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Immersion Suit Flotation Testing

REACT Report

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Homeland Security

N O T I C E

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16. Abstract (MAXIMUM 200 WORDS)

After the October 2015 sinking of the SS EL FARO with loss of life, a Coast Guard (CG) Marine Board of Investigation (MBI) reviewed why searchers could not relocate the remains of a victim in an immersion suit. A board member requested CG Research and Development Center (RDC) help in determining the extent of previous immersion suit experiments separate from the testing requirements in 46 CFR 160 and whether the immersion suits EL FARO carried retained flotation capability after extended time in the water.

The RDC planned and conducted a test to see if weighted mannequins in the same type of immersion suits EL FARO carried, showed any loss of flotation after a two-week period. The RDC moored two weighted mannequins in immersion suits in the basin at Little Sand Island, Mobile River, AL. The tethered, but free-floating mannequins remained in the water for a two-week period.

The observations indicated no-to-little loss of flotation, with an extremely small amount of water intrusion into each suit (less than one liter of water). However, the suits did accrue a significant amount of marine vegetative growth that masked the apparent waterlines of the immersion suits.

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EXECUTIVE SUMMARY

Subsequent to the October 2015 sinking of the Steamship (SS) EL FARO with loss of life, a Coast Guard (CG) Marine Board of Investigation (MBI) reviewed why searchers could not relocate the remains of a victim in an immersion suit. A board member requested CG Research and Development Center (RDC) help in determining the extent of previous immersion suit experiments (separate from the testing requirements in Title 46 Code of Federal Regulations (CFR), Section 160) and whether the immersion suits EL FARO carried retained flotation capability after extended time in the water.

The RDC planned and conducted a test to see if weighted mannequins in the same type of immersion suits showed any loss of flotation after a two-week period. Researchers used mass-distribution information from the Tri-Service Aeromedical Research Panel to ballast a “plus-size” male mannequin to best reflect the weight distribution of a large, adult male. After a “trial run” at the RDC in New London, CT, including floating a weighted mannequin in a swimming pool, the test team disassembled and moved all the gear and equipment to the Joint Maritime Test Facility (JMTF) in Mobile, AL for actual deployment.

The RDC test team selected the JMTF’s Little Sand Island Basin for deployment location due to its relatively-close, but out-of-the-mainstream location near the JMTF, so the experiment would have a better chance to succeed without the risk of having the mannequins disturbed by commercial and recreational vessel traffic, and so US Naval Research Laboratory (NRL) contingent transiting to Little Sand Island and the ex-USS SHADWELL test vessel could conduct regular, twice-daily observations of the mannequins’ condition.

The test team spent a full day attaching and reattaching the ballast to the mannequins, inserting the weighted mannequins into the immersion suits, outfitting each suited mannequin with a chlorinated polyvinyl chloride (CPVC) measurement-reference frame, and determining a “dry weight.” On 8 June 2016, with the assistance of the NRL contingent and their landing craft, the RDC team moored two weighted mannequins in immersion suits in the basin at Little Sand Island, Mobile River, AL. The tethered, but free-floating mannequins remained in the water for a two-week period.

Throughout the two-week period, observations indicated no-to-little loss of flotation, with an extremely small amount of water intrusion into each suit (less than one liter of water). However, the suits did accrue a significant amount of marine vegetative growth that masked the apparent waterlines of the immersion suits.

On 23 June 2016, RDC used Aids to Navigation Team (ANT) Mobile’s vessel CG 64350 with crane to recover mannequins. Initial recovery weight (measured with a 50,000-lb load cell (dynamometer)) showed an estimated 20 and 30 pounds increase in weight for each mannequin. Once reweighed (on the same electronic platform scale initially used on 8 June), each weighted mannequin and immersion suit combination did reflect an approximate ten-pound increase in weight. However, when the test team drained the immersion suits, they recovered less than one liter of water from each suit. The team surmised that the heavy, wet marine vegetative growth significantly affected the weight.

Though environmental conditions were benign for the two-week period, the test team concludes that the Coleman-Stearns I590 immersion suits did not appreciably lose flotation during the test.

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LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

ANT	Aids to Navigation Team
CFR	Code of Federal Regulations
CDT	Central Daylight Time
CG	Coast Guard
CG-ENG-4	Coast Guard Headquarters Office of Design and Engineering Standards, Life Saving and Fire Safety Division
cm	Centimeter
CPVC	Chlorinated polyvinyl chloride
F	Fahrenheit
in	Inches
JMTF	Coast Guard Joint Maritime Test Facility
kg	Kilogram
Kt	Knot, nautical miles per hour
lb	Pound
LCM	Landing Craft, Mechanized
MBI	Marine Board of Inquiry
NOAA	National Oceanographic and Atmospheric Administration
NRL	U.S. Naval Research Laboratory
PORTS	Physical Oceanographic Real-Time System
PSU	Practical Salinity Units
RDC	Coast Guard Research and Development Center
REACT	Rapid Evaluation and Analysis of Critical Technologies
RO-CON	Roll-On, Roll-Off Container vessel
SOLAS	International Safety of Life At Sea Treaty
SS	Steam Ship
TANB	Trailerable Aids to Navigation Boat
Var	Variable wind direction

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1 BACKGROUND

On 1 October 2015, the Steamship (SS) EL FARO, a 790-foot, U. S. Flag, combination roll-on, roll-off-container (RO-CON) vessel sank in the Atlantic Ocean, northeast of Crooked Island, Bahamas during Hurricane Joaquin. On 4 October, searchers located an unidentified, deceased crewmember in an immersion suit. On subsequent searches, searchers were not able to relocate the victim and suit.

1.1 Introduction

Though finding an object at sea, especially in post-hurricane conditions, and subsequently relocating that same object is inherently difficult, investigators for the Commandant Marine Board of Investigation raised a concern as to whether an immersion suit in general, and the make and model said to be aboard the SS EL FARO, in particular, would retain flotation capability after 5 days (and possibly as long as fourteen days).

The investigator initially inquired of the CG Headquarters Lifesaving and Fire Safety Division (CG-ENG-4) as to whether there are any models, studies or anecdotal evidence that would indicate how long a survival suit with a deceased body would or could be expected to float. CG-ENG-4 is responsible for the development and implementation of regulations and standards for Lifesaving Equipment under Title 46 Section 160 of the Code of Federal Regulations (46 CFR 160). Though they are involved in immersion suit standards development, and have participated in wave-tank demonstrations as seen in Figure 1[1], CG-ENG-4 did not have background information on development of the existing immersion suit performance standard, which includes “The measured buoyancy must not be reduced by more than 5% after 24 hours submersion in fresh water.”[2]

CG-ENG-4 recommended the investigator contact the Research and Development Center (RDC) as another source of background information. After an initial discussion, the investigator specifically posed the following question to RDC: "How long a survival suit with a deceased body would or could be expected to float. The water temperature was reported to be approximately 81 degrees." In response to the investigator’s request, the RDC planned and conducted a test to see if weighted mannequins in the same type of immersion suits used aboard EL FARO showed any loss of flotation after a two-week period.

[1] CG-ENG-4 email, 11 Apr 16
[2] 46CFR160.171-11. Immersion Suits, Performance

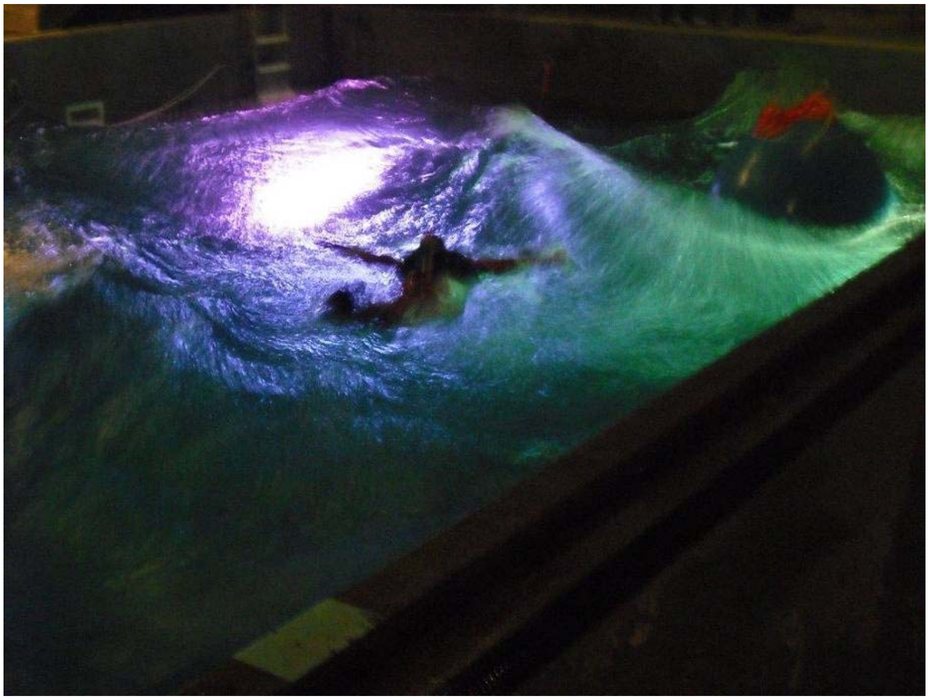

Figure 1. Immersion-suit clad CG-ENG-4 representative in wave tank.

1.1.1 The Coleman-Stearns I590 Immersion Suit

The Coleman-Stearns I590 immersion suit is designed to provide both flotation and prevention from water ingestion/aspiration, and also provides protection against hypothermia.

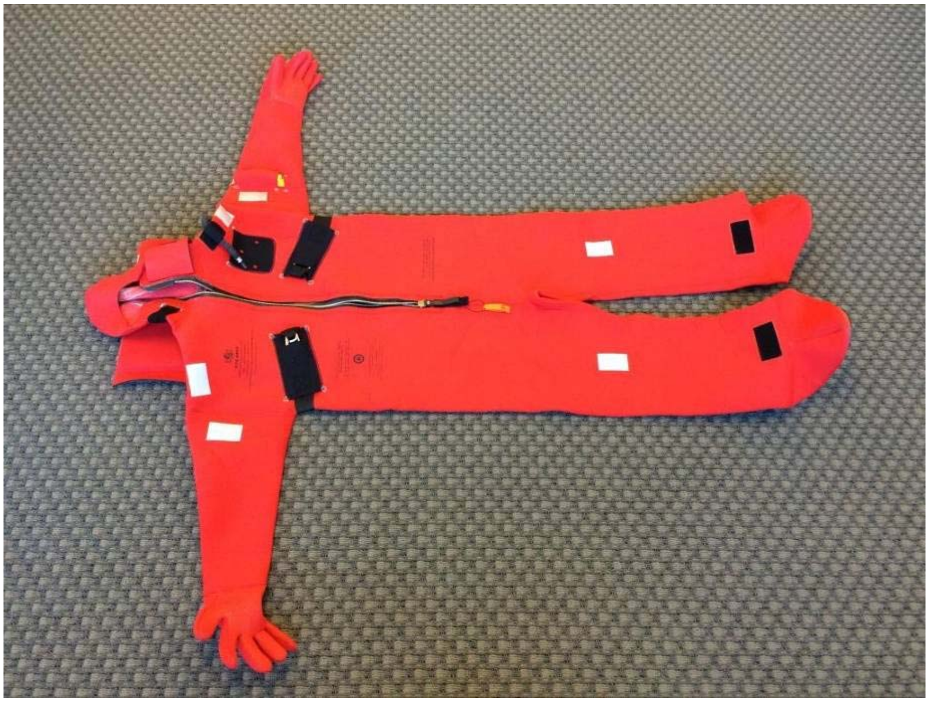

Figure 2. Coleman-Stearns I590 immersion suit.

To comply with 46 CFR 160.171, the "suit must have a stable floating position in which the wearer's head must be tilted to a position between 30° and 80° above the horizontal, with the mouth and nose at least 120 mm (4 ¾ in.) above the surface of the water."[3]

As the Coleman-Stearns I590 Immersion Suit is available in sizes from "Adult Oversize" to "Child/Small Adult," we chose the "Adult Universal," which is rated for a chest size of 30-52 inches (in) (76-132 centimeters (cm)) and weight from 110-330 pounds (lb) (50-150 kilograms (kg)).

Appendix A is the Coast Guard Certificate of Approval for the I590 Adult Universal immersion suit.

For this test, RDC used one, approximately five year-old suit that saw occasional use for training aboard a local CG cutter, and a second, fresh from the factory, brand-new suit. RDC staff carefully inspected the older suit, and found no signs of wear, abrasion, tears or rips, nor material failure, including adhesive seals. Because we received this suit from the CG Cutter ALBACORE, throughout the test we referred to this suit as "suit-A," and later "mannequin A."

2 PROCEDURES

2.1 Test Concept Development and Preparations

Within two days of the request, the project lead proposed the following:

- Conduct a two-week observation/exposure period, in the vicinity of Joint Maritime Test Facility, Little Sand Island, in Mobile Bay, AL.
- Use weighted mannequins to simulate human body mass proportions inside the specific immersion suits.
- Conduct two separate, concurrent trials: one weighted mannequin in a brand-new suit, another in an older (used) suit, appearing undamaged to visual inspection.

The suited mannequins would be marked to note change in apparent waterline.

The team would tether and moor the test gear in the basin near ex-USS SHADWELL. Mooring/tethering would allow for change in tide and swing with wind.

An observer would note and monitor the suits' apparent waterline twice daily, and after 14 days, the team would retrieve test gear and drain/measure quantity of water (if any) from suits.

The test team made clear that this effort would be completely outside the regulatory performance requirements of 46CFR160.171.

[3] 46 CFR 160.171, Ibid.

2.1.1 Review of Available Information

The team looked into how to best-simulate the person in the water, in an immersion suit. Informal queries indicated that other lifejacket and thermal protective testing used types of instrumented mannequins, however RDC did not have one available, and the project team considered both articulated and rigid mannequins. Review of multiple sources showed that articulated mannequins were relatively small for filling out the universal adult suit, so the team settled on a "plus-size," male, rigid display mannequin.

Additionally, the team needed to find appropriate guidance for how to "weight" or "ballast" the mannequins. A search provided the reference "Anthropometry and Mass Distribution for Human Analogues, Volume I: Military Male Aviators;"[4] this provided a basis for how-best to ballast the mannequins.

The project team also considered appropriate venues for the experiment. Ideally, the project desired a site with relatively warm water, ability to moor and tether the mannequins in a fairly "obscure" area to deter the curious from disturbing the devices, and a relatively shallow area so as to allow a simple mooring arrangement, both in weight and hardware requirements.

2.1.2 Venue Selection

In the Joint Maritime Test Facility, RDC has access to vessels and personnel to conduct various types of field testing, including access to the ex-USS SHADWELL, a landing-ship hull used for vessel related testing, and a "burn pan" available for fire testing. Being in Mobile, AL, the project could expect relatively warm water as noted in the original request, a strong probability of daily, late-afternoon thunderstorms with associated rain and wind gusts, and an area subject to surveillance that was somewhat separated from commercial and recreational vessel traffic.

2.1.3 Outfitting the Mannequins

As noted above, we used the information from Anthropometry and Mass Distribution for Human Analogues. The table from the manuscript (Appendix B) provided values for "Mass Distribution of the Body Segments." From this information, we created a table that took into account the mannequin weight distribution (gross assumption) and the amount of ballast per body segment needed to reach an approximate 210 lb male (Table 1).

A standard RDC experiment process is to try out all equipment and gear arrangements at RDC before field deployment. This held true in the case of outfitting the mannequins. Before deployment, we wanted to be sure that the weighted mannequin and suit combination actually did float, and did have a margin of stability so as not to invert.

As the mannequins were rigid, and we would need to "muscle" them into the immersion suits; we fastened the individual ballast weights to the mannequins with nylon webbing and diver's belt buckles, then over-taped the buckles so as not to puncture the immersion suit from the inside. Figure 3 shows a partially ballasted mannequin, and Figure 4 shows the ballasted mannequin in the immersion suit prior to initial flotation testing.

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[4] Anthropometry and Mass Distribution for Human Analogues, Volume I: Military Male Aviators, Tri-Service Committee of the Tri-Service Aeromedical Research Panel, Ft. Rucker, AL, March 1988.

Table 1. Weight distribution for mannequin and ballast combination.

Body-mass Distribution from Appendix A			Conversion to pounds		Sum	Sum	Mannequin weight distribution	Ballast weight desired	Number of diver weights (by size) per body segment		
Body Segment	kg		lb		lb	%	lb	lb	6 lb	4 lb	2 lb
Head	4.4		9.7		9.7	4.5%	1.7	8.0	1	1	
Neck	1.2		2.6		2.6	1.2%	0.5	2.2			
Thorax	30.5		67.2		67.2	31.3%	11.9	55.4	10		
Abdomen	2.9		6.4		6.4	3.0%	1.1	5.3			
Pelvis	14.6		32.2		32.2	15.0%	5.7	26.5	4		1
Upper Arm (L-R)	2.4	2.4	5.3	5.3	10.6	4.9%	1.9	8.7		2	
Forearm (L-R)	1.6	1.6	3.5	3.5	7.1	3.3%	1.2	5.8		2	
Hand (L-R)	0.6	0.6	1.3	1.3	2.6	1.2%	0.5	2.2			
Thigh (L-R)	11.8	11.8	26.0	26.0	52.0	24.2%	9.2	42.8	6	2	
Calf (L-R)	4.5	4.5	9.9	9.9	19.8	9.2%	3.5	16.3		4	
Foot (L-R)	1.1	1.1	2.4	2.4	4.9	2.3%	0.9	4.0	0	2	
Total		**97.6**		**215.2**	**215.2**	**100.0%**	**38.0**	**177.2**	**126 lb**	**52 lb**	**2 lb**
Boots			2.0	2.0				**4.0**			**2**

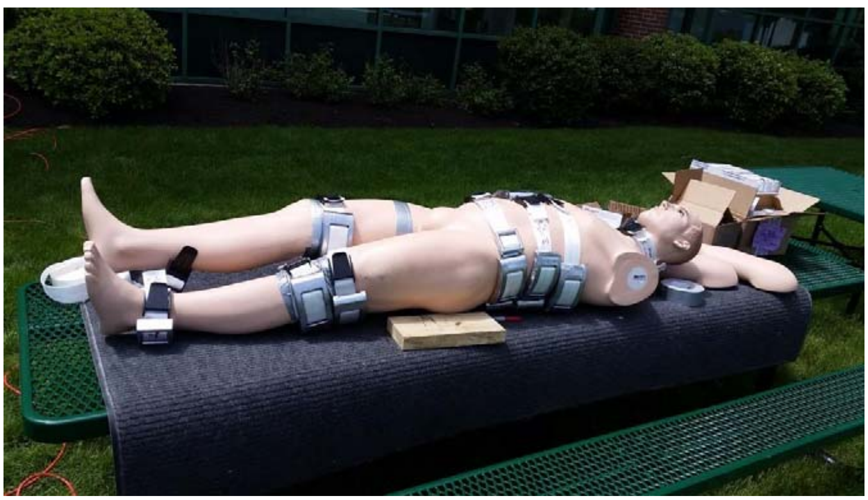

Figure 3. Partially ballasted mannequin at RDC before initial flotation trial.

Figure 4. Ballasted mannequin in immersion suit.

2.1.4 Ballasted Mannequin in Immersion Suit Flotation Test

The project team wanted to test the gear in a relatively-benign environment, and one that would provide clear, clean water for observations. The team arranged with the Coast Guard Academy Physical Education department to use the Billard Hall pool. Though the actual experiment test area in Mobile Bay is brackish water, the less-dense, chlorinated pool water provided a conservative estimate as to the depth to which the weighted mannequin would sink.

The initial flotation test (see Figure 5) indicated conditions that differ from a "real world" situation. First, in "normal" immersion-suit wear, the wearer's posture is often different than shown in Figure 5. In a resting position, a wearer's body would exhibit a bend at the waist-pelvis region, where the rump would sink lower, with the feet and legs tending upward. This, in-turn, would cause the wearer's torso and head to rest at a greater angle with respect to the surface of the water. Second, for our mannequin, both weighted arms appeared to swivel or detach from their initial positions alongside the mannequin torso. The immersion suit kept the arms captive, but did not provide the rigidity as initially desired. For comparison, Figure 6 gives an example of an actual wearer's position in the water. For our purposes, we accepted the difference in flotation aspect as an experiment constraint.

Figure 5. Weighted mannequin/immersion suit flotation trial.

Figure 6. Actual person in immersion suit[5].

2.1.5 Mooring Arrangement

The project team needed to develop a mooring arrangement so as to let the weighted mannequin float freely, yet remain in one place. To accomplish this, we constructed a relatively-standard, shallow-water mooring as shown in Figure 7. Of note, so as to allow relatively free flotation and rotation about the mooring float, we used a tether connecting the mooring to the built-in immersion suit harness, reeved through a section of CPVC pipe so as not to wrap the tether around the mooring itself (a "stand-off" tube). Expecting tidal and wind-generated motion, we used a 75-pound, pyramid anchor, with 20 feet of 3/8 inch mooring chain.

As with the ballasted mannequin, the team fully assembled the mooring arrangement at RDC before field deployment.

2.1.6 Test Plan and Final Preparations

Preparing the mannequins and moorings for deployment gave the team an opportunity to understand how unwieldy the weighted, suited mannequins were. This knowledge gave a basis for deployment and retrieval procedures incorporated in the experiment test plan (Appendix C). After equipment assembly and testing at RDC, we disassembled everything, packed it and shipped it to JMTF Mobile where the team would reassemble the gear for in-water deployment. This included both 75-pound anchors, 350 pounds of lead diver weights, two mannequins, mooring chain, floats, and ancillary hardware.

[5] http://www.setsail.com/survival-training-part-5-immersion-suits/

Figure 7. Mooring arrangement.

2.2 Equipment Mobilization and Deployment

The plan was to assemble all equipment on the first day, deploy equipment on the second day using a Naval Research Laboratory (NRL) vessel assigned to JMTF; then conduct an initial, follow-up observation approximately 24 hours after deployment.

2.2.1 On-site Outfitting and Preparation

The first step was to re-ballast the mannequins as before, using the divers' weights, belts and buckles, and over-taping (Figure 8). After initial ballasting, a problem occurred. During a logistics run for PVC tubing, the fiberglass thigh stub-end for a removable leg mount detached at the seam due to shear force created by the weights. Though the display mannequin was not designed for anything but a "stand-up" mode, the failure indicated the joint relied only on a narrow, resin and filler seam (Figure 9). We tried, unsuccessfully, to find a fiberglass repair-kit at one of the CG units at the Mobile facility, so decided to try to "bandage" the seam with duct tape, applied parallel to the axis of the leg, then wrapped circumferentially (Figure 10).

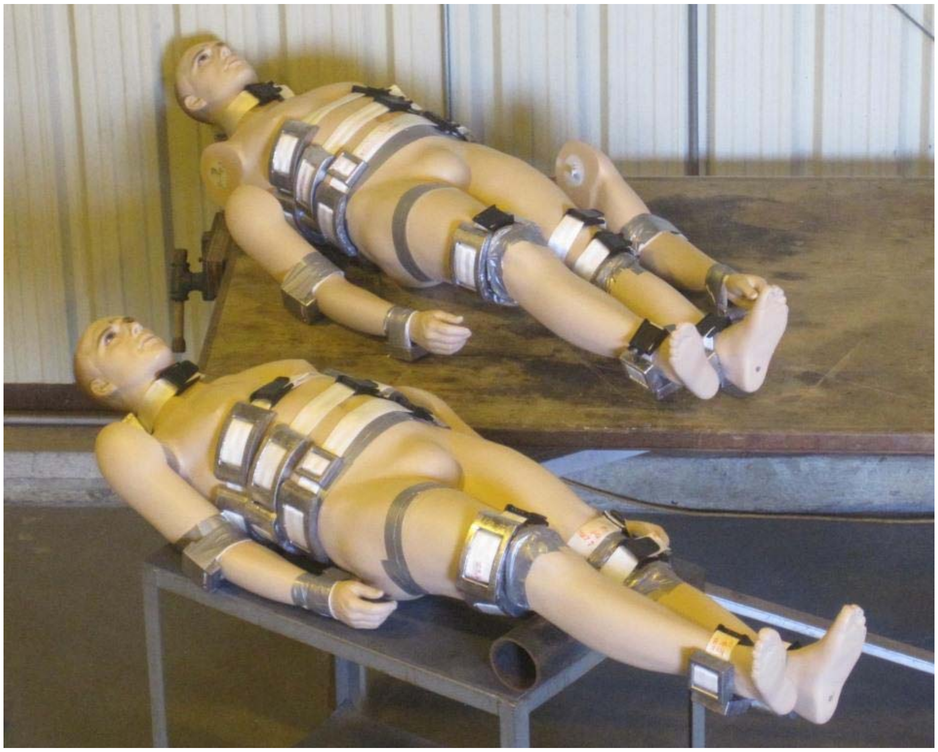

Figure 8. Weighted mannequins before taping at JMTF.

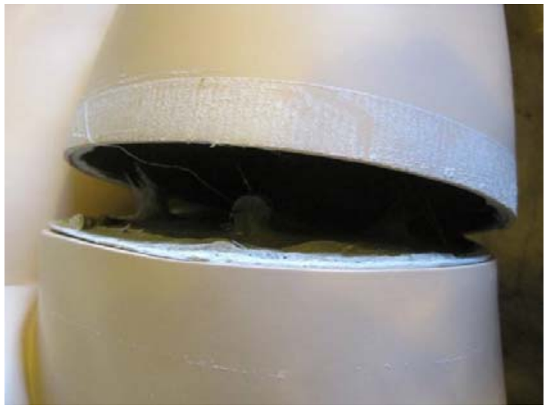

Figure 9. Mannequin leg-joint separation.

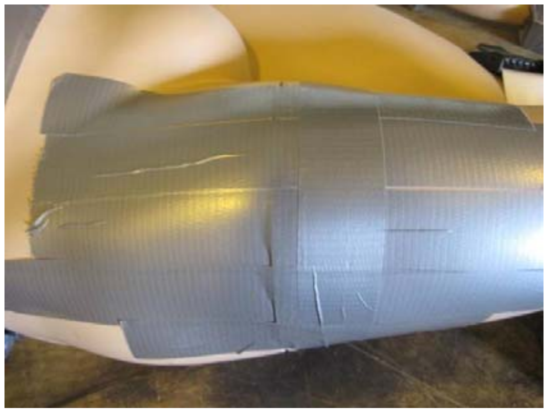

Figure 10. Mannequin duct-tape “bandage.”

After ballasting and suiting the mannequins, the team constructed a frame of ¾-in CPVC tube and fittings around each mannequin to support vertical “measurement posts.” One-inch red and greed retro-reflective tape strips, spaced one inch apart, provided a means to tell whether the mannequins lost buoyancy during the deployment (Figure 11).

Figure 11. Mannequin in suit with measuring posts.

Upon completing the outfitting, the team realized that the plan for attaching the tether and "stand-off" tube needed reconsideration. As planned, the team intended to have the tether/stand-off tube attach to the swivel-shackle beneath the mooring buoy. When the team had the suited mannequin on the outfitting bench, they recognized that the angle for the immersion suit harness clip to the bottom of the buoy would impart a downward force and bind up, preventing a free swing. Instead, the team decided that attaching the tether-stand-off tube to the mooring-buoy's top ring would provide a better lie. Though attaching to the top ring is not standard mooring practice, for the anticipated two-week deployment, the team did not expect any excessive wear.

The team then weighed each fully-outfitted mannequin on an electronic platform scale, being extremely careful not to puncture the suits on the sharp edges of the scale, by using an immobilization backboard, as seen extending past the mannequin in Figure 11, above. Pre-deployment weight was 210 pounds for each mannequin, including suit.

2.2.2 Deployment

Using a telehandler and pallets, JMTF staff and test team loaded all gear onboard the 35-foot NRL Landing Craft Mechanized (LCM-3), and proceeded to the test site in the Little Sand Island basin. The NRL LCM operator recommended a site closer to the east side of the basin than indicated on the test plan due to recent dredge-pipe staging activity (Figure 12). Estimated water depth was 12 feet.

For deployment, the LCM crew lowered the bow ramp, the test team and JMTF staff staged the first mooring on the ramp, put the tethered buoy in the water, then put the anchor over the side, allowing the chain to run free. Next, the team used the immobilization backboard to carefully slide the mannequin into the water; then attached the tether/stand-off to the mannequin, making sure that the tether/stand-off did not foul (Figure 13). Figure 14 shows the mannequins shortly after deployment, at approximately 0830 Central Daylight Time (CDT) on 8 June 2016. The initial readings on the measurement posts were:

Mannequin A-Green Bands: Left side: 8 bands visible. Right Side: 8 bands visible
Mannequin B-Red Bands: Left side: 8 bands visible. Right Side: 8 bands visible

Figure 12. Actual versus intended deployment site, Little Sand Island basin.

Figure 13. LCM-3 at deployment location, bow ramp lowered, mannequin ready for deployment.

Figure 14. Mannequins shortly after deployment.

2.3 Observations and Measurements

Over the two-week deployment period from 8-23 June, observers recorded the general aspect of the mannequins, the visible number of measurement bands, and weather conditions. We planned for twice-daily observations during the workweek by an NRL temporary employee. On weekends, CG Sector Mobile provided either an Auxiliarist or active duty member, to take observations, operations permitting.

With someone making observations in the morning and in the afternoon, the observer could rapidly detect if any significant change occurred in the mannequins' flotation. If this were to occur, the observers were to contact RDC immediately. Throughout the test, one person, an NRL temporary employee, took most of the observations. For weekends, CG Sector Mobile active duty and Auxiliarist members took measurements on routine harbor patrols.

Figure 15 gives an example of a completed Flotation Testing Data Sheet that was specified in the test plan. The RDC team encouraged the observers to provide any and all input they thought might indicate conditions and possible changes.

Appendix D lists all observations, copied verbatim from the individual flotation testing data sheets. RDC also provided a digital camera for the observers to photograph the mannequins, daily. Appendix E is a daily photo record of the mannequins.

USCG R&D Center/Joint Maritime Test Facility Immersion Suit Flotation Test Plan
June 2016 – Version 1.0

Flotation Testing Data Sheet			
DATE 6/15/16		TIME 0720	
OBSERVER (optional) K... T...			
Wind Direction	NE	Wind Velocity	calm (almost stagnant air)
Wave height (inches or feet)	calm (1-2in)		
Mannequin A - GREEN Markings			
Number of tape bands visible- Left Side	8	Number of tape bands visible- Right Side	7
Mannequin B- RED Markings			
Number of tape bands visible- Left Side	8	Number of tape bands visible- Right Side	8

Mannequin A - more tilted to right side
Mannequin B - still slightly tilted to right side
* legs of both mannequins submerged except for toes of boots as well as arms submerged except for fingers of gloves and shoulders

Comments

Figure 15. Example of completed Flotation Testing Data Sheet.

On 23 June 2016, at approximately 1000 CDT, immediately before recovery, the RDC team made final visual measurement readings:

Mannequin A: Left side: 8 bands visible. Right Side: 8 bands visible
Mannequin B: Left side: 8 bands visible. Right Side: 8 bands visible

Figures 16 and 17 taken just before the time of recovery clearly indicate that both mannequins exhibit ***significant*** grassy marine growth about their "waterlines," especially over the legs and arms.

Figure 16. Mannequin A – pre recovery 23 June 2016.

Figure 17. Mannequin B – pre recovery 23 June 2016.

2.4 Mannequin Recovery and Post-recovery Measurements

After deployment with the NRL LCM-3, the RDC test team fully realized the need to conduct retrieval using a vessel equipped with a davit or crane, and enough clear deck space to carefully maneuver the heavy mannequins. The RDC's JMTF staff conducted liaison with Aids to Navigation Team (ANT) Mobile to arrange for recovery assistance on a not-to-interfere with primary mission basis. Conveniently, ANT Mobile had availability on 23 June 2016, allowing a full, fourteen-day-plus experiment period.

In the interim, the RDC test team updated the recovery procedures in the test plan, and forwarded to the ANT for input and suggestions.

2.4.1 Recovery Preparations

ANT Mobile had two different types of vessels available for equipment recovery (Figure 18), a 25-foot, outboard-powered Trailerable Aids to Navigation Boat (TANB) with side access port and davit (foreground), and a 64-foot, twin engine, large buoy boat (CG 64350), with telescoping crane.

Figure 18. ANT Mobile TANB (foreground) alongside CG 64350 at Sector Mobile moorings.

The RDC test team and JMTF staff member met with ANT Mobile staff on 22 June 2016 to discuss the next-day's evolution, review procedures, and evaluate alternatives and contingencies. As the test plan called for using a Stokes litter (frame and mesh) (Figure 19) to minimize any disturbance to the mannequins, e.g., any amount of water in the suit or accrued marine growth, the ANT staff and RDC test team readily concluded that the TANB was not large enough to accommodate personnel, two stokes litters with recovered mannequins, and any mooring equipment. Further, the favored, low freeboard of the TANB would not be realized, as the lower side access port panel could not be removed (for stability purposes) if the weight on the davit exceeded 200 pounds, a definite given, since pre-deployment was 210 pounds for each mannequin.

Figure 19. Stokes litters for mannequin recovery.

Figure 20. CG 64350 deck with Stokes litters.

As Figure 20 above shows, the amount of clear, working deck space and the large boom available on CG 64350 more than made up for the TANB's low freeboard. One other additional benefit (not shown) is CG64350's ability to "spud-down" into the bottom by lowering two columns near the deck edge, providing an extremely stable recovery platform, and minimizing the effect of wind and current.

2.4.2 Recovery Operations

On 23 June 2016, CG 64350 got underway with the RDC team and JMTF member embarked. On arrival at the Little Sand Island basin, CG 64350 maneuvered to a location between the moored mannequins, and spudded down. As part of ANT Mobile's cooperative effort, ANT leadership considered this an opportunity to conduct crewmember swim qualifications, and offered to have the swimmers assist in maneuvering the mannequins into the Stokes litters. The ANT deck supervisor conducted an extremely thorough safety briefing, specifically detailing procedures, potential hazards and risks, and mitigation strategies before beginning the recovery operation. Extremely calm conditions in the basin favored the operations.

The swimmers first safely and successfully completed their swim qualification tests, and waited until a Stokes litter was lowered into the water. We had installed a dynamometer (load cell) between the crane whip-hook and lifting shackle, to weigh the Stokes litter without mannequin, then once clear of the water, with mannequin.

Once the litter was afloat after lowering to the water, the swimmers disconnected it and maneuvered mannequin A into the litter, secured the mannequin with side straps, hooked the litter to the shackle, then swam clear before the crane operator hoisted the litter and mannequin. The operator brought the litter and mannequin over the deck, with the combination at an approximately 30-degree angle from horizontal. The RDC team recorded the load-cell weight; then pierced one immersion suit heel while over a collection bucket. After no water flowed out, the team put a second bucket under the other heel, pierced it, and again waited for water to flow out. None did.

The crew, RDC and JMTF team then recovered mannequin B by the same procedure. Again no water drained.

The swimmers came aboard, and with both Stokes litter/mannequin combinations lying horizontally on deck CG 64350 recovered the two mooring arrangements, secured all gear to deck, then returned to the Sector Mobile docks.

We must reemphasize the amount of marine growth that formed on the mannequins during the two-week deployment. Though clearly visible in the pre-recovery photographs above (Figures 16 and 17), Figure 21, taken immediately after recovery of Mannequin A, provides further documentation the extent of the marine growth.

Figure 21. Mannequin A, post-recovery, extensive marine growth.

2.4.3 Demobilization

At the dock, CG 64350 used its telescoping crane to move the suited mannequins and mooring systems to pallets on the dock. From there, the JMTF staff transferred all test equipment to the apron at the JMTF building for further analysis and disassembly.

The team reweighed the mannequins at JMTF on the same electronic platform scale used before deployment. As the amount of marine growth on the immersion suits began to attract insects in the 90-degree F midday temperatures, the team decided to remove the immersion suits as quickly as possible, cutting the suits apart to expedite mannequin removal with as little human contact with the marine growth as possible. While removing the suits, the test team noticed small amounts of water pooled in the immersion suits in the area of the buttocks and feet, so the team collected and measured that water using the buckets, for which the team had a sounding rod, graduated at one liter increments. During disassembly, the team recovered less than one liter of water per suit. Also, while removing the diver weights, the team did notice that most of the weight belts were slightly damp to touch, but without any measureable quantity of water.

3 RESULTS

The test relied on two distinct methods for determining whether any loss of flotation occurred, comparison of twice-daily readings on the measurement tubes along with twice-daily photographs, and net weight changes pre-deployment and post-recovery.

3.1 Daily measurement records and images

Appendix D includes all daily measurement records. Table 2 excerpts initial readings, final readings, record of maximum excursion, and average readings into a summary table.

Table 2. Summary of daily measurements.

Event	Date/Time	Mannequin A visible marks		Mannequin B visible marks	
		Left Side	Right Side	Left Side	Right Side
Deployment	8 Jun 16 - 0800	8	8	8	8
Retrieval	23 Jun 16 - 0930	8	7.5	8	8
Max Excursion	15 Jun 16 – 0720*	8	7	8	8
Average	-----	8	7.3	8	8

Initial readings on "measurement posts," with one-inch tape bands, one-inch apart, indicated that both mannequins were floating higher than the lowest mark. At this stage, there was nothing to do about the measurement marks, however the accompanying photos for each reading allowed a good comparison of flotation height. Comparison of Figures 22 and 23 indicate a distinct "list" for Mannequin A.

Figure 22. Mannequin A- deployment 0800 8 June 2016.

Figure 23. Mannequin B – deployment 0800 8 June 2016.

The notes in the daily measurement record (Appendix D) frequently indicate an almost continuous list to the right for Mannequin A. Though not reflected in the flotation testing data sheet notes, photos starting on 15 June (Appendix E) document the appearance of marine growth at the approximate waterline for both mannequins. As pre-recovery photos (Figures 16 and 17, earlier) show, over the final seven days, the marine growth became quite significant.

Regarding Mannequin A's list, the test team believes that as they fastened the ballast weights, they may have skewed the weight to one side of the mannequin torso. From the photos or the observation records, we cannot determine if Mannequin B's "broken leg" affected its list or trim. What is apparent in all photos is the overall trim of the mannequins (torso higher than the legs) due to the nature of the rigid mannequins used.

3.2 Weighing and Draining Mannequins, Post Recovery

Table 3 below provides a comparison of mannequin/immersion suit weights. As we used the same electronic platform scale for pre-deployment and post-recovery weighing, and checked calibration with a 6-pound weight, the RDC team is fairly confident of those two readings. On CG 64350, while assured of the load cell's accuracy, we did not check it against a known weight. Another issue is that the Stokes litter and mannequin combination were shedding excess water from the scrim of the immersion suit and the acquired marine growth before, during, and after reading the load cell.

Table 3. Mannequin weight comparison.

Event	Date/Time	Mannequin A		Mannequin B		Tare	
		Gross weight	Net Weight	Gross Weight	Net Weight	Device	Weight
Pre-deployment at JMTF	7 Jun 2016 – 1705 7 Jun 2016 - 1720	223 lb	**210 lb**	223 lb	**210 lb**	backboard	13 lb
Retrieval (on CG 64350)	23 Jun 2016 – 0958 23 Jun 2016 - 1024	240 lb	**240 lb**	230 lb	**230 lb**	Zeroed load cell	n/a
Post-recovery at JMTF	23 Jun 2016 – 1200 23 Jun 2016 – 1205	266 lb	**220 lb**	269 lb	**221 lb**	Stokes litter	46 lb 48 lb

After the post-recovery weighing, the RDC team opened the immersion suit for Mannequin A, and noticed pooled water in area of lower back/buttocks, as mentioned earlier. As best possible, we collected this and any additional water from the legs and arms into a six-gallon bucket. Using a pre-marked tube section (smallest gradation of one liter), we measured approximately three-quarters liter (approximately 1.7 pounds) from Mannequin A. We followed the same procedures, and recovered less than one-third liter (approximately 0.7 pounds) from Mannequin B. Figures 24 and 25 show the measure results.

Figure 24. Mannequin A- post-recovery drained water.

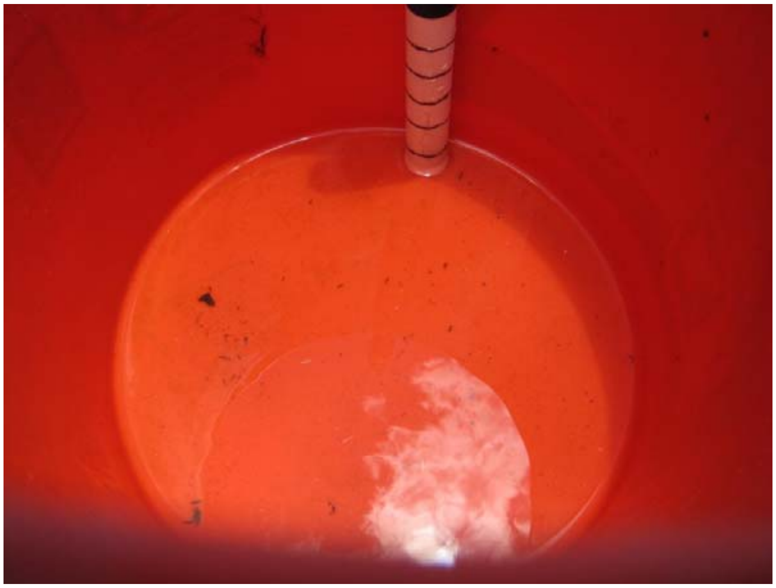

Figure 25. Mannequin B- post-recovery drained water.

Due to the extreme mid-day temperatures and gathering insects, RDC did not weigh the damp, heavily fouled immersion suits. Also, nylon webbing that held weights to mannequins was “damp” to touch. RDC team did not weigh the damp webbing.

3.3 Results Summary

After reviewing all flotation testing data sheet entries and the associated, twice-daily photographs, and comments from observers; the immersion suits did not lose a significant amount of buoyancy. We recovered more “measured” water from older suit (Mannequin A) than from the new suit; but even so, it was less than two pounds. The significant amount of marine growth fouling, especially on arms and legs, obscured the actual suit material from view during the second-week’s observations; and most likely contributed to the net gain in weight from pre-deployment to post-recovery.

Throughout the two-week period, observers recorded conditions in the basin as relatively calm, with only one day’s observation recording “light chop.” These conditions would not necessarily lead to water intrusion around the face seal. Further, though climatology indicates long-term, average June rainfall totals of 6.1 inches; during the test period 8-23 June 2016, Mobile Regional Airport (approximately 11 miles from the test site) recorded only 0.68 inches of rain. (This definitely did not match up to the “daily, late-afternoon thunderstorms that locals told the test team they could expect.)

RDC estimated the salinity for the Little Sand Island basin from NOAA PORTS conductivity measurements at Mobile State Docks, approximately 3 miles upstream. The maximum for the period was 16.7 practical Salinity Units (PSU), with a specific gravity of 1.0125 (medium brackish water), only on daily tidal peaks. The buoyancy difference between freshwater and the medium brackish water experienced daily would not have been easily detected by visual observation, especially when once obscured by the marine growth fouling.

4 CONCLUSIONS

For the conditions tested, the Coleman-Stearns I-590 immersion suits did not lose apparent buoyancy over a two-week period. The test team found only small amounts of water in either suit after the testing.

The placid test conditions in no way replicated storm conditions, and did not offer insight as to whether water could enter the suit around the face seal.

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APPENDIX A. IMMERSION SUIT CERTIFICATION

U. S. Department of Homeland Security

United States Coast Guard

Certificate of Approval

Coast Guard Approval Number: 160.171/241/0 Expires: 20 December 2018

IMMERSION SUIT (SOLAS)

THE COLEMAN COMPANY INC.
3600 N HYDRAULIC
WICHITA KS 67219

Model I950 ThermaShield Immersion Suit, size Adult Universal, for persons weighing 50-150 kg (110-130 lb) and a maximum of 191 cm (75 inches) in height, insulated buoyant "IMMERSION SUIT", for use without a lifejacket.

Suit complies with SOLAS and the IMO LSA Code (Res. MSC.48(66), as amended through Res. MSC.207(81)); evaluated and tested in accordance with Res. MSC.81(70), as amended through Res. MSC.226(82).

Outfitted with user activated breathing tube system for enhanced thermal protection.

Style A suit has removable gloves, hand warming cuff with exhaust valve, zipper positioned slightly off center, and formed boots.

Style B suit has integral gloves, zipper centered, and formed boots. Suit has no hand warming cuff or exhaust valve.

Identifying Data: 46 CFR 160.171 and UL Report File No. MQ 545, Vol. 1 (Sections 5 and 6).

Production inspections conducted by Underwriters Laboratories, Inc. (UL). Each suit bears the UL Classification Mark.

Factory Locations: See UL report file for current factory locations.

This certificate is issued based on the UL Report dated December 20, 2013.

*** END ***

THIS IS TO CERTIFY THAT the above named manufacturer has submitted to the undersigned satisfactory evidence that the item specified herein complies with the applicable laws and regulations as outlined on the reverse side of this Certificate, and approval is hereby given. This approval shall be in effect until the expiration date hereon unless sooner canceled or suspended by proper authority.

GIVEN UNDER MY HAND THIS 20th DAY OF DECEMBER 2013, AT WASHINGTON D.C.

K. J. HEINZ
Chief, Lifesaving and Fire Safety Division
BY DIRECTION OF THE COMMANDANT

DEPT. OF HOMELAND SECURITY, USCG, CGHQ-10030
(REV. 3-03)

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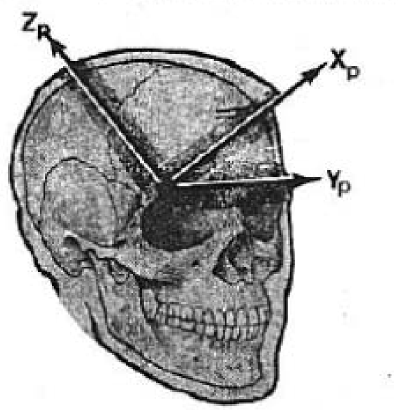
APPENDIX B. MASS DISTRIBUTION OF BODY SEGMENTS

Excerpt from "Anthropometry and Mass Distribution for Human Analogues"

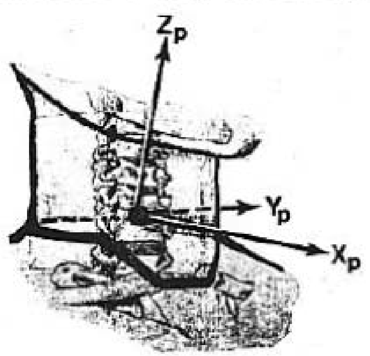
TABLE 2

MASS DISTRIBUTION OF THE BODY SEGMENTS
(mass in kilograms; moments of inertia in kilograms/cm^2;
X is anterior; positive rotation is clockwise)



HEAD				
	Segment Mass	Moments X	Moments Y	Moments Z
SMALL	4.0	193	219	144
MID-SIZE	4.2	206	235	153
LARGE	4.4	218	250	161

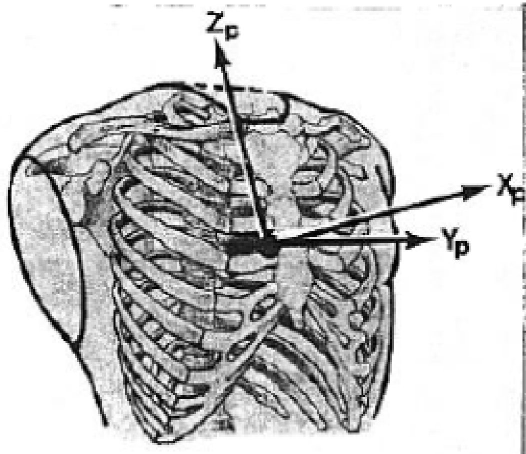
The principal axes are rotated -36° about the Y_a axis.



NECK				
	Segment Mass	Moments X	Moments Y	Moments Z
SMALL	0.9	13	16	19
MID-SIZE	1.1	18	22	28
LARGE	1.2	23	27	35

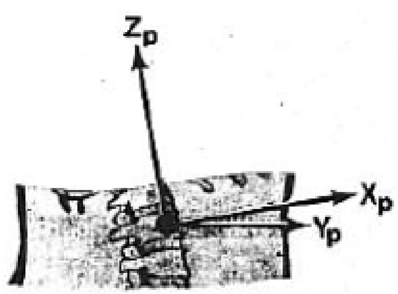
The principal axes are rotated +22.2° about the Y_r axis.

TABLE 2 (cont'd)



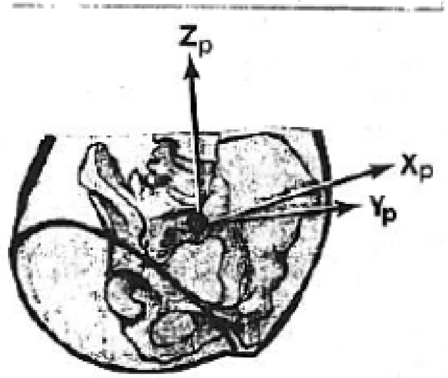
THORAX	Segment Mass	Moments X	Moments Y	Moments Z
SMALL	18.6	3233	2347	1975
MID-SIZE	24.9	5224	3857	3284
LARGE	30.5	7002	5202	4432

The principal axes are rotated -12° about the Y_r axis.



ABDOMEN	Segment Mass	Moments X	Moments Y	Moments Z
SMALL	1.9	108	58	160
MID-SIZE	2.4	175	99	266
LARGE	2.9	233	133	356

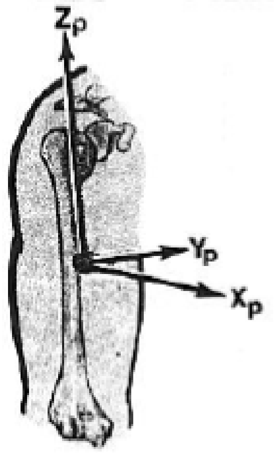
The principal axes are coincident with the reference axes.



PELVIS	Segment Mass	Moments X	Moments Y	Moments Z
SMALL	8.6	651	587	746
MID-SIZE	11.8	1116	1028	1298
LARGE	14.6	1519	1408	1773

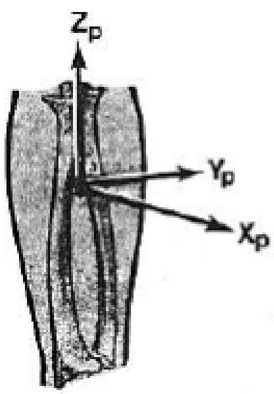
The principal axes are rotated -24° about the Y_r axis.

TABLE 2 (cont'd)



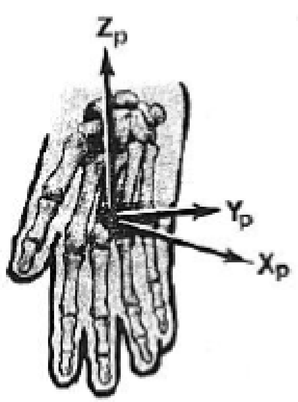
UPPER ARM	Segment Mass	Moments X	Y	Z
SMALL	1.5	85	85	17
MID-SIZE	2.0	141	141	29
LARGE	2.4	192	192	39

The Z_p axis is coincident with the Z_r axis and the X_p and Y_p axes are degenerate.



FOREARM	Segment Mass	Moments X	Y	Z
SMALL	1.1	61	61	9
MID-SIZE	1.4	90	90	14
LARGE	1.6	117	117	18

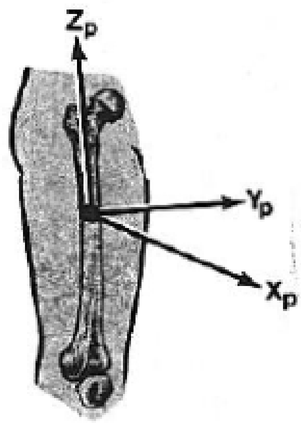
The Z_p axis is coincident with the Z_r axis and the X_p and Y_p axes are degenerate.



HAND	Segment Mass	Moments X	Y	Z
SMALL	0.5	10	8	3
MID-SIZE	0.5	13	11	4
LARGE	0.6	16	13	5

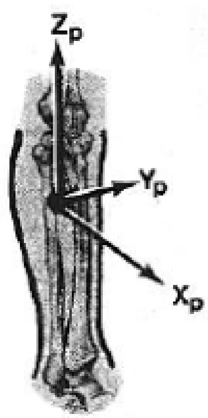
The principal axes are coincident with the reference axes with the hand aligned as shown in Figure 1.

TABLE 2 (cont'd)



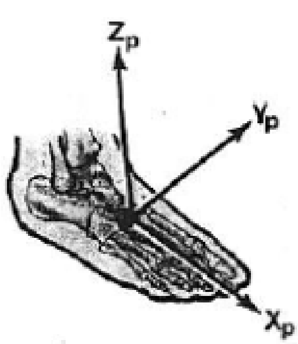
THIGH				
	Segment Mass	Moments X	Y	Z
SMALL	7.7	1093	1093	289
MID-SIZE	9.8	1652	1652	452
LARGE	11.8	2175	2175	595

The Z_p axis is coincident with the Z_r axis and the X_p and Y_p axes are degenerate.



CALF				
	Segment Mass	Moments X	Y	Z
SMALL	3.1	406	406	48
MID-SIZE	3.8	606	606	71
LARGE	4.5	798	798	92

The Z_p axis is coincident with the Z_r axis and the X_p and Y_p axes are degenerate.



FOOT				
	Segment Mass	Moments X	Y	Z
SMALL	0.8	6	31	33
MID-SIZE	1.0	8	44	46
LARGE	1.1	11	56	59

The principal axes are coincident with the reference axes with the feet aligned as shown in Figure 1.

APPENDIX C. EXPERIMENT TEST PLAN

USCG R&D Center/Joint Maritime Test Facility Immersion Suit Flotation Test Plan
June 2016 – Version 1.0

Contents

USCG R&D Center/Joint Maritime Test Facility Immersion Suit Flotation Test Plan
June 2016 – Version 1.0

1. **Purpose:**

This experiment will evaluate any changes to the flotation of a weighted mannequin in a Coleman-Stearns Model ISS-590i Adult Universal buoyant IMMERSION SUIT, approval 160.171/0000203 over a two-week exposure period in brackish water. This test will attempt to answer a question, posed by the Investigations National Center of Expertise with respect to the loss of life after the sinking of the SS El Faro. I.e., as asked, "How long a survival suit with a deceased body would or could be expected to float. The water temperature was reported to be approximately 81 degrees."

2. **Method Summary:**

Duration: 2 week observation/exposure period
Location: Vicinity of Joint Maritime Test Facility, Little Sand Island, Mobile Bay, AL.

Concept:

a. Weighted mannequin to simulate human body mass proportions inside Coleman (Stearns) Model ISS-590i Adult Universal buoyant IMMERSION SUIT, approval 160.171/0000203. Face area NOT sealed with tape/adhesive to prevent influx of water around mannequin head. As indicated by a member of the Lifesaving and Fire Safety Branch of the Coast Guard's Office of Design and Engineering Standards, it is not uncommon for small gaps to occur between a wearer's face and the immersion suit. (See figure.)

b. Two separate, concurrent trials: mannequin in a brand-new suit, mannequin inside an older (used), but apparently UNDAMAGED to visual inspection.

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c. Outfitted mannequins will have a neutrally-buoyant "measurement cage," indicators near head/torso area to note change in apparent waterline.

d. Tether/moor test gear in basin near ex-USS Shadwell. Allow for change in tide and swing with wind.

e. Note and monitor apparent waterline twice daily.

f. after 14 days, retrieve test gear and drain/measure quantity of water (if any) from suits.

Note: This effort will be completely outside the regulatory performance requirements of 46CFR160.171, HOWEVER, the Research and Development Center expects to make the results publicly available, after consideration by the requesting authority.

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3. **Tentative Schedule**

6-Jun-16	RDC test team arrive	Mobile AL
7-Jun-16	RDC test team Mobilize test gear, outfit mannequins, assemble moorings	JMTF Mobile AL
8-Jun-16	RDC/NRL Load test gear on NRL vessel,	JMTF Mobile AL
8-Jun-16	RDC/NRL deploy test gear, initial & supplemental readings & photos	Little Sand Is Basin
9-Jun-16	RDC test team take am readings with NRL	Little Sand Is Basin
9-Jun-16	RDC test team depart	Mobile AL
9-Jun-16	NRL take pm readings/photos	Little Sand Is Basin
10-Jun-16	NRL take am/pm readings/photos	Little Sand Is Basin
11-Jun-16	CG Aux take am/pm readings/photos	Little Sand Is Basin
12-Jun-16	CG Aux take am/pm readings/photos	Little Sand Is Basin
13-Jun-16	NRL take am/pm readings/photos	Little Sand Is Basin
14-Jun-16	NRL take am/pm readings/photos	Little Sand Is Basin
15-Jun-16	NRL take am/pm readings/photos	Little Sand Is Basin
16-Jun-16	NRL take am/pm readings/photos	Little Sand Is Basin
17-Jun-16	NRL take am/pm readings/photos	Little Sand Is Basin
18-Jun-16	CG Aux take am/pm readings/photos	Little Sand Is Basin
19-Jun-16	CG Aux take am/pm readings/photos	Little Sand Is Basin
20-Jun-16	NRL take am/pm readings/photos	Little Sand Is Basin
21-Jun-16	NRL take am readings/photos	Little Sand Is Basin
22-Jun-16	RDC test team arrive	Mobile AL
22-Jun-16	RDC/JMTF meet ANT Mobile for TANB/BU familiarization	SEC Mobile AL
23-Jun-16	RDC/ANT retrieve test gear w/ANT vessel	Little Sand Is Basin
23 Jun 16	RDC weigh, drain, measure test gear	Little Sand Is Basin
23-Jun-16	RDC/ANT Unload test gear from ANT vessel	SEC Mobile AL
23-Jun-16	RDC re-weigh, drain, measure test gear (if necessary)	JMTF Mobile AL
23-Jun-16	RDC De-mobilize test gear, disassemble mannequins & moorings	JMTF Mobile AL
24-Jun-16	RDC test team depart	Mobile AL

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4. Participants/Contact information

Unit	Component	Name	Telephone	email
CG R&D Center	Environment & Waterways	Jim Fletcher		
CG R&D Center	Project Manager	M. J. "Lew" Lewandowski		
CG R&D Center	Project Officer	Chuck Clark		
CG R&D Center	Finance	Manuel Lomba		
CG R&D Center	Finance	SK3 Jordan Folker		
CG R&D Center	Contracting	Helen Carnes		
CG R&D Center	Administration	Christine Wadsworth		
JMTF	CG	MK1 Lauren Goodell		
JMTF	CG	Mike Hering		
JMTF	NRL	Hung Phamh		
CG Sector Mobile	CGAux Coordinator	LT(jg) Alex Gomez		
CG ANT Mobile	OIC	BMC David Mottel		
Invest COE	Investigator	Keith Fawcett		

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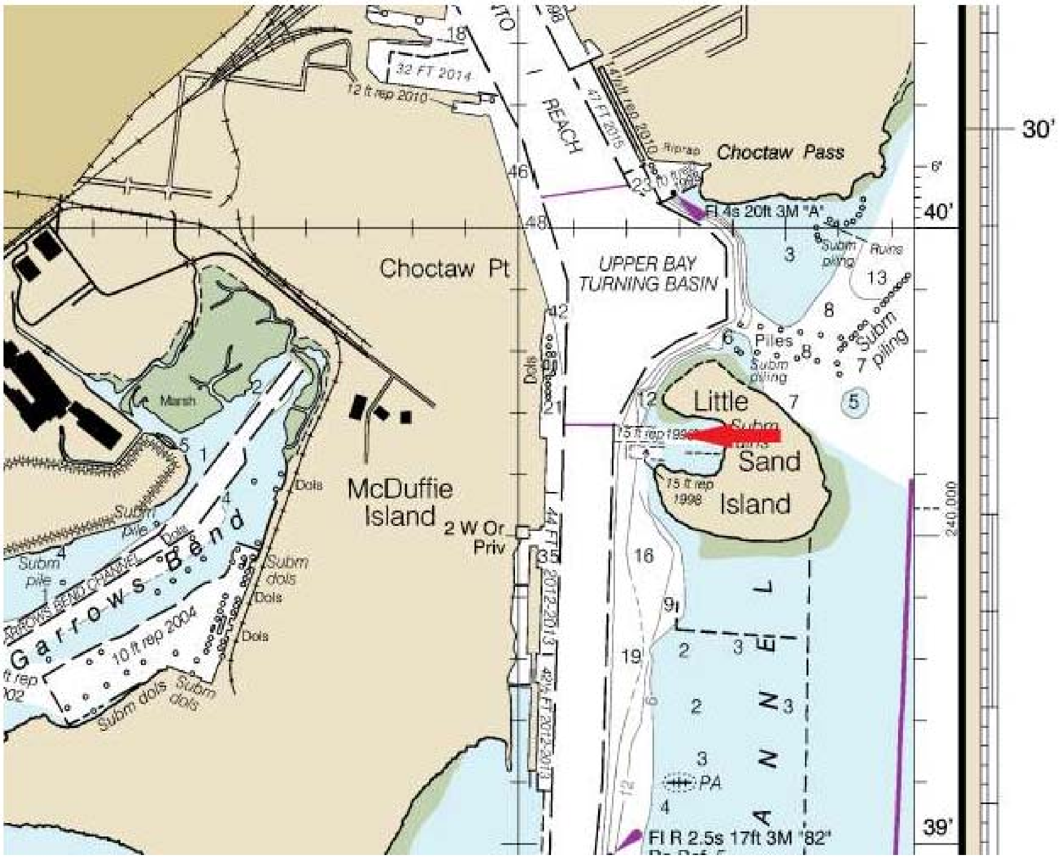
5. Location:

The test team will locate the two outfitted mannequins in the basin surrounded by Little Sand Island, at the mouth of the Mobile River, Alabama. Estimated water depth is approximately 10 feet.



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6. **Test Set-up**

Mobilize test gear, outfit mannequins, assemble moorings

Mobilize test gear

Shipment 1:

Box 1 - Immersion suit (15#)
Box 2 - Mannequin (40#)
Box 3 - Pyramid Anchor (75#)
Box 4 - Mooring Buoy and chain (20#)
Box 5 - Mooring Buoy and Chain (20#)
Box 6 - Anchor (75#)

Shipment 2

Box 1 - Rigging gear (15#)
Box 2 - Ballast (45#)
Box 3 - Ballast (65#)
Box 4 - Ballast (85#)
Box 5 - Ballast (65#)
Pelican Case – Ballast (110#)
Stretcher, Immobilization Board

Shipment 3
Box 6 - Mannequin (40#)

Items for pick-up in Mobile

3 ea, 10' x ¾" CPVC pipe
10 ea, ¾" CPVC s x s x s tee
8 ea, ¾" CVPC street elbow
8 oz. PVC cement

Determine any missing items & procure as necessary.

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Outfit mannequins

Weights to mannequin:

Connect torso to hip-left leg; duct-tape waist joint. Connect right leg to hip; duct-tape joint. Strap lead weights to mannequin as shown in following table and photo examples. Overtape weight belts to cover gaps between weights. Connect hands to arms; duct-tape joints. Strap weights to arms. Overtape weights with duct tape.

Outfitted Weights	6#	4#	2#	Total
Neck	1	1		10
Chest	5			30
Chest 2	5			30
Waist	4		1	26
Right Leg	3			18
Right Ankle		3		12
Left Leg	1	1		10
Left Leg Top	1			6
Left Ankle		2	1	10
Left Arm/Wrist		2		8
Right Arm/Wrist		2		8
	120	44	4	170
Mannequin + suit (est)				38
TOT (est)				208

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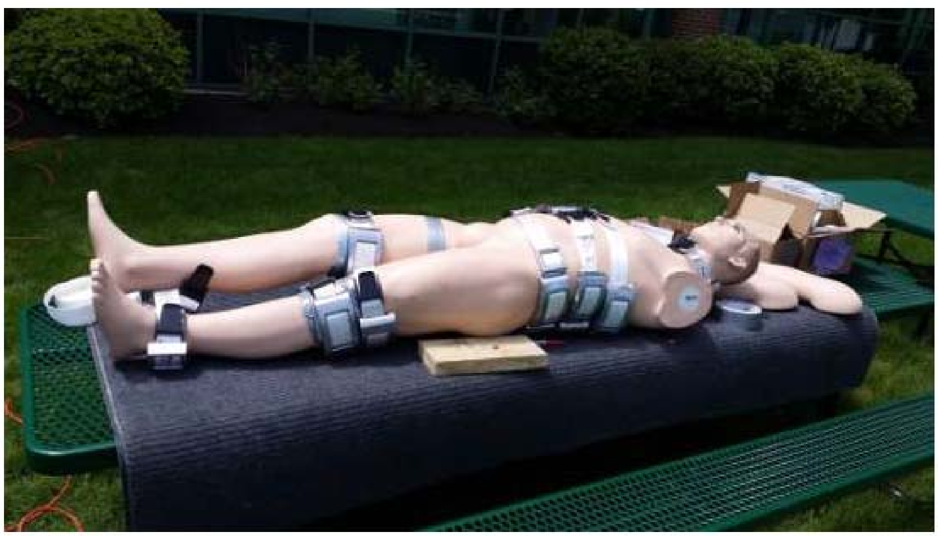

Mannequin into immersion suit:

Insert mannequin legs and torso into immersion suit. Insert arms into immersion suit, then connect to torso. Duct-tape arm-torso joints. The weighted, suited mannequin shown in next figure.

Initial Weight.

Weigh each mannequin individually on a balance-type or calibrated freight scale if available. If necessary to weigh the mannequin in an upright position, exercise caution to assure no

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damage to immersion suit or that weight-belts/weights do not change their position on the mannequin.

Record this weight, as this will be the first data point in the data collection process. Take a photo of weight reading, if visible.

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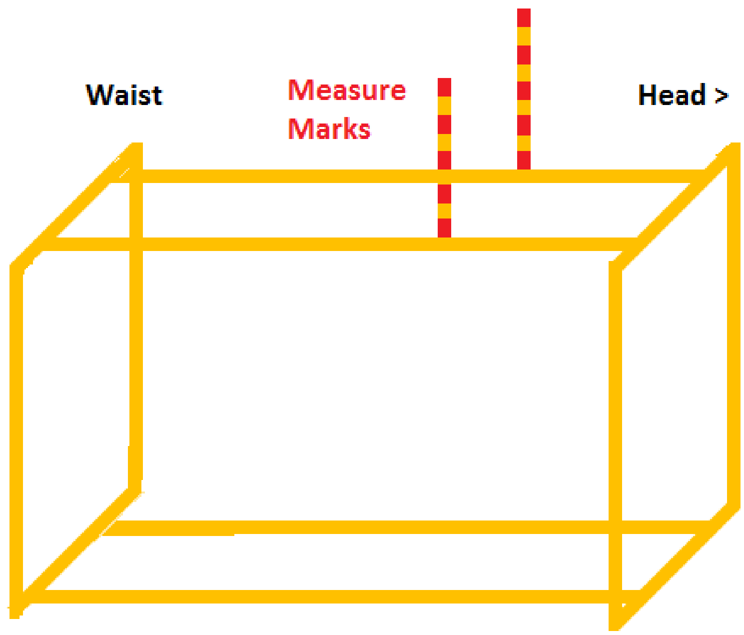
Assemble and attach measurement cage to mannequin:

Assemble CPVC pipe lengths and fittings around suited mannequin as shown:



The two vertical measurement sections are closer to the head. The vertical sections of the cage itself fit near the arm-torso seam of the immersion suit, and near the waist. One measurement cage has red, retroreflective, 1"-wide marks, 1" apart; the other, green marks.

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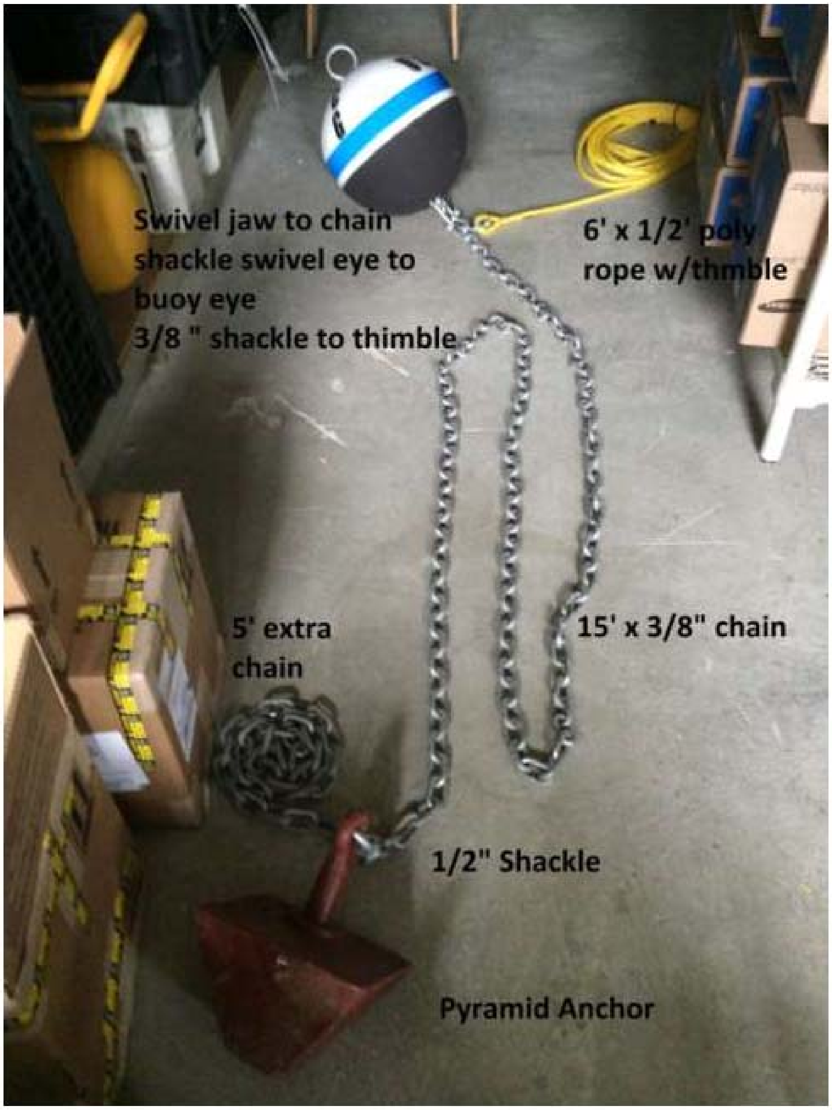
Assemble moorings:

Follow photo example



Note: (1) Reeve approximately 7-1/2' of the ½" poly line through 6-1/2' x ¾" CPVC pipe ("spreader-arm"), then splice second thimble into eye for connecting to immersion suit harness clip.

Note (2) In actual deployment, if necessary to provide a better "lie" between the mooring and the chest-mount harness clip, attach the 3/8" shackle and thimble to the mooring buoy-top ring.

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Note (3) Use seizing wire on all shackles to prevent their backing out.

Loading and Transporting Outfitted Mannequins

Though strapped and taped to the mannequin, the heavy lead weights will shift if personnel do not exercise extreme caution while moving, loading, or adjusting the mannequin. The test team "floated" a weighted mannequin in a pool, with the result being a relatively-flat floating aspect.

As such, all handlers should keep the outfitted mannequin in a relatively-horizontal position. Four handlers should use a "back-board" (Stretcher, Immobilization Board) to move the mannequins.

Vehicle transportation must also use as horizontal an angle as possible. Ideally three or four persons should carry the outfitted mannequin on the back-board, and lie the outfitted mannequin on a relatively clean, protected surface to prevent inadvertent immersion suit damage.

7. Safety

All experiment participants loading, deploying, or retrieving the mannequins must wear suitable lifejackets. The vessel operator will serve as overall safety observer, and will call a stop to any activity they deem unsafe to personnel or the vessel. Any participant will call a stop, at any time if they perceive an apparent safety issue. Loading, deployment or retrieval will stop until participants rectify the apparent situation.

Participants shall be aware of the hazards dealing with heavy, awkward objects, particularly the

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interaction with a floating vessel. Note that as the vessel changes trim or heel while loading deploying, retrieving and unloading, a participant's balance may change, and if the participant is handling a heavy object, they can easily stress, strain, or injure muscle or connective tissue trying to offset any vessel motion.

During loading deploying, retrieving and unloading, participants shall use mechanical devices as available to assist in handling heavy objects.

Bights of chain or rope can easily become hazards. Do not place any body parts outboard of any chain, rope or tether while deploying or retrieving the mannequins or moorings.

8. **Mannequin Deployment:**

The test team will use a Naval Research Lab vessel to deploy the mannequins and their moorings. The team will consider two alternatives, depending on vessel type and environmental conditions. In either case, handlers must lower the mannequins in the water at the most horizontal angle possible.

Deploy the mannequins separately, in a location relatively clear of the normal transit path to and from the Little Sand Island landing and debarkation areas. Deploy the mannequins at least 20 feet apart so as to allow a full, clear swing radius (plus margin) for both mannequins.

<u>Alternative 1</u>.

1. Allow a clear area on the vessel for the mooring chain to run free, without obstruction.
2. Place mooring buoy in water, with spreader-bar shackled to buoy, chain and anchor remaining on deck.
3. Slide anchor off vessel, keeping clear as chain runs out
4. As buoy stabilizes, connect spreader bar to mannequin immersion suit chest-harness clip
5. With back-board providing smooth surface, slide mannequin into water, feet first

<u>Alternative 1</u>.

1. Allow a clear area on the vessel for the mooring chain to run free, without obstruction.
2. Connect spreader bar thimble to mannequin immersion suit chest-harness clip.
3. Place mooring buoy in water, chain and anchor remaining on deck.
4. Slide anchor off vessel, keeping clear as chain runs out
5. With back-board providing smooth surface, slide mannequin into water, feet first, spreader bar attached
6. As buoy stabilizes, connect spreader bar from to mannequin immersion suit chest-harness clip to buoy eye with shackle.

After deployment of first mannequin, observe position and trim, and any list, determine if there appear to be any conditions that will prevent or limit movement or rotation about the buoy, and take action if applicable. If necessary to reconfigure spreader bar, do so. After mannequin reaches and apparent steady-state, use vessel to block any wave action and photograph measurement marks and record on data sheet. Unless water surface is absolutely calm, use average of the wave crests and troughs for reading.

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Deploy second mannequin following initial procedures, or note any changes in procedures from the first deployment.

9. Monitoring and Observation

Frequent, regular monitoring of the outfitted mannequin floatation characteristics is the most important aspect of this project. The experiment requires twice-daily readings of the measurement tubes. The test team recommends a morning reading between 0700 and 0830 local time, and an afternoon reading between 1500 and 1630 local time.

The experiment also requires photographs of the complete, outfitted mannequins, from a distance close enough to show minor changes, especially the water level near the face-opening. The experiment recommends one photo, above and from the side of the mannequin as seen in the “pool photo” on page 13 of this test plan.

The experiment team encourages multiple photographs, and will provide a digital camera (that will require later download). If possible, we encourage one cell phone photo of each mannequin during each observation, and request the observer send as an email attachment to Mr. Lewandowski and LT Clark at the email addresses in the participant list on page 5.

The table on the next page lists the required information. The table may be reproduced locally for recording observations on scene, then left with MK1 Goodell at the JMTF office.

Since the outfitted mannequins may either take on water or accumulate marine growth over the intended two-week deployment period, some change in flotation might occur. If an observer notices a “significant” loss in flotation between subsequent observations, enter remarks in the comment section, and immediately advise Mr. Lewandowski and LT Clark by phone.

If floating objects or debris “foul” the mannequin, photograph the fouling, and the test team will determine if observers will need to take action on a subsequent observation trip.

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Flotation Testing Data Sheet			
DATE		TIME	
OBSERVER (optional)			
Wind Direction		Wind Velocity	
Wave height (inches or feet)			
Mannequin A - GREEN Markings			
Number of tape bands visible- Left Side		Number of tape bands visible- Right Side	
Mannequin B- RED Markings			
Number of tape bands visible- Left Side		Number of tape bands visible- Right Side	
Comments			

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10. Mannequin Retrieval

The experiment schedule calls for a two-week deployment. Should events occur that require earlier retrieval, the schedule will change accordingly.

On retrieval, the test requires the total weight of the outfitted mannequin. This could include marine growth, water in the suit, or other causes.

Method:

1. Maneuver recovery vessel next to mannequin so personnel can easily reach the chest.
2. Pass a tending line through the chest strap snap-hook on the immersion suit, up past the mannequin's head; hand-hold the line, or make fast to vessel.
3. Unclip test tether/spreader bar from immersion suit chest strap, keeping strap connected metal D-ring to snap-hook.
4. Gently and slowly maneuver recovery vessel toward "safer" water (toward center of cove), ensuring the test subject remains connected, the head does not create a large wake, and that the head remains above water at all times.
5. The stokes litter has four wires, one from each corner of the litter, connected near the chest area by an oval spring clip. Position the litter so the four wires are out of the way as best possible, for the mannequin. (Personnel may need to use a boat hook to keep bridle legs apart.) Connect a tending line to the foot area to aid in guiding the litter under the mannequin, which should avoid the need for a person to enter the water.
6. Place the litter in the water at the head of the mannequin, and allow the foot area to sink while maintaining the tending line.
7. Guide the litter under the mannequin using the tending line, and the mannequin through the lifting bridle.
8. Clip the bridle to the hoist hook.
9. Hoist the litter from the water; using the tending lines to prevent spin. The litter should tend nearly horizontal, with the head area slightly elevated.
10. Position the litter over the deck, above the collection buckets.
11. One at a time, cut the heel of the immersion suit and collect the accumulated water in the buckets.
12. If needed, individually cut the fingers of the suit and collect the accumulated water in the buckets.
13. Measure the water and record on the form, return the water to Mobile Bay. Perform this step as often as necessary.
14. Place the litter on the deck.
15. Unhook the litter from the hoist hook.
16. Unceremoniously roll the mannequin out of the litter on to a blanket or backboard (for ease of transport).
17. Reset litter for the second mannequin, and repeat steps 1-16.
18. After second mannequin has been removed, and the litter is safe on deck, recover test buoys, chain, and anchors.

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APPENDIX D. DAILY FLOTATION TEST OBSERVATION RECORDS

Table D-1. Daily observation records.

Date	Time	Observer	Wind direction	Wind speed (Kt)	Wave height (in)	Mannequin A (Green Marks) Marks Visible		Mannequin B (Red Marks) Marks Visible		Observer Comments
						Left Side	Right Side	Left Side	Right Side	
8-Jun-16	0800	KT	SSE	6	<12	8	8	8	8	A-left foot lower in water, both-waterline 3-4 in below marks
8-Jun-16	1305	CC	VAR	LIGHT	3	8	8	8	8	Both appear same as morning obs
8-Jun-16	1500	KT	SSW	10	8	7	8	8	8	A-right shoulder approx 4 in lower than left. Left foot still lower than right. B-right foot under water
9-Jun-16	0730	KT	NW	2	2-3	8	7-1/2	8	8	A-Left foot almost completely submerged; left side bands 4-5 inches out of the water B- Tilted to the right; both feet more submerged than 6/8 w/right foot lower; left side markers 4-5 inches out of water; right -side markers 2-3 inches out of water
9-Jun-16	1500	KT	SW	1	<3	8	7	8	8	A-Tilted to left side with right foot almost completely submerged; right-side bands 5-6 in out of water B-Still fairly level with hands approx 3 in out of water; feet 1/2 submerged
10-Jun-16	0900	KT	E	1	2	8	8	8	8	A-Left foot almost completely submerged; last band on right side at water level but completely visible; left-side bands clear of water by ~5in B-level; shins under water w/toes out of water; bands out of water by 4 inches
10-Jun-16	1300	KT	NW	2	6-8	8	8	8	8	Not much change since 9:00 am. Both mannequins have submerged arms
11-Jun-16	1220	LP	S	2	2-4	8	8	8	8	Green mannequin is listing to the right
11-Jun-16	1645	LP	N	6-8	6	8	8	8	8	Green mannequin is listing to the right

Table D-1. Daily observation records (Continued).

Date	Time	Observer	Wind direction	Wind speed (Kt)	Wave height (in)	Mannequin A (Green Marks) Marks Visible		Mannequin B (Red Marks) Marks Visible		Observer Comments
						Left Side	Right Side	Left Side	Right Side	
12-Jun-16	0945	LP	NE	2-4	calm	8	8	8	8	Green mannequin is listing to the right. The left calf of the leg is submerged, only the toes of the boot above water
12-Jun-16	1315	LP	SSE	6-8	4-6	8	8	8	8	
13-Jun-16	0730	KT	SSE	<1	2	8	7-1/2	8	8	A-Left foot: only toes above water; greatly tilted on right shoulder B-still fairly level; arms submerged; ankles submerged
13-Jun-16	1230	KT	ESE	<1	3-4	8	7-1/2	8	8	Not much change in band visibility or submersion from 0730. A-Still tilted to right side B-Still fairly level; feet almost completely submerged
14-Jun-16	0730	KT	VAR	<1	<1	8	7-1/2	8	8	No change from 6/13/16
14-Jun-16	1445	KT	SW	<1	calm	8	7-1/2	8	8	A-no notable change B-slighrt right-side tilt (by maybe 1/2-1 in)
15-Jun-16	0720	KT	NE	calm	1-2	8	7	8	8	A-More tilted to right side B-Still slightly tilted to right side Legs of both mannequins submerged except for toes of boots as well as arms submerged except for fingers of gloves and shoulders
15-Jun-16	1500	KT	N	calm	2-3	8	7	8	8	A-Leaning more to right side B-Leveled out again
16-Jun-16	0730	KT	E	2	5-6	8	7-1/2	8	8	No notable changes
16-Jun-16	1400	KT	NE	barely breezy	2-3	8	8	8	8	A-Still greatly tilted to right side B-No significant change
17-Jun-16	-	-	-	-	-	-	-	-	-	No log sheets
18-Jun-16	0800	PW	350T	2.1	smooth	8	7	8	8	
18-Jun-16	1550	PW	254T	1.8	smooth	8	7	8	8	

Table D-1. Daily observation records (Continued).

Date	Time	Observer	Wind direction	Wind speed (Kt)	Wave height (in)	Mannequin A (Green Marks) Marks Visible		Mannequin B (Red Marks) Marks Visible		Observer Comments
						Left Side	Right Side	Left Side	Right Side	
19-Jun-16	0745	PW	080T	10.2	light chop	8	7	8	8	
19-Jun-16	1600	PW	141T	12.8	light-mod chop	8	7	8	8	
20-Jun-16	0900	KT	NW	calm	3-4	8	7-1/2	8	8	Arms and legs under water save for tips of gloves and boots
20-Jun-16	1345	KT	N	calm	1-2	8	7-1/2	8	8	Both show signs of legs and arms more under water: both heads still above water; not much change in tilt for either
21-Jun-16	0730	KT	S	<1	2-3	8	7-1/2	8	8	A-Right thumb of glove only out of water; left arm-only finger tips of glove out of water; not change in legs B-Finger tips of gloves only out of water; no change in legs
21-Jun-16	1439	KT	N	<1	1-2	8	7-1/2	8	8	No notable change since morning
22-Jun-16	0730	KT	N	<1	1-2	8	7	8	8	A-left arm and leg barely still above water: right arm completely submerged B-no noticeable change
22-Jun-16	1444	KT	N	calm	calm	8	8	8	8	Not much change in status
23-Jun-16	0930	ML	WNW	8	4	8	7-1/2	8	8	Lots of slime/growth

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APPENDIX E. DAILY PHOTO RECORD

Figure E-1. 8 June Afternoon – Mannequin A.

Figure E-2. 8 June Afternoon - Mannequin B.

Figure E-3. 9 June Morning - Mannequin A.

Figure E-4. 9 June Morning - Mannequin B.

Figure E-5. 10 June Morning – Mannequin A.

Figure E-6. 10 June Morning - Mannequin B.

Figure E-7. 11 June Afternoon – Mannequin A.

Figure E-8. 11 June Afternoon - Mannequin B.

Figure E-9. 12 June Morning – Mannequin A.

Figure E-10. 12 June Morning - Mannequin B.

Figure E-11. 13 June Morning – Mannequin A.

Figure E-12. 13 June Morning - Mannequin B

Figure E-13. 14 June Afternoon – Mannequin A.

Figure E-14. 14 June Afternoon – Mannequin B.

Figure E-15. 15 June Morning – Mannequin A.

Figure E-16. 15 June Morning - Mannequin B.

Figure E-17. 16 June Afternoon – Mannequin A.

Figure E-18. 16 June Afternoon - Mannequin B.

Figure E-19. 17 June Morning – Mannequin A.

Figure E-20. 17 June Morning - Mannequin B.

Figure E-21. 18 June Afternoon – Mannequin A

Figure E-22. 18 June Afternoon - Mannequin B.

Figure E-23. 19 June Afternoon – Mannequin A.

Figure E-24. 19 June Afternoon - Mannequin B.

Figure E-25. 20 June Afternoon – Mannequin A.

Figure E-26. 20 June Afternoon – Mannequin B.

Figure E-27. 21 June Morning – Mannequin A.

Figure E-28. 21 June Afternoon - Mannequin B.

Figure E-29. 22 June Morning – Mannequin A.

Figure E-30. 22 June Morning - Mannequin B.