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Evaluation and Testing of Eye, Nose, and Mouth Protection for Biological Hazards to Support a Consensus Standard

Jeremy R Gouzd

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**Evaluation and Testing of Eye, Nose, and Mouth Protection for Biological
Hazards to Support a Consensus Standard**

Jeremy R. Gouzd

Dissertation submitted to

**College of Engineering and Mineral Resources
at West Virginia University**

in partial fulfillment of the requirements
for the degree of

**Doctor of Philosophy
In
Occupational Safety and Health**

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**Morgantown, West Virginia
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**Keywords: Eyewear, Eye Protection, Face Protection, PPE,
Spurt, Spray**

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Abstract

Evaluation and Testing of Eye, Nose, and Mouth Protection for Biological Hazards to Support a Consensus Standard

Jeremy R. Gouzd

Eye protection is one of the greatest personal protective equipment items that has ever been made readily available to workers. In almost every occupation there will be some hazard that requires the worker to wear eye protection. Nearly three out of five injured workers were not wearing eye protection at the time of the accident or were wearing the wrong kind of eye protection for the job. Eye injuries alone cost more than \$300 million per year in lost production time, medical expenses and worker compensation (Matela, 2012). Eye protection should be integrated with other PPE to achieve head-to-toe protection. It should be fit to the individual worker or be adjustable so it can provide sufficient coverage. According to a BLS survey, 94 percent of the injuries to workers wearing eye protection resulted from objects or chemicals going around or under the protective device (Matela, 2012). When it comes to safety glasses, users need to know they've been rigorously tested, and held up to a set of industry standards. This knowledge allows wearers to be confident that their safety glasses will do their job, so workers can focus on the task at hand without worrying about whether their eyes are, in fact, protected. Whenever an employee or employer needs to reference standards on eye protection they generally are referred to ANSI Z87.1. Although this standard covers many occupational hazards there are still a few that are not addressed. These hazards are that of biological hazards such as blood borne pathogens. ANSI Z87.1 does not cover eye protectors for biological hazards. A committee was formed and concluded that a new standard ANSI Z87.62 standard will include a variety of testing procedures that mimic the different types of biological hazard exposures that can be experienced (spurt and spray). The most common occupations that are seen to have the highest incidence rate of these hazards projected at the workers eyes would be nurses, doctors performing procedures, dental healthcare workers, and laboratory workers in the health related research fields. A subcommittee has been formed to try and 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. A test apparatus, testing method, and standard for which eye and face protectors will be tested on, has been created in correlation to this standard to test that protectors are providing adequate worker protection.

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CHAPTER 1 - INTRODUCTION

1.1 Background

The ANSI-ISEA Z87.1 American National Standard for Occupational and Educational Personal Eye and Face Protection Devices addresses many workplace hazards where eye and face protection is required. This standard is performance-based to allow for other designs and product types to be implemented to meet end user's needs. The standard also focuses on helping the end user select PPE that is most appropriate for his/her specific work environment.

ANSI Z87 committee has determined that a subcommittee needed to be formed to create a new standard. New test methods within the new ANSI Z87.62 standard will include a variety of testing procedures that mimic the different types of biohazard exposures that can be experienced (spurt and spray). ANSI has approved the ANSI Z87.62 subcommittee to look at "...criteria related to the general requirements, testing, permanent marking, selection, care and use of protectors to minimize or prevent exposure to the wearer's eyes and/or face caused by biological hazards including, but not limited to blood, body fluids or other potentially infectious materials (OPIMs) or microorganisms, viruses or toxins from a biological source that can affect human health. This standard is NOT intended to address hazards related to transmission of an infectious agent by particles, dust, or droplet nuclei that are suspended in the air, and which may require other additional forms of protection"(ANSI Z87.62).

Note that OSHA directs workers to see ANSI Z87.1 for appropriate eye and face

protection. In a vast majority of industry, workers are exposed to flying particles, liquid chemicals, gases or vapors, and blood borne pathogens. When a worker refers to ANSI Z87.1, it specifically states that blood borne pathogens are not covered in the standard.

“Certain hazardous exposures are not covered in this standard. These include, but are not limited to: blood borne pathogens, X-rays, high-energy particulate radiation, microwave, radio-frequency radiation, lasers, masers, and sports and recreation” (ANSI Z87.1).

1.2 Objectives

Project Need

This project is focusing on establishing minimum performance-oriented standard for a product that is widely used but for which no current standard exists for healthcare and related personnel, research facilities, or product manufacturers. Once minimum performance-oriented standards have been established, it will allow workers to be able to reference ANSI Z87.62 and have guidance for eye protectors for protection against biological hazards.

Focus

A subcommittee (ANSI Z87.62 Eye and Face Protection Used against Biological Hazards) has been formed to try and resolve this issue by creating a new standard, to include a more detailed description of the proper eye and face protection that workers exposed to biological hazards should be using. A testing method for eye and face protectors has been created to test that protectors are providing adequate worker

protection.

In recent version and updates of the ANSI Z87.1 standards, protective eye wear are required to have efficient and easy-to-understand lens and frame markings. These markings help to make the selection process simpler and have increases in compliance (Eldridge 2017). All safety markings for ANSI Z87.1-2015 safety eyewear must be permanently and clearly marked on the frame or lens. This marking requirement includes goggles and face shields as well as safety glasses. A similar marking will be created to identify PPE that have been verified to protect against biological hazards.

Some of the types of biological hazards to workers in these types of working environments are debris, blood, and other bodily fluids. Very infrequently, a worker may choose to wear a face shield, which offers improved protection for debris as well as blood and other bodily splashes. This method is hardly ever used due to higher costs and many other inconveniences and discomforts caused to the wearer (Arsenault, 2016). In the Z87.1 standard, guidance for splash could lead a user choose to wear a face shield as well as a secondary protector such as safety glasses. If the worker does not need impact protection, this combination suggested by the standard could be unnecessary extra protection.

Dental care workers report routes of exposure most commonly in places where a user's glasses meet their mask. Front and side routes of entry are adequately blocked by a wearer's safety glasses, however, bottom and top gaps remain completely exposed. This puts the wearer at increased risk of exposure to blood borne pathogens (Arsenault, 2016). (See figure 1-1 and 1-2 below)

Figure 1-1: Bottom Gaps-Side View

Figure 1-2: Bottom Gaps- Bottom View

1.3 Benefits of the research

After completion of this project, we will be able to implement a standard into Z87.1 to protect a user from representative biological hazards and a establish minimum performance-oriented standard for a product that is widely used for which a new and current standard will exist for healthcare and related personnel; research and healthcare facilities; product manufacturers. We will also be able to set forth criteria related to the general requirements, testing, permanent marking, selection, care and use of protectors to minimize or prevent exposure to the wearer's eyes and/or face caused by biological hazards including, but not limited to blood, body fluids or other potentially infectious materials (OPIMs) or microorganisms, viruses or toxins from a biological source that

can affect human health. This project's main objective is to establish a standard testing apparatus that all tests will be performed on or of a similar and equivalent testing apparatus to ensure concise and consistent testing across the broad spectrum of safety manufacturers and end users. It is designed to simulate high risk occupations with biological hazards and where eye and face PPE are worn. After the completion of the test apparatus and results have been obtained, these methods and data will provide input to the ANSI Z87.62 standard.

CHAPTER 2 – REVIEW OF LITERATURE

2.1 Blood Borne Pathogens; Not Covered In Standard – the problem

2.1.1 Problem

Blood poses high risk to health in a laboratory or clinical setting due to transmissions in the workplace when infected person's blood enters another person's bloodstream through an open wound or a mucous membrane. These risks are greatest among healthcare workers, including: nurses, surgeons, laboratory assistants, doctors, phlebotomists, and laboratory technicians. Some standard precautions when working in and around these occupational hazards are to use the universal precautions. Universal precautions is an approach to infection control to treat all human blood and certain human body fluids as if they were known to be infectious for HIV, HBV and other blood borne pathogens. One of the best ways to prevent and protect yourself from infected blood is to wear appropriate personal protective equipment: gloves, goggles, etc. as required.

Many different job environments are covered in great detail in ANSI Z87.1 and end users are provided with ample amounts of information for selecting the correct eye and face protectors. However, within ANSI-ISEA Z87.1 there is no information on the use of protectors to aid against the risk of working with biological hazards such as blood borne pathogens.

Inside the OSHA general requirements standard “1910.133,” it states;

1910.133(a)

General requirements.

1910.133(a) (1)

The employer shall ensure that each affected employee uses appropriate eye or face protection when exposed to eye or face hazards from flying particles, molten metal, liquid chemicals, acids or caustic liquids, chemical gases or vapors, or potentially injurious light radiation.

1910.133(a) (2)

The employer shall ensure that each affected employee uses eye protection that provides side protection when there is a hazard from flying objects. Detachable side protectors (e.g. clip-on or slide-on side shields) meeting the pertinent requirements of this section are acceptable.

1910.133(a) (3)

The employer shall ensure that each affected employee who wears prescription lenses while engaged in operations that involve eye hazards wears eye protection that incorporates the prescription in its design, or wears eye protection that can be worn over the prescription lenses without disturbing the proper position of the prescription lenses or the protective lenses.

1910.133(a) (4)

Eye and face PPE shall be distinctly marked to facilitate identification of the manufacturer.

1910.133(b)

Criteria for protective eye and face protection.

1910.133(b) (1)

Protective eye and face protection devices must comply with any of the following consensus standards:

1910.133(b) (1)(i)

ANSI/ISEA Z87.1-2010, Occupational and Educational Personal Eye and Face Protection Devices, incorporated by reference in § 1910.6;

1910.133(b) (1) (ii)

ANSI Z87.1-2003, Occupational and Educational Personal Eye and Face Protection Devices, incorporated by reference in § 1910.6; or

1910.133(b) (1) (iii)

ANSI Z87.1-1989 (R-1998), Practice for Occupational and Educational Eye and Face Protection, incorporated by reference in § 1910.6;

1910.133(b) (2)

Protective eye and face protection devices that the employer demonstrates are at least as effective as protective eye and face protection devices that are constructed in accordance with one of the above consensus standards will be deemed to be in compliance with the requirements of this section (UNITED STATES DEPARTMENT OF LABOR).

When a worker goes to ANSI Z87.1, they will find a chart (as shown below-Table 1 and Table 2) which covers most all things that could be found in a working

environment except for biological hazards. Within ANSI Z87.1, a worker would also find information on “Hazard Assessment” which gives a brief overview of how to correctly conduct an assessment. It also gives information on “Identifying Sources of Hazards” during a working conditions walk through. This summary of “Identifying Sources of Hazards,” even includes a section for “dust, sparks, spray, and mist,” but these are for non-biohazardous particles (Table 2-1 and Table 2-2; ANSI Z87.62, pg. 46-52).

Hazard	Protectors	Limitations	Marking ¹
IMPACT - Chipping, grinding, machining, masonry work, riveting, and sanding			
Flying fragments, objects, large chips, particles, sand, dirt, etc.	<ul style="list-style-type: none"> • Spectacles with side protection • Goggles with direct or indirect ventilation • Faceshield worn over spectacles or goggles • Welding helmet worn over spectacles or goggles • Loose-fitting respirator worn over spectacles or goggles • Full-facepiece respirators 	<p>Caution should be exercised in the use of metal frame protective devices in electrical hazard areas. Metal frame protective devices could potentially cause electrical shock and electrical burn through contact with, or thermal burns from exposure to the hazards of electrical energy, which include radiation from accidental arcs.</p> <p>To provide adequate protection, ensure goggles fit tightly to the face.</p> <p>Atmospheric conditions and the restricted ventilation of a protector can cause lenses to fog. Frequent cleaning may be required.</p>	<p>Impact rated:</p> <p>• (spectacle lens) Z87+ (all other lens) Z87+ (plano frame) Z87-2+ (Rx frame)</p>
HEAT - Furnace operations - pouring, casting, hot dipping, gas cutting, and welding			
Hot sparks	<ul style="list-style-type: none"> • Spectacles with side protection • Goggles with direct or indirect ventilation • Faceshield worn over spectacles or goggles • Loose-fitting respirator worn over spectacles • Full-facepiece respirator 	<p>Spectacles, cup and cover type goggles do not provide unlimited facial protection.</p> <p>Operations involving heat may also involve optical radiation. Protection from both hazards shall be provided.</p>	<p>NOTE: There are currently no marking designations for eye protection to heat or high-temperature exposure in the ANSI/ISEA Z87.1-2015 standard.</p>
Splash from molten metal	<ul style="list-style-type: none"> • Faceshield worn over goggles • Loose-fitting respirator worn over spectacles or goggles • Full-facepiece respirator 		

Table 2- 1: Eye and Face Protector Selection Guide 1

Hazard	Protectors	Limitations	Marking ¹
High temperature exposure	<ul style="list-style-type: none"> • Screen faceshield over spectacles or goggles • Reflective faceshield over spectacles or goggles 		
CHEMICAL – Liquids, acid and chemical handling, degreasing, plating.			
Splash, droplets and sprays	<ul style="list-style-type: none"> • Goggles with indirect ventilation (eyecup or cover type) • Faceshield worn over goggles • Loose-fitting respirator worn over spectacles or goggles • Full-facepiece respirator 	<p>Atmospheric conditions and the restricted ventilation of a protector can cause lenses to fog. Frequent cleaning may be required.</p> <p>To provide adequate protection, ensure goggles fit tightly to the face.</p>	Splash/droplet: D3
Irritating Mist	<ul style="list-style-type: none"> • Goggle with no ventilation (cover type) • Faceshield worn over goggles • Loose-fitting respirator worn over spectacles or goggles • Full-facepiece respirator 	<p>Atmospheric conditions and the restricted ventilation of a protector can cause lenses to fog. Frequent cleaning may be required.</p> <p>To provide adequate protection, ensure goggles fit tightly to the face.</p>	NOTE: There are currently no marking designations for eye protection to irritating mists exposure in the ANSI/ISEA Z87.1-2015 standard.
DUST - Woodworking, buffing, general dusty conditions			
Nuisance dust	<ul style="list-style-type: none"> • Goggles with direct or indirect ventilation (eyecup or cover type) • Full-facepiece respirator 	<p>Atmospheric conditions and the restricted ventilation of a protector can cause lenses to fog. Frequent cleaning may be required.</p> <p>To provide adequate protection, ensure goggles fit tightly to the face.</p>	Dust: D4
Fine dust	<ul style="list-style-type: none"> • Goggles with indirect ventilation or no ventilation • Full-facepiece respirator 	To provide adequate protection, ensure goggles fit tightly to the face.	Fine dust: D5
OPTICAL RADIATION			
Infrared Radiation (IR)	<ul style="list-style-type: none"> • Spectacles with side protection • Goggles with direct or indirect ventilation • Faceshield worn over spectacles or goggles • Welding helmet worn over spectacles or goggles • Loose-fitting respirator worn over spectacles or goggles • Full-facepiece respirators 	<p>For proper fit of protector; there shall be no penetration of direct infrared spectra light in all non-lens areas.</p> <p>Side shields shall have filtering capability equal to or greater than the front lenses.</p>	IR: R and scale number

Table 2-2: Eye and Face Protector Selection Guide 2

In the OSHA standard, it 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. The selection guide for these protectors doesn't include all possible routes of entry (front, side, bottom, and top) or biological hazards such as blood borne pathogens. Since the standard calls for the employer to supply the employee with the most appropriate eye protector, they then would need to provide an eye protector that encompasses all entry routes and hazards such as blood borne pathogens.

2.2 Identifying and Categorizing Workplace Hazards

2.2.1 Hazards

Healthcare personnel are at risk for occupational exposure to blood borne pathogens. Blood borne pathogens are pathogenic microorganisms present in the human blood that can lead to diseases. The primary concerns of blood borne pathogens are hepatitis B virus (HBV), hepatitis C virus (HCV), and human immunodeficiency virus (HIV). HBV causes serious liver disease (Hepatitis B), which can become a chronic condition that causes permanent scarring of liver, leading to liver failure or liver cancer; there are an estimated 2,000-4,000 deaths per year in U.S.(CDC, 2015). HBV is much more transmissible than HIV and 50% of infected people are unaware that they have HBV (CDC, 1997). Hepatitis C Virus (HCV) attacks the liver and leads to inflammation. Chronic infection develops in 75%-85% of patients with 70% developing active liver disease (CDC n.d.), and can result in long-term health problems, even death. Most

infected people have no symptoms and don't know they are infected until decades later when liver damage shows up in routine tests. Human Immunodeficiency Virus (HIV) causes Acquired Immunodeficiency Syndrome (AIDS) and attacks the immune system cells which weakens and eventually destroys the immune system thus, leaving the body at higher risk of developing serious conditions such as pneumonia or cancer. It is estimated that close to 1 in 5 are unaware they are infected. Once a person is infected, the human body cannot get rid of the HIV completely. Some people experience flu-like symptoms (fever, chills, rash, night sweats, muscle aches, sore throat, fatigue, swollen lymph nodes, or mouth ulcers) 2-4 weeks after infection, while others may not feel sick and be unaware of their infection (CDC, 2015).

2.2.2 Transmission in the Workplace

In most work situations, transmission is most likely to occur because of accidental puncture from contaminated needles, broken glass, or other sharps; contact between broken or damaged skin and infected body fluids; or contact between mucous membranes and infected body fluids. For example, if someone infected with HBV cut their finger on a piece of glass, and then you cut yourself on the now infected piece of glass, it is possible that you could contract the disease. Anytime there is blood-to-blood contact with infected blood or body fluids, there is a slight potential for transmission. Unbroken skin forms an impervious barrier against blood borne pathogens. However, infected blood can enter your system through:

- Open sores
- Cuts
- Abrasions
- Acne

- Any sort of damaged or broken skin such as sunburn or blisters

Blood borne pathogens may also be transmitted through the mucous membranes of the eyes, nose and mouth. Important factors that influence the overall risk for occupational exposures to blood borne pathogens include the number of infected individuals in the patient population and the type and number of blood contacts. Most exposures do not result in infection. Following a specific exposure, the risk of infection may vary with factors such as these:

- The pathogen involved
- The type of exposure
- The amount of blood involved in the exposure
- The amount of virus in the patient's blood at the time of exposure

Using appropriate barriers such as gloves, eye and face protection, or gowns when contact with blood is expected can prevent many exposures to the eyes, nose, mouth, or skin.

Exposure to blood-borne pathogens poses a serious risk to health care workers (HCWs). Assessment of the risk of blood-borne pathogen transmission in the health care setting requires information derived from various sources, including surveillance data, studies of the frequency and preventability of blood contacts, seroprevalence studies among patients and HCWs, and prospective studies that assess the risk of seroconversion after an exposure to infected blood. Factors influencing the risk to an individual HCW over a lifetime career include the number and types of blood contact experienced by the worker, the prevalence of blood-borne pathogen infection among patients treated by the worker, and the risk of transmission of infection after a single blood contact.

There are many modes of blood-borne pathogen transmission in the health care setting; blood-borne pathogen transmission occurs predominantly by percutaneous or mucosal exposure of workers to the blood or body fluids of infected patients (American Red Cross, 2001). Occupational exposures that may result in HIV, HBV, or HCV transmission include needle stick and other sharps injuries; direct inoculation of virus into cutaneous scratches, skin lesions, abrasions, or burns; and inoculation of virus onto mucosal surfaces of the eyes, nose, or mouth through accidental splashes. HIV, HBV, and HCV do not spontaneously penetrate intact skin, and airborne transmission of these viruses does not occur.

The mode of transmission that this study is most concerned and directed towards is transmission through the eye, nose or mouth. If the conjunctiva of the eye is compromised; bacteria, viruses, and fungi can easily penetrate into the eye, blood vessels, or vitreous / aqueous humor. These risks are exacerbated by abrasions, swelling, allergies, infection, inflammation, dryness, conjunctivitis, sty, recent surgery, and workers who wear contacts. Below is Figure 2-1 that outlines the eye and its anatomy. The possible routes of transmission for the eyes are highlighted.

Semi-Transparent Skin
Covering: First Line of
Defense

Figure 2-1: Anatomy of Eye

Source: (Mitchell 2016)

<https://www.lhup.edu/~dsimanek/scenario/labman3/eye.htm>

2.3 Occupations

High Hazard occupations that use eye and face protection can be sorted and analyzed based on a risk assessment and the most common biological hazard that is seen with each situation. The broad range of hazards that are being compared are propelled droplets, splashes, sprays, and other potentials infectious materials. The most common occupations that are seen to have the highest incidence rate of these hazards projected at the workers eyes would be nurses, doctors performing procedures, dental healthcare

workers, and laboratory workers in the health related research fields (Mitchell 2016).

Below is Table 2-3 which summarizes what specific occupational work environment gets the most exposure, subsequent infections, illnesses, and seroconversions.

ICU	Influenza, HIV
ER / Isolation	SARS
Patient Room	HBV
Lab / Research	Herpes B Virus
Lab / Diagnostic	HIV, HCV
Lab	Plague
Ortho Surgery	Hepatitis, HIV
Dental	HIV
Security / Police	HCV
Veterinary	Rabies
Relief Workers	Ebola

Table 2-3: Reports in Occupational Work Environment

Source: (Mitchell 2016)

2.3.1 Surgeons / Physicians / Nurses (Involved in procedure)

The risk of blood borne pathogen transmission through accidental exposure is low, it is still at 0.5% for needle stick injury with percutaneous needles and at 0.1% for mucous membrane exposure (Beltrami et al., 2000). This mucous membrane exposure can be transmitted through ocular contact. While most surgeons take precautions to avoid needle stick injuries, potential infection via fluid exposure to the eyes might not be as well recognized

as a hazard. Non sharps (mucocutaneous) exposure poses a problem as well. Such exposure can arise from incidents ranging from accidental splashing of blood into the eyes or a skin cut when starting or removing an I.V. catheter to disposing of body fluids or dressing an open wound. A 2003 study found nurses had a higher mucocutaneous exposure rate than physicians and medical technologists. More than one-third (39%) of registered nurses and one-fourth (27%) of licensed practical nurses said they'd experienced one or more mucocutaneous blood exposures in the previous 3 months—but few reported their exposures (Delisio, 2017).

Looking at statistical data that categorizes the occupation of medical personal from the International Safety Center, one can see that the Doctors and Nurses are the highest exposed workers (Table 2-4).

What is the job category of the exposed worker?		
1 Doctor (attending staff) specialty	19	8.9%
2 Doctor (intern/resident/fellow) specialty	9	4.2%
3 Medical student	1	1.9%
4 Nurse	115	54.0%
6 Respiratory therapist	5	2.3%
7 Surgery attendant	4	1.9%
8 Other attendant	2	0.9%
9 Phlebotomist/ Venipuncture/ IV team	2	0.9%
10 Clinical laboratory worker	3	1.4%
11 Technologist (non lab)	9	4.2%
15 Other, describe	26	12.2%
16 Paramedic	3	1.4%
18 C.N.A./H.H.A.	10	4.7%
20 Security	2	0.9%

Table 2-4: Exposed Medical Workers

Source: (Mitchell 2016)

The data goes in depth to show where the exposure occurred. As seen, direct patient

care is the greatest cause of splashes. This is due to the fact that patients have a lot of fluid, i.e. these exposure are happening where the patients are. 75.6% are from direct patient contact (Table 2-5). Furthermore in Table 2-6, data shows that the eyes or conjunctiva is the most exposed part in the total records at 65.7%.

Where did the exposure occur?		
1 Patient room/ward	86	40.4%
2 Outside patient room	4	1.9%
3 Emergency department	16	7.5%
4 Intensive/Critical care unit	19	8.9%
5 Operating room/Recovery	36	16.9%
6 Outpatient clinic/Office	11	5.2%
10 Procedure room	6	2.8%
11 Clinical laboratories	4	1.9%
14 Other, describe	20	9.4%
16 Labor and delivery room	10	4.7%
17 Home-care	1	0.5%
Total records: 213		

Table 2-5: Exposure Setting

Source: (Mitchell 2016)

Was the exposed part?		
Intact skin	50	23.1%
Non-intact skin	29	13.4%
Eyes (conjunctiva)	142	65.7%
Nose (mucosa)	8	3.7%
Mouth (mucosa)	17	7.9%
Other exposed parts	22	10.2%
Total records: 216		

Table 2-6: Exposed Body Part

Source: (Mitchell 2016)

In a study that was done to quantify how frequently body fluids splash the mask and lens of protective glasses it was found that from a total of 384 operations, 174 (45%) showed blood or body fluid splash on the lens (Davies, 2007). A high incidence of

splashes was found in vascular surgical procedures (79%). All amputations showed splashes onto the protective lens of the eye protector. Also, the study showed that 50% of laparoscopic cases resulted in blood or body fluid splash on the protective lens (Davies, 2007). This study demonstrated that an overall 45% risk of blood and bodily fluid splash on protective spectacle lens during surgery. This agrees with previous studies where blood splash contamination recorded on spectacles and protective eye shields has varied from 25-51%. This study has shown significantly more incidents of blood and body fluid splash when undertaking vascular operations and amputations. Vascular surgery does expose a surgeon to blood splash frequently due to common use of bone cutters and power saws. Blood and bodily fluids are often sprayed into the operating room. Not only is the primary surgeon at risk but their assistants were shown to be equally at risk of blood and bodily fluid splash to their eyes. With the abundance of HIV and hepatitis, it seems prudent to protect oneself against possible routes of transmission. The prevalence of HIV and hepatitis is increasing; therefore, although the transmission risk of HIV and hepatitis is low, the overall risk cannot be ignored. In a prospective epidemiological study performed on patients undergoing invasive radiological procedures in France, 944 patients were screened for hepatitis C virus. Ninety-one patients (10%) tested positive for hepatitis C, of whom 82 (90%) had a positive viremia result demonstrating a high potential for contamination through blood contacts (Davies, 2007).

Some surgeons and assistants will rely on their prescription spectacles as sole eye protection. With the majority of these spectacles being of a slim design, their effectiveness as an eye protector decreases. When looking at a survey done to assess

current operating theatre eye wear practices, out of 71 surgeons, 84.5% that used their prescription eyewear as their eye protector had experienced prior periorbital blood splashes to the facial region, of those 19 (26.8%) admitted to having been impacted in the eye (Chong, 2007). Personal estimates of rates of facial blood splash varied widely, from 0 to 21.7 events per month, while twelve (16.9%) had previously intraoperatively un-gowned to clean themselves following a facial blood splash, and 6 (8.5%) had sought infectious disease testing following conjunctival contamination (Chong, 2007). Two (2.8%) admitted to contracting an illness from palpebral fissure contamination, comprising 1 case of viral papilloma and 1 case of conjunctivitis (Chong, 2007).

Experience	No. Participants (% population)
Facial blood splashes previously?	60 (84.5)
Blood splash getting into the eye previously?	19 (26.8)
Had intraoperatively ungowned to clean after a blood splash?	12 (16.9)
Sought infectious disease testing following a blood splash?	6 (8.5)
Contracted an infectious disease from a blood splash?	2 (2.8)

Table 2-7: Personal Experience with Facial Blood Splashes

In an article written on the risks of blood splashes to the eye during surgery a study was approved and conducted by the Ethics Committee of the Faculty of Health Sciences of the University of Cape Town (Table 2-7). The study was undertaken to determine the incidence of blood splashes to the eyes during surgery. After the study concluded and results were analyzed it was found that the incidence of blood splashes (ocular) was 45%; the study also found that the risk of mucocutaneous exposure via

blood splashes to the eyes is either underestimated or not fully appreciated by health care workers (Silva, Mall, Panieri, Stupart, & Kahn, 2009).

2.3.2 *Dentist / Dental Care workers*

Dental practice presents opportunities for cross-contamination. The dentist's face is at high-risk of infection transmission. A large number of pathogens are localized in the oral cavity, which can be transmitted in different ways during dental procedures, usually by means of air/water syringe and high-speed instruments. Two basic ways for spreading pathogenic microorganisms in a dental practice are blood and saliva through droplets of infected patients. The greatest risks for the dentist are hepatitis B and C viruses, and HIV virus that spread through blood and cause life-threatening diseases. Eye injuries can vary from mild irritation to blindness. The use of eye protection, such as protective goggles and visors, reduces the risk of eye damage or complete loss of vision while working with dangerous and floating materials. Therefore, all precautions should be taken, even when performing common procedures for which the risk expectancy is relatively low. Porter et al. investigated occupational injuries reported in dental hospitals over a period of 9 years and found that eye injuries accounted for 10% of incidents (Porter, 1990). Similarly, Wazzen et al. examined the 1 month prevalence of ocular injuries and infections among dental personnel which consists of dental assistants, dentists and technicians for which he found the foreign body related injury prevalence of dental personal, the dentists and technicians was 42.3% (Wazzen, 2001). Research shows that approximately 48% of all dental providers suffer some sort of ocular trauma during their careers. It is worth noting that during one year, 27.6% of the dentists had contact with infectious material via damaged skin, and 28.1% of the

dentists reported trans-mucosal contact. Half (54.7%) of the dentists reported splashing infectious material on the conjunctiva of the eye (Garus-Pakowska, 2017).

Other research has demonstrated the inadequacy of the present dental mask and regularly worn protective eye wear. Some dental workers wear dental masks and protective eye wear while performing their routine procedures. However, just a general off the shelf eye protector is not sufficient enough. These eye protectors generally conform to ANSI Z87.1 for their impact ratings but the standard has nothing to conform to on blood borne pathogens. Dr. Peter Arsenault conducted experiments and published a report showing the different entry routes for exposures to the user's eyes. He states, "Also, the unavoidable generation of the bottom gaps renders the combination of regular protective eyewear and non-full face shield dental mask an unreasonably dangerous combination, since it is reasonably foreseeable that dental debris may reach the eyes of the dental practitioner through such open bottom gaps" (Arsenault, 2016).

Dr. Arsenault goes on to report a firsthand account of a student with an eye injury. The report states:

When I treated this patient I took all of the necessary precautions which include wearing a gown, gloves, face mask, and loupes with frames for eye protection. While cleaning the margins with a piece of floss some of the patient's saliva splashed into my eye. The patient's gingiva was bleeding and it was possible that some of his blood had splashed into my eye too.

When this occurred my facemask and loupes were fully tightened. I was confused how this happened, so I examined how my loupes sat on my face and noticed a slight opening between my face and the frames just lateral to the ridge of my nose. I noticed there was a space not protected by my loupe frame or facemask which left my eyes exposed at certain angles. Even though I followed all the mandatory safety guidelines, my eyes were still susceptible to flying debris and an infectious disease. Immediately after the incident I went to the emergency room to wash my eye and was prescribed prophylaxis medication” (Arsenault, 2016).

The account goes on to talk about the medications he had to be on for treating an incident for infectious disease.

“The medications I took had dramatic side effects that made doing simple things feel more difficult. Fortunately, I was able to recover without any major problem. However, I believe the situation could have been avoided with proper eye protection. The current standard for eye wear is unacceptable and requires improvements for the safety of all dentists” (Arsenault, 2016).

2.3.3 Health Care / Laboratory Workers

When it comes to occupational risks in the health care working environment, most people think of slips, trips, and falls right away. There are many other very hazardous risks that tend to get overlooked. These come in the form of blood borne

pathogens exposures and infectious diseases. Most commonly, these hazardous risks are transmitted through sharps and bodily fluids (Splish Splash, 2003). These splashes, also known as mucocutaneous blood exposures can transfer pathogens through the eyes, nose, or mouth. Clinical lab work is at a very high risk because specimens that are in the lab are there because they are already suspected to have a contagion of some kind. Below Table 2-8 shows an outline of what the exposures are a result of. As one can see, the majority of the exposures in this type of setting is from specimen container leaks.

Table 2-8: Health Care / Laboratory Exposure from Various Tasks

Source: (Mitchell 2016)

Other health care and laboratory work is performed with more than just human contact. Many clinical lab workers may help with research while working on animals such as primates. In some cases there have been documented incidents where an

exposure has happened when working with animals. In 1997 a female worker at a primate center died from Cercopithecine herpesvirus (B virus) infection following a mucocutaneous exposure. This exposure happened after working with a rhesus macaque where biologic material splashed into her right eye. The worker was not wearing any eye protection due to the nature of task being deemed a “low risk.” After the exposure to the eye, the worker wiped it and then irrigate the eye with water about 45 minutes later. After many ongoing days of hospital visits and ophthalmologists consults, the worker died 42 days later from refractory respiratory failure (NIOSH, 1999).

A study was done to simulate mucocutaneous exposures from a splash of infectious material onto the eye of a chimpanzee. This experiment was conducted involving direct eye inoculation of a chimpanzee with hepatitis B material that was known to be infectious. 50 micro liters of HLD-1 plasma (hepatitis B) was placed on the corneal surface of the eyes of the anesthetized chimpanzee (25 micro liters each eye). The Chimpanzee was refrained from rubbing its eyes for 10 minutes; afterward the eyes were gently blotted with absorbent tissue to remove excess fluid. After 9 weeks of observing the chimpanzee, it was found to be seropositive for hepatitis B surface antigen. After more observations over 25 weeks the chimpanzee was found to test positive for the last serological marker tested during the resolution of the disease. The results of this study directly confirm that eye inoculation of blood from hepatitis B patient may result in infection of a susceptible individual (Bond, Peterson, Favero, Ebert, & Maynard, 1982). It is certain for reasonable and prudent recommendations that workers use protective eyeglasses in and instance where direct or indirect splashing of bodily fluids from a hepatitis B patient is

possible (Bond, Peterson, Favero, Ebert, & Maynard, 1982).

Nurses and health care workers provide relentless care to patients on a daily basis. Many tasks might be considered “not so hazardous.” However, when you consider that nurses and other health care workers empty cups and containers, wash dirty bed pans, clean urine bottles, and handle catheter bags; these tasks then start to become more concerning. According to a 2003 study, 39 percent of registered nurses and 27 percent of licensed practical nurses experienced at least one mucocutaneous blood exposure (splash) in 3 months (Splish Splash, 2003). Many of these incidents go under reported. This is due to the inconvenience that it takes for the health care provider to report to employee health. It also can lead to a large list of tests to check for or treat for a transmissible disease. If anything is discovered that could result in infection, a round of prophylaxis is usually required for the health care provider. This medicine then leads to costly medical bills and a few weeks of feeling miserable. Occupational exposures such as splashes can lead to lost work days, financial burden, and physical impairment. They also can take an emotional toll on those exposed (Splish Splash, 2003).

Another study led by Doebbeling et. al. at the Veterans Administration found that in the previous three months, roughly 38 percent of RNs had experienced some sort of mucocutaneous blood exposure (a splash containing blood that lands on a caregiver where it could transfer a pathogen such as the eyes, nose or mouth). They also found that only about 73 percent of these injuries were reported (Doebbeling, 2003). Gershon et al. surveyed many different types of healthcare workers found that about 29 percent of respondents had some sort of exposure incident in the previous six

months, of which, only about 44 percent were reported. To create significant change, as stated in the study by Gershon, “There must be a culture of safety. Senior leadership must endorse measures that will lead to a safer environment. These include availability of PPE, design of the environment to decrease contamination and utilizing devices that are engineered to be safer” (Gershon, 2000).

There are many studies being done to research and prove that splashes to the eye are a very prominent problem that isn’t being addressed enough to protect health care workers. In a study done of US Medical students in Botswana, they found this issue to be almost as prominent as incident with sharps. Students were asked to describe each individual exposure, and were asked about whether the exposure was reported when it occurred, the circumstances surrounding the exposure, and whether PEP (post-exposure prophylaxis) was taken. Of the 82 students who received the survey, 67 responded. Seventeen of 67 (25.4%) reported having a blood or body fluid exposure; eight were needle sticks, and nine were splashes. All splashes were eye splashes (Merlin, et al., 2010).

Many articles reviewed the use of face shields in the workplace. Most people still do not think that even a face shield is adequate protection against biological hazards (Roberge, 2016). From a journal review on face shields for infection control, Raymond Roberge discusses their uses and the additional need for research on infection control.

Face shields are PPE that are commonly used as barrier protection for infection control purposes by numerous workers. There currently is no standard regarding

face/eye protection from biological hazards and this deficit needs to be remedied as quickly as possible. Due to the lack of a good facial seal peripherally that can allow for liquid penetration, face shields should not be used as solitary face/eye protection, but rather as adjunctive to other PPE (protective facemasks, goggles, etc.). Given the dearth of available data regarding the appropriate use of face shields for infection control, scientifically sound research needs to be conducted on the use of this form of PPE (Roberge, 2016).

2.4 Risks

The risk following a blood exposure to the eye, nose or mouth is unknown, but is believed to be very small; however, HCV infection from a blood splash to the eye has been reported. For HIV, the average risk of HIV infection after a needle stick or cut exposure to HIV-infected blood is 0.3% (about 1 in 300). The risk after an exposure of the eye, nose or mouth to HIV-infected blood is estimated to be on average, 0.1% (about 1 in 1000) (CDC, 2015).

2.4.1 Risk Assessment

Safety Professionals use a risk matrix to assess the various risks of hazards (and incidents) and other safety events. Severity is the amount of damage or harm a hazard could create and is ranked on a four point scale.

- Catastrophic 4 - Operating conditions are such that human error, environment, design deficiencies, element, subsystem or component failure, or procedural deficiencies may commonly cause death or major system loss,

thereby requiring immediate cessation of the unsafe activity or operation.

- Critical 3 - Operating conditions are such that human error, environment, design deficiencies, element, subsystem or component failure or procedural deficiencies may commonly cause severe injury or illness or major system damage thereby requiring immediate corrective action.
- Marginal 2 - Operating conditions may commonly cause minor injury or illness or minor systems damage such that human error, environment, design deficiencies, subsystem or component failure or procedural deficiencies can be counteracted or controlled without severe injury, illness or major system damage.
- Negligible 1 - Operating conditions are such that personnel error, environment, design deficiencies, subsystem or component failure or procedural deficiencies will result in no, or less than minor, illness, injury or system damage.

(Risk Matrix Calculations)

Probability is the likelihood of the hazard occurring and is ranked on a five point scale:

- Frequent 5 - Likely to occur often in the life of an item
- Probable 4 - Will occur several times in the life of an item
- Occasional 3 - Likely to occur sometime in the life of an item.
- Remote 2 - Unlikely but possible to occur in the life of an item.
- Improbable 1 - So unlikely, it can be assumed occurrence may not be experienced

Risk Assessment –The Risk Assessment Values are determined by multiplying the

scores for the Probability and Severity values together. The following Table 2-9 displays the default risk assessment values (Risk Matrix Calculations).

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

Table 2-9: Risk Assessment Table

Source: (Risk Matrix Calculations)

Given that the risk of infection after an exposure is relatively low (1 in 1000) due to exposure of the eye, nose, or mouth gives a notion that the risk should be in a moderate to low category. However, the probability of being exposed is relatively high within the occupation, given that statistics report it happening frequently and more than once a year and the severity of this risk is serious or disabling and life threatening, this puts the risk assessment matrix for these occupations for biological hazards of splashes to the eyes in a “High” category.

2.5 Summary

According to the World Health Organization's description of health, health is a state of complete physical, mental, and social well-being and not merely the absence of disease (WHO). Eye health is becoming an increasingly important subject both for the health care system and the society. Workers need to be more aware of the potential risks and dangers when working in and around biological hazards that have potentials for splashes and spurts to the facial region. Since transmissions of infections and injuries of the eye may go unnoticed; chronic eye injuries are possible. There are many protective measures which can help to provide good protection for eye health. Eye protectors can reduce the risk of eye damage or complete loss of vision while working in hazardous conditions. Though there are numerous technological and medical advances in eye protectors for health care workers; there are still many incidents and injuries that do occur. Most health care workers refer to ANSI Z87.1 for information of eye protectors and proper selection. ANSI Z87.1 is lacking in the biological hazards and blood borne pathogens category for selection of eye protectors. Many research articles prove that there is a problem that needs to be addressed for protection against splashes and spurts to the eyes of the health care worker. ANSI Z87.62 will allow workers to have a reference and have guidance for eye protectors for protection against biological hazards. This project gives a test apparatus and standard criteria that all eye and face protectors for biological hazards will be performed on. This will ensure concise and consistent testing across the broad spectrum of safety manufacturers and end users for eye and face protectors.

CHAPTER 3 –TEST APPARATUS / METHODS

3.1 General test setup description

This study evaluates the efficiency of manufacturer's eye and face PPE for protection against biological hazards such as blood borne pathogens. The test apparatus is replicating the hazards that a worker would see in average working conditions. The majority of these hazards are coming from the human body such as sneezes/coughs, puncture wounds, saliva/mucous, or instances of low velocity splashes from containers in laboratory conditions. The test apparatus replicates these conditions to best match the patterns, velocities, and volumes that would be a biological hazard to the worker. Eye protectors will be selected and placed on the anthropometric head as if being worn for occupational hazards. The headform will be adjusted at the specified distance for the specific criteria being tested (spurt or spray). The test will be conducted at varying headform locations and angles. Immediately after each shot at each location, the eye, nose, and mouth of the headform will be evaluated for any droplets of fluid. If any fluid is found to be on the eye, nose or mouth, then the eye protector and coordinating ensemble (eye protector and face mask) fails the test. This angle and location will be noted and the testing will continue to evaluate other locations and angles. Once testing is concluded, if the protector has any failure spots, then that particular eye protector will fail the criteria to be labeled for protector against biological hazards under ANZI Z87.62. If the eye protector passes all the testing locations, then that particular eye protector passes and is allowed to be labeled for protection against biological hazards under ANZI Z87.62.

3.2 Test Parameters

3.2.1 *Spurt and Spray*

One criteria of a “shot” that will be used in evaluating eye protectors is the spurt test.

The spurt is used to simulate a small arterial puncture or similar situation from a human at average blood pressure velocities. This speed of the simulated fluid for a “spurt” will be replicating the pressure from which an average human body could expel blood. These ranges will be from a low of 80 mmHg to a high of 160 mmHg. These two ranges are equivalent to 10.7 and 21.3 kPa. These two pressures will have stream velocities projected from the nozzle of 450 and 635 cm/s respectively. The proposed velocity for the test will be 635 cm/s to replicate a worst case scenario. Based on ASTM F1862 Standard Test Method for Resistance of Medical Face Masks to Penetration by Synthetic Blood test criteria of a max volume of 2 ml, the volume of fluid that will be expelled for this test apparatus will follow that of which will be 2 ml (ASTM F1862-Blood Spurt Tester). The spurt was tested at 30.48 cm. This is based off the average distances that health care workers operate from their patients (Neck Health 2008). This is to test for the worst case scenario of being close to the patient. The nozzle for the spurt will be set at a horizontal distance of 30.48 cm for all spurt testing locations. The spurt criteria is achieved by using a detachable straight tubbed cannula fitted to the nozzle (Figure 3-1).

Figure 3-1: Spurt Cannula

The apparatus will also be testing eye and face protectors for protection against “spray”. This spray is to replicate a human cough or sneeze. The speed of the fluid for a “spray” will be replicating the pressure from which an average human could expel a spray. The range of a sneeze and cough were conducted from a study by Hidekazu Nishimura. Nishimura concluded that the highest most common velocity is around 300 – 500 cm/s at a horizontal distance of 30-60 cm(11.8-23.6”) (Nishimura, Sakata et al. 2013). The concentration of particles, optimal spray pattern and coverage is what the spray category will be mostly concerned with. This spray is mostly around 30-35 cm horizontally. The nozzle for the spray will be set at a distance of 30.48 cm horizontal to the point of impact. Based on personal interviews of Dr. Arsenault, the volume of fluid

that will be sprayed at the headform will be that of at least 0.5 ml and no more than 1 ml. (Arsenault). This spray criteria is achieved by using a detached spray tipped cannula fitted to the nozzle (Figure 3-2).

Figure 3-2: Spray Cannula

3.2.2 Headform Locations

Both the Spurt and Spray categories will be using the same shot target locations on the headform at their specified horizontal distances. The protector device shall be placed on the headform in the designated wearing position. For the spurt and spray dispensing shots, the headform will be manipulated into 4 main locations. These locations will share a common reference point from which all locations will be measured. The exact

center between the eyes on the headform was used to aim all target locations. The first 2 locations will be with the headform centered across the sagittal plane. The sagittal plane divides the body into left and right. On a person it would pass through the midline structures such as the spine and navel. The first centered sagittal plane shot will be with the headform tilted posteriorly 30 degrees off the coronal plane (Figure 3-3). The nozzle should be aimed 1" below the center point of eyes on the bridge of the nose. The second sagittal plane shot will be with the headform titled anteriorly 30 degrees off the coronal plane (Figure 3-4). The nozzle should be aimed 2" above the center point of the eyes on the forehead of the headform. The angle of which the headform will be tilted anteriorly and posteriorly is capturing the average angle at which a health care worker would angle their head to in relation to the patients head (Pirvu, 2014). The third and fourth shot will be to the left and right temple area of the headform. The headform will be centered across the sagittal and coronal plane in a vertical fashion. A coronal plane is any vertical plane that divides the body into ventral and dorsal sections (belly and back). On a person's head, this would divide it into the front (facial portion) and back (back of the head). It then needs to be turned 55 degrees to the left and right for the third and fourth shot respectively, and not centered at the bridge (Figure 3-5, Figure 3-6) (Arsenault, 2016). The nozzle should be adjusted to the same height of the center point of the eyes for the targeted location. These manipulations will be referred to as Up, Down, Right, and Left; as they are shown in order below. The target locations above (2") and below (1") the center point of the eyes was chosen to get more varying locations for spurts and sprays. If every shot was placed at the center point of the eyes on the headform manipulations then the test would not be examining any other areas of protection from the eyewear but the center

point (in between the eyes / bottom gap). By varying these locations 2'' above, 1'' below, 55 degree left and right, the test is examining more areas of protection of the eye wear and mask. (Top, Bottom, Left, Right) This in addition to the Range of Protection test which the target location is always at the center point of the eyes gives a large range of examination of the ensembles protection.

Figure 3-3: Posteriorly Titled 30 Degrees

Figure 3-4: Anteriorly Tilted 30 Degrees

Figure 3-5: 55 Degrees Turned Right

Figure 3-6: 55 Degrees Turned Left

3.2.3 *Velocities*

The velocities that will be used for the speed of the spurt and spray are based off of averages of human bodily fluids that could be expelled naturally. 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 through a known area (1). Since the electronic dispensing unit can easily control the period of time and pressure at which the stream exits from, the flow velocity can be calculated. It is also easier and more accurate to measure the weight rather than the volume of the spurt and knowing the density of the fluid being used.

$$v = Q/tA \quad (3-1)$$

v = flow velocity

Q = flow volume

t = duration of the flow

A = *cross sectional area of the orifice*

$$\omega = Q\delta \quad (3-2)$$

δ = *density of the test fluid*

ω = weight of the spurt

Q = *volume of the spurt*

By using the difference in weight of streams shot in known times and using a derived equation, the steady state streams exit velocity can be estimated (3)

$$(\omega_2 - \omega_1) = v \frac{\pi \delta d^2}{4} (t_2 - t_1) \quad (3-3)$$

This equation can also be represented as:

$$(\omega_2 - \omega_1) = \frac{v(t_2 - t_1)}{C} \quad (3-4)$$

$$C = \frac{4}{\pi \delta d^2} \quad (3-5)$$

The constant C (5) can be recalculated for fluids with other specific gravities that are less than 0.995 or greater than 1.015. It can also be recalculated when using different sized diameter cannulas on the nozzle. The equation for the value C can also be used to build tables of target velocities for limits and different spurt weights for varying test requests. Figure 3-16 shows tables built for easy calculation for target weights and velocities. This table has been rebuilt and manipulated for these tests from ASTM F1862. During experimentation with the different velocities and pressures, I was able to use a chronograph to validate the exit velocities with the estimated velocities using the Excel equations (Figure 3-7). A forecasted graph through Excel aids in getting a quick estimate of the pressure needed in the container for exit velocities (Figure 3-8).

Another useful forecasted graph to estimate exit velocities during tester setup is weight vs velocity (Figure 3-9). These forecasted graphs are making predictions about a value based on past and present data by using analysis of trends.

	A	B	C	D	E	F	G	H	I	J	K
1		Spurt 1 (1.5s)	Spurt 2 (1.5s)		Spurt 1 (0.5s)	Spurt 2 (0.5s)	$V = C(\omega_2 - \omega_1)$				
2	Spurt 1	5	4	Spurt 1	2.4	2	$V =$	404.19	cm/s		
3	Spurt 2	4.5	4.2	Spurt 2	2.4	2					
4	Spurt 3	4.45	4.1	Spurt 3	2.4	2					
5	Average	4.65	4.10	Average	2.40	2.00					
6		Spurt weight in grams (before hole)	Spurt weight in grams (after hole)		mmHg	80	120	160			
7	1.5 s	4.65	4.10	g	Target Vel	450	550	635	cm	Target Stream Velocities	
8	0.5 s	2.40	2.00	g							
9	difference	2.25	2.10	g	Tank Pres	4.95	6.5	8.3	psi	Approximate tank pressure for reference	
10		93.3%			wt. @ 1.5 s	3.82	4.73	5.52	g	Approximate spurt weight for 1.5s for reference.	
11											
12		Approximate time for 2ml spurt through hole.									
13		0.50	sec		Upper Limit	2.56	3.12	3.61	g	Weight limits for 2% velocity range.	
14		Steady state pressure and velocity of this spurt.			Target	2.5	3.06	3.53	g		
15		64.6633125	mmHg		Lower Limit	2.45	3	3.46	g		
16		403.986857	cm/sec								
17					C	179.64	velocity to time conversion factor.				
18						1.005	Specific gravity of the synthetic blood being used.				
19							(Must be updated if fluid s.g. is <0.995 or >1.015)				
20											
21	Canula Dia.	d (cm)	0.084			0.9982	Specific gravity of water				
22	weight of spurt	ω									
23	density of fluid	δ	1.005								
24	Velocity	v									
25	time	t			$C = 4\pi h \delta d^2$	179.64					
26	Area	A									
27	Flow Volume	Q									
28		π	3.14								
29											
30											

Figure 3-7: Excel Velocity Calculations and Tables

Figure 3-8: Predicted Velocity using Mass vs cm/s with Upper and Lower Limit Lines

Figure 3-9: Predicted Velocity using PSI vs cm/s

3.3 Test Equipment

3-10.1	Anthropometric Headform
3-10.2	Articulating Base
3-10.3	Milling Table
3-10.4	Dispensing Unit
3-10.5	Pressurized Container
3-10.6	Uni-Slide
3-10.7	Nozzle

Figure 3-10: Overall Test Setup

3.3.1 Anthropometric Headform

The headform that will be used for this test will be the medium sized anthropometric European headform of the 50th percentile adult male due to its existing prevalence in ANSI Z87 (ANSI-ISEA Z87.1, 2015). Unless otherwise specified by the manufacturer, the medium sized headform will be used. If the selected eye protector explicitly states that it is for a smaller head, then a smaller sized anthropometric headform (or equivalent) will be used for testing. Once the size of the headform is selected for the testing, all tests will be conducted with the same headform. Other headforms may be used if known or demonstrated to give equivalent results (Figure 3-10.1, Figure 3-11, and Figure 3-12).

Figure 3-11: Headform Measurements

Dimension	Value	
	Medium size head	Small size head
a	218 mm (8.6 in.)	205 mm (8.1 in.)
b	111 mm (4.4 in.)	110 mm (4.3 in.)
c	144mm (5.7 in.)	131mm (5.2 in.)
d	178 mm (7.0 in.)	166mm (6.5 in.)
e	45 mm (1.8 in.)	42 mm (1.7 in.)
f	18 mm (0.7 in.)	18 mm (0.7 in.)
g	60 mm (2.4 in.)	53 mm (2.1 in.)
h	111 mm (4.4 in.)	110 mm (4.3 in.)
Radius i	10 mm (0.4 in.)	10 mm (0.4 in.)
j	58 mm (2.0 in.)	48 mm (1.9 in.)
k	156 mm (6.1 in.)	146 mm (5.7 in.)
l	64 mm (2.5 in.)	54 mm (2.1 in.)
m	52 mm (2.0 in.)	48 mm (1.9 in.)
n	134 mm (5.3 in.)	118 mm (4.6 in.)

Table 3-1: European Anthropometric Headform Measurements

Source: (ANSI-ISEA Z87.1, 2015)

Figure 3-12: Anthropometric Headform

3.3.2 Articulating Headform Base

The headform for which the eye protectors will be placed on needs to be able to be manipulated in varying angles and rotations around a central point. This is possible by mounting the headform onto an articulating base. The base can be rotated 360 degrees and has the ability for the headform to be angled nearly 90 degrees downward in any direction. Having this ability to manipulate the headform into varying angles and

rotations allows the test to best replicate how a workers head would be angled during their working conditions (Figure 3-10.2, Figure 3-13).

Figure 3-13 Articulating Base

3.3.3 Milling Table

To be able to compensate for varying distances and locations on the headform, the articulating base will be mounted onto a milling table. By having the headform mounted onto the milling table, it gives 12” of longitudinal travel and 7.5” of transverse travel. This will allow the headform great range of locations for testing. The milling table also offers precise adjustments for both lateral and transverse movement for easy replications of testing (Figure 3-10.3, Figure 3-14).

Figure 3-14: Milling table

3.3.4 Dispensing Unit

The fluid that will be used to assess penetration will be dispersed through an electronic digital dispenser. The DC 200 which will be used for testing offers a wide variety of dispensing applications. It has precise accuracy for dispensing specific volumes. It also has multi regulators for input air pressure which can be set to ensure consistent pressure all throughout the dispensing time. This controlling makes it easy to get

precise shots of fluid across all tests for consistency (Figure 3-10.4, Figure 3-15).

Figure 3-15: Dispensing Unit

3.3.5 Pressurized Container

The pressurized container in the test apparatus contains the fluid which is air fed to the nozzle for delivery. On top of the container is an external air regulator which controls the exit velocity of the shot of fluid. The increase or decrease of air pressure in the tank is proportional to the increase or decrease of exit velocity (Figure 3-10.5, Figure 3-16).

Figure 3-16: Pressurized Container

3.3.6 Uni-slide

A Uni- slide stand is set up in the middle of the apparatus and offers a large range of vertical travel for the nozzle. The Uni-slide stand has a horizontal mounting bracket with which the dispensing nozzle is attached. The vertical travel of the slide allows the test to place the shot upon the headform at any vertical distance wanted. It allows for a very wide range of test requested locations for future testing. The slide has a screw track driven hand crank which gives high precision to vertical adjustments (Figure 3-10.6, Figure 3-17).

Figure 3-17: Uni-Slide

3.3.7 Dispensing Nozzle

The dispensing valve chosen for this test apparatus is a multipurpose poppet-type pneumatic valve. It can dispense a wide range of liquids viscosity with precision making it ideal for the use of fluid / bodily fluids. This style of dispensing valve has its own shot volume control valve making it much more efficient at dialing in exact shot volumes for repeated testing. The valve also has a built in negative pressure control that eliminates the lumping at the end of the needle after dispensing shots. This negative pressure control feature aids in precise consistent shots (Figure 3-10.7, Figure 3-18).

Figure 3-18: Nozzle

3.3.8 Fluid

The fluid that will be used in the dispensing of shots at specific locations on the headform will be a mixture of saline and a surfactant. This new recipe yields a fluid that has physical properties much more similar to the physical properties of blood. The main property that is most concerning is having the correct viscosity of the fluid to that of blood. The average viscosity of blood is 3-4 centipoise (cP). The surface tension range for blood and body fluids is approximately 42 – 60 dynes/cm (Harkins and Harkins). The lower end of the range of surface tension, the higher penetration it will have. By using the saline, it is simulating the typical bodily fluids that could be expelled or come in contact with another person. Using the Saline in addition to a fast-acting surfactant will simulate a worst case scenario as well as bring the surface tension properties much closer to real blood properties (Portnoff). In addition to the saline and a fast acting surfactant, we added fluorescein dye which is highly visible under blue light. This dye will aid in detection of any fluid on the eye of the headform and will yield in clear decisions of pass or fail results.

3.4 Testing

3.4.1 Hypothesis

This test apparatus is designed to evaluate the efficacy of eye and face protection against biological hazards such as blood borne pathogens. The null hypothesis of this study is that current ANSI Z87.1 eye protectors will not pass the criteria from this test to be labeled for protection against biological hazards.

By using this test apparatus and testing procedure, typical eye and face protection was tested against the testing apparatus to see how effective they are with the apparatus's replicated biohazardous conditions. These tests evaluate coverage protection from biohazards, however they will not evaluate the ability of PPE to be decontaminated from biohazards. With this testing apparatus we are looking for a test method to represent or mimic the biological hazards that are found in the workplace environments of clinical laboratories, surgical/nursing, and dentistry. When looking at these occupations the probability of being exposed is relatively high, given that statistics report it happening frequently and more than once a year. The severity of this risk is serious or disabling and life threatening which puts the risk assessment for these occupations for biological hazards of splashes to the eyes and face as a high risk. The testing apparatus will sufficiently produce repeatable testing criteria and standards across a range of eye and face protectors that are being used in the 3 occupational settings. We are using this testing apparatus and test method to develop a basis of testing of eye and face protectors that reduce exposures to the areas of concern for the hazardous occupations mentioned.

3.4.2 Eye and Face Protectors

Types, models, and combinations of eye and face protection vary from occupation to occupation, e.g. a surgeon will don different eye and face PPE than a dentist would, therefore a variety of samples will be collected from different manufacturers and occupational settings. The different types, styles, and combinations of currently used eye and face protectors will be from the main high hazard occupations that are being explored (Dental, Health Care, and Laboratory). To determine the most popular brands/models, a one question survey will be sent to health care professionals in the

various fields to ascertain their preference. The top models will be evaluated using the criteria described below, regardless if they are stamped with ANSI Z87.1 or not.

All tests being conducted will be randomized for the order in which they are conducted (Spurt positions 1-4 / Spray positions 1-4). The first initial spurt tests will all be conducted at a high velocity as well as high volume of fluid (2ml spurt / 1ml spray). If the PPE passes, then there will not be any subsequent tests done under the proven assumption that if the PPE passes at high velocity and high volume then it would also pass at a lower velocity or lower volume. If the PPE fails at the High velocity and High volume, then it will be considered for examination testing under lower velocities and lower volumes of fluid.

A “high” exit velocity will be in the range of 600 cm/s. This is to mimic the varying velocities of fluids found within an occupational environment. A “high” volume of fluid will be 2 ml. A data sheet will be logged with the model and style of eye protector being tested prior to testing and then completed with the test results during testing. (Table 3-2).

3.4.3 Test Criteria / Near Miss Ratings

All PPE tests that are conducted will receive a Pass or Fail criteria. All tests that are given a Pass or Fail rating will also be measured for the distance that the fluid is in relation to the Pass or Fail. If the test passes then the fluid that is closest to the perimeter of the eyes, nose, or mouth will be measured and recorded. If the test fails then the fluid that is closest to the center of the area of concern (Eye, Nose, or Mouth), will be measured and recorded. The quadrant that the fluid which is measured is in will also be recorded. This quadrant is set up as a simple XY graph with corresponding

quadrants (Figure 3-19).

Figure 3-19: Quadrants on Headform

This test will be conducted 10 times for every ensemble that is being evaluated. A near miss rating could be given at a later date for more testing of products and helpful descriptions of how a product performs. This rating would be based off distances circling the perimeter such as fictitious concentric circles. Each region between the fictitious concentric rings will be what determines the ratings. These concentric circles will be 5mm each. If the fluid is within the concerned area then it would fail and the rating therefore would be a 4. If fluid is within 5mm of the perimeter or the eyes, nose, or mouth, then the rating would be a 3; if fluid is within 10mm of the perimeter or the eyes, nose, or mouth, then the rating would be a 2; if fluid is within 15mm of the perimeter or the eyes, nose, or mouth, then the rating would be a 1; if the fluid is at a greater distance than 15mm from the perimeter of the eyes, nose, or mouth then it

would get a rating of 0. With each shot, the distance from the perimeter of the area of concern to the closest fluid would be record in the data sheet as well.

Another criteria that was evaluated is the range of protection for every ensemble. For this range of protection evaluation, the headform's ensemble will be tested on a horizontal plane and rotated about it. These degrees of rotation will be tested at 0, 30, 60, and 90 degrees of rotation to the right, and then 30, 60, and 90 degrees to the left (degrees of rotation are oriented from the nozzle being the origin). The headform's ensemble will then be tested on a vertical plane. These degrees of rotation will be tested at 0, 30, 60, and near 90 degrees of rotation to the up, and then 30, 60, and near 90 degrees to the down (degrees of rotation are oriented from the nozzle being the origin) (Figure 3-20: Range of Protection Horizontal, Figure 3-21: Range of Protection Vertical, Table 3-3: Range of Protection Data Sheet).

With this experimental design the outcomes are categorical and are dependent variables with two possible values (Pass or Fail) and all factors are categorical or indicator functions, the best model to use is a 2 x 4 logistic regression.

By using a 2x4 table we can get a good look at unadjusted preliminary data from which we can draw estimates about the ensembles. Based on the time frame and limited resources (money and material) we decided upon a sample size of 10 replications. With this sample size it will give us 80 observations per ensemble with 800 total observations. This will provide a 2 x 4 x 10 model which can be looked at for interactions between ensemble and Spurt/Spray as well as interactions between ensemble and head positions.

1	Brand	Model			Eyes			Nose			Mouth		
	x 10				Pass Fail	Dist. to closest fluid (mm)	Quadrant	Pass Fail	Dist. to closest Fluid (mm)	Quadrant	Pass Fail	Dist. to closest Fluid (mm)	Quadrant
1	Spurt	High Vel. 635 cm/s	High Vol. (2 ml)	Up
2	Spurt	High Vel. 635 cm/s	High Vol. (2 ml)	Down
3	Spurt	High Vel. 635 cm/s	High Vol. (2 ml)	Right
4	Spurt	High Vel. 635 cm/s	High Vol. (2 ml)	Left
1	Spray	500 cm/s	1 ml	Up
2	Spray	500 cm/s	1 ml	Down
3	Spray	500 cm/s	1 ml	Right
4	Spray	500 cm/s	1 ml	Left

Table 3-2: Eye Protector Data Sheet

Figure 3-20: Range of Protection Horizontal

Figure 3-21: Range of Protection Vertical

Repeat x 1					Eyes			Nose			Mouth		
					Pass Fail	Dist. To Closest Fluid mm	Quadrant	Pass Fail	Dist. To Closest Fluid mm	Quadrant	Pass Fail	Dist. To Closest Fluid mm	Quadrant
90	Spurt	High Vel. 635 cm/s	High Volume 2ml	Horizontal plane									
60	Spurt	High Vel. 635 cm/s	High Volume 2ml	Horizontal plane									
30	Spurt	High Vel. 635 cm/s	High Volume 2ml	Horizontal plane									
0	Spurt	High Vel. 635 cm/s	High Volume 2ml	Horizontal plane									
30	Spurt	High Vel. 635 cm/s	High Volume 2ml	Horizontal plane									
60	Spurt	High Vel. 635 cm/s	High Volume 2ml	Horizontal plane									
90	Spurt	High Vel. 635 cm/s	High Volume 2ml	Horizontal plane									
90	Spurt	High Vel. 635 cm/s	High Volume 2ml	Vertical Plane									
60	Spurt	High Vel. 635 cm/s	High Volume 2ml	Vertical Plane									
30	Spurt	High Vel. 635 cm/s	High Volume 2ml	Vertical Plane									
0	Spurt	High	High	Vertical									

		Vel. 635 cm/s	Volume 2ml	Plane									
30	Spurt	High Vel. 635 cm/s	High Volume 2ml	Vertical Plane									
60	Spurt	High Vel. 635 cm/s	High Volume 2ml	Vertical Plane									
90	Spurt	High Vel. 635 cm/s	High Volume 2ml	Vertical Plane									
90	Spray	500 cm/s	1 ml	Horizontal plane									
60	Spray	500 cm/s	1 ml	Horizontal plane									
30	Spray	500 cm/s	1 ml	Horizontal plane									
0	Spray	500 cm/s	1 ml	Horizontal plane									
30	Spray	500 cm/s	1 ml	Horizontal plane									
60	Spray	500 cm/s	1 ml	Horizontal plane									
90	Spray	500 cm/s	1 ml	Horizontal plane									
90	Spray	500 cm/s	1 ml	Vertical Plane									
60	Spray	500 cm/s	1 ml	Vertical Plane									
30	Spray	500 cm/s	1 ml	Vertical Plane									
0	Spray	500 cm/s	1 ml	Vertical Plane									
30	Spray	500 cm/s	1 ml	Vertical Plane									
60	Spray	500 cm/s	1 ml	Vertical Plane									
90	Spray	500 cm/s	1 ml	Vertical Plane									

Table 3-3: Range of Protection Data Sheet

3.4.4 Blue light Detection

A strong blue light is used to shine onto the headform for optimal visual inspection of a pass or fail rating of any fluid that may reach the headforms eyes. A light source of 494 nm (light blue) will make a 512 nm color (bright green) of the fluid.

3.4.5 Sight Laser

The addition of a small battery operated cross haired laser will be mounted to the mounting bracket on the Uni-slide (Figure 3-22). This laser will project bright horizontal and vertical lines onto the anthropometric head for leveling and aligning it into its specified test manipulations quickly and efficiently (Figure 3-23). Although this sight laser is not a “must have” for this apparatus to function, it will highly aid in testing.

Figure 3-22: Laser Mounting to Uni-Slide Bracket

Figure 3-23: Laser Projected onto Headform

3.4.6 Pass / Fail criteria

Once the eye wear and corresponding ensemble (e.g. eye protector and face mask) is mounted on the European 50th percentile or equivalent headform in a wearer's normal position, the tester will then verify the target locations / distances to be accurate. The tester will then turn on the blue light used for visual indication of any fluid on the eyes, nose, or mouth of the headform and ensure that the lighting is suitable for inspection. The tester will administer a single shot of fluid to the targeted area, ensuring that the fluid hits the target area of the headform, the tester will then visually inspect the headforms eyes, nose, and mouth for any fluid within 5 sec of impact. If the tester suspects that there is fluid on the eye of the headform, they may use a cotton absorbent

swab or similar item to lightly daub the eye area. If there is no evidence of fluid on the headforms eyes, nose, or mouth, then the eye protector and corresponding ensemble passes that particular targeted location for the specified shot criteria. 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 of the headform then the eye protector fails that particular targeted location; if there is evidence of fluid on the nose or mouth of the headform then the face mask fails that particular targeted location. The tester will record what type of shot the eye protector or face mask failed on (spurt or spray) as well as the targeted location (Up, Down, Right, Left) (Table 3-1).

Referencing Figures 3-24 through 3-30 below are some preliminary tests done to show the detection of the dye in a blue light with a spray and spurt test on the headform. The headform was not manipulated with any angles and was placed 30.48 cm away with a targeted location centered at the bridge of the nose. The headform was angled for the best light condition for a picture but was not angled for the duration of the test. The exit velocity was estimated to be around 435 cm/s. If this location and particular eye protector were to be placed in the testing criteria, they would have passed the spray test but would have failed the spurt test. Once the spray and spurt were administered, the headform was thoroughly wiped off and checked to make sure there was no residual fluid left behind (Figure 3-26).

Figure 3-24: Spray Test- Glasses On

Figure 3-24 photo was immediately taken after the spray was conducted. The glasses will be removed carefully and a visual inspection of the eyes will take place next to determine if this is a “Pass” or “Fail.”

Figure 3-25: Eye Criteria Spray Test without Glasses- “Pass”

After the glasses have been removed a detailed visual inspection was conducted on the eyes of the headform. Figure 3-25 shows that no fluid is on the eyes of the headform therefore classifying this particular section of the spray test as a “Pass” This example

test is solely looking at penetration to the eyes of the wearer. The nose and mouth are not part of this test shot. The wearer should be wearing other appropriate PPE to protect the nose and mouth area. When conducting a test on complete PPE attire on the headform, a pass or fail will also be assigned to the equipment being used to protect the nose and mouth. If any fluid or fluid residue is within the area of concern for the nose then a “Fail” is assigned. If any fluid or fluid residue is within the area of concern of the mouth then a “Fail” is assigned. If fluid outside of the perimeter of the area of concern of the nose or mouth then a “Pass” will be assigned.

Figure 3-26: Cleaned Headform

Figure 3-26 shows that after a test has been conducted the headform can easily be wiped off and visually checked for any leftover fluid or fluid residue. The test apparatus was then changed over to next conduct a spurt test.

Figure 3-27: Spurt Test - Glasses On

Figure 3-27 photo was taken immediately after the spurt test was conducted. The glasses will be removed carefully and a visual inspection of the eyes will take place next to determine if this is a “Pass” or “Fail.”

Figure 3-28: Spurt Test without Glasses – “Fail”

After the glasses have been removed a detailed visual inspection was conducted on the eyes of the headform. Figure 3-28 shows that fluid is on the eyes of the headform

therefore classifying this particular section of the spurt test as a “Fail”

As one can clearly see that for a pass or fail it is very easily distinguished whether or not the fluid has penetrated the glasses and is on the eye of the headform or not (Figure 3-28). In the following figures (Figure 3-29 and 3-30), one can see the entire shot (spray and spurt) as it exits from the nozzle and impacts on the targeted location of the headform. From there one can see how the fluid dispersers depending on the different shot pattern. The spurt is much more penetrable to the headforms eyes than the spray is. Whereas the spray covers more facial area than the spurt. This test was conducted as an example to show how the fluid is used for verifying pass and fail criteria. When a real test is conducted the headform will be fully fitted with appropriate eye and face protection which covers the nose and mouth.

Figure 3-29: Spray in Real Time

Figure 3-30: Spurt in Real Time

3.5 Defining Positions and Perimeters

3.5.1 Eye

The size of the human adult eye is approximately 24.2 mm (transverse) x 23.7mm (sagittal). The eyeball size may vary from about 21mm to 27mm in the transverse plane (Bekerman, 2014). When considering the human orbit, the height is usually 35 mm whereas the typical width is approximately 40 mm (Turvey, 2012). The average aperture height of the eye is around 10-14mm while the eyelid covers about another 2-3 mm of the eye itself. The average dimensions of the human eyelid are around 28-32 mm wide and around 4-5 mm in height/thickness when the eye is opened (Eyeplastics). This total height of the eye and eyelids are around 23-25 mm from bottom to top. Through other studies done on the anatomy of the eye and orbit size, adults were found to have heights and widths slightly larger than that of 35 and 40mm. Other studies show that the thicknesses and widths of the eyelid vary a few millimeters as well. Therefore, it would be reasonable to want to protect at distances slightly greater than these parameters. Since the parameters stated previously are only averages of adults. There are some outliers that would need to have the parameters a little bigger. To accommodate the variety in sizes, an ellipse shape is used with height of 35mm and width of 50mm. The height should remain the same because this distance is based off the orbital bone. This distance will cover the height of the eye plus the eye lids when opened. The reason that the width needs to be lengthened is that the eye lid runs across the horizontal plane of the eye and leaves areas exposed such as the corners of the eye and the tear duct. This oversized parameter is to take in account for adults having larger sized eyes, varying sized tear ducts, and larger orbital sockets. By using an

oversized elliptical parameter the eye will then be completely encompassed (Figure 3-32). Any fluid or fluid residue that is found within the perimeter of the ellipse will be considered a “fail” for the eye. The ellipse parameters will have its dimensions based off the center of the eye. From there a major and minor axis will be created of lengths of 35mm in height (minor) and 50mm in width (major). This ellipse shape will follow the orbital bone. The 45 degree diagonal measurements will be 42 mm in length (Figure 3-31).

Figure 3-31: Graph of Ellipse

(Elsevier, 2008)

Figure 3-32: Average Eye Measurements

3.5.2 Nose

Nose exposure will be evaluated using the 6 landmarks shown below. Connecting the points from 1-3-2-5-6-4-1 creates a perimeter along the bottom surface area of the nose. Any fluid or fluid residue that is found within this perimeter will be considered a “fail” for the nose.

(Etoz, 2011)

Figure 3-33: Anthropometric Nose landmarks

The nose perimeter measurements are defined in Figure 3-33 and Table 3-5 below for the European anthropometric headform.

1-2	Alare, the point where the nasal blade (ala nasi) extends farthest out.
3	Subnasal, the midpoint of the columella base.
4-5	The most convex point of lateral cruris of alar cartilage.
6	Pronasal, the most prominent point on the nasal tip.

Table 3-4: Anthropometric Nose Landmarks

Figure 3-34: Nose measurement of most convex point- Points 4-5.

1-3	27 mm
3-2	27 mm
1-4	18 mm
2-5	18 mm
4-6	20 mm
5-6	20 mm
4-5	25 mm
3-6	22 mm

Table 3-5: Nose Landmark Measurements

3.5.3 Mouth

Figure 3-35 shows anthropometric landmarks that are widely used for the mouth. A perimeter formed by connecting the points (1-2-3-4-5-1) defines the mouth. Any fluid or fluid residue that falls within this perimeter will be considered a “fail” for the mouth.

The perimeter will start at the left oral commissure or cheilion. This is where the lateral aspects of the vermilion of the upper and lower lips join. (Figure 3-35-point 1) From point 1, the perimeter will travel along the contour of the line formed by the vermilion border of the upper lip. In a frontal view, this line resembles an archer's bow, which curves medially and superiorly from the commissures to the paramedian peaks located at the bases of the pillars of the philtrum (crista philtrae) (Figure 3-35- points 2 and 3) with an inferior convexity lying between those peaks. The philtrum is the vertical groove in the midline of the upper lip bordered by these lateral pillars (ridges). From points 2-3, the perimeter will travel to point 4 which resides as the right oral commissure or cheilion (Figure 3-35-point 4). From point 4, the perimeter will travel along the contour of the line formed by the vermilion border of the lower lip until it reaches the lowest apex of the lower lip, which will be point 5. From point 5 the line will continue along the contour of the line formed by the vermilion border of the lower lip until it reconnects with point 1.

Source: (Raschke, et al., 2016)

Figure 3-35: Anthropometric Mouth Landmarks

The mouth perimeter measurements are defined in Figure 3-36 and Table 3-6 below for the European anthropometric headform.

Figure 3-36: Mouth measurement between left and right oral commissure-Points 1-4.

1-2	31 mm
2-3	10 mm
3-4	31 mm
4-5	33.5 mm
5-1	33.5 mm
1-4	56.5 mm
2-5	18 mm
3-5	18 mm

Table 3-6: Mouth Landmark Measurements

CHAPTER 4 - Results

4.1 Overview of Testing and Results

This study evaluated the efficacy of protection of different ensembles that are currently used in occupational settings with high probability of biohazard exposure. This test apparatus is designed to mimic those hazards where PPE is needed for eye and face protection. Significant results and observations were found in a few areas within the make-up of each ensemble and between ensembles themselves. Each ensemble (10 total) will be referred to as a corresponding letter (A-J). This is to refrain from mentioning any brands, makes, or models of PPE that were used in testing. Some description of the ensemble will be given. All ensembles (eye protector and face mask) were assembled based on the survey that was appointed to high hazards occupational settings in the surrounding areas. The specific names of these occupational work settings will also be omitted from the results.

4.1.1 Statistical Analysis Overview

When comparing two ensembles, a sample size of $n=80$ for each ensemble provides 80% statistical power (at a type I rate $[\alpha]$ of 0.05) to detect a difference in the error rates of 21%. This study will have enough power to detect a difference if one ensemble has a pass rate of 50% and another ensemble has a pass rate of 71%. Or if one ensemble has a pass rate of 50% and the other has a pass rate of 29%. The power to detect larger differences in the pass rates will be greater than 80%. With smaller variances (pass rates larger or smaller than 50%), the study will have 80% power to detect smaller differences. The results will be further discussed in the following chapter.

4.2 Overview of Ensembles

4.2.1 Pass Rate of Eyes

Ensemble			Eyes						
			Up	Down	Left	Right	PassRate		
A	Spurt	Pass	10	0	10	10	30	LCI	80%
		Fail	0	10	0	0	10	UCI	95%
	Spray	Pass	10	10	10	10	40	70	
		Fail	0	0	0	0	0	10	88%
B	Spurt	Pass	2	0	10	10	22	LCI	68%
		Fail	8	10	0	0	18	UCI	87%
	Spray	Pass	10	10	10	10	40	62	
		Fail	0	0	0	0	0	18	78%
C	Spurt	Pass	10	10	10	10	40	LCI	NA
		Fail	0	0	0	0	0	UCI	NA
	Spray	Pass	10	10	10	10	40	80	
		Fail	0	0	0	0	0	0	100%
D	Spurt	Pass	8	8	10	10	36	LCI	74%
		Fail	2	2	0	0	4	UCI	91%
	Spray	Pass	0	10	10	10	30	66	
		Fail	10	0	0	0	10	14	83%
E	Spurt	Pass	9	10	10	10	39	LCI	96%
		Fail	1	0	0	0	1	UCI	10%
	Spray	Pass	10	10	10	10	40	79	
		Fail	0	0	0	0	0	1	99%
F	Spurt	Pass	3	1	10	10	24	LCI	56%
		Fail	7	9	0	0	16	UCI	77%
	Spray	Pass	5	4	10	10	29	53	
		Fail	5	6	0	0	11	27	66%
G	Spurt	Pass	0	0	10	10	20	LCI	25%
		Fail	10	10	0	0	20	UCI	45%
	Spray	Pass	0	7	1	0	8	28	
		Fail	10	3	9	10	32	52	35%
H	Spurt	Pass	4	2	10	10	26	LCI	49%
		Fail	6	8	0	0	14	UCI	71%
	Spray	Pass	2	10	10	0	22	48	
		Fail	8	0	0	10	18	32	60%
I	Spurt	Pass	0	0	10	10	20	LCI	44%
		Fail	10	10	0	0	20	UCI	66%
	Spray	Pass	0	10	7	7	24	44	
		Fail	10	0	3	3	16	36	55%
J	Spurt	Pass	0	0	10	10	20	LCI	18%
		Fail	10	10	0	0	20	UCI	37%
	Spray	Pass	0	0	2	0	2	22	
		Fail	10	10	8	10	38	58	28%

Table 4-1: Ensemble Eyes Pass Rate

Figure 4-1: Eyes Pass Rate

Looking at Table 4-1, one can see that Ensemble C (100%) and Ensemble E (99%) had the highest pass rates in the area of concern of the eyes. This is shown again graphically in Figure 4-1. The total pass rate of all ensembles for the eyes was 69%.

4.2.2 Pass Rate of Nose

Ensemble			Nose						
			Up	Down	Left	Right	PassRate		
A	Spurt	Pass	10	2	10	10	32	LCI	83%
		Fail	0	8	0	0	8	UCI	97%
	Spray	Pass	10	10	10	10	40	72	
		Fail	0	0	0	0	0	8	90%
B	Spurt	Pass	10	10	10	10	40	LCI	NA
		Fail	0	0	0	0	0	UCI	NA
	Spray	Pass	10	10	10	10	40	80	
		Fail	0	0	0	0	0	0	100%
C	Spurt	Pass	10	10	10	10	40	LCI	NA
		Fail	0	0	0	0	0	UCI	NA
	Spray	Pass	10	10	10	10	40	80	
		Fail	0	0	0	0	0	0	100%
D	Spurt	Pass	10	10	10	10	40	LCI	NA
		Fail	0	0	0	0	0	UCI	NA
	Spray	Pass	10	10	10	10	40	80	
		Fail	0	0	0	0	0	0	100%
E	Spurt	Pass	10	10	10	10	40	LCI	NA
		Fail	0	0	0	0	0	UCI	NA
	Spray	Pass	10	10	10	10	40	80	
		Fail	0	0	0	0	0	0	100%
F	Spurt	Pass	10	1	10	10	31	LCI	82%
		Fail	0	9	0	0	9	UCI	96%
	Spray	Pass	10	10	10	10	40	71	
		Fail	0	0	0	0	0	9	89%
G	Spurt	Pass	8	0	10	10	28	LCI	77%
		Fail	2	10	0	0	12	UCI	93%
	Spray	Pass	10	10	10	10	40	68	
		Fail	0	0	0	0	0	12	85%
H	Spurt	Pass	10	3	10	10	33	LCI	85%
		Fail	0	7	0	0	7	UCI	97%
	Spray	Pass	10	10	10	10	40	73	
		Fail	0	0	0	0	0	7	91%
I	Spurt	Pass	2	3	10	10	25	LCI	73%
		Fail	8	7	0	0	15	UCI	90%
	Spray	Pass	10	10	10	10	40	65	
		Fail	0	0	0	0	0	15	81%
J	Spurt	Pass	9	2	10	10	31	LCI	82%
		Fail	1	8	0	0	9	UCI	96%
	Spray	Pass	10	10	10	10	40	71	
		Fail	0	0	0	0	0	9	89%

Table 4-2: Ensemble Nose Pass Rate

Figure 4-2: Nose Pass Rate

Looking at Table 4-2, one can see that Ensemble B, C, D, and E (100%) had the highest pass rates in the area of concern of the Nose. This is shown again graphically in Figure 4-2. The total pass rate of ensembles for the nose is 93%. The pass rate is 24% higher for the nose than the eyes.

4.2.3 Pass Rate of Mouth

Ensemble			Mouth						
			Up	Down	Left	Right	PassRate		
A	Spurt	Pass	10	4	10	10	34	LCI	87%
		Fail	0	6	0	0	6	UCI	98%
	Spray	Pass	10	10	10	10	40	74	
		Fail	0	0	0	0	0	6	93%
B	Spurt	Pass	10	4	10	10	34	LCI	87%
		Fail	0	6	0	0	6	UCI	98%
	Spray	Pass	10	10	10	10	40	74	
		Fail	0	0	0	0	0	6	93%
C	Spurt	Pass	10	10	10	10	40	LCI	NA
		Fail	0	0	0	0	0	UCI	NA
	Spray	Pass	10	10	10	10	40	80	
		Fail	0	0	0	0	0	0	100%
D	Spurt	Pass	10	9	10	10	39	LCI	96%
		Fail	0	1	0	0	1	UCI	100%
	Spray	Pass	10	10	10	10	40	79	
		Fail	0	0	0	0	0	1	99%
E	Spurt	Pass	10	10	10	10	40	LCI	NA
		Fail	0	0	0	0	0	UCI	NA
	Spray	Pass	10	10	10	10	40	80	
		Fail	0	0	0	0	0	0	100%
F	Spurt	Pass	10	0	10	10	30	LCI	80%
		Fail	0	10	0	0	10	UCI	95%
	Spray	Pass	10	10	10	10	40	70	
		Fail	0	0	0	0	0	10	88%
G	Spurt	Pass	8	7	10	10	35	LCI	88%
		Fail	2	3	0	0	5	UCI	99%
	Spray	Pass	10	10	10	10	40	75	
		Fail	0	0	0	0	0	5	94%
H	Spurt	Pass	10	3	10	10	33	LCI	85%
		Fail	0	7	0	0	7	UCI	97%
	Spray	Pass	10	10	10	10	40	73	
		Fail	0	0	0	0	0	7	91%
I	Spurt	Pass	1	3	10	10	24	LCI	71%
		Fail	9	7	0	0	16	UCI	89%
	Spray	Pass	10	10	10	10	40	64	
		Fail	0	0	0	0	0	16	80%
J	Spurt	Pass	6	1	10	10	27	LCI	76%
		Fail	4	9	0	0	13	UCI	92%
	Spray	Pass	10	10	10	10	40	67	
		Fail	0	0	0	0	0	13	84%

Table 4-3: Ensemble Mouth Pass Rate

Figure 4-3: Mouth Pass Rate

Looking at Table 4-3, one can see that Ensemble C and E (100%) and Ensemble D (99%) had the highest pass rates in the area of concern of the Mouth. This is shown again graphically in Figure 4-3. The overall ensembles pass rate for the Mouth is 92%. The overall ensembles pass rate is 23% higher for the mouth than the eyes, and 1% lower than the overall ensembles pass rate for the nose.

4.2.4 Pass Rate of Total Ensemble

Ensemble			Total Ensemble Pass Rate			
A	Spurt	Pass	96	LCI	86%	
		Fail	24	UCI	94%	
	Spray	Pass	120	216		
		Fail	0	24		90%
B	Spurt	Pass	96	LCI	86%	
		Fail	21	UCI	94%	
	Spray	Pass	120	216		
		Fail	0	24		90%
C	Spurt	Pass	120	LCI	NA	
		Fail	0	UCI	NA	
	Spray	Pass	120	240		
		Fail	0	0		100%
D	Spurt	Pass	115	LCI	91%	
		Fail	5	UCI	97%	
	Spray	Pass	110	225		
		Fail	10	15		94%
E	Spurt	Pass	119	LCI	99%	
		Fail	1	UCI	100%	
	Spray	Pass	120	239		
		Fail	0	1		99.60%
F	Spurt	Pass	85	LCI	76%	
		Fail	35	UCI	86%	
	Spray	Pass	109	194		
		Fail	11	46		81%
G	Spurt	Pass	83	LCI	66%	
		Fail	37	UCI	77%	
	Spray	Pass	88	171		
		Fail	32	69		71%
H	Spurt	Pass	92	LCI	76%	
		Fail	28	UCI	86%	
	Spray	Pass	102	194		
		Fail	18	46		81%
I	Spurt	Pass	69	LCI	66%	
		Fail	51	UCI	78%	
	Spray	Pass	104	173		
		Fail	16	67		72%
J	Spurt	Pass	78	LCI	61%	
		Fail	42	UCI	73%	
	Spray	Pass	82	160		
		Fail	38	80		67%

Table 4-4: Total Ensemble Pass Rate

Figure 4-4: Total Ensemble Pass Rate

Figure 4-5: 95% Confidence Interval Plot of Ensembles Performance

Looking at Table 4-4, one can see that Ensemble C (100%) and Ensemble E (99.6%) had the highest total ensemble pass rate. This is shown again graphically in Figure 4-4. This comparison is also further confirmed with Figure 4-5 to show their performance and significance to each other's performance.

4.2.5 Left and Right Eye Failures

Left Eye			Right Eye		
Quadrant	Total		Quadrant	Total	
L Q1	26	20%	R Q1	24	22%
L Q2	28	22%	R Q2	17	15%
L Q3	32	25%	R Q3	27	25%
L Q4	41	32%	R Q4	42	38%
L Total	127	54%	R Total	110	46%
Total Fail 237					

Table 4-5: Left and Right Eye Failures

	LCI	UCI		LCI	UCI
L Q1	13	27	R Q2	9	22
L Q2	15	29	R Q1	14	30
L Q3	18	33	R Q3	17	33
L Q4	24	40	R Q4	29	47

Table 4-6: Left and Right Quadrant CI

Figure 4-6: Left and Right Eye Failures

Left Eye			Right Eye		
127	237		110	237	
prop	0.535865	54%	prop	0.464135	46%
SE	0.032395	0.032	SE	0.032395	0.032
LCI	0.472371	47%	LCI	0.400641	40%
UCI	0.599359	60%	UCI	0.527629	53%

Table 4-7: Left and Right Eye Statistical Analysis

When looking at Table 4-7, one can see that there is no significant difference between right or left eyes, or between quadrants within the eyes. This also proves to ensure that the test apparatus is consistent within its testing operations.

4.3 Pass Rate of Spurt vs Spray

	Spray	Spurt	Spray	Spurt
A	40	30	100%	75%
B	40	22	100%	55%
C	40	40	100%	100%
D	30	36	75%	90%
E	40	39	100%	98%
F	29	24	73%	60%
G	8	20	20%	50%
H	22	26	55%	65%
I	24	20	60%	50%
J	2	20	5%	50%
Total	69%	69%		

Table 4-8: Pass Rate of Eyes – Spurt vs Spray

Figure 4-7: Pass Rate of Eye Criteria – Spurt vs Spray

	Spurt	Spray	Spurt	Spray
A	32	40	80%	100%
B	40	40	100%	100%
C	40	40	100%	100%
D	40	40	100%	100%
E	40	40	100%	100%
F	31	40	78%	100%
G	28	40	70%	100%
H	33	40	83%	100%
I	25	40	63%	100%
J	31	40	78%	100%
Total	85%	100%		

Table 4-9: Pass Rate of Nose – Spurt vs Spray

Figure 4-8: Pass Rate of Nose Criteria – Spurt vs Spray

	Spurt	Spray	Spurt	Spray
A	34	40	85%	100%
B	34	40	85%	100%
C	40	40	100%	100%
D	39	40	98%	100%
E	40	40	100%	100%
F	30	40	75%	100%
G	35	40	88%	100%
H	33	40	83%	100%
I	24	40	60%	100%
J	27	40	68%	100%
Total	84%	100%		

Table 4-10: Pass Rate of Mouth – Spurt vs Spray

Figure 4-9: Pass Rate of Mouth Criteria – Spurt vs Spray

Spurt	953	79%
Spray	1075	90%

Table 4-11: Overall Ensemble Pass Rate of Spurt vs Spray

Figure 4-10: Overall Ensemble Pass Rate of Spurt vs Spray

	LCI	UCI
Spurt	77	82
Spray	88	91

Table 4-12: CI of Overall Pass Rate of Spurt vs Spray

Figure 4-11: CI of Overall Pass Rate of Spurt vs Spray

Analysis of Maximum Likelihood Estimates						
Parameter		DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
type1	Spray-E	1	0.0627	0.1120	0.3130	0.5758
type1	Spray-N	1	8.0958	56.8641	0.0203	0.9581
type1	Spray-M	1	7.9343	60.3654	0.0173	0.8954

Table 4-13: Statistical Analysis of Spurt vs Spray

Table 4-13 above is looking at the significance of spurt vs spray between the 3 areas of concern (Eyes, Nose, and Mouth). It is found that there is no significant difference between spurt and spray by the SAS data output.

4.4 Pass Rate per Position

		Up	Down	Left	Right
Spurt	Pass	46%	31%	100%	100%
Spray	Pass	47%	81%	80%	67%
Eyes	Total	47%	56%	90%	84%

Table 4-14: Eyes Pass Rate per Position

Figure 4-12: Eyes Pass Criteria per Position

Contrast Test Results			
Contrast	DF	Wald Chi-Square	Pr > ChiSq
1 v 2	1	8.8573	0.0029
1 v 3	1	94.6000	<.0001
1 v 4	1	90.3394	<.0001
2 v 3	1	64.7605	<.0001
2 v 4	1	60.2873	<.0001
3 v 4	1	0.3214	0.5707

Table 4-15: Eye Positions Contrasts

In Table 4-15, we comparing the significance between positions 1, 2, 3, and 4 when looking at the results from the eyes. One can see that the only 2 positions that are not significantly different. Therefore we can conclude that there are differences in between positions 1 and 3, 1 and 4, 2 and 3, and 2 and 4 (1-Up, 2-Down, 3-Left, and 4-Right).

		Up	Down	Left	Right
Spurt	Pass	89%	51%	100%	100%
Spray	Pass	100%	100%	100%	100%
Nose	Total	95%	76%	100%	100%

Table 4-16: Nose Pass Rate per Position

Figure 4-13: Nose Pass Criteria per Position

Contrast Test Results			
Contrast	DF	Wald Chi-Square	Pr > ChiSq
1 v 2	1	36.6124	<.0001
1 v 3	1	0.0053	0.9420
1 v 4	1	0.0053	0.9420
2 v 3	1	0.0088	0.9254
2 v 4	1	0.0088	0.9254
3 v 4	1	0.0000	1.0000

Table 4-17: Nose Positions Contrasts

In Table 4-17, we are comparing the significance between positions 1, 2, 3, and 4 when looking at the results from the nose. Therefore we can conclude that there are differences in between positions 1 and 2. (1-Up, 2-Down, 3-Left, and 4-Right). Due to many of the nose positions having high passing rates the contrasts between positions are limited in their detection level.

		Up	Down	Left	Right
Spurt	Pass	85%	51%	100%	100%
Spray	Pass	100%	100%	100%	100%
Mouth	Total	93%	76%	100%	100%

Table 4-18: Mouth Pass Rate per Position

Figure 4-14: Mouth Pass Criteria per Position

Contrast Test Results			
Contrast	DF	Wald Chi-Square	Pr > ChiSq
1 v 2	1	26.2149	<.0001
1 v 3	1	0.0055	0.9408
1 v 4	1	0.0055	0.9408
2 v 3	1	0.0081	0.9283
2 v 4	1	0.0081	0.9283
3 v 4	1	0.0000	1.0000

Table 4-19: Mouth Positions Contrasts

In Table 4-19, we are comparing the significance between positions 1, 2, 3, and 4 when looking at the results from the mouth. Therefore we can conclude that there are differences in between positions 1 and 2 (1-Up, 2-Down, 3-Left, and 4-Right). Due to many of the mouth positions having high passing rates the contrasts between positions are limited in their detection level.

Figure 4-15: Total Pass Rate per Position per Area of Concern

Figure 4-16: Overall Total Pass Rate per Position

Figure 4-15 shows the total pass rate for each position per area of concern. While Figure 4-16 shows the overall total pass rate per position when combining the pass rate of all three of the areas of concern (Eyes, Nose, and Mouth).

Other very useful results that were gathered from the testing apparatus is Table 4-20

(below) which depicts the mean, standard deviation, variance, and an upper and lower 95% confidence interval of the distance of passes for each ensemble for spurt and spray. Table 4-20 for the eye criteria is useful to reflect the reliability of the estimates based on the observed data. These confidence intervals are intended to offer assurance that all data obtained in the future with this apparatus and procedure should include the true value of the data with a given level of confidence. Any future group mean can be compared to these and declared "the same" or "different."

Obs	Ensemble	position2	type1	mean	standdev	variance	low95	up95
1	A	Down	Spray	16.6750	0.9278	0.861	16.011	17.339
2	A	Left	Spray	19.0750	3.0092	9.055	16.922	21.228
3	A	Left	Spurt	20.2540	1.7025	2.898	19.036	21.472
4	A	Right	Spray	17.9860	2.3538	5.540	16.302	19.670
5	A	Right	Spurt	17.8100	3.4714	12.050	15.327	20.293
6	A	Up	Spray	24.4920	1.4595	2.130	23.448	25.536
7	A	Up	Spurt	19.3350	6.7772	45.931	14.487	24.183
8	B	Down	Spray	40.8980	11.7074	137.064	32.523	49.273
9	B	Down	Spurt	55.5500	.	.	.	.
10	B	Left	Spray	42.8860	9.2647	85.834	36.258	49.514
11	B	Left	Spurt	33.6970	15.1501	229.525	22.859	44.535
12	B	Right	Spray	44.6010	8.1343	66.167	38.782	50.420
13	B	Right	Spurt	41.2080	25.3405	642.143	23.080	59.336
14	B	Up	Spray	59.4590	5.1856	26.890	55.749	63.169
15	B	Up	Spurt	18.5150	23.5679	555.444	-193.234	230.264
16	C	Down	Spray	34.4650	1.9207	3.689	33.091	35.839
17	C	Down	Spurt	34.0290	9.8360	96.746	26.993	41.065
18	C	Left	Spray	40.8160	5.8184	33.854	36.654	44.978
19	C	Left	Spurt	51.1580	5.0464	25.466	47.548	54.768

Obs	Ensemble	position2	type1	mean	standdev	variance	low95	up95
20	C	Right	Spray	42.8390	7.2155	52.064	37.677	48.001
21	C	Right	Spurt	53.5110	2.7375	7.494	51.553	55.469
22	C	Up	Spray	51.2840	4.7379	22.448	47.895	54.673
23	C	Up	Spurt	37.4980	2.8049	7.867	35.492	39.504
24	D	Down	Spray	20.5730	11.4871	131.954	12.356	28.790
25	D	Left	Spray	13.1800	2.5994	6.757	11.321	15.039
26	D	Left	Spurt	20.9470	3.3058	10.928	18.582	23.312
27	D	Right	Spray	11.8240	3.3774	11.407	9.408	14.240
28	D	Right	Spurt	18.8220	5.7901	33.526	14.680	22.964
29	D	Up	Spurt	7.9050	10.4336	108.861	-0.818	16.628
30	E	Down	Spray	29.4540	8.2486	68.040	23.553	35.355
31	E	Down	Spurt	43.5033	3.7424	14.005	34.207	52.800
32	E	Left	Spray	48.9350	10.2740	105.556	41.585	56.285
33	E	Left	Spurt	47.3380	6.7367	45.383	42.519	52.157
34	E	Right	Spray	47.3250	8.0792	65.274	41.545	53.105
35	E	Right	Spurt	42.8280	5.0567	25.571	39.211	46.445
36	E	Up	Spray	52.7410	17.8736	319.466	39.955	65.527
37	E	Up	Spurt	26.6233	23.0622	531.864	8.896	44.350
38	F	Down	Spray	5.0850	2.6481	7.013	0.871	9.299
39	F	Down	Spurt	.	.	.	.	.
40	F	Left	Spray	10.6120	1.9871	3.948	9.191	12.033
41	F	Left	Spurt	16.2080	4.9092	24.101	12.696	19.720
42	F	Right	Spray	10.9920	4.6364	21.497	7.675	14.309
43	F	Right	Spurt	15.2190	2.8195	7.950	13.202	17.236
44	F	Up	Spray	16.1360	4.1840	17.506	10.941	21.331
45	F	Up	Spurt	3.4433	1.9358	3.747	-1.366	8.252
46	G	Down	Spray	3.2086	0.8650	0.748	2.409	4.009
47	G	Left	Spurt	17.1930	5.8286	33.973	13.023	21.363
48	G	Right	Spray	0.0810	.	.	.	.

Obs	Ensemble	position2	type1	mean	standdev	variance	low95	up95
49	G	Right	Spurt	12.9430	2.4144	5.829	11.216	14.670
50	H	Down	Spray	6.3850	1.3051	1.703	5.451	7.319
51	H	Down	Spurt	1.4100	0.7071	0.500	-4.943	7.763
52	H	Left	Spray	8.0910	2.6350	6.943	6.206	9.976
53	H	Left	Spurt	13.1900	5.2152	27.199	9.459	16.921
54	H	Right	Spray	11.3610	2.8547	8.149	9.319	13.403
55	H	Right	Spurt	12.3670	4.0398	16.320	9.477	15.257
56	H	Up	Spray	6.3700	.	.	.	.
57	H	Up	Spurt	8.8950	3.4778	12.095	3.361	14.429
58	I	Down	Spray	2.7100	1.2866	1.655	1.790	3.630
59	I	Left	Spray	2.4957	0.5940	0.353	1.946	3.045
60	I	Left	Spurt	17.2420	3.3224	11.038	14.865	19.619
61	I	Right	Spray	3.6800	1.9467	3.790	1.880	5.480
62	I	Right	Spurt	15.4920	3.8213	14.602	12.758	18.226
63	J	Left	Spurt	21.2210	4.7275	22.350	17.839	24.603
64	J	Right	Spray	3.8650	0.6576	0.432	-2.043	9.773
65	J	Right	Spurt	19.2300	4.1360	17.106	16.271	22.189

Table 4-20: Overall 95% CI of Pass Distance per Ensembles for Eye Criteria

Spurt				Spray		
Type	Order	Random		Type	Order	Random
1	4	0.110105		1	3	0.771812
1	1	0.866044		1	4	0.899898
1	3	0.575045		1	2	0.620639
1	2	0.209213		1	1	0.253192
2	4	0.100062		2	3	0.434974
2	3	0.64155		2	1	0.67247
2	1	0.271539		2	4	0.107855
2	2	0.639137		2	2	0.48079
3	2	0.308732		3	4	0.485787
3	1	0.035325		3	1	0.034049
3	3	0.61792		3	2	0.626298
3	4	0.644714		3	3	0.065569
4	4	0.454954		4	3	0.972744
4	3	0.515109		4	1	0.755114
4	2	0.146152		4	4	0.509375
4	1	0.279676		4	2	0.007701
5	2	0.247228		5	2	0.677996
5	1	0.272828		5	4	0.473996
5	4	0.896784		5	3	0.672279
5	3	0.342129		5	1	0.391638
6	1	0.241775		6	2	0.416609
6	2	0.127472		6	4	0.599407
6	4	0.706046		6	3	0.503911
6	3	0.821264		6	1	0.584669
7	4	0.490619		7	4	0.495893
7	1	0.477712		7	2	0.321757
7	3	0.095565		7	1	0.630011
7	2	0.049422		7	3	0.623625
8	4	0.871248		8	1	0.21115
8	1	0.330814		8	2	0.595587
8	2	0.8773		8	3	0.781672
8	3	0.359281		8	4	0.607079
9	1	0.389863		9	2	0.149353
9	4	0.103653		9	4	0.000394
9	3	0.722085		9	3	0.890708
9	2	0.3049		9	1	0.194994
10	3	0.206174		10	4	0.577079
10	1	0.781835		10	3	0.717418
10	4	0.415395		10	2	0.18312
10	2	0.740884		10	1	0.994418

Table 4-21: Random Number Generator for Testing Order

In Table 4-21 one will see how the order of testing was randomized. This table was created in Excel where the type and order was assigned to the random number that was

generated. The “order” was then sorted by “type” making each series of position (1-4) randomized for the 10 replications of each spurt and spray categories.

CHAPTER 5 - Discussion

5.1 Overview of Findings

During the initial start of this project the original hypothesis was stated that current ANSI Z87.1 eye protectors will not pass the criteria from this test to be labeled for protection against biological hazards. The test matrix was set up to include 10 ensembles (e.g eye protector and face mask) that were currently being used in high hazard occupations for biological protection. Out of the 10 ensembles that were tested on the apparatus for spurt and spray protection, only 1 ensemble passed the testing criteria fully (Ensemble C). This particular ensemble did not have any failures on any of the head manipulations in any of the areas of concern. The other 9 ensembles failed in 1 or more of the head manipulations. Within this general result, 90% of the eye and face protection currently used for biological hazard protection would not pass proposed Z87.62 testing criteria.

5.2 Overview of Ensembles

5.2.1 Total Pass Rate of Areas of Concern

When looking at the particular areas of concern (Eyes, Nose, and Mouth) we can see that the Nose and the Mouth were more effectively protected than the eyes for this testing procedure. The Nose and the Mouth 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 the Mouth are more adequately covered by most face masks and leave fewer and smaller gaps than eye protectors tend to do. The face mask tend to press tightly against the face which seals most areas. Most face masks also have a built in wire strip at the top which a wearer is instructed to conform to the curvature of the

nose and upper cheeks. This also aids in closing the gaps for added protection to the Nose and Mouth. Eye protectors that were testing 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 gap, bottom gap and side gaps). Most eye protectors do provide some sort of side protection but few had adequate protection for the top and bottom gaps.

5.2.2 Comparing Pass Rate of Areas of Concern

When looking at individual ensembles pass rates for the Eyes, we can see that Ensemble C (100%) and E (99%) proved to provide the best protection. The next highest total pass rate for the eyes was Ensemble A (88%). Looking at the overall pass rate for the Nose we can see that there are multiple ensembles that offered a high level of protection. Ensemble B, C, D, and E, all had a pass rate of 100%. The next highest was Ensemble A at 90%. The Overall pass rate for the Nose was again 24% higher than that of the eyes. Comparing the pass rates now with that of the Mouth we again can see higher levels of protection for passing rates. Ensembles C and E both had a passing rate of 100%, while the next highest are Ensemble D (99%) and Ensemble G (94%). The overall ensembles pass rate is 23% higher for the mouth than the eyes, and 1% lower than the overall ensembles pass rate for the nose. Looking at the Total Ensemble pass rate, we can see that Ensemble C was the only one to have zero failures, therefore having a pass rate of 100%. However, Ensemble E did complete the testing procedure with an end Total Ensemble Pass Rate of 99.6% making it a very close 2nd for best protective Ensemble. When comparing the Ensembles to each other based on their performance, we can look into a histogram plot using the ensembles upper and

lower confidence intervals to analyze significance between them (Figure 4-5). Since Ensemble C had a passing rate of 100% it cannot have true confidence intervals, however I included it on the analysis to represent a perfect score (Figure 4-4). Ensemble C and E have significantly better protective performance than the other 8 ensembles. From this plot, a conclusion can also be drawn that Ensemble D has significantly better protective performance than Ensembles F, G, H, I, and J, but cannot determine a difference between Ensemble A and B.

5.3 Left and Right Eye Comparison

When looking at Table 4-5 and Table 4-7, we can conclude that testing between the Left and the Right eye were consistently even. This helps to see how much variance is within the test procedure and apparatus itself. The ideal perfect test would have the same amount of failures in the Left eye as the Right eye but due to testing error, fluid being unpredictable, and human error this might not happen. However, the statistical analysis of the data between the left and the right eye showed that the left nor the right eye had significant differences in failures between them. Further, we can look at Table 4-6 and see that there is no significant difference between any quadrants in the Left eye to its corresponding quadrant in the Right eye. This demonstrates that the test apparatus and method are consistent within its testing operations.

5.4 Pass Rate of Spurt vs Spray

5.4.1 Pass Rate of Spurt vs Spray - Eyes

Looking at the specific area of concern of the Eyes in regards to the pass rate of Spurt vs Spray we can see that in Table 4-8 and Figure 4-7 that the Spray looks graphically

to be much more consistent at passing. When this data is broken down in the table by percentages of all the ensembles it actually comes out to be 69% for both Spurt and Spray pass rates. When looking at the overall total passes for the eyes of spurt and spray there was no statistical significant difference between the 2 tests. This is further conveyed by looking at the SAS data output in Table 4-13 for the Eyes section.

5.4.2 Pass Rate of Spurt vs Spray – Nose

Looking at the specific area of concern of the Nose in regards to the pass rate of Spurt vs Spray we can see that in Table 4-9 and Figure 4-8, we can see that there was a much higher rate of Passing than in the Eyes as shown in other areas previously. When looking at the table we can see that the Spray had a 100% pass rate while the Spurt had an 85% pass rate. When looking at the SAS data output in Table 4-13 for the Nose section, it reports that there is no statistical difference between Spurt and Spray.

However, the large amount of 10/10 or 100% pass rates causes the power of the test to decrease quickly because of the decrease in variance as the rate gets closer to 100%. This causes the test to lose power of being able to detect small differences within the data set. Hence, the data output to report no significant difference between spurt and spray for the Nose. This is why we must also look to the data table to see the actual percent passing rate and draw conclusions from it.

5.4.3 Pass Rate of Spurt vs Spray – Mouth

Looking at the specific area of concern of the Mouth in regards to the pass rate of Spurt vs Spray we can see that in Table 4-10 and Figure 4-9, we can see that there was a much higher rate of Passing than in the Eyes as shown in other areas previously. When looking at the table we can see that the Spray had a 100% pass rate while the Spurt had

an 84% pass rate. When looking at the SAS data output in Table 4-13 for the Mouth section, it reports that there is no statistical difference between Spurt and Spray. However, the large amount of 10/10 or 100% pass rates causes the power of the test to decrease quickly because of the decrease in variance as the rates get closer to 100%. This causes the test to lose power of being able to detect small differences within the data set. Hence, the data output to report no significant difference between spurt and spray for the Mouth. This is why we must also look to the data table to see the actual percent passing rate and draw conclusions from it. Both the Nose and the Mouth show to have more failures in Spurt than in Spray. This conclusion is also supported by Table 4-12, which does show that there is a significant difference in Spurt vs Spray. This is due to the volume and concentration of this volume delivered to a more specific target location. The Spurt delivers 2ml of fluid to a very small area, where as the spray delivers 1ml of fluid to a very spread out area. Most all of the failures that were to the Nose and Mouth were due to a “Run Through” of fluid. This was caused by the fluid not actually penetrating through the mask but from running through the seal from top to bottom. The “Run Through” would leave a small trail of fluid from where it initially impacted down the nose and mouth. Occasionally the fluid would stop at the nose and not make it to the mouth or bypass the nose and hit the mouth due to the larger surface area of the mouth.

5.5 Pass Rate per Position

5.5.1 Pass Rate per Position –Eyes

When looking at Table 4-14, we can see that the majority of the passes in the Eyes were in the Left or Right (90% and 84%) head manipulation position. The majority of

the failures were in the Up position (pass rate- 47%). Looking at Table 4-15, the contrasts of the positions, we can conclude that there is no significant difference between position 3 and 4 (Left and Right). We can conclude that all other interactions between positions are significantly different when compared in the eye area. This is supported by Table 4-14.

5.5.2 Pass Rate per Position –Nose

When looking at Table 4-16, we can see that the majority of the passes in the Nose were in the Left or Right (100% and 100%) head manipulation position. This was closely followed by the Up position with a pass rate of 95%. The majority of the failures were in the Down position (pass rate- 76%). Looking at Table 4-17, we can conclude that there is a significant difference between positions 1 and 2 (Up and Down). All other interactions between positions show no significant difference. This is supported by Table 4-16.

5.5.3 Pass Rate per Position –Mouth

When looking at Table 4-18, we can see that the majority of the passes in the Mouth were in the Left or Right (100% and 100%) head manipulation position. This was closely followed by the Up position with a pass rate of 93%. The majority of the failures were in the Down position (pass rate- 76%). Looking at Table 4-19, we can conclude that there is a significant difference between positions 1 and 2 (Up and Down). All other interactions between positions show no significant difference. This is supported by Table 4-18.

5.5.4 Total Pass Rate per Position per Area of Concern

When looking at Figure 4-15, we can see that Left and the Right positions have the highest passing rate for the Eyes, Nose, and Mouth; closely followed by the Up

positions. The Down position as a whole appears to present itself with the lowest passing rate. Going even further by looking at Figure 4-16, we can see that the Down position has the lowest pass rate overall with 17%. The second lowest is the Up position with 19% and the highest pass rates are Left and Right positions with 24% each.

5.6 Range of Protection Tests

A pilot test was also conducted for a “Range of Protection Test.” This test only had 1 replication of each position for each ensemble due to time and material constraints.

This was a means to measure how far each Ensemble would offer protection on a horizontal and vertical plane. This test did prove to have some interested findings that could be further investigated. Some of the generalized findings of all ensembles are seen in Tables 5-1.

Position	Eyes	Nose	Mouth
Pass Rate			
90 R	85%	100%	100%
60 R	90%	100%	100%
30 R	75%	100%	100%
0	50%	80%	85%
30 L	75%	100%	100%
60 L	90%	100%	100%
90 L	85%	100%	100%
90 U	45%	95%	100%
60 U	40%	95%	95%
30 U	30%	95%	95%
30 D	50%	95%	100%
60 D	75%	90%	100%
90 D	80%	85%	95%

Table 5-1: Pass Rates of Range of Protection Tests

From Table 5-1, we can see that in the areas of concern of the Nose and Mouth that the 0 degree target location is the position with the lowest pass rate. This is a straight on

target location to the bridge of the nose centered across the eyes. The lowest Pass rate for the area of concern for the Eyes was 30 degree up. We can see that the majority of the failures were in the looking “Up” position. This pilot Range of Protection Test was to do a quick investigation of other areas of protection with ensembles.

5.7 Summary of Tests

By looking at all the data as a whole and by running the tests first hand, I can conclude that the test apparatus does operate efficiently and is very repeatable with little variance. I also conclude that it ensures concise and consistent testing across the broad spectrum of safety manufacturers and end users. This provides an important first step to simulate high risk biological hazardous occupations where eye and face PPE are worn.

5.7.1 Limitations of Experiment

During the Range of Protection Tests, one limitation of the testing apparatus is that it cannot have a target location of a complete 90 degree posterior or anterior head tilt. This is due to how the head is attached to the articulating base and milling table. It is also due to the range of travel that which the nozzle is mounted to. If the range of travel was longer and the articulating base gave more clearance, then it would be able to test a true 90 degree posterior or anterior head tilt.

Experimental data must always be evaluated with due consideration to the accuracy of measurement equipment used and human error of running the test operations. Many

measurements were taken to have the error reduced to a minimal amount. The addition of the cross haired laser made a huge impact on the consistency of leveling the head during its different manipulations. A standalone self-leveling laser was also used to reduce the error in head positioning. This self-leveling laser was used to ensure the cross hair lasers degree of level was correct. A spirit level was also used to triple check the degree of level during testing operations.

This study addresses the regulatory aspects of Eye and Face Protection and not Respiratory protection. The researcher recognizes that 1 head form does not include race or other head sizes outside of the 50th percentile. Future research will include more heads and more anthropometric characteristics. It can also include testing on human subjects with no hazardous fluid. The researcher recognizes such real-life conditions such as sweating and skin conductivity may affect results. Future research may address this.

CHAPTER 6 - Conclusions and Recommendations

6.1 Conclusions

When looking back at the individual data reports of all the ensembles, we can draw some conclusions about how each ensemble performed and why. As stated earlier the 2 ensembles that had the best protective performance were Ensemble 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%. These 2 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 in the 4 head manipulations and all tests in the Range of Protection Test. Ensemble E also used the same idea of a face shield but was built within the mask and protruded upwards. Ensemble E only failed in one position of the 4 manipulations and another in the Range of Protection Tests. In these particular positions it presented a small gap between the face shield and the mask that was not adequately sealed in the Up position. Because of this slight gap, it caused failures. If this gap was closed by either sealing it or extended the face shield downward more, then I believe this Ensemble E would pass completely. The eye and face protectors that incorporate a “shield” into their design perform best for protection against biological hazards.

When taking the eyes only into consideration, the bottom gap is the position in which the most amount of failures occur. 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 2 were of a “full face shield” type and 1 was a mask built for

bottom gap protection in addition to separate eye protectors. All 3 of these ensembles protected the best against this bottom gap from spurts and sprays.

The other position that is hard to protect against penetration around is the top gap or the “Down” position. This position is hard to protect because of the gap that is left between the eye protector and the forehead. The ensembles that did the 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 that completely passed this test used a foam pad that made that seal possible. This allowed for no fluid to get through. Even if the ensemble did not have an actual “seal,” ones that did contour to the forehead performed better.

Other conclusions that can be made about ensembles are that the eye protectors that have more of a side shield to accommodate for the side gaps do tend to protect better. Some of the eye protectors, though sleek in appearance, did not protect as well as others that had a larger surface area to the sides. The classic “lab safety glasses” design of eye protectors that were tested performed best at protection against spurts and sprays from the sides.

When looking at the SAS data output, it gives a skewed outlook on significant differences with Spurt vs Spray in some areas. This is why the data has been analyzed in multiple ways to draw the best conclusions. After analyzing the data in several areas, it can be concluded that Spurt and Spray are significantly different (Table 4-12). For this reason it is crucial to keep both elements within the test procedure. By using

both aspects of Spurt and Spray, the test is able to investigate PPE's protective performance at a much broader spectrum.

6.2 Recommendations for Future Work

Some recommendations for future work would be to gather more data and have a larger sample size. It's good to have large data sets because the larger the data set, the more we can extract insights that we trust from that data set. This is especially true when looking at the Range of Protection Test. I think that for future work this test would be beneficial to further investigate using more replications. In this study, time and material constraints only allowed for 1 replication per ensemble. I would recommend going as far as 10 replications or more depending on time and material.

Another aspect of this test that could be further investigated is to decrease the degrees for when the Range of Protection Test tested at. In this study, we looked at positions separated every 30 degrees. By increasing the positions tested, or decrease the gap between degrees, the test would give more specific data for each ensemble and a more precise "Range of Protection". I would recommend to test at every 10 degrees.

Another alteration to the test apparatus that could be made for the betterment of testing would be to increase the travel distance on the Uni-Slide stand. By increasing this travel distance the nozzle would be able to have more target locations at a lower angle. This would give the head manipulation a true 90 degree posterior or anterior tilt.

Another aspect that could be positively altered is to give the articulating base more clearance when moving the headform at extreme degrees. With these two changes it would give the test apparatus an even greater variety of testing options.

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APPENDIX A: WORK INSTRUCTIONS

1. PURPOSE

This establishes the procedure to evaluate the protective performance of eye and face protection from a small velocity stream (spurt and spray) of synthetic blood Eye and Face PPE Tester.

2. SCOPE

This procedure applies to the operation of the instrument when used to test the protective performance eye and face protection in simulation of high hazard occupations where biological hazards from spurts and sprays are present.

3. SUMMARY OF TEST METHOD

3.1. OPERATION

3.1.1. A volume of synthetic blood is disbursed at an ensemble by a pneumatically controlled valve from a set distance to simulate the spurt or spray of blood or other body fluid onto the ensemble. Any evidence of synthetic blood penetration on the areas of concern constitutes a failure.

3.1.2. Results are reported in the test matrix as pass/fail, the distance from failure or to passing, and the quadrant of a failure for each area of concern.

3.2. EVALUATION

3.2.1. Ensembles are evaluated at velocities of 635 cm/s for spurt and estimated of 300-500 cm/s for spray. These velocities correspond to the velocity exiting a small arterial at human blood pressure of 160 mm/Hg as well as the max average velocity of human sneeze/cough with sufficient spray pattern at the specified average distance of 30.48 cm.

4. MATERIALS AND SET-UP

4.1. MATERIALS REQUIRED

4.1.1. Test ensembles (eye protector and face mask or complete unit) and synthetic blood solution.

4.1.2. Lab coat, safety glasses, gloves, *not necessary but helpful*-laser level, spirit level, cross hair laser mounted to nozzle platform.

4.2. PREPARATION OF TEST APPARATUS AND CALIBRATION

4.2.1. Install a clean spurt cannula on the front of the nozzle valve. The cannula attaches to the exit of the valve. The standard size for this method is a 1.27 cm (0.5 in.) long 18 gauge stainless steel cannula with an internal diameter of 0.084 cm (0.033 in.) Deviations from the standard cannula must be noted in the test

report.

- 4.2.2. Fill the reservoir with fresh synthetic blood (approximately 1 liter) (see Fluid Preparation SOP at end).
- 4.2.3. Adjust the reservoir pressure to deliver the desired steady-state fluid velocity (~6.5 psi) a target velocity of 635 cm/s)
- 4.2.4. Set the valve timer to 0.5 seconds. Collect and weigh the amount of liquid delivered over a 0.5 second spurt.
- 4.2.5. Set the valve timer to 1.5 seconds. Collect and weigh the amount of liquid delivered over a 1.5 second spurt.
- 4.2.6. Calculate the difference in weight of the two spurts.
- 4.2.7. Adjust the reservoir pressure and repeat steps 4.2.3 to 4.2.6. until the weight difference is within the target range shown in Table 1 below. Record this weight.

Weight Difference (g) for a 1 Second Difference in Spurt Duration.

<u>Target Velocity (cm/s)</u>	<u>Minimum (g)</u>	<u>Target (g)</u>	<u>Maximum (g)</u>
635	3.466	3.537	3.607
550	3.002	3.063	3.124
450	2.456	2.506	2.556

Table 1. Target difference in weights plus lower and upper limits for a velocity range within 2% of the target.

- 4.2.8. Record the pressure in the reservoir and use this as the initial reservoir pressure in subsequent testing to expedite set-up.
- 4.2.9. Once the reservoir pressure has been set (per target velocity), maintain the same pressure in tank throughout testing.

4.3. POSITIONING OF THE CANNULA NOZZLE

- 4.3.1. Aim the nozzle so that the stream makes contact where the center of the cross hair lasers is pointing on the headform (assuming the laser has been installed and leveled).

Example Test Order of Positions will be Up-1, Down-2, Left-3, Right-4

- 4.3.2. Set the valve time to ~0.44 sec. for Spurt and ~.60 sec. for Spray. Squirt the fluid into a graduated cylinder to ensure that 2ml-spurt or 1ml spray is being delivered. Adjust the valve time accordingly to achieve 2ml or 1ml.

- 4.3.3. Place the headform in the desired head manipulation for the testing order.

(Up-1) The headform must be centered and anteriorly titled 30 degrees. The headform must be 30.48 cm away from the tip of the cannula to the target locations. The target location for this position is 2" above the center point of the midline from the left and right eye on the forehead. Adjust the uni-slide mount so the sighted in cross hair laser is at this point

(Down-2) The headform must be centered and posteriorly titled 30 degrees. The headform must be 30.48 cm away from the tip of the cannula to the target locations. The target location for this position is 1" below the center point of the midline from the left and right eye on the bridge of the nose. Adjust the uni-slide mount so the sighted in cross hair laser is at this point

(Left-3) The headform must be centered across the coronal and sagittal plane in a vertical fashion. Adjust the uni-slide mount so the sighted in cross hair laser is aimed at the center point between the eyes across the midline from the left and right eye. Rotate the headform clockwise 55 degrees. This is the target location (temple area). The headform must be 30.48 cm away from the tip of the cannula to the target location.

(Right-4) The headform must be centered across the coronal and sagittal plane in a vertical fashion. Adjust the uni-slide mount so the sighted in cross hair laser is aimed at the center point between the eyes across the midline from the left and right eye. Rotate the headform counter-clockwise 55 degrees. This is the target location (temple area). The headform must be 30.48 cm away from the tip of the cannula to the target location.

- 4.3.4. Once the headform is adjust into the position specified by the testing order and aimed to the target location corresponding to the head manipulation, Don the PPE for this test. Check to make sure the target location is still accurate with the nozzle, press the pedal to shoot the fluid onto the headform.
- 4.3.5. Within 5 sec. of shooting the fluid onto the headform, carefully remove the PPE and check for any fluid within the areas of concentration. Measure record the data into the test matrix with a caliper. If the fluid is within an area of concern it is deemed a failure. Measure from the center of area of concern to the closest fluid droplet and record this data. Record the quadrant that the fluid is in. If the fluid is outside the area of concern, measure from the perimeter of this area of concern to the closest fluid droplet and record this data.
- 4.3.6. After the completion of a set of "spurts" or "sprays", ensure that the test apparatus is delivering 2 ml or 1ml of test liquid by collecting and weighing the output passing through the targeting hole. If the delivered

output has shifted more than (2%), repeat the calibration procedure in Sections 4.2.4.

4.4. CLEANING

- 4.4.1. If the cannula is left for 1 hour or more without use after passing synthetic blood during testing, replace with a clean cannula and clean the used cannula by immersing in isopropyl alcohol for 24 hours and rinsing with distilled water.
- 4.4.2. Following testing, clean system lines and the reservoir with distilled water. Do not use isopropyl alcohol or other solvents on the valve or system lines, they could damage the valve.

5. TEST PROCEDURE AND QUALITATIVE EVALUATION

5.1. TEST PROCEDURE AND EVALUATION

- 5.1.1. Once the headform is adjusted into the position specified by the testing order and aimed to the target location corresponding to the head manipulation, Don the PPE for this test. Check to make sure the target location is still accurate with the nozzle, press the pedal to shoot the fluid onto the headform.
- 5.1.2. Within 5 sec. of shooting the fluid onto the headform, carefully remove the PPE and inspect for any fluid within the areas of concentration. The use of the blue light makes inspection much more effective. Measure and record the data into the test matrix with a caliper. If the fluid is within an area of concern it is deemed a failure. Measure from the center of area of concern to the closest fluid droplet and record this data. Record the quadrant that the fluid is in. If the area of concern passes, measure from the perimeter of this area of concern to the closest fluid droplet and record this data.
- 5.1.3. After the completion of a set of “spurts” or “sprays”, ensure that the test apparatus is delivering 2 ml or 1ml of test liquid by collecting and weighing the fluid. If the delivered output has shifted more than (2%), repeat the calibration procedure in Sections 4.2.4.

6. REPORTS

See Test Matrix

	x 10				Pass Fail	Dist. to closest fluid (mm)	Quadrant	Pass Fail	Dist. to closest Fluid (mm)	Quadrant	Pass Fail	Dist. to closest Fluid (mm)	Quadrant
1	Spurt	High Vel. 635 cm/s	High Vol. (2 ml)	Up
2	Spurt	High Vel. 635 cm/s	High Vol. (2 ml)	Down
3	Spurt	High Vel. 635 cm/s	High Vol. (2 ml)	Right
4	Spurt	High Vel. 635 cm/s	High Vol. (2 ml)	Left
1	Spray	500 cm/s	1 ml	Up
2	Spray	500 cm/s	1 ml	Down
3	Spray	500 cm/s	1 ml	Right
4	Spray	500 cm/s	1 ml	Left

7. SETTING UP LANDMARKS

7.1 Eyes

The ellipse parameters will have its dimensions based off the center of the eye. From there a major and minor axis will be created of lengths of 35mm in height (minor) and 50mm in width (major). This ellipse shape will follow the orbital bone. The 45 degree diagonal measurements will be 42 mm in length (Figure 6-1: Graph of Ellipse).

Figure 7-1: Graph of Ellipse

(Elsevier, 2008)

Figure 7-2: Average Eye Measurements

7.2 Nose

Nose exposure will be evaluated using the 6 landmarks shown below. Connecting the points from 1-3-2-5-6-4-1 creates a perimeter along the bottom surface area of the nose. Any fluid or fluid residue that is found within this perimeter will be considered a “fail” for the nose.

(Etoz, 2011)

Figure7-3: Anthropometric Nose landmarks

The nose perimeter measurements are defined in Figure 6-2 and Table 6-2 below for the European anthropometric headform.

1-2	Alare, the point where the nasal blade (ala nasi) extends farthest out.
3	Subnasal, the midpoint of the columella base.
4-5	The most convex point of lateral cruris of alar cartilage.
6	Pronasal, the most prominent point on the nasal tip.

Table 7-1: Anthropometric Nose Landmarks

Figure 7-4: Nose measurement of most convex point- Points 4-5.

1-3	27 mm
3-2	27 mm
1-4	18 mm
2-5	18 mm
4-6	20 mm
5-6	20 mm
4-5	25 mm
3-6	22 mm

Table 7-2: Nose Landmark Measurements

7.3 Mouth

Figure 4-5 shows anthropometric landmarks that are widely used for the mouth. A perimeter formed by connecting the points (1-2-3-4-5-1) defines the mouth. Any fluid or fluid residue that falls within this perimeter will be considered a “fail” for the mouth.

The perimeter will start at the left oral commissure or cheilion. This is where the lateral aspects of the vermilion of the upper and lower lips join. (Figure 6-5-point 1) From point 1, the perimeter will travel along the contour of the line formed by the vermilion border of the upper lip. In a frontal view, this line resembles an archer's bow, which curves medially and superiorly from the commissures to the paramedian peaks located at the bases of the pillars of the philtrum (crista philtrae) (Figure 6-5-points 2 and 3) with an inferior convexity lying between those peaks. The philtrum is the vertical groove in the midline of the upper lip bordered by these lateral pillars (ridges). From points 2-3, the perimeter will travel to point 4 which resides as the right oral commissure or cheilion (Figure 6-5-point 4). From point 4, the perimeter will travel along the contour of the line formed by the vermilion border of the lower lip until it reaches the lowest apex of the lower lip, which will be point 5. From point 5 the line will continue along the contour of the line formed by the vermilion border of the lower lip until it reconnects with point 1.

Source: (Raschke, et al., 2016)

Figure 7-5: Anthropometric Mouth Landmarks

The mouth perimeter measurements are defined in Figure 6-6 and Table 6-4 below for the European anthropometric headform.

Figure 7-6: Mouth measurement between left and right oral commissure-Points 1-4.

1-2	31 mm
2-3	10 mm
3-4	31 mm
4-5	33.5 mm
5-1	33.5 mm
1-4	56.5 mm
2-5	18 mm
3-5	18 mm

Table 7-3: Mouth Landmark Measurements

8. PICTURES

Figure 8-1. Pressure control gauge/reducer and Reservoir

Figure 8-2. Cannula on the front of the pneumatic-controlled valve

Figure 8-3. Anthropometric headform and grid with quadran

Figure 8-4. Cross Hair Laser on Platform

Figure 8-5. Spurt cannula

Figure 8-6. Spray cannula

Figure 8-7: Posterior and Anterior head Manipulations

Figure 8-8: Left and Right head Manipulations

Figure 8-9. Overall Setup

9. Fluid Preparation SOP

Fluid Preparation SOP

(saline + fluorescein + surfactant):

0.9 % saline
0.002 M fluorescein
0.1 % surfynol 104H

For 1 Liter:

9 g NaCl
0.752 g fluorescein
1.0 mL surfynol 104H
diH₂O to 1 L

- a. Place magnetic stir bar in 1 L Erlenmeyer flask and weigh both with triple beam balance to determine tare weight.
- b. Add 1000 g auxiliary weight to opposite end of balance beam
- c. Weigh NaCl on a scientific balance and add to flask, rinsing with diH₂O as needed
- d. Weigh fluorescein on a scientific balance and add to flask, rinsing with diH₂O as needed
- e. Add remaining volume of diH₂O until indicator at the end of balance beam is level with the zero indicator on the balance base.
- f. Transfer flask to magnetic stirrer and create a strong vortex.
- g. Using an Eppendorf micropipettor device and disposable tip, carefully pipet the surfynol 104H into the solution, rinsing tip several times.
- h. Allow solution to mix with a strong vortex for 30 minute.

APPENDIX B: APPARATUS BUILDING INSTRUCTIONS

All materials listed below are what is recommended for building materials. These materials or materials of equivalence are to be used when constructing this apparatus.

The apparatus is to be mounted on a solid sheet of material rigid enough to hold each part in a stable and sturdy position. This was done by using a 24" x 48" x 1/2" sheet of LDPE as shown below (Figure 1).

Figure 1: Top View of Apparatus

The next step is to mount the milling table to the LDPE sheet. The milling table used in this apparatus is a Grizzly 6" x 18.5" compound table (Figure 2). To mount the table it is necessary to raise the milling table 1.5" above the LDPE sheet. This was done by use two 1.5x1.5" 80/20 stock bar that was cut into two 11" long pieces. The 2 pieces then have a 1/2 hole drilled through the center of the 80/20 stock bar. Each hole is drilled at 1.5" in from each end. Next, the milling tables anchor points are to be aligned with the holes in the 80/20 stock bar and fitted to be squared with the corner of the LDPE sheet. The milling table is held down through the 80/20 stock bar and the LDPE sheet by four 3/8"-2" hex bolts along 1-1/4" washers and corresponding nuts (Figure 3 and Figure 4). To be able to bolt the milling table down, the LDPE must have 4 aligned holes drilled at 1/2". These 4 holes must also have a counter sunk hole to allow for the hex head of the bolt to sit beneath the bottom of the LDPE sheet (Figure 5). This counter sunk hole should be around 7/8" wide.

Figure 2: Milling Table

Figure 3: Inside View of Milling Table Anchored to LDPE Sheet

Figure 4: Outside View of Milling Table Anchored to LDPE Sheet

Figure 5: Counter Sunk Hole with Through Bolt

After getting the milling table attached to the LDPA platform sheet, the next step is to attach the headform to the articulating base. The articulating base is made from ThorLabs and is shown in the CAD file below (Figure 6).

Figure 6: Articulating Base Layout

The UK Anthropometric headform is attached to the articulating base by using two 2” dry wall screws. Both of the headforms center ear holes must be aligned directly to the center of the articulating base. The wood screws can then be inserted in any appropriated hole of the articulating base and into the base of the neck of the headform. The optimal screw pattern would be 1 screw on either side of the pedestal (Figure 7).

Figure 7: Articulating Base Screw Pattern

After attached the anthropometric head to the articulating base, the base then needs to be attached to the milling table. This is done using two $\frac{3}{16}$ " -1-1/4" fully threaded bolts, corresponding nuts, and $\frac{1}{2}$ " washers (Figure 8, Figure 9, and Figure 10).

Figure 8: Top View of Articulating Base Attachment

Figure 9: Side View of Articulating Base Attachment

Figure 10: Close Up of Bolt on Articulating Base Attachment

The next piece of the apparatus that needs to be anchored to the LDPE sheet platform is the uni-slide stand. Given that the milling table is 6 ½" tall, the uni-slide stand then needs to be

raised on a platform itself to have matching heights for adequate nozzle projection (Figure 11). This platform can be built into a simple rectangular 4"x4" box by using LDPE, polycarbonate, PTFE, or equivalent materials. This rectangular box can also be bought; either method is sufficient as long as the stand can remain stable and is raised at least 6 1/2". The box used to raise the uni-slide in this apparatus was built out of PTFE sheets. Two pieces were cut into 3"x 6 1/2" and two more 4"x 6 1/2". These four pieces were screwed together using 3/4" plastic screws (Figure 12). The box ends remain open. The uni slide will then sit atop the box and is screwed down into the top of the fabricated box through the uni slides pre drilled holes using four 3/4" plastic screws (Figure 13).

Figure 11: Uni-Slide Attached to Fabricated Box

Figure 12: Fabricated Box

Figure 13: Uni-Slide Screwed to Box

After securing the uni-slide stand to the fabricated box, the next step is to attach the nozzle to the uni-slides mounting bracket. The nozzle is secured to the mounting bracket by one 3/16"-1/2" fully threaded hex head bolt. The nozzle is held by using the M5 mounting hole (Figure 14). A locking washer is also needed between the bolt head and the bottom of the mounting bracket for tension purposes (Figure 15 and Figure 16).

Figure 14: Nozzle Diagram

Figure 15: Mounted Nozzle on Bracket

Figure 16: Bottom View of Mounting Bracket

After getting the nozzle mounted to the uni-slides mounting bracket, it is important to get the nozzle as square and in the center as possible on the bracket before completely tightening it down (Figure 17).

Figure 17: Top View of Nozzle Mounted

The next step is securing the fabricated box to the LDPE sheet platform. (At this point the nozzle should already be attached to the uni-slide mount and the uni-slide should be attached to the fabricated box) The nozzle needs to be placed in a manner so that when it is shot the fluid would pass directly through the center of the milling table or to the center of the anthropometric head (Figure 18). The edge of the fabricated box should also run parallel with the edge of the LDPE sheet platform (Figure 18).

Figure 18: Orientation of Nozzle and Uni-Slide

After getting the orientation of the nozzle stand to that of the milling table and anthropometric head, it will then need to be anchored down. This can be achieved by the same method as the milling table. By using four 1-1/4" plastic screws that are drilled and countersunk from the bottom of the LDPE sheet platform (Figure 19 and Figure 20).

Figure 19: Fabricated Box Secured to LDPE Sheet

Figure 20: Countersunk Hole for Uni-Slide Box

The next step is to connect air pressure to the pressurized container and dispensing unit with an airline capable of supply consistent pressure of at least 70 psi. These two air inlets are fed by a ¼" push connection (Figure 21 and Figure 22). After running the airline to the container and dispensing unit, another ¼" airline needs to be connected from the dispensing unit to the nozzle (Figure 23 and Figure 24). After connecting all of airlines to the container, dispenser, and nozzle; the next step is to connect the pressurized container reservoir to the nozzle (Figure 25 and Figure 26).

Figure 21: Supply Air Line Connection into Container

Figure 22: Supply Air Line Connection into Dispenser

Figure 23: Air Line from Dispenser to Nozzle-Dispenser Output

Figure 24: Air Line from Dispenser to Nozzle-Nozzle Input

Figure 25: Fluid line from Pressurized Container Reservoir to Nozzle

Figure 26: Fluid line Into Nozzle from Pressurized Container Reservoir to Nozzle
After the airlines and fluid line is connected, the power cord and foot pedal must be connected to the dispensing unit. Both of these connections are made at the back of the dispensing unit (Figure 27 and Figure 28).

Figure 27: Connections at Back of Dispenser

Figure 28: Foot Pedal and Connections for Dispenser

Parts List

McMaster-Carr

- (1) LDPE Sheet 24"x48"x1/2" Part# 8657K616
- (1) 80/20 1"x1"-24" 47065T101
- (4) Hex bolt 3/8"-2" 91309A632
- (4) Hex nuts 3/8"-16 95462A031
- (4) 1-1/4" flat washer 90107A040
- (2) Dry wall screws 90093A400
- (2) 3/16 Hex bolts 91309A626
- (2) 3/16 Hex nuts
- (3) 1.125" washers 91525A268
- (1) LDPE sheet 24"x24" 8657K416
- (24) No.4 - 3/4"Screws 90380A120
- (4) No. 8 1-1/4" Screws 92325A319
- (1) 0-30 PSI Pressure Gauge 4089K61

Grizzly

- (1) 6" x 18.5" compound Table - G8750

ThorLabs

- (1) Articulation base – SL20

Velmex

- (1) UniSlide Elevating Table-T=9.5" - B2912W1

Ellsworth

- (1) Poppet Valve - VP300
- (1) Pressure Tank Stainless Steel Special - IJ2601N-SS-SP
- (1) Digital Dispenser-Valve Controlled - DC200

Fluid Preparation SOP

(saline + fluorescein + surfactant):

0.9 % saline
0.002 M fluorescein
0.1 % surfynol 104H

For 1 Liter:

9 g NaCl
0.752 g fluorescein
1.0 mL surfynol 104H
diH₂O to 1 L

- i. Place magnetic stir bar in 1 L Erlenmeyer flask and weigh both with triple beam balance to determine tare weight.
- j. Add 1000 g auxiliary weight to opposite end of balance beam
- k. Weigh NaCl on a scientific balance and add to flask, rinsing with diH₂O as needed
- l. Weigh fluorescein on a scientific balance and add to flask, rinsing with diH₂O as needed
- m. Add remaining volume of diH₂O until indicator at the end of balance beam is level with the zero indicator on the balance base.
- n. Transfer flask to magnetic stirrer and create a strong vortex.
- o. Using an Eppendorf micropipettor device and disposable tip, carefully pipet the surfynol 104H into the solution, rinsing tip several times.
- p. Allow solution to mix with a strong vortex for 30 minute.

APPENDIX C: ENSEMBLE TEST DATA

position1	type1	type2	type3	position2	passfail	eyes distance	quad1	passfail	nose distance2	quad2	passfail	mout distance3	quad3	Ensemble
1	Spurt	635 cm/s	2ml	Up	Pass	22.32	-	Pass	5.69	-	Pass	33.61	-	A
2	Spurt	635 cm/s	2ml	Down	Fail	1.26	L Q2	Fail	Ran Thru	Q3	Fail	Ran Thru	Q2/Q3	A
3	Spurt	635 cm/s	2ml	Right	Pass	17.91	-	Pass	50.4	-	Pass	50.79	-	A
4	Spurt	635 cm/s	2ml	Left	Pass	20.49	-	Pass	50.14	-	Pass	36.14	-	A
1	Spray	500 cm/s	1ml	Up	Pass	26.32	-	Pass	74.45	-	Pass	78.26	-	A
2	Spray	500 cm/s	1ml	Down	Pass	17.19	-	Pass	71.22	-	Pass	93.4	-	A
3	Spray	500 cm/s	1ml	Right	Pass	13.29	-	Pass	48.26	-	Pass	37.58	-	A
4	Spray	500 cm/s	1ml	Left	Pass	15.13	-	Pass	41.94	-	Pass	33.5	-	A
1	Spurt	635 cm/s	2ml	Up	Pass	22.42	-	Pass	3.36	-	Pass	35.87	-	A
2	Spurt	635 cm/s	2ml	Down	Fail	18.42	L Q3	Fail	Ran Thru	Q4	Fail	Ran Thru	Q2/Q4	A
3	Spurt	635 cm/s	2ml	Right	Pass	19.25	-	Pass	56.08	-	Pass	39.09	-	A
4	Spurt	635 cm/s	2ml	Left	Pass	18.28	-	Pass	38.59	-	Pass	34.9	-	A
1	Spray	500 cm/s	1ml	Up	Pass	22.52	-	Pass	70.68	-	Pass	77.54	-	A
2	Spray	500 cm/s	1ml	Down	Pass	17.63	-	Pass	67.83	-	Pass	92.19	-	A
3	Spray	500 cm/s	1ml	Right	Pass	17.37	-	Pass	43.96	-	Pass	32.53	-	A
4	Spray	500 cm/s	1ml	Left	Pass	23.04	-	Pass	43.2	-	Pass	38.16	-	A
1	Spurt	635 cm/s	2ml	Up	Pass	23.01	-	Pass	72.4	-	Pass	77.85	-	A
2	Spurt	635 cm/s	2ml	Down	Fail	17.35	R Q4	Fail	Ran Thru	Q2/Q3	Pass	5.84	-	A
3	Spurt	635 cm/s	2ml	Right	Pass	17.49	-	Pass	56.52	-	Pass	46.2	-	A
4	Spurt	635 cm/s	2ml	Left	Pass	21.89	-	Pass	50.84	-	Pass	48.19	-	A
1	Spray	500 cm/s	1ml	Up	Pass	26.57	-	Pass	76.23	-	Pass	78.35	-	A
2	Spray	500 cm/s	1ml	Down	Pass	16.87	-	Pass	68.08	-	Pass	92.44	-	A
3	Spray	500 cm/s	1ml	Right	Pass	19.95	-	Pass	46.05	-	Pass	36.8	-	A
4	Spray	500 cm/s	1ml	Left	Pass	23.96	-	Pass	41.56	-	Pass	33.65	-	A
1	Spurt	635 cm/s	2ml	Up	Pass	4.91	-	Pass	45.72	-	Pass	81.97	-	A
2	Spurt	635 cm/s	2ml	Down	Fail	21.6	L Q2	Fail	Ran Thru	Q4	Fail	Ran Thru	Q1/Q4	A
3	Spurt	635 cm/s	2ml	Right	Pass	16.28	-	Pass	54.66	-	Pass	30.24	-	A
4	Spurt	635 cm/s	2ml	Left	Pass	20.46	-	Pass	62.82	-	Pass	43.66	-	A
1	Spray	500 cm/s	1ml	Up	Pass	23.4	-	Pass	73.51	-	Pass	74.55	-	A
2	Spray	500 cm/s	1ml	Down	Pass	15.75	-	Pass	71.99	-	Pass	97.16	-	A
3	Spray	500 cm/s	1ml	Right	Pass	18.23	-	Pass	45.84	-	Pass	37.59	-	A
4	Spray	500 cm/s	1ml	Left	Pass	16.84	-	Pass	44.11	-	Pass	36.48	-	A
1	Spurt	635 cm/s	2ml	Up	Pass	8.59	-	Pass	2.75	-	Pass	30.55	-	A
2	Spurt	635 cm/s	2ml	Down	Fail	11.5	L Q3	Fail	Ran Thru	Q3/Q4	Fail	Ran Thru	Q1/Q4	A
3	Spurt	635 cm/s	2ml	Right	Pass	18.14	-	Pass	46.22	-	Pass	45.95	-	A
4	Spurt	635 cm/s	2ml	Left	Pass	18.11	-	Pass	49.46	-	Pass	52.76	-	A
1	Spray	500 cm/s	1ml	Up	Pass	23.37	-	Pass	74.6	-	Pass	76.1	-	A
2	Spray	500 cm/s	1ml	Down	Pass	18.16	-	Pass	68.29	-	Pass	97.22	-	A
3	Spray	500 cm/s	1ml	Right	Pass	19.03	-	Pass	44.56	-	Pass	37.52	-	A
4	Spray	500 cm/s	1ml	Left	Pass	15.21	-	Pass	41.46	-	Pass	39.12	-	A
1	Spurt	635 cm/s	2ml	Up	Pass	21.94	-	Pass	74.79	-	Pass	82.14	-	A
2	Spurt	635 cm/s	2ml	Down	Fail	22.43	R Q1	Fail	Ran Thru	Q3	Fail	Ran Thru	Q2/Q3	A
3	Spurt	635 cm/s	2ml	Right	Pass	20.62	-	Pass	31.47	-	Pass	34.26	-	A
4	Spurt	635 cm/s	2ml	Left	Pass	22.14	-	Pass	52.44	-	Pass	45.33	-	A
1	Spray	500 cm/s	1ml	Up	Pass	25.79	-	Pass	75.05	-	Pass	75.93	-	A
2	Spray	500 cm/s	1ml	Down	Pass	16.51	-	Pass	71.97	-	Pass	92.85	-	A
3	Spray	500 cm/s	1ml	Right	Pass	14.68	-	Pass	43.07	-	Pass	29.09	-	A
4	Spray	500 cm/s	1ml	Left	Pass	19.71	-	Pass	44.55	-	Pass	31.82	-	A
1	Spurt	635 cm/s	2ml	Up	Pass	23.76	-	Pass	3.56	-	Pass	338.68	-	A
2	Spurt	635 cm/s	2ml	Down	Fail	17.24	L Q3	Pass	1.82	-	Pass	2.54	-	A
3	Spurt	635 cm/s	2ml	Right	Pass	19.33	-	Pass	47.34	-	Pass	51.98	-	A
4	Spurt	635 cm/s	2ml	Left	Pass	18.04	-	Pass	56.91	-	Pass	52.42	-	A
1	Spray	500 cm/s	1ml	Up	Pass	24.35	-	Pass	74.52	-	Pass	74.71	-	A

2	Spray	500 cm/s	1ml	Down	Pass	15.12	-	Pass	70.67	-	Pass	96.91	-	A
3	Spray	500 cm/s	1ml	Right	Pass	21.03	-	Pass	40.79	-	Pass	34.5	-	A
4	Spray	500 cm/s	1ml	Left	Pass	20.81	-	Pass	51.61	-	Pass	33.21	-	A
1	Spurt	635 cm/s	2ml	Up	Pass	23.19	-	Pass	75.45	-	Pass	77.36	-	A
2	Spurt	635 cm/s	2ml	Down	Fail	16.25	R Q1	Fail	Ran Thru	Q3	Fail	Ran Thru	Q2/Q3	A
3	Spurt	635 cm/s	2ml	Right	Pass	8.86	-	Pass	34.93	-	Pass	53.02	-	A
4	Spurt	635 cm/s	2ml	Left	Pass	21.16	-	Pass	50.55	-	Pass	52.5	-	A
1	Spray	500 cm/s	1ml	Up	Pass	25.58	-	Pass	73.83	-	Pass	80.39	-	A
2	Spray	500 cm/s	1ml	Down	Pass	17.21	-	Pass	70.16	-	Pass	93.54	-	A
3	Spray	500 cm/s	1ml	Right	Pass	18.3	-	Pass	42.84	-	Pass	38.54	-	A
4	Spray	500 cm/s	1ml	Left	Pass	18.94	-	Pass	43.61	-	Pass	37.62	-	A
1	Spurt	635 cm/s	2ml	Up	Pass	23.39	-	Pass	76.25	-	Pass	88.6	-	A
2	Spurt	635 cm/s	2ml	Down	Fail	18.19	R Q4	Fail	Ran Thru	Q3	Pass	4.86	-	A
3	Spurt	635 cm/s	2ml	Right	Pass	18.9	-	Pass	49.4	-	Pass	51.97	-	A
4	Spurt	635 cm/s	2ml	Left	Pass	19.49	-	Pass	48.41	-	Pass	35.14	-	A
1	Spray	500 cm/s	1ml	Up	Pass	23.93	-	Pass	74.95	-	Pass	79.12	-	A
2	Spray	500 cm/s	1ml	Down	Pass	15.84	-	Pass	71.56	-	Pass	94.63	-	A
3	Spray	500 cm/s	1ml	Right	Pass	19.23	-	Pass	44.51	-	Pass	35.26	-	A
4	Spray	500 cm/s	1ml	Left	Pass	19.66	-	Pass	49.26	-	Pass	34.12	-	A
1	Spurt	635 cm/s	2ml	Up	Pass	19.82	-	Pass	6.99	-	Pass	32.54	-	A
2	Spurt	635 cm/s	2ml	Down	Fail	19.23	L Q2	Pass	3.12	-	Pass	2.45	-	A
3	Spurt	635 cm/s	2ml	Right	Pass	21.32	-	Pass	55.25	-	Pass	44.62	-	A
4	Spurt	635 cm/s	2ml	Left	Pass	22.48	-	Pass	51.28	-	Pass	47.81	-	A
1	Spray	500 cm/s	1ml	Up	Pass	23.09	-	Pass	74.44	-	Pass	75.32	-	A
2	Spray	500 cm/s	1ml	Down	Pass	16.47	-	Pass	72.95	-	Pass	93.11	-	A
3	Spray	500 cm/s	1ml	Right	Pass	18.75	-	Pass	44.65	-	Pass	37.72	-	A
4	Spray	500 cm/s	1ml	Left	Pass	17.45	-	Pass	41.36	-	Pass	39.24	-	A
1	Spurt	635 cm/s	2ml	Up	Pass	1.85	-	Pass	58.38	-	Pass	76.92	-	B
2	Spurt	635 cm/s	2ml	Down	Pass	55.55	-	Pass	105.58	-	Pass	125.68	-	B
3	Spurt	635 cm/s	2ml	Right	Pass	68.72	-	Pass	73.78	-	Pass	61.23	-	B
4	Spurt	635 cm/s	2ml	Left	Pass	49.42	-	Pass	67.71	-	Pass	62.45	-	B
1	Spray	500 cm/s	1ml	Up	Pass	68.46	-	Pass	115.63	-	Pass	134.9	-	B
2	Spray	500 cm/s	1ml	Down	Pass	30.8	-	Pass	81.68	-	Pass	100.62	-	B
3	Spray	500 cm/s	1ml	Right	Pass	39.95	-	Pass	70.72	-	Pass	45.65	-	B
4	Spray	500 cm/s	1ml	Left	Pass	39.41	-	Pass	39.76	-	Pass	33	-	B
1	Spurt	635 cm/s	2ml	Up	Fail	0.75	L Q1	Pass	37.64	-	Pass	57.14	-	B
2	Spurt	635 cm/s	2ml	Down	Pass	-	-	Pass	NA	-	Pass	NA	-	B
3	Spurt	635 cm/s	2ml	Right	Pass	54.47	-	Pass	67.47	-	Pass	53.96	-	B
4	Spurt	635 cm/s	2ml	Left	Pass	56.54	-	Pass	72.23	-	Pass	61.46	-	B
1	Spray	500 cm/s	1ml	Up	Pass	48.42	-	Pass	65.66	-	Pass	59.87	-	B
2	Spray	500 cm/s	1ml	Down	Pass	70.21	-	Pass	120.23	-	Pass	110.15	-	B
3	Spray	500 cm/s	1ml	Right	Pass	29.23	-	Pass	79.73	-	Pass	102.3	-	B
4	Spray	500 cm/s	1ml	Left	Pass	37.55	-	Pass	68.26	-	Pass	41.39	-	B
1	Spurt	635 cm/s	2ml	Up	Fail	8.49	L Q1	Pass	45.68	-	Pass	70.37	-	B
2	Spurt	635 cm/s	2ml	Down	Pass	-	-	Pass	NA	-	Pass	NA	-	B
3	Spurt	635 cm/s	2ml	Right	Pass	49.92	-	Pass	63.95	-	Pass	51.2	-	B
4	Spurt	635 cm/s	2ml	Left	Pass	37.46	-	Pass	47.01	-	Pass	41.54	-	B
1	Spray	500 cm/s	1ml	Up	Pass	59.78	-	Pass	97.79	-	Pass	123.16	-	B
2	Spray	500 cm/s	1ml	Down	Pass	38.99	-	Pass	87.95	-	Pass	113.45	-	B
3	Spray	500 cm/s	1ml	Right	Pass	47.63	-	Pass	52.27	-	Pass	37.12	-	B
4	Spray	500 cm/s	1ml	Left	Pass	47.47	-	Pass	55.62	-	Pass	33.67	-	B
1	Spurt	635 cm/s	2ml	Up	Fail	2.67	R Q2	Pass	18.26	-	Pass	44.38	-	B
2	Spurt	635 cm/s	2ml	Down	Pass	-	-	Pass	NA	-	Pass	NA	-	B
3	Spurt	635 cm/s	2ml	Right	Pass	69.83	-	Pass	87.4	-	Pass	73.9	-	B

4	Spurt	635 cm/s	2ml	Left	Pass	47.1	-	Pass	68.5	-	Pass	64.19	-	B
1	Spray	500 cm/s	1ml	Up	Pass	60.23	-	Pass	89.32	-	Pass	115.18	-	B
2	Spray	500 cm/s	1ml	Down	Pass	30.21	-	Pass	94.51	-	Pass	112.32	-	B
3	Spray	500 cm/s	1ml	Right	Pass	45.83	-	Pass	47.25	-	Pass	35.02	-	B
4	Spray	500 cm/s	1ml	Left	Pass	44.32	-	Pass	51.22	-	Pass	31.64	-	B
1	Spurt	635 cm/s	2ml	Up	Fail	5.05	L Q2	Pass	36.08	-	Pass	55.98	-	B
2	Spurt	635 cm/s	2ml	Down	Pass	-	-	Pass	NA	-	Pass	NA	-	B
3	Spurt	635 cm/s	2ml	Right	Pass	25.63	-	Pass	75.98	-	Pass	63.27	-	B
4	Spurt	635 cm/s	2ml	Left	Pass	42.61	-	Pass	69.09	-	Pass	49.97	-	B
1	Spray	500 cm/s	1ml	Up	Pass	58.55	-	Pass	98.73	-	Pass	123.16	-	B
2	Spray	500 cm/s	1ml	Down	Pass	44.24	-	Pass	104.99	-	Pass	115.34	-	B
3	Spray	500 cm/s	1ml	Right	Pass	53.77	-	Pass	62.17	-	Pass	47.81	-	B
4	Spray	500 cm/s	1ml	Left	Pass	50.54	-	Pass	59.4	-	Pass	25.76	-	B
1	Spurt	635 cm/s	2ml	Up	Fail	5.97	R Q2	Pass	4.8	-	Pass	32.18	-	B
2	Spurt	635 cm/s	2ml	Down	Pass	-	-	Pass	NA	-	Pass	NA	-	B
3	Spurt	635 cm/s	2ml	Right	Pass	12.28	-	Pass	66.57	-	Pass	50.4	-	B
4	Spurt	635 cm/s	2ml	Left	Pass	13.66	-	Pass	70.25	-	Pass	56.62	-	B
1	Spray	500 cm/s	1ml	Up	Pass	55.75	-	Pass	95.73	-	Pass	110.11	-	B
2	Spray	500 cm/s	1ml	Down	Pass	43.44	-	Pass	102.84	-	Pass	120.05	-	B
3	Spray	500 cm/s	1ml	Right	Pass	51.53	-	Pass	55.48	-	Pass	45.58	-	B
4	Spray	500 cm/s	1ml	Left	Pass	48.45	-	Pass	53.34	-	Pass	21.23	-	B
1	Spurt	635 cm/s	2ml	Up	Pass	35.18	-	Pass	83.58	-	Pass	85.75	-	B
2	Spurt	635 cm/s	2ml	Down	Pass	-	-	Pass	NA	-	Pass	NA	-	B
3	Spurt	635 cm/s	2ml	Right	Pass	74.89	-	Pass	79.11	-	Pass	60.56	-	B
4	Spurt	635 cm/s	2ml	Left	Pass	29.45	-	Pass	51.74	-	Pass	49.67	-	B
1	Spray	500 cm/s	1ml	Up	Pass	59.62	-	Pass	115.07	-	Pass	134.58	-	B
2	Spray	500 cm/s	1ml	Down	Pass	40.26	-	Pass	99.97	-	Pass	124.12	-	B
3	Spray	500 cm/s	1ml	Right	Pass	38.84	-	Pass	68.34	-	Pass	47.59	-	B
4	Spray	500 cm/s	1ml	Left	Pass	29.16	-	Pass	58.62	-	Pass	38.45	-	B
1	Spurt	635 cm/s	2ml	Up	Fail	2.51	L Q4	Pass	30.69	-	Pass	55.81	-	B
2	Spurt	635 cm/s	2ml	Down	Pass	-	-	Pass	NA	-	Pass	NA	-	B
3	Spurt	635 cm/s	2ml	Right	Pass	17.71	-	Pass	55.96	-	Pass	45.45	-	B
4	Spurt	635 cm/s	2ml	Left	Pass	20.31	-	Pass	49.17	-	Pass	45.09	-	B
1	Spray	500 cm/s	1ml	Up	Pass	61.23	-	Pass	109.57	-	Pass	105.22	-	B
2	Spray	500 cm/s	1ml	Down	Pass	38.76	-	Pass	102.2	-	Pass	112.69	-	B
3	Spray	500 cm/s	1ml	Right	Pass	36.45	-	Pass	62.32	-	Pass	45.23	-	B
4	Spray	500 cm/s	1ml	Left	Pass	27.16	-	Pass	55.36	-	Pass	39.68	-	B
1	Spurt	635 cm/s	2ml	Up	Fail	0	L Q1	Pass	20.27	-	Pass	50.12	-	B
2	Spurt	635 cm/s	2ml	Down	Pass	-	-	Pass	NA	-	Pass	NA	-	B
3	Spurt	635 cm/s	2ml	Right	Pass	8.67	-	Pass	36.16	-	Pass	49.77	-	B
4	Spurt	635 cm/s	2ml	Left	Pass	14.69	-	Pass	53.83	-	Pass	49.14	-	B
1	Spray	500 cm/s	1ml	Up	Pass	63.93	-	Pass	109.61	-	Pass	92.52	-	B
2	Spray	500 cm/s	1ml	Down	Pass	29.53	-	Pass	79.66	-	Pass	101.67	-	B
3	Spray	500 cm/s	1ml	Right	Pass	52.62	-	Pass	54.27	-	Pass	42.65	-	B
4	Spray	500 cm/s	1ml	Left	Pass	53.54	-	Pass	52.47	-	Pass	30.74	-	B
1	Spurt	635 cm/s	2ml	Up	Fail	9.36	R Q1	Pass	35.05	-	Pass	61.59	-	B
2	Spurt	635 cm/s	2ml	Down	Pass	-	-	Pass	NA	-	Pass	NA	-	B
3	Spurt	635 cm/s	2ml	Right	Pass	29.96	-	Pass	76.09	-	Pass	58.34	-	B
4	Spurt	635 cm/s	2ml	Left	Pass	25.73	-	Pass	67.69	-	Pass	59.12	-	B
1	Spray	500 cm/s	1ml	Up	Pass	58.62	-	Pass	97.78	-	Pass	119.27	-	B
2	Spray	500 cm/s	1ml	Down	Pass	42.54	-	Pass	105.23	-	Pass	101.2	-	B
3	Spray	500 cm/s	1ml	Right	Pass	50.16	-	Pass	51.73	-	Pass	44.34	-	B
4	Spray	500 cm/s	1ml	Left	Pass	51.26	-	Pass	53.64	-	Pass	31.73	-	B
1	Spurt	635 cm/s	2ml	Up	Pass	42.07	-	Pass	95.7	-	Pass	89.12	-	C

2	Spurt	635 cm/s	2ml	Down	Pass	9.58	-	Pass	67.78	-	Pass	93.61	-	C
3	Spurt	635 cm/s	2ml	Right	Pass	51.13	-	Pass	64.38	-	Pass	77.87	-	C
4	Spurt	635 cm/s	2ml	Left	Pass	41.91	-	Pass	67.14	-	Pass	81.29	-	C
1	Spray	500 cm/s	1ml	Up	Pass	51.62	-	Pass	104.57	-	Pass	81.98	-	C
2	Spray	500 cm/s	1ml	Down	Pass	38.24	-	Pass	89.49	-	Pass	113.94	-	C
3	Spray	500 cm/s	1ml	Right	Pass	45.49	-	Pass	81.28	-	Pass	82.68	-	C
4	Spray	500 cm/s	1ml	Left	Pass	43.94	-	Pass	74.16	-	Pass	78.07	-	C
1	Spurt	635 cm/s	2ml	Up	Pass	39.25	-	Pass	91.25	-	Pass	87.01	-	C
2	Spurt	635 cm/s	2ml	Down	Pass	34.57	-	Pass	79.27	-	Pass	102.31	-	C
3	Spurt	635 cm/s	2ml	Right	Pass	53.19	-	Pass	67.68	-	Pass	51.04	-	C
4	Spurt	635 cm/s	2ml	Left	Pass	47.02	-	Pass	59.05	-	Pass	56.22	-	C
1	Spray	500 cm/s	1ml	Up	Pass	59.35	-	Pass	103.79	-	Pass	85.18	-	C
2	Spray	500 cm/s	1ml	Down	Pass	35.17	-	Pass	82.93	-	Pass	110.7	-	C
3	Spray	500 cm/s	1ml	Right	Pass	35.2	-	Pass	78.17	-	Pass	72.09	-	C
4	Spray	500 cm/s	1ml	Left	Pass	37.15	-	Pass	74.76	-	Pass	69.13	-	C
1	Spurt	635 cm/s	2ml	Up	Pass	35.79	-	Pass	87.04	-	Pass	90.7	-	C
2	Spurt	635 cm/s	2ml	Down	Pass	40.21	-	Pass	88.31	-	Pass	109.42	-	C
3	Spurt	635 cm/s	2ml	Right	Pass	52.13	-	Pass	66.45	-	Pass	58.91	-	C
4	Spurt	635 cm/s	2ml	Left	Pass	45.86	-	Pass	58.12	-	Pass	57.42	-	C
1	Spray	500 cm/s	1ml	Up	Pass	44.02	-	Pass	93.27	-	Pass	81.51	-	C
2	Spray	500 cm/s	1ml	Down	Pass	34.57	-	Pass	84.85	-	Pass	111.31	-	C
3	Spray	500 cm/s	1ml	Right	Pass	42.45	-	Pass	60.36	-	Pass	62.65	-	C
4	Spray	500 cm/s	1ml	Left	Pass	39.09	-	Pass	67.69	-	Pass	56.5	-	C
1	Spurt	635 cm/s	2ml	Up	Pass	39.81	-	Pass	85.12	-	Pass	89.53	-	C
2	Spurt	635 cm/s	2ml	Down	Pass	30.82	-	Pass	79.5	-	Pass	103.63	-	C
3	Spurt	635 cm/s	2ml	Right	Pass	53.14	-	Pass	78.27	-	Pass	70.57	-	C
4	Spurt	635 cm/s	2ml	Left	Pass	55.92	-	Pass	75.13	-	Pass	73.69	-	C
1	Spray	500 cm/s	1ml	Up	Pass	46.05	-	Pass	99.24	-	Pass	72.65	-	C
2	Spray	500 cm/s	1ml	Down	Pass	31.93	-	Pass	87.75	-	Pass	109.27	-	C
3	Spray	500 cm/s	1ml	Right	Pass	42.85	-	Pass	81.06	-	Pass	61.68	-	C
4	Spray	500 cm/s	1ml	Left	Pass	40.93	-	Pass	80.27	-	Pass	58.36	-	C
1	Spurt	635 cm/s	2ml	Up	Pass	38.14	-	Pass	88.56	-	Pass	88.78	-	C
2	Spurt	635 cm/s	2ml	Down	Pass	31.26	-	Pass	80.54	-	Pass	105.46	-	C
3	Spurt	635 cm/s	2ml	Right	Pass	56.81	-	Pass	77.43	-	Pass	72.56	-	C
4	Spurt	635 cm/s	2ml	Left	Pass	54.62	-	Pass	81.23	-	Pass	70.45	-	C
1	Spray	500 cm/s	1ml	Up	Pass	56.78	-	Pass	103.92	-	Pass	80.06	-	C
2	Spray	500 cm/s	1ml	Down	Pass	35.04	-	Pass	87.38	-	Pass	111.25	-	C
3	Spray	500 cm/s	1ml	Right	Pass	35.83	-	Pass	74.43	-	Pass	70.49	-	C
4	Spray	500 cm/s	1ml	Left	Pass	36.02	-	Pass	81.52	-	Pass	73.01	-	C
1	Spurt	635 cm/s	2ml	Up	Pass	31.89	-	Pass	84.12	-	Pass	81.26	-	C
2	Spurt	635 cm/s	2ml	Down	Pass	29.89	-	Pass	78.92	-	Pass	101.61	-	C
3	Spurt	635 cm/s	2ml	Right	Pass	51.12	-	Pass	70.14	-	Pass	68.42	-	C
4	Spurt	635 cm/s	2ml	Left	Pass	55.69	-	Pass	73.26	-	Pass	69.87	-	C
1	Spray	500 cm/s	1ml	Up	Pass	52.96	-	Pass	101.8	-	Pass	77.68	-	C
2	Spray	500 cm/s	1ml	Down	Pass	33.16	-	Pass	85.62	-	Pass	112.43	-	C
3	Spray	500 cm/s	1ml	Right	Pass	43.45	-	Pass	31.36	-	Pass	62.34	-	C
4	Spray	500 cm/s	1ml	Left	Pass	38.11	-	Pass	67.26	-	Pass	56.25	-	C
1	Spurt	635 cm/s	2ml	Up	Pass	37.51	-	Pass	85.49	-	Pass	85.83	-	C
2	Spurt	635 cm/s	2ml	Down	Pass	42.81	-	Pass	91.25	-	Pass	113.44	-	C
3	Spurt	635 cm/s	2ml	Right	Pass	50.58	-	Pass	75.54	-	Pass	65.04	-	C
4	Spurt	635 cm/s	2ml	Left	Pass	48.26	-	Pass	80.81	-	Pass	69.35	-	C
1	Spray	500 cm/s	1ml	Up	Pass	53.84	-	Pass	102.31	-	Pass	79.15	-	C
2	Spray	500 cm/s	1ml	Down	Pass	34.65	-	Pass	84.16	-	Pass	110.38	-	C
3	Sprav	500 cm/s	1ml	Right	Pass	43.45	-	Pass	61.63	-	Pass	63.24	-	C

4	Spray	500 cm/s	1ml	Left	Pass	38.98	-	Pass	68.69	-	Pass	55.12	-	C
1	Spurt	635 cm/s	2ml	Up	Pass	35.13	-	Pass	86.21	-	Pass	84.19	-	C
2	Spurt	635 cm/s	2ml	Down	Pass	40.23	-	Pass	85.12	-	Pass	110.26	-	C
3	Spurt	635 cm/s	2ml	Right	Pass	52.32	-	Pass	76.01	-	Pass	68.92	-	C
4	Spurt	635 cm/s	2ml	Left	Pass	51.69	-	Pass	75.48	-	Pass	66.13	-	C
1	Spray	500 cm/s	1ml	Up	Pass	48.62	-	Pass	105.78	-	Pass	83.47	-	C
2	Spray	500 cm/s	1ml	Down	Pass	36.33	-	Pass	87.19	-	Pass	113.41	-	C
3	Spray	500 cm/s	1ml	Right	Pass	43.58	-	Pass	80.06	-	Pass	62.86	-	C
4	Spray	500 cm/s	1ml	Left	Pass	41.91	-	Pass	79.89	-	Pass	59.36	-	C
1	Spurt	635 cm/s	2ml	Up	Pass	36.98	-	Pass	84.56	-	Pass	88.23	-	C
2	Spurt	635 cm/s	2ml	Down	Pass	39.72	-	Pass	84.95	-	Pass	102.68	-	C
3	Spurt	635 cm/s	2ml	Right	Pass	56	-	Pass	80.63	-	Pass	65.38	-	C
4	Spurt	635 cm/s	2ml	Left	Pass	54.99	-	Pass	76.32	-	Pass	62.91	-	C
1	Spray	500 cm/s	1ml	Up	Pass	51.48	-	Pass	101.69	-	Pass	77.14	-	C
2	Spray	500 cm/s	1ml	Down	Pass	32.15	-	Pass	83.46	-	Pass	110.9	-	C
3	Spray	500 cm/s	1ml	Right	Pass	35.83	-	Pass	75.34	-	Pass	70.33	-	C
4	Spray	500 cm/s	1ml	Left	Pass	36.28	-	Pass	82.51	-	Pass	72.94	-	C
1	Spurt	635 cm/s	2ml	Up	Pass	38.41	-	Pass	81.2	-	Pass	90.21	-	C
2	Spurt	635 cm/s	2ml	Down	Pass	41.2	-	Pass	82.56	-	Pass	105.36	-	C
3	Spurt	635 cm/s	2ml	Right	Pass	58.69	-	Pass	83.11	-	Pass	69.51	-	C
4	Spurt	635 cm/s	2ml	Left	Pass	55.62	-	Pass	84.22	-	Pass	71.21	-	C
1	Spray	500 cm/s	1ml	Up	Pass	48.12	-	Pass	106.23	-	Pass	76.35	-	C
2	Spray	500 cm/s	1ml	Down	Pass	33.41	-	Pass	86.53	-	Pass	112.57	-	C
3	Spray	500 cm/s	1ml	Right	Pass	60.26	-	Pass	71.75	-	Pass	62.11	-	C
4	Spray	500 cm/s	1ml	Left	Pass	55.75	-	Pass	67.82	-	Pass	65.89	-	C
1	Spurt	635 cm/s	2ml	Up	Pass	3.68	-	Pass	20.2	-	Pass	40.35	-	D
2	Spurt	635 cm/s	2ml	Down	Fail	11.6	L Q3	Fail	Ran Thru	Q2/Q3	Fail	Ran Thru	Q2/Q3/Q4	D
3	Spurt	635 cm/s	2ml	Right	Pass	20.62	-	Pass	31.47	-	Pass	34.26	-	D
4	Spurt	635 cm/s	2ml	Left	Pass	22.14	-	Pass	62.44	-	Pass	50.3	-	D
1	Spray	500 cm/s	1ml	Up	Fail	3.96	R Q1	Pass	37.69	-	Pass	48.63	-	D
2	Spray	500 cm/s	1ml	Down	Pass	1.44	-	Pass	40.62	-	Pass	61.4	-	D
3	Spray	500 cm/s	1ml	Right	Pass	13.43	-	Pass	33.11	-	Pass	26.06	-	D
4	Spray	500 cm/s	1ml	Left	Pass	15.25	-	Pass	36.05	-	Pass	34.18	-	D
1	Spurt	635 cm/s	2ml	Up	Pass	6.61	-	Pass	46.61	-	Pass	66.13	-	D
2	Spurt	635 cm/s	2ml	Down	Fail	17.84	R Q4	Pass	2.05	-	Pass	2.1	-	D
3	Spurt	635 cm/s	2ml	Right	Pass	22.13	-	Pass	40.18	-	Pass	48.21	-	D
4	Spurt	635 cm/s	2ml	Left	Pass	20.7	-	Pass	54.6	-	Pass	43.04	-	D
1	Spray	500 cm/s	1ml	Up	Fail	9.11	L Q4	Pass	28.92	-	Pass	44.82	-	D
2	Spray	500 cm/s	1ml	Down	Pass	19.7	-	Pass	75.15	-	Pass	97.43	-	D
3	Spray	500 cm/s	1ml	Right	Pass	12.65	-	Pass	38.29	-	Pass	34.06	-	D
4	Spray	500 cm/s	1ml	Left	Pass	8.82	-	Pass	34.21	-	Pass	33.07	-	D
1	Spurt	635 cm/s	2ml	Up	Pass	7.16	-	Pass	46.59	-	Pass	62.12	-	D
2	Spurt	635 cm/s	2ml	Down	Fail	19.19	R Q4	Pass	29.34	-	Pass	52.36	-	D
3	Spurt	635 cm/s	2ml	Right	Pass	19.33	-	Pass	47.34	-	Pass	51.98	-	D
4	Spurt	635 cm/s	2ml	Left	Pass	18.04	-	Pass	56.91	-	Pass	52.42	-	D
1	Spray	500 cm/s	1ml	Up	Fail	1.45	R Q1	Pass	32.22	-	Pass	43.01	-	D
2	Spray	500 cm/s	1ml	Down	Pass	1.36	-	Pass	25.81	-	Pass	49.92	-	D
3	Spray	500 cm/s	1ml	Right	Pass	5.61	-	Pass	34.51	-	Pass	31.28	-	D
4	Spray	500 cm/s	1ml	Left	Pass	10.38	-	Pass	32.84	-	Pass	32.97	-	D
1	Spurt	635 cm/s	2ml	Up	Pass	1.59	-	Pass	45.03	-	Pass	65.79	-	D
2	Spurt	635 cm/s	2ml	Down	Fail	18.6	R Q4	Pass	24.21	-	Pass	47.55	-	D
3	Spurt	635 cm/s	2ml	Right	Pass	20.52	-	Pass	50.07	-	Pass	49.41	-	D
4	Spurt	635 cm/s	2ml	Left	Pass	22.39	-	Pass	51.09	-	Pass	57.01	-	D
1	Spray	500 cm/s	1ml	Up	Fail	7.25	L Q4	Pass	38.71	-	Pass	52.98	-	D

2	Spray	500 cm/s	1ml	Down	Pass	12.58	-	Pass	61.61	-	Pass	85.46	-	D
3	Spray	500 cm/s	1ml	Right	Pass	11.11	-	Pass	36.79	-	Pass	33.06	-	D
4	Spray	500 cm/s	1ml	Left	Pass	14.1	-	Pass	36.02	-	Pass	32.32	-	D
1	Spurt	635 cm/s	2ml	Up	Pass	2.96	-	Pass	45.7	-	Pass	68.31	-	D
2	Spurt	635 cm/s	2ml	Down	Fail	11.63	L Q3	Pass	38.27	-	Pass	53.54	-	D
3	Spurt	635 cm/s	2ml	Right	Pass	8.86	-	Pass	34.93	-	Pass	53.02	-	D
4	Spurt	635 cm/s	2ml	Left	Pass	21.16	-	Pass	50.55	-	Pass	52.5	-	D
1	Spray	500 cm/s	1ml	Up	Fail	10.06	R Q3	Pass	25.9	-	Pass	50.53	-	D
2	Spray	500 cm/s	1ml	Down	Pass	29.55	-	Pass	74.81	-	Pass	96.87	-	D
3	Spray	500 cm/s	1ml	Right	Pass	9.33	-	Pass	36.29	-	Pass	37.07	-	D
4	Spray	500 cm/s	1ml	Left	Pass	15.65	-	Pass	37.64	-	Pass	35.06	-	D
1	Spurt	635 cm/s	2ml	Up	Fail	14.16	R Q1	Pass	44.95	-	Pass	65.94	-	D
2	Spurt	635 cm/s	2ml	Down	Fail	23.29	R Q1	Pass	47.29	-	Pass	67.1	-	D
3	Spurt	635 cm/s	2ml	Right	Pass	27.34	-	Pass	45.11	-	Pass	55.2	-	D
4	Spurt	635 cm/s	2ml	Left	Pass	22.49	-	Pass	55.84	-	Pass	62.62	-	D
1	Spray	500 cm/s	1ml	Up	Fail	6.67	L Q4	Pass	33.06	-	Pass	48.02	-	D
2	Spray	500 cm/s	1ml	Down	Pass	25.76	-	Pass	75.49	-	Pass	94.97	-	D
3	Spray	500 cm/s	1ml	Right	Pass	13.21	-	Pass	34.71	-	Pass	31.63	-	D
4	Spray	500 cm/s	1ml	Left	Pass	12.77	-	Pass	36.31	-	Pass	32.85	-	D
1	Spurt	635 cm/s	2ml	Up	Pass	5.62	-	Pass	43.03	-	Pass	71.44	-	D
2	Spurt	635 cm/s	2ml	Down	Fail	16.77	R Q1	Pass	2.95	-	Pass	26.82	-	D
3	Spurt	635 cm/s	2ml	Right	Pass	25.21	-	Pass	45.86	-	Pass	31.85	-	D
4	Spurt	635 cm/s	2ml	Left	Pass	19.19	-	Pass	44.92	-	Pass	35.4	-	D
1	Spray	500 cm/s	1ml	Up	Fail	21.21	L Q1	Pass	39.31	-	Pass	50.19	-	D
2	Spray	500 cm/s	1ml	Down	Pass	29.01	-	Pass	76.93	-	Pass	101.91	-	D
3	Spray	500 cm/s	1ml	Right	Pass	14.82	-	Pass	40.26	-	Pass	30.41	-	D
4	Spray	500 cm/s	1ml	Left	Pass	16.79	-	Pass	41.22	-	Pass	34.74	-	D
1	Spurt	635 cm/s	2ml	Up	Fail	21.45	R Q1	Pass	2.91	-	Pass	29.22	-	D
2	Spurt	635 cm/s	2ml	Down	Fail	17.22	R Q4	Pass	38.33	-	Pass	59.73	-	D
3	Spurt	635 cm/s	2ml	Right	Pass	18.21	-	Pass	53.04	-	Pass	56.84	-	D
4	Spurt	635 cm/s	2ml	Left	Pass	14.2	-	Pass	54.09	-	Pass	42.51	-	D
1	Spray	500 cm/s	1ml	Up	Fail	11.99	L Q1	Pass	53.55	-	Pass	43.01	-	D
2	Spray	500 cm/s	1ml	Down	Pass	30.91	-	Pass	76.93	-	Pass	98.54	-	D
3	Spray	500 cm/s	1ml	Right	Pass	12.32	-	Pass	41.61	-	Pass	38.57	-	D
4	Spray	500 cm/s	1ml	Left	Pass	10.29	-	Pass	32.9	-	Pass	30.21	-	D
1	Spurt	635 cm/s	2ml	Up	Pass	2.38	-	Pass	46.34	-	Pass	67.27	-	D
2	Spurt	635 cm/s	2ml	Down	Fail	13.05	13.05	Pass	13.82	-	Pass	34.57	-	D
3	Spurt	635 cm/s	2ml	Right	Pass	14.35	-	Pass	54.8	-	Pass	40.17	-	D
4	Spurt	635 cm/s	2ml	Left	Pass	22.47	-	Pass	60.66	-	Pass	47.84	-	D
1	Spray	500 cm/s	1ml	Up	Fail	16.06	L Q4	Pass	34.64	-	Pass	48.02	-	D
2	Spray	500 cm/s	1ml	Down	Pass	27.31	-	Pass	77.88	-	Pass	97.48	-	D
3	Spray	500 cm/s	1ml	Right	Pass	17.39	-	Pass	35.11	-	Pass	33.64	-	D
4	Spray	500 cm/s	1ml	Left	Pass	13.55	-	Pass	37.6	-	Pass	35.23	-	D
1	Spurt	635 cm/s	2ml	Up	Pass	33.24	-	Pass	81.94	-	Pass	103.51	-	D
2	Spurt	635 cm/s	2ml	Down	Fail	23.03	L Q3	Fail	Ran Thru	Q3/Q4	Fail	Ran Thru	Q1/Q4	D
3	Spurt	635 cm/s	2ml	Right	Pass	11.65	-	Pass	52.64	-	Pass	59.83	-	D
4	Spurt	635 cm/s	2ml	Left	Pass	26.69	-	Pass	60.15	-	Pass	60.21	-	D
1	Spray	500 cm/s	1ml	Up	Fail	5.29	R Q4	Pass	39.83	-	Pass	54.78	-	D
2	Spray	500 cm/s	1ml	Down	Pass	28.11	-	Pass	70.83	-	Pass	93.19	-	D
3	Spray	500 cm/s	1ml	Right	Pass	8.37	-	Pass	35.05	-	Pass	30.06	-	D
4	Spray	500 cm/s	1ml	Left	Pass	14.2	-	Pass	34.98	-	Pass	36.93	-	D
1	Spurt	635 cm/s	2ml	Up	Pass	67.26	-	Pass	122.22	-	Pass	94.8	-	E
2	Spurt	635 cm/s	2ml	Down	Pass	-	-	Pass	NA	-	Pass	NA	-	E
3	Spurt	635 cm/s	2ml	Right	Pass	47.15	-	Pass	65.2	-	Pass	46.98	-	E

4	Spurt	635 cm/s	2ml	Left	Pass	52.47	-	Pass	58.92	-	Pass	37.6	-	E
1	Spray	500 cm/s	1ml	Up	Pass	64.61	-	Pass	110.68	-	Pass	75.5	-	E
2	Spray	500 cm/s	1ml	Down	Pass	45.27	-	Pass	99.04	-	Pass	117.96	-	E
3	Spray	500 cm/s	1ml	Right	Pass	55.82	-	Pass	54.21	-	Pass	36.44	-	E
4	Spray	500 cm/s	1ml	Left	Pass	55.32	-	Pass	51.95	-	Pass	37.38	-	E
1	Spurt	635 cm/s	2ml	Up	Fail	5.69	R Q2	Pass	1.45	-	Pass	32.36	-	E
2	Spurt	635 cm/s	2ml	Down	Pass	-	-	Pass	NA	-	Pass	NA	-	E
3	Spurt	635 cm/s	2ml	Right	Pass	49.2	-	Pass	64.89	-	Pass	48.15	-	E
4	Spurt	635 cm/s	2ml	Left	Pass	50.86	-	Pass	57.45	-	Pass	39.54	-	E
1	Spray	500 cm/s	1ml	Up	Pass	65.51	-	Pass	114.19	-	Pass	84.45	-	E
2	Spray	500 cm/s	1ml	Down	Pass	32.03	-	Pass	85.29	-	Pass	108.24	-	E
3	Spray	500 cm/s	1ml	Right	Pass	32.09	-	Pass	62.05	-	Pass	43.8	-	E
4	Spray	500 cm/s	1ml	Left	Pass	30.41	-	Pass	52.83	-	Pass	47.83	-	E
1	Spurt	635 cm/s	2ml	Up	Pass	1.64	-	Pass	4.18	-	Pass	33.28	-	E
2	Spurt	635 cm/s	2ml	Down	Pass	47.32	-	Pass	94.82	-	Pass	116.5	-	E
3	Spurt	635 cm/s	2ml	Right	Pass	45.87	-	Pass	67.45	-	Pass	38.1	-	E
4	Spurt	635 cm/s	2ml	Left	Pass	50.31	-	Pass	60.29	-	Pass	41.85	-	E
1	Spray	500 cm/s	1ml	Up	Pass	6.68	-	Pass	41.26	-	Pass	57.69	-	E
2	Spray	500 cm/s	1ml	Down	Pass	38.05	-	Pass	93.83	-	Pass	115.13	-	E
3	Spray	500 cm/s	1ml	Right	Pass	40.31	-	Pass	64.15	-	Pass	42.75	-	E
4	Spray	500 cm/s	1ml	Left	Pass	46.59	-	Pass	62.51	-	Pass	49.65	-	E
1	Spurt	635 cm/s	2ml	Up	Pass	28.41	-	Pass	5.02	-	Pass	35.35	-	E
2	Spurt	635 cm/s	2ml	Down	Pass	-	-	Pass	NA	-	Pass	NA	-	E
3	Spurt	635 cm/s	2ml	Right	Pass	48.17	-	Pass	66.32	-	Pass	36.51	-	E
4	Spurt	635 cm/s	2ml	Left	Pass	53.47	-	Pass	59.93	-	Pass	33.21	-	E
1	Spray	500 cm/s	1ml	Up	Pass	48.05	-	Pass	91.13	-	Pass	110.23	-	E
2	Spray	500 cm/s	1ml	Down	Pass	33.63	-	Pass	87.57	-	Pass	108.86	-	E
3	Spray	500 cm/s	1ml	Right	Pass	49.07	-	Pass	53.28	-	Pass	37.47	-	E
4	Spray	500 cm/s	1ml	Left	Pass	52.27	-	Pass	51.76	-	Pass	32.46	-	E
1	Spurt	635 cm/s	2ml	Up	Pass	51.86	-	Pass	98.1	-	Pass	74.85	-	E
2	Spurt	635 cm/s	2ml	Down	Pass	-	-	Pass	NA	-	Pass	NA	-	E
3	Spurt	635 cm/s	2ml	Right	Pass	45.12	-	Pass	60.21	-	Pass	48.56	-	E
4	Spurt	635 cm/s	2ml	Left	Pass	46.56	-	Pass	54.98	-	Pass	39.62	-	E
1	Spray	500 cm/s	1ml	Up	Pass	49.04	-	Pass	79.72	-	Pass	80.06	-	E
2	Spray	500 cm/s	1ml	Down	Pass	19.54	-	Pass	75.79	-	Pass	92.75	-	E
3	Spray	500 cm/s	1ml	Right	Pass	53.64	-	Pass	56.21	-	Pass	39.07	-	E
4	Spray	500 cm/s	1ml	Left	Pass	58.96	-	Pass	59.77	-	Pass	41.91	-	E
1	Spurt	635 cm/s	2ml	Up	Pass	4.37	-	Pass	33.23	-	Pass	55.23	-	E
2	Spurt	635 cm/s	2ml	Down	Pass	-	-	Pass	NA	-	Pass	NA	-	E
3	Spurt	635 cm/s	2ml	Right	Pass	40.45	-	Pass	64.74	-	Pass	46.2	-	E
4	Spurt	635 cm/s	2ml	Left	Pass	58.39	-	Pass	64.79	-	Pass	51.38	-	E
1	Spray	500 cm/s	1ml	Up	Pass	65.78	-	Pass	114.02	-	Pass	84.52	-	E
2	Spray	500 cm/s	1ml	Down	Pass	20.75	-	Pass	74.46	-	Pass	94.5	-	E
3	Spray	500 cm/s	1ml	Right	Pass	38.29	-	Pass	61.17	-	Pass	40.86	-	E
4	Spray	500 cm/s	1ml	Left	Pass	63.56	-	Pass	72.06	-	Pass	54.67	-	E
1	Spurt	635 cm/s	2ml	Up	Pass	4.99	-	Pass	44.6	-	Pass	69.15	-	E
2	Spurt	635 cm/s	2ml	Down	Pass	-	-	Pass	NA	-	Pass	NA	-	E
3	Spurt	635 cm/s	2ml	Right	Pass	41.54	-	Pass	65.74	-	Pass	45.61	-	E
4	Spurt	635 cm/s	2ml	Left	Pass	41.39	-	Pass	63.73	-	Pass	49.32	-	E
1	Spray	500 cm/s	1ml	Up	Pass	68.19	-	Pass	104.78	-	Pass	83.24	-	E
2	Spray	500 cm/s	1ml	Down	Pass	24.56	-	Pass	75.68	-	Pass	103.13	-	E
3	Spray	500 cm/s	1ml	Right	Pass	53.25	-	Pass	59.86	-	Pass	40.63	-	E
4	Spray	500 cm/s	1ml	Left	Pass	36.3	-	Pass	52.76	-	Pass	37.53	-	E
1	Spurt	635 cm/s	2ml	Up	Pass	40.93	-	Pass	83.26	-	Pass	104.8	-	E

2	Spurt	635 cm/s	2ml	Down	Pass	39.84	-	Pass	88.35	-	Pass	109.8	-	E
3	Spurt	635 cm/s	2ml	Right	Pass	40.04	-	Pass	64.74	-	Pass	46.2	-	E
4	Spurt	635 cm/s	2ml	Left	Pass	39.56	-	Pass	69.79	-	Pass	51.83	-	E
1	Spray	500 cm/s	1ml	Up	Pass	51.66	-	Pass	103.24	-	Pass	83.04	-	E
2	Spray	500 cm/s	1ml	Down	Pass	32.16	-	Pass	84.81	-	Pass	106.97	-	E
3	Spray	500 cm/s	1ml	Right	Pass	53.63	-	Pass	58.36	-	Pass	37.6	-	E
4	Spray	500 cm/s	1ml	Left	Pass	55.14	-	Pass	68.15	-	Pass	52.28	-	E
1	Spurt	635 cm/s	2ml	Up	Pass	26.62	-	Pass	75.59	-	Pass	40.31	-	E
2	Spurt	635 cm/s	2ml	Down	Pass	-	-	Pass	NA	-	Pass	NA	-	E
3	Spurt	635 cm/s	2ml	Right	Pass	34.51	-	Pass	55.23	-	Pass	40.13	-	E
4	Spurt	635 cm/s	2ml	Left	Pass	39.11	-	Pass	57.43	-	Pass	52.21	-	E
1	Spray	500 cm/s	1ml	Up	Pass	54.72	-	Pass	100.82	-	Pass	82.61	-	E
2	Spray	500 cm/s	1ml	Down	Pass	22.65	-	Pass	76.58	-	Pass	98.73	-	E
3	Spray	500 cm/s	1ml	Right	Pass	44.61	-	Pass	62.18	-	Pass	42.13	-	E
4	Spray	500 cm/s	1ml	Left	Pass	42.96	-	Pass	57.54	-	Pass	37.84	-	E
1	Spurt	635 cm/s	2ml	Up	Pass	13.53	-	Pass	47.91	-	Pass	75.32	-	E
2	Spurt	635 cm/s	2ml	Down	Pass	43.35	-	Pass	96.45	-	Pass	114.15	-	E
3	Spurt	635 cm/s	2ml	Right	Pass	36.23	-	Pass	49.23	-	Pass	37.54	-	E
4	Spurt	635 cm/s	2ml	Left	Pass	41.26	-	Pass	50.87	-	Pass	38.92	-	E
1	Spray	500 cm/s	1ml	Up	Pass	53.17	-	Pass	105.44	-	Pass	76.91	-	E
2	Spray	500 cm/s	1ml	Down	Pass	25.9	-	Pass	82.53	-	Pass	102.4	-	E
3	Spray	500 cm/s	1ml	Right	Pass	52.54	-	Pass	59.89	-	Pass	45.82	-	E
4	Spray	500 cm/s	1ml	Left	Pass	47.84	-	Pass	60.39	-	Pass	46.09	-	E
1	Spurt	635 cm/s	2ml	Up	Pass	1.26	-	Pass	44.83	-	Pass	69.43	-	F
2	Spurt	635 cm/s	2ml	Down	Pass	0.01	L Q2	Fail	Ran Thru	Q3/Q4	Fail	Ran Thru	Q1,Q2,Q3,Q4	F
3	Spurt	635 cm/s	2ml	Right	Pass	15.93	-	Pass	40.77	-	Pass	41.39	-	F
4	Spurt	635 cm/s	2ml	Left	Pass	15.3	-	Pass	38.13	-	Pass	24.49	-	F
1	Spray	500 cm/s	1ml	Up	Pass	12.61	-	Pass	37.07	-	Pass	46.77	-	F
2	Spray	500 cm/s	1ml	Down	Pass	6.76	-	Pass	58.7	-	Pass	71.9	-	F
3	Spray	500 cm/s	1ml	Right	Pass	4.23	-	Pass	34.38	-	Pass	36.35	-	F
4	Spray	500 cm/s	1ml	Left	Pass	9.56	-	Pass	38.45	-	Pass	33.21	-	F
1	Spurt	635 cm/s	2ml	Up	Fail	17.63	L Q3	Pass	30.25	-	Pass	53.86	-	F
2	Spurt	635 cm/s	2ml	Down	Fail	11.82	L Q4	Fail	Ran Thru	Q4	Fail	Ran Thru	Q1/Q4	F
3	Spurt	635 cm/s	2ml	Right	Pass	7.76	-	Pass	38.54	-	Pass	37.26	-	F
4	Spurt	635 cm/s	2ml	Left	Pass	22.34	-	Pass	43.88	-	Pass	37.5	-	F
1	Spray	500 cm/s	1ml	Up	Fail	6.2	R Q4	Pass	36.09	-	Pass	40.81	-	F
2	Spray	500 cm/s	1ml	Down	Fail	5.33	L Q1	Pass	25.64	-	Pass	45.86	-	F
3	Spray	500 cm/s	1ml	Right	Pass	12.57	-	Pass	37.18	-	Pass	41.04	-	F
4	Spray	500 cm/s	1ml	Left	Pass	10.11	-	Pass	35.13	-	Pass	40.21	-	F
1	Spurt	635 cm/s	2ml	Up	Fail	7.72	R Q1	Pass	40.72	-	Pass	38.12	-	F
2	Spurt	635 cm/s	2ml	Down	Fail	5.556	L Q2	Fail	Ran Thru	Q3/Q4	Fail	Ran Thru	Q1,Q2,Q3,Q4	F
3	Spurt	635 cm/s	2ml	Right	Pass	15.24	-	Pass	42.88	-	Pass	36.09	-	F
4	Spurt	635 cm/s	2ml	Left	Pass	18.13	-	Pass	39.55	-	Pass	30.38	-	F
1	Spray	500 cm/s	1ml	Up	Fail	6.62	R Q4	Pass	35.84	-	Pass	38.45	-	F
2	Spray	500 cm/s	1ml	Down	Pass	1.17	-	Pass	46.36	-	Pass	70.52	-	F
3	Spray	500 cm/s	1ml	Right	Pass	12.43	-	Pass	31.46	-	Pass	36.19	-	F
4	Spray	500 cm/s	1ml	Left	Pass	13.87	-	Pass	30.23	-	Pass	38.69	-	F
1	Spurt	635 cm/s	2ml	Up	Fail	8.09	L Q3	Pass	32.49	-	Pass	36.84	-	F
2	Spurt	635 cm/s	2ml	Down	Fail	9.87	L Q3	Pass	On Line	Q3	Fail	Ran Thru	Q2/Q3	F
3	Spurt	635 cm/s	2ml	Right	Pass	18.31	-	Pass	49.85	-	Pass	44.58	-	F
4	Spurt	635 cm/s	2ml	Left	Pass	15.86	-	Pass	38.31	-	Pass	38.02	-	F
1	Spray	500 cm/s	1ml	Up	Pass	20.27	-	Pass	34.4	-	Pass	46.91	-	F
2	Spray	500 cm/s	1ml	Down	Pass	6.65	-	Pass	59.76	-	Pass	84.39	-	F
3	Spray	500 cm/s	1ml	Right	Pass	9.89	-	Pass	35.37	-	Pass	40.41	-	F

4	Spray	500 cm/s	1ml	Left	Pass	7.47	-	Pass	35.23	-	Pass	45.89	-	F
1	Spurt	635 cm/s	2ml	Up	Pass	4.12	-	Pass	45.41	-	Pass	46.81	-	F
2	Spurt	635 cm/s	2ml	Down	Fail	23.71	R Q4	Fail	Ran Thru	Q3/Q4	Fail	Ran Thru	Q1,Q2,Q3,Q4	F
3	Spurt	635 cm/s	2ml	Right	Pass	16.07	-	Pass	33.95	-	Pass	27.8	-	F
4	Spurt	635 cm/s	2ml	Left	Pass	9.84	-	Pass	47.89	-	Pass	44.61	-	F
1	Spray	500 cm/s	1ml	Up	Pass	19.54	-	Pass	36.28	-	Pass	42.97	-	F
2	Spray	500 cm/s	1ml	Down	Fail	20.11	L Q4	Pass	50.98	-	Pass	64.69	-	F
3	Spray	500 cm/s	1ml	Right	Pass	7.28	-	Pass	32.96	-	Pass	39.58	-	F
4	Spray	500 cm/s	1ml	Left	Pass	9.25	-	Pass	30.26	-	Pass	41.54	-	F
1	Spurt	635 cm/s	2ml	Up	Fail	11.24	R Q2	Pass	44.15	-	Pass	43.15	-	F
2	Spurt	635 cm/s	2ml	Down	Fail	24.12	R Q1	Fail	Ran Thru	Q3	Fail	Ran Thru	Q2/Q3	F
3	Spurt	635 cm/s	2ml	Right	Pass	15.73	-	Pass	42.74	-	Pass	37.9	-	F
4	Spurt	635 cm/s	2ml	Left	Pass	23.56	-	Pass	41.94	-	Pass	36.49	-	F
1	Spray	500 cm/s	1ml	Up	Pass	17.36	-	Pass	36.41	-	Pass	47.48	-	F
2	Spray	500 cm/s	1ml	Down	Fail	23.86	L Q1	Pass	50.05	-	Pass	61.06	-	F
3	Spray	500 cm/s	1ml	Right	Pass	5.21	-	Pass	31.69	-	Pass	33.95	-	F
4	Spray	500 cm/s	1ml	Left	Pass	8.63	-	Pass	29.51	-	Pass	34.12	-	F
1	Spurt	635 cm/s	2ml	Up	Fail	8.24	L Q3	Pass	44.26	-	Pass	39.63	-	F
2	Spurt	635 cm/s	2ml	Down	Fail	7.63	R Q2	Fail	Ran Thru	Q3	Fail	Ran Thru	Q2/Q3	F
3	Spurt	635 cm/s	2ml	Right	Pass	17.13	-	Pass	46.31	-	Pass	40.13	-	F
4	Spurt	635 cm/s	2ml	Left	Pass	12.35	-	Pass	36.13	-	Pass	23.49	-	F
1	Spray	500 cm/s	1ml	Up	Fail	13.25	R Q2	Pass	31.03	-	Pass	38.47	-	F
2	Spray	500 cm/s	1ml	Down	Fail	15.97	R Q4	Pass	25.53	-	Pass	48.67	-	F
3	Spray	500 cm/s	1ml	Right	Pass	13.99	-	Pass	40.67	-	Pass	45.9	-	F
4	Spray	500 cm/s	1ml	Left	Pass	12.46	-	Pass	39.16	-	Pass	43.15	-	F
1	Spurt	635 cm/s	2ml	Up	Pass	4.95	-	Pass	47.86	-	Pass	41.7	-	F
2	Spurt	635 cm/s	2ml	Down	Fail	9.05	R Q4	Fail	Ran Thru	Q3	Fail	Ran Thru	Q2/Q3	F
3	Spurt	635 cm/s	2ml	Right	Pass	16.11	-	Pass	41.17	-	Pass	39.42	-	F
4	Spurt	635 cm/s	2ml	Left	Pass	19.23	-	Pass	38.55	-	Pass	31.48	-	F
1	Spray	500 cm/s	1ml	Up	Pass	10.9	-	Pass	35.24	-	Pass	48.03	-	F
2	Spray	500 cm/s	1ml	Down	Fail	24.49	R Q2	Pass	40.14	-	Pass	61.25	-	F
3	Spray	500 cm/s	1ml	Right	Pass	10.17	-	Pass	42.37	-	Pass	45.78	-	F
4	Spray	500 cm/s	1ml	Left	Pass	11.98	-	Pass	45.61	-	Pass	44.78	-	F
1	Spurt	635 cm/s	2ml	Up	Fail	12.92	L Q4	Pass	43.64	-	Pass	33.76	-	F
2	Spurt	635 cm/s	2ml	Down	Fail	17.35	L Q3	Fail	Ran Thru	Q3/Q4	Fail	Ran Thru	Q1,Q2,Q3,Q4	F
3	Spurt	635 cm/s	2ml	Right	Pass	14.58	-	Pass	39.44	-	Pass	37.47	-	F
4	Spurt	635 cm/s	2ml	Left	Pass	16.73	-	Pass	45.61	-	Pass	41.24	-	F
1	Spray	500 cm/s	1ml	Up	Fail	13.98	L Q4	Pass	37.74	-	Pass	46.99	-	F
2	Spray	500 cm/s	1ml	Down	Fail	23.93	L Q4	Pass	47.02	-	Pass	59.95	-	F
3	Spray	500 cm/s	1ml	Right	Pass	14.72	-	Pass	42.51	-	Pass	45.64	-	F
4	Spray	500 cm/s	1ml	Left	Pass	12.23	-	Pass	46.78	-	Pass	47.26	-	F
1	Spurt	635 cm/s	2ml	Up	Fail	4.94	R Q4	Pass	40.7	-	Pass	39.47	-	F
2	Spurt	635 cm/s	2ml	Down	Fail	24.64	L Q2	Fail	Ran Thru	Q4	Fail	Ran Thru	Q1/Q4	F
3	Spurt	635 cm/s	2ml	Right	Pass	15.33	-	Pass	41.49	-	Pass	40.73	-	F
4	Spurt	635 cm/s	2ml	Left	Pass	8.74	-	Pass	39.56	-	Pass	36.62	-	F
1	Spray	500 cm/s	1ml	Up	Fail	14.3	R Q3	Pass	32.84	-	Pass	42.2	-	F
2	Spray	500 cm/s	1ml	Down	Pass	5.76	-	Pass	58.67	-	Pass	71.1	-	F
3	Spray	500 cm/s	1ml	Right	Pass	19.43	-	Pass	35.7	-	Pass	43.15	-	F
4	Spray	500 cm/s	1ml	Left	Pass	10.56	-	Pass	32.13	-	Pass	36.84	-	F
1	Spurt	635 cm/s	2ml	Up	Fail	11.19	R Q4	Pass	1.09	-	Fail	Ran Thru	Q1/Q4	G
2	Spurt	635 cm/s	2ml	Down	Fail	19.22	R Q4	Fail	Ran Thru	Q2/Q3	Pass	5.46	-	G
3	Spurt	635 cm/s	2ml	Right	Pass	14.63	-	Pass	42.94	-	Pass	51.36	-	G
4	Spurt	635 cm/s	2ml	Left	Pass	23.12	-	Pass	45.08	-	Pass	50.02	-	G
1	Spray	500 cm/s	1ml	Up	Fail	10.86	R Q3	Pass	36.87	-	Pass	53.33	-	G

2	Spray	500 cm/s	1ml	Down	Pass	4.82	-	Pass	31.63	-	Pass	53.17	-	G
3	Spray	500 cm/s	1ml	Right	Fail	20.82	L Q4	Pass	40.63	-	Pass	40.21	-	G
4	Spray	500 cm/s	1ml	Left	Fail	14.51	R Q3	Pass	35.46	-	Pass	36.55	-	G
1	Spurt	635 cm/s	2ml	Up	Fail	3.34	L Q3	Fail	Ran Thru	Q3	Fail	Ran Thru	Q2/Q3	G
2	Spurt	635 cm/s	2ml	Down	Fail	6.61	L Q3	Fail	Ran Thru	Q1/Q4	Pass	9.91	-	G
3	Spurt	635 cm/s	2ml	Right	Pass	18.42	-	Pass	47.02	-	Pass	46.85	-	G
4	Spurt	635 cm/s	2ml	Left	Pass	20	-	Pass	47.16	-	Pass	51.44	-	G
1	Spray	500 cm/s	1ml	Up	Fail	14.44	R Q4	Pass	41.42	-	Pass	56.61	-	G
2	Spray	500 cm/s	1ml	Down	Fail	16.56	R Q2	Pass	37.56	-	Pass	61.07	-	G
3	Spray	500 cm/s	1ml	Right	Fail	24.52	L Q1	Pass	35.81	-	Pass	34.89	-	G
4	Spray	500 cm/s	1ml	Left	Fail	8.38	R Q3	Pass	28.35	-	Pass	37.76	-	G
1	Spurt	635 cm/s	2ml	Up	Fail	1.07	L Q3	Pass	1.01	-	Pass	34.6	-	G
2	Spurt	635 cm/s	2ml	Down	Fail	20.72	R Q2	Fail	5.33	Q2	Pass	25.32	-	G
3	Spurt	635 cm/s	2ml	Right	Pass	13.03	-	Pass	45.28	-	Pass	31.22	-	G
4	Spurt	635 cm/s	2ml	Left	Pass	26.96	-	Pass	46.36	-	Pass	57.62	-	G
1	Spray	500 cm/s	1ml	Up	Fail	3.12	L Q3	Pass	35.8	-	Pass	55.39	-	G
2	Spray	500 cm/s	1ml	Down	Pass	3.68	-	Pass	43.91	-	Pass	64.05	-	G
3	Spray	500 cm/s	1ml	Right	Fail	15.98	L Q4	Pass	31.64	-	Pass	34.42	-	G
4	Spray	500 cm/s	1ml	Left	Fail	14.52	R Q3	Pass	31.2	-	Pass	41.15	-	G
1	Spurt	635 cm/s	2ml	Up	Fail	0.66	L Q4	Pass	On Line	Q1/Q2	Pass	27.6	-	G
2	Spurt	635 cm/s	2ml	Down	Fail	16.33	L Q2	Fail	Ran Thru	Q2/Q3	Fail	Ran Thru	Q2/Q3	G
3	Spurt	635 cm/s	2ml	Right	Pass	10.02	-	Pass	48.2	-	Pass	49.98	-	G
4	Spurt	635 cm/s	2ml	Left	Pass	13.5	-	Pass	46.4	-	Pass	41.96	-	G
1	Spray	500 cm/s	1ml	Up	Fail	1.49	L Q4	Pass	34.49	-	Pass	51.35	-	G
2	Spray	500 cm/s	1ml	Down	Pass	3.06	-	Pass	39.05	-	Pass	58.56	-	G
3	Spray	500 cm/s	1ml	Right	Pass	0.081	-	Pass	38.62	-	Pass	38.83	-	G
4	Spray	500 cm/s	1ml	Left	Fail	16.27	R Q3	Pass	25.34	-	Pass	37.13	-	G
1	Spurt	635 cm/s	2ml	Up	Fail	2.86	L Q3	Pass	1.54	-	Pass	31.31	-	G
2	Spurt	635 cm/s	2ml	Down	Fail	11.64	L Q1	Fail	5.64	Q1	Pass	15.83	-	G
3	Spurt	635 cm/s	2ml	Right	Pass	12.06	-	Pass	47.72	-	Pass	39.25	-	G
4	Spurt	635 cm/s	2ml	Left	Pass	11.86	-	Pass	49.92	-	Pass	40.91	-	G
1	Spray	500 cm/s	1ml	Up	Fail	6.24	R Q4	Pass	31.12	-	Pass	52.83	-	G
2	Spray	500 cm/s	1ml	Down	Pass	2.03	-	Pass	41.03	-	Pass	59.87	-	G
3	Spray	500 cm/s	1ml	Right	Fail	14.48	L Q4	Pass	29.76	-	Pass	36.26	-	G
4	Spray	500 cm/s	1ml	Left	Fail	16.97	R Q3	Pass	34.72	-	Pass	37.23	-	G
1	Spurt	635 cm/s	2ml	Up	Fail	1.29	R Q2	Pass	1.98	-	Pass	23.31	-	G
2	Spurt	635 cm/s	2ml	Down	Fail	9.76	R Q1	Fail	Ran Thru	Q1/Q2/Q3	Pass	5.09	-	G
3	Spurt	635 cm/s	2ml	Right	Pass	14.32	-	Pass	47.19	-	Pass	34.46	-	G
4	Spurt	635 cm/s	2ml	Left	Pass	17.7	-	Pass	49.4	-	Pass	53.92	-	G
1	Spray	500 cm/s	1ml	Up	Fail	12.44	L Q4	Pass	35.25	-	Pass	54.78	-	G
2	Spray	500 cm/s	1ml	Down	Fail	16.83	L Q4	Pass	31.06	-	Pass	51.1	-	G
3	Spray	500 cm/s	1ml	Right	Fail	17.69	L Q4	Pass	35.38	-	Pass	34.55	-	G
4	Spray	500 cm/s	1ml	Left	Fail	13.5	R Q3	Pass	31.27	-	Pass	32.45	-	G
1	Spurt	635 cm/s	2ml	Up	Fail	3.86	L Q3	Pass	1.81	-	Pass	27.45	-	G
2	Spurt	635 cm/s	2ml	Down	Fail	13.42	R Q4	Fail	6.94	Q2	Pass	24.37	-	G
3	Spurt	635 cm/s	2ml	Right	Pass	12.36	-	Pass	43.69	-	Pass	50.64	-	G
4	Spurt	635 cm/s	2ml	Left	Pass	22.12	-	Pass	44.8	-	Pass	49.48	-	G
1	Spray	500 cm/s	1ml	Up	Fail	5.44	R Q4	Pass	31.42	-	Pass	51.9	-	G
2	Spray	500 cm/s	1ml	Down	Pass	3.01	-	Pass	46.27	-	Pass	65.81	-	G
3	Spray	500 cm/s	1ml	Right	Fail	14.61	L Q4	Pass	33.51	-	Pass	32.78	-	G
4	Spray	500 cm/s	1ml	Left	Fail	16.01	R Q3	Pass	33.98	-	Pass	31.47	-	G
1	Spurt	635 cm/s	2ml	Up	Fail	1.98	R Q2	Pass	0.55	-	Pass	21.76	-	G

2	Spurt	635 cm/s	2ml	Down	Fail	7.69	L Q3	Fail	Ran Thru	Q1/Q4	Fail	Ran Thru	Q1/Q4	G
3	Spurt	635 cm/s	2ml	Right	Pass	11.2	-	Pass	49.23	-	Pass	47.68	-	G
4	Spurt	635 cm/s	2ml	Left	Pass	12.25	-	Pass	45.62	-	Pass	40.39	-	G
1	Spray	500 cm/s	1ml	Up	Fail	12.33	L Q3	Pass	33.09	-	Pass	53.8	-	G
2	Spray	500 cm/s	1ml	Down	Fail	2.44	L Q4	Pass	18.6	-	Pass	44.38	-	G
3	Spray	500 cm/s	1ml	Right	Fail	14.82	L Q4	Pass	33.4	-	Pass	34.92	-	G
4	Spray	500 cm/s	1ml	Left	Fail	12.87	R Q3	Pass	28.91	-	Pass	32.55	-	G
1	Spurt	635 cm/s	2ml	Up	Fail	0.77	R Q1	Fail	Ran Thru	Q1/Q4	Pass	14.2	-	G
2	Spurt	635 cm/s	2ml	Down	Fail	12.53	L Q3	Fail	Ran Thru	Q4	Fail	Q1/Q2/Q3	-	G
3	Spurt	635 cm/s	2ml	Right	Pass	12.67	-	Pass	54.45	-	Pass	48.11	-	G
4	Spurt	635 cm/s	2ml	Left	Pass	15.86	-	Pass	59.26	-	Pass	44.98	-	G
1	Spray	500 cm/s	1ml	Up	Fail	9.68	R Q4	Pass	35.68	-	Pass	51.23	-	G
2	Spray	500 cm/s	1ml	Down	Pass	3.11	-	Pass	37.56	-	Pass	55.41	-	G
3	Spray	500 cm/s	1ml	Right	Fail	14.52	L Q4	Pass	30.64	-	Pass	38.56	-	G
4	Spray	500 cm/s	1ml	Left	Fail	15.69	R Q3	Pass	32.33	-	Pass	40.21	-	G
1	Spurt	635 cm/s	2ml	Up	Fail	12.27	L Q2	Pass	2.36	-	Pass	16.13	-	G
2	Spurt	635 cm/s	2ml	Down	Fail	4.27	R Q4	Fail	4.27	Q1	Pass	24.55	-	G
3	Spurt	635 cm/s	2ml	Right	Pass	10.72	-	Pass	51.26	-	Pass	45.62	-	G
4	Spurt	635 cm/s	2ml	Left	Pass	8.56	-	Pass	47.26	-	Pass	41.23	-	G
1	Spray	500 cm/s	1ml	Up	Fail	11.22	L Q3	Pass	33.25	-	Pass	50.36	-	G
2	Spray	500 cm/s	1ml	Down	Pass	2.75	-	Pass	36.12	-	Pass	49.51	-	G
3	Spray	500 cm/s	1ml	Right	Fail	12.23	L Q4	Pass	30.23	-	Pass	33.26	-	G
4	Spray	500 cm/s	1ml	Left	Fail	14.78	R Q3	Pass	31.74	-	Pass	34.51	-	G
1	Spurt	635 cm/s	2ml	Up	Fail	14.45	L Q3	Pass	3.01	-	Pass	33.09	-	H
2	Spurt	635 cm/s	2ml	Down	Pass	0.91	-	Pass	44.73	-	Pass	66.37	-	H
3	Spurt	635 cm/s	2ml	Right	Pass	15.23	-	Pass	45.38	-	Pass	35.42	-	H
4	Spurt	635 cm/s	2ml	Left	Pass	16.48	-	Pass	44.72	-	Pass	33.64	-	H
1	Spray	500 cm/s	1ml	Up	Fail	7.03	L Q2	Pass	34.28	-	Pass	58.75	-	H
2	Spray	500 cm/s	1ml	Down	Pass	5.78	-	Pass	44.97	-	Pass	76.8	-	H
3	Spray	500 cm/s	1ml	Right	Pass	9.54	-	Pass	48.39	-	Pass	33.47	-	H
4	Spray	500 cm/s	1ml	Left	Pass	10.62	-	Pass	45.98	-	Pass	29.17	-	H
1	Spurt	635 cm/s	2ml	Up	Pass	12.97	-	Pass	2.95	-	Pass	31.32	-	H
2	Spurt	635 cm/s	2ml	Down	Fail	17.76	R Q1	Pass	2.26	-	Fail	Ran Thru	Q2/Q3	H
3	Spurt	635 cm/s	2ml	Right	Pass	12.02	-	Pass	45.52	-	Pass	36.63	-	H
4	Spurt	635 cm/s	2ml	Left	Pass	15.22	-	Pass	44.54	-	Pass	39.52	-	H
1	Spray	500 cm/s	1ml	Up	Fail	4.55	R Q4	Pass	44.7	-	Pass	67.76	-	H
2	Spray	500 cm/s	1ml	Down	Pass	6.53	-	Pass	48.76	-	Pass	69.43	-	H
3	Spray	500 cm/s	1ml	Right	Pass	13.96	-	Pass	50.1	-	Pass	32.81	-	H
4	Spray	500 cm/s	1ml	Left	Pass	10.52	-	Pass	39.03	-	Pass	21.28	-	H
1	Spurt	635 cm/s	2ml	Up	Fail	9.22	L Q2	Pass	6.8	-	Pass	36.73	-	H
2	Spurt	635 cm/s	2ml	Down	Fail	4.53	R Q2	Pass	35.05	-	Pass	59.81	-	H
3	Spurt	635 cm/s	2ml	Right	Pass	16.04	-	Pass	53.63	-	Pass	39.48	-	H
4	Spurt	635 cm/s	2ml	Left	Pass	15.27	-	Pass	48.52	-	Pass	38.39	-	H
1	Spray	500 cm/s	1ml	Up	Fail	15.26	L Q2	Pass	36.46	-	Pass	60.74	-	H
2	Spray	500 cm/s	1ml	Down	Pass	7.01	-	Pass	56.56	-	Pass	82.25	-	H
3	Spray	500 cm/s	1ml	Right	Pass	15.48	-	Pass	53.85	-	Pass	40.23	-	H
4	Spray	500 cm/s	1ml	Left	Pass	6.76	-	Pass	37.79	-	Pass	22.29	-	H
1	Spurt	635 cm/s	2ml	Up	Pass	9.45	-	Pass	7.26	-	Pass	35.79	-	H
2	Spurt	635 cm/s	2ml	Down	Fail	13.88	R Q4	Fail	Ran Thru	Q2/Q3	Fail	Ran Thru	Q2/Q3	H
3	Spurt	635 cm/s	2ml	Right	Pass	8.82	-	Pass	54.96	-	Pass	41.88	-	H
4	Spurt	635 cm/s	2ml	Left	Pass	12.54	-	Pass	52.49	-	Pass	53.23	-	H
1	Spray	500 cm/s	1ml	Up	Fail	9.6	L Q2	Pass	39.85	-	Pass	60.2	-	H
2	Spray	500 cm/s	1ml	Down	Pass	5.03	-	Pass	47.3	-	Pass	70.37	-	H
3	Spray	500 cm/s	1ml	Right	Pass	8.11	-	Pass	50.64	-	Pass	38.77	-	H
4	Spray	500 cm/s	1ml	Left	Pass	9.43	-	Pass	39.72	-	Pass	23.62	-	H
1	Spurt	635 cm/s	2ml	Up	Pass	4.5	-	Pass	8.56	-	Pass	36.59	-	H

2	Spurt	635 cm/s	2ml	Down	Fail	2.45	L Q4	Fail	Ran Thru	Q4	Fail	Ran Thru	Q1/Q4	H
3	Spurt	635 cm/s	2ml	Right	Pass	9.58	-	Pass	50.23	-	Pass	42.21	-	H
4	Spurt	635 cm/s	2ml	Left	Pass	11.21	-	Pass	48.27	-	Pass	40.54	-	H
1	Spray	500 cm/s	1ml	Up	Fail	5.96	R Q3	Pass	31.24	-	Pass	56.15	-	H
2	Spray	500 cm/s	1ml	Down	Pass	6.04	-	Pass	56.17	-	Pass	79.7	-	H
3	Spray	500 cm/s	1ml	Right	Pass	10.13	-	Pass	45.19	-	Pass	31.1	-	H
4	Spray	500 cm/s	1ml	Left	Pass	8.69	-	Pass	38.56	-	Pass	23.37	-	H
1	Spurt	635 cm/s	2ml	Up	Fail	14.71	R Q1	Pass	45.65	-	Pass	67.83	-	H
2	Spurt	635 cm/s	2ml	Down	Fail	15.25	L Q4	Fail	Ran Thru	Q1/Q4	Fail	Q2/Q3	-	H
3	Spurt	635 cm/s	2ml	Right	Pass	11.37	-	Pass	54.36	-	Pass	42.61	-	H
4	Spurt	635 cm/s	2ml	Left	Pass	7.25	-	Pass	47.46	-	Pass	44	-	H
1	Spray	500 cm/s	1ml	Up	Fail	7.91	L Q2	Pass	33.38	-	Pass	56.97	-	H
2	Spray	500 cm/s	1ml	Down	Pass	5.13	-	Pass	41.79	-	Pass	60.91	-	H
3	Spray	500 cm/s	1ml	Right	Pass	14.39	-	Pass	51.03	-	Pass	38.56	-	H
4	Spray	500 cm/s	1ml	Left	Pass	5.64	-	Pass	34.34	-	Pass	27.18	-	H
1	Spurt	635 cm/s	2ml	Up	Fail	5.31	R Q1	Pass	2.54	-	Pass	31.72	-	H
2	Spurt	635 cm/s	2ml	Down	Fail	11.13	L Q4	Fail	Ran Thru	Q1/Q4	Fail	Ran Thru	Q1/Q4	H
3	Spurt	635 cm/s	2ml	Right	Pass	5.16	-	Pass	47.14	-	Pass	41.13	-	H
4	Spurt	635 cm/s	2ml	Left	Pass	20.58	-	Pass	48.24	-	Pass	46.94	-	H
1	Spray	500 cm/s	1ml	Up	Fail	8.45	L Q4	Pass	28.69	-	Pass	58.5	-	H
2	Spray	500 cm/s	1ml	Down	Pass	5.27	-	Pass	51.83	-	Pass	73.93	-	H
3	Spray	500 cm/s	1ml	Right	Pass	14.09	-	Pass	39.21	-	Pass	31.52	-	H
4	Spray	500 cm/s	1ml	Left	Pass	2.59	-	Pass	45.4	-	Pass	31.47	-	H
1	Spurt	635 cm/s	2ml	Up	Pass	8.66	-	Pass	3.26	-	Pass	30.19	-	H
2	Spurt	635 cm/s	2ml	Down	Pass	1.91	-	Fail	Ran Thru	Q1/Q4	Pass	11.18	-	H
3	Spurt	635 cm/s	2ml	Right	Pass	19.47	-	Pass	35.23	-	Pass	48.92	-	H
4	Spurt	635 cm/s	2ml	Left	Pass	19.83	-	Pass	47.48	-	Pass	44.59	-	H
1	Spray	500 cm/s	1ml	Up	Pass	6.37	-	Pass	45.27	-	Pass	66.03	-	H
2	Spray	500 cm/s	1ml	Down	Pass	9.45	-	Pass	52.21	-	Pass	72.05	-	H
3	Spray	500 cm/s	1ml	Right	Pass	8.38	-	Pass	50.64	-	Pass	37.85	-	H
4	Spray	500 cm/s	1ml	Left	Pass	11.21	-	Pass	41.63	-	Pass	23.52	-	H
1	Spurt	635 cm/s	2ml	Up	Fail	12.75	L Q2	Pass	65.63	-	Pass	97.7	-	H
2	Spurt	635 cm/s	2ml	Down	Fail	14.32	L Q2	Fail	Ran Thru	Q1/Q4	Fail	Ran Thru	Q1/Q4	H
3	Spurt	635 cm/s	2ml	Right	Pass	12.46	-	Pass	58.46	-	Pass	25.91	-	H
4	Spurt	635 cm/s	2ml	Left	Pass	8.26	-	Pass	43.69	-	Pass	49.38	-	H
1	Spray	500 cm/s	1ml	Up	Fail	14.95	R Q1	Pass	50.2	-	Pass	69.44	-	H
2	Spray	500 cm/s	1ml	Down	Pass	6.68	-	Pass	57.64	-	Pass	79.43	-	H
3	Spray	500 cm/s	1ml	Right	Pass	8.42	-	Pass	51.94	-	Pass	40.3	-	H
4	Spray	500 cm/s	1ml	Left	Pass	7.78	-	Pass	35.42	-	Pass	32.84	-	H
1	Spurt	635 cm/s	2ml	Up	Fail	15.23	L Q2	Pass	8	-	Pass	35.94	-	H
2	Spurt	635 cm/s	2ml	Down	Fail	21.6	R Q4	Fail	Ran Thru	Q2/Q3	Fail	Ran Thru	Q2/Q3	H
3	Spurt	635 cm/s	2ml	Right	Pass	13.52	-	Pass	54.63	-	Pass	29.24	-	H
4	Spurt	635 cm/s	2ml	Left	Pass	5.26	-	Pass	48.59	-	Pass	45.01	-	H
1	Spray	500 cm/s	1ml	Up	Fail	2.28	L Q2	Pass	37.93	-	Pass	63.29	-	H
2	Spray	500 cm/s	1ml	Down	Pass	6.93	-	Pass	59.09	-	Pass	82.28	-	H
3	Spray	500 cm/s	1ml	Right	Pass	11.11	-	Pass	50.26	-	Pass	38.37	-	H
4	Spray	500 cm/s	1ml	Left	Pass	7.67	-	Pass	44.9	-	Pass	29.96	-	H
1	Spurt	635 cm/s	2ml	Up	Fail	19.02	L Q4	Pass	39.57	-	Pass	61.21	-	I
2	Spurt	635 cm/s	2ml	Down	Fail	19.51	R Q4	Pass	2.75	-	Pass	3.26	-	I
3	Spurt	635 cm/s	2ml	Right	Pass	19.59	-	Pass	39.55	-	Pass	29.07	-	I
4	Spurt	635 cm/s	2ml	Left	Pass	15.69	-	Pass	56.74	-	Pass	31.52	-	I
1	Spray	500 cm/s	1ml	Up	Fail	6.91	L Q1	Pass	31.2	-	Pass	61.46	-	I
2	Spray	500 cm/s	1ml	Down	Pass	3.84	-	Pass	34.74	-	Pass	59.91	-	I
3	Spray	500 cm/s	1ml	Right	Fail	18.24	L Q4	Pass	33.98	-	Pass	49.41	-	I

4	Spray	500 cm/s	1ml	Left	Pass	1.43	-	Pass	35.38	-	Pass	39.97	-	I
1	Spurt	635 cm/s	2ml	Up	Fail	11.95	L Q1	Fail	Ran Thru	Q4	Fail	Ran Thru	Q1/Q4	I
2	Spurt	635 cm/s	2ml	Down	Fail	14.73	R Q4	Pass	2.15	-	Pass	4.67	-	I
3	Spurt	635 cm/s	2ml	Right	Pass	13.27	-	Pass	40.46	-	Pass	30.6	-	I
4	Spurt	635 cm/s	2ml	Left	Pass	18.37	-	Pass	51.49	-	Pass	49.08	-	I
1	Spray	500 cm/s	1ml	Up	Fail	5.67	L Q4	Pass	32.77	-	Pass	62.06	-	I
2	Spray	500 cm/s	1ml	Down	Pass	3.33	-	Pass	34.73	-	Pass	57.07	-	I
3	Spray	500 cm/s	1ml	Right	Pass	2.95	-	Pass	34.3	-	Pass	45.09	-	I
4	Spray	500 cm/s	1ml	Left	Pass	2.95	-	Pass	34.38	-	Pass	34.93	-	I
1	Spurt	635 cm/s	2ml	Up	Fail	15.61	R Q1	Fail	Ran Thru	Q2/Q3	Fail	Ran Thru	Q2/Q3	I
2	Spurt	635 cm/s	2ml	Down	Fail	11.37	L Q3	Fail	Ran Thru	Q4	Fail	Ran Thru	Q2/Q3	I
3	Spurt	635 cm/s	2ml	Right	Pass	14.02	-	Pass	48.97	-	Pass	25.89	-	I
4	Spurt	635 cm/s	2ml	Left	Pass	14.14	-	Pass	47.12	-	Pass	37.21	-	I
1	Spray	500 cm/s	1ml	Up	Fail	3.24	R Q4	Pass	37.89	-	Pass	57.56	-	I
2	Spray	500 cm/s	1ml	Down	Pass	4.59	-	Pass	33.83	-	Pass	58.71	-	I
3	Spray	500 cm/s	1ml	Right	Fail	22.98	L Q4	Pass	42.81	-	Pass	40.65	-	I
4	Spray	500 cm/s	1ml	Left	Fail	21.36	R Q3	Pass	34.76	-	Pass	40.95	-	I
1	Spurt	635 cm/s	2ml	Up	Fail	19.77	L Q2	Fail	Ran Thru	Q3	Fail	Ran Thru	Q2/Q3	I
2	Spurt	635 cm/s	2ml	Down	Fail	16.47	R Q3	Fail	Ran Thru	Q2/Q3	Fail	Ran Thru	Q2/Q3	I
3	Spurt	635 cm/s	2ml	Right	Pass	12.98	-	Pass	41.46	-	Pass	45.08	-	I
4	Spurt	635 cm/s	2ml	Left	Pass	24.78	-	Pass	41.12	-	Pass	37.58	-	I
1	Spray	500 cm/s	1ml	Up	Fail	17.02	R Q1	Pass	33.66	-	Pass	54.69	-	I
2	Spray	500 cm/s	1ml	Down	Pass	4.02	-	Pass	37.21	-	Pass	62.57	-	I
3	Spray	500 cm/s	1ml	Right	Pass	2.33	-	Pass	34.49	-	Pass	30.21	-	I
4	Spray	500 cm/s	1ml	Left	Pass	2.51	-	Pass	35.38	-	Pass	44.6	-	I
1	Spurt	635 cm/s	2ml	Up	Fail	15.34	R Q4	Fail	Ran Thru	Q1	Fail	Ran Thru	Q1/Q4	I
2	Spurt	635 cm/s	2ml	Down	Fail	15.71	R Q4	Fail	Ran Thru	Q3/Q4	Fail	Ran Thru	Q2/Q3	I
3	Spurt	635 cm/s	2ml	Right	Pass	11.97	-	Pass	49.09	-	Pass	38.49	-	I
4	Spurt	635 cm/s	2ml	Left	Pass	15.9	-	Pass	50.52	-	Pass	37.47	-	I
1	Spray	500 cm/s	1ml	Up	Fail	18.46	R Q4	Pass	38.47	-	Pass	59.52	-	I
2	Spray	500 cm/s	1ml	Down	Pass	2.25	-	Pass	31.69	-	Pass	55.65	-	I
3	Spray	500 cm/s	1ml	Right	Pass	7.55	-	Pass	50.37	-	Pass	44.24	-	I
4	Spray	500 cm/s	1ml	Left	Pass	2.74	-	Pass	38.57	-	Pass	42.01	-	I
1	Spurt	635 cm/s	2ml	Up	Fail	17.39	L Q3	Fail	Ran Thru	Q2/Q3	Fail	Ran Thru	Q2/Q3	I
2	Spurt	635 cm/s	2ml	Down	Fail	7.09	R Q4	Fail	Ran Thru	Q3	Fail	Ran Thru	Q1/Q4	I
3	Spurt	635 cm/s	2ml	Right	Pass	22.25	-	Pass	40.72	-	Pass	26.62	-	I
4	Spurt	635 cm/s	2ml	Left	Pass	18.56	-	Pass	34.12	-	Pass	31.56	-	I
1	Spray	500 cm/s	1ml	Up	Fail	3.35	R Q4	Pass	38.66	-	Pass	59.47	-	I
2	Spray	500 cm/s	1ml	Down	Pass	1.88	-	Pass	33.68	-	Pass	55.43	-	I
3	Spray	500 cm/s	1ml	Right	Pass	3.21	-	Pass	36.45	-	Pass	49.12	-	I
4	Spray	500 cm/s	1ml	Left	Pass	2.74	-	Pass	40.23	-	Pass	51.02	-	I
1	Spurt	635 cm/s	2ml	Up	Fail	16.03	R Q4	Fail	Ran Thru	Q3	Fail	Ran Thru	Q2/Q3	I
2	Spurt	635 cm/s	2ml	Down	Fail	8.64	L Q3	Fail	Ran Thru	Q4	Fail	Ran Thru	Q1/Q4	I
3	Spurt	635 cm/s	2ml	Right	Pass	16.1	-	Pass	55.16	-	Pass	41.28	-	I
4	Spurt	635 cm/s	2ml	Left	Pass	12.31	-	Pass	51.26	-	Pass	35.78	-	I
1	Spray	500 cm/s	1ml	Up	Fail	9.24	L Q4	Pass	34.68	-	Pass	55.26	-	I
2	Spray	500 cm/s	1ml	Down	Pass	0.68	-	Pass	30.48	-	Pass	51.03	-	I
3	Spray	500 cm/s	1ml	Right	Pass	1.56	-	Pass	31.21	-	Pass	48.75	-	I
4	Spray	500 cm/s	1ml	Left	Fail	19.23	R Q3	Pass	33.61	-	Pass	47.89	-	I
1	Spurt	635 cm/s	2ml	Up	Fail	5.23	L Q3	Pass	3.42	-	Fail	Ran Thru	Q1/Q4	I
2	Spurt	635 cm/s	2ml	Down	Fail	14.69	L Q4	Pass	2.51	-	Pass	1.54	-	I
3	Spurt	635 cm/s	2ml	Right	Pass	20.19	-	Pass	37.45	-	Pass	29.7	-	I
4	Spurt	635 cm/s	2ml	Left	Pass	16.87	-	Pass	52.36	-	Pass	31.25	-	I
1	Sprav	500 cm/s	1ml	Up	Fail	20.48	R Q1	Pass	36.43	-	Pass	56.96	-	I

2	Spray	500 cm/s	1ml	Down	Pass	1.45	-	Pass	36.47	-	Pass	57.05	-	I
3	Spray	500 cm/s	1ml	Right	Pass	3.65	-	Pass	35.26	-	Pass	54.23	-	I
4	Spray	500 cm/s	1ml	Left	Pass	3.12	-	Pass	33.59	-	Pass	51.24	-	I
1	Spurt	635 cm/s	2ml	Up	Fail	14.25	R Q4	Fail	Ran Thru	Q2/Q3	Fail	Ran Thru	Q2/Q3	I
2	Spurt	635 cm/s	2ml	Down	Fail	12.1	L Q3	Fail	Ran Thru	Q3	Fail	Ran Thru	Q2/Q3	I
3	Spurt	635 cm/s	2ml	Right	Pass	12.27	-	Pass	41.64	-	Pass	31.06	-	I
4	Spurt	635 cm/s	2ml	Left	Pass	17.48	-	Pass	50.49	-	Pass	49.28	-	I
1	Spray	500 cm/s	1ml	Up	Fail	22.31	L Q1	Pass	38.04	-	Pass	61.37	-	I
2	Spray	500 cm/s	1ml	Down	Pass	1.72	-	Pass	26.83	-	Pass	52.74	-	I
3	Spray	500 cm/s	1ml	Right	Fail	20.26	L Q4	Pass	19.54	-	Pass	48.51	-	I
4	Spray	500 cm/s	1ml	Left	Fail	17.54	R Q3	Pass	29.65	-	Pass	49.21	-	I
1	Spurt	635 cm/s	2ml	Up	Fail	12.01	L Q2	Fail	Ran Thru	Q4	Fail	Ran Thru	Q1/Q4	I
2	Spurt	635 cm/s	2ml	Down	Fail	13.4	L Q3	Fail	Ran Thru	Q1/Q2/Q3/Q4	Fail	Ran Thru	Q1/Q2/Q3/Q4	I
3	Spurt	635 cm/s	2ml	Right	Pass	12.28	-	Pass	41.46	-	Pass	46.08	-	I
4	Spurt	635 cm/s	2ml	Left	Pass	18.32	-	Pass	40.21	-	Pass	35.48	-	I
1	Spray	500 cm/s	1ml	Up	Fail	8.69	L Q4	Pass	35.98	-	Pass	55.53	-	I
2	Spray	500 cm/s	1ml	Down	Pass	3.34	-	Pass	34.11	-	Pass	55.11	-	I
3	Spray	500 cm/s	1ml	Right	Pass	4.51	-	Pass	33.67	-	Pass	48.56	-	I
4	Spray	500 cm/s	1ml	Left	Pass	1.98	-	Pass	30.48	-	Pass	45.22	-	I
1	Spurt	635 cm/s	2ml	Up	Fail	6	L Q2	Pass	3.56	-	Pass	6.46	-	J
2	Spurt	635 cm/s	2ml	Down	Fail	7.5	R Q4	Fail	Ran Thru	Q4	Fail	Ran Thru	Q1/Q4	J
3	Spurt	635 cm/s	2ml	Right	Pass	15.5	-	Pass	38.56	-	Pass	32.35	-	J
4	Spurt	635 cm/s	2ml	Left	Pass	26.08	-	Pass	59.23	-	Pass	57.84	-	J
1	Spray	500 cm/s	1ml	Up	Fail	14.62	L Q4	Pass	36.3	-	Pass	47.6	-	J
2	Spray	500 cm/s	1ml	Down	Fail	2.52	L Q4	Pass	34.24	-	Pass	51.02	-	J
3	Spray	500 cm/s	1ml	Right	Fail	15.24	L Q1	Pass	36.64	-	Pass	36.33	-	J
4	Spray	500 cm/s	1ml	Left	Fail	16.31	R Q3	Pass	27.33	-	Pass	34.13	-	J
1	Spurt	635 cm/s	2ml	Up	Fail	9	L Q1	Pass	2.75	-	Pass	3.25	-	J
2	Spurt	635 cm/s	2ml	Down	Fail	16.5	L Q1	Fail	Ran Thru	Q4	Fail	Ran Thru	Q1/Q4	J
3	Spurt	635 cm/s	2ml	Right	Pass	23.75	-	Pass	45.49	-	Pass	35.38	-	J
4	Spurt	635 cm/s	2ml	Left	Pass	25.89	-	Pass	60.82	-	Pass	61.41	-	J
1	Spray	500 cm/s	1ml	Up	Fail	4.22	R Q3	Pass	38.09	-	Pass	53.89	-	J
2	Spray	500 cm/s	1ml	Down	Fail	0.5	L Q2	Pass	19.79	-	Pass	41.87	-	J
3	Spray	500 cm/s	1ml	Right	Pass	4.33	-	Pass	35.07	-	Pass	38.34	-	J
4	Spray	500 cm/s	1ml	Left	Fail	22.34	R Q2	Pass	38.56	-	Pass	30.8	-	J
1	Spurt	635 cm/s	2ml	Up	Fail	4.29	R Q4	Pass	56.47	-	Pass	33.78	-	J
2	Spurt	635 cm/s	2ml	Down	Fail	24	L Q1	Fail	Ran Thru	Q4	Fail	Ran Thru	Q1/Q4	J
3	Spurt	635 cm/s	2ml	Right	Pass	14.56	-	Pass	36.32	-	Pass	28.89	-	J
4	Spurt	635 cm/s	2ml	Left	Pass	23.6	-	Pass	55.45	-	Pass	47.65	-	J
1	Spray	500 cm/s	1ml	Up	Fail	11	R Q3	Pass	37.5	-	Pass	58.74	-	J
2	Spray	500 cm/s	1ml	Down	Fail	0.25	L Q1	Pass	18.68	-	Pass	48.08	-	J
3	Spray	500 cm/s	1ml	Right	Fail	17.03	L Q1	Pass	36.27	-	Pass	36.54	-	J
4	Spray	500 cm/s	1ml	Left	Fail	22.86	R Q2	Pass	31.07	-	Pass	33.62	-	J
1	Spurt	635 cm/s	2ml	Up	Fail	7.5	R Q4	Pass	27.94	-	Pass	31.53	-	J
2	Spurt	635 cm/s	2ml	Down	Fail	22.75	R Q4	Fail	ran thru	Q3	Fail	ran thru	Q2/Q3	J
3	Spurt	635 cm/s	2ml	Right	Pass	23.06	-	Pass	44.93	-	Pass	32.87	-	J
4	Spurt	635 cm/s	2ml	Left	Pass	22.22	-	Pass	52.83	-	Pass	50.12	-	J
1	Spray	500 cm/s	1ml	Up	Fail	8	L Q1	Pass	28.54	-	Pass	48.77	-	J
2	Spray	500 cm/s	1ml	Down	Fail	0.46	R Q4	Pass	13.25	-	Pass	39.48	-	J

3	Spray	500 cm/s	1ml	Right	Fail	16.43	L Q1	Pass	36.63	-	Pass	37.25	-	J
4	Spray	500 cm/s	1ml	Left	Fail	24.79	R Q1	Pass	26.47	-	Pass	31.12	-	J
1	Spurt	635 cm/s	2ml	Up	Fail	2.43	R Q1	Pass	19.87	-	Pass	34.84	-	J
2	Spurt	635 cm/s	2ml	Down	Fail	16.46	L Q3	Fail	ran thur	Q4	Fail	ran thru	Q1/Q4	J
3	Spurt	635 cm/s	2ml	Right	Pass	22	-	Pass	52.37	-	Pass	45.67	-	J
4	Spurt	635 cm/s	2ml	Left	Pass	18.17	-	Pass	56.51	-	Pass	47.2	-	J
1	Spray	500 cm/s	1ml	Up	Fail	0.33	L Q1	Pass	14.53	-	Pass	41.42	-	J
2	Spray	500 cm/s	1ml	Down	Fail	14.78	R Q3	Pass	30.88	-	Pass	45.58	-	J
3	Spray	500 cm/s	1ml	Right	Fail	23	L Q4	Pass	38.92	-	Pass	37.04	-	J
4	Spray	500 cm/s	1ml	Left	Fail	15.64	R Q3	Pass	22.79	-	Pass	33.78	-	J
1	Spurt	635 cm/s	2ml	Up	Fail	2.58	L Q1	Pass	2	-	Fail	ran thru	Q1/Q4	J
2	Spurt	635 cm/s	2ml	Down	Fail	3.28	L Q1	fail	ran thru	Q3	Fail	ran thru	Q2/Q3	J
3	Spurt	635 cm/s	2ml	Right	Pass	25.14	-	Pass	52.47	-	Pass	44.56	-	J
4	Spurt	635 cm/s	2ml	Left	Pass	14.4	-	Pass	52.74	-	Pass	41.31	-	J
1	Spray	500 cm/s	1ml	Up	Fail	5.23	R Q2	Pass	37.05	-	Pass	49.48	-	J
2	Spray	500 cm/s	1ml	Down	Fail	1.2	R Q4	Pass	7.45	-	Pass	29.2	-	J
3	Spray	500 cm/s	1ml	Right	Pass	3.4	-	Pass	29.02	-	Pass	31.11	-	J
4	Spray	500 cm/s	1ml	Left	Fail	23.3	R Q3	Pass	34.97	-	Pass	36.01	-	J
1	Spurt	635 cm/s	2ml	Up	Fail	1.33	L Q2	Pass	3.64	-	Fail	ran thru	Q1/Q4	J
2	Spurt	635 cm/s	2ml	Down	Fail	11.13	L Q2	Fail	ran thru	Q4	Fail	ran thru	Q1/Q4	J
3	Spurt	635 cm/s	2ml	Right	Pass	19.76	-	Pass	58.07	-	Pass	43.47	-	J
4	Spurt	635 cm/s	2ml	Left	Pass	24.46	-	Pass	36.96	-	Pass	53.26	-	J
1	Spray	500 cm/s	1ml	Up	Fail	10.18	R Q3	Pass	33.65	-	Pass	50.99	-	J
2	Spray	500 cm/s	1ml	Down	Fail	1.87	L Q3	Pass	22.02	-	Pass	43.96	-	J
3	Spray	500 cm/s	1ml	Right	Fail	24.31	L Q4	Pass	29.85	-	Pass	35.19	-	J
4	Spray	500 cm/s	1ml	Left	Fail	16.88	R Q1	Pass	27.88	-	Pass	33.92	-	J
1	Spurt	635 cm/s	2ml	Up	Fail	11.18	R Q1	Pass	14	-	Pass	28.71	-	J
2	Spurt	635 cm/s	2ml	Down	Fail	17.6	L Q2	Fail	Ran Thru	Q4	Fail	ran thru	Q1/Q4	J
3	Spurt	635 cm/s	2ml	Right	Pass	19.01	-	Pass	45.56	-	Pass	28.09	-	J
4	Spurt	635 cm/s	2ml	Left	Pass	25.78	-	Pass	40.53	-	Pass	26.34	-	J
1	Spray	500 cm/s	1ml	Up	Fail	17.81	L Q1	Pass	40.36	-	Pass	50.81	-	J
2	Spray	500 cm/s	1ml	Down	Fail	0.91	R Q3	Pass	28.74	-	Pass	45.82	-	J
3	Spray	500 cm/s	1ml	Right	Fail	1.15	L Q4	Pass	36.45	-	Pass	39.24	-	J
4	Spray	500 cm/s	1ml	Left	Fail	18.52	R Q4	Pass	34.37	-	Pass	35.36	-	J
1	Spurt	635 cm/s	2ml	Up	Fail	10.32	L Q2	Pass	20.29	-	Pass	39.87	-	J
2	Spurt	635 cm/s	2ml	Down	Fail	2.87	L Q2	Fail	Ran Thru	Q3	Fail	Ran thru	Q2/Q3	J
3	Spurt	635 cm/s	2ml	Right	Pass	15.11	-	Pass	41.9	-	Pass	29.02	-	J
4	Spurt	635 cm/s	2ml	Left	Pass	17.09	-	Pass	40.01	-	Pass	30.7	-	J
1	Spray	500 cm/s	1ml	Up	Fail	17.18	R Q2	Pass	37.69	-	Pass	50.84	-	J
2	Spray	500 cm/s	1ml	Down	Fail	1.17	R Q3	Pass	17.06	-	Pass	46.92	-	J
3	Spray	500 cm/s	1ml	Right	Fail	21.25	L Q3	Pass	33.45	-	Pass	35.28	-	J
4	Spray	500 cm/s	1ml	Left	Fail	7.08	R Q4	Pass	30.36	-	Pass	34.24	-	J
1	Spurt	635 cm/s	2ml	Up	Fail	4.47	L Q2	Fail	Ran Thru	Q3	Fail	Ran Thru	Q2/Q3	J
2	Spurt	635 cm/s	2ml	Down	Fail	12.59	L Q3	Pass	1.75	-	Fail	Ran Thru	Q1/Q4	J
3	Spurt	635 cm/s	2ml	Right	Pass	14.41	-	Pass	42.83	-	Pass	33.39	-	J
4	Spurt	635 cm/s	2ml	Left	Pass	14.52	-	Pass	43.08	-	Pass	32.25	-	J
1	Spray	500 cm/s	1ml	Up	Fail	21.51	L Q1	Pass	29.13	-	Pass	49.26	-	J
2	Spray	500 cm/s	1ml	Down	Fail	3.2	L Q1	Pass	22.95	-	Pass	44.24	-	J
3	Spray	500 cm/s	1ml	Right	Fail	19.02	L Q4	Pass	34.32	-	Pass	37.47	-	J
4	Spray	500 cm/s	1ml	Left	Fail	15.93	R Q2	Pass	25.72	-	Pass	33.1	-	J

APPENDIX D: SAS DATA OUTPUT

The LOGISTIC Procedure

Model Information	
Data Set	WORK.A
Response Variable	eyespf
Number of Response Levels	2
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	800
Number of Observations Used	800

Response Profile		
Ordered Value	eyespf	Total Frequency
1	0	563
2	1	237

Probability modeled is eyespf=0.

Class Level Information										
Class	Value	Design Variables								
position1	1	1	0	0						
	2	0	1	0						
	3	0	0	1						
	4	-1	-1	-1						
type1	Spray	1								
	Spurt	-1								
Ensemble	A	1	0	0	0	0	0	0	0	0
	B	0	1	0	0	0	0	0	0	0
	C	0	0	1	0	0	0	0	0	0
	D	0	0	0	1	0	0	0	0	0
	E	0	0	0	0	1	0	0	0	0
	F	0	0	0	0	0	1	0	0	0

Class Level Information										
Class	Value	Design Variables								
	G	0	0	0	0	0	0	1	0	0
	H	0	0	0	0	0	0	0	1	0
	I	0	0	0	0	0	0	0	0	1
	J	-1	-1	-1	-1	-1	-1	-1	-1	-1

Model Convergence Status

Quasi-complete separation of data points detected.

Warning: The maximum likelihood estimate may not exist.

Warning: The LOGISTIC procedure continues in spite of the above warning. Results shown are based on the last maximum likelihood iteration. Validity of the model fit is questionable.

Model Fit Statistics		
Criterion	Intercept Only	Intercept and Covariates
AIC	974.245	524.657
SC	978.930	590.241
-2 Log L	972.245	496.657

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	475.5886	13	<.0001
Score	361.8529	13	<.0001
Wald	157.3174	13	<.0001

Type 3 Analysis of Effects			
Effect	DF	Wald Chi-Square	Pr > ChiSq
position1	3	122.5091	<.0001
type1	1	0.3130	0.5758
Ensemble	9	128.1231	<.0001

Analysis of Maximum Likelihood Estimates						
Parameter		DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept		1	3.0071	21.7286	0.0192	0.8899
position1	1	1	-2.1815	0.2230	95.7103	<.0001
position1	2	1	-1.3424	0.2066	42.2004	<.0001
position1	3	1	1.8694	0.2547	53.8631	<.0001
type1	Spray	1	0.0627	0.1120	0.3130	0.5758
Ensemble	A	1	-0.0517	21.7311	0.0000	0.9981
Ensemble	B	1	0.2385	21.7315	0.0001	0.9912
Ensemble	C	1	13.3205	195.6	0.0046	0.9457
Ensemble	D	1	-1.3241	21.7302	0.0037	0.9514
Ensemble	E	1	2.5303	21.7476	0.0135	0.9074
Ensemble	F	1	-1.7854	21.7302	0.0068	0.9345
Ensemble	G	1	-4.1692	21.7309	0.0368	0.8479
Ensemble	H	1	-1.4167	21.7302	0.0043	0.9480
Ensemble	I	1	-2.6410	21.7303	0.0148	0.9033

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
position1 1 vs 4	0.022	0.010	0.048
position1 2 vs 4	0.050	0.023	0.106
position1 3 vs 4	1.240	0.590	2.606
type1 Spray vs Spurt	1.134	0.731	1.758
Ensemble A vs J	104.534	35.706	306.037
Ensemble B vs J	139.734	45.680	427.444
Ensemble C vs J	>999.999	<0.001	>999.999
Ensemble D vs J	29.287	11.091	77.334
Ensemble E vs J	>999.999	161.369	>999.999
Ensemble F vs J	18.464	7.135	47.783
Ensemble G vs J	1.702	0.743	3.901
Ensemble H vs J	26.695	10.153	70.188

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
Ensemble I vs J	7.848	3.164	19.462

Association of Predicted Probabilities and Observed Responses			
Percent Concordant	92.3	Somers' D	0.848
Percent Discordant	7.5	Gamma	0.850
Percent Tied	0.2	Tau-a	0.354
Pairs	133431	c	0.924

The SAS System

The LOGISTIC Procedure

Model Information	
Data Set	WORK.A
Response Variable	nosepf
Number of Response Levels	2
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	800
Number of Observations Used	800

Response Profile		
Ordered Value	nosepf	Total Frequency
1	0	737
2	1	63

Probability modeled is nosepf=0.

Class Level Information										
Class	Value	Design Variables								
position1	1	1	0	0						
	2	0	1	0						
	3	0	0	1						
	4	-1	-1	-1						
type1	Spray	1								
	Spurt	-1								
Ensemble	A	1	0	0	0	0	0	0	0	0
	B	0	1	0	0	0	0	0	0	0
	C	0	0	1	0	0	0	0	0	0
	D	0	0	0	1	0	0	0	0	0
	E	0	0	0	0	1	0	0	0	0
	F	0	0	0	0	0	1	0	0	0

Class Level Information										
Class	Value	Design Variables								
	G	0	0	0	0	0	0	1	0	0
	H	0	0	0	0	0	0	0	1	0
	I	0	0	0	0	0	0	0	0	1
	J	-1	-1	-1	-1	-1	-1	-1	-1	-1

Model Convergence Status

Quasi-complete separation of data points detected.

Warning: The maximum likelihood estimate may not exist.

Warning: The LOGISTIC procedure continues in spite of the above warning. Results shown are based on the last maximum likelihood iteration. Validity of the model fit is questionable.

Model Fit Statistics		
Criterion	Intercept Only	Intercept and Covariates
AIC	443.129	133.337
SC	447.814	198.922
-2 Log L	441.129	105.337

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	335.7918	13	<.0001
Score	241.2354	13	<.0001
Wald	41.0603	13	<.0001

Type 3 Analysis of Effects			
Effect	DF	Wald Chi-Square	Pr > ChiSq
position1	3	36.6243	<.0001
type1	1	0.0203	0.8868
Ensemble	9	23.4097	0.0053

Analysis of Maximum Likelihood Estimates						
Parameter		DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept		1	20.6033	96.9257	0.0452	0.8317
position1	1	1	-5.6956	64.6752	0.0078	0.9298
position1	2	1	-9.5151	64.6761	0.0216	0.8830
position1	3	1	7.6053	144.6	0.0028	0.9581
type1	Spray	1	8.0958	56.8641	0.0203	0.8868
Ensemble	A	1	-4.0433	44.4794	0.0083	0.9276
Ensemble	B	1	10.4283	233.9	0.0020	0.9644
Ensemble	C	1	10.4283	233.9	0.0020	0.9644
Ensemble	D	1	-1.5728	44.4816	0.0013	0.9718
Ensemble	E	1	10.4283	233.9	0.0020	0.9644
Ensemble	F	1	-4.4617	44.4796	0.0101	0.9201
Ensemble	G	1	-5.7610	44.4803	0.0168	0.8969
Ensemble	H	1	-3.6525	44.4792	0.0067	0.9346
Ensemble	I	1	-6.8914	44.4808	0.0240	0.8769

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
position1 1 vs 4	<0.001	<0.001	>999.999
position1 2 vs 4	<0.001	<0.001	>999.999
position1 3 vs 4	1.000	<0.001	>999.999
type1 Spray vs Spurt	>999.999	<0.001	>999.999
Ensemble A vs J	2.360	0.376	14.830
Ensemble B vs J	>999.999	<0.001	>999.999
Ensemble C vs J	>999.999	<0.001	>999.999
Ensemble D vs J	27.921	3.415	228.254
Ensemble E vs J	>999.999	<0.001	>999.999
Ensemble F vs J	1.553	0.245	9.836
Ensemble G vs J	0.424	0.067	2.662
Ensemble H vs J	3.489	0.559	21.792

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
Ensemble I vs J	0.137	0.022	0.869

Association of Predicted Probabilities and Observed Responses			
Percent Concordant	99.0	Somers' D	0.982
Percent Discordant	0.8	Gamma	0.985
Percent Tied	0.3	Tau-a	0.143
Pairs	46431	c	0.991

The SAS System

The LOGISTIC Procedure

Model Information	
Data Set	WORK.A
Response Variable	mouthpf
Number of Response Levels	2
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	800
Number of Observations Used	800

Response Profile		
Ordered Value	mouthpf	Total Frequency
1	0	741
2	1	59

Probability modeled is mouthpf=0.

Class Level Information										
Class	Value	Design Variables								
position1	1	1	0	0						
	2	0	1	0						
	3	0	0	1						
	4	-1	-1	-1						
type1	Spray	1								
	Spurt	-1								
Ensemble	A	1	0	0	0	0	0	0	0	0
	B	0	1	0	0	0	0	0	0	0
	C	0	0	1	0	0	0	0	0	0
	D	0	0	0	1	0	0	0	0	0
	E	0	0	0	0	1	0	0	0	0
	F	0	0	0	0	0	1	0	0	0

Class Level Information										
Class	Value	Design Variables								
	G	0	0	0	0	0	0	1	0	0
	H	0	0	0	0	0	0	0	1	0
	I	0	0	0	0	0	0	0	0	1
	J	-1	-1	-1	-1	-1	-1	-1	-1	-1

Model Convergence Status

Quasi-complete separation of data points detected.

Warning: The maximum likelihood estimate may not exist.

Warning: The LOGISTIC procedure continues in spite of the above warning. Results shown are based on the last maximum likelihood iteration. Validity of the model fit is questionable.

Model Fit Statistics		
Criterion	Intercept Only	Intercept and Covariates
AIC	423.172	147.969
SC	427.857	213.554
-2 Log L	421.172	119.969

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	301.2031	13	<.0001
Score	215.7963	13	<.0001
Wald	34.0715	13	0.0012

Type 3 Analysis of Effects			
Effect	DF	Wald Chi-Square	Pr > ChiSq
position1	3	26.2271	<.0001
type1	1	0.0173	0.8954
Ensemble	9	26.6381	0.0016

Analysis of Maximum Likelihood Estimates						
Parameter		DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept		1	20.4299	100.6	0.0413	0.8390
position1	1	1	-6.1559	65.4768	0.0088	0.9251
position1	2	1	-9.0621	65.4775	0.0192	0.8899
position1	3	1	7.6090	146.4	0.0027	0.9586
type1	Spray	1	7.9343	60.3654	0.0173	0.8954
Ensemble	A	1	-3.5928	46.7437	0.0059	0.9387
Ensemble	B	1	10.1180	245.9	0.0017	0.9672
Ensemble	C	1	10.1180	245.9	0.0017	0.9672
Ensemble	D	1	-1.9675	46.7463	0.0018	0.9664
Ensemble	E	1	10.1180	245.9	0.0017	0.9672
Ensemble	F	1	-4.8867	46.7438	0.0109	0.9167
Ensemble	G	1	-3.2577	46.7439	0.0049	0.9444
Ensemble	H	1	-3.9170	46.7437	0.0070	0.9332
Ensemble	I	1	-6.8762	46.7454	0.0216	0.8831

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
position1 1 vs 4	<0.001	<0.001	>999.999
position1 2 vs 4	<0.001	<0.001	>999.999
position1 3 vs 4	1.000	<0.001	>999.999
type1 Spray vs Spurt	>999.999	<0.001	>999.999
Ensemble A vs J	9.617	1.750	52.837
Ensemble B vs J	>999.999	<0.001	>999.999
Ensemble C vs J	>999.999	<0.001	>999.999
Ensemble D vs J	48.857	6.373	374.556
Ensemble E vs J	>999.999	<0.001	>999.999
Ensemble F vs J	2.637	0.531	13.102
Ensemble G vs J	13.446	2.359	76.620
Ensemble H vs J	6.955	1.303	37.122

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
Ensemble I vs J	0.361	0.069	1.875

Association of Predicted Probabilities and Observed Responses			
Percent Concordant	98.7	Somers' D	0.976
Percent Discordant	1.0	Gamma	0.980
Percent Tied	0.3	Tau-a	0.134
Pairs	43719	c	0.988

APPENDIX E: Curriculum Vitae

CURRICULUM VITAE

Jeremy R. Gouzd
Laboratory Technician Level II
NIOSH
Evaluation and Testing Branch
Phone: 304.285.6031
Email: Ltv5@cdc.gov
JGouzd2@gmail.com

Education:

B.S. - Mechanical Engineering, Fairmont State University, 11/2013, High Honors Scholar graduate

M.S. – Education-Professional Studies, Fairmont State University, 5/2015

Certifications:

IS-00100.b – Introduction to Incident Command System ICS-100
IS-00200.b – Single Resources and Initial Action Incident, ICS-200
IS-00700.b – National Incident Management System (NIMS), ICS-700
IS-00800.b – National Response Framework, ICS-800
AWR-130 - Incident Response to Terrorist Bombing - Awareness

Work Experience:

Laboratory Technician Level II at NIOSH in the Evaluation and Testing Branch

Major project responsibilities and leadership roles:

- ***Conduct Laboratory Experiments Related To Analytical Research For Stockpile Investigation And Research.*** I use industry-accepted standards to test and evaluate a variety of personal protective equipment (PPE) such as respirators and isolation gowns worn by healthcare workers. Duties include ensuring the equipment meets manufacturer specifications to successfully perform testing. Operate TSI 8130 Filter Testers for Salt (NaCl) to determination of particulate Filter Efficiency Level for N95, N99, N100 Filters against solid particles. Including the determination of Inhalation Resistance Test, Exhalation Resistance Test, and Exhalation Valve Leakage Test.

- ***Work With Senior Project Officers To Implement Complex Sampling Plans.*** Operate And Maintain All Industrial Equipment For Field Readiness for preparation of field samples from occupationally-exposed workers. Field samples include fire fighter turnout gear and respirators that were involved in a fatality and evaluated as part of NIOSH's Fire Fighter Fatality Investigation Prevention Program (FFFIPP). The equipment must be prepped and ready at all times to prepare for turnout gear and respirator investigations, which are often high-profile and confidential. Regularly follow a chain of custody with evidence and all paperwork in a sensitive manner. All chain of custody evidence must be thoroughly documented upon arrival, signed in and out of the evidence cage, and documentation of its departure. Photo and written documentation is recorded as the package arrives, during the opening of package, and very specific details of the PPE as the visual inspection is completed. Respond to Requests for Information from senior project officers for the PPE evaluation results from the NIOSH FFFIPP. Designed and built new test equipment that allows more efficient and accurate tests to be conducted. Gained competency of laboratory equipment and standard test procedures used for investigations in the FFFIPP including Air Flow test, Rated service time test, positive pressure test, static pressure test, Gas flow test, Remaining service life indicator test (mechanical and electronic), and Exhalation resistance test.
- ***Calibrate Wide-Range Of Industrial Equipment To Ensure Valid Measurement Of Data.*** Calibrate and maintain equipment prior to use of all test devices used for these bench tests. I Follow Property Procedures To Track Laboratory Equipment by keeping detailed logs for each laboratory device and coordinate with manufacturers when calibration is needed by obtaining quotes, preparing appropriate forms, and shipping the equipment. Set up numerous quotes and estimates for purchasing of equipment and testing devices, which involves keeping track of laboratory equipment and its statuses.
- ***Conduct Laboratory Experiments Related To Analytical Research.*** I use industry-accepted standards to test and evaluate a variety of personal protective equipment (PPE) such as respirators and isolation gowns worn by healthcare workers. Duties include ensuring the equipment meets manufacturer specifications to successfully perform testing. Gained competency in the PPE testing equipment such as Frazier Differential Pressure Air Permeability Tester, Instron Tensile Tester. I have also gained knowledge and experience related to testing according to industry standards for various types of respirators for penetration by synthetic blood according, including calibration of instrument and conditioning of samples.
- ***Follow Established Decontamination Procedures Of Field Samples.*** As part of the FFFIPP program, I must maintain good safety hygiene practices and follow decontamination and clean up guidelines after testing. I ensure

appropriate PPE and sufficient ventilation is always used during the visual inspection and testing of PPE. I use procedures of maintaining a clean decontamination process with contaminated units. Having the knowledge of correct PPE is vital in testing contaminated field samples.

- **Document And Prepare Analyses And Reports Of Study Findings And Test Results.** Documenting fire fighter PPE investigations includes taking detailed records on appropriate data sheets, in putting the records into the electronic reports, and taking photographs. After the testing and evaluations are complete, I use the analyses and reports of the findings from the bench tests results and prepare a final report. These reports contain detailed information on the PPE investigations, equipment used, and the findings. I enter the reports into the computer and file the hard copies in appropriate locations.