INDUSTRIAL FACE SHIELD PERFORMANCE TEST

Donald L. Campbell, Ph.D

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health
Appalachian Laboratory for Occupational Safety and Health
Morgantown, West Virginia 26505
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Results are reported from tests on a group of 37 face shield models to determine the extent of compliance with the requirements of the American National Standards Institute (ANSI) Z8.7.1-1968 standard. The models, randomly selected from a listing of all models advertised as meeting the ANSI requirements, are considered to be representative of face shield models currently available to the industrial user. Overall performance of the shields on impact, penetration and flammability tests of the window was found to exceed the ANSI requirements. However, only two of the 37 were found to be in compliance with all of the ANSI requirements. Many of the failures are considered to be from minor variation with the ANSI standard. The report outlines the testing procedure and recognizes that some areas of the ANSI standard are subject to interpretation. Also pointed out is a hazard associated with using a face shield instead of primary eye protection.

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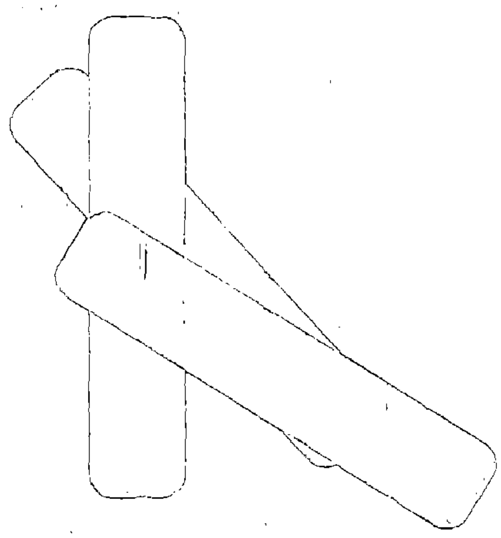


ABSTRACT

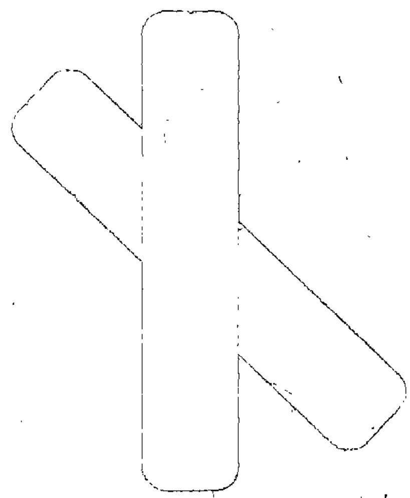
The report describes the results of tests conducted on a group of thirty-seven face shield models to determine the extent of compliance with the requirements of the American National Standards Institute (ANSI) Z87.1-1968 standard. These models, randomly selected from a listing of all models advertised as meeting the ANSI requirements, are considered to be representive of face shield models currently available to the industrial user. The impact, penetration, and flammability tests of the window are considered to be the ANSI tests that relate most directly to the level of safety provided the user. The overall performance in these three tests was found to exceed the ANSI requirements. Only two of the thirty-seven models were, however, found to be in compliance with all of the ANSI requirements. Many of the failures are considered to result from minor variation with the ANSI standard. The report outlines the testing procedure and recognizes that certain areas of the ANSI standard are subject to interpretation. Also pointed out is a hazard associated with using a face shield instead of primary eye protection.

INTRODUCTION

This report describes the results of industrial face shield tests conducted by the National Institute for Occupational Safety and Health (NIOSH), Testing and Certification Branch (TCB). These tests were performed on a group of face shield models randomly selected from those models advertised as meeting the American National Standards Institute (ANSI) standard.[1] The face shields were evaluated, individually and as a group, to determine the extent of compliance with the ANSI Z87.1-1968 standard. The information presented in this report is intended to increase the safety community's awareness of the relative qualities of the industrial face shields now available.

Eye and face protective devices, including face shields, are now required by the Occupational Safety and Health Act of 1970 to be used in certain industrial situations. The law requires, in these situations, the use of devices complying with ANSI Z87.1.[2] At present, safety personnel must rely on the manufacturers' advertising claims to identify appropriate devices. These claims are usually based on tests conducted by the manufacturer or by independent testing laboratories for the manufacturer.

NIOSH is interested in the level of protection provided by these devices. It is important, therefore, to know the extent to which currently available devices comply with present standards. As a means of generating technical information concerning personal protective devices, NIOSH has established the Testing and Certification Branch in Morgantown, West Virginia. TCB has the capability for testing industrial helmets, safety-toe shoes, linemen's rubber gloves, and eye and face protective devices. This report is part of a continuing series of reports on the performance of these personal protective devices.



SELECTION OF DEVICES FOR TESTING

Each face shield considered for testing consisted of a headgear and a detachable window. There are three classifications of headgear in the ANSI standard: headgear without crown protector, headgear with crown protector, and headgear with both crown and chin protectors. Each of these will accommodate any of five window types: clear transparent, colored transparent, wire screen, combination of plastic and wire screen, and fiber window with filter plate mounting. Face shield models with or without crown protectors coupled to a clear transparent window are considered to be the most popular and, hence, were chosen for these tests.

So that these test results would be a reflection of the performance of face shields currently available to the industrial user, care was taken to select a representative sample. As a first step, a list was made of all face shield models sold in the United States and advertised as being in compliance with the ANSI standard. References to the "OSHA standard" or the "Federal standard" were taken to imply reference to the ANSI standard. The list was based on a survey of all commonly available information such as manufacturers' literature and safety equipment directories.

Windows and headgear are, in general, sold separately and many combinations are often possible. To eliminate multiple listings of a single window or headgear, the list was compiled by recording the names of all clear transparent windows--with the headgear to be selected later. It is estimated that approximately one-third of the available windows were not included, because

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they were not advertised as meeting the ANSI standard. The list was further shortened by eliminating, as much as possible, repetition of otherwise identical models sold under different names by different distributors.

Next, by a method of random selection, forty windows, representing approximately one-fifth of the total list, were chosen to be tested. For each of these, a list of compatible headgear (with crown protector) was constructed from the manufacturers' literature. One headgear was chosen, again by random selection, for each window. If headgear with crown protection were not available, the selection was made from a list of headgear without crown protection.

Ten samples of each selected model were purchased, when possible, through a distributor rather than directly from the manufacturer.

TESTING PROGRAM

The requirements and tests discussed in this report are those of ANSI Z87.1. For a detailed description of these requirements one should refer to the standard itself. Some of the requirements, however, are subject to a variety of interpretations. The purpose of this section is to state the NIOSH interpretation of these areas and to present the details of the overall testing program. It will also provide, for those not familiar with the ANSI tests, a brief description indicating the nature of each test.

Each face shield model was evaluated in terms of the following performance and design tests.

Performance Tests

Transmittance

The ANSI standard specifies that the face shield window shall transmit not less than 85 percent of the incident visible light. To determine this so called luminous transmittance, a Coleman EPS-3T spectrophotometer was used to measure the spectral transmittance. The luminous transmittance, T , was then calculated from the following weighted average:

$$T_\ell = \frac{\Sigma\ T(\lambda)\ E(\lambda)\ P(\lambda)}{\Sigma\ E(\lambda)\ P(\lambda)} ,$$

where

$T(\lambda)$ = spectral transmittance of window,

$E(\lambda)$ = relative spectral irradiance of standard CIE source A, and

$P(\lambda)$ = relative spectral sensitivity of photopic observer.

The value of $T(\lambda)$ was measured from 400 to 760 nanometers in steps of 10 nm. The coefficients $E(\lambda)$ and $P(\lambda)$ were taken from NBS monograph 104.[3]

For use in the spectrophotometer, a 2-by-2-inch section was cut from the center portion of two windows. Care was taken to insure that sections chosen were clean and unscratched. The results of this test were judged by considering the average of these two samples.

Corrosion

This test is a measure of the extent to which the operation of the face shield is likely to be affected by corrosion during its day-to-day use in the industrial environment. The test consists of exposing the device, under controlled conditions, to the corrosive effects of salt spray (fog) for a period of 48 hours. A Singleton (Model SCCH-21) corrosion test chamber, adjusted to the specifications of the ASTM B117-64 test method,[4] was used to conduct this test. If, at the completion of the test, a device was totally usable, it was judged to have passed.

Flammability

The ANSI standard specifies a maximum burning rate of 3 inches per minute for windows and 2.5 inches per minute for all other components. In evaluating this group of face shields, the burning rate was determined for all exposed plastic materials of the headgear and window.

The ANSI standard describes the test procedure for plastic windows. Basically, the burning rate is determined by inserting one end of a 5-by-1/2-inch strip into the flame of a Bunsen burner and then measuring the time required for the flame to travel a specified distance. To supply those details of the test procedure not supplied by Z87.1, use was made of the test methods of the ASTM D635-72 flammability test.[5] The test procedure used was the ASTM test method modified to comply with the specific requirements of the ANSI standard. These modifications include the use of a 1/2-inch flame and a 10-second ignition time. Before ignition the test strip extended 10 mm beyond the edge of a wire screen. A timer was started upon application of the flame and stopped when the flame reached a mark scribed 100 mm from the end of the strip. Testing was continued until either three strips burned the entire 100 mm or three strips failed to burn the entire length. In the first case, the average burning rate was used to determine pass or fail. In the second case, the material was classified as self-extinguishing and, hence, considered to pass.

Impact

In accordance with the ANSI standard, the face shield was horizontally mounted on a wooden headform. Additional support was provided at the lower end of the window by a wooden block contoured to fit the curved window. A 7/8-inch diameter steel ball, weighing approximately 1.56 ounces, was dropped from a height of 50 inches onto the window. To pass this test, the window must not have been fractured or separated from the headgear. Five samples of each model were subjected to this test. If any one of the five failed, the model was considered to have failed.

The ANSI test, being strictly a pass/fail test, does not provide a quantitative measure of the level of impact protection. To estimate this impact protection, the impact energy necessary to cause failure was determined for each model. The results of these extended measurements were not used as a basis for determining pass or fail and are reported in terms of the overall performance of the group tested rather than model-by-model.

If a model incorporated a crown protector, the crown protector was also subjected to the standard impact test. This test was conducted with the face shield mounted on a vertical headform. The window was tilted up and supported on its lower end. The angle of tilt was such that the path of the falling steel ball was perpendicular to the surface of the crown protector. Failure of any of the five samples tested was considered sufficient reason to fail the model.

Penetration

Again the face shield was horizontally mounted on a wooden headform. A dart, consisting of a Singer number 25 needle mounted to a 1.56-ounce body, was dropped from a height of 50 inches onto the window. To pass this test the windows, from each of the five samples tested, must not have been fractured, pierced, or separated from the headgear. As with the window impact test, and for the same reason, an attempt was made to determine the performance level of the group by increasing its impact energy until the device failed.

Disinfection

This test was conducted to determine if face shields are deteriorated by the use of common disinfecting agents. Each device tested was thoroughly cleaned with soap and water, completely rinsed, carefully dried with a lint-free towel, immersed in a disinfecting hypochlorite solution for 10 minutes, removed and allowed to air dry, then examined for possible deterioration. A device was judged to have failed if the deterioration could conceivably interfere with the use or purpose of the device. This same procedure was then repeated using a disinfecting phenol solution. The test was conducted with these solutions at a temperature of 24° C $\pm$ 6° C. The disinfecting solutions were used at the concentration specified by the manufacturer.

Design Test

Sections 5.2.5, 5.2.6, and 5.2.7 of the ANSI standard indicate numerous general design requirements. This test consisted of an inspection of each device to determine compliance with these requirements. Inspected were features such as range of head size adjustment, manufacturer's identification, window dimensions, and the detachability of the window.

Testing Order

Because the test results could conceivably depend upon the testing order, care was taken to eliminate interference between two or more tests. Past experience has indicated the following testing sequence will eliminate interference between tests and yet maximize the number of samples available for each test. Initially each model was inspected for compliance with the ANSI design requirements. Samples of each model were divided into two groups of five. Each device of the first group was subjected to the impact test. Next, two of the five were used to determine the failure impact energy and then subjected to the corrosion test. The remaining three were then set aside for use in the flammability test, if needed.

The second group of five was subjected to the penetration test. After this test, three of the five were used to obtain samples for the transmittance test, and the flammability test. The remaining two were used to determine the penetration failure energy and then subjected to the corrosion test. Two samples to be used for the disinfection test were selected from any of those not used in the corrosion test and not destroyed by the physical tests. This testing order is also illustrated in the flow chart, Figure 1, on page 19 of this report.

TEST RESULTS

The results of the six performance tests are presented in Table 1, pages 20-22, and design test results are presented in Table 2, pages 23-25. An f indicates the face shield was determined not to be in compliance with that particular test or requirement of the ANSI standard. Notice that, of the forty models originally selected for testing, only thirty-seven were actually tested. The others were either never received or were received too late for testing.

Performance Tests

Transmittance

Eighteen of the 37 models tested had a luminous transmittance less than 85 percent and, hence, did not comply with the ANSI standard. Coincidentally, the pass/fail limit of 85 percent was also the exact average of all models tested. There was little variation from that average value; except for six models, all were within 5 percent of this average value. The three Watchemoket models had the best performances in this test, and were slightly outside this range, having a transmittance of 91 percent. The three models below 80 percent were the Cesco 700-M8 (77 percent) and the Glendale models 860 and 960 (79 and 78 percent, respectively).

The windows on the two Jackson models were supposedly identical. Thus, it is interesting to note that one model passed this test, while the other failed. One had a transmittance of 82 percent and the other, 87 percent. Because each model was purchased from a differenct distributor, it is quite likely that they were from two different manufacturing lots. This is the only case where such apparent manufacturing variation was observed.

Corrosion

All models examined passed this test. Slight corrosion was observed on some models, but it was always insufficient to interfere with performance.

Flammability

The window was by far the best component in this test. Not only were all the burning rates below the limit for windows of 3.0 inches/min., but all except seven were below the more stringent 2.5 inches/min. required for all other components. This is especially significant when one considers that the window, because of its size and exposure, is the component most likely to be a serious hazard.

The headgear did not, in general, perform as well. Twelve of the thirty-seven failed. Excessive headgear burning rates were responsible for the failure of each Fendall and each Glendale model. Both Jackson models failed because of the snap restraint--a minor component of the headgear used to position snaps. The other five failures were due to failure of the sweat-band attached to the headgear. The crown protectors performed well; no failures resulted from excessive burn rates of this component. If the head-gear had attachments, such as sweatbands or snap restraints, the results are listed separately in Table 1 under the column entitled "Attachments."

Impact

All but the Willson (V-3, V-84) passed the impact test. The window of that model became detached from the headgear under impact. It was determined that this failure resulted from the absence of two attachment components (two small bolts that provide additional means of attachment between the headgear and window). The absence of these components would not be apparent to the user, and these face shields could be mistakenly used with these components missing. When these components were incorporated into the face shield it easily passed both the impact and penetration test.

The results of the tests conducted at a higher impact energy were quite interesting. The overall performance is significantly above that required by the ANSI standard. Table 3, on page 26, indicates these results. It is noteworthy that more than half of the models were able to withstand impact energies 25 times greater than the ANSI requirements.

Those models incorporating a crown protector were crown impacted and all were judged to pass the standard impact test. Crown impacts at higher energies were not conducted.

Penetration

All models except one passed this test. This failure resulted from the window of the Willson (V-3, V-84) becoming detached as previously described for the impact test.

When the impact energy was doubled, fifteen models passed this test. When the energy was doubled again, resulting in a four-fold increase, five of the models still were not penetrated. Thus, as in the case of the impact test, the overall performance was well above that required by the ANSI standard.

Disinfection

All but two models passed this test. The two failures occurred during the first 10-minute disinfection cycle and were caused by the sweatband becoming unglued from the headband. Because of the very sticky surface presented to the forehead of the user, these devices were considered unusable.

Some of those models constructed from fiber tended to deform slightly during this test, but the performance was unaffected by the disinfection procedure.

Design Test

Only fifteen of the thirty-seven face shield models were found to be in compliance with the design requirement of the standard. Reference to Table 2 reveals the specific area judged not to be in compliance with the standard. Only those requirements where failures were observed are listed in this table. A large number of failures were due to the simple inability of many face shields to accommodate a 6 1/2 headsize. Also, contrary to the ANSI requirement, the marking on several models was insufficient to identify the manufacturer.

The ANSI standard also requires the windows to be easily removable and replaceable. The U. S. Safety model and three Cesco models were found not to be in compliance with this requirement. The window attachment mechanism, identical in each of these models, fractured and became unusable while attempting to remove and replace the windows. Thus, replacement of a damaged window could well involve replacing the entire device.

OBSERVATIONS AND CONCLUSIONS

Only two of the thirty-seven face shield models tested were determined to be in complete compliance with the ANSI Z87.1-1968 standard as required by the Occupational Safety and Health Act. Many of the failures were due to minor variations from the requirements of the standard. The impact, penetration, and flammability tests of the window are considered to be the ANSI tests that relate most directly to the level of safety provided the user. The overall performance in these three tests was found to exceed the ANSI requirements.

This group of face shields can best be further discussed by considering the performance from three points of view: the ability to protect the user from specific hazards; the extent to which the device itself is a hazard; and its durability.

Face shields are intended to provide protection against hazards such as sparks, splashes, chips, and other flying projectiles. The tests most closely relating to these primary hazards are the impact and penetration test. With the exception of one model, the performance in both of these important tests was good. In fact, many models were found to provide the user with a level of protection far above the ANSI requirement. Most, however, of these models did not provide the user with lateral protection of the eye and face. Twenty-eight of the models examined in this study allow direct side exposure of the eye. The ANSI standard recommends basic eye protection, such as goggles or spectacles with side shields, to be worn underneath the face shield. If this is done, the hazard to the eye is substantially eliminated. However, there is the danger that a user, not being conscious of this limited protection, may use the face shield instead of, rather than in addition to, the basic eye protection recommended by the ANSI standard.

A face shield itself could be a hazard if, for example, it disturbed the vision of the user or were constructed of highly flammable material. With regard to disruption of the user's vision, the transmittance test is the only ANSI test that applies. Overall, the performance in this test was poor: eighteen models failed. However, these failures would be significant only to the worker using the device where illumination is poor or marginal. It was also observed that in certain lighting situations an annoying facial reflection interfered womewhat with the wearer's vision. It is worth noting that this problem is reduced in those models having a crown protector which acts to shade the wearer's face from direct illumination.

This group of face shields is considered to have performed well in the flammability tests, even though several failures were detected. These failures were largely the result of small components of the headgear. There were no failures of the window, the most important component in this test.

Both the corrosion test and the disinfection test relate directly to the durability of the device. In general, these face shields were quite durable when subjected to these tests. The weak point in the durability is the tendency of the windows, after routine use and cleaning, to become scratched and abrased. The resulting haze can, in harsh lighting situations, disrupt the visual acuity of the worker. For this reason the ANSI standard's requirement of easily replaceable windows is considered to be an important feature. The durability of these devices is, then, a function of the care with which the window is handled and of the availability and use of replacement windows.

In summary, the industrial user may find it difficult to identify and obtain face shields that comply fully with the ANSI standard. In that situation, it is hoped that the possibility of obtaining an inadequate device can be reduced by considering the information presented here and determining the significance of the reported failures in terms of the intended use of the device.

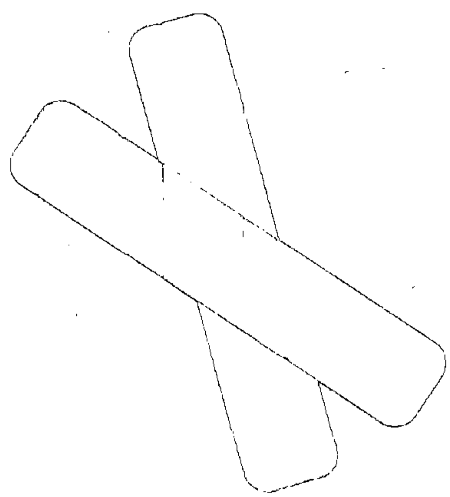

FIGURE 1. Testing Flow Chart

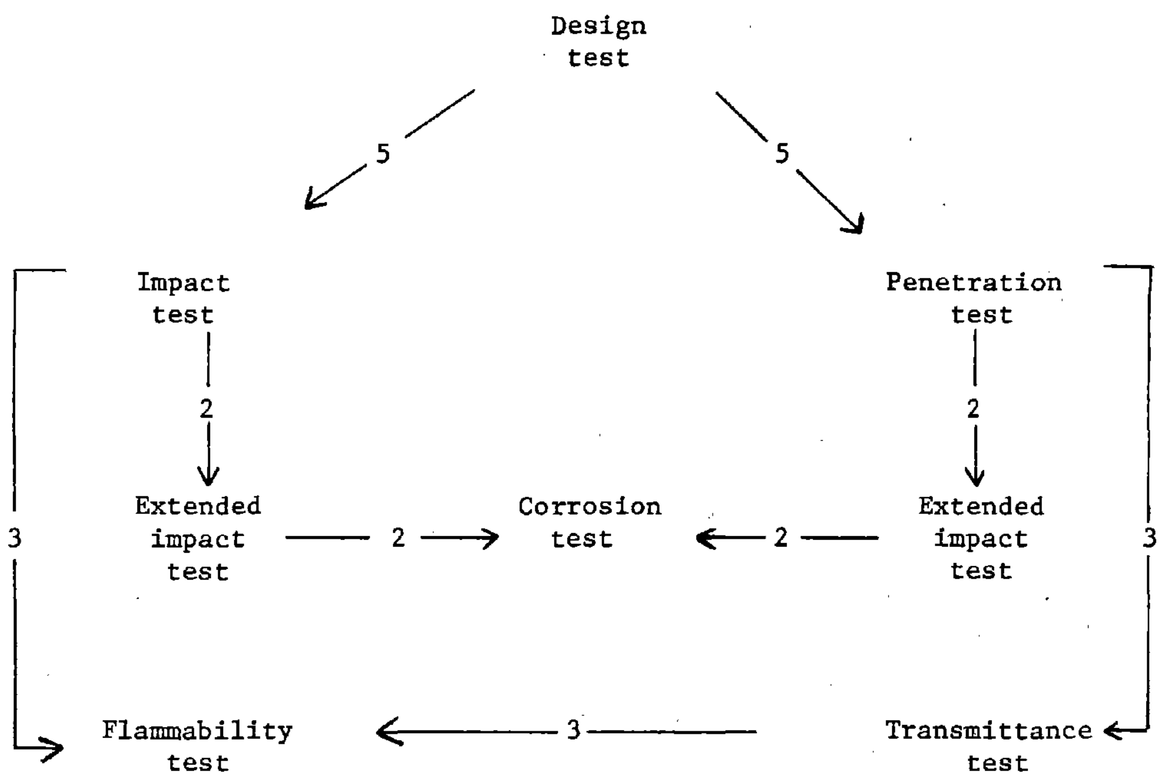

TABLE 1.--PERFORMANCE TEST RESULTS

Manufacturer (headgear, window)	Window impact	Window penetration	Transmittance	Corrosion	Disinfection	Flammability: Window	Flammability: Headgear	Flammability: Attachments
American Optical (H9A, W64)	p	p	p	p	p	p	p	f
American Optical (H2, W85)	p	p	p	p	p	p	p	p
American Optical (H10, W94-15)	p	p	f	p	f	p	p	
Cesco (700-G4, 700-46)	p	p	p	p	p	p	p	
Cesco (700-G4, 700-68)	p	p	f	p	p	p	p	
Cesco (790-W-G-3, 790-40)	p	p	p	p	p	p	p	
Cesco (790-Y-G-3, 790-V0)	p	p	p	p	p	p	p	
Cesco (700-G4, 700-M8)	p	p	f	p	p	p	p	
Dockson (1135H, 26804)	p	p	f	p	f	p	p	
Fendall (4, 3046)	p	p	f	p	p	p	f	p
Fendall (3, 3048)	p	p	f	p	p	p	f	p
Fibre-Metal (F300, 4118 vinyl)	p	p	p	p	p	p	p	
Fibre-Metal (F-90, 4168 prop.)	p	p	f	p	p	p	p	

TABLE 1.--Continued

Manufacturer (headgear, window)	Window impact	Window penetration	Transmittance	Corrosion	Disinfection	Flammability		
						Window	Headgear	Attachments
Fibre-Metal (F-90, 6118 prop.)	p	p	p	p	p	p	p	
Glendale (5100, 860)	p	p	f	p	p	p	f	p
Glendale (5100, 940)	p	p	f	p	p	p	f	p
Glendale (5100, 960)	p	p	f	p	p	p	f	p
Jackson (170-S W/35S, 8040)	p	p	f	p	p	p	p	f
Jackson (J-10, 8040)	p	p	p	p	p	p	p	f
MSA (48275, 48274)	p	p	p	p	p	p	p	f
MSA (791300, 791306)	p	p	p	p	p	p	p	
MSA (791300, 791310)	p	p	f	p	p	p	p	
MSA (791300, 95683)	p	p	p	p	p	p	p	
MSA (41865, 72002)	p	p	p	p	p	p	p	f
Morse (47, W4764)	p	p	p	p	p	p	p	f

Table 1. --Continued

Manufacturer (headgear, window)	Window impact	Window penetration	Transmittance	Corrosion	Disinfection	Flammability: Window	Flammability: Headgear	Flammability: Attachments
Sellstrom (300R, 9-WCP-4-300)	p	p	f	p	p	p	p	
Sellstrom (300, 9-AWCP-4-300)	p	p	p	p	p	p	p	
Sellstrom (320R, 7-WCP-4-320)	p	p	p	p	p	p	p	
Sellstrom (380R, 8-AWCP-4-380)	p	p	f	p	p	p	p	
Sellstrom (380, 6-AWCP-4-380)	p	p	p	p	p	p	p	
Sellstrom (380R, 6-WCP-4-380)	p	p	f	p	p	p	p	
U.S. Safety (424000, 434800)	p	p	f	p	p	p	p	
Watchemoket (6 x 10 CURVED C)	p	p	p	p	p	p	p	
Watchemoket (8 x 10 CURVED C)	p	p	p	p	p	p	p	
Watchemoket (10 x 10 CURVED C)	p	p	p	p	p	p	p	
Willson (V-3, V-84)	f	f	f	p	p	p	p	f
Willson (E1, E-84)	p	p	f	p	p	p	p	

TABLE 2.--DESIGN TEST RESULTS

Manufacturer (headgear, window)	Headband adjustment	Headgear marking	Window marking	Window height	Window detachability
American Optical (H9A, W64)	p	p	p	p	p
American Optical (H2, W85)	p	p	p	p	p
American Optical (H10, W94-15)	p	p	p	p	p
Cesco (700-G4, 700-46)	f	p	p	p	f
Cesco (700-G4, 700-68)	f	p	p	p	f
Cesco (790-W-G-3, 790-40)	f	f	p	p	p
Cesco (790-Y-G-3, 790-V0)	f	f	p	p	p
Cesco (700-G4, 700-M8)	f	p	p	p	f
Dockson (1135H, 26804)	p	p	p	p	p
Fendall (4, 3046)	p	p	p	p	p
Fendall (3, 3048)	p	p	p	p	p
Fibre-Metal (F300, 4118 vinyl)	p	p	p	p	p
Fibre-Metal (F-90, 4168 prop.)	f	p	p	p	p

Manufacturer (headgear, window)	Headband adjustment	Headgear marking	Window marking	Window height	Window detachability
Fibre-Metal (F-90, 6118 prop.)	f	p	p	p	p
Glendale (5100, 860)	p	p	p	p	p
Glendale (5100, 940)	p	p	p	p	p
Glendale (5100, 960)	p	p	p	p	p
Jackson (170-S W/35S, 8040)	p	p	p	p	p
Jackson (J-10, 8040)	p	p	p	p	p
MSA (48275, 48274)	p	p	p	p	p
MSA (791300, 791306)	p	f	p	p	p
MSA (791300, 791310)	p	f	p	p	p
MSA (791300, 95683)	p	f	p	p	p
MSA (41865, 72002)	p	p	p	p	p
Morse (47, W4764)	p	p	p	p	p

Manufacturer (headgear, window)	Headgear adjustment	Headgear marking	Window marking	Window height	Window detachability
Sellstrom (300R, 9-WCP-4-300)	f	p	p	p	p
Sellstrom (300, 9-AWCP-4-300)	f	p	p	p	p
Sellstrom (320R, 7-WCP-4-320)	f	p	p	p	p
Sellstrom (380R, 8-AWCP-4-380)	f	p	p	p	p
Sellstrom (380, 6-AWCP-4-380)	f	p	p	p	p
Sellstrom (380R, 6-WCP-4-380)	f	p	p	p	p
U.S. Safety (424000, 434800)	f	p	p	p	f
Watchemoket (6 x 10 CURVED C)	p	p	f	f	p
Watchemoket (8 x 10 CURVED C)	p	p	f	p	p
Watchemoket (10 x 10 CURVED C)	p	p	f	p	p
Willson (V-3, V-84)	f	p	p	p	p
Willson (E1, E-84)	f	p	p	p	p

TABLE 3.--EXTENDED IMPACT TEST

	Impacting Mass (gm.)	Drop Height (in.)	Impact Energy*	Performance
(ANSI test)	44.7	50	1	36 of 37 passed
	44.7	108	X 2	34 of 37 passed
	287.0	108	X 13.8	24 of 37 passed
	535.0	108	X 25.8	20 of 37 passed

* multiple of ANSI impact energy

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