

**Naval Sea Systems Command
Fire Protection Division
Washington, DC**



**Wearability Assessment of SCBA
Equipment Aboard U.S. Navy Ships**

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WEARABILITY ASSESSMENT OF SCBA EQUIPMENT ABOARD U.S. NAVY SHIPS

PURPOSE

The following is an assessment of the wearability of open-circuit, self-contained breathing apparatus by firefighters aboard U.S. Navy ships.

BACKGROUND

In the past, U.S. Navy damage control and fire-fighting personnel used Oxygen Breathing Apparatus (OBA) equipment to provide breathing air in unsafe ambient conditions. Reference (1) identifies a number of areas where OBAs do not fulfill the necessary requirements. One of the options proposed to meet firefighter's equipment requirements is to replace the OBAs with open-circuit Self-Contained Breathing Apparatus (SCBA) equipment. The configuration of SCBA equipment differs from the configuration of an OBA (for example, SCBAs are worn on the back as opposed to the front-worn OBA). These differences in configuration raise concerns about wearability of SCBA equipment by firefighters aboard U.S. Navy ships. To address these concerns, a series of tests were conducted on the ex-USS SHADWELL to assess the capability of firefighters to maneuver shipboard obstacles while wearing a firefighter ensemble and breathing apparatus. This report summarizes the results of the ex-USS SHADWELL breathing apparatus wearability tests.

This report also summarizes the results of an SCBA trial use evaluation conducted by Navy Non-Developmental Items (NDI) on board the USS KIDD (DDG 993) from June 1 to September 2, 1994. Part of this evaluation was to record crew member opinion on SCBA equipment use and wearability versus the Navy OBA.

SUMMARY

Results of tests conducted aboard ex-USS SHADWELL and USS KIDD show that, with respect to wearability issues, usage of SCBAs by shipboard firefighters is a viable alternative to the Navy Type A-4 OBA. The results show that firefighters wearing SCBAs could perform the same functions as firefighters wearing OBAs. The results also show that use of SCBAs with 30-minute air cylinders offer shipboard firefighters the best mobility. Use of SCBAs with 60-minute air cylinders can significantly limit the mobility of shipboard firefighters. Use of SCBAs with 45-minute air cylinders cause some significant mobility problems, but provide firefighters with better mobility than SCBAs with 60-minute air cylinders.

Test subjects that wore SCBAs with 30-minute air cylinders had better mobility in confined spaces, better range of motion, and better forward vision as compared with test subjects that wore the OBA. In addition, the SCBAs do not have breathing air bags that are susceptible to collapse while the firefighter is in a confined area such as a scuttle.

Firefighters aboard USS KIDD commented that it was much easier to don and doff an SCBA than an OBA. Donning and doffing an SCBA required less time and assistance and required less training. The results for the FFBA show that test subjects had severe mobility problems that would limit its use by shipboard firefighters.

Tables 1 and 2 summarize the results of wearability tests conducted aboard ex-USS SHADWELL. Table 1 provides a summary description of the subjects involved in the testing. Table 2 provides results for each obstacle encountered by the test subjects. The results are based upon a review of References 2 and 3. The following is a summary of the results from the ex-USS SHADWELL testing.

Test subjects that wore SCBAs with 30-minute air cylinders experienced only a few minor mobility problems while traversing the test route. Test subjects that wore SCBAs with larger air cylinders (45-minute and 60-minute) experienced several significant mobility problems. The test subjects were not able to pass through an 18 inch scuttle and had some problems passing through a 21 inch hatch. The larger air cylinders tended to become caught (near the air cylinder valve) on the knife edge of the hatch. The test subjects had difficulty descending an inclined ladder. The usual practice of the test subjects was to face away from the inclined ladders while descending. Air cylinders larger than 30-minutes tended to bump (near the air cylinder valve) against the steps of the ladder. The test subjects had difficulty when maneuvering through confined spaces such as small tanks or narrow passageways. The overall width of the SCBA (with the larger air cylinder) and test subject was about as wide as the confined space being traversed. The air cylinder tended to bump nearby obstacles which slowed the test subject's movements.

Test subjects commented that the overall fit and comfort of the SCBA were good. It was noted that some devices need a chest strap to better support the unit and prevent strain on the firefighter's back and shoulders.

Test subjects that wore the OBA aboard ex-USS SHADWELL experienced several significant problems with mobility and often experienced collapsed breathing air bags. Breathing air bags collapsed most often when test subjects passed through tight accesses (such as an 18 inch scuttle and a 21 inch hatch), and when test subjects had to maneuver in a prone position (such as in a water tank cell). Some test subjects also reported that the OBA would move around on the body more than an SCBA, and that the OBA put a strain on the upper back around the shoulder area. Test subjects also commented that the OBA restricted mobility in the front of the body and restricted forward vision. The restricted forward vision caused problems during transition from ladders to decks.

Significant mobility problems were also encountered by a test subject that wore the Firefighter Breathing Apparatus (FFBA). Because of the size of the FFBA, the test subject had difficulty passing through a 21 inch hatch and was not able to pass through an 18 inch scuttle without first doffing the apparatus. The test subject had some difficulty with ascending and descending inclined ladders due to the size of the unit. The device tended to strike the ladder railings and other obstacles near the ladder, and tended to bump against the steps of the ladder. Moving through narrow passageways while wearing the FFBA was also difficult due to the size of the unit. Because of these problems, the test subject's movements were slower than test subjects that wore the smaller breathing apparatus (SCBA and OBA). The test subject commented that often the air hoses leading to the mask became caught on obstacles. In one instance, during egress from a water tank cell through a 21 inch manhole, the mask became caught and was pulled away from the test subject's face.

No details were available regarding the specific obstacles that firefighters aboard USS KIDD encountered. For the wearability assessment aboard USS KIDD, the results are based upon the information provided by Reference 4. Most of the firefighters aboard USS KIDD commented that they would want SCBAs to be standard personnel protection equipment in a repair locker. The few concerns of the firefighters included: (1) several SCBAs lacked a chest strap that would better support the device and limit fatigue to the firefighter's shoulders and back; and (2) the device should have some means of voice amplification.

DISCUSSION

Sixteen test subjects (11 men and 5 women) of varying physique and age participated in SCBA wearability tests conducted aboard ex-USS SHADWELL. Table 1 provides a summary description (age, height, and weight) of the test subjects. The sixteen test subjects are experienced Navy firefighters, some of whom are instructors at Navy fire-fighting schools. Test subjects were outfitted in full firefighter ensembles and a breathing apparatus for each test. The breathing apparatus used were four models of open-circuit SCBAs and two models of closed-circuit apparatus. The open-circuit apparatus used were the MSA Custom 4500 MMR, the Survivair SIGMA, the ISI Magnum, and the Scott Air-Pak. The closed-circuit apparatus used were the Firefighter Breathing Apparatus (FFBA) and the Navy Type A-4 Oxygen Breathing Apparatus (OBA). The OBA was included in the tests to provide baseline results to assess SCBA wearability. Three different size air cylinders (30-minute, 45-minute and 60-minute) were used with the open-circuit SCBAs.

Tests performed aboard ex-USS SHADWELL consisted of three to five test subjects at a time, with different breathing apparatus, traversing a predetermined route aboard the ship. The route contained obstacles aboard a ship that a firefighter might encounter, including confined spaces (narrow passageways and water tank cells), an 18 inch scuttle and a 21 inch hatch, vertical and inclined ladders, and a vertical escape trunk. The water tank cell

dimensions are 2.25 feet high by 3 feet wide by 8 feet long. At the end of each test, test subjects had to crawl the length of a water tank cell and egress through a 21 inch vertical manhole. Test subjects were videotaped as they managed each obstacle during the tests (Reference 2). Test subjects then documented their opinions on the fit of the breathing apparatus, their mobility while wearing the apparatus, and any problems that they encountered during the tests (Reference 3). Table 2 provides a summary of SCBA wearability assessment aboard the ex-USS SHADWELL, including a description of specific wearability observations made for each type of obstacle described above.

Eighteen SCBAs were issued to USS KIDD for use from June 1 to September 2, 1994 to evaluate the performance of SCBAs aboard the ship (Reference 4). Assessment of SCBA wearability aboard USS KIDD was part of the evaluation. Table 1 provides a summary description (age, height, and weight) of the test subjects used aboard USS KIDD. The 18 SCBAs issued to the ship consisted of five MSA Custom 4500s, five Survivair SIGMAs, five ISI Magnums, and three Scott Air-Paks. Three different size air cylinders (30-minute, 45-minute and 60-minute) were used with the SCBAs.

During the three month shipboard evaluation period, firefighters used the SCBAs while responding to five main space fire drills, thirteen at-sea fire party drills, numerous gas-free engineering jobs, and one casualty response. Firefighters aboard USS KIDD also practiced donning and doffing the SCBA (with assistance and without assistance), and evaluated the fit of each apparatus while wearing a full firefighter's ensemble. Results of SCBA wearability assessment aboard the USS KIDD are included in the summary section of this report.

REFERENCES

1. "Review of Replacement Alternatives for the Navy Oxygen Breathing Apparatus," September 1994.
2. Videotape of SCBA Wearability Tests Performed Aboard ex-USS SHADWELL September 12-13, 1994.
3. SCBA Fit and Access Appraisal Checklists and Data Sheets for Tests Conducted aboard ex-USS SHADWELL September 12-13, 1994.
4. CINCLANTFLT Letter Serial N432/004331, "Shipboard (USS KIDD) Assessment of SCBA Wearability," dated October 24, 1994.

Table 1

SCBA Wearability Assessment Conducted Aboard
USS KIDD (DDG 993) and ex-USS SHADWELL

	USS KIDD	ex-USS SHADWELL	
Tests Conducted	A 3-month period of SCBA shipboard performance evaluations was conducted aboard USS KIDD. Assessment of SCBA wearability was part of this evaluation. During this time, firefighters used the apparatus during 5 main space fire drills, 13 at-sea fire party drills, numerous gas-free engineering jobs, and one casualty response. Test subjects also evaluated donning and doffing SCBAs, and evaluated the fit of each apparatus while wearing a full firefighter ensemble.	Two days of tests were performed aboard ex-USS SHADWELL. Tests consisted of 3 to 5 test subjects at a time, wearing different breathing apparatus, traversing a predetermined route aboard ship. The route contained shipboard obstacles that a firefighter might encounter including confined spaces (narrow passageways and water tank cells), an 18" scuttle and a 21" hatch, inclined and vertical ladders, and a vertical escape trunk.	
Breathing Apparatus	<u>18 Total</u> 5 MSA Custom 4500 MMR 5 Survivair SIGMA 5 ISI Magnum 3 Scott Air-Pak	<u>26 Total</u> 6 MSA Custom 4500 MMR 5 Survivair SIGMA 2 ISI Magnum 3 Scott Air-Pak 1 FFBA 9 ORA	
Number of Test Subjects	At least 18 (all men)	16 Total (11 men and 5 women)	
Age of Test Subjects	Average: 24 yrs Oldest: 41 yrs Youngest: 19 yrs	<u>Men</u> Average: 31 yrs Oldest: 36 yrs Youngest: 24 yrs	<u>Women</u> Average: 31 yrs Oldest: 36 yrs Youngest: 27 yrs
Height of Test Subjects	Average: 5'- 11" Tallest: 6'- 4" Shortest: 5'- 4"	<u>Men</u> Average: 5'- 10" Tallest: 6'- 3" Shortest: 4'- 11"	<u>Women</u> Average: 5'- 5" Tallest: 5'- 9" Shortest: 5'- 1"
Weight of Test Subjects	Average: 176 lbs. Heaviest: 230 lbs. Lightest: 125 lbs.	<u>Men</u> Average: 190 lbs. Heaviest: 230 lbs. Lightest: 165 lbs.	<u>Women</u> Average: 150 lbs. Heaviest: 175 lbs. Lightest: 125 lbs.

Table 2

Results of SCBA Wearability Assessment
Conducted Aboard ex-USS SIADWELL

Obstacle	Wearability Assessment	Comments
Ascending a vertical, open ladder	<u>SCBA, 30-min.</u> - no mobility problems	Test subjects that wore SCBAs had no mobility problems when ascending a vertical, open ladder.
	<u>SCBA, 45-min.</u> - no mobility problems	
	<u>SCBA, 60-min.</u> - no mobility problems	
	<u>FFBA</u> - minor mobility problems	The shoulder-to-shoulder width of the FFBA caused the test subject to bump the apparatus against the ladder surroundings (presumably, bulkhead-mounted equipment) several times.
	<u>OBA</u> - minor mobility problems	Test subjects that wore the OBA had restricted forward vision that caused difficulty finding the first ladder rung.
Descending a vertical, escape trunk ladder	<u>SCBA, 30-min.</u> - no mobility problems	Test subjects that wore SCBAs with 30-minute air cylinders accomplished this task satisfactorily. Test subjects that wore SCBAs with 45-minute and 60-minute air cylinders stated that they often became stuck near the bottom of the vertical, escape trunk ladder because of the tightness of the escape trunk and the size of the breathing apparatus.
	<u>SCBA, 45-min.</u> - minor mobility problems	
	<u>SCBA, 60-min.</u> - minor mobility problems	
	<u>FFBA</u> - minor mobility problems	The shoulder-to-shoulder width of the FFBA caused a tight fit between the apparatus and the escape trunk. The test subject had to move slowly and carefully to avoid bumping the apparatus against the surroundings.
	<u>OBA</u> - minor mobility problems	Test subjects that wore the OBA had restricted forward vision that caused difficulty finding the first ladder rung.
Vertical ladder (open or escape trunk) to deck transition	<u>SCBA, 30-min.</u> - no mobility problems	Test subjects that wore SCBAs had no mobility problems when moving from a vertical ladder to the deck.
	<u>SCBA, 45-min.</u> - no mobility problems	
	<u>SCBA, 60-min.</u> - no mobility problems	

Table 2 (Continued)

Results of SCBA Wearability Assessment
Conducted Aboard ex-USS SHADWELL

Obstacle	Wearability Assessment	Comments
Vertical ladder (open or escape trunk) to deck transition (continued)	FFBA - no mobility problems	The test subject that wore the FFBA had no mobility problems when moving from a vertical ladder to the deck.
	OBA - minor mobility problems	Test subjects that wore the OBA stated that they had difficulty making the transition from a vertical ladder to the deck because of the restricted forward vision when wearing an OBA. Wearing the OBA also limited the test subject's range of motion because of the length of the apparatus on the front of the body.
Ascending an inclined ladder through a 21" horizontal hatch	SCBA, 30-min. - no mobility problems	Test subjects that wore SCBAs with 30-minute air cylinders had no problems passing through the 21" hatch. Test subjects that wore 45-minute and 60-minute air cylinders had difficulty passing through the hatch because of the size of the air cylinder. The top of the air cylinder would bump against the edge of the hatch.
	SCBA, 45-min. - minor mobility problems	
	SCBA, 60-min. - minor mobility problems	
	FFBA - minor mobility problems	The shoulder-to-shoulder width of the FFBA caused a tight fit between the apparatus and the edge of the hatch. The test subject's movements were slow and cautious when ascending through the 21" hatch as compared with the movements of test subjects that wore other breathing apparatus.
OBA - significant mobility problems	Several test subjects experienced collapsed OBA breathing air bags while passing through the 21" hatch. These test subjects were following proper procedures for passing through shipboard hatches while wearing an OBA.	
Descending an inclined ladder through a 21" horizontal hatch	SCBA, 30-min. - no mobility problems	Most test subjects had satisfactory mobility while wearing apparatus with a 30-minute air cylinder. A few of the air cylinders became caught (near the air cylinder valve) on the knife edge of the hatch. This problem occurred more often for test subjects wearing apparatus with 45-minute and 60-minute air cylinders. Test subjects that used 30-minute air cylinders needed less time to pass through the 21" hatch than test subjects that wore other breathing apparatus.
	SCBA, 45-min. - minor mobility problems	
	SCBA, 60-min. - minor mobility problems	

Table 2 (Continued)

**Results of SCBA Wearability Assessment
Conducted Aboard ex-USS SHADWELL**

Obstacle	Wearability Assessment	Comments
Descending an inclined ladder through a 21" horizontal hatch (continued)	<u>FFBA</u> - minor mobility problems	The shoulder-to-shoulder width of the FFBA caused a tight fit between the apparatus and the edge of the hatch. The test subject's movements were slow and cautious when descending through the 21" hatch as compared with the movements of test subjects that wore other breathing apparatus.
	<u>OBA</u> - significant mobility problems	Several test subjects experienced collapsed OBA breathing air bags while passing through the 21" hatch. These test subjects were following proper procedures for passing through shipboard hatches while wearing an OBA.
Passing through a confined space (water tank cell)	<u>SCBA, 30-min.</u> - no mobility problems	Test subjects that wore SCBAs with 30-minute air cylinders had no mobility problems. Test subjects with larger air cylinders had problems because the small size of the water tank cell limited the test subject's movements. One test subject wearing a 60-minute air cylinder had doffed the apparatus before entering the water tank cell. Another test subject wearing a 60-minute air cylinder had significant problems moving because of the size of the apparatus.
	<u>SCBA, 45-min.</u> - minor mobility problems	Test subjects had to crawl on the deck of the water tank cell just before exiting through a 21" vertical manhole. (The mobility assessment for passing through the vertical manhole is given below.) In preparing to pass through the manhole, most test subjects remained on their hands and knees on the deck. A few test subjects lay on their backs before attempting to exit through the 21" vertical manhole.
	<u>SCBA, 60-min.</u> - significant mobility problems	
	<u>FFBA</u> - minor mobility problems	The test subject had minor problems with mobility because the shoulder-to-shoulder width of the FFBA and the small size of the water tank cell limited the test subject's movements.
	<u>OBA</u> - minor mobility problems	A few test subjects reported that their range of motion was severely limited because of the length of the OBA on the front of the person's body.

Table 2 (Continued)

Results of SCBA Wearability Assessment
Conducted Aboard ex-USS SHADWELL

Obstacle	Wearability Assessment	Comments
Egress from a confined space (water tank cell) through a 21" vertical manhole	<u>SCBA, 30-min.</u> - no mobility problems	Most test subjects that wore SCBAs with 30-minute air cylinders maneuvered this obstacle satisfactorily. Test subjects that wore SCBAs with 45-minute air cylinders had some difficulty because the air cylinders bumped the edge of the manhole. Test subjects that wore SCBAs with 60-minute air cylinders had significant mobility problems passing through the 21" manhole. One test subject doffed the apparatus before passing through the manhole. Another test subject went through head first and on his hands and knees. The air cylinder bumped the edge of the manhole several times until, after a significant amount of time, the test subject squeezed their body and the apparatus through the manhole.
	<u>SCBA, 45-min.</u> - minor mobility problems	
	<u>SCBA, 60-min.</u> - significant mobility problems	
	<u>FFBA</u> - significant mobility problems	The shoulder-to-shoulder width of the FFBA caused a tight fit between the apparatus and the edge of the manhole. The test subject passed through the manhole feet first and on his back. The air hose to the face piece caught on the manhole and pulled the face mask away from the test subject's face.
	<u>OBA</u> - significant mobility problems	Several test subjects experienced collapsed OBA breathing air bags while passing through the 21" vertical manhole. These test subjects were following proper procedures for passing through shipboard manholes while wearing an OBA.
Ascending an inclined ladder	<u>SCBA, 30-min.</u> - no mobility problems	Test subjects that wore SCBAs with 30-minute and 45-minute air cylinders had no problems with mobility when ascending an inclined ladder. Test subjects that wore 60-minute air cylinders had minor problems with mobility. The larger size of the 60-minute air cylinders caused them to bump against the ladder railings and the ladder surroundings.
	<u>SCBA, 45-min.</u> - no mobility problems	
	<u>SCBA, 60-min.</u> - minor mobility problems	
	<u>FFBA</u> - minor mobility problems	The shoulder-to-shoulder width of the FFBA caused it to bump against the ladder railings and the ladder surroundings.

Table 2 (Continued)

Results of SCBA Wearability Assessment
Conducted Aboard ex-USS SHADWELL

Obstacle	Wearability Assessment	Comments
Ascending an inclined ladder (continued)	<u>OBA</u> - no mobility problems	Test subjects that wore OBAs had no mobility problems when ascending an inclined ladder.
Descending an inclined ladder	<u>SCBA, 30-min.</u> - no mobility problems	Test subjects that wore SCBA's with 30-minute air cylinders had no problems with mobility when descending an inclined ladder. Test subjects with larger air cylinders descended slower because the air cylinders bumped (near the air cylinder valve) against the steps of the ladder. This occurred while test subjects descended facing away from the ladder which was the most common way test subjects descended the inclined ladder.
	<u>SCBA, 45-min.</u> - minor mobility problems	
	<u>SCBA, 60-min.</u> - minor mobility problems	
	<u>FFBA</u> - minor mobility problems	The size of the FFBA caused it to bump against the steps of the ladder and slow the test subject's descent.
<u>OBA</u> - no mobility problems	Test subjects that wore OBAs had no mobility problems when descending an inclined ladder.	
Ascending an inclined ladder through an 18" horizontal scuttle	<u>SCBA, 30-min.</u> - minor mobility problems	Test subjects that wore SCBA's with 30-minute air cylinders had problems with the top of the air cylinders bumping against the knife edge of the scuttle. Very slow, careful movement was required to pass through the scuttle.
	<u>SCBA, 45-min.</u> - significant mobility problems	Most test subjects that wore SCBA's with 45-minute or 60-minute air cylinders were unable to ascend through an 18" scuttle without doffing the apparatus first and passing it through separately. One test subject wearing a 45-minute air cylinder was unable to pass through the scuttle. (He did not attempt to pass through the scuttle by doffing the apparatus.) Another test subject got caught between the edges of the scuttle. This test subject managed to pass through the scuttle after a significant amount of time.
	<u>SCBA, 60-min.</u> - significant mobility problems	
	<u>FFBA</u> - significant mobility problems	The test subject that wore the FFBA could not pass through the scuttle while wearing the apparatus because the shoulder-to-shoulder width of the FFBA was too large. The FFBA had to be doffed and passed through separately.

Table 2 (Continued)

Results of SCBA Wearability Assessment
Conducted Aboard ex-USS SHADWELL

Obstacle	Wearability Assessment	Comments
Ascending an inclined ladder through an 18" horizontal scuttle (continued)	<u>OBA</u> - significant mobility problems	Several test subjects experienced collapsed OBA breathing air bags while passing through the 18" scuttle. These test subjects were following proper procedures for passing through shipboard scuttles while wearing an OBA. The OBA also often caught on the edge of the scuttle.
Descending an inclined ladder through an 18" horizontal scuttle	<u>SCBA, 30-min.</u> - minor mobility problems	Test subjects that wore SCBAs with 30-minute air cylinders had problems with the air cylinders becoming caught (near the air cylinder valve) on the knife edge of the scuttle. Very slow, careful movement was required to descend through the scuttle.
	<u>SCBA, 45-min.</u> - significant mobility problems	
	<u>SCBA, 60-min.</u> - significant mobility problems	Test subjects that wore SCBAs with 45-minute or 60-minute air cylinders were not able to descend through an 18" scuttle without doffing the apparatus first and passing it through separately.
	<u>FFBA</u> - significant mobility problems	The test subject that wore the FFBA was unable to descend through the scuttle while wearing the apparatus. The FFBA had to be doffed and passed through separately.
	<u>OBA</u> - significant mobility problems	Several test subjects experienced collapsed OBA breathing air bags while passing through the 18" scuttle. These test subjects were following proper procedures for passing through shipboard scuttles while wearing an OBA. The OBA also often caught on the edge of the scuttle.
Passing through a confined space (narrow passageway)	<u>SCBA, 30-min.</u> - no mobility problems	Test subjects that wore SCBAs with 30-minute air cylinders had no mobility problems in a narrow passageway. Test subjects with larger air cylinders had minor mobility problems because of the air cylinder bumping against objects surrounding the narrow passageway.
	<u>SCBA, 45-min.</u> - minor mobility problems	
	<u>SCBA, 60-min.</u> - minor mobility problems	
	<u>FFBA</u> - minor mobility problems	The size of the FFBA caused it to bump against the surroundings of the narrow passageway and slow the test subject's movement.
	<u>OBA</u> - no mobility problems	Test subjects that wore OBAs had no mobility problems passing through the narrow passageway.