

MEDICAL RESEARCH DEPARTMENT



U. S. Submarine Base  
New London

FIELD TEST OF DARK ADAPTATION OF DIVERS

Final Report  
on  
Bureau of Medicine and Surgery  
Research Division Project  
X-663 (Av-241-p)

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on  
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U.S.NAVAL MEDICAL RESEARCH LABORATORY  
U.S.Naval Submarine Base  
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unclassified*

### Summary

1. Data are presented on 120 dives in water of a depth of 15 to 18 feet in which the bottom was very muddy and tide and current conditions such as to make the advantages of dark adaptation difficult to measure. Subjective improvement, however, was reported by all 60 divers.

2. Data are presented on 42 dives in 170 feet of water half of which were by dark-adapted divers who showed definitely measurable improvement in vision and who universally expressed their opinion that dark adaptation improved underwater vision markedly.

3. Preliminary experiments of rod and cone function under varying degrees of illumination and of oxygen tension are reported.

4. The advantages of dark adapting divers is more evident on days in which meteorological and other conditions are such as to provide low illumination on the bottom, that is, on days during which the sun is partially or completely obscured.

5. The practicability of dark adapting divers by dark adaptation goggles worn until the diver was "on bottom" has been demonstrated. It was found that once dark-adapted, a diver's vision will remain constant unless radical change in light intensity occurs.

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### Historical Data

On 13 January 1945 Lt. I. A. Everley (HC) U.S.N. reported to the Planning Officer for Submarine Search and Rescue his conception and development of a technique of dark adaptation of divers to increase their efficiency in decreased illumination as is most often encountered in diving.

The Planning Officer for Submarine Search and Rescue forwarded it to ComSubsLant via the Commanding Officer, U.S. Naval Submarine Base, New London, Connecticut. The Commanding Officer of the Submarine Base forwarded it to ComSubsLant, who forwarded it with favorable endorsement to BuShips via BuMed. All these commands and Bureaus viewed the technique as being of distinct merit and BuMed authorized this research project designed to further demonstrate the advantages of the dark adaptation of divers with a view to recommending its adoption by the Service.

### Preliminary Investigation

Modification of the diving helmet by the insertion of red plexiglass in the ports proved impractical and tended to decrease vision on bottom and a means of removing them after reaching bottom did not prove satisfactory. The most satisfactory method to dark adapt proved to be the wearing of dark adaptation goggles for 30 minutes prior to a dive and allowing them to remain in place until reaching bottom. It is conceivable that in extremely low illumination the goggles could be removed before reaching bottom with no untoward effect.

It was considered desirable to investigate the influence of high pressure and its effect upon night vision and visual acuity. The recompression chamber aboard the U.S.S. ORION (AS18) was selected as the site of an analysis to detect any grossly adverse influence that pressure changes would have on rod and cone vision. The chamber was favorably located in that the amount of illumination could be controlled. Six

divers, Snellen eye charts, dark adapting goggles, and the recompression chamber were employed to investigate the pressure effects on visual acuity. The procedure was divided into two phases, that concerned with central (cone) vision, and that concerned with peripheral (rod) vision. In determining the influence of pressure on central (cone) vision, the recompression chamber was rigged with all ports open, the door to the compartment housing the recompression chamber was left open, and a Snellen chart was placed 10 feet away from the subjects. All test letters on the Snellen chart with the exception of the 10-foot test letters were blacked out. Two men at a time were placed under pressure. Their vision in all cases was 20/20 or in this case 10/10 as tested in the recompression chamber before descent.

All men descended to a depth of 200 feet gauge. Their vision was again taken and found to be 10/10. Upon interrogating the men when they reached the surface, they all stated that they could not detect any apparent difference in their visual acuity.

The next step was to determine, with the facilities at hand, the influence of pressure on peripheral (rod) vision. For this study the recompression chamber ports were closed with the exception of one that was located in the far end of the chamber well within the compartment housing the chamber. The compartment door was left open. A Weston Master Light Meter was used in an attempt to determine the light intensity within the chamber but this meter was not delicate enough to register in these conditions. A', B', and C', divers not dark adapted, were placed in the chamber with the door secured and allowed to dark adapt. Their vision under these conditions was then determined; A', B', and C' took about 6 minutes to adapt to a degree permitting 10/10 vision. A', B', and C' came out of the chamber and A, B, and C donned dark adapting goggles for a period of 30 minutes. This period of time was taken in order to cancel any dark adaptation which A', B', and C' may have had. The divers were placed in pairs: A and A'; B and B'; C and C'. A, B, and C were all dark adapted with dark adapting goggles for a period of thirty minutes as stated above. Each set of divers was sent to a depth of 200 feet gauge. Upon removal of the goggles, vision of A, B, and C

upon reaching the bottom was not 10/10. It took an average of 5.5 minutes for A', B' and C' to adapt to 10/10 under these dimly illuminated conditions. The only apparent discrepancy in visual acuity was found in the time for adaptation of A', B' and C'. They stated that following adaptation they could not see any difference in their ability to see the test letters as compared to the same procedure which was carried out on the surface.

### Discussion

Sixty students in the school for second class divers, over a period of some months made training dives from the dock at the Submarine Base, New London, Conn. in fifteen to eighteen feet of water. Each made two successive dives, the first being light adapted and the second dark adapted. Conditions on the bottom were such that there was practically no visibility due to the mud stirred up by the movement of the divers and to the tide and current conditions. All of these divers noted slight improvement in vision on the dark adapted dive, however the greatest distance at which any object could be identified was only four feet and so variable as to preclude accurate measurement. Thus the advantages of dark adaptation in muddy water was only subjectively demonstrated.

Those divers participating in the tests in 170 feet of water were from the U.S.S. ORION (AS18) and the U.S.S. MALLARD ARS#4. At 0500, 25 March 1946 the U.S.S. MALLARD got underway from Balboa, Canal Zone, for practice diving and salvage operations. At 1000 a four-point moor had been established due west of Pajaros Island of the Pear Archipeligo in the Bay of Panama. Each diver was given a complete physical examination as outlined by the Manual of the Medical Department (Rev.-1945) #21134. They were all given night vision tests with the radium plaque adaptometer.

The depth of the water in this moor was 170 feet. The injection temperature was 66, which did not change appreciably during the time of diving operations. The morning was set aside to determine the approximate time that would be consumed with each test dive, and to check upon all the influencing factors.

Two divers at a time were to be sent down, one dark adapted and the other not dark adapted. The diver who was dark adapted was to wear his goggles for a period of 30 minutes before being dressed in a Standard Navy Deep-Sea Diving Dress. The diver who was dark adapted was to descend first and upon reaching the bottom he was to pick up a circling line and back away from the descending line paralleling the current. It was found in initial studies that if the diver backed against the current he kicked up enough silt so as the current would pick it up and consequently interfere with the visibility of the second diver. Also, if the first diver down backed against the current the silt and sediment kicked up by the arrival of the second diver would drift in the direction of the first diver, consequently again reducing visibility; thus, the dark adapted diver walked parallel to the current to the end of his circling line.

When the dark-adapted diver had reached the bottom the diver who was not dark-adapted started his descent, and the latter, who upon reaching the bottom, indicated such over the phone and the dark-adapted diver, who at this time was standing at the end of the circling line was instructed to kick off his goggles. The time the dark-adapted diver removed his goggles was recorded and the time he sighted the non-dark-adapted diver standing at the base of the circling line was recorded. The non-dark-adapted diver was instructed to indicate over the phone when he sighted the dark-adapted diver. He was to use the circling line as a guide for direction in locating the dark-adapted diver. The time recorded for adaption of the non-dark adapted diver was the interval between the time he reached the bottom and the time he sighted the dark-adapted diver.

The length of circling line which was used was 25 feet. This length of line was selected because the average approximated visibility on the bottom was between 30 to 40 feet. The weather conditions, amount of illumination, type of bottom, clarity and refractibility of the water and the estimation of the current were all determined on the initial morning dives.

It was decided that because weather conditions would be very important influencing factors on the divers visibility to standardize the notation of such, in order to eliminate any chance of confusion for those inspecting this report, and for equity as far as the tests were concerned, reference was made to the Blue Jackets Manual, and the U.S. Navy Deck Log and were followed in determining the approximate amount of illumination. For example, on Monday, 25 March 1946, at 1000 there was cirrus cloud formation with about 1/10 of the sky obscured and the intensity of the sun was almost at a maximum.

On making the initial morning dives the following facts were revealed:

- (1) It would take approximately 30 minutes or longer to carry out a single test as outlined above.
- (2) The bottom, in the words of the divers, was "sticky" and "gooey", and being about 12 to 18 inches of green sandy clay and relatively flat.
- (3) The current was approximated at being from  $1\frac{1}{2}$  to 2 knots.
- (4) By stirring up the bottom it reduced visibility considerably in the direction of the current.
- (5) The dark-adapted diver when instructed to remove his goggles was able to see the non-dark-adapted diver immediately, who was standing at the base of the descending line, a distance of 25 feet.
- (6) The dark-adapted diver stated that when he had descended about 30 feet he was unable to see anything.
- (7) Upon removing the goggles the dark-adapted diver stated that it was like walking from a dark room into a lighted room.

- (8) It took the non-dark-adapted diver 3 minutes and 10 seconds to see the dark-adapted diver, and he stated that he was only able to see the dim outline of the dark-adapted diver. While on the other hand the dark-adapted diver stated he was able to make out the face plate and other recognizable parts of the Deep-Sea-Dress.
- (9) The range of visibility established by dark-adaptation seemed to remain constant.

DARK ADAPTATION TEST DIVES

Monday: 25 March 1946.

Dive #1:

Depth: 170 feet.

Measured distance of visibility: 25 feet.

Current: estimated 2 knots.

Weather conditions: Water is smooth; high cirrus clouds; 1/10 sky obscured.

Time of Dive: 1300.

- (a) Dark-adapted diver: saw N.D.A.D.\* on removal of his adaptation goggles.
- (b) Non-Dark-Adapted diver: saw D.A.D.\* in 4 minutes and 20 seconds.

Remarks: Range of visibility of D.A.D.\* did not change, but N.D.A.D.\* range of visibility increased as he became dark-adapted.

Dive #2:

Time: 1345

Conditions and other data remained the same.

- (a) D.A.D.\* saw N.D.A.D.\* 30 seconds after removal of the goggles.
- (b) N.D.A.D.\* saw D.A.D.\* in 2 minutes and 30 seconds.

Remarks: N.D.A.D.\* states his range of visibility was gradually increasing with his length of stay on the bottom.

Dive #3:

Time: 1430

Conditions: ~~Cirroc~~stratus cloud formation: 4/10 of the sky obscured.

Other data as was given in Dive #1 remained the same.

- (a) D.A.D.\* saw N.D.A.D.\* very dimly at first, moved to the twenty foot mark and was able to see the N.D.A.D.\*
- (b) N.D.A.D.\* saw D.A.D.\* very dimly at 5 minutes.

\*D.A.D.: Dark-Adapted Diver

\*N.D.A.D.: Non-Dark-Adapted Diver.

Remarks: Both stated that they could see much better when the D.A.D. moved to the 20 foot mark on the 25 foot circling line. D.A.D. could see more detail than N.D.A.D. after both had been down for 7 minutes.  
Estimated maximum visibility for today on the bottom was between 30 and 35 feet. Weather for diving was excellent. Average adaptation time: 3 minutes and 1 second.

Tuesday: 26 March 1946

Dive #4:

Time: 0800

Depth: 170 feet.

Measured distance of visibility: 25 feet.

Current: 1 knot.

Weather conditions: Partly cloudy; 4/10 sky obscured; altostratus cloud formation.

- (a) D.A.D. saw N.D.A.D. immediately.
- (b) N.D.A.D. saw D.A.D. at 4 minutes.

Remarks: D.A.D. stated that visibility was excellent when he removed his goggles, but that it was as "black as pitch" before he removed his goggles.

Dive #5:

Time: 0915

Conditions and other influencing data remained the same as they were in Dive #4.

- (a) D.A.D. saw N.D.A.D. in 30 seconds.
- (b) N.D.A.D. saw D.A.D. in 5 minutes.

Remarks: D.A.D. stated that he was looking away from the descending line at the time he took off his goggles.

Dive #6:

Time: 1000

Conditions: Cirrus cloud formation; 2/10 sky obscured, sun not obscured by any cloud formation, other conditions remained the same as noted in Dive #4.

- (a) D.A.D. saw N.D.A.D. immediately.
- (b) N.D.A.D. saw D.A.D. in 3 minutes and 30 seconds.

Remarks: Sun is not obscured and the range of visibility on the bottom is apparently increasing.

Dive #7:

Time: 1300

Current:  $\frac{1}{2}$  knot.

Weather conditions: 1/10 sky obscured; high cirrus cloud formation; sun not obscured by clouds.

- (a) D.A.D. saw N.D.A.D. immediately.
- (b) N.D.A.D. saw D.A.D. in 4 minutes.

Dive #8:

Time: 1350

Other data same as for dive #7.

- (a) D.A.D. saw N.D.A.D. immediately.
- (b) N.D.A.D. saw D.A.D. in 4 minutes and 30 seconds.

Dive #9:

Time: 1500

Current: estimated at  $1\frac{1}{2}$  knots.

Weather conditions: 5/10 sky obscured; cirrocumulus cloud formation.

Other data same as Dive #8.

- (a) D.A.D. saw N.D.A.D. immediately.
- (b) N.D.A.D. saw D.A.D. in 4 minutes and 45 seconds.

Dive #10

Time: 1555

Weather conditions: 9/10 sky obscured; sky becoming over-cast; high cirrocumulus cloud formation with low cumulus clouds. Sun's outline can still be seen behind clouds.

- (a) D.A.D. unable to see N.D.A.D. at 25 feet; moved to 20 feet and could barely make out the dim outline. At 15 feet was able to see N. D.A.D. fairly well.
- (b) N.D.A.D. unable to see the D.A.D. after 6 minutes on the bottom and was brought to the surface.

Remarks for the days diving:

- (1) Visibility up until late afternoon was estimated at between 30 and 40 feet.
- (2) Weather and other conditions remain excellent for diving.
- (3) Last dive revealed the true advantage of dark-adapting divers.

Wednesday, 27 March 1946.

Dive #11:

Time: 0800

Depth: 170 feet

Measured distance of visibility: 25 feet.

Current: estimated at 2 knots.

Weather conditions: relatively high stratus clouds; sky obscured; a definite overcast; very calm water, "glassy".

- (a) D.A.D. unable to see N.D.A.D. at 25 feet after 2 minutes; moved to the 20 foot marker; able to make out the dim outline of the N.D.A.D.
- (b) N.D.A.D. after 6 minutes could make out the D.A.D.

Remarks: The N.D.A.D. stated that the visibility on the bottom was poor and estimated the range of visibility at about 15 feet.

Wednesday, 27 March 1946 contd

Dive #12:

Time: 0940.

Weather conditions: 5 to 7/10 sky obscured; cumulus cloud formation predominant with some stratus clouds. Outline of the sun seen through the clouds.

- (a) D.A.D. saw N.D.A.D. immediately.
- (b) N.D.A.D. saw D.A.D. in 4 minutes and 35 secs.

Remarks: D.A.D. stated that he could make out the outline of the N.D.A.D. but not much more. N.D.A.D. stated that he could make out a shape, and as the shape moved toward him it took the form of a diver.

Dive #13:

Time: 1030.

Current: 1 knot.

Weather conditions: 4/10 sky obscured; cumulus clouds; sun appearing through cirrostratus clouds.

- (a) D.A.D. saw N.D.A.D. immediately.
- (b) N.D.A.D. saw D.A.D. in 4 minutes and 5 secs.

Dive #14.

Time: 1300.

Weather conditions: high cirrus clouds with low hanging cumulus; 5/10 sky obscured; sun's outline appears through the cloud formation.

- (a) D.A.D. saw N.D.A.D. immediately.
- (b) N.D.A.D. saw D.A.D. in 3 minutes and 55 seconds.

Dive #15.

Time: 1350.

Weather conditions and data same as Dive #14.

- (a) D.A.D. saw N.D.A.D. immediately.
- (b) N.D.A.D. saw D.A.D. in 3 minutes.

Wednesday, 27 March 1946 contd.

Dive #16.

Time: 1505.

Weather conditions: 7/10 sky obscured; developing overcast with cumulus clouds and high stratus clouds. Sun's outline still remaining.

(a) D.A.D. saw N.D.A.D. immediately.

(b) N.D.A.D. saw D.A.D. in 4 minutes and 5 seconds.

Remarks for the days diving: Conditions remain ideal for diving. There was some degree of overcast which definitely influenced the adaptation time of the N.D.A.D. on the bottom. The average visibility was from 20 to 30 feet.

Thursday, 28 March 1946.

Dive #17.

Time: 0800

Depth: 170 feet.

Measured distance of visibility: 25 feet.

Current:  $1\frac{1}{2}$  knots.

Weather conditions: 7/10 sky obscured; high stratus clouds with slight low cumulus cloud formation.

(a) D.A.D. saw N.D.A.D. immediately.

(b) N.D.A.D. saw D.A.D. in 4 minutes and 15 secs.

Dive #18.

Time: 0850.

Weather conditions: sky is clearing; 5/10 sky obscured; high stratus clouds; low cumulus clearing.

(a) D.A.D. saw N.D.A.D. immediately.

(b) N.D.A.D. saw D.A.D. in 3 minutes and 45 secs.

Thursday, 28 March 1946 contd

Dive #19

Time: 1015.

Weather conditions: sky 1/10 obscured; few low cumulus clouds; sun not obscured.

(a) D.A.D. saw N.D.A.D. immediately.

(b) N.D.A.D. saw D.A.D. in 2 minutes and 50 secs.

Dive #20:

Time: 1300.

Weather conditions and other data have not changed appreciably since Dive #19.

(a) D.A.D. saw N.D.A.D. immediately.

(b) N.D.A.D. saw D.A.D. in 2 minutes and 30 secs.

Dive #21:

Time: 1400.

Weather conditions: 5/10 sky obscured; high stratus clouds developing and low cumulus clouds persisting. Sun is partially obscured by cloud formation.

(a) D.A.D. saw N.D.A.D. immediately.

(b) N.D.A.D. saw D.A.D. in 3 minutes and 5 secs.

Remarks: This was the final set of divers sent down. All who participated in the tests were in accord with the advantage given the diver by dark adaptation.

TABLE OF ADAPTATION TIMES RESULTANT OF THESE TESTS

	No. of Dives	Adaptation Time of each dive in secs.	Averaged Adaptation Time
MONDAY:	1	260	3.9 minutes.
	2	150	
	3	300	
TUESDAY:	4	240	4.53 minutes.
	5	300	
	6	210	
	7	240	
	8	270	
	9	285	
	10	360 plus	
WEDNESDAY:	11	360	4.24 minutes
	12	275	
	13	245	
	14	235	
	15	180	
	16	245	
THURSDAY:	17	255	3.3 minutes
	18	225	
	19	170	
	20	150	
	21	185	

Average adaptation time for 4 days of diving:

4.08 minutes.

### Conclusion

Dark adaptation of Divers proved entirely practical and feasible. No modification of the standard Diving helmet seemed indicated. It is considered desirable that the entire Naval service be informed of these tests in order that advantage of this technique may be utilized when and as indicated.

*Downgraded to  
unclassified*