# DONNING TIMES OF MARINE ABANDONMENT IMMERSION SUITS UNDER SIMULATED EVACUATION CONDITIONS

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# Donning Times of Marine Abandonment Immersion Suits Under Simulated Evacuation Conditions

By

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## ABSTRACT

Maritime emergencies often occur rapidly in unpredictable circumstances. In a scenario where a vessel or offshore installation evacuation is necessary, personal flotation and thermal protection greatly increases the chances of survival for individuals immersed in water. Marine abandonment immersion suits, intended to be donned quickly, can provide effective protection against these dangers and prolong life. The ability to locate and correctly don an immersion suit before vessel or installation abandonment is critical to survival. The Canadian immersion suit standard (CAN/CGSB-65.16-2005) dictates that a suit must be unpacked and properly donned without assistance within 2-minutes.

Thirty-two participants, with similar knowledge and training performed donning exercises using two differing manufactures marine abandonment immersion suits under simulated maritime conditions, involving varying combinations of environmental motion and lighting states. Participant donning times, donning task errors and peak heart rates were observed for each trial. Across all conditions the mean donning time was 102.7 seconds (SD=39.6 sec), with a significant difference between donning time and suit manufacturer ($p<.0001$). Although overall mean donning time was below the 2-minute requirement, in total there was a 26.1% failure rate in the completion of full donning tasks within 2-minutes, with donning task error rates observed as high as 56.3%. These data suggest that the current standard should be revisited with the implementation of a more performance based, real-world applicable approach to immersion suit donning.



**Keywords:** Immersion Suit, Donning Time, Abandonment, Marine Safety

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As a proud Newfoundlander, born and raised, I have grown up steeped in the history and sad reality of maritime tragedies at the hands of our environment, both past and present. I am immensely proud to be part of a research discipline that has direct, practical, real-world application with the ability to help save lives, not only of Newfoundlanders and Canadians but individuals engaged in maritime activities around the world.


*"I have been impressed with the urgency of doing. Knowing is not enough; we must apply. Being willing is not enough; we must do."*

*- Leonardo da Vinci*

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| | |
|---|---|
| BPM | Beats Per Minute |
| CGSB | Canadian General Standards Board |
| FAO | Food and Agriculture Organization |
| FW | FitzWright |
| ILO | International Labour Organization |
| MUN | Memorial University of Newfoundland |
| MS | Mustang |
| OSSC | Offshore Safety and Survival Centre |
| PFD | Personal Flotation Device |
| TSBC | Transportation Safety Board of Canada |
| USD | United States Dollar |

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# CHAPTER 1: INTRODUCTION

The earth's surface is nearly three quarters covered by water. More than nine thousand years ago early seafarers were setting sail to explore the Aegean Sea, located between the mainlands of modern day Greece and Turkey (Bass, 1972). Over time humans learned the value and importance of large bodies of water and their multitude of social and economic benefits which could be exploited once seafaring skills were developed. From the primitive foraging of waters by early humans, to the establishment of the Columbian Exchange between the New and Old Worlds, to modern day aquaculture and natural resource exploration and extraction there is, and has historically been, a massive importance placed upon human activity on, adjacent to, and above water. Some of the most important contributors to modern civilization, globalization and the world's economy are dependent on humans operating within marine environments and are sectors which continue to see dramatic growth.

In 2007 the total global value of seaborne trade was estimated to be 7.7 trillion United States Dollars (USD) (IHS Global Insight, 2009). In the same year ocean liner operations and shipbuilding were estimated to be 436.3 billion USD, generating 13.5 million direct and related jobs (IHS Global Insight, 2009). Between 2009 and 2015 more than 490 billion USD are expected to be spent on world offshore oil and gas drilling, an increase of over 25% from the previous eight years (Global Markets Direct, 2009). Commercial fishing world exports in 2008 reached a record high value of fish and fishery products at 102 billion USD, a staggering 83% increase from just eight years earlier (Food and Agriculture Organization [FAO], 2010). Considering the plethora of additional marine activities including international military operations, coast guards, commercial tourism, pleasure crafts, scientific and commercial research pursuits to name only a handful, it becomes apparent that society is heavily dependent upon human activity adjacent to and upon large bodies of water.

Outside of the Tropics, the majority of major bodies of water on the planet have temperatures lower than 20°C, well below suitable conditions for the human body to maintain homeostasis and thus prolonged exposure (Golden & Tipton, 2002). With large numbers of people working, living and being transported on and around marine environments where water temperatures and harsh surroundings are hazardous to life, the necessity for effective safety and protective equipment is clear. The marine safety industry is a multi-billion dollar sector which offers an endless array of products, services and equipment to a diverse market, with applications from large scale industrial operations to personal leisure activities. A flotation device and thermal coverage provide essential protection from the inherent dangers present in the event of cold water immersion. When in good operational condition, appropriately sized and donned correctly, an immersion suit (also commonly referred to as a "survival suit") is an effective device to combat the hazards of immersion in colder waters, ultimately lengthening the time of life preservation (Transport Canada, 2003).

Immersion suits are available in a number of designs, intended for a variation of applications and usages. This work focuses specifically on marine abandonment immersion suits donned in marine emergency situations. These one piece, full body watertight dry suits are not intended to be worn continuously while performing work at sea due to their bulky, heavy design and so are packed in carry bags and stored for use only when necessary. In an emergency, marine abandonment immersion suits (referred to from here on in this work interchangeably as "marine abandonment immersion suit(s)", "immersion suit(s)" and "suit(s)") are intended to be located and donned rapidly, providing the flotation and thermal protection needed in the event of direct immersion. However, simply possessing an immersion suit while at sea does not guarantee effective or complete protection, even if successfully accessed and donned.

Anecdotal evidence has shown that even when immersion suits are located nearby, problems with the suit system can arise, leading to unfavorable outcomes. Immersion suits are surprisingly fragile and even small flaws or minor damage can have serious consequences for the wearer during an emergency. It is of vital importance that when the suit is donned it creates a watertight barrier around the individual. There are several well documented problems which jeopardize the watertight integrity of an immersion suit that can lead to compromised thermal protection and flotation effectiveness. If an immersion suit is the incorrect size for the individual, water ingress is inevitable. A suit which is too large will be ineffective in creating tight seals around the wrists and face, permitting water leakage, as well as creating buoyancy control issues, affecting the individual's ability to remain upright and stable in the water. Conversely, a suit which is too small may not be able to contain the individual, affect their mobility and ultimately prevent the individual from properly sealing themselves within the suit, thereby permitting the ingress of water. It is of critical importance that immersion suits are in good physical condition and well maintained. Significant wear on the shell, small holes, torn and dried out seals, and zipper corrosion are some common issues which have the ability to severely compromise a suit's integrity.

Assuming an immersion suit is in newly manufactured condition and correctly sized for the individual intending to use it, there are still significant challenges to suit donning in an emergency situation. First and foremost an immersion suit must be successfully accessed and retrieved. Secondly, the individual intending to use the suit system must possess the knowledge and proficiency to correctly execute the tasks required to successfully don a suit. These tasks in and of themselves can pose great risk. In reality the conditions at sea in which an individual is required to don an immersion suit are potentially quite difficult and dangerous, making successful suit retrieval and donning arduous and even impossible. Incorporating immersion suit donning procedures in an emergency response plan and training regime is important for individuals who are at risk of direct contact with cold water. The ability to successfully locate, retrieve and correctly don an immersion suit on a vessel or an offshore installation in distress can mean the difference between life and death. In a scenario where time is of critical importance speed, accuracy and success of immersion suit donning tasks are imperative. Disseminating information to immersion suit users on important, practical topics ranging from proper maintenance and storage to periodic training, familiarization and donning procedures would help improve safety in an inherently dangerous environment.

Of all the occupations that require protection, particularly from cold shock, swimming failure and hypothermia, professional fishermen are most at risk (Brooks, 2003). Eighty-eight percent of all fishing deaths are caused by drowning or hypothermia (Sorum, 2006). The capsizing or sinking of small fishing vessels usually happens rapidly and the decision to abandon a vessel is often made quickly by panicked individuals, who in many cases have little warning and must don immersion suits quickly (Transportation Safety Board of Canada [TSBC], 2001).

The current Canadian standard for immersion suit systems (Canadian General Standards Board [CGSB], 2005) specifies that an individual must be able to successfully unpack and don an immersion suit without assistance, in two minutes or less (CAN/CGSB-65.16-2005). This standard does not stipulate if the two minute donning time is achievable or appropriate in real-world conditions at sea where immersion suits are intended to be used. Generally, safety and emergency response training facilities teach and test immersion suit donning to trainees in static conditions on land in stable, benign environments. Much like the national standard itself, this training approach does not necessarily reflect the realities or demands of an evacuation at sea in which individuals would be forced to don an immersion suit.

Current regulations regarding donning times do not address the dynamic, chaotic conditions usually present in a marine emergency. Given the great difference between the calm, stable, comfortable conditions of a typical practice and training environment when compared to the panicked, motion rich conditions of an actual marine emergency, intuition would suggest that there would be considerable benefit from establishing immersion suit standards, as well as physically testing and practicing donning skills in conditions as near to real as possible. With regards to marine environments, it is imperative that performance based standards are established and tailored to adequately reflect real-world situations individuals are likely to encounter during an emergency.

### 1.1. PURPOSE OF STUDY

The purpose of this study is to use an empirical research approach to determine whether individuals with similar experience, training and knowledge can successfully complete the tasks required to don a marine abandonment immersion suit under conditions that simulate circumstances found on a vessel at sea. The research has a broad application which reaches into many industries and sectors of the maritime trade. From regulatory bodies and professional mariners, to oil companies and recreational boating enthusiasts, the goal of this work is to better inform and prepare people for maritime emergencies. Experimental data will be compared and scrutinized against the two minute donning time requirement dictated by the current Canadian General Standards Board Immersion Suit Systems National Standard of Canada (CGSB, 2005).

### 1.2. SIGNIFICANCE OF STUDY

As far as could be determined, there is no empirical, peer-reviewed research published in the English language on marine abandonment immersion suit donning times. This study will provide fundamental quantitative data on the duration of time required to don marine abandonment immersion suits across a variety of simulated emergency conditions involving motion and lighting combinations. The results and conclusions from this research will address knowledge gaps which can inform regulators, manufacturers, safety and survival trainers and concerned individuals with the goal of better preparing persons for maritime emergencies, ultimately with the aim to help save lives.

### 1.3. RESEARCH QUESTION

This study will test the following hypothesis:

1. Can a novice successfully complete all tasks required to fully don a marine abandonment immersion suit within a two minute period, regardless of the environmental condition?

## 1.4. LIMITATIONS

There are several limitations in the experimental design that should be considered when interpreting these results:

1. It is nearly impossible to induce the physiological and psychological responses individuals would exhibit under a potentially life-threatening emergency scenario within a controlled laboratory environment. These experimental trials must be considered as simulated events.

2. The laboratory environment where data collection took place was dry, quiet and temperature controlled at approximately 20°C. All trials took place with the participant contained within a 2m x 2m platform with railings, a comparatively spacious setting and favourable environment to what may be found in many areas on a vessel or marine offshore platform during an emergency.

3. An acclimation period for each trial was included in the experimental design to ensure participants were both aware and accustomed to the motion and lightening combinations of a specific test condition. In reality, a vessel in peril at sea potentially has very random motions and unexpected, rapidly changing conditions. However, due to the nature of this experiment, the equipment involved and the tasks being carried out, a standardized acclimation period was implemented in each trial condition to maximize participant safety.

## 1.5. ASSUMPTIONS

The following assumptions are made in this experiment:

1. Simulated donning environments reflect the conditions and demands likely to be experienced during an emergency immersion suit donning event.

2. Learning effects inherent in a repeated measures research design will be mitigated by the randomization of trial order.

## 1.6. DEFINITIONS

| | |
|---|---|
| *Capsize:* | to turn over. |
| *Cold Water*: | a water temperature of 25°C or lower (Neifer, 2006). |
| *Down flood:* | the entry of seawater through any opening into the hull or superstructure of and undamaged vessel. |
| *Founder*: | to sink out of control. |
| *Heel/list*: | tilt to one side. |
| *Large Fishing Vessel*: | a commercial fishing vessel exceeding 24.4 meters in length or 150 Gross Tons (Canada Shipping Act, 2009). |
| *MAYDAY:* | international distress signal. |
| *Small Fishing Vessel:* | a commercial fishing vessel not exceeding 24.4 meters in length or 150 Gross Tons (Transport Canada, 2010). |

# CHAPTER 2: REVIEW OF LITERATURE

## 2.1. INTRODUCTION

Commercial fishing is one of the world's oldest professions and is widely considered to be the most dangerous occupation, with death rates well above other occupational groups (Brooks, Howard, & Neifer, 2005; Dzugan, 2010; FAO, 2005b; Laursen, Hansen, & Jensen, 2008; Lincoln, & Lucas, 2010; Roberts, 2004). There are a reported 43.5 million fishers and fish farmers globally (FAO, 2005a). Fishers, aquaculturists and those supplying services and goods to them assure the livelihoods and well-being of a total of approximately 520 million people, representing nearly eight percent of the world's population (FAO, 2005a). Each year, the global fishing industry experiences 24,000 deaths and 24 million non-fatal injuries (International Labour Organization [ILO], 2000). In various industrialized nations, occupational fatality rates have been reported to range from approximately sixteen to seventy-nine times higher than the occupational fatality rates of other sectors within the same country (Conway, 2006).

In Canada there are approximately 20,000 small fishing vessels and each year approximately 49 commercial fishing vessels are lost (TSBC, 2004b). In 2008 there were a total of 359 documented shipping accidents alone (TSBC, 2009). Annually, commercial fishing boats are frequently involved in more shipping accidents than any other classification of vessel. In 2008, ten of the total thirteen shipping accident fatalities in Canada involved fishing vessels (TSBC, 2009). The TSBC reported that the four main factors contributing to death in the Canadian fishing industry are persons falling overboard, foundering, capsizing and sinking of vessels, with more than ten fishermen's lives lost every year in Canadian waters specifically from drowning and hypothermia (TSBC, 2001). Often when a vessel sinks the crew is forced to abandon ship where protection from the environment and the threat of hypothermia plays a major factor in survival (TSBC, 2001).

## 2.2. IMMERSION IN COLD WATER

### 2.2.1. Cold Water Survival

For humans there is a narrow temperature range in which water feels completely comfortable, referred to as the thermo-neutral zone. For a resting human body this temperature range is from approximately 33.0°C to 34.0°C (Piantadosi, 2003). Golden and Tipton (2002) state that most oceans and major bodies of water of the world are cooler than the thermo-neutral water temperature for a naked human body. In fact, outside of the tropics the majority of water temperatures are below 20°C, thus human bodies will lose heat to the surrounding water. Neifer (2006) states that prolonged immersion in any water below 35°C will eventually lead to hypothermia.

In the North Atlantic Ocean water temperatures rarely exceed 15°C, even during the warmest period of the year (Piantadosi, 2003). Keatinge (1969) found that the human body begins cold shock responses at water temperatures below 25°C. Although cold water is defined at, or below 25°C, significant effects of cold water immersion occur in water below 15°C (Neifer, 2006). Death from drowning will occur in a lightly dressed individual, even while wearing a lifejacket approximately, one hour after immersion in a water temperature at 5°C, two hours in water at 10°C, or in six hours or less at 15°C (Golden, 1996). In reality there are numerous factors that affect survival times for an individual in cold water, including temperature differential, clothing insulation, rate of agitation of the water, body heat production by shivering and exercise, ratio of body mass to surface, subcutaneous fat thickness, state of physical fitness, diet prior to immersion, physical behavior and body posture in the water (Brooks, 2003). In a scenario where an individual is forced to abandon their vessel directly into cold water for an extended period of time, flotation assistance and thermal protection against exposure are crucial elements for survival.

### 2.2.2. Classifying Cause of Death

Until approximately sixty-five years ago death from cold water immersion was generally attributed to drowning, without taking into account the effects of cold water on the human body. However, Golden and Tipton (2002) note that there is now a preoccupation with hypothermia and protection from it, while in reality it is not necessarily the only hazard, and perhaps not even the greatest threat from cold water immersion. This area of research is often promoted by media, safety equipment manufactures and regulatory bodies, which consequently shapes the understanding of the general public. An individual's physical incapacitation which leads to swim failure (drowning) is one of the major attributions of open water fatalities, however, drowning is only the end result of a series of physiological responses which are likely to be the actual cause of death from immersion in cold water (Golden & Tipton, 2002). Golden and Hervey (1981) identified four distinct stages in which a human immersed in cold water may become incapacitated and die: (1) initial immersion (cold shock), (2) short term immersion (swimming failure), (3) Long-term immersion(hypothermia), and (4) Post-rescue collapse. Focus has traditionally been centered on hypothermia, which has greatly influenced survival policies, regulations and equipment manufacturers while the other three stages were considered exclusively of academic interest (Brooks, McCabe, & Lamont, 2001). There is still little consideration given to the physiological impact resulting from the first two stages of immersion in the design of emergency equipment (Brooks, 2003). Although hypothermia is a serious threat to survival when immersed in cold water, it is important to understand that this is merely a piece of a puzzle which contains many parts. It is easy and convenient to label a victim's death to have occurred from hypothermia, when usually there are more factors at play.

## 2.3. PROTECTION AGAINST COLD WATER IMMERSION

Immersion suits provide the best protection from cold and exposure when immersed in water (Transport Canada, 2003). Immersion suits, also referred to as anti-exposure suits, marine abandonment suits, poppy suits and survival suits are in essence a full body garment designed to cover the body of an individual in a water tight, or semi-water tight enclosure to prevent the occurrence of cold responses (Brooks, 2003). In the event that an individual is immersed in cold water as the result of accident, the primary functions of immersion suits are to provide flotation and thermal protection (Brooks, 1986; Gaul, & Mekjavic, 1987).

These suits, as defined by the Canadian General Standards Board Immersion Suit Systems standard fall into two categories: (1) constant wear immersion suits, and (2) marine abandonment immersion suits (CGSB, 2005). Constant wear immersion suits are designed to be routinely worn for activities on or near water in anticipation of accidental immersion in water, but permit physical activity by the wearer to such an extent that actions may be undertaken without undue encumbrance. These suits are generally lighter, less bulky and provide less thermal protection than marine abandonment suits. Marine abandonment immersion suits are designed to be rapidly unpacked and donned in the event of an evacuation. Both abandonment and constant wear immersion suits must have the following characteristics:

1. Reduce thermal shock upon entry into cold water.
2. Delay the onset of hypothermia during immersion in cold water.
3. Provide flotation and reduce the risk of drowning.
4. Do not impair the wearers' ability to perform fundamental survival actions.

## 2.4. HISTORY

### 2.4.1. Early Records of Death from Cold Water & Initial Safety Equipment

From the biblical era until the middle of the twentieth century death from cold water immersion was not well known or understood and was generally overlooked and ignored (Brooks et al., 2001). Initial observations of death from cold water exposure have been noted and discriminated from drowning as far back as ancient times. In 450 B.C. death from cold water immersion was specifically noted by Greek historian and storyteller Herodotus of Halicarnassus who wrote "those who could not swim perished from that cause, others from cold" (Brooks, 2003, p.7). However, it was not until the nineteenth century, after thousands of years of maritime activity and a countless number of lives lost at sea, when initial lifesaving apparatuses were first patented and widely employed in the western world. In 1854 British Captain John Ross Ward adapted an 18th century design by Frenchman Col de Galacy and developed a ground-breaking piece of marine safety equipment: the lifejacket (Golden & Tipton, 2002). The apparatus, which was made for the United Kingdom's Royal National Lifeboat Institution, was constructed of cork and configured to be worn as a vest around an individual, similar to present day lifejacket designs. Cork life vests flourished and were still being used up to and during World War II, some ninety years later (Brooks, 1995). In 1869 a revolutionary life-saving apparatus design was patented, fitting the modern day requirements and construction of an immersion suit. Its design integrated a waterproof full body suit, a lifejacket, head protection, a signaling device and arm paddles for mobility and control in water ("English Mechanic", 1869).

### 2.4.2. The Twentieth Century

Events which transpired in the first half of the twentieth century and the consequences of a multitude of tragedies lead to the realization that drastic change was needed in the maritime world. It was not until the second half of the century when the effects of cold water immersion on the human body were widely accepted and understood. Repeatedly, even when presented with clear indicators and irrefutable proof, cold water immersion as a cause of death was generally overlooked or ignored.

After the sinking of the Titanic in April of 1912 with the loss of over 1400 lives, an investigative committee was established to ensure a similar tragedy would not be repeated. The committee members, similar to the scientific community and the general public, knew little of the consequences of cold water immersion on the human body and completely ignored one survivor's account that even the victims wearing lifebelts in the frigid, but calm water had died of cold (Brooks, 2008). In fact, none of the 1489 people who entered the water survived more than an hour even though most were wearing life jackets (Golden & Tipton, 2002). Survivors later described how the cries for help from those in the water had all but disappeared within half an hour (Golden & Tipton, 2002). In 1914, two years after the sinking of the Titanic, the International Maritime Organization was established, which eventually produced the Safety of Life at Sea regulations, the first international maritime code of its kind. However, during committee discussions no thought was given to personal thermal protection, the focus was on floating in water and not the effect of the cold (Tipton & Brooks, 2008).

### 2.4.3. World War I & II

In the thirty-one year period encompassing the two world wars numerous immersion suits were manufactured with their designs based on practical trials and experiments. Despite this documented research and participation from various private, academic and military intuitions and the tens of thousands of individuals who perished in cold water environments during this relatively short time span, the proponents struggled to attract attention and to have immersion suits widely adopted (Brooks, 2003). Although the knowledge and technology existed to widely implement the use of an effective immersion suit design, widespread distribution did not occur. In fact Brooks (2003) states that during the Second World War none of the Navies on the Allied or Axis side employed immersion suits. Despite the enormous loss of life during the wars, the general focus and importance was placed, as it had been for hundreds of years, on the prevention of drowning and not on protection from cold water exposure (Golden & Tipton, 2002).

### 2.4.4. Post World War II

The aftermath of World War II spawned a boom in scientific research and increased attention with regards to the consequences of cold water immersion in relation to human survival. Shortly after the end of the war, published reports and an expanding body of scientific knowledge helped lay the foundation for human physiological research in extreme conditions, as well as highlighting the inadequacies of the safety equipment and designs which lead to considerable loss of life in maritime environments (Brooks, 2003). It was soon generally accepted that hypothermia was the principle cause of death from sudden cold water immersion and that the best protection was a dry suit. International companies began to design and manufacture immersion suits for sale, yet it was not until the 1980's that an international immersion suit standard was developed and disseminated (International Maritime Organization, 1983).

Originally immersion suits were developed for military application, however in the post-world war world the demand for quality immersion suits for commercial uses increased dramatically. The expanding offshore oil and maritime industries required more effective and better designed immersion suits in large quantities (Brooks, 2003). A nineteen eighties report described the poor quality of even brand new immersion suits citing issues still facing manufactures today: leaking, zippers seizing up, ties on suits and gloves tearing on initial donning and little concern shown to sizing and fit (Brooks, 1986). By the mid-nineties newer, more effective materials were replacing the fabrics originally used for the outer shells and the quality of waterproof zippers improved. However, the durability and comfort of neck and wrist seals continued to be problematic. The equipment in service for both military and commercial operations had performed "surprisingly poorly" during real accidents (Brooks, 2008).

### 2.4.5. 21$^{st}$ Century Immersion Suits: Old Designs, Old Problems

The modern concept and design of immersion suits date back to World War II (Vanggaard, 2007). These suits were constructed of leather or neoprene fabric, closed by a waterproof zipper with tight rubber seals at the neck and wrists (Brooks, 2003). The same general design of the immersion suit developed during World War II is still common today. A Canadian research trial performed in 1943 identified issues critical to suit construction: lightness, simplicity, wrist and neck seals, zippers, closure and drawstrings, ease of donning, integral or separate gloves and flammability (Hiscock, 1980). Manufactures are continually researching and refining immersion suit materials and designs, however, immersion suits generally exhibit the same inadequacies and problems they did over seventy years ago.

## 2.5. IMMERSION SUIT CHARACTERISTICS

### 2.5.1. Immersion Suit Sizing

Immersion suit sizing criteria is based on stature and mass ranges. According to the current Canadian National Standard (CGSB, 2005), immersion suits are to be available in three adult sizes (small, universal and jumbo), one child size as well as individualized custom fits. "Universal" suits are available for general and unspecified users using a "one size fits most" approach (see Table 2-1). A Transport Canada report suggested that the majority of suits purchased are the universal size (TSBC, 2007). In practice, liberal size ranges create a risk for individuals at either end of the size range, potentially resulting in improper fit, thereby placing individuals at risk. The use of other criteria beyond stature and mass might better aid suit design, improving the fit of seals and the suits in general. This approach may also require an increase of standard available suit sizing options, eliminating the principle of a universal suit size (TSBC, 2007).

**Table 2-1: CGSB Marine Abandonment Suit Sizes (CAN/CGSB-65.16-2005)**

| Suit Size | Stature (cm) | Mass (kg) |
|---|---|---|
| **Adult** | | |
| Small | 120 to 170 | 40 to 100 |
| Universal | 150 to 200 | 50 to 150 |
| Jumbo | 170 to 220 | 100 to 150 or greater |
| **Child** | 100 to 150 | 18 to 40 |
| **Custom** | Any height | Any mass |

### 2.5.2. Hand Protection

There has been a vast amount of research done on the loss of manual performance in the first 10-15 minutes of immersion. During exposure to cold environments vasoconstriction reduces blood flow throughout the body. This reduced blood flow and temperature renders the limbs useless, particularly the hands and fingers, decreasing the chances of successfully completing vital tasks reliant on manual strength or dexterity.

Various mitten and glove designs have been utilized for immersion suits to combat loss of dexterity in the hands in cold environments, however, there are trade-offs with each design. Mittens have a smaller hand and finger surface which provides increased thermal protection, but are less dexterous than gloves. Conversely, gloves have a larger hand and finger surface area, thus contributing to an increase in heat loss compared to mittens, although providing greater finger mobility, facilitating better performance in tasks needing increased dexterity. There is also the question of incorporating the hand protection as an integral part of the suit or separately, making it necessary to don the gloves after the suit is on. Brooks (2008) states that gloves (or mittens) are better separated and stowed on the sleeve of the suit rather than incorporating them as an integral part of the suit. This allows the hands to be free and able to carry out emergency tasks that could otherwise be hindered by bulky gloves or mittens.

The trade-off created by the inverse relationship between traditional hand protection and manual dexterity has yet to be adequately addressed. With no physical protection of the hands, one's tactility and dexterity is quickly reduced by cold water immersion, while the ability to perform even the simplest tasks may be severely compromised. Conversely, when hands are physically protected the generally bulky construction of immersion suit gloves or mittens reduce an individual's dexterity and ability to perform necessary tasks, their presence ultimately being counterproductive.

During the sinking of the Estonia in the Baltic Sea people onboard accessed emergency flares which were vacuum packed in polythene bags. However these flares were unusable simply because the individuals exposed to the cold with no hand protection did not have the grip strength or tactility required to open the bags. One survivor described his frustration with poor manual dexterity which lead him to try his teeth to open the bags, eventually pulling out several teeth and failing to successfully access any of the flares ("Joint Accident Investigation Commission", 1997). From this example one would assume that a combination of packaging redesign and/or the presence of hand protection would have likely remedied the situation, producing a successful outcome. However, there have been various documented emergency scenarios that conflict with this concept, revealing that hand protection can be detrimental. In 1998 the small Canadian fishing vessel *Atlantic Prize* listed heavily, downflooded and began to sink while returning to port from the Grand Banks off the island of Newfoundland. All crew successfully located and donned immersion suits during their abandonment procedures, however, it was noted that they struggled to pick up, control and launch the life raft using the handholds due to the bulky design of their immersion suit gloves (TSBC, 2000a). These examples demonstrate that both bare hands and hands encumbered by traditional bulky protection can prevent individuals from executing relatively simple tasks vital to survival during an emergency, and thus stressing the need for increased attention and development.

The hand in general is particularly hard to protect as hand protection such as gloves and mittens only insulate hands and fingers. When an individual's core body temperature decreases effective long-term thermal protection of the hands and fingers is made difficult because of vasoconstriction (Golden & Tipton, 2002). The root cause of the problem is the necessity to maintain adequate core body temperature, which in turn preserves effective blood flow throughout the body and allows peripheral tissues within the hand and feet to retain heat. In reality, external hand protection acts as a secondary player in maintaining the temperature of the hands and fingers because it is directly affected by core body temperature and the circulatory system's ability to maintain adequate blood flow.

### 2.5.3. Importance of Appropriately Fitted, Maintained and Donned Immersion Suits

The watertight integrity of immersion suits is a critical factor (Brooks et al., 2001). Ensuring one's immersion suit is the correct size, well maintained and donned correctly are vital elements in preventing water ingress, increasing thermal protection and ultimately facilitating survival. Even when a vessel is carrying immersion suits for one hundred percent of its crew associated risks still remain.

The thermal conductivity of water is about twenty-five times that of air, though this effect is reduced due to the body's physiological responses to cold water exposure (shivering, vasoconstriction, etc.). Typically humans cool anywhere from 2-5 times faster in water compared to air of the same temperature (Brooks, 2003). A leakage of water into an immersion suit of as little as 500 grams results in a 30% loss of thermal protection, 40% for a leak of 1000g and nearly 60% for a leak of 3000g (Allan, Higgenbottam, & Redman, 1985). Ensuring one's immersion suit is in good condition as well as donned correctly with tight seals, maximizes thermal protection and improves one's chances of survival. Brooks et al. (2001) note that instructors at a Canadian survival training center routinely take a roll of duct tape to sea with them and offer anybody with loose fitting seals the opportunity to tighten them up using the duct tape. A particularly fragile and easily overlooked component of immersion suits are their zippers. Easily damaged and corroded by repeated use, storage and exposure to the elements in training, the importance of a properly maintained zipper in keeping dry and warm when immersed in cold water is evident (TSBC, 2003). All aforementioned considerations must be addressed in order to maximize an immersion suit's watertight integrity in order to increase the wearer's probability of survival.

### 2.5.4. Critical Donning Tasks

Completing the initial donning tasks correctly and quickly provides essential, vital physical protection of the most important areas of the body (see Figure 2-1). Successfully unpacking, getting ones limbs within the suit and fully sealing the zipper ensures that the individual has a watertight, insulated, flotation capsule when the suit is in good condition, properly sized and correctly donned.

**Figure 2-1: Completion of Critical Tasks**

Following completion of these donning tasks the only directly exposed areas of the body are the hands and part of the face. Although important, thermal protection of the hands is not essential to survival, providing hand function is maintained for performing crucial tasks (Brooks, 2003). Gloves and mittens can provide thermal protection, however, as discussed earlier, traditional immersion suit hand protection designs are often bulky and greatly reduce hand and finger function, which have the potential to hinder the ability to carry out survival operations. There are clear trade-offs between donning traditional hand protection or leaving the hands bare and exposed. An immersion suit must be considered as a complete system and the Canadian Standard takes into account the immersion suit as a whole, including hand protection. Therefore, when examining immersion suit donning tasks in terms of a hierarchal arrangement, the actions which provide the highest benefits should receive the greatest attention.

### 2.6. CARRIAGE AND DONNING REGULATIONS

Currently, Transport Canada does not require small fishing vessels (of which there are approximately 19,500 across Canada) to carry immersion suits as it does with large fishing vessels (TSBC, 2007). Immersion suits are classified as alternative safety equipment, which is promoted for use on vessels by coast guard, safety training facilities and even Transport Canada, however despite this immersion suits are not required by law to be carried onboard small fishing vessels. The TSBC has expressed its concern over the slow review progress in this area because statistics have continually shown that cold water immersion is having a deadly impact on Canadian fishermen working on small fishing vessels. Although the national regulations do not require immersion suits onboard small fishing vessels, in 1995 the province of British Columbia made it mandatory that every fishing vessel (regardless of size) must carry a good quality, proper fitting immersion suit for each crewmember onboard ("Workers Compensation Act", 1996). No such regulation exists in Newfoundland and Labrador.

## 2.7. SAFETY CULTURE

Few would dispute that fishermen participate in an inherently dangerous and hazardous occupation. One of the problems noted with commercial fishermen in North America is that many trivialize or totally deny the dangers associated with their occupation (Poggie & Pollnac, 1988; Poggie, Pollnac, & Jones, 1995; Poggie, Pollnac, & VanDusen, 1996; Pollnac, Poggie, & VanDusen, 1995; Binkley, 1991; 1995). This stems from a long history of tragedy and life lost at sea, where death has traditionally been an accepted occurrence and is considered to be an occupational hazard (Brooks, 2003).

In general people tend to underestimate risk, and with each successive safely completed voyage a person's perception that chances of an accident are low are validated. An individual's increased comfort level and familiarization with an environment or system is associated with an increase in complacency leading to the higher likelihood of unsafe practices, and thus placing a vessel at greater risk (TSBC, 2004b). Poggie and Pollnac (1997) note that even when fishermen admit the dangers of their occupation they claim that danger affects other fishermen, but not themselves, because they are careful.

The TSBC states that unsafe practices are not uncommon on small fishing vessels and can be due to a combination of reasons, including the absence of a safety culture, misperception of risk and a lack of awareness (TSBC, 2008). It is suggested that Marine Emergency Duties courses within Canada reinforce the idea that risk and safety are embedded in the vessel and its technologies, and do not directly deal with the risks of day-to-day fishing (Power, 2008). Brooks et al. (2001) found that generally, individuals who either work on or fly over water have confidence in immersion suits and believe that they would survive in them in case of an incident. They go on to note that these results were found despite considerable anecdotal evidence that survival suits were poorly constructed, leaked badly and had a lot of general customer dissatisfaction with fit, comfort and sartorial elegance. A study looking at fishermen's perceptions of occupational dangers found that individuals subjected to the safety course had a heightened concern of the dangers of occupational fishing compared to those who had not attended the course (Poggie & Pollnac, 1997). Farther afield, outside of the commercial fishing industry, maritime safety and water safety in general is an important topic. In the twenty year span between 1978 and 1998, more than 5300 passengers were killed in ferry accidents around the world, making ferry travel ten times more dangerous than air travel (Faith, 1998). Golden and Tipton (2002) state that globally, there are still approximately 140,000 open water deaths per year, even with the increased sophistication of coast guards, training programs and tighter safety regulations. A better safety culture must grow within the industry for the technology and research to truly have a positive impact.

## 2.8. SEAFARER TRAINING

### 2.8.1. Training, Education & Certification

Over the past decade, stricter training requirements have come into effect for persons who own, operate or work on fishing vessels in Canada. Small commercial vessel owner/operators must comply with the Marine Personal Regulations (SOR/2007-115) found under Section 100 of the current Canada Shipping Act (Canada Shipping Act, 2009). The master and the authorized representative of a vessel must ensure that before an individual is assigned to a particular duty, he receives the onboard familiarization and safety training set out in the Maine Emergency Duties Training (Transport Canada, 2007b). Applicable certificates range from a Pleasure Craft Operator Card to several levels of Marine Emergency Duties courses which cover various safety and emergency topics. Certificates are issued for vessels based on criteria such as vessel type, length, weight and operating areas. Ultimately, it is the duty of the master and the vessel's authorized representative to ensure that crews are trained and adequately certified to perform their assigned duties with regards to onboard vessel operations. All commercial and fishing vessels, regardless of length, must have a certified master (Transport Canada, 2007a).

Training, education and certification are specifically tailored for the many areas of seafaring. From ship cooks to master mariners there are specific requirements for a plethora of maritime positions to ensure that individuals are sufficiently qualified for any given job. Each certification has differing requirements, varying amounts of time spent in classroom education and hands on sessions, which include both practical and written examinations to verify an adequate level of knowledge and skill. Certifications may or may not require periodic recertification and continued education depending on the level. There are many avenues available for education including provincial fisheries schools, community colleges and various public and private organizations which offer courses and training.

Certification is not required for persons working on a vessel in a position such as a deckhand until they have worked a certain amount of time at sea or if the minimum required number of crew have completed training for a particular vessel. This allows for individuals within Canada to legally assume positions onboard commercial fishing vessels that potentially have no background or training in the field, no experience on water, fishing vessel operations or safety and emergency procedures. It is the duty of the operator of a vessel to ensure the crew is adequately trained and certified. Although safety and training regulations and governance have drastically improved, there are still clear regulatory shortcomings when untrained novice individuals can legally be hired to work in one of the most dangerous occupations on the planet.

### 2.8.2. Training Facilities

Within Canada, marine and offshore installation safety and emergency response training facilities are set up and run independently of one another. These facilities must be accredited by Transport Canada, industry organizations such as the Canadian Association of Petroleum Producers, and provincial education authorities. In Newfoundland and Labrador, the Marine Institute of Memorial University (MUN) provides general and advanced marine training for ship officers and crew, and marine aspects of offshore petroleum installation operation. Through its Offshore Safety and Survival Centre (OSSC) and satellite facilities, the Marine Institute provides specialized training in marine emergency duties including medical first aid and care, vessel firefighting and escape, marine survival, Search and Rescue, and land based residential, commercial, and industrial and aircraft fire fighting. A range of safety and emergency response training courses for the offshore petroleum, marine transportation, aviation, fishing and land based industries are offered. Training courses for respective areas are designed and implemented by the OSSC, which are approved by national and international regulatory or other external approving agencies. Other Canadian provinces and countries have similarly accredited facilities and training programs structured and operated in the same fashion.

### 2.8.3. Immersion Suit Training

Immersion suit education and training is dealt with in a variety of courses which allocate varying amounts of time on the topic. Depending on the specific requirements for a course, a total time of anywhere from one to seven hours may be spent specifically on immersion suits. In essence, immersion suit instruction can be broken down into two parts: (1) classroom education, and (2) practical, hands-on training.

Typically, classroom immersion suit education is taught within a two hour training session dealing with the topics of personal buoyancy and flotation. This session includes such issues as personal flotation devices (PFD), cold water survival strategies and water entry and maneuvering. Of the two hours spent on this section approximately one hour deals specifically with immersion suits. Information relayed in this session ranges from the very basics of the purpose of an immersion suit and its design features to donning instructions and demonstrations of proper procedures for entering, maneuvering and extending survival times in water.

Depending on the specific course, hands-on, practical sessions with the suit may be anywhere from one to five hours in duration. Generally, each course has approximately one hour allocated to the donning of immersion suits. To use the OSSC as an example, many of their courses require students to don a suit once in a lighted, dry condition and the second time in the dark. Each student is required to fully don their immersion suit successfully in 2-minutes as per the National Standard of Canada (CGSB, 2005). For reasons of practicality and convenience the majority of training facilities train and test this 2-minute standard with its students in a stable, benign environment. However these brief donning scenarios do not represent the difficulties of evacuations at sea and leave a large gap between training and reality.

After successfully completing the donning test, students move on to in-water training within a controlled, indoor pool where basic skills are taught and practiced both individually and within groups. Depending on the course and specific requirements, up to five hours could be spent using immersion suits in other circumstances, including life raft exercises, open-ocean swimming and various rescue scenarios. Training facilities like the OSSC also offer community based ocean condition training performed in the local ports of communities around Newfoundland.

### 2.8.4. Vessel Emergency Drills

Transport Canada recommends "periodic" emergency drills as well as regular practice and training in the use of the lifesaving and firefighting equipment carried onboard all ships; a vague requirement at best. In reality it is up to the owner and operator of each vessel to ensure that the crew has sufficient knowledge and awareness of a particular vessel's equipment and emergency procedures. With regards to immersion suits, a TSBC investigation revealed that practice drills are rarely carried out and that suits are usually purchased and then stowed until an emergency arises (TSBC, 2007). Furthermore, the buyers seldom educate themselves on the suits instructions, functions and limitations, and are not tried for size (TSBC, 2007).

## 2.9. CANADIAN FISHING VESSEL ANECDOTAL EVIDENCE

The body of anecdotal evidence which has accumulated over the centuries and the abundance of scientific research conducted over the past one hundred years illustrates the dangers of immersion in cold water. There are volumes of documented, real-world incidents in which individuals have perished in cold water, none more poignant than several high profile, large scale tragedies of the twentieth century. The following is a sample of evidence which specifically involves fishing vessel incidents within Canadian waters in which immersion suits, or lack thereof, had an impact on the outcome of an incident. Information has been cited from official TSBC marine investigation reports. They are broken into seven categories:

1. No Immersion Suit(s) Onboard
2. Failure to Access Immersion Suit(s)
3. Poorly Maintained Immersion Suit(s)
4. Incorrectly Sized Immersion Suit(s)
5. Inappropriate Immersion Suit Design for Environment
6. Inadequate Crew Knowledge of Safety Equipment
7. Immersion Suit Use Leading to Survival

### 2.9.1. No Immersion Suit(s) Onboard

The absolute worst-case scenario occurs when an individual is forced to abandon a vessel directly into cold water without thermal protection or flotation. The cold shock response begins at water temperatures below 25°C and significantly worsens at temperaturesbelow15°C (Keatinge, 1969; Tipton, 1992; Tipton, Stubbs, & Elliot, 1991).

Water temperatures of 15°C are rarely exceeded in the North Atlantic Ocean throughout the year (Piantadosi, 2003). In relation to small commercial fishing vessels, the following is an example of a vessel equipped with minimal safety equipment, with a crew who were new and unfamiliar with the vessel in which they were sailing.

The small fishing vessel *Lannie & Sisters II* sank off the coast of Newfoundland in September of 2006 (TSBC, 2008). Originally the crew of five had left port intending to fish mackerel, however, within nine hours of beginning the journey they were told by the owner to return to port because the entire crew's employment was terminated. The vessel first stopped in Fleur de Lys to drop off two crewmembers and a 3.3 meter boat and then sailed to Lushes Bight where the remainder of the crew departed while removing all PFDs, immersion suits, gas for a portable generator and twelve distress flares from the vessel. Two new individuals were instructed to sail the vessel to its home port fifty-seven nautical miles away the following morning. The two new crewmembers were briefed by members of the recently terminated fishing crew about some of the issues with the vessel. It was documented that the two new delivery crew was made aware of a steady ingress of water through the stuffing box and problems with the vessel's transmission. They were also shown the activation switch for the bilge pump which had been changed since being in port. With limited familiarity of the vessel, and minimal safety equipment onboard the two delivery crew began their journey crossing Notre Dame Bay. It was reported that there were no PFDs onboard at the time of the voyage and it is unknown whether the new crew were aware that these devices had been removed. When the vessel was overdue for arrival in Mings Bight, Search and Rescue and various fishing vessels in the area were notified just after midnight to begin a search. Although *Lannie & Sisters II* was equipped with two VHF radiotelephones, a mobile phone and twelve flares, no distress signal was received. The vessel was discovered partially submerged the next morning and later that afternoon the body of one crewmember was found, while the second crew member is still missing and presumed drowned. The weather conditions at the time of the incident were reported as being good, with winds 5 to 15 knots and an air temperature earlier that day between 11°C and 18°C. The accident report concludes that due to the inadequate maintenance and upkeep of the stuffing box the vessel likely experienced a steady ingress of water and eventually foundered. However, because there were no survivors or witnesses, this event and its occurrence is only speculation.

The sinking of *Lannie & Sisters II* highlights the dangers of operating a vessel at sea. Even in a scenario with a seemingly short duration on the water, a straightforward delivery in benign weather conditions, with no fishing activity occurring turned into a tragedy. The general lack of safety culture which is so consistently documented within the fishing industry is evident throughout this report. Firstly, the vessel was apparently stripped of all safety equipment, even the most basic and essential items including PFDs. Secondly, the vessel went to sea with known maintenance issues, with no great concern expressed from either of the parties. Thirdly, the two individuals hired had limited familiarity with the vessel, its operating systems and equipment. There are many factors at play in this scenario. The presence of immersion suits, with their inherent thermal protection and flotation properties, would have increased survival chances if the two individuals were able to don them successfully. This obvious failure to follow basic safety practices transformed a straightforward sailing of a small fishing vessel back to its home port into its sinking and the tragic loss of two lives.

### 2.9.2. Failure to Access Immersion Suit(s)

There have been instances where there was adequate safety equipment onboard a vessel, however, the crew were unable to access or don the equipment. Due to the generally rapid sinking of small vessels, placement of immersion suits and their easy accessibility onboard is essential. A popular storage area crews use onboard small fishing boats for their immersion suits are in their cabins, an area which may be inaccessible during an emergency (TSBC, 2006). There is no "best" storage area for immersion suits due to the high variability of emergency scenarios and crew member locations. This introduces the element of pure chance, complicating the planning of systematic vessel evacuation procedures.

The small fishing vessel *Pacific Charmer* sank off the coast of Vancouver Island in December of 1997 in calm waters at a temperature of 6.6°C with four crewmembers and one Department of Fisheries and Oceans Canada (DFO) observer onboard (TSBC, 2000c). The report noted that the vessel was carrying life-saving equipment in-excess of the regulations: two six-person inflatable life rafts, two lifebuoys, nine PFD, smoke signals and flares, a four person rigid fiberglass boat as well as an immersion suit for each member onboard, which were stored in the crews accommodation area located on the main deck. It is estimated that shortly before 01:30 the vessels center of gravity was compromised, heeling gradually to starboard and continuing to an angle of approximately forty degrees. The continual heeling was caused by a shift in the contents of the ship and stowage of equipment and the vessel subsequently downflooded and sank. It was reported that seawater entered the crews' accommodation area, among other locations and the crewmembers did not have enough time to retrieve the survival equipment or broadcast a distress message due to the rapid sinking of the vessel. The heel angle progressively increased and the five individuals quickly abandoned the overturning vessel as it started to sink. All individuals onboard entered the water in only the jeans and sweatshirts in which they had been working, save for the DFO observer who was wearing an inflatable PFD. The Emergency Position Indication Radio Beacon from the vessel began automatically transmitting soon after the vessel sank and was first received by authorities by 01:40. Commercial fishing vessels in the area were notified of the possible emergency situation and attempted to make contact with the *Pacific Charmer*, without success. Shortly thereafter Canadian and American rescue personnel were dispatched via water and air. Approximately one and a half hours after the estimated sinking time two of the crew were found alive, as well as the DFO observer who was wearing a PFD. Sometime later a third member of the vessel was also recovered alive. The recovered crewmembers were conscious, while the DFO observer was unconscious, and all required medical attention. The bodies of the fourth and fifth members of the vessel were found floating unconscious face down in the water. The three surviving members of the vessel were treated for hypothermia and survived while the cause of death of the two crew were classified as succumbing to hypothermia, and drowning.

#### 2.9.3. Poorly Maintained Immersion Suit(s)

There have been numerous accidents involving vessels carrying immersion suits which in an emergency have been successfully accessed, however the suits were in poor condition or damaged in one form or another. Immersion suits must be properly maintained to ensure maximum effectiveness, reducing the likelihood of water ingress and increasing chances of survival.

An example of poorly maintained immersion suits having a direct impact in a maritime accident is in the case of the fishing vessel *Hili-Kum* (TSBC, 1997). In April of 1995 the vessel and its three crew was sailing through the Hecate Strait off the coast of British Columbia and encountered deteriorating weather, with gale to storm force winds and rough seas. There were large amounts of water spraying on the afterdeck and the stern began settling ever deeper into the water. The captain soon switched on the bilge pump and ordered the cook to retrieve the immersion suits. All three crewmembers donned immersion suits, however the zippers on the captain's and deckhand's suits were defective. The cook transmitted a MAYDAY message at 01:28 and lowered the inflatable liferaft onto the vessels foredeck. The crew then entered the six person inflatable liferaft, cut the painter line and successfully drifted away from the sinking vessel. Sometime later the liferaft capsized and the crew crawled out of the canopy and onto the overturned liferaft. The cook, who had received survival training, was able to right the liferaft and board it although the other two members were unable to hold on. The raft drifted away in the strong winds with only the cook onboard.

Throughout the night the liferaft capsized several times but the cook was able to right and successfully board it each time. He was rescued, alive over six hours after the MAYDAY signal was sent. It was later revealed that the captain and deckhand, who were both wearing defective immersion suits, succumbed to hypothermia and drowned. The captain's body was found wearing an immersion suit but the body of the deckhand was never discovered. An empty immersion suit was found floating in the water, suggesting that the suit was not donned properly, was improperly sized for the individual, or both.

It was reported that the two defective immersion suits were purchased from another vessel in 1978, some seventeen years earlier. That vessel sank in November of 1978 and the immersion suits were not recovered until the vessel was salvaged in April of 1979. It could not be confirmed that any maintenance was done on the suits after they were recovered. The suit worn by the survivor was in good condition and appeared to be a newer production than the other two suits, which were classified being in fair condition. The zippers of the two victims' suits were unserviceable, missing several teeth, corroded, torn and stuck, attributable to the corrosion by salt water and lack of lubrication. Poggie and Pollnac (1997) note that although fishermen do comply with new safety regulations, by attaining the required safety equipment, there is in many cases evidence that compliance is superficial and the equipment is only purchased to satisfy said regulations, without obtaining any extensive training of how to use it. Ensuring that safety equipment in good working order is essential, especially immersion suits, which are prone to wear and tear. The *Hili-Kum* incident demonstrates that although the crew successfully located and donned immersion suits, the poor condition in which they were in lead to an ingress of water and ultimately the death of two individuals.

### 2.9.4. Incorrectly Sized Immersion Suit(s)

Immersion suits generally come in liberal sizes based on stature and mass ranges. Even though an individual may fall within the manufacturer's size specification it does not guarantee that the suit will fit properly, even if it is brand new and flawless. The following is an incident in which the immersion suits onboard a vessel in peril were both insufficient in number and inadequate sizes for the individuals involved.

On an October night in 2001 the small fishing vessel *Kella-Lee* was sailing in Queen Charlotte Sound, British Columbia carrying a crew of four (TSBC, 2004a). They encountered progressively deteriorating weather with increasingly high winds and rough seas causing the vessel to roll and pitch heavily. Shortly after 22:00 three of the deckhands onboard awoke to a loud banging noise and with great difficulty due to the vessel's movement, two of the three immediately donned immersion suits. The deckhands made their way to the wheelhouse to meet the owner/operator who was on watch. Water was downflooding into the engine compartment through the deck hatches and the vessel soon heeled quickly to starboard while the violent seas and heaving swells continued to toss the vessel about with the water level in the hold increasing. The winds were estimated to be between 80-90 knots at the time of the occurrence with 8-10 meter swells. The third deckhand donned the last immersion suit and the operator/owner, who was wearing no thermal protection, gave the order to abandon the severely listing vessel while transmitting a MAYDAY distress call. The liferaft was successfully deployed and two deckhands as well as the owner/operator climbed into the raft, however the third deckhand failed to board and clung to the outside of the raft from the water. The liferaft eventually overturned leaving all four clinging to the sides, while continuously trying to avoid being struck by the boom of the ship. One deckhand and the owner/operator had to let go of the liferaft for this reason and were immediately swept away. Later one of the two remaining deckhands managed to right the life raft and climb onboard while the other member was swept away. Eventually the vessel sank, leaving only one crewmember onboard the liferaft.

Ultimately two deckhands survived. The first survivor was rescued from the water 7.5 hours after the MAYDAY was broadcast, while the second was rescued from the liferaft 17.5 hours after the distress call. The bodies of the third deckhand and owner/operator of the vessel were recovered, both of whom were determined to have succumbed to hypothermia and drowned. It is not possible to verify the actual safety equipment carried onboard, however, it was reported that there were no standard lifejackets on the vessel. The vessel was equipped with a six person inflatable liferaft, a fiber glass dinghy, an Emergency Position Indicating Radio Beacon and three extra-large sized immersion suits. This was both an insufficient number of immersion suits for the four people onboard, as well as being too large for the members of the crew. One survivor who spent considerable time in the water reported ingress of water through the suit collar because the suit was too large for him, leaving large gaps.

An inadequately sized immersion suit, even if in perfect condition, poses similar risks as a poorly maintained, leaky suit. If an immersion suit is too large for an individual, seals around the head, neck and wrists will not fit properly, conversely if a suit is too small the seals or zipper will be unable to seal properly. Ultimately both instances can lead to ingress of water. Research shows that even small amounts of water ingress in an immersion suit greatly reduce its thermal effectiveness. A suit which properly fits to an individual's body will provide tight seals and protection from leakage.

### 2.9.5. Inappropriate Immersion Suit Design for Environment

Canada is a vast country encompassing a very large and diverse marine environment. It borders on three oceans including the Artic, and safety equipment that is deemed to be appropriate for vessels operating in southern Canada are not necessarily adequate for the protection of vessels and crews operating in the country's isolated northern regions.

In August of 2000 the fishing vessel *Avataq* with its crew of four, encountered gale force winds while in Hudson Bay, approximately ten nautical miles south of Arviat, Nunavut (TSBC, 2002). The vessel began to take on water and with its bilge pumps nonoperational the vessel eventually foundered with all four crewmembers perishing. Several days after the incident two of the four crewmembers were found in the vessels debris field, both clothed in full-length PFD coveralls. The coroner determined that both victims died of hypothermia, while the other two crew members were classified as missing and presumed dead. The estimated survival time of victims wearing the same model suits in 8°C water is five hours, a period well surpassed before Search and Rescue located the individuals. The constant wear suits worn by the recovered victims were in serviceable condition but were not equipped with marker lights or sound signaling devices.

Constant wear suits provide less effective thermal protection than full immersion suits. The advantage of the constant wear suit is that it is lighter and less bulky then full immersion suits, yet still provide a form of protection from the environment and thus are more practical and preferred to wear while performing work duties. While better than wearing regular work clothing, constant wear suits are not adequately insulated or designed for northern, isolated waters such as Hudson Bay, even in the warmest periods of the year.

### 2.9.6. Inadequate Crew Knowledge of Safety Equipment

Crewmembers of vessels equipped with adequate safety equipment must have the skills and knowledge to be able to use said equipment properly to fully take advantage of it in an emergency. Without adequate knowledge and training concerning equipment contained on a vessel the crew may be at just as much risk compared to having no safety equipment present at all.

The small fishing vessel *Westisle* and its crew of seven was sailing in rough seas off the west coast of Vancouver Island in March of 1999 (TSBC, 2000b). Seawater accumulated in increasing quantities on deck and downflooded into the cargo hold which created a starboard list. Suddenly, unsecured deck cargo shifted and the vessel heeled to an angle of 70 degrees. The captain transmitted a MAYDAY call and while preparations were being made to abandon the vessel, the engineer descended into the machinery space to help ballast the vessel, reducing the starboard list and avoiding capsizing. During this time a deckhand successfully deployed the vessel's eight person inflatable liferaft, while other crew members repositioned the deck winch to help return the vessel to a near upright position. The main engine soon failed but the vessel stayed upright and afloat with minimal damage to the ship and no injuries sustained. The vessel was later towed back to land.

In this particular incident there were no injuries, persons overboard or loss of life. The important lesson from this event occurred during the crew's preparation to abandon the ship. The vessel was carrying adequate life-saving equipment, including seven standard lifejackets, an eight-person inflatable liferaft and seven immersion suits, which were not required under law to be carried on the vessel. Although the crew was made aware of the storage location of lifesaving equipment, no drills were ever conducted. The crew, the majority of which had just recently joined the vessel, had never tried on the lifejackets or immersion suits until they prepared to abandon the vessel during the incident. It was discovered that six of the seven crewmembers' lifejackets and immersion suits were too small and were unable to be used because of their above average build. Two of the crew members managed to don the lifejackets but had to remove them because they were too tight around the neck, causing breathing difficulty.

If ballasting had not been successful in righting the vessel and preventing its capsizing, the majority of the crew would have been forced to abandon the vessel without lifejackets or immersion suits to protect against hypothermia and drowning, potentially leading to a much different outcome. Knowledge of not only where safety equipment is located and how to use it but also ensuring that it is appropriately sized for the crew onboard is necessary in ensuring that the chances of survival are increased during an emergency at sea.

### 2.9.7. Immersion Suit Use Leading to Survival

The research performed since the end of World War II has not surprisingly proved that a human can survive longer in cold water while wearing an immersion suit then without one. Having a well maintained suit for each member onboard a vessel can only increase chances of survival in a vessel or offshore installation abandonment. The following incident is an example of a prepared, trained crew who successfully abandoned their sinking ship and survived for over six hours in the Atlantic Ocean.

In November of 1998 the fishing vessel *Atlantic Prize* and its six crewmembers was returning from the Southern Grand Banks fishing grounds headed for St. John's, Newfoundland (TSBC, 2000a). At approximately 01:55 the vessel became sluggish in returning to upright after several rolls and after approximately one minute the vessel developed a permanent list to starboard with the afterdeck partially submerged. The engineer went to the engine room and started the bilge pumps while the master and crew were called to the wheelhouse where a MAYDAY signal was broadcast. Upon returning to the wheelhouse the engineer reported ingress of water below deck. All crewmembers prepared for abandonment by donning immersion suits, which were stowed in the wheelhouse and then launched a ten-person liferaft. Subsequently it was carried away by the wind before being prepared or boarded. The six individuals abandoned the vessel into the water and were evenly separated into two groups. Within ten minutes of abandonment it was reported that the ship sank. One group of three boarded an aluminum skiff which had broken free from the vessel, allowing them to remain relatively warm until they were rescued approximately 5.5 hours later. The second group of three remained in the water where they placed their backs to the wind/sea and linked arms to stay secured together. They were successfully rescued approximately 6.5 hours later, suffering from mild hypothermia. The crew of the *Atlantic Prize* had been working together for several years and had practiced the donning of immersion suits and emergency drills regularly. Their drills included going over the side of the vessel into the water while at sea. As a result of these drills it was noted that the zippers on several suits were worn and one inflation tube did not work but they were not in such overall disrepair to compromise the effectiveness of the suits.

The success of evacuating a quickly capsizing vessel during rough weather conditions was attributed to the crews numerous training drills over the preceding years, the easy accessibility of the immersion suits and training. These factors combined to give the crew the confidence and knowledge to stay together, warm and afloat in the frigid North Atlantic for nearly seven hours before being rescued. It is noted that normal seasonal water temperatures for the area is 8°C to 10°C, however, because of a deviation in the Gulf Stream at the time of the occurrence, the water temperature was 14°C, which helped increase survival times of the crewmembers while waiting for Search and Rescue. When recovered the crewmembers were described as chilled but not incapacitated.

Despite the success of the abandonment and rescue this event does highlight the necessity for maintaining and repairing worn immersion suits, which may be damaged through use over time. Regardless, the sinking of the *Atlantic Prize* showcases the effectiveness of a properly equipped vessel and a prepared crew, who implemented a textbook evacuation with a successful conclusion.

# CHAPTER 3: METHODOLOGY

## 3.1. INTRODUCTION

The experimental protocol was established to permit an empirical research approach to examine how novices with common experience, training and knowledge of marine abandonment immersion suits perform donning tasks in a variety of real-world conditions within a controlled experiment. Anecdotal evidence has shown that there have been instances where individuals employed within the fishing industry have not garnered sufficient knowledge or practical experience of immersion suit function, failing to complete donning tasks during a crisis at sea. Initial immersion suit exposure could take place during a marine emergency when one may be forced to don a suit under life and death circumstances. Research criteria were established to examine simulated pre-vessel abandonment procedures for individuals under worst case scenarios: people who are both minimally trained and unfamiliar with equipment which must be utilized to help save their life in various motion and lighting states. This test procedure does take some liberties for the sake of participant safety and standardization, however, the research design does measure how a similar group of individuals cope with immersion suit donning in a variety of simulated adverse, dynamic conditions in which immersion suits are designed to be used. Volunteer participants performed the experiment in one session which lasted approximately two and a half hours within a laboratory in St. John's, Newfoundland. The experimental protocol was approved by the Human Investigation Committee (HIC) of Memorial University of Newfoundland.

### 3.2. PARTICIPANTS

Eighteen males and fourteen females (*n*=32; age 22.88±2.01 yrs; stature 173.51±8.62 cm; mass 75.58±12.91 kg) were recruited through posters, electronic communication, presentations and word of mouth (see Appendix A). Participant demographics are reported in Table 3-1. Volunteer participants were contacted and sent a standardized information e-mail detailing the experiment (see Appendix B). This initial communication formed a secondary screening and informed participants of the expectations and requirements for data collection. It was required that participants had no prior experience with donning marine abandonment immersion suits and had not worked in a marine setting. Females who were, or had the possibility of being pregnant, individuals with underlying heart or respiratory illness and vestibular system problems were also eliminated from participating in the experiment. Upon arrival at the laboratory participants were informed of their surroundings, equipment, expectations and, if willing to participate, signed participation consent forms and completed several screening questionnaires (see Appendix C).

**Table 3-1: Participant Demographics**

| | Sex | | | | | | Circumference (cm) | | | | Breadth (cm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | Age (yrs) | RHR (BPM) | Stature (cm) | Mass (kg) | Neck | Wrist | Waist | Hip | Shoulder | Waist |
| Mean | 18 | 14 | 22.88 | 77.88 | 173.51 | 75.58 | 35.58 | 16.68 | 87.70 | 100.69 | 43.70 | 29.94 |
| SD | | | 2.01 | 12.81 | 8.62 | 12.91 | 3.45 | 1.29 | 8.33 | 5.93 | 3.41 | 2.02 |
| Max. | | | 29.00 | 108.00 | 192.30 | 103.15 | 43.30 | 19.60 | 109.50 | 113.50 | 50.00 | 34.90 |
| Min. | | | 19.00 | 48.00 | 158.10 | 52.65 | 30.30 | 14.20 | 70.30 | 90.00 | 36.40 | 26.50 |

## 3.3. EQUIPMENT

### 3.3.1. Participant Test Clothing

In the pre-trial information email it was detailed that the participant was required to wear standardized attire while partaking in the experiment. This consisted of athletic shorts, t-shirt, cotton socks and laced athletic sneakers worn beneath a pair of standard, one-piece work coveralls issued by the investigator. The coveralls were available in various sizes and were donned and tested by participants prior to the beginning of the experiment to confirm adequate comfort and mobility. If necessary, tape was utilized and applied around the wrists and ankles to tailor any excess material and ensure a comfortable fit around the extremities. Participants who used corrective lenses were asked to wear contact lenses or remove their eyewear for the duration of the experiment. All jewelry and watches were also required to be removed, while long hair was tied back from the face.

### 3.3.2. Immersion Suits

Two models of immersion suits from different manufacturers were used in the research. Both suits are approved by various international regulatory bodies and are widely available throughout Canada. Fundamentally, both suit systems have similar designs and are intended for the same purpose. Classified as marine abandonment immersion suits, they are intended for rapid donning and are designed to provide flotation and thermal protection for extended periods against the hazards of harsh environments and direct water immersion. Both immersion suits are full body watertight dry suits, enclosed by a main zipper on the anterior side. They are designed with liberal size ranges, intended to fit a wide array of body types and are stored within carry bags. In addition to the standard size suits, both manufacturers offer custom fit models for individuals. Only the standard suit sizes were available to participants of this research. The two suit models provide tethered hand protection stored in arm pockets, as well as a face shield designed to cover the cheeks and mouth. Both features are intended to be fitted after first enclosing the body within the suit. Participants were randomly assigned an immersion suit model prior to data collection and after anthropometric measurements were taken an appropriately sized suit was issued based on the manufacturer's size specifications. A brief outline of the two suit systems, their principal features and differences are outlined below.

#### *3.3.2.1. FitzWright Explorer 9700*

The FitzWright Explorer 9700 marine abandonment immersion suit (referred to as "FitzWright (FW)") is constructed from a one-layer neoprene fabric. This design is available in three sizes: Adult Small, Adult Universal and Adult Jumbo (see Table 3-2), while all suit exteriors are red in colour with black interiors. All suits had the optional lifting harness installed and orientated as per manufacturer's instructions. Foot protection is integral to the immersion suit itself. The dorsal side of the boots uses the same soft fabric as the rest of the suit, while the bottom is fitted with a rubber, gripped sole to increase foot traction and stability.

**Table 3-2: FitzWright 9700 Size Ranges**

| | Stature (cm) | Mass (kg) |
|---|---|---|
| **Adult Small** | 147-168 | <68 |
| **Adult Universal** | 168-185 | 55-114 |
| **Adult Jumbo** | 180-198 | <146 |
| **Custom Make** | Any | Any |

The hand protection of the FW is a hybrid glove/mitten design (referred to as a "glove" hereafter). The index finger and thumb have separate compartments from the other digits, allowing for increased mobility and tactility of the hand compared to a traditional mitten design. Although this hand protection design allows for increased efficiency of the hand and fingers, its physical surface area is increased, thus contributing to larger heat loss and theoretically increasing detrimental effects on hand performance in comparison to traditional mittens. Each glove is stowed in the forearm section of the suit in an open compartment, allowing the tethered hand protection to be released by simply pulling it straight down. The glove itself is completely black, including its wrist straps and Velcro pieces, which are intended to tightly secure the wrist cuff seal and entrance to the protected hand.

### *3.3.2.2. Mustang Ocean Commander OC8001*

The Mustang Ocean Commander OC8001 marine abandonment immersion suit (referred to as "Mustang (MS)") is constructed with an outer shell made of polyurethane coated nylon fabric. It is fitted with a removable thermal liner secured within the suit by a series of snap buttons and this construction is claimed to be 45% lighter than conventional neoprene suits. All suits issued were the manufacturers Adult Universal size, which offers a very large mass and stature range (see Table 3-3).

**Table 3-3: Mustang Ocean Commander OC 8001 Size Ranges**

| | Stature (cm) | Mass (kg) |
|---|---|---|
| **Adult Universal** | 150-200 | 50-150 |
| **Custom Make** | Any | Any |

In contrast to the FW, this particular model of MS immersion suit does not include the lifting harness. The suits' exterior was yellow in colour with the removable thermal liner coloured black. Like the FW, the boots are an integral part of the immersion suit, however the MS boots are more robust, made of thicker rubber and designed more like a traditional rubber boot (see Figure 3-1). The hand protection design of the MS is a standard four digit mitten with detached thumb. The palmar side of the mitten consists of a textured, black surface intended for increasing grip and reducing slippage, while the dorsal side is a smooth red material. Like the FW, the MS has all black straps and Velcro pieces attached to the mittens used to create a tighter seal at the wrists. The MS mitten stowage compartments, like the FW, are located on the forearms. However, the mittens of the MS are accessed by releasing them from a compartment covered by a flap closed by both Velcro and a single snap button.

**Figure 3-1: Comparison of Integral Immersion Suit Footwear: MS & FW (L-R)**

### 3.3.3. Immersion Suit Carry Bag

Both immersion suits are intended to be neatly folded and stowed within a carry bag, which allows for easy storage, protection and transportation. Generally, all immersion suit carry bags have the same straightforward design and possess many similar properties: one opening sealed by snap buttons and carry handles located on the side and bottom of the bag. Both bags also have information printed on the exterior of the bag pertaining to manufacturer's details, donning instructions, as well as approval from respective regulatory bodies.

### 3.3.4. Inspection & Repackaging

Once issued to the participant, the same suit was used for each of their seven trials. Between each trial, immersion suits were thoroughly inspected for any wear and damage prior to repackaging. If a suit was damaged in either the donning or doffing phase of a trial, it was immediately replaced by an identical model and size suit. Immersion suits were repackaged following the respective manufacturer's guidelines, while out of sight of the participants. When necessary, talcum powder was applied to the cuffs of the immersion suit and participants hands to eliminate any perspiration. Suits used throughout the research were regularly sent to refurbishing facilities for servicing, which included professional inspection, cleaning and repair. The investigator carefully monitored immersion suits and ensured that all were in proper working order during each trial, free from even minor defects.

### 3.3.5. Experimental Instruments

#### *3.3.5.1. Data Collection Facility*

Data collection occurred within an indoor laboratory. This area was a spacious, windowless, dry room with constant and controlled lighting, noise and air temperature (approximately 20°C).

#### *3.3.5.2. Six Degrees of Freedom Electric Motion Platform*

To expose the participant to vessel-like motions in a controlled setting, a six degrees of freedom electric motion platform (MOOG Inc. Series 6DOF2000E Electric Motion Platform, East Aurora, New York) was fitted with a 2m x 2m metal platform to simulate any number of flat areas located on a vessel or offshore installation. The platform perimeter was equipped with 103 centimeter high railings which fully enclosed the area where immersion suit donning took place. A canopy covered three sides and the roof of the platform at a height of 215 centimeters to ensure that identical visual stimuli were present for each participant over the course of the experiment (see Figure 3-2). One side was left open for safety considerations to ensure that the investigator had direct visual and physical access to the participant at all times.

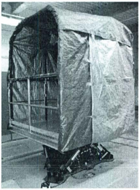

**Figure 3-2: Motion Platform With Railings and Canopy**

### *3.3.5.3. Heart Rate Monitor*

A standard heart rate monitoring system consisting of a chest strap transmitter (Polar T-61 CODED) and heart rate wristwatch (Polar 610i) was attached slightly inferior the sternum. Ultra sound gel (EcoGel 200 Multi-Purpose Ultrasound Gel) was applied to the contact points of the transmitter to enhance signal conduction. Due to the obstructive and intrusive nature of a wristwatch during rapid donning of an immersion suit designed with watertight wrist seals, the heart rate collection system was modified. The wrist watch was affixed to the chest transmitter, thus not interfering with donning tasks, yet still within adequate range to collect the heart rate data for future analysis. The system collected one data point every five seconds.

### *3.3.5.4. Video Cameras*

Each experimental trial was visually recorded and saved for further data analysis and reduction via two video camera systems. The first video camera equipped with a night vision capture feature and affixed with a wide angle lens (Sony Super HAD Color

CCD Underwater Camera, Sony Electronics Inc., San Diego, California) was mounted within the motion platform and was capable of capturing the entire area of the platform in both light and dark conditions. A live feed from this camera was streamed to external monitors so the investigator could closely monitor each participant throughout each trial. The second video camera, only capable of capturing the lighted trials (Sony HDR-XR100 Handycam Camcorder, Sony Electronics Inc., San Diego, California) was mounted outside of the motion platform, recording the entire area of the motion platform opposite the night vision camera.

## 3.4. EXPERIMENTAL VARIABLES

### 3.4.1. Dependent Variables

#### *3.4.1.1. Timing and Success of Donning Tasks*

Each trial's video record was analyzed for both the timing and successful completion of tasks necessary to fully don an immersion suit. Complete and correct immersion suit donning consists of performing several movements which may or may not be completed in the following order:

1. Unpack suit from the storage bag
2. Remove footwear
3. All limbs within suit (both feet in suit shoes & hands through wrist cuffs)
4. Fully seal zipper with hood over head
5. First hand protection donned with Velcro strap attached
6. Second hand protection donned with Velcro strap attached
7. Attach face shield

### *3.4.1.2. Maximum Heart Rate*

Heart rate data was collected over the duration of the experiment. The maximum heart rate attained by the participant during each of the seven trials performed during the experiment was analyzed and transcribed.

## 3.4.2. Independent Variables

### *3.4.2.1. Platform Conditions*

Three platform conditions were used in the experiment, "Stable", "List" and "Motion". The baseline platform orientation condition "Stable", consisted of the platform remaining in a static, flat position throughout the trial. "Stable" represents the most benign platform condition, level and free of any movement. The "List" condition had the platform orientated to a 15 degree angle relative to the ground on one axis, remaining static at that angle for the duration of the trial. The "List" condition recreates a scenario of a grounded or foundered vessel, in which there is no platform movement, yet the individual is orientated on an angle. The final platform condition, "Motion", used all six degrees of freedom, which simulated the dynamic motions experienced on a small fishing vessel at sea in swells.

### *3.4.2.2. Lighting Conditions*

Two lighting conditions were used in the protocol: "Light" and "Dark". In both cases identical lighting environments within the laboratory, as well as the surrounding area, were present and constant over the course of the entire experiment. The "Light" condition had all laboratory lights activated, which provided normal ambient room lighting. The "Dark" condition had all laboratory lights turned off, including the shielding of the investigator's computer monitors to prevent light leakage, creating a black-out setting within the laboratory.

#### *3.4.2.3. Experimental Conditions*

Experimental trials consisted of six different platform orientation and lighting combinations, which made up a total of seven donning trials (see Table 3-4). The baseline condition, "Stable, Light" was implemented twice, as the first and last condition for all participants to observe learning effects. Conditions two through six were randomized.

**Table 3-4: Experimental Conditions**

| Condition | Platform Orientation | Lighting | Abbreviation |
|---|---|---|---|
| 1 | Stable | On | S-ON-1 |
| 2 | List | On | L-ON |
| 3 | Motion | On | M-ON |
| 4 | Stable | Off | S-OFF |
| 5 | List | Off | L-OFF |
| 6 | Motion | Off | M-OFF |
| 7 | Stable | On | S-ON-2 |

## 3.5. EXPERIMENTAL PROCEDURE

### 3.5.1. Pre-Trial Procedure

After the participant had signed the required forms and had been briefed on the experimental expectations the investigator began the pre-trial procedure. This consisted of taking anthropometric measurements, recording baseline heart rate, and participant examination of donning instructions (see Appendix D and F). For the most part the investigator answered any general questions the participant had, but did not release information on the construction or design of immersion suits, donning time regulations or donning procedures until all seven trials had been completed.

#### *3.5.1.1. Anthropometric Measurements*

A series of anthropometric measurements were taken prior to the experimental trials including stature, body mass, neck, wrist, waist and hip circumferences. Shoulder and waist breadth were measured using a pair of anthropometric calipers (Anthropometer Model 01290, Lafayette Instrument Company Lafayette, Indiana). Breadth measurements, waist and hip circumferences were purposely taken over test clothing, due to the clothing's presence and interaction while donning an immersion suit. After the participant's anthropometric measurements were taken an appropriately sized immersion suit was issued based on the manufacturer's size specifications.

#### *3.5.1.2. Baseline Heart Rate*

The participants were instructed to sit in a comfortable chair, place their forearms on the rests provided while setting their feet flat on the ground. They were told to remain relaxed, breath normally and stay as motionless as possible for a period of ten minutes. During this period within the laboratory minimal stimuli were present for the participant, ensuring an accurate and reliable baseline measurement.

#### *3.5.1.3. Immersion Suit Donning Instructions*

After the completion of the baseline heart rate measurement the participant was instructed to remain seated and was given a sheet of written, point form instructions for immersion suit donning to study for a period of five minutes (see Appendix D). The picture-less instructions were generated by the investigator, which included similar general text content and layout derived from the original instructions issued by FW and MS for their respective immersion suits (see Appendices E & F). Both manufacturers' instructions are very similar and are also similar to the majority of current generic immersion suit designs. The investigator gave minimal, standardized verbal instructions with regards to the construction and donning procedures of immersion suits. A brief description of the real–world scenario the experiment was intended to recreate was given, namely, that the participant is onboard a vessel in peril and has been ordered to don an immersion suit with the intention of abandoning the vessel directly into the water. Three main points were stated:

1. Fully don the immersion suit as quickly as possible.
2. The criteria for a complete and successfully donned suit are defined by accomplishing all of the tasks listed on the print instructions.
3. Donning tasks did not necessarily have to be completed in the order in which they appeared on the instruction sheet however, all tasks were required to be completed for the suit to be considered fully donned.

### 3.6. DATA COLLECTION

Once the five minute period of immersion suit instruction examination had lapsed, the participant entered the motion platform donning area and was given a final briefing before beginning the first trial. This included acclimation and rest period procedures, demonstration of the starting signal and discussion of the criteria which defined the completion of a trial.

### 3.6.1. Initial Starting Positions

#### *3.6.1.1. Immersion Suit Carry Bag Position*

The immersion suit carry bag was orientated identically for each trial. The bag was positioned transversely across the platform floor against the railing with the opening faced to the left in relation to the participant. The manufacturer's instructions for suit donning printed on the exterior of each bag was faced towards the ground so that during trial acclimation periods prior to donning the participant would not have access to the information. All donning and care instructions provided within the carry bag or attached to the suit which were present at the time of rental (or at the time of purchase) were removed prior to performing the trials.

#### *3.6.1.2. Participant Starting Position*

The participant was instructed to stand in a standardized starting position located across the marked centerline of the platform where their feet were approximately 0.65 meters away from the immersion suit carry bag. The participant was instructed to stand erect for the duration of the acclimation period. However, during the "Motion" condition the participant was allowed to hold onto the side railing for stabilization, if necessary.

### 3.6.2. Trial Acclimatization Period

For each experimental condition a standardized acclimation period was implemented to allow for the participant to adjust and adapt to the various combinations of platform orientation and lighting. Participants were not briefed on the length of trial acclimation period, but were told only a time range in which the trial would begin. "Stable" and "List" conditions received an acclimation period of thirty seconds while "Motion" conditions were issued an acclimation period of sixty seconds. Differing acclimation period lengths were selected based on the appropriateness in relation to platform movement and time required to adequately adjust to conditions. The "Motion" condition was given a longer acclimation period to allow the participant to adjust to the continuous and dynamic platform movements. Varying the acclimation period durations also introduced randomness to the trial, preventing the participant from accurately predicting the start point, as well as reducing boredom and monotony. At the end of the acclimation period the participant was directed to begin donning by the standardized and previously demonstrated starting signal.

Both the "Light" and "Dark" trials began following the same acclimation period as the corresponding motion condition. Between all trials, including the pre-trial procedure, the laboratory was restored to normal ambient room lighting, the same lighting level used for the experiments "Light" condition. During "Dark" trials laboratory lights were turned out immediately before implementing the motion acclimation period.

Once a trial was initiated and the participant was exposed to the trial conditions they were asked if they were ready to continue. Upon receiving a positive response the investigator then gave the standardized verbal message acknowledging the acclimation period had begun and the start signal would be implemented momentarily: "Anytime within the next 2-minutes the trial will begin". Upon completion of the respective acclimation period the investigator initiated the starting signal and the participant began suit donning tasks. Task timing began upon the initiation of the start signal. A trial was deemed complete after either:

1. The participant had met the donning criteria.
2. The investigator had signalled the end of the trial.
3. The participant had stopped and/or given the signal to end the trial.

### 3.6.3. Rest Periods

A rest period was provided at the conclusion of each trial and was ended when the participant had reached their individualized recovery threshold, defined as 60% of their age predicted maximum heart rate, represented in Beats Per Minute (BPM) (Larson & Potteiger, 1997). The recovery threshold equation is defined as:

$$\text{Recovery Threshold (BPM)} = (220 - \text{Participant Age}) \times 0.60$$

Once the participant's heart rate had dropped and stabilized below their recovery threshold heart rate value, the participant was deemed "recovered" and the next trial was initiated. Due to the nature of the study and the demands placed on the investigator between each trial, a minimum rest period of five minutes was established. This ensured that the investigator had adequate time to tend to the logistics of preparing for the upcoming trial. If the participant was not recovered after five minutes, the rest period was extended until the participant had reached the criteria as defined above.

After each trial, the motion and lighting conditions were returned to baseline (stable platform, lights on). While remaining on the platform the suit was doffed with the assistance of the investigator, while the participant donned and fully tied their sneakers. A chair was placed on the motion platform in which the participant could rest and recover while they were given bottled water and the donning instruction sheet. During this time the investigator inspected, prepared and repackaged the immersion suit for the upcoming trial. Once the participant was recovered the chair, donning instructions and water were removed from the platform and the participant was instructed to assume the starting position in preparation for the next trial.

# CHAPTER 4: RESULTS & DISCUSSION

There were a total of 32 participants allocated equally between the two immersion suits conditions. Each completed seven donning trials (for a total of 224 donning trials undertaken in this study). In all, nine of the trials were unsuccessfully collected and/or had improperly saved video data (7 FW; 2 MS) and were not included in the final analyses (see Table 4-1). In total 95.98% of the video data of all donning trials were available for statistical analyses. The heart rate monitor and its data collection equipment were independent of the camera equipment and yielded a slightly higher success of data collection. Only heart rate data for five donning trials failed to be correctly collected and saved, equalling a total of 97.8% available files which was used for data and statistical analysis.

**Table 4-1: Total Trials Used for Each Suit & Experimental Timing Analyses**

| | | | n |
|---|---|---|---|
| **Immersion Suit** | 1 | FitzWright | 105 |
| | 2 | Mustang | 110 |
| **Condition** | 1 | Stable - Light On 1 | 32 |
| | 2 | List – Light On | 31 |
| | 3 | Motion - Light On | 30 |
| | 4 | Stable – Light Off | 31 |
| | 5 | List – Light Off | 30 |
| | 6 | Motion – Light Off | 29 |
| | 7 | Stable – Light On 2 | 32 |

A mixed design 2-factor repeated measures ANOVA was used to examine both immersion suits and experimental condition effects. All statistically significant primary effects were scrutinized using Fisher's Least Significant Difference (LSD) post-hoc analyses. Statistical analyses performed on immersion suit donning tasks and heart rate data identified violations of homogeneity of variance as determined by Levene's test for homogeneity of variance. This violation can be attributed to the large range of values and outliers found within some of the analyses of donning tasks. Due to the nature of this study and its analysis against a criterion-referenced standard, these outliers should not be considered statistical anomalies but are of critical importance and interest in the reporting and interpretation of the experimental results. Ultimately, the applications of these results are directed towards real-world emergency scenarios and safety training. Understanding how emergency circumstances can affect how individuals act and perform vital tasks that impact immersion suit donning times does not warrant the removal of larger values within the data set, due to them being of value and appropriate in this analysis and content.

A secondary analysis was imposed to examine the homogeneity of variance. The analyses of donning time tasks and heart rate data to experimental condition were performed using the adjusted F scores, as per Welsh's F test within a one-way ANOVA (Kao & Green, 2008). These results reported only one donning task was in violation of homogeneity of variance: attachment of the face shield, a task which produced several large outliers (see Figure 4-1). According to the assumptions of the Welsh's F test, all other donning tasks were not considered extreme violations of homogeneity of variance, indicating a parametric approach to data analyses could be undertaken. Original values analyzed using a mixed 2-factor repeated measures ANOVA are reported because the Welsh's F test did not change the statistical interpretation of the original analyses. The time data collected and its application to emergency evacuation procedures warrant that the original, unaltered or untransformed data complete with outliers remain in the statistical analyses.

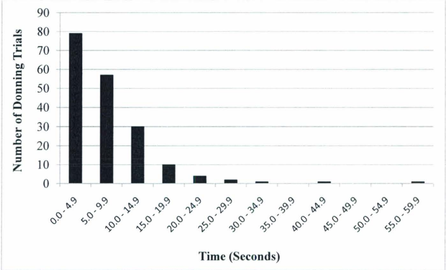


**Figure 4-1: Distribution of All Participant Attempts at Attaching the Face Shield**

## 4.1. RESEARCH CONSIDERATIONS

It is important to put the experimental data collected into perspective to potential real-life situations. The following factors could greatly increase donning times, failure rates, abandonment procedures and success, as well as suit effectiveness and ultimately human survival. Although the experimental design attempted to address ecological validity concerns, these environmental demands are considerably benign compared to the realities of maritime abandonment. Such real-world emergency variables are technologically, physically and ethically impossible to recreate under laboratory settings. This is the first experiment examining the quantitative measurement of marine abandonment immersion suit donning times under diverse environmental conditions. Before interpreting these data, the reader should be aware of those factors that might make donning times even longer in real-world settings.

#### 4.1.1. Donning Environment

Simulated deck motions and environmental lighting conditions were used in the experimental protocol in the attempt to replicate more realistic evacuation conditions compared to those used in standard training environments. The platform area where participants performed donning tasks was relatively large, measuring 2m x 2m, giving the participant ample space to move around and sit or lie down without being obstructed during the duration of donning. The platform itself was enclosed with railings suitable for grabbing onto for stabilization and security during motions. In comparison to the laboratory, real-world donning conditions could include greater challenges, including crowded, confined, wet spaces and more forceful deck accelerations, among other variables which would further hinder donning performance, thus increase times and decrease success rates.

#### 4.1.2. Immersion Suit Characteristics

All immersion suits used in the research were in new condition and in perfect working order. During the testing period, these were regularly brought to qualified refurbishing and maintenance facilities for professional inspection and repair. Generally, a single immersion suit was not used for more than two participants, or a total of fourteen donning trials. Each suit was correctly folded and packed, as per manufacturers' instructions, had adequately lubricated zippers, correctly installed liners and unbroken seals and fabric. Each participant was fitted to their respective suit model following the individual manufacture's sizing specifications, ensuring the correctly sized suit for their morphology. In reality, these immersion suit characteristics, which were all controlled for and monitored within the experiment, may not be present in the real-world. Any number of flaws, disrepair, or incorrect sizing in immersion suits could add to donning times, as well as degrade the suits effectiveness once the individual is exposed to the water.

Immersion suit carry bags were placed in front of the participant prior to the beginning of each trial. The donning times collected in this research truly measure the amount of time it takes a participant to unpack and don an immersion suit. Participants were standing fully erect, clothed, awake and aware of their surroundings. It is important to understand that in applying this to an emergency scenario, the time it takes prepare (e.g. get out of bed, become orientated to the situation, etc.), locate and retrieve the immersion suit would further increase the length of time to don the suit.

### 4.1.3. Participant Characteristics

Participants were all under the age of thirty, in generally good health and reported no severe injuries or major fatigue at the time of data collection. All participants were novices with regards to the details and practice of donning of immersion suits prior to participation in the research and were only exposed to the written donning instructions prior to the start of the first data collection session. Over the course of the experiment participants gained more experience with an immersion suit, became practiced and learned the donning tasks and varying environmental condition combinations.

Participants were required to wear typical athletic clothing (t-shirt, shorts, cotton socks and low-topped athletic sneakers), and prior to donning trials were issued an appropriately sized pair of one piece work coveralls. The removal of all jewelry and accessories was performed in the pre-trial procedure to ensure that no negative interaction or damage would affect suit integrity or donning times. Participants were required to have good vision to participate in the study. Immersion suit donning is generally inhibited by eyewear and those forced to don and abandon with uncorrected vision may require extra time to complete the tasks. Long hair was also tied back and out of the way from both obstructing participants vision, as well as interfering with physically donning the head piece and sealing the zipper of a suit.

Participants were required to wear low-topped laced athletic footwear. Differing work boot designs predominantly found at sea may or may not take longer to doff in comparison to low topped laced athletic footwear used in this experiment. Many doffed their shoes by stepping on the heel of the shoe and simply slipping out of them without untying the laces. Standard fishermen's rubber boots, although without laces and extending high up the shins may have to be taken off in a different manner, while laced steel toe work boots would most likely have to be untied in order to be removed. It can be hypothesized that factors such as increasing age, decaying fitness, increased fat mass, lack of recurrent training, improper dress and physical and mental preparation would result in incremental increases in donning times in comparison to this data set.

### 4.2. TOTAL SUIT DONNING TIME

Figure 4-2 displays all immersion suit donning trial times analysed. Overall, it took participants a mean of 102.7 seconds (SD=39.6 sec) to perform all donning tasks across all conditions, 17.3 seconds less than required by the current Canadian Standard. This empirical data would appear at first to support the validity of the 2-minute standard. However, a more comprehensive analysis of the figures reveals more alarming findings.

The most prominent being that in total, 56 of the total 215 donning trials collected were above the 2-minute donning requirement, representing a 26.1% failure rate in comparison to the regulatory standard.

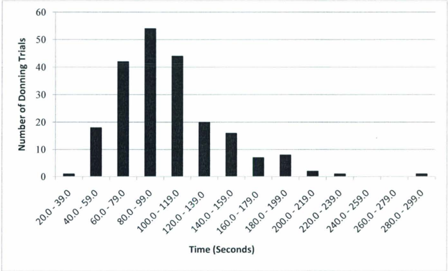


**Figure 4-2: Participant Donning Trial Task Times**

The statistical analysis showed a significant difference between the experimental conditions and the time it took to don a suit ($F=7.1$; $p<.0001$). A post-hoc analysis revealed that there was a significant difference between the baseline "Stable – Light On 1" and "List – Light On" ($p=.002$) and "Stable – Light On 2" ($p<.0001$) (see Table 4-2). As expected, when comparing the identical environmental conditions of the first and last trial a significant difference was found. However, the only other significant difference between the baseline condition was "List – Light On", implying that both the darkness and motion variables did not have a significant impact upon donning times. No significant interaction effects were observed (p=.632).

**Table 4-2: Experimental Condition Analysis: Total Suit Donning**

| (I) Condition | (J) Condition | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval for Difference | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| **S-ON-1** | **L-ON** | 27.423 | 8.779 | 0.002 | 10.112 | 44.734 |
| | **M-ON** | 12.929 | 8.861 | 0.146 | -4.544 | 30.401 |
| | **S-OFF** | 7.910 | 8.779 | 0.369 | -9.401 | 25.222 |
| | **L-OFF** | 14.406 | 8.851 | 0.105 | -3.046 | 31.859 |
| | **M-OFF** | -10.490 | 8.955 | 0.243 | -28.148 | 7.167 |
| | **S-ON-2** | 39.719 | 8.707 | 0.000 | 22.550 | 56.888 |

Upon examination of total mean times by condition "Motion – Light Off" resulted in the longest time value at 125.6 seconds (SD=40.2 sec), the only condition having a mean time over the 2-minute time requirement (see Figure 4-3). The conditions with the second and third largest time values were "Stable – Light On 1" and "Stable – Light Off" at 116.4 and 107.7 seconds, respectively. Interestingly the two stable conditions took longer than "Motion – Light On" and both list conditions. In each condition at least one participant failed to meet the 2-minute donning requirement, the maximum recorded time being 299.0 seconds, nearly two and a half times more than the required time set out by legislation.

When comparing the first and last trial (both stable platform with lights on) a mean reduction of 39.7 seconds (34.1%) occurred. Even though all but one of the conditions produced mean times under the current established time requirement, it is important to note that each condition's standard deviation generated large time ranges from 30.3 to 49.6 seconds. This represents a high degree of variability in donning an immersion suit and vital time during an emergency and abandonment procedure.

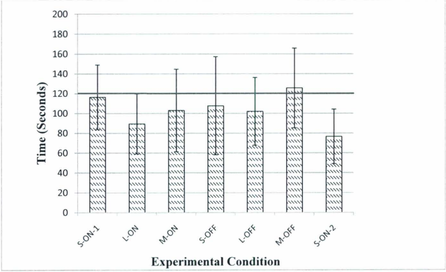


**Figure 4-3: Total Mean Times of All Immersion Suit Donning Tasks**

### 4.3. TOTAL SUIT DONNING: COMPARING SUITS

A significant difference (F=31.4; p<.0001) was found between the total donning time for the two suit types. The MS suit took a mean time 26.7 seconds (SE= 4.8 sec) less than the FW to completely don across all conditions, while both suit mean total donning times were below the 2-minute time requirement over all conditions (FW=115.9 sec; MS=90.1 sec). In comparing the number of donning trials in which participants failed to meet the 2-minute time requirement MS reported a 15.5% failure rate while the FW reported a 37.1% failure rate (see Figure 4-4).

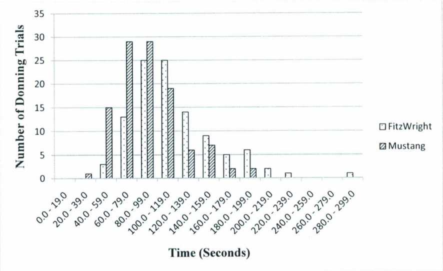


**Figure 4-4: Total Participant Donning Trial Task Times: Comparing Suits**

As found in the analysis of both suits combined, when the two suits were analyzed separately across all conditions, "Motion – Light Off" produced the largest mean times (FW=139.2 sec; MS=114.6 sec). The FW mean total donning time over the 2-minute time requirement occurred in three of the seven experimental conditions: "Stable – Light On 1", "Stable – Light Off" and "Motion – Light Off", while the MS suit mean time was below 2-minutes for all seven conditions. The FW had maximum times well over the 2-minute time allotment in each condition, ranging from 184.0 seconds to 299.0 seconds with the MS reported donning times of one or more participants above the required donning time in 5 of the 7 conditions, ranging from 127.0 seconds to 191.0 seconds. Two MS conditions, "List – Light On" and "Stable – Light On 2", yielded maximum times below the 2-minute time requirement (113.0 sec and 97.0 sec, respectively).

## 4.4. DONNING SUB-TASKS

The required operations which make up a complete immersion suit donning were derived into three broad categories. From these broader categories four donning sub-tasks were identified and analysed (see Table 4-3). Overall the MS suit was quicker in three of the four sub-tasks which culminated in a total donning time 26.7 seconds quicker than the FW.

**Table 4-3: Immersion Suit Donning Sub-Tasks**

| Category | Sub-Task | |
|---|---|---|
| **Critical Tasks** | 1 | All Limbs Within Suit |
| | 2 | Hood On, Zipper Fully Sealed |
| **Hand Protection** | 3 | Hand Protection Tasks |
| **Face Protection** | 4 | Face Shield Attachment |

### 4.4.1. Critical Tasks

The critical donning tasks are defined as the bare minimum, essential tasks which need to be carried out if abandonment to cold water is imminent. Completion of these tasks will provide watertight integrity to the majority of one's body, thus providing a level of thermal protection, as well as allowing the suit to provide effective flotation while in the water. These tasks involve first locating and unpacking the suit from its carry bag, removing footwear, getting all of the limbs within the suit itself and then donning the hood and fully sealing the zipper. In completing these tasks an individual has sealed the suit, providing thermal protection for the majority of their body, excluding only the hands and portions of the face. Although having exposed hands is not ideal, the critical tasks represent the most important tasks with the largest benefits and pay off in terms of thermal protection and safety when completed correctly.

When combining the initial two sub-tasks that represent the critical tasks a total mean time of 58.7 seconds (SD=24.4 sec) was reported. No significant difference was found between the suit type and the time it took to complete the critical donning tasks ($F=2.7$; $p<.101$). The MS mean time was reported to be 56.6 seconds, while the FW took slightly over four seconds longer to complete at 60.9 seconds. These results suggest that if a person can access their immersion suit easily, in approximately one minute they should be able to complete the minimum tasks required to have effective flotation, watertight integrity and thermal protection for the majority of the body. However completion times of critical tasks had a large range reported from 21.0 seconds to 152.0 seconds. There were eight occurrences where participants failed to complete the critical donning tasks even within the 2-minute time requirement.

There was a significant difference due to donning condition in the time it took to complete critical donning tasks ($F=7.8$; $p<.0001$). A post-hoc analysis revealed that there was a significant difference between the baseline "Light On – Stable 1" and "List – Light On" ($p=.017$), "Motion – Light Off" ($p=.009$), and "Stable – Light On 2" ($p<.0001$) (see Table 4-4). Like the total donning time there was a significant difference found between the first and last trials as would be expected with trials having identical environmental variables. The learning and experience participants gained over the course of the study donning times were in general significantly shorter. Similarly, a significant difference between the baseline and "Motion – Light Off" can be attributed not as strongly to the learning effect due being a randomized protocol, but because of the challenging combination of darkness and motion inherent in the condition itself.

**Table 4-4: Experimental Condition Analysis: Critical Tasks**

| (I) Condition | (J) Condition | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval for Difference | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| **S-ON-1** | **L-ON** | 13.483 | 5.616 | 0.017 | 2.410 | 24.557 |
| | **M-ON** | -1.040 | 5.668 | 0.855 | -12.217 | 10.137 |
| | **S-OFF** | 7.829 | 5.616 | 0.165 | -3.244 | 18.903 |
| | **L-OFF** | 6.565 | 5.662 | 0.248 | -4.599 | 17.729 |
| | **M-OFF** | -15.161 | 5.728 | 0.009 | -26.456 | -3.866 |
| | **S-ON-2** | 20.031 | 5.570 | 0.000 | 9.049 | 31.014 |

However, "Motion – Light Off" was the condition with produced the longest mean donning times for both suits at 82.4 seconds for the FW and 75.0 seconds for the MS (see Figure 4-5), while the longest maximum times were observed for both suits in darkened environments: "List – Light Off" (FW=152.0 sec) and "Motion – Light Off" (MS=135.0 sec). Interestingly there was a significant difference found between the baseline and "List – Light On" yet no significance between baseline and "List – Light Off", or "Motion – Light On" conditions which are a seemingly "easier" combination of environmental variables. The two sub-tasks which make up the critical tasks are divided and discussed below. No significant interactions between the main effects were found (p=.445).

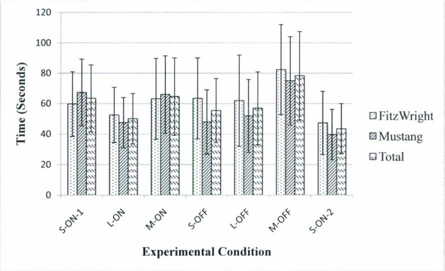


**Figure 4-5: Mean Time of Critical Donning Tasks**

#### *4.4.1.1. Sub-Task 1: All Limbs Within Suit*

This initial donning task encompassed the moment from which a participant was standing erect and was given the starting signal to the moment when they had successfully gotten both feet fully within the suit boots and hands through each of the sleeve's wrist cuffs. A participant must bend down to pick up the storage bag, remove the suit, lay it out on the platform floor, remove footwear and then proceed to manoeuvre the body inside. When broken down, this task represents the most arduous body movement and physical exertion of any of the donning sub-tasks. Figure 4-6 displays the mean times it took participants to get their limbs within an immersion suit in each condition. In total the task took a mean time of 40.9 seconds (SD=16.0 sec) over all conditions to complete, with times ranging from as little as 16.0 seconds to as long as 131.0 seconds. There was a statistical significance found between the two suits ($F=10.7$; $p=.001$), with the MS suit times being shortest in all 7 conditions, averaging a total task time of 6.2seconds (SE=1.9 sec) less than the FW (FW=43.7 sec; MS=38.3 sec).

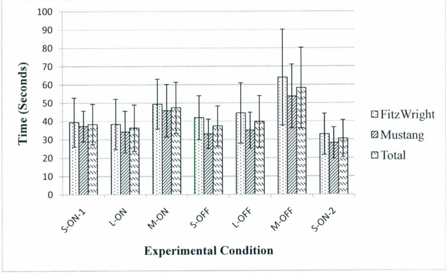


**Figure 4-6: Mean Time Required To Get All Limbs Within Suit**

The statistical analysis revealed a significant difference due to donning condition in the time it took to get participants limbs within a suit (F=13.4; p<.0001). A post-hoc analysis revealed that there was a significant difference between the baseline "Stable – Light On 1" and "Motion – Light On" (p=.009) and "Motion – Light Off" (p<.0001) and "Stable – Light On 2" (p=.024) (see Table 4-5). For each suit both motion conditions ("Motion - Light On" & "Motion - Light Off") had the longest mean task donning times (FW=49.4 sec, 63.9 sec, respectively; MS=45.8 sec, 53.6 sec, respectively). No significant interaction effects were observed (p=.864).

**Table 4-5: Experimental Condition Analysis: Sub-Task 1**

| (I) Condition | (J) Condition | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval for Difference | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| **S-ON-1** | **L-ON** | 2.056 | 3.461 | 0.553 | -4.768 | 8.881 |
| | **M-ON** | -9.255 | 3.530 | 0.009 | -16.216 | -2.294 |
| | **S-OFF** | 0.815 | 3.461 | 0.814 | -6.010 | 7.639 |
| | **L-OFF** | -1.423 | 3.489 | 0.684 | -8.303 | 5.458 |
| | **M-OFF** | -20.430 | 3.530 | 0.000 | -27.391 | -13.469 |
| | **S-ON-2** | 7.813 | 3.433 | 0.024 | 1.044 | 14.581 |

### *4.4.1.2. Sub-Task 2: Hood On With Zipper Fully Sealed*

Upon successfully getting one's body and limbs within the suit, the next prescribed task is to don the head/hood piece and pull the anterior zipper up to the chin to fully seal the body compartment. Figure 4-7 reports the mean times it took participants to complete the task across all conditions. In total sub-task 2 took a mean of 18.1 seconds, with times ranging from 5.0 seconds to 79.0 seconds. There was no significant different between the two suits in the time it took to complete this task (F=.08; p=.780).

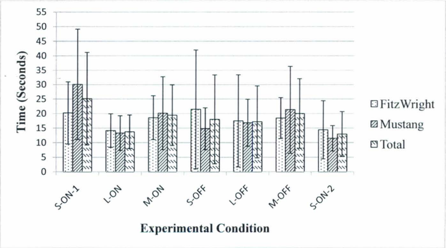


**Figure 4-7: Mean Time Required to Don Hood and Fully Seal Zipper**

The statistical analysis revealed that there was a significant difference between donning conditions and the time it took to don a suit (F=3.8; p=.001). A post-hoc analysis revealed a significant difference between the baseline "Stable – Light On 1" and all conditions except the two involving motion (see Table 4-6). As expected, a significant difference was found between the first and last experiential trials "Stable – Light On 1" and "Stable – Light On 2". There was also a significant difference between the baseline and both list conditions, as well as "Stable – Light Off", however not with either of the motion conditions. These results, coupled with the total donning times, suggest that initial exposure to an immersion suit even in the most benign, friendly environment is as detrimental as dynamic motion environments are on the time it takes to complete donning tasks. For each suit the longest mean and maximum times were found in stable environments. The FW being in the "Stable – Light Off" condition taking a mean time of 21.5 seconds with also with the maximum time of any condition reported at 79.0 seconds, while the MS longest mean time occurred in the baseline condition "Stable – Light On 1" taking 30.1 seconds. No significant interaction effects were observed (p=.175).

**Table 4-6: Experimental Condition Analysis: Sub-Task 2**

| (I) Condition | (J) Condition | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval for Difference | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| **S-ON-1** | **L-ON** | 11.427 | 2.987 | 0.000 | 5.538 | 17.316 |
| | **M-ON** | 5.786 | 3.046 | 0.059 | -0.221 | 11.793 |
| | **S-OFF** | 7.015 | 2.987 | 0.020 | 1.125 | 12.904 |
| | **L-OFF** | 7.988 | 3.011 | 0.009 | 2.050 | 13.925 |
| | **M-OFF** | 5.269 | 3.046 | 0.085 | -0.738 | 11.276 |
| | **S-ON-2** | 12.219 | 2.962 | 0.000 | 6.378 | 18.060 |

### 4.4.2. Factors Affecting Completion of Critical Tasks

The following section is a discussion of issues observed during the completion of critical tasks which impacted donning procedure, success rate, and ultimately time. Further sections throughout this chapter deal with aspects of immersion suit design and their observed influence on donning performance and results. Although outside of the immediate scope of the project these observations provide insights into factors which impact immersion suit donning.

#### *4.4.2.1. Suit Sizing*

Ideally, everyone working on or adjacent to cold water should have access to custom fitted immersion suits. However, this is neither practical nor feasible when dealing with the mass marketing, purchasing and distribution of marine abandonment immersion suits. Ultimately, the aim of regulatory bodies, coast guards and training/education facilities is to promote and educate the highest percentage of individuals in the industry with regards to the importance of immersion suits, as well as how maintain, don and use them effectively and correctly. Thus, general size ranges are a convenient way to design, manufacture and market immersion suits to a wide range of body types, allowing for greater general coverage and protection across the population. Both custom fit and general, generic size ranges of immersion suits have their own specific advantages and disadvantages.

The greatest advantage of a general size range immersion suit is that in the case of an emergency, a universal or standard adult sized immersion suit *should* fit a large percentage of individuals of the adult population, allowing for watertight integrity within the suit. A more general, larger suit size range also encourages vessels and owners to purchase immersion suits, knowing that they should fit the majority of their crew, without having to buy or change suits as crew compliments turn over. Another advantage of general size ranges is that if rapid donning is necessary, crew members may be able to don a suit at hand, not necessarily a personal suit, but one that can be accessed and donned quickly in critical abandonment situations. General size range suits allow for people of a varying range of morphologies to use the same sized suit, making it simpler, easier and more probable that a suit of acceptable size is conveniently available during an emergency.

Ironically, the greatest advantage of a general size range immersion suit is also its greatest liability. The majority of immersion suit manufacture size ranges only take into account stature and mass when formulating size ranges. In reality, this form of suit size ranges does not reflect the unique individual body morphologies across a population. Humans are not simply scaled versions of each other. Even those individuals who are within the stature and mass ranges specified for a particular suit size may fail to fit correctly into the same suit. Individual proportions of body parts including the extremities, trunk, neck and head are highly variable within individuals who have similar stature and mass, so that what may fit one may not fit another. Although it is expected that an individual will be able to correctly fit a suit appropriate to their size it is of the utmost importance that the seals and zipper of the suit are tight to ensure watertight integrity, an issue which has been cited as one of the major problems with general size ranges. Without properly fitting seals as a barrier against water ingress an immersion suit is essentially rendered useless and hazardous if excess water enters the suit and weighs it down, reducing not only its thermal properties, but also its flotation properties.

Participants with smaller morphologies, who were at the lower end of a specified size range for a particular immersion suit tended to get "lost" within the suit. This occurred predominately in participants whose stature was lower on the size range of a given suit. It was observed numerous times that the suit material was too long for their body. When attempting to fully seal the zipper, excess suit material straightened out and failed to conform correctly to the body. Participants were unable to fit their head within the head piece due to the large length of the suit in proportion to the individual's stature. This severely compromised the watertight integrity of the suit by leaving a large gap around the face and neck, while also obstructing vision and contributing to participants feeling very uncomfortable and restricted in their movements. Generally, participants whose statures were in the mid to higher regions of the manufacturer's size range fit more comfortably within the suit, had tight seals and also had a greater mobility and functionality of their body in all aspects of the suit system during donning tasks and when fully adorned.

No participant had substantial problems with an immersion suit being too small or large for their morphologies in comparison with the manufacture sizing range. Observations suggest that participants fitted best within an immersion suit with tight seals at the face and wrists when they were in the middle to upper range of a manufactures stature and mass size range. Individuals whose stature and mass fit within the lower region of a particular size range may benefit from using a smaller immersion suit size, which would still potentially fit their body. This would have the advantage of increasing mobility due to a reduction of excess suit material, while aiding in easier, less cumbersome donning (e.g. decreasing donning times), and most importantly providing tighter seals, ensuring the suit's watertight integrity when worn.

#### *4.4.2.2. Dangers & Inconvenience of Footwear Removal*

The removal of footwear is one of the initial steps in donning a conventional marine abandonment immersion suit. This design and procedure leaves an individual highly exposed and vulnerable during both the donning process and throughout extended cold water immersion. During suit donning, the act of removing footwear makes the individual unstable, increasing the chance of falling. Once footwear is removed, the unprotected feet are potentially exposed to wet, slippery, cold environments and objects that may cause injury. Upon donning an immersion suit and abandoning directly into water, bare or socked feet within boots become chilled and are difficult to keep warm during extended periods of immersion.

If immersion suits were manufactured with the option to don without having to take off footwear it would aid in two areas. Firstly, it would eliminate a potentially hazardous donning task, putting an individual at risk for injury and failure to don an immersion suit. Secondly, allowing for footwear to be worn within the immersion suit also provides much needed additional, heavy thermal protection around the feet, reducing heat loss during cold water immersion. Allowing footwear to be worn within the suit is a simple and potentially effective way to shorten donning times, decrease the probability of injuries, increase successful donning attempts and provide extra thermal protection to an area which is particularly exposed and difficult to keep warm. Research and development of the feasibility and safety of incorporating this feature would be beneficial.

#### *4.4.2.3. Lifting Harness*

An immersion suit lifting harness is intended to aid in the retrieval of an individual from the water by helicopter, deck crane or manually. Lifting harnesses are generally an optional addition on immersion suits and are available for both the FW and MS suit models, but in this research study only the FW was equipped with the lifting harness.

The lifting harness did not have a consistent negative impact in donning procedures or timing. During the vigorous movements of rapid donning procedures the harness frequently became dislodged which commonly occurred in two ways. The first was that the harness physically released from the Velcro straps located around the chest to hold the piece in place. The second common issues had the lifting harness come out from the participant's legs and dangle from the side of their suit out of its intended position. The manufacture specifies the harness is to be looped between the legs when packed into its storage bag and remain in that position while donned, providing optimal positioning for retrieval. These two problems do not completely render the lifting harness ineffective but do contribute to making rescue operations more difficult and even impossible for rescuers.

Although these two problems occurred frequently, the majority of participants successfully dealt with the situation and continued to don the immersion suit in a generally correct manner. However, there were two trials during which the lifting harness played a direct role in severely hindering and, in one of the two cases, completely obstructing even the initial task of immersion suit donning.

One participant donning the suit in the "Stable, Dark" condition became entangled in the lifting harness while trying to get his arms and shoulders into the suit. After some time he took the suit off, unhooked the harness from the buckle and then successfully donned the suit. He spent 59.0 seconds of his total 135.0 second donning time trying to get his zipper sealed, only to be hindered by the interaction of the lifting harness. Interestingly, of all his donning trials it was only during this scenario that he failed to achieve the mandatory 2-minute time requirement. To put this in perspective, the average donning time required by this participant to seal the zipper in his other experimental conditions was 8.2 seconds, compared to the 59.0 seconds it took when the lifting harness became entangled in the suit.

The second participant who encountered trouble donning the immersion suit due to the interaction of the lifting harness did not realize or remedy the problem and ultimately failed to complete any of the required donning tasks during the "Motion, Dark" condition. Similar to the first participant, he got his lower body into the suit, but in doing so the lifting harness became entangled within the midsection of the suit. The participant, after a long struggle and many attempts, failed to get his arms within the suit sleeves and to seal the zipper. This was due to the harness's altered orientation which occurred during the unpacking and donning process. After over three minutes at attempting to remedy the problem the participant gave up, disorientated, exhausted and frustrated, ultimately failing to complete all of the donning tasks.

Further study into lifting harness design, positioning, attachment methods and their interaction during immersion suit donning is required to provide an optimal device which is effective, yet does not have the potential to severely hinder the immersion suit donning process or other vital survival tasks.

#### *4.4.2.4. Anterior Zipper*

In general, all immersion suit anterior zippers performed very well during experimental donning trials. However, even though each zipper was in perfect working order and adequately lubricated there were some issues participants encountered which both increased donning times and decreased comfort levels while donning and wearing the suits. The major issue with the immersion suit zipper was that sealing it became difficult when the zipper and suit material were orientated such that it was not possible to close the zipper unless by applying a straight pull with flattened fabric. This occurred with participants who were generally on the lower region of an immersion suit size, which created excessive folded and bunched material around the trunk of individual which impeded zipper closure. This both added time onto the second sub-task and caused considerable frustration among many of the participants, even though zippers were in proper working order and well lubricated.

Several participants complained that when the suit was fully donned, zipper teeth were too close to the mouth, making the face and mouth area feel uncomfortable, as well as making them nervous when attempting to completely seal the suit by pulling the zipper to their face/mouth region. This nervousness or hesitation lead to participants failing to completely seal the zipper, and thus compromising the watertight integrity of the suit by leaving the face and neck inadequately sealed. The rearrangement and redesign of the anterior zipper which is offset from the mouth to the side of the face or neck could reduce participant hesitation.

### 4.4.3. Hand Protection

#### *4.4.3.1. Sub-Task 3: Hand Protection Tasks*

A large percentage of total task donning times were spent on tasks related to hand protection, second only to the initial task involving the gross movement tasks of unpacking and manoeuvring oneself inside the suit (see Figure 4-8).

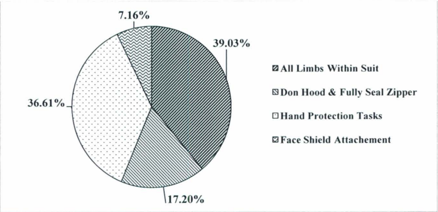


**Figure 4-8: Combined Suit Sub-Task Donning Time Percentages**

The duration of hand protection tasks started from the moment a participant began attempting to release the gloves or mittens from the storage compartments located in each sleeve to having the hand protection donned with adequate satisfaction and Velcro wrist straps attached around each wrist. The hand protection donning task consists of four operations:

1. Release and Don First Hand Protection
2. Release and Don Second Hand Protection
3. Attachment of First Velcro Wrist Strap
4. Attachment of Second Velcro Wrist Strap

In total, across all conditions hand protection tasks mean time was 37.6 seconds (SD=21.1 sec), with times ranging from 10.0 seconds to 160.0 seconds (see Figure 4-9). This large time range found for a task consisting of releasing hand protection from storage pockets and donning illustrates the difficulty and trouble individuals experience with current immersion suit hand protection designs. The seemingly transferrable task of putting on a pair of gloves or mittens showed to give participants many problems in donning immersion suit hand protection. This issue has been documented in literature and anecdotally for decades, yet no widespread action has been taken.

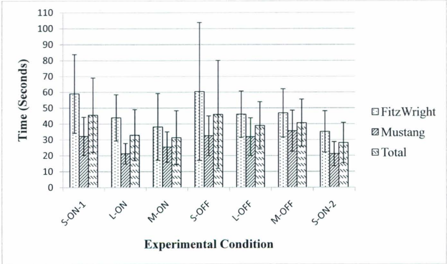


**Figure 4-9: Mean Time of All Hand Protection Tasks**

A significant difference was found between the suits (F=56.9; p<.0001), with the MS taking a mean time of 18.5 seconds (SE=2.5 sec) less than the FW (FW=47.1 sec; MS=28.6 sec). The statistical analysis showed a significant difference between donning condition and the time it took to complete all tasks associated with the hand protection (F=5.0; p<.0001). A post-hoc analysis revealed that there was a significant difference between the baseline "Stable – Light On 1" and "List – Light On" (p=.004) and "Motion – Light On" (p=.003) and "Stable – Light On 2" (p<.0001) (see Table 4-7). Interestingly this is the identical condition interaction result found in total suit donning tasks, indicating that hand protection tasks had major influence in the total donning time. The FW suit had higher maximum donning times then the MS in each of the conditions, while the MS reported the fastest donning times in each condition. The longest mean time of the FW was produced in the "Stable – Light Off" condition at 60.4 seconds, while the longest mean time of the MS was "Motion – Light Off" at 35.6 seconds. There were no significant main effects interaction (p=.315).

**Table 4-7: Experimental Condition Analysis: Sub-Task 3**

| (I) Condition | (J) Condition | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval for Difference | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| **S-ON-1** | **L-ON** | 13.023 | 4.523 | 0.004 | 4.104 | 21.941 |
| | **M-ON** | 13.804 | 4.565 | 0.003 | 4.802 | 22.805 |
| | **S-OFF** | -0.856 | 4.523 | 0.850 | -9.775 | 8.062 |
| | **L-OFF** | 6.627 | 4.560 | 0.148 | -2.364 | 15.618 |
| | **M-OFF** | 4.389 | 4.613 | 0.343 | -4.707 | 13.486 |
| | **S-ON-2** | 17.531 | 4.486 | 0.000 | 8.686 | 26.376 |

### 4.4.4. Factors Affecting Completion of Hand Protection Donning Tasks

#### *4.4.4.1. Donning the Second Glove or Mitten*

In donning the first glove or mitten, one is able to use their opposite bare hand to secure and position the hand protection, allowing for an unfettered hand and its digits to perform the tasks unobstructed. When donning the second glove or mitten, the opposite hand and digits are now within a bulky shell of the recently donned hand protection, resulting in reduced dexterity. This has the potential to reduce the accuracy and effectiveness of donning the second hand protection, leading to severely hindered hand performance while donning tasks, as well as any necessary emergency procedures. This can greatly reduce the usefulness of hand protection, as well as introduce a series of negative outcomes related to the degraded performance of the clumsily covered hands and fingers themselves.

Pre-attached, watertight hand protection may be a substantial improvement because they would reduce donning tasks, errors and overall donning times, as well as providing the individual greater options in an emergency. Once donned the entire suit would be fully intact and water tight, eliminating the need to release, don and secure two separate gloves or mittens which account for an average of 37.6 seconds, or 36% of total donning time. Brooks (2008) states that gloves (or mittens) are better as a separate item stowed on the sleeve rather than incorporating them into the suit itself allowing for hands to be free and have the ability to carry out emergency tasks that would otherwise be potentially hindered by bulky gloves or mittens. However, designing the option for pre-intact hand protection which allows for removal via zipper or other attachment would permit individuals to remove the hand protection, if necessary for greater hand and digit function in performing tasks. Another viable option would be to implement a two stage hand protection system. A pre-attached thin inner glove or mitten would provide allow effective hand function while providing some thermal protection, and a second, thicker outer shell could be released and donned separately when needed.

#### *4.4.4.2. Hand Protection Storage Compartments*

Both manufacturers have their tethered hand protection stored in forearm compartments, intended to be released and donned once an individual is in the suit. However, ease of hand protection accessibility and effectiveness of their security varied due to storage compartment design, both having their individual advantages and disadvantages.

The FW gloves are stored in an open, unsealed compartment allowing them to be easily removed with little obstruction to overcome. Although this design is very open and accessible it can lead to gloves being released from their storage compartments at unwanted times, especially during the vigorous and violent initial movements of unpacking and donning an immersion suit. If the tethered gloves are pre-maturely released this does in fact eliminate an operation the individual must perform. However, dangling hand protection has the potential to get caught in surrounding obstructions, damaging the suit, entangling the individual and potentially preventing the completion of donning tasks. One participants' pre-maturely released hand protection was caught inside the suit, as he was attempting to seal the zipper and the tether prevented him from doing so. The participant performing the donning quickly realized the problem, extracted the tether and hand protection from the inside of the suit and continued donning the suit. If the immersion suit is donned and the individual does not intend to use the hand protection, released and dangling gloves or mittens can pose potential impediments to individuals in abandonment scenarios.

In contrast, the MS suit, also featuring forearm hand protection storage design, features a flap of material sealed by Velcro and a single snap button. This design securely stores the tethered mitten, with its release requiring intention and a specific action to be carried out by the individual. Although this more secure design conveniently keeps the mittens stored out of the way until wanted, its reduced accessibility can potentially hinder the mitten from being released. At sea with reduced visibility, compromised hand function and the presence of violent motions and wet surroundings could make deployment of hand protection impossible with this storage compartment design.

#### *4.4.4.3. Obstructed Entry of the Mustang Hand Protection*

It was discovered that the MS hand protection storage system has a crucial design flaw which can physically prevent the hands entry into the mitten. Once released from its compartment, the flap originally intended to seal the storage compartment prior to use via Velcro has the ability to attach with the wrist strap Velcro located on the mitten, ultimately blocking the entrance into the hand protection (see Figure 4-10). This obstruction, firmly secured in place may not be easily removed if the individual cannot identify the easily over-looked problem.

Throughout the research this problem occurred sporadically, which both increased hand protection donning times and prevented individuals from completing the task. Although this system packs securely and conveniently away in the forearm in comparison to the FW, once released this design can have detrimental effects on the success of hand protection donning.

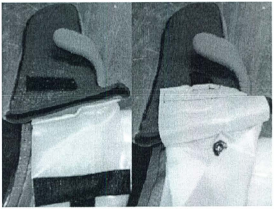

**Figure 4-10: Mustang Mitten Storage Flap Causing Obstruction to Mitten Entrance**

### 4.4.5. Face Protection

#### *4.4.5.1. Sub-Task 4: Face Shield Attachment*

The completion of the face shield task revealed a mean time of 7.4 seconds (SD=7.0 sec) across all conditions, with times ranging from 1.0 to 55.0 seconds (see Figure 4-11). A significant difference was found between suits ($F=18.5$; $p<.0001$), the MS face shield, on average, took 4.2 seconds (SE= 1.0 sec) less time to don then the FW face shield (FW=9.6 sec; MS=5.5 sec).

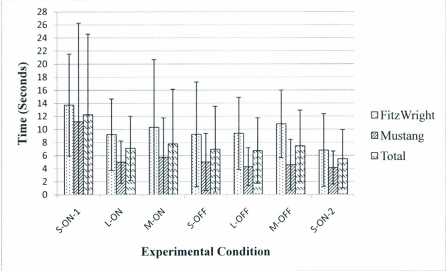


**Figure 4-11: Mean Time Required To Attach Face Shield**

A significant difference was found between the experimental condition and the time it took to don the face shield (F=2.3; p=.034). A post-hoc analysis revealed that there was a significant difference between the baseline and all other conditions: "Stable – Light On 1" and all other conditions (see Table 4-8). The baseline condition "Stable – Light On 1" yielded the longest donning times (FW=13.8 sec; MS=11.2 sec), as well as the maximum times (FW=31.0 sec; MS=55.0 sec). It was observed that after initial exposure to the immersion suit MS participants shortened their remaining six trials by at least 5.5 seconds, with times ranging from 4.1 to5.7 seconds, while all FW trials remained slightly higher ranging from 6.8 to10.8 seconds after initial exposure. No significant interaction effects were observed (p=.961).

**Table 4-8: Experimental Condition Analysis: Sub-Task 4**

| (I) Condition | (J) Condition | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval for Difference | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| **S-ON-1** | **L-ON** | 5.359 | 1.976 | 0.007 | 1.459 | 9.259 |
| | **M-ON** | 4.433 | 1.995 | 0.028 | 0.494 | 8.371 |
| | **S-OFF** | 5.351 | 1.978 | 0.008 | 1.446 | 9.255 |
| | **L-OFF** | 5.631 | 1.991 | 0.005 | 1.701 | 9.561 |
| | **M-OFF** | 4.764 | 2.008 | 0.019 | 0.799 | 8.728 |
| | **S-ON-2** | 6.999 | 1.949 | 0.000 | 3.151 | 10.847 |

### 4.4.6. Factors Affecting Completion of Face Shield Attachment

Highly variable results were found in face shield attachment, leading to a violation in homogeneity of variance. In comparison to the other donning tasks affixing the face shield was not physically or technically more difficult. Problems arose with many participants due to the face shields physical design and configuration. The face shield was attached via Velcro to the side of the hood in order to keep it out of the way until needed. Many participants failed to visually locate the folded face shield once they had donned their head piece (see Figure 4-12). Once their hand protection was donned many did not have the tactile sensitivity to locate or pull the face shield off the Velcro and, if successful, many could not control it to position it across their face because of a lack of dexterity. There were also multiple instances of the face piece itself not being of adequate length to fit across the face to reach its Velcro attachment. This was mainly due to how the participants head was positioned within the hood. These empirical results and anecdotal evidence suggest that an improved design of face shield system is required to increase the likelihood of successful identification, release and attachment.

**Figure 4-12: Storage Position of Face Shield**

### 4.5. ORDER EFFECT OF DONNING TRIALS

As a post-hoc analyses, donning conditions were assessed for order effects, to examine to what extent participants "learned" over the course of the experiment. Figure 4-13 describes the mean total donning times of participants in the order in which they completed each trial. In general, donning times were reduced with each successive donning trial and was independent of the condition demands (e.g. motions and lighting). A significant difference in the trial ordering and total time to don an immersion suit was observed ($F=6.3$; $p<.0001$). A post-hoc analysis revealed that there was a statistical difference between the first trial a participant donned a suit in and the fifth ($p=.018$) and sixth ($p=.016$) and the seventh ($p<.0001$). The statistically insignificant times of the initial donning attempts coupled with the repeated significance of the final trials suggest that a particular level of repeatable performance and learning has occurred. These findings propose that the most efficient and effective way to optimize immersion suit donning training would be to perform five consecutive donning trials (with adequate rest periods) within a training session for significant student learning to occur.

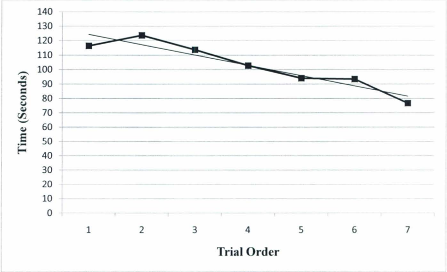


**Figure 4-13: Mean Donning Times of Participant Trials in Sequential Order**

In general, the donning times and the number of participants who failed to fully complete the tasks in under 2-minutes, decreased with each successive trial attempted (see Figure 4-14). These data suggest that the more practice, exposure and familiarity you have with an immersion suit, the quicker you will be able to complete the tasks. It is most obvious to compare the first to the last donning trial (Stable, Light On) as they were always performed first and last. The first trials mean time was recorded at 116.4 seconds, while the seventh trial, in the identical environment produced a mean time of 76.7 seconds, a reduction of 39.7 seconds, or 34.1%.

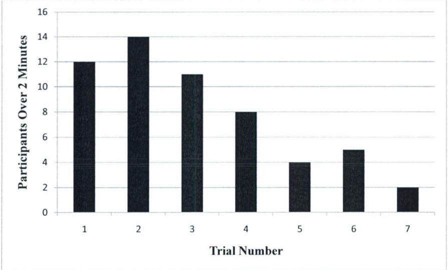


**Figure 4-14: Donning Trials Over 2-Minutes in Sequential Order**

### 4.6. HEART RATE

#### 4.6.1. Age Predicted Peak Heart Rate

Age predicted peak heart rate can be used to represent cardiovascular effort, and thus used as an indicator of how hard an individual is working while performing a task. These data were derived to find each participant's individual age predicted maximum heart rate, represented as a percentage and statistically analysed. Overall, mean peak cardiac output was 82.1% of participants' theoretical maximum, defined as vigorous-intensity physical activity by the Centers for Disease Control and Prevention (2011). Figure 4-15 details the percentage of the participant's theoretical peak heart rate in each condition; the maximum attainable value being 100%. Heart rate values ranged from a moderate 52.3% cardiac intensity to 100.0% of participants' predicted maximum heart rate. Donning an immersion suit is by no means extended physical activity, nor is it uniform in its physical demands or intensity, however, the rapid escalation of physical demand and stress placed on the cardiovascular and muscular systems has the potential to have negative consequences on even healthy, active individuals.

A significant difference was reported between suits ($F=6.3$, $p<.0001$), with the FW suit reporting a mean of 5.9%, or 12.1 BPM less than those who used the MS suit. It is important to note that in each of the conditions recorded values of 93.4% to 100% maximum theoretical cardiac output were reported, while nobody reported maximum values lower than 52.3% of their maximum.

No significant difference was found between experimental condition and the heart rate percentage of age predicted maximum heart rate ($p=.149$), revealing that the amount of effort required to don an immersion suit is not significantly different between motion or stable conditions. No significant interaction effects were observed ($p=.912$). Highest peak mean heart rate percentages for both suits were found in both motion conditions, FW "Motion – Light Off" at 83.2% and MS in the "Motion – Light On" condition at 87.9%. FW maximum values were reported at 97.5% for both "Motion – Light On" and "Motion – Light Off", while the MS maximum value was reported as 100.0% in "Motion – Light On".

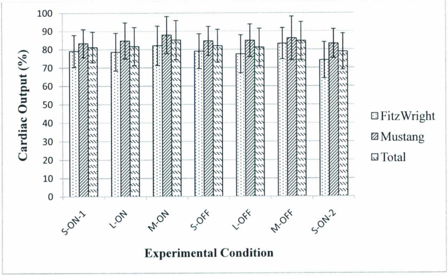


**Figure 4-15: Theoretical Age Predicted Peak Heart Rate Mean Percentage**

### 4.7. DONNING TASK ERRORS

Throughout each of the participants' seven donning trials, the majority of individuals at some point made one or more donning task errors. These incomplete tasks were identified and subdivided into two categories: the first when a participant failed to execute a donning sub- task(s) altogether (e.g. not attempting to attach the face shield). The second when a participant attempted a specific donning task(s), however failed to correctly complete said task(s) (e.g. recognizing and attempting to attach a Velcro wrist strap, but failing to correctly attach and secure the strap). If a participant failed to execute a task altogether, data were not available and thus not included within the statistical analyses. For a task which was attempted but not successfully completed, the amount of time spent on the task was reported and used for analyses, but categorized as incomplete.

Analyses of donning errors were performed by using the original four donning sub-tasks broken down into greater detail for a total of seven items (see Table 4-9).

**Table 4-9: Donning Task Error Analysis**

| Category | | | Donning Error Groupings |
|---|---|---|---|
| **1** | **Critical Tasks** | 1 | All Limbs Within Suit |
| | | 2 | Hood On, Zipper Fully Sealed |
| **2** | **Hand Protection Tasks** | 3 | 1st Hand Protection Donned |
| | | 4 | 1st Velcro Wrist Strap Attached |
| | | 5 | 2nd Hand Protection Donned |
| | | 6 | 2nd Velcro Wrist Strap Attached |
| **3** | **Face Shield** | 7 | Face Shield Attachment |

### 4.7.1. Total Donning Task Errors

Figure 4-16 reveals the percentage of total errors made over all conditions for each donning task. These values include both delineations of errors previously discussed above. Overall, 8.0% of donning tasks had some form of error, whether it was classified as simply not attempting the task, or attempting the task but failing to execute, or complete the task correctly. Although eight percent appears to be a low failure rate the ramifications of a donning error could jeopardize the suit's overall integrity, compromise the protection of the individual and pose a hindrance to emergency operations which may need to be carried out. It is also necessary to note that each of the tasks recorded at least one error, meaning that even the initial, critical tasks which are necessary for the suit to retain its most basic lifesaving properties were not completed by some participants. Generally, the tasks which saw the majority of the errors were those requiring finer motor skills. The first two sub-tasks are classified as larger movement, gross motor tasks while donning hand protection and attachment of the face shield require fine manual tactility and dexterity.

The task which resulted in the highest number of errors was attaching the face shield which incurred a 19.5% error rate across all conditions and suits. There were some issues with the shield being too tight to affix across the face, as well as the vision problems some participants encountered while affixing it. However, in general this task is not overly challenging compared to some of the more fine motor movements required to complete the hand protection and wrist strap tasks. The majority of the participants' issues with the face shield arose from the fact that the face shield was attached to the immersion suit hood, which was out of the participant's field of view once their hood was donned. Many participants simply could not successfully locate the face shield, while others who knew its location, did not have the hand dexterity and/or perception to detach the face shield. The tasks which resulted in the next two highest error rates were the attachment of the first and second Velcro wrist straps, at 12.1% and 18.1% error rates respectively. These tasks are arguably the hardest of immersion suit donning, which require the highest degree of perception, hand dexterity and precision. After donning the suit's hand protection one must detach the Velcro from its original position, correctly wrap it around the wrist and attach the male and female sides of the Velcro together with little to no visual contrast between Velcro, wrist strap or hand protection (all black). Donning of the second hand protection resulted in a total error rate of 1.4%, while the first hand protection resulted in 0.5%. The increase of the second hand protection over the first may be attributed to the decrease of hand dexterity and manoeuvrability once the first hand protection is donned. The two critical tasks "All Limbs Within Suit" and "Hood

On/Zipper Up" reported 0.5% and 3.7% error rates, respectively. These two figures may be looked at as the most concerning. If multiple participants cannot correctly unpack, don and seal the suit in a laboratory setting, real-world conditions would likely lead to increased donning errors and times.

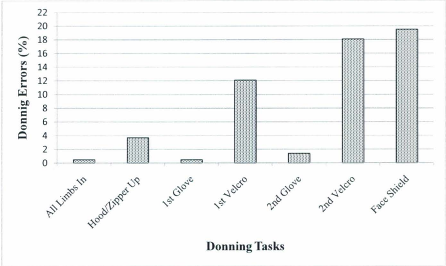


**Figure 4-16: Percentage of Total Donning Task Errors**

### 4.7.2. Comparison of Donning Task Errors Across Experimental Conditions

Figure 4-17 reports the total percentage of donning task errors within each condition. The majority of task errors are from three tasks: 1st Velcro, 2nd Velcro and the face shield, ranging up to 56.3% failure rates for tasks specific conditions. The highest mean percentage of donning errors occurred with the face shield at 19.2%, followed closely by the 2nd Velcro at 18.2% and 1st Velcro with 12.2% errors. In terms of experimental condition values ranged from 5.1% to 12.5% task errors. Interestingly, "Stable – Light On 1" recorded the highest task error rate when observing across all conditions. At 12.5%, participants' initial exposure to a suit in benign conditions recorded higher than that of all motion and darkness condition combinations. This result, as discussed in terms of donning time, suggests that initial exposure produces higher error rates (as well as higher donning times) then if an individual had some exposure to an immersion suit and donning it within darkness and motion conditions.

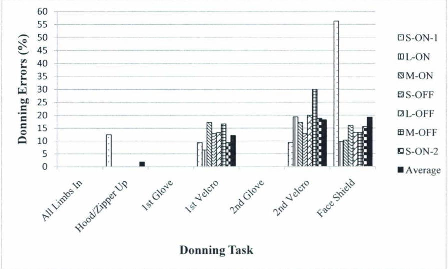


**Figure 4-17: Donning Task Errors in Comparison to Experimental Condition**

#### 4.7.3. Failure to Execute a Donning Task

Failure to execute a donning task is defined as a participant who did not attempt a task whatsoever, by either not realizing a task needed to be carried out, or forgetting to implement the task. Figure 4-18 shows the comparison between suit manufactures donning tasks which were not executed or attempted. In total only the two Velcro tasks and the face shield were not attempted. For both suit types, the face shield reported the task with highest percentage non-attempts (FW=17.3%, MS=11.8%), while the Velcro tasks reported less than 3.0% non-attempts.

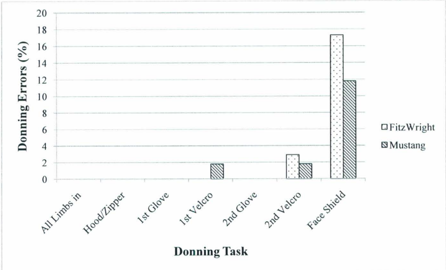


**Figure 4-18: Donning Tasks Not Executed**

### 4.7.4. Donning Task Attempted, But Failed to be Correctly Completed

Figure 4-19 reports the percentage of donning tasks which were attempted by the participants but were not completed correctly. This gives a more representative picture of the percentage of errors certain tasks evoke in comparison to how many times they are actually attempted.

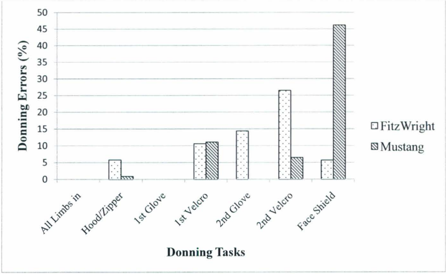


**Figure 4-19: Donning Tasks Attempted, But Not Correctly Completed**

### 4.7.5. Total Donning Task vs. Critical Task Errors

Figure 4-20 illustrates the comparison between the four donning sub-tasks which make up the criteria for a fully donned suit, and the two donning tasks which represent the critical donning tasks. Similarly to what is seen in section *4.7.2. Comparison of Donning Task Errors Across Experimental Conditions*, the highest percentage of donning errors for both divisions is found in the baseline "Stable – Light On 1", followed by "Motion – Light Off". In each condition the critical donning tasks have a lower percentage of errors, ranging from zero to a maximum of 6.3%, while the total donning tasks errors percentage ranges from 4.6% to 12.5%.

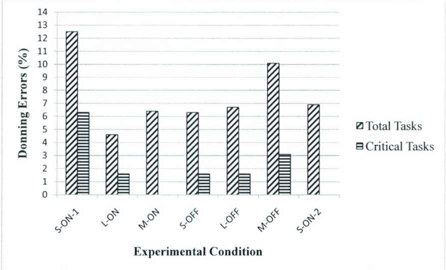


**Figure 4-20: Total Donning Tasks vs. Critical Tasks – Comparison of Errors**

In terms of comparing all four donning sub-tasks which form a fully donned immersion suit and the initial two "critical tasks" one can divide them into two categories: the gross movement critical tasks and the finer motor movement tasks which require greater hand dexterity to don hand protection and the face shield. Overall, it is vital to stress the importance of an immersion suit as a complete system however there is a benefit of discussing the critical tasks separately from the other sub-tasks. They represent greater protection for the body's vitals, require less time to complete, require less fine, tactile movements, and produce higher completion rates and lower task errors. Although on completion of the critical tasks the hands and face are still exposed, one can still survive immersed with a fully sealed, watertight immersion suit than if a zipper or seal was not properly set because attention was diverted to donning the hand protection or face piece. Ultimately an immersion suit leak has far more serious consequences than an exposed face or hand.

# CHAPTER 5: CONCLUSION

This is the first empirical research investigating whether untrained subjects could meet the time required to don a marine abandonment immersion suit, as established by Canadian regulatory standards (CGSB, 2005). The standard specifies that the suit must be unpacked and donned within 2-minutes. However, this criterion has never been assessed in settings likely to reflect marine evacuation conditions.

From this study it can be concluded that although the participants mean donning times were measured to be less than 2-minutes across all experimental conditions, in 26.1% of the trials, the subject failed to meet this standard. From a due diligence perspective, it is unacceptable that more than a quarter of all donning attempts failed to satisfy the 2-minute regulation and that nearly every participant made one or more donning task errors over the course of their trials. These results strongly support the need to revisit the suitability of the current standard.

It is critical in these circumstances that research methodologies and training approaches are established to adequately reflect the environmental conditions which individuals are likely to experience. This would then permit the establishment of defensible, research-informed, performance-based standards that would be more likely to ensure that all personnel can successfully don an abandonment suit within the critical time period and increase the chances for successful survival and rescue.

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# APPENDIX A:

## PARTICIPANT RECRUITMENT POSTER

# RECRUITMENT FOR SCIENTIFIC RESEARCH PROJECT

### "Donning Times of Marine Abandonment Immersion Suits Under Simulated Evacuation Conditions"

Memorial University's School of Human Kinetics & Recreation & Marine Institute investigators are conducting research on the donning times of marine abandonment immersion suits in simulated marine conditions.

We are looking to recruit healthy males and females, over the age of 19 to volunteer for this experiment. The study consists of performing one, 2.5 hour session at a laboratory located in the Engineering building at Memorial University. You will be asked to don (put on) a marine immersion suit 7 separate times in a variety of motion and lighting conditions. THERE IS NO WATER IMMERSION INVOLVED IN THIS EXPERIMENT WHATSOEVER, all trials take place in a dry laboratory set at general room temperature.

If you have any of the following criteria, you will NOT be eligible for the study:

- Worked in a marine setting or had prior experience with immersion (survival) suits
- Large susceptibility to motion sickness
- Pre-existing cardiovascular conditions
- Pregnant

Testing for the study will run through to the end of January 2011; evening and weekend lab times are available. If you are interested in volunteering or have any questions, please contact Steven Mallam at:

## smallam@mun.ca

# APPENDIX B:

## STANDARDIZED INFORMATION LETTER

Thank you for your interest in participating in the research study **"Donning Times of Marine Abandonment Immersion Suits Under Simulated Evacuation Conditions".** The following is important information regarding your participation:

1. It is important that you have had no prior experience in donning immersion suits. If you have had experience with immersion suits or worked professionally in a marine environment then we CAN NOT included you as a study subject.

2. When attending a session please wear athletic, laced footwear (ex. running sneakers, cross trainers, etc.).

3. Please wear comfortable non-restrictive clothing (ex. shorts & t shirt). You will be asked to wear a pair of one piece work coveralls over your clothing.

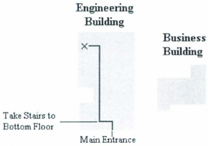
4. Please refrain from the following:

    - Wearing any jewellery/watches.

    - Wearing eyeglasses (if you have contact lenses please wear).

    - Consuming caffeine three (3) hours before your trial.

The laboratory is located on the bottom floor of the Engineering and Applied Sciences Building at Memorial University St. John's campus in the **Fluids & Hydraulics Laboratory, EN 1035 (see map below).** As you walk through the doors on your left hand side there is a fenced in area where the laboratory is located.




If you have any questions do not hesitate to contact Steven Mallam at:

Email: smallam@mun.ca
Mobile: 709-693-0327
Laboratory phone number: 709-864-6765

Thank you,
Steven Mallam

# APPENDIX C:

## VOLUNTARY CONSENT FORMS FOR HUMAN SUBJECT PARTICIPATION

School of Human Kinetics and Recreation
Memorial University of Newfoundland
Offshore Safety and Survival Centre

## Consent to Take Part in Research

**TITLE**: Donning Times of Marine Abandonment Immersion Suits Under Simulated Evacuation Conditions

**INVESTIGATOR(S)**: Dr. Scott MacKinnon, Steven Mallam, Graham Small

**You have been invited to take part in a research study. It is up to you to decide whether to be in the study or not. Before you decide, you need to understand what the study is for, what risks you might take and what benefits you might receive. This consent form explains the study.**

**The researchers will:**

- **discuss the study with you**
- **answer your questions**
- **keep confidential any information which could identify you personally**
- **be available during the study to deal with problems and answer questions**

### 1. Introduction/Background:

During maritime emergencies time is of the essence, anecdotal evidence from reports of incidents in which vessels have sunk rapidly and incidents where crewmembers have delayed donning immersion suits shows that incorporating immersion suit donning time into emergency response planning is essential. Investigating donning time of an immersion suit on a motion simulator can determine whether this factor significantly increases the time needed to prepare to evacuate and thus emergency response planning times at sea.

### 2. Purpose of study:

The purpose of this study is to investigate the extent to which a moving platform simulating a ship deck at sea impairs the ability of an individual to don an immersion suit. This information will identify means in which motions effects on donning time may be mediated.

**3. Description of the study procedures and tests:**

The study will be performed over two three hour-long sessions. During the first session there will be a standard information session to explain the procedures and the immersion suits. You will be asked to don two differing models of immersion suits over a variety of simulated motion conditions that will be completed in random order over the two sessions (see Figure 1). Note that each suit and motion condition will be complete in a lighted and darkened room. Therefore you will be required to don a suit 20 times throughout the duration of the experiment. Each trial has been allotted 10 minutes to allow you to rest in between trials. All sessions will be videotaped.

| MOTION BED | IMMERSION SUIT | LIGHT |
|---|---|---|
| Stable (Baseline) | Suit 1 | On |
| Static List | Suit 2 | Off |
| Motion | | |

Figure 1: Experimental Matrix

**4. Length of time:**

You will be expected to come to two three hour-long testing sessions.

**5. Possible risks and discomforts:**

The procedure poses minimal risk to the participant. The physical risk of injury has been minimized by completely padding the motion simulator platform railing with standard gym mats. Feelings of nervousness or self-consciousness may arise as a result of having your actions recorded and monitored by practitioners. There may be a chance of some feelings of discomfort such as motion sickness from the movement of the motion simulator. If you begin to feel symptoms of motion sickness, such as dizziness, headaches, stomach aches or nausea notify the investigators and the simulator will be stopped immediately. Participation in this study is strictly voluntary, thus you are free to withdraw at any time.

**6. Benefits:**

It is not known whether this study will benefit you.

7. **Liability statement:**

Signing this form gives us your consent to be in this study. It tells us that you understand the information about the research study. When you sign this form, you do not give up your legal rights. Researchers or agencies involved in this research study still have their legal and professional responsibilities.

8. **What about my privacy and confidentiality?**

Protecting your privacy is an important part of this study. Every effort to protect your privacy will be made. However it cannot be guaranteed. For example we may be required by law to allow access to research records.

When you sign this consent form you give us permission to

- Collect information from you
- Share information with the people conducting the study
- Share information with the people responsible for protecting your safety

**Access to records**

The members of the research team will see study records that identify you by name. Other people may need to look at the study records that identify you by name. This might include the research ethics board. You may ask to see the list of these people. They can look at your records only when one of the research team is present.

**Use of records**

The research team will collect and use only the information they need for this research study.

This information will include your

- date of birth
- sex
- height
- weight
- hip/waist measurement
- experience of working in moving environments

Your name and contact information will be kept secure by the research team in Newfoundland and Labrador. It will not be shared with others without your permission. Your name will not appear in any report or article published as a result of this study.

Information collected for this study will be kept for 5 years.

If you decide to withdraw from the study, the information collected up to that time will continue to be used by the research team. It may not be removed. This information will only be used for the purposes of this study. Information collected and used by the research team will be stored in Room 3054 INCO Building, MUN and Scott N. MacKinnon is the person responsible for keeping it secure.

**Your access to records**

You may ask to see the information that has been collected about you.

**9. Questions:**

If you have any questions about taking part in this study, you can meet with the investigator who is in charge of the study at this institution. That person is: Scott MacKinnon (737-7249).

**Dr. Scott N. MacKinnon – phone # 709-737-7249**

Or you can talk to someone who is not involved with the study at all, but can advise you on your rights as a participant in a research study. This person can be reached through:

**Office of the Human Investigation Committee (HIC) at 709-777-6974 or Email: hic@mun.ca**

After signing this consent you will be given a copy.

## Signature Page

**Study title**: Donning Times of Marine Abandonment Immersion Suits Under Simulated Evacuation Conditions

**Name of principal investigator**: Dr. Scott N. MacKinnon

**To be filled out and signed by the participant:**

| | Please check as appropriate: |
|---|---|
| I have read the consent. | Yes { } No { } |
| I have had the opportunity to ask questions/to discuss this study. | Yes { } No { } |
| I have received satisfactory answers to all of my questions. | Yes { } No { } |
| I have received enough information about the study. | Yes { } No { } |
| I have spoken to the researcher(s) & they have answered my questions. | Yes { } No { } |
| I understand that I am free to withdraw from the study. | Yes { } No { } |

- at any time
- without having to give a reason
- without affecting my future [student status, etc.]

| | |
|---|---|
| I understand that it is my choice to be in the study and that I may not benefit. | Yes { } No { } |
| I agree to be video/audio taped. | Yes { } No { } |
| I agree to take part in this study. | Yes { } No { } |

____________________________ __________________________

Signature of participant Date

____________________________ __________________________

Signature of witness (if applicable) Date

**<u>To be signed by the investigator or person obtaining consent</u>**

I have explained this study to the best of my ability. I invited questions and gave answers. I believe that the participant fully understands what is involved in being in the study, any potential risks of the study and that he or she has freely chosen to be in the study.

________________________________________ ________________________

Signature of investigator/person obtaining consent Date

Telephone number: 709-737-7249

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

# PAR-Q & YOU

**(A Questionnaire for People Aged 15 to 69)**

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

| YES | NO | | |
|---|---|---|---|
| ☐ | ☐ | 1. | **Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?** |
| ☐ | ☐ | 2. | **Do you feel pain in your chest when you do physical activity?** |
| ☐ | ☐ | 3. | **In the past month, have you had chest pain when you were not doing physical activity?** |
| ☐ | ☐ | 4. | **Do you lose your balance because of dizziness or do you ever lose consciousness?** |
| ☐ | ☐ | 5. | **Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?** |
| ☐ | ☐ | 6. | **Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?** |
| ☐ | ☐ | 7. | **Do you know of any other reason why you should not do physical activity?** |

**If you answered**

## YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

## NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

**DELAY BECOMING MUCH MORE ACTIVE:**

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

**PLEASE NOTE:** If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

**No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.**

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ________________________________

SIGNATURE ________________________________ DATE ____________________

SIGNATURE OF PARENT ________________________________ WITNESS ____________________
or GUARDIAN (for participants under the age of majority)

**Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.**



continued on other side...

## QUESTIONNAIRE ON PREGNANCY, VESTIBULAR PROBLEMS, IMMERSION SUIT EXPERIENCE & FITNESS PARTICIPATION

Research Project Title: ***Donning Time of Immersion Suits in Simulated Maritime Environments***

Principal Investigator: Dr. Scott N. MacKinnon, MUN, (709) 737-7249
Co-investigators: Steven Mallam, Graham Small

**NOTE:** Females who are or might be currently pregnant and individuals with vestibular system (or balance organ) problems may not participate in the experiment.

**FOR FEMALES ONLY: PREGNANCY**

1. Are you pregnant? Yes No

2. Is there a possibility that you are now pregnant? Yes No

Acceptable reasons for answering NO to the second question are: contraception by birth control pills, sexual abstinence, and menstruation within 1-2 weeks of experiment.

---

**ALL SUBJECTS: VESTIBULAR PROBLEMS**

1. Have you ever been or are you currently diagnosed with or taken medications for labyrinthitis, vertigo, dizziness, Meniere's disease or any other disease of the hearing or balance system?

Yes No (see last page for descriptions of these vestibular problems)

2. Have you ever suffered a serious head injury? double vision? etc. Yes No

---

**ALL SUBJECTS: Experience of Donning Immersion Suits**

1. Have you ever donned an immersion suit in any situation (whether it was at sea or on land)?

Yes No

**ALL SUBJECTS: PHYSICAL ACTIVITY PARTICIPATION**

1. On average how many times per week do you participate in physical activity?

0 1-2 3-4 5-6 7+

---

**ALL SUBJECTS:**

To the best of my knowledge, I have answered these questions truthfully.

Volunteer's Name ______________________________________

Signature: ______________________________________ Date: ____________________________

Investigator (s):

Signature: ______________________________________ Date: ____________________________

**Brief Descriptions of Vestibular Problems**

**Labyrinthitis** is a balance disorder. It is an inflammatory process affecting the labyrinths that house the vestibular system (which sense changes in head position) of the inner ear. In addition to balance control problems, a labyrinthitis patient may encounter hearing loss and tinnitus. Labyrinthitis is usually caused by a virus, but it can also arise from bacterial infection, head injury, extreme stress, an allergy or as a reaction to a particular medicine. Both bacterial and viral labyrinthitis can cause permanent hearing loss, although this is rare. Labyrinthitis often follows an upper respiratory tract infection (URI).

**Vertigo** is a specific type of dizziness, a major symptom of a balance disorder. It is the sensation of spinning or swaying while the body is actually stationary with respect to the surroundings. There are two types of vertigo: subjective and objective. There is a *subjective* vertigo when a person has a false sensation of movement. In the case of *objective vertigo*, the surroundings appear to move past a person's field of vision. The effects of vertigo may be slight. It can cause nausea and vomiting and, in severe cases, it may give rise to difficulties with standing and walking.

**Dizziness** describes a number of subjective symptoms, which the patient may describe as feelings of lightheadedness, floating, wooziness, giddiness, confusion, disorientation or loss of balance. Causes may stem from a variety of failures of equilibrioception, hypotension, cerebral hypoxia or a reaction to environmental chemicals or drugs.

**Ménière's disease** is a disorder of the inner ear that can affect hearing and balance. It is characterized by episodes of dizziness and tinnitus and progressive hearing loss, usually in one ear. It is caused by an increase in volume and pressure of the endolymph of the inner ear. The symptoms of Ménière's are variable; not all sufferers experience the same symptoms. However, so-called "classic Ménière's" is considered to comprise the following four symptoms.

- Periodic episodes of rotary vertigo or dizziness.
- Fluctuating, progressive, unilateral (in one ear) or bilateral (in both ears) hearing loss.
- Unilateral or bilateral tinnitus.
- A sensation of fullness or pressure in one or both ears.

# APPENDIX D:

## RESEARCH IMMERSION SUIT DONNING INSTRUCTIONS

# IMMERSION SUIT DONNING INSTRUCTIONS

1. Remove suit from storage bag.

2. Remove your footwear.

3. Pull on as you would a pair of overalls.

4. Pull hood over head.

5. Fully close zipper with a slow, even pull (tilt head back).

6. Remove gloves from arm pockets and don.

7. Attach Velcro straps on gloves around wrists (to create a double seal).

8. Attach face piece found on hood across your mouth.

IT IS IMPORTANT THAT YOU DON THE SUIT AS QUICKLY & AS ACCURATLEY AS POSSIBLE ACCORDING TO THESE INSTRCUTIONS

# APPENDIX E:

## FITZWRIGHT IMMERSION SUIT DONNING INSTRUCTIONS

# FitzWright "Explorer" Immersion Suit
# Combinaison d'immersion FitzWright
# Model 9700

**ADULT - UNIVERSAL SIZE** **ADULTE - GRANDEUR UNIVERSELLE**



### *Donning Instructions:*

1. REMOVE SHOES
2. Pull on as you would a pair of overalls.
3. Pull hood over head.
4. Close zipper with a slow, even pull.
5. Remove gloves from arm pockets and don.
6. Inflate life vest only after entering water.

### *Façon De S'habiller*

1. ENLEVEZ LES SOULIERS
2. Endossez de le même façon qu'une salopette.
3. Tirez le capuchon sur la tête.
4. Fermez lentement la fermeture éclair
5. Enlevez les gants des poches, portez-les.
6. Gonfler l'oreiller dès que vous êtes entre dans l'eau.

### *Care and Maintenance*

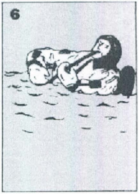
Do Not Dry Clean - Buoyant Material is closed cell neoprene.

1. After use rinse with cool or luke warm fresh water.
2. Allow to drip dry.
3. Lubricate zipper with paraffin wax.
4. Glue tears with neoprene contact cement.
5. Store with zipper in open position.
6. Do not store in high temperature area.

### *Soin et entretien*

Ne pas nettoyer à sec - La matière flottable est composée de cellules fermées en néoprène.

1. Rincez avec l'eau fraiche froide ou tiède après usage.
2. Laissez égoutter.
3. Lubrifiez la fermeture eclair avec de la parraffine Solide.
4. Collez les déchirures à l'aide de colle de contact néoprène.
5. Entreposez avec la fermeture éclair en position ouverte.
6. Ne pas entreposer dans un endroit chaud.


**OPERATION OF INFLATOR:** 1. Bring inflation hose to mouth. 2. Push inflation valve in with teeth and blow. 3. Release between breaths. 4. Continue until fully inflated.

**FONCTIONNEMENT DU GONFLEMENT.** 1. Mettez le tuyau de gonflement dans la bouche. 2. Poussez la valve de gonflement avec les dents et soufflez. 3. Déclanchez la valve entre respirations. 4. Continuez jusqu'à-ce qu'il soit gonflé

Made in Canada By "FitzWright" Co. Ltd., Langley, B.C. Canada
Fabriqué au Canada par "FitzWright" Co. Ltd., Langley, B.C. Canada

# APPENDIX F:

## MUSTANG IMMERSION SUIT DONNING INSTRUCTIONS

# OCEAN COMMANDER OC8001

IMMERSION SUIT / COMBINAISON FLOTTANTE

| | |
|---|---|
| Complies with/ Conforme aux normes: | **S.O.L.A.S. 74 / 96** |
| Model / Modèle: | **OC8001** |
| Adult/Adulte: | **Universal / Universel** |
| Body Weight / Poids: | **110 - 330 lbs (50 - 150 kg)** |
| Height / Taille: | **59 - 78 in. (1.5 - 2 m)** |


**MUSTANG SURVIVAL**
3810 Jacombs Road
Richmond, BC
Canada V6V 1Y6
TEL 1.800.661.6181
EMAIL mustang@mustangsurvival.com
www.mustangsurvival.com


**WARNING: THERE IS A RISK OF ENTRAPMENT IN A SUBMERGED COMPARTMENT DUE TO THE BUOYANCY OF THE SUIT.**

**AVERTISSEMENT: IL Y A RISQUE DE RESTER PRIS AU PIÈGE DANS UN ENVIRONNEMENT SUBMERGÉ CAUSE DE LA FLOTTABILITÉ DU VÊTEMENT.**

**CANADIAN COAST GUARD APPROVAL #**
**T.C. 029-070-039**

## Donning Instructions / Mode D'emploi

**1** Remove footwear, climb into suit. Use pull tabs at back of boot to assist donning. Pull on suit as coveralls. Use pull tabs above each wrist to assist wrist seal over hand.

Enlevez vos chaussures, entrez dans la combinaison. Utilsez les languettes à l'arrière de la botte pour vous aider à enfiler. Enfilez la combinaison comme un couvre-tout. Tirez sur les languettes de chaque poignet pour vous aider à passer le poignet par-dessus la main.

**2** Hood on, tip head, pull up zipper by toggle.

Avec le capuchon en place, inclinez la tête et remontez la fermeture éclair par la barrette.

**3** Don gloves from arm pockets. Secure each at wrist.

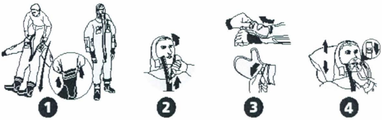
Revêtez les gants à partir des poches de manche. Fermez-les au niveau des poignets.

**4** Inflate head support by depressing inflation tube cap and blowing into mouthpiece.

Gonflez le support de tête en retirant le bouchon du tube de gonflement et en soufflant dans l'embouchure.

**5** The Ocean Commander Immersion Suit comes equipped with a rescue light. The rescue light will automatically activate upon immersion in water.

La combinaison isolante Ocean Commander est équipée d'une lampe de sauvetage qui s'actionne automatiquement au contact de l'eau.




## Folding Instructions / Instructions Pour Plier

**1** Lay the suit out flat. **A)** Unzip front zipper. **B)** Turn suit over, front side down.

Étendre la combinaison à plat.
**A)** Descendre la fermeture éclair devant.
**B)** Renversez la combinaison, le côté de devant en bas.

**2** Grasping both boots at the top of the ankles, 2"–3" above the top of the boot, and fold them over.

Agrippex les deux bottes au-dessus des chevilles, 2" à 3" au-dessus du haut de lat botte et repliez-les une sure l'autre.

**3** Continue to: **A)** Fold the ankles up to the waist. **B)** & **C)** Fold arms across the chest and roll the whole suit up.

Continuez à: **A)** Plier les chevilles jusqu'à la taille. **B)** & **C)** Plier les bras en croix sur la poitrine et rouler toute la combinaison.

**4** Insert folded suit into bag.

Insérez la combinaison roulée dans le sac de transport.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