EVALUATING EY FOR BIOLOGI

A New Approach

By Jeremy R. Gouzd, Gary L. Winn and James R. Harris

NEARLY ALL OCCUPATIONS present hazards that require workers to wear eye protection. Users need to know that safety glasses have been rigorously tested and evaluated to a set of industry standards. This knowledge allows wearers to be confident that their safety glasses will do the job, so that workers can focus on the task at hand without worrying about whether their eyes are, in fact, protected.

Whenever employees or employers need to reference standards on eye protection, they generally are referred to ANSI Z87.1-2020. Although this standard covers many occupational hazards, a few are not addressed, including biological hazards such as bloodborne pathogens. ANSI Z87.1 does not cover eye protectors for biological hazards. A subcommittee was formed to develop a new standard, ANSI Z87.62, which will include various testing procedures that mimic the different types of biological hazard exposures that can be experienced (spurt and spray). Some targeted occupations with expected exposures to these hazards include nurses, doctors performing procedures, dental healthcare workers and laboratory workers in health-related research fields. A draft test apparatus, testing method and standard have been created to test whether PPE is providing adequate worker protection.

Background

According to Matela (2008), nearly three in five workers who suffered eye injuries were not wearing eye protection at the time or were wearing the wrong kind of eye protection for the job, and 94% of the eye and face injuries to workers wearing eye protection resulted from objects or chemicals going around or under the protective device. OSHA (2016) standard 29 CFR 1910.133 dictates that an employer must provide appropriate eye protection, which then leads the worker to ANSI for its descriptions of hazards and selections of different protectors.

However, when a worker refers to ANSI Z87.1, it specifically states that bloodborne pathogens are not covered in the standard: "Certain hazardous exposures are not covered in this standard. These include, but are not limited to: bloodborne pathogens, X-rays, high-energy particulate radiation, microwaves, radio-frequency radiation, lasers, masers, and sports and recreation" (ANSI/ISEA, 2020).

Because ANSI Z87.1 does not cover eye protectors for biological hazards, a subcommittee was formed in 2016 to resolve this issue by creating a new standard, ANSI Z87.62, to include a more detailed description of the proper eye and face protection that workers exposed to biological hazards should be using given varied needs and occupations. Not long after, a test apparatus, testing method and standard for which eye and face protectors will be tested on was created in correlation to this standard to test that PPE are providing adequate worker protection. ANSI Z87.1 is specifically the standard that establishes the criteria for using, testing, marking, choosing and maintaining eye protection to prevent or minimize injuries from eye hazards. The authors' test, test apparatus, and results are to set and support these criteria to include those of biological hazards.

Recognizing the Hazards in the Workplace

Healthcare personnel in all industries are at risk for occupational exposure to bloodborne pathogens. This includes personnel who treat or care for injured workers. Bloodborne pathogens are pathogenic microorganisms present in the human blood that can lead to diseases. The primary concerns from bloodborne pathogens are hepatitis B (HBV), hepatitis C (HCV) and human immunodeficiency virus (HIV). HBV causes serious liver disease, which can become a chronic condition that causes permanent scarring of the liver, leading to liver failure or liver cancer; nearly 2,000

KEY TAKEAWAYS

- Infectious transmissions can occur through contact with the eyes and face. ANSI Z87.1 covers many occupational hazards, but some biological hazards are not addressed.
- The standard establishes criteria for using, testing, marking, choosing and maintaining eye protection to prevent or minimize injuries from eye hazards.
- This article presents a test, test apparatus and results to set and support the ANSI Z87.1 criteria to include those of biological hazards.

FIGURE 1
RISK ASSESSMENT MATRIX

Probability	Severity: Catastrophic: 4	Critical: 3	Marginal: 2	Negligible: 1
Frequent: 5	High: 20	High: 15	High: 10	Medium: 5
Probable: 4	High: 16	High: 12	Serious: 8	Medium: 4
Occasional: 3	High: 12	Serious: 9	Medium: 6	Low: 3
Remote: 2	Serious: 8	Medium: 6	Medium: 4	Low: 2
Improbable: 1	Medium: 4	Low: 3	Low: 2	Low: 1

Note. Adapted from "Risk Matrix Calculations: Severity, Probability and Risk Assessment," by IndustrySafe, 2018.

YE PROTECTION
CAL HAZARDS

HBV-related deaths occur per year in the U.S. (CDC, 2020). HBV is much more transmissible than HIV and 50% of infected people are unaware that they have HBV (Institute of Medicine, 2010). HCV attacks the liver and leads to inflammation. Chronic infection develops in 75% to 85% of patients, with 70% developing active liver disease, and can result in long-term health problems and death. Most infected people have no symptoms and do not know they are infected until decades later when liver damage shows up in routine tests. Bloodborne pathogens may also be transmitted through the mucous membranes of the eyes, nose and mouth.

While most healthcare workers take precautions to avoid needlestick injuries, a perhaps less well recognized hazard is potential infection via fluid exposure to the eyes. Such exposure can arise from incidents ranging from accidental splashing of blood into the eyes or a skin cut when starting or removing an IV catheter, to disposing of body fluids or dressing an open wound. A 2003 study found that nurses had a higher mucocutaneous exposure rate than physicians and medical technologists. More than one-third (39%) of registered nurses and more than one-fourth (27%) of licensed practical nurses said they had experienced one or more mucocutaneous blood exposures during the previous 3 months, but few reported their exposures (Delisio, 2012).

According to NIOSH (2008), first responders also face unique and uncontrolled settings with the possibility of large volumes of

FIGURE 2
ANTHROPOMETRIC HEAD FORM TEST MANIPULATION

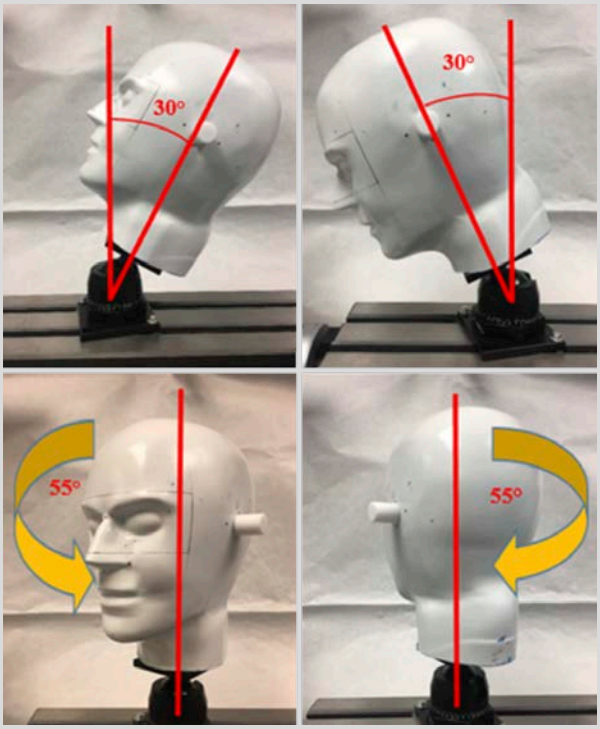


FIGURE 3
EXAMPLE OF CURRENT EYE & FACE PROTECTION

FIGURE 4
OVERALL TEST SETUP

Anthropometric head form (1); articulating base (2); milling table (3); dispensing unit (4); pressurized container (5); uni-slide (6); nozzle (7)

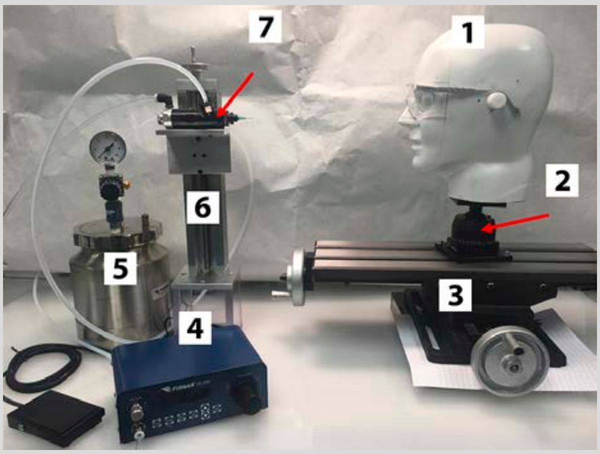


FIGURE 5
TEST PROJECTIONS OF FLUID FOR SPURT (LEFT) & SPRAY (RIGHT)

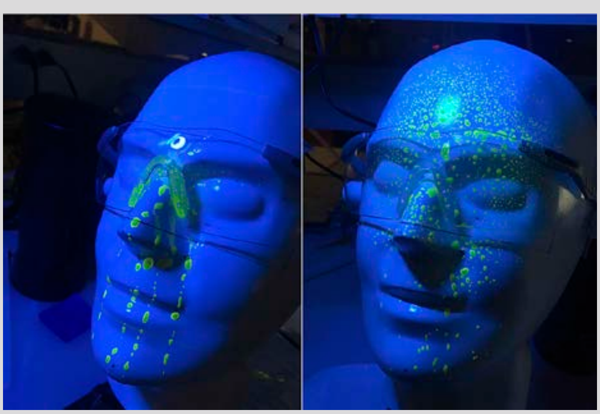
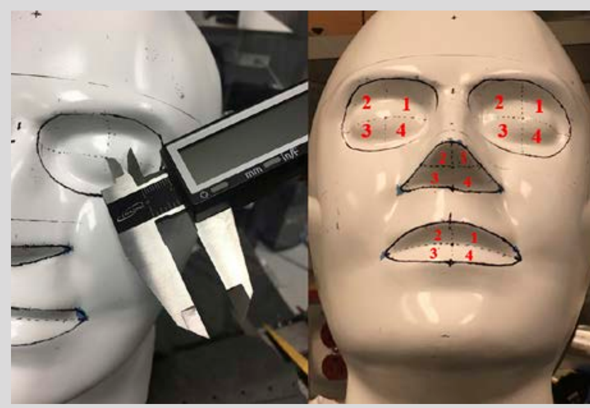


FIGURE 6
UP & DOWN POSITIONS

FIGURE 7
LEFT & RIGHT POSITIONS

FIGURE 8
LAYOUT OF QUADRANTS FOR AREAS OF CONCERN



blood. Exposure risk is increased in these situations, especially with uncooperative patients. These workers can be easily exposed to bloodborne pathogens and other potentially infectious materials in their jobs. Emergency responders may perform urgent, invasive procedures, treat open wounds, perform mouth-to-mouth resuscitation and use various means to stop bleeding.

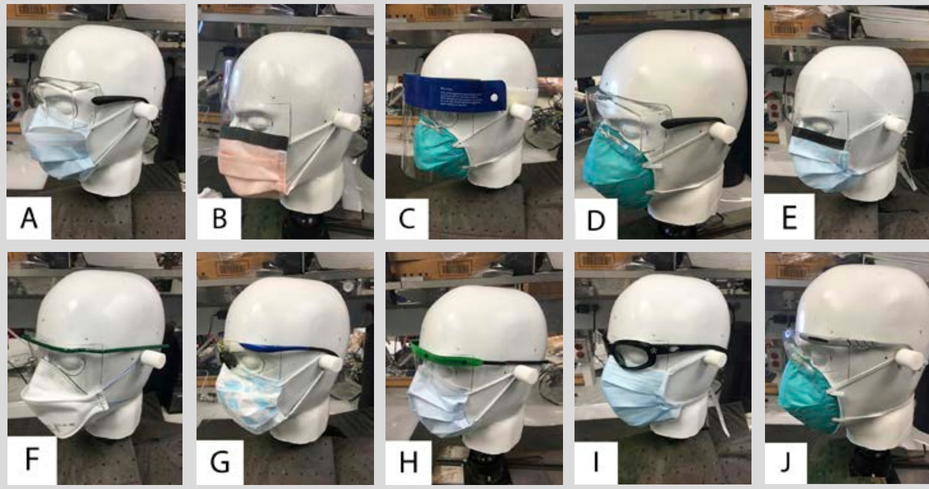
Even though the risk of infection after an exposure is relatively low, the probability of being exposed is relatively high within the healthcare industry. With a high frequency and severity of this risk that is serious or disabling and life threatening, a risk assessment matrix would classify the risk in a "high" category for splashes to the eye (Figure 1, p. 20). Workers must be more aware of the potential risks and dangers when working in and around biological hazards that have potential for splashes and spurts to the facial region.

General Methods Used to Establish Testing

This study evaluated the efficiency of manufacturers' eye and face PPE for protection against biological hazards such as bloodborne pathogens. The test apparatus replicates the hazards that a worker would see in average working conditions. The majority of these hazards come from the human body such as sneezes or coughs, puncture wounds, saliva or mucous, or instances of low-velocity splashes from containers in laboratory conditions. The test apparatus replicated these conditions to best match the patterns, velocities and volumes in an exposure.

FIGURE 9
ENSEMBLES, PASS RATE & VISUALS

Ensemble	Pass rate
A	90%
B	90%
C	100%
D	94%
E	99%
F	81%
G	71%
H	81%
I	72%
J	67%



Eye protectors were selected and placed on the anthropometric head as if being worn for occupational hazards. The head form was adjusted at the specified distance for the criteria being tested (spurt or spray). Two of the main criteria being tested were a large volume droplet delivered in a specific location (spurt), then much smaller droplets spread out over a larger target location (spray). Both the spurt and spray were designed to mimic pressure (based on blood pressure) at which the human body can expel fluids: 250 in./s and 197 in./s, respectively.

Parameters of the Test Apparatus

The test matrix was run with four head manipulations or positions (Figure 2, p. 21). These positions were chosen to best mimic the exposure entry routes for eye protectors. The manipulations were up (1), down (2), left (3) and right (4). Each head manipulation was tested with the spurt and spray criteria. As shown in Figure 2, in the first position the head form was tilted posteriorly 30° (top left). In the second position, the head form was tilted anteriorly 30° (top right). The angle at which the head form was tilted anteriorly and posteriorly captured the average angle at which a healthcare worker would angle their head in relation to the patient's head. The third and fourth projections are to the left and right temple area of the head form.

Working Hypothesis

At the start of this project, the original hypothesis was that currently used eye and face protectors (Figure 3, p. 21) would not pass the test criteria to be labeled for protection against biological hazards.

Figure 4 shows the test setup for the project. The dispensing unit (4) makes it easy to get precise shots of fluid across all tests for consistency. The nozzle (7) is controlled by air input from the dispensing unit and is where the different cannulas are attached. The velocity of the stream that exits the test apparatus is deduced from the volume of the stream produced over a known period of time. Since the electronic dispensing unit can easily control the period of time and pressure at which the stream exits, the flow velocity can be calculated. The fluid used is a mixture of saline and a surfactant (Portnoff et al., 2019). Its physical properties are very similar to blood. Added fluorescein dye makes the fluid highly visible under blue light. This dye aids in detection of any fluid on the eye of the head form and yields clear decisions of pass or fail results. If there is no evidence of fluid on the head form's eyes, nose or mouth, then the eye protector and corresponding ensemble passes.

The eye protector and corresponding face mask must pass all spurt and spray target locations for it to pass the entire test. If there is evidence of fluid on the eyes, nose or mouth of the head form, then the eye protector fails and the corresponding ensemble fails. Figure 5 illustrates example tests showing the highly visible fluid under blue light as well as the difference in projections between spurt (left) and spray (right).

FIGURE 10
TOTAL PASS RATE PER AREA OF CONCERN PER POSITION

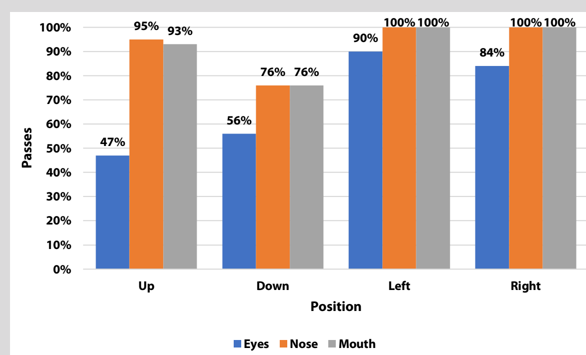


FIGURE 11
GAPS CAUSING ROUTES OF ENTRY

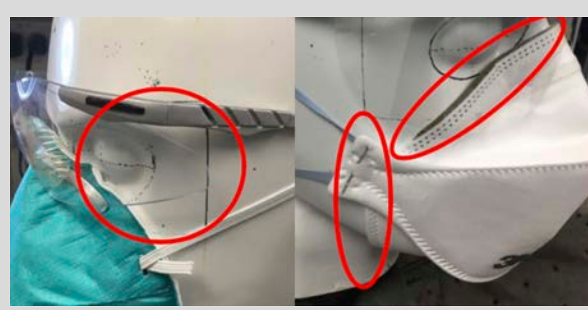


Figure 6 shows two examples of PPE that were tested: up position (left) and down position (right). Figure 7 shows two examples of PPE that were tested: left position (left) and right position (right).

The areas of concern (i.e., eyes, nose, mouth) were mapped out into an XY graph with quadrants labeled 1 through 4 (Figure 8). The origin of this graph is the center of each area of concern. This was done to better report the results of any failures. These areas of concern were chosen by defining a perimeter for each area. These perimeters were created based on average adults' "facial landmarks" for each area. The perimeters for each area were slightly oversized to accommodate outliers in the average facial landmark measurements.

If a failure occurred, it was measured from the center to the closest fluid droplet. This method allows the test data to show not only the distance that the failure occurred, but also where in the area of concern it occurred.

The eye protector and face mask are referred to as an ensemble. The eye protector and face mask could be a single unit, such as an integrated visor face mask, or separate, such as standard lab safety glasses and a respirator or surgical mask. Many different high-hazard occupations were contacted to learn what PPE workers wear when performing their jobs. These ranged from various departments within hospitals, EMS, dental care, research laboratories and veterinarian settings. The researchers gathered enough supplies to adequately test 10 replications of each ensemble for the four head manipulations. A total of 10 ensembles were collected (Figure 9, p. 23). Each ensemble is referred to with a corresponding letter (A through J). All ensembles were assembled based on reports from high-hazard occupational settings in the surrounding areas (near Morgantown, WV).

Results: How the Ensembles Performed

The two ensembles that had the best protective performance were ensembles C and E. Ensemble C had an overall protective performance pass rate of 100%, while ensemble E had an overall pass rate of 99.6%.

As Figure 10 (p. 23) shows, the left and right positions had the highest passing rate for the eyes, nose and mouth, closely followed by the up position. The down position as a whole demonstrated the lowest passing rate.

The nose and mouth were more effectively protected than the eyes. They had a total pass rate of 93% and 92%, respectively, while the total pass rate for the eyes was 69%. This can be expected, as the nose and mouth are more adequately covered by most face masks and leave fewer and smaller gaps than eye protectors tend to do. The face mask tends to press tightly against the face, which seals most areas. Most face masks can conform to the curvature of the nose and upper cheeks. This aids in closing the gaps for added protection to the nose and mouth. Eye protectors that were tested did not have these features. Some sit at the face closer than others, which aided in protection to the eyes, but most still had large gaps. The eye protectors that performed best were built in an effort to close these gaps (top, bottom and side gaps, Figure 11, p 23). Most eye protectors provide some sort of side protection, but few had adequate protection for the top and bottom gaps.

What Type of Ensemble Workers Should Wear

By looking at all the data as a whole and by running the tests firsthand, it can be concluded that the test apparatus operates efficiently and is easily repeatable. A reliable test apparatus also ensures concise and consistent testing across the broad spectrum of safety manufacturers and end users. It easily accepts and tests the various donning of currently used PPE. This provides an important first step to simulate high-risk biological hazardous occupations in which eye and face PPE are worn. This test apparatus provides a very good building block for testing and further investigation of biological hazards and eye and face protection.

As noted, the two ensembles that had the best protective performance were ensembles C and E. These two ensembles both utilized the effectiveness of a face shield. Ensemble C was a full-face shield that was sealed at the forehead and hung downward. Because of this, it passed all tests. Ensemble E also used the same idea of a face shield but was built within the mask and protruded upwards. The eye and face protectors that incorporate a shield into their design perform best for protection against biological hazards.

FIGURE 12
GAPS BETWEEN EYE PROTECTOR & NOSE & MOUTH PROTECTOR

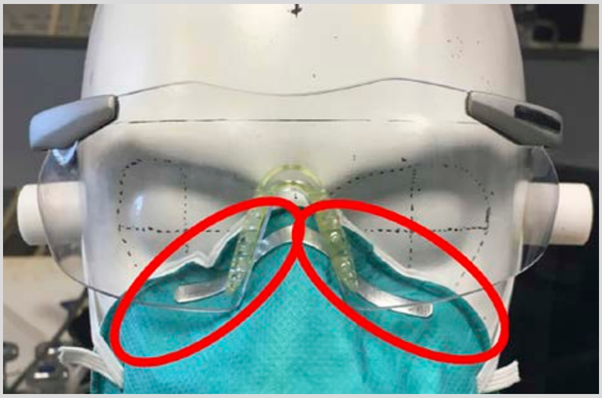


FIGURE 13
GAP BETWEEN EYE PROTECTOR & WEARER'S FOREHEAD

When taking only the eyes into consideration, the bottom gap (Figure 12) is the area where the most failures occurred. The up position was designed to investigate this area. This bottom gap is hard to seal solely with eye protectors unless they are built specifically to seal this gap. This is why a face shield design protects best in this area. Of the ensembles tested, two were the full-face-shield type and one was a mask built for bottom gap protection that had small shields built on the mask specifically for protection in this area. Because of the design of these three ensembles, they protected the best against this bottom gap from spurts and sprays.

The other area that is hard to protect against penetration around is the top gap (Figure 13), or the down position. This position is hard to protect because of the gap that remains between the eye protector and the forehead. The ensembles that performed best in this area tended to sit very close to the forehead to minimize fluid penetration. The best way to protect against spurts and sprays in this position is to seal this gap. Ensemble C, which completely passed this test, incorporated a foam pad that made the seal possible. This allowed no fluid to get through. Even if the ensemble did not have an actual seal, those that contoured to the forehead performed better.

The authors conclude the following:

•A face shield type ensemble (Figure 14) offers the overall best protection.

•Users of this type of ensemble are advised that this protection is recommended when an occupation involves higher amounts of fluid and high chance of fluid (e.g., operations, surgeries and procedures where splatter is expected).

FIGURE 14

FACE SHIELD TYPE ENSEMBLE

FIGURE 15

ENSEMBLES THAT CONFORM TO FACE

If the authors were to recommend certain types of ensembles for certain occupations, they would suggest the use of the full-face shield or ensembles that at least implement the face shield aspects into their product for tasks or occupations in which a worker could expect splatter. That is:

•Ensembles that conform to the face (Figure 15) are recommended for occupations less likely to expect splatter.

•Ensembles that take the gaps (bottom, top, side) into consideration are suitable for occupations in which the splatter hazard is present and could occur.

For dental healthcare workers and lab workers who are not necessarily guaranteed to encounter a splash or spurt, the authors recommend an ensemble that is not as bulky as a face shield. They recommend one of the ensembles that still ranked very high, where the eye protector's design takes into consideration sealing the gaps, and one that better conforms to a user's face.

Summary

The ANSI Z87.62 subcommittee's primary concern was to create a standard testing apparatus and testing criteria for eye and face protectors when biological hazards are present. ANSI Z87.1 is lacking in the biological hazards and bloodborne pathogens category for selection of eye protectors. ANSI Z87.62 will allow workers to have a reference and guidance for eye and face protectors for protection against biological hazards. This project provided an initial test apparatus and standard criteria with which all eye and face protectors for biological hazards can be evaluated. It ensures concise and consistent testing across the broad spectrum of safety manufacturers and end users for eye and face protectors. It provides a good notion of the designs that eye and face protection should consider for best overall protection.

At the start of this project, the original hypothesis was that currently used eye and face protectors would not pass the test criteria to be labeled for protection against biological hazards. The project's testing apparatus found that most eye and face protectors being used in the healthcare work setting are not meeting the needs of users for adequate eye and face protection. This testing apparatus and newly formed standard (ANSI Z87.62) will provide a guideline for what eye and face protection is needed. It will be a foundation for future testing of new eye and face protection designed for the healthcare setting. It will also lead to more specific research of biological hazards for eye and face protection. **PSJ**

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