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The following precis of the paper has been prepared by Dr John Knight.

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THERMAL PROBLEMS OF DIVING

Glen Egstrom

In 1965 Cousteau stated that cold was the biggest problem for divers. It still is. Water temperatures in California vary between 5°C or a bit more in winter to the low 20s in summer. These temperatures require good thermal protection if the diver is not to get thoroughly chilled. Even so cold terminates many dives and divers shiver when they come out of the water.

Humans can adapt to cold. This was demonstrated by studies of the Korean diving women, or Ama, carried out in 1966. They dive without protection or insulation. They are fitter than their non-diving compatriots. They dive two three hour shifts a day with a thirty minute break between sitting by a fire. They free dive in shallower water up, to 10 metres, once every two minutes. For deeper dives, up to 30 metres, they use a weight to take them down. They average a bottom time of a minute. At 30 metres they dive once every four minutes. They have real cold adaptation with a raised BMR and a lower shivering threshold. Measurements showed that they voluntarily stop diving when they reach a rectal temperature of 34°C.

The best insulation is a dry suit. There was an American in the 1890s who had made a reputation in winter rescues at sea. A rubber manufacturer made him a waterproof suit to help him in his rescues. It was so efficient that he was able to have it developed into a drysuit which allowed him to float down rivers all over the world. This principle was taken up during the Second World War when an immersion suit over flying clothes effectively prolonged survival in Arctic seas many times. Until the advent of the immersion suit the pilots of crashed planes were dead when picked up, often within five or ten minutes of ditching.

The wet suit works by trapping a layer of water against the body. This layer warms up to skin temperature and is insulated from the rest of the ocean by the bubbles in the neoprene. Wet suits are compressed with depth and so become much less efficient insulators. For best results the hood should be integral with the jacket, which should have a spine pad, to fill the vertebral gutter and reduce water movement in the suit. The most efficient wetsuit is skin two sides (smooth both sides) as this is the minimum surface area. Textured wetsuits have an extra surface area of about 30%. This leads to extra evaporative cooling out of the water. Nylon 2 has even more extra surface area to loose heat from.

Electrically heated suits have been tried and found wanting as there are troubles with wires breaking at movement points.

The best method of adding heat to the diver that is in use at the moment is the hot water suit. Hot water is pumped down to the diver through an umbilical. The umbilical restricts his mobility by one third.

Dry suits are excellent insulation, but have buoyancy problems. Thermal regulation is controlled by the hypothalamus and is automatic.

Man functions in a range of ±3°C. He is incapacitated soon after exceeding these limits. The comfort range is only 1.5°C each way and the body undergoes considerable changes to maintain itself in this range. Man contains about 6,000 to 7,000 calories. He develops problems if he loses or gains 300,000 calories.

When core temperature drops 1°C metabolic heat production is increased, and shivering starts if it has not already started. When the body is cold, and is removed from the cold environment, the core temperature continues to drop, the afterdrop, which can be as much 2°C. This can cause problems with cardiac action.

Vasoconstriction and continuing cold eventually leads the cold dilatation. Here the blood vessels become temporarily unconstricted, allowing normal blood flow. This warms the extremity, and heat loss rises. Then the blood vessels contract again. The process is repeated at intervals.

If you get hypothermic enough to stop shivering and feel good, you are likely to vasodilate due to lack of central control as you have little heat production you lose heat very rapidly.

At 34° C there is a definite drop in performance. Below that performance is very poor.

A well protected diver in a quarter inch wet suit will demonstrate a decrease in efficiency after an hour at a water temperature of 65°F; he has a 30% loss at 40°F. Simple well learnt tasks are less affected than complicated less well learnt ones. Fine digital manipulation suffers an 80% loss after one hour in cold water. Manual assembly offers a 60% loss.

High heat loss areas are the head, which has virtually neither insulation nor vasoconstrictive capacity, base of neck, sides of chest and axillae, and the groins. This has been demonstrated by thermography.

Heat adaptation; those from hot climates feel colder in cold water than those accustomed to the cold water. When you move to the tropics you dive without a wet suit at first, but soon find that a wet suit is necessary to preserve thermal balance.

Hayward et al. have shown slower cooling in water if groups huddle close or if individuals adopt Heat Escape Lessening Posture. This is a significant improvement over drown proofing as you keep your head out of the water and so loose less heat.

Divers are not only at risk from cold, for two men died in the North Sea oil fields from hyperpyrexia. A combination of circumstances resulted in extra pressure being added to a warmed chamber and the heat load of compression was fatal.

In saturation diving divers lose weight. Some of it is water loss, but some of it is body tissue. Up to 25 lb have been lost by divers in saturation in the North Sea. By losing body weight the diver loses heat tolerance. The lean lose weight faster than the fat.

Rewarming methods range from hot baths, to inhalational warming (which has problems to overcome) to passive warming.

Hayward et al. have designed a jacket, which looks like a thick windproof slicker, which has quarter inch neoprene inside it, which is for use on boats or watersides. If you fall in the jacket is buoyant and floats you had up, and there is a flap inside which allows it to convert to the top half of a wet suit so providing good thermal protection. The U-Vic Thermofloat is available in Australia from Protector (safety equipment firm).