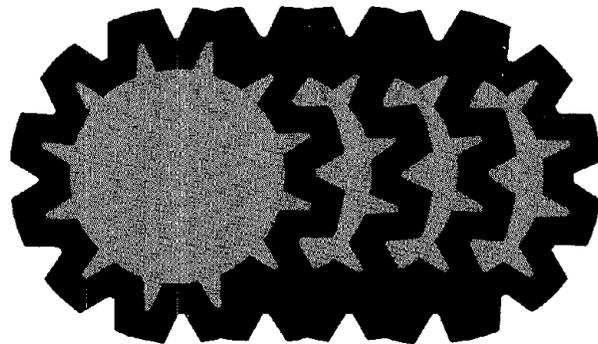


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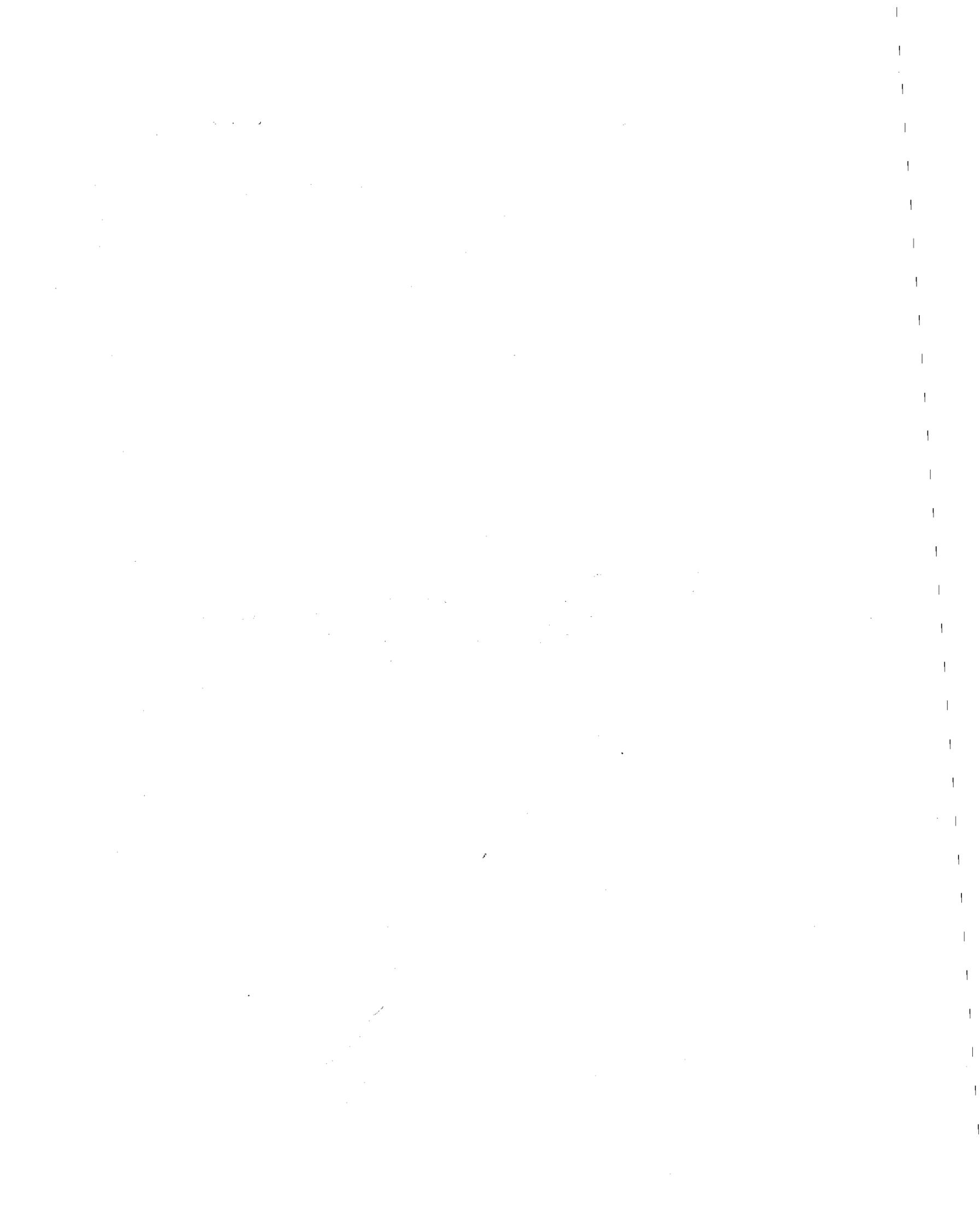
**TECHNICAL INFORMATION**

## **A REPORT ON THE PERFORMANCE OF FIREFIGHTERS' HELMETS**



**U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE / Public Health Service**  
**Center For Disease Control / National Institute For Occupational Safety And Health**

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#### ABSTRACT

Samples of 8 models of firefighters' helmets were purchased by the National Institute for Occupational Safety and Health (NIOSH). These helmets were evaluated and tested for conformance to American National Standards Institute (ANSI) Standard Z89.1-1969.<sup>1</sup> The impact tests were performed using both the standard method and an electronic force measurement system. The two force measurement methods were compared. Four of the 8 models tested were in conformance with ANSI Z89.1-1969 performance requirements.

The contributions of William G. Fletcher and James R. Love, the technicians who performed the tests, and Ruth B. Linn, who typed the report, are gratefully acknowledged.

## INTRODUCTION

In addition to its certification program, the National Institute for Occupational Safety and Health (NIOSH) Testing and Certification Branch (TCB) of the Appalachian Laboratory for Occupational Safety and Health (ALOSH) in Morgantown, West Virginia is working to develop a body of technical information concerning personal protective devices offered for use by United States industry. In addition to the data on firefighters' helmets presented in this report, TCB is presently collecting data on safety toe shoes, industrial safety helmets, eye and face protective devices, and lineman's rubber gloves.

Sections 1910.132 and 1910.135 of the Occupational Safety and Health Standards (29 CFR 1910)<sup>2</sup> require the use of helmets conforming with ANSI Z89.1 by persons exposed to conditions capable of causing head injuries. TCB conducted a survey of many of the available fire fighters' helmets to determine the extent of their conformance with ANSI Z89.1. Two of the helmet models tested were not advertised as complying with ANSI Z89.1, but are being marketed for use by fire fighters.



## SELECTION AND TESTING

### Selection

A list of available models of firefighters' helmets was compiled from catalogs furnished by suppliers listed in Best's Safety Directory<sup>3</sup> and from advertisements in safety periodicals. Twelve models were identified and nine were ordered. All models advertised as meeting the requirements of ANSI Z89.1 were ordered and tested, and two models for which conformance to the requirements of ANSI Z89.1 was not claimed were also ordered and tested.

Orders for helmets were placed with manufacturers or manufacturer's representatives during August, 1975. Sixty specimens of each of those models advertised as meeting ANSI Z89.1 and twenty specimens of each of the other models were ordered.

### Examination and Tests

The following is a summary of the examinations and tests which were performed on the selected helmets, in accordance with ANSI Z89.1:

1. Check-in examination - The characteristics examined were component construction, suspension adjustment instructions, crown clearance, and size range and adjustment.
2. Weight - Ten specimens were weighed and the average weight was reported.
3. Penetration - A 1-pound penetrator with a 35° tip angle was

dropped from 10 feet above the helmets. The depth of penetration perpendicular to the helmet shell was measured, and the average for ten helmets reported.

4. Impact - An 8-pound steel shot was dropped from 5 feet above the helmets. The ball, headform, and force measurement device were center aligned by means of a plumb bob. The force transmitted through the helmets was measured for all models by use of an electronic force measurement system (described in Appendix A). Specimens from those models advertised as meeting the requirements of ANSI Z89.1 were also tested using the Brinell force measurement system specified in ANSI Z89.1. Tests were performed on specimens conditioned at 0° F and 120° F. No specimen from any model was impacted more than once.
5. Water absorption - Ten helmet shells were conditioned at 120° F for 4 hours, weighed, soaked in tap water for 24 hours, towel dried, and reweighed. The average percentage of water absorbed was reported.
6. Insulation resistance - Ten helmet shells were subjected to 2200 volts AC and the average leakage current was reported.
7. Flammability - Ten specimens cut from helmet shells were tested using the procedure of the American Society for Testing and Materials (ASTM) Standard D635-74. The metal cabinet inside the laboratory hood, indicated as optional by ASTM, was not used. The average time of burning and average extent of burning were reported.

A flow chart indicating the sequence of testing is presented in Figure 1.

#### Test Methods and Equipment

Requirements and tests described in ANSI Z89.1 are the performance standard recognized by OSHA for firefighters' helmets. There are, however, a few specifications in ANSI Z89.1 which are subject to varying interpretations. The methods used by TCB for these specifications are discussed below along with the discussion of the electronic force measurement system used for most of the impact tests.

The impact resistance test requires that an 8-pound ball be dropped onto the helmets from a height of 5 feet. TCB used an 8-pound shot dropped in free fall from an electromagnet. ANSI Z89.1 requires use of aluminum bars as force transducers. The Brinell formula was used to calculate the force transmitted through the helmet to the aluminum bars during impact when the Brinell system described in ANSI Z89.1 was used. The aluminum bars are required to have an average Brinell hardness of between 21 and 24. The standard does not, however, impose any requirements on the allowable variation in the hardness of individual bars. TCB established a maximum allowable variation of 0.88 Brinell units between the two ends of a bar 7 inches long. A variation of that amount will limit the error due to hardness variations to less than 2.5 percent. Twenty helmets from each model advertised as meeting the requirements of ANSI Z89.1 were tested using this method.

A second set of impact tests was performed using the load cell measurement system described in Appendix A. Forty helmets from models advertised as meeting ANSI Z89.1 and 20 helmets from the other two models were tested using this method.

It should be noted that ANSI Z89.1 performance levels in the impact test were not modified. The modification was only in the method of measuring the force transmitted through the helmet.

ANSI Z89.1 requires use of a penetrator with an included tip angle of 35° and weighing 1 pound, but does not specify the method of drop. The penetrator used by TCB was dropped through a guide tube from 10 feet above the helmet being tested. The depth of penetration was measured perpendicular to the helmet shell.

The method of orienting flammability specimens is not specified in ANSI Z89.1 and the flammability standard<sup>4</sup> specifies use of flat specimens. Since it was impossible to obtain flat specimens from the helmets, flammability specimens were positioned with the concave side facing downward at a 45° angle from horizontal with the ends of the specimen about 10 mm above the gauze.

## RESULTS

The ANSI Z89.1 tests were divided into two classifications for analysis. The first classification is comprised of those tests which result in measurements on a continuous scale (Impact Resistance, Penetration Resistance, Insulation Resistance, and Water Absorption). The second classification is comprised of all other tests.

The results of all tests in the first classification were subjected to a pass/fail analysis in which the test results were statistically tested for conformance with the requirements of ANSI Z89.1. The statistical analysis procedure used is described in Appendix B. The results of tests in the second classification were not subjected to the statistical test.

The statistical test used for analysis of test results in the first classification assumes that the model being examined fails to satisfy the requirements of ANSI Z89.1 until conformance with the standard is proven.

The tables of test results (Tables 2 through 5) indicate whether the model in question was judged as passing (P), failing (F), or questionable (Q) when compared with requirements of the ANSI standard. A discussion of criteria used to judge results for a model as questionable may be found in the description of indifference intervals in Appendix B.

### Summary of Results

There were two models tested which did not claim conformance with the requirements of ANSI Z89.1. Results of the tests on these two models (American Sport 1000 and Federal FH-2) are presented in the tables, but no indication of the performance rating for the test is made. Some of these tests were not applicable to these helmets since they are of a design similar to that of vehicular helmets. Because of their design, these helmets do not comply with several of the requirements of the standard. The following analysis of the test data does not include either of these models. Results of some of the tests on these helmets are discussed later in this report.

About 67 percent of the models satisfied all the performance related criteria of ANSI Z89.1, and 50 percent of the models satisfied all the requirements of the standard.

### Impact Resistance

As indicated in Table 7, TCB's Brinell test system produces transmitted force measurements which are  $117.2 \pm 27.2$  pounds higher than those obtained by the use of the load cell system. An examination of the standard deviations in Tables 2a through 2d shows that those obtained from measurements taken on the Brinell system are, on the average, about 22 percent higher than those obtained from measurements taken on the load cell system. As is indicated in Appendix A, the total inaccuracy of the load cell system is less than 2.5 percent. Therefore, most of the variance in the Brinell data can

probably be attributed to the unrepeatability and inaccuracy of the Brinell system although some data variance is attributable to the fact that a relatively small number of specimens were tested.

Most models advertised as meeting ANSI Z89.1 satisfied those requirements when the data from the load cell tests was examined. Data from the Brinell tests, however, indicate that only one model could be reported as satisfying the ANSI requirements. If the load cell results are adjusted by the amount identified as the difference between test methods, only one model could be reported as satisfying the ANSI requirements.

As is evident, the two force measurement systems yield significantly different results. It is commonly believed that most of the difference is due to the use of a static force measurement system (the Brinell system) to measure a dynamic event. While the load cell system measures the actual peak transmitted force, the Brinell system seems to measure an "integrated" (and consequently higher) transmitted force. There is some evidence which indicates that the impression ball in the Brinell system actually strikes the aluminum bar several times during impact, thus contributing to the higher "integrated" force measurement.

The Brinell system problems described above indicate that the load cell system is more accurate for measurements of peak transmitted force. Therefore, it was decided to evaluate the helmets using the data from the load cell impacts. The Brinell test data are presented only for comparison.

#### Insulation Resistance

All models tested were found to satisfy the requirements.

#### Penetration Resistance

All models satisfied the ANSI criteria. In fact, the average depth of penetration was only about 35 percent of the depth allowed by the standard.

#### Flammability

All models were self-extinguishing as required by the standard. That is, the flame did not burn the entire length of the specimens.

#### Size Range and Marking

The MSA Topguard 454698 had the required size range but not the headband adjustment markings. In this model, the headband is adjusted to size by counting the adjustment holes, a technique that could be confusing. This is considered to be a non-performance characteristic.

#### Suspension Adjustment Instructions

The National Safety Supply 800 was the only model furnished without instructions. This is considered to be a non-performance characteristic.

#### Crown Clearance

All models had sufficient crown clearance to satisfy the requirements of the standard.

### Water Absorption

All models satisfied the requirements of the standard. In fact, none of the models absorbed more than 18 percent of the allowable amount of water. Different shell materials and variations in the amount of label and foam rubber residue on the shells resulted in the wide differences in percent water absorbed by the various models.

### Weight

All models satisfied the requirements of the standard.



## OBSERVATIONS

There were two helmet models (National Safety Supply 800 and Cairns 770) which failed to satisfy the impact performance requirements because of what appeared to be quality control problems. The suspension stitching broke on one of the National Safety Supply 800 helmets. One of the Cairns 770 helmets had the suspension assembled improperly (the crown straps were not crossed).

The wide range of standard deviations in test results indicates that tighter controls on product variability are possible. In most cases, however, the variability within a given model is not sufficient to make it difficult to satisfy requirements of the standard when testing is performed on the load cell system.

The load cell impact test system is less subject to error than the Brinell system and capable of more repeatable results. This is evidenced by the fact that, on the average, standard deviations obtained through load cell testing are much lower than those obtained through Brinell testing of apparently identical helmets within a given model.

The two models not claiming conformance to Z89.1 transmit about twice as much force as current Z89.1 helmets transmit during a 40 foot-pound apex impact. These two models have protective padding extending down the inside of the shell which apparently offers some protection from side impacts (probably not available from current Z89.1 helmets).

There have been reports from firefighters that some thermoplastic helmets have melted while on their heads in actual fire fighting conditions. This seems to be due to the high temperature characteristics of thermoplastics. Polycarbonate, which is considered to have "Good" high temperature strength, is limited to exposures of about 250° F. A man dressed in a flight suit, on the other hand, can withstand temperatures of 300° F for several minutes and 400° F for several seconds without injury.<sup>5</sup> Since a firefighter's turnout gear provides quite a bit of thermal insulation, he should also be able to tolerate the above exposures. This situation then becomes something of a paradox. The firefighter's helmet, which is supposed to protect him from the environment, may succumb to the environment and become the injury causing agent. An increase in conditioning temperature appears to be justified.

## CONCLUSIONS AND RECOMMENDATIONS

Since the load cell system is more accurate and repeatable and more easily specified than the Brinell system, its adoption would be expected to result in more consistent test results between laboratories than is possible with the Brinell system. It is therefore recommended that the Brinell system be replaced by the load cell system, or a similar system, for impact testing.

It appears that at least some companies have quality control problems which need to be more closely monitored. The user should closely examine new helmets for any assembly errors or obvious defects.

Based on available information concerning the characteristics of plastics at temperatures in the vicinity of 300° F, it is recommended that users expecting to work in such environments require impact testing on helmets conditioned at a temperature of at least 300° F for at least 3 minutes.<sup>6</sup>

As discussed earlier, TCB found it necessary to further define several of the ANSI tests. The specific tests involved were flammability, penetration, insulation resistance, and impact. Further definition of those tests needs to be made in the testing standard.

Three of the six helmets advertised as meeting requirements of ANSI Z89.1 fall short in one respect or another. In two of the three cases, quality control problems appear to be responsible at least in part for failure of those models. The other failure was the result of non-conformance to a non-performance criteria.

#### REFERENCES

- 1 "American National Standard Safety Requirements for Industrial Head Protection". American National Standards Institute, 1430 Broadway New York, NY 10018. Standard No. Z89.1-1969. 1969. 15p.
- 2 "Occupational Safety and Health Standards". Department of Labor, Occupational Safety and Health Administration, Washington, DC. Standard 29CFR1910. June 17, 1974. 343p.
- 3 Best's Safety Directory. Morristown, NJ. A. M. Best Company. 1975. p. 57.
- 4 "Standard Method of Test for Flammability of Self Supporting Plastics," American Society for Testing and Materials. 1916 Race St., Philadelphia, PA 19103. Standard No. D635-74. 1974. 4p.
- 5 Occupational Safety and Research Specifically Related to Personal Protection. National Institute for Occupational Safety and Health, Office of Extramural Activities, Cincinnati, Ohio 45202. May 1975. 236p.
- 6 "Development of Criteria for Industrial and Firefighters' Head Protective Devices," National Institute for Occupational Safety and Health, Division of Laboratories and Criteria Development, Cincinnati, Ohio 45202. January 1975. p. 66.
- 7 Experimental Statistics, NBS Handbook No. 91. U. S. Government Printing Office, Washington, DC 20402. August, 1963.



#### APPENDIX A

The load cell force measurement system used for most of the impact resistance tests utilized the following equipment:

1. Quartz piezoelectric load cell, Kistler Model 907A.
2. Charge amplifier, Kistler model 593A.
3. Peak meter indicator, Kistler model 538A.
4. Bandwidth limiting filter, Kistler model 545A17.
5. Digital panel meter, Digitec model 277-3.
6. Oscilloscope, Tektronix model R564B with model 3B3 and 3A6 plug-ins.

The overall accuracy of the primary measurement system (items 1 through 5) is  $\pm 2.5$  percent. Item 6 was used to provide photographic records of impacts for which an abnormality was noticed either in the oscilloscope display or in the helmet. In one instance it was used to obtain an estimate of the peak force transmitted when the helmet bottomed against the headform.

In order to simulate the Brinell test system as closely as possible, a ball dropped from an electromagnet was used as opposed to a guided drop mass. The backup mass for the load cell-headform assembly consisted of a poured concrete slab imbedded in the ground and surfaced with a one inch steel plate. The sensitive axis of the load cell, the headform, and the electromagnet were all center-aligned by means of a plumb bob and the load cell-headform assembly was clamped in position to eliminate shifting in position and "ringing" in the load cell output.

The primary measurement system was checked for accuracy before and after the test series by the use of a 12,000 pound capacity compression tester which has an accuracy of better than 0.5 percent.

## APPENDIX B

The statistical test used in this report was the Student t test of a hypotheses on a mean. The method of application of this test is well recognized and can be found in most books dealing with statistical methods. The null and alternative hypotheses ( $H_0$  and  $H_a$  respectively) were chosen to correspond to the position taken by a consumer who questions the performance of a given helmet model until that performance is proven at a chosen level of confidence. That is, the helmet is assumed to be failing unless proven otherwise. This assumption results in hypotheses of the form

$$H : m \geq m_0$$

$$H_a : m < m_0$$

where  $m_0$  is the maximum average value allowed for that test and  $m$  is the average value which would be measured for a given helmet model if an infinitely large number of helmets were tested. The above choice of  $H_0$  and  $H_a$  corresponds to the null hypothesis representing failure of the helmet to satisfy the requirements of ANSI Z89.1 while the alternative hypothesis corresponds to satisfaction of those requirements.

The test of the hypothesis  $H_0: m \geq m_0$  is based on the statistic

$$T = \frac{\bar{X} - m_0}{s/\sqrt{n}}$$

where  $\bar{X}$  is the measured average value for a given helmet model,  $n$  is the

sample size and  $s$  is the sample standard deviation calculated from the formula

$$s^2 = \frac{n \sum (X_i)^2 - (\sum X_i)^2}{n(n-1)}$$

where  $X_i$  represents the test result for an individual helmet from the model being evaluated.

The statistical tests used in this report were performed at a 95 percent confidence level ( $\alpha = 0.05$ ) and with 95 percent probability of detecting a difference of the magnitude specified below in the discussion of the indifference interval ( $\beta = 0.05$ ). Further discussion of the test method used and tabulated values of the  $t$  distribution can be found in Section 3 and Table A-4 of reference 7.

Use of the  $t$  statistic results in acceptance of the alternative hypothesis if the calculated value of  $T$  satisfies the relationship

$$T < -t_{\alpha, n-1}$$

where  $t_{\alpha, n-1}$  is the tabulated value of  $t$  at the chosen level of significance. Values of  $t$  not satisfying the above relationship result in acceptance of the null hypothesis, and thus a report that the helmet model failed to satisfy the requirements of ANSI Z89.1.

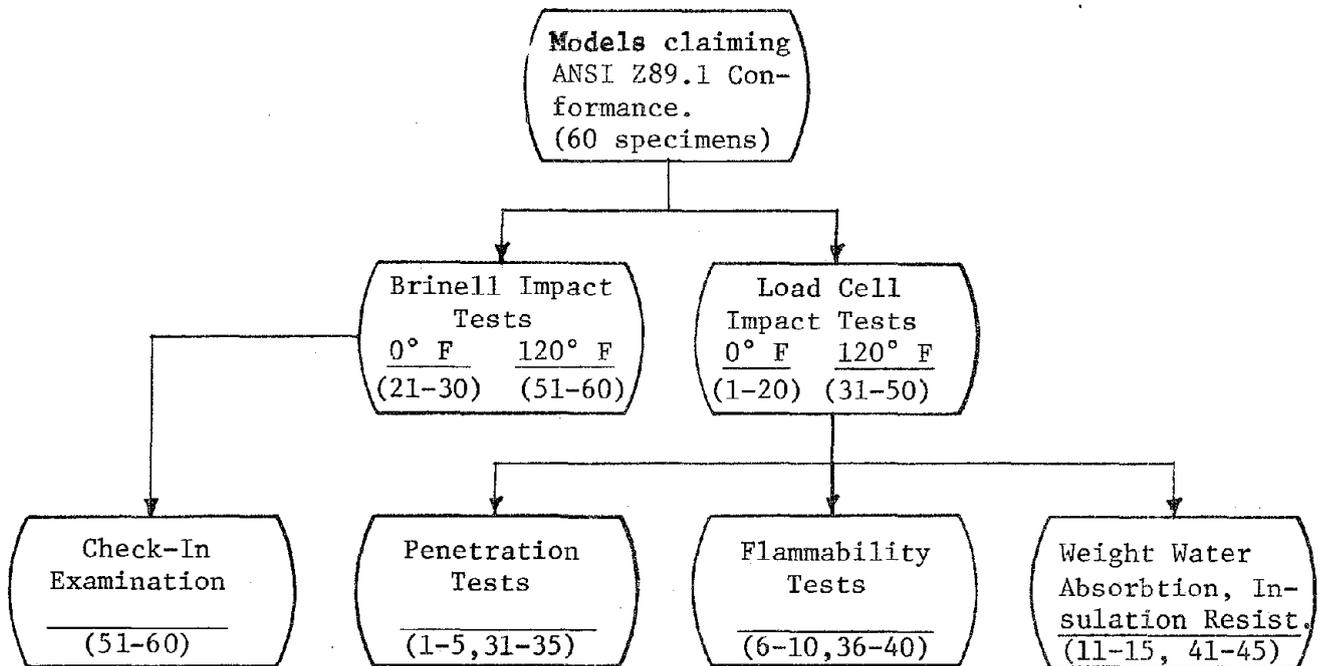
The sample sizes used allow detection of negative differences of reasonable magnitudes at least 95 percent of the time between the mean value of the model being tested and the value specified by ANSI Z89.1 for each test being evaluated. Differences as small as 0.80 times the standard

deviation for the tests in which a sample size of 20 was used, and 1.07 times the standard deviation for tests in which a sample size of 10 was used, can be detected.

In those cases in which the difference between the measured mean and the required mean is not at least as great as stated, the model is reported as questionable (Q) since its mean value lies in the indifference interval.

The indifference interval is defined as the region  $-0.80 < D < 0.80$  for a sample size of 20 and  $-1.07 < D < 1.07$  for a sample size of 10 where D is defined as

$$D = \frac{\text{measured mean} - \text{required mean}}{\text{sample standard deviation}} .$$



Note: Numbers in parentheses are the specimen numbers used in that test.

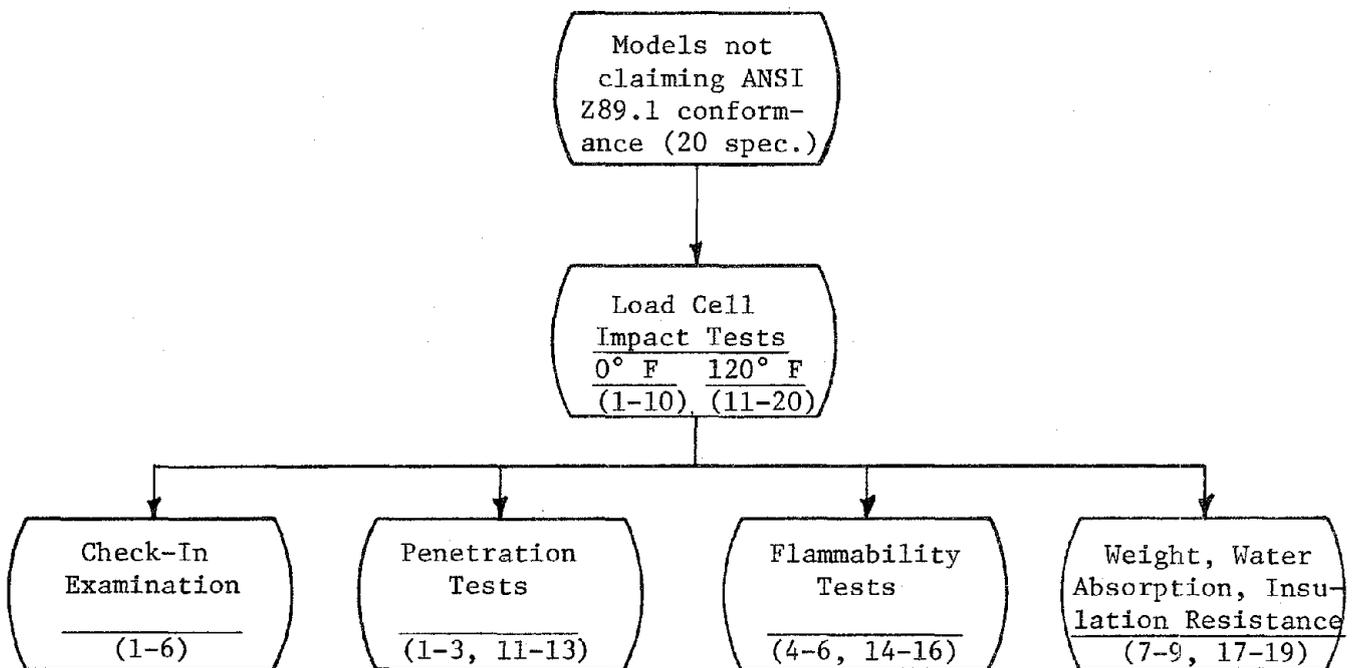


Figure 1: Testing flowchart for firefighters' helmets.



American Sport Co.  
1000



E. D. Bullard Co.  
503A



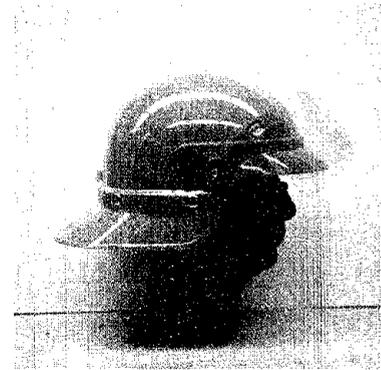
E. D. Bullard Co  
1003E



Cairns & Bros., Inc.  
770



Cairns & Bros., Inc.  
880



Federal Sign & Signal  
Corp. FH-2



MSA 454698



National Safety  
Supply Co. 800

Figure 2: Photographs of firefighters' helmets tested.

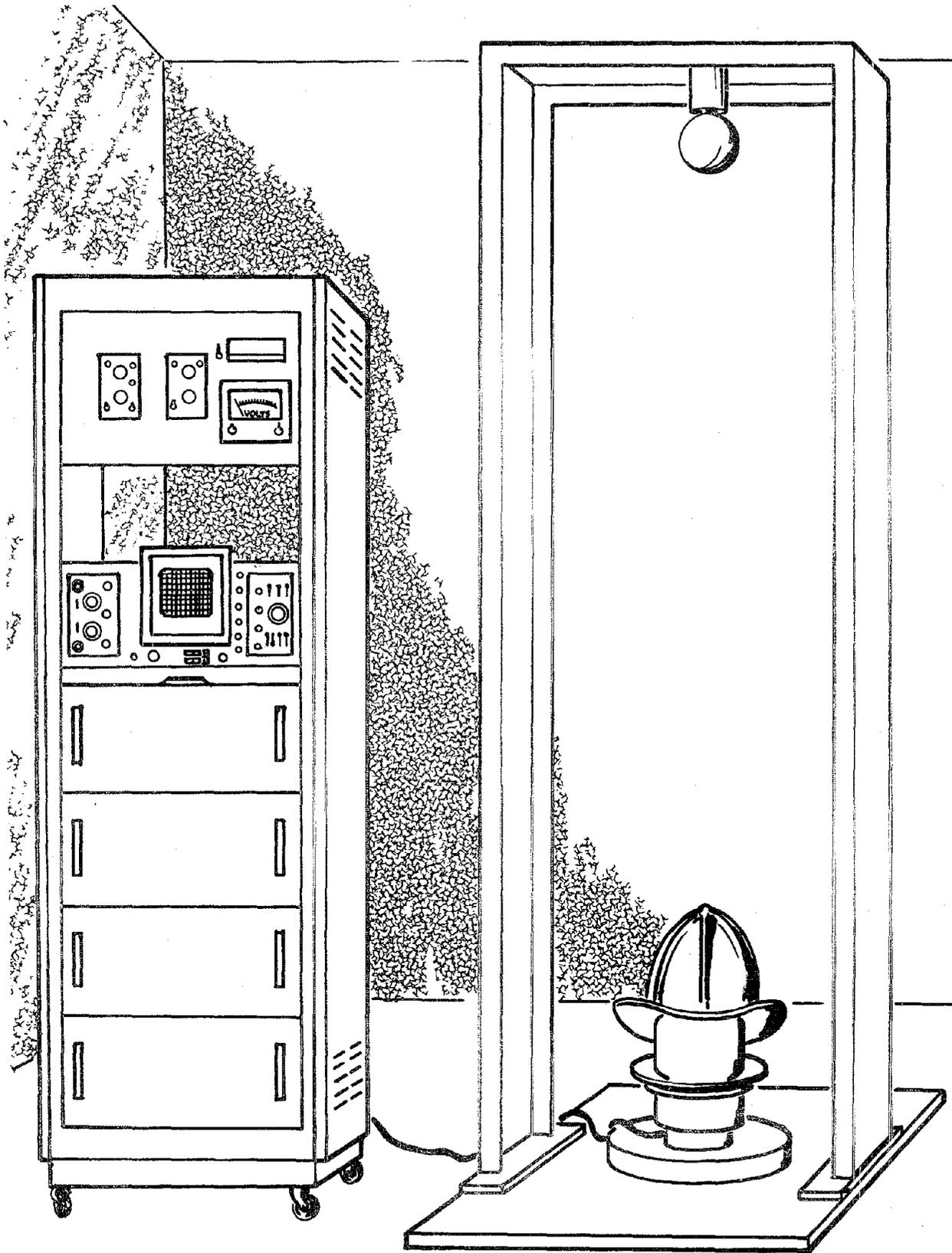


Figure 3. Representation of load cell impact test system.

Table 1: ANSI Z89.1-1969 requirements for Class D firefighters' helmets.

Test	Requirements
Impact Resistance	The average force at each test temperature must not be greater than 850 pounds with no individual force exceeding 1000 pounds.
Insulation Resistance	The average leakage current at an applied potential of 2.2 KV-AC must not exceed 3 milliamperes.
Penetration Resistance	The average depth of penetration must not exceed 9.5 millimeters.
Flammability	The thinnest section of the shell must be self extinguishing.
Component Construction	The shell must have a continuous brim at least 1 1/4 inches wide; a sweatband must be provided; the shell must be marked to indicate the manufacturer and ANSI classification.
Size Range and Marking	The headbands must be adjustable in 1/8 size increments; size range and adjustment must be permanently marked on the headbands.
Suspension Adjustment Instructions.	Instructions must be supplied with each helmet.
Crown Clearance	The clearance must be at least 1.00 inch.
Weight	No complete helmet can exceed 850 grams.
Water Absorption	The shell must not absorb more than 5.0 percent water.

Table 2a: Results of load cell impact tests on firefighters' helmets conditioned at 0° F.

Mfr./Model	Ave. Force	Max. Force	No. 1000#	s*	D*	t*	n*	P/F/Q*
American Sport** 1000	1813.5	2065	10	167.30	5.76	18.21	10	+
Bullard 503A	765.6	903	0	78.64	-1.07	-4.80	20	P
1003E	685.5	841	0	78.53	-2.09	-9.37	20	P
Cairns 770	817.6	911	0	95.52	-0.34	-1.52	20	Q
880	779.3	830	0	37.36	-1.89	-8.47	20	P
Federal FH-2**	1480.4	1706	10	83.41	7.56	23.90	10	+
MSA 454698	730.4	827	0	82.70	-1.45	-6.31	19	P
National Safety Supply 800	730.4	702	0	69.29	-3.68	-16.45	20	P

\* See Appendix B

\*\*Not advertised as meeting ANSI Z89.1.

+ Not applicable.

Table 2b: Results of load cell impact tests on firefighters' helmets conditioned at 120° F.

Mfr./Model	Ave. Force	Max. Force	No. 1000#	s*	D*	t*	n*	P/F/Q*
American Sport** 1000	1503.6	1590	9	59.23	11.03	33.10	9	+
Bullard 503A	619.3	712	0	61.07	-3.78	-16.90	20	P
1003E	642.1	751	0	60.95	-3.41	-15.25	20	P
Cairns 770	757.2	2100++	1	317.07	-0.29	-1.31	20	F
880	646.5	671	0	19.78	-10.29	-44.85	19	P
Federal FH-2**	1967.3	2325	10	275.11	4.06	12.84	10	+
MSA 454698	672.0	694	0	14.95	-11.91	-53.26	20	P
National Safety Supply 800	565.9	1274+++	1	182.21	-1.56	-6.61	18	F

\* See Appendix B

\*\*Not advertised as meeting ANSI Z89.1

+ Not applicable.

++Suspension stitching broke.

+++Suspension assembled improperly.

Table 2c: Results of Brinell impact tests on firefighters' helmets conditioned at 0° F.

Mfr./Model	Ave. Force	Max. Force	No. 1000#	s*	D*	t*	n*	P/F/Q*
American Sport** 1000	-----	-----	-----	-----	-----	-----	-----	-----
Bullard 503A	903.8	1311	1	147.04	0.37	1.16	10	F
1003E	895.3	991	0	61.02	0.74	2.35	10	Q
Cairns 770	882.7	1200	1	125.28	0.26	0.83	10	F
880	810.3	912	0	40.16	-0.99	-3.13	10	Q
Federal FH-2**	-----	-----	-----	-----	-----	-----	-----	-----
MSA 454698	809.6	893	0	62.35	-0.65	-1.95	9	Q
National Safety Supply 800	630.2	718	0	67.52	-3.26	-9.77	9	P

\* See Appendix B

\*\*Not advertised as meeting ANSI Z89.1.

Table 2d: Results of Brinell impact tests on firefighters' helmets conditioned at 120° F.

Mfr./Model	Ave. Force	Max. Force	No. 1000#	s*	D*	t*	n*	P/F/Q*
American Sport** 1000	-----	-----	-----	-----	-----	-----	-----	-----
Bullard 503A	857.2	1248	1	145.98	0.05	0.16	10	F
1003E	919.9	1446	1	189.28	0.37	1.17	10	F
Cairns 770	767.0	1413	1	229.90	-0.36	-1.14	10	F
880	714.7	763	0	34.97	-3.87	-12.24	10	P
Federal FH-2**	-----	-----	-----	-----	-----	-----	-----	-----
MSA 454698	758.6	918	0	102.20	-0.89	-2.68	9	Q
National Safety Supply 800	580.1	780	0	129.44	-2.09	-6.57	10	P

\* See Appendix B

\*\*Not advertised as meeting ANSI Z89.1.

Table 3: Results of insulation resistance, penetration resistance, and flammability tests on firefighters' helmets.

Mfr./Model	Insulation Resist.		Penetration		Flammability		
	proof current, ma	P/F/Q*	ave. depth, mm	P/F/Q*	ave.extent of burning, mm	ave.time of burning, sec.	P/F/Q*
American Sport 1000	0.47	+	3.98	+	burned at 2.39 cm/min		+
Bullard 503A	0.90	P	3.00	P	40.2	114.5	P
1003E	0.78	P	7.35	P	22.1	73.7	P
Cairns 770	0.49	P	2.65	P	13.0	29.3	P
880	0.53	P	2.83	P	8.1	26.0	P
Federal FH-2	0	+	2.63	+	18.4	37.4	+
MSA 454698	0.75	P	3.20	P	11.9	12.4	P
National Safety Supply 800	0.65	P	2.53	P	14.0	17.9	P

\* See Appendix B

+ Not advertised as meeting ANSI Z89.1.

Table 4: Results of check-in inspection, weight, and water absorption tests on firefighters' helmets.

	Check-in Inspection			Crown Clearance		Ave. Weight		Ave. Water Absorb.	
	Component Construction	Size Range & Marking	Susp. Adj. Instr.	in.	P/F	gm.	P/F	%	P/F
	P/F	P/F	P/F						
American Sport 1000	*	*	*	_____	*	836.1	*		*
Bullard 503A	P	P	P	1 3/16	P	463.3	P	0.44	P
1003E	P	P	P	1 1/2	P	640.1	P	0.62	P
Cairns 770	P	P	P	1 1/4	P	834.1	P	0.87	P
880	P	P	P	1 1/2	P	768.7	P	0.05	P
Federal FH-2	*	*	*	_____	*	1293.4	*	_____	*
MSA 454698	P	F**	P	1 1/2	P	456.5	P	0.13	P
National Safety Supply 800	P	P	F	1 3/8	P	501.5	P	0.19	P

\* Not advertised as meeting ANSI Z89.1.

\*\*Size adjustment not marked on the headband.

Table 5: Summary of results of tests on firefighters' helmets by model.

Mfr./Model	Number of tests passed*	Number of performance tests passed**	Overall rating P/F/Q+
American Sport 1000	9	6	++
Bullard 503A	11	8	P
1003E	11	8	P
Cairns 770	9	6	F
880	11	8	P
Federal FH-2	8	6	++
MSA 454698	10	8	P
National Safety Supply 800	9	7	F

\* Eleven tests were performed on the devices. Brinell impact test (Tables 2c and 2d not included.)

\*\* Eight tests were considered to be performance tests. Brinell impact tests not included.

+ See Appendix B.

++ Not advertised as meeting ANSI Z89.1.



Table 7: Comparison of load cell and Brinell test methods on Class D firefighters' helmets.+

Test	n*	load cell system (lbs.)	Brinell system (lbs.)	average difference (lbs.)	95% confidence band** (lbs.)
0°F impact	56	718.6	825.5	106.9	+33.8
120°F impact	58	627.8	756.4	128.6	+42.9
0°F and 120°F impact	114	627.8	791.4	117.3	+27.2

\* Number of paired data points.

\*\*Defined as  $\pm Ks$  where  $s$  is the standard deviation of the observed differences of the data pairs and  $K$  is chosen such that there is 95 percent confidence that the true average difference lies within this range.

+ The two helmets with suspension failures (one Cairns 770 and one National Safety Supply 800) not included.