



U.S. CONSUMER PRODUCT SAFETY COMMISSION
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May 2, 2005

Ms. Barbara Davis
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1655 Scott Boulevard
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Reference – *Accessibility of Hazardous Moving Parts in the Throat of a Document (Paper) Shredder – New Probe Concept*

Dear Ms. Davis:

The staff of the U.S. Consumer Product Safety Commission (CPSC) appreciates this opportunity to comment* on the Underwriters Laboratories Inc. (UL) draft document, *Accessibility of Hazardous Moving Parts in the Throat of a Document (Paper) Shredder – New Probe Concept*, which was sent in a March 3, 2005 email. We would also like to extend our appreciation to the UL task group members who participated in the review and development of proposals for new performance requirements for paper shredders.

The CPSC staff believes that a new probe is needed to address finger injuries associated with paper shredders available to consumers, especially for young children. The CPSC staff has reviewed the specifications for the proposed probe and has the following comment:

- The UL proposed probe does not address the compressibility of children's fingers. The data used to develop the proposed probe was obtained from a study of 300 participants; however, the data do not include finger reach when an external force pulls on the finger. "Figure 5" of the *New Probe Concept* uses maximum reach (length) for various widths (thicknesses) of openings in a test fixture. The finger reach-to-width ratio does not take into account finger compression, which would change the finger length-to-thickness ratio. For example, if a finger was inserted as far as possible into the slotted test fixture and then force was used to pull the finger further into the test fixture, the length-to-thickness ratio would increase (i.e., for the same slot thickness, the reach length would increase).

* The comments in this letter are those of the CPSC staff and have not been reviewed or approved by, and may not necessarily represent the views of, the Commission.

The CPSC staff believes that injuries occur when the shredder mechanism pulls the children's fingers into the shredder opening after the finger and paper become wedged in the shredder opening. CPSC staff believes that the probe thickness should be reduced slightly to account for the compressibility of children's fingers.

The CPSC staff is not aware of information on compressibility of human fingers. In the attached analysis, we provide one approach to developing probe dimensions with a compressibility correction. The CPSC staff adjusted the anthropometric data obtained from a study of over 8,100 children using varying compression values to account for compressibility of children's fingers. The CPSC staff suggested probe dimensions are based on the anthropometric data and assumptions regarding the compressibility of a child's finger. The following assumptions and techniques were used to determine the CPSC staff suggested probe dimensions:

- 65 durometer rubber rods of different diameters were used to correlate to the compressibility of children's fingers.
- 20 lbs. of force was used to determine percent compressibility of the rubber rods.
- For children of the same age group, thicker fingers were assumed to be more compressible (more soft tissue) than thinner fingers.

While different combinations of these variables can be explored and plotted to consider alternative probe dimensions, the staff believes that the assumptions above are a reasonable approach that results in minor adjustments in the UL proposed probe, which could result in improved performance in reducing the risk of serious finger injuries to children. The appendix to this letter contains calculations and illustrations of the CPSC staff suggested probe design. When compared with the UL proposed probe, the maximum thickness of the CPSC staff suggested probe is reduced by 1.64 mm.

A description of the probe that the CPSC staff believes would better capture hazards for children follows:

- Rounded tip with a 2.25 mm radius,
- Constant thickness of 4.5 mm for the length between 2.25 mm to 30 mm,
- Constant slope from 30 mm to 60 mm and from 60 mm to 100 mm,
- The probe thickness for lengths greater than 100 mm would be the same as in the UL proposed probe.

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Thank you again for the opportunity to comment on the UL proposed probe design. We look forward to participating in further standards development for paper shredders to reduce the number and severity of injuries to consumers associated with these products.

Sincerely,

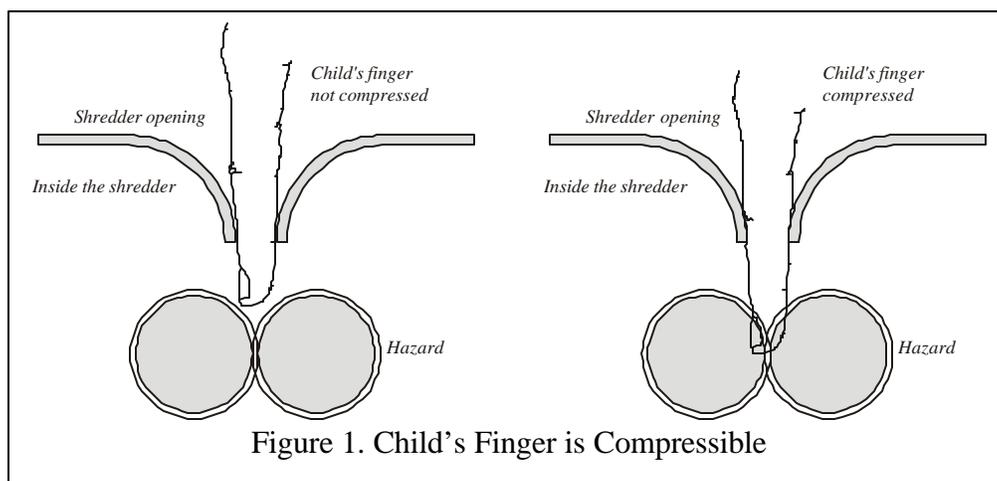
A handwritten signature in black ink, appearing to read 'Arthur Lee', with a large, sweeping initial 'A'.

Arthur Lee

APPENDIX

Addressing Compressibility of Fingers

The thickness of the proposed UL probe does not account for the compressibility of children's fingers. "In young children and especially infants, the body may be characterized by more extensive soft tissue" (Synder, 1975). The CPSC staff believes that paper shredder incidents occur when the shredder mechanism pulls the finger into the shredder opening after the finger and paper become wedged in the shredder opening, as shown in Figure 1.



"Figure 5" of the *New Probe Concept* uses maximum reach (length) for various widths (thicknesses) of openings in a test fixture. The finger reach-to-width ratio does not take into account finger compression, which would change the finger length-to-thickness ratio. For example, if a finger was inserted as far as possible into the slotted test fixture and then force was used to pull the finger further into the test fixture, the length-to-thickness ratio would increase (i.e., for the same slot thickness, the reach length would increase).

To determine how the finger length-to-thickness ratio may change from finger compression, the following anthropometric data were used to calculate the graphs that follow:

- *Physical Characteristics of Children as Related to Death & Injury for Consumer Product Safety Design*. (1975). Snyder, R; Spencer, M.; Owings, C.; and Schneider, L.

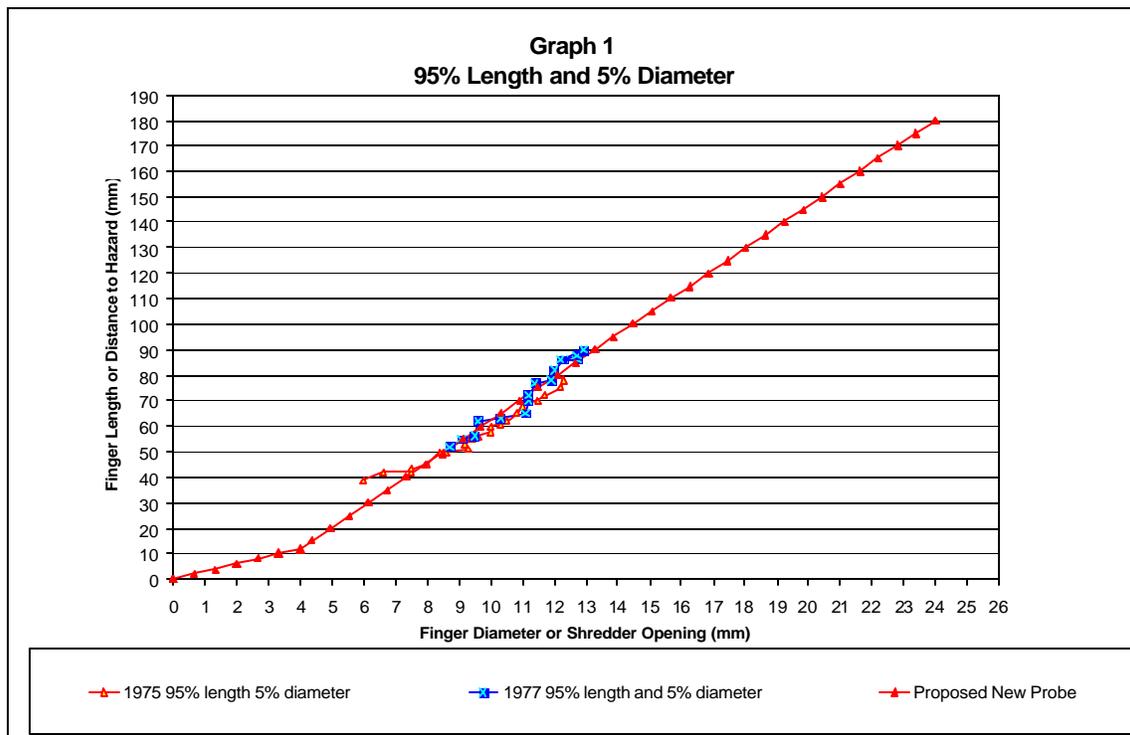
Forty-one body measurements were obtained on over 4,000 infants and children from birth to age 13. Measurements were taken with electronic calipers that displayed caliper opening and pressure applied on the caliper face. In all, children were measured at 76 different geographical locations.

- *Anthropometry of Infants, Children, and Youths to Age 18 for Product Safety Design.* (1977). Snyder, R.; Schneider, L.; Owings, C.; Reynolds, H.; Golomb, D.; and Schork, M.

This 1977 study is a continuation and extension of the 1975 survey and was an attempt to provide a more complete source of useful anthropometric data on children and youths through age 18. A total of 87 functional body measurements were taken on a sample of over 4,100 infants, children and youths representing the U.S. population aged 2 weeks through 18 years.

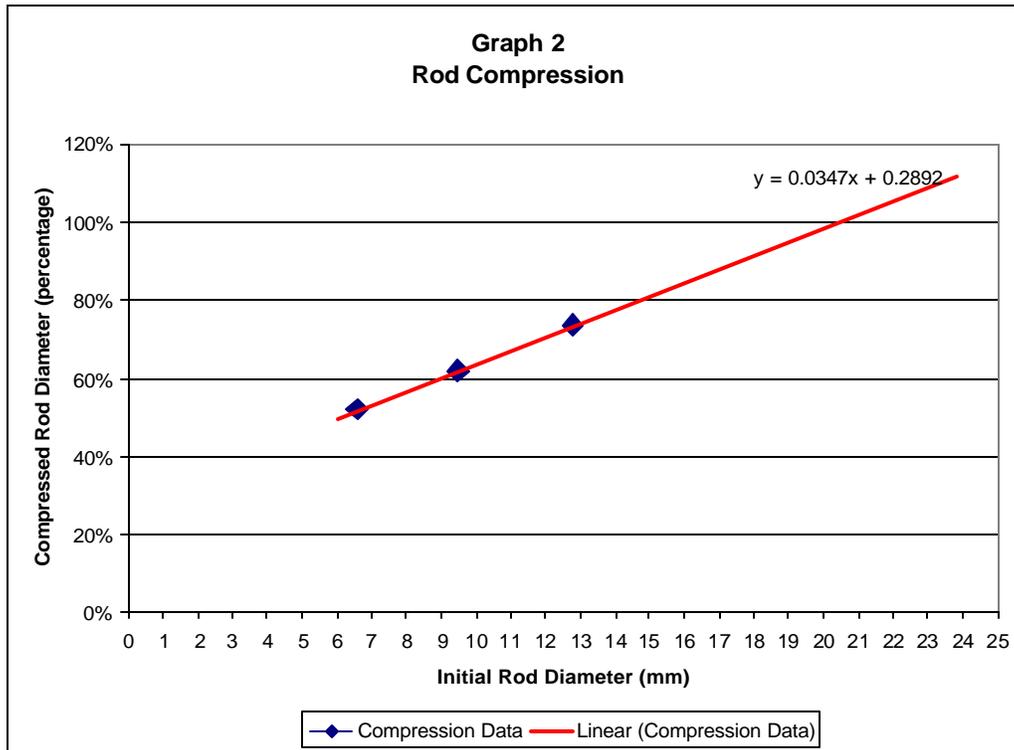
Since children have more soft tissue than adults and the measuring results could vary with the operator using the calipers, the 1975 and 1977 data were obtained using electronic calipers with pressure gauges on the measuring face. The values reported in the 1975 and 1977 data represent a pressure of 0.5 psi on the test subjects.

In Graph 1, the proposed UL probe is plotted against the 1975 and 1977 anthropometric data. The 95th percentile in length and 5th percentile in diameter were used for the children's data. In general, the proposed probe captures hazards for children's fingers using the 1975 and 1977 data.

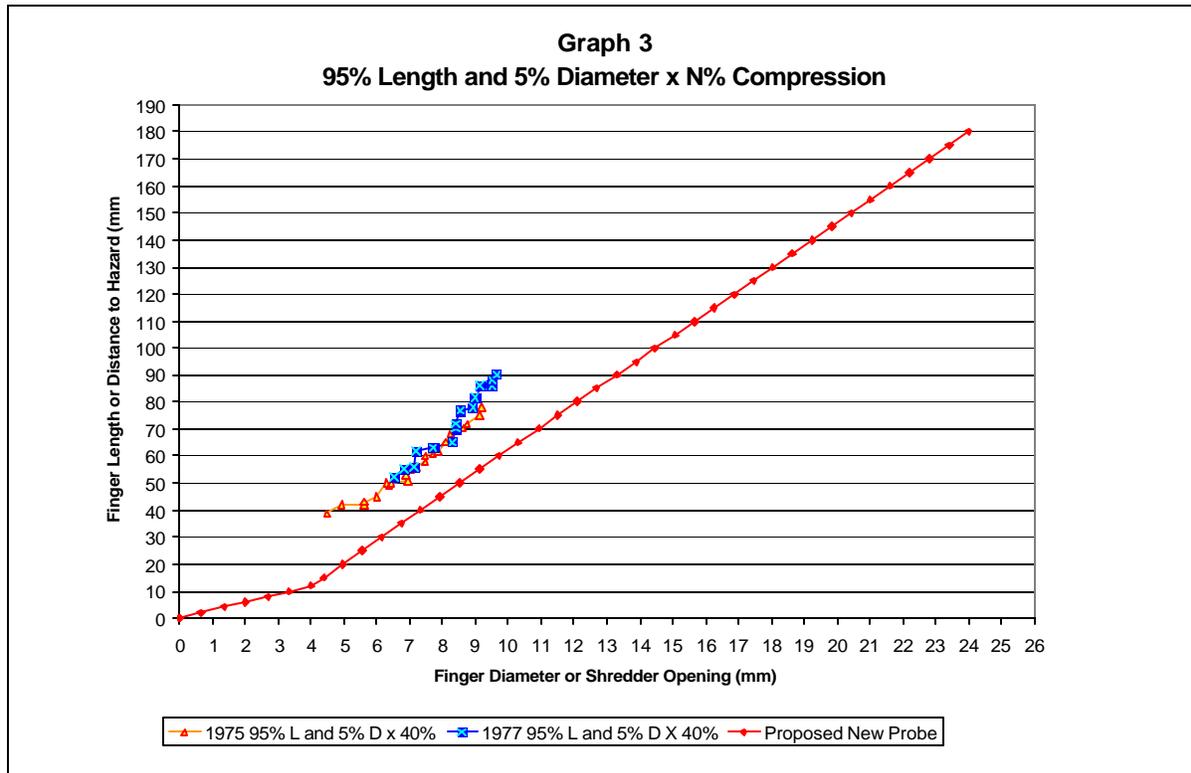


The CPSC staff report, *An Evaluation of Finger Injuries to Home Document (Paper) Shredder Machines* (December 2004), describes the method staff used to calculate the amount of compression for various diameter rods, as shown in Graph 2. The rods were compressed under

20 lbs. of force. For rod diameters greater than 13mm, the compression was estimated using simple linear interpolation. For rods greater than approximately 20mm, the compression would be 0%. It can be seen in Graph 2 that the smaller the initial rod diameter, the higher the compressed percentage.



Using the CPSC staff methodology, the resulting finger size after it has been compressed can be determined. Graph 3 shows the 5th percentile finger diameter being compressed using the data from Graph 2. In this case, the proposed probe would not capture hazards for children's fingers. Since it may be impractical to address the smallest finger sizes attained through this method, in the following graphs, the amount of compressibility was adjusted based on finger size (a 5th percentile finger diameter would be on the small side and would most likely contain less soft tissue, and a 95th percentile finger diameter would be on the larger side and would likely contain more soft tissue).



The tables below list the initial rod diameters and final rod diameters under 20 lbs of compression. The percent compressed is the compression value for each initial rod diameter. For finger diameters greater than 17 mm, the compression value is 0.

Initial Rod Diameter (mm)	Final Rod Diameter (mm)	Compression Value
6	2.98	50.26%
6.1	3.06	49.91%
6.2	3.13	49.57%
6.3	3.20	49.22%
6.4	3.27	48.87%
6.5	3.35	48.53%
6.6	3.42	48.18%
6.7	3.50	47.83%
6.8	3.57	47.48%
6.9	3.65	47.14%
7	3.72	46.79%
7.1	3.80	46.44%
7.2	3.88	46.10%
7.3	3.96	45.75%
7.4	4.04	45.40%

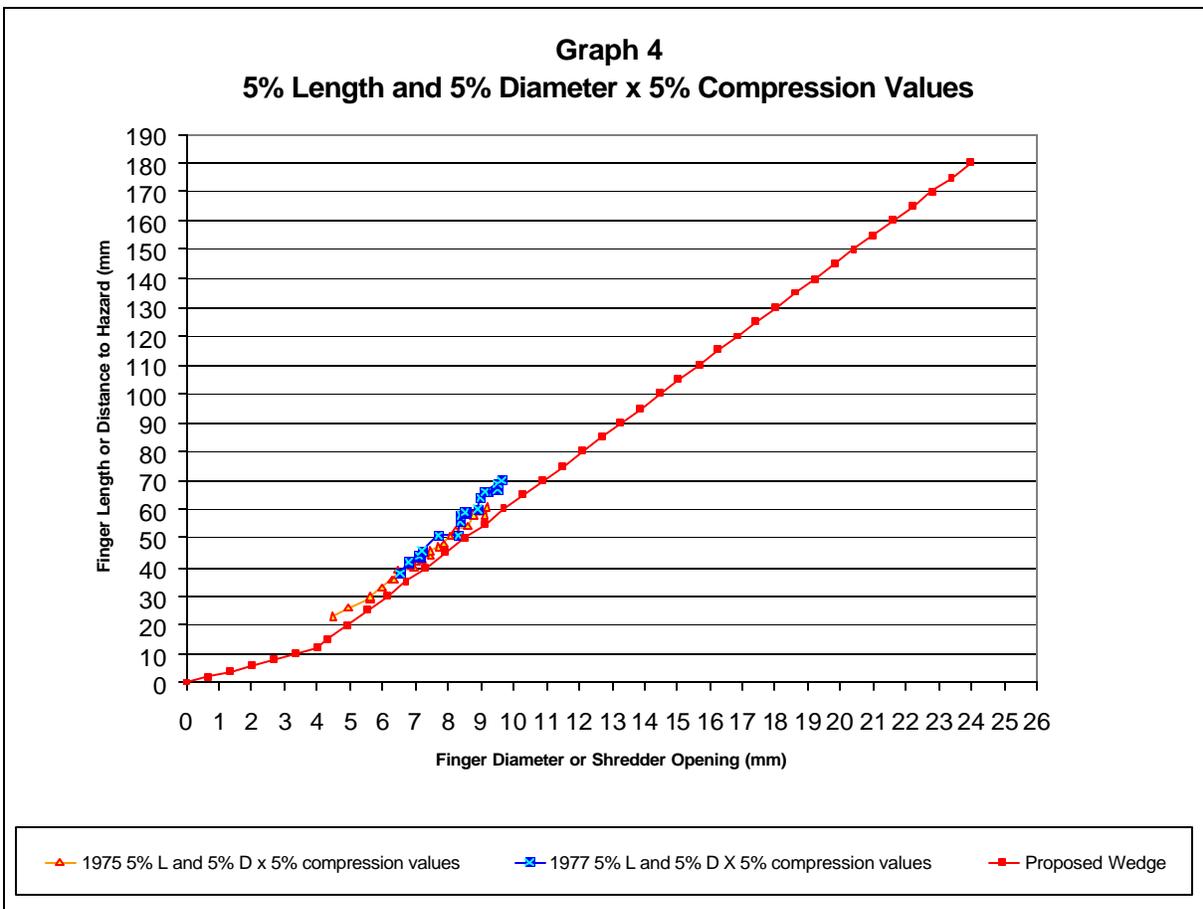
Initial Rod Diameter (mm)	Final Rod Diameter (mm)	Compression Value
7.5	4.12	45.06%
7.6	4.20	44.71%
7.7	4.28	44.36%
7.8	4.37	44.01%
7.9	4.45	43.67%
8	4.53	43.32%
8.1	4.62	42.97%
8.2	4.70	42.63%
8.3	4.79	42.28%
8.4	4.88	41.93%
8.5	4.97	41.59%
8.6	5.05	41.24%
8.7	5.14	40.89%
8.8	5.23	40.54%
8.9	5.32	40.20%

Initial Rod Diameter (mm)	Final Rod Diameter (mm)	Compression Value
9	5.41	39.85%
9.1	5.51	39.50%
9.2	5.60	39.16%
9.3	5.69	38.81%
9.4	5.78	38.46%
9.5	5.88	38.12%
9.6	5.97	37.77%
9.7	6.07	37.42%
9.8	6.17	37.07%
9.9	6.26	36.73%
10	6.36	36.38%
10.1	6.46	36.03%
10.2	6.56	35.69%
10.3	6.66	35.34%
10.4	6.76	34.99%
10.5	6.86	34.65%
10.6	6.96	34.30%
10.7	7.07	33.95%
10.8	7.17	33.60%
10.9	7.27	33.26%
11	7.38	32.91%
11.1	7.49	32.56%
11.2	7.59	32.22%
11.3	7.70	31.87%
11.4	7.81	31.52%
11.5	7.91	31.18%
11.6	8.02	30.83%
11.7	8.13	30.48%
11.8	8.24	30.13%
11.9	8.36	29.79%
12	8.47	29.44%
12.1	8.58	29.09%
12.2	8.69	28.75%
12.3	8.81	28.40%
12.4	8.92	28.05%
12.5	9.04	27.71%
12.6	9.15	27.36%
12.7	9.27	27.01%
12.8	9.39	26.66%
12.9	9.51	26.32%
13	9.62	25.97%
13.1	9.74	25.62%
13.2	9.86	25.28%
13.3	9.98	24.93%

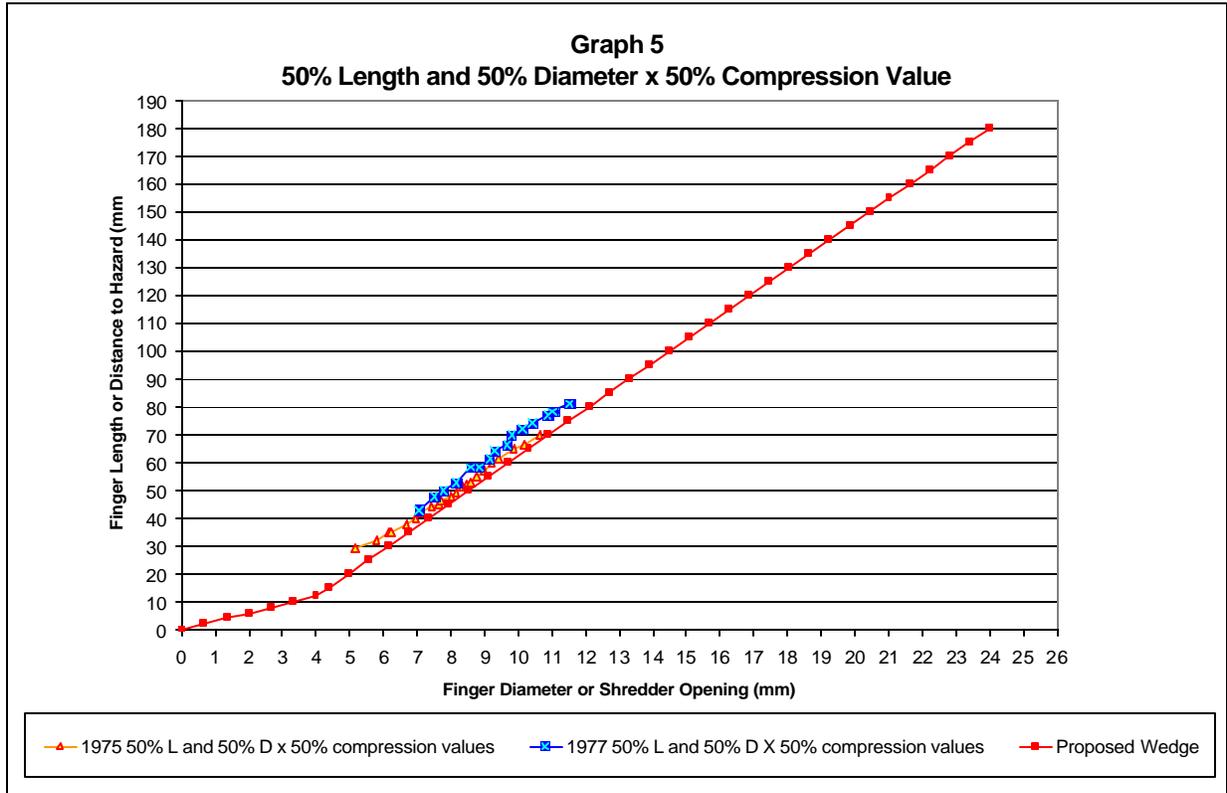
Initial Rod Diameter (mm)	Final Rod Diameter (mm)	Compression Value
13.4	10.11	24.58%
13.5	10.23	24.24%
13.6	10.35	23.89%
13.7	10.47	23.54%
13.8	10.60	23.19%
13.9	10.72	22.85%
14	10.85	22.50%
14.1	10.98	22.15%
14.2	11.10	21.81%
14.3	11.23	21.46%
14.4	11.36	21.11%
14.5	11.49	20.77%
14.6	11.62	20.42%
14.7	11.75	20.07%
14.8	11.88	19.72%
14.9	12.01	19.38%
15	12.15	19.03%
15.1	12.28	18.68%
15.2	12.41	18.34%
15.3	12.55	17.99%
15.4	12.68	17.64%
15.5	12.82	17.30%
15.6	12.96	16.95%
15.7	13.09	16.60%
15.8	13.23	16.25%
15.9	13.37	15.91%
16	13.51	15.56%
16.1	13.65	15.21%
16.2	13.79	14.87%
16.3	13.93	14.52%
16.4	14.08	14.17%
16.5	14.22	13.83%
16.6	14.36	13.48%
16.7	14.51	13.13%
16.8	14.65	12.78%
16.9	14.80	12.44%
17	14.94	12.09%

Graphs 4, 5, and 6 show the resultant finger length vs. diameter after the finger has been compressed under a specific compression value. The compression values were adjusted based on finger size (a 5th percentile finger diameter would be on the small side and would most likely contain less soft tissue, and a 95th percentile finger diameter would be on the larger side and would likely contain more soft tissue).

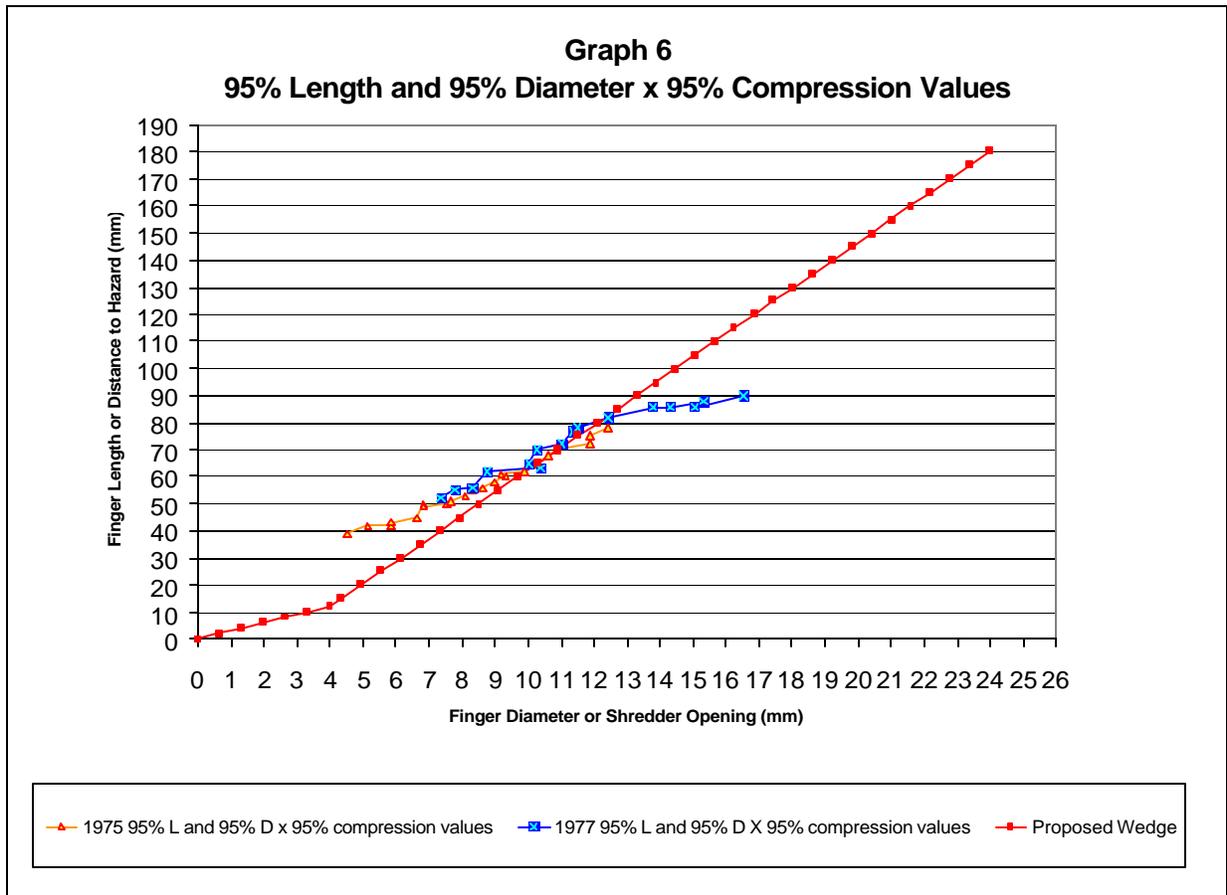
Graph 4 shows the 1975 and 1977 children's anthropometric data for 5th percentile children's fingers (length and diameter) under 20 lbs. of compression. The compression values were reduced by 95% or 5% of the compression values to accommodate the likelihood of less soft tissue for smaller fingers.



Graph 5 shows the 1975 and 1977 children's anthropometric data for 50th percentile children's fingers (length and diameter) under 20 lbs. compression. The compression values were reduced by 50% to accommodate the likelihood of some soft tissue for smaller fingers.



Graph 6 shows the 1975 and 1977 children's anthropometric data for 95th percentile children's fingers (length and diameter) under 20 lbs. compression. The compression values were reduced by 5% or 95% of the compression values to accommodate the likelihood of more soft tissue for smaller fingers.



For Graphs 4 and 5, the UL proposed probe is very close to the 5th and 95th percentile children's fingers under compression (with the appropriate compression values). For both graphs, the data falls just inside the proposed probe line.

For Graph 6, the proposed probe captures compressed finger diameters greater than 11 mm, but not for smaller finger diameters. This corresponds to children around the age of 9 years old. The proposed probe would not capture hazards for children under 9 years old with 95th percentile finger diameters that become compressed.

Graph 7 shows the data plotted from Graphs 4, 5, and 6. The graph also shows a suggested probe edge line to capture the compressibility of children’s fingers. For thicknesses of 4.5 mm or less, the probe would be a constant thickness of 4.5 mm. The tip of the probe would have a tip radius of 2.25 mm.

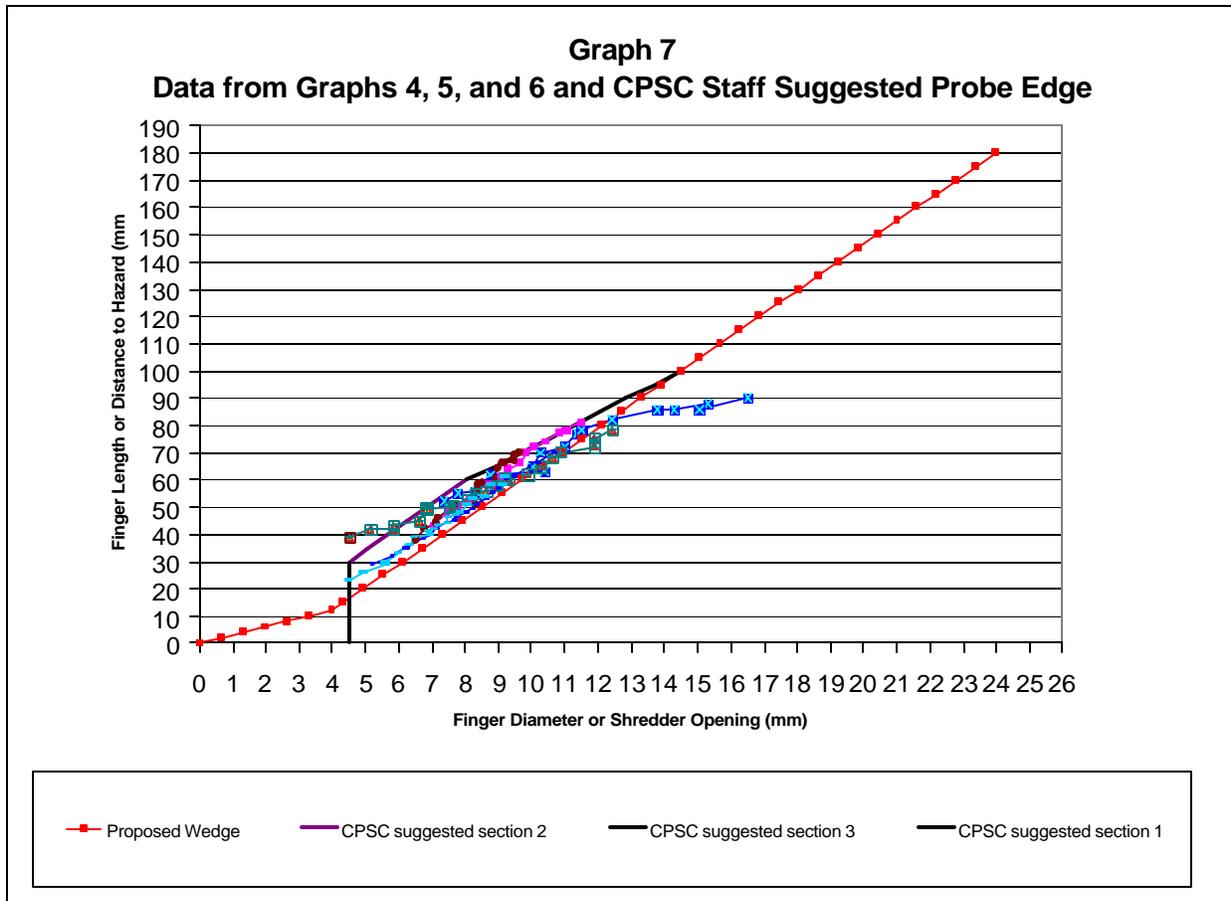


Figure 2 shows a diagram of the probe that the CPSC staff believes would capture the compressibility of children’s fingers. The joint locations (30mm, 60mm, and 100mm) would remain the same as those shown in the UL proposed probe. Section 1 (0 mm to 30 mm) would be a constant thickness of 4.5 mm and have a 2.25 mm radius tip. Section 2 (30 mm to 60 mm) would have the same slope (3.4 degrees) as the UL proposed probe for the same section, but have a different *y intercept (b)*.

$$y = 0.11905x + b$$

$$4.50 = 0.11905 * 30 + b$$

$$b = 0.9285$$

The equation for Section 2 is $y = 0.11905x + 0.9285$. The angle between the tapered edges would be 6.8° .

Section 3 (between 60 mm and 100 mm) would differ slightly from the UL proposed probe. The slope for section 3 would be:

$$\text{slope} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{14.48 - 8.07}{100 - 60} = 0.1603$$

$$y = 0.1603x + b \quad , y \text{ is a function of penetration } x$$

$$8.07 = 0.1603 * 60 + b$$

$$b = -1.5480$$

The equation for Section 3 is $y = 0.1603x - 1.548$.

The angle relative to the center axis of the probe can be calculated by the following equation:

$$\arctan \frac{\left(\frac{y_2}{2} - \frac{y_1}{2}\right)}{(x_2 - x_1)} = \text{angle} \quad , \text{ where } x \text{ is the penetration and } y \text{ is the thickness}$$

$$\text{angle} = \arctan \frac{\left(\frac{14.8}{2} - \frac{8.07}{2}\right)}{(100 - 60)} = \arctan(0.0736) = 4.8^\circ$$

The angle of the slope between the joints at 60 mm and 100 mm is increased slightly to 4.8° , as shown below. (The total angle between tapered edges increased to 9.6°). The actual thickness at the same penetration depth is smaller for the CPSC staff suggested probe than for the UL proposed probe.

Figure 3 shows an overlay of the CPSC staff suggested probe and the UL proposed probe. The taper of Section 2 (from 30 mm to 60 mm) is the same for the CPSC staff suggested probe and the UL proposed probe.

The force perpendicular to the edges of Section 3 (from 60 mm to 100 mm) of the CPSC staff proposed probe would be slightly greater than the UL proposed probe because of the increased angle. The perpendicular force would decrease to 59.7 lbs. The force perpendicular to the edge of the probe can be calculated by the equation:

$$\sin(\text{angle}) = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{\text{Force}}{\text{ForceNormal}}$$

$$\text{Force perpendicular to one tapered edge} = \frac{10}{2 \sin(9.6^\circ / 2)} = 59.7 \text{ lbs.}$$

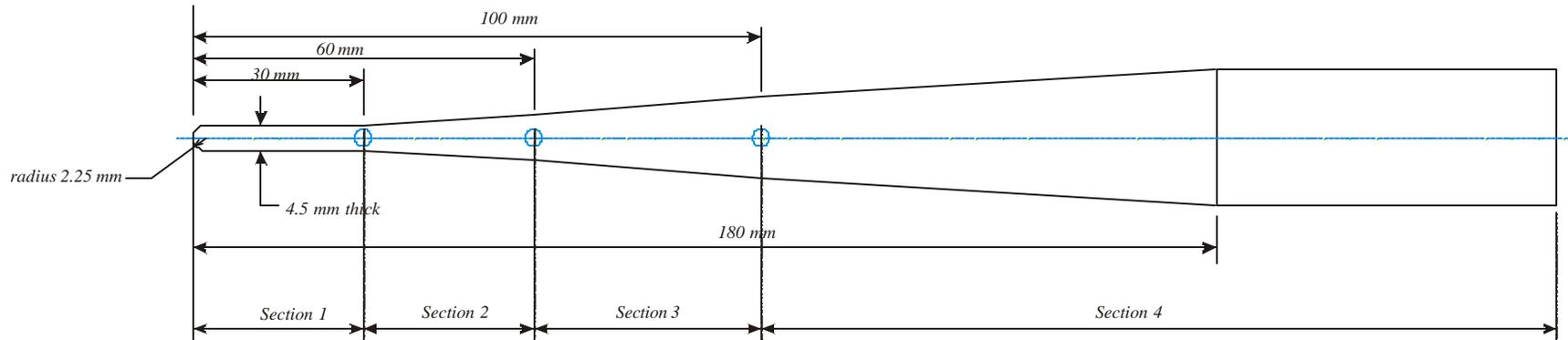


Figure 2. CPSC Staff Suggested Probe (see Table 1)

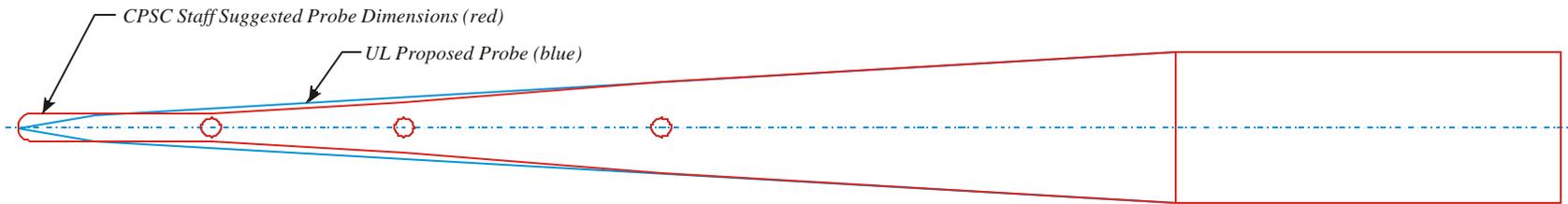


Figure 3. CPSC Staff Suggested Probe and UL Proposed Probe

Table 1 lists the CPSC staff suggested probe dimensions and Figure 4 shows an isometric drawing of the CPSC staff proposed probe.

Table 1. CPSC Staff Suggested Probe Dimensions

Tip	Penetration Distance - mm	Probe Thickness – mm	Comments
Tip	0	0	The tip is rounded with a 2.25 mm radius.
Section 1	2.25	4.50	Continuous thickness
	4	4.50	
	6	4.50	
	8	4.50	
	10	4.50	
	12	4.50	
	15	4.50	
	20	4.50	
25	4.50		
Joint	30	4.50	Joint
Section 2	35	5.10	Angle between taper edges 6.8 degrees
	40	5.69	
	45	6.29	
	50	6.88	
	55	7.48	
Joint	60	8.07	Joint
Section 3	65	8.87	Angle between taper edges 9.6 degrees
	70	9.67	
	75	10.47	
	80	11.28	
	85	12.08	
	90	12.88	
	95	13.68	
Joint	100	14.48	Joint
Section 4	105	15.07	Angle between taper edges 6.8 degrees
	110	15.67	
	115	16.26	
	120	16.86	
	125	17.45	
	130	18.05	
	135	18.64	
	140	19.24	
	145	19.83	
	150	20.43	
	155	21.02	
	160	21.62	
	165	22.21	
	170	22.81	
	175	23.40	
180	24.00		
	> 180	24.00	Continuous thickness

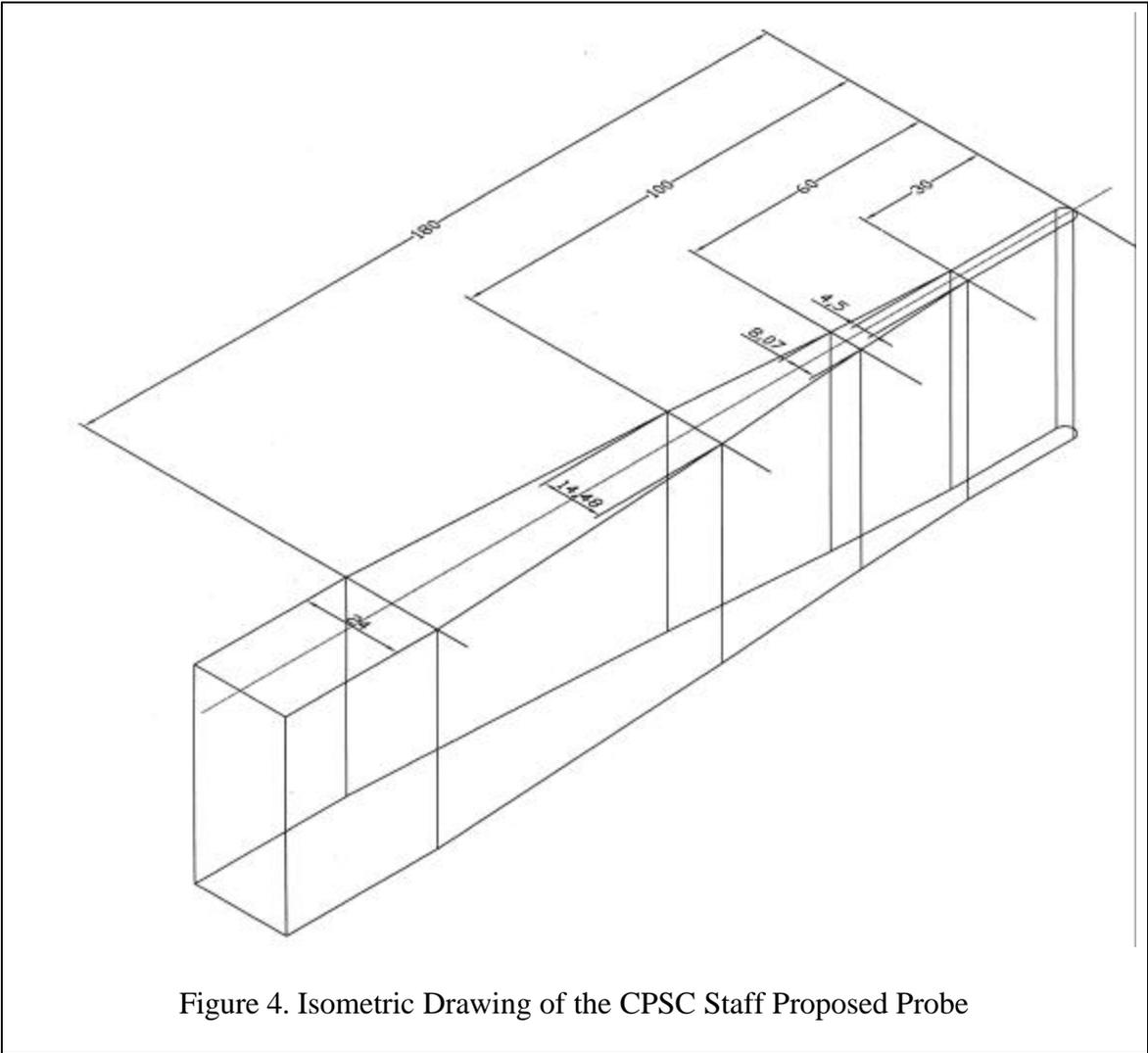


Figure 4. Isometric Drawing of the CPSC Staff Proposed Probe