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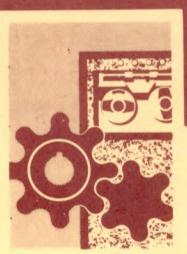

TECHNICAL REPORT

Impact Performance of Safety Eyecup Goggles

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health

IMPACT PERFORMANCE OF SAFETY EYECUP GOGGLES

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ABSTRACT

This report describes impact tests of eyecup safety goggles advertised as meeting the requirements of the ANSI Z87.1 standard and therefore as suitable for use by U. S. workers. This report presents the results of three safety goggle testing programs conducted in 1977, 1978, and 1979. The 1978 and 1979 tests are follow-up tests prompted by the poor performance of many models in the 1977 tests. A description of each test is included along with a discussion of the test results. In each of the three testing programs, the overall performance was consistently poor. Thirty-one percent of all models tested failed the frame impact test and 44 percent failed the lens impact test.

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ACKNOWLEDGMENT

The contributions of Bob Irwin, who edited the report, and Ruth Linn, who typed the report, are gratefully acknowledged by the authors.

INTRODUCTION

The Division of Safety Research of the National Institute for Occupational Safety and Health (NIOSH) conducts testing programs to evaluate personal protective equipment currently available to the U. S. worker. This equipment includes safety helmets, safety-toe shoes, linemen's rubber gloves, and eye and face protective devices. This report is one of a series concerning such devices and is a follow-up to a report on eyecup goggles published by NIOSH in 1977 (NIOSH 77-165).[1]

The 1977 NIOSH report indicated that many eyecup goggles available in this country were defective and exposed the worker to serious and unnecessary eye hazard. Nearly one-half of the models tested failed the lens impact test. These failures are serious because, when a lens fractures, the lens itself becomes a serious hazard. Sharp needle-like glass fragments are produced that can be driven into the eye.

The results presented in that report were discussed with goggle manufacturers, representatives of the Occupational Safety and Health Administration (OSHA), organized labor, and other interested parties. We at NIOSH believed the attention focused on these lens defects would stimulate the goggle manufacturers to take action and eliminate defective lenses from their products.

To determine if corrective action has been taken, NIOSH has conducted two follow-up testing programs. The first was conducted in 1978, one year after the publication of the 1977 report. The second was conducted in 1979, one year later. Thus, a total of three testing programs, approximately one year apart, have been conducted.

Only the most important of the numerous tests conducted in 1977 were used in the follow-up programs. These were the two tests of impact resistance, lens impact and frame impact. The follow-up results are disappointing. The quality of eyecup goggles available to the U. S. worker has not improved. More than one-half of the models tested in 1979 failed.

Details of the testing programs are presented in the remaining sections of this report.

SAMPLING

Sampling procedures, identical in each of the three testing programs, were designed to obtain a collection of eyecup goggles representative of those available to the U. S. worker.

A word of emphasis is appropriate. The key word in the above statement is "available." Reliable inferences cannot be made about eyecup goggles "in use by" or "sold to" U. S. workers. To obtain such information one would need to weigh the test results presented in this report according to the number of each model in use or sold in this country--numbers not available to NIOSH.

Sample Selection

The first step in the sampling process was to compile a list of eyecup goggles sold in the United States and advertised as being in compliance with the ANSI Z87.1 standard.[2] References to the "OSHA standard"[3] or "Federal standard" were taken to imply reference to the ANSI standard. The list was based on a survey of all available information such as manufacturers' literature and Best's Safety Directory.[4]

Twenty goggles of every model identified were then ordered. Since the impact properties are primarily determined by the lens, all variations of goggle frames were ignored in the identification of unique models. All goggles which had the same lenses and were available from a particular manufacturer were considered the same model. Therefore, since most manufacturers use only a single lens design, only one model was ordered from most manufacturers.

Sample Procurement

The sampling was possibly biased because of our inability to purchase anonymously; all purchases were made through normal HEW procurement channels. Bias could have entered in two ways. Individual manufacturers could have supplied hand-picked goggles not typical of their normal product line. Or, individual manufacturers, having no confidence in the quality of their product, could simply ignore our purchase orders and supply no goggles for testing. We have no way of knowing if, or to what extent, this bias occurred.

Of 29 models ordered in the 1979 program, 22 were received. This response rate was typical of all three testing programs.

Sample Size

We are not satisfied with our process of selecting sample sizes for these

testing programs. It was not possible to select a sample size in a systematic way without knowing the maximum acceptable failure rate. The present ANSI Z87.1 standard is incomplete and does not specify that rate. Without it, the normal statistical methods of selecting sample size could not be applied.

For our tests, we have chosen a sample size of 20, a number at least large enough to allow detection of gross failure rates on the order of 1 in 10 or greater. Failure rates on the order of 1 in 100 or 1 in 1000 will simply not be reliably detected in the testing programs.

Even though we believe the maximum failure rate should be well below the levels detectable in this program, we did not think it appropriate to undertake the expense of conducting programs to detect failure rates on the order of, say, 1 in 100--at least not until a maximum allowable failure rate is, in fact, defined.

TESTING PROGRAMS

Two impact tests were conducted in each of the three testing programs, a "lens impact" test and a "frame impact" test. Lens impact is a lens-only test in which the lens is removed from its frame and impacted on a standardized test fixture. Frame impact is a lens-in-frame test in which the lens is impacted without removal from its frame.

Both impact tests are outlined in the ANSI Z87.1 standard. The details of the lens impact test are well defined. Those of the frame impact test are not. It was, therefore, necessary for us to fill in several details of the frame impact test. Where this was necessary, test details most likely to produce meaningful, realistic test results were chosen. The details of each of these two tests are presented below.

Lens Impact

The lens impact test is conducted by mounting the lens on a metal test block and striking it with a 1.00-inch diameter steel ball weighing 2.4 ounces. The ball was dropped from a height of 50 inches onto the lens center. The lens does not rest directly on the metal block, but on a thin circular rubber gasket cemented to the metal block. The thickness of the gasket is 1/8 inch, and the internal and external diameters of the gasket are 42 and 52 mm, respectively. All lenses were impacted on the front surface, as defined by the orientation of the lens in the goggle frame when received.

Twenty lenses from 10 goggle specimens of each model were subjected to the lens impact test. A model was considered to fail if one or more of the twenty lenses fractured.

Frame Impact

This test was conducted by placing the goggle on a headform in the normal wearing position. Both the left and right lenses were struck with a 1.00-inch diameter steel ball weighing 2.4 ounces and dropped from a height of 50 inches. In order to pass this test, the lens must not break or be dislodged from the frame. As in the lens impact test, all lenses were impacted on the front surface, as defined by the orientation of the lens in the frame when received.

Shortly after the 1977 tests were completed, an improved headform, the Alderson Research 50th percentile male, became available. This headform was used in the 1978 and 1979 tests.

Test Results

The results of the 1977 tests were presented and discussed in the previous publication (NIOSH publication number 77-165). The 78 and 79 test results are presented in Tables 1 and 2 of this report and are discussed below. Table 3 compares the results of all three testing programs.

1978 Tests

Seven of the 22 models tested failed the lens impact test. Six of those seven also failed the frame impact test. These 6 were the only failures in the frame impact test; in no case did a lens pass lens impact but fail frame impact. In all frame impact test failures, lenses were fractured rather than dislodged from their frames.

Of the 22 models tested, two used curved glass lenses and one used flat plastic lenses. The remaining 19 models used flat glass lenses. All failures were confined to the flat glass lenses.

Following the publication of the 1977 report, it was suggested that the high lens failure rate may have resulted from lenses that were improperly reversed in the frame. The ANSI Z87.1 standard requires all lenses to be marked with the manufacturer's logo. It is common practice to use this logo to indicate the front, or exposed, side of the lens. In order to eliminate defective lenses, most manufacturers impact their lenses on the front prior to sale. It was hypothesized that lenses which had presumably been tested in this manner would not necessarily be impact resistant when struck on the reverse side. To investigate this hypothesis, the 1978 and 1979 impact test results and corresponding lens orientation for each model were examined. Table 1 shows, for each model, the test results for lenses reversed in the frame (logo facing inward) and for those in the normal orientation (logo facing outward.) Table 1 reveals that of the 19 models using flat glass lenses, 13 had one or more lenses reversed. Further inspection reveals the lens failures are not confined to reversed lenses in either the frame or lens impact tests. And, the failure rates are not significantly higher for the reversed lenses. If the hypothesis is correct and there is a "reverse impact effect," it is far too insignificant to account for the high failure rate observed in these tests.

There were several changes in certain models which occurred between the 1977 and 1978 tests. The American Safety Model, which was previously tested under the name Babbitt, has added a cover lens, an additional lens mounted in front of the main lens. While the addition of the cover lens resulted in some improvement in the frame impact results, the model still failed both impact tests. In the Glendale model the glass lens, which previously failed both tests, was replaced by a plastic lens which passed both tests.

1979 Tests

Twelve of the 22 models tested failed the lens impact test. Seven of these 12 also failed the frame impact. In no case did a model pass the lens

impact test and fail the frame impact.

One model used curved glass lenses and another used flat polycarbonate lenses. All failures were confined to the 20 remaining flat glass lenses.

As in the 1978 results, the high failure rate cannot be explained by lens reversal (see Table 2).

Comparison of 1977, 1978, and 1979 Results

For each of the three testing programs the model failure rate (number of failing models/number of models tested) is presented below for each of the two impact tests.

Test Program	Frame Impact Model Failure Rate	Lens Impact Model Failure Rate
1977	8/24 (33%)	11/24 (46%)
1978	6/22 (27%)	7/22 (32%)
1979	7/22 (32%)	12/22 (55%)

The figures above include all models, even those with plastic or curved glass lenses--lens types which have never failed in any of these three testing programs. If we had considered only those models with flat glass lenses, the failure rates would, of course, be significantly higher.

The lens failure rates are presented below. All lenses, including plastic and curved glass,are included.

Test Program	Frame Impact Lens Failure Rate	Lens Impact Lens Failure Rate
1977	19/240 (7.9%)	48/478 (10.0%)
1978	37/440 (8.4%)	63/440 (14.3%)
1979	24/440 (5.5%)	59/440 (13.4%)

The frame impact failure rate may have been reduced by the increased use of cover lenses. In the 1977 tests, no models used cover lenses. In the 1978 tests, two models used cover lenses. And, in the 1979 tests three models used cover lenses. Of these three models, one failed both the lens impact and frame impact tests.

CONCLUSIONS AND RECOMMENDATIONS

The quality of eyecup goggles available to the workforce of the United States has not improved measurably since serious defects were identified in the 1977 NIOSH publication.[1] There has been no successful effort by some goggle manufacturers to improve the quality of the glass lenses in these widely-used goggles.

Several goggle manufacturers continue to market defective and unsafe products, even after being informed of the serious problems. We can only conclude that these manufacturers have either (1) made no serious effort to monitor the quality of their lenses, or (2) knowingly market defective lenses, or (3) do not understand the mechanics of lens fracture and are mistakenly relying on inadequate quality control tests. We are not able to determine which of these is true.

On the other hand, goggles from several manufacturers have consistently performed well in these tests. We certainly recommend that anyone purchasing eyecup goggles--especially those users who cannot test and evaluate the goggles they purchase--select products whose manufacturers have consistently marketed high-quality goggles.

However, we must qualify the above recommendation. We believe the available data is sufficient to indicate a serious problem with several of the models tested here. The data are not, however, sufficient for us to conclude, with any level of confidence, that those models which performed well in these programs are free of defects. As previously discussed, the sample sizes used in these programs allow us to detect very high failure rates, but do not permit detection of small, but significant, failure rates. These and other limitations of our sampling methods, also previously discussed, do not allow us to confidently predict that a particular model is free of excessive defects. Therefore, we recommend that those models being considered for purchase should be tested if possible.

For those who cannot evaluate impact resistance, we recommend asking for a written statement of lens quality from the manufacturer. Specifically, we recommend asking for (1) a statement that a statistically valid testing program has been conducted to measure the lens impact failure rate, (2) a statement of the maximum expected lens failure rate, and (3) a statement of the level of confidence associated with the stated maximum failure rate. A responsive manufacturer would, for example, indicate: "a statistically valid testing program has been conducted to evaluate the lens failure rate. Based on that program, we are 95% confident that the lens failure rate is less than one-half of one percent (1 in 200)." In that statement, 1/2% is the maximum failure rate and 95% is the confidence level. We would consider a maximum failure rate greater than 1.0%, at a 95% confidence level, to be

unacceptable. Also considered unacceptable is a manufacturer's response indicating that it is unnecessary to determine failure rates because all lenses are impact-tested before sale and, of course, only the survivors are sold. We have not seen evidence that the survivors of these pre-sale impact tests will necessarily survive a second impact.

REFERENCES

1. Tests of Eyecup Goggles, HEW (NIOSH) Publication No. 77-165, NIOSH Printing Office, Cincinnati, Ohio. 1977. 23 p.

2. U.S.A. Standard Practice for Occupational and Educational Eye and Face Protection, American National Standards Institute, New York, New York. Standard No. Z87.1-1968. 1968. 32 p.

3. Federal Register. Volume 39, Number 125, Part II, Subpart I, Section 1910.133, p. 23670. June 27, 1974. (Code of Federal Regulations, Title 29, Part 1910. Subpart I, Section 1910.133.)

4. Best's Safety Directory. Morristown, N. J., A. M. Best Company. 1976. p. 109.

TABLE 1 1978 IMPACT TEST RESULTS

Manufacturer/Model/ Lens Type*	Frame Impact				Lens Impact			
	** Rate	Total	+ Out	++ In	** Rate	Total	+ Out	++ In
Aden 5051/f		0/20	0/5	0/15		0/20	0/3	0/17
American Industrial 501/f		0/20	0/5	0/15	5%F	1/20	0/7	1/13
American Optical 325-C/c		0/20	0/20	0/0		0/20	0/20	0/0
American Optical 325-CB/f		0/20	0/19	0/1		0/20	0/20	0/0
American Safety C-1010/f	10%F	2/20	0/9	2/11	60%F	12/20	4/10	8/10
Cesco 557-C/f		0/20	0/19	0/1		0/20	0/20	0/0
Dockson 90-08/f	30%F	6/20	3/3	3/17	30%F	6/20	0/1	6/19
Eastern Safety 600-MH/f		0/20	0/4	0/16		0/20	0/0	0/20
General Scientific A-207/f	40%F	8/20	8/19	0/1	60%F	12/20	12/20	0/0
Glendale Optical GC-4/p		0/20	0/14	0/6		0/20	0/12	0/8
Jackson Products GR-70/f		0/20	0/20	0/0		0/20	0/20	0/0
Michell 575/f	45%F	9/20	9/20	0/0	30%F	6/20	6/20	0/0
MSA 791017/f		0/20	0/14	0/6		0/20	0/16	0/4
Morse Safety 708H/f	40%F	8/20	8/20	0/0	65%F	13/20	13/20	0/0
Norton Company 5023/f		0/20	0/15	0/5		0/20	0/20	0/0
O.K.I. GR-70/f		0/20	0/15	0/5		0/20	0/20	0/0
Pulmosan G-576/f	20%F	4/20	4/20	0/0	65%F	13/20	13/20	0/0
Union Carbide 702F04/f		0/20	0/20	0/0		0/20	0/20	0/0
U.S.Safety 2312101/f		0/20	0/19	0/1		0/20	0/20	0/0
U.S.Safety 231200/c		0/20	0/20	0/0		0/20	0/20	0/0
Willson CC702/f		0/20	0/20	0/0		0/20	0/20	0/0
Willson CC702R/f		0/20	0/20	0/0		0/20	0/20	0/0

Data Format: #failing/#tested *f=flat glass p=flat plastic c=curved glass
**F-Indicates model failed and failure rate.
+Out-Indicates that the logo was on the lens surface facing outward as worn.
++In-Indicates that the logo was on the lens surface facing inward as worn.

TABLE 2 1979 IMPACT TEST RESULTS

Manufacturer/Model/ Lens Type*	Frame Impact ** Rate	Frame Impact Total	Frame Impact + Out	Frame Impact ++ In	Lens Impact ** Rate	Lens Impact Total	Lens Impact + Out	Lens Impact ++ In
American Optical 325C-40164/f		0/20	0/20	0/0		0/20	0/20	0/0
American Optical 325CB-40168/f		0/20	0/20	0/0		0/20	0/20	0/0
Bouton 690-c/f	10%F	2/20	2/20	0/0	20%F	4/20	4/20	0/0
Cesco 557-T/f		0/20	0/17	0/3	5%F	1/20	1/20	0/0
Dockson 90-08/f	20%F	4/20	1/9	3/11	45%F	9/20	5/8	4/12
Eastern Safety 600-MH/f		0/20	0/17	0/3	5%	1/20	1/16	0/4
Fendall 540/f		0/20	0/20	0/0		0/20	0/20	0/0
Fibre-Metal VGC-2/f	35%F	7/20	7/20	0/0	80%F	16/20	16/20	0/0
Gateway 501/f	10%F	2/20	2/19	0/1	5%F	1/20	1/20	0/0
General Scientific GR-70/f		0/20	0/9	0/11		0/20	0/3	0/17
Glendale Optical GC-4/p		0/20	0/0	0/20		0/20	0/1	0/19
Guardian 557-C/f		0/20	0/20	0/0		0/20	0/20	0/0
Jackson GR-70/f		0/20	0/8	0/12		0/20	0/11	0/9
Michell 690-C/f		0/20	0/20	0/0	15%F	3/20	3/20	0/0
M.S.A. 791017/f		0/20	0/19	0/1	5%F	1/20	1/18	0/2
Morse 708-H/f		0/20	0/20	0/0	10%F	2/20	2/18	0/2
Norton 5024/f		0/20	0/20			0/20	0/20	0/0
Pulmosan G575-400039/f	15%F	3/20	3/19	0/1	65%F	13/20	13/20	0/0
Sellstrom 661-LCA/f	10%F	2/20	1/13	1/7	20%F	4/20	2/12	2/8
Thermacote 40-01250/f	20%F	4/20	3/7	1/13	20%F	4/20	3/12	1/8
U.S. Safety Service 231200/c		0/20	0/20	0/0		0/20	0/20	0/0
Willson CC70/f		0/20	0/20	0/0		0/20	0/20	0/0

Data Format: #failing/#tested *=flat glass p=flat plastic c=curved glass
**F-Indicates model failed and failure rate.
+Out-Indicates that the logo was on the lens surface facing outward as worn.
++In-Indicates that the logo was on the lens surface facing inward as worn.

TABLE 3 Comparison of 1977, 78, and 79 Impact Test Results

Manufacturer-Lens Type*	1977 Frame Impact	1977 Lens Impact	1978 Frame Impact	1978 Lens Impact	1979 Frame Impact	1979 Lens Impact	Cumulative Frame Impact	Cumulative Lens Impact
Aden - f			0/20	0/20			0/20	0/20
American Industrial - f	1/10	1/20	0/20	1/20			1/30	2/40
American Optical - f	0/10	0/20	0/20	0/20	0/40	0/40	0/70	0/80
American Optical - c	0/10	0/20	0/20	0/20			0/30	0/40
American Safety - f (formerly Babbitt)	2/10	2/20	2/20	12/20			4/30	14/40
Bausch & Lomb - c	0/10	0/20					0/10	0/20
Bouton - f					2/20	4/20	2/20	4/20
Cesco - f	0/10	0/20	0/20	0/20	0/20	1/20	0/50	1/60
Dockson - f	1/10	5/20	6/20	6/20	4/20	9/20	11/50	20/60
Eastern Safety - f	0/10	4/20	0/20	0/20	0/20	1/20	0/50	5/60
Fendall - f					0/20	0/20	0/20	0/20
Fibure-Metal - f	0/10	0/20			7/20	16/20	7/30	16/40
Gateway - f					2/20	1/20	2/20	1/20
General Scientific - f	4/10	10/20	8/20	12/20	0/20	0/20	12/50	22/60
Glendale - p			0/20	0/20	0/20	0/20	0/40	0/40
Glendale - f	2/10	4/20					2/10	4/20

Data Format: #failing/#tested *f=flat glass p=flat plastic c=curved glass.

TABLE 3--continued

Manufacturer-Lens Type*	1977 Frame Impact	1977 Lens Impact	1978 Frame Impact	1978 Lens Impact	1979 Frame Impact	1979 Lens Impact	Cumulative Frame Impact	Cumulative Lens Impact
Guardian - f	0/10	0/20			0/20	0/20	0/30	0/40
Guardian - c	0/10	0/20					0/10	0/20
Jackson - f	0/10	1/20	0/20	0/20	0/20	0/20	0/50	1/60
Michell - f	3/10	9/18	9/20	6/20	0/20	3/20	12/50	18/58
M.S.A. - f	0/10	0/20	0/20	0/20	0/20	1/20	0/50	1/60
Morse - f			8/20	13/20	0/20	2/20	8/40	15/40
Norton - f (formerly welsh)	0/10	0/20	0/20	0/20	0/20	0/20	0/50	0/60
O.K.I. - f	0/10	1/20	0/20	0/20			0/30	1/40
Pulmosan - f	4/10	10/20	4/20	13/20	3/20	13/20	11/50	36/60
Sellstrom - f					2/20	4/20	2/20	4/20
Thermacote - f					4/20	4/20	4/20	4/20
Union Carbide - f	0/10	0/20	0/20	0/20			0/30	0/40
U.S. Safety - f	0/10	0/20	0/20	0/20			0/30	0/40
U.S. Safety - c	0/10	0/20	0/20	0/20	0/20	0/20	0/50	0/60
Willson - f	2/20	1/40	0/40	0/40	0/20	0/20	2/80	1/100

Data Format: #failing/#tested *f=flat glass p=flat plastic c=curved glass

* U.S. GOVERNMENT PRINTING OFFICE: 1979-657-061/5802

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