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ABSTRACT

The purpose of these Federal safety guidelines is to reduce the severity and frequency of injury associated with public playground equipment under conditions of normal use and reasonably foreseeable misuse. Safety guidelines regarding: (1) assembly, installation, maintenance instructions and identification; (2) materials of manufacture and construction; (3) sharp points and edges, protrusions, and pinch and crush points; (4) equipment that rotates about a vertical axis; (5) entrapment; and (6) falls from equipment are suggested. The guidelines apply to playground equipment intended for use in play areas of parks, schools, institutions, multiple family dwellings, private resorts and recreation developments, and other areas of public institutional use. They do not apply to amusement park equipment, equipment normally intended for sports use, or to home playground equipment. In addition, components of equipment intended solely for use by the handicapped and necessarily modified to safely accommodate such users, are exempt from the requirement(s) applicable to those components. The supporting rationale for the specifications and requirements is extensively discussed. (Author/RH)

PUBLIC PLAYGROUND EQUIPMENT

Project 426

Suggested Safety Guidelines and Supporting Rationale for Public Playground Equipment

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I. INTRODUCTION

In 1975, the Consumer Product Safety Commission (CPSC) responded to a petition to develop a standard for Public Playground Equipment and selected the National Recreation and Park Association (NRPA) to develop such a standard. The NRPA thereupon formed a development panel consisting of representatives from consumer, industry, and buyer/installer communities and called upon the Franklin Institute Research Laboratories for technical assistance. Approximately a year later, in April 1976, the NRPA submitted a proposed standard to the CPSC 1/. The CPSC elected to revise that standard and sought technical assistance from the National Bureau of Standards (NBS). In 1978, CPSC requested that the Bureau expand its role to include further assistance in the review and rework of the proposed standard for public playground equipment. The objective of this effort was to provide the CPSC with a set of suggestions and recommendations for use in formulating the final version of the Public Playground Standard.

It was recognized early that much of the supporting rationale would not be completely objective due to deficiencies in the hard data. Therefore, the CPSC requested that the requirements be separated into two documents for probable publication as a standard and a Federal guideline. The criteria for including topics in the standard were that the requirements relating to these topics be based on objective test methods and supported with appropriate rationale. Six topics were selected for inclusion in the standard. These were:

1. Swing Assembly Structural Integrity
2. Swing Assembly Moving Impact
3. Straight Slide Surface Incline
4. Straight Slide Surface Exit Region
5. Straight Slide Surface Side Height
6. Straight Slide Ladders and Stairways

That task was completed in April 1978, and a memorandum report, "Suggested Safety Requirements and Supporting Rationale for Swing Assemblies and Straight Slides," 2/ was submitted to the CPSC.

The remaining topics in the NRPA proposed standard were addressed in the phase that followed. This report contains the recommended requirements and supporting rationale for these topics.

In preparing both the standard and guidelines, the greatest difficulty was encountered in obtaining data to support the requirements. This problem also plagued the developers of the NRPA document. Information relating the frequency and severity of injuries to physical properties of

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playground equipment and use habits are almost non-existent. Consequently, most of the requirements in the standard and guideline are based on the materials developed by NRPA, supplemented by objective analyses and engineering judgements.

In addition, in developing the requirements and arriving at specifications that might be effective in reducing potentials for injury, it was difficult to foresee potential hazards which might indirectly be encouraged by the requirements. This concern was repeatedly emphasized, but time and resources were not available to evaluate the full ramifications of each requirement.

Several important differences between this report, the first report (April 1978) and the standard proposed by the NRPA are worth noting.

The protective barrier height requirement in the first memorandum report specifies a minimum height of 36 inches. This is the standing center of gravity of a maximum user. The barrier height required in this report is 38 inches. This change is necessary to account for the thickness of footwear and for settling, warping, or other aging effects of the equipment. This change should also be made to the requirement in the first report.

The format for numbering sections and paragraphs was changed to conform with guidelines in the Federal Register Document Drafting Handbook, 1975. Also, the ordering of sections is different from that used in the NRPA proposed standard.

The sections "Safety Requirements, General" (1514.4) and "Referenced Tables and Figures" (1514.12) of the NRPA proposed standard have been deleted. However, applicable parts of those sections have been introduced in different sections of this report.

The section "Surfaces Under Equipment" (1514.10) is not included since this research had not been completed at time of issue of this report.

The recommended minimum use zones provided by the NRPA are not included because they don't permit composite units and are too general for the variety of playground equipment. Instead, a requirement is included requiring that the manufacturer provide this information for each apparatus.

A section on the entrapment of parts of the body other than the head has been added.

The sub-sections "Moving Ladders or Climbing Devices" and "Ladders and Stairway Heights" and the differentiation between high, intermediate, and low level equipment and between slide heights of the section "Falls from Equipment" (1514.9) of the NRPA proposed standard have been dropped because the height criteria are

arbitrary and not supportable by data or analyses. Results of research now underway will provide a better understanding of the impact characteristics of surfacing materials relative to different fall heights and a basis for developing equipment height requirements.

The completely subjective test method for identifying pinch and crush points suggested by the NRPA was omitted because it emphasizes a single body part and, in general, will not identify all such points because of the many configurations constituting pinch and crush points.

Protruding bolts are not excluded from the protrusion test as was the case in the NRPA proposed standard.

The exclusion of slow rotating equipment from meeting the base configuration requirement is omitted. The types of injuries addressed by this requirement are not solely dependent on velocity; mass is also an important variable.

The spiral slide test methods have been deleted because they are unreliable. The requirements in this report were derived from analyses of two modes of lateral discharge.

The anthropometric data used by the NRPA were taken from the University of Michigan report, "Physical Characteristics of Children as Related to Death and Injury for Consumer Product Design and Use" published in 1975. Data used in the first report (April 1978) and this report were obtained from a more recent report by the University of Michigan, published in 1977 3/.

II. SUGGESTED SAFETY GUIDELINES FOR PUBLIC PLAYGROUND EQUIPMENT

1514.1 Purpose and Scope

The purpose of these guidelines is to reduce the severity and frequency of injury associated with public playground equipment under conditions of normal use and reasonably foreseeable misuse. The guidelines apply to playground equipment intended for use in play areas of parks, schools, institutions, multiple family dwellings, private resorts and recreation developments, and other areas of public institutional use. They do not apply to amusement park equipment, equipment normally intended for sports use, or to home playground equipment. In addition, components of equipment intended solely for use by the handicapped and necessarily modified to safely accommodate such users, are exempt from the requirement(s) applicable to those components.

1514.2 Definitions

(a) The following definitions apply for the purpose of these guidelines:

(1) Accessible - any part of the equipment that may be contacted by any body part under conditions of normal use or reasonably foreseeable misuse.

(2) Composite unit - a combination of two or more play devices linked together to provide a variety of play activities in one integral unit (e.g., a combination climber, slide and balance beam).

(3) Entrance height - the vertical distance between the underlying surface and the uppermost part of the inclined sliding surface of a slide.

(4) Entrapment - any condition which impedes withdrawal of a body or body part that has penetrated an opening.

(5) Fasteners - those parts of the equipment such as clamps, bolts, hooks, screws, or other hardware used to join components.

(6) Hand railing - a device intended for use by the hands to provide body balance and support in maintaining a specific body posture.

(7) Ladder - a device having a slope greater than 50 degrees from a horizontal plane, and consisting of a series of rungs or steps on which a person may step while ascending or descending.

(8) Longitudinal component - a component which provides an opportunity for climbing and is within 45 degrees from a horizontal plane.

(9) Maximum user - a twelve year old child. Measurements of maximum user characteristics are the 95th percentile values for combined sexes.

(10) Minimum user - a five year old child. Measurements of minimum user characteristics are the 5th percentile values for combined sexes.

(11) Normal use - use of the equipment in a manner intended by the designer or manufacturer or which conforms to play patterns that have been established by traditional practice.

(12) Opening - a space bounded partially or completely by edges or surfaces of a structure.

(13) Pinch and crush point - the point at which the movement of elements relative to each other or to a fixed component represents a pinching, crushing, or shearing hazard to any body part.

(14) Protective barrier - a side enclosing device around an elevated surface that aids in the prevention of falls to lower levels.

(15) Protrusion - an element or component that protrudes from the equipment in any plane or direction in a manner posing a potential impact hazard.

(16) Reasonably foreseeable misuse - use of the equipment in a manner not originally intended by the designer or manufacturer and not considered customary, but which may be anticipated through knowledge of children's behavioral patterns when using such equipment.

(17) Rotating equipment - any equipment which rotates about a vertical axis, such as merry-go-rounds, whirls, maypoles, etc.

(18) Rung - a ladder crosspiece which is intended to be used as a foot support and as a hand grip in the normal use of the ladder.

(19) Sharp edge - any edge that can cut the skin during normal use or reasonably foreseeable misuse.

(20) Slide - an apparatus having an inclined surface used for sliding.

(21) Spiral slide - a slide whose sliding surface (chute) when projected onto a horizontal plane is curved.

(22) Stability - the ability of an apparatus to withstand maximum anticipated forces which act to tip or slide the equipment when properly assembled and installed.

(23) Stairway - a device having a slope of 50 degrees or less from a horizontal plane and consisting of a series of steps which can be used for ascending or descending.

(24) Step - a horizontal crosspiece of a ladder or stairway intended for use primarily as a foot support.

(25) Straight slide - a slide whose sliding surface when projected onto a horizontal plane is not curved.

(26) Suspended member - that part of a swing assembly which is intended to be occupied by one or more users in the act of swinging.

(27) Suspended elements - those parts of the swing assembly, such as chains, ropes, cables, tubes, etc., that are used to suspend a suspended member from an overhead supporting structure.

(28) Swing - play equipment used for swinging, consisting of the supporting structure and one or more swing assemblies.

(29) Swing assembly - an apparatus intended for use by one or more users for swinging, consisting of a suspended member and its necessary suspending elements and fasteners.

(30) Underlying surface - the top level of the natural ground or surfacing material placed under and around the equipment.

(31) Use zone - the total space under and around installed equipment that is necessary for the user to complete the intended activity (e.g., swinging out, exiting from a slide, etc.).

1514.3 Assembly, Installation, Maintenance Instructions and Identification

(a) Instructions

(1) Requirements

The manufacturer shall include the following with each piece of equipment or composite unit:

(i) Instructions and necessary drawings, photos, or other illustrations for proper assembly that includes torque specifications for bolts and nuts and a listing of all components that includes part names and numbers.

(ii) Instructions and necessary drawings, photos, or other illustrations that provide essential information for installing the equipment or composite unit in accordance with the safety design intentions of the manufacturer and the requirements of these guidelines. For swing assemblies, these instructions shall include the manufacturer's recommended maximum suspending element length.

(iii) The manufacturer's recommended use zones for determining the placement of equipment.

(iv) Instructions for the general maintenance of the equipment or composite unit.

(b) Identification

(1) Requirement

A durable label shall be permanently attached to each piece of equipment or composite unit identifying:

(i) manufacturer

(ii) equipment model

(iii) month and year of manufacture

This label shall be placed on the equipment in a prominent location.

1514.4 Materials of Manufacture and Construction

(a) Durability

(1) Requirement

Equipment shall be constructed using materials that have a demonstrated record of durability in the playground or a similar outdoor setting. New materials without a demonstrated record of durability shall be tested in a manner considered appropriate by the manufacturer. Certification of those test results shall be provided upon request.

(b) Finish

(1) Requirement

Materials subject to corrosion or deterioration shall be plated, galvanized, painted, preserved, or otherwise treated to resist these effects. The manufacturer shall ensure that users of the playground equipment cannot ingest, inhale, or absorb through body surfaces any hazardous substance used in the treatment process.

(c) Stability

(1) Requirement

The equipment, when properly installed, shall withstand maximum anticipated forces tending to tip or slide the equipment. The manufacturer or designer shall provide certification that the equipment, if installed as directed in the installation instructions or as specified on construction drawings, will withstand maximum anticipated forces generated by the users.

(d) Hardware

(1) Requirement

Lock washers, self-locking nuts, or other locking means shall be provided for all nuts and bolts. Fasteners and connecting and covering devices when torqued and installed in accordance with the manufacturer's instructions shall not loosen or be removable without the use of tools.

(e) Strength of Individual Components and Structures

(1) Requirement

The playground equipment, when tested in accordance with paragraph (e)(2) of this section, shall withstand the specified loads. During and after the test there shall be no visible crack or breakage of any component. There shall be no other form of permanent deformation of any component that may adversely affect the structural integrity or safe use of the equipment.

(2) Test Method

The equipment shall be assembled and installed in accordance with the manufacturer's instructions. Individual components and the supporting structure shall be tested separately. The load for each test shall be determined and applied as specified in the following paragraphs. The load shall be applied gradually, attaining (but not exceeding) the specified value, and shall be maintained for at least five minutes. Where specified, the load shall be applied through appropriate load distribution devices having the dimensions shown in figure 1.

NOTE: If a structural member supports more than one apparatus, all apparatus shall be loaded simultaneously.

(i) Swing Assemblies and Structures Supporting Swing Assemblies

(A) Individual Swing Assemblies

Individual swing assemblies shall be tested in accordance with section 1514.4B of "Suggested Safety Requirements and Supporting Rationale for Swing Assemblies and Straight Slides."

(B) Structures Supporting Swing Assemblies

Center an appropriate load distribution device at each position intended to be occupied by a user on all swing assemblies. Simultaneously load each load distribution device with the force specified in table 1.

TABLE 1

Type of Swing Assembly	Vertical Downward Force in Pounds to Be Applied Per Load-Distribution Device	
	Structures Supporting One Assembly	Structures Supporting Two or More Assemblies
Single occupancy swing assembly	1200	900
Multiple occupancy swing assembly	725	600

(ii) Components and Structures Subjected to Vertical Loads

Estimate the number of simultaneous users, N, of a component or structure as specified in paragraphs (ii)(A) through (ii)(F) of this section. Place N load-distribution devices on the component or structure in a manner that simulates the anticipated load distribution. Simultaneously load each load-distribution device with a vertical downward force F_t given by the following equation:

$$F_t(\text{pounds}) = 300\ (N + 1)/N$$

(A) Individual Longitudinal Components

Measure the length of the component, L (in inches), and determine N from table 2.

NOTE: It is sufficient to test one of several components identical in size, material and method of construction.

NOTE: Components such as side pieces of ladders, top support bar or pipe of swing assemblies and the like, whose main function is obviously to support other components, need not be tested by this procedure.

TABLE 2

Length of the Component in Inches	Estimated Number of Simultaneous Users	
$L < 24$	$N = 1$	
$24 \leq L < 88$	$N = L/16$	Where necessary round off to the nearest integer. Round up if the fractional part is .5.
$L \geq 88$	$N = (L + 72)/32$	

(B) Structures Containing Two or More Longitudinal Components

Count the number of longitudinal components, L, and determine N from table 3.

TABLE 3

Number of Longitudinal Components	Estimated Number of Users	
$L \leq 5$	$N = L$	
$L > 5$	$N = (L + 5)/2$	When N is not an integer, round down to the next integer

(C) Individual Surfaces

For playground equipment surfaces such as decks, platforms, ramps, stair steps, or the like, compute the surface area, A (in square feet), and determine N from table 4.

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TABLE 4

Area of the Surface in Square Feet	Estimated Number of Users	
$A \leq 1$	$N = 1$	
$1 < A \leq 10$	$N = A$	Where necessary round off to the nearest integer. Round up if the fractional part is .5.
$A > 10$	$N = (A + 10)/2$	

(D) Structures Supporting Two or More Surfaces

Estimate the number of users, N, for each surface from table 4. Obtain N by summing the estimates for each surface:

$$N = N_1 + N_2 + N_3 \ldots$$

(E) Slide Beds

Estimate the number of users, N, as follows:

$$N = L/36,$$

where L is the length of the slide bed in inches.

(F) Other Structures

For other structures such as merry-go-rounds, see-saws, spring rockers or the like, estimate the number of simultaneous users, N, as follows:

(1) For apparatus with designated occupancy arrangements, N is equal to the number of designated occupancies.

(2) For apparatus without designated occupancy arrangements, make a reasonable estimate of N, including allowances for foreseeable misuse.

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(iii) Components Subjected to Lateral Loads

Components subjected to lateral loads such as guard rails, handrails, sides of barriers and enclosures, and the like, shall be subjected to the two separate tests specified below.

(A) Concentrated Load

Place an appropriate load distribution device on the component at any point to produce the most adverse effect. Apply a 460 pound horizontal force to the load distribution device in a direction perpendicular to the length of the component and away from the enclosed structure.

(B) Distributed Load

Apply a horizontal force, F, in a direction perpendicular to the length of the component and away from the enclosed structure. The force shall be applied near the top of the component and evenly distributed over the entire length of the component.

The test force is given by:

$$F(\text{pounds}) = 150L,$$

where L is the length of the component in feet.

1514.5 Sharp Points and Edges, Protrusions, Pinch and Crush Points

(a) Sharp Points and Edges

(1) Requirement

Following assembly in accordance with the manufacturer's instructions, there shall be no accessible sharp edges or points that can cut or puncture human tissue. The exposed open ends of all tubing not resting on the ground, or otherwise covered, shall be provided with caps or plugs that cannot be removed without the use of tools. Smooth finished caps, covers, or the equivalent, shall be provided for the purpose of covering accessible bolt ends. When properly torqued, the length of the

protruding bolt end shall be such that the cap or covering fits against the nut or surrounding surface. The caps or coverings shall not be removable without the use of tools.

NOTE: If the edge or point is questionable in terms of its injury potential it should be judged as being sharp.

(b) Pinch and Crush Points

(1) Requirement

There shall be no accessible pinch, crush or shear points caused by components moving relative to each other or to a fixed component when the equipment is moved through its anticipated use cycle. The determination of such points shall be based on the likelihood of entrapping a body appendage and the configuration and closing force of the components.

(c) Protrusions

(1) Requirement

When tested in accordance with paragraph (c)(2) of this section, no protrusion shall extend beyond the back surface of any of the three gauges having dimensions shown in figure 2.

(2) Test Method

Successively place each gauge (see figure 3) over each protrusion. If the requirement of paragraph (c)(1) of this section is not met, the equipment fails the test.

(3) Exclusions

Excluded from the requirement of paragraph (c)(2) of this section are the following:

(i) Protrusions that are inaccessible, with the exception of those that may be contacted by a child falling from the equipment.

(ii) Protrusions on the front and rear surfaces of suspended members of swing assemblies. These are subject to the requirement of section 1514.4D1 of the "Suggested Safety Requirements and Supporting Rationale for Swing Assemblies and Straight Slides."

(d) Suspended Hazard

(1) Requirement ✓

There shall be no cable, wire, rope or similar component suspended between components within 45 degrees of the horizontal that could be impacted by a child moving rapidly (greater than walking speed). Cables, ropes and other such items located 7 feet or more above the ground or equivalent surface are excluded from this requirement.

NOTE: It is not the intent of this requirement to eliminate such items as guard railings or series of ropes or cables such as cargo nets and climbing grids. This should be considered when evaluating a potential hazard.

1514.6 Equipment That Rotates About a Vertical Axis

(a) Speed

(1) Requirement

When measured in accordance with paragraph (a)(2) of this section, the measured speed, S_c, of the equipment shall meet the following requirement:

S_c (revolutions per minute) $\leq 66.4/\sqrt{R}$

where R is the maximum radius of the equipment in feet.

(2) Test Method

(i) Have a male adult, while standing in one location relative to the equipment, manually rotate the equipment to the maximum speed he can achieve.

NOTE: The adult shall be between 18 and 34 years of age, weigh between 150 and 190 pounds, and have a height between 68 and 73 inches.

(ii) Repeat the above procedure three times, using different subjects to rotate the equipment. Compute the average of these 3 trials (S_c).

(iii) Measure the maximum radius, R, of the equipment. If S_c meets the requirement of paragraph (a)(1), the equipment is acceptable.

(b) Base Configuration

(1) Requirements

The rotating component of all rotating apparatus intended to support standing or seated users shall incorporate a continuous base. The base shall meet the following requirements:

(i) The surface of the base shall be continuous with no opening between the axis and the periphery that permits a rod having a diameter of 0.3 inches to penetrate through the surface.

(ii) No component of the apparatus shall extend beyond the perimeter of the base.

(iii) The difference in the distances between the outermost and innermost points on the periphery of the base shall not exceed 2.0 inches (see figure 4).

1514.7 Entrapment

(a) General

(1) Requirement

Accessible components of moving apparatus and components adjacent to sliding surfaces (protective barriers, sides, handrails, etc.) shall not be of a configuration that can entrap any part of a user's body.

NOTE: The intent of this requirement must be considered in evaluating possible sources of entrapment. The intent is to ensure that a child's arms, hands, or other body parts cannot become lodged in the equipment when the momentum of the child or equipment is sufficient to cause injury or a loss of balance.

(b) Head Entrapment

A component or group of components shall not form an angle or opening that can trap a user's head. Angles and openings

that are accessible in accordance with paragraph (b)(2) of this section shall meet the following requirements.

(1) Requirements

(i) Angles formed by adjacent surfaces (see figure 5) on the boundary of an accessible opening, must exceed 55 degrees, or,

(ii) the distance between two opposing interior surfaces forming the boundary of an accessible opening shall not be less than 7 inches when measured perpendicular to each surface (see figure 6).

NOTE: For components that do not form a vertex as illustrated in figure 7, the angle is determined from the projected lines of intersection. This angle must meet the requirement of paragraph (b)(1)(i) of this section. Parallel surfaces must meet the requirement of paragraph (b)(1)(ii).

(2) Test Method

Attempt to insert a probe having dimensions shown in figure 8. If the probe penetrates an opening to a depth of at least 4 inches, or if the unbounded part of a partially bounded opening is at least 1.75 inches wide (see figure 9), the opening is accessible. If the opening meets the requirements of paragraph (b)(1) of this section, it is acceptable.

(3) Exclusions

(i) Angles less than 55 degrees whose lower leg projects more than 10 degrees below horizontal are excluded.

(ii) Angles and portions of accessible openings less than 24 inches above the ground or similar surface which provides the same opportunity as the ground for supporting the body are excluded.

(iii) Accessible openings that are completely unbounded by a lower surface are excluded (see figure 10).

(iv) Angles less than 55° that have been filled or similarly covered such that requirement

(b)(1)(ii) of this section is met are excluded (see figure 11).

1514.8 Falls from Equipment

(a) Elevated Surfaces

(1) Requirement

An elevated surface intended for use as a platform, deck, walkway, landing, transitional surface, or similar walking surface shall have a protective barrier at least 38 inches in height that completely surrounds the surface, except for necessary entrance and exit openings. The barrier shall not provide an opportunity for climbing on or over, or for falling through, and shall preclude the possibility of entrapment.

(b) Hand Gripping Components

(1) Requirement

Components intended to be grasped by the hands, such as rungs of horizontal ladders, climbing bars, hand rails, and the like, shall not exceed 1.6 inches in diameter or in the maximum cross-sectional dimension.

(c) Ladders and Stairways

(1) Requirement

(i) Slope

When measured from a horizontal plane:

(A) Ladders with rungs shall have a slope between 75 and 90 degrees.

(B) Ladders with steps shall have a slope between 50 and 75 degrees.

(C) Stairways shall have a slope no greater than 35 degrees.

(ii) Steps and Rungs

(A) Steps and rungs shall be horizontal (± 2 degrees).

(B) Steps and rungs shall be at least 15 inches wide (see figure 12).

(C) Steps and rungs shall be evenly spaced. The spacing shall be between 7 and 11 inches (see figure 12).

(D) Steps shall have a tread depth of 3 inches or more if the risers are open and 6 inches or more if the risers are closed (see figure 12).

(iii) Hand Rails

(A) Stairways and ladders with steps shall have continuous hand rails on both sides. The railings shall be designed to maintain the user in an upright position over each step.

(d) Slip-Resistant Surfaces

(1) Requirement

Components intended primarily for use by the feet shall have a finish that is slip-resistant under wet and dry conditions.

(e) Spiral Slide Chute Contour (Outer Portion)

(1) Requirement

When measured in accordance with 1514.9(e)(2), the chute contour shall satisfy either of the following conditions at all portions of the slide:

(i) If the primary mode of possible lateral discharge is determined to be tipping, then the effective edge height, y (see figure 19), shall satisfy:

$$y \geq y_c,$$

where

$$y_c = 9.5 - 6.5 \quad \frac{1.6\ (H/R)\tan\theta + 1}{1.6\ (H/R) - \tan\theta}$$

or = 2.5 inches, whichever is greater

(ii) If the primary mode of possible lateral discharge is determined to be lateral sliding,

then the effective banking angle, ϕ (see figure 20), shall satisfy:

$$\phi \geq \phi_c$$

where

$$\phi_c = \tan^{-1}(1.6\ H/R) - 11.3^{\circ}$$

NOTE: Values for y_c and ϕ_c have been computed for different values of H, R and θ and are included in appendix A.

NOTE: A chute contour is taken in a plane perpendicular to the inclination and outer edge of the sliding surface (see figure 13).

NOTE: All parameters are illustrated in figures 13 through 20.

(2) Test Method

(i) Determine the primary mode of possible lateral discharge as follows:

(A) The primary mode of lateral discharge is tipping if the chute contour is composed of perpendicular lines (see figure 14).

(B) The primary mode of lateral discharge is lateral sliding if the chute contour is a continuous curve with no abrupt change in the curvature (see figure 15).

(C) For chutes whose contour is such that the primary mode of lateral discharge is not obvious, construct a radius gauge shown in figure 16. If the radius of the chute contour is less than the radius of the gauge (this occurs when the gauge contacts the chute contour at two points as shown in figure 17b) the primary mode of lateral discharge is tipping; otherwise, the primary mode is lateral sliding.

(ii) Measure H, the vertical distance between the top of the sliding surface and the lowest point of the chute contour (see figure 13).

(iii) Measure R as shown in figure 18a if the primary mode of lateral discharge is tipping, or as shown in figure 18b if the mode is lateral sliding.

(iv) If the primary mode of lateral discharge is tipping, measure θ and y as shown in figure 19, and determine if the requirement of paragraph (e)(1)(i) is met.

(v) If the primary mode of lateral discharge is lateral sliding, measure ϕ by placing a bar 10 inches in length on the contour such that one end of the bar is touching the outermost edge of the chute, as shown in figure 20. Place an inclinometer on this bar, measure angle ϕ and determine if requirement (e)(1)(ii) is met.

(f) Spiral Slide Chute Contour (Inner Portion)

(1) Requirement

When measured in accordance with figure 21, the contour of the chute at the inner portion shall be such that

$d \geq 2.5$ inches

NOTE: The central support, where present, can be taken as the inner edge.

(g) Spiral Slide Exit Region: Slope, Length, Height and Radius of Curvature

(1) Requirement

Spiral slides shall meet the requirements of 1514.5C of the "Suggested Safety Requirement and Supporting Rationale for Swing Assemblies and Straight Slides."

(h) Slide Surface Entrance

(1) Requirement

Spiral slides shall meet the requirements of 1514.5D of the "Suggested Safety Requirement and Supporting Rationale for Swing Assemblies and Straight Slides."

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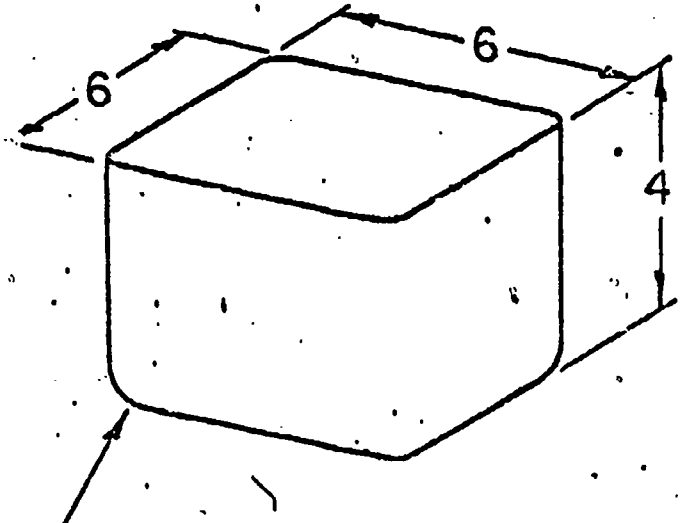
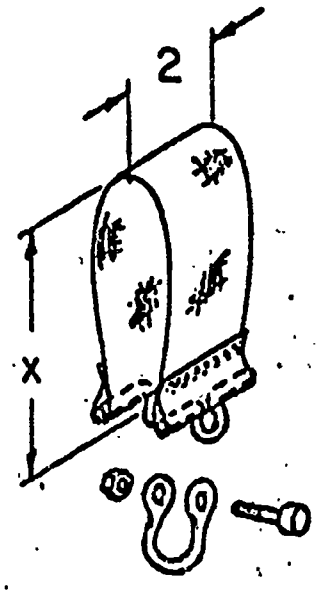
BLOCK



1/2 Rad (APPLIES TO ALL EXCEPT 4 TOP EDGES)



STRAP

NOTE: (1) BLOCK MADE OF ANY RIGID MATERIAL.
(2) VARY DIMENSION "x" AS REQUIRED.
(3) ALL DIMENSIONS ARE IN INCHES.

FIG 1 – LOAD DISTRIBUTION DEVICES

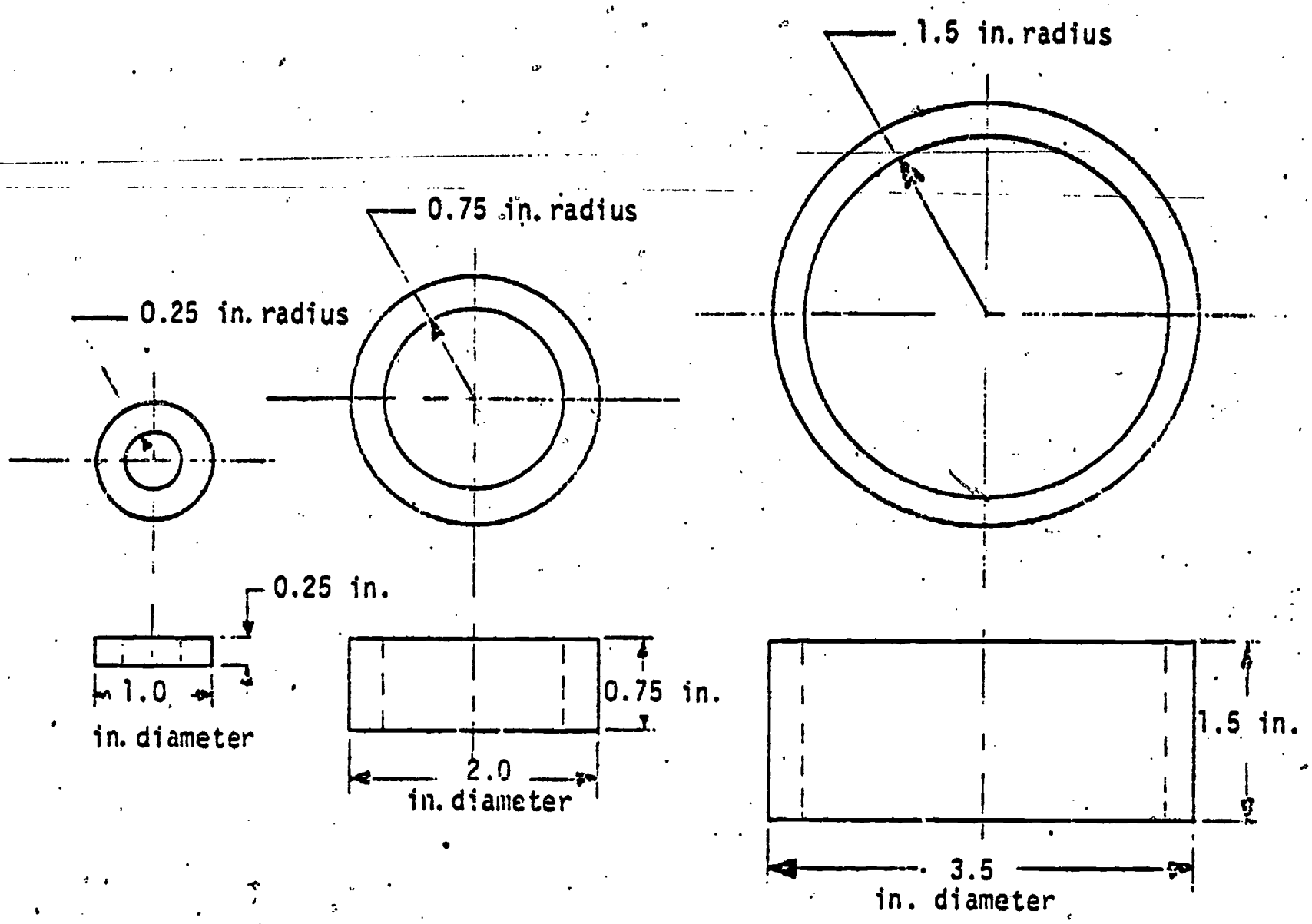


FIG 2. PROTRUSION TEST GAUGES

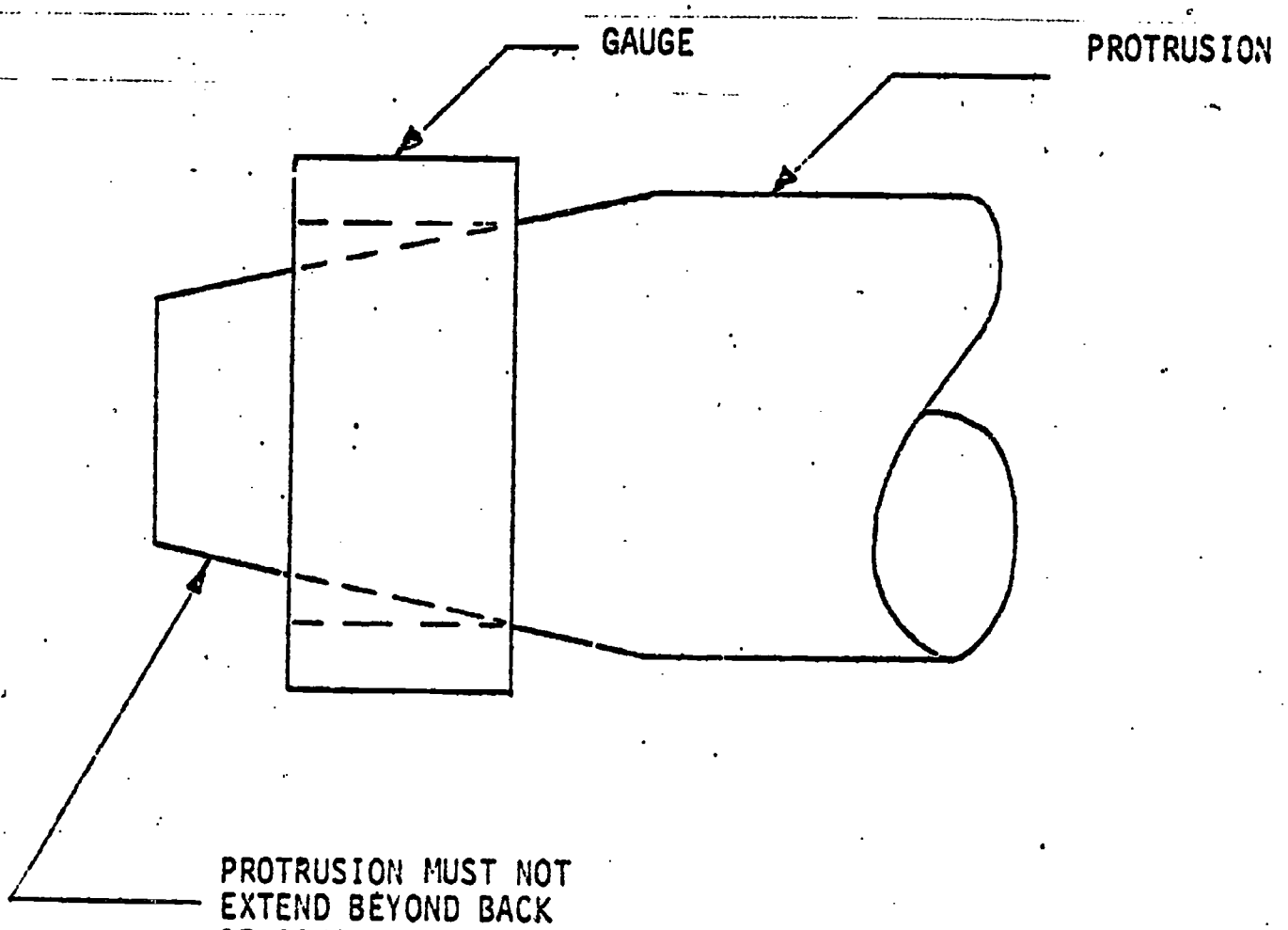
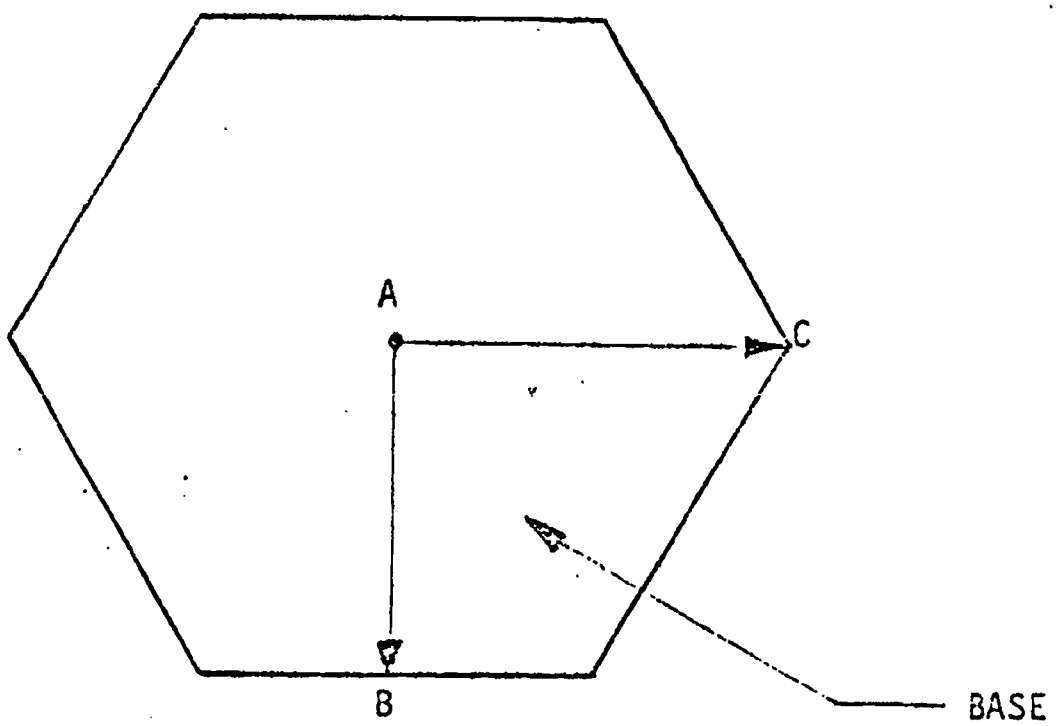


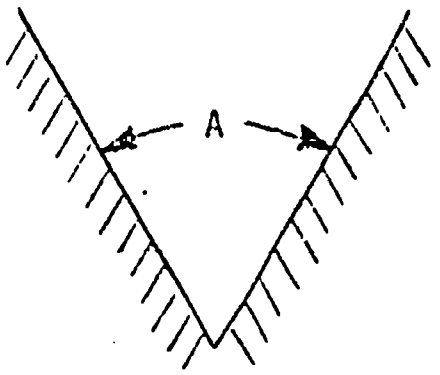
FIG 3. PROTRUSION TEST



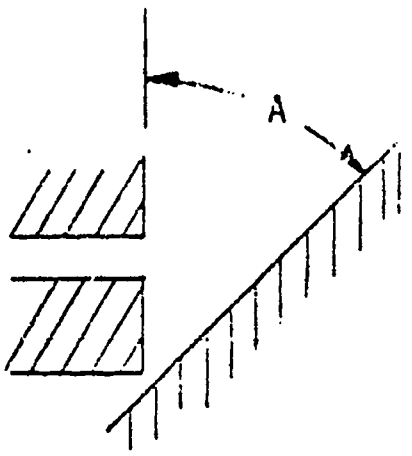
A = AXIS OF ROTATION
B = INNERMOST POINT ON THE PERIPHERY
C = OUTERMOST POINT ON THE PERIPHERY

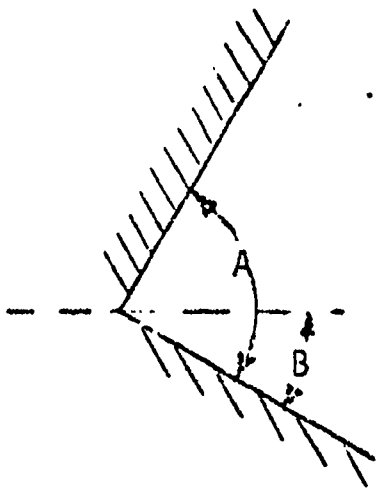
THE DIFFERENCE BETWEEN DISTANCES AC
AND AB MUST NOT EXCEED 2.0 INCHES.

FIG 4. OUTERMOST AND INNERMOST POINTS ON THE PERIPHERY OF THE BASE



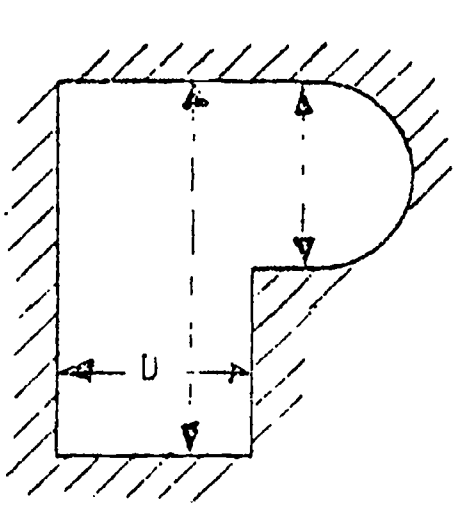
ANGLE A MUST EXCEED 55°

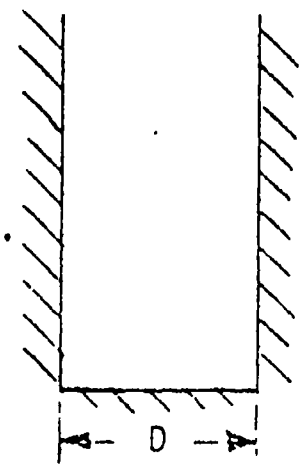


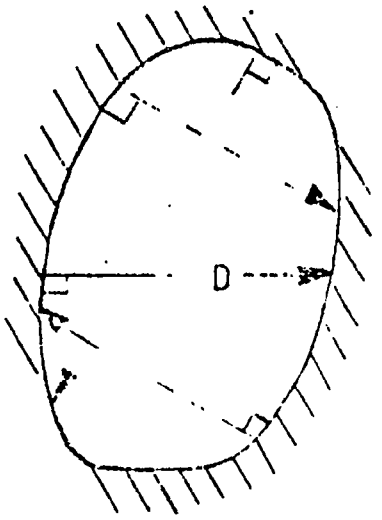


ANGLE A IS EXCLUDED IF ANGLE B IS MORE THAN 10° BELOW HORIZONTAL

FIG 5. ANGLES OF ACCESSIBLE OPENINGS







D MUST NOT BE LESS THAN 7 INCHES

FIG 6. PERPENDICULAR DISTANCE BETWEEN OPPOSING SURFACES

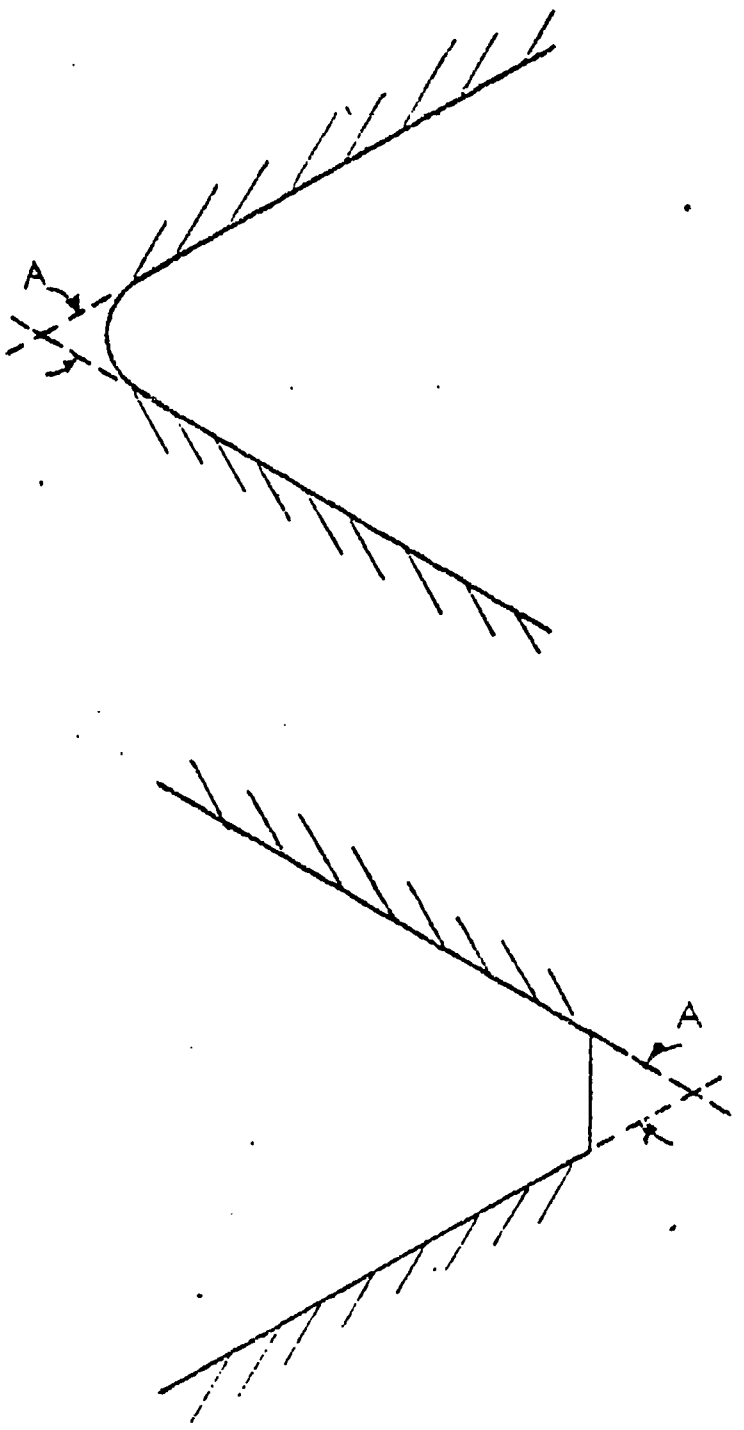


FIG 7. PROJECTED LINES OF INTERSECTION FOR DETERMINING ANGLE A

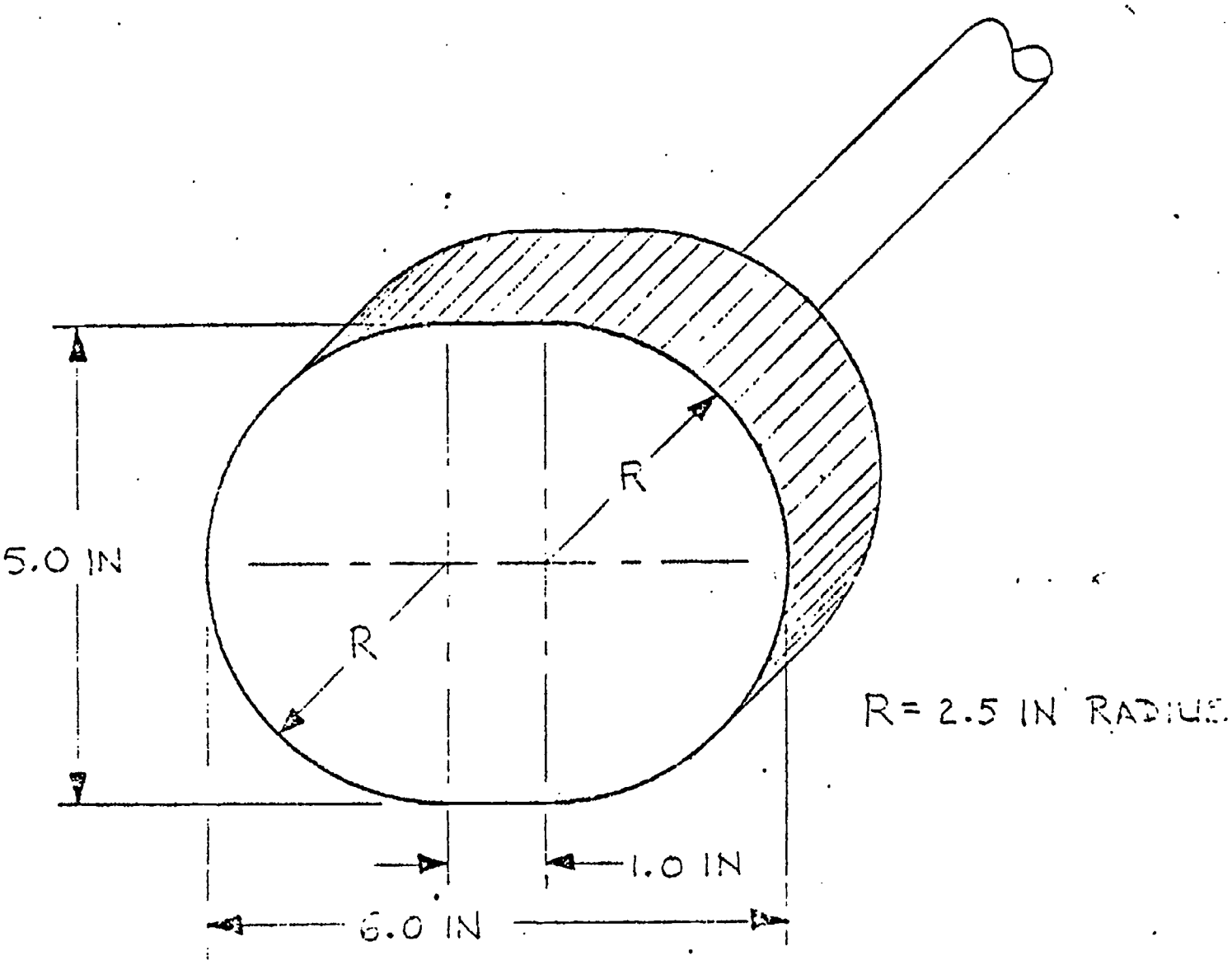
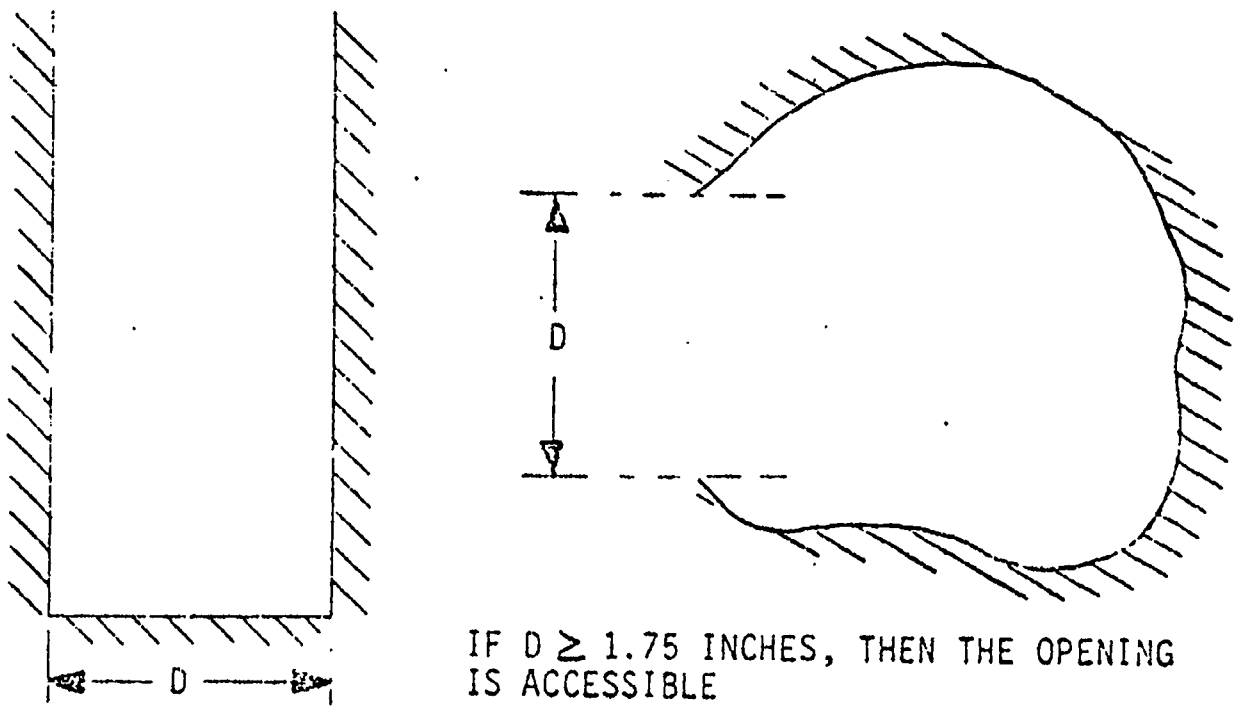


FIG 8. PROBE FOR DETERMING ACCESSIBLE OPENINGS



IF D ≥ 1.75 INCHES, THEN THE OPENING IS ACCESSIBLE

FIG 9. PARTIALLY BOUNDED OPENINGS

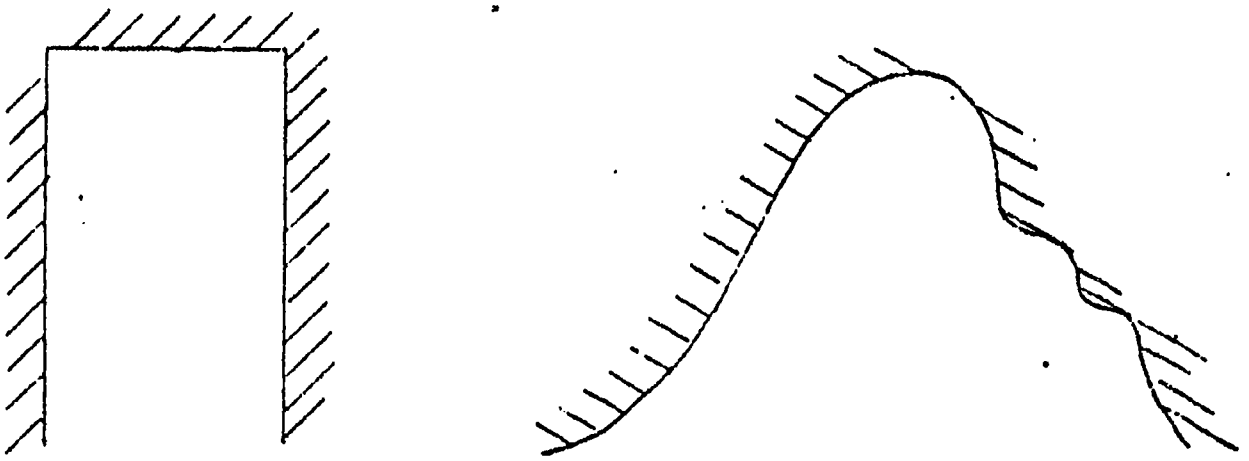


FIG 10. UNBOUNDED LOWER SURFACE EXCLUSION

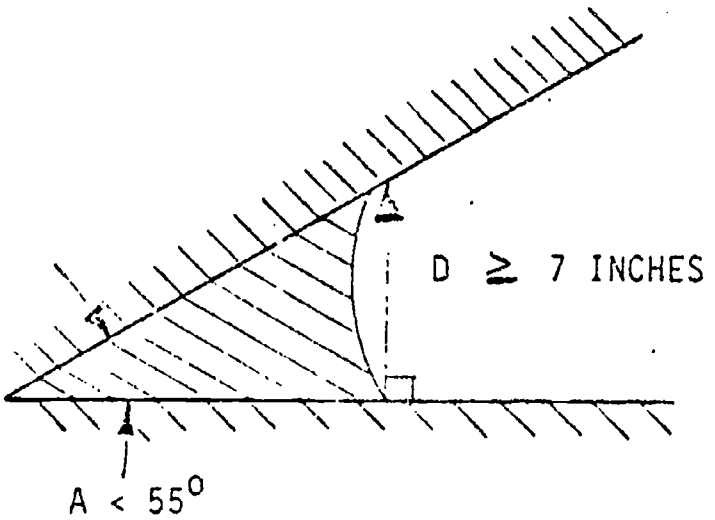
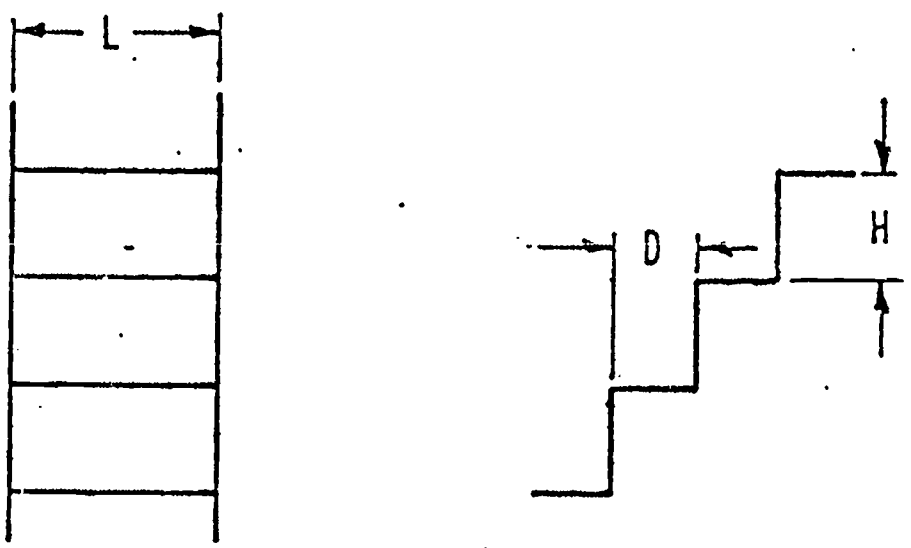


FIG 11. LESS THAN 55° ANGLE EXCLUSION

D ≧ 3 INCHES, IF OPEN
D ≧ 6 " , IF CLOSED

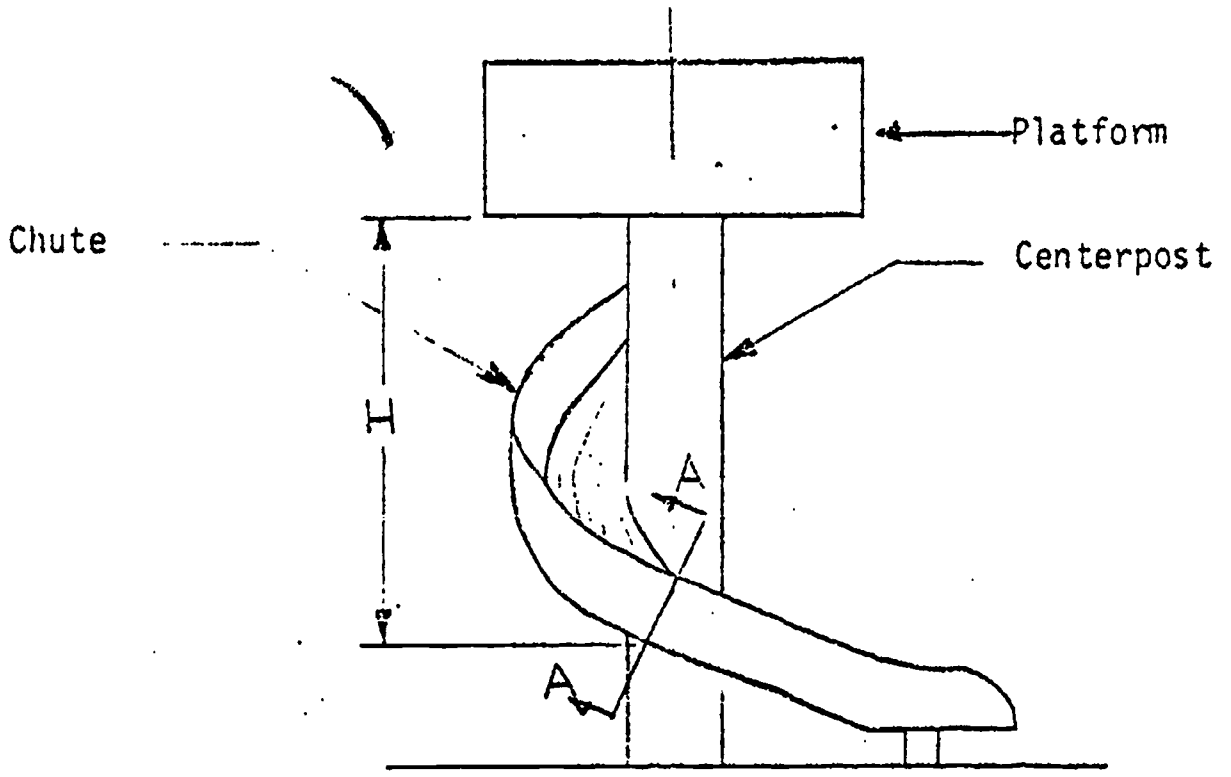
7 INCHES ≦ H ≦ 11 INCHES

L = 15 INCHES MINIMUM



FRONT — ELEVATION — SIDE

FIG 12—STEPS & RUNGS



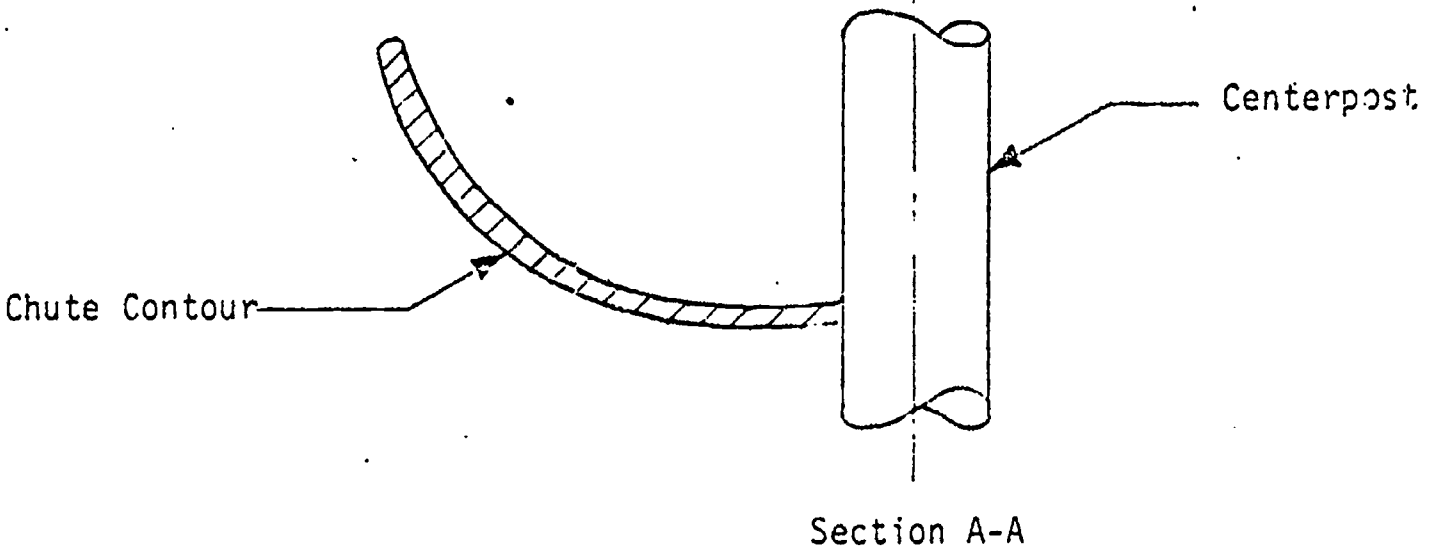


FIG 13. SCHEMATIC CROSS SECTION OF THE CHUTE SHOWING CONTOUR AND H

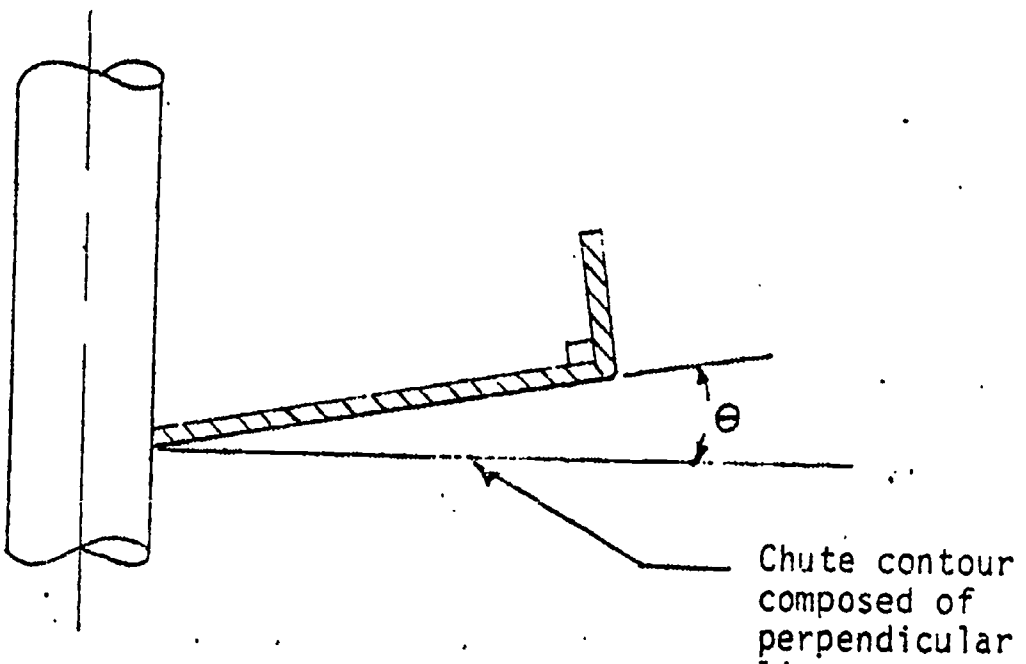


FIG 14. CROSS SECTION OF CHUTE WHOSE PRIMARY MODE OF LATERAL DISCHARGE IS TIPPING

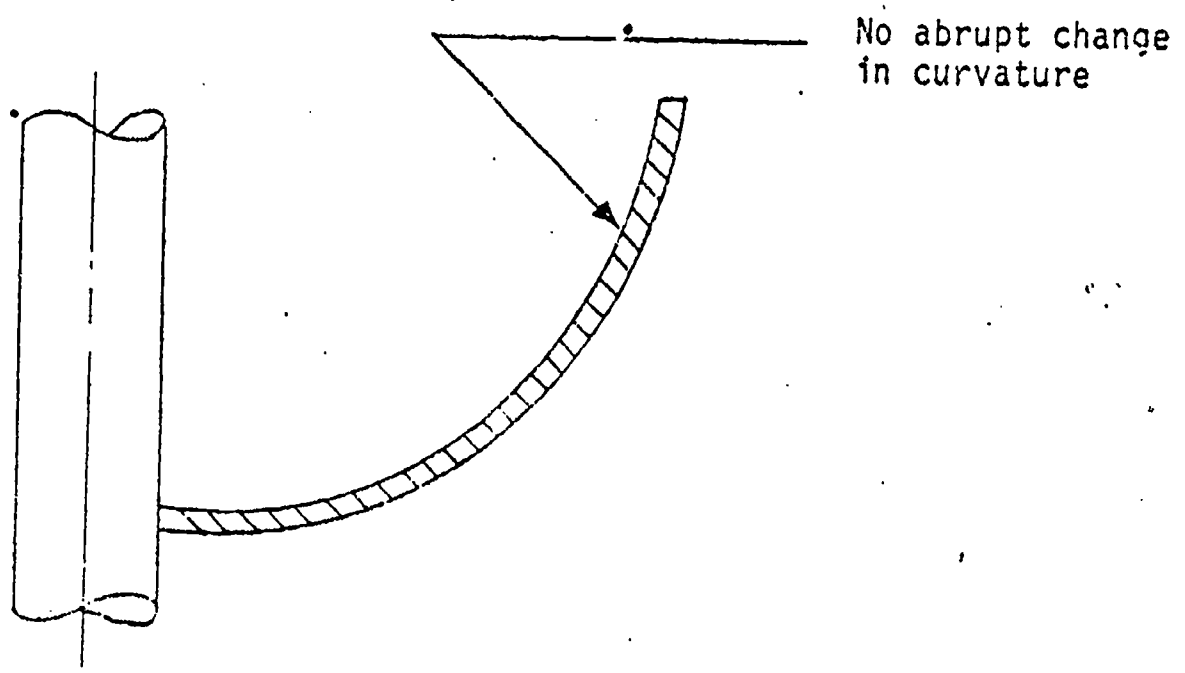


FIG 15. CROSS SECTION OF CHUTE WHOSE PRIMARY MODE OF LATERAL DISCHARGE IS SLIDING

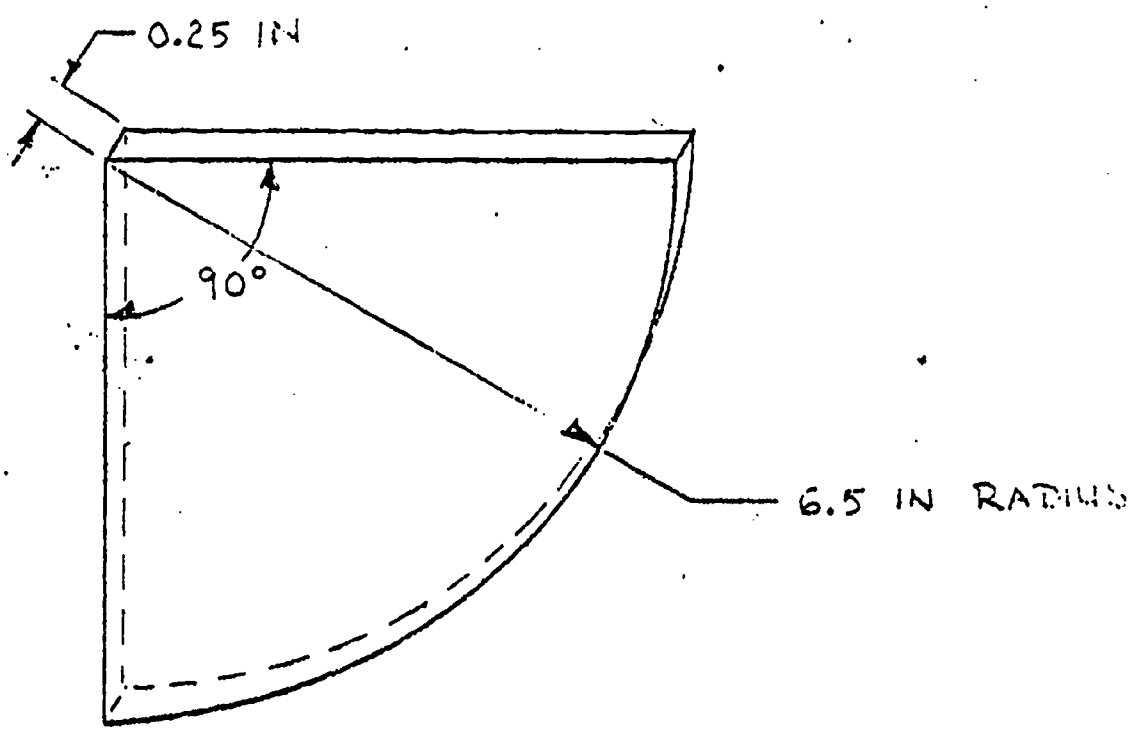


FIG 16. RADIUS GAUGE TO DETERMINE THE PRIMARY MODE OF LATERAL DISCHARGE

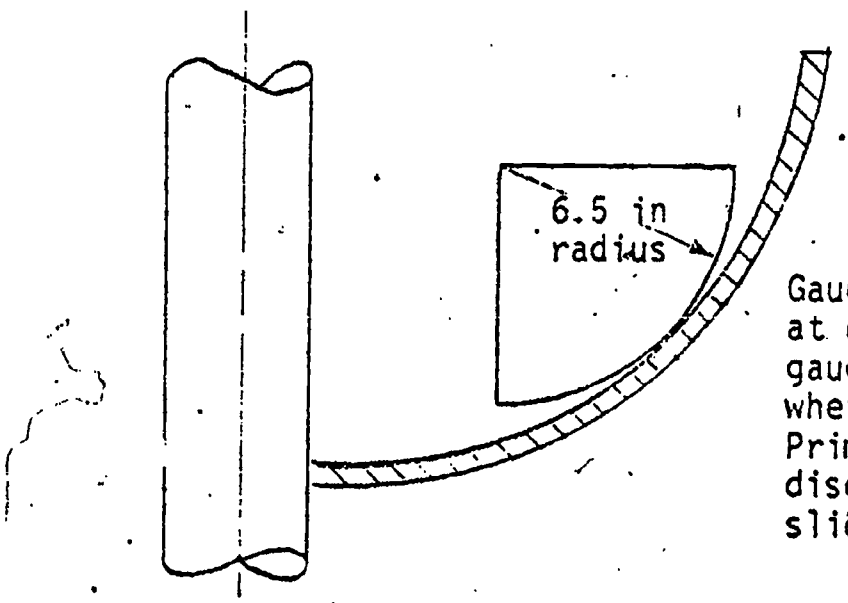


FIG 17a.

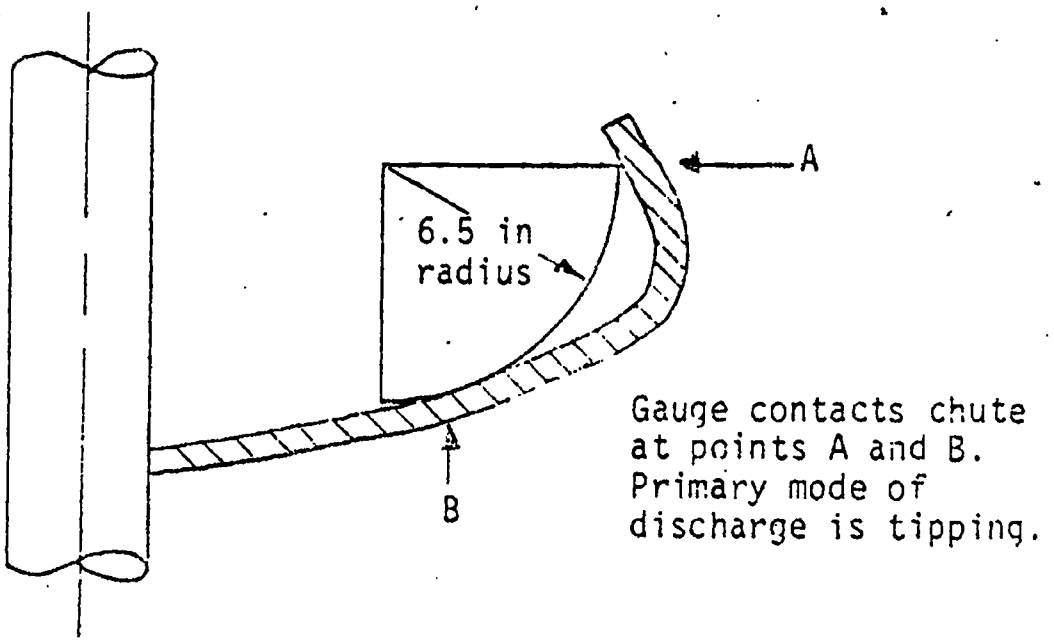


FIG 17b.

FIG 17. USE OF GAUGE TO DETERMINE PRIMARY MODE OF LATERAL DISCHARGE

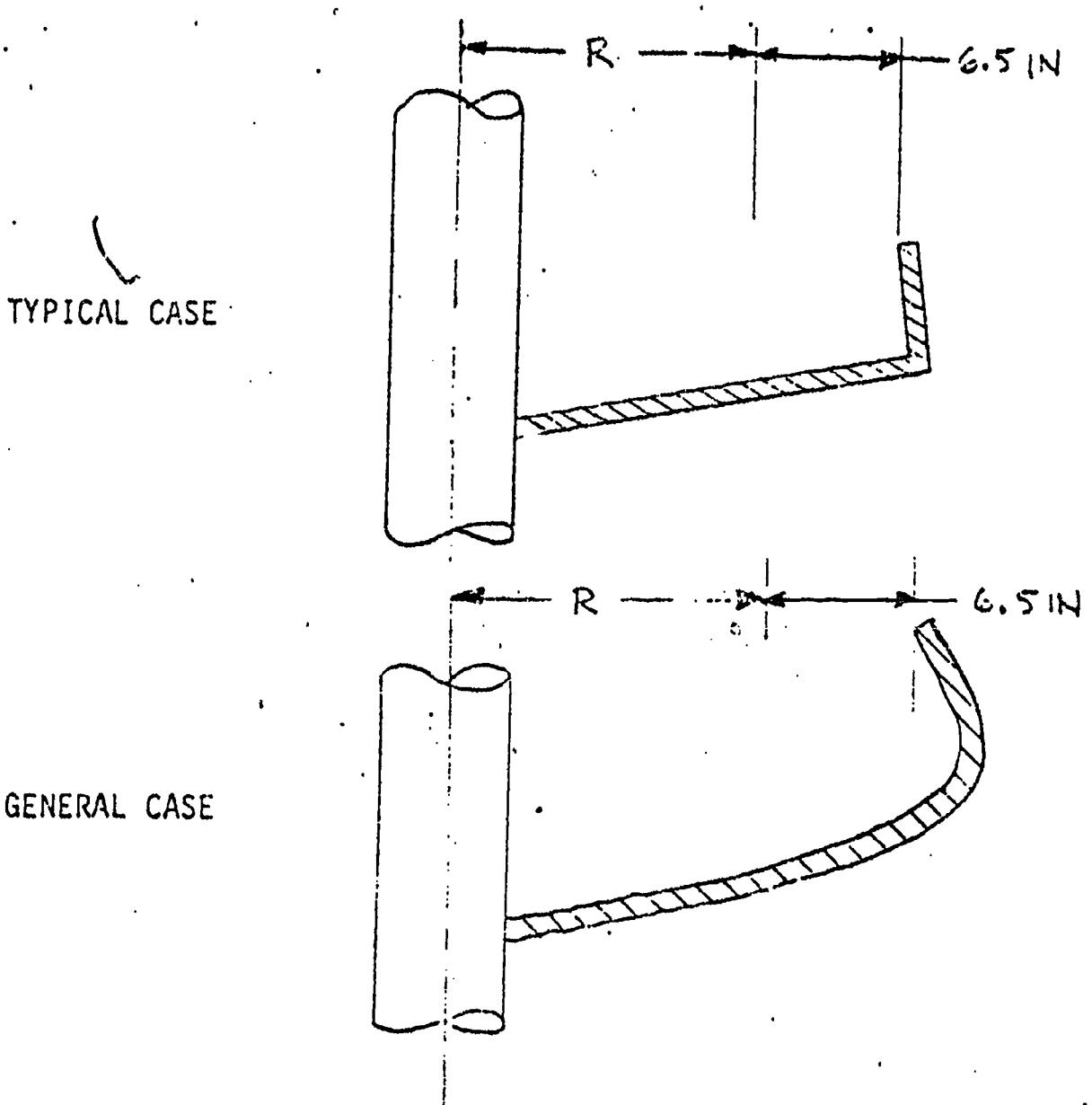


FIG 18a. TIPPING MODE

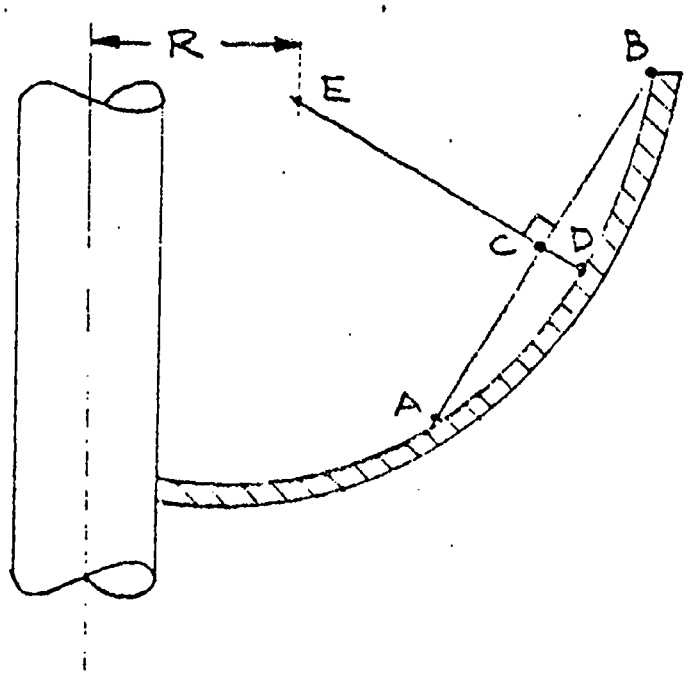


FIG 18b. LATERAL SLIDING MODE

FIG 18. SCHEMATIC OF PROCEDURE TO MEASURE R

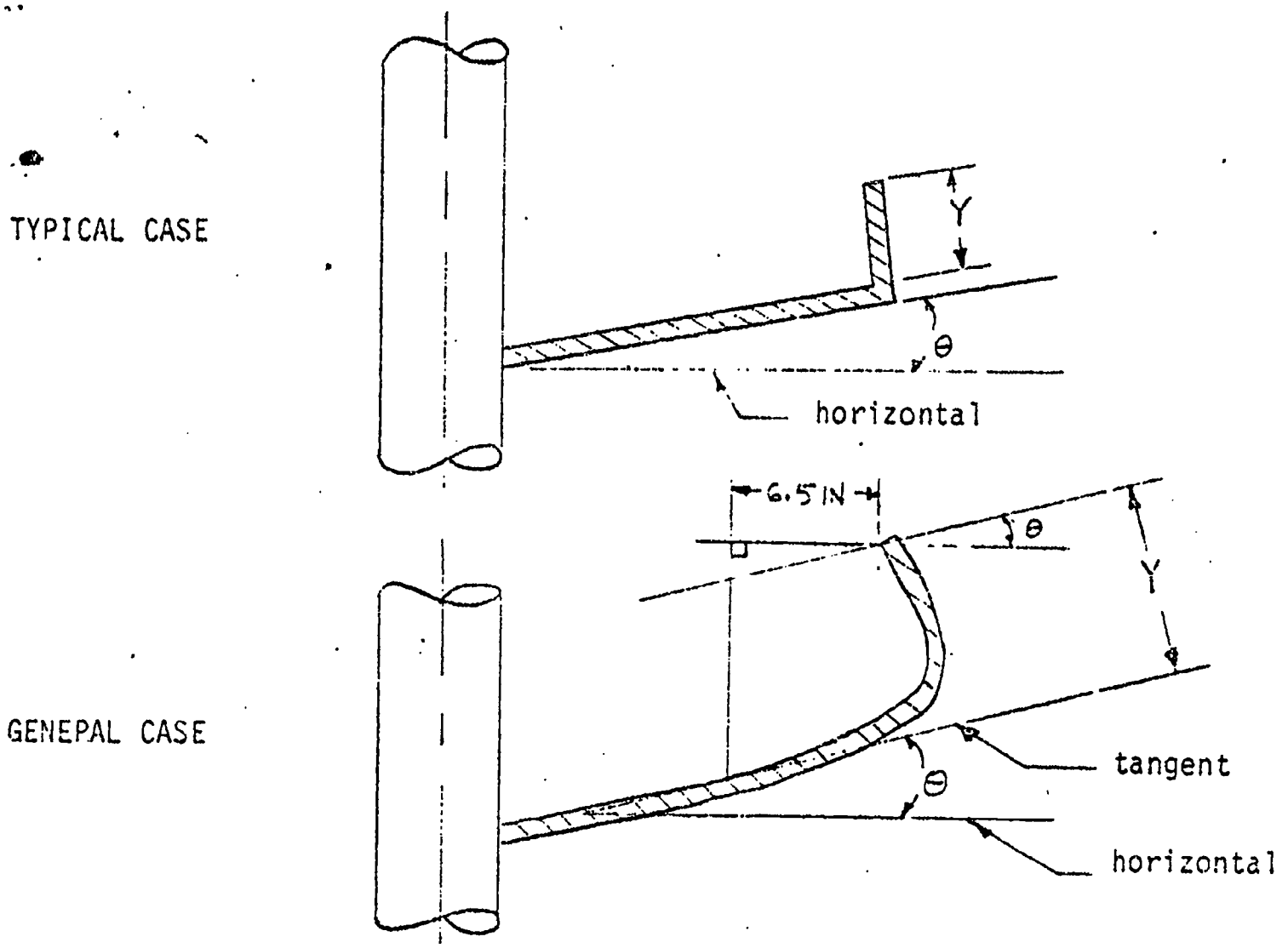


FIG 19. SCHEMATIC OF PROCEDURE TO MEASURE y and θ

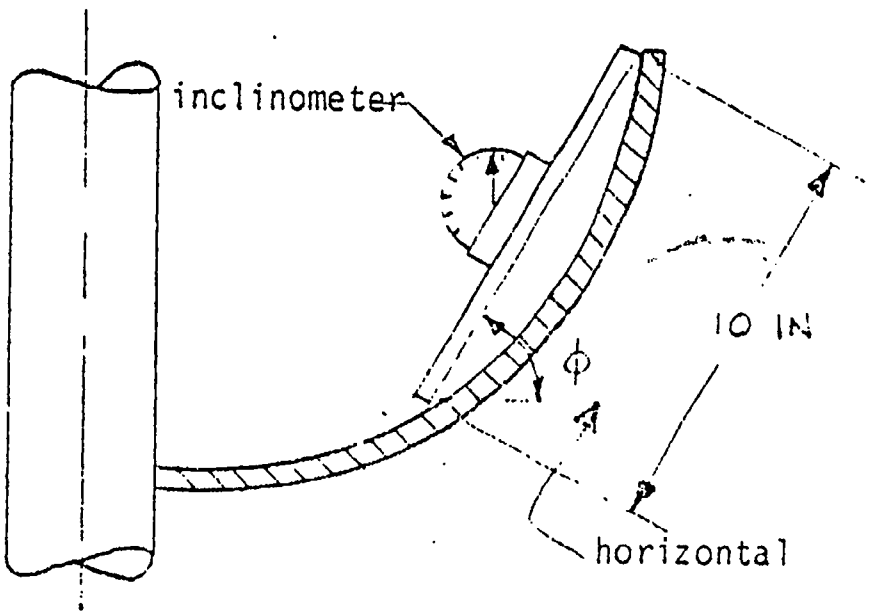
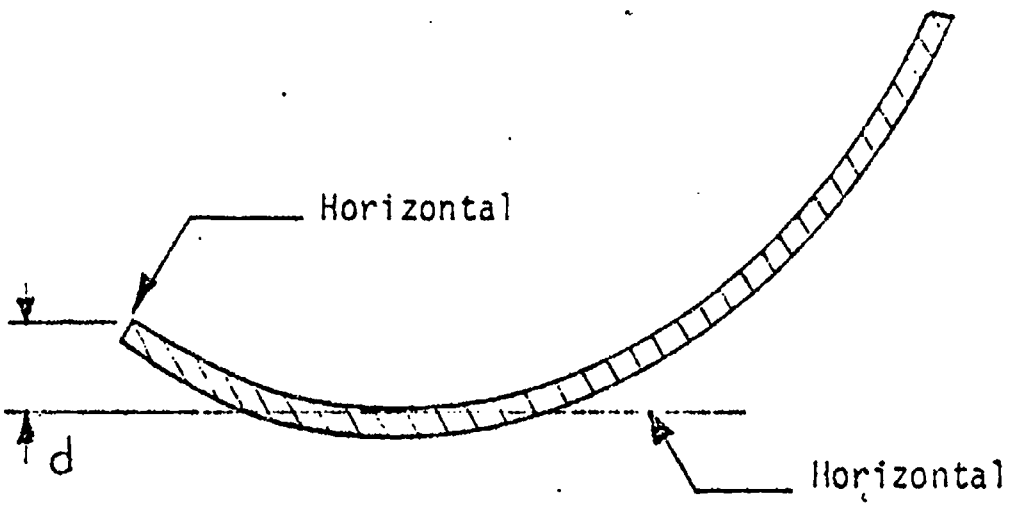


FIG 20. SCHEMATIC OF PROCEDURE TO MEASURE ρ



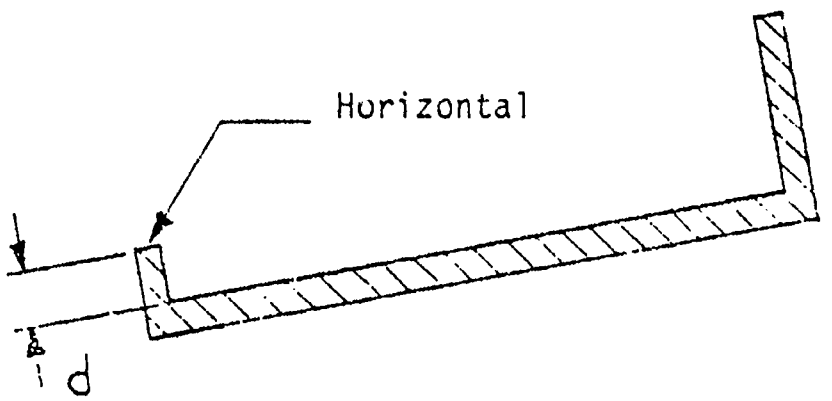


FIG 21. SCHEMATIC SHOWING MEASUREMENT OF d

III. SUPPORTING RATIONALE

1514.3 Assembly, Installation and Maintenance Instructions and Identification

The rationale for including installation and maintenance instructions with each piece of equipment or composite unit is fairly obvious. If playground equipment is improperly installed or maintained, the intent of these guidelines as well as the manufacturer's interest in safe play equipment, may be negated. The manufacturer has control over his product up to delivery, then it becomes the responsibility of the buyer/installer. The manufacturer is in the best position to have expert knowledge concerning proper methods of installation and maintenance and consequently should provide this information. Literature included with the equipment is a practical method for conveying this information: it ensures that the buyer/installer is provided necessary information for proper installation and maintenance.

It is also important for the source and date of manufacture of a piece of equipment to be available so that in the event a hazard is discovered, the manufacturer can be readily identified and consulted concerning the deficiency and remedy.

1514.4 Materials of Manufacture and Construction

Durability/Finish

The requirements to use proven durable materials in the construction of playground equipment and to plate, galvanize, paint or otherwise treat materials that are subject to deterioration are intended to minimize the possibility of hazards resulting from abnormal wear, weathering, fatigue, or other unexpected forms of degradation. The concept of durability relating to playground equipment is, however, subjective. Playground equipment, as with any mechanical device, has a finite service life. This interval is determined by the materials used in construction, the frequency and intensity of use to which the equipment is subjected, exposure to the elements, and the effectiveness of equipment maintenance. A more conclusive requirement and test method addressing these factors could be developed. However, this may not be justified, for the NRPA writes:

> There is little evidence that durability represents a problem at the present time on public playground equipment, nor is there evidence of basic material deterioration that has caused failure of the equipment and a resulting injury. Competition in the public playground market has resulted in a high level of durability in current equipment. Buyer/installers have generally insisted on heavy-duty

equipment that does not have to be replaced within what they consider to be a reasonable period of time.

This requirement, therefore, ensures a continued "high level of durability."

Stability

The intent of this requirement is to ensure that the equipment cannot be overturned by the user or a group of users when properly installed. No test method is specified here as stability can normally be computed using standard practices. Stability depends on the manner in which the equipment is installed in the ground; footing sizes and depths will vary depending on local soil conditions. Section 1514.3(a) of the guidelines requires that specific installation guidance be given the buyer/installer.

Hardware

The manufacturer is required to provide lock washers, lock nuts, or other types of locking devices for all bolts and nuts. This ensures that these devices are available to the buyer/installer and when installed in accordance with the manufacturer's instructions, bolts and nuts cannot easily be loosened through normal operation of the equipment or be removed by children. In general, all fasteners and covering devices should not be removable without the use of tools.

Strength of Individual Components and Structures

The intent of these requirements is to ensure that playground equipment and its components are designed with adequate strength to withstand load conditions resulting from the normal use and reasonably foreseeable misuse. However, it is difficult to calculate actual loads due to the many ways in which users can use or misuse playground equipment. Furthermore, variations in the design and configuration of playground apparatus make it impossible to devise a test procedure applicable to all. The strength requirements are based on anthropometric data 3/, engineering judgement, and applicable sections of building codes 4/.

A playground apparatus, or a component of playground equipment, is considered to have adequate strength if it can support, without failure, a minimum superimposed static test load equal to two and one-half (2 1/2) times the anticipated live load. This test load factor is commonly used by structural engineers, and is recommended in the BOCA Basic Building Codes 4/. The determination of anticipated live loads for different components of playground equipment and different playground apparatus is explained in the following sub-sections.

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Anticipated live loads are estimated by assuming that all users are maximum users, each weighing 120 pounds. This corresponds to a use condition with the maximum live load.

To ensure that applied test loads reasonably simulate actual load conditions, it is recommended that loads be applied through appropriate load distribution devices, such as blocks or straps having dimensions shown in figure 1.

Swing Assemblies and Structures Supporting Swing Assemblies

Supportive technical rationale for testing individual swing assemblies is given in the section 1514.4B of the "Suggested Safety Requirements and Supporting Rationale for Swing Assemblies and Straight Slides." For testing the strength of structures supporting only one swing assembly, the test loads determined for individual swing assemblies are appropriate. The use conditions assumed for individual swing assemblies are much less likely to occur simultaneously for two or more swing assemblies. Therefore, these test loads are not suitable for testing structures that support two or more swing assemblies. For estimating these test loads, the following use conditions are assumed: 1) each swing assembly is occupied by the number of users for which it is designed, 2) each user weighs 120 pounds, 3) a single occupancy swing is swung through a 180 degree arc, 4) a multiple occupancy swing is swung through a 120 degree arc, and 5) each swing assembly behaves like a simple pendulum. Live loads corresponding to these conditions are 360 pounds per user for single occupancy swings, and 240 pounds per user for multiple occupancy swings. Applying the test load factor (2 1/2), the recommended test loads are 900 pounds per user for single occupancy swings and 600 pounds per user for multiple occupancy swings.

Components and Structures Subjected to Vertical Loads

The live load for a given component or playground apparatus is based on the estimated number of simultaneous users of the component or apparatus, and an overload factor to allow for shock and vibration resulting from the user's activities. One user can shock load a component giving rise to an overload equal to his/her weight. Several users, say K, can shock load a component giving rise to an overload equal to their combined weight. However, this calculated live load is excessive because it is unlikely that K users would shock load the component at the same instant. The live load per user (user's weight plus overload) should therefore decrease as the number of users increase. An appropriate relationship for determining the live load can be obtained from,

$$F_L = \frac{W(N + 1)}{N} = \frac{120(N + 1)}{N}$$

where F_l is the live load per user in pounds, N is the number of simultaneous users, and W is the weight of a maximum user (120 pounds).

As shown in figure 22, this equation provides a systematic decrease in the live load per user as the number of users increases. As stated earlier, the test load should be two and one-half times the live load.

The procedures for estimating the number of simultaneous users of different components and apparatus are discussed in the following paragraphs. These procedures are based in part on anthropometric measurements of a maximum user and, in part, on subjective judgement and anticipated use patterns.

Individual Longitudinal Components

Longitudinal components include climbing bars and tubes, ladder rungs and steps, railings, cross pieces of A-frames, and the like.

A component which is just long enough (about 4 inches) to provide room for a hand or foot hold can be occupied by only one user. However, users need more than this minimum length component to carry out their play activities. It may be assumed that shorter components will be used to capacity, but that the likelihood of a component being used to capacity decreases as its length increases.

Based on these considerations, the procedure specified in the test method provides a reasonable means for estimating the number of simultaneous users.

It is assumed that the primary function of components that make an angle of 45 degrees or greater with the horizontal is to support other components, and such components need not be tested individually. Also, some components of playground apparatus, whose main function is obviously to support other components (such as side pieces of ladders, top support bars or pipes of swing assemblies, and the like) need not be tested individually. The strength of these components is tested when the supported components are loaded.

Structures Containing Two or More Longitudinal Components

Playground apparatus that contain two or more longitudinal components include climbing apparatus, ladders, and the like. Apparatus of this type having a few longitudinal components are likely to be used to capacity. An apparatus which has a large number of longitudinal components is unlikely to have each component occupied simultaneously. The procedure specified in the test method provides a means for estimating the number of

simultaneous users. The procedure assumes that individual components are occupied by at most one user each.

Individul Surfaces

Playground equipment surfaces include decks, platforms, ramps, stair steps, and the like. In general, surfaces having a small area (less than 20 square feet) are more likely to be used to capacity than those with larger areas. The minimum surface area occupied by a maximum user is approximately one square foot, based on the shoulder breadth (26 inches) and foot length (10 inches) of a maximum user. The procedure specified in the test method provides a means for estimating the number of simultaneous users.

Slide Beds

A reasonably foreseeable misuse condition of slides is for more than one child to occupy the slide bed at the same time. The procedure specified in the test method for estimating the maximum number of simultaneous users is based on the length of the slide bed and the seated length of a maximum user. The seated length is taken to be the average of the maximum user's waist and trochanteric heights.

Components Subjected to Lateral Loads

Components of playground equipment that are subjected to lateral forces include guardrails, handrails, sides of barriers and enclosures, and the like.

The requirements of this subsection are partly based on applicable sections of an NBS performance standard for guardrails 5/. It is assumed that these components of playground equipment are subjected to two live loads described in that report.

1. Accidental load (A). The accidental load, A, is a concentrated force not exceeding 300 pounds.

2. Surge load (S). The surge load, S, is a force of 100 pounds per foot distributed over the length of the component.

The numerical values for the accidental load, A, were derived from the results of dynamic load tests using anthropometric dummies falling backward from a standing position against an instrumented mock-up rail. The dummies utilized in these tests were representative of the 95th percentile adult male weighing about 197 pounds. The surge load, S, was obtained from another experiment using representatives of the 50th percentile adult male weighing about 162 pounds 6/.

If it is assumed that the results of these experiments can be scaled down for 12 year-old children on the basis of weight alone, then the anticipated accidental live load, F_1, and live surge load. F_2, applicable to playground equipment components are given below.

$$F_1 = 300\ (120/197) = 183 \text{ pounds}$$

$$F_2 = 100\ (97/162) = 60 \text{ pounds/foot}$$

In the above calculations of F_1 and F_2, the 95th percentile and 50th percentile weights are used respectively.

These components of playground equipment should be tested for both anticipated load conditions separately. Therefore, two different tests are recommended. Applying the test load factor (2 1/2), test loads corresponding to F_1 and F_2 are 460 pounds and (150)L pounds respectively, where L is the length of the component in feet.

1514.5 Sharp Points and Edges, Protrusions, and Pinch and Crush Points

Sharp Points and Edges

This requirement is intended to preclude accessible points and edges that may lacerate or puncture human tissue. An objective test procedure for determining sharp points and edges has not been developed, although research in this area relative to other products is continuing. The results of that research may eventually have application to playground equipment. In the interim, the potential for a point or an edge to puncture or lacerate human tissue must be based on judgement alone.

Since the ends of tubing are capable of lacerating tissue on impact, plugs or caps are required to cover all exposed ends.

The exposed threaded ends of bolts are generally of a diameter that could cause a puncture, eye injury, or laceration. The requirement that bolt ends that protrude beyond the nut or surrounding surface be capped or covered is intended to remove these hazards. It should be noted, however, that the bolt end and covering is a protrusion and, therefore, subject to the requirement of section 1514.5(c)(1).

Pinch and Crush Points

Components that move relative to each other or to a fixed component can cause serious injuries such as amputations, fractures, and contusions. No test method is provided because the configuration and location of such points varies considerably as does the potential for injury in terms of the body part that may be entrapped and the forces which may be exerted.

Protrusions

These requirements are intended to prevent protrusions that may puncture, impale, produce an eye or ear injury or which are catch points for clothing that could result in falls. Protrusions of this type are identified if they protrude beyond the back surface of any of the three specified gauges.

A small diameter protrusion, because of its small surface area, generally presents a greater risk of penetration than does a larger protrusion. The gauges, therefore, have been dimensioned accordingly. The specific dimensions are based on judgements; the thickness and inside diameter dimensions were proposed by the NRPA. The gauge with the smallest opening ensures that no protrusion smaller than 0.5 inch diameter extends more than 0.25 inch from the surrounding surface. The gauge with the 1.5 inch opening ensures that no protrusion with a diameter between 0.5 inch and 1.5 inches extends beyond 0.75 inch. This is especially critical because a protrusion not meeting this requirement could project into the eye socket to a depth that could result in a serious injury. The third gauge has an inside diameter of 3.0 inches and is 1.5 inches thick. Thus, protrusions having a diameter between 1.5 and 3.0 inches cannot extend more than 1.5 inches beyond the surrounding surface.

The width of each gauge, that is, the difference between the outside radius and inside radius is substantially smaller than that proposed by the NRPA. The argument for a larger width is based on a premise that several protrusions clustered together act as a surface (see figure 23) and consequently do not present the hazard that a single protrusion does. This premise may be valid for protrusions on the interior of such an arrangement but not necessarily for those on the exterior. For example, consider protrusions A and C of figure 23: Such protrusions are capable of contacting the eye. The eye itself protrudes from the eye socket. The gauge width specified in this requirement is 0.25 inch for each gauge. This width will treat all but closely clustered protrusions as individual protrusions.

No distinction is made between horizontal and vertical protrusions. Since a child can attain many different positions while playing on most equipment, it is improbable that the injuring potential of a protrusion is significantly dependent upon its orientation. For this reason, the requirement in this section does not differentiate between horizontal and vertical protrusions.

Suspended Hazards

This requirement is intended to ensure that individual wires, cables, ropes, cords or the like are not suspended in a manner that a user could contact them, especially at head or neck level, while moving rapidly between the points from which the item is suspended.

This type of injury could occur from a child riding a bicycle or running and contacting a cable at neck height. Cables, ropes, or other such items that are located 7 feet or higher above the ground or other surface form which a user could develop momentum, are exluded from this requirement.

1514.6 Equipment That Rotates About a Vertical Axis

Speed

The intent of this requirement is to reduce the risk of falls and subsequent injuries resulting from excessive speed of rotating equipment.

Based on limited injury data it appears that falls associated with the speed of rotating equipment occur as follows: 1) a user may lose his/her balance when getting on or off the equipment; or 2) a user may be thrown off the moving equipment by the action of centrifugal force.

Ideally, for a user to maintain balance when getting on or off the equipment, the speed of the equipment should be zero. However, a user who is getting on or off moving equipment can maintain a reasonable balance if he/she moves (runs or walks) with a velocity (speed as well as direction) equivalent to that of the rotating equipment just before getting on or immediately after getting off the equipment. In actual play conditions, children generally get on or off the equipment while it is moving, hence the maximum attainable speed of rotation should be limited. This limiting value of the speed should be within the running capabilities of the users of the equipment.

A study by John A. DeBenedictis 7/, indicates that an eight-year old is capable of running 100 yards in 13 seconds. However, this speed (23 ft/sec) is probably beyond the capability of most eight-year olds. Data on the running capabilities of children in general are not available. Also, the running capability varies among children of the same age group. Therefore, the speed at which users can get on or off the moving equipment without losing their balance can only be arrived at subjectively.

The second way in which falls occur from rotating equipment is through the action of the centrifugal force. The magnitude of centrifugal force acting on a user who is occupying a rotating apparatus is given by:

$$F = \frac{W}{g}\left(\frac{\pi^2 N^2}{900} r\right) \qquad (1)$$

where:

F = centrifugal force (pounds)

W = weight of the user (pounds)

g = acceleration due to gravity (ft/sec^2)

r = radius of the circle described by the user's center of gravity (ft)

N = rotational speed of the equipment or of the user occupying the equipment (rpm)

This force is maximum when r is equal to the maximum radius, R, of the rotating equipment, or

$$F_{max} = \frac{W}{g} \left(\frac{\pi^2 N^2 R}{900}\right) \qquad (2).$$

The force, F, acts along the radius, r, passing through the user's center of gravity and is directed away from the axis of rotation. This force tends to pull the user off the equipment. This action of centrifugal force is resisted by: 1) the user's act of gripping the handholds provided for this purpose, and 2) the force of friction between the user and equipment. The magnitude of the force of friction in some situations may be negligible. In these situations, the pull of centrifugal force is primarily resisted by the user's act of gripping the handholds. Hence, the maximum allowable magnitude of centrifugal force must be less than or equal to the magnitude of the force that the user is capable of supporting with his/her arms while gripping the handholds. Data concerning this capability for users of the equipment are not available. However, children have often been observed doing chinups or swinging through large arcs while holding onto overhead components, thus supporting, for a short while, a force equivalent to twice their weight. For longer durations, it is assumed that most children are capable of supporting a force equivalent to one and one-half times their weight while holding onto handholds. Hence, the maximum magnitude of centrifugal force should be less than or equal to one and one-half times the user's weight (W), that is,

$$F_{max} = \frac{W}{g} \left(\frac{\pi^2 N^2 R}{900}\right) \leq 1.5\ W \qquad (3).$$

Equation (3) may be solved to obtain the maximum permissible rotational speed, N_c, of the moving equipment as,

$$N_c = \left(\frac{30}{\pi}\right) \sqrt{1.5\ \frac{g}{R}} = \frac{66.4}{\sqrt{R}} \qquad (4).$$

The peripheral speed, V, of the rotating equipment corresponding to N_c, may be obtained as,

$$V(ft/sec) = \frac{\pi}{30} RN_c = 6.94 \sqrt{R} \qquad (5).$$

Equations (4) and (5) are utilized to calculate the values of N_c and V for nominal values of R. These values of N_c and V are given in table 5.

TABLE 5

R (ft)	N_c (rpm)	V (fps)
2	46.9	9.8
3	38.3	12.0
4	33.2	13.1
5	29.7	15.5
6	27.1	17.0
7	25.1	18.4

The maximum radius of most rotating equipment is between 2 and 7 feet. The peripheral speed, V, corresponding to the permissible rotational speed, N_c, for rotating equipment with maximum radii in this range, are well within the running speed of 23 ft/sec quoted earlier. Limiting the maximum speed attainable during actual play conditions to the values of N_c should reduce the frequency of falls associated with the speed of rotating equipment.

The rotational speed attained by any given piece of equipment depends on the magnitude of the angular impulse applied to accelerate it; the larger the applied impulse the greater the attained speed. Therefore, it is essential to specify the magnitude of angular impulse that should be applied during a test. This impulse should approximate that experienced by equipment during actual play conditions.

The data regarding the magnitude of impulse experienced by rotating equipment during actual play conditions are not available. Therefore, it is impossible to objectively develop a mechanical device for accelerating the equipment during testing. Also, since

rotating equipment is manufactured in many styles, it would be difficult, if not impossible, to develop a single device for this purpose. For these reasons the basic procedure for testing recommended by NRPA, although subjective, is adopted, particularly, in view of the fact that such equipment during actual use is often spun by adults (parents or older siblings of users). To ensure some element of uniformity, it is recommended that the adult spinning the equipment for the test should have the following characteristics 8/.

Age: 18 years to 34 years

Weight: 150 to 190 pounds

Height: 68 to 73 inches

Base Configuration

The outermost point on the periphery of a horizontally rotating apparatus circumscribes an area over which all components of the apparatus will pass. A child walking or falling into that region will be impacted by a component of the apparatus. Requirements of this section are intended to restrict access to this region by requiring that rotating apparatus incorporate a continuous and approximately circular base. This base will 1) prevent falls from the equipment onto the ground and in the path of the apparatus, 2) prevent any part of the user's body from contacting stationary objects beneath the rotating apparatus, and 3) act as a barrier at the periphery of the apparatus, thus preventing a child from walking into the equipment's path.

The difference in the distances between the axis and the innermost and outermost points on the periphery of the base is not permitted to exceed 2.0 inches, therefore ensuring an approximately circular base. This difference provides a reasonable manufacturing tolerance and should not diminsh the intent of this section.

Openings in the base that permit a rod 0.3 inch in diameter to penetrate through the base would permit a child's finger to penetrate this surface. This could result in a fractured or amputated finger. Consequently, such openings are prohibited.

1514.7 Entrapment

General

The objective of this requirement is to preclude the possibility that a child's hands, legs, or other parts of the body could be entrapped by the equipment when the momentum of the child or equipment is sufficient to cause an injury or a loss of balance. Should entrapment occur, a child could fall or be thrown from the

equipment, dragged by a moving apparatus, or injured in some manner. One example of an arrangement of components that could result in entrapment is illustrated in figure 24. The orientation and accessibility of these components are such that the hand or arm of a sliding child could become lodged at the vertex formed by the rail and side of the slide bed. This illustrates only one of several possible sources of entrapment. The determination that an entrapment hazard exists should be guided by the location, orientation, and accessibility of components, and the user's anticipated activity.

Head Entrapment

This section is concerned with entrapment of the head that could lead to strangulation. Entrapment may occur when part of an accessible opening, partially or completely enclosed, is too small to allow withdrawal of the head. Strangulation may result if the entrapped individual is unable to support his/her weight by means other than the head and neck. Openings that permit the insertion of the head or the insertion of the neck into a partially enclosed opening may be hazards that result in fatalities.

A single, approximately horizontal edge, say a one-inch diameter bar, will not trap the head of an otherwise unsupported individual because the neck will permit the head to rotate backward, thereby releasing the individual. However, a second bar, placed essentially parallel and above the first at a distance less than the head height of the individual will prevent this rotation and consequently trap the individual's head. Similarly, if the upper bar is replaced by two bars perpendicular to the first and approximately parallel at a distance less than head width apart, the head will be prevented from rotating back and releasing the individual. Preventing this form of entrapment is the underlying motivation for the requirements of this section.

A test based solely on the ability to insert a probe (simulating head dimensions) as the means for identifying potential hazardous openings does not take into account the configuration of many hazardous openings. For example, consider the two arrangements of components illustrated in figure 25.

The first arrangement will not permit the insertion of a probe but will permit the insertion of the neck. An individual in this position and having lost the ability for normal support will be trapped. The second arrangement permits the insertion of the probe. However, the lower right region of the opening will produce the same result as the first arrangement.

A probe is specified in the guidelines to determine which openings are accessible. The dimensions of the probe represent the head height and width of the minimum user. Openings that do not permit

the insertion of the probe but are not completely enclosed are accessible if the unbounded part of the opening is greater than the neck diameter of the minimum user. The neck breadth of the minimum user is 2.6 inches. The 1.75 inch dimension specified in the requirement is based on this measure but is reduced to account for compression of the neck tissues.

Regarding the requirements, the minimum distance between two opposing surfaces (7 inches) is based on the head height of the maximum user. The estimated head height for this user is 8.5 inches. However, allowing for compression and a slightly smaller distance between the top of the head and a point in front of the neck resulted in a 7 inch specification. This dimension is not applied to adjacent surfaces forming an angle for obvious reasons. Instead a minimum angle is specified. The particular angle of 55 degrees is used or has been proposed in other playground standards 1/, 9/ & 10/. The rationale is based on best engineering judgement.

A number of exclusions to the requirement have been included. An angle with the lower leg more than 10 degrees below horizontal is excluded since the user would tend to "roll out" or "slide out" of such a configuration. This is also the reason for excluding openings that are not enclosed by a lower surface. Surfaces and angles less than 24 inches above the ground or similar horizontal surfaces are exempt from the requirements because an entrapped user's feet will touch the ground or surface, thus providing necessary support. The standing erect height up to the bony prominence slightly below the neck of the minimum user is 31 inches.

1514.8 Falls from Equipment

Elevated Surfaces

Falls from equipment are among the most common types of playground accidents and often result in serious injuires. In many instances it is likely that surfacing material placed beneath the equipment is a major factor in determining the effects of a fall. Research pertaining to the impact characteristics of different surfacing materials is underway. Results of that research will provide a better understanding as to protective qualities of different surfacing materials relative to various fall heights. This section, therefore, focuses on the prevention of falls. Requirements in this section address protective barriers, hand gripping surfaces, ladders and stairways. Protective barriers satisfying the requirements of section 1514.8(a)(1) should prevent accidental falls from an elevated surface. The 38 inch minimum height requirement ensures that the maximum user's standing center of gravity is below the top surface of the barrier. The standing center of gravity plus a tolerance to allow for settling, warping

or other aging effects is a recommended height for protective barriers 5/. The maximum user's standing center of gravity is 36 inches. The 38 inch dimension includes the recommended tolerance and an allowance for footwear.

Hand Gripping Components

The requirement of this section ensures that the diameter or maximum cross-sectional dimensions of all components intended to be grasped by the hands are such that they provide a satisfactory grip to all users. Because of the range in hand dimensions between the minimum and maximum user it is impossible to provide an optimum diameter for components; a diameter sized to a minimum user's hand may be "too small" for a maximum user and, conversely, a diameter sized to a maximum user's hand may be "too large" for a minimum user. A component having a diameter that is "too large," in general, is less desirable than a component that is "too small." Therefore, the requirement of this section specifies a maximum dimension based on the minimum user's hand size.

Figure 26 depicts an arrangement of the hand gripping an overhead cylindrical component. This represents a situation where the user's grip is subjected to the maximum force. The ability to sustain this grip while supporting the body's weight depends on the direction and magnitude of the forces exerted by the muscles of the fingers and hand. Forces must be exerted by these muscles to oppose the gravitational force acting on the body. Consider the case where the diameter of the cylinder is such that the finger tips do not extend past the vertical plane at the top of the cylinder. Squeezing action would not be possible, and a grip could not be sustained.

An adequate gripping surface is judged to be one that permits the gripping part of the hand to encompass at least 50% of the cylinder's circumference, as shown in figure 26a. The gripping parts of the hand are those between the crotch of the thumb and the tip of the index finger, as illustrated in figure 26b. This dimension for the minimum user is 2.54 inches. This is 50% of the circumference of a cylinder having a diameter of 1.6 inches. Components intended for use by both hands and feet are covered by this requirement because the hand-gripping function is considered more critical to safety.

Ladders and Stairways

The requirements of section 1514.8(c) and supporting rationale were taken from the NRPA documents.

The intent of the requirements for steps and rungs is to ensure that ladder and stairway steps and rungs are of a dimension and spacing that provide safe standing and stepping surfaces. The

required width of 15 inches or more is based on the shoulder width of the maximum user, which is 15.4 inches. The user should not have to reach inward to hold the side of a ladder or the hand rails of a stairway or ladder.

The tread depth requirement of a minimum of 3 inches is intended to provide sufficient contact surface for the foot which, in the case of an open stairway, will extend beyond the depth of the tread. If the stairway is closed, sufficient depth must be provided so that enough of the center portion of the foot can come in contact with the tread for good balance and support.

The spacing of steps and rungs is critical. When ascending a ladder or stairway, the user subconsciously adjusts to the step spacing and, although large deviations are easily identified and compensated for, relatively small deviations result in tripping hazards. Therefore, uniform spacing is required. Further, the user should not have to step above knee height from one step to another. The knee height of a minimum user is 11.4 inches. Therefore, an appropriate range of the spacing was judged to be between 7 and 11 inches. In addition, the spacing of rungs less than 7 inches could be an entrapment hazard (see requirement of section 1514.7(b)(1)(ii)).

The stepping surfaces should be approximately level in all directions so that the user does not slide sideways or from front to back. However, a slight tolerance is allowed ($\pm$ 2°) and, in fact, is probably desirable to facilitate drainage.

Continuous hand rails are required on both sides of ladders and stairways to provide security in ascending and descending. It is not possible to provide hand rails at a height ideal for all users. However, the railings should be designed to maintain the user in a generally upright position over each step, so that the user is not forced to lean back or reach substantially forward in order to use the hand rail.

Slip-Resistant Surfaces

The requirement of this section is intended to reduce the possibility for falls that occur through loss of footing. The requirement applies to surfaces used primarily by the foot such as platforms, decks, steps, and the like. Because of the wide range in materials used in the construction of playground equipment and footwear, and environmental factors to which the equipment is exposed, an objective requirement and test procedure is impractical. The decision as to whether or not a surface is "too slippery" must be made subjectively.

1514.9 Spiral Slide Chute Contour (Outer Portion)

The intent of these requirements is to reduce the risk of lateral discharge of the user.

Centrifugal force is the mechanism which induces the likelihood of lateral discharge when descending through turns. Depending on the chute contour, the user may tip or slide off the edge.

Many factors influence the likelihood of lateral discharge including the geometry of the sliding surface and user, the coefficient of friction between the sliding surface and user, the banking angle, the slide inclination and height, and the user's actions. In order to assess the likelihood of lateral discharge as a function of measurable slide parameters, two simple mathematical models have been constructed: the first describes the tipping mode, the second the sliding mode. In each, the user is modeled as a rigid body and the centrifugal force, F, is computed as follows:

$$F = \frac{W}{g} \cdot \left(\frac{V^2}{R}\right) \qquad (1)$$

where V = instanteous speed
g = gravitational acceleration
W = user's weight
R = radius of curvature of the turn

and the velocity is computed as

$$V = \sqrt{2gH(1 - \mu\cot\alpha)} \qquad (2)$$

where H = vertical distance the user has descended
μ = coefficient of friction between the user and the sliding surface
α = average angle of inclination of the slide along the longitudinal axis.

Tipping Mode

A cross-section of a spiral slide chute and the forces acting on the user's center of gravity are shown schematically in figure 27.

If the tipping moment, M_T, due to the centrifugal force exceeds the restoring moment, M_R, due to the user's weight, lateral discharge is likely. To avoid this possibility, it is required that

$$M_R \geq M_T \qquad (3)$$

where

$$M_R = (F\sin\theta + W\cos\theta)d$$

$$M_T = (F\cos\theta - W\sin\theta)(S - y)$$

where S = perpendicular distance of the center of gravity of a seated user to his/her buttock plane or the sliding surface
y = effective edge height (figure 27)
d = half of the lower torso breadth
θ = banking angle.

Then (3) becomes

$$(F\sin\theta + W\cos\theta)d \geq (F\cos\theta - W\sin\theta)(S - y)$$

or,

$$y \geq S - d\ \frac{(F/W)\ \tan\theta + 1}{(F/W) - \tan\theta},$$

and using (1) and (2)

$$y \geq S - d\ \frac{(2H/R)(1 - \mu\cot\alpha)\tan\theta + 1}{(2H/R)(1 - \mu\cot\alpha) - \tan\theta} \qquad (4)$$

Sliding Mode

A cross section of the chute and the forces acting on the user's center of gravity are shown schematically in figure 28.

The tangential component of centrifugal force, F_t, tends to slide the user towards the outer edge of the chute. This action of F_t is opposed by the tangential component of the user's weight, W_t and friction, F_f. This phenomenon is typical of curved bed slides but can also occur on flatbed slides.

In order for sliding to cease, it is required that

$$F_t \leq W_t + F_f \qquad (5)$$

Or

$$W\sin\phi + (W\cos\phi + F\sin\phi) \geq F\cos\phi \qquad (6)$$

where ϕ is the effective banking angle.

Equation (6) becomes

$$\frac{\tan\phi + \quad}{1 - \mu\tan\phi} \geq \frac{F}{W}$$

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Or letting $\mu = \tan \gamma$

$$\tan(\phi + \gamma) \geq \frac{F}{W} \quad .$$

Or, $\phi \geq \tan^{-1}(\frac{F}{W}) - \tan^{-1} \mu \quad .$

Or, $$\phi \geq \tan^{-1} \frac{2H(1 - \mu \cot \alpha)}{R} - \tan^{-1}\mu. \qquad (7)$$

Values for Parameters

The effective banking angle, ϕ, is the angle that the chord AB makes with the horizontal (see figure 29). The lower torso breadth of the maximum user is 13 inches. However, because of the curvature of the buttocks, the effective length of chord AB is judged to be 10 inches.

The coefficient of friction, μ, depends upon the user's attire and environmental conditions. The NRPA obtained two values for μ, based on limited data: 0.4 (between clothing and stainless steel) and 0.25 (between burlap and stainless steel). Because of the limited data, a value of $\mu = 0.2$ will be used in the calculations to provide a margin of safety.

The angle of inclination, α, varies from slide to slide. However, a nominal value of equal to 45 degrees, which is within the range of measured values for two types of slides, simplifies the calculations.

Using these values of μ and α equations (4) and (7) can be written as,

$$y_c \geq 9\ 5 - 6.5\ (\frac{1.6(H/R)\tan\theta + 1}{1.6\ (H/R) - \tan\theta}\ ) \qquad (9)$$

$$\phi_c \geq \tan^{-1}(1.6\ H/R) - 11.3^{\circ} \quad . \qquad (10)$$

For large banking angles, equation 9 yields very small values for the edge height. However, to ensure an adequate hand and foot guide, a minimum edge height of 2.5 inches is recommended. This is consistent with side height requirements for straight slides 2/.

For some chute configurations, it may be difficult to determine, by visual inspection, whether the primary mode of possible lateral discharge is tipping or lateral sliding. If the radius of curvature of the chute contour is larger than 6.5 inches at all points of the contour, then the primary mode of lateral discharge is probably due to lateral sliding, otherwise the primary mode of

possible lateral discharge is tipping. This radius of curvature corresponds to one half the lower torso breadth of the maximum user. In addition, for values of α between 30 and 60 degrees, the effect of α on y_c and ϕ_c is negligible.

Spiral Slide Chute Contour (Inner Portion)

Spiral slides with central support should preclude the possibility of a user falling off the inner edge. The slide with no central support should have a chute with an inner edge that provides a restraint equivalent to that required for straight slides. The rationale for the side restraint of straight slides is given in the rationale of the "Suggested Safety Requirements and Supporting Rationale for Swing Assemblies and Straight Slides."

Spiral Slide Exit Region

See section 1514.4.c of 1/.

Spiral Slide, Slide Surface Entrance

See section 1514.4.d of 1/.

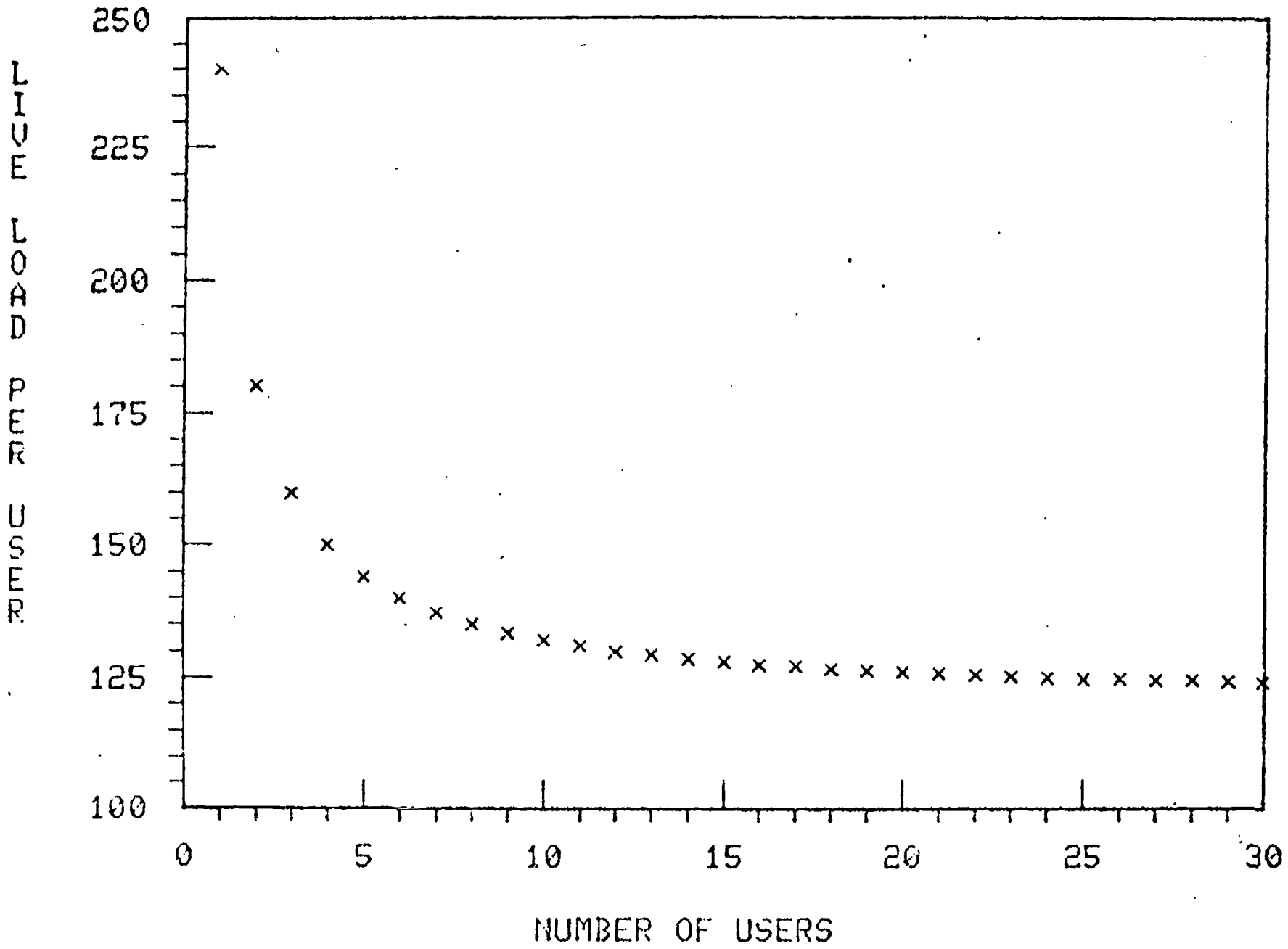
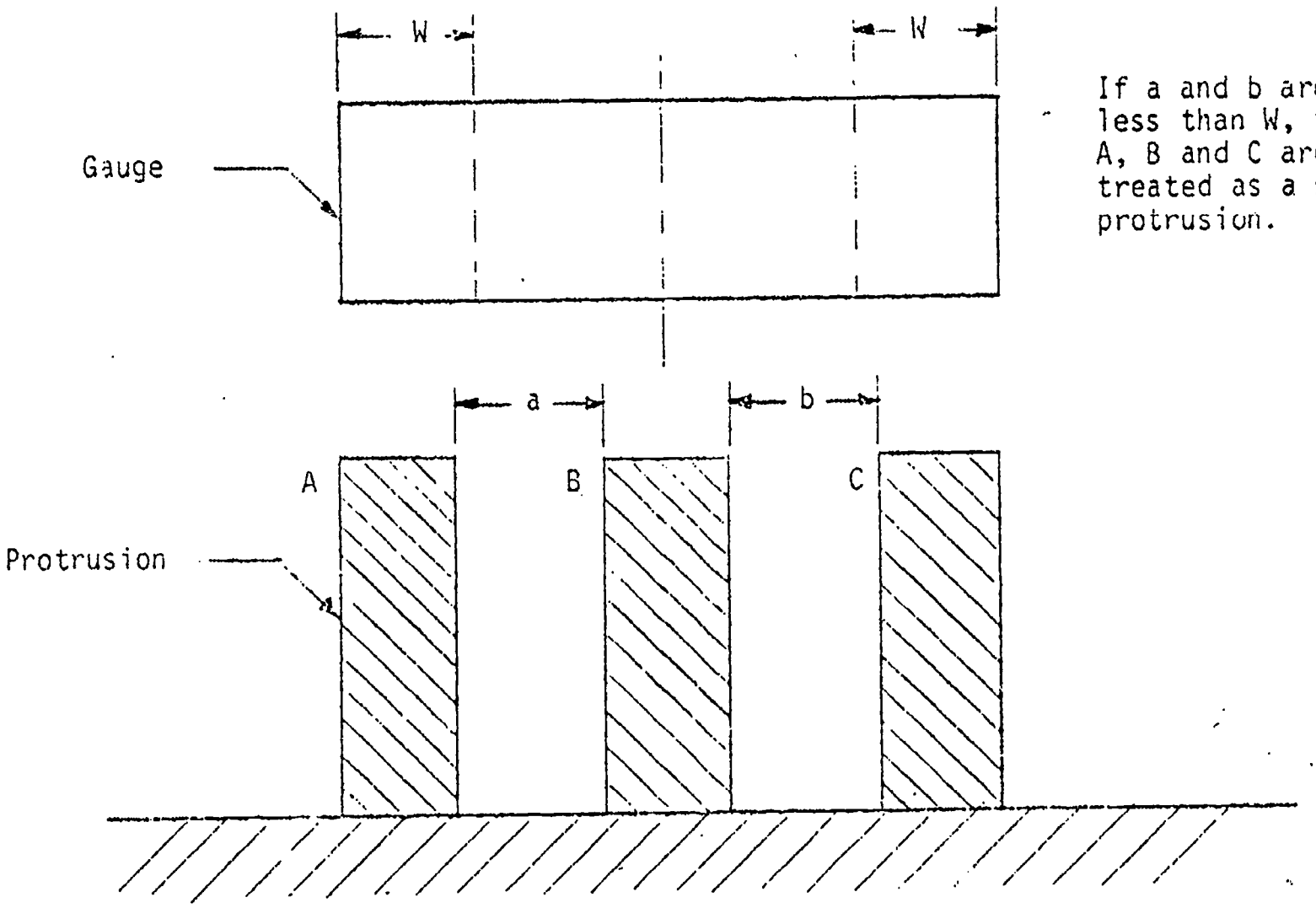


FIG 22. ESTIMATED LIVE LOAD



If a and b are less than W, then A, B and C are treated as a single protrusion.

FIG 23. AN ARRANGEMENT OF PROTRUSIONS THAT ACT AS A SINGLE PROTRUSION

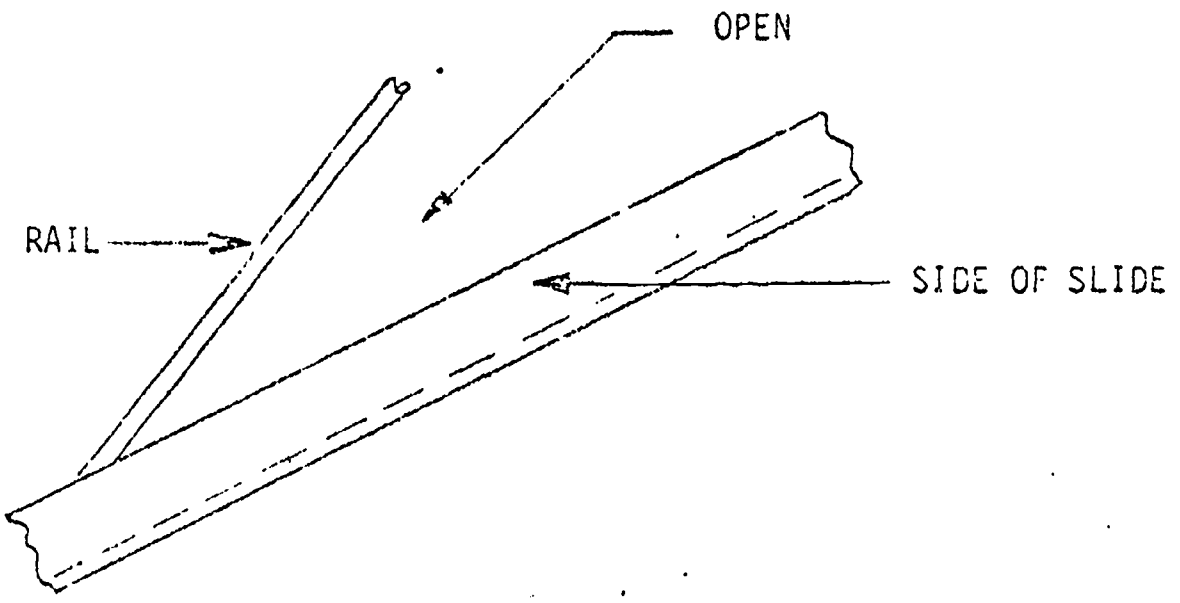
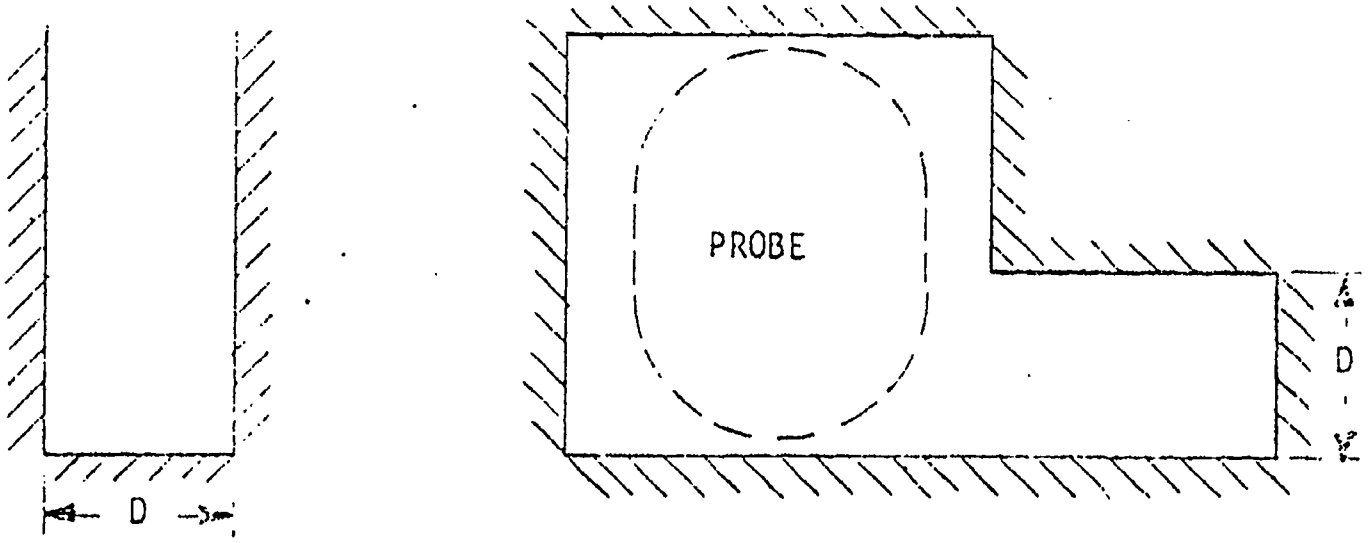
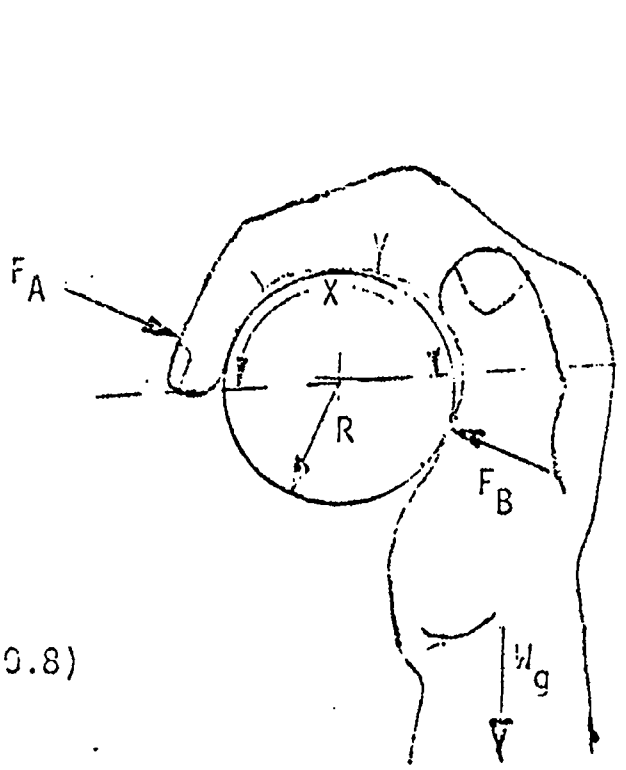


FIG 24. AN ARRANGEMENT OF COMPONENTS THAT COULD RESULT IN ENTRAPMENT



D { less than minimum probe dimension
  { greater than neck diameter

FIG 25. EXAMPLES OF POTENTIALLY HAZARDOUS OPENINGS THAT MAY NOT BE DETECTABLE WITH A PROBE



$\pi R \leq X$

$R \leq \frac{X}{\pi}$ (=0.8)

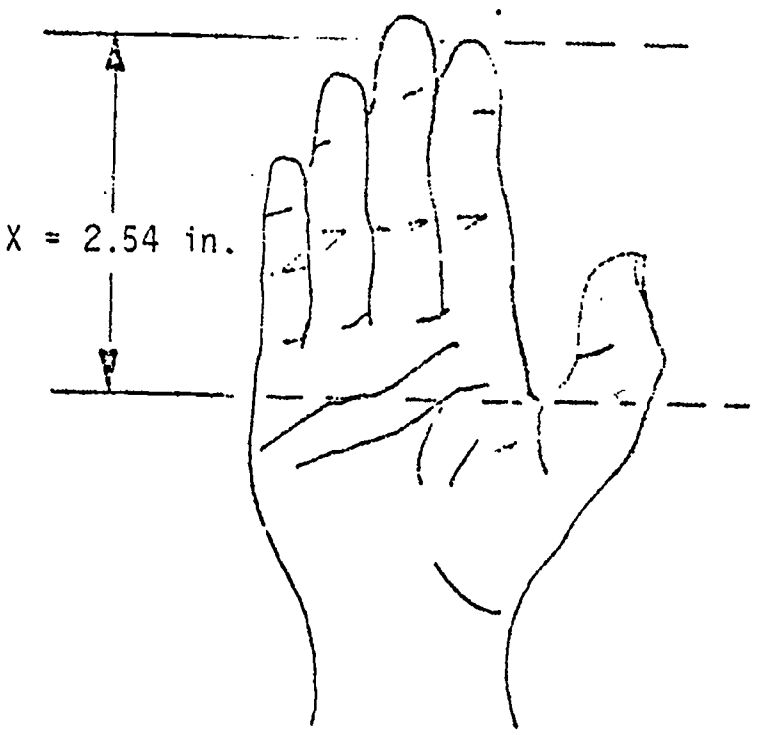


FIG 26a. FIG 26b.

FIG 26. HAND AND GRIPPING SURFACE DIMENSIONS

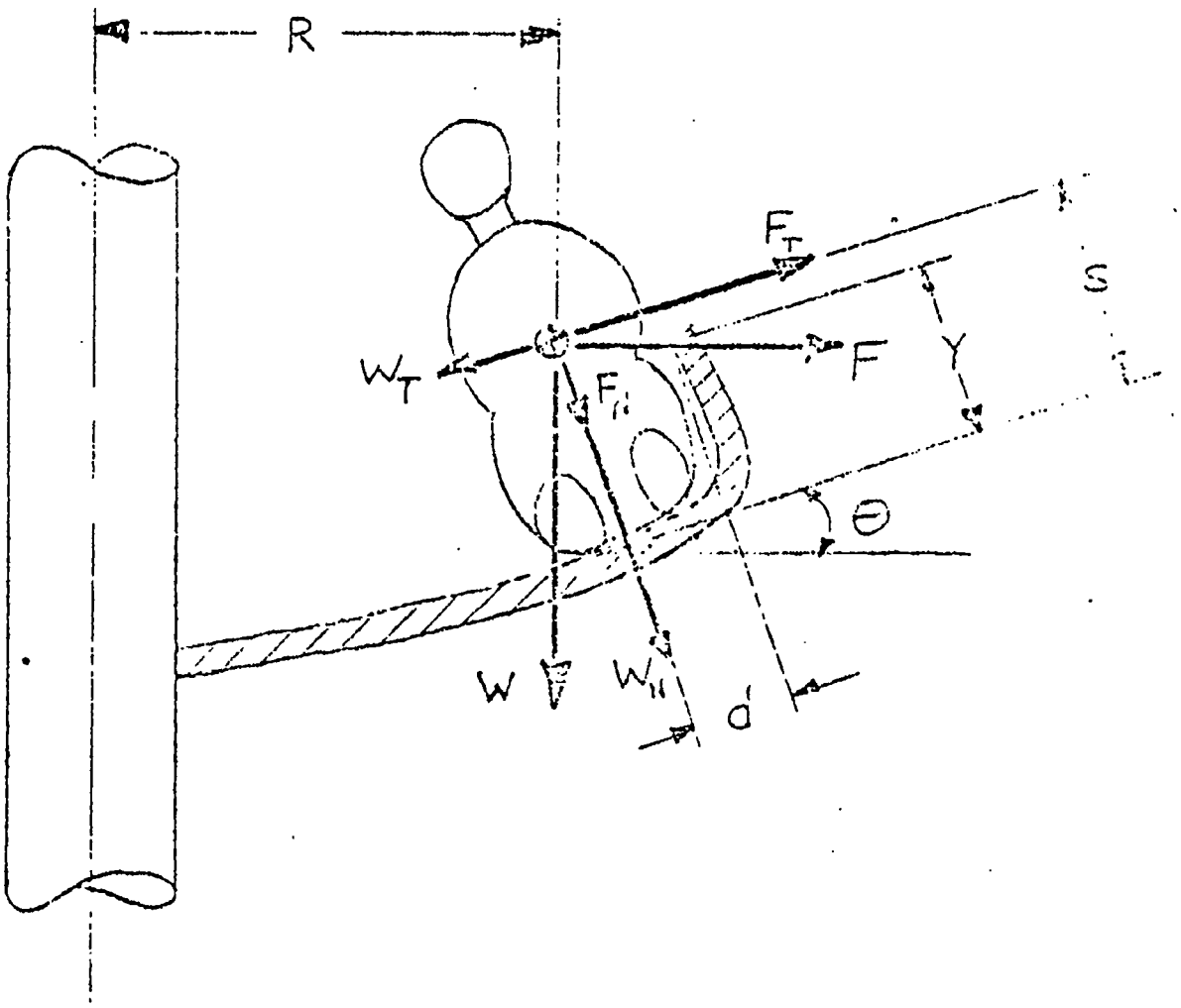


FIG 27. SCHEMATIC OF TIPPING MODE

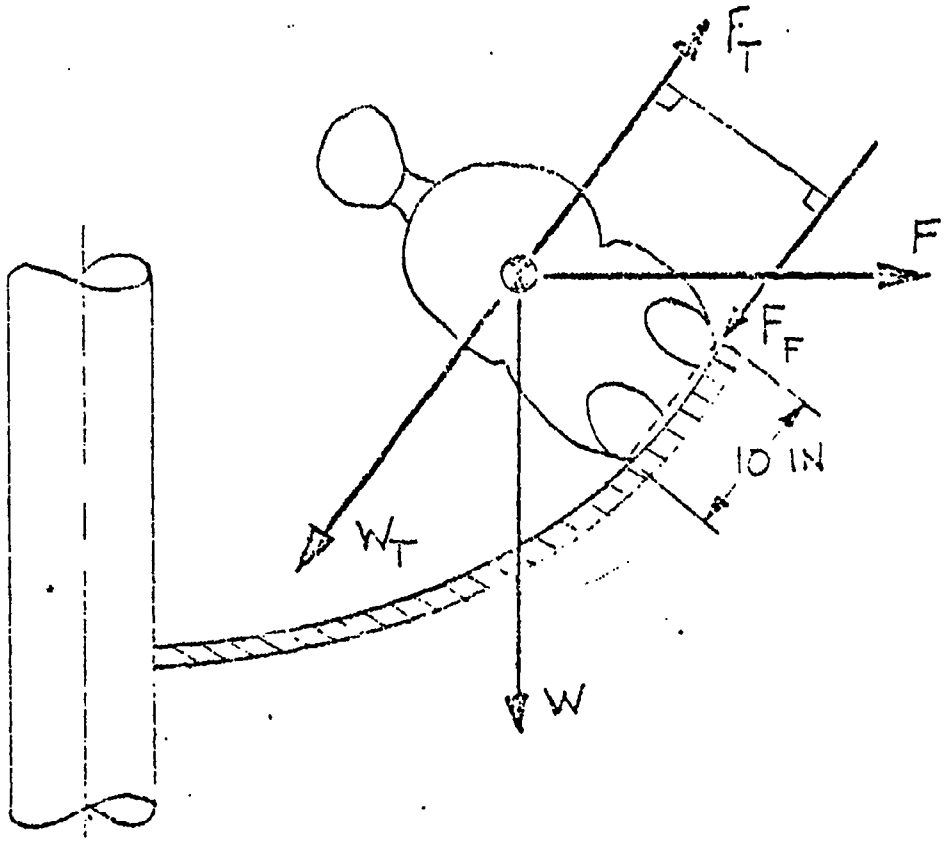


FIG 28. SCHEMATIC OF LATERAL SLIDING MODE

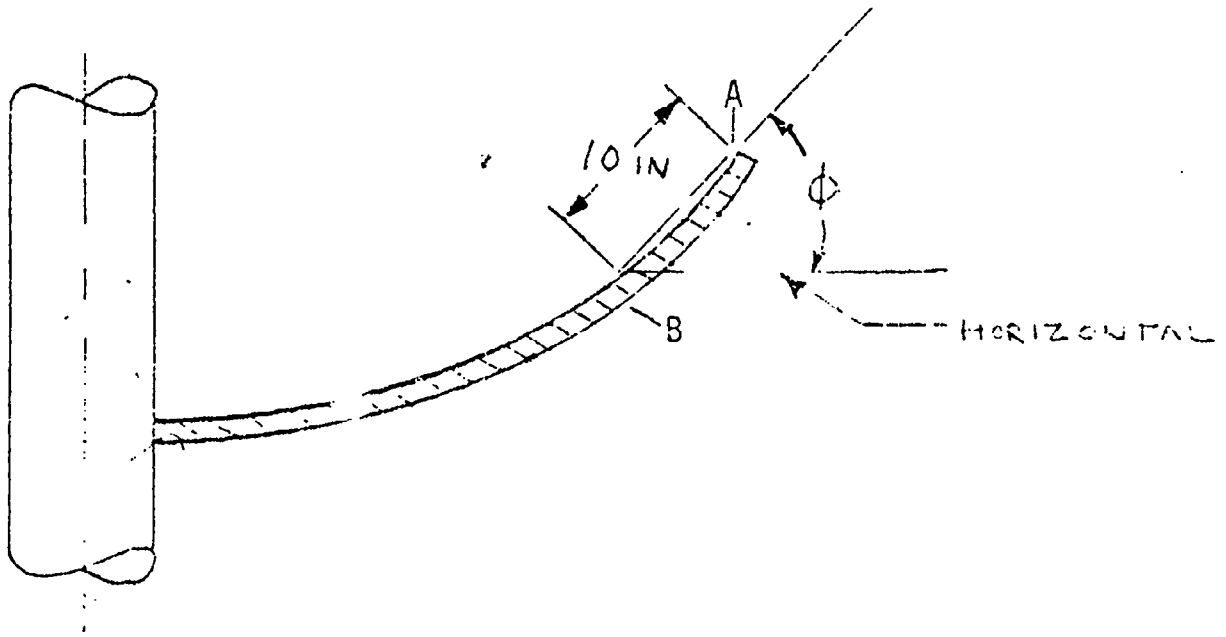


FIG 29. SCHEMATIC SHOWING CHORD AB and ϕ

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APPENDIX A

Minimum Effective Edge Heights (y_c) and the Minimum Effective Banking Angles ϕ_c for Nominal Values of R, Θ, and H.

TABLE 1. Minimum Effective Edge Heights, y_c: R = 15 Inches

$$y_c = 9.5 - 6.5 \frac{1.6\ (H/R)\ \tan\theta + 1}{1.6\ (H/R) - \tan\theta}$$

R = 15"

H \ θ	0°	10	15	20	25	30	35	40
48"	8.2	7.0	6.3	5.6	4.8	3.8	2.8	
60	8.5	7.3	6.6	5.9	5.1	4.3	3.3	
72	8.7	7.5	6.8	6.1	5.4	4.5	3.6	
84	8.8	7.6	7.0	6.3	5.5	4.7	3.8	2.7
96	8.9	7.7	7.0	6.4	5.7	4.9	3.9	2.9
108	8.9	7.8	7.1	6.5	5.8	5.0	4.1	3.0
120	9.0	7.8	7.2	6.5	5.8	5.0	4.2	3.1
132	9.0	7.9	7.3	6.0	5.9	5.1	4.2	3.2
144	9.1	7.9	7.3	6.6	5.9	5.2	4.3	3.3
156	9.1	8.0	7.3	6.7	6.0	5.2	4.3	3.3
168	9.1	8.0	7.4	6.7	6.0	5.3	4.4	3.4
180	9.2	8.0	7.4	6.7	6.0	5.3	4.4	3.4

TABLE 2. Minimum Effective Edge Heights, y_c: R = 21 Inches

$$y_c = 9.5 - 6.5 \frac{1.6\ (H/R)\ \tan\theta + 1}{1.6\ (H/R) - \tan\theta}$$

R = 21"

H \ θ	0°	10	15	20	25	30	35	40
48"	7.7	6.4	5.7	5.0	4.0	2.9		
60	8.1	6.8	6.1	5.4	4.5	3.6		
72	8.3	7.1	6.4	5.7	4.9	4.0	2.9	
84	8.5	7.3	6.6	5.9	5.1	4.3	3.2	
96	8.6	7.4	6.8	6.1	5.3	4.5	3.5	
108	8.7	7.5	6.9	6.2	5.4	4.6	3.7	2.5
120	8.8	7.6	7.0	6.3	5.6	4.7	3.8	2.7
132	8.9	7.7	7.0	6.4	5.6	4.8	3.9	2.8
144	8.9	7.7	7.1	6.4	5.7	4.9	4.0	3.0
156	9.0	7.8	7.2	6.5	5.8	8.9	4.1	3.0
168	9.0	7.8	7.2	6.5	5.8	5.0	4.2	3.1
180	9.4	7.9	7.2	6.6	5.9	5.1	4.2	3.2

TABLE 3. Minimum Effective Banking Angle, ϕ_c

$\phi_c = \tan^{-1}(1.6\ H/R) - 11.3^{\circ}$				
	ϕ			
R / H	15"	18"	21"	24"
48"	68°	66°	63°	61°
60	70	68	66	65
72	71	70	68	67
84	72	71	70	69
96	73	72	71	70
108	74	73	72	71
120	74	73	72	76
132	75	74	73	72
144	75	74	73	73
156	75	75	74	73
168	76	75	74	74
180	76	75	75	74