TABLE 2.—PHASE II—INCIDENCE AND PERCENTAGE OF TIPOVER WITH LARGE MULTIPLE TUBE DEVICES ON GRASS OR 1.0-INCH HIGH DENSITY POLYURETHANE UPHOLSTERY FOAM—Continued

Device	Grass	Foam
	64%	50%
3[b]	27/50	3/50*
	54%	6%
4[b]	30/50	36/50
	60%	72%
5	0/90	0/50
	0%	0%
6[a]	10/50	25/50*
	20%	50%
7	0/50	0/50
	0%	0%
8	0/90	0/50
	0%	0%
9	0/50	0/50
	0%	0%

*Significantly different from grass, $P<0.05$.
[a] Device has no base.
[b] Device modified to increase tipover rate.

The three modified devices (numbers 2, 3, and 4) were also tested on grass in unmodified form, and they rarely tipped over. Seven of the nine large devices that were tested have particleboard bases (all except 1 and 6). Unless they were modified, devices with bases tipped over only rarely (see table 2), once in 400 tests on grass. On the other hand, the two devices without bases (1 and 6) tipped over more frequently on grass, 14 times in 100 tests (see table 2).(6 and 8)

In addition to testing large devices, the staff tested two devices with tube diameters less than or equal to 1.0 inch on grass and on 1.0-inch high density foam. With one of these devices, the tipover rate was significantly greater with foam than with grass (99 tipovers out of 100 on foam compared with 62 out of 100 on grass). This limited testing of small devices did not support such a dynamic test for small multiple tube devices.(6 and 8)

The staff concluded that the dynamic stability test it studied could not reasonably form the basis for a standard addressing the tipover hazard with large multiple tube devices. Particularly problematic was the dynamic test's inconsistency. Among the large devices, there were two cases (devices 1 and 6) in which foam significantly *over-predicted* the tipover rate with grass. This means that a device could fail to comply with such a dynamic standard even though it is stable when tested on grass. In other words, such a standard would be excessively stringent.(6 and 8)

In another case (device 3) foam significantly *under-predicted* the tipover rate with grass. This means that a device could be very unstable when operated on grass but could actually comply with such a dynamic standard based on the foam test.(6 and 8) Such a standard would not reliably protect consumers.

In statistical terminology, the lack of agreement between foam and grass is due to a highly significant ''interaction'' between the device and test surface. That is, different devices behave differently on different foams, and one cannot predict which foam (if any) would be appropriate for which device. Thus, the staff determined that there was not sufficient agreement between tipover rates on 1.0-inch thick high density foam and on grass.(8)

Moreover, the sensitivity of the dynamic stability test is limited. In other words, unless a device is very unstable and tips over in frequent firings, the chances of discovering its tipover potential are low. It would require observing a very large number of samples to increase the chance of detecting a tipover. This is impractical for routine compliance testing.(8) Use of a sensitive test is important for these devices because a tipover can lead to a fatality.

3. The Tip Angle Test

Because the testing on foam did not provide a reliable dynamic test, the staff considered whether a static test based on the physical properties of large multiple tube devices could be developed. The staff measured the dimensions, mass and static tipover resistance (''tip angle'') of all the devices tested. The angle at which a device will first tip over depends on its base-height ratio, mass and center of gravity. A device's dynamic stability—i.e., its ability to remain upright—depends on its tip angle as well as other factors such as its lift force, the firing order, and the time between firings. As explained below, the staff found that tip angle was one measure that could predict qualitatively whether a device would tip over while functioning and also be sufficiently sensitive for routine compliance testing.(9)

The staff measured the tip angle of devices by placing one edge of the device against a mechanical stop approximately 1/16-inch high (to prevent sliding) at the edge of a horizontal hinged platform. The platform was slowly raised from the horizontal until the device tipped over. The tip angle was considered to be the angle at which the device first tips over. The test was repeated for each edge of the device to determine the minimum tip angle. In this manner, the staff measured the tip angle for the nine large devices that had been subjected to the dynamic tests, including the unmodified forms of devices 2, 3, and 4.(9)

The staff then compared these measurements and the results of the dynamic tests to determine whether there was a relationship between the minimum tip angle of a device and its dynamic stability on grass (see table 3).(9)

TABLE 3.—STATIC TIPOVER RESISTANCE AND DYNAMIC TIPOVER RATE OF LARGE MULTIPLE TUBE DEVICES

Minimum tip angle (degrees)	Tipover rate on grass		Device
	Percent	Incidence	
37	64	32/50	[a] 2
37	20	10/50	6
37	8	4/50	1
35, 42[b]	54	27/50	[a] 3
40	60	30/50	[a] 4
61	0	0/90	5
64	0	0/50	7
65	2.5	1/40	4
68	0	0/40	2
69	0	0/50	9
70	0	0/40	3
78, 80[b]	0	0/90	8

[a] Device modified to increase tipover rate.
[b] Different samples of same device.

The staff conducted supplemental tests on large devices other than those it had examined when considering a dynamic test. One device was a modified form of device 1, that originally had no base. The staff glued a 12 inch (30.5 cm) square particleboard base to the device. With this modification, the tip angle increased from 37 degrees to 68 degrees. The tipover incidence on grass also decreased, from 4/50 to 0/50. The additional test with this device demonstrates that a device can be modified by adding a base, and the device's stability will improve.(9)

The second additional device that the staff tested, an imported one, had a square plastic base. The tip angle of this device ranged from 54 to 55 degrees (based on measurements of four individual samples) and it did not tip over in 50 tests on grass.(16)[3]

Because none of the seven devices originally tested had tip angles between 43 and 61 degrees, the staff modified the base of a device with a large

[3] The staff previously tested this type of device (tip angle: 52–55 degrees and tipover rate: 2/40), but the bases of some of the devices were cracked. Therefore, the staff does not consider the earlier tests to be reliable and has not considered them in determining an appropriate tip angle.(10 and 11)