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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

The report describes tests of flexible fitting safety goggles advertised as meeting the requirements of the ANSI Z87.1 Standard. An attempt was made to include all models currently available in the United States having clear lenses and direct ventilation. A general description of each test is included along with a discussion of the test results. Fifty individual models were tested. Several variations from the requirements of the standard were noted. The majority of these variations were minor in that they do not relate directly to the safety of the user. There were no failures in the more important impact and penetration tests. A potential hazard associated with eye exposure is discussed.

# INTRODUCTION

Flexible fitting goggles with direct ventilation are intended to protect the wearer's eyes, eye sockets, and adjacent facial area from particles and flying objects, such as those encountered in chipping, grinding, and machining operations. The Occupational Safety and Health Act of 1970[1] requires that such devices be used in certain industrial situations and that they comply with the American National Standards Institute's standard Z87.1-1968.[2] This report describes a testing program to determine the extent to which goggles currently available in the United States comply with that standard.

In addition to its certification program, the Testing and Certification Branch is developing a body of technical information concerning personal protective devices currently available to the industrial worker. These devices include 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.

## SELECTION OF DEVICES

This program was designed to test all models of flexible fitting safety goggles available in the United States and advertised as being in compliance with the ANSI Z87.1 standard.

Flexible fitting safety goggles are available with either clear or tinted lenses and with direct or indirect ventilation. In order to standardize the testing program, we elected to test only the direct ventilation, clear lens version of each model. An attempt was made to identify and purchase all currently available models. If a particular model was not tested, we were either unaware of the existence of that model or unable to obtain it in time for testing. Also not included were models which were, as indicated in manufacturers' literature, simple recombinations of lenses and frames already included in the testing program.

# TESTING PROGRAM

The requirements and tests of this program are those of the ANSI Z87.1-1968 standard. Many of these tests are subject to a variety of interpretations, and often a choice of several different test methods is possible. In these situations we chose the test procedure that yielded the most meaningful results--both in terms of accuracy and in terms of safety to the user. We worked exclusively within the ANSI standard and did not evaluate or modify the requirements of that standard.

Twelve individual goggles of each model were purchased and tested. The tests were conducted in the sequence indicated by the "Testing Flow Chart" presented in Figure 1. This test sequence was designed to maximize the number of goggles available for each test, while also eliminating possible interference between two or more tests.

## Performance Tests

### Impact and Penetration

The primary function of a goggle is to protect the eye from the hazard of flying projectiles. The impact and penetration tests relate directly to this function and are, therefore, of primary importance.

The impact test was conducted by mounting the goggle on a horizontally positioned headform and impacting each lens with a 1.00 inch steel ball, weighing 2.4 ounces, dropped from a height of 50 inches onto the approximate center of the lens surface. If the lens was cracked in any way or dislodged from any part of the frame it was considered to have failed.

The penetration test was conducted by mounting the goggle on a headform and dropping a dart, consisting of a Singer number twenty-five needle attached to a 1.56 ounce steel body, from a height of 50 inches onto the horizontal surface of the lens. If a lens was cracked, dislodged, or pierced through its inner surface, it was considered to have failed.

Ten lenses, the left and right lens of 5 goggles, were subjected to the impact test. Ten different lenses were similarly subjected to the penetration test.

In both tests the failure of a single lens was considered sufficient reason to fail the model.

<u>Haze and Luminous Transmittance</u>

Clear safety goggle lenses are required to transmit at least 89 percent of the incident visible light and exhibit not more than 6 percent haze. Haze represents light that is not transmitted directly through the lens but instead is scattered in other directions by impurities in the lens material or irregularities on the lens surface.

Four lenses, the left and right lenses of 2 goggles, were tested for both haze and transmittance with a Gardner model UX-10 hazemeter having a model PG-5500 digital readout. Procedure A and light source A of the ASTM test method D1003-61T were used.[3]

The haze and luminous transmittance for each model was calculated by averaging the four individual results and rounding to the nearest 0.1 percent.

Flammability

Plastic materials used in the construction of flexible fitting goggles may not burn faster than 1.06 mm/sec. Since the ANSI Z87.1 Standard does not specify all of the details needed for testing, additional information was obtained from ASTM test method D635-72, Standard Method of Test for Flammability of Self-Supporting Plastics.[4] Consequently, this phase of testing was conducted according to the ASTM method with modifications to comply with the ANSI Z87.1 Standard and to accommodate the irregular sample shapes. These modifications included the use of a 3/4" high Bunsen burner flame and a ten-second ignition time.

Two 70 mm x 12.7 mm samples were cut from each frame and from each window. Samples were cut from the thinnest part of each component, and care was taken to avoid uneven portions. A line was scribed across each sample 50 mm from one end.

Each sample was tested by placing the end nearest the scribed line in a ring stand clamp such that the sample's longitudinal axis was horizontal and the sample was approximately 10 mm above a 100 mm square, 20-mesh piece of wire gauze held by a second clamp. The sample was adjusted so that its free end was approximately 10 mm beyond the edge of the wire gauze and the scribed line was at least 10 mm from the clamp. Lens samples were positioned such that their widths were inclined 45° while the more flexible frame samples were positioned with their widths in a vertical plane.

Samples were ignited by holding the Bunsen burner at a 45° angle such that the tip of the flame just touched the lower edge of the sample for a period of ten seconds. A stopwatch was started when the flame contacted the sample, and the time required for the flame to reach the scribed line was recorded. If the sample ignited and burned to the scribed line, it was designated as burning, and a burn rate was computed. If the sample would not ignite, or if the flame went out before reaching the scribed line, the sample was classified as self-extinguishing.

Testing continued until five samples were classified the same. Then, this classification was recorded for the component. If the component was classified as burning, an average burning rate was calculated to determine if the component passed or failed. In addition, a statistical test, based on the student t distribution, was used to determine the level of confidence for each result.[5] If there was not at least 90 percent confidence in the pass/fail rating, the result was considered to be inconclusive. Components classified as self-extinguishing were considered passing.

Refractive Power

As used in this report, the term "refractive power test" includes four individual optical tests: the prismatic power test, the spherical power test, the cylindrical power test, and the definition test. The prismatic power test measures the extent to which the lens acts as a prism and optically displaces the object being viewed. The prismatic effect is most serious when this displacement is different for each of the two eyes. This "prismatic imbalance" is disturbing since the left eye and the right eye must each "look" in slightly different directions to focus on an object. The human visual system can easily adjust to slight amounts of prismatic imbalance. The

ANSI standard limits the prism to a maximum of 1/16 diopter in any direction. This guarantees that the prismatic imbalance can never be greater than 1/8 diopter, an amount easily accommodated by most individuals. The spherical and cylindrical power considered in these tests corresponds to the spherical and cylindrical powers prescribed in corrective spectacles. Ideally, for any non-corrective lens, these powers should be zero. It is, of course, not possible to require every lens to be absolutely perfect, and a tolerance level must be established. The ANSI standard sets a tolerance of $\pm$ 1/16 diopter for both the spherical and cylindrical powers. As used in this report, spherical power refers to the maximum refractive power in any meridian, while the cylindrical power refers to the maximum difference in refractive power between any two meridians.

The ANSI definition test is apparently intended to be a measure of the extent to which the visual acuity of an individual is affected by the presence of the lens. (One, but not the only, method of expressing visual acuity is in the familiar opthalmic notation of "20/20" or "20/40.") The definition test is a "catch-all" in that it is sensitive to a multitude of optical defects: surface waves and distortion, scratches, haze, bubbles, inhomogeneity, etc.

These tests were performed basically as outlined in the NBS Special Publication 374.[6] Both the left and right lens of five goggles were evaluated for each model. Each test was conducted by viewing perpendicularly through each lens with a Gaertner model M522 11-power telescope having a 19 mm objective aperture and focusing on a target 35 ft. away. A plane mirror was used to fold the 35 ft. optical path for a more compact test system. The geometrical center of each lens was positioned on the optical axis of the telescope unless, by a simple visual observation, localized defects were present in the central viewing area of the lens. In this case the most severe localized defect was positioned on the telescope's optical axis. Defects within 1/2" of the lens edge were not considered.

The prismatic power test was conducted simply as a pass/fail test. If the field of view was displaced by more than 0.2625 inch, the prismatic power of the lens was greater than 1/16 diopter and the lens was considered to have failed. To eliminate possible error due to variation in the positioning of the observer's eye, all measurements were made only after parallax had been eliminated between the telescope's cross-hairs and the test target.

The spherical and cylindrical power tests were both conducted with a target composed of radial lines. By observing this radial target, an attempt was first made to identify the axis of cylinder for the lens. The refractive power was then measured both along and perpendicular to this axis. The largest of the two was the spherical power and the difference between the two was cylindrical power. To eliminate possible focussing error in these measurements, the telescope focussing was determined by the elimination of parallax.

The definition test was conducted according to a pass/fail criteria. In order to pass the test, the number 20 test pattern must have been resolved when viewing the NBS test target. Otherwise the lens was considered to have failed. The pattern was considered to be resolved when each of the three lines were individually distinguishable.

An additional note of background for the definition test is appropriate. The ANSI standard does not require the test to be performed by any particular method. However, one suggested method employs an 8 power telescope and requires the number 20 pattern to be "clearly resolved". This method is unfortunately quite subjective and consistent results are difficult to obtain from one observer to another. It has been our experience that the subjectivity of this test can be greatly reduced by using an 11-power telescope and requiring the individual pattern lines to be "individually distinguishable." This method may be slightly less severe than that employing the 8-power telescope; but, because of the subjectivity involved, a comparison is difficult.

Water Absorption

The ANSI Z87.1 standard specifies that plastic materials used in flexible fitting goggles may not absorb water in excess of 5 percent of the dry weight of the material. The lens and frame of each model were tested according to Federal Test Method Standard Number 406, Method 7031.[7] Samples were conditioned according to paragraph 4.1.1 and tested as outlined in Procedure A.

Two samples from each component, approximately 1" x 3", were conditioned at 50° C for 24 hours and weighed. The samples were then immersed in distilled water at 23° C for 24 hours and reweighed. The percentage of water absorbed was calculated from the two weights. Also included in the test was a correction to allow for water soluble material.

The percent of water absorbed for each component was calculated by averaging the results for the two samples. If the average was less than or equal to

3 percent, the component was marked passing; otherwise, two additional samples were tested and a new average was calculated from the four sample rates. The new average was then used to determine compliance or non-compliance with the 5 percent requirement.

Corrosion and Disinfection

Both the corrosion and the disinfection tests relate directly to the durability of the goggle. The corrosion test is a measure of the extent to which a device will be affected by the corrosive effects of its day-to-day use, while the disinfection test is a measure of the deterioration that may result from routine disinfection procedures.

The corrosion test consists of exposing the device to a salt spray (fog) for a period of 48 hours and then examining for corrosive effects. A Singleton model SCCH-21 corrosion test chamber, adjusted to the specifications of the ASTM B117-64 test method, was used to create the salt spray environment.[8]

Each goggle subjected to the disinfection test was thoroughly cleaned with soap and water, completely rinsed, dried, immersed in a disinfecting hypochlorite solution for 10 minutes, removed and allowed to air dry, and then examined for possible deterioration. The procedure was then repeated using a disinfecting phenol solution. The test was conducted at room temperature (24° C ± 6° C) with the solutions at the concentrations specified by their manufacturer.

If, at the completion of these tests, a goggle was totally usable, it was considered to have passed.

## Design Test

The ANSI standard for flexible fitting safety goggles establishes several design requirements including provision of a minimum lens thickness of 0.050 inches and a minimum angle of vision of 90°. In addition, the standard requires the devices to have flexible and comfortable frames, adjustable headbands, and provisions for protecting the eyes from direct exposure. Also, the manufacturer's marking must appear on both lens and frame. Each model was tested for compliance with these requirements and also to identify any design characteristic which could interfere with the wearer's safety. Several individuals were observed closely while wearing each model.

The ANSI requirement that goggles protect the user from direct exposure to the eyes was determined to be critically important. Failure of a model to provide this protection could seriously jeopardize the wearer's safety, and therefore each model was carefully scrutinized for deficiencies in this regard.

## TEST RESULTS

The results of the performance tests are summarized in Table 1, pages 27-31, and the design test results are summarized in Table 2, pages 32-35. The individual test results are discussed in the remainder of this section.

### Performance Tests

#### Impact and Penetration

All models passed both the impact and penetration tests. Not a single lens failure was observed in these important tests.

To obtain an estimate of the actual performance level of this group of goggles, both the impact and penetration tests were repeated at twice the energy of the standard ANSI test. The impact test was repeated at twice the original height while the penetration test was repeated using a double weight penetrator. Of the fifty models, forty-three survived the double energy impact test without a single failure and thirty-two survived the double energy penetration test without a failure. Therefore, as a group, these models easily exceed the performance level specified by the ANSI standard.

#### Haze and Transmittance

All models easily passed the haze test. The maximum haze allowed is 6 percent, and forty-eight of the fifty models had an average haze value of less than 2 percent. The highest value was 3.3 percent.

It should be mentioned that some of the goggles have coated lenses to reduce fogging. In general, most of these scratched more easily during cleaning than the uncoated lenses. Therefore, the coated lenses required special handling. This should be considered in selecting goggles for use in areas where the lens may need to be cleaned frequently. Improper cleaning tends to increase the haze.

In the transmittance test, nineteen of the fifty models had an average transmittance less than 89 percent, the minimum allowed. Three of these were within 0.4 percent (the accuracy of the testing instrument) of the minimum requirement and were considered inconclusive. This represents a failure rate of thirty-two percent.

Two of the models tested had two-piece lenses with an air space between them to reduce fogging. Inherent in this type of construction is a lower transmittance due to the two additional surfaces, unless a costly non-reflective coating is used. While testing was not conducted to determine the fog reducing tendency of these models, it would seem the advantage of the fog reducing design would more than offset the disadvantage of a lower transmittance level.

Of the two tests, the haze test is considered the most important, since the presence of haze, or scattered light, directly disturbs the visual acuity of the wearer, while a reduced transmittance would only be a problem at reduced illumination levels.

Flammability

Seventeen of the fifty models had both lenses and frames which passed the flammability test. An additional seventeen lenses and nine frames also passed, but their counterpart components were found to yield either inconclusive or failing results. Four lenses and fourteen frames had burning rates too close to the maximum allowed (1.06 mm/sec.) to clearly state pass or fail. Ten frames and ten lenses failed the test, but only three models had failures in both the lens and frame. Two models had two-piece lenses. For the MSA model, the front half, which was noticeably thinner, failed, and the back half passed, while the Glendale lens yielded inconclusive results for both halves.

Fifteen frames, eleven lenses, and the back half of the MSA two-piece lens were found to be self-extinguishing. The range of burning rates for the remaining components was 0.34 to 1.60 mm/sec. for lenses and 0.58 to 1.41 mm/sec. for frames.

Refractive Power

The refractive power test results are tabulated in Table 1. For the prism and definition tests the number shown is the number of passing lenses. For the spherical and cylindrical power tests both the number passing and the number failing are shown. Note that in some cases the total is less than ten, the number tested. In such cases, these lenses yielding inconclusive test results were not included in the total. A test was considered inconclusive when distortion in the lens prevented adequate viewing through the telescope or when the result was within ± 1/160 diopter of the ANSI pass/fail value.

Of the 500 individual lenses evaluated, 176 exceeded the maximum of 1/16 diopter allowed by the ANSI standard for prism, 116 failed the definition test, fifty-one exceeded the spherical power requirements, and forty-seven exceeded the maximum allowable cylindrical power. Nine models were totally free from individual failures. Many more models were characterized by a small number of individual failures.

It is interesting to compare these test results with a simple visual observation of lens quality. In those particular models with a large number of failures in the prismatic power test, we were not able to detect, while briefly wearing the goggle, discomfort or loss of visual acuity.

A slight disruption of visual acuity was noticable in those models having a high failure rate in the definition test.

The spherical and cylindrical powers of those models with a high failure rate, while often detectable when holding the goggle at arm's length, were not noticable when wearing the goggle. These observations are quite subjective and are mentioned here only to place these test results in perspective for the reader unfamiliar with the magnitude of these optical terms. To that same end, it should be mentioned that plastic or glass spectacle lenses will typically pass these same tests quite easily.

Water Absorption

Flexible fitting goggles performed very well in this test. Only one model, the Babbitt 1200, failed, the lens having an absorption rate just over 5 percent. Forty-eight of the fifty models had frames with absorption rates less than 1 percent. The absorption rates of the other two were between 2 percent and 3 percent.

Twenty models had lenses with absorption rates less than one percent. Sixteen fell between 2 percent and 3 percent. Of the remaining fourteen, six were between 3 percent and 4 percent, 7 were between 4 percent and 5 percent, and the one failure, mentioned above, was slightly over 5 percent.

The lens that failed was one of nine which were coated to prevent fogging. This failure may be associated with the coating, as three of the other coated lenses were in the 4-5 percent range; however, the remaining five coated lenses all had absorption rates less than one percent.

We are not aware either of the basis for the water absorption requirement or of any hazard or difficulty associated with the absorption of water by these goggles. Because only 1 model failed the results, of the water absorption test are not presented in Table 1.

Corrosion and Disinfection

All models were judged to have passed both of these tests. After each test all models were free from deterioration that could interfere with the use of the device.

## Design Test

The results of the design test are summarized in Table 2. We consider the elimination of eye exposure to be the most important ANSI design requirement. Two models are listed as failing the eye exposure requirement. These two models, the Dockson "Cheepee" and the Watchemoket "Cheepee", are identical in design and allow direct exposure of the eye from the side. These failures are associated with the use of a rigid, rather than a flexible, frame.

While inspecting these goggles for design features, two other possible exposure problems were evident. The first concerned the size of the ventilation openings on the Watchemoket models 440, 440M, and 440P. The openings, 4.4 mm in diameter, were significantly larger than those of any other model and could present an eye exposure problem during chipping or grinding operations. The ANSI standard does not specifically limit the size of ventilation openings; but, as a reference point, it can be noted that the largest ventilation opening permitted for a spectacle sideshield is 1.5 mm.

An additional eye exposure problem involves the incompatability of certain individuals with certain goggles. A goggle that provides totally adequate eye protection for most wearers may, for a few individuals, allow direct exposure of the eye around the nose area and, less frequently, from the side. The problem is not considered to be a design defect and can easily be eliminated by selecting a model more compatible with the facial features of the individual. It is, however, necessary and important that the user make a conscious effort to inspect for this potential problem.

We have made no attempt to measure or classify the "comfort" of each model. It is appropriate, however, to point out that, as might be expected, there was a significant difference in the comfort provided by the various models and that the opinion of each model's comfort varies from individual to individual. This is significant since it again indicates that each individual user must have the opportunity to select from several models.

It was also observed that the "softness" of the plastic frame had a great influence on the comfort of the goggle and the ability to accommodate a wide range of facial features and, therefore, reduce the problem of direct eye exposure from the nose area.

All models except the Dockson "Cheepee" and Watchemoket "Cheepee" complied with the ANSI lens thickness requirement. The lens thicknesses of these two were just under the ANSI minimum of 0.050 inch.

In several instances, as indicated in Table 2, the manufacturer was not identified on the lens and frame as required.

All models were judged to provide an angle of vision greater than 90 degrees. That is, all models were found to provide at least a 90 degree cone of vision for each eye when the distance from the eye to the lens is 20 mm and the separation of the pupils is 68 mm. Individuals with larger or smaller pupil separation will, in general, experience a reduced field of view.

All models tested can be worn over spectacles. A few models, identified in Table 2, may have difficulty accommodating the larger spectacle sizes. In considering this question of spectacle clearance, an attempt was made to wear each model over a spectacle with 50 mm lenses and a bridge size of 26 mm, the largest dimensions specified in the ANSI standard for spectacles. Surprisingly, the results were quite subjective. A model that is adequate for one individual can present a problem to another individual wearing the same spectacles.

The importance of these subjective features of comfort, spectacle clearance and angle of vision must not be underestimated since they could very well determine when, or if, eye protection is used.

# CONCLUSIONS AND RECOMMENDATIONS

Several variations from the requirements of the ANSI standard have been noted. The majority of these variations are minor in that they do not relate directly to the safety of the user.

The impact, penetration, and eye exposure requirements do relate directly to the safety of the user and are considered to be of primary importance. With only two exceptions, all models did well in these important areas.

There were a significant number of failures in the flammability test, a test that also relates to the wearer's safety. Of the fifty models tested, eighteen failed. It is difficult to assess the seriousness of these failures. We can only note that the majority of the failing burn rates are below the 1.27 mm/sec. burn rate allowed for welding helmets and that the highest burn rate (1.60 mm/sec) is considerably less than that of cellulose nitrate, a material specifically prohibited by the ANSI standard. When samples of cellulose nitrate were tested, using these same test procedures, the burn rate was approximately 12 mm/sec. This would seem to indicate that those failures whose burn rates are only slightly above the ANSI provisions introduce a potential problem, but one which would not be serious in most working situations.

Inspection of the overall results presented in the tables and text will reveal that a few models are seriously deficient in one or more of the ANSI requirements. On the other hand, there are many models that either completely comply with the ANSI standard or vary from it in minor ways. From the latter group we believe that several adequate models can be selected.

In working with this selection of models, it has become clear that many subjective features are important to primary eye protection. These features have been discussed in the text and include: the elimination of eye exposure, comfort, angle of vision, and spectacle clearance. Because of this situation, we strongly recommend that each individual user must have the opportunity to select from a variety of models. Only then can the user be assured of obtaining a comfortable goggle that provides total eye protection.

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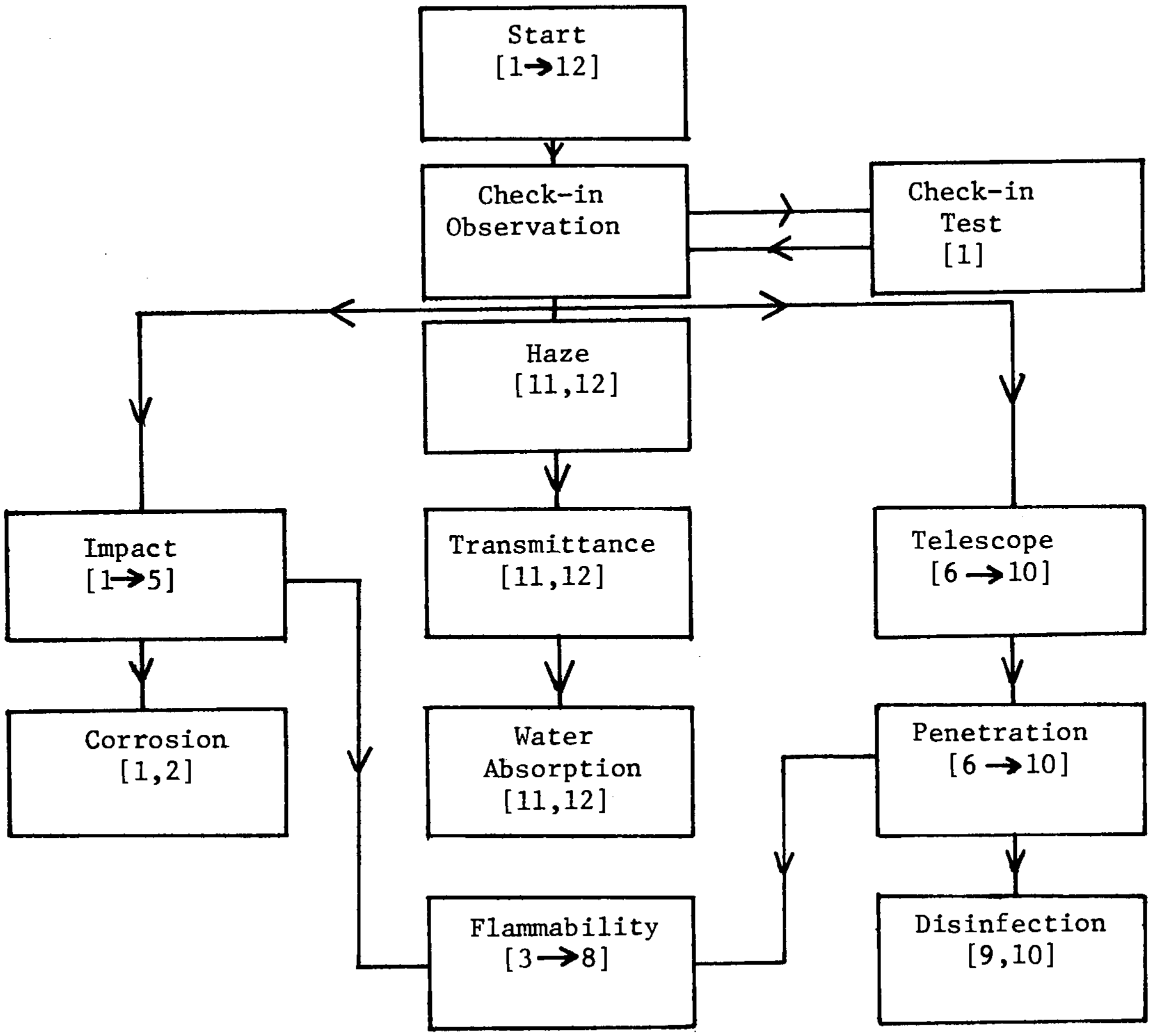
FIGURE 1.-- GOGGLE TEST FLOW CHART*




* The [ ]'s indicate the specimen numbers that are to be subjected to each test.

TABLE 1.--PERFORMANCE TEST RESULTS**

| Manufacturer Model | Impact* | Penetration* | Haze (Max=6%) | Transmittance (Min=89%) | Flammability (Max=1.06mm/sec) | | Refractive Power | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Spherical+ | | Cylindrical+ | |
| | | | | | Lens | Frame | Prism* | Definition* | Pass | Fail | Pass | Fail |
| Aden Supply 50 | 10 | 10 | 0.4 | 89.6 | 0.34 | 0.85 | 8 | 10 | 10 | 0 | 10 | 0 |
| American Industrial 1575-N | 10 | 10 | 0.6 | 88.7I | SE | 0.67 | 1 | 1 | 0 | 0 | 0 | 0 |
| American Optical 482B | 10 | 10 | 0.4 | 89.6 | SE | 1.14I | 3 | 8 | 10 | 0 | 10 | 0 |
| American Optical 482 BAF | 10 | 10 | 0.5 | 90.5 | SE | 1.21F | 7 | 8 | 10 | 0 | 10 | 0 |
| Babbitt 1100 | 10 | 10 | 0.9 | 85.9F | 0.80 | SE | 10 | 9 | 9 | 1 | 9 | 1 |
| Babbitt 1200 | 10 | 10 | 1.6 | 85.1F | 0.84 | SE | 10 | 10 | 10 | 0 | 10 | 0 |
| Bausch & Lomb 5W-71C | 10 | 10 | 0.6 | 84.4F | 0.93 | 0.80 | 10 | 7 | 7 | 3 | 8 | 2 |
| Bouton 554 | 10 | 10 | 0.6 | 88.8I | SE | 1.24F | 10 | 10 | 10 | 0 | 10 | 0 |
| Cesco 520-A | 10 | 10 | 0.6 | 90.7 | 1.26F | SE | 6 | 6 | 10 | 0 | 9 | 0 |
| Cesco 520-C | 10 | 10 | 2.2 | 77.4F | 0.68 | 1.07I | 10 | 10 | 10 | 0 | 10 | 0 |
| Cesco 520-P | 10 | 10 | 0.6 | 88.9I | SE | 1.07I | 10 | 6 | 10 | 0 | 10 | 0 |

* Number passing out of 10 samples tested.
** All failures are indicated by F; I indicates inconclusive results; SE indicates self-extinguishing.
*** Two piece lens with air space.
+ Ten samples were tested; any not listed as passing or failing were inconclusive.

TABLE 1.--continued

| Manufacturer Model | Impact* | Penetration* | Haze (Max=6%) | Transmittance (Min=89%) | Flammability (Max=1.06mm/sec) Lens | Flammability Frame | Prism* | Definition* | Refractive Power Spherical+ Pass | Spherical+ Fail | Cylindrical+ Pass | Cylindrical+ Fail |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cesco 520-CF | 10 | 10 | 0.9 | 87.8F | 0.94 | 1.19F | 9 | 8 | 7 | 0 | 9 | 0 |
| Dockson Cheepee | 10 | 10 | 1.1 | 90.8 | 1.00I | 0.82 | 2 | 5 | 0 | 7 | 0 | 10 |
| Eastern E-4 | 10 | 10 | 0.9 | 90.4 | 1.31F | 1.25F | 7 | 9 | 6 | 2 | 8 | 1 |
| Eastern NF-E-4 | 10 | 10 | 0.9 | 86.1F | 0.68 | 1.35F | 10 | 10 | 9 | 1 | 9 | 1 |
| Fibre-Metal VG-10 | 10 | 10 | 0.6 | 82.2F | 0.81 | SE | 9 | 6 | 4 | 4 | 4 | 4 |
| General Scientific 8000 E | 10 | 10 | 0.9 | 90.3 | 1.51F | 1.30F | 10 | 7 | 7 | 1 | 10 | 0 |
| Glendale 300 | 10 | 10 | 1.1 | 88.3F | 0.34 | 1.40F | 5 | 9 | 4 | 6 | 5 | 3 |
| Glendale 3005 *** | 10 | 10 | 3.3 | 83.4F | 1.02I 1.11I | 1.11I | 0 | 8 | 0 | 8 | 0 | 10 |
| Glendale 4000 | 10 | 10 | 0.7 | 86.2F | 0.81 | 1.22I | 10 | 10 | 10 | 0 | 10 | 0 |
| Jackson JP-1 | 10 | 10 | 0.9 | 90.2 | 1.45F | 1.25F | 8 | 8 | 8 | 0 | 10 | 0 |
| Martindale M-4 | 10 | 10 | 0.8 | 90.7 | 1.28F | 1.10I | 8 | 10 | 8 | 0 | 10 | 0 |

* Number passing out of 10 samples tested.
** All failures are indicated by F; I indicates inconclusive results; SE indicates self-extinguishing.
*** Two piece lens with air space.
\+ Ten samples were tested; any not listed as passing or failing were inconclusive.

TABLE 1.--continued

| Manufacturer Model | Impact* | Penetration* | Haze (Max=6%) | Transmittance (Min=89%) | Flammability (Max=1.06mm/sec) Lens | Flammability Frame | Prism* | Definition* | Refractive Power Spherical+ Pass | Spherical+ Fail | Cylindrical+ Pass | Cylindrical+ Fail |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Michell 728 | 10 | 10 | 0.7 | 91.8 | 1.11I | SE | 3 | 4 | 0 | 0 | 0 | 0 |
| MSA 791223 | 10 | 10 | 0.5 | 89.0I | 0.41 | SE | 10 | 10 | 10 | 0 | 10 | 0 |
| MSA 791229 | 10 | 10 | 1.8 | 88.0F | SE | SE | 8 | 10 | 10 | 0 | 10 | 0 |
| MSA 791230 *** | 10 | 10 | 1.7 | 82.7F | 1.60F SE | SE | 0 | 8 | 10 | 0 | 10 | 0 |
| Morse 1140 | 10 | 10 | 1.1 | 91.7 | 1.20F | SE | 5 | 2 | 1 | 0 | 1 | 0 |
| Morse 1148 | 10 | 10 | 0.5 | 91.0 | SE | SE | 2 | 0 | 0 | 0 | 0 | 0 |
| Regal 1550 | 10 | 10 | 1.2 | 85.1F | 0.81 | 0.95I | 10 | 10 | 8 | 0 | 8 | 0 |
| Schuberth 1500 | 10 | 10 | 1.2 | 90.1 | 1.26F | 1.20I | 9 | 10 | 7 | 0 | 10 | 0 |
| Sellstrom 880 LCP | 10 | 10 | 0.7 | 85.7F | 0.86 | 0.85 | 7 | 9 | 10 | 0 | 10 | 0 |
| Union Carbide 44 | 10 | 10 | 0.8 | 87.2F | 0.82 | SE | 7 | 8 | 3 | 0 | 2 | 0 |
| U. S. Safety 291003 | 10 | 10 | 1.2 | 90.1 | 1.14F | SE | 9 | 9 | 10 | 0 | 10 | 0 |

* Number passing out of 10 samples tested.
** All failures are indicated by F; I indicates inconclusive results; SE indicates self-extinguishing.
*** Two piece lens with air space.
+ Ten samples were tested; any not listed as passing or failing were inconclusive.

Table 1.--continued

| Manufacturer Model | Impact* | Penetration* | Haze (Max=6%) | Transmittance (Min=89%) | Flammability (Max=1.06mm/sec) Lens | Flammability Frame | Prism* | Definition* | Refractive Power Spherical+ Pass | Spherical+ Fail | Cylindrical+ Pass | Cylindrical+ Fail |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| U. S. Safety 295004 | 10 | 10 | 1.3 | 89.5 | 1.07I | SE | 6 | 7 | 9 | 0 | 10 | 0 |
| U. S. Safety 295503 | 10 | 10 | 0.5 | 89.7 | SE | SE | 9 | 7 | 10 | 0 | 10 | 0 |
| U. S. Safety 271503 | 10 | 10 | 0.7 | 89.9 | SE | 0.63 | 0 | 10 | 10 | 0 | 10 | 0 |
| Watchemoket 440 | 10 | 10 | 0.2 | 93.2 | 0.63 | 1.08I | 8 | 10 | 10 | 0 | 10 | 0 |
| Watchemoket 440 M | 10 | 10 | 0.2 | 93.2 | 0.68 | 0.88 | 4 | 10 | 10 | 0 | 10 | 0 |
| Watchemoket 440 P | 10 | 10 | 0.2 | 93.2 | 0.61 | 1.00I | 5 | 10 | 10 | 0 | 10 | 0 |
| Watchemoket 41 | 10 | 10 | 0.6 | 86.5F | 0.88 | 0.93I | 8 | 7 | 7 | 2 | 7 | 3 |
| Watchemoket 7V-AC | 10 | 10 | 0.6 | 91.4 | 0.86 | 1.41F | 6 | 0 | 3 | 0 | 2 | 1 |
| Watchemoket Cheepee | 10 | 10 | 1.2 | 90.9 | 0.64 | 0.80 | 4 | 6 | 1 | 9 | 4 | 6 |
| Welsh 1070 | 10 | 10 | 0.6 | 91.1 | 1.30F | 0.89 | 0 | 10 | 4 | 2 | 7 | 3 |
| Welsh 1074 | 10 | 10 | 0.7 | 91.4 | 1.18F | 0.58 | 0 | 9 | 2 | 3 | 7 | 2 |

* Number passing out of 10 samples tested.
** All failures are indicated by F; I indicates inconclusive results; SE indicates self-extinguishing.
*** Two piece lens with air space.
+ Ten samples were tested; any not listed as passing or failing were inconclusive.

TABLE 1.--continued

| Manufacturer Model | Impact* | Penetration* | Haze (Max=6%) | Transmittance (Min=89%) | Flammability (Max=1.06mm/sec) | | Refractive Power | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Lens | Frame | Prism* | Definition* | Spherical+ Pass | Spherical+ Fail | Cylindrical+ Pass | Cylindrical+ Fail |
| Welsh 1010 | 10 | 10 | 1.1 | 91.1 | 0.98I | 0.98I | 10 | 10 | 9 | 0 | 10 | 0 |
| Welsh 1024 | 10 | 10 | 0.6 | 89.9 | SE | 1.14F | 1 | 3 | 4 | 2 | 7 | 0 |
| Wilkie Optical WO-1002 | 10 | 10 | 0.4 | 91.2 | 0.47 | SE | 1 | 0 | 1 | 0 | 1 | 0 |
| Willson 301 | 10 | 10 | 0.4 | 89.6 | 0.39 | 1.00I | 10 | 10 | 10 | 0 | 10 | 0 |
| Willson 301 M | 10 | 10 | 0.7 | 90.2 | SE | 1.11I | 9 | 10 | 10 | 0 | 10 | 0 |
| Willson 391 | 10 | 10 | 0.4 | 89.6 | 0.39 | 0.77 | 10 | 10 | 10 | 0 | 10 | 0 |

* Number passing out of 10 samples tested.
** All failures are indicated by F; I indicates inconclusive results; SE indicates self-extinguishing.
*** Two piece lens with air space.
\+ Ten samples were tested; any not listed as passing or failing were inconclusive.

TABLE 2.--DESIGN REQUIREMENTS

| Manufacturer Model | Eye Exposure | Lens Thickness | Ample Spectacle Clearance | Manufacturer Marking | |
|---|---|---|---|---|---|
| | | | | Lens | Frame |
| Aden Supply 50 | p | p | p | p | p |
| American Industrial 1575-N | p | p | p | p | p |
| American Optical 482B | p | p | p | p | p |
| American Optical 482 BAF | p | p | p | p | p |
| Babbitt 1100 | p | p | p | p | p |
| Babbitt 1200 | p | p | p | p | p |
| Bausch & Lomb 5W-71C | p | p | p | F | p |
| Bouton 554 | p | p | p | p | p |
| Cesco 520-A | p | p | p | F | p |
| Cesco 520-C | p | p | p | p | p |
| Cesco 520-P | p | p | p | p | p |
| Cesco 520-CF | p | p | p | p | p |
| Dockson Cheepee | F | F | p* | p | p |

* May not be suitable to cover large frame spectacles.

TABLE 2.--continued

| Manufacturer Model | Eye Exposure | Lens Thickness | Ample Spectacle Clearance | Manufacturer Marking | |
|---|---|---|---|---|---|
| | | | | Lens | Frame |
| Eastern E-4 | p | p | p* | p | p |
| Eastern NF-E-4 | p | p | p* | p | p |
| Fibre-Metal VG-10 | p | p | p | F | F |
| General Scientific 8000 E | p | p | p* | p | F |
| Glendale 300 | p | p | p | p | p |
| Glendale 3005 | p | p | p | p | p |
| Glendale 4000 | p | p | p | p | p |
| Jackson JP-1 | p | p | p* | p | p |
| Martindale M-4 | p | p | p* | p | F |
| Michell 728 | p | p | p | F | P |
| MSA 791223 | p | p | p | p | p |
| MSA 791229 | p | p | p | p | p |
| MSA 791230 | p | p | p | p | p |

* May not be suitable to cover large frame spectacles.

TABLE 2.--continued

| Manufacturer Model | Eye Exposure | Lens Thickness | Ample Spectacle Clearance | Manufacturer Marking | |
|---|---|---|---|---|---|
| | | | | Lens | Frame |
| Morse 1140 | p | p | p | p | p |
| Morse 1148 | p | p | p | p | p |
| Regal 1550 | p | p | p | p | p |
| Schuberth 1500 | p | p | p* | p | p |
| Sellstrom 880 LCP | p | p | p | p | p |
| Union Carbide 44 | p | p | p | F | p |
| U. S. Safety 291003 | p | p | p | p | p |
| U. S. Safety 295004 | p | p | p | p | p |
| U. S. Safety 295503 | p | p | p | p | p |
| U. S. Safety 271503 | p | p | p | p | p |
| Watchemoket 440 | p | p | p | F | p |
| Watchemoket 440M | p | p | p* | F | p |
| Watchemoket 440P | p | p | p | F | p |

* May not be suitable to cover large frame spectacles.

TABLE 2.--continued

| Manufacturer Model | Eye Exposure | Lens Thickness | Ample Spectacle Clearance | Manufacturer Marking Lens | Manufacturer Marking Frame |
|---|---|---|---|---|---|
| Watchemoket 41 | p | p | p | F | p |
| Watchemoket 7V-AC | p | p | p* | F | p |
| Watchemoket Cheepee | F | F | p* | p | p |
| Welsh 1070 | p | p | p | F | p |
| Welsh 1074 | p | p | p | F | p |
| Welsh 1010 | p | p | p | p | p |
| Welsh 1024 | p | p | p | p | p |
| Wilkie Optical WO-1002 | p | p | p | p | p |
| Willson 301 | p | p | p | p | p |
| Willson 301-M | p | p | p | p | p |
| Willson 391M | p | p | p | p | p |

* May not be suitable to cover large frame spectacles.



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