THE TESTING OF LIFE-JACKETS

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During the last two years, there has been increased interest in life-saving equipment for merchant seamen. Life-rafts have been greatly improved and attention has also been turned to the efficiency of life-jackets.

This paper deals with a particular aspect of the design of life-jackets, and describes a method of testing them. The work was done in 1943-45 for the Royal Air Force. Despite the lapse of time it seems appropriate to present our findings briefly, as we do not know of any similar work reported more recently.

It occasionally happens that a seafarer is afloat in an unconscious state in a life-jacket; it is then imperative that his life-jacket should support him so that his face is clear of the water. Even if consciousness is maintained it is obviously desirable that the design of the jacket should be such that a weak or injured man is supported in a good position without effort on his part.

Trials have often been made in which the pseudo-victim, encased in a life-jacket, attempts to remain passive when placed in the water. It has been found impossible for the conscious volunteer to remain quite inert, particularly when things seem to be going wrong. Quite small movements of the arms or legs, or brief inspiration and breath-holding can markedly alter the floating position of a man trying to be "inert". The truly inert subject in the trials to be described fell into some most unusual positions which a conscious subject would instinctively avoid.

Method

The subject was deeply anaesthetized with a volatile anaesthetic. An endotracheal tube with an inflatable cuff was used to prevent water entering the subject's lungs when his head became immersed and the pharynx was packed for extra security. The anaesthetic gases were conveyed to the endotracheal tube and exhaled gases were conducted away by a double lumen, corrugated, non-kinking tube which was weighted by wrapping solder wire round it so that it had neutral buoyancy.

Thus, the effect of the buoyancy of the tube upon the head position was negligible, a fact which was confirmed by moving the tube around to different angles.

The subject was 5 ft. 7½ in. tall and weighed 10 stone. He wore, in addition to the life-jacket or protective suit being tested, battle-dress, service underwear, and a seaman's sweater. It had been found that flying boots usually came off in the sea, so they were not worn. Seaboot stockings were donned but these also came off very quickly during the trials, and are missing in most photographs.

Four trials were made: two in fresh water in a swimming pool which allowed underwater photography, one in still salt water (3.5% sodium chloride) and one in salt water in a pool fitted with a wave machine which produced a disturbed, choppy "sea" with waves up to 3 ft. trough-to-crest height.

Some 20 flotation garments were tested. It is not proposed here to repeat the specific comments upon them, which were recorded in official minutes and reports. An attempt will, however, be made to illustrate the behaviour of some types of flotation gear, and some of the defects from which they may suffer.

Results

The jackets and flotation garments which we tested may be divided into three functional groups: (1) Those which support the subject in a horizontal position; (2) those which support him in a supine position inclined at about 45° to the surface; and (3) those which support him vertically.

Subject Unsupported by Life-jacket.—Before the tests began we thought it would be interesting to learn what would happen to an unconscious subject, breathing lightly and not supported by a life-jacket, when placed in fresh water. He sank promptly (Fig. 1). The trunk tends to sink a little after the legs but the subject soon came to rest in a horizontal position on the floor of the tank.

Horizontal Floating Position.—A garment in which the buoyancy extends over both the trunk and legs floats the subject horizontally on the surface of the

FIG. 1.—No life-jacket.

FIG. 2.—Buoyant overall, stable when supine.

FIG. 3.—As (2), underwater view.

FIG. 4.—Buoyant overall, stable when prone.

FIG. 5.—As (4), underwater view.

FIG. 6.—Buoyant overall in rough water.

FIG. 7.—Buoyant overall, rough water, stable when prone.

FIG. 8.—Life-jacket, supine 45° position.

FIG. 9.—As (8), underwater view.

FIG. 10.—Supine, 45° jacket, start of "self righting".

FIG. 11.—As (10), further stage.

FIG. 12.—As (10), "self righting" almost complete.

FIG. 13.—As (10), "self righting" in rough water, first stage.

FIG. 14.—As (13), further stage.

FIG. 15.—As (13), "self righting" completed.

FIG. 16.—Effect of shifting buoyancy.

FIG. 17.—As (16), underwater view.

FIG. 18.—As (16), rough water.

FIG. 19.—Buoyancy too small and too low.

FIG. 20.—As (19), underwater view.

FIG. 21.—Harness unsatisfactory.

FIG. 22.—As (21), underwater view.

FIG. 23.—Same jacket as (21), harness now corrected.

FIG. 24.—Vertical type life-jacket.

FIG. 25.—As (24), underwater view.

FIG. 26.—Vertical jacket, "self-righting" first stage.

FIG. 27.—As (26), further stage.

FIG. 28.—Head support incomplete.

FIG. 29.—Good head support.

water (Fig. 2). Fig. 3 shows the underwater view. In this supine position the subject is stable, and the garment appears attractive. However, it is equally stable if the subject, by any mischance, gets into the prone position. Figs. 4 and 5 show this, in calm water. The arms and legs drop slightly and exert a keel-like effect so that a considerable force is required to turn the subject. It was not found possible to cause a sufficient turning force by any buoyancy compartment of tolerable bulk attached to the subject's body. It seems probable that the construction of a horizontally floating, buoyant garment with self-righting properties will be difficult or impossible. Figs. 6 and 7 illustrate the stability of both supine and prone positions when the subject floats in rough water.

Floating Supine at 45° to Surface.—Fig. 8 shows a typical life-jacket which produces this posture and Fig. 9 is an underwater view. Buoyancy extending down the chest is responsible for the slightly curved inclined position.

In a well-designed garment of this type, when the subject is deliberately placed face downwards, the legs first drop until the body comes to lie at about 45° and the head is then drawn above the surface by a twisting action to which the arms and legs offer little resistance, since they are close to the axis of twist. The underwater views of this process are shown in Figs. 10, 11, and 12 (smooth water), and in Figs. 13, 14, and 15 (rough water). Fig. 13 shows a slightly earlier stage in the process than does Fig. 10, and the legs have not yet dropped.

This "self-righting by twisting" can be prompt and a well-designed garment of this type not only offers great resistance to immersion of the head but very promptly pulls the face clear if, by mischance, it becomes immersed. This effect can be more prompt and definite than any other type of self-righting motion which was seen.

Life-jackets which aim at this 45° position are, however, subject to a number of possible defects.

Fig. 16 shows a jacket which maintains the subject supine at 45° when he is placed in the water in that position. Here, however, there is too much buoyancy on the back, and it is too low down. Moreover, the garment is air-filled and the site of maximum buoyancy may change with movement of air within the inflated chamber. As a result, many positions are stable; Fig. 16 shows the position to which the subject and jacket returned after being placed face downwards. Fig. 17 shows the underwater view and Fig. 18 shows that the position is similar in rough salt water; it will be seen that the nose and mouth are fully immersed.

Fig. 19 shows another jacket which supports the

wearer with the head clear of the water and with the body at 45° to the surface, if he be placed in this position. However, the garment has very bad self-righting properties because the buoyancy is too small and it is symmetrical: furthermore, the point of maximum buoyancy can shift. Figs. 19 and 20 show the positions to which he returned after the subject had been disturbed.

A life-jacket may be well designed, but unless it is firmly attached to the wearer it may fail completely in its purpose. Fig. 21 shows a life-jacket whose harness for attachment was quite unsatisfactory. The subject easily became partially dislodged from the jacket, so that although the jacket remained well placed upon the surface, the subject's nose and mouth became immersed (Figs. 21 and 22). When this defect of the harness was corrected, however, the jacket performed excellently and gave very prompt self-righting. It is shown in rough water in Fig. 23.

The Vertical Floating Position.—When the buoyancy is concentrated around the neck, the subject will float vertically as in Figs. 24 and 25. When placed face downwards he seemed to "right" by a process of tilting only, as may be seen in Figs. 26 and 27, the final position being as in Fig. 24.

This process was slower than self righting by twisting, since more resistance is offered to the movement in the water. The position of the head, as in Fig. 24, is well clear of the water. It can hardly fall forward and become immersed; nevertheless, unless it is well supported it may fall sideways.

Fig. 28 shows a jacket of the upright-floating type in which the head can fall sideways, and although not quite immersed, the nose and mouth are perilously close to the water.

Fig. 29 shows a life-jacket in which effective precautions have been taken to prevent sideways movements of the head by means of a kapok collar structure. Although the high, and substantially vertical, head position of this type of jacket has certain merits, it has one disadvantage. Unless the relation of waves and wind is very abnormal, the subject will float face towards the waves. In this upright floating position his face will be exposed to a good deal of lop and spray. In the 45° position, the buoyancy chamber of the life-jacket can be made to serve as a wave break to divide the waves and keep the face comparatively clear. Fig. 15 illustrates this.

Discussion

The qualities aimed at in a good life-jacket are many, and they vary considerably with the particular conditions in which it is to be used.

The design of jackets so that they are comfortable, buoyant, robust, easy to inflate and adjust, able to carry ancillary equipment, etc., and yet allow the subject to swim, is properly the task of engineers.

The engineer needs medical assistance, however, because the human body contributes most of the buoyancy to the subject-life-jacket combination so that the body's variations must be considered.

If dummies could be made, representative of the various types of men, women, and children, they would be of great help to engineers interested in this work. The dummies would have to be correct in weight, in total and distributed buoyancy, in the location of centres of gravity, and in flexibility. The many photographs and films obtained during these trials might be helpful for comparison between the behaviour of any proposed dummy and that of a truly inert human subject.

Since satisfactory dummies did not exist, we had to adopt the procedure we have described. Despite its clear limitations, we believe it gave some information which was more objective than that yielded by previous trials. Our trials dealt only with the floating position of the subject and life-jacket and it must always be remembered that a good basic floating position is only one of the many attributes which a life-jacket should possess. Trials like these cannot alone determine which is a good life-jacket and which a bad one.

From these investigations some tentative proposals may be made.

(1) Sometimes life-jackets are the property of the wearer and then they may fit reasonably well; speed of donning may be balanced against efficiency of the attachment, and a well-balanced garment may be chosen. Sometimes the life-jackets belong to the vessel and may have to be donned urgently. Then it is often required that they should be freely interchangeable between all men, women, and even children, that they should function even if put on back to front and that donning should be simple and very speedy. When reversibility can be dispensed with, life-jackets which float the subject supine at about 45° to the water's surface, seem to have the following advantages:—

(a) High density additions to the mass of the subject, as, for example, metal equipment carried by soldiers, are less likely to cause trouble than in other postures. Only if this equipment were suspended from the head or back of the shoulders would it be likely to tilt the subject backwards and even then the moment of force would be small. Suspended from the chest or lower part of the body such masses may tend to tip the subject forward, but 45° of forward tilt can be tolerated before the subject becomes upright, in which position, if the

jacket be well designed, it is still unlikely that his face would be immersed. To tilt him further, very large masses would be needed since, in this type of jacket, the maximum buoyancy is necessarily concentrated on the chest.

Similar considerations apply to forces of waves tending to tilt the subject.

In the case of jackets producing an upright floating position, the angular movement forward before potential danger occurs is small. This does not, of course, mean that the upright floating position may not be the best possible when the carriage of heavy equipment is unlikely, when wide interchangeability of jackets is needed, and when rapidity of donning and reversibility are considered essential.

(b) If the 45° position is used, it is possible to make the self righting of the subject, from dangerous to safe positions, rapid and decisive. At its best, the twisting motion seen with this type of jacket was found to be more prompt and rapid than any other self-righting motion.

(2) Whatever form of jacket be used, the following points must be heeded:—

(a) The buoyancy must not be so symmetrically distributed that several positions of stability become possible by small changes of posture of the subject within the harness.

(b) The possibility of shift of the position of maximum buoyancy, which is inherent in all inflated life-jackets, unless they are very tightly distended, must either be eliminated or allowed for.

(c) The harness which attaches the jacket to the subject must maintain, in all conditions, a satisfactory relationship between them. It is useless for the jacket to float in an ideal position if the subject has largely fallen away from it.

(3) Flotation garments which support the subject in a horizontal position will be unlikely to possess self-righting properties. While they may be stable with the subject supine, supporting the nose and mouth clear of the water, they are likely also to be stable with the subject prone and the face immersed, and considerable effort may be needed to extricate him from this lethal situation.

Most water-tight suits used for protection against cold and immersion will necessarily render the subject's legs buoyant and float him horizontally. Against the large advantages of protection which they give must be set the lack of the self-righting property.

Summary

A technique is described whereby an anaesthetized, inert man was used as a subject to test the basic flotation properties of life-jacket/subject combinations.

The results of four trials are described and illustrated, and certain tentative opinions expressed. For application where rapidity of donning and wide interchangeability of the life-jacket are not required, it is suggested that there are advantages in jackets which float the subject supine at 45° to the surface.

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