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Inflatable Emergency Equipment I: Evaluation of Individual Inflatable Aviation Life Preserver Donning Tests

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16. Abstract

The emergency landing of US Airways Flight 1549 in the Hudson River in January 2009 brought significant attention to the usability of aviation inflatable life preservers. In its accident investigation report (NTSB/AAR-10/03), the National Transportation Safety Board noted that of those passengers who retrieved aviation life preservers following the emergency landing, the majority indicated that they had difficulty donning them. They also found that the preflight safety briefing had not included life preserver donning information or a donning demonstration because the flight was not an extended overwater operation.

Additionally, only 8% of passengers reported reading the safety briefing card (which included donning instructions) before or during the [approximately 6-minute] flight. The NTSB subsequently recommended that the Federal Aviation Administration "Revise the life vest performance standards contained in [Technical Standard Order; TSO] C13f to ensure that they result in a life vest that passengers can quickly and correctly don."

This study examined life preserver donning performance relative to different levels of instructional information provided to test participants. Five levels of instruction ranged from none at all up to a typical air carrier preflight briefing and donning demonstration. Life preserver exemplars included those currently installed on transport airplanes (including the models carried on board US Airways Flight 1549) and older models approved under earlier versions of TSO-C13, as well as a prototype vest developed at the Civil Aerospace Medical Institute. The test procedure generally followed the donning test requirements of TSO-C13f. Results showed that none of the life preservers included in the study met the donning requirements using the TSO-C13f donning test, regardless of the type and amount of instructions provided to naïve test participants. Even when times for package opening and reading instructional markings were removed, the TSO time and percentage requirements were not achieved. Recommendations for modification of the donning test procedure are included.

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Inflatable Emergency Equipment I: Evaluation of Individual Inflatable Life Preserver Donning Tests

INTRODUCTION

The Federal Aviation Administration (FAA) requires that all extended overwater (EOW) flights conducted under domestic and flag operating rules (Title 14 Code of Federal Regulations [CFR] Parts 121.339, 125.209, 135.167) carry life preservers and other safety flotation devices for passengers and crew. For aircraft other than helicopters, an extended overwater operation is formally defined as one that is "over water at a horizontal distance of more than 50 nautical miles from the nearest shoreline…" (14 CFR Part 1.1). In addition, the passengers on such flights must be orally briefed on ditching procedures and the use of required flotation equipment, which generally includes a demonstration of life preserver donning and use. The oral briefing must also be supplemented by printed safety cards that include the same information (14 CFR Parts 121.571, 125.327, 135.117).

According to a 1985 Safety Study by the National Transportation Safety Board (NTSB), "virtually all aircraft used by Parts 121, 125 and 135 operators use one or more" of the 179 airports in the U.S. that are "located within 5 miles of a body of water of at least one-quarter square mile surface area." Cosper and McLean (1998) also noted that 44 of the 50 busiest U.S. airports in 1996 were within 5 miles of a significant body of water. Consequently, "many passengers are exposed to risk of inadvertent water impact near an airport, whether or not their flight is classified as an extended overwater flight" and most water contact accidents do occur close to an airport during the critical takeoff and landing phases of flight (NTSB, 1985a).

FAA Technical Standard Order (TSO) C13 outlines the minimum design and performance requirements aviation life preservers must meet before they can be TSO-approved flotation equipment for use on civil transport aircraft. The TSO comprises life preserver design, materials, and construction practices deemed necessary for safety, durability, functionality, and usability. Until 1983, however, there was no requirement for a donning demonstration as part of the certification process for aviation life preservers. That requirement was adopted as part of TSO-C13 revision d, which states, "It must be demonstrated that an adult, after receiving only the customary preflight briefing on the use of life preservers, can don the life preserver within 15 seconds unassisted while seated. …The donning demonstration is begun with the unpackaged life preserver in hand."

While TSO-C13d includes methods for testing and showing compliance with its requirements, it does not specify a limit on the number of donning attempts permitted, or the percentage of attempts that have to be successful. It appears that a single successful demonstration would be sufficient to obtain TSO-C13d certification. (A description of typical TSO-approval procedures can be found in 14 CFR Part 21, Subpart O.)

Issuance of TSO-C13d coincided with a life preserver donning study at the FAA Civil Aerospace Medical Institute (CAMI) by Rasmussen and Steen (1983), who found that no single design, among four TSO-certified life preservers evaluated in their study, proved easier to don than any other. Importantly, however, only one of the 100 study participants successfully donned a life preserver within 15 seconds. Failure to don the life preservers *correctly* (with a time allowance of up to two minutes) ranged from 8% to 28%. Two non-aviation "angler-vest" life preservers were also included in the study. These vests were redesigned somewhat to approximate TSO-approved vests, including the addition of flotation chambers and inflation means. The angler vests showed significantly fewer donning failures and faster donning times, due ostensibly to their similarity to a typical garment having a familiar wide-toothed zipper closure and obvious front and back.

Rasmussen and Steen concluded that for "passenger safety… to be improved through the use of existing TSO devices, it will probably have to be achieved through a stronger than usual emphasis on correct usage during passenger briefings and require more than passive or elective attention by the passengers… and increased passenger familiarization with, and participation in, safety procedures." Furthermore, in response to the "new" donning requirement in the then-just-published TSO C13d, Rasmussen and Steen stated:

Meeting this certification criterion may or may not be indicative of the donning performance of a representative passenger population under even the most favorable conditions, much less under the adverse conditions that may exist in an actual emergency situation. The results of this study strongly suggest that reliance on a single donning performance demonstration is not indicative of general passenger donning performance (p. 11).

The 1985 NTSB Safety Study, *Air Carrier Overwater Emergency Equipment and Procedures* (1985a), identified several problems with respect to "packaging, donning and operation of aviation life preservers by uninstructed subjects under stress." Citing multiple instances of difficulties opening the plastic packaging, the NTSB recommended that time spent attempting to open the life preserver package should be included in the donning test 15-second time limit. The report also referenced the donning superiority of Rasmussen and Steen's angler vest, for which the donning procedure was "self-evident," needing few, if any, donning instructions, including markings on the device. The favored angler vest contained only a single inflation chamber, which would have precluded TSO-approval at the time, hence the NTSB recommended acceptance of single inflation chamber designs that otherwise met design and performance requirements. In order to simulate the conditions of a water-impact accident better, the NTSB also recommended that timed donning tests be conducted without the use of briefing card instructions or

a donning briefing/demonstration. While there was no recommendation to test life preserver donning in water, the Safety Study did make note of a study of unplanned water-contact cases by Johnson (1984), which showed that most of the individuals who retrieved under-seat life preservers exited the aircraft before donning them, suggesting that survivors would likely have to do so in the water.

Shortly thereafter, the Survival Research Unit at CAMI developed a prototype life preserver, with a primary goal of increased thermal protection for the wearer (Reuschhoff, Higgins, Burr & Branson, 1985). For their prototype, the developers took advantage of the rapid donning characteristic shown by Rasmussen and Steen (1983) for the sleeveless "garment style" angler vest, with an internal air bladder and a conventional wide-toothed zipper positioned down the center front for closure. The single polyurethane-coated nylon air bladder was designed to fit closely to the wearer's upper torso by incorporating heat-sealed "ribs" across the front and upper back to restrict water entry between the preserver and wearer, thus providing increased thermal protection. The lower back of the vest was made of one-eighth inch thick neoprene closed-cell foam for additional thermal protection and to provide ample stretch for larger adults. A cinch-able belt was attached at the waist to provide better fit for smaller adults and further restrict water entry (Fig. 1). Donning times for the 26 naive test participants ranged from 11.1 to 30.9 seconds ($M_{\text{donningtime}}$ = 17.5 seconds).

The 1986 "e" revision of TSO-C13 included a more comprehensive description of donning characteristics and method for the donning test, and increased the time allotted for donning to 25 seconds. A minimum, representative, population sample, distributed across age groups and gender, was established for test participants, as was a pass/fail percentage, a requirement for using real or simulated air carrier coach class seating, inclusion of package opening in the test method, and the stipulation that no donning information other than that in a typical preflight briefing and donning demonstration could be provided to test participants. The expectation was that the donning test would distinguish whether a particular life preserver design could be donned quickly and correctly. The test procedure was retained fully, without modification, in TSO-C13f (1992).

The emergency landing of US Airways Flight 1549 in the Hudson River in January 2009 brought significant, fresh attention to the usability of aviation life preservers. In its accident investigation report (NTSB/AAR-10/03), the NTSB noted that, of those passengers who retrieved aviation life preservers following the emergency landing, the majority indicated that they had difficulty donning them. They also found that the preflight safety briefing had not included life preserver donning information or a donning demonstration because the flight was not an extended overwater operation. Additionally, only 8% of passengers reported reading the safety briefing card (which included donning instructions), before or during the approximately 6-minute flight. As a result, the NTSB recommended that the FAA "Revise the life vest performance standards contained in [TSO] C13f to ensure that they result in a life vest that passengers can quickly and correctly don," identifying passengers' incorrect use of the waist strap as a common cause of incorrect donning (Recommendation A-10-85). Again, citing the study by Rasmussen and Steen (1983), the NTSB noted the superior donning performance of the experimental "angler-vest" and questioned whether the fact that it did not have a waist strap made it more efficient and effective.

Figure 1. Front and back view of CAMI prototype life preserver.

In response, the FAA cited an ongoing project it had requested of the SAE International S-9 Cabin Safety Provisions Technical Committee, i.e., the development of Aerospace Standard (AS) 1354, Individual Inflatable Life Preservers to replace the Aerospace Recommended Practice (ARP1354A) of the same name. This extensive project had begun in 2004 and was intended to evaluate all life preserver design and performance criteria in support of a further revision of TSO-C13. To address the safety concern identified by NTSB recommendation (A-10-85), the FAA requested special emphasis by the S-9 Committee to determine potential improvements to the life preserver donning requirements.

In addition to assessing the test methods and pass/fail criteria for donning, the technical committee had been discussing whether to provide a "briefing and donning demonstration" to test participants as part of the donning test procedure, since passengers may not receive or pay attention to the safety briefing before attempting to don a life preserver in an actual emergency. Relevant questions included whether an oral donning briefing is necessary, whether the information on a typical safety briefing card is sufficiently comprehensible, and whether a dedicated demonstration of life preserver donning is necessary with regard to both test conditions and standard practice in service. As a result of the discussions, the SAE S-9 Committee requested that a study be conducted by the Cabin Safety Research Team at CAMI to get answers to the questions at hand, as well as to reassess the donning test procedures and success criteria, especially for new life preserver designs.

This report details the findings of this latest study, which examined life preserver donning performance relative to different levels of instructional information provided to test participants. The instruction ranged from none at all to a typical air carrier preflight briefing and donning demonstration. The test procedure generally followed the donning test requirements of TSO- C13f: (1) actual/simulated coach class seating with a row of seats in front of participants, creating a 31" seat pitch, (2) test participants began with the seat belt fastened and the possibility that they could release the buckle and rise from seat, but not move out of the seat row, (3) a 25-second time limit that started when the test participant had both hands on the packaged life preserver and stopped when the life preserver was donned, secured, and adjusted for fit, and (4) for TSO compliance, at least 75% of the total number of test participants had to don the life preserver completely and correctly within the 25-second time limit.

Life preserver exemplars included those currently installed on transport airplanes (including the models carried on board US Airways Flight 1549) and older models approved under earlier versions of TSO-C13, as well as the prototype vest developed by CAMI (Fig. 1). The intent in testing the older designs was to replicate, in part, the TSO-device results of the Rasmussen and Steen (1983) study; the CAMI vest was included for comparison as a zipper-closure model. The findings will support development of SAE AS1354 and revision of TSO-C13.

METHOD

Facilities/Materials

The research was conducted in the Cabin Safety Research Laboratory, CAMI, located in Oklahoma City, OK. Tables and chairs were set up in the laboratory entry so the research facilitator and participants could review the informed consent (Appendix A) and general information about the study (Fig. 2).

Figure 2. Study participants review study procedure and informed consent materials in the research lab with research facilitator.

Two privacy cubicles, in which participants recorded their demographic information and responses to computerized pre- and post-test questionnaires (Appendices B, E – H), were equipped with a table and chair, computer and monitor, calibrated weight scale, and tape measure (Fig. 3).

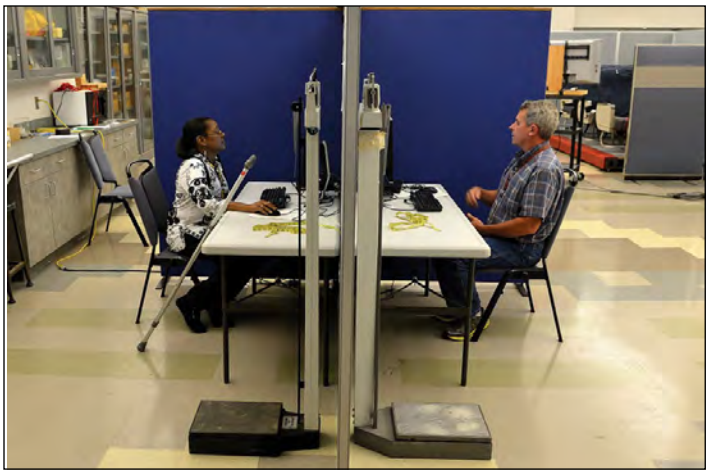

Figure 3. Study participants record demographic information and answer pre- and post-test questions in privacy cubicle equipped with computer, weight scale, and tape measure.

Seating Apparatus. Three rows of air carrier coach class triple-seat assemblies, configured with a 31" seat pitch and typical aviation seat belts, were secured on a wooden base (Fig. 4). The right-hand seats of the second and third rows were each used to seat one test participant per trial. Placards identifying the test sequence number and the life preserver being used were positioned on the side of the seatback. The test area was partitioned to minimize potential distractions during the donning trials.

Instructional Media. A standardized, general introductory video briefing without donning information, recorded against a plain background in the research lab (Appendix C), was provided to all test participants. Simulated passenger safety briefings/demonstrations, recorded in the CAMI 747 Aircraft Environment Research Facility and specific to each instruction condition (Appendix D), were provided to test participants according to

Figure 4. Study participants, seated in airplane mock-up, watch the recorded safety briefing before the life preserver donning portion of the test trial.

test condition. The safety briefings were identical except for the information applicable to the specific instruction condition. Both the general introductory briefing and safety briefing/demonstration were delivered to the research participants on a 42" flat-screen display mounted atop a rolling cart equipped with a DVD player (Fig. 4). Folded, 8.5" x 11" laminated passenger safety briefing cards with donning instructions appropriate for the specific test condition (Appendix I) were placed in the seatback pockets in front of the test participants.

Data Recording and Reduction. A Sony® PMW-EX3 high-definition video camera mounted on a tripod was placed to best capture the actions of individual participants throughout the test trials (Fig. 5). Close-up shots of the placards identifying the test sequence number and life preserver were taken for later identification and, following the recording of the donning test itself, close-up shots captured detailed results of each donning trial. Each trial recording was transferred to an individual Microsoft (MS) Windows Media Video (*.wmv) file and a digital time code was applied to establish timing. The first and final video "frames," based on 30 frames per second, in which a motion was begun or

Figure 5. The actions of the study participants were video-recorded.

completed, were entered into a MS Excel® spreadsheet and then converted to decimal fractions of a second used to calculate the various donning function times, as defined below. These were entered into IBM SPSS® version 21 for statistical analysis.

"*TSO Test Time*" was defined as the period that began with the last moment the test participant had his or her hand on the life preserver package pull-tab or finger holds, about to open the package. The period ended when he or she completed fastening and adjusting the life preserver attachment system (i.e., the last moment the test participant touched the waist strap before either a) signaling completion by raising arms or b) cessation of all activity if there was no arm-raising signal). This measure follows the timing procedure for the donning test in TSO-C13f, although "adjusted for fit" is not clearly defined in the TSO.

"*Package Opening Time*" was defined as the period that began with the last moment the test participant had his or her hand on the life preserver package pull-tab or finger holds, about to open the package, and ended at the moment he or she had a hand on the life preserver in the package to remove it. It is a subset of TSO Test Time.

"Donning Time" was defined as the period that began with the test participant having both hands on the life preserver, out of the package, and ended when he or she completed fastening and adjusting of the attachment system. It is a subset of TSO Test Time.

"*Reading Time*" was defined as the period that the test participant spent examining the instructional markings on the life preserver, which began when he or she had one or both hands on the life preserver, holding it up and/or changing orientation to study the markings and ended when he or she began to don the life preserver. This amount of time was subtracted from "Donning Time" to produce "*Modified Donning Time*." It is a subset of TSO Test Time.

The TSO Test Time is an "all inclusive" time that comprises actions such as package opening, reading instructional markings, donning, and anything in between. However, the subsets, Package Opening Time, Donning Time, Reading Time, and Modified Donning Time, are not cumulative and do not "add up" to the TSO Test Time.

Life Preservers. Nine different life preservers, representative of designs certified for use under TSO-C13d or C13f, were used in the study. All were international rescue yellow, with battery-powered survivor locator lights, oral inflation tubes, manual inflation triggering devices with pull tabs and CO_2 cartridges, and designed to be reversible. The experimental life preserver developed and tested at CAMI (Rueschhoff, Higgins, Burr, & Branson, 1985), fitted with comparable inflation systems, was also included in the study. Packaged inflatable life preservers, with and without instructional markings, were supplied by original equipment manufacturers (TSO-C13f OEMs). Life preserver types tested by Rasmussen and Steen (1983) were pulled from Cabin Safety stock and sealed in new packaging.

Photographs illustrating the front and back of each life preserver in the unopened package, each life preserver as it came out of the package, and each "unfurled" life preserver are included, along with an associated description of each life preserver, in Appendix J. The life preservers have been designated only by letters; manufacturer and model designations have been obscured in the photographs and are not included in the descriptions or discussion.

Experimental Design

This study was designed to assess the effects of five levels of life preserver donning instruction on test participant donning time, from none at all, up to and including a standard air carrier preflight briefing and donning demonstration. Briefing/Demonstration scripts for each Donning Instruction Condition are included in Appendix C. Life preservers with different types of attachment points and instructional markings were used within each instruction condition, as indicated in Table 1 and described in Appendix J. Each donning trial began with the packaged life preserver on the test participant's lap; a buzzer was used to indicate the start of each trial.

The research hypothesis included the assumption that donning procedures for the common design of aviation life preservers, i.e., U-shaped dual-inflation chambers with a single waist strap (TSO-C13f approved), would be apparent, and that donning instructions would not be needed to accomplish complete and correct donning within the TSO time limit of 25 seconds.

Donning Instruction Condition "A." No information was given to test participants regarding life preserver donning. The only reference to life preservers in the typical passenger safety briefing for this instruction condition was, "The airplane is also equipped with life preservers." OEMs supplied new life preservers (Q, R, S, T) without any instructional markings and life preservers pulled from CAMI stock (U, V, W, X, Y, Z), had the instructional markings (pictograms and text) blacked out. Within Condition A, the life preservers were categorized by (5) design types, according to the number and style of attachment points (and single flotation chamber of Y), since fastening the waist strap attachment had been problematic for the passengers on US Airways Flight 1549, in addition to being the most common hindrance observed by Rasmussen and Steen (1983).

Donning Instruction Condition "B(A)." Within Conditions B(A), B, C, and D, the life preservers were identified by the design of their instructional markings, since the number and style of attachment points were similar. Life preservers Q, R, S, T and Y were tested in this condition, all with instructional markings, using the safety briefing from Condition A, which only pointed out, "The airplane is also equipped with life preservers." This condition simulated an actual emergency event in which passengers were not briefed on the use of life preservers or did not pay attention to a briefing that did occur, although instructional markings were provided on the life preserver for reference.

Table 1. Experimental Design

Donning Instructions	Life Preserver Attachment Points Life Preserver Identifier			Total ***N***
	One side-release buckle Dual chamber **Q/R/S/T**	Two side-slide strap adjusters Dual chamber **U**	Two swivel snap hooks Dual chamber **V/W/X**	
A. No instructions in briefing; No instructional markings on life preserver	*N* = 24	*N* = 6	*N* = 12	
	One side-release buckle Single chamber **Y**	CAMI Experimental Vest with Zipper **Z**		
	N = 6	*N* = 6		54

	Pictogram Type Life Preserver Identifier					
	3 figures 6 steps **Q**	4 figures 4 steps **R**	4 figures 5 steps **S**	6 figures 5 steps **T**	5 figures 5 steps (Single chamber) **Y**	
B(A). No reference to markings in briefing; Instructional markings on life preserver	*N* = 6	*N* = 6	*N* = 6	*N* = 6	*N* = 6	30
B. Markings referenced in briefing; Markings on life preserver	*N* = 6	*N* = 6	*N* = 6	*N* = 6		24
C. Instructions on briefing card; Markings on life preserver	*N* = 6	*N* = 6	*N* = 6	*N* = 6		24
D. Instructions/ Demonstration in briefing; Markings on life preserver	*N* = 6	*N* = 6	*N* = 6	*N* = 6		24
Total	24	24	24	24	6	**156**

Donning Instruction Condition "B." Life Preservers Q, R, S, and T were tested in this condition. Reference to the instructional markings was made in the safety briefing, which included the statements, "Since our flight will take us over water, the airplane is equipped with life preservers with donning instructions printed on the life preserver. If an emergency occurs, open the life preserver package, remove and open the life preserver, then follow the pictorial instructions on the life preserver."

Donning Instruction Condition "C." Life Preservers Q, R, S, and T were tested in this condition. The safety briefing directed the test participant to look over the briefing card instructions (Appendix C), "Since our flight will take us over water, the airplane is equipped with life preservers located under your seat. Instructions for using the life preserver are on the Passenger Safety Card located in the seatback pocket in front of you. Please take a moment to review the instructions. When you are finished, put the card back in the pocket." The research facilitator paused the briefing until the test participant replaced the card in the seat pocket.

Donning Instruction Condition "D." Life Preservers Q, R, S, and T were tested in this condition. The safety briefing included a close-up of a donning demonstration with voice-over instructions, "Since our flight will take us over water, the airplane is equipped with life preservers located under your seat. To use the life preserver, pull off the tear tab to open the package, and then remove the life preserver from the package. Put the life preserver over your head. Bring the strap around your waist and insert the tab into the buckle. Pull the strap so it is tightly secured around your waist."

Participants

Federal employees and contractors at CAMI and the Mike Monroney Aeronautical Center participated in the study. They received no compensation beyond the satisfaction of knowing that they had contributed to aviation safety. Participants were instructed to bring eyeglasses if they needed them to read.

The 156 participants, 69 males and 87 females, ranged in age from 23 to 75 years (M_{age}= 46.9 years). Figure 6 illustrates the distribution of participant age in each Donning Instruction Condition in a boxplot. Age distributions resemble typical normal distributions rather than the minimum number of participants for each decade age range specified in the TSO. (Each box encloses the middle 50% of ordered age values, from 25th to 75th percentile. The interior line represents the median age. The bracket lines, or "whiskers," show the range of ages that fall within 1.5x the range of the box. The small circle indicates a statistical outlier, beyond 1.5, but less than 3 box lengths.)

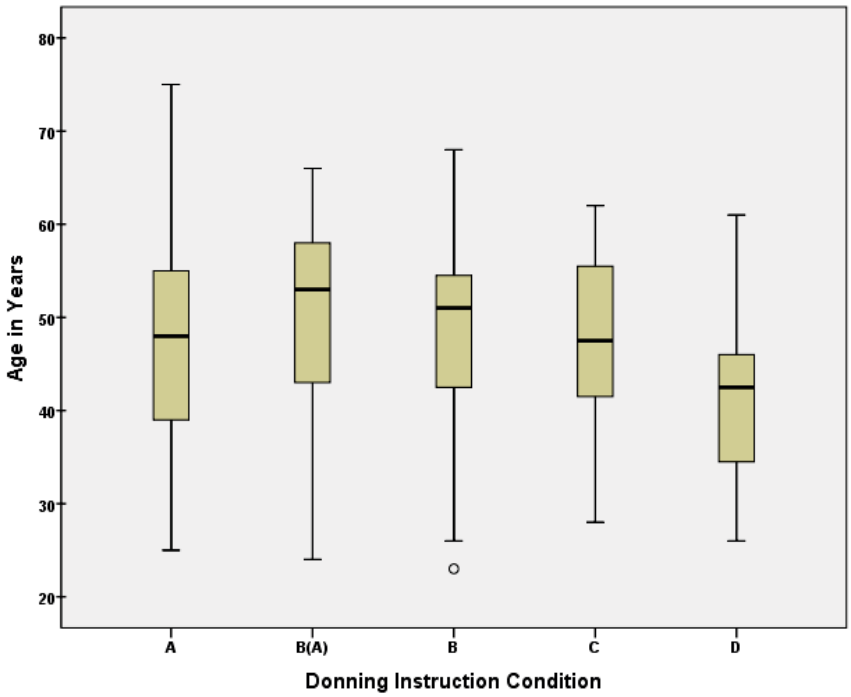

Figure 6. Boxplot distribution of Participant Age for each Donning Instruction Condition.

Participant demographics are presented in Table 2. All personal data were self-reported; the measurements were not verified. Participants in each group did not differ significantly in age, weight, waist measurement, education, or number of flights taken. While the mean height of the participants in Condition B was 3 inches less than those in Group A, 3.2 inches less than those in Group B(A), and 3.1 inches less than those in Group D, height was not shown to affect donning performance.

Table 2. Summary of Participant Demographics

	Donning Instruction Condition					
	A*	**B(A)***	**B***	**C***	**D***	**Overall**
Gender *N* =	54	30	24	24	24	156
Male	57.4%	60.0%	12.5%%	37.5%	33.3%	44.2%
Female	42.6%	40.0%	87.5%	62.5%	66.7%	55.8%
Mean Age in Years	46.7	50.2	48.3	47.5	41.3	46.9
Minimum	25	24	23	28	26	23
Maximum	75	66	68	62	61	75
Mean Girth in Inches	34.8	37.7	36.5	38.5	36.4	36.4
Minimum	20	29	27	31	27	20
Maximum	50	47	49	50	49	50
Mean Height in Inches	67.8	68.0	64.8	66.3	67.9	67.2
Minimum	59	59	59	60	63	59
Maximum	76	76	73	71	74	76
Mean Weight in Pounds	183.5	201.6	172.9	188.8	183.0	186.1
Minimum	115	139	124	128	110	110
Maximum	356	300	246	319	282	356
Mean Education in Years	15.6	15.6	14.5	14.9	15.1	15.3
Minimum	12	12	12	12	12	12
Maximum	20	20	20	20	20	20
Mean Number of Flights	5.1	2.9	2.7	3.4	4.2	3.9
Minimum	0	0	0	0	0	0
Maximum	20	14	13	12	20	20
% <= 10 last year	82%	97%	96%	96%	88%	90%

*A: No instructions in briefing/ No instructional markings on life preserver
*B(A): No reference to markings in briefing/ Instructional markings on life preserver
*B: Markings referenced in briefing/ Markings on life preserver
*C: Instructions on briefing card/ Markings on life preserver
*D: Instructions/ Demonstration in briefing/ Markings on life preserver

Chi-square analysis of the Pre-Test question responses indicated that life preserver experience of participants was similar in each subject group (Table 3).

Procedure

Test participants were escorted to the research lab, two at a time, by a research facilitator and introduced to the research team. Participants were briefed as to the nature and risks of the study, and the informed consent document (Appendix A) was reviewed. Once all questions had been answered and consent confirmed, the test participants were directed to one of two privacy cubicles. They completed a short computerized demographic questionnaire that included questions about their familiarity with personal flotation devices, Appendix B. (The responses to the pre-test questionnaire are summarized in Table 3.) The final page of the questionnaire instructed the participants to go to their designated seats in the aircraft seat mock-up. The research facilitator confirmed their seats and reminded them that they would see a video of General Instructions (Appendix C), then the simulated passenger safety briefing video (Appendix D), as applicable, and they would have an opportunity to ask questions before the life preserver donning portion of the study. The research facilitator answered any questions by reiterating the instructions already given. Following the videos, the facilitator gave a final instruction, "Remember, when you hear the buzzer, open the package, remove the life preserver, don it completely, make all attachments, and adjust for fit as quickly as you can! We are simulating an emergency! When you are finished, raise your arms. Finally, you may not come out of your seat row or leave the mock-up during the test." Once the test participants completed donning, they were asked to step off the seat mock-up and face the camera for video recording; the facilitator then checked for complete and correct donning, pointing out any errors. They were then instructed to return to their cubicles to complete the post-test questionnaire (Appendices E-H). The research facilitator discussed life preserver retrieval, correct and complete donning, appropriate inflation, and addressed final questions. Participants were escorted to the exit, asked not to discuss their experience with others, and were thanked for their contribution to aviation safety.

Table 3. Summary of Pre-Test Responses

	Donning Instruction Condition					
	A*	**B(A)***	**B***	**C***	**D***	**Overall**
Have you ever traveled by plane where the use of life preservers was explained or demonstrated?						
No	18.5%	20.0%	12.5%	20.1%	20.8%	18.6%
Yes	81.5%	80.0%	87.5%	79.2%	79.2%	81.4%
If yes, did you pay attention to the explanation/demonstration?						
No	4.5%	4.2%	14.3%	5.3%	0.0%	5.5%
Yes	95.5%	95.8%	85.7%	94.7%	100.0%	94.5%
Did you consider the explanation/ demonstration adequate if you might have needed to use the life preserver?						
No	25.0%	16.7%	9.5%	15.8%	21.1%	18.9%
Yes	75.0%	83.3%	90.5%	84.2%	78.1%	81.1%
Have you ever used a life preserver in connection with water activities such as boating or water skiing?						
No	14.8%	13.3%	4.2%	12.5%	25.0%	14.1%
Yes	85.2%	86.7%	95.8%	87.5%	75.0%	85.9%
If yes, approximately how long ago was the last time you used the device?						
Mean (yrs)	7.0	7.2	7.4	5.4	8.4	7.0
Minimum	1 wk	1 wk	1 wk	1 wk	1 wk	1 wk
Maximum	20 yrs	20 yrs	20 yrs	20 yrs	20 yrs	20 yrs
If you have used life preservers at least occasionally, what type have you used most often?						
Non-inflatable	79.6%	73.3%	79.2%	70.8%	62.5%	74.4%
Mouth-inflated	0.0%	3.3%	0.0%	0.0%	0.0%	0.6%
Automatic-inflating	5.6%	0.0%	8.3%	16.7%	0.0%	5.8%
None of the above	14.8%	23.4%	12.5%	12.5%	37.5%	19.2%

*A: No instructions in briefing/ No instructional markings on life preserver
*B(A): No reference to markings in briefing/ Instructional markings on life preserver
*B: Markings referenced in briefing/ Markings on life preserver
*C: Instructions on briefing card/ Markings on life preserver
*D: Instructions/ Demonstration in briefing/ Markings on life preserver

RESULTS

Chi-square analysis of the Pre-Test question responses indicated that life preserver experience of participants was similar in each Donning Instruction Condition group (Table 3).

Recall that the overall TSO Test Time included the subsets of Package Opening Time, Donning Time, and Reading Time. These times interacted to confound measurement of the actual donning time; thus, package opening time and reading time were extracted to produce a Modified Donning Time, which gave a more accurate measure of donning time, per se.

TSO Test Time

TSO Test Times ranged from 16.5 to 196.0 seconds ($\mathbf{M}_{\text{TSO donning time}}$ = 52.4 seconds), measured from package opening to final adjustment. Of the demographic variables (flight history, education level, age, height, weight, waist measurement, and gender), only participant age and flight history were correlated with TSO Test Time (r = 0.32, df = 154, p < .01; r = -0.24, df = 154, p < .01, respectively). Controlling for age and flight history, analysis of covariance (ANCOVA) indicated that the amount and type of donning instruction the participants received had a significant effect on donning time ($F(4, 149) = 4.32$, p < .01). Since the life preserver types used in the instruction conditions differed, further analysis of instruction conditions was based on the life preserver types common to each condition. Figure 7 shows mean TSO Test Times for each life preserver type within each donning instruction condition, which are also listed in Tables 4 through 8.

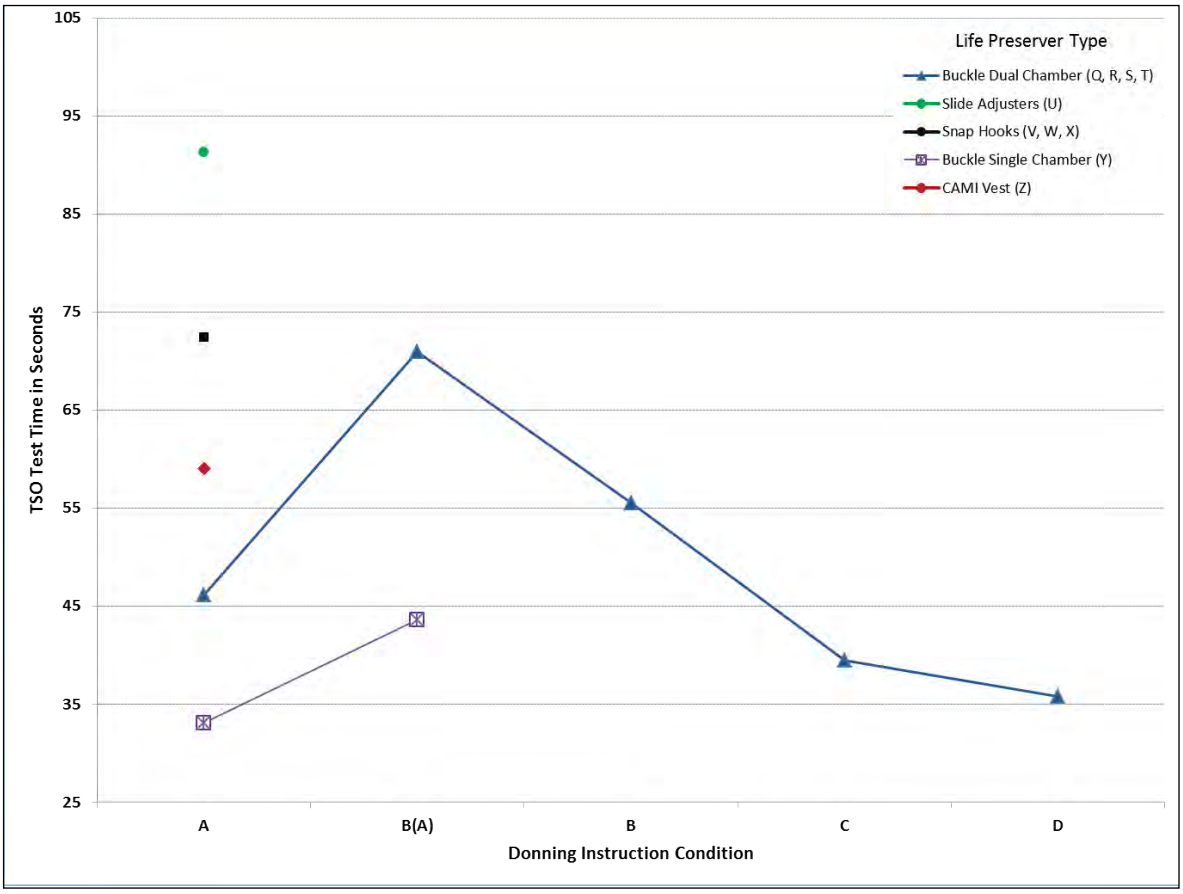

Figure 7. Mean TSO Test Time for each Life Preserver Type in each Instruction Condition

For condition A (Table 4), times ranged from 16.5 to 173.0 seconds. ANCOVA showed that the main effect of life preserver type (identified by attachment points) was significant ($F(4, 47) = 6.38$, $p < .01$). Of the 54 total dons, there were 35 correct and complete dons, but only four (7.4%) were completed within the TSO time limit of 25 seconds, nowhere near the 75% "pass" requirement. Only the T and Z life preservers were correctly donned in all trials. The Y life preserver had the most TSO "passes," but these accounted for only 33.3% (2 of 6) of the donning trials with that life preserver.

In Donning Instruction Conditions B(A), B, C, and D, all life preservers had similar attachment points but the pictographic instructional markings for donning differed.

Table 4. TSO Test Times for each Life Preserver Type by Attachment Points: Donning Instruction Condition A

	No instructions in briefing/ No instructional markings on life preserver								
Attachments	**1 Side-Release Buckle Dual-Chamber**				**2 Side-Slide Strap Adjusters**	**2 Swivel Snap-Hooks**	**1 Side-Release Buckle Single-Chamber**	**CAMI Vest with Zipper**	**Overall**
Life Preserver	**Q**	**R**	**S**	**T**	**U**	**VWX**	**Y**	**Z**	
N	6	6	6	6	6	12	6	6	54
Mean Time (s)	58.9	42.3	45.4	37.9	91.3	72.4	33.1	59.0	57.0
Minimum Time	43.4	21.0	16.5	25.0	38.8	28.0	20.8	42.7	16.5
Maximum Time	79.7	70.0	89.0	49.9	173.0	158.7	57.2	75.2	173.0
Correct Dons	5	3	5	6	2	5	3	6	35
<= 25 s	0	0	1	1	0	0	2	0	4
"PASS" Percentage:	0.0%	0.0%	17%	17%	0.0%	0.0%	33%	0.0%	7.4%

In Donning Instruction Condition B(A) (Table 5), TSO Test Times ranged from 20.5 to 196.0 seconds, not differing significantly across Life Preserver Type. However, when compared with Condition A, the times for Life Preserver T were significantly longer when the instructional markings were present, but not referred to in the passenger safety briefing ($t = -2.95$, $df = 6.6$, $p = .01$, unequal variances). Of the 30 total dons in Donning Instruction Condition B(A), there were 17 complete and correct dons, but only one trial with the Y life preserver was completed within 25 seconds, i.e., a TSO "pass." None of the life preservers was correctly donned in all trials.

Table 5. TSO Test Times for each Life Preserver Type by Pictograms: Donning Instruction Condition B(A)

	No reference to markings in briefing/ Instructional markings on life preserver					
Pictogram Type	**3 Figures 6 Steps**	**4 Figures 4 Steps**	**4 Figures 5 steps**	**6 Figures 5 Steps**	**5 Figures 5 Steps Single-Chamber**	**Overall**
Life Preserver	**Q**	**R**	**S**	**T**	**Y**	
N	6	6	6	6	6	30
Mean Time (s)	80.7	59.8	78.7	64.5	45.6	65.5
Minimum Time	36.7	38.2	22.9	35.8	20.5	20.5
Maximum Time	193.1	89.7	196.0	98.7	98.2	196.0
Correct Dons	4	2	3	4	4	17
<= 25 s	0	0	0	0	1	1
"PASS" Percentage:	0.0%	0.0%	0.0%	0.0%	17%	3.3%

In Donning Instruction Condition B (Table 6), TSO Test Times ranged from 17.3 to 102.2 seconds, not differing significantly across Life Preserver Type. Of the 24 total dons in Donning Instruction Condition B, there were 18 complete and correct dons, but none were completed within 25 seconds. Only Life Preserver Q was correctly donned in all trials. (Note that Life Preserver Y (single inflation chamber) was not included in this or the remaining conditions. See explanation in Appendix J.)

Table 6. TSO Test Times for each Life Preserver Type by Pictograms: Donning Instruction Condition B

	Markings referenced in briefing/ Markings on life preserver				
Pictogram Type	**3 Figures 6 Steps**	**4 Figures 4 Steps**	**4 Figures 5 Steps**	**6 Figures 5 Steps**	**Overall**
Life Preserver	**Q**	**R**	**S**	**T**	
N	6	6	6	6	24
Mean Time (s)	55.4	50.0	54.8	62.0	55.5
Minimum Time	32.3	17.3	36.0	48.9	17.3
Maximum Time	90.1	102.2	87.0	89.9	102.2
Correct Dons	6	4	4	4	18
<= 25 s	0	0	0	0	0
"PASS" Percentage:	0.0%	0.0%	0.0%	0.0%	0.0%

In Donning Instruction Condition C (Table 7), TSO Test Times ranged from 18.1 to 58.0 seconds, not differing significantly across Life Preserver Type. Of the 24 total dons in Donning Instruction Condition C, 18 were complete and correct dons, but only two were completed within 25 seconds. Only Life Preserver T was correctly donned in all trials.

Table 7. TSO Test Times for each Life Preserver Type by Pictograms: Donning Instruction Condition C

	Instructions on briefing card/ Markings on life preserver				
Pictogram Type	**3 Figures 6 Steps**	**4 Figures 4 Steps**	**4 Figures 5 Steps**	**6 Figures 5 Steps**	**Overall**
Life Preserver	**Q**	**R**	**S**	**T**	
N	6	6	6	6	24
Mean Time (s)	48.8	33.8	37.2	38.0	39.5
Minimum Time	37.3	28.2	22.4	18.1	18.1
Maximum Time	58.0	50.5	52.3	57.1	58.0
Correct Dons	4	3	5	6	18
<= 25 s	0	0	1	1	2
"PASS" Percentage:	0.0%	0.0%	17%	17%	8.3%

In Donning Instruction Condition D (Table 8), TSO Test Times ranged from 17.6 to 109.1 seconds, also not differing significantly across Life Preserver Type. Of the 24 total dons in Donning Instruction Condition D, 17 were complete and correct dons, and five were completed within 25 seconds. Only Life Preserver Q was correctly donned in all trials. Life Preserver T had the most TSO "passes," with 50% (3 of 6) of the donning trials completed within 25 seconds.

A two-way ANCOVA, comparing TSO Test Times for Life Preservers Q, R, S, and T across all Donning Instruction Conditions, showed a significant main effect of Instruction Condition ($F(4, 98) = 5.41$, $p = .01$), as longer donning times were associated with the presence of instructional markings on the life preserver that were not referred to in the safety briefing, i.e., Condition B(A). There was no effect of Life Preserver Type and no interaction effects.

Experience with life preservers in water activities was negatively correlated with TSO Test Time in Donning Instruction Condition A ($r = -0.33$, $p < .05$), whereas the amount of time since the last use of such a device was positively correlated with longer TSO Test Time in Condition B(A) ($r = 0.59$, $p < .01$). No other life preserver experience variable was correlated with this donning time measure in any of the instruction conditions.

Package Opening Time

Life preserver packaging materials and designs differed greatly, as evidenced by the Package Opening Times (Table 9), which showed the difficulty participants experienced with some of the packages. (See Appendix J for full descriptions of life preserver packages.)

Table 8. TSO Test Times for each Life Preserver Type by Pictograms: Donning Instruction Condition D

	Instructions/Demonstration in briefing/ Markings on life preserver				
Pictogram Type	**3 Figures 6 Steps**	**4 Figures 4 Steps**	**4 Figures 5 Steps**	**6 Figures 5 Steps**	**Overall**
Life Preserver	**Q**	**R**	**S**	**T**	
N	6	6	6	6	24
Mean Time (s)	39.5	47.7	32.8	23.4	35.8
Minimum Time	26.5	20.7	18.3	17.6	17.6
Maximum Time	70.9	109.1	42.5	29.6	109.1
Correct Dons	6	4	3	4	17
<= 25 s	0	2	0	3	5
"PASS" Percentage:	0.0%	33%	0.0%	50%	20.8%

Table 9. Package Opening Times for each Life Preserver Package Type

	Life Preserver Package Type					
Package Opening Time	**Q**	**R**	**S**	**T**	**CAMI**	**Overall**
N	**30**	**30**	**30**	**30**	**36**	156
Mean Time (s)	9.7	5.0	3.6	5.5	2.3	5.1
Median Time	6.4	4.2	3.0	4.0	2.1	3.6
Minimum Time	2.1	1.5	1.4	1.3	1.1	1.1
Maximum Time	37.9	20.3	8.2	17.2	4.6	37.9

The boxplot in Figure 8 illustrates the varied distributions of package opening times. The small circles indicate statistical outliers (beyond 1.5 box lengths), and the stars show extreme values (beyond 3 box lengths, cf. *SPSS Base Applications Guide, 1999,* pg. 41*).*

Of the demographic variables, only age was correlated with package opening time (r = 0.18, df = 154, p = .03). Therefore, age was included as a covariate in the following analyses. A one-way ANCOVA showed a significant main effect of Life Preserver Package Type (F(4, 150) = 12.16, p < .01), accounting for 27% of the variance in package opening time. Subsequent pairwise comparisons indicated that participants took significantly longer to open package Q than each of the other packages, and significantly less time to open the CAMI package than all but package S. Package opening times for packages R, S, and T did not differ significantly from each other.

Donning Time

Recall that this time was measured from the moment both hands of the test participant were on the life preserver (out of its package) to the moment of final waist strap adjustment. Donning Times ranged from 11.7 to 190.0 seconds ($\boldsymbol{M}_{\text{Donning Time}}$ = 45.2 seconds). Of the demographic variables, participant age and flight history were correlated with Donning Time (r = 0.29, df = 154, p < .01; r = -0.21, df = 154, p < .05, respectively). Controlling for age and flight history, ANCOVA indicated that the amount and type of donning instruction the participants received had a significant effect on donning time (F(4, 149) = 5.05, p < .01).

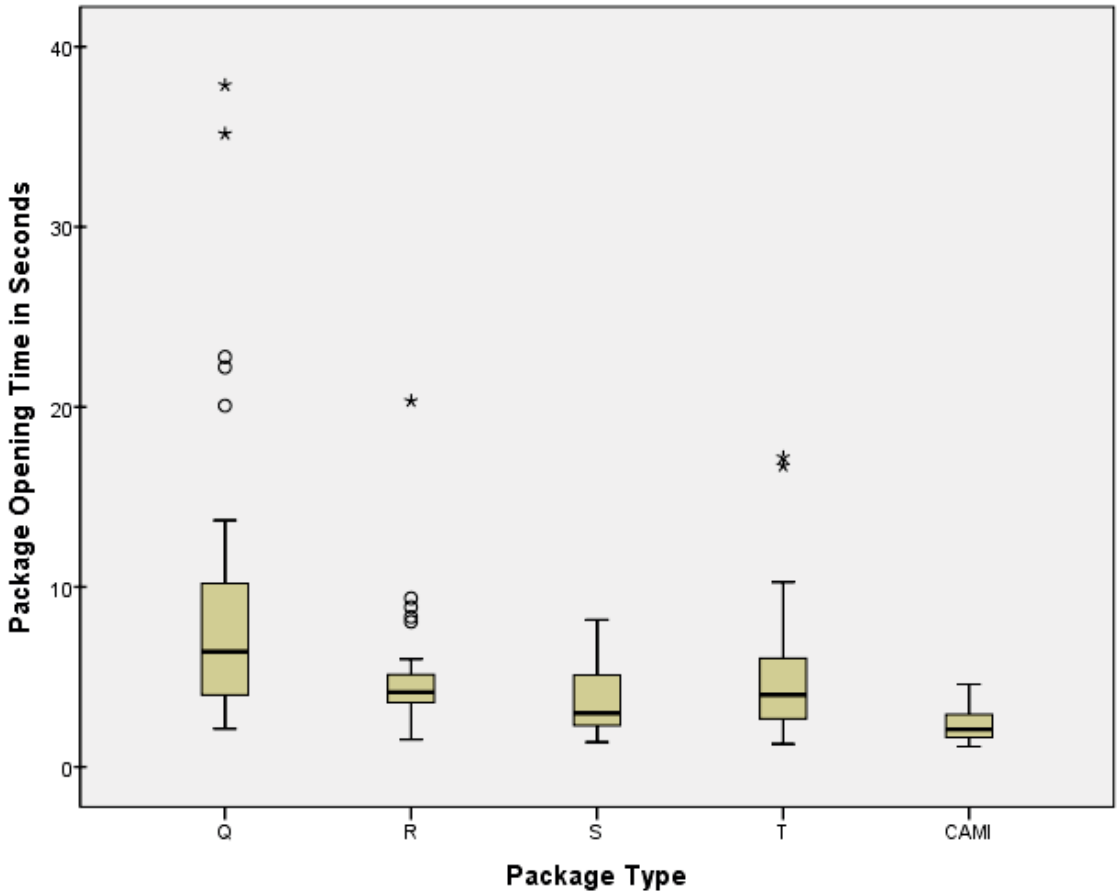

Figure 8. Boxplot distribution of Package Opening Time for each package type.

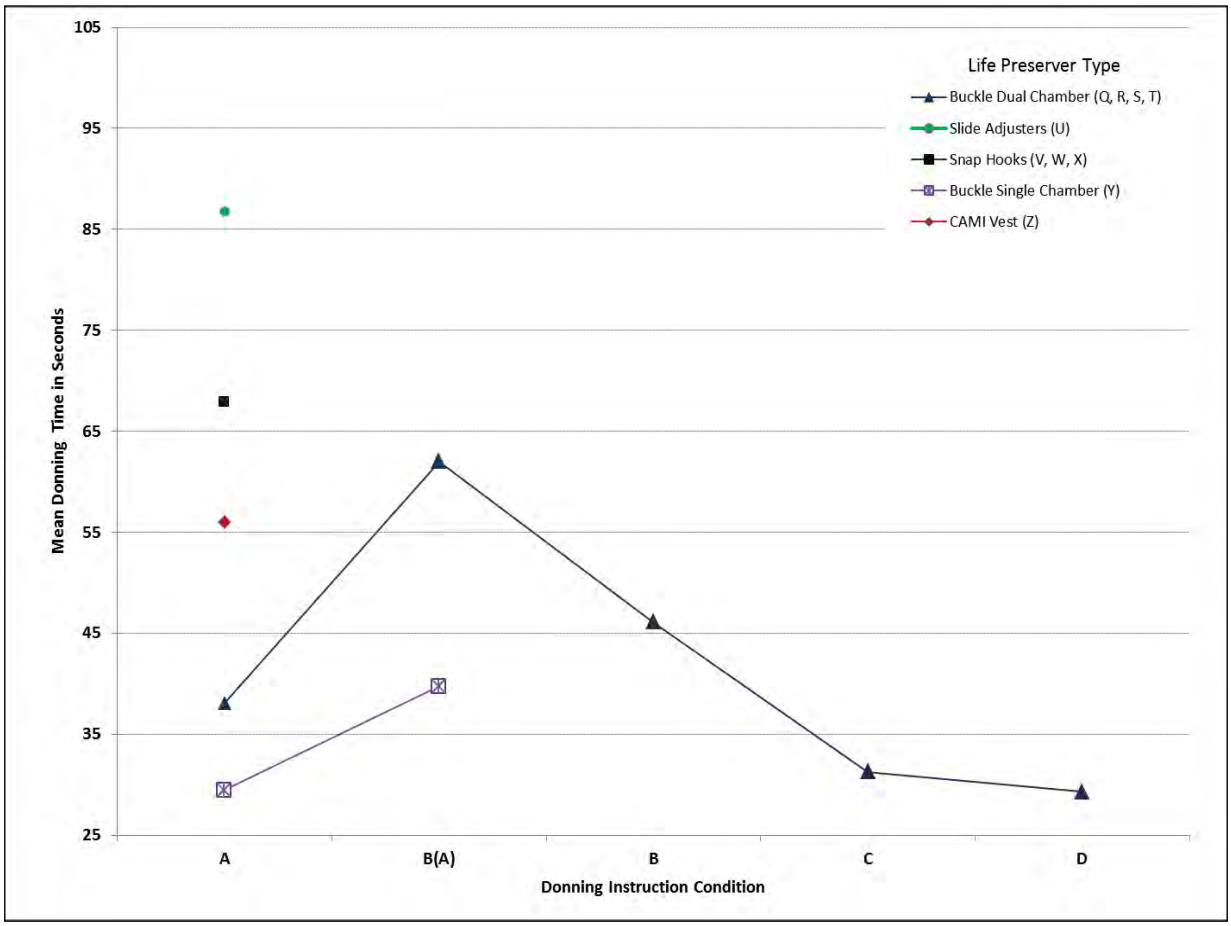

Figure 9. Mean Donning Time for each Life Preserver Type in each Instruction Condition

Figure 9 shows mean Donning Times for each Life Preserver Type within each Donning Instruction condition; the donning times are further explained in Tables 10–14.

For Condition A (Table 10), times ranged from 13.6 to 166.5 seconds. ANCOVA showed that the main effect of Life Preserver Type (by attachment points) was significant ($F(4, 47) = 7.46$, $p < .01$). Of the 54 total dons (35 complete and correct), six (11.1%) were completed within 25 seconds, two more than the number of complete and correct dons using the TSO Test Time measure (see Table 4). In addition to Life Preserver Y, which had been responsible for the two "passes" using the TSO Test Time, Life Preserver S was also donned within 25 seconds in two trials.

Table 10. Donning Times for each Life Preserver Type by Attachment Points: Donning Instruction Condition A

	No instructions in briefing/ No instructional markings on life preserver								
Attachments	**1 Side-Release Buckle Dual-Chamber**				**2 Side-Slide Strap Adjusters**	**2 Swivel Snap-Hooks**	**1 Side-Release Buckle Single-Chamber**	**CAMI Vest with Zipper**	**Overall**
Life Preserver	**Q**	**R**	**S**	**T**	**U**	**VWX**	**Y**	**Z**	
N	6	6	6	6	6	12	6	6	54
Mean Time (s)	45.9	34.2	39.7	32.5	86.8	67.9	29.5	56.0	51.2
Minimum Time	35.2	15.0	13.6	21.6	35.1	23.7	18.4	39.1	13.6
Maximum Time	70.1	61.0	83.9	45.3	166.5	154.8	53.5	72.4	166.5
Correct Dons	5	3	5	6	2	5	3	6	35
<= 25 s	0	1	2	1	0	0	2	0	6
"PASS" Percentage:	0.0%	17%	33%	17%	0.0%	0.0%	33%	0.0%	11.1%

In Donning Instruction Condition B(A) (Table 11), Donning Times ranged from 16.1 to 190.0 seconds. Donning times did not differ significantly across Life Preserver Type. When compared with Condition A, the donning times for life preserver T were significantly longer when the instructional markings were present, but not referred to in the passenger safety briefing (t = -2.33, df = 10, p = .01, equal variances). Of the 30 total dons, two more dons (Life Preservers S and T) were completed within 25 seconds than when using the TSO Test Time measure (see Table 5). Still, only 10% of the total dons were completed correctly within 25 seconds.

In Donning Instruction Condition B (Table 12), Donning Times ranged from 11.7 to 87.1 seconds, not differing significantly across Life Preserver Type. Of the 24 total dons, only Life Preserver Q was donned within 25 seconds (once), whereas none had met the time requirement using the TSO Test Time measure (see Table 6).

Table 11. Donning Times for each Life Preserver Type by Pictograms: Donning Instruction Condition B(A)

	No reference to markings in briefing/ Instructional markings on life preserver					
Pictogram Type	**3 Figures 6 Steps**	**4 Figures 4 Steps**	**4 Figures 5 Steps**	**6 Figures 5 Steps**	**5 Figures 5 Steps Single-Chamber**	**Overall**
Life Preserver	**Q**	**R**	**S**	**T**	**Y**	
N	6	6	6	6	6	30
Mean Time (s)	68.0	51.8	73.2	54.7	39.7	57.5
Minimum Time	19.9	31.6	20.1	24.2	16.1	16.1
Maximum Time	168.1	82.8	190.0	90.7	94.5	190.0
Correct Dons	4	2	3	4	4	17
<= 25 s	0	0	1	1	1	3
"PASS" Percentage:	0.0%	0.0%	17%	17%	17%	10.0%

Table 12. Donning Times for each Life Preserver Type by Pictograms: Donning Instruction Condition B

	Markings referenced in briefing/ Markings on life preserver				
Pictogram Type	**3 Figures 6 Steps**	**4 Figures 4 Steps**	**4 Figures 5 Steps**	**6 Figures 5 Steps**	**Overall**
Life Preserver	**Q**	**R**	**S**	**T**	
N	6	6	6	6	24
Mean Time (s)	41.0	42.1	48.6	52.7	46.1
Minimum Time	24.5	11.7	30.3	41.3	11.7
Maximum Time	56.8	87.1	77.6	82.5	87.1
Correct Dons	6	4	4	4	18
<= 25 s	1	0	0	0	1
"PASS" Percentage:	17%	0.0%	0.0%	0.0%	4.2%

For Donning Instruction Condition C (Table 13), Donning Times ranged from 13.1 to 51.7 seconds, not differing significantly across Life Preserver Type. Of the 24 total dons, 6 (25%) were completed within 25 seconds, four dons more than the number of complete and correct dons using the TSO Test Time measure (see Table 7). Life Preserver T showed the greatest increase from one to three.

Table 13. Donning Times for each Life Preserver Type by Pictograms: Donning Instruction Condition C

	Instructions on briefing card/ Markings on life preserver				
Pictogram Type	**3 Figures 6 Steps**	**4 Figures 4 Steps**	**4 Figures 5 Steps**	**6 Figures 5 Steps**	**Overall**
Life Preserver	**Q**	**R**	**S**	**T**	
N	6	6	6	6	24
Mean Time (s)	38.5	27.0	30.7	28.9	31.2
Minimum Time	20.8	20.8	13.1	14.2	13.1
Maximum Time	51.7	44.0	43.0	42.4	51.7
Correct Dons	4	3	5	6	18
<= 25 s	1	1	1	3	6
"PASS" Percentage:	17%	17%	17%	50%	25.0%

In Donning Instruction Condition D (Table 14), Donning Times ranged from 13.8 to 100.5 seconds, also not differing significantly across Life Preserver Type. Eight (33.3%) of the 24 dons were accomplished within 25 seconds, three more than the number of complete and correct dons using the TSO Test Time measure (see Table 8). Life Preserver Q increased from none to two, and Life Preserver T increased from three to four completed dons within 25 seconds.

For Instruction Conditions B(A), B, C, and D, the overall mean donning times decreased, and the total number of correct dons within 25 seconds increased, as the type and amount of instruction increased. Across all Instruction Conditions, the total number of donning time "passes" for Life Preservers Q, R, S, T, and Y increased from 12 to 24 (of total 132 dons), or from 9.1% to 18.2%.

Having observed a life preserver donning demonstration in the past was negatively correlated with Donning Times in Conditions B and C (r = -0.45, p < .05; r = -0.42, p < .05, respectively). Use of life preservers in water activities was negatively correlated with Donning Time in Donning Instruction Condition A (r = -0.35, p = .01), and the amount of time since the last use of such a device was positively correlated with Donning Time in Condition B(A) (r = 0.54, p < .01). No other life preserver experience variable was correlated with this donning time measure in any of the instruction conditions.

Table 14. Donning Times for each Life Preserver Type by Pictograms: Donning Instruction Condition D

	Instructions/Demonstration in briefing/ Markings on life preserver				
Pictogram Type	**3 Figures 6 Steps**	**4 Figures 4 Steps**	**4 Figures 5 Steps**	**6 Figures 5 Steps**	**Overall**
Life Preserver	**Q**	**R**	**S**	**T**	
N	6	6	6	6	24
Mean Time (s)	29.9	40.4	28.4	18.4	29.3
Minimum Time	19.9	17.8	15.3	13.8	13.8
Maximum Time	49.1	100.5	35.8	23.2	100.5
Correct Dons	6	4	3	4	17
<= 25 s	2	2	0	4	8
"PASS" Percentage:	33%	33%	0.0%	67%	33.3%

Reading Time

Of the 102 participants who were included in Donning Instruction Conditions B(A), B, C, and D, in which all the life preservers had imprinted instructional markings, 77.5% spent some amount of time looking at the markings at some point during the donning process. Two participants in B(A) spent 100 or more seconds looking at the markings. These two outlying cases were removed from further analysis in order to achieve more equal distributions for Reading Time across Donning Instruction Conditions.

The mean time spent reading the life preserver instructional markings for Donning Instruction Conditions B(A) and B was not significantly different (12.3 and 13.7 seconds, respectively); the markings were the same but the instruction to look at them differed. However, the mean times for reading markings in Instruction Conditions C and D (4.5 and 3.3 seconds, respectively), in which other instructions from the briefing card and the full demonstration were available, differed significantly from the reading times in Conditions B(A) and B, in pairwise comparisons, by a one-way analysis of variance (ANOVA, $F(3, 96) = 11.5$, $p < .01$). Table 15 includes a summary of Reading Times for each Instruction Condition.

Table 15. Summary of Reading Times for Life Preserver Instructional Marking

Donning Instruction Condition	Minimum time (s)	Maximum time (s)	Mean time (s)	Median time (s)
B(A):No reference to markings in briefing/Instructional markings on life preserver	0.0	39.7	12.3	9.6
B: Markings referenced in briefing/ Markings on life preserver	1.4	34.0	13.7	12.5
C: Instructions on briefing card/ Markings on life preserver	0.0	21.4	4.5	3.7
D: Instructions/ Demonstration in briefing/ Markings on life preserver	0.0	32.2	3.3	1.0
Overall	1.4	39.7	8.6	5.5

Modified Donning Time

To hone in on life preserver donning and to meet the statistical assumption of homogeneity of variances, a final donning time was calculated that excluded time spent on package opening and reading of instructional markings, i.e., *Modified Donning Time*. Calculation of this variable was augmented by excluding three additional extreme-value cases from the B(A) Donning Instruction Condition analysis, as the test participants had such difficulty that they eventually gave up without completing the donning process. Including only the TSO-C13f approved dual inflation chamber life preservers (Q, R, S, T) common to all Donning Instruction Conditions, a one-way ANOVA, using this measure as the dependent variable, showed a significant effect of Donning Instruction Condition, $F(4, 112) = 2.99$, $p = .02$. Subsequent multiple comparisons indicated that only Condition A and D differed significantly from each other. As the amount, type, and content of donning instruction increased, the average Modified Donning Time decreased.

Table 16 includes a summary of Modified Donning Times for each Instruction Condition. The overall median time was 28.73 seconds, with 37.6% of the individual donning times falling at or below 25 seconds and 54% at or below 30.2 seconds.

For the single-inflation chamber life preserver (Y) tested in Donning Instruction Conditions A and B(A), the Modified Donning Times are summarized in Table 17. The overall median time was 25 seconds, with 67% of the individual donning times at 30.1 seconds or less. There was no significant difference between modified donning times for Conditions A and B(A).

Table 16. Summary of Modified Donning Times for Dual-Inflation Chamber Life Preservers

Donning Instruction Condition	Minimum time (s)	Maximum time (s)	Mean time (s)	Median time (s)
A: No instructions in briefing/No instructional markings on life preserver	13.6	83.9	38.1	35.0
B(A):No reference to markings in briefing/Instructional markings on life preserver	9.7	90.7	35.5	28.7
B: Markings referenced in briefing/ Markings on life preserver	6.0	70.1	33.2	30.7
C: Instructions on briefing card/ Markings on life preserver	12.4	42.6	26.8	26.7
D: Instructions/ Demonstration in briefing/ Markings on life preserver	11.3	68.3	26.0	23.6
Overall	6.0	90.7	31.8	28.7

Table 17. Summary of Modified Donning Times for Single-Inflation Chamber Life Preservers (Y)

Donning Instruction Condition	Minimum time (s)	Maximum time (s)	Mean time (s)	Median time (s)
A: No instructions in briefing/No instructional markings on life preserver	18.4	53.5	29.5	24.6
B(A):No reference to markings in briefing/Instructional markings on life preserver	16.07	84.9	34.2	25.0
Overall	16.7	84.9	31.8	25.0

Post-Test Questionnaire

Summaries of post-test responses for each Instruction Condition are included in Appendix K.

Chi-square tests of independence showed a significant relationship between the type of life preserver worn by the test participant and the reported difficulty of donning the life preserver ($X^2(7, N = 156) = 35.4, p < .01$). Although there was not a statistically significant relationship between the type of life preserver donned and the Donning Instruction Condition, more people in Condition A than any other Condition indicated that they had donning difficulties, with the highest percentages for Life Preservers U, V/W/X, Y and Z. Those who donned Life Preserver T in Condition A did not report any difficulty.

Table 18. Donning Difficulties

Source of Difficulty	Percentage of all participants
Opening package	18%
General donning confusion	18%
Orientation (determining front/back, top/bottom)	27%
Fastening/unfastening/adjusting waist strap	21%
Rubber band on strap	5%
General waist strap confusion	14%
Neck opening too small	14%
Understanding upside-down instructional markings on life preserver	7%
Confusion about battery	2%
Concern about inflation	4%

The primary sources of donning difficulties reported by participants are summarized in Table 18. Of those donning Life Preserver R, 20% reported difficulty with unfastening the buckle on the waist strap before it could be donned. The majority of the package opening difficulties (63%) was reported for packages Q and R. Thirty percent of those who donned Life Preserver T reported problems getting the life preserver over their head, especially while wearing eyeglasses or earrings. All of the participants who donned the CAMI vest reported difficulty fastening or closing the zipper, and 67% reported that the vest did not fit well.

When asked how well they thought they would have done had the event been an actual emergency, the majority of the participants reported "about the same" across all Donning Instruction Conditions and Life Preserver Types. However, confidence in being prepared for an actual over-water evacuation was significantly related to the type of life preserver ($X^2(7, N = 156) = 16.7, p < .05$) and instruction condition ($X^2(4, N = 156) = 11.1, p < .05$).

For Donning Instruction Conditions B(A), B, C, and D, a significant relationship was shown between instruction condition and whether the instructions printed on the equipment or the package were read, with more people in Condition B reporting that they had read the instructions ($X^2(4, N = 156) = 11.1, p < .05$), which they had been instructed to do in the briefing. Except for confusion about the instructional markings on the life preservers being upside-down and difficulties understanding the package-opening instructions, there were no other noteworthy comments regarding instructions. However, 18% of the participants in conditions A and B(A) reported that they had expected some kind of briefing and/or donning demonstration.

Expert Benchmark

None of the life preservers included in the study met the donning requirements using the donning test procedure in TSO-C13f, regardless of the type and amount of instructions provided to the naïve test participants. Even when the times for package opening and reading the instructional markings were removed from the overall TSO Test Time, the time and percentage requirements were not achieved.

As a result, 32 life preserver "experts" (20 flight attendant instructors and 12 Cabin Safety research staff) were enlisted to establish a donning time "benchmark" for comparison with the naïve test participants' donning times. Only Q, R, S, and T life preservers were tested. The life preservers donned by the flight attendant instructors were all packaged in CAMI replacement packages, which were among the easiest to open. Those donned by the research staff were in original manufacturer's packaging. The TSO Test Times, Package Opening Times, and Donning Times are listed in Tables 19–21. Since none of the experts looked at the instructional markings, Modified Donning Time was not assessed.

Table 19. TSO Test Times for Life Preserver Experts

Life Preserver	Q	R	S	T	Overall
N	8	8	8	8	32
Mean Time (s)	20.2	23.3	19.9	18.3	20.4
Minimum Time	12.3	16.9	10.7	11.8	10.7
Maximum Time	29.0	35.4	27.0	25.6	35.4
Correct Dons	7	6	6	8	27
<= 25 s	6	3	3	7	19
"Pass" Percentage:	75%	38%	38%	88%	59%

Table 20. Package Opening Times for Life Preserver Experts

	Life Preserver Package Type					
Package Opening Time	**Q**	**R**	**S**	**T**	**CAMI**	**Overall**
N	3	3	3	3	20	32
Mean Time (s)	3.9	3.3	1.7	2.7	1.4	2.0
Minimum Time	2.8	1.3	1.5	1.8	0.7	0.7
Maximum Time	6.0	6.0	2.1	3.8	3.3	6.0

Table 21. Donning Times for Life Preserver Experts

Life Preserver	Q	R	S	T	Overall
N	8	8	8	8	32
Mean Time (s)	17.3	20.2	17.8	15.9	17.8
Minimum Time	10.4	14.8	8.3	8.9	8.3
Maximum Time	23.0	32.9	25.6	21.8	32.9
Correct Dons	7	6	6	8	27
<= 25 s	7	4	5	8	24
"Pass" Percentage:	88%	50%	63%	100%	75%

Note: Donning Time does not include package opening.

Only life preserver types Q and T were correctly donned by experts within 25 seconds at the rate required by TSO-C13f, whether using the TSO Test Time measure (Table 19) or the Donning Time measure (Table 21). As with the naïve test participants, Packages Q and R took longer to open, but expertise appears to have produced faster opening overall.

DISCUSSION

Although emergency water landings by transport category aircraft are infrequent, most have occurred near an airport, close to shore, during the takeoff or landing phases of flight. When they do occur, equipment imperfections, the ineffectiveness of instruction techniques, and the lack of adequate crew training may become apparent. However, the infrequency of water accidents is often cited as the reason for not integrating research findings relative to the improvement of water survival equipment (Cosper & McLean, 1998). The findings of the current study highlight the shortcomings that result from this misconception.

The usability of aviation life preservers has been studied repeatedly since the 1960s, seeking "more comfortable, standardized, and less complicated life [preservers] for use in air carrier aircraft" (NTSB, 1985a). Interestingly, the same problems reported by Rasmussen and Steen (1983), Johnson (1984), Rasmussen, Chittum, and Saldivar (1984) and the NTSB (1985a) were manifest again in the real-world experience of passengers on US Airways Flight 1549 (NTSB, 2010), as well as in the current study. That is, the adjustable waist straps were not fastened correctly, if at all,

nor were they tightened; confusion was evident as to the top/bottom or front/back of the devices and whether they should be put on like a vest or over the head. However, contrary to previous findings, donning of the prototype CAMI vest in this current study proved to be as difficult as the others, given the inclusion of an adjustable waist strap, which was an attempt to make it "universal" in size. Problems fastening and closing the zipper were also encountered.

Donning Time

The application of the TSO life preserver donning test procedure has been shown in this study to produce unreliable data, possibly the result of varied interpretation of the test conditions specified in TSO-C13f, not to mention the variables in TSO donning that interact to produce poor performance in service. The results of this study indicate that multiple enhancements to the TSO test procedure are necessary to solve at least part of this problem.

Once actual (modified) donning time was identified (i.e., removing the highly variable package opening and instructional marking reading times), the differences in donning times among the dual chamber life preservers with a side-release buckle were found to result from the amount, type, and content of the donning instructions. This is a predictable outcome, and it underscores the need to address the issue of presenting a "briefing and donning demonstration" to test participants during donning tests, since passengers may not receive or pay attention to the safety briefing before attempting to don a life preserver in an actual emergency. However, even *with* the briefing and donning demonstration, the life preservers included in the study did not achieve the requirement for 75% correct and complete dons within the 25-second time limit, except when donned by experts who were knowledgeable and/or well-trained in donning procedures.

Additional difficulties that added time to donning the life preserver were associated with two particular problems for participants: 1) determining the front from the back (or top from bottom) and 2) handling the waist strap. Even though life preservers are reversible, this design characteristic was not always apparent to the test participants. In particular, Life Preserver Y was especially confusing because the inflation mechanism was only on one side of this single-inflation-chamber design. Test participants suggested that a marking such as "REVERSIBLE" or "FRONT/BACK" be included on life preservers. Waist straps have also been identified as problematic in other research and in practice. In this study, the smaller buckles were more difficult to operate, especially the buckle on Life Preserver R, which came out of the package with the buckle already fastened and needing to be unfastened for use. The straps on Life Preservers Q and S were secured by rubber bands and were more difficult to unfurl and adjust if the rubber bands were not completely removed. In contrast, the wider and heavier webbed-fabric straps on Life Preservers S and T were more easily adjusted and less problematic, especially if they became slightly twisted when being buckled. The large fabric tab attached to the waist strap for tightening appeared to aid in adjustment of Life Preserver T, as well.

Package Opening

Life preserver packaging has long been a problem, as evidenced by previous research and accident reports, and it clearly influences the usability of the life preserver. Packaging designed to preserve and protect its contents often means that strong, tight seals and heavy, durable materials are used in its construction, and thus it may be difficult for users to open. Even for the experts in this study, the sturdy packages for the Q and R life preservers had higher overall opening times than the others. Such problems are compounded by the reduced dexterity and strength associated with advanced age, disability, or cold and wet environmental conditions. Vincent and Tipton (1988) found that exposure of forearms or hands to cold water (5° C) produced significant reductions in grip strength within 2 minutes of immersion. Moreover, the absence of clear opening instructions can result in significant delays when the need for rapid actions adds stress to an emergency situation.

In addition to hand strength, visibility and simplicity of the opening mechanism play important roles in the ease of opening the package. Studies have shown that large bag-type plastic packages with straight-pull strips/tabs used for opening are among the easiest types of packages to open for the weakest groups, i.e., older females and people with hand problems. A longer tab (10 mm or more) that enables the use of a power or key grip rather than a pinch grip results in greater forces applied by both healthy people and those with reduced capability (Department of Trade and Industry (DTI), 2003; Heiniö, Ånström, Antvorskov, Mattson & Østergaard, 2008; Marks, et al., 2011). DTI (2003) reported that large bags with the straight-pull tab opening mechanism yielded greater force for opening among people over 50 years of age (39.6 N, 8.9 lbs). Tabs made of rough materials that provide more friction between the skin and the material also allow higher pull strength values.

Figure 10. Female test participant struggles to open package of Life Preserver Q. She was able to remove the life preserver from the package after 37.9 seconds.

The packaging requirements in TSO-C13f are vague: "A package must be provided for the life preserver for storage of the life preserver on board the aircraft. The means of opening the package must be simple and obvious, and must be accomplished in one operation without the use of any tool or excessive physical force." The variability in the interpretation of this requirement is apparent in this study when one considers the time it took test participants to open the different types of packages, the difficulties they had in figuring out how to open particular packages, and the apparent force required to tear open some packages (e.g., Fig. 10).

The package for Life Preserver Q consisted of heavy, soft plastic with finger holes for opening. For those who had problems opening this package, the difficulties centered on confusion about *how* to open the package *and* failure of the package to tear along its intended tear line. The finger holes with "PULL" arrow instructions were not readily understood. In some cases, the plastic stretched before it tore outside of the tear line and across the package, requiring a significant amount of force. These two issues resulted in the greatest variability of package opening times among all the packages.

Life Preserver Package R was constructed of the thickest vinyl, although its perforated tear line required less force to open than Package Q. However, the greatest difficulty came from identification of the opening *procedure*. The transparent nature of the vinyl allowed the printed "PULL" arrows on both sides to be seen from either side, seeming to suggest that one should hold the red dots on each side of the package and pull them apart, rather than to indicate grasping the dots on only one side and pulling the top off the package.

Packages S, T, and CAMI were similar in design, constructed of similar weight vinyl, and utilized a simple pull-tab to open. The most apparent problem among these was with Package T. With the "PULL TO OPEN" instruction on the right side of the package, but the pull tab on the left side, some people tried to tear open the vinyl from the "PULL" side rather than by grasping the red pull tab and pulling in the direction of the hash-mark "arrows." The CAMI package that had a simple "PULL" message on the pull tab, but no arrows, appeared to be the best-understood instruction, and the pull tab/stitching configuration with the lighter-weight vinyl made it the easiest to open.

To ensure that life preserver packaging can be opened quickly and easily by most people, additional criteria for packages should be included in the design/performance standards, based on several factors: a) the mechanism for opening, b) the pull-force required to open the package, and c) the comprehensibility of package opening instructions.

Instructional Markings

All of the life preserver packages used in this study included instructional markings for opening, but some were not clearly understood, even though they appeared to be "simple" and "obvious" to us. While comprehension of the markings was not measured in this study, it is apparent that, in addition to the markings on life preservers, comprehension of the package markings should be assessed as part of performance testing.

The majority of participants who participated in the B(A), B, and C Donning Instruction Conditions reported that they were confused by the instructions for donning the life preserver. Some of that confusion was due to the upside-down orientation of the

instructional markings on the life preserver, which is required by TSO-C13f ("Instructions pertaining to operations which would normally be accomplished after the life preserver has been donned must be oriented so that the wearer…may read them while in the water"). Given that the instructional markings on the life preserver may be the only instruction passengers actually refer to in a real emergency, comprehension of the life preserver markings should be assessed as part of performance testing.

Passenger Education

Passenger attention to safety information has gotten worse since Johnson's 1979 study, which showed that approximately 70% of survey respondents reported that they paid attention to oral safety briefings ***and*** read the safety information card. In a series of follow-up surveys, Corbett and McLean (2004, 2007) found that people who reported that they attended to safety information had fallen to between 30 and 40%, and even they could not correctly identify information included in the briefing or card. The NTSB found similar results in accident investigations and safety studies (1985b, 2000, 2010) and has repeatedly made recommendations for the FAA to "conduct research on, and require … operators to implement creative and effective methods of overcoming passenger's inattention and providing them with safety information" (2010).

As with the instructional markings on life preservers and packaging, the life preserver usage information in pictograms on passenger safety briefing cards is not well understood. Studies have shown that people do not fully comprehend the complex message that is represented by the multiple-segment pictograms used to illustrate life preserver usage, even when they are given an unlimited amount of time to study the pictogram (Corbett & McLean, 2008; Weed, Corbett, & McLean, 2014). In the current study, the test participants were instructed to look at the safety briefing card and given ample time to do so. While the simulated card showed only life preserver usage information from a real passenger safety card, just the segments relative to the study were included and enlarged to fill the 8.5" x 11" page (Appendix I). Since the test participants in Instruction Condition C knew that they would have to use the life preserver, they may have paid more attention to the instructions, resulting in faster donning and more complete and correct dons within 25 seconds (25%) than shown by those in Instruction Conditions A, B(A), and B. These "passes" were not adequate, however, to meet the 75% criterion of TSO-C13f.

Unfortunately, any recommendation for "…operators to brief passengers on all flotation equipment installed on an airplane, including a full demonstration of current life vest retrieval and donning procedures, before all flights, regardless of route" would be inconsequential unless passengers are persuaded to commit their attention to this and other safety information and learn the fundamental safety actions presented to them (e.g., Chittaro, 2012).

RECOMMENDATIONS

This study has identified several difficulties that test participants experienced during life preserver donning tests conducted in accordance with TSO-C13f. Additional problems were identified as being products of the test method itself. The following recommendations result from these findings.

Package Opening

The pull force necessary to operate the opening mechanism should be mechanically demonstrated not to exceed 40 N (9 lbs), *or* demonstrated in less than 7 seconds by at least 8 of 10 females over the age of 60, without preview of instructions. Timing should start when the test participant has both hands on the package, ready to open, and end when the package is fully opened (e.g., the pull tab/strip is completely removed). A nick or cut should not be introduced in the edge of the material at the tear line unless it is normally a part of the package design.

Package opening should be tested separately from donning. Operation of the opening mechanism should be demonstrated within 10 seconds by 8 of 10 females with reduced dexterity simulated by the chilled-hands or gloved-hands and without preview of instructions. Timing should start when the test participant has both hands on the package, ready to open, and end when the life preserver is fully removed from the package.

In cases for which additional participants are required, 75% of the total number of test participants for each demonstration must complete package opening within the allowed time.

Attachment Points

Operation of all attachment fittings (e.g., zippers, buckles, snaps, hooks) should be demonstrated by at least 8 of 10 females with reduced dexterity simulated by chilled-hands or gloved-hands test within 10 seconds to include both fastening *and* unfastening. In cases for which additional participants are required, 75% of the total number of test participants must complete operation of all attachment fittings within the allotted time.

Comprehension of Instructional Markings

Instructional markings should be assessed with the test method used by Corbett, McLean and Cosper (2008) which was an adaptation of ISO 9186:2001 (International Organization for Standardization, *Graphical symbols – Test methods for judged comprehensibility and for comprehension*). Because of the urgent nature of the actions demanded by the emergency situation that the markings address, acceptance criteria for minimum comprehension should be set at 80%, with a time limit for examining the markings not to exceed one minute.

Donning Instruction

The provision of a typical preflight safety briefing and demonstration relies on the unrealistic assumption that all passengers will receive this level of instruction in service. In fact, may

passengers do not receive such instruction or pay attention to the safety briefing, indicating that *unless* significant advancements are made in conveying safety information and assuring passenger attention, there should be no donning instructions beyond the markings on the life preserver itself.

Life Preserver Donning

The life preserver donning test should include only the donning activity, starting with the life preserver on the test participant's lap, outside of the package, but still folded as it would have come from the package. Timing starts when the participant has both hands on the life preserver. Timing ends when the participant has the life preserver completely donned, secured, and adjusted for fit. The time for completion of the donning test should be set at 25 seconds. At least 75% of the total number of participants must complete donning, unassisted, within the allowed time (including at least 60% in each age group, as specified in the TSO). The donning test should be captured by a time-encoded video recording that would allow for precise donning time measurement.

CONCLUSION

This study has shown that, while life preserver and package design have significant effects on life preserver usage, the amount, type, content and test participant comprehension of instructions exert the greatest influence on performance in the TSO-C13f life preserver donning test. Rasmussen and Steen's (1983) conclusion still seems apropos: [for] "passenger safety…to be improved through the use of existing TSO devices, it will probably have to be achieved through a stronger than usual emphasis on correct usage during passenger briefings and require more than passive or elective attention by the passengers…and increased passenger familiarization with, and participation in, safety procedures." Furthermore, as the donning performance of the cabin safety experts in this study confirmed, knowledgeable, well-prepared passengers are the key to success in any emergency situation.

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APPENDIX A

CIVIL AEROSPACE MEDICAL INSTITUTE

Individual's Consent to Voluntarily Participate in a Research Project

I, _____, understand that this research project entitled *Inflatable Emergency Equipment: Evaluation of individual inflatable life preserver donning tests* is being sponsored by the Federal Aviation Administration and is being directed by C. L. Corbett, MA, of the Civil Aerospace Medical Institute (CAMI), Oklahoma City, OK.

PURPOSE: I understand that this project is designed to evaluate certification procedures of aviation life preservers.

CONFIDENTIALITY ASSURED: I understand that all records of this study will be kept confidential, and that I will not be identified by name in any reports or publications about this study, except where photographs may include my picture.

DESCRIPTION OF STUDY PROCEDURE: I understand that I will privately record demographic information (gender, age, height, weight, waist measurement) and provide life preserver experience information before the study trials begin. I will receive instructions to don a life preserver and my actions will be video-recorded. I will provide feedback about the research experience.

DISCOMFORT AND RISKS: I understand that the probability of harm or discomfort anticipated in this research is not greater than that encountered in daily life or during the performance of routine examinations and tests. I will not be exposed to stressful situations and the risk of injury as a result of participating in this study is extremely remote.

PARTICIPANT RESPONSIBILITIES: I agree to allow still photographs and/or videos to be made of me as required during the research, with the understanding that these records are the property of the U.S. Government, and that I am not entitled to monetary or other benefits, now or in the future, for the use of this material. I understand that I will not be identified by name in any pictures or videos of me that are used. I understand that it is important to follow instructions, perform the tasks to the best of my ability, and to be accurate and honest with my responses to demographic and test questions.

BENEFITS: The major benefit to the flying public and me will be improved safety on commercial aircraft.

PARTICIPANT'S ASSURANCES: I understand that my participation in this study is voluntary and that I may withdraw at any point without penalty.

I have read this consent document. I understand its contents, and I freely consent to participate in this study under the conditions described. All my questions have been answered to my satisfaction. I understand that I may contact Cynthia L. Corbett at 405-954-7528, should I have additional questions.

_____	_____
Signature of Participant	Date
_____	_____
Signature of Investigator	Date
_____	_____
Signature of Witness	Date

APPENDIX B

Pre-Test Questionnaire

Please enter your age (in years)

Please enter your height (in inches)

Please enter your waist measurement (in inches)

Please enter your weight (in pounds)

Please select your gender (Male, Female, Other)

On average, how many flights do you take per year?

What is your highest completed level of education?

1. Have you ever traveled by plane where the use of life preservers was explained or demonstrated? Yes No

2. If the answer to Question 1 is "yes," did you pay attention to the explanation/demonstration? Yes No

   Did you consider the explanation/demonstration adequate if you might have needed to use the life preserver? Yes No

3. Have you ever used a life preserver in connection with water activities such as boating or water skiing? Yes No

4. If the answer to Question 3 is "yes," approximately how long ago was the last time you used such a device?

5. If you have used life preservers at least occasionally, what type have you used <u>most often</u>?

   Non-inflatable Mouth-inflated Automatic-inflating None of the above

6. Do you know how to correctly and completely don an aviation life preserver? Yes No

Thank you for providing your personal information and previous flotation device experience. Please go to seat number [4 or 7] and await further instructions from the researcher.

<u>Please do not close this form.</u>

APPENDIX C

General Introductory Instructions

Welcome to the Cabin Safety Research Lab!

The experiment in which you are about to participate is part of a water survival and passenger safety study. Our present concern is with determining how effectively different designs of life preservers can be donned in case of an emergency.

You are seated on a seat that is similar to those found on passenger airplanes; please fasten your seatbelt. Video cameras will record your actions.

Following this introduction, a simulated passenger information briefing will be presented on this video monitor. Please give it your undivided attention.

Within a few minutes of the conclusion of the passenger information briefing a buzzer will sound to indicate the start of the trial. The buzzer will now sound for demonstration and familiarization purposes only.

(Sound of buzzer.)

The next time you hear the buzzer, you are to open the life preserver package and don the life preserver as quickly as possible. Once the life preserver is completely donned, raise your arms to indicate that you are finished.

Please do not imitate the actions of the other people participating in this study. They may be wrong!

We are about ready to begin the test.

Here is your life preserver. (Research facilitator hands packaged life preserver to test participant, face up.) Please place it on your lap while you watch the passenger information briefing. Then, when you hear the buzzer, open the package and don the life preserver completely and as quickly as you can. Then raise your arms when you are finished.

APPENDIX D
Passenger Information Briefing/Demonstration Script

Please take a moment to review some important safety information.

To fasten your seat belt, insert the metal end into the buckle. The length may be changed by adjusting the buckle strap. To release the buckle, lift up on the top part of the buckle. Seat belts should be kept fastened when the “Fasten Seat Belt” sign is on.

Exits are located in the forward, center, and rear sections of the airplane cabin. Since our flight will take us over water, each exit is equipped with an evacuation device we can use as a slide or a raft.

For Donning Instruction Condition A and B(A): The airplane is also equipped with life preservers.

The cabin air is carefully controlled for your comfort. However, any extreme change would release the oxygen masks. If the masks drop down from the compartment overhead, pull the nearest mask toward you until the tubing is fully extended and place the mask over your nose and mouth. Adjust the headbands.

For Donning Instruction Condition B: Since our flight will take us over water, the airplane is equipped with life preservers with donning instructions printed on the life preserver. If an emergency occurs, open the life preserver package, remove and open the life preserver, then follow the pictorial instructions on the life preserver.

For Donning Instruction Condition C: Since our flight will take us over water, the airplane is equipped with life preservers located under your seat. Instructions for using the life preserver are on the Passenger Safety Card located in the seatback pocket in front of you. Please take a moment to review the instructions. When you are finished, put the card back in the pocket. (Pause to allow time for card review.)

For Donning Instruction Condition D: Since our flight will take us over water, the airplane is equipped with life preservers located under your seat. To use the life preserver, pull off the tear tab to open the package, and then remove the life preserver from the package. Put the life preserver over your head. Bring the strap around your waist and insert the tab into the buckle. Pull the strap so it is tightly secured around your waist.

Please be sure your seatbelt is fastened, your tray table is stowed and locked, your seatback is upright and we will be prepared for departure.

(Buzzer sounds after a few seconds.)

APPENDIX E
Post-test Questionnaire

Donning Instruction Condition A

1. Did you experience any difficulties in donning the life preserver?

   NO YES Comment

2. What was the main source of difficulty you encountered in donning the life preserver?

3. If this had been an actual emergency aboard an airplane, instead of a test, how well do you think you would have done?

   Better About the same Worse

   Do you think you would have felt confident that you were prepared for an actual over-water evacuation?

   NO YES Comment

4. What changes in design, if any, do you think would improve the ease of donning and securing the life preserver?

5. Please list any ideas or impressions you have regarding your participation in this project.

   Thank you for your participation in our study!

   Please inform the researcher that you are finished and have a nice day!

APPENDIX F
Post-test Questionnaire

Donning Instruction Condition B and B(A)

1. Did you read the instructions on the equipment or package?

   NO YES Comment

2. Did you experience any confusion or uncertainty in following the instructions for donning the life preserver?

   NO YES Comment

3. How useful were the instructions in helping you don the life preserver?

   Adequate Marginal Inadequate

4. How well do you think you would have done if no information had been given?

   Better About the same Worse

5. Did you experience any difficulties in donning the life preserver?

   NO YES Comment

6. What was the main source of difficulty you encountered in donning the life preserver?

7. If this had been an actual emergency aboard an airplane, instead of a test, how well do you think you would have done?

   Better About the same Worse

   Do you think you would have felt confident that you were prepared for an actual over-water evacuation?

   NO YES Comment

8. What changes in design, if any, do you think would improve the ease of donning and securing the life preserver?

9. Please list any ideas or impressions you have regarding your participation in this project.

Thank you for your participation in our study!

Please inform the researcher that you are finished and have a nice day!

APPENDIX G
Post-test Questionnaire

Donning Instruction Condition C

1. How useful in helping you don the life preserver were the instructions given on the Briefing Card?

   Adequate Marginal Inadequate

2. How well do you think you would have done if no information had been given?

   Better About the same Worse

3. Did you experience any confusion or uncertainty in following the instructions for donning the life preserver?

   NO YES Comment

4. Did you experience any difficulties in donning the life preserver?

   NO YES Comment

5. What was the main source of difficulty you encountered in donning the life preserver?

6. Did you read any of the instructions on the equipment or packaging?

   NO YES Comment

7. If the answer to Question 6 is “yes,” did the printed instructions provide any clarification that helped you don the life preserver?

   NO YES Comment

8. If this had been an actual emergency aboard an airplane, instead of a test, how well do you think you would have done?

   Better About the same Worse

   Do you think you would have felt confident that you were prepared for an actual over-water evacuation?

   NO YES Comment

. What changes in design, if any, do you think would improve the ease of donning and securing the life preserver?

9. Please list any ideas or impressions you have regarding your participation in this project.

Thank you for your participation in our study!

Please inform the researcher that you are finished and have a nice day!

APPENDIX H
Post-test Questionnaire

Donning Instruction Condition D

1. How useful in helping you don the life preserver were the instructions given during the Briefing and Donning Demonstration?

   Adequate Marginal Inadequate

2. How well do you think you would have done if no information had been given?

   Better About the same Worse

3. Did you experience any confusion or uncertainty in following the instructions for donning the life preserver?

   NO YES Comment

4. Did you experience any difficulties in donning the life preserver?

   NO YES Comment

5. What was the main source of difficulty you encountered in donning the life preserver?

6. Did you read any of the instructions on the equipment or packaging?

   NO YES Comment

7. If the answer to Question 6 is “yes,” did the printed instructions provide any clarification that helped you don the life preserver?

   NO YES Comment

8. If this had been an actual emergency aboard an airplane, instead of a test, how well do you think you would have done?

   Better About the same Worse

   Do you think you would have felt confident that you were prepared for an actual over-water evacuation?

   NO YES Comment

9. What changes in design, if any, do you think would improve the ease of donning and securing the life preserver?

10. Please list any ideas or impressions you have regarding your participation in this project.

Thank you for your participation in our study!

Please inform the researcher that you are finished and have a nice day!

APPENDIX I
Briefing Card Illustration

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APPENDIX J

Life Preservers

Life preserver Q (Fig. J-1) was used in all Donning Instruction Conditions. It has dual inflation chambers and is secured at the front with a nylon webbing waist strap fitted with a single plastic tab and a side-release buckle. In the package, the strap is folded and secured with a rubber band on the tab end that must be removed before it can be buckled and the strap adjusted for fit. The life preserver is vacuum-packed in a heat-sealed, vinyl pouch (10.62 mil single sheet thickness) with two "finger" holes accompanied by arrows indicating the direction to "PULL" to open. The life preserver in the unopened package weighs 20.6 oz. The life preserver is certified for use under TSO-C13f.

Figure J-1. Life Preserver Q with packaging

Except for those used in the "No Instruction" condition, the life preserver has an instruction pictogram consisting of three simple figures, each with (A)/(B) steps for donning, printed upside-down on the left side of the life preserver, on both front and back (Fig. J-2).

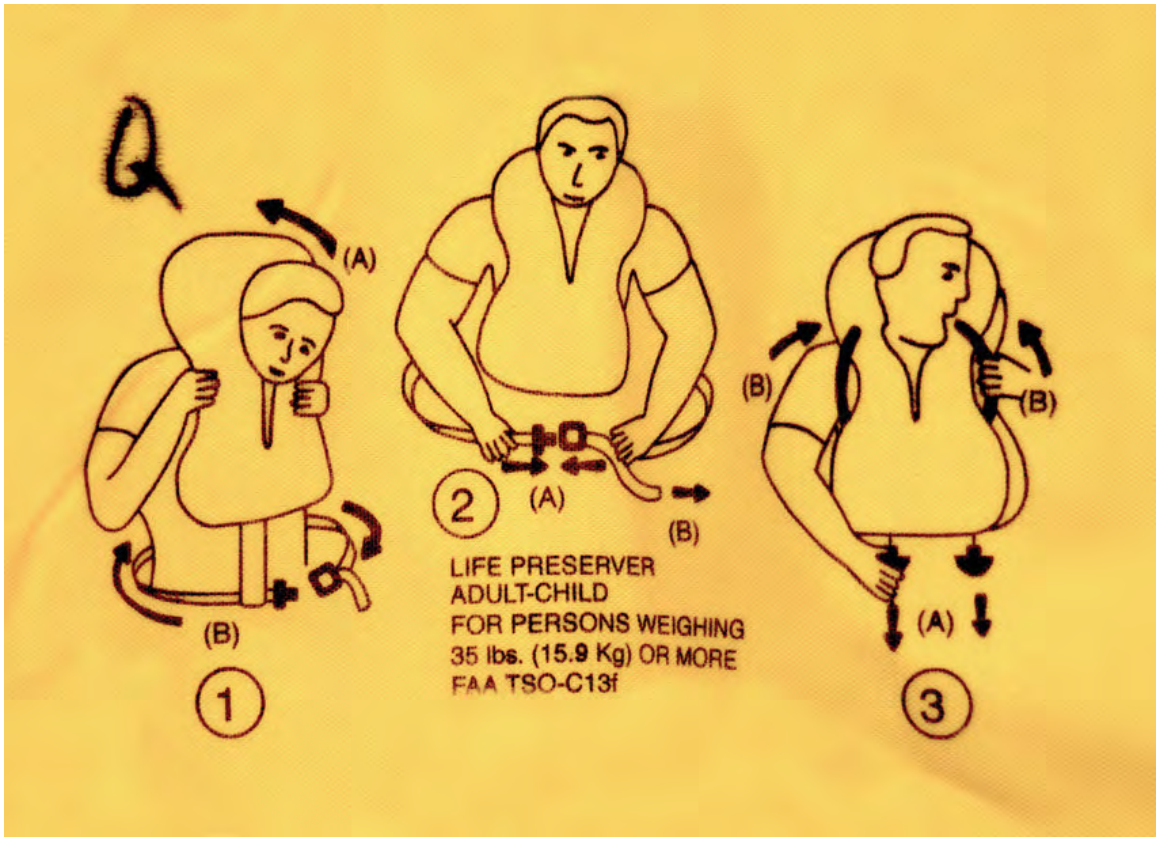

Figure J-2. Life Preserver Q instructional markings

Life preserver R (Fig. J-3), used in all Donning Instruction Conditions, has dual inflation chambers, is secured at the front with a nylon webbing waist strap fitted with a single plastic tab and a side-release buckle. In the package, the tab and buckle are fastened together and thus, after opening, must be unfastened before the waist strap can be pulled around the waist, (re)buckled, and adjusted for fit. The life preserver is packaged in a heat-sealed, vinyl pouch (11.42 mil single sheet thickness) with a perforated tear strip and arrows indicating the direction to "PULL" the tabs to open. The life preserver in its unopened package weighs 18.7 oz. The life preserver is certified for use under TSO-C13f.

Except for those used in the "No Instruction" condition, a 4-step instruction pictogram consisting of four figures, one expected to be viewed before donning (upper left side), and the other three to be viewed once the life preserver is placed over the head (lower right side), is printed on the front and the back of the reversible life preserver (Fig. J-4).

Figure J-3. Life Preserver R with packaging

Figure J-4. Life preserver R instructional markings

Life preserver S (Fig. J-5) is comprised of dual inflation chambers and is secured at the front with a nylon webbing waist strap fitted with a single plastic tab at one end that must be inserted into the plastic retaining buckle on the other end. In the package, the strap is folded and secured with a rubber band on the tab end that must be removed before it can be buckled and the strap adjusted for fit. A whistle is stowed between the two main panels of the inflation chambers. The life preserver is packaged in a plastic pouch (3.54 mil single sheet thickness), with a tear-tab sewn at the top, and arrows indicating the direction to "PULL" printed on the tab. The packaged life preserver weighs 19.2 oz. It is certified for use under TSO-C13f. Life preserver "S" was used in all Donning Instruction Conditions.

Except for those used in the "No Instruction" condition, a 5-step instruction pictogram consisting of four figures, one at the top left, expected to be viewed before donning, and the other three across the bottom, expected to be viewed once the life preserver has been donned, is printed on front and back of the reversible life preserver (Fig. J-6).

Figure J-5. Life Preserver S with packaging

Figure J-6. Life Preserver S instructional markings

Life preserver T (Fig. J-7) was used in all Donning Instruction Conditions. It has dual inflation chambers and is secured at the front with a nylon webbing waist strap fitted with a single plastic tab and a side-release buckle. A large fabric tab is attached at the end of the webbing with the instruction to "PULL TO TIGHTEN." In the package, the waist strap is folded but loose. The life preserver is packaged in a plastic pouch (4.72 mil single sheet thickness), with a fabric tear-tab sewn on one side at the top, and instruction to "TEAR TO OPEN" printed on the other side at the top. The packaged life preserver weighs 20.5 oz. It is certified for use under TSO-C13f.

Except for those used in the "No Instruction" Condition, a 5-step instruction pictogram is provided. It consists of six figures, one at the top left, which is expected to be viewed before donning, and the others across the bottom, which are expected to be viewed once the life preserver has been donned. The pictogram is printed on front and back of the reversible life preserver. The final "step" is not numbered and is duplicated on the left and right sides, with arrows pointing to the oral inflation tubes located between the inflatable chambers (Fig. J-8).

Figure J-7. Life Preserver T with packaging

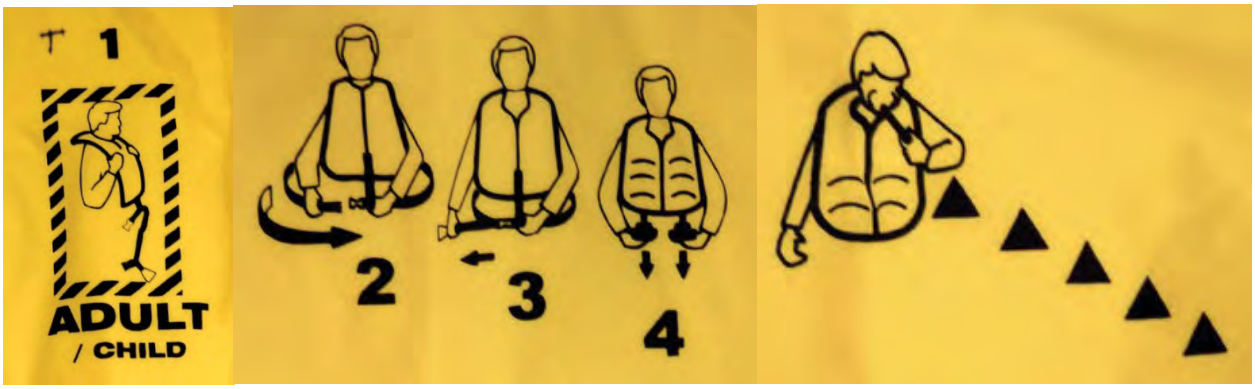

Figure J-8. Life Preserver T instructional markings.

Life preserver U (Fig. J-9) has dual inflation chambers and has a back panel that is attached to the middle of the nylon webbing waist strap. The ends of the waist strap are attached in front to a dual web-lock strap adjuster assembly that is connected to a short frontal strap. Yellow fabric adjust-to-fit tabs are attached at each end of the waist strap that was threaded through white plastic slides. The waist strap is slipped over the head and shoulders when donning. All donning instructions were obscured because this life preserver was only donned in the "No Instruction" condition and was included because of the unique variation of the attachment point compared to the other life preservers, and because the same type was tested by Rasmussen and Steen (1983). Manufactured in 1991 and certified for use under TSO-C13d, the life preserver was retrieved from CAMI stock, and was repacked/heat-sealed in a "standard" tear-tab pouch (Fig. J-10), having a 4.33 mil single sheet thickness. Repacked, the life preserver weighed 23.2 oz.

Figure J-9. Life Preserver U

Figure J-10. Standard "tear tab" replacement package used for repacking life preservers. A single layer sheet measured 4.33 mil thick.

Life preservers V, W, and X (Fig. J-11), also tested by Rasmussen and Steen (1983), have dual inflation chambers and a back panel which is attached to the middle of the waist strap. Both ends of the waist strap are fitted with a web-lock strap adjustor to which a metal hook with a swivel-mounted snap-latch is attached. The hooks are fastened to a metal ring secured to a short frontal strap. All donning instructions were obscured because these life preservers were only donned in the "No Instruction" condition. While manufactured by different companies, the life preservers are almost identical in their design and the attachment points are the same. Four from each manufacturer were included, manufactured between 1991 and 1997, and were certified as meeting TSO-C13d.

Figure J-11. Life Preserver V, W, X with packaging

This type of life preserver may still be carried on some aircraft, as a 2013 passenger safety briefing card from a major U.S. air carrier includes a donning instruction pictogram for the double swivel snap hook attachment life preserver (Fig. J-12). The life preservers were retrieved from CAMI stock, and repacked/heat-sealed in a "standard" tear-tab pouch, 4.33 mil single sheet thickness. Repacked, the life preservers weighed between 21.8 and 23.2 oz.

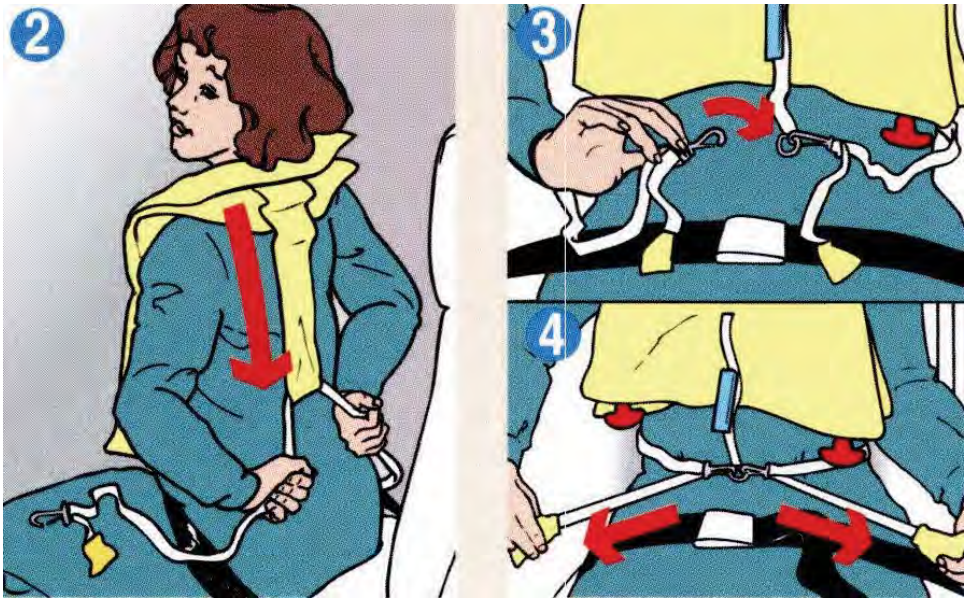

Figure J-12. Passenger safety briefing card illustration of life preserver donning procedure.

Life preserver Y (Fig. J-13) was used in Donning Instruction Conditions A and B (A). It has a single inflation chamber and is fitted with a waist strap with a plastic tab at one end that is inserted into a plastic retaining buckle in front, similar to the dual-chamber models. It was incorporated into the study after the research facilitators observed the test participants inserting their arms between the panels of the dual-chamber designs. Manufactured in 2010 and certified as meeting TSO-C13f, the life preserver was retrieved from CAMI stock, and repacked/heat-sealed in a "standard" tear-tab pouch, 4.33 mil single sheet thickness. In the package, the waist strap is folded but loose. Repacked, the life preserver weighs 13.5 oz.

Figure J-13. Life Preserver Y with packaging

Except for those used in the "No Instruction" Condition, a 5-step instruction pictogram, consisting of 5 figures is provided. The figure at the top right is expected to be viewed before donning. The 3 on the bottom right and the 1 on bottom left, are expected to be viewed once the life preserver has been donned. All of the figures are printed on the front and the back of the reversible life preserver. The final "step" on the bottom left is not numbered and is smaller in size then the other figures (Fig. J-14).

Life preserver Z (Fig. J-15), which does not have any instructional markings, is a prototype developed in 1985 at CAMI. It was included because of the rapid donning characteristics of the garment-style vest shown by Rasmussen and Steen (1983), and referenced by the NTSB in its accident report for the Hudson River landing (NTSB/AAR-10/03). The life preservers were retrieved from CAMI stock, and repacked/heat-sealed in a "standard" tear-tab pouch, 4.33 mil single sheet thickness. Repacked, the life preserver weighed 20.6 oz.

Figure J-14. Life preserver Y instructional markings

Figure J-15. Life Preserver Z

APPENDIX K
Summary of Post-Test Responses

Table K-1. Summary of Post-Test Responses

Donning Instruction Condition A: No instructions in briefing/No instructional markings on life preserver

	Life Preserver								
	Q	**R**	**S**	**T**	**U**	**VWX**	**Y**	**Z**	**Overall**
Did you experience any difficulties in donning the life preserver?									
No	33%	33%	67%	100%	0%	0%	17%	0%	31%
Yes	67%	67%	33%	0%	100%	100%	83%	100%	69%
If this had been an actual emergency aboard an airplane, instead of a test, how well do you think you would have done?									
Worse	33%	17%	0%	33%	33%	42%	17%	17%	26%
About the same	67%	67%	83%	67%	67%	58%	67%	83%	69%
Better	0%	16%	17%	0%	0%	0%	16%	0%	5%
Do you think you would have felt confident that you were prepared for an actual over-water evacuation?									
No	83%	33%	33%	17%	67%	67%	17%	17%	36%
Yes	17%	67%	67%	83%	33%	33%	83%	83%	64%

Table K-2. Summary of Post-Test Responses

Donning Instruction Condition B(A) : No reference to markings in briefing/Instructional markings on life preserver

	Life Preserver					
	Q	**R**	**S**	**T**	**Y**	**Overall**
Did you experience any difficulties in donning the life preserver?						
No	33%	67%	50%	50%	67%	53%
Yes	67%	33%	50%	50%	33%	47%
If this had been an actual emergency aboard an airplane, instead of a test, how well do you think you would have done?						
Worse	67%	50%	33%	33%	33%	28%
About the same	33%	50%	50%	67%	67%	65%
Better	0%	0%	17%	0%	0%	7%
Do you think you would have felt confident that you were prepared for an actual over-water evacuation?						
No	67%	83%	50%	50%	17%	53%
Yes	33%	17%	50%	50%	83%	47%
Did you read the instructions on the equipment or package?						
No	50%	60%	67%	67%	100%	69%
Yes	50%	40%	33%	33%	0%	31%
Did you experience any confusion or uncertainty in following the instructions for donning the life preserver?						
No	33%	40%	50%	33%	50%	41%
Yes	67%	60%	50%	67%	50%	59%
How useful were the instructions in helping you don the life preserver?						
Inadequate	17%	60%	17%	33%	33%	31%
Marginal	50%	20%	50%	34%	34%	38%
Adequate	33%	20%	33%	33%	33%	31%
How well do you think you would have done if no information had been given?						
Worse	33%	40%	33%	33%	33%	34%
About the same	67%	40%	50%	67%	67%	59%
Better	0%	20%	17%	0%	0%	7%

Table K-3. Summary of Post-Test Responses

Donning Instruction Condition B : Markings referenced in briefing/Markings on life preserver

	Life Preserver				
	Q	**R**	**S**	**T**	**Overall**
Did you experience any difficulties in donning the life preserver?					
No	67%	33%	83%	50%	58%
Yes	33%	67%	17%	50%	42%
If this had been an actual emergency aboard an airplane, instead of a test, how well do you think you would have done?					
Worse	33%	50%	0%	33%	29%
About the same	50%	50%	100%	67%	67%
Better	17%	0%	0%	0%	4%
Do you think you would have felt confident that you were prepared for an actual over-water evacuation?					
No	33%	17%	0%	50%	25%
Yes	67%	83%	100%	50%	75%
Did you read the instructions on the equipment or package?					
No	33%	50%	0%	0%	21%
Yes	67%	50%	100%	100%	79%
Did you experience any confusion or uncertainty in following the instructions for donning the life preserver?					
No	17%	67%	67%	17%	42%
Yes	83%	33%	33%	83%	58%
How useful were the instructions in helping you don the life preserver?					
Inadequate	17%	17%	0%	0%	8%
Marginal	17%	33%	17%	50%	29%
Adequate	66%	50%	83%	50%	63%
How well do you think you would have done if no information had been given?					
Worse	67%	33%	33%	50%	46%
About the same	33%	67%	67%	33%	50%
Better	0%	0%	0%	17%	4%

Table K-4. Summary of Post-Test Responses

Donning Instruction Condition C: Instructions on briefing card/Markings on life preserver

	Life Preserver				
	Q	**R**	**S**	**T**	**Overall**
Did you experience any difficulties in donning the life preserver?					
No	33%	50%	67%	83%	58%
Yes	67%	50%	33%	17%	42%
If this had been an actual emergency aboard an airplane, instead of a test, how well do you think you would have done?					
Worse	0%	17%	0%	17%	8%
About the same	100%	67%	67%	67%	75%
Better	0%	16%	33%	16%	17%
Do you think you would have felt confident that you were prepared for an actual over-water evacuation?					
No	33%	50%	0%	33%	29%
Yes	67%	50%	100%	67%	71%
Did you read the instructions on the equipment or package?					
No	50%	33%	67%	50%	50%
Yes	50%	67%	33%	50%	50%

If yes, did the printed instructions provide any clarification that helped you don the life preserver?					
No	33%	50%	0%	0%	25%
Yes	67%	50%	100%	100%	75%
Did you experience any confusion or uncertainty in following the instructions for donning the life preserver?					
No	33%	50%	67%	83%	58%
Yes	67%	50%	33%	17%	42%
How useful were the instructions in helping you don the life preserver?					
Inadequate	0%	0%	0%	0%	0%
Marginal	33%	50%	16%	0%	25%
Adequate	67%	50%	83%	100%	75%
How well do you think you would have done if no information had been given?					
Worse	50%	17%	50%	50%	42%
About the same	50%	83%	50%	50%	58%
Better	0%	0%	0%	0%	0%

Table K-5. Summary of Post-Test Responses

Donning Instruction Condition D: Instructions/Demonstration in briefing/Markings on life preserver

	Life Preserver				
	Q	**R**	**S**	**T**	**Overall**
Did you experience any difficulties in donning the life preserver?					
No	33%	50%	67%	83%	58%
Yes	67%	50%	33%	17%	42%
If this had been an actual emergency aboard an airplane, instead of a test, how well do you think you would have done?					
Worse	17%	50%	17%	50%	33%
About the same	83%	33%	67%	50%	59%
Better	0%	17%	16%	0%	8%
Do you think you would have felt confident that you were prepared for an actual over-water evacuation?					
No	17%	17%	0%	33%	17%
Yes	83%	83%	100%	67%	83%
Did you read the instructions on the equipment or package?					
No	33%	83%	50%	100%	67%
Yes	67%	17%	50%	0%	33%
If yes, did the printed instructions provide any clarification that helped you don the life preserver?					
No	50%	100%	33%	0%	50%
Yes	50%	0%	67%	0%	50%
Did you experience any confusion or uncertainty in following the instructions for donning the life preserver?					
No	83%	50%	67%	67%	67%
Yes	17%	50%	33%	33%	33%
How useful were the instructions in helping you don the life preserver?					
Inadequate	0%	17%	0%	0%	4%
Marginal	17%	17%	0%	17%	13%
Adequate	83%	66%	100%	83%	83%
How well do you think you would have done if no information had been given?					
Worse	83%	0%	100%	83%	67%
About the same	17%	83%	0%	17%	29%
Better	0%	17%	0%	0%	4%