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16. Abstract

A simple, lightweight, life-support infant flotation device incorporating reliable self-righting, thermal protection and automatic self-ventilation is described. This design concept utilizes prior data relative to the centers of gravity of infants and small children and exhibits excellent self righting. Thermal protection is incorporated through the use of insulative neoprene foam in construction of the submerged portion of the device. Anesthetized adolescent primates exhibiting body weights and metabolic requirements equivalent to that of an infant or small child were used to test and confirm ventilatory capability as induced by air or water motion.

An evaluation of the capability of the device to deter shark attack indicated that the infant flotation device, when occupied by anthropomorphic dummies or anesthetized primates, was less attractive to sharks than anthropomorphic dummies wearing a standard yellow color inflatable life vest.

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EVALUATION OF AN IMPROVED FLOTATION DEVICE EOR INFANTS AND SMALL CHILDREN

A survey of accident histories of prior open sea transport aircraft ditchings indicates that a number of small children or infants involved in such an accident did not survive. Due to the relationship between the center of gravity and stature, the present life jackets may not maintain the body of a small child in an upright position. Simple movements, such as holding the hands above the head, will shift the center of gravity to the extent that the child may rotate, submerging the face and head. In choppy water, the child or adult life preserver provides little protection for either infant or small child from inspiration of water. Efforts by adults to support a child under the adverse environmental conditions encountered in open sea ditchings are frequently ineffective.

Cold water immersion poses another difficult and challenging problem. The specific heat of water is approximately 1,000 times that of air, a given volume of water being capable of taking up to 1,000 times the heat of a comparable volume of air.[1] Infants and small children have a body surface area per unit of body mass 2–3 times that of an adult.[2] Additionally, the total body weight of infants and small children ranges from 1/20 to 1/5 that of an adult with a commensurate reduction in total stored or specific heat. Survival times are, therefore, drastically reduced due to the larger surface area per unit of body mass and the reduced quantity of heat initially available to maintain body core temperature. In order to test and evaluate a more protective flotation device based on known anthropomorphic and physiological characteristics of infants and small children, a series of experiments was conducted as described below.

METHODS AND RESULTS

A simple, lightweight, life-support infant flotation device (IFD) was designed and tested extensively. Primary design considerations included: (1) reliability of buoyancy, stability and self-righting characteristics; (2) self-ventilation; (3) thermal protection; (4) impact injury minimization; and (5) ability to deter shark attack.

A prototype infant flotation device constructed to meet these criteria has been previously described.[3] Briefly, the flotation portion of the IFD consists of two separate inflatable buoyant compartments of equal diameter, one a complete horizontal circular tube and the other a vertical half-circle sewn to the perimeter of the horizontal segment. Inflation is accomplished by a 16–gm. carbon dioxide cylinder attached to each of the inflatable compartments. A means for orally inflating each compartment is also provided. The half-circle compartment is designed to assume a vertical position at right angles to the full-circle flotation compartment in order to support a protective canopy or enclosure. (Figure 1) This transparent canopy enclosure is secured by means of a zipper and velcro closure. The lower portion of the IFD consists of a tapered bag fabricated of 1/4-inch unicellular thermal insulative neoprene rubber foam. This design provides a minimum surface area and avoids the familiar problem of "insulation of small cylinders." The upper portion of the neoprene bag nears its attachment to the horizontal flotation ring is flared quite radically so as to provide a diaphragm action when the device is floating in water and cause a "pumping" or breathing action through the snorkel, ventilating the device in choppy water. In calm water the front canopy may be left open. A padded seat with shoulder straps limits vertical displacement of the child if dropped into the sea in an inverted attitude. A lanyard permanently attached to the IFD and terminating in a swivel snap is provided for direct connection to the "D" ring of the adult's life vest. Total weight of the IFD is approximately 4½ pounds. With certain modification, including the enlargement of di-

FIGURE 1. Initial prototype of the infant flotation device occupied by a child anthropomorphic dummy.

mensions and a moderate increase in weight, the device could be adapted for use by larger children and possibly even adults. The capability of the IFD to fulfill each of the above requirements was tested and evaluated as follows.

1. *Buoyancy, stability and self-righting:* A series of field tests was carried out using an anthropomorphic dummy, representative of a 3-year-old child. Since small infant anthropomorphic dummies were not available, dolls were obtained and modified such as to exhibit body weight and centers of gravity of children 4 months to 2½ years of age. Using these dummies, stability and seaworthiness of the IFD were evaluated under a variety of wind and wave conditions. Tests of self-righting and impact integrity were carried out by dropping the IFD (occupied by a dummy) into water from various heights and release attitudes.

FIGURE 2. Photograph of infant flotation device occupied by a baboon. Lanyard to the left supports intravenous and continuous carbon dioxide sampling tubes.

As measured by a Dillon underwater load cell, the total buoyancy of the IFD approximates 46 pounds. This is approximately twice the buoyancy of the inflatable vest carried by the airlines. Adequate buoyancy and stability is provided by the remaining compartment in case of failure of either compartment. The stability by reason of the location of the center of gravity has been shown by test to be excellent in smooth and rough water.[3 6] Water impact tests carried out from cliffs 13 to 21 feet in height indicated excellent self-righting when the IFD containing the dummy was released in a variety of attitudes. When released in the inverted position, the center of gravity is such that the IFD tends to right itself before entry into the water.

2. *Ventilation and carbon dioxide accumulation:* Carbon dioxide accumulation and ventilation of the IFD were studied under minimal

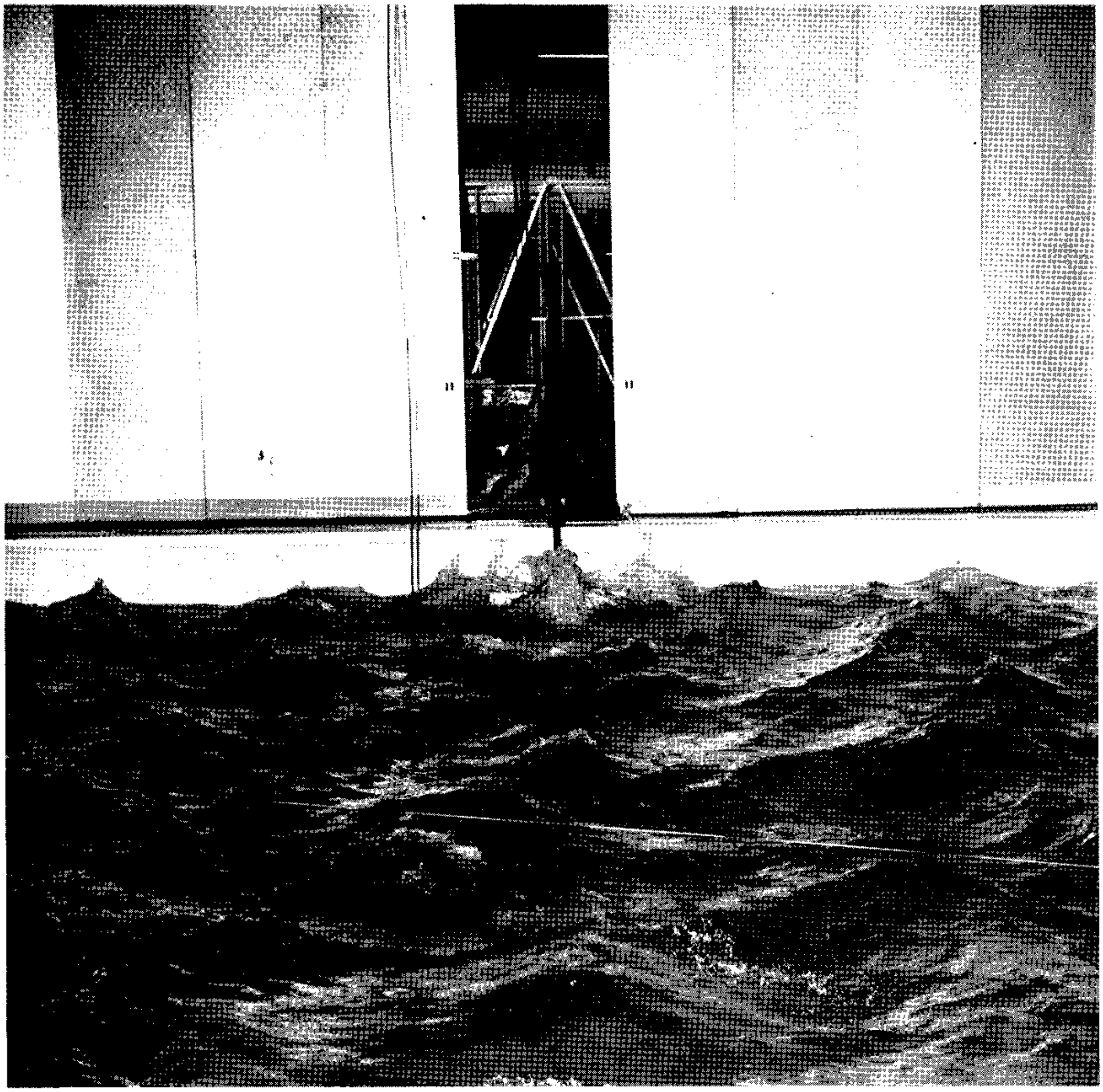

FIGURE 3. Photograph of wave generator. Frequency and amplitude of waves are controlled by variation in speed and stroke of the apparatus.

and increased wind and wave conditions. Anesthetized primates (baboons) exhibiting body weights and metabolic activity (CO_2 production and O_2 consumption) equivalent to that of a small child were utilized in these experiments. A tranquilized (8 mg./Kg. Sernalyn^R) baboon was seated in the IFD, the canopy secured, and the IFD placed in an indoor pool. (Figure 2) For the extended anesthesia desired in these experiments, Pentobarbital Sodium was administered intravenously as required. A wavemaker was designed and constructed in order to produce a variety of wave conditions. (Figure 3) Variable speed fans and accurate wind velocity measuring equipment were utilized to produce air movement. Carbon dioxide concentration within the device was continuously monitored by passing a sample of air from the IFD through a Beckman Spinco LB-1 Medical Gas Analyzer and returning it unchanged by analysis to the IFD. (Figure 4) In an evaluation of the ventilatory

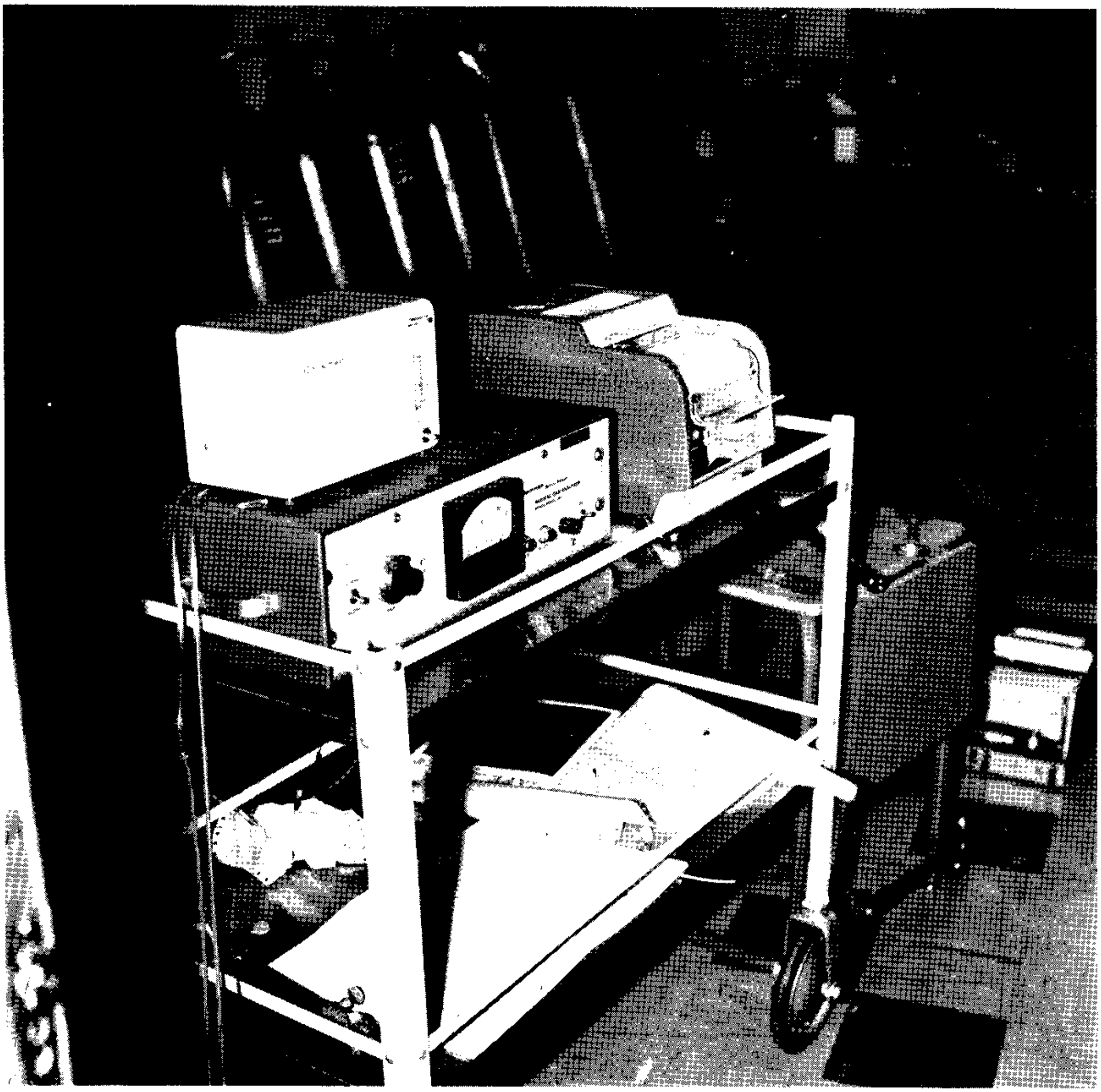

FIGURE 4. Apparatus for continuously monitoring and recording carbon dioxide accumulation within the infant flotation device.

capability of the device, it was found that after 3 hours in 6-inch waves, the carbon dioxide concentration did not exceed 0.75%. (Figure 5) By creating an artificial condition in an indoor pool and isolating the device from all water motion and air currents, it was possible to produce an accumulation of 6.4% CO_2 in a period of 30 minutes. Upon initiation of a very light air movement (3 mph), the CO_2 dropped to 0.5% in less than 5 minutes.

3. *Thermal protection:* The thermal conductivity of neoprene foam approximates 4.5 kcal./sq.m./hr./°C./per cm. thickness. Based upon the immersed surface area of a 3-year-old child, the heat loss attributable to Newtonian cooling through the ¼-inch neoprene foam may be crudely estimated at 3 kcal. per °C. The total basal heat production of a 2½ to 3-year-old child ranges from 25 to 30 kcal. However, there is no information relative to the CLO value of skin and subcutaneous tissue. In addition, that portion of the body not immersed is subject to heat loss due to convection, conduction, radiation, and evaporation. These variables are not accounted for in the above calculation. Under certain conditions, the transparent canopy may produce a heat gain due to the "greenhouse effect." Due to these variables, a precise and accurate calculation of heat loss is not possible. However, it is obvious that considerable increase in body heat retention and survival time may be realized with this device. The IFD may be deflated and used as a thermal bassinet in a life raft. Similarly, on land, the IFD provides excellent anti-exposure capability.

4. *Impact protection:* Although not tested and evaluated, it would appear that the IFD, by nature of its construction, would provide protection from impact injury. Critical portions of the body—face, heat, thorax—would receive some degree of impact protection since the inflatable compartments surrounding this area would function in a similar manner to air bag designs for automotive and aviation crash injury minimization.

5. *Ability to deter shark attack:* It has been reported in the literature that color and reflectivity of immersed objects appear to have some effect upon encouraging or deterring attack by predatory marine life. Evaluations of a baglike device designed by Dr. Scott Johnson and known as the Johnson Shark Screen indicate that darker, non-reflective bags of large size and indefinite shape which concealed the human form appear to deter shark attack by sharks in captivity and in their natural habitat.[4 5]

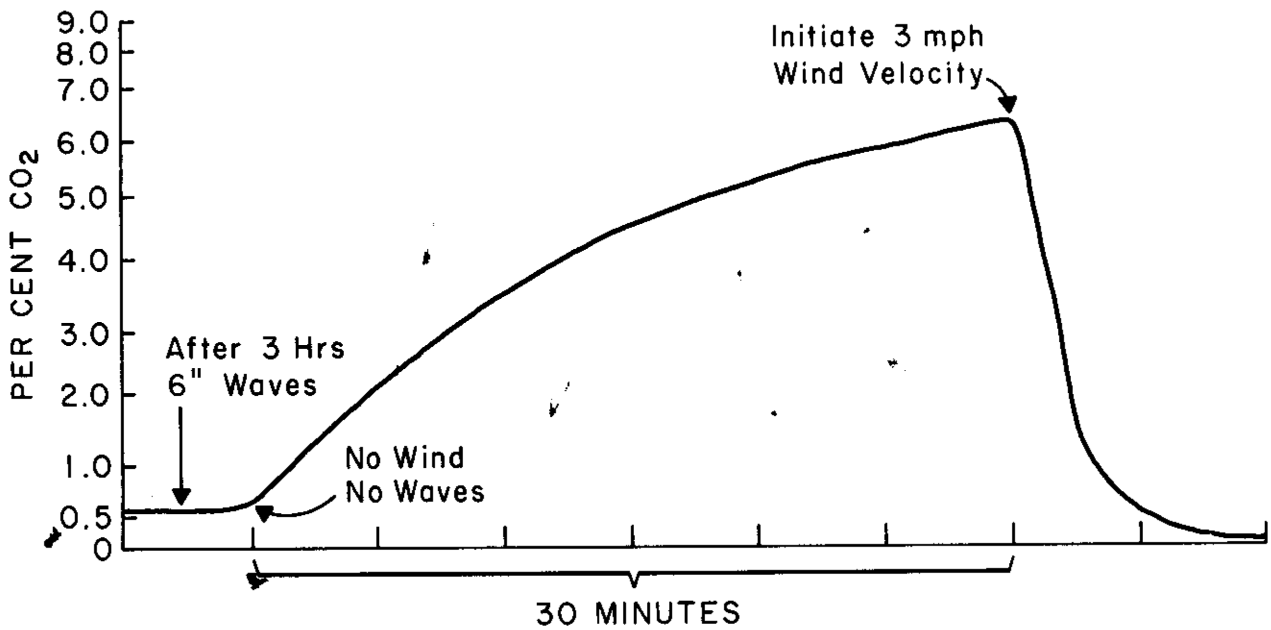

FIGURE 5. Sample recording showing the effect of 6-inch waves, very calm water without air movement, and a 3-mph. air movement without wave action.

Prototypes of the IFD incorporating black, non-reflective and brightly-colored immersed surfaces were fabricated. However, the IFD design differs from the shark screen in that the immersed portion is much smaller and, due to thermal and ventilatory design considerations, does not completely conceal the configuration of the child occupying the device. Each of these IFD's occupied by an anthropomorphic child dummy or primate was repeatedly exposed to captive coastal and bottom feeding sharks in the Mote Marine Laboratory shark pens, Siesta Key, Florida. Species used in these experiments included brown sharks *(carcharhinus milberti)*, tiger sharks *(galeocerdo cuvieri)* and bull sharks *(carcharhinus leucas)*, all of which are known to be dangerous to man. As a control, anthropomorphic dummies, wearing standard inflatable life jackets only, were introduced into the shark pen concurrently with the IFD's. Reaction of the sharks was recorded by surface and underwater motion picture cameras operated by divers utilizing SCUBA equipment.

Tests of the shark deterrency of the IFD carried out at the Mote Marine Laboratory indicated that the IFD was less attractive to sharks than an anthropomorphic dummy in a standard life vest. The sharks used in the testing program were noticeably more active and aggressive at night, especially toward the anthropomorphic dummy equipped with the life vest. Their initial reaction to the IFD containing the tranquilized baboon was to congregate in the opposite end of the shark pen and avoid the animal. Previous studies have indicated that most species of sharks will not attack hairy mammals such as swimming laboratory rats. However, with the IFD enclosing the baboon, the hair was not visually apparent. It would appear that unfamiliar olfactory stimulation or movements of the tranquilized animal may have accounted for the unusual shark behavior. Preliminary analysis of recent tests of the IFD exposed to deep water (Pacific) sharks in their natural habitat indicate preferential attack on anthropomorphic dummies equipped with the more highly reflective and conspicuous standard aircraft inflatable (yellow) life preservers.

SUMMARY

1. A flotation device concept for infants and small children incorporating life-support and survival capabilities is described. In addition to its application to aviation safety, the device is of potential value for boating and other forms of marine transportation.

2. The IFD provides in excess of 46 pounds of buoyancy and, as recorded by surface and underwater photography, demonstrates excellent self-righting and stability.

3. Ventilation is accomplished by motion of the device in water and/or flow of air across the snorkel device. Either a 3-mph breeze or 6-inch waves was sufficient to limit the CO_2 accumulation to less than 0.75%. In still water the canopy may be opened without compromising the occupant's safety.

4. Water has a specific heat approximately 1000 times that of air so that each cubic centimeter of water contacting the skin is capable of taking up a thousand times more heat from the body than a comparable volume of air for a given change in temperature.[1] Protection from the effects of immersion in cold water is provided by unicellular neoprene foam which limits the heat loss of that portion of the body submerged. The remainder of the body not subjected to immersion may be enclosed in the canopy, reducing heat loss, and protecting the occupant from exposure and immersion of the respiratory system in rough seas.

5. Both the red and the black infant flotation devices, containing anthropomorphic dummies or baboons, were less attractive to sharks than an anthropomorphic dummy wearing a standard yellow inflatable life vest.

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