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Test and Evaluation of Baby Walkers and Walker-Jumpers

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Engineering Mechanics Section
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Washington, D.C. 20234

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Final Report

Prepared for

Consumer Product Safety Commission
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NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

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ABSTRACT

Accident reports from hospital emergency rooms were surveyed to determine the probable causes of accidents involving baby walkers and walker-jumpers. Test methods were developed to simulate service conditions to determine if the characteristics leading to accidents are present in all or only a few of the items on the market. These test methods include tests for dynamic and static stability, step roll-over stability, plastic bead strength, durability, and location of scissor joints. The test methods and performance criteria are intended to supply information leading to federal safety standards.

Key words: Accident reports: baby walkers; infants; safety standards; test methods; walker-jumpers.

1. INTRODUCTION

Accident reports received through the Bureau of Product Safety (now part of the Consumer Product Safety Commission) listed many injuries, mostly lacerations, abrasions, or fractures in the face, head, and shoulder areas, to 7-14 month-old children as a result of accidents involving baby walkers and walker-jumpers. Most injuries resulted from the walker tipping over after being run into a stopping mechanism, such as carpet molding, gravel, raised concrete, floor heating vents, and door sills. Other accidents involved the walker being run over a step or down a flight of stairs, and finger lacerations caused by "scissor" joints. An investigation was undertaken to determine what characteristics of the walkers possibly led to the accidents, to determine if these characteristics were inherent to all or only a few of the items on the market, and to determine appropriate test methods and performance criteria so that federal safety standards could be written. Situations investigated included dynamic stability (moving walker runs into a stop), static stability (stopped walker is tipped over by a standing child), stability when running over a single step, location of scissor joints relative to child sitting in jumper, strength of plastic beads within reach of child's mouth, and durability.

2. TEST PROGRAM AND RESULTS

2.1 Dynamic Stability

Since the majority of the accidents involved the dynamic stability of the walker, the first and largest effort was directed toward understanding this problem.

If the walker is considered to be a rigid system (i.e. frame deflections, spring extensions, etc. are neglected), the mechanics of the event of the walker hitting a stop are straightforward. For the walker to tip over, the kinetic energy before impact must be greater than the energy required to rotate the walker to the unstable equilibrium position (see fig. 1), or mathematically,

$$\frac{V^2}{2g} \geq \left[L^2 + H^2\right]^{1/2} - H,$$

where V is velocity, g is the acceleration due to gravity, and L and H are the horizontal and vertical dimensions from the axis of rotation to the center of gravity. On a horizontal surface, the velocity is fixed by the capabilities of the user, so the stability of the walker is determined by the location of the center of gravity.

To get some indication as to the speeds attained by children in walkers, two 10 month old "volunteers", a 22 lb* (10 kg) and an 18 lb (8.2 kg) female, were timed while using walkers in the laboratory. Both were allowed to move over an unobstructed course, with enticement from parents (see fig. 2), in a variety of walkers, including their own. Times to traverse 5-ft (1.5-m) distance markings were taken to determine some rough indication of maximum speed. One child achieved a maximum speed of 2.5 feet per second (0.76 m/s), and the other 4 feet per second (1.2 m/s). Parents of both indicated that it seemed that the children went faster at home in their natural environment. Another important observation was that both children achieved maximum speed going backwards. This seems logical since it appears to be easier for a child to sit and propel himself backwards than to stand and run forward. This is significant since the center of gravity of most walkers is closer to the back wheels than to the front.

Based on the speeds measured and the comments that the children may go faster at home in their own surroundings, it was decided to test at speeds of 4 and 6 feet per second (1.2 and 1.8 m/s). The walkers were tested in forward, backward, and sideways orientations, and impacted obstructions 0.25, 0.50, and 1.0 in (0.6, 1.3, and 2.5 cm) high.

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*Units for physical quantities in this paper are given in both the U. S. Customary Units and the International System Units (SI).

These obstructions were intended to simulate carpet molding, door sills, or other raised obstructions. A plastic doll, approximately the size of a 1 year old child, was weighted with lead to 26.5 pounds (12 kg), with the center of gravity located approximately 6 in (15 cm) above the crotch. This weight is the 90th percentile weight of a 14 month-old child (data received from Dr. Richard Snyder, Univ. of Michigan). Several physicians consulted agreed that this was an appropriate upper limit for children who use walkers. The location of the center of gravity of the weighted doll was at the same location as the c.g. of a child. The doll was placed in the walker during all dynamic stability tests, and restrained in approximately the same position as a child would use for that direction of motion, i.e., sitting back for backward travel, leaning forward for forward travel.

The test setup for dynamic stability tests is shown in fig. 3. The walker is placed on a flywood ramp at the height necessary to generate the required test speed, as determined by trial runs, and restrained at this position by a string. The wheels are alined in the direction of intended motion, and the obstruction placed in the path of intended motion far enough away from the ramp so that the walker will be completely off the ramp before impact. The walker is released by burning the string, impacts the obstruction, and either stops, rolls over the obstruction, or tips over. Approximately ten replicate runs were taken for each combination of parameters, and runs in which the walker rotated (changed orientation) before impact were not considered good runs. Tests with some combinations of parameters were not run if the results could be logically anticipated. For example, if a series of forward runs at 6 ft/s (1.8 m/s) into a 1.0-in (2.5-cm) obstruction resulted in the walker stopping, it was judged that runs at slower speeds into lower obstructions would result in the walker stopping or rolling over the obstruction, both "passing" results, so the tests were not run. One result was observed contradictory to this assumption, specimen 7 in the backwards orientation (see table 2). This walker stopped after impacting the 1-in (2.5-cm) barrier but tipped after impacting the 0.5-in (1.3-cm) barrier. The geometry of this particular walker is such that the metal rim impacted the 1-in (2.5-cm) barrier and prevented the walker from tipping, while the rim went over the 0.5-in (1.3-cm) barrier, allowing the wheels to impact it, and it tipped. No other walkers tested had a similar geometry.

The results of dynamic stability tests run on thirteen walkers and walker-jumpers are given in tables 1-3. For all test situations, replicate tests were run until at least 70 percent had the same result. Note that only three of the items tested (specimen Nos. 11B, 12A, and 13) did not tip over with any combination of parameters, while one (specimen No. 7) tipped over with only one combination of parameters, and another (specimen No. 9A) tipped with only two. All others tipped with at least 4 out of the maximum of 18 combinations of parameters.

These tests simulate the walker running into raised barriers, but there are other hazards, such as gravel at the end of driveways or heating vents in a floor, that may cause the walker to stop or tip. For these situations, the results with 1-in (2.5-cm) barrier may be applicable, since no walkers rolled over the obstruction. For this situation, for 6 combinations of parameters (2 speeds and 3 orientions), four had no tips and another had only one.

As a general rule, the walkers that did not tip or tipped the fewest number of times were the ones with wider wheel bases and lower centers of gravity.

2.2 Static Stability

It was felt that one source of possible accidents could involve static stability, i.e., a child tipping the walker over from a standing position and falling over on top of it. To prevent this, the length from the seat crotch to the ground with the walker tipped to the unstable equilibrium position must be greater than the child's leg length (see fig. 4). The dimensions for forward and sideways tip of thirteen walkers are given in table 4. This data can be correlated with leg length data when they become available to determine the safety of each walker.

2.3 Single-Step Roll-Over Tests

While it is probably impractical to expect a walker to go down a flight of stairs without tipping, there is some thought that it might not be unreasonable to expect it to run off a single step without tipping. This might provide some protection for occurrences such as running off a raised patio, into a sunken den or family room, etc.

The ramp for the dynamic stability test was placed on a 7.8-in (20-cm) high platform and tests run at two speeds, 2 and 4 feet per second (0.6 and 1.2 m/s), and the three orientations (see fig. 5). The slower speeds were used because it was felt that the walker would be more likely to tip at slower speeds. The results of these tests are given in table 5. None of the walkers passed the test for all combinations of parameters.

2.4 Location of Scissor Joints

The shortest distances from the armpit of the doll seated in the walkers to any exposed scissor joints were measured and are given in table 6. These data can be correlated with arm length data when they become available to determine the safety of each walker.

2.5 Plastic Bead Strength

Several walkers have plastic beads within reach of the child's mouth that could possibly break if bitten. The compressive breaking strengths of these beads were determined and the lowest value and average value for beads from each walker are given in table 7. All shattered into small jagged pieces. The average breaking force for the different types of beads ranged from 27 to 490 lbf (120 to 2180 N). This lowest value would seem to be within the biting force capability of a child.

2.6 Durability

To determine the ability of the walker-jumpers to withstand repeated impacts, a canvas bag with 25 pounds (13 kg) of lead shot was dropped repeatedly from a height of 2 in (0.5 cm) into the walker seat. Six walker-jumpers were tested in this configuration, specimen numbers 1, 2, 9B, 10B, 11A, and 12B. All withstood 10,000 cycles without any visable damage. It should be noted that the cloth seat of specimen No. 5 ripped during dynamic stability testing (see footnote a, Table 2) before it could be tested for durability. An identical specimen could not be procured to determine if this model would have passed the durability test.

3. DISCUSSION

The tests run in this program were intended to simulate to some extent actual use conditions while keeping the test apparatus as simple as possible. The only test for which any analytical correlation exists, the dynamic stability test, showed good correlation between experimental results and analytical prediction based on energy considerations as described earlier. This would indicate that this is a valid test method for determining dynamic stability characteristics.

4. CONCLUSION

An analysis of hospital accident reports and inspection of available walker-jumpers indicated probable and possible causes of injuries to infants. The test methods were developed to determine the performance characteristics of walkers, and to determine if the characteristics leading to accidents are inherent to a given item. These test methods and performance criteria can be used to aid in writing federal safety standards.

Table 1 - Results of Dynamic Stability Tests, Forward Orientation

Specimen number	Speed: 4 ft/s (1.2 m/s) Obstruction Height 0.25 in (0.6 cm)	0.5 in (1.3 cm)	1.0 in (2.5 cm)	Speed: 6 ft/s (1.8 m/s) Obstruction Height 0.25 in (0.6 cm)	0.5 in (1.3 cm)	1.0 in (2.5 cm)
1	R	R	S	R	R	S
2	R	S	S	R	S	S
3	R	T	T	T	T	T
4	R	S	S	R	S	S
5	T	T	T	T	T	T
6	R	S	S	R	S	S
7	R	S	S	R	S	S
8	R	T	T	R	T	T
9A	-	-	-	-	-	S
10A	-	S	S	R	T	T
11B	-	-	-	-	-	S
12A	-	-	-	-	S	S
13	-	-	-	-	S	S

R - walker rolled over obstruction

S - walker impacted obstruction and stopped without tipping over

T - walker impacted obstruction and tipped over

Table 2 - Results of Dynamic Stability Tests, Backward Orientation

Specimen number	Speed					
	4 ft/s (1.2 m/s) Obstruction Height			6 ft/s (1.8 m/s) Obstruction Height		
	0.25 in (0.6 cm)	0.5 in (1.3 cm)	1.0 in (2.5 cm)	0.25 in (0.6 cm)	0.5 in (1.3 cm)	1.0 in (2.5 cm)
1	R	R	S	R	T	T
2	R	T	T	R	T	T
3	R	S	S	R	T	T
4	R	S	S	R	S	S
5	(a)	(a)	(a)	R	T	(a)
6	R	S	S	R	S	S
7	R	S	S	R	T	S
8	R	T	T	R	T	T
9A	-	-	-	-	-	S
10A	-	S	S	R	T	T
11B	-	-	-	-	-	S
12A	-	-	-	-	-	S
13	-	-	-	-	S	S

R - walker rolled over obstruction

S - walker impacted obstruction and stopped without tipping over

T - walker impacted obstruction and tipped over

(a) - During testing, a seam in the cloth seat of specimen number 5 completely separated so that it would no longer support the doll so testing was discontinued.

Table 3 - Results of Dynamic Stability Tests, Sideways Orientation

Specimen number	Speed: 4 ft/s (1.2 m/s) Obstruction Height 0.25 in (0.6 cm)	0.5 in (1.3 cm)	1.0 in (2.5 cm)	Speed: 6 ft/s (1.8 m/s) Obstruction Height 0.25 in (0.6 cm)	0.5 in (1.3 cm)	1.0 in (2.5 cm)
1	R	R	S	R	T	T
2	R	S	T	R	T	T
3	R	T	T	R	T	T
4	R	T	T	R	T	T
5	(a)	(a)	(a)	(a)	(a)	(a)
6	R	T	T	R	T	T
7	R	S	S	R	S	S
8	R	S	S	R	T	T
9A	-	R	S	R	T	T
10A	-	T	S	R	T	T
11B	-	-	-	-	S	S
12A	(b)	(b)	(b)	(b)	(b)	(b)
13	-	-	-	R	S	S

R - walker rolled over obstruction

S - walker impacted obstruction and stopped without tipping over

T - walker impacted obstruction and tipped over

(a) - During testing, a seam in the cloth seat of specimen number 5 completely separated so that it would no longer support the doll, so testing was discontinued.

(b) - The rear wheels of specimen number 12A were fixed so direct sideways motion was impossible.

Table 4 - Seat Crotch to Floor Distance for Loaded Walkers in the Unstable Equilibrium Position.

Specimen number	Forward Tip		Sideways Tip	
	in	cm	in	cm
1	10.5	26.7	7.8	19.8
2	12.2	31.0	7.8	19.8
3	9.8	24.9	9.8	24.9
4	11.6	29.5	9.0	22.9
5	(a)	(a)	(a)	(a)
6	9.8	24.9	8.2	20.8
7	9.2	23.4	9.0	22.9
8	9.0	22.9	10.5	26.7
9A	10.0	25.4	6.8	17.3
10A	10.6	26.9	8.2	20.8
11B	10.6	26.9	9.0	22.9
12A	9.4	23.9	7.6	19.3
13	8.0	20.3	8.8	22.4

(a) Specimen damaged during previous testing.

Table 5 - Results of One-Step Roll-over Tests, Step Height 7.8 in (20 cm).

Specimen number	Forward Orientation		Backward Orientation		Sideways Orientation	
	2 ft/s (0.6 m/s)	4 ft/s (1.2 m/s)	2 ft/s (0.6 m/s)	4 ft/s (1.2 m/s)	2 ft/s (0.6 m/s)	4 ft/s (1.2 m/s)
1	R	R	T	T	T	T
2	R	R	T	T	T	T
3	T	T	T	T	T	T
4	R	R	R	R	T	T
5	(a)	(a)	(a)	(a)	(a)	(a)
6	(a)	(a)	(a)	(a)	(a)	(a)
7	T	T	T	T	T	T
8	T	T	T	T	T	T
9A	R	R	T	T	T	T
10A	T	T	T	T	T	T
11B	R	R	T	R	T	R
12A	R	R	T	R	(b)	(b)
13	T	T	T	T	T	T

T - walker tipped over

R - walker rolled over step without tipping

(a) - walker damaged in previous tests

(b) - fixed wheels prevented sideways motion

Table 6 - Distances from Armpit to Exposed Scissor Joints in Walker Jumpers

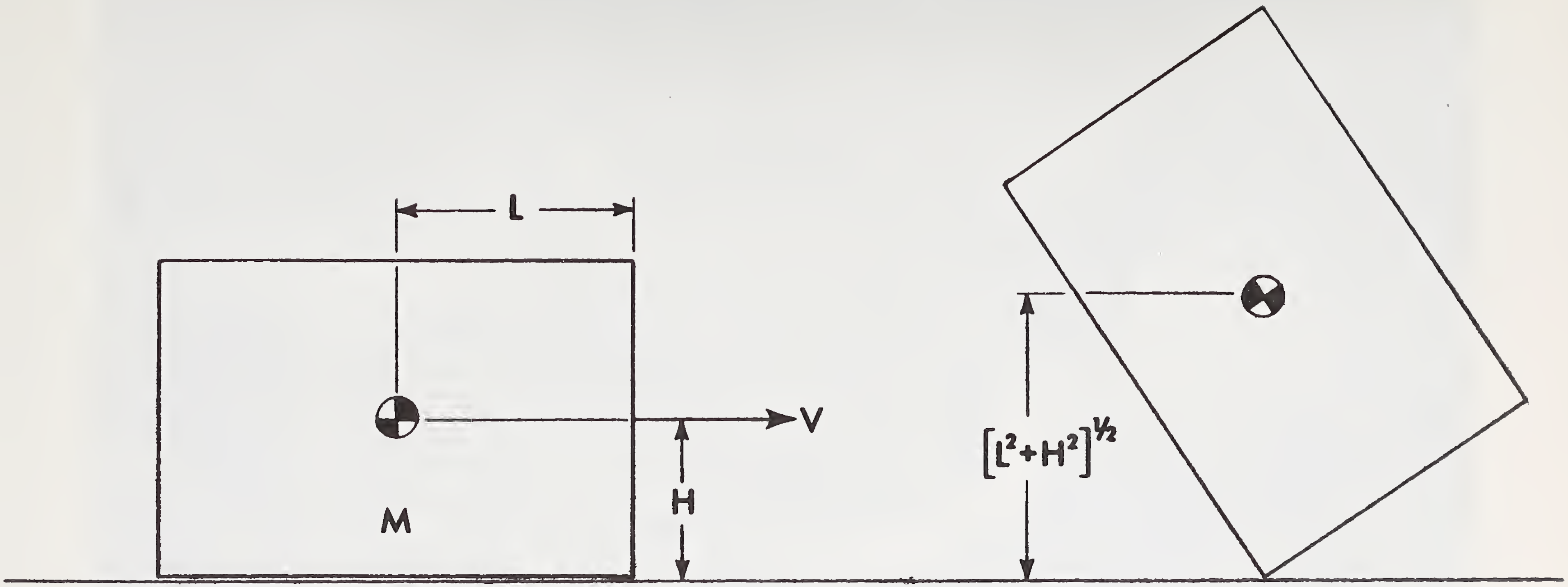
Specimen number	Distance to Scissor Joint in	Distance to Scissor Joint cm
1	4.2	10.7
2	5.0	12.7
3	6.5	16.5
4	4.5	11.4
5	(a)	(a)
6	(b)	(b)
7	(b)	(b)
8	(b)	(b)
9A	4.0	10.2
10A	(b)	(b)
11B	9.0	22.9
12A	4.0	10.2
13	(b)	(b)

(a) - specimen broken during previous tests

(b) - no exposed scissor joints

Table 7 - Compressive Breaking Strengths of Plastics Beads from Walkers

Specimen Number	Minimum Breaking Strength		Average Breaking Strength	
	lbf	N	lbf	N
1	323	1440	344	1530
2	296	1320	311	1380
3	190	845	190	845
4	97	431	100	445
6	27	120	27	120
7	331	1470	344	1530
8	479	2130	490	2180



$$\tfrac{1}{2}MV^2 \geq Mg\left[(L^2+H^2)^{1/2} - H\right]$$

or

$$\frac{V^2}{2g} \geq (L^2+H^2)^{1/2} - H$$

Figure 1 - Required conditions for tip-over due to dynamic instability

Figure 2 - Walker Jumper in use during determination of speeds

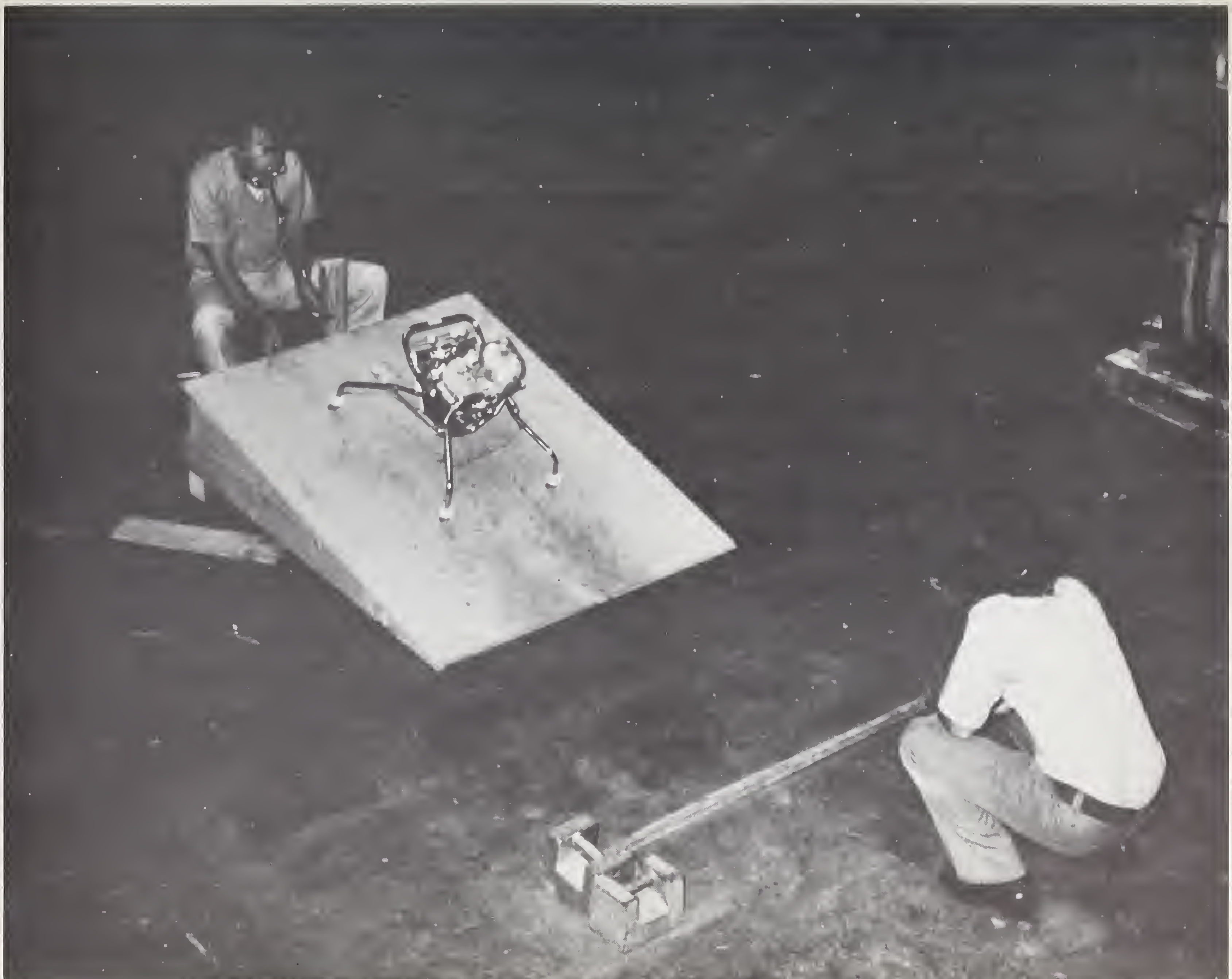


Figure 3 - Dynamic stability test setup.

Figure 4 - Static stability measurement

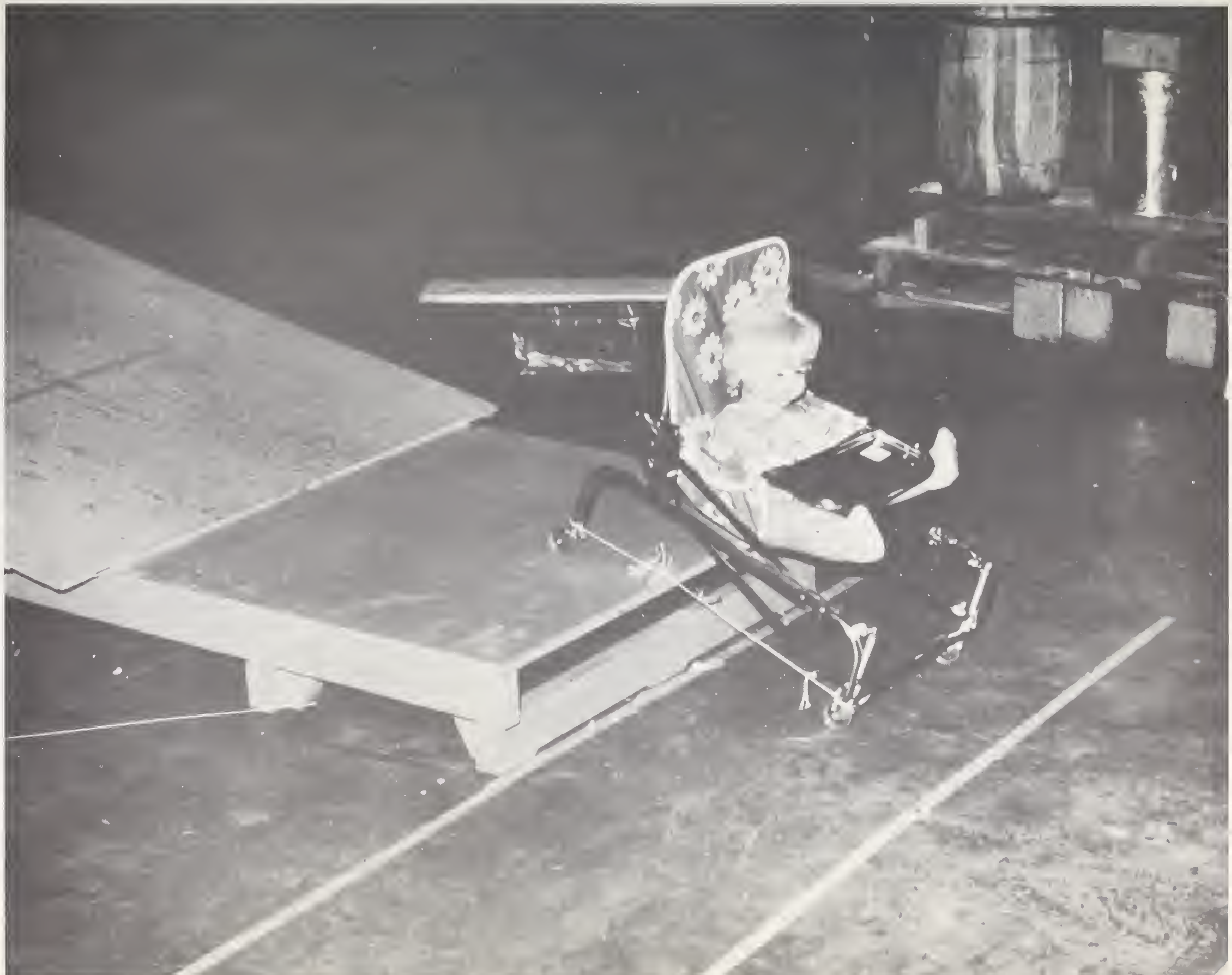


Figure 5 - Single-step rollover stability test.

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15. SUPPLEMENTARY NOTES

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

Accident reports from hospital emergency rooms were surveyed to determine the probable causes of accidents involving baby walkers and walker-jumpers. Test methods were developed to simulate service conditions to determine if the characteristics leading to accidents are present in all or only a few of the items on the market. These test methods include tests for dynamic and static stability, step roll-over stability, plastic bead strength, durability, and location of scissor joints. The test methods and performance criteria are intended to supply information leading to federal safety standards.

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

Accident reports; baby walkers; infants; safety standards; test methods; walker-jumpers.

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