5.5 MATERIALS OF MANUFACTURE AND CONSTRUCTION

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5.5.1 DURABILITY AND FINISH

5.5.2 HARDWARE

5.5.1 DURABILITY AND FINISH

Guideline content:

The current Handbook explains that the materials used to construct playground equipment should have "a demonstrated record of durability in the playground or a similar outdoor setting." For new materials, the manufacturer may need to test durability through appropriate procedures. (Volume 1; Volume 2, 5.1)

Deterioration or corrosion of equipment materials is a major concern. Materials should be finished (plated, galvanized, painted, preserved, or otherwise treated) to prevent rust or rot, as necessary. However, it is noted that "the manufacturer should ensure that users of the playground equipment cannot ingest, inhale, or absorb through body surfaces any hazardous substances used in the treatment process." (Volume 1; Volume 2, 5.2)

Probable rationale:

The above recommendations "are intended to minimize the possibility of hazards resulting from abnormal wear, weathering, fatigue, or other unexpected forms of degradation." The NBS recognized that the life of a piece of playground equipment is finite, and that durability depends on variables such as the materials of manufacture and construction, the frequency and intensity of use, exposure to the elements, and the effectiveness of maintenance. (NBS 1978a)

Although "a more conclusive requirement and test method addressing these factors could be developed," the NBS decided that this may not be justified. As explained by the NRPA,

> 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.

In addition to this rationale, the wide range of materials used for playground equipment would make it difficult to reach consensus on a test method or to determine an acceptable criterion for allowable corrosion. (NBS, 1978a; NRPA, 1976a)

The NRPA-proposed safety standard and technical rationale contained more detailed information with regard to finishes than is included in the current CPSC Handbook. It explained that "painted surfaces must conform to Federal regulations assuring lead-free paint." Similarly, application of wood preservatives should be in accordance with current standards of the American Wood Preservers Association. It is noted that there are wood preservatives on the market (e.g., CCA, Type C) which are acceptable for use on accessible parts of equipment. Inaccessible parts of equipment would not need to comply with the "non-harmful" specification; a different type of preservative could be applied where wood is either below ground level or enclosed so that it is not accessible to children playing on the equipment. (NRPA 1976a, 1976b)

Issues:

High quality materials and construction are essential to ensure the durability of playground equipment (Bowers, 1988a, 1988b). Esbensen (1987) noted that the higher the quality of the equipment, the more durable it is likely to be. A specification in the Seattle draft standards (1986) also supports the importance of durability and is similar to the CPSC guidelines: "select materials for general strength and durability, resistance to deterioration, and ability to withstand heavy use by both children and adults; and, based on a demonstrated record in heavy-use outdoor play environments." Beckwith (1985) concluded that it is generally safe to assume that the playground equipment manufactured by any of the well-established national companies is of acceptable durability.

The most widely discussed concern is that of potential corrosion or deterioration. Different materials have different advantages and disadvantages with regard to durability, as discussed below. The standards reviewed (Australian standards, AS 1924, Part 1, 1981; British standards, BS 5696: Part 2, 1986; German standards, DIN 7926, Part 2, 1985; Canadian draft standards, CAN/CSA-Z614, 1988; Seattle draft standards, 1986) contain detailed specifications for various materials suitable for the manufacture of playground equipment, and also provide lists of applicable national standards. Some of the materials addressed in these standards include the following: steel, aluminum, cast iron, copper and copper alloys, various woods, various plastics, chains, cables, ropes, concrete, and masonry.

Moore et al. (1987) and Stoops (1985) reported that metal equipment has traditionally proven very durable because of its great strength. However, steel is subject to rust, both on the exterior and interior (Frost, 1980; Moore et al., 1987). The problem of exterior rust is exacerbated in coastal areas due to the humidity and salt; such corrosion can cause cut and puncture injuries as well as reduce structural integrity (J. Frost, personal communication, February 1989). To prevent exterior rust on metal equipment, it is typically galvanized (Beckwith, 1985; Moore et al., 1987); the Canadian draft standards recommend that all metal be galvanized or otherwise treated to resist corrosion, which is similar to the CPSC guidelines. Moore et al. point out that most steel equipment is fabricated from structural tubing, and because the inside is not galvanized, interior rust can become a problem jeopardizing its strength. They explain that "proper footings will reduce water accumulation in pipes in many installations and this removes most of the problem." Therefore, it is very important to carefully follow the manufacturer's installation specifications for footings (see Section 5.4.1). Another strategy employed by some manufacturers is to use water pipe; however, as Moore et al. recognize, "this material is not fabricated for structural use and must be used in the heaviest gauges in order to approximate the strength of structural tubing."

The Play For All Guidelines (Moore et al., 1987) also reports that aluminum is now being used as a material for playground equipment. It is slightly more expensive and does not have the strength of steel, but "its superior resistance to rust makes it an attractive choice." In coastal areas or other locations with very wet climates, aluminum frames should be considered.

Both Beckwith (1985) and Moore et al. (1987) discuss a relatively new technology called "powder coating" as an option to galvanization of metal equipment. This is an electrostatic process involving the dry application of an epoxy, nylon, or polyester plastic as a powder, which is then oven cured and bonded to the surface of steel or aluminum. The many color options of this finish are a major advantage. Beckwith concluded that powder coating is at least as durable as galvanizing. Moore et al. explain that powder coating over galvanizing is being used to provide extra protection for steel in harsh environments. In current catalogs, many manufacturers specify that they use powder coating techniques as a means for adding exterior color, while also increasing the durability of their equipment. Beckwith further explained that "there is also some evidence that this plastic coating is less conductive, making it cooler in summer and less 'sticky' in winter," in comparison to galvanized metal which has the disadvantages of heating up in the sun and freezing in the cold (Aronson, 1988; Geiger, 1988). The importance of shading metal slide chutes in particular has been widely noted (see Section 5.7.1.3.7).

Wood is also widely used to construct playground equipment. However, as stated by Beckwith (1985), "wood-based systems cannot come close to matching the long term durability of metal." Because of problems with wood rot and insect attack where wood is in contact with soil, the primary distinction between the potential deterioration of wood and metal equipment concerns the upright support posts (Beckwith, 1988; J. Frost, personal communication, February 1989; Moore et al., 1987; Stoops, 1985). Stoops reported that the Seattle Department of Parks and Recreation has had poor experiences with wood equipment due to the rainy climate of the Pacific Northwest. The most serious problem has been severe rot damage where wooden posts contact the ground; Stoops noted that the use of sand and sawdust for protective surfacing has aggravated the problem because they retain moisture. One technique to avoid such wood rot is the use of concrete footings to prevent contact between the wooden posts and the ground. The Seattle draft standards recommend anchoring wooden equipment with special footings as a positive alternative to burying wood posts in the ground. They state that all wooden components should be a minimum of 6 inches above grade. Because excessive moisture in the soil is a leading cause of wood rot, areas which are prone to flooding should not have wooden playground equipment. Stoops also discussed rot damage on wooden members "where end grain fiber has been exposed or where ultraviolet light caused checking and cracking," causing water penetration. The wood deterioration experienced in the Seattle Department of Parks and Recreation has sometimes been so severe that equipment had to be dismantled or removed from the play area after only a decade of use. In comparison, Moore et al. (1987) note that metal can be treated adequately to last 25 years, if one wants the same equipment that long.

Various fungi can cause wood rot both above and below ground, and wood can also be destroyed by wood-boring insects such as termites. Either one of these forms of deterioration can weaken wooden playground equipment and may cause it to collapse. Wood preservatives are, therefore, used to protect against such attacks.

Stoops (1985) also noted that the use of chemical preservatives to pressure treat wood is a common strategy to protect manufactured equipment. Simpson (1988) and the Seattle draft standards both specifically recommend that all wooden components be pressure treated. Similarly, the <u>Play For All Guidelines</u> (Moore et al., 1987) suggests that all wood used to construct playground equipment should be preserved to resist deterioration. Foreign standards reviewed contain various specifications with regard to the protection of wood equipment. The British standards stipulate that "the surfaces of all parts not naturally resistant to corrosion or deterioration shall be protected by surface coating or impregnation." In addition, the British standards recognize that providing a higher degree of surface protection from the beginning, even though this may raise initial costs, may later achieve benefits in reduced maintenance, especially in harsher climates. The German standards state that "wooden parts shall be designed so that rain can run or drip off unhindered and there will be no accumulation of water. If this cannot be assured, preventive chemical wood preservatives will also be required." The Canadian draft standards specify that all wood which is in contact with the ground or within 16 inches of such contact should be pressure treated.

Regardless of the type of material, it is extremely important that the processes and substances used to prevent rust, rot, or insect invasion are not toxic or hazardous in any way to the users (Aronson, 1988; Bowers, 1988a; Esbensen, 1987; Frost, 1986a, U. of Texas, 1989, unpublished manuscript, personal communication, February 1989; Simpson, 1988; Stoops, 1985; Werner, 1982; Australian standards; British standards; Canadian draft standards; Seattle draft standards). In the case of metal equipment, there is the concern regarding the lead content of paints and coatings used to galvanize or otherwise protect it; there are federal regulations which mandate the use of lead-free paint, as noted by the NRPA (1976a). In the case of wood equipment, there is concern regarding the toxicity of chemicals used to pressure treat it; Frost recognized that the use of toxic materials on playground equipment needs to be regulated but that no federal agency currently protects children from the use of toxic wood preservatives. Preston (1988) noted that the current CPSC guidelines only recommend that hazardous substances not be used; he suggested that the guidelines include information on what substances are acceptable. The Australian standards give detailed specifications for various materials regarding different types of paints, wood preservatives, and other finishing systems, including references to other Australian standards for compliance. Similarly, the British standards also list other British standards with which all wood preservatives for playground equipment must comply.

Many sources provided information as to what they deemed unacceptable or acceptable wood preservatives. Following a recent CPSC study of pressure treated playground equipment wood Lee (1990d) reported that creosote, pentachlorophenol, tributyl tin oxide are "considered too toxic or irritating for use on playground equipment." Others have also identified creosote and pentachlorophenol as chemicals which should not be used in wood preservatives for playground equipment (Esbensen, 1987; Frost, 1986a; Simpson, 1988; Stoops, 1985; Australian standards; Canadian draft standards). The Australian standards do not allow the use of timber freshly treated with chlorinated hydrocarbon pesticides.

The most commonly used wood preservatives for playground equipment in the U.S. are arsenicals such as chromated copper arsenate (CCA) and ammoniacal copper zinc arsenate (ACZA) (Karels, 1989, cited in Lee, 1990d). Bundy (1988, cited in Lee 1990d) reported that borates, quinolinolates, and naphthenates are less toxic alternatives; further, woods such as cedar that are naturally resistant can be used. "However, these alternatives may not necessarily have the same long term effectiveness in preventing rot and insect damage."

Others have also identified CCA as an acceptable preservative for playground equipment, but there are various limits or qualifying statements with these recommendations. The NRPA (1976a) is the least restrictive, noting that CCA Type C can be used on accessible parts of wood playground equipment. The Seattle draft standards lists CCA as a widely used, acceptable preservative, recognizing that "some groups advocate sealing to eliminate all risk of ingestion or absorption." The Play For All Guidelines (Moore et al., 1987) describe copper arsenate as "the treatment of choice for in-ground wood provided that the treated surface is low in residual arsenic salts (4% solution is typical)."

The Australian standards address the use of CCA preservatives in detail. If timber treated with CCA is used, it is essential to have a 3-week interval between treatment and construction, but because freshly treated timber may cause corrosion of metal hardware if not completely dried, it is preferable to allow a 6-week interval unless the hardware is specially protected. In addition, because there are toxic chemicals in CCA treatments, it is important to remove all scraps or offcuts of treated wood from the playground site, and this wood should not be burned in confined spaces. Esbensen (1987) also noted that pressure-treated wood should not be disposed of by burning because of toxic fumes.

There appears to be some controversy over the use of arsenic preservatives to treat playground equipment wood. For example, while the sources above find the use of arsenic preservatives acceptable, others appear to have cautioned against it: Simpson (1988) warned that some commercial preservatives contain arsenic, and seemed to be recommending that these be avoided; and, Esbensen (1987) stated that ammoniacal copper arsenate (ACA) should not be used.

Because there may be some uncertainty regarding the extent of the hazards presented by pressure-treated wood, Esbensen (1987) recommended that these materials not be used to build an entire playground structure. Designs can minimize a child's contact with wood preservatives. "For example, you can use other wood types, containing no potentially toxic preservatives, on ladders, stairs, or ramps, where young children are most likely to grasp; then use pressure-treated wood only for the structural parts most subject to wood rot."

Although the popularity of wood playground equipment has grown, and much of it is treated with arsenic, which is known to be toxic, data and assessment procedures are lacking with regard to the actual exposure of children to the arsenic and the level of cancer risk associated with wood playground equipment (EPA, 1981, 1984, cited in Lee, 1990a). As noted above, the CPSC recently conducted research in order to estimate the skin cancer risk from dislodgeable arsenic on pressure treated playground wood. The concern regarding arsenic residue on wood playground equipment is its possible ingestion resulting from hand-to-mouth exposure (Lee, 1990a). For a detailed account of these studies the reader is referred to the CPSC reports (Jain, 1990; Lee, 1990a, 1990b, 1990c, 1990d).

The above referenced CPSC research sampled new playground equipment wood from major U.S. manufacturers and analyzed it for dislodgeable arsenic (Lee, 1990d). Further, estimates of exposure levels resulting from hand-to-mouth contact and possible ingestion, as well as estimates of the skin cancer risk, were assessed. The dislodgeable arsenic levels on five of the seven playground equipment wood samples were below the detection limit of 6.3 ug/100 cm^2; the highest estimated skin cancer risk presented by these samples was less than 1 case per million children (Lee, 1990a, 1990d). The average levels for the few samples which had detectable dislodgeable arsenic were less than 35 ug/100 cm^2; the average estimated skin cancer risk presented by these samples was about 3 to 4 cases per million children (Lee, 1990a, 1990d).

In addition, the CPSC research studied "whether reduction of dislodgeable arsenic levels, and thus estimated risks, could be accomplished by the application of coatings" (Lee, 1990d). The results indicated that neither a water repellant/sealer nor an oil-based wood stain significantly reduced dislodgeable arsenic levels; "levels after coating were not statistically different from those before the coatings were applied."

Lee (1990d) recognized that the dislodgeable arsenic levels found in the CPSC study were considerably lower than those reported from earlier research by the California Department of Health Sciences (1983, 1984, cited in Lee, 1990d). One of the possible explanations for this difference is quite encouraging, as stated by Lee:

> ...the wood preservers and playground equipment manufacturers may now be more aware of the occupational hazard posed by arsenic residue on the wood and have altered preserving procedures to minimize residue formation. Although most manufacturers do not specifically order wood according to the [AWPA] C17 standard, some manufacturers have indicated that they specifically order pressure treated wood that is visibly free of residues.

Lee (1990a) concluded that the CPSC results suggest the technologies and practices required to minimize levels of dislodgeable arsenic on playground equipment wood may already be available. Further, wood preservers and playground equipment manufacturers should be encouraged to continue identifying and using such procedures.

Werner (1980) concluded that the CPSC's general guidelines on durability and finish were "quite adequate," but that more specific information on materials was lacking, which is similar to remarks made by Preston (1988) noted above. He suggested that manufacturers should have to consider the qualities, and advantages and disadvantages of different treatment processes for metal (galvanization, no galvanization) and wood (salts, creosote, pentachlorophenol). Although none of the current catalogs include a detailed comparison of possible treatments, most manufacturers specify what process is used to protect their materials from corrosion. In addition, a few manufacturers state the actual chemical preservatives used, while others only indicate that they are in compliance with certain standards. Simpson (1988) recognized that it is the specifier's job to ensure that no dangerous substances are used in playground settings. The Seattle draft standards note that "suppliers and specifiers may be required to verify non-toxicity"; Moore et al. (1987) recommend that purchasers "insist on complete documentation of treatment materials and residual arsenigens"; they further stipulate that "the manufacturer shall certify that wood treatment complies with the C-17 standard of the American Wood Preservers Association."

In addition to the potential hazards associated with wood rot and treatments to prevent it, another concern regarding wood equipment is that of splintering, which is discussed in conjunction with the hazards of sharp points, corners, and edges (see Section 5.2.2). While metal materials have the advantage of being non-splintering, wood materials do not get hot and cold to the touch in the harsher seasons (Geiger, 1988; Simpson, 1988). Beckwith (1985) noted two other advantages for wood materials: impacting a wooden deck probably carries less risk than striking a metal edge; and, wooden decks have improved traction when wet, unlike slippery metal platforms.

Beckwith (1985) and Stoops (1985) both pointed out that playground structures which combine the advantages of metal and wood materials are now available; support posts which are responsible for the structural integrity of the equipment are metal, while wood is used for decks. Therefore, the problems of rot and deterioration of wood posts caused by contact with the ground are eliminated. Current catalogs indicate that many manufacturers combine various materials to achieve maximum durability and safety for different components of equipment. Galvanized steel and aluminum are widely used metals; pressure-treated pine and natural redwood are widely used woods.

Moore et al. (1987) observed that many plastics have also proven durable as a material for playground equipment. For example, they note that high-density polyethylene is used for spiral slides, spring rocking equipment, and panels on platforms and modular equipment; current catalogs illustrate many such designs. The Play For All Guidelines explain that "in general, the use of plastics increases the visual appeal of environments by offering a great range of color and form. The lack of heat build up, rounded edges and softness are generally positive play values." Caution is suggested for the use of fiberglass because of its low impact resistance. Another application of plastic recognized by Moore et al. is the use of polyvinyl chloride (PVC) as a soft coating for chains and decks. A few manufacturers indicate in their catalogs that this treatment is used to provide a non-slippery, easy-to-grasp surface.

Various ropes, cables, and chains are common materials on playgrounds, used for flexible climbing nets and as the suspending elements for swings. Moore et al. (1987) point out that climbing nets "require frequent inspection and replacement on public playgrounds because of their low durability." They also explain that chain on climbing nets is generally not a good substitute for rope because it is harsh and often presents pinch points; however, vinyl coating, as discussed above, "can greatly improve the quality." There is also a new design which, as explained by Moore et al., provides both flexibility and durability: it is a "wire cable woven with polypropylene rope." Current catalogs indicate that certain manufacturers offer such cables for flexible climbing nets as well as in place of chains to suspend swings. Suspending elements of swings are discussed in Section 5.7.2.3.2.

Recommendations:

Although the current guidelines for durability and finish are reasonable, the inclusion of more specific information regarding acceptable finishes is warranted.

Playground equipment should be manufactured and constructed only of materials which have a demonstrated record of durability in the playground or similar outdoor setting. Any new materials should be tested accordingly for durability by the manufacturer.

A major concern for playground equipment materials is that of corrosion or deterioration. Metals should be painted, galvanized, or otherwise treated to prevent rust; woods should either be naturally rot- and insect-resistant or preserved to avoid such deterioration. Regardless of the material or the treatment process, the manufacturer should ensure that the users of playground equipment cannot ingest, inhale, or absorb any potentially hazardous amounts of substances through body surfaces as a result of contact with equipment. All paints and other similar finishes should comply with federal regulations which enforce the use of lead-free materials. Arsenical wood preservatives should be used in accordance with the specifications of the American Wood Preservers Association C17 standard. It is recommended that purchasers and installers obtain documentation from the manufacturer that none of the preservatives or treatments applied to the equipment present any hazards to the users; such information sheets from the manufacturer should be readily available to all consumers.

Because creosote, pentachlorophenol, and tributyl tin oxide are too toxic or irritating, they should not be used as preservatives on playground equipment wood; it is also recommended that finishes which contain pesticides not be used. One acceptable wood preservative for playground equipment is chromated copper arsenate (CCA), provided that the level of dislodgeable arsenic is minimized. Wood preservers and playground equipment manufacturers are encouraged to identify and practice technologies and procedures which minimize the level of dislodgeable arsenic.

5.5.2 HARDWARE

Guideline content:

Volume 2 of the current Handbook contains the following general specifications regarding hardware.

> Lock washers, self-locking nuts, or other locking means should be provided for all nuts and bolts. Fasteners and connecting and covering devices, when torqued and installed in accordance with the manufacturer's instructions, should not loosen or be removable without the use of tools. (Volume 2, 5.4)

The Handbook also contains other specifications regarding S hooks, protective caps for bolts, and the hazards of protruding bolts; these are discussed in Sections 5.7.2.3.2, 5.2.2, and 5.2.3 of this report, respectively. (Volume 1; Volume 2, 7.1, 7.3)

Probable rationale:

The intent of these recommendations is to ensure that when the hardware supplied by the manufacturer is installed as directed, nuts, bolts, and other critical connecting pieces cannot be loosened either through normal use of the equipment or intentionally by a child. Another goal is to protect children from injuries caused by hooks or other hardware which are hazardous in an open position. (NBS, 1978a; NRPA, 1976a)

Issues:

Esbensen (1987) noted that "all fastenings should be of a secure type," while Moore et al. (1987) call for the use of vandal-resistant hardware. The British (BS 5696: Part 2, 1986) and the Canadian draft (CAN/CSA-Z614, 1988) standards both recommend that nuts, bolts, screws, and other fasteners should be secure against loosening. The Canadian draft standards explain that this can be acheived by using lock washers, self-locking nuts or another means of equal security; further, they stipulate that no hardware should be removable without the use of tools. The specifications in the Canadian draft standards are comparable to the current CPSC guidelines. Similarly, the German standards (DIN 7926, Part 2, 1985) also mandate that all connecting hardware be protected against self-loosening while the equipment is in use as well as against unauthorized loosening. The Seattle draft standards (1986) address the security of hardware in terms basically identical to those of the CPSC.

The standards reviewed also contain specifications regarding hardware for the joints of moving parts. The Australian (AS 1924, Part 1, 1981) and German standards are very similar. The Australian standards require fasteners and connecting pins of components which have relative motion through a joint to be secured against loosening. The German standards also stipulate that suspension points, bedding points, and pivots on equipment must be protected from unauthorized intervention. They further state that such hardware must be interchangeable and require little maintenance. The Australian standards recommend the use of either sintered bronze or themoplastic bearings, and these should be self-lubricating where possible, or else designed to require minimal maintenance. The

Seattle draft standards state that "all weight bearing points that carry movable loads shall be made of durable materials and filled with long wearing, accessible, easy to lubricate bearings." (Moving joints are discussed more thoroughly in conjuction with hardware for swing hanger mechanisms, in Section 5.7.2.3.2.)

One further issue discussed in the Australian and German standards is the potential corrosion of connecting hardware. The Australian standards note that all fastening components must comply with the Australian standard applicable to the material from which they are made. In addition, "due cognizance shall be taken of the significance of the electrolytic corrosion effects of dissimilar metals in contact." It is further noted that joints and connections must be designed "to prevent the entry of water whether by capillary action or by other means." The German standards are not as specific but do state that all connection pieces "shall be protected against corrosion." Although the British standards do not mention corrosion, they do include a list of other British standards with which fasteners and bearings should be in compliance.

Recommendations:

All fasteners and connecting and covering devices should not loosen or be removable without the use of tools, when torqued and installed in accordance with the manufacturer's instructions, as currently stated in the guidelines. Lock washers, self-locking nuts, or other locking means should be provided for all nuts and bolts to protect them from detachment. Hardware in moving joints should also be secured against unintentional or unauthorized loosening. In addition, all fasteners should be designed to avoid corrosion, either of the hardware itself or of the materials they connect. Bearings used in moving joints should be easy to lubricate and maintain. All hooks, including S hooks, should be tightly closed (see Sections 5.7.2.3.2 and 5.2.5).

Section 5.2.3 discusses additional recommendations regarding hardware on playground equipment.

5.6 ACCESS AND PLATFORMS

5.6 ACCESS AND PLATFORMS

5.6.1 ACCESS

5.6.1.1 Stairways, ladders, and ramps

5.6.1.1.1 Access slope

5.6.1.1.2 Steps and rungs
5.6.1.1.2.1 Vertical rise
5.6.1.1.2.2 Tread depth
5.6.1.1.2.3 Ladder rung diameter
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5.6.1.2 Other means of access

5.6.1.2.1 Spiral stairways

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5.6.1.2.3 Arch ladders

5.6.2 TRANSITION FROM ACCESS TO PLATFORM

5.6.3 PLATFORMS

5.6.3.1 Design considerations

5.6.3.2 Guardrails, protective barriers

5.6.3.3 Stepped platforms

5.6.3.4 Landings

5.6.1 ACCESS

Access to platforms can take many forms, such as conventional ramps, stairways with steps, and ladders with steps or rungs, but also includes other climbing components that can provide access, such as climbing nets, arch ladders, and tire climbers. Climbing components which serve as accesses are typically designed to be more challenging than stairways and stepladders, and so require better balance and coordination of the users (see Figure 5.6-1). Rung ladders are generally considered to present a level of challenge intermediate between stairways or stepladders and climbing components.

The biomechanics of climbing, stepping, grasping, balancing, pulling, and posture for children of different ages are complex, and represent some contradictory needs. Sufficient data are not available for all ages and aspects of access usage. Therefore, while problems related to accesses are recognized and addressed widely, consensus on specifications is not unanimous.

5.6.1.1 Stairways, ladders, and ramps

Stairways, stepladders, and rung ladders are distinguished in the CPSC guidelines and in foreign standards by the range of slopes permitted for each access type. Stairways have steps intended primarily for foot support, whereas ladders may have either steps or rungs, typically distinguished by their cross-sectional shape and their depth from front to back. Rungs are generally round in cross-section, are intended to be used for both foot support and hand support, and are sometimes the only type of ladder crosspiece permitted on ladders with relatively steep slopes. Additional recommendations in the literature and in some of the foreign standards pertain to the dimensions and design of steps and rungs, and handrails on stairways, ladders, and ramps.

5.6.1.1.1 Access slope

Guideline content:

Ladders and stairways are discussed independently of any equipment type in Volume 2 of the current guidelines. However, in Volume 1 they are addressed under the heading of slides, although the discussion of steps and rungs and presumably of slope and handrails is intended to include access to other types of equipment as well. The guidelines do not address the use of ramps for access to equipment.

Both Volume 1 and Volume 2 specify that, when measured from a horizontal plane, the slope of stairways should not exceed 35 degrees, the slope of ladders with steps should be between 50 and 75 degrees, and the slope of ladders with rungs should be between 75 and 90 degrees. Volume 1 explicitly states that these ranges of permissible slopes for different access modes are intended to prevent unnatural or unusual climbing angles. (Volume 1; Volume 2, 11.3.1)

Probable rationale:

The NBS reported that the supporting rationale for ladder and stairway slope was taken from the NRPA rationale. The slope requirements were selected to be appropriate for the nature of the ladder or stairway and its mode of use. After reviewing standards for stairways and ladders from OSHA, ANSI, and other sources, the NRPA concluded that there are two important reasons why these standards may not be applicable to playground stairways and ladders. First, ladders or stairways on playground equipment are usually intended only for ascending to an elevated surface, and not for climbing back down, whereas ladders or stairways used in industrial or residential settings are used for both ascending and descending. Second, the general standards for ladders or stairways were not intended to apply exclusively to children, and so they may not be optimal for the anthropometrics of children. (NBS 1978a, 1978b; NRPA, 1976a)

Some inconsistencies among different general standards were noted. For example, the preferred slope and typical slope for ladders on ships were reported as 60 degrees and 68 degrees, respectively (Human Engineering Guide to Equipment Design, 1963), whereas OSHA specified that ladder slopes between 60 and 75 degrees should be avoided. However, the literature was consistent in recommending that rung ladders have a slope between 75 and 90 degrees from the horizontal. The intent is "to keep the user in a generally upright position while ascending or descending a ladder to prevent falling through the openings between the rungs." On the other hand, for stepladders it is optimal for the user to be positioned over each step during ascent, and slopes greater than 75 degrees did not meet this criterion. When stairways are intended for descending as well as ascending, slopes greater than 35 degrees from the horizontal make it difficult and hazardous for the user to descend the stairway in a forward position. (NRPA, 1976a)

Brown (1978) reported that inappropriate ladder incline was a causal factor for slide injuries in the 1978 Special Study. Her review of in-depth investigations from 1976, 1977, and 1978 also identified falling back off a ladder as a contributing cause for slide injuries. Data on the specific slopes associated with these fall injuries may not have been available.

Issues:

Sweeney (1980) criticized the slope recommendations for ladders because they were based on the industrial standard for ladders without railings, but were intended to apply to ladders with railings. The use of railings on a ladder changes the angle of inclination of the user's body and his or her center of gravity, and thus affects the direction of a fall from the ladder. Ladders that meet the CPSC slope specifications are so steep that children who lose their grip will tend to fall backward, rather than forward onto the rungs or steps of the ladder.

While the CPSC recommends that ladders with steps have continuous handrails on both sides, handrails are not required on ladders with rungs, which have the steepest slopes (75-90 degrees). Thus, it would appear that Sweeney's comments apply to all stepladders and to only those rung ladders that have handrails. Although angle of inclination of access ladders is not specified in current catalogs, ladders with rungs are rarely shown with handrails on the sides. In the observational study, children climbing rung ladders typically used the rungs above their current foot position or the side supports of the ladder for hand support; when the rung ladder was not at a 90 degree angle to the surface below, children were observed leaning in toward the ladder. Whether a child is more at risk of falling backward from a ladder than forward onto the ladder depends not only on the presence or absence of a railing, but also on the height of the railing, the specific slope of the ladder, and the typical mode of use by the child. Data are not available on these variables to permit a systematic evaluation of Sweeney's point. Since substantial proportions of slide injuries have been attributed to falls from access ladders (Butwinick, 1980; the detailed incident analysis of 1988 data), and inappropriate slopes have been implicated in some injuries on access ladders (Brown, 1978), such an evaluation appears to be necessary.

A summary of slopes that have been recommended in foreign standards for ramps, stairways, step ladders, and rung ladders is presented in Table 5.6 - 1. The highest slope allowed for access ramps ranges from 15 degrees in the Australian standards (AS 1924, Part 2, 1981) to 38 degrees in the British standards (BS 5696: Part 2, 1986). The British further specify that at angles of 15 degrees or more, the ramp surface must have footholds. While the CPSC guidelines and Seattle draft standards recommend a maximum slope of 35 degrees for stairways, the Australian and British standards and the Canadian draft standards (CAN/CSA-Z614, 1988) permit slopes as high as 45 to 55 degrees for stairways with treads or steps.

The Australian standards have the most restrictive range of slopes for stepladders, 60 to 65 degrees, and do not permit accesses with slopes over 45 degrees and up to 60 degrees. The CPSC guidelines do not recommend the use of slopes between 35 and 50 degrees for stairways or ladders. Although the CPSC, Seattle, and Australia specify a higher range of slopes for rung ladders than for stepladders, both the British standards and Canadian draft standards permit ladders to have either rungs or steps at slopes between 55 and 90 degrees. The only age-related restriction on access slope is found in the Seattle draft standards, which rule out the use of rungs as climbing devices for preschool-age children. The German standards (DIN 7926, Part 3, 1979) for ladder incline apply only to slide access. Most standards require that slide access meet the general requirements for access (Canadian draft, British, and Australian standards).

Frost (U. of Texas, 1989, unpublished manuscript) endorsed the current CPSC guidelines for access slope; in their discussion of slide access, the Play For All Guidelines (Moore et al., 1987) recommends slopes for stairways and stepladders that are identical to the CPSC guidelines. Esbensen (1987) recommended that ladders used for access to slides and climbing structures be inclined at 75 degrees to the horizontal, but did not specify whether this applies to stepladders, rung ladders, or both.

Recommendations:

There is a lack of data relating different slopes of ramps, stairways, and ladders to mode of use, potential for fall, and probable direction of fall for children. Where injury data are available on the incidence of falls from slide ladders (Butwinick, 1980; the detailed incident analysis), they do not provide information on the access slope. Research should be oriented toward possible age-related differences in how children use ramps, stairways, and ladders, in order to evaluate whether some combinations of slope and mode of access are more hazardous for one age group than another.

No changes are warranted in the current CPSC guidelines for access slope, unless additional research demonstrates a need. Although rung ladders provide a challenging alternative to stairways for school-age children, it is recommended that rung ladders not be used as accesses on equipment intended for preschool children. Toddlers may not have the requisite upper body strength, balance, or body control to safely negotiate rung ladders. In addition, it is especially important that younger children be able to descend an access if they decide to halt their ascent. Climbing back down the access is easier on stepladders and stairways than on rung ladders, since rung ladders have the highest slopes (75-90 degrees) and are not equipped with handrails.

5.6.1.1.2 Steps and rungs

Since the standards include specifications for rise, tread depth for open and closed risers, tread or rung width, and rung diameter, these values are summarized for stairways and for ladders in Tables 5.6 - 2 and 5.6 - 3, respectively. Note that the German standards (DIN 7926, Part 3, 1979) apply only to slide access, and that the slopes intended for stairways and ladders vary across standards.

5.6.1.1.2.1 Vertical Rise

Guideline content:

The current guidelines recommend that steps and rungs be evenly spaced, and that the distance between steps and rungs, as measured between the top surfaces of two consecutive steps or rungs, be between 7 and 11 inches. Volume 1 states that this spacing is intended to accommodate the arm and leg reaches of children. (Volume 1; Volume 2, 11.3.2.3)

Probable rationale:

The rationale was taken from the NRPA documents. The even spacing of steps and rungs was considered critical, because 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." The 7- to 11-inch spacing between consecutive steps or rungs was chosen to take into account the knee height (11.4 inches) of the minimum user, apparently a 5th percentile 5-year-old. The user should not have to step above knee height from one step to the next, and a lower height was judged to be optimal. Distances between steps or rungs less than 7 inches were ruled out because they would pose an entrapment hazard. (NBS, 1978a, 1978b; NRPA, 1976a)

In the 1978 Special Study, distance between foot and hand supports was implicated as a causal factor in climbing equipment-related injuries (Brown, 1978). This distance may have been too far to accommodate the leg or arm reach of children, and some victims may have misjudged the distance of the next hand or foot support. Brown concluded that spacing of bars intended for foot or hand support should be appropriate for the reach envelopes of the intended user. However, the proportion of injuries incurred on the access-like components of climbing equipment, such as step and rung ladders, was not reported.

Issues:

In an Australian survey of playground accidents, several injuries were attributed to inappropriate spacing of steps or rungs on ladders, which caused children to slip through the openings and sustain serious neck, head, and facial injuries (Parry, 1982, cited in King and Ball, 1989). In their survey of elementary school playground equipment, Bruya and Langendorfer (1988) found that 63% of climbing structures had distances between "horizontal climbing levels" that fell within the 7 to 11 inch range recommended by the CPSC. It is unclear whether this survey item applied to horizontal ladders only, or included access-type ladders as well.

All of the foreign standards reviewed are in agreement with the CPSC recommendation that steps and rungs be evenly spaced. Requirements from different standards for the vertical rise between consecutive steps or rungs are summarized in Table 5.6 - 2 for stairways, and in Table 5.6 - 3 for step and rung ladders. In general, whereas the CPSC recommendations for vertical rise apply to steps or rungs on any type of access, other standards specify different acceptable ranges, depending on the slope of the access.

A comparison of recommendations for the spacing between steps and rungs is complicated by the fact that the procedure for measuring this distance varies across standards, and is sometimes not explicitly defined. Consistent with the current CPSC guidelines, the British standards (BS 5696: Part 2, 1986) and Seattle draft standards (1986) measure the distance between the top surfaces of two consecutive treads (i.e., steps) or rungs. Whether rise is defined in this way or, alternatively, as the vertical distance between the top surface of one step and the bottom surface of the next higher step cannot be determined from figures provided in the Australian standards (AS 1924, Part 2, 1981) or the Canadian draft standards (CAN/CSA-Z614, 1988). The German standards do not state or illustrate how the rise of rungs or steps is measured.

The only specification for footholds on ramps comes from the British standards: a ramp surface that has an incline of 15 degrees or higher is required to have footholds spaced between 6.9 and 14.2 inches apart, when the distance is measured between the front edges of consecutive footholds.

In all of the standards reviewed, with the exception of the Seattle draft standards, the minimum acceptable rise between stairway steps is lower than the 7-inch minimum distance recommended in the current CPSC guidelines; the maximum rise in most standards is lower than the CPSC's 11 inch specification (see Table 5.6 - 2). The minimum distance between steps is 3.9 or 4 inches in the Canadian draft, Australian, and British standards. However, the British specification applies only to stairways having a slope between 15 and 45 degrees; stairways between 45 and 55 degrees must have a minimum rise of 6 inches. The upper limit on rise is specified as 7.9 inches (British standards), 8.7 inches (Australian standards), and 10 inches (Canadian draft standards). The Seattle draft standards stipulate different ranges of acceptable rises, depending on the intended users: stairways on structures for preschool-age children should have rises between 6 and 10 inches apart, and for school-age children, 7 to 16 inches apart. In addition, the riser, or space between stairway steps, must be filled in if it is open more than 5 inches. Although the Seattle draft standards define vertical rise in the same way that the current guidelines do, they use the interior distance between the top surface of one step and the bottom surface of the next higher step as the criterion for whether the riser must be filled in. Similar to Seattle, Canadian standards require that open risers between stairway steps be filled in or closed if the rise is between 4 and 10 inches. The German standards for stairway access to slides specify a lower minimum distance between steps when risers are open (4.7 inches) than when they are closed (5.9 inches).

Standards for ranges of acceptable vertical rises between the steps and rungs of ladders are summarized in Table 5.6 - 3. In the Canadian draft standards, the spacing for closed ladder steps and rungs is identical to that for stairway steps, 4 to 10 inches. However, when ladder steps and rungs have open risers, the distance should not be less than 10 inches. Similar to the Canadian standards, Seattle requires a minimum distance of 10 inches between open steps and rungs to reduce the potential for entrapment; the rise should not exceed the average knee height of the intended age group, up to a maximum distance of 14 inches. Minimum rises of 6.9 or 7.9 inches and maximum rises of 9.8 to 12.6 inches are found in the Australian, British, and German standards; these ranges have a fair degree of overlap with the current guidelines.

As discussed above, part of the technical rationale for the 7 to 11 inch spacing in the current guidelines is to avoid entrapment hazards. Since the CPSC currently specifies that rise be taken as the distance between the top surfaces of two consecutive steps, the measurement of the interior distance between steps is confounded with the thickness of the step itself. As a result, the interior distance between steps will not necessarily satisfy head entrapment criteria. In view of this problem, many individuals have reportedly suggested a 9 inch minimum for the interior distance between ladder steps and rungs, measured from the top surface of one step to the bottom surface of the next higher step (Preston, 1988).
The ASTM draft standard for home playground equipment (1988) specifies that the vertical spacing between rungs of slide ladders should apply to the space between the top rung and the underside of the slide bed. This recommendation could be extended to regulate the space between the top rung or step of stairways and ladders and the underside of platforms. Such a revision to the current guidelines would ensure that this area would meet entrapment hazards. In addition, Esbensen (1987) pointed out that the space between the top rung of a ladder and a platform can present a pinching hazard for fingers. It can be argued that the step from the top of the access to the platform should conform to the recommendation for even spacing between steps and rungs. When children are making the transition from the top step or rung to the platform above, a deviation from the spacing they negotiated on the stairway or ladder may pose a trip hazard.

In some of the standards reviewed above, distinctions between open and closed risers indicate an effort to eliminate entrapment hazards. Esbensen (1987) recommended that openings between rungs greater than 4.25 inches or less than 9 inches must be filled to avoid entrapment hazards. Similarly, the playground safety checklist used in the SCIPP survey (1988) requires risers to be filled in when rungs or steps on multi-purpose climbers are more than 4.25 inches or less than 9 inches apart.

Taking into account the knee height of the user to determine an acceptable range for vertical rise has received some support in the literature (Aronson, 1988; Esbensen, 1987). Esbensen recommended that the stairway step rise for a preschool-age user should be between 6 and 10 inches, which is the same range required in the Seattle draft standards for stairways intended for preschoolers. Esbensen based his range on the knee height of a minimum (9 inches) and maximum (13 inches) 2-year-old user.

Recommendations:

Steps and rungs should be evenly spaced, as currently stated in the guidelines. This recommendation should also apply to the space between the top rung or step of stairways or ladders and the top surface of platforms.

Vertical rise should simultaneously satisfy two criteria: 1) the distance between the top surfaces of two consecutive steps or rungs should not exceed the step height of the youngest intended user; 2) the distance between the opposing interior surfaces of consecutive steps or rungs and the distance between the top step or rung of accesses and the underside of platforms should preclude the possibility of entrapment. Note that these criteria are based on different measurements of distance between steps or rungs. For the minimum user in the older age group, a 5th percentile 4-year-old, step height is 12 inches. Therefore, steps and rungs intended for use by 4- to 12-year-olds should not have vertical rises greater than 12 inches. Step height for a 5th percentile 2-year-old, the minimum user in the younger age group, is 8.8 inches, and so the vertical rise of steps and rungs intended for 2- to 5-year-olds should not exceed 9 inches. These maximum values for vertical rise are reasonable, given that accesses to play structures are intended to be climbed. Step height seems to be a more reasonable criterion than knee height, on which the current guidelines are based. With regard to the second criterion, vertical rise should not pose an entrapment hazard. Therefore, risers on stairways and stepladders should be closed if the distance between the opposing interior surfaces of consecutive steps is between 3.5 inches and 9 inches in order to satisfy the entrapment requirements (see Section 5.2.6). Since the design of rung ladders does not permit risers to be closed, rung ladders should not be used if the interior distance between consecutive rungs is between 3.5 and 9 inches.

5.6.1.1.2.2 Tread depth

Guideline content:

Volume 2 of the current guidelines recommends a minimum tread depth of 3 inches for steps with open risers and a minimum of 6 inches for steps with closed risers. Tread depth corresponds to the horizontal distance between the front and rear top edges of a tread. (Volume 2, 11.3.2.4)

Probable rationale:

The supporting rationale came from the NRPA documents. The 3-inch minimum depth for steps with open risers was intended to provide adequate contact surface for the foot, which will extend beyond the depth of the step. The 6-inch minimum depth for steps with closed risers was judged to provide sufficient depth so that "enough of the center portion of the foot can come in contact with the tread for good balance and support." (NRPA, 1976a)

In the 1978 Special Study, some slide-related injuries appeared to be caused by inappropriate step depth; Brown (1978) concluded from these data that criteria for step depth should take into account the way in which a child uses a ladder and the size of the intended user.

Issues:

Consistent with the current CPSC guidelines, tread depth is typically depicted in other standards as the horizontal distance between the front and rear top edges of a step. The Australian standards that pertain to stairways give specifications for "projected tread" rather than tread depth. Projected tread refers to the horizontal distance between the front edges of consecutive steps. Thus, projected tread will be less than tread depth, as defined above, if the front edge of one step extends horizontally over the surface of the next lower step.

A comparison of tread depth specifications from different standards is presented in Tables 5.6 - 2 and 5.6 - 3. Like the current CPSC guidelines, some standards specify different depths for open and closed risers, particularly for steps on ladders. In many standards, tread depth is a function of access slope. Requirements for tread depth do not apply to rungs, with the exception of the German standards which govern rungs that are square in cross-section.

In general, steps on stairways are associated with larger minimum tread depths than ladder steps. In addition to the current guidelines, only the British standards require different stairway tread depths, depending on whether risers are open or closed, and this distinction only applies to steeper stairways with slopes between 45 and 55 degrees. For treads with open risers, the treads must be between 3.9 and 8.7 inches deep; this minimum depth is somewhat higher than the 3 inches recommended by the CPSC. The British and the Seattle draft standards specify a 5.9- or 6-inch minimum depth for closed risers, which is virtually identical to the CPSC guidelines for closed risers. Seattle indicates a maximum depth of 14 inches for stairway treads. For stairways with 15 to 45 degree inclines, the British standards require that tread depths be between 8.7 and 13.8 inches; a similar range is applied to stairways with slopes between 15 and 45 degrees in the Australian standards. A 9-inch minimum tread depth exceeds the CPSC recommendations, as does the German requirement that steps on stairway access to slides be at least 7.9 inches deep. The Canadian draft standards permit only closed risers on stairway treads, and those treads must be a minimum of 5 inches deep. Thus, the Canadian standards are unique in prescribing a minimum depth for stairway treads that is less than the 6-inch minimum recommended in the current guidelines.

With regard to ladders, all of the standards reviewed, except the German standards, specify minimum depths for open (3 inches) and closed (6 inches) steps that are identical to the current CPSC recommendations. Germany states that square rungs and steps on slide ladders should be between 1 and 3.2 inches deep.

Aronson (1988) proposed that steps be deep enough to accommodate at least three-quarters of the length of the user's foot. However, she did not specify whether this criterion should be applied to steps with open risers, closed risers, or both. The foot length of a 95th percentile 12-year-old, the maximum user of steps intended for older children, is 10 inches. Therefore, Aronson's recommendation would translate to a 7.5-inch minimum depth for steps used by 4- to 12-year-olds. By contrast, the 3-inch and 6-inch minimum tread depths in the current CPSC guidelines represent a little less than one third and two thirds of the maximum user's foot length, respectively. According to Aronson, steps intended for 2- to 5-year-olds would have to be at least 5.4 inches deep, to accommodate the foot length (7.2 inches) of the maximum user, a 95th percentile 5-year-old. None of the standards reviewed contained age-specific requirements for tread depth.

Recommendations:

For school-age children, no changes in the current recommendations for tread depth on stepladders are warranted: minimum tread depth for stepladders should be 3 inches for steps with open risers and 6 inches for steps with closed risers. However, the tread depth that is adequate for stepladders is not sufficient for stairways. For stairways, the user's feet and legs provide the primary support and lift for ascent, whereas for stepladders, upper body strength and hand support contribute considerably to ascent. Because the user relies almost exclusively on foot support to climb stairways, a larger contact surface for the foot is warranted than for stepladders. Therefore, treads on stairways should be at least 8 inches deep for both open and closed risers, to provide adequate support for the foot of the maximum user, a 95th percentile 12-year-old, whose foot length is 10 inches. This minimum depth is more consistent with specifications in the foreign standards.

Since preschool-age children have a less developed sense of balance and less upper body strength than older children, for this age group, step depths on both stairways and stepladders should be more conservative. Moreover, it is important that younger children have the option to halt their ascent and go back down the access. A larger contact surface for the foot will facilitate descent. Therefore, the minimum tread depth on stairways and stepladders, for both open and closed risers, should be 7 inches. This minimum depth accommodates virtually the entire length of the foot (7.2 inches) of the maximum user, a 95th percentile 5-year-old.

5.6.1.1.2.3 Ladder rung diameter

Guideline content:

The current guidelines do not address the diameter of rungs on ladders separately from other components that are intended to be grasped by the hands. For a general discussion of the recommendations for hand gripping components, refer to the section on handrails (see Section 5.6.1.1.3.2).

Probable rationale:

Not applicable.

Issues:

Specific ranges for the diameters of rungs on access ladders are provided in the foreign standards, and are summarized in Table 5.6 - 3. The Canadian draft, British, and German standards are in agreement on a minimum diameter of one inch. Maximum diameters range from 1.4 inches (German standards) to 1.75 inches (Canadian draft standards). The German standards for rung diameter apply only to round rungs. For rungs that are not circular in cross-section, the British standards specify that the rung not exceed 1.5 inches in depth and that the top surface of the rung adhere to the same range of diameters (1 to 1.5 inches) that applies to round rungs. The Australian standards are less specific, stating only that "rungs of non-circular section shall have equivalent sections suitable for gripping." As previously mentioned, in the German standards square rungs must have depths between 1 inch and 3.2 inches.

The only rationale for rung diameter requirements is provided in the Canadian draft standards, which state that "rungs provide the greatest security if the child's hand encloses most of the rung." Evaluations of rung diameter in the literature were not specific to ladder rungs, and so will be discussed in the general section on handrails. In some current catalogs, diameters of 1.31 or 1.33 inches were specified for rungs used on ladders.

Recommendations:

Separate recommendations for the diameter of ladder rungs are not warranted. The Canadian draft, Seattle draft, and Australian standards for the diameter of ladder rungs are identical to their recommendations for the diameter of handrails. The observational study indicated that ladder rungs are typically used for hand support as well as foot support, which is not surprising given that rung ladders do not usually have handrails, and that rungs and side supports are the only components available as hand grips. Moreover, in the literature, ladder rung diameter is typically discussed in the context of handgripping components. Therefore, the diameter of ladder rungs should follow the general recommendations for handgripping components (see Section 5.6.1.1.3.2).

5.6.1.1.2.4 Tread or rung width

Guideline content:

The current guidelines state that steps and rungs should be a minimum of 15 inches wide. (Volume 1; Volume 2, 11.3.2.2)

Probable rationale:

The rationale was taken from the NRPA documents. The minimum width was based on the maximum user's shoulder width, so that the user does not have to reach inward to hold the handrails of a stairway or ladder or the side supports of a ladder. In addition, by accommodating the shoulder width of maximum users, they are able to "extend [their] arms outward from the median plane of the body for support during ascent and descent." (NBS, 1978a, 1978b; NRPA, 1976a)

Brown (1978) attributed some slide-related injuries in the 1978 Special Study data to inappropriate step width on slide ladders.

Issues:

Standards for step width on stairways and for step and rung width on ladders are summarized in Tables 5.6 - 2 and 5.6 - 3, respectively. The Seattle draft standards and German standards are the only standards consistent with the CPSC's minimum width for stairway steps and rungs. The German standards apply only to slide access for which the free height of fall is more than 3.3 feet.

For stairways with slopes between 15 and 45 degrees, Australian and British standards specify a minimum width of 23.6 inches, which is considerably higher than the 15 inch minimum width in the current guidelines. The British provide separate requirements for stairways inclined between 45 and 55 degrees: steps should be at least 11 inches wide. Maximum values for stairway step width are also provided in the British standards, and range from 17.7 inches for 45-55 degree stairways to 70.9 inches for 15-45 degree stairways. The Canadian draft standards do not regulate the width of steps on stairways. Only the Australian standards require a different minimum width (17.7 inches) for steps on stairways intended for use by preschoolers.

For the width of steps and rungs on ladders, Australian and British standards specify lower minimum values than they did for stairway steps. Following their distinction between the slopes appropriate for stepladders and rung ladders, the Australian standards permit a lower minimum width for rungs (11.2 inches) than for steps (17.7 inches) on public equipment. When the intended users are preschool age, the minimum width required for steps is the same as that for rungs, 11.2 inches. The minimum widths that apply to ladder rungs and steps in the British (9.1 inches) and Canadian draft standards (12 inches) fall below the 15-inch minimum recommended in the current guidelines. Maximum widths, which are provided in the Canadian draft, Australian, British, and German standards, range from 17.7 inches to 23.6 inches; for preschool-age children, Australia states that step width on ladders should not exceed 20.1 inches.

In summary, the Australian and British standards specify a higher minimum for stairway step width than the current guidelines do. Minimum widths that are lower than the CPSC's 15-inch minimum tend to be associated with steeper accesses, such as 45 to 55 degree stairways (British standards), 55-90 degree step and rung ladders (Canadian draft and British standards), and 65-90 degree rung ladders (Australian standards). Australia's age-specific recommendations provide for narrower access on equipment for preschool-age children than on public equipment in general.

Recommendations:

The rationale behind the current guidelines for step and rung width seems reasonable: to facilitate the use of handrails or side supports and thus improve the stability of the user. The shoulder width of the maximum user represents a reasonable lower limit for step and rung width that will permit stable hand support. To accommodate the shoulder width (15.7 inches) of the maximum user of equipment intended for older children, a 95th percentile 12-year-old, the minimum width of steps and rungs on all types of access should be 16 inches.

Younger children, those aged 2 to 5 years, need a separate recommendation. For the maximum user in this age group, a 95th percentile 5-year-old, shoulder width is 11.5 inches. Therefore, steps and rungs on all types of access intended for preschoolers should be at least 12 inches wide.

Most standards stipulate a maximum width for steps and rungs. It is important to note that as step and rung widths increase beyond the minimum 16 inches for older children and 12 inches for younger children, the child is less likely to be able to hold handrails on both sides of the access. That step and rung widths often exceed the current minimum recommendation was supported by a review of current catalogs. On multi-use equipment, the side support posts of a platform are often used as the side supports of rungs which provide vertical access to the platform. In addition, stairways to platforms are often as wide as the platform, typically 3 or 4 feet. For older children, modes of access wider than the minimum 16 inches do not appear to pose a hazard, since this age group does not require use of both handrails during ascent and descent. However, hand support is more critical for preschool-age children, particularly on stepladders, which are steeper than stairways and which require climbing up rather than walking up. If handrails are too far apart, preschoolers may find it difficult to apply sufficient force to pull themselves up a stepladder in the vertical direction. To ensure that the minimum preschool user can make use of handrails on both sides of a stepladder, the maximum width of steps should be 21 inches. This value accommodates the shoulder breadth (8.7 inches) of the minimum user, a 5th percentile 2-year-old, with an allowance on either side for the acromion-radiale length (5.9 inches). These anthropometric measurements were used to estimate the distance between the elbows of the minimum user when his or her arms are extended out from the shoulder.

5.6.1.1.2.5 Horizontal orientation; slip-resistant surfaces; contrasting colors

Guideline content:

The current guidelines recommend that steps and rungs be horizontal to within plus or minus 2 degrees. (Volume 1; Volume 2, 11.3.2.1)

Under the section on falls from equipment, Volume 1 states that components intended mainly for use by the feet should have a finish that is slip-resistant under both wet and dry conditions. Slip-resistant materials on steps and rungs may improve the user's gripping ability and increase the amount of sensory feedback received from the stepping surface while climbing. Volume 2 addresses the use of slip-resistant surfaces for steps and rungs in the sections on climbing equipment and slides, and suggests that steps and rungs be highly textured, corrugated, or grooved, and that the slip-resistant finish be permanent. (Volume 1; Volume 2, 11.4)

Volume 1 recommends that bright, contrasting colors be used on rungs or steps of climbing equipment to "help children to perceive distances more accurately, thus improving their spatial judgment." (Volume 1)

Probable rationale:

The NBS rationale for horizontal orientation was based on the NRPA documents. Stepping surfaces that are approximately level in all directions were intended to keep the user from sliding sideways or from front to back. The two degree deviation from horizontal has the advantage of improving drainage. (NBS, 1978a, 1978b; NRPA, 1976a)

NBS intended that the recommendation for slip-resistant surfaces apply to surfaces used primarily by the feet, including steps, platforms, and decks. The purpose was to reduce the incidence of falls due to loss of footing; loss of grip as a cause of falls was not addressed in the NBS rationale for this recommendation. An objective criterion and test procedure for adequate slip resistance was considered impractical, since there are a wide range of materials used for playground equipment and footwear, and a wide range of environmental factors to which the equipment is exposed. Thus, "the decision as to whether or not a surface is 'too slippery' must be made subjectively." (NBS, 1978a)

In her review of the 1978 Special Study data, Brown (1978) found that the presence of moisture on the equipment, hand, or shoe led to some climbing-related accidents. She suggested that materials with a high coefficient of friction might improve a child's hand gripping ability.

The rationale for using bright, contrasting colors on steps and rungs of climbing equipment was explicitly stated in Volume 1 of the guidelines: to improve children's spatial judgment by helping them to perceive distances more accurately. (Volume 1)

Brown (1978) reported that some climbing equipment-related accidents in the 1978 Special Study appeared to be caused by the child misjudging the distance of the next support member for hand and foot placement. As a remedial strategy to aid distance perception, she proposed that bright, contrasting colors be used on climbing equipment.

Issues:

Horizontal orientation. The British and Australian standards require that all surfaces intended for contact by the feet be horizontal, except for ramps; Australia also exempts access provided by climbing frames from this requirement. The Seattle draft standards state that steps and rungs should be horizontal.

Slip-resistant surfaces. Other standards specify that the surfaces of steps and rungs be slip-resistant. The Australian and Canadian draft standards apply this requirement to ramps, steps, and treads, while the British standards specifically include rungs. Modes of access or bars that are components of climbing equipment are excluded from this requirement in the British and Australian standards. The Seattle draft standards simply state that all walking surfaces should have a slip-resistant finish, under both wet and dry conditions.

Consistent with the CPSC recommendation to use textured, corrugated, or grooved materials for stepping surfaces, the Australian standards suggest the following materials for providing durable slip-resistant surfaces: narrow width slats, cleats, perforated or embossed metal, ribbed or grooved metal or plastics, or timber that does not have finely sanded, painted, or polished surfaces. When stepping surfaces are treated with matte or slip-resistant paints, varnishes, resins, or polishes on timber, they must be periodically retreated. In such cases where the slip-resistant finish is not durable, the manufacturer is required to include the need to retreat the surfaces at regular intervals in the installation instructions. By contrast, the Canadian draft standards state that a finish or coating used to provide slip resistance should not require reapplication.

In the German standards, stairs and landings that provide access to slides must have "slip-proof" treads; a minimum coefficient of friction and a test procedure for determining its value are specified. The surface sample must be wetted with water before the friction index is measured. Consistent with this testing procedure, both the current guidelines and the Seattle draft standards explicitly state that stepping surfaces should be slip-resistant under wet conditions. The Seattle draft standards do not permit log-end rounds or timber ends to be used for stairway steps, since these materials retain moisture and promote slippery moss growth. Davis (1980) argued that most materials, especially wood, will fail the slip-resistant requirement when wet, and suggested that the current CPSC recommendation be modified to read: "Where the material can realistically be scored, grooved or ribbed, it should be."

Bright, contrasting colors. Consistent with the current guidelines, the playground safety checklist used in the SCIPP survey (1988) contains an item on whether rungs are painted in bright or contrasting colors. However, none of the standards reviewed contained a comparable recommendation.

Recommendations:

Horizontal orientation. Steps and rungs should be horizontal within a tolerance of plus or minus 2 degrees.

Slip-resistant surfaces. Steps, rungs, and other components intended primarily for use by the feet should have a finish that is slip-resistant under wet and dry conditions. Permanent treatments are preferable. However, when non-durable treatments are used to provide slip-resistant surfaces, manufacturers should include information in the installation instructions regarding how often to retreat the materials.

5.6.1.1.2.6 Other design considerations

Additional design considerations covered in other standards include the structural security and replaceability of steps and rungs, as well as methods to discourage the use of an access or the equipment being accessed by smaller children. Requirements concerning the structural security of the access as a whole are also included in this section.

Guideline content:

The current guidelines do not make any recommendations about the structural security or replaceability of steps and rungs. They do not suggest that rung or step ladders providing access to equipment intended for older children be designed to discourage its use by younger children.

Probable rationale:

Not applicable.

Issues:

The structural security of rungs and steps, or of the complete access, is addressed in various ways. The German standards (DIN 7926, Part 1, 1985) require that steps and rungs be permanently attached to the side supports, which means that "positive connections that cannot be undone or shifted" must be used for wooden components. The British standards state that when access is required to the top of any equipment, other than climbing equipment, it should be fixed permanently. Similarly, the Seattle draft standards and Esbensen (1987) recommended that stairways, ladders, steps, and rungs be firmly anchored to prevent unpredictable movements during climbing. However, unlike the British standards, Esbensen stated that access to climbing structures be firmly secured. The Canadian draft, Seattle draft, and British standards do not permit steps and rungs to rotate when grasped; the Seattle draft standards also specify that steps and rungs should not wobble.

The Canadian draft and German standards address the method for attaching rungs and steps to the side supports of the access: nails or wood screws should not be used as the sole means of connecting steps and rungs to their side structures. The Australian and British standards stipulate that steps and rungs, or the entire access, must be replaceable on all public equipment. Other design requirements for steps are as follows: the edges of steps must be properly finished German standards; step nosing, or the effective projection of a tread when risers are closed, should not exceed one inch (Canadian draft standards); and a groove on the top edge of ladder steps is recommended as a handhold for small hands (Seattle draft standards). Among current catalogs reviewed, one manufacturer provides a groove on the upper surface of each ladder step, and illustrates its use as a handhold.

The Play For All Guidelines (Moore et al. 1987) states that closed risers can create a slip hazard if they fill with sand, and therefore recommends that steps with closed risers have holes "too small to catch fingers but large enough to let grains of sand through without clogging." A review of current catalogs indicated that stairways and stepladders providing access to equipment often have closed risers. At least three manufacturers provide perforated steps and/or risers, which would appear to minimize the accumulation of sand on steps when risers are closed.

Three standards suggest various treatments of steps and rungs to discourage the use of equipment intended for school-age children by preschool-age children. The Australian standards recommend that the maximum vertical rise of 11.8 inches be used between rungs on ladders. The Canadian draft standards state that the lowest rung(s) on ladders may be removed; consistent with this strategy, the Seattle draft standards specify that the first access step or rung be at least 14 inches high, which is equal to the knee height of a 95th percentile 5-year-old. Esbensen (1987) also endorsed removing the bottom rung of access to tall equipment intended for older children, especially on public school or public park equipment. The playground safety checklist used in the SCIPP (1988) survey suggests that the bottom access rung to equipment that is 6.5 to 8 feet high should be removed if preschoolers have access to the equipment. None of these methods for discouraging the use of advanced equipment by younger children place a limit on how high above ground the first rung of a ladder can be. It is conceivable that some rung heights would be hazardous, even for older users.

The Seattle draft standards (1986) specify that ramps should not be used where they allow preschool-age children to climb up to structures with play challenges that are appropriate only for older children. In addition, on multi-use equipment, slides and ladders should be separated to prevent jumping from one structure to the other. Using the same rationale, Esbensen (1987) recommended that slide chutes and ladders not be placed in close proximity on climbing structures.

Recommendations:

Steps and rungs should be securely attached to their side supports, and should not turn or wobble when grasped. Stairways and ladders should be firmly anchored so that they do not move while a child is climbing. Since broken or missing steps and rungs can be a maintenance problem, it is recommended that steps and rungs be replaceable. When risers are closed, stairways and ladders should be designed in a way that prevents the accumulation of sand, water, or other materials on or between steps, without presenting any finger entrapment hazards (see Section 5.2.6.4).

When the potential fall height from equipment is relatively high, the strategy of placing the lowest step or rung of an access ladder high enough to discourage preschoolers from using equipment intended for older children appears to have some merit. Given the overlapping distributions of step height for preschool- and school-age children, as these age groups have been defined throughout this report, this strategy cannot be fully successful. However, if the minimum user from the older group is defined as a 5th percentile 6-year-old, placing the first foothold of a ladder at the maximum step height (15.9 inches) of this minimum user can achieve some safety benefit for toddlers (2- to 3-year-olds). Based on standard deviations for step height reported in Snyder et al. (1977), it is estimated that if the first foothold is usable by a 5th percentile 6-year-old, it is high enough to preclude use by about 87% of toddlers. Therefore, on ladders that provide access to relatively high equipment, there is a safety benefit in placing the first foothold 16 inches above the underlying surface.

Since it is probably easier for young children to crawl up ramps than to crawl or climb up stairways and ladders, ramps should not lead up to structures that are too advanced for toddlers and preschool-age children.

5.6.1.1.3 Handrails

Handrails on stairways and stepladders are typically intended to provide hand support and to steady the user. Handrail requirements include the maximum elevation permitted without handrails, handrail height and diameter, and other design considerations.

5.6.1.1.3.1 Maximum elevation without handrail; handrail height

Guideline content:

The current guidelines state that stairways and stepladders should have continuous handrails on both sides; they do not specify a maximum elevation above which stairways and stepladders should have handrails. (Volume 1; Volume 2, 11.3.3)

The design of the handrails, including their height, should allow the user to maintain an upright position over each step. Beyond this general design requirement, no minimum or maximum heights of handrails are recommended. (Volume 1; Volume 2, 11.3.3)

Probable rationale:

The intent of the general recommendation for continuous handrails is to provide security for the user during ascent and descent. (NBS, 1978a, 1978b)

With regard to handrail height, it is not feasible to select one height for handrails that will be optimal for all users. However, railings should be designed so that users are able to maintain an upright position over each step, and can use the railings without having to lean back or reach substantially forward. (NBS, 1978a, 1978b)

Brown (1978) noted that some slide-related injuries in the 1978 Special Study were caused by children being unable to reach handrails on accesses to slides. Using in-depth investigations from 1976 to 1978, Brown identified one injury scenario in which younger children were unable to reach the handrails at the bottom of the slide access. After crawling up the steps to a point where the rails were reachable, victims lost their balance and fell as they attempted to stand up.

Issues:

A summary of maximum elevations permitted without handrails and heights of handrails required in the standards is provided in Table 5.6 - 4. Only the German standards (DIN 7926, Part 3, 1979), which pertain to slide access, have separate regulations for the height of handrails on stepladders and stairways. The Canadian draft (CAN/CSA-Z614, 1988) and Australian (AS 1924, Part 2, 1981) standards specify handrail heights for both upper and lower handrails, and distinguish between handrails used by school-age and preschool-age children.

Like the current CPSC guidelines, the Canadian draft and Australian standards require continuous handrails on both sides of ramps, stairways, and stepladders, but exempt rung ladders from this requirement. The Australian standards provide the rationale that on rung ladders, the rungs themselves are used as handrails. The observational study showed that on ladders with rungs, children tended to use the rungs for hand support as they climbed up the ladder. Current catalogs indicated that stairways and stepladders typically have handrails, while rung ladders do not.

The Canadian draft standards apply only to modes of access that are more than 24 inches high. The British standards (BS 5696: Part 2, 1986) state that handrails should be provided "in all cases where the access to equipment, with the exception of climbing frames" exceeds 19.7 inches above the underlying surface. In both the British and Seattle draft standards (1986), it is unclear whether handrails are necessary on rung ladders.

The Australian and German standards regulate the maximum height above ground or a lower landing at which handrails must begin: 47.2 inches for public equipment and 31.5 inches for preschool equipment (Australian standards), and 23.6 inches for slide stepladders (German standards). With regard to how high handrails must extend at the upper end of the access, the Seattle draft standards require that handrails on stairways and ladders extend a minimum of 24 inches above the upper platform, and the Australian standards specify that handrails "extend at least as high as a point vertically above the outer edge of the platform, landing or equipment served."

Consistent with the current guidelines, a consumer guide to safer play spaces published by the Canadian Institute of Child Health (1985, cited in King and Ball, 1989) recommended that handrails be positioned so that users can maintain an upright position as they climb. Esbensen (1987) advocated the use of adequate railings on playground equipment to help prevent falls, but did not specify height dimensions for handrails. In current catalogs, continuous handrails are provided on both sides of a stairway or stepladder, sometimes with both an upper and lower handrail on each side. The observational study indicated that children generally use handrails on stepladders. On stepladders to slides, children tended to move their grip forward to a higher position on the handrails before ascending to the next higher step.

The question of how high handrails should be to help prevent falls has received some study for adult users (Maki, Bartlett, and Fernie, 1984, 1985; Pauls, 1985). One criterion for evaluating handrail height is based on a biomechanical analysis of handrail use. Maki et al. (1984) pointed out that "the best handrail design will allow users to position the upper extremity in a way that will enable them to generate the largest stabilizing forces and moments should they slip or trip while traversing a stairway." The maximum stabilizing forces and moments exerted on handrails by adults in a stationary, upright position were used to estimate their ability to recover from a loss of balance during stairway descent. For adults, increases in handrail height (in the range between 32 and 42 inches) were associated with increases in the maximum forces and moments that can counteract undesirable body motion during the initial stages of a fall. Taking into account these data as well as user preferences, Maki et al. (1984, 1985) concluded that the optimal range for handrail height is between 36 and 38 inches for stairways with slopes of 33, 41, and 49 degrees. For steeper accesses, the effect of handrail height on an adult's ability to recover balance currently appears unknown.

Thus, there is evidence that adults are better able to recover from a stumble and arrest a fall on descent if their support point is higher up. Consistent with this finding, informal field observations collected by J. Pauls (personal communication, August 1989) indicate that when given a choice, children tend to use a higher handrail. For example, if there is a double handrail, children will use the higher rail, even if it is at or above their shoulder height. Also, when handrails are infilled with vertical rails or netting, children will reach at or above shoulder height for hand support. Pauls recommended a handrail height between 28 and 32 inches to accommodate 2- to 4-year-olds. The lower limit of this range exceeds the suprasternale height of a 5th percentile 2-year-old (26.2 inches), and the upper limit is slightly lower than the suprasternale height of a 95th percentile 4-year-old (33.2 inches). (Suprasternale height is used to approximate shoulder height.) The observational study showed that on steeper accesses, such as stepladders to slides, children tended to hold the handrail higher up than they did on stairways, apparently to facilitate pulling themselves up in the vertical direction; their grip location often appeared to be at or above shoulder height. Data on the biomechanics of handrail use by children are not available. The biomechanics are likely to vary depending on the slope of the access, the age of the child, and whether the child is ascending or descending.

In the Canadian draft and Australian standards, illustrations show handrail height as the vertical distance between the top front edge of a step and the top surface of the rail above it. By contrast, the British standards measure handrail height from the top rear edge of each step, which means that handrail heights in the British standards are not directly comparable to those in the Canadian draft and Australian standards. Also, in the German standards, the height of handrails on stepladders to slides is apparently measured as the perpendicular distance above the side supports of the ladder, and not as the vertical distance above each step. The Australian standards specify that handrails should be parallel to the slope of the access.

Maximum heights for upper and lower handrails provided in the Australian and Canadian draft standards are almost identical, with values of about 40 inches for the upper handrail and 20 inches for the lower handrail; the Canadian draft standards specify lower minimum heights for upper and lower handrails than the Australian standards. Since the British standards prohibit any intermediate horizontal or near horizontal rails that can be used as steps for climbing on handrails, they do not appear to permit a lower handrail (Ramsey and Preston, 1989). To accommodate smaller users without providing a lower handrail, the British range of acceptable handrail heights has a minimum value of 20 inches, which is identical to the maximum lower handrail height found in the Australian and Canadian draft standards.

On equipment intended for use by preschool-age children, the Australian standards specify higher handrail heights (17.7-27.6 inches) than the Canadian draft standards, which state that upper and lower handrails for preschoolers should be from 10-16 inches high and from 10-12 inches high, respectively. One problem with the Canadian requirements is that the distance between upper and lower handrails may pose an entrapment hazard. The Canadian draft standards address this issue for school-age users when they stipulate that the distance between upper and lower handrails should not be less than 10 inches. However, this 10-inch minimum distance between upper and lower handrails is inconsistent with the permissible ranges of handrail heights for preschoolers.

Recommendations:

Continuous handrails should be provided on both sides of all stairways and stepladders, regardless of the height of the access. Because rung ladders are more steeply inclined (75 to 90 degrees) than other types of access, it seems reasonable for children to use rungs or ladder side supports for hand support. Therefore, rung ladders can be exempted from the handrail recommendations. When the maximum height of a ramp exceeds 24 inches, continuous handrails should be provided on both sides of the ramp.

Handrail height should be between 21 and 38 inches for school-age children, and between 20 and 26 inches for preschool-age children. Handrail height should be taken as the vertical distance between the top front edge of a step (tread nosing) and the top surface of the handrail above it. The upper limits of these ranges are based on elbow heights of the maximum users in each age group, a 95th percentile 12-year-old (38 inches) among older children and a 95th percentile 5-year-old (26 inches) among younger children. Elbow height was estimated from the difference between the user's suprasternale height and shoulder-to-elbow length. The minimum values for handrail height were based on elbow heights of a 5th percentile 4-year-old (21 inches) for older children and a 5th percentile 2-year-old (20 inches) for younger children. Informal field observations (J. Pauls, personal communication, August 1989) and the observational study suggest that children sometimes choose to grasp handrails at shoulder height or higher, particularly on steeper accesses. Therefore, even handrail heights at the upper end of the range do not appear to be unreasonable for most users in the age group. For example, the upper limit for handrail height recommended for younger children approximates the suprasternale height (26.1 inches) of the minimum user. For older users, the upper limit of 38 inches is about 9.5 inches higher than the suprasternale height (28.5 inches) of the minimum user, a 5th percentile 4-year-old, but is only 2.5 inches higher than the suprasternale height (35.6 inches) of a 95th percentile 5-year-old. Choosing a maximum handrail height that is suitable for the minimum user is more critical for younger users than for older users, since younger children probably use their arms more in climbing to compensate for their less developed leg strength.

Since double handrails could encourage children to climb on them, it is preferable to provide only one handrail. Handrails should be available for use at the appropriate height beginning with the first step. How high the railings should extend at the upper end of the access is addressed in the section on transition from access to platform (see Section 5.6.2).

5.6.1.1.3.2 Handrail diameter

Guideline content:

The current guidelines for the diameter of hand gripping components apply to rungs of horizontal ladders, climbing bars, and handrails. Volume 2 states that any rungs intended to be grasped by the hands should not be more than 1.6 inches in diameter "or in the maximum cross-sectional dimension." The maximum diameter takes into account the hand size of a minimum user, defined as a 5-year-old child. In the event that a 1.6 inch diameter component cannot meet structural requirements, any alternate component or design must not seriously impair the hand gripping potential of the user. Volume 1 states that a 1.6 inch diameter provides a comfortable and secure grip for an average 5-year-old, and recommends that the rung be cylindrical in cross-section. It should be noted that while Volume 1 recommends that gripping components be approximately 1.6 inches in diameter, Volume 2 refers to 1.6 inches as the maximum diameter. (Volume 1; Volume 2, 11.2)

Probable rationale:

The rationale for accommodating the hand size and grip of a minimum user, rather than that of a maximum user, is given in the following excerpt from the NBS supporting rationale document. (NBS, 1978a)

> 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.

NBS proceeded to explain the basis of the 1.6-inch minimum diameter. When the hand is gripping an overhead cylindrical component, the user's grip is subjected to the maximum force, and so this is used as the test condition. The ability to sustain this grip and, at the same time, support 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." If a cylinder allows the gripping parts of the hand to contact at least 50% of the its circumference, it is considered an adequate gripping surface. The gripping parts of the hand are those between the tip of the index finger and the crotch of the thumb. This measurement for the minimum user is 2.54 inches, which corresponds to 50% of the circumference of a cylinder with a 1.6-inch diameter. This recommendation applies to components intended to support both hands and feet, because it is assumed that a secure hand grip is more critical to safety. In the 1978 Special Study, some slide-related and climbing equipment-related injuries were due to the diameter of handrails being inappropriate for the minimum user's hand size (Brown, 1978).

NBS's evaluation of NRPA's proposed standards for the diameter of hand-gripping components should also be considered. NRPA recommended that components intended for gripping by the hands be from .75 to 1.5 inches in diameter. Their rationale was that when the user's hand encloses the rung or bar, there should be at least a .25 inch overlap in gripping, presumably between the thumb and the middle finger. Adding .25 inch to the inside grip diameter of a minimum and a maximum user results in diameters of .75 and 1.75 inches, respectively. The 1.75-inch diameter was judged as too large for the grip size of younger children, and so 1.5 inches was chosen as the maximum diameter. NBS criticized NRPA's recommendation on the grounds that in some situations, gripping components within this range would not satisfy requirements for structural integrity. NBS's concern that the recommended diameters be consistent with structural requirements is reflected in Volume 2, which states that alternate designs may be necessitated "when structural requirements cannot reasonably be met by 1.6 inch diameter components." (NBS, 1976, 1978a, 1978b; NRPA, 1976a, 1976b)

Issues:

Unlike the current CPSC guidelines, all of the other standards reviewed specified a minimum diameter for handrails. The standards for handrail diameter are presented in Table 5.6 - 4. As stated previously, the Canadian draft, Seattle draft, and Australian standards require the same range of diameters for handrails as for ladder rungs. The Australian, British, and Seattle draft standards are in approximate agreement on a minimum diameter of .71 or .75 inches and a maximum diameter of 1.5 or 1.57 inches. The German and Canadian draft standards specify a higher minimum diameter (1 inch), and a maximum diameter (1.75 or 1.8 inches) that exceeds the current CPSC recommendation of 1.6 inches.

Esbensen (1987) and the SCIPP playground safety checklist (1988) applied the same specifications to handrails as they did to climbing rungs: both sources specified a range between 1.5 and 1.75 inches, although Esbensen targeted this recommendation for younger users (2- to 5-year-olds). The Play For All Guidelines advocates smaller diameters for rails on climbers (1-1.25 inches), and Aronson (1988) stated that rails and bars intended for use by preschoolers should be cylindrical and no more than 1 inch in diameter. In their survey of elementary school playground equipment, Bruya and Langendorfer (1988) found that the average diameter of hand and foot holds on climbing equipment was 2.45 inches, which exceeds the CPSC's maximum diameter by almost 1 inch. Several current catalogs show diameters of 1.13 and 1.33 inches for handrails, hand loops, and rungs; one manufacturer indicated that upper and lower handrails on slide stepladders were 1.5 to 1.63 inches in diameter. D. Thompson (personal communication, February 1989) recommended that there be a separate grip diameter specification for 2- to 5-year-olds.

Various criteria have been proposed to ensure that the diameter of gripping components is appropriate for the intended age group. The Seattle draft standards for diameter specify that the thumb should be locked around the hand-gripping component to meet the fingers. To satisfy this criterion, gripping components should not exceed 1 inch in diameter for a 5th percentile 4-year-old, or .9 inches in diameter for a 5th percentile 2-year-old. These estimates were based on inside grip diameter, which is the maximum diameter at which the tips of the thumb and middle finger just touch. Esbensen recommended a less stringent criterion: handrail and rung diameter should allow a child's hand to enclose more than two-thirds of the gripping component. This would mean that gripping components should be less than 1.53 inches in diameter for a 5th percentile 4-year-old, and less than 1.3 inches in diameter for a 5th percentile 2-year-old. The 1.3-inch maximum diameter for the minimum user among preschool-age children falls below the range of diameters specified by Esbensen for this age group.

In their study of gripping strength measurements of children, Owings et al. (1977) reported that little information is available on the relationship between the growth of the hand and strength. They pointed out that hand size may not be the only determinant of hand strength. The ASTM Subcommittee on the continuum of skills and size differences of children conducted a review of anthropometric data, and found that strength measurements (e.g., grip strength) do not match the rapid growth rate observed in children during the first 5 years of life (ASTM Task Group F15.29, 1989).

Measurements of hand strength indicate that, just as a large object can be difficult for a small hand to grasp, a small rod can be difficult for a larger hand to grasp (Owings et al., 1977). This point is illustrated when grip strength is examined as a function of age and the distance between the gripping surfaces. The squeeze test for grip strength requires the child to squeeze the handle of a grip fixture together with his or her entire hand. Squeeze force is measured in units of pound force (lbf). The distance between the two parallel handles of the grip fixture can be adjusted to mimic the squeezing of different sized objects. The forces exerted in squeezing the handle of the grip fixture may be somewhat different from the forces required to sustain the child's grip on a cylindrical component, such as a handrail or rung (J. Pauls, personal communication, August, 1989). For example, in the squeeze test for grip strength, the anterior surfaces of the second knuckles of the four fingers and thumb are the only parts of the hand to contact the grip fixture, whereas additional parts of the fingers and hand are typically in contact with the surface of a cylindrical component, when the user is gripping the component. Moreover, the grip fixture is not oriented to simulate the position of a handrail in use (Maki, Bartlett, and Fernie, 1983). However, in the absence of data on grip strength for cylindrical components, and subject to the caveats noted above, the distance between the gripping surfaces in the squeeze test will be used to approximate the diameter of a cylindrical hand gripping component.

Results of the squeeze test for grip strength are presented in Table 5.6 - 5 as a function of the distance between gripping surfaces, for the minimum and maximum users in the 2- to 5-year-old age group, and for the minimum user in the 4- to 12-year-old age group. Since data were not available for a 95th percentile 12-year-old, the 95th percentile 10-year-old was used instead. The smallest grip diameter tested, .79 inches, is not optimal for any of these users. The general pattern is that the 1.2 inch diameter is associated with higher grip strengths for the minimum users, while the 1.6 inch diameter yields higher grip strengths for the maximum users. In summarizing grip strength data, Owings et al. (1977) reported that for children between 2.5 and 5 years of age, grip strength reaches a maximum for the 1.2 inch diameter, and then levels off; for children 5 years of age and older, however, grip strength peaks for the 1.6-inch diameter and then gradually tapers off.

Recommendations:

Components intended to be grasped by the hands, such as handrails, ladder rungs, and climbing bars, should have a diameter or maximum cross-sectional dimension between 1 and 1.5 inches. Placing a lower limit on diameter is warranted by grip strength data: the smallest distance between gripping components that was tested (0.79 inches) was associated with the lowest grip strengths, for all of the ages sampled. It is suggested that the diameter of hand gripping components be closer to the optimum value for the minimum user in each age group. As far as can be determined from the crude distribution of grip strength as a function of grip diameter, the grip strength of minimum users among both preschool- and school-age children peaks at the 1.2 inch diameter. In addition, the 1.2 inch diameter allows almost three-quarters of a 5th percentile 2-year-old's hand and 85% of a 5th percentile 4-

year-old's hand to enclose the component. Therefore, to benefit the weakest users in both age groups, a value close to the midpoint of the 1 to 1.5 inch range of diameters might be preferred.

5.6.1.1.3.3 Other design considerations

Guideline content:

The current guidelines do not address design features of handrails other than height and diameter.

Probable rationale:

Not applicable.

Issues:

The Australian and Canadian draft standards state that handrails should be supported to allow unrestricted movement of the hand along its upper surface (Australia) or gripping surface (Canada). Whether gripping surface refers to the upper surface or to the entire circumference of the handrail is not specified in the Canadian draft standards. The Australian standards require a minimum "hand clearance" of 2.4 inches for upper handrails on public equipment and 1.6 inches for handrails on preschool equipment. Ramsey and Preston (1989) described hand clearance as the minimum clearance to an adjacent member. These minimum values for hand clearance presumably accommodate the maximum depth of the hand, and ensure that no adjacent components prevent users from gripping the handrails.

The Seattle draft standards specify that handholds should not turn or wobble. Similarly, the playground safety checklist used in the SCIPP survey (1988) of playground equipment required that handholds stay in place when grasped. In their discussion of handrails on access stairways for slides, the German standards state that handrails should not be open at the ends. The British standards permit handrails to be offset by as much as 3 inches, and imply that they can be offset by more than that amount if the handrails are infilled. Offset appears to refer to the horizontal distance between the outside edge of the surface supporting the handrail and the interior edge of the handrail.

Recommendations:

While allowing for hand clearance along the upper surface of a handrail seems reasonable, a review of catalogs showed that this is not currently a problem in handrail design. Therefore, this point seemed too detailed to warrant a recommendation in the handbook.

5.6.1.2 Other means of access

5.6.1.2.1 Spiral stairways

Guideline content:

The current guidelines do not address dimensions for spiral stairways.

Probable rationale:

Not applicable.

Issues:

Because steps on spiral stairways are narrower at the inside edge than at the outside edge, special attention must be given to provide adequate room for both feet on each step and to devise a method for measuring tread depth. The Canadian draft (CAN/CSA-Z614, 1988) and Australian (AS 1924, Part 2, 1981) standards for spiral stairways are very similar. Both standards state that spiral stairways may be used for inclines between 15 and 65 degrees, and must adhere to the same requirements for rise and tread depth that apply to stairways and ladders. However, the location on the step at which the measurements for rise and tread depth must be taken is governed by the outside radius of the spiral stairway. The Canadian draft requirements specify that for stairways with an outside radius between 19.7 inches and 35.4 inches, measurements should be made at 70% of the width of the step, measured from the inner edge of the step. For stairways with an outside radius between 35.4 inches and 70.9 inches, the position corresponds to 60% of the width of the step; for larger outside radii, the measurement should be taken at 50% of the width of the step. The Australian standards differ from the Canadian draft standards only with respect to the ranges of outside radii: measurements must be taken at 70%, 60%, and 50% of the width of the step for outside radii between 19.7 and 39.4 inches, between 39.4 and 78.7 inches, and greater than 78.7 inches, respectively. Thus, in both these standards, the larger the outside radius of the spiral stairway, the closer to the inner edge of the step rise and tread depth must be measured. In addition, both standards prohibit outside radii less than 19.7 inches and steps whose inner edge is less than 3 inches deep. The Canadian draft standards state that other requirements for access apply, presumably including regulations for handrails and equal spacing of steps.

The British (BS 5696: Part 2, 1986) and German (DIN 7926, Part 3, 1979) standards concerning spiral stairways are not as detailed as the ones discussed above. The British standards contain the following requirements for spiral and helical stairs and ramps: 1) vertical rise must be between 6.9 and 9.1 inches for steps; 2) projected tread, "measured tangentially at centre of tread," must be between 5.9 and 10.8 inches for steps; 3) step width must be between 17.7 to 21.7 inches; 4) slope should not exceed 38 degrees for steps or ramps; and 5) headroom must be provided for up to 70.9 inches above the surfaces of steps or ramps. In addition, treads must be equally spaced, and balusters (i.e., vertical supports) used to support handrails either should not have spaces greater than 3.9 inches in width or should be infilled. The German standards for spiral stairways apply only to slide access: at the inner edge of the step, the tread should not be less than 3.9 inches deep, or less than 2 inches if the steps have open risers.

On one of the playgrounds sampled in the observational study, a spiral stairway had individual loop-shaped handrails on the outside edges of some of the steps, rather than a continuous handrail. The lack of continuous hand support appeared to make ascent and descent awkward for some of the younger children.

Recommendations:

Spiral stairways should meet the general requirements for stairway access, including uniformity of rise, riser height, handrails, and tread width. Even on steeper spiral stairways, the mode of use is similar to that for stairways and does not typically involve pulling the body in a vertical direction. The outer edge of the step should meet the minimum depth criteria for steps on stairways: 8 inches for 4- to 12-year-olds, and 7 inches for 2-to 5-year-olds. The inner edge of each step should be at least 3 inches deep for both age groups. These recommendations for the minimum depth of the inner edge and outer edge apply to spiral stairways with both open and closed risers.

The minimum dimensions for tread width and depth ensure an adequate area for both feet on the outer portion of each step. The foot support area was considered adequate if it met the following criteria: when measured from the outer edge of a step, the area should be at least 12 inches wide for older children, and at least 8.5 inches wide for younger children; and, the inner edge of the area should be at least 4 inches deep for both age groups. Minimum width of the foot support area is based on the hip breadth at trochanter of the maximum user in each age group, a 95th percentile 12-year-old (12.1 inches) for older children and a 95th percentile 5-year-old (8.3 inches) for younger children. Hip breadth approximates the minimum separation of the feet that is necessary for adequate foot support. For both age groups, the outer portion of a step having the minimum recommended width and depth will provide a foot support area that satisfies the criteria discussed above.

Although the design of handrails along both sides might not be possible when the inner edge of steps forms the axis of a spiral stairway, a continuous handrail should be provided along the outside perimeter of the steps.

5.6.1.2.2 Climbers with non-rigid components

Modes of access like net climbers and chain climbers use a grid of ropes or chains for climbing. These non-rigid components can be supported in a variety of ways. The vertical components of the grid are typically suspended from a horizontal bar at the top of the access and anchored in the ground or attached to a horizontal bar at the bottom of the access. Some manufacturers incorporate side support bars into the design, and suspend the horizontal components of the grid from these side supports. One manufacturer uses arch-shaped side supports for a net climber. Since net and chain climbers have flexible components that do not provide a steady means of support, and therefore require more advanced balance abilities than conventional ladders, they should be evaluated separately from accesses with rigid components.

A typical tire climber is a 2 X 3 matrix of tires suspended by chains from the side support posts of a platform, and anchored at the bottom by chains in the ground. Because tire climbers are anchored with non-rigid components and the tires themselves do not provide rigid foot support, they are classified as flexible climbers.

Guideline content:

The current guidelines address modes of access with non-rigid components, such as net or chain climbers, only in the context of suspended hazards. Volume 2 states that "any cables, wires, ropes, or similar components suspended between other components within 45 degrees of the horizontal are not recommended because they could be impacted by a rapidly moving child." However, such items as cargo nets and climbing grids are not intended to be eliminated by this recommendation. (Volume 2, 7.4)

Probable rationale:

Volume 2 explains that this recommendation is intended to eliminate the hazard of a rapidly moving child colliding with a suspended component. In their supporting rationale, NBS emphasized the hazards of impact with suspended components at the head or neck level, which can result when a child is riding a bicycle or running near a suspended cable, wire, or rope. No explanation is given for excluding cargo nets and climbing grids from the recommendation. (NBS, 1978a)

The NRPA had proposed that moving ladders, net climbers, chain climbers, and similar devices "which do not provide a fixed, steady means of support" should not be used to achieve heights greater than 8 feet above the underlying surface. Their technical rationale was that, because these climbing devices are not steady, the risk of falls is greater than it is for fixed climbing devices. In their evaluation of this recommendation, the NBS judged the NRPA's rationale to be adequate, but subjective, and referred to the proposed standard as adequate but debatable. (NBS, 1976; NRPA, 1976a, 1976b)

Issues:

The Australian (AS 1924, Part 2, 1981) and Canadian draft (CAN/CSA-Z614, 1988) standards contain requirements for cargo nets, moving ladders, and similar devices that do not have fixed or steady climbing components. The Seattle draft standards (1986) address chain and "webbed" climbers, and the German standards (DIN 7926, Part 1, 1985) contain specifications for chain climbers. Both the Seattle draft and Canadian draft standards mandate that climbers with non-rigid components be securely fastened. The Seattle draft standards specify that net and chain grids be fixed along all edges, or at least at the top and the bottom. As mentioned above, some manufacturers secure net and chain climbers only at both ends. The Seattle draft standards also state that connection points within the climbing grid should be checked for wear. Consistent with these standards, Esbensen (1987) suggested that climbing nets and suspension nets be firmly and safely connected, and this recommendation corresponds to an item on the SCIPP playground safety checklist (1988). The Canadian draft standards state that any single rope must be attached at both ends.

According to the Australian standards, the height of the surface at the top of the access determines whether a net climber or similar device is permitted: on public equipment, non-rigid climbers must not be used to access surfaces that are more than 8.2 feet above the ground or underlying surface; on equipment intended for children five years of age or younger, the limit is 5.9 feet. Similarly, the NRPA (1976b) proposed that flexible climbing devices not be used to reach heights greater than 8 feet above the underlying surface, as discussed above. The Canadian draft standards state that the type of non-rigid access that is appropriate for an elevated surface depends on the angle of inclination and the height of the surface. Current catalogs illustrate the use of net and chain climbers to access platforms up to 6 feet high. On equipment designed for preschool-age children, net and chain climbers typically lead to platforms that are 3 feet high. Only one of the catalogs reviewed indicated the angle of inclination of a net climber (45 degrees); other net and chain climbers appeared to be steeper, particularly at the end closest to the platform.

Other requirements for flexible climbing devices focus on materials of construction. The Seattle draft standards require that cargo nets and climbing chains be made of plastic coated steel or vinyl coated heavy duty chain. For chain climbers, the German standards state that chain links should have a maximum opening of .31 inches in one direction. To avoid finger entrapment between the links and connecting pieces, chain climbers should have short links. Connecting pieces, such as bolts, washers, screws, nuts, and rivets should be protected against corrosion. With regard to rope and net climbers, the German standards contain separate specifications for sheathed wire ropes and fiber or textile-type ropes. Fiber-sheathed wire rope is recommended for use on unsupervised playground equipment; the wires inside the strands reduce the likelihood of damage and the resulting hazards. Each strand of wire must be sheathed with yarn made of synthetic or natural fibers. When fiber ropes are used for rope and net climbers, the strands must have a soft and non-slip covering, such as hemp. Monofilament polypropylene and polyethylene ropes or similar materials are not allowed. In current catalogs, one manufacturer indicated that steel wire enclosed in plastic is used for net climbers; another manufacturer specified that chains for chain net climbers are 4/0 steel with poly-vinyl-chloride coating.

Beckwith (1988) and the Play For All Guidelines (1987) report that rope and net climbers are designed to minimize the risk of falls from platforms by reducing the potential fall distance. Beckwith classified flexible climbers (i.e., net and chain climbers) as soft balance activities that both offer the highest motor challenge for children and maintain a high level of popularity.

Current catalogs show that grids are typically comprised of parallel horizontal components connected to parallel vertical components; this design enables a child to place both feet at the same level before climbing higher. In another design, adjacent steps are staggered, apparently encouraging the user to climb to a higher level with each alternating step. Observational data indicated that, when climbing stairways, younger children tended to climb one step at a time, bringing both feet to the same level before climbing to the next step; older children were able to ascend by alternating feet on successive steps. Thus, given that flexible climbing components do not provide the steady foot support that conventional steps do, the grid with staggered components may be too advanced for the balance capabilities of younger users.

Net and chain climbers that are currently manufactured may be suspended from a horizontal bar at the level of the platform or somewhat higher than the platform. The size of the opening between the horizontal bar and the edge of the platform can vary considerably. One in-depth investigation from the detailed incident analysis showed a distance of 3 inches between the horizontal bar from which a chain climber was suspended and the edge of the platform.

Flexible accesses do not have handrails on the sides. As with rung ladders, children are expected to use the climbing components and side supports, which can be rigid or non-rigid, for hand support.

Recommendations:

Flexible climbing devices which provide access to platforms should be securely anchored below ground level and securely connected to the structure at the top. When components of a climbing grid are attached to a horizontal bar at the bottom of the access, the horizontal bar should be buried below ground level to eliminate a potential trip hazard. Connections between ropes, cables, or chains within the climbing grid or between tires should be securely fixed. Spacing between the horizontal and vertical components of a climbing grid should satisfy all entrapment criteria (see Section 5.2.6). The area between the rigid horizontal bar from which net and chain climbers are suspended and the edge of the platform should also be designed in accordance with the recommendations given in the entrapment section (see Section 5.2.6). When flexible climbers are intended for use by children 5 years of age and under, it is recommended that they be designed to readily allow users to bring both feet to the same level before ascending to the next level.

Since flexible climbing devices are designed to be more challenging than conventional accesses, they should not be the sole access to other components of equipment. There should be a less challenging option for access, such as stairways or stepladders, to ensure that children use flexible climbing devices because they are willing to assume the challenge and not because they are forced to use them.

Steel-belted radials should not be used in tire climbers because of the potential hazard of protruding metal bands.

5.6.1.2.3 Arch ladders

Arch ladders consist of metal or wood rungs attached to convex side supports, and are used for access to equipment intended for both older and younger children.

Guideline content:

The current guidelines do not address arch ladders or tire climbers.

Probable rationale:

Not applicable.

Issues:

Arch ladders do not have handrails; in the observational study, children were observed to use rungs and the edge of the platform for hand support. In principle, if children were to lose their footing on a typical arch ladder, they would fall forward onto the rungs rather than backward onto the ground. Several manufacturers use arch ladders to access platforms that are 72 or 78 inches high. In one design, the rungs are wood and square in cross-section; at the top of the ladder, the wood rungs are close together and form a horizontal surface that is 42 inches above ground, with no hand supports. In the observational study, two children were observed to have difficulty at the top of an arch ladder: one child faltered as he rose from a kneeling position, and the other fell through the rungs. Also, in one catalog, a child is shown hanging upside down from a rung by her knees. This mode of use would conflict with the use of the arch ladder to access a platform.

Recommendations:

Since arch ladders are designed to be more challenging than conventional accesses, they should not be the sole access to other components of equipment. There should be a less challenging option for access, such as stairways or stepladders, to ensure that children use the arch ladder because they are willing to assume the challenge and not because they are forced to use it.

Arch ladders whose top rungs form a horizontal surface should have handholds at the transition point at the top of the ladder to help users maintain their balance as they move from a climbing to a standing position, as discussed in the following section.

5.6.2 TRANSITION FROM ACCESS TO PLATFORM

Guideline content:

The CPSC guidelines for straight slides state that all slides should be designed to facilitate the transition between the access ladder, platform, and sliding surface. Protective barriers around slide platforms that are more than 30 (Volume 2) or 48 (Volume 1) inches high are intended to help the user maintain balance during this transition. However, the current guidelines do not contain provisions for continuing handrails from the top of the slide access to the slide platform, and do not address the general issue of transition from accesses to platforms on equipment other than slides (see Section 5.7.1.3.2). In their proposed standards for continuous handrails on both sides of ladders and stairways, the NRPA explicitly stated that handrails should also be provided at the top of accesses "to provide security in transition between surfaces or levels." (Volume 1; Volume 2, 11.5.4, 11.5.4.2.1; NRPA, 1976b)

Probable rationale:

The recommendations for protective barriers around platforms are intended to aid in the transition between a climbing position at the top of the slide access and a sitting position on the sliding surface, because transitions between positions and activities pose the greatest risk for falls (see Section 5.7.1.3.1). Protective barriers around elevated surfaces will be discussed in Section 5.6.3.2. The NBS supporting rationale for protective barriers does not address the transition between ladder and platform, and, with regard to hand support, states that "adequate handholds for a minimum and maximum user in standing and seated postures should be incorporated into the barrier design." Whether these handholds are recommended at the entrance to the platform or at the entrance to the slide chute is not specified. The NRPA reiterated in their technical rationale that handrails at the top of ladders and stairways are intended to provide security as the user moves from the access to the platform to be negotiated. (NBS, 1978b; NRPA, 1976a)

Issues:

The Australian standards (AS 1924, Part 2, 1981) address the transition from accesses to platforms for slide platforms and for any platforms with guardrails. For slides, handrails on accesses should continue over the platform and end at the beginning of the slide chute. In general, when gaps are made in guardrails around platforms to provide entry and exit points to accesses, vertical handrails must be installed on each side. The Australian standards also specify that handrails on accesses should extend at least as high as a point vertically above the outer edge of the platform. Moreover, to reduce the risk of users being pushed from entry and exit points on platforms, designs should incorporate continuous railings, handgrips, or other suitable measures. Similarly, the Seattle draft standards (1986) require that entry and exit openings to platforms that are more than 30 inches high have protective side railings and/or hand grips. The German standards (DIN 7926, Part 3, 1979) provide for the continuation of handrails on the slide stepladder into the bannister on the slide platform.

The detailed incident analysis of 1988 data revealed that at least 6 out of 17 falls from a slide ladder were from the top portion of the ladder; the in-depth investigations often did not provide sufficient information to determine whether the fall occurred from the top of the ladder.

When access is provided by stairways or stepladders, the side handrails can be designed to merge with the handrails or protective barrier around the platform so that continuous hand support is available during transition from the top of the access to the platform. A review of current catalogs indicated that side railings on stairways and stepladders typically extend high enough to provide hand support for a user at the entrance to the platform. This may be accomplished with a vertical or loop handrail at the top of the access. Handrails are often connected to the side support posts of the platform, or the railings or protective barrier around the platform. However, some manufacturers permit a gap between the vertical or loop handrails at the top of the access and the side support posts of the platform. In one design that appeared in two catalogs, steps to a platform did not have side railings; loop handrails attached to the side support posts of the platform were provided for hand support at the top of the stairway.

As noted in a previous section, most standards do not require continuous handrails on rung ladders. Moreover, other modes of access, such as flexible climbers, arch ladders, and tire climbers, are not usually equipped with side handrails. Hand support at the top of these types of accesses is often provided by vertical or loop handrails located on both sides of the platform entrance. Vertical handrails are usually perpendicular to the outer edge of the platform, and may be attached to the vertical edge of the protective barrier on either side of the entrance to the platform. Loop handrails may extend over the sides of the access at its top, either in line with the side supports of the ladder or angled towards each other. An alternate form of support, recommended by Frost (1980) to aid in the transition from ladder to platform, is the overhead horizontal bar. As seen in catalogs, this bar is attached to the side support posts of the platform, and appears to be several feet above the outer edge of the platform.

The observational study showed that vertical and loop handrails were often provided at the top of accesses without side handrails, including vertical rung ladders, arch ladders, and chain climbers; one chain climber and one ramp had overhead horizontal bars. One child was observed to have difficulty climbing to the top rung when no handholds were provided at the top of a vertical rung ladder. When vertical or loop handrails were present, some children used them to get from the top of the access to the platform, while others used the edge of the platform instead. One child, who was holding onto vertical handrails at the top of a vertical rung ladder, was observed to lose his footing; the use of the handrails apparently helped to prevent a fall. Overhead horizontal bars were not consistently used by children as they moved from the access to the platform. One pattern of use was for children to kneel on the platform before standing, and one child used the overhead bar to pull himself from a kneeling position on the platform to a standing position. Since children must extend their arms above their heads to reach the bar, hand support at the top of the access is interrupted. By contrast, vertical or loop handrails at the sides of the platform can be positioned so that if children have to move their hands from the rungs or side supports of the access to the handrails, they do not have to move them very far. Users must also avoid hitting their heads on the overhead bar as they enter the platform area.

Recommendations:

On any transition from an access mode to a platform, handrails or handholds should be adequate to provide support until the user has fully achieved the desired posture on the platform. Therefore, on stairways and stepladders, there should be some provision for continuation of side handrails from the access to the platform, to provide uninterrupted hand support as users move from the top of the access to the platform. Any opening bounded by a handrail and an adjacent vertical structure (e.g., vertical support post for a platform or vertical slat of a protective barrier) should not pose an entrapment hazard (see Section 5.2.6).

On accesses that do not typically have side handrails, such as rung ladders, flexible climbers, arch climbers, and tire climbers, special attention should be given to providing hand support to facilitate the transition between the top of the access and the platform. The optimal design depends, in part, on the slope of the access. For example, on steeper ladders, children do not have to lean forward in order to reach vertical handrails that are perpendicular to the platform edge, whereas on less steep accesses, this handrail design may be more difficult to reach than loop handgrips that extend over the top of the ladder.

Based on limited observational data, overhead bars typically appear to be less effective than alternative means of providing hand support during transition from access to platform.

5.6.3 PLATFORMS

Many play structures currently offered by manufacturers consist of tiered platforms or decks, with varied modes of access to and from platforms, and different play events attached to platform levels, such as slide chutes and suspension bridges. Also, intermediate platforms may serve as landings on stairways and ladders. Platforms are typically square in shape, but may also have other shapes, and are often constructed from wood, steel, or aluminum. Most recommendations for platforms pertain to guardrails or protective barriers used to help prevent falls from platforms; some recommendations address other design features of platforms and contain specific requirements for stepped platforms and intermediate platforms.

5.6.3.1 Design considerations

Guideline content:

As stated previously in the section on slip-resistant surfaces, the current guidelines recommend that components intended primarily for use by the feet should have a slip-resistant finish under wet and dry conditions. This recommendation is intended to apply to platforms and decks. (Volume 1; Volume 2, 11.4)

No other design features of platforms are addressed, other than the use of protective barriers.

Probable rationale:

Refer to the probable rationale in the section on slip-resistant surfaces of steps and rungs.

Not applicable.

Issues:

In their discussion of platforms, decks, ramps, and roofs, the Seattle draft standards (1986) state that "platforms and decks sized to accommodate small groups are conducive to cooperative play," and that modular platforms about 4 feet square "are usually successful." Platforms, decks, and other walking surfaces should have non-slip surfaces, and be free of algae, moss, or other growths. A moss remover and retardant should be applied as necessary, and dirt build-up should be removed with annual pressure washing.

In addition, the Seattle draft standards recommend adding roofed areas to some platforms to provide shelter in wet or hot weather. Roofs should be designed to prevent access out onto the top. In Schulte's study (1984, cited in King and Ball, 1989) of accidents on unsupervised playgrounds, one injury was attributed to climbing on the roof of a "playcabin." Roofs over play structures were addressed in a 1988 playground safety inspection checklist published by the NRPA. A clearance of at least 78 inches is required between the roof and the underlying platform. Consistent with the Seattle draft standards, the NRPA specifies that support posts for the roof should not provide access to the roof. In addition, the dripline of the roof should extend at least 4 inches outside the edge of the platform the roof is sheltering, and there should not be exposed rafters, beams, girders, or trusses underneath the roof structure. The British standards (BS 5696: Part 2, 1986) contain requirements for roofed enclosures on slide access platforms: the interior should have a "clear headroom" between 4.1 and 6.6 feet, and any part of the exterior that is more than 8.2 feet above ground should be designed to discourage climbing.

The Canadian draft standards (CAN/CSA-Z614, 1988) require that all platform decking have a minimum of 2.5% of its total area open to permit drainage. In addition, any openings used for drainage should not exceed .51 inches, presumably to prevent finger entrapment. However, based on anthropometric data, openings must be less than .31 inches to prevent entry by the index finger of a 5th percentile 2-year-old. Current catalogs showed that metal and vinyl-coated metal platform surfaces are often perforated, allowing for drainage. The size of openings used was not reported in any of the catalogs. When platforms are constructed from wood planks, there appear to be gaps between the planks; one manufacturer currently uses plastic components to maintain a .25 inch gap between adjacent planks, "to dissipate expansion and contraction forces due to changes in humidity and temperature." In apparent disagreement with the Canadian draft standards, Esbensen (1987) recommended that platforms on climbing structures have solid flooring, so that sand and grit cannot fall through openings in the platform onto children playing below. In the catalogs sampled, solid surfaces appeared to be used much less frequently for platforms than perforated metal surfaces or wood planks.

Recommendations:

It is recommended that platforms and decks have surfaces that are slip-resistant under wet and dry conditions. Openings should be provided to allow for drainage; however, any such openings should not present a finger entrapment hazard (see Section 5.2.6.4). Roofed areas should be designed to prevent children from climbing onto the roof.

5.6.3.2 Guardrails, protective barriers

All the standards reviewed contain some provision for guardrails or barriers on platforms and other elevated surfaces, to help prevent falls to the underlying surface. Protective barriers have more stringent requirements than guardrails in that, in addition to preventing falls over the edge, protective barriers should also be designed to preclude access under or through them (NRPA, 1976b). Most standards do not clearly distinguish between these two levels of protection, and terms like guardrail and barrier are not used consistently in the literature.

Guideline content:

Volume 2 addresses protective barriers in its general discussion of elevated surfaces, and also in its treatment of the slide surface entrance. Recommendations for barriers that are specific to slides are discussed in Section 5.7.1.3.2.2.

An elevated surface that is more than 30 inches above the underlying surface, and that is intended for use as a "platform, deck, walkway, landing, transitional surface, or similar walking surface" should have a protective barrier at least 38 inches in height. The barrier should completely surround the surface except for necessary entrance and exit openings. The design of barriers should prevent falls through the barrier, prevent entrapment, and deter climbing on the barrier. Elevated surfaces where a protective barrier would interfere with the intended use of the equipment are exempt from this recommendation; these surfaces include "balance beams, most climbing apparatus, platforms or other equipment tiered or layered in a manner which would preclude a fall of more than 30 inches." Protective barriers also do not apply to ladders and stairways. (Volume 2, 11.1)

Volume 2 also specifically states that protective barriers at least 38 inches high should surround slide platforms, except for necessary exit and entrance openings. This recommendation applies to slides with an entrance height greater than 30 inches. Like barriers on elevated surfaces, barriers on slide platforms are intended to prevent falls through the barrier, prevent entrapment, and discourage climbing. Volume 1 also recommends the use of protective barriers on slide platforms to help prevent falls, but permits a maximum slide height of 4 feet without barriers, in contrast to the 30-inch maximum height allowed in Volume 2. Solid barriers or barriers with vertical rather than horizontal bars are suggested as designs that may discourage climbing. (Volume 1; Volume 2, 11.5.4.2)

Probable rationale:

As stated in the current guidelines and in the NBS rationale, protective barriers are intended to prevent accidental falls from equipment. Rutherford (1979) reported that 72% of public playground equipment-related accidents in the 1978 Special Study were due to falls.

<u>Maximum elevation without barriers</u>. The rationale for the 30-inch maximum height of surfaces without barriers was based on precedents established by major building codes, including the Uniform Building Code-1976, Section 1716, and the One and Two Family

Dwelling Code, 1975, Section R215. These codes were considered appropriate by NBS for two reasons: 1) the codes were devised to provide protection to the public, including children between 5 and 12 years of age; 2) the protective structures covered in the building codes and the current guidelines have the same functional intent. (NBS, 1978a, 1978b)

Minimum height of barrier. The 38-inch minimum height for barriers ensures that the maximum user's standing center of gravity is below the top surface of the barrier. The 38-inch dimension was based on the standing center of gravity (36 inches) of a 95th percentile 12-year-old, with allowances added for settling, warping, or other aging effects and for footwear. In their 1976 report, A model performance standard for guardrails, the NBS recommended that the height of protective barriers should take into account the user's standing center of gravity and a tolerance for settling, warping, or other aging effects. (NBS, 1978a, 1978b)

Design considerations. To prevent a foreseeable hazardous use, the design of a barrier should neither encourage nor facilitate climbing on or over the top of the barrier, and should prevent a minimum user from falling through. For example, since horizontal intermediate bars below the top of a barrier may look like a ladder to users, and therefore encourage climbing, this barrier design should not be used on elevated surfaces. The recommendation that barriers be designed to prevent entrapment is self-explanatory, given that barriers may contain openings that pose entrapment hazards. Barriers may be constructed from any material that satisfies the above recommendations, and need not be solid or opaque. Transparent or open screen barriers are preferable over solid or opaque barriers, because they facilitate supervision and permit the user to see out from the elevation, eliminating the feeling of confinement. (NBS, 1978a, 1978b)

Issues:

Standards for guardrails and barriers on elevated surfaces are summarized in Table 5.6-6. The structures governed by requirements for guardrails or barriers vary somewhat across standards. The CPSC guidelines for protective barriers apply to walking surfaces, such as platforms, decks, and landings, and to slide platforms in particular, but not to ladders and stairways. The Australian standards (AS 1924, Part 2, 1981) require guardrails on platforms and landings, and also on the sides of inclined accesses, such as stairways. The British standards (BS 5696: Part 2, 1986) state that guardrails are necessary "in all cases where the access to equipment, with the exception of climbing frames, is more than 19.7 inches above ground level or other adjacent surface." Although platforms, ramps, and slide accesses are explicitly covered by this requirement, it is unclear whether other types of access are also required to have guardrails. In contrast, the NRPA (1976b) proposed that stairways and ladders be exempt from having protective barriers. Their rationale was that handrails at a suitable gripping height are more important on stairways and ladders than a protective barrier whose top surface is too high for proper use as a handrail.

Consistent with the current guidelines, other standards do not include ladders and stairways in their requirements for guardrails. The Canadian draft standards (CAN/CSA-Z614, 1988) for guardrails apply to all standing surfaces and platforms; similarly, the Seattle draft standards (1986) require guardrails on any standing or climbing surface. Recall that the current guidelines exempt most climbing equipment from the recommendation for protective barriers. The German standards (DIN 7926, Part 1, 1985) specify that fall guards be provided on pedestals and platforms.

Fall height criteria for guardrails and barriers. The maximum height permitted for a platform without guardrails is 19.7 inches in the British standards and 24 inches for school-age users in the Canadian draft standards; thus, guardrails are required beginning at lower elevations than the 30-inch limiting height recommended in the current guidelines and in the Seattle draft standards. On platforms intended for preschool-age children, the Canadian draft standards specify a maximum elevation of 18 inches without guardrails, which is similar to the Australian upper limit of 19.7 inches on platforms designed for preschoolers. On public equipment, the Australian standards require that platforms higher than 47.2 inches be protected with guardrails. Frost (U. of Texas, 1989, unpublished manuscript) regarded 48 inches as an excessive height for a platform without guardrails. In the German standards, "fall guards" are required if fall height exceeds 6.6 feet. (The German standards do not define fall guards.) Also, the maximum height of a platform above a given ground surface is contingent on whether or not the platform is protected by fall guards that extend at least 33.5 inches above the surface of the platform. For example, sand and fine gravel are acceptable surfacing materials under platforms protected by fall guards for fall heights up to 13.1 feet; without fall guards, the highest permissible fall height for a platform is 9.8 feet.

Esbensen (1987) supported the use of protective siding on climbing structures that lead users to levels 30 inches or more above the underlying surface. The SCIPP survey (Helsing et al., 1988) indicated that on 97% of playgrounds with climbers, climber platforms that were 30 inches or more above ground did not have 38 inch high barriers.

Butwinick (1980) criticized the NBS for applying only one recommendation for barriers to all walking surfaces higher than 30 inches. She proposed that the degree of protection required on a platform should increase as a function of probable severity of injury resulting from a head-first fall to the underlying surface. Although precise relationships between fall height and severity of injury are not known, peak g, an acceleration-based measure, has been reported to correlate with AIS injury levels of the head. On the assumption that soil is the most common surface under equipment, Butwinick used the soil impact test results reported by the NBS (1979b), in combination with data on the probable severity of injury associated with different peak g levels, to establish the degree of protection needed at various fall heights for a head-first fall. Butwinick's recommendations were as follows. For platforms and other walking surfaces up to 4 feet high, injury resulting from a head-first fall would tend to be minimal, and so a guardrail is not necessary. For platforms more than 4 feet high and up to 6 feet high, guardrails should be provided. Protective barriers should be used on all platforms over 6 feet high and up to 10 feet high, because the peak g levels indicate moderate to severe, and possibly irreversible, injury. Walking surfaces over 10 feet high, including climbing structures, should be totally enclosed.

For further discussion of data relating acceleration-based impact measures to severity of head injury, see Section 5.1. It is important to recognize that potential for head injury should not be the sole criterion for determining guardrail and barrier requirements; fractures to body extremities can result from relatively low heights (NRPA, 1976a).

The NRPA (1976b) also proposed different degrees of protection around elevated surfaces, depending on the potential fall height. Guardrails were recommended for walking surfaces between 4 feet and 8 feet high. Any surface elevated more than 8 feet and up to 12 feet should have a protective barrier, and surfaces more than 12 feet in height should be totally enclosed. As discussed previously, the NRPA distinguished between guardrails and protective barriers in their proposed standards. Although both guardrails and protective barriers are intended to help prevent falls, the design of protective barriers has additional constraints: protective barriers must not permit access under or through them. Thus, the NRPA's proposed standards for guardrails and barriers are less conservative than Butwinick's proposed guidelines. The NBS (1976) stated that the NRPA's fall height criteria for guardrails and protective barriers were based on subjective judgment, and that alternatives would also be subjective, given the current state of knowledge.

Height of guardrails and barriers. The Australian standards specify that the top rail of guardrails on public equipment should be at least 35.4 inches above the standing surface or step nosing of stairways and stepladders. This height is somewhat lower than the 38 inch minimum height recommended in the current guidelines. On equipment intended for preschoolers, the minimum height is 27.6 inches, which is slightly higher than the standing center of gravity (26.9 inches) of a 95th percentile 5-year-old. The German standards require that fall guards be at least 27.6 inches high on platforms and pedestals intended for all users, while the Canadian standards specify a slightly lower minimum height of 24 inches on standing surfaces with fall heights of 36 inches or more. In the British standards, the minimum height of guardrails depends on the height of the surface above ground. Platforms between 19.7 and 39.4 inches in height should have guardrails at least 19.7 inches high. For platforms between 39.4 and 59.1 inches above ground level, the minimum height of the guardrail increases as a linear function of fall height, up to a value of 35.4 inches. Only the Seattle draft standards provide a minimum barrier height (42 inches) that is greater than the CPSC's 38-inch minimum value.

Butwinick (1980) and the Play For All Guidelines (Moore et al., 1987) supported the 38-inch minimum height for protective barriers recommended in the current guidelines. F. Wallach (personal communication, February 1989) questioned whether barriers on a surface 30 inches high are warranted by injury data, and stated that a 38-inch barrier on top of a platform 30 inches in height may create a 68-inch elevation for jumping off equipment. Preston (1988) pointed out that the top of a 38 inch high barrier is above the eye level of a 4-year-old, and so the minimum barrier height may have to be lowered to accommodate preschool-age children. Consistent with the NBS rationale, Esbensen (1987) recommended that the standing center of gravity be used to determine the heights of guardrails on platforms. In addition, the stature of users must be considered to ensure that they are visible and that they can see out from the platform. Taking these two variables into account, Esbensen suggested that guardrails be 24 inches high for 1- to 3-year-olds, and 28-32 inches high for 3- to 6-year-olds. The SCIPP playground safety checklist (1988) indicates that barriers around equipment intended for preschoolers should be 30 inches high.

Design considerations. Consistent with the current guidelines, some standards place constraints on the design of guardrails to discourage climbing by users, and to prevent them from falling off or through the guardrails. The Australian standards permit guardrails to be of monolithic or non-monolithic construction. The requirements for non-monolithic guardrails are as follows. Support posts should not be more than 6.6 feet apart, and the area between the walking surface and the top rail should be filled in. The material used for infill should be shatter and splinter proof, and should be fixed by welding, lugs, clips, or other suitable means. To discourage climbing, the infill should be designed in such a way that space in the infill and between the infill and the guardrail frame is not used for a toehold or foothold. At fall heights up to 8.2 feet above ground for public equipment, and up to 5.9 feet for preschool equipment, an intermediate horizontal rail located halfway between the standing surface or step nosing and the top rail may be used instead of infill. Like the Australian standards, the Canadian draft standards permit the use of horizontal components below the top rail of guardrails. To preclude entrapment, any clear distances between components on guardrails should not be between 4 and 10 inches. Clear distance is measured perpendicular to the components, and is defined as the distance between adjacent edges of adjacent components. The maximum clear distance between horizontal components should be 12 inches, and between vertical components, 4 inches. Thus, clear distances between horizontal components are effectively limited to the range between 10 and 12 inches.

By contrast, the British standards prohibit the use of intermediate horizontal or near horizontal rails beneath the top rail since they can be used as steps for climbing the guardrail. Infilling below guardrails is required, and the infill should not form wedge, finger, hand, limb, or head traps. A wedge trap is defined as "any trap formed by an acute angle between two or more adjacent parts that converge in a downward direction." When vertical components are used they should not be spaced more than 3.9 inches apart; when perforated material is used for the infilling, the maximum hole size in any direction should be 1 inch. Insofar as possible, solid infill materials should be shatter proof. The Seattle draft standards require that infilling on barriers consist of either solid panels or vertical components, to prevent climbing on the barrier. Thus, horizontal components appear to be ruled out. In addition, the tops of barriers should not provide a walking or sitting surface. The German standards simply state that fall guards should not encourage climbing, and do not contain requirements for different types of infill.

In recommending that protective barriers be designed to discourage climbing, as noted above in the probable rationale, the NBS intended to preclude the use of intermediate horizontal bars below the top of a protective barrier. The British and Seattle draft standards are therefore consistent with the current guidelines. There is considerable support in the literature for not permitting horizontal bars as infill on a barrier to deter children from climbing the barrier (Beckwith, 1985; Christiansen, 1988; Esbensen, 1987; Moore et al., 1987). The detailed incident analysis of 1988 data included one climbing equipment-related injury in which a 3-year-old climbed up on a horizontal railing beneath the top bar of a guardrail on a platform. When she leaned over the top rail, the victim was pushed from behind by another child, and fell head and shoulder first off the guardrail to the ground below. In addition, the observational study indicated that when two parallel horizontal rails served as guardrails on a platform, children sometimes climbed on them or underneath them and used them to exit from the deck. For example, one child used the horizontal rails like a ladder and jumped to the ground from the top rail. Another child hung from the top rail on the outside of the guardrail while supporting his feet on an intermediate horizontal railing beneath the top rail. In one accident scenario described by Beckwith (1985), when children sit on the top of guardrails and hook their feet into the lower horizontal rungs, they can easily be pushed back off the structure, and break both legs. However, Frost (1980) suggested that it may be desirable to encourage climbing on protective barriers. For example, the barrier itself may serve as an entry or exit area for a platform with multiple accesses.

According to the Play For All Guidelines, there is agreement among manufacturers that, since horizontal railings are usually constructed in the same way as ladders, they do not satisfy the CPSC's recommendation that protective barriers be nonclimbable. However, the SCIPP survey (Helsing et al., 1988) indicated that on 79% of the playgrounds sampled with climbers, safety bars on barriers were horizontal rather than vertical, and so did not prevent children from climbing to greater heights. Barrier designs recognized as being consistent with the current guidelines include the following: vertical wooden slats or metal rails whose spacing does not create an entrapment hazard; solid panels with clear plastic bubbles or cutouts to facilitate supervision; and wire mesh panels which also permit supervision (Beckwith, 1985; Moore et al., 1987). Esbensen (1987) recommended that vertical bars not be between 4.25 and 9 inches apart, to avoid an entrapment hazard. Consistent with the British and Australian standards, the SCIPP playground safety checklist (1988) specifies that spaces between vertical components of barriers should not exceed 4 inches.

A review of current catalogs showed that barriers were frequently constructed from vertical wooden slats or metal bars attached to a horizontal bar at the top and bottom of the barrier. One manufacturer specified that the vertical rails on barriers have no gaps greater than 4 inches or less than 7 inches, and, on equipment designed for 2- to 5-year-olds, no gaps between 3 and 9 inches. L. Witt (personal communication, March 1989) pointed out that some older models of guardrails around platforms currently found on playgrounds have vertical components spaced as widely as 40 inches apart. Another common barrier design was a solid panel with either cutouts or clear plastic bubbles to permit viewing out from the platform. The use of clear materials on solid panels is consistent with the CPSC recommendation that barriers be designed to facilitate supervision; F. Wallach (personal communication, February 1989) and the Play For All Guidelines also raised the issue that solid barriers hinder supervision, especially of small children. In 1985, Beckwith noted that several manufacturers offered enclosures for platforms with two or more horizontal rungs that can be climbed. In current catalogs, guardrails consisting of two or more horizontal bars were sometimes used on the sides of platforms that were more than 30 inches above ground level, and on platforms and access ramps for 5, 6, and 11 foot high spiral slides. This guardrail design, and those in which vertical components are spaced widely apart, would easily allow a user to fall through to the surface below. In the detailed incident analysis, one 5-year-old child stepped or slipped off the edge of a 42-inch high platform. The side of the platform from which the victim fell had two horizontal railings, presumably serving as a guardrail. However, the space between the lower railing and the platform was sufficient to allow the victim to fall through.

There has been some confusion reported regarding how to determine what constitutes a nonclimbable barrier (Moore et al., 1987). Preston (1988) raised the question whether barriers should be designed to prevent only inadvertent falls, or, in addition, to prevent a deliberate effort to pass through openings in the barrier. The latter intention would seem to place more stringent constraints on the design of barriers; for example, it may be necessary to place an upper limit on the space between vertical components to ensure that children cannot deliberately climb through the opening.

F. Wallach (personal communication, February 1989) recommended that two sets of handrails be attached to the barrier of an elevated surface, one at a level appropriate for the height of younger children and one at the top of the barrier for older children. Given that a lower handrail could provide a foothold for climbing to the top of the barrier, it is questionable whether this recommendation could be made consistent with the nonclimbability criterion.

Recommendations:

The recommendations for guardrails and protective barriers should apply to walking surfaces such as platforms, decks, walkways, landings, and transitional surfaces. These recommendations should also apply to any portions of stairways and ramps that exceed the minimum height requirements specified below. As stated in the current guidelines, an elevated surface is exempt from these recommendations if having a protective barrier would interfere with the intended use of the equipment; this includes balance beams, most climbing equipment, and platforms that are layered so that fall height does not exceed 30 inches on equipment intended for older children (4- to 12-year-olds), and 20 inches on equipment for younger children (2- to 5-year-olds).

Maximum elevation without guardrails and protective barriers. On equipment intended for older children, an elevated surface that is more than 30 inches above the underlying surface should have a guardrail or protective barrier to prevent falls. The 30 inch maximum height for elevated surfaces without guardrails or protective barriers is consistent with the 1975 One and Two Family Dwelling Code requirements for guardrails (Section R215) on which the current CPSC guidelines are based, and with the 1986 edition (Section R215) of this building code. The minimum degree of protection that should be provided depends on the height of the platform. For platforms greater than 30 inches and less than or equal to 48 inches high, guardrails are acceptable although a full protective barrier always provides greater protection. Platforms that exceed 48 inches in height should have a protective barrier.

Since younger children have poorer coordination and balance and are more vulnerable to injury than school-age users, guardrails or protective barriers are warranted at lower elevations. A guardrail or protective barrier should be used when platforms exceed 20 inches in height. Guardrails are acceptable for platforms greater than 20 inches and less than or equal to 30 inches high, but a full protective barrier may be preferable for this age group since it affords a greater degree of protection from falls. Protective barriers should be used for platforms that exceed 30 inches in height.

Minimum height of guardrails and protective barriers. On elevated surfaces intended for older children, guardrails and protective barriers should be at least 38 inches high, as stated in the current guidelines. This minimum height ensures that the standing center of gravity of the maximum user (35.8 inches), a 95th percentile 12-year-old, is below the top surface of the guardrail or protective barrier. The 2-inch allowance takes into account footwear as well as settling, warping, or other aging effects of the construction materials. For the 2- to

5-year-old group, a minimum height of 29 inches is recommended to accommodate the standing center of gravity of a 95th percentile 5-year-old (26.9 inches). The same 2-inch tolerance used for the older group is applied to the younger group.

Design considerations. Both guardrails and protective barriers should be designed to prevent inadvertent or unintentional falls off the platform, to discourage climbing on the barrier, to preclude the possibility of entrapment, and to facilitate supervision. Guardrails and protective barriers should completely surround the elevated surface except for necessary entrance and exit openings. The following recommendations for infill apply to both guardrails and protective barriers: horizontal cross-pieces should not be used as infill for the space below the top rail because they provide footholds for climbing; when solid panels are used as infill, it is a good idea to provide some transparent areas to facilitate supervision and to permit viewing from the platform; any openings should be designed to prevent finger entrapment (see Section 5.2.6.4).

The 38-inch and 29-inch minimum heights for guardrails on platforms intended for older and younger children, respectively, protect the maximum user in each age group (a 95th percentile 12-year-old or 5-year-old) from unintentional falls off the platform. However, the guardrail should also extend low enough to prevent the minimum user from inadvertently stepping under the guardrail. Therefore, on equipment intended for older children, the bottom components of the guardrail should extend at least as low as 26 inches. This height corresponds to the chest height at axilla (26.1 inches) of the minimum user, a 5th percentile 4-year-old. For the younger age group, the bottom components of the guardrail should extend at least as low as 23 inches, based on the chest height at axilla (23.6 inches) of a 5th percentile 2-year-old. To prevent head entrapment, guardrails should not have openings between 3.5 and 9 inches (see Section 5.2.6).

Since protective barriers have the additional constraint of not permitting users to climb through or under them, openings in the barrier should be less than 3.5 inches. Vertical infill for protective barriers may be preferable for younger children because the vertical components can be grasped at whatever height the user chooses as a handhold.

5.6.3.3 Stepped platforms

On some multi-use structures, platforms are layered or tiered, so that falls from a higher platform can be terminated by a lower platform rather than by the ground surface. The height differential between adjacent platforms has been addressed in some standards and in the literature.

Guideline content:

The only reference to stepped platforms is in Volume 2, which states that if platforms are layered or tiered so that fall height does not exceed 30 inches, these surfaces are exempt from the protective barrier recommendation. (Volume 2, 11.1)

Height differential. The current guidelines do not address the maximum height differential between adjacent platforms.

Probable rationale:

The rationale was explicitly stated in Volume 2: stepped platforms need not have protective barriers if they do not have potential fall heights greater than 30 inches. Moreover, the use of stepped platforms to access higher levels of the structure would be hindered by the addition of protective barriers, and, therefore, in such cases, protective barriers are not required.

Height differential. Not applicable.

Issues:

Bowers (1988b) suggested that using a pyramidal or stepped arrangement of platforms with a safe distance between adjacent levels would reduce the potential fall distance, and facilitate access to higher levels of the play structure. "Safe distance" between adjacent levels was defined as a distance that allows the user to jump or fall to the next lower level without sustaining a serious injury. Similar views were expressed by Moore et al. (1987) and Beckwith (1988). Beckwith pointed out that, since platforms are typically wide and flat, children can regain their balance more easily after a fall from one platform to another, in comparison to a fall to the ground surface.

Height differential. The improvement in safety depends on the height differential between adjacent platforms. As Beckwith (1988) noted, some multi-level structures have distances of 3 and 4 feet between adjacent platforms, and use internal ladders to provide access between them. Bowers (1988a) recommended a maximum vertical distance of 18 inches between one platform level and the next, for both school-age and preschool-age users. Beckwith suggested that fall distances between platforms not exceed 16 inches. For school-age children, the Canadian (CAN/CSA-Z614, 1988) and Seattle draft standards specify a maximum height differential of 24 inches and 16 inches, respectively. Both standards require that distances between stepped platforms intended for preschool-age children be 12 inches or less. The Canadian draft standards add that if height differentials exceed the maximum values, a means of access such as a stairway or ladder must be provided.

Recommendations:

The step height of the minimum user among older children, a 5th percentile 4-year-old, is 12 inches, while that of the minimum younger user, a 5th percentile 2-year-old, is 8.8 inches. However, it is reasonable to assume that children climb between platform levels, rather than using stepped platforms like stairways. Therefore step height is too conservative as an estimate of the maximum height differential between stepped platforms. For school-age children and preschool-age children, the maximum difference in height between stepped platforms should not exceed 18 inches and 12 inches, respectively. These maximum values are consistent with most recommendations in the literature and with standards which address stepped platforms designed for preschoolers.

5.6.3.4 Landings

Guideline content:

The current guidelines do not address the use of landings ("intermediate platforms").

Probable rationale:

Not applicable.

Issues:

The Canadian draft (CAN/CSA-Z614, 1988) and Australian (AS 1924, Part 2, 1981) standards contain specifications for intermediate platforms on accesses to all types of equipment; the British standards provide for intermediate platforms on slide accesses only (see Section 5.7.1.3.1.4). The Australian standards do not permit the vertical rise of any one continuous ramp, stairway, or ladder to exceed 8.2 feet above the underlying surface; if accesses are higher than 8.2 feet, intermediate landings must be provided. Entry to and exit from intermediate landings should be offset or represent a change in direction of at least 90 degrees. Landings should be at least twice as wide as the access, and at least 3.3 feet long. These requirements are virtually identical to those contained in the British standards; however, the British standards apply only to slide accesses. The British standards exempt spiral staircases from the requirements for intermediate platforms. The Canadian draft standards for intermediate landings apply to accesses to climbing structures, with the exception of free standing slides. Intermediate landings must be used when the vertical rise of stairways or ladders intended for school-age children exceeds 7.8 feet, and when accesses intended for preschoolers are more than 4.9 feet high. The requirements for the relative positions of entry and exit points on intermediate landings are the same as those in the Australian and British standards. Landings should be at least 3 feet square.

The Canadian draft standards provide an explicit rationale for the use of intermediate landings for stairways and ladders: landings provide a standing surface where children can decide not to continue their ascent and have an alternative means of descent. This rationale is implicit in the British standards, since an illustration of permissible entry and exit points from an intermediate platform shows an alternative exit. In the discussion of intermediate platforms on slide access (see Section 5.7.1.3.1.4), the point is made that such platforms give children the opportunity to halt their ascent and climb back down. The "no way out" problem was documented as a cause of slide-related falls in the 1978 Special Study (Brown, 1978), but could also arise when children ascending high climbing structures change their minds about how high they want to climb. Moreover, the use of intermediate platforms reduces the potential fall height, in comparison to what it would be from a very high continuous line of access.

Recommendations:

Consider incorporating landings on accesses to equipment for preschool-age children, because there are certain advantanges which younger children especially may benefit from:

landings would help to eliminate the "point of no return" situation for children who are hesitant to continue; they would provide resting areas when the access ladder or stairway is a long climb or as places to wait when traffic gets congested, (it would be safer for children to wait on a platform than on the rungs or steps of a ladder or stairway); and, they would reduce the distance of falls down a ladder, such as when a child's foot slips and he or she slides back down the ladder.

Table 5.6 - 1

Comparison of Standards for Slopes: Ramps, Stairways, Stepladders, and Rung Ladders

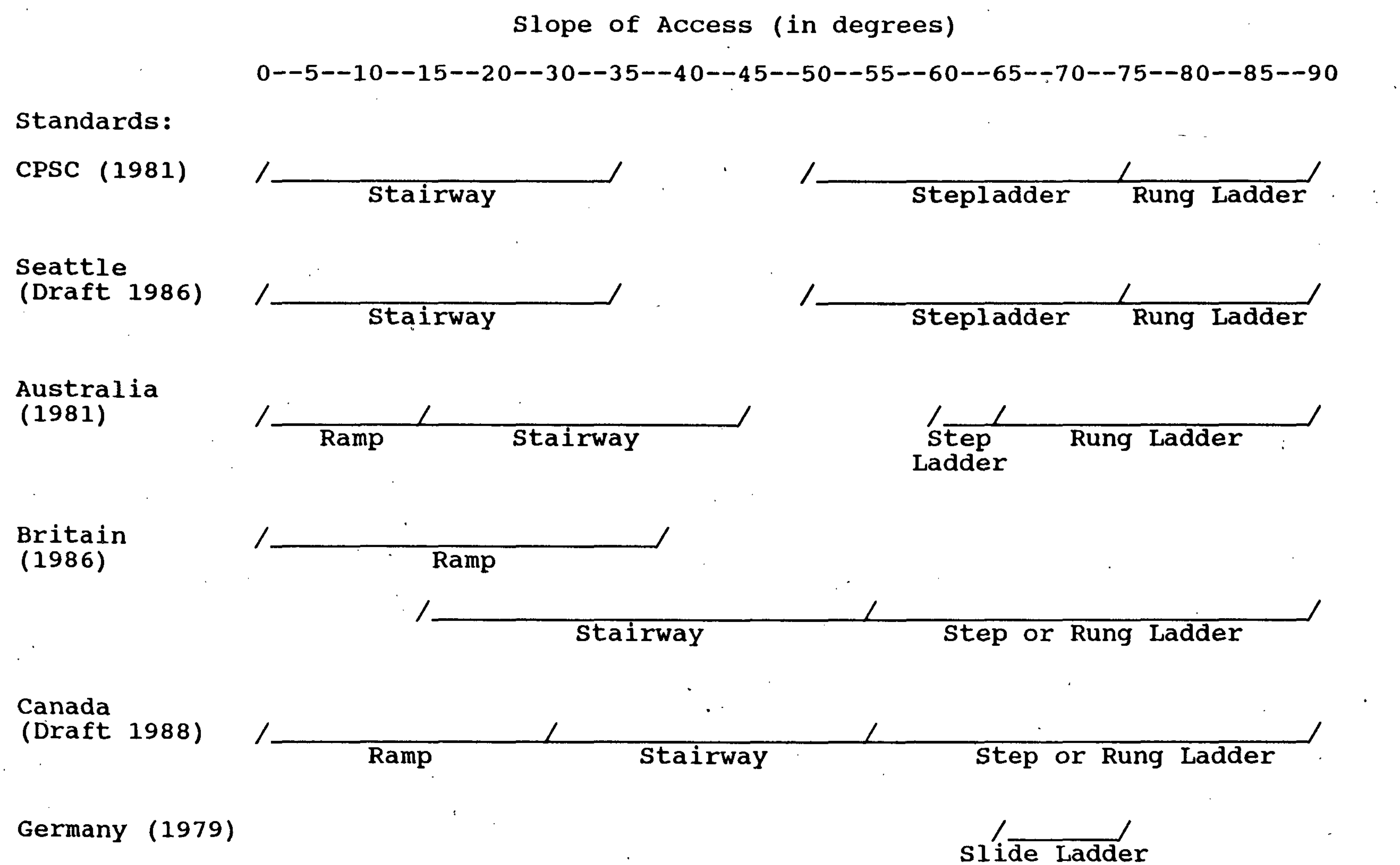


Table 5.6 - 2
Comparison of Standards for Dimensions of Steps on Stairways
(All dimensions given in inches.)

	CPSC (1981)	Seattle (Draft 1986)	Australia (1981)	Britain (1986)	Canada (Draft 1988)	Germany (1979)
Stairways:						
Slope	$\leq 35^{o}$	$\leq 35^{o}$	$15\text{-}45^{o}$	$15\text{-}45^{o}/45\text{-}55^{o}$	$30\text{-}55^{o}$	(Slide Stairways)
Vertical Rise	7-11	School: 7-16 Preschool: 6-10	3.9-8.7	3.9-7.9/5.9-7.9	4-10	Open Riser: ≤4.7 Closed Riser: ≤5.9
Tread Depth						
Open Riser	≥3	- -	8.9-13.8	8.7-13.8/3.9-8.7	- -	≥7.9
Closed Riser	≥6	6-14	8.9-13.8	8.7-13.8/≥5.9	≥5	≥7.9
Tread Width	≥15	- -	Public: 23.6 Preschool: 17.7	23.6-70.9/11-17.7	- -	15.8-23.6

Table 5.6 - 3
Comparison of Standards for Dimensions of Steps or Rungs on Ladders
(All dimensions given in inches.)

	CPSC (1981)	Seattle (Draft 1986)	Australia (1981)	Britain (1986)	Canada (Draft 1988)	Germany (1979)
Ladders:						
Slope	Step/Rung 50-75°/75-90°	Step/Rung 50-75°/75-90°	Step/Rung 60-65°/65-90°	55-90°	55-90°	65-75°
Vertical Rise	7-11/7-11	Open: 10-14/10-14	6.9-10.8/6.9-11.8	6.9-12.6	Open: ≥ 10 Closed: 4-10	7.9-9.8
Tread Depth		≥3/- -				1-3.2
Open Riser	≥3/- -		≥3/- -	≥3	≥3/- -	
Closed Riser	≥6/- -		≥5.9/- -	≥5.9	≥6/- -	
Tread or Rung Width	≥15/≥15	≥15/≥15	60-65°: Public: 17.7-23.6 Preschool: 11.2-20.1 65-90°: 11.2-20.1	9.1-17.7	12-20	15.8-23.6
Rung Diameter	≤1.6	Hand-gripping Components: .75-1.5	Round: .75-1.5	1-1.5	1-1.75	Round: 1-1.4

Table 5.6 - 4
Comparison of Standards for Handrails on Stairways and Ladders
(All dimensions given in inches.)

	CPSC (1981)	Seattle (Draft 1986)	Australia (1981)	Britain (1986)	Canada (Draft 1988)	Germany (1979)
Handrails:						
Maximum Elevation without Handrail	- -	- -	- -	19.7	24	Slide Stepladders: 39.4 Slide Stairways: 4 Steps
Handrail Height Upper Rail	- -	- -	Public: 31.5-39.4 Preschool: 17.7-27.6	19.7-35.4	School: 28-40 Preschool: 10-16	Slide Stepladders: 5.9-7.9 Slide Stairways: 23.6-31.5
Lower Rail			Public: 15.8-19.7	Not Permitted	School: 12-20 Preschool: 10-12	
Handrail Diameter	≤1.6	.75-1.5	.75-1.5	.7-1.6	1-1.75	1-1.8

Table 5.6 - 5

Grip Strength, Measured by Squeeze Force, as a Function of Distance Between the Gripping Surfaces and of Age*

Squeeze force is given in units of pound force (lbf).

	Distance Between Gripping Surfaces (inches)			
	.79	1.2	1.6	2.0
Age				
5th percentile 2-year-old (minimum user among 2- to 5-year-olds)	3.1	6.2	5.3	--
95th percentile 5-year-old (maximum user among 2- to 5-year-olds)	15.7	28.7	30.7	27.6
5th percentile 4-year-old (mimimum user among 4-to 12-year olds)	5.1	9.5	8.4	6.2
95th percentile 10-year-old (oldest user for which data available)	30.9	46.5	55.1	52.7

* Taken from Owings et al. (1977)

Table 5.6 - 6
Comparison of Standards for Guardrails and Barriers on Elevated Surfaces

	CPSC (1981)	Seattle (Draft 1986)	Australia (1981)	Britain (1986)	Canada (Draft 1988)	Germany (1979)
Guardrails:						
Structures to which guardrails apply	Platforms, walkways, landings,	Platforms, any standing or climbing surface	Platforms, landings, sides of inclined access ways	Platforms, ramps, slide access	All standing surfaces and platforms	Pedestals, platforms
Maximum elevation without guardrail	30" (Volume 2) 48" (Volume 1, slide platforms)	30"	Public: 47.2" Preschool: 19.7"	19.7"	School: 24" Preschool: 18"	78.7"
Minimum height of guardrails	38"	42"	Public: 35.4" Preschool: 27.6"	19.7-39.4" depending on fall height	24"	27.6"
Construction	Solid barriers; barrier with vertical, rather than horizontal, components	Top rail with infill; top rail with solid panels; top rail with vertical components	Monolithic; top rail with infill Public: for fall heights ≤ 8.2 feet, top rail and intermediate horizontal rail Preschool: for fall heights ≤ 5.9 feet, top rail and intermediate horizontal rail	Top rail with infill; top rail with vertical components (spaced ≤ 3.9"); no intermediate horizontal components beneath top rail	Top rail with vertical components; top rail with horizontal components (spaced 10-12" apart)	Should not encourage climbing

FIGURES

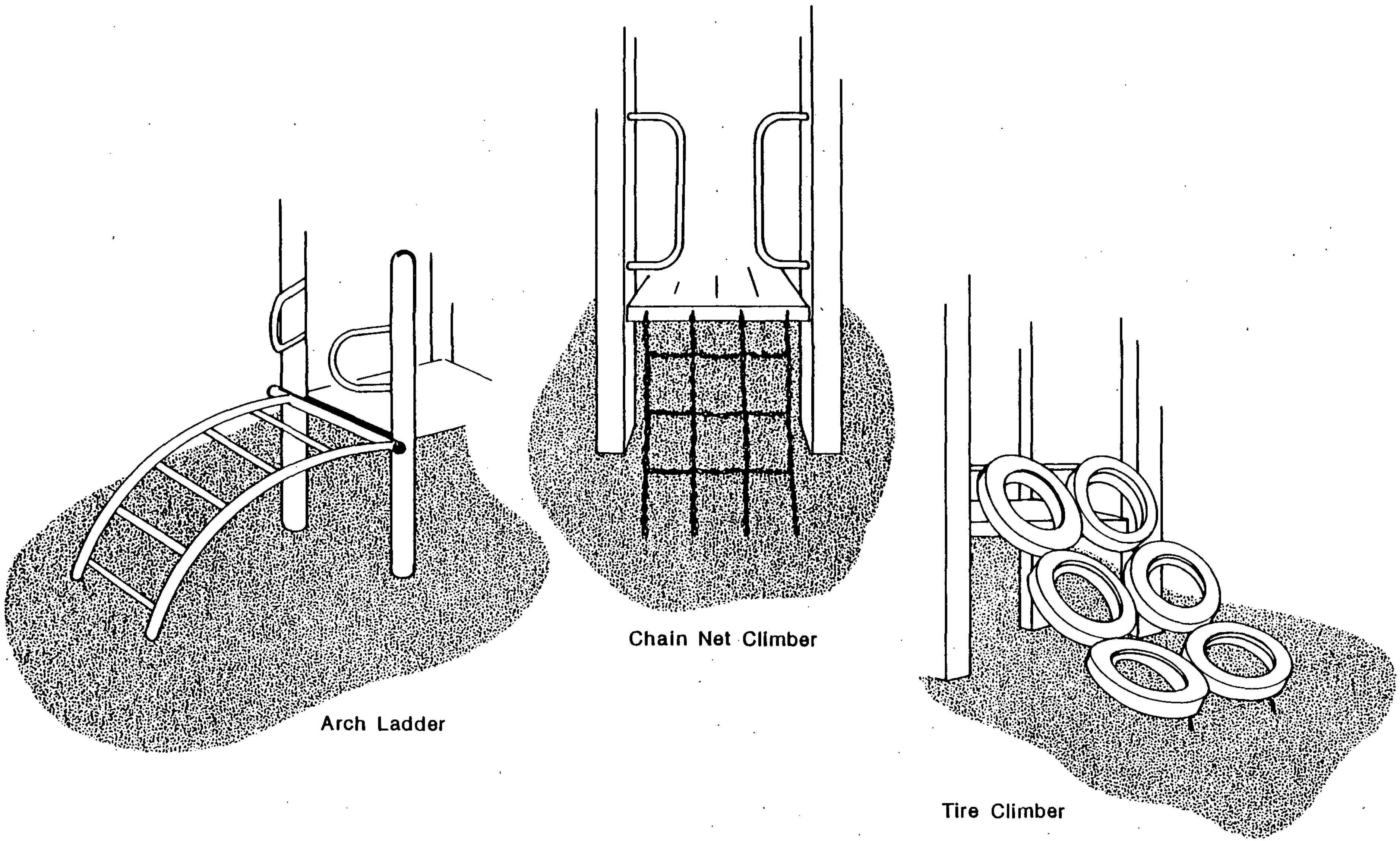
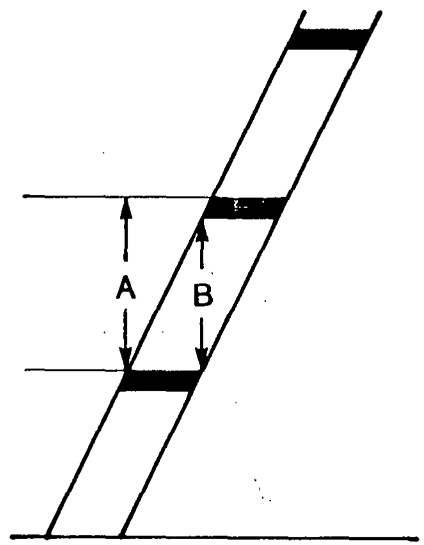


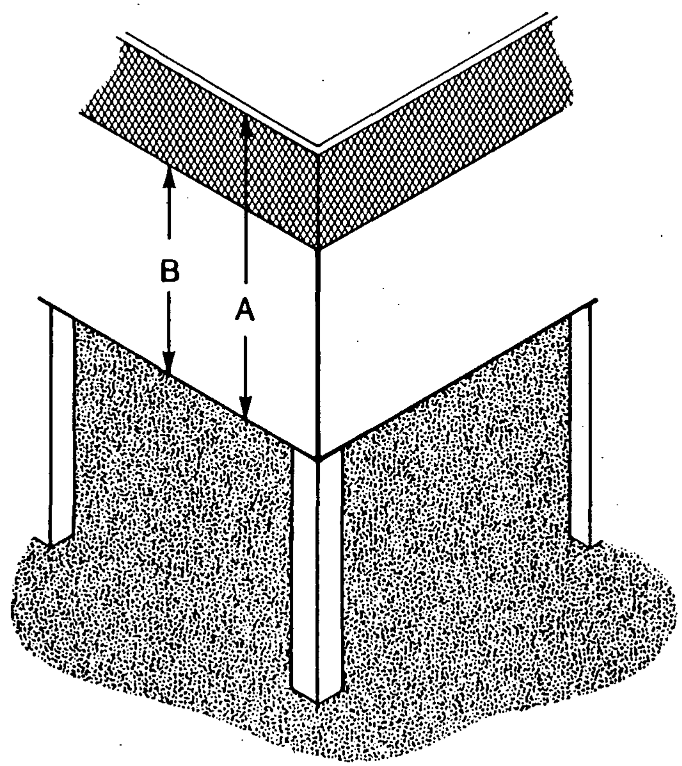
FIGURE 5.6 – 1: EXAMPLES OF MORE CHALLENGING MODES OF ACCESS



A = 12" maximum for older children
or
9" maximum for younger children

B = for open risers:
<3.5" or >9" for older children
or
<3.5" for younger children

FIGURE 5.6 – 2: VERTICAL RISE CRITERIA FOR STEPS



A = 38" minimum for older children
or
29" minimum for younger children

B = 26" maximum for older children
or
23" maximum for younger children

Note: Guardrails should be designed to prevent inadvertent or unintentional falls off the platform, to discourage climbing on the barrier, to preclude the possibility of entrapment, and to facilitate supervision. Refer to text for detailed recommendations regarding infill.

FIGURE 5.6 – 3: GUARDRAILS ON ELEVATED SURFACES

5.7 TYPES OF EQUIPMENT

5.7 TYPES OF EQUIPMENT

5.7.1 SLIDES

5.7.2 SWINGS

5.7.3 CLIMBING EQUIPMENT

5.7.4 MERRY-GO-ROUNDS

5.7.5 SEESAWS

5.7.6 SPRING ROCKING EQUIPMENT

5.7.1 SLIDES

5.7.1 SLIDES

5.7.1.1 PATTERNS OF SLIDE USE

5.7.1.2 REVIEW OF SLIDE INJURY DATA

5.7.1.3 STRAIGHT SLIDES

5.7.1.3.1 Slide access
5.7.1.3.1.1 Slide ladders and stairways
5.7.1.3.1.2 Traffic on ladders and stairways to slides
5.7.1.3.1.3 Multiple access to slides
5.7.1.3.1.4 Intermediate platforms on slide access

5.7.1.3.2 Slide surface entrance
5.7.1.3.2.1 Slide platforms
5.7.1.3.2.2 Protective barriers
5.7.1.3.2.3 Maximum height of slides
5.7.1.3.2.4 Attachment of slides to multi-use equipment

5.7.1.3.3 Slide chute
5.7.1.3.3.1 Slide surface slope
5.7.1.3.3.2 Slide surface width
5.7.1.3.3.3 Sides of slide chutes
5.7.1.3.3.4 Chute shape and depth

5.7.1.3.4 Exit region
5.7.1.3.4.1 Slope of the exit region
5.7.1.3.4.2 Length of the exit region
5.7.1.3.4.3 Height of the exit region
5.7.1.3.4.4 Radius of curvature of the exit region
5.7.1.3.4.5 Slide exit edges

5.7.1.3.5 Slide support structures

5.7.1.3.6 Materials

5.7.1.3.7 Layout and spacing of slides; use, fall zones

5.7.1.3.8 Protective surfacing

5.7.1.4 EMBANKMENT SLIDES

5.7.1.5 SPIRAL SLIDES

5.7.1.1 PATTERNS OF SLIDE USE

The most common slide on playgrounds is the conventional straight slide (see Figure 5.7.1 - 1).

Level of motor-skill development determines, in part, whether or not children can negotiate the access or chute of a slide, and the manner in which they do so. Developmental data suggest that children have the basic ability to climb to the top of a slide before they are capable of maintaining balance while sliding down the chute. According to Esbensen (1987), children at approximately 15 months of age can climb stairs without the use of a railing, and between 2 and 2 1/2 years of age, become capable of walking up and down stairs without support, and of using arms and legs alternately to climb up ladders. However, children below 18 months of age may have difficulty remaining upright as they slide (Moore et al., 1987), and even 2-year-olds may not have adequate body control to maintain continuous balance as they slide (Esbensen, 1987). The risk is that a child this age or younger may fall backward as they slide, particularly if they are moving quickly, or may fall over the side of the chute. During the observational study, several very young children did not exhibit the body control and balance needed to exit a slide standing up: they simply slid off the end of the chute and onto the ground, landing either in a seated position or on their backs..

In terms of mode of use, 2-year-olds tend to ascend the ladder with care, sitting down at the top, and sliding down feet first and sitting up (Beckwith, cited in King and Ball, 1989). By 3 years of age, balance is better developed, and the child's increasing confidence in his or her abilities may lead to more adventurous use of slides. Beckwith distinguished among the sliding behaviors of children 3 years and older as follows: 3-year-olds will slide down the chute in a variety of positions, such as head first or backwards, 4-year-olds run up the chute, 5-year-olds jump from the top of the slide, and 6-year-olds may begin to lose interest in slides altogether. Although children under 6 years of age are more likely to use slides than older children, the older children will still play on slides depending on the availability of other types of equipment.

Injury data support the occurrence of slide activities which do not conform to intended use. An analysis (Brown, 1978) of NEISS-based in-depth investigations revealed the following factors as contributing to slide-related injuries: falling back off the access ladder, falling while waiting in line, roughhousing or being in a hurry, jumping, slipping, sliding head first, being pushed, and crowding, particularly on the platform. Brown hypothesized that the "thrill" from the sliding experience decreases with simple repetition, which prompts children to experiment with alternate, potentially unsafe, modes of use after mastering the "normal" ones.

The observational data suggested that alternate uses of slides are very common, the most frequent being that of children climbing up the chute from the bottom. Younger children who attempted this often lost their grip or their balance and slid, at least partially, back down the chute. Sometimes a child would start climbing up from the bottom while another was ready to slide down from the top or vice versa, which presents the danger of collisions. Many other creative sliding methods were also observed repeatedly: children descending on their stomachs, either feet or head first; children lying on their backs or on their sides as they slide; children coming down on their knees; and children walking down or just standing on the chute.

Aronson (1988) stated that most toddlers are not ready to use "standard slides" without close adult supervision, because their modes of use need to be constrained. Consistent with this view, Esbensen (1987) noted that a 3-year-old will exhibit more daring, and attempt movements which may be beyond their developmental capabilities. The question of developmental readiness is complicated by the fact that a child's proficiency in using a slide will depend, in part, on how well the slide has been scaled to accommodate his or her motor skills and physical dimensions. In a playground equipment manual published by the Child Accident Prevention Foundation of Australia, Ozturk (1987, cited in King and Ball, 1989) pointed out that "the typical slide is designed for the child aged between 8 and 12 years--although children of this age rarely show any interest in this piece of equipment, thus leaving the smaller children the problem of dealing with an item built for children who are at least twice their age."

5.7.1.2 REVIEW OF SLIDE INJURY DATA

Results from different injury studies, including the detailed incident analysis of 1988 injury data, show agreement on a number of issues. 1) Slide-related injuries may be disproportionately high among younger children (0-4 years of age) as compared to older children (5-14 years of age) (King and Ball, 1989). 2) In most studies, the majority of slide-related injuries were attributed to falls. 3) Relative to other equipment types, slides have accounted for high rates of concussions, skull fractures, and facial fractures. 4) The pattern of slide-related injuries may be different for younger children (0-4 years of age) than for older children (5-14 years of age): injuries to the head and face appear to be more common among younger children, whereas upper limb injuries are more frequent among older children (King and Ball, 1989).

The studies cited in this section are more thoroughly discussed in the Injury Data Overview (see Section 3). Although Rutherford's (1979) analysis of 1978 NEISS data only addressed injuries which occurred on public playground equipment, most other data sources such as King and Ball's (1989) discussion of 1982-86 NEISS data, 1987 NEISS data, and 1982-86 CAIRE data, addressed injuries associated with both public and home playground equipment. Therefore, these data are presented only to give a general impression of typical age-related injury patterns and scenarios and are not intended to be directly compared. The detailed incident analysis of 1988 data for slide-related injuries is based on a review of 40 cases.

Slide-related injuries. In the NEISS-based 1978 Special Study of public playground equipment, slides were estimated to account for 16% of all equipment-related injuries (Rutherford, 1979). A British study of Inner London school playgrounds showed 7% of equipment-related injuries due to slides. A recent report (Morbidity and Mortality Weekly Report, 1988) of NEISS data on playground-related injuries (including home and school equipment) among preschoolers occurring between 1983 and 1987 attributed 26% of all equipment-related injuries to slides. The variation among estimates of slide-related injuries in different studies may be due to differences in the types of locations sampled (home vs. school or public playgrounds), in the availability of equipment during the different time periods covered or in different countries, or to some combination of factors. In their discussion of data from the Inner London Educational Authority, King and Ball (1989) explained the low percentage of slide-related injuries as due to the low availability of slides on the school playgrounds sampled.

Few studies provide estimates of the availability of slides relative to other equipment on public playgrounds. A survey of playground surfaces conducted in 1978 indicated that slides account for 12% of all public playground equipment units in the U.S. (Rutherford, 1979). Combining this information with results of the 1978 Special Study of injuries on public playground equipment, Rutherford concluded that the frequency of slide-related injuries is roughly proportional to the availability of slides on public playgrounds. A recent survey of elementary school playgrounds (Bruya and Langendorfer, 1988) yielded a comparable estimate of the relative frequency of slides (10%, including flat and tube slides).

Age of victims: Rutherford (1979) reported the following breakdown for the ages of children injured in slide-related incidents from the 1978 Special Study data: 21%, 0- to 4-year-olds; 46%, 5- to 7-year-olds; 24%, 8- to 10-year-olds; 8%, 11- to 14-year-olds; 1% 15-year-olds and older.

Data reported by King and Ball (1989) have shown disproportionately high estimates for the percent of slide injuries occurring among preschoolers. NEISS data on equipment-related injuries for the period from 1982-86 indicated that 0- to 4-year-olds accounted for 45% of all slide-related injuries; 1987 NEISS data showed that 47% of all slide-related injuries involved this age group. Canadian CAIRE data from 1982-86 showed that 45% of all slide-related injuries were incurred by 0- to 4-year-olds. In these three studies, slides were associated with a higher percentage of injuries among preschoolers than any other type of equipment, including swings.

King and Ball (1989) argued that, since there were one half as many 0- to 4-year-olds as 5- to 14-year-olds in the total U.S. and Canadian child populations during the periods covered by the NEISS and CAIRE injury studies, a 45% rate of injury on slides among younger children is disproportionately high. That is, younger children tend to be at greater risk from slide-related injuries than older children. As King and Ball pointed out, other factors, such as frequency of use, may have contributed to the high rate of slide injuries among younger children. Slides may be more popular among younger children than among older children, resulting in greater exposure of younger children to slides. Since both the NEISS and CAIRE injury data under discussion include home playground equipment, where younger children are likely to have daily access to slides, these data are even more likely to reflect age-related differences in use levels than if they included only public playground equipment.

Mode of injury. The 1978 NEISS-based Special Study (Rutherford, 1979) showed that 78% of slide-related injuries were due to falls or to falls/impact with stationary equipment. Falls from height accounted for 84% of slide-related injuries in the 1982-86 CAIRE dataset (reported in King and Ball, 1989).

In the detailed incident analysis, 27 of 40 slide-related injuries were caused by falls to the surface, and an additional 8 were caused by falls which included impact with stationary equipment, producing a total of 35 of 40 injuries on slides attributable to some type of fall. However, it must be noted that even though the majority of slide-related injuries involved falls, many of these falls were from the access ladder, and so were really unrelated to the slide portion itself.

When mode of injury is examined by age group in the detailed incident analysis, falls and falls/impact with stationary equipment account for most of the slide-related injuries among victims of all ages.

Butwinick (1980) examined 126 in-depth investigations of slide-related injuries "through 1978," and made a determination of where on the slide the fall occurred. She found that 37% of all slide-related injuries involved falls from either the platform, the top of the slide, or the top third of the slide bed, 23% involved falls from the access ladder, and 9% were falls from the bottom two thirds of the slide bed. The remaining cases consisted of falls for which the location could not be determined (4%), and injuries that appeared to involve causes other than falls, such as injuries associated with "exit landings" (12%), impacts with the slide (11%), and miscellaneous causes (6%). It is unclear from Butwinick's discussion whether the injuries attributed to exit landings included any falls. Assuming that the exit landing cases did not involve falls, about half (51%) of all the falls from slides occurred from the platform, the top of the slide, or the top third of the slide bed; almost one third (32%) of falls were from the ladder.

The detailed incident analysis indicated that a high proportion of slide-related injuries were due to falls from the ladder (18 of 40). As far as can be determined from the injury descriptions, falls from the platform, the top of the slide, and the top third of the slide bed accounted for 8 of the 40 slide-related injuries. However, in 5 of the 40 slide injury cases in the analysis there was insufficient information to determine whether a fall was from the top third or lower two thirds of the slide bed, and so the percentage of injuries from the top third of the slide may have been underestimated. Falls from the bottom two thirds of the slide bed were clearly indicated in 4 of the 40 slide-related injuries. Only 5 of the 40 slide-related injuries did not involve falls.

Pinch points, protrusions, and sharp edges accounted for 11% of slide-related injuries reported in the 1978 Special Study on public playground equipment (Rutherford, 1979). In the detailed incident analysis, there were two cut or puncture injuries and no pinch or crush injuries. A recent survey of elementary school playgrounds (Bruya and Langendorfer, 1988) revealed that 34% of the slides sampled had sharp corners, edges, or projections.

Entrapment of body parts and clothing entanglement have also been documented as causes of slide-related injuries. Inspection of equipment on the playgrounds of three Massachusetts communities revealed that about half (53%) of the playgrounds had slides with head-entrapment areas, defined in the report as "any space between 4 1/4 and 9 inches"; side railings posed the most common head-entrapment hazard found on slides (Helsing et al., 1988). In addition, 56% of playgrounds had slides with V-entrapment areas, which can cause clothing to get caught and result in strangulation. One scenario for V-entrapment on slides was described in the supporting rationale for the CPSC guidelines (NBS, 1978a): a rail at the side of a slide that forms a vertex with the side of the slide chute may trap the hand or arm of a sliding child. About two thirds (68%) of the playgrounds were reported to have finger traps on slides.

Rutherford and Kelly (1981) examined cases of accidental strangulation with strings occurring between 1973 and 1980, and involving children under 5 years of age. In these cases, something around the victim's neck, typically clothing, caught on another product, tightened around the neck, and resulted in strangulation. Rutherford and Kelly pointed out that ligature strangulation can be caused by clothing becoming entangled with protruding objects, or from clothing becoming wedged in an opening or angular space on playground equipment. Thus, it appears that the survey data reported above on protrusions, head entrapment, and V-entrapment areas are pertinent to the incidence of strangulation. In 13 of 29 play equipment-related strangulations, clothing or a rope caught on part of the equipment, usually an upright post of a slide or handrails at the top of the slide. It is unclear from the report exactly how many strangulations occurred on slides, but Rutherford and Kelly classified the "majority" of these 13 accidents as slide-related.

The CPSC provided ten additional in-depth investigations from 1980 to 1988 to study clothing entanglement incidents. Seven of the ten involved slides. The typical scenario was that the child's clothing, often a jacket, got caught on a protruding bolt or other components at the top of the slide causing the child to strangle upon sliding down the chute. All of these incidents were fatal cases of asphyxiation. Clothing entanglement is discussed more thoroughly in the review of injury data for general hazards (see Section 5.2.1).

Other characteristics of incident. The detailed incident analysis showed that more than half (24 of 40) of all slide-related injuries occurred during initiation of the task sequence, which includes climbing to the top of the slide, moving from the access ladder or stairway to the slide platform, and activities on the platform prior to sliding down the chute. Five of the 40 slide-related injuries occurred during primary use (sliding down the chute); 3 of 40 occurred during termination (dismount from the slide in the exit region). The remaining injuries involved climbing up the slide chute (5 cases), climbing down the ladder (2 cases), or jumping from the ladder (1 case).

The proportion of 6- to 14-year-olds (13 of 20) injured during initiation was not appreciably different from the corresponding proportion of 0- to 5-year-olds (11 of 20), in the detailed incident analysis. For the older children, more than one-third (5 of 13) of injuries that occurred during initiation were attributed to interaction with other children, including roughhousing and horseplay. By contrast, only 1 of the 11 injuries sustained by younger children during initiation involved interaction. Interaction with other children, in general, contributed to more injuries in the 6- to 14-year-old group (6 of 20) than in the 0- to 5-year-old group (3 of 20).

Injury patterns. There is some indication that, relative to injuries sustained on other types of equipment, falls from slides are responsible for a high percentage of serious head and facial injuries. Chalmers and Langley (1988, cited in King and Ball, 1989) analyzed New Zealand injury data on falls from playground equipment which required hospital admission. One quarter of the sample sustained intracranial injuries (including concussion, but excluding skull fracture). In their discussion of these data, King and Ball reported that intracranial injuries were associated primarily with slides and were the most frequent type of injury sustained by 0- to 4-year-olds. Similarly, Butwinick (1980) found that almost half of the 56 concussions and skull fractures resulting from surface impact between 1972 and 1979 were caused by falls from slides. Although the New Zealand fall injury data for children admitted to hospitals and the NEISS data analyzed by Butwinick are biased towards more serious injuries, slides appear to be strongly implicated in injuries due to falls.

Consistent with this view, King and Ball (1989) showed that, relative to other types of equipment-related injuries, a greater percentage of slide injuries consisted of serious head injuries, including concussion, internal head injury, and skull fractures (based on 1982-86 CAIRE data and 1987 NEISS data). In the CAIRE study, slides were associated with the highest rate of internal head injuries when compared to other equipment; King and Ball suggested that these injuries were caused by falling from the ladder or top of the slide.

Discussion by King and Ball (1989) of 1985-86 NEISS data, 1987 NEISS data, and 1982-86 CAIRE data allows an age-related comparison of the proportion of injuries classified by body location of the injury and severity. A higher proportion of head and facial injuries was found among 0- to 4-year-olds than among 5- to 14-year-olds; in fact, head injuries were up to three times as frequent among younger children than among older children. By contrast, upper limb injuries were sustained by older children approximately twice as frequently as they were by younger children. In terms of severity for both age groups, most of the facial injuries were contusions and lacerations, and more than half the upper limb injuries consisted of fractures. For younger children, superficial injuries to the face, including contusions and lacerations, were the most common mode of injury. King and Ball suggested that the higher percentage of superficial injuries to the face for 0- to 4-year-olds could have been due to their sliding down face forward. The second most frequent type of slide-related injury among younger children consisted of serious head injuries, the majority of which were internal head injuries. Upper limb fractures were the predominant type of injury among older children, and the next most common mode of slide-related injury among older children was superficial facial injury.

In the detailed incident analysis, head and facial injuries were more common than upper limb injuries; upper limb fractures were more frequent among 5- to 14-year-olds than among 0- to 4-year-olds.

Playground equipment-related mortality data for the period between 1973 and 1977 (Rutherford, 1979) provides additional support for the importance of serious head injuries attributed to falls from slides. Rutherford reported that slide-related injuries are the most common cause of deaths resulting from playground equipment injuries; of 13 deaths reported for slides, 9 were caused by falls, and 8 of these resulted from head injuries.

5.7.1.3 STRAIGHT SLIDES

5.7.1.3.1 Slide access

Recommendations pertaining to slide access are quite limited in the CPSC guidelines. Access to slides is typically by means of ladders with rungs or steps, stairways with steps, or other designs such as multiple level decks of a tiered structure. Following the details of slide ladders and stairways, three additional topics addressed in the technical literature but not covered by the current guidelines are discussed: traffic on ladders and stairways to slides, multiple access, and intermediate platforms. In addition to these recommendations, all access to slides should also conform to the recommendations in the general discussion of access to playground equipment (see Section 5.6.1).

5.7.1.3.1.1 Slide ladders and stairways

Guideline content:

The current guidelines do not address ladders and stairways for slides separately from ladders and stairways for other equipment. There is one set of general recommendations for ladders and stairways, which is included in the heading under slides in Volume 1 but which is discussed independently of any equipment type in Volume 2. For detailed discussion, refer to the general section on ladders and stairways, Section 5.6.1.1. (Volume 1; Volume 2, 11.3)

Probable rationale:

Because no recommendations are given specifically for slide ladders and stairways, refer to the general section as noted above.

Issues:

Slope, steps and rungs, and handrails have been identified in the technical literature as issues significant to slide ladders and stairways in particular.

As previously discussed, many slide-related injuries involve falls from the ladder or stairways. Brown (1978) identified inappropriate ladder inclination as one cause of these falls, based on her review of the CPSC 1978 Special Study. In the same report, Brown's review of NEISS data from 1976, 1977, and 1978 indicated that toppling backward off slide ladders contributes to slide-related injuries.

Sweeney (1980) also noted that children tend to fall back from ladders and offered the following explanation. She noted that the recommendation for ladder inclination is based on an industrial standard. However, this information is not directly applicable: the industrial standard is for a ladder without railings, while most playground ladders, especially those for slides, will have railings. Only ladders with rungs are exempted from the current CPSC recommendation to provide continuous handrails on both sides of ladders and stairways. When using a railing to assist in climbing up a ladder, a person's center of gravity is changed, which then affects the direction of a potential fall. Sweeney explained that playground ladders which have inclines as steep as those recommended in the NBS documents would cause a child to fall *backward* if he lost his grip, instead of falling forward onto the ladder and being able to catch himself.

This view of slide ladders and stairways as potentially hazardous is also reflected in the Play For All Guidelines (Moore et al., 1987). Specific slope recommendations are made for different types of slide access: ladders with steps should have an angle of 50°-75° from the horizontal; stairways should have an angle of 35° or less from the horizontal. These angles are identical to the current CPSC guidelines (Volume 2, 11.3.1). However, the CPSC makes these recommendations for ladders and stairways in general, rather than specifically for slides. In addition, the Play For All Guidelines does not mention ladders with rungs as a means of access to slides, although detailed specifications were made for other types of slide access (i.e., ladders with steps and stairways with steps). It is unclear whether this omission means that they do not endorse the use of ladders with rungs for slides. The Seattle draft standards (1986) state that ladders with rungs are not appropriate for preschool children as part of any type of equipment, including slide access, but do not present the underlying rationale. No similar age-specific recommendations are made in the CPSC guidelines regarding ladders.

The Play For All Guidelines also makes specific recommendations for steps to slides, after noting the CPSC's general treatment of steps. It states that unless the steps are fully enclosed, free standing slides should be avoided; however, no specific rationale for enclosing the steps is given. The Seattle draft standards also deal with enclosure of slide steps and do provide some justification for the measure: "Enclose the risers of steps and ladders to free-standing slides to prevent children falling through or being pulled off." Neither the Play For All Guidelines nor the Seattle draft standards give any dimensions for steps of ladders or stairways which provide access to slides in particular. The CPSC guidelines give different dimensions for tread depths, in general, depending on whether the risers are open or closed (Volume 2, 11.3.2.4), but they do not specifically address slide steps. One further recommendation for slide steps is given in the Play For All Guidelines: in order to eliminate any slipping hazard on the closed treads due to accumulation of sand, small holes should be used, provided they are "too small to catch fingers but large enough to let grains of sand through without clogging."

Brown (1978) concluded from her reviews of NEISS injury data that criteria for the width of steps, depth of steps, and handrails on slide ladders need to be based on the manner in which children use the ladders as well as the size of the intended user. This suggests that different dimensions should be specified for children of different ages; however, this is true for ladders and stairways in general. For example, a more conservative estimate of the necessary contact surface for the foot may be appropriate for preschoolers, or the diameter of handrails may need to be adjusted for these younger children.

One other handrail problem was identified by Brown's (1978) review of slide-related injuries. From the CPSC 1978 Special Study data, the following injury scenario became apparent: "children cannot reach the hand rails at the bottom of the slide and subsequently crawl up the ladder a few steps to the point the rails are reachable. In transition from crawling up the steps to standing in an upright position, some victims lost their balance and fell." Brown concluded that this represents a case in which the product and the size of the user do not match. The details of various anthropometric measures relevant to steps and handrails are discussed in the context of general ladders and stairways.

German standards (DIN 7926, Part 3, 1979) for playground equipment do give specific details for slide ladders and stairways; however, this is their only discussion of ladders and stairways. The requirements they outline for slope, steps and rungs, and handrails, as well as those for other dimensions, are generally comparable to what is stated in other foreign standards which deal with ladders and stairways separately from any type of equipment. Therefore, all of these standards are addressed together in the general ladders and stairways section.

Recommendations:

There does not appear to be sufficient justification to treat ladders and stairways which access slides separately from other ladders and stairways on playground equipment. The issues raised in the context of slides are important; however, they are relevant to all ladders and stairways and will, therefore, be considered in our general recommendations (see Section 5.6.1.1).

5.7.1.3.1.2 Traffic on ladders and stairways to slides

Guideline content:

No recommendations are made in the current guidelines which affect the traffic on ladders or stairways which access slides.

Probable rationale:

Not applicable.

Issues:

One factor contributing to the hazardous nature of slide ladders and stairways is their traffic patterns and tendency to become over-crowded, which was seen frequently during the observational study. Traditional slides are designed to accommodate only one child at a time with single-file ladders. However, children do not always play in a "single-file" manner. Bowers (1988a) commented that when children play in exploratory or creative ways, the risk of injury is increased due to the single-use, wait-your-turn design of slides. For example, it is common to see more than one child on a ladder, sometimes trying to climb in opposite directions. The detailed incident analysis showed six cases in which interaction with another child on the ladder or at the top of the slide contributed to the incident. Among these cases, the most common scenario involved someone behind the victims pushing them or otherwise causing them to fall. Simpson (1988) claimed that "better manufacturers" had eliminated single-file ladders.

In the Play For All Guidelines (Moore et al., 1987), attention is drawn to the problem younger children have in being unable to climb down if they get scared during the ascent up slide stairways. It is also noted that older children often use the stairs as a place for "horseplay." With these problems in mind, they suggest replacing stairway access to slides with decks as part of a composite structure. A similar idea is Bowers' (1988a) recommendation to use multiple level platforms for slide access. Designs such as this would help to reduce the hazards of heavy traffic on slide ladders and stairways. By integrating the slide with a deck structure, more space would be available for alternative play behaviors, as Brown (1978) recommended, and the wait-your-turn situation that characterizes single-use, free standing slides would be minimized.

The width of ladders and stairways is discussed in the general section (see Sections 5.6.1.1.2 and 5.6.1.2.1); however, there are certain standards which pertain to the width of slide ladders. The German standards specify that slide accesses must be 16-24 inches wide, when the free height of fall exceeds 40 inches. Considering that the shoulder breadth of a 95th percentile 12-year-old is 16 inches, it would seem that the intent is single-file use. The German standards also state that slide ladders should not be wider than the platform they serve, but do not give a minimum height at which this goes into effect. The Seattle draft standards state that single slides over 8 feet in length which are above grade must have single-file access on ladders, but that they must also offer multiple means of access to the slide so that an alternative "means of retreat" is available. They do not provide a dimension for the width of slide ladders.

Standards that either imply (German) or recommend (Seattle) single-file access oppose the suggestions of several playground designers to use multiple decks for slide access. However, the standards are probably addressing the more traditional, single-use, straight slide, and have not dealt with the type of access most appropriate for more contemporary slide designs. The designers mentioned above tend to support more modern configurations which eliminate this traditional single-use slide design as a whole, not just the single-file design of the ladder.

The Seattle draft guidelines present another issue regarding traffic on slide ladders and stairways. They recognize the importance of separating the slide access from the sliding board so that children cannot fall from the sliding board to an adjacent tread. This recommendation is repeated in their discussion of modular play equipment: "Locate slides and ladders separately from one another to prevent jumping from steps to slides midway." This idea of not placing slides and ladders parallel to one another was also supported by Esbensen (1987). However, some manufacturers currently offer slides with slide chutes and access stairways that are parallel and adjacent to each other. Moreover, this access design is depicted in the Play For All Guidelines as a way to make slides more accessible, especially for non-ambulatory children; and is supported by Beckwith (1988) as well.

Recommendations:

Younger children may benefit from single-file stepladders or stairways for ascent to slides. Being able to hold handrails on both sides could help them to maintain better balance and support while climbing. If access to slides which are intended for use by preschoolers are single-file, they should be at least 12 inches but not more than 21 inches wide, as described in the general recommendations regarding access.

In contrast to stepladders which should always be single-file for younger children, stairways wide enough for more than one child are manageable for this age group. The shoulder breadth of the maximum user, a 95th percentile 5-year-old, is 11.5 inches. Therefore, stairways intended for use by more than one young child at a time should be at least 30 inches wide, which includes some allowance for space between users.

Older children tend to have higher rates of injury on ladders and stairways because they are more often involved in rough-housing while competing for access. Therefore, wider access to accommodate more than one user at a time may be preferable for slides intended for school-age children. The shoulder breadth of the maximum user, a 95th percentile 12-year-old, is 16 inches. Ladders or stairways intended for use by more than one child at a time should, therefore, be at least 40 inches wide, which includes some allowance for space between users.

When access to the top of a slide is single-file, it is useful to provide an alternative exit from the platform, such as another ladder or stairway. This will help alleviate problems caused by the "point of no return" situation children often find themselves in, especially younger ones, if they are hesitant to descend down the slide chute.

Slide chutes should not be positioned adjacent to the ladders or stairways which access them. Separation of these components is intended to prevent jumping or falling from the ladder or stairway access directly to the sliding board and vice versa.

5.7.1.3.1.3 Multiple access to slides

Guideline content:

The current guidelines do not include discussion of multiple means of access to sliding boards.

Probable rationale:

Not applicable.

Issues:

Several people support the idea of providing multiple and varied means of access to one sliding board by incorporating more than one access route (e.g., ladders, stairways, or other designs) in the slide structure. In fact, as traditional slides are being replaced with more modern ones, it is typical to find slides attached to broad platforms which are accessible from several directions (Frost, 1980; Simpson, 1988).

There is evidence that use of access ladders and stairways as alternative means of *exit* is important. In their discussion of injury data from the Canadian Accident Injury Reporting and Evaluation System (CAIRE), King and Ball (1989) identified lack of multiple access to slides as a possible factor contributing to injuries. This is particularly true for younger children, who may change their minds about going down the slide and require a different exit route from the top of the slide. Brown (1978) also highlighted multiple access as a factor which helps to lessen the chance of a child getting into a "point of no return" situation.

The Seattle draft standards address this issue by recommending a "means of retreat" other than the access ladder at the top of slides which are more than 8 feet long and above grade, as previously discussed. They also note that a slide attached to a platform may have both a stairway and a ladder. Varied means of access is advocated by Esbensen (1987) as well, who warns against the exclusive use of stairways. Although stairways are helpful for younger slide users, they do not provide much of a challenge to the older children. Therefore, ladders should be included as well.

As mentioned above, modern designs often attach slides to platforms of multi-use equipment. Bowers (1988a) is an advocate of these designs and recommended the use of platforms at various levels as a means to increase accessibility. The German standards acknowledge this approach by noting that one or more items of play equipment may replace typical slide access such as a ladder or stairway. (Designs incorporating this form of access would be similar to multi-use equipment as commonly seen today in the United States.) Also, the German standards specify that "several accesses are permitted on multiple slides." However, they do not specifically recommend multiple access for single slides. Canadian draft standards (CAN/CSA-Z614, 1988) recommend multiple means of access from elevated surfaces which are more than 6 feet high, with the exception of free standing slides. Thus, when a slide is attached to an elevated surface greater than 6 feet, multiple access is required; however, it is not required for slides which are attached to a lower elevated surface or for single-function, traditional slides.

Recommendations:

It is recommended that multiple means of access be provided for slide entrance platforms. Stairways are generally more manageable for younger children, while older children enjoy the greater challenge of ladders.

By including two or more access routes, alternatives to descent down the slide chute are available, which is particularly important for solving the "no way out" problem common to younger children. Furthermore, additional exit options from the platform would help resolve a foreseeable use of ladders that has been identified in the detailed incident analysis: several children were injured when attempting to climb down the ladder, although the ladder is generally intended for climbing up. Having more than one access to choose from may minimize interference between a child climbing down the ladder and children who are climbing up one of the accesses.

Designs which incorporate multiple means of access to larger platforms could increase the overall safety of free standing slides.

5.7.1.3.1.4 Intermediate platforms on slide access

Guideline content:

The current guidelines do not address the use of intermediate platforms.

Probable rationale:

Not applicable.

Issues:

Three countries address intermediate platforms in their playground standards: Great Britain, Australia, and Canada. The inclusion of intermediate platforms along slide access routes could help to eliminate the "point of no return" for children who begin their ascent to a slide but are fearful of continuing. Also, they could help reduce some of the problems associated with heavy traffic up to the slide by giving children a platform to wait on rather than only steps or rungs.

Although the content of the British (BS 5696: Part 2, 1986) and Australian (AS 1924, Part 2, 1981) standards for intermediate platforms, including all dimensions given, are identical, there is an important difference. The British standards are stated specifically for access to slide platforms while the Australian and Canadian draft standards apply to ladder and stairway access in general. Therefore, discussion here focuses on the British version, while another section addresses the details of intermediate platforms for any type of equipment (see Section 5.6.3.4). The British standards state that if a slide platform is more than 8.2 feet above ground level, intermediate platforms are required, and the intervals must not exceed 8.2 feet. An exception is made for spiral staircases. Entry and exit to the intermediate platform must either be completely offset or produce a change in direction of not less than 90°, so that the line of access is not continuous. The platform itself must be twice as wide as the access and at least 3.3 feet long.

A recommendation related to the idea of intermediate platforms is the use of multiple level platforms for slide access, which has already been mentioned briefly (Bowers, 1988a; Moore et al., 1987). Bowers (1988a) defined a safe distance between platforms as "one in which each child is able to jump purposely or fall accidentally to the next level without sustaining a serious injury." He went on to state that 18 inch distances are reasonable for preschoolers. Incorporating multiple level platforms is a means to facilitate climbing to higher equipment, while also minimizing the potential fall distances and therefore risk of injury (Bowers, 1988b). This design concept can be viewed as a series of intermediate platforms leading to a slide platform. The intervals would be much closer than those specified in the foreign standards.

Recommendations:

Intermediate platforms for all types of equipment are addressed together (see Section 5.6.3.4), because the detailed recommendations do not need to be different when such landings are incorporated into slide accesses.

5.7.1.3.2 Slide surface entrance

Guideline content:

Volume 2 refers specifically to the slide surface entrance, recommending that all slides have features which facilitate the transition to the inclined sliding surface. Further recommendations are made regarding the platform and protective barriers, which apply to slides with an entrance height of more than 30 inches. Volume 1 gives some of these recommendations but does not frame them as Volume 2 does in its introduction to slide surface entrances. An important difference from Volume 2 is that the minimum height for requiring protective barriers is 30 inches, but in Volume 1 it is 4 feet. (Volume 1; Volume 2, 11.5.4)

Probable rationale:

According to the 1978 Special Study, 78% of slide-related injuries involve falls. The greatest opportunity for falling comes in transitions between positions or activities. During slide use, the primary transition is between the top of the ladder or other access, and the sliding surface as the child moves from a climbing to a sitting position. The upper one-third of the slide chute has been identified as the most hazardous section. In order to reduce the hazards and facilitate moving from the ladder to the sliding surface, a platform and protective barriers are required at the top of the slide. (Brown, 1978; NBS, 1978b; Rutherford, 1979)

Issues:

The CPSC guidelines for the slide surface entrance focus on easing the transition from the ladder to the slide itself. However, in recommending the inclusion of a platform, regardless of its size, they have added a step to this transition. Rather than one move from ladder to slide, as the CPSC discusses, there are really two separate actions: the transition from ladder to platform and the transition from platform to slide. Thus, it would be more appropriate to address the issues of these two areas separately.

<u>Transition from ladder to platform</u>: This change in movement from climbing up the ladder, or stairways, to standing on the platform is considered an especially important transition (Frost, 1980; Ridenour, 1987). Without some attention to safety from falls, children are at great risk at this point. Handrails are discussed in the general context of ladders and stairways; however, continuation of handrails from the slide access to its platform is a key factor in facilitating this move, provided they are the appropriate size and at the appropriate height (Mallo, 1988; Moore et al., 1987). Another strategy was identified by Frost (1980), who suggested that an overhead horizontal bar could be helpful to children. Some current slide designs utilize such a bar but at the transition between the platform and the slide chute.

<u>Transition from platform to slide</u>: Although the guidelines do address this transition in their recommendations for protective barriers on slides, which are discussed in detail below, there are additional issues which warrant attention. The rationale for this section of recommendations indicates that the top portion of the slide is the critical area for protection

from falls. Butwinick (1980) presented an analysis of 126 slide in-depth investigations through 1978. She concluded that falls from the platform, from the top of the slide, and from the top third of the slide incline together accounted for 37% of all these slide-related injuries. Because of the large proportion this represented, she believed that more specific recommendations for this area were needed and that the definition of the "critical area" for potential falls needed to be more precise. Her views are further explained in the discussion of protective barriers.

Concern regarding this movement from the platform to the sliding surface is shared by many experts. A common recommendation is to incorporate a design which encourages children to sit before sliding rather than walking or running (Esbensen, 1987; Mallo, 1988). Acknowledging this, Preston (1988) mentioned that a horizontal bar at the top of the slide had been suggested by several people as a means not only to aid in the transition but also to prevent falls. The Seattle draft standards (1986) repeat this recommendation for a top rail. The Play For All Guidelines (Moore et al., 1987) acknowledges the importance of reducing exposure to falls during this transition, but also points out that devices designed to do so must not introduce any new hazards. With regard to single rails, these guidelines recognize the opportunity given to children to engage in "skin-the-cat" type actions. The Play For All Guidelines considers the use of double rails or vinyl coated chains better designs. The observational data indicated that children very frequently hang and swing from a horizontal bar placed at the entrance to a slide chute, and they also tend to climb or sit on the bar. Such behaviors do not appear safe and any designs which incorporate a barrier of some kind (i.e., a bar or chain) across the slide entrance should not encourage these use patterns. One young child who repeatedly climbed up the slide chute from the bottom came very close to hitting her head on the horizontal bar as she stood up straight upon reaching the platform, illustrating another hazard of the design, since this use pattern is to be expected for children of all ages.

Another suggestion in the Seattle draft standards is to place a tunnel at the top of slides to provide protection from falls. However, as Brown (1978) noted and as supported by observational data, these structures are often climbed on and, therefore, present a hazard of falls possibly from an even greater height.

Some type of hand grip at the entrance to the slide chute can aid in the transition between platform and chute. Review of playground equipment catalogs indicated that vertical and loop handrails or handgrips located on both sides of the entrance to the slide chute are used in current slide designs. These handrails are typically perpendicular to the platform, and may be attached to the vertical edge of the protective barrier on either side of the chute entrance. As seen during the observational study, children can run their hands down the full extent of the vertical grip for continuous hand support while lowering themselves from a standing to a sitting position. This typical use of the handgrips appeared to be beneficial to the users, especially the younger children. Further, when children were climbing up the slide chute, vertical or loop handgrips helped them to regain a fully upright position as they stepped onto the platform.

Certain foreign standards address the need to facilitate sitting before sliding as well. The Canadian draft standards (CAN/CSA-Z614, 1988) include recommendations for a "sitting section" at the very top of the slide chute. The idea is to give children a place other than the platform to sit on while getting ready to slide down the chute. Specifications for this section are as follows: length should be a maximum of 12 inches; slope should not exceed 5° below the horizontal plane of the starting platform; protective side enclosures should diminish in a smooth curve from the guard rail height used for the platform to the side wall height, and they should be designed so that the flow of hand movement is not obstructed. The British standards (BS 5696: Part 2, 1986) make a recommendation with the same general intent as the Canadian's sitting section: a short length of horizontal surface is allowed at the commencement of the slide chute.

Also relevant is the Seattle draft standard which recommends that the slide bed be installed either flush with the entry platform or in a way that provides a smooth transition. Similarly, the German standards (DIN 7926, Part 3, 1979) specify that the transitional part between the seat area (the German version of a slide platform) and the take-off area (the very top of the slide) must not vary much in height, and there must not be any gaps. Joints in this section are permitted only if they do not jeopardize safety. Moreover, the retaining sides used on the seat area should merge into the sides and handrails of the chute section in a way that does not impede the user's movement. The latter measure is similar to the Canadian recommendation for merging the guard rails on the platform with the sides of the chute.

Coleman and Vickers (1982, cited in Winter, 1988) observed seven cases in which children's fingers were amputated, over a period of three years at Royal Children's Hospital of Brisbane. All of these were associated with slides which had a space greater than 2.54 inches between the platform and the slide chute. Winter noted that "double welding with obviation of space would have been good prevention in these cases." Another similar amputation incident has been reported since the Coleman and Vickers study. Any gap such as this is clearly hazardous given that children often place their hands down to support themselves as they move from standing to sitting and risk getting a finger stuck when sliding down the chute. Observational data indicated that there are indeed slides with these dangerous spaces between the platform and chute on playgrounds.

The following two sections, platforms and protective barriers, discuss the CPSC guidelines and highlight in more detail the need to separately address both the transition from ladder to platform and the transition from platform to slide chute.

Recommendations:

Transition from the ladder to the platform

Provisions for continuing handrails from the top of the access to the slide platform are included in the general section on access to equipment (see Section 5.6.1.1.3.1).

Transition from the platform to the slide chute

Slides should be designed and constructed so that there are not spaces or gaps between the platform and the start of the sliding surface.

Horizontal bar. Some slide designs currently include a horizontal bar or chain at the top of the slide chute. However, the horizontal bar could conceivably lead to more unsafe uses of the slide than it prevents. For example, children may launch themselves down the slide chute by flipping over the bar, jumping off the bar, or swinging from the bar. The extent to which the horizontal bar has contributed to injuries is unknown. Since older children are more likely than younger children to misuse the horizontal bar, and since older children have less of a need than younger children for help in maintaining balance during the transition from platform to slide chute, the horizontal bar does not seem warranted for this age group. Whether the benefits to children between 2 and 5 years of age outweigh the risks is an open question. Adoption of the horizontal bar on slides intended for younger children cannot be supported until the risks of its misuse have been investigated. Any slide design which incorporates a barrier across the front of the chute should not encourage climbing or other hazardous behaviors.

Handholds at the entrance to the slide chute. Vertical or loop handrails placed on both sides of the slide chute entrance are recommended because they provide continuous hand support as children lower themselves to a sitting position. Any opening bounded by a handgrip and an adjacent vertical structure (e.g., vertical support post for a platform deck, vertical slats of protective barrier) must not pose an entrapment or strangulation hazard (see Sections 5.2.5 and 5.2.6).

To facilitate the transition from the platform to the sliding surface, the handholds should extend high enough to provide hand support for a maximum user in a standing position, and low enough to provide hand support for a minimum user in a sitting position. To accommodate a maximum user who begins to use the handhold in a standing position, the handhold should be at least 38 inches high on equipment intended for 4- to 12-year-olds, and 26 inches high on equipment for 2- to 5-year-olds. These heights correspond to the elbow height measured from a standing position of the 95th percentile user from each age group, and were estimated from the difference between the user's suprasternale height and shoulder-to-elbow length. To provide hand support for a seated minimum user, the handhold should extend at least as low as the user's elbow, or about 5 inches and 4 inches for older and younger users, respectively. The difference between a user's sitting mid-shoulder height and shoulder-to-elbow length was used to approximate the elbow height of a seated 5th percentile user from each age group. In summary, to provide continuous hand support as a child lowers himself or herself from a standing to a sitting position, it is recommended that handholds extend from 5 inches or less to at least 38 inches above the platform for older users, and from 4 inches or less to a minimum of 26 inches above the platform for younger users (see Figure 5.7.1 - 2).

5.7.1.3.2.1 Slide platforms

Guideline content:

Both guidelines recommend that the entrance to a slide chute be a horizontal platform which is at least 10 inches in length and at least as wide as the contiguous inclined surface. (Volume 1; Volume 2, 11.5.4.1)

Probable rationale:

As discussed above, the general intent of these recommendations is to help children make the transition from the ladder to the slide chute. The only more specific rationale given is that the 10-inch length corresponds to the maximum user's foot length; and therefore, a horizontal platform at least this long will help provide foot support during the change from a climbing to a sliding posture. (NBS, 1978b)

Issues:

In a safety inspection of 57 elementary school playgrounds in Philadelphia, Ridenour (1987) found that 46% of the slides had platforms which did not meet the CPSC specification, and another 11% had no platform at all. Although this suggests that many slides currently on the market do not have platforms even 10 inches long, the guideline for this dimension has been criticized as not long enough. Also, the foreign standards which regulate this dimension each require longer platforms for slide entrances.

Frost (1980; U. of Texas, 1989, unpublished manuscript) suggested that a 10-inch deck is too small to aid children in the transition which it is provided for and that a 24-inch platform would more realistically serve this purpose. Further, he noted that this is an example of the guidelines being geared toward outmoded single-use equipment, when they should be addressing more modern playgrounds. Typical modern "superstructures" incorporate decks which are 4 feet square as slide entrances.

The Canadian draft standards require a minimum distance of 18 inches between the top riser of the stair and the top lip of the chute, which is almost twice the length recommended by the CPSC. Although the German standards for slide entrances are slightly different in terminology, certain specifications can still be compared. In dealing with the transition from the ladder to the slide, they require a seat area not intended for standing, rather than a platform. It appears they assume children will move directly from climbing up the ladder to sitting on the slide. The depth (which would correspond to the CPSC length dimension) of this area must be between 11.8 and 15.8 inches. Even the lower end of this range is greater than the CPSC 10-inch minimum, and at the upper end it is one and one-half times the CPSC recommendation.

While there is some difference of opinion, the width of platforms is not as controversial as their length. The Canadian draft standards are identical to the CPSC guideline, recommending that the minimum width of the platform be equal to the width of the slide. Although neither the Seattle draft or German standards address slide platforms specifically, both have width requirements applicable to the slide chute entrance. The Seattle draft standards state that the slide entry should be no wider than the width of the sliding surface; slide entry refers to the opening in the barrier at the tope of the chute. The German standards require the width of the seat area to be the same as the slide; the seat area is a near-horizontal area at the top of the slide which is integral with the chute.

Brown (1978) noted that the minimum size of the platform should be determined by typical play patterns on slide ladders and the size of intended users. The rationale for the platform length does take into account the maximum user's foot length, but neither the length nor width recommendation has dealt with play behaviors, as Brown suggested. Brown pointed out that narrow platforms become congested when children are waiting their turn, and do not provide enough space for alternative behaviors. Wider platforms can accommodate more than one child at a time and their alternative behaviors, and therefore would be safer (Brown, 1978; Henniger et al., 1982).

The literature does not contain any criticism of the CPSC's recommendation that slide platforms should be horizontal. It seems plausible to assume that platforms are intended to be horizontal, unless a different slope is specifically stated. The standards which address slide platforms do not deal with a requirement for slope. An exception is Germany, which requires that the slope of the seat area in the direction of the sliding surface not exceed 5 degrees. However, recall that this seat area is not intended for standing on, and so it is not really a traditional platform by nature. This may be why it was not automatically assumed to be a horizontal surface.

Recommendations:

Given the injury data for falls at the top of the slide during the transition between standing and sitting, and the social interaction (including roughhousing) that occurs among children waiting to slide, a platform that is only long enough to accommodate the foot length of the maximum user does not seem adequate. Since children typically lower themselves into a sitting position when they are on the platform, it seems reasonable for the platform to accommodate the buttock-to-knee measurement of the maximum user. The buttock-knee length for a 95th percentile 12-year-old is 22 inches, and for a 95th percentile 5-year-old is 15 inches. Therefore, it is recommended that platforms intended for use by 4- to 12-year-olds and by 2- to 5-year-olds be at least 22 inches and 15 inches long, respectively.

Although 22 inches is more conservative than the lengths specified in the Canadian draft and German standards for the platform or seat area, both standards recommend an additional sitting-down area at the top of the slide, which effectively extends the length of the platform or seat area. Canadian draft standards allow this sitting section to be up to 12 inches long, and German standards specify a minimum length of 24 inches for the take-off area at the top of the slide chute. When the lengths of these additional sitting-down areas are taken into account, the 22-inch recommendation for the platform length does not appear to be excessive.

Length of the platform will usually not be an issue when the slide is attached to the deck of a multi-use structure, because decks are typically at least 3 feet square.

The current guideline for platform width allows for the attachment of slides to decks or platforms that are wider than the slide chute. However, the surface area of the platform should accommodate the number of children who can be expected on the platform at one time. In general, when there is only one access, the platform should be at least as wide as the stairway/ladder access or the sliding chute, whichever is wider. In the case of a multiple level deck structure, a lower deck may serve as a play surface in and of itself, while also providing access to a higher deck that functions as a slide platform. In this case, the deck to which the slide is attached can be narrower than the deck one level below.

If an access is wide enough to accommodate more than one user, the platform area should also accommodate more than one user without crowding. The recommendation for the minimum width of accesses intended for more than one user (see Section 5.7.1.3.1.2) has implications for platform width. Accesses intended for more than one user should be a minimum of 40 inches wide for older children and a minimum of 30 inches wide for younger children. Thus, in order for the platform to be as wide as the access, it would have to be at least 40 inches or 30 inches wide, depending on the user age group. As an additional measure, to ensure that children can move around safely on the platform when access is intended for more than one user at a time, it is recommended that the minimum length, as discussed above, be extended to increase the platform's surface area.

Finally, in the case of more than one access to a slide platform, the platform area should accommodate at least as many users as the accesses do, without crowding. For example, if there are two single-file accesses, there should be adequate room for two users on the platform. If there are two accesses, one of which accommodates two users abreast, the platform area should accommodate three users.

The platform slope should be horizontal, as the guidelines currently state.

5.7.1.3.2.2 Protective barriers

Guideline content:

Volume 2 discusses protective barriers in the context of elevated surfaces and then repeats these recommendations for slides with two additions. The barriers, except for necessary entrance and exit should completely surround the platform *and* extend down the sides of the inclined surface. The barriers should extend at least 14 inches down the slide chute at a minimum height of 21 inches. The second addition explains that barriers for slide platforms should enable both the minimum and maximum user to maintain body balance and support during the transition between ladder, platform, and sliding surface. Also, Volume 2 explains that the protective barrier recommendations may not be appropriate for all slides: embankment, tunnel, and extra wide slides which accommodate more than one user, are noted as examples. Volume 1 discusses protective barriers only in its treatment of slides; there is no separate section for elevated surfaces. There is an inconsistency between the two volumes as to the minimum height at which protective barriers are required. Volume 1 states that slides over 4 feet high should have protective barriers at least 38 inches high. However, Volume 2 recommends the use of barriers for elevations of 30 inches or more. (Volume 1; Volume 2, 11.5.4, 11.5.4.2)

The details of protective barriers on elevated surfaces which do not directly apply to slides are discussed in a general section (see Section 5.6.3.2). However, in addition to the specifications discussed below, it is important to recognize that protective barriers on slide platforms should also follow all of the general recommendations regarding the height and nonclimbability of barriers and the prevention of entrapment.

Probable rationale:

The general intent of recommendations for protective barriers, slide-specific or in general, is to prevent falls to the surface. The technical rationale for features of protective barriers that are not specific to slides is discussed in the general section mentioned above.

The specifications unique to slide platform barriers are intended to provide protection from side falls at the top of the slide as the user moves from standing to sitting, and prior to attaining a sliding velocity. This area was determined to be "critical" for potential falls. It would be unreasonable to compromise the barrier height in order to have a lower barrier which could double as a hand rail; therefore, adequate handholds for minimum or maximum users in standing and seated positions should be designed into the barrier. It is unclear what the exact location of such handholds was intended to be. That is, should they be around the entire barrier or only at the entrance to the chute? It appears that the recommendation for handholds to aid in the transition from standing to sitting was never incorporated into the guidelines as such. The only correlation which can be drawn from this discussion of handholds in the NBS rationale documents to the guidelines is the general statement that the barriers should facilitate both minimum and maximum users in maintaining body balance and support. The barriers are supposed to provide protection from falls off the slide chute prior to attaining sliding velocity. The dimensions chosen correspond to anthropometric measures: the barrier is to extend a minimum of 14 inches down the sliding surface based on the maximum user's elbow to hand measurement; the barrier is to be at least 21 inches above the sliding surface based on the maximum user's shoulder height when seated. Furthermore, as will be discussed in a later section, these barriers should be separate from, but overlap with the side walls which extend down the entire length of the sliding surface. (NBS, 1978b; NRPA, 1976a)

Issues:

In Brown's (1978) reviews of NEISS data, she commented that "the conventional slide does not provide much protection against falls from the top." Many others apparently agree. Basic recommendations only noted that slide platforms need safety barriers or guard rails (Helsing et al., 1988; D. Thompson, personal communication, February 1989), while others specifically called for enclosed platforms at slide entrances (Seattle, 1986; Esbensen, 1987). The Seattle draft standards, as well as recommendations from Butwinick (1980), included all slides over 4 feet above grade in their treatment of protective barriers, which highlights the inconsistency found in the guidelines as to exactly what height necessitates the use of such enclosures.

Butwinick (1980) heavily criticized the protective barrier recommendations as they pertain to slides. As noted in discussion of the transition from platform to slide, Butwinick does not feel that the "critical area" is sufficiently addressed: "the area NBS defines as 'critical' does not extend down the slide incline far enough to effectively reduce injury." Her analysis of in-depth investigations, also previously mentioned, indicated that several children fell over the side of the slide just after the short guard rails at the top of the slide chute ended. Some of these falls may have been prevented if the rails extended further down the slide bed. The CPSC appears to have defined the "critical area" based on the maximum user's elbow-to-hand measure, which is 14 inches. (The recommendation is that the barriers extend 14 inches down from the top of the slide.) Butwinick stated that it would be more appropriate to use the maximum user's seated rump-to-sole measure, which is 37 inches. If the recommendation corresponded to this anthropometric measure, protection from falls over the side in the upper region of the slide would be improved. Butwinick's rationale behind this is that protection should be provided until the child begins descent down the inclined surface, which would be consistent with the NBS rationale discussed above.

An interesting parallel can be drawn to the German standards, which regulate the "take-off area" of the chute separately. This area must not have any curves or undulations from the seat area and must be protected so that children cannot fall off the sides. The take-off area must be at least 24 inches long; therefore, we can infer that these German standards mandate extension of the protection around the seat area for a minimum of 24 inches. These standards do not, however, specify the type of protection which is to be provided.

Recommendations:

A common deficiency of current slide design is the lack of protective railings at the top of the slide chute. The purpose of continuing the protective barrier down the top of the slide chute is twofold: 1) to prevent falls over the side of the slide during the transition from standing to sitting, and 2) to prevent falls over the side when the seated user has not yet gained momentum. Both older and younger children are at risk for the first type of fall, although older children have the advantage of better balance and body control. However, the second type of fall is primarily a problem for younger children, who tend to proceed more cautiously than older children at the top of the slide; older children gain speed faster and so are not as prone to lateral discharge once they are seated. For these reasons, the length of the slide chute protected by the continuation of the protective barrier should be a minimum of 25 inches on equipment intended for both younger and older children (see Figure 5.7.1 - 3). This measure corresponds to the maximum 5-year-old user's seated rump-to-sole measure, and so provides a conservative barrier length for 2- to 5-year-olds who are more at risk for falls from the top of the slide chute. The length of the barrier need not be as conservative for older children, and the 25-inch length is adequate for the maximum 12-year-old user.

The current minimum height recommendation of 21 inches for protective barriers at the top of the slide chute protects the 95th percentile 12-year-old user from falls. On slides intended for 2- to 5-year-olds, a 16-inch height is sufficient, based on the sitting mid-shoulder height of the 95th percentile 5-year-old user (see Figure 5.7.1 - 3).

All protective barriers intended for both older and younger children should be designed to prevent smaller users from falling through the barrier. This can be achieved either through the use of infill or other measures, so long as they are consistent with the recommendations that protective barriers be non-climbable and preclude the possibility of entrapment (see Section 5.6.3.2).

5.7.1.3.2.3 Maximum height of slides

Guideline content:

The current guidelines do not make any recommendations as to the maximum allowable height of slides, or of any playground equipment. For a general discussion of maximum height, refer to Section 5.1.3.6.

Probable rationale:

Not applicable.

Issues:

Brown (1978) noted that slides may vary in height from 4 to 16 feet. The 1978 Special Study data indicated that 78% of all slide-related injuries involved falls, and more than three quarters (78%) of these falls were from distances of 6 feet or higher. We have seen that, relative to deaths and injuries that occur on other types of equipment, falls from slides are associated with a higher percentage of deaths (Rutherford, 1979), and a higher percentage of serious head and facial injuries (Butwinick, 1980; Chalmers and Langley, 1988, cited in King and Ball, 1989). Because the severity of injury generally increases with the height of the fall, this variable needs to be addressed.

The Play For All Guidelines (Moore et al., 1987) concludes that freestanding slides should be restricted "to 64 inches vertical fall height or to the limits defined by the test results of the safety surface material installed, whichever is smaller." Frost (1980) also discussed the maximum height of equipment. He concluded that no equipment needed to be higher than 7 feet. Slides at this height which have appropriate inclinations provide both excitement and challenge. Furthermore, increasing slide heights beyond 7 feet would only serve to extend the excitement, which children could get from going down the slide again. Similar recommendations for maximum slide height were given by D. Thompson (personal communication, February 1989), who said they should be no more than 6 to 8 feet, and by Beckwith (1988), who said slide elevations must not exceed 80 inches from ground level. The British standards allow the greatest slide heights: normally accessible parts of slides, such as their access, platform, and sliding surface, "should be designed so that a child cannot fall freely from the slide to the ground or other adjacent surface a greater distance than 8.33 feet."

Recommendations:

Slides should follow the age-specific maximum fall height recommendations given for all types of equipment (see Section 5.1.3.6).

5.7.1.3.2.4 Attachment of slides to multi-use equipment

Guideline content:

The current guidelines do not specifically address slides which are attached to multi-use equipment, also commonly referred to as "superstructures."

Probable rationale:

Not applicable.

Issues:

Throughout this discussion of slides, attention is given to the fact that modern playground equipment is typically designed in the form of superstructures. This multi-use design often includes slides attached to large platforms, which have multiple means of access and serve the slide as well as other equipment. Preston (1988) questions whether the guidelines as written are appropriate for slides attached to multi-use equipment.

Recommendations:

Because these superstructure designs are increasingly popular, the slide recommendations should take them into account. The implications of attaching slides to multi-use equipment were considered for each slide recommendation, and are discussed in sections when multi-use structures warrant special treatment.