establish interim standards for other items of home playground equipment (such as slides, climbing apparatus, merry-go-round, etc.) are suggested below.

Case studies. An in-depth study should be made of accidents related to home playground equipment. The study should include investigation of such factors as the cause of the accident, the product and the component of the product involved, the child's activities leading to the mishap, age of the child involved, age and conditions of the product involved, type and severity of injury sustained by the individual involved, etc. Some case studies have been conducted by the Consumer Product Safety Commission. However, the number of cases investigated by the Commission is too few to represent a statistically meaningful sample, in light of the number of reported accidents.

Anthropometric studies. Studies should be undertaken to generate data concerning physical measurement of children of all ages. These data should include sizes of fingers and toes, arm reach, popliteal height; weight; sizes of feet and hands; effective masses and moments of inertia of various body parts, etc.

Behavior studies. An investigation of children's activities associated with home playground equipment, especially during unsupervised playing, should be undertaken. Data on the behavior of children may help in establishing limits for misuse and/or abusive use of the equipment. In addition, these data may provide some assistance in finding means to minimize mishaps resulting from Category C hazards; these data would also help in planning consumer education programs.

Strength capability studies. Studies of the strength capabilities of children of all ages should be undertaken. These investigations should determine the forces that children are capable of exerting when pushing, pulling, and gripping, as well as velocities and momenta which children are capable of generating when hitting or kicking. Presently available information is limited to the forces that children of ages 2 to 6 years are capable of exerting when pulling, pushing and gripping.

Effects of weathering and aging. Investigations of the effects of weathering and aging on the strength of the equipment and its various components should be undertaken. If feasible these investigations should study strength reduction rate in terms of percent strength reduced per one year of environmental exposure, and strength preservation techniques. The results of such studies by providing strength prevention techniques may be of help in consumer education programs.

Criteria for other items of the equipment. Studies to develop criteria for establishing interim standards for such items of home playground equipment as slides, climbing apparatus, merry-go-rounds, see-saws, etc., are being conducted at NBS as a continuation of the project.

Concluding Remarks

It is difficult at present to establish safety standards for home playground equipment because most of the needed information is either not available or very limited in scope. However, based upon the suggested criteria, interim standards for swing sets may be developed. Promulgation of interim standards would be expected to reduce the number of mishaps due to design and construction defects of the product or mitigate the trauma resulting from these mishaps. The development of interim standards is desirable primarily because approximately half of the swing set related mishaps are due to design and construction defects of the product. Furthermore, as the state of the art advances, the interim standards can be appropriately revised.

No means other than consumer education is presently available to control the remaining mishaps. Consumer education may reduce these mishaps.

Appendix A

Brief Description of the Impact Test Apparatus

The apparatus which was used for measuring the magnitudes of peak impulsive force resulting from the impact of differently constructed swing seats is shown in Figure 8. The apparatus consists of a force transducer fastened to an eopxy headform in the vicinity of the location of the nose. The headform is mounted on a slide which is restrained to move linearly in a horizontal plane in the direction of the impact. The mass of the headform-sled assembly is approximately 5 kg. The static force requried to initiate motion of the headform-sled assembly is about 9 N.

The force transducer used has the following specifications:

charge sensitivity	$\simeq$ 9.2 pC/N
frequency response	= 4000 Hz
capacitance	= 191 pF
Maximum Allowable Load	= 4450 N

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Table 1. Incidence of Mishaps Involving Home Playground Equipment By Specific Product (Neiss Data, July 1972 to August 1973 [1]

Product	No. of Cases	Percentage
Climbing Apparatus	274	11.0
Seesaws	89	3.6
Slides	394	15.8
Swings	1593	64.1
Not Specified	137	5.5
Total	2487	100.0

Table 2. Incidence of Mishaps Involving Home Playground Equipment By Specific Product Based on 76 Investigated NEISS Reported Cases [2]

Product	No. of Cases	Percentage
Climbing Apparatus	4	5.3
Merry-Go-Round	2	2.6
Seesaws	1	1.3
Slides	13	17.1
Swings	54	71.1
Trapeze	2	2.6
Total	76	100.0

Table 3. Incidence of Swing Set Related Mishaps from 54 Investigated Cases [2]

Hazard (Component directly or indirectly involved in mishaps)	Number of Mishaps	Hazard Category	Remarks
Pinch Points (glider and lawn swing hinge joints, and chain links)	5 (9.3%)	A	Product defect, presents direct risk of injury.
Protrusions (exposed bolts, nuts, wire ends, S-hooks, sharp corners and edges, etc.)	5 (9.3%)	A	Product defect, presents direct risk of injury. In some cases the exposed protrusion had resulted from the deterioration of the product.
Swing Seats (glider and single occupancy swing seats)			
1. Seat struck a child	12 (22.2%)	A	Product defect, presents a direct risk of injury if a poorly designed seat hits a child.
2. Child fell from seat	6 (11.0%)	C	Child fell out of seat by slipping or by being pushed hard.
Spacing (horizontal, i.e. in between the members, vertical, i.e. clearance above the ground)	4 (7.4%)	A,B	The swings are placed too close to each other and to the frame of the set. The unrestrained mobility of certain swings combined with inadequate spacing results in mishaps. Improper installation may result in too little clearance above the ground.
Poor Strength (various load carrying components)	3 (5.5%)	A,B	If the product has inadequate strength when new it will be in category A. However, all three mishaps investigated indicated that the equipment had deteriorated.

Table 3. Continued

Hazard (Component directly or indirectly involved in mishaps)	Number of Mishaps	Hazard Category	Remarks
Instability	1 (1.9%)	A	The swing set tipped over. The swing sets are usually sold without anchorage. Anchors are sold as accessories.
Accessibility of High Frame Members (cross bar and top bar)	15 (27.7%)	C	Present indirect risk of injury. Children climbed upoon these members fell and were injured.
Trapeze	2 (3.8%)	C	Children lost their grip, fell and were injured.
Swing Set Frame	1 (1.9%)	C	Child playing in the vicinity of the equipment fell against or ran into the swing set frame.

Table 4. Brief Description of Swing Set Related Mishaps [3]

Number	Mishap Description	Hazard	Hazard Category
1	One young girl had eye knocked out of socket when struck by a glider seat.	Poor seat design	A
2	A child had cornea lacerated when swing chain broke and hit her in the eye.	Poor strength	A
3	A 4-year old boy was caught between frame and glider seat and sustained a lacerated head.	Spacing	A
4	Several children suffered severe lacerations and tissue avulsions in the inguinal area when caught on "S" hooks on chains; others have faces caught requiring extensive suturing.	Protrusions	A
5	Some pre-kindergardners who caught fingers in the hinge joints of gliders had part of the finger amputated.	Pinch points	A
6	A 2 1/2 year old girl fractured her leg when dismounting from a moving glider.	Spacing, vertical	B
7	A 9-year old girl sustained skull fracture when struck by the swing seat.	Poor seat design	A

Table 4. Continued

Number	Mishap Description	Hazard	Hazard Category
8	A 7-year old girl lacerated her arm as she slipped while climbing on the top bar of the swing set.	Accessibility of high frame members	C
9	A 4-year old girl suffered injury of the optic nerve when falling and striking the pipe framework of a lawn swing.	Exposed pipe	A
10	A 6-year old had finger amputated when caught in chain linkage.	Pinch point	A
11	A 9-year old girl was injured when the cross bar loosened and struck her on the head.	Poor strength	B
12	A young girl was swinging double, fell out and bruised shoulder.	Swing seat	C

Table 4A. Conversion Factors from SI Units to Customary Units

Quantity	To Change From SI	To Customary	Multiply By
Force	Newton (N)	Pound (lb_f)	0.225
Length	Millimetre (mm)	Inch (in)	0.039
Length	Centimetre (cm)	Inch (in)	0.394
Length	Metre (m)	Inch (in)	3.937
Length	Metre (m)	Foot (ft)	0.328
Mass	Kilogram (kg)	Pound (lb_m)	2.205
Pressure	Newton per square metre (N/m^2)	Pounds per square inch (psi)	0.145×10^{-3}

Table 5. Magnitude of Forces that Children are Capable of Exerting When Pushing, Pulling, Gripping, and Pulling-Apart Objects [14] and [15]

Age Group Years	Type of Value	Force Magnitude in Newtons							
		Push		Pull		One-Hand Grip		Pull-Apart	
		Female	Male	Female	Male	Female	Male	Female	Male
2	95th percentile	88	105	167	171	49	49	55	43
	Average	49	62	90	103	25	31	31	29
	5th percentile	30	30	53	40	4.5	4.5	13	16
3	95th percentile	131	125	176	191	68	73	60	60
	Average	74	81	121	122	38	42	42	42
	5th percentile	18	47	78	56	18	18	22	22
4	95th percentile	202	252	256	269	98	108	68	79
	Average	117	145	160	180	60	69	52	54
	5th percentile	56	71	85	107	29	36	28	35
5	95th percentile	235	269	269	282	127	137	81	85
	Average	153	175	204	220	85	91	61	68
	5th percentile	95	91	107	126	50	56	46	46
6	95th percentile	257	281	282	296	137	176	94	100
	Average	175	209	224	250	98	118	74	80
	5th percentile	111	131	145	171	56	76	55	52

Table 6. Penetration of Children's Fingers in Holes (H) and Slots (S) [7]

Hole Diameter Or Slot Width			Finger Penetration in Centimetre		
in	(mm)		10th Percentile	50th Percentile	90th Percentile
1/8	(0.32)	H	0.00	0.05	0.07
		S	0.09	0.10	0.16
3/16	(0.48)	H	0.05	0.07	0.13
		S	0.11	0.21	0.26
1/4	(0.64)	H	0.07	0.18	0.30
		S	0.40	0.72	1.00
5/16	(0.79)	H	0.17	0.40	0.50
		S	1.00	2.05	2.45
3/8	(0.95)	H	0.35	0.82	1.30
		S	2.42	2.78	3.60
7/16	(1.11)	H	1.27	2.18	2.42
		S	3.88	4.42	4.96
1/2	(1.27)	H	2.99	3.89	4.40
		S	4.30	5.01	5.95
3/4	(1.91)	H	5.44	6.12	6.78
		S	7.20	8.50	9.98

Table 7. 50th Percentile Values of Children's Weight, Arm Length, and Popliteal Height [8]*

Age, Years	Weight, kg		Popliteal Height, m		Arm Length, m	
	Female	Male	Female	Male	Female	Male
4	16.7	17.2	0.416	0.424	0.254	0.241
5	19.0	19.5	0.450	0.455	0.254	0.278
6	20.8	21.8	0.480	0.478	0.278	0.294
7	23.0	24.0	0.510	0.518	0.292	0.305
8	25.8	26.3	0.536	0.546	0.317	0.330
9	28.5	29.3	0.564	0.569	0.330	0.343
10	31.7	32.2	0.592	0.594	0.330	0.355
11	35.8	34.8	0.622	0.617	0.366	0.355
12	40.3	39.0	0.652	0.642	0.373	0.368
13	45.3	43.5	0.676	0.668	0.381	0.394

Table 8. Injury Threshold Data [12]

Injury	Threshold		Remarks
	Criterion	Value	
Contusion	Force divided by area - F/A	3.5×10^6 N/m^2	Experiments conducted with cadavers. Contact area of the injuring object 6.45×10^{-4}.
Laceration and Puncture	F/A	9.0 to 69.0×10^6 N/m^2	Vary with geometry of the injuring object and skin tissue properties. Experiments conducted with cadavers and excised skin tissue.
Skull Fracture	Force -F, and impactor area -A	F(N)	
Frontal area		4000	Impact loading; intact cadaver heads were impacted by falling impactor. Impactor mass 0.9 to 4.8 kg, impactor surface area 6.45 cm^2
Temporal area		2000	
Zygoma		900	

Table 9. Results of Tests Performed to Determine Whether Or Not the Certain Protrusions Found on a Swing Set Were Sharp

Protrusion Tested	Test Results		Remarks
	Sharp	Not Sharp	
Bolts	5	0	Tests were performed with the exposed threaded surface of the bolts.
Square Nuts	10	0	
Hexagonal Nuts	1	4	One nut had sharp burrs created by tightening.
Pipe holding the glider seat	2	0	Old rusted equipment, exposed pipe.
Wire ends at the chain links.	5	5	New swing set, chain not rusted.

Table 10. Results of Impact Tests Conducted to Measure the Relative Hazardousness of Swing Seats

Seat Description	Swing Angle, θ Degree	Peak Value of Impulsive Force Newtons	Seat Thickness* mm
<u>Glider Seats</u>			
Old metallic	20	2200	26
New plastic	20	800	60
<u>Single Occupancy Swing Seats</u>			
Old wooden	30	4900	20
Old metallic	30	2100	21
New plastic	30	1400	34
New plastic, modified	30	900	34

*Seat thickness varied in value, the value given in the table is the value of thickness at or near the impacting region.

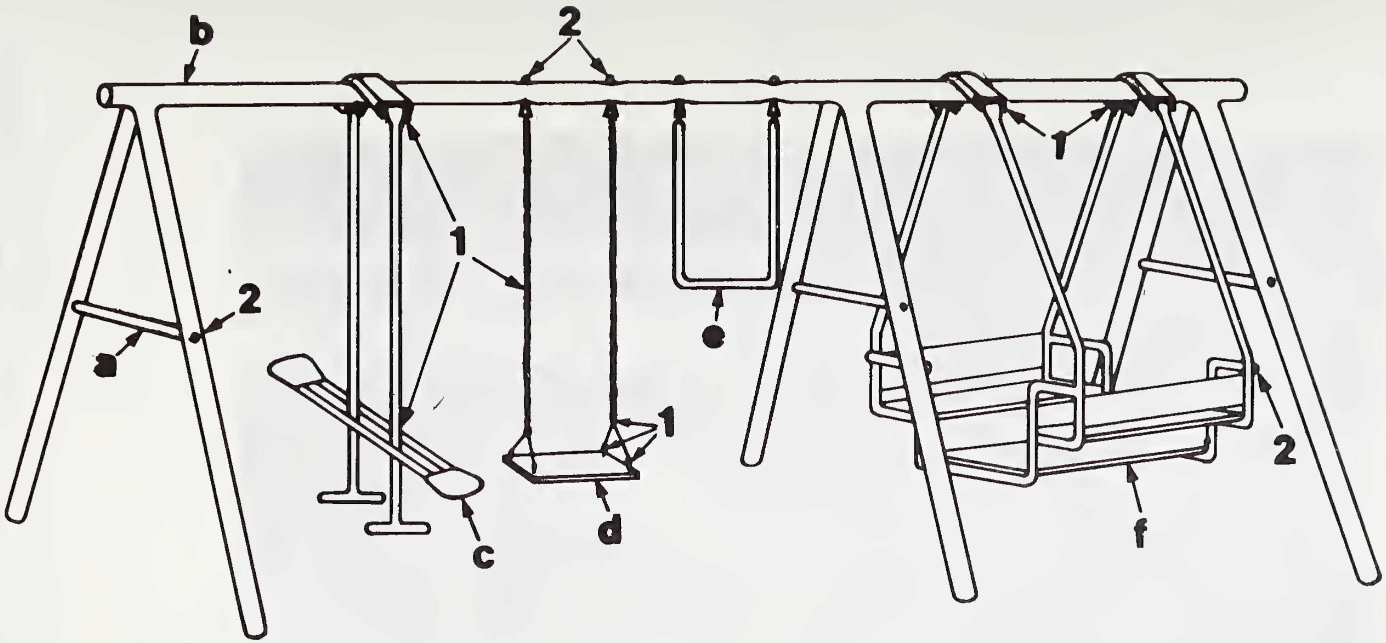


Figure 1. SCHEMATIC REPRESENTATION OF DIFFERENT TYPES OF SWINGS USUALLY FOUND IN HOME PLAYGROUND SWING SETS.

Figure 2. Pinch point, juncture of two hinged components.

Figure 3. Finger entrapping slot.

Figure 4. Shoe string catching protrusion.

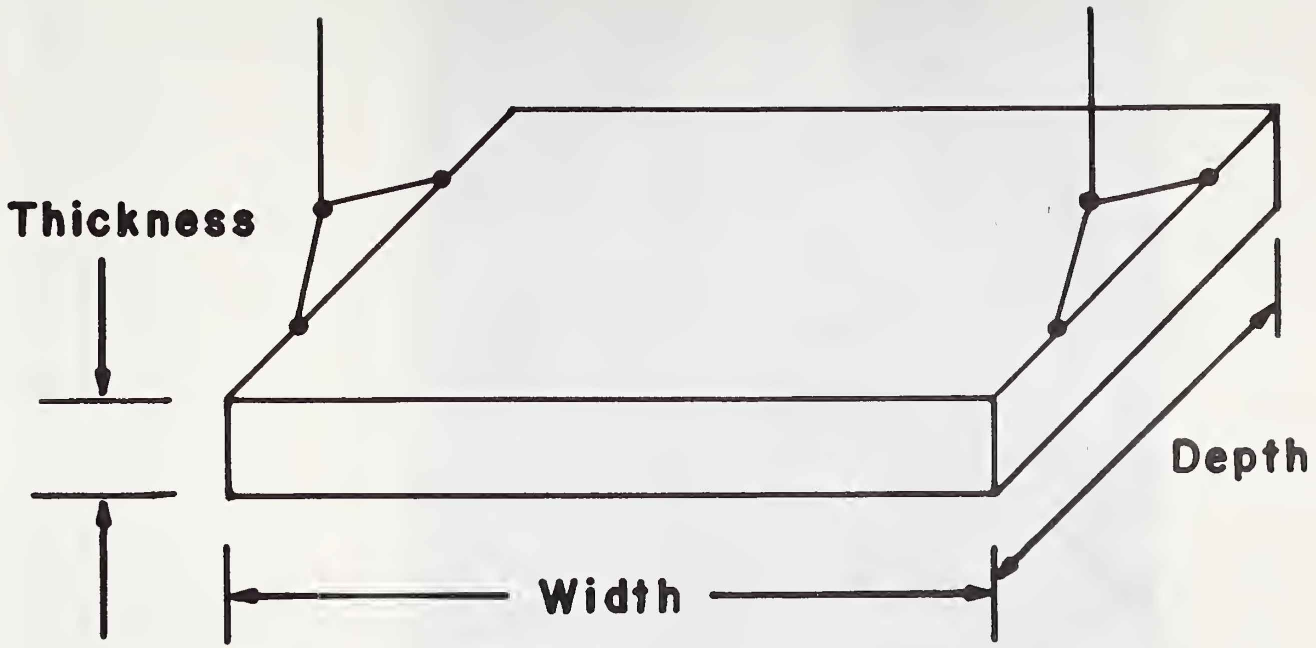
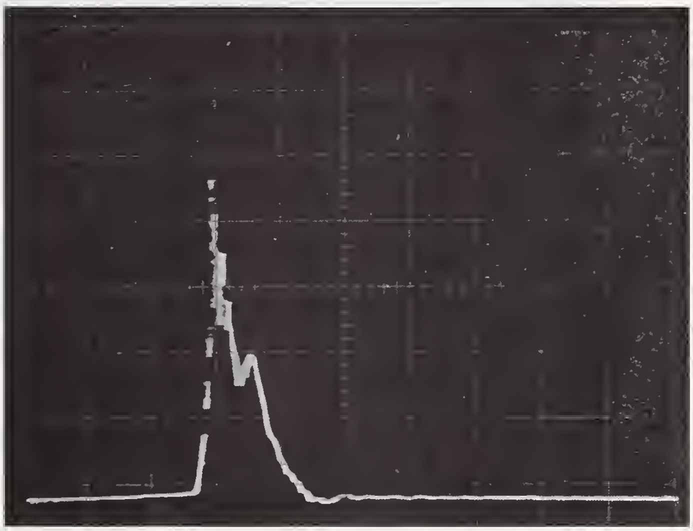


FIGURE 5. SCHEMATIC DIAGRAM OF A SINGLE OCCUPANCY SWING SEAT

Figure 6. Apparatus used for determining the relative hazardousness of swing seats in impact loading.

Force - 445 N/div.



Time - 5 ms/div.

Figure 7. Typical force-time record of impulse resulting from the impact of metal glider seat with the apparatus shown in figure 6.

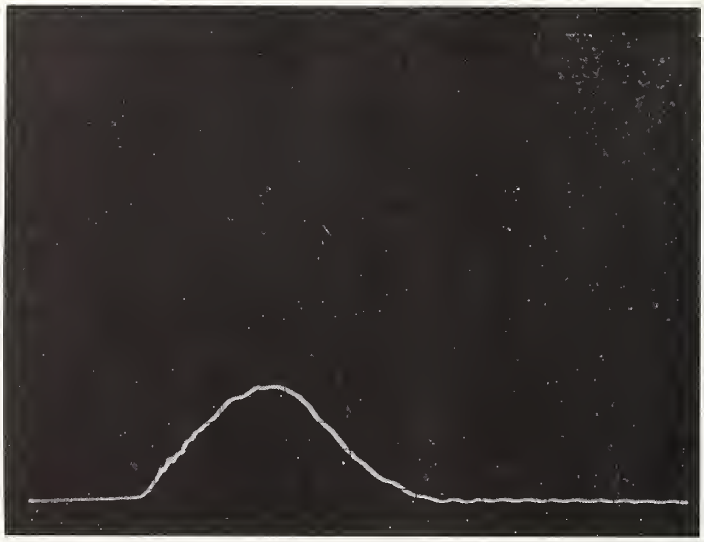
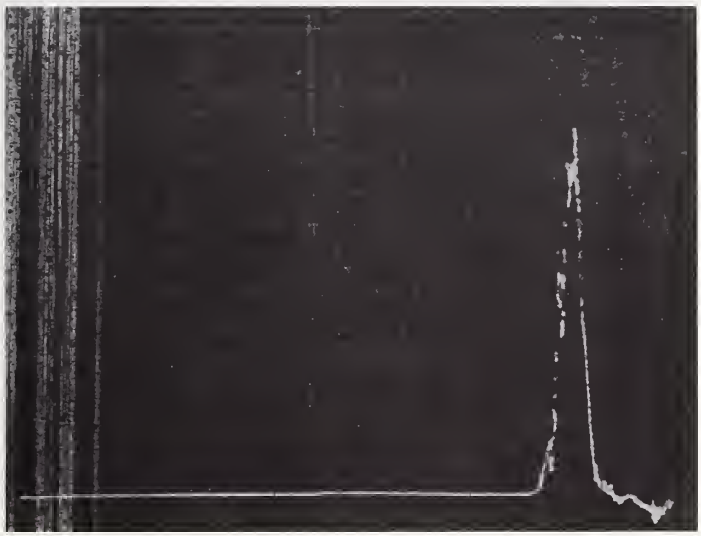


Figure 8. Typical force-time record of impulse resulting from the impact of the plastic glider seat with the apparatus shown in figure 8.

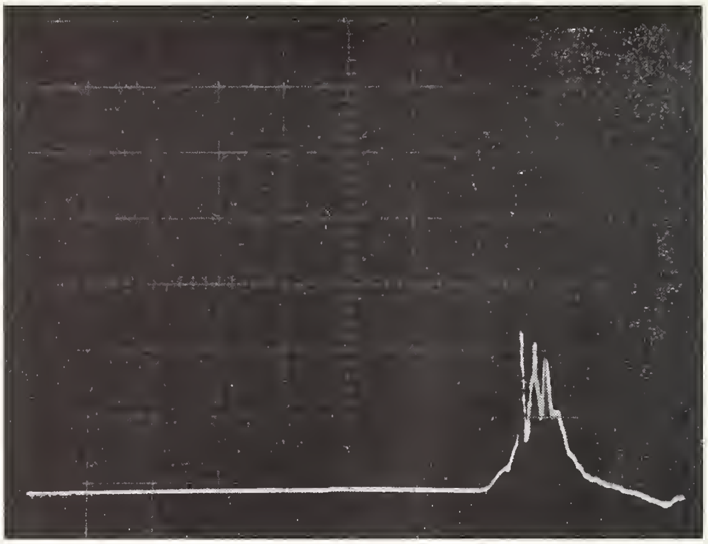
Force - 890 N/div.



Time - 2 ms/div.

Figure 9. Typical force-time record of impulse resulting from the impact of wooden single occupancy swing seat with the apparatus shown in figure 8.

Force - 890 N/div.



Time - 2 ms/div.

Figure 10. Typical force-time record of impulse resulting from the impact of metal single occupancy swing seat with the apparatus shown in figure 8.

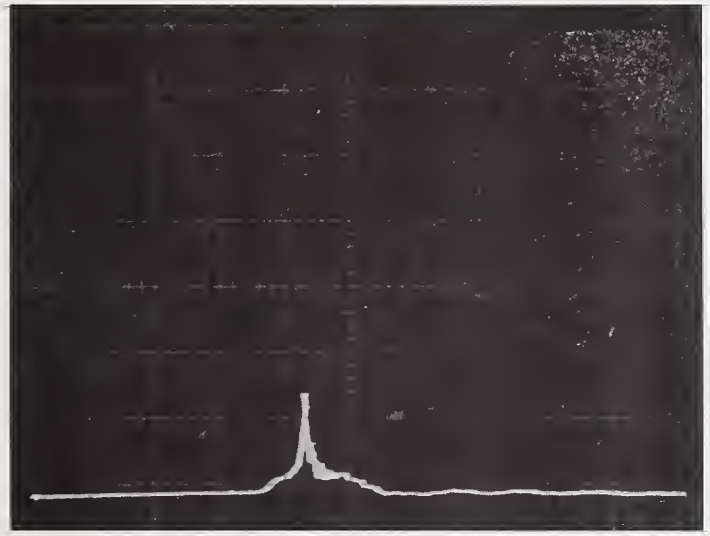
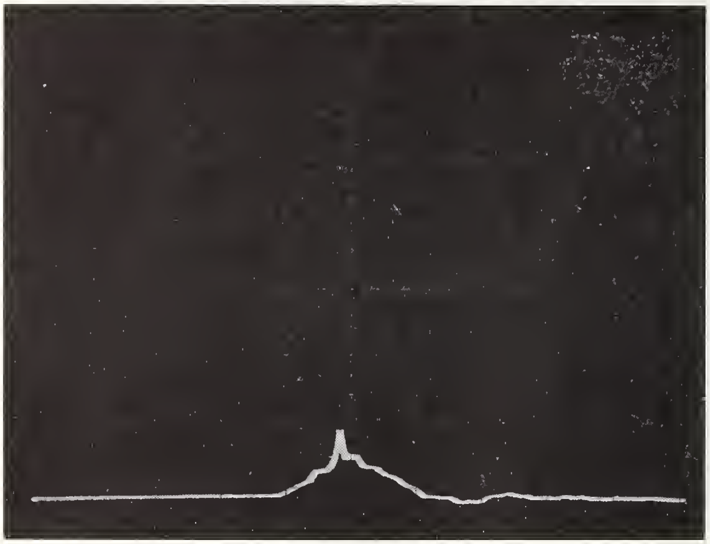


Figure 11. Typical force-time record of impulse resulting from the impact of plastic single occupancy swing seat with the apparatus shown in figure 8.

Force - 890 N/div.



Time - 2 ms/div.

Figure 12. Typical force-time record of impulse resulting from the impact of the modified plastic single occupancy swing seat with the apparatus shown in figure 8.

Figure 13. Metal glider seat.

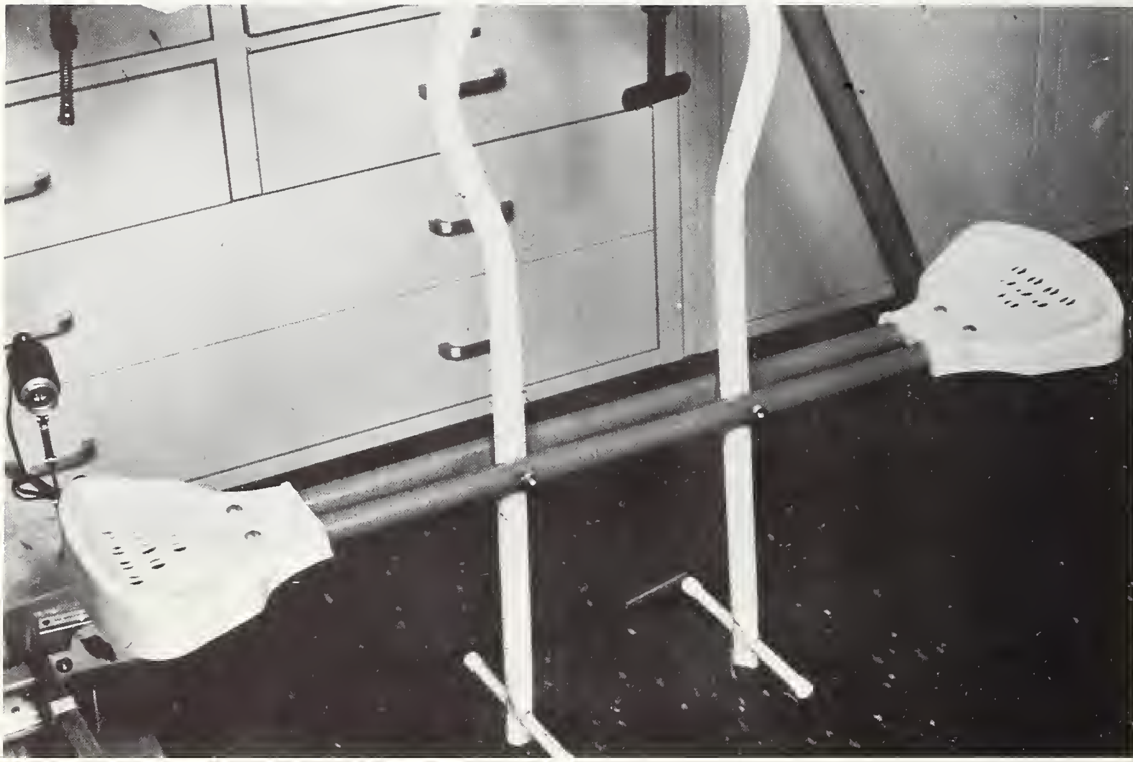


Figure 14. Plastic glider seat.

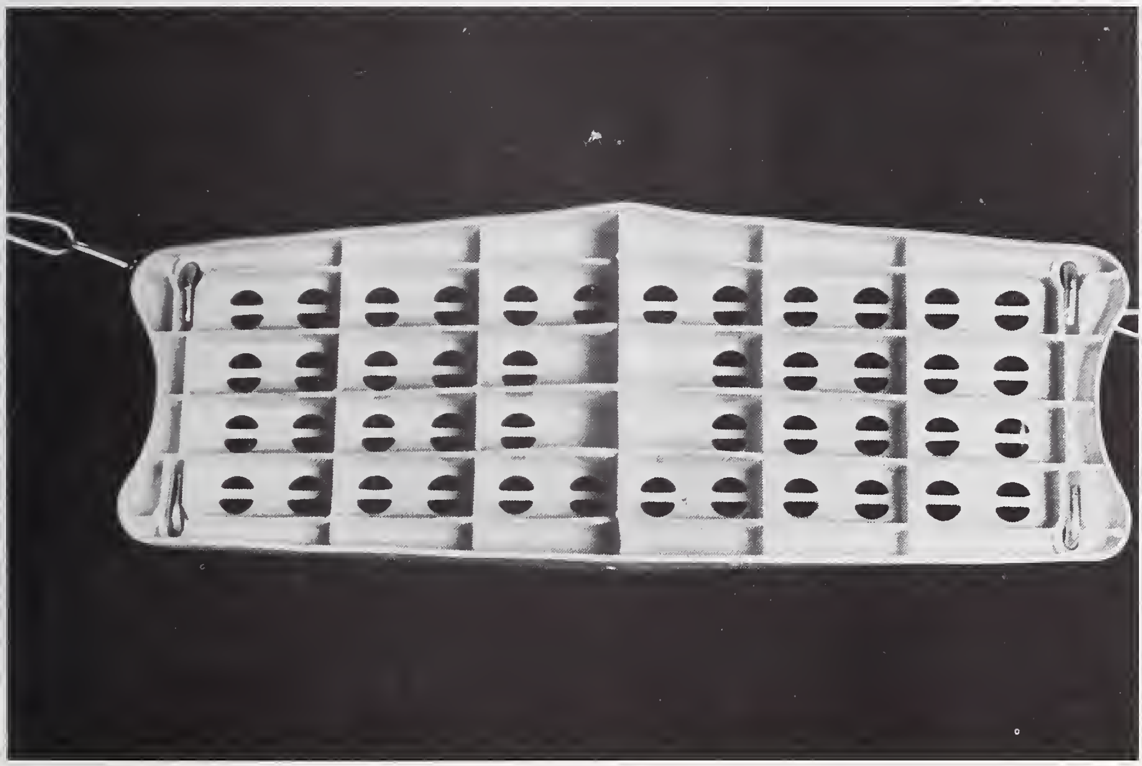


Figure 15. Bottom surface of the new plastic single occupancy swing seat.

Notice the ribs from one side of the seat have been cut.

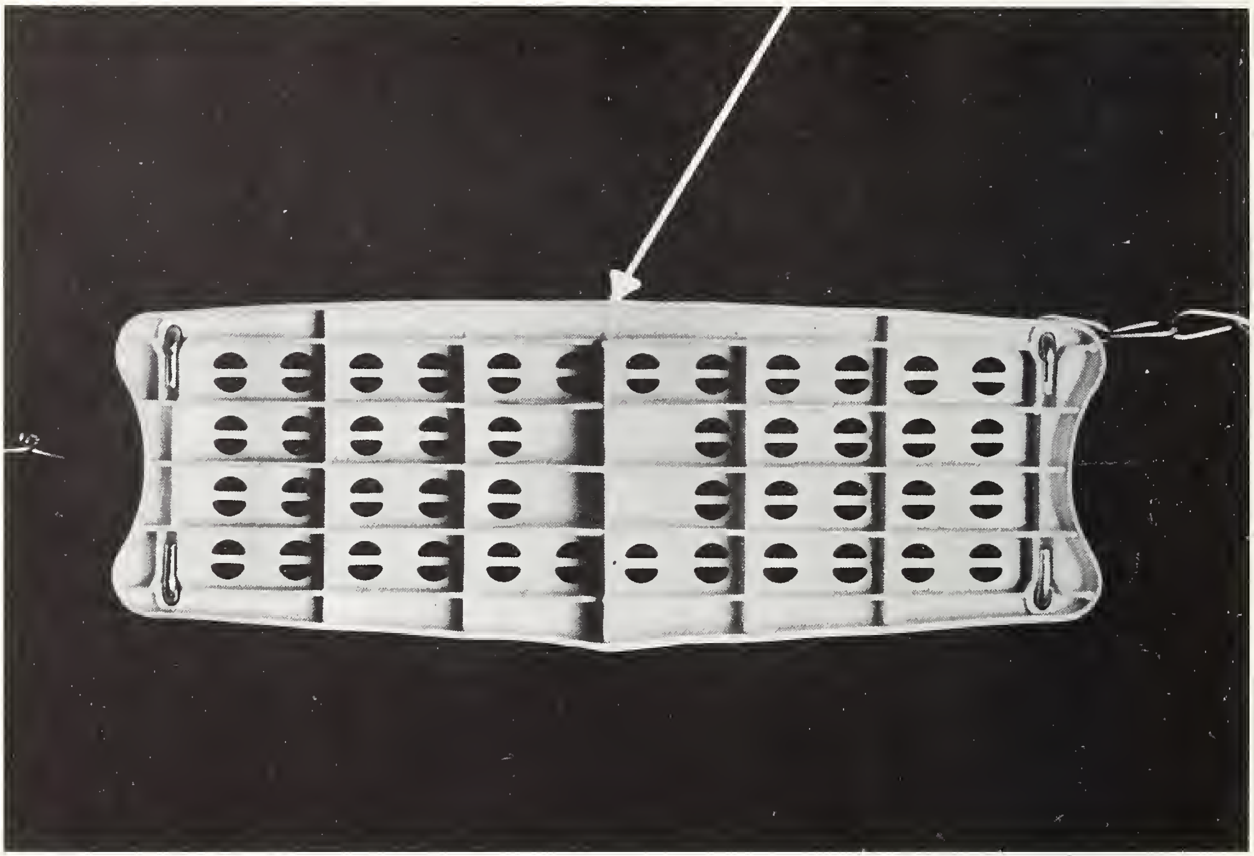
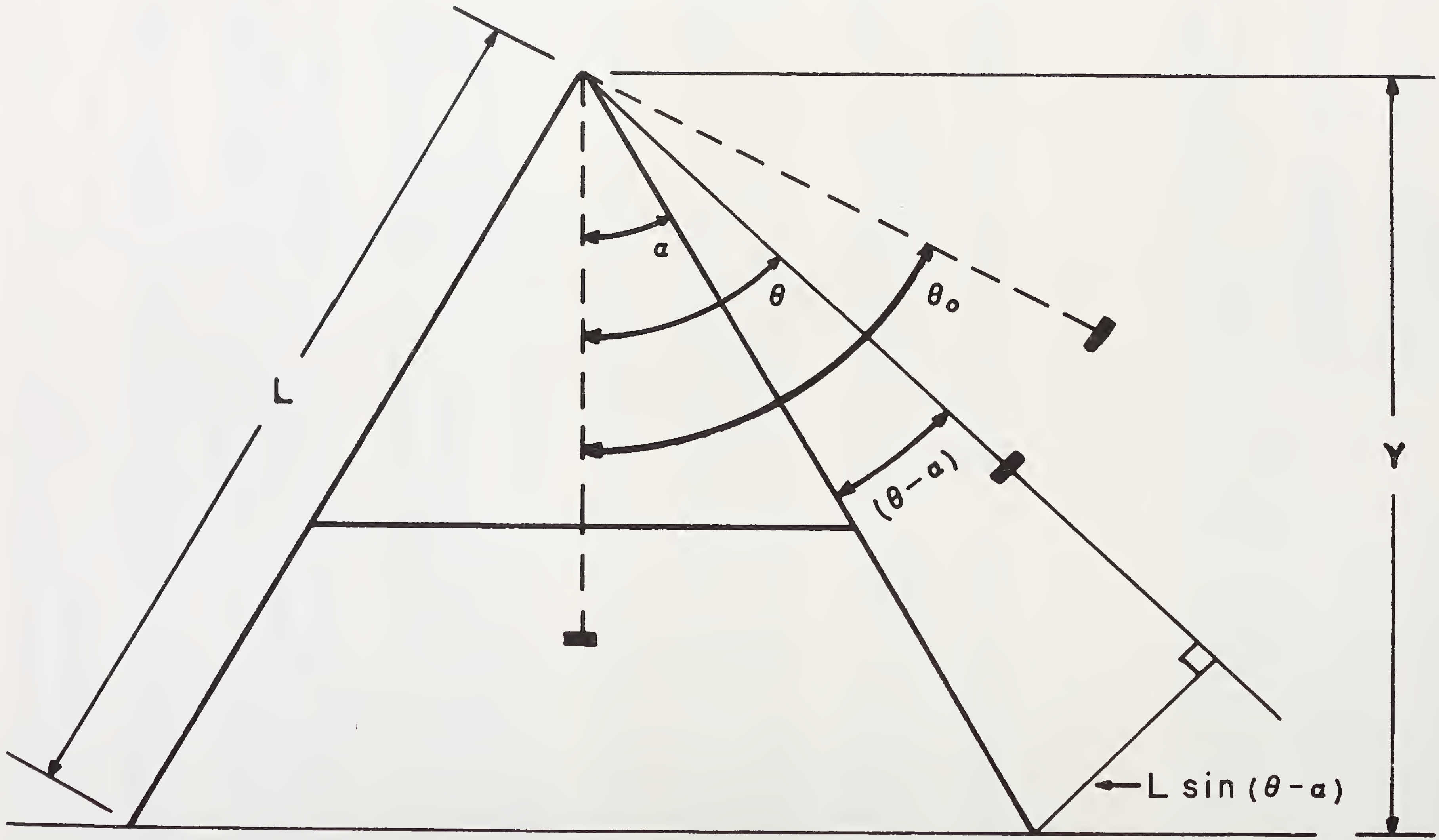


Figure 16. Modification made in the plastic single occupancy swing seat shown in figure 17.



SCHEMATIC SIDE VIEW OF SWING SET WITH SUSPENDED SWING

FIGURE 17.

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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.)*

Summaries of swing set related accident investigations were examined in order to identify the hazards associated with swing sets. Approximately half of the swing set related mishaps were directly attributed to the design and construction defects of the products. The other half of the recorded mishaps results from improper installation, deterioration or misuse of the product.

Some necessary information, such as anthropometric data, injury threshold data, loading conditions representing child-hazard interactions, and loads applied to certain components to swing sets is presented.

Quality criteria and test methods are suggested, to establish safety standards for reducing hazards due to design and construction defects of the equipment.

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)* Component; criteria; development; equipment; home playground; hazard; hazardousness; identification; mishap; misuse; product defect; safety standard; swing set; test method

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