#B25 Diver Thermal Protection in Cold Water Immersion

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Abstract

Background: Diver thermal protection continues to limit diving scenarios. Previous work has shown that a diver thermal protection system (DTPS) comprised of a heating/cooling system and 6 zone tube suit could protect divers, in hot and cold water, but it had limitations of size, pressure compensation and power consumption. The purpose of this project is to modify the DTPS for use in cold water, minimizing its size and power requirement and eliminate pressure compensation.

Materials and Methods: The original DTPS has been redesigned to provide protection in only cold water. Two smaller (3"cylinder, 24" long) units, that do not require pressure compensation, perfuse a two zone tube suit (MDTPS). Men will dive (n = 8) for up to 3 hrs in 5-20^oC water using the MDTPS while skin temperatures (Ts) and core T (Tc) are measured. The relationship between the T of the water supplied to the tube suit will be varied from 31^oC to 34^oC while measurements of Ts, Tc and power consumption will be determined to establish the suit perfusion T that minimizes power requirement.

Results: Four subjects are currently participating. The MDTPS set to perfuse the suit with 34^oC water maintained Tc at 37.1^oC and Ts of the torso, fingers and toes at 32.2, 25.8, 20^oC respectively, all within acceptable limits. Total electrical power to heat the divers was 588W, and thermal energy delivered was 320W. Further reductions in power are expected as the perfusion T is lowered in the two zone suit while maintaining acceptable T_C and Ts.

Summary: These preliminary results indicate that the MDTPS can keep divers' Ts and Tc within acceptable limits. With a suit perfusion T of 34^oC , the power requirement remains high. It is expected that reduction of the suit perfusion T will lower the power requirement while maintaining Ts and Tc.

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Introduction

•Divers are exposed to water temperatures below thermoneutral for prolonged periods of time.

•Current diver protections systems do not provide adequate protection.

•Previous studies have shown that a Diver Thermal Protection System (DTPS) could protect divers' in both cold and hot water.

•The DTPS maintained body thermal status, utilizing an independently perfused six zone tube suit that provided total body coverage.

Fig. 1. Original DTPS

•The DTPS had advantages of heating/cooling capabilities, did not use consumables, was rugged and reliable.

• However, this system had some limitations; notably size, power consumption, and required pressure compensation

Purpose

▪Adapt the original DTPS into a smaller package, using fewer zones while providing total body coverage (mini-DTPS).
▪Test the mini-DTPS to determine the minimal temperature of the water that the tube suit could be perfused with to maintain skin temperatures (T) above 20^oC and the core T above 36 ^oC in waters as cold as 5 ^oC at rest.
▪Determine the thermal power requirements to heat the diver and the electrical power to run the DTPS.

Protocol

- Initially 4 divers would be exposed to cold water Temperatures of 5,10,15,20,25 ^oC
- Divers wore the mini-DTPS and a two zone tube suit (see Figure for zone configuration) under a 6mm wet suit breathing from scuba.
- Inlet water T to the tube suit was varied from 31^oC to 34^oC in individual experiments.
- Measurements of Tskin and Tcore were made continuously for up to 3hrs.
- Measurements of thermal energy to heat the diver were determined from the flow through the tube suit and the delta T between the inlet-outlet of each of the two zones.

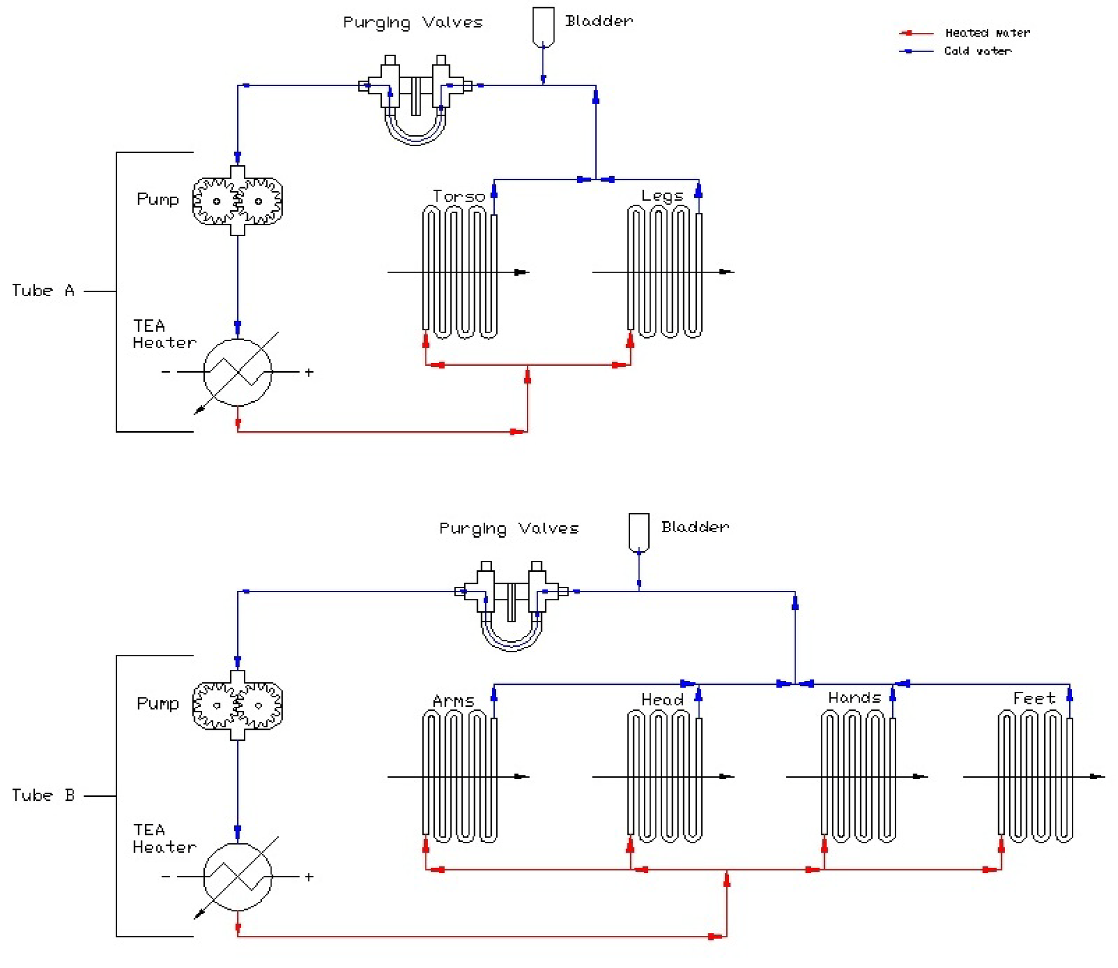
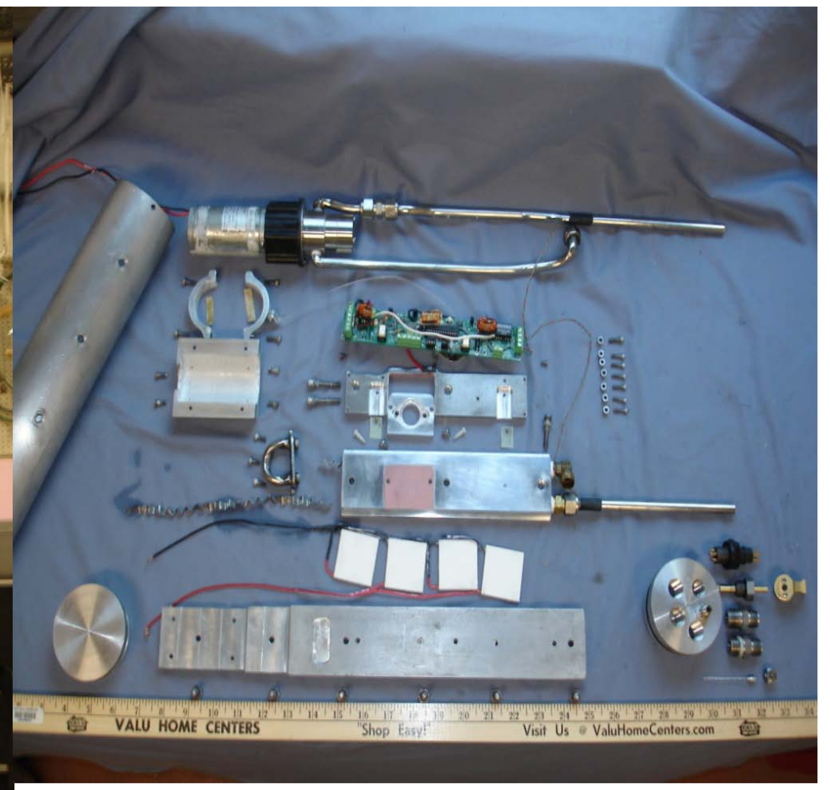


Fig. 2. Tubesuit Configuration

- Tube A perfuses the torso and legs and is driven by one mini-DTPS
- Tube B perfuses the arms, head, hand, feet and is driven simultaneously by a second DTPS
- This design considers the pressure drop in the two zones and optimizes the flow to each zone taking into consideration the heat balance of the body segments.

Mini-DTPS on a diver

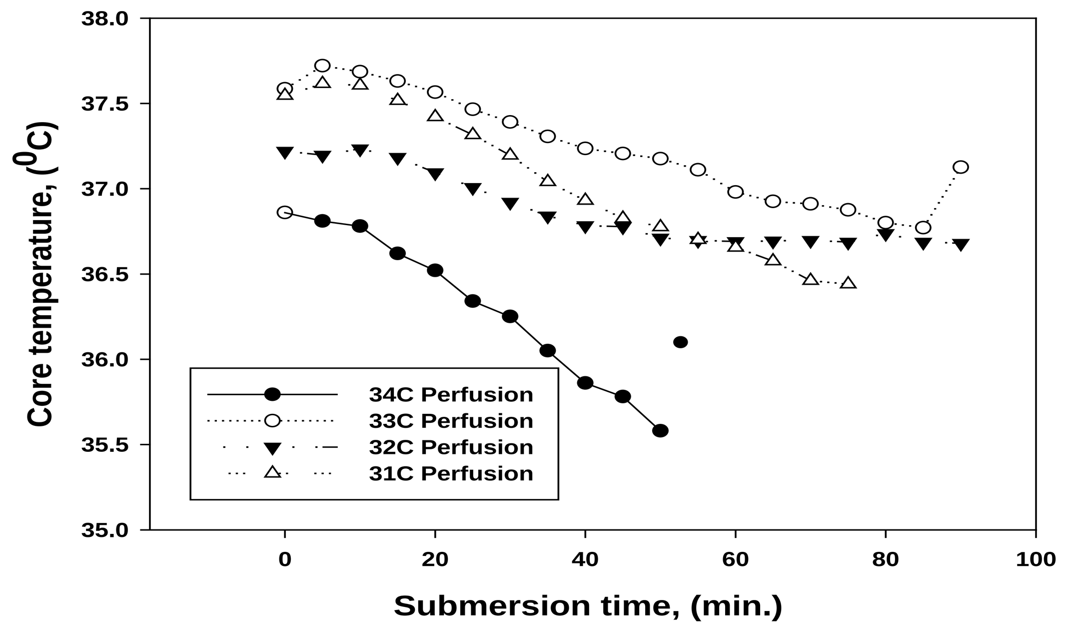
Internal Components



Upper: circulating pump; Upper controller;
Middle: Thermal Electric unit;
Lower heat sink;
Remaining: assembly parts

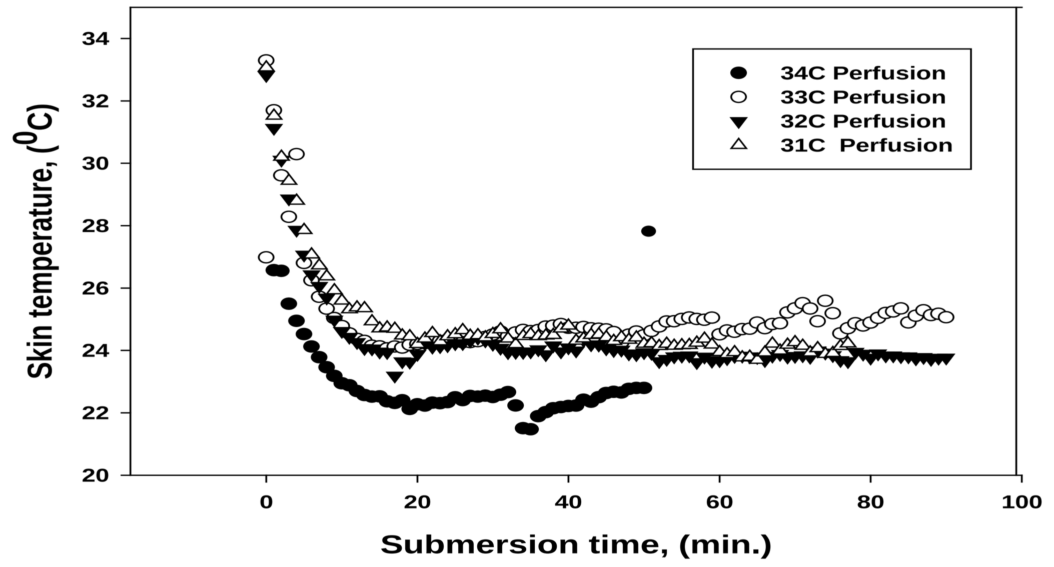
Results

Core temperature (5 ^oC)



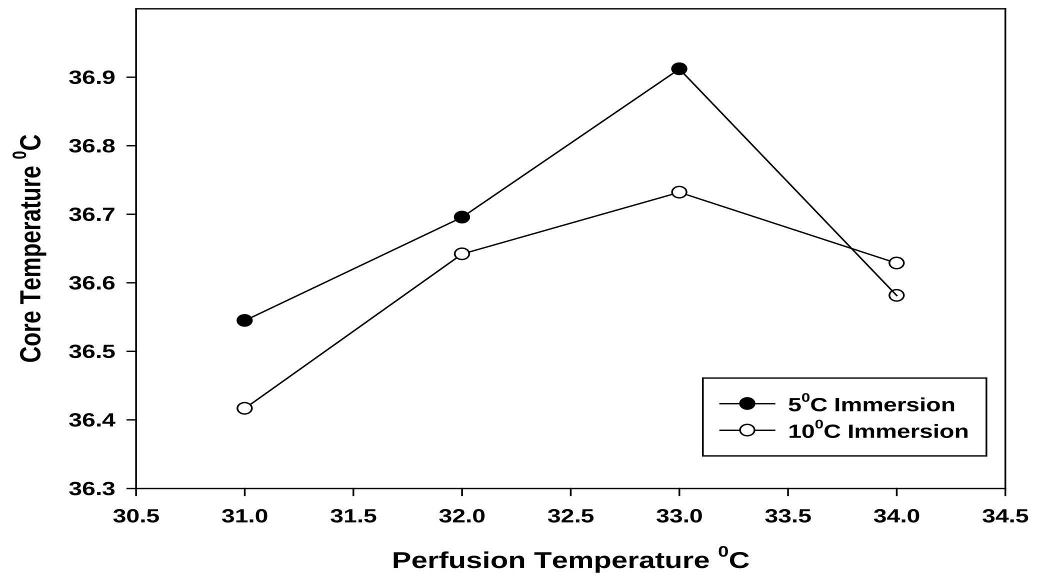
•Core T with 34^oC perfusion of the tube suit did not remain above desired level
•Core T with 33, 32, and 31 ^oC perfusion of the tube suit remained above desired level

Finger temperature (5 ^oC)



•Finger temp remained above desired level for all perfusion temperatures

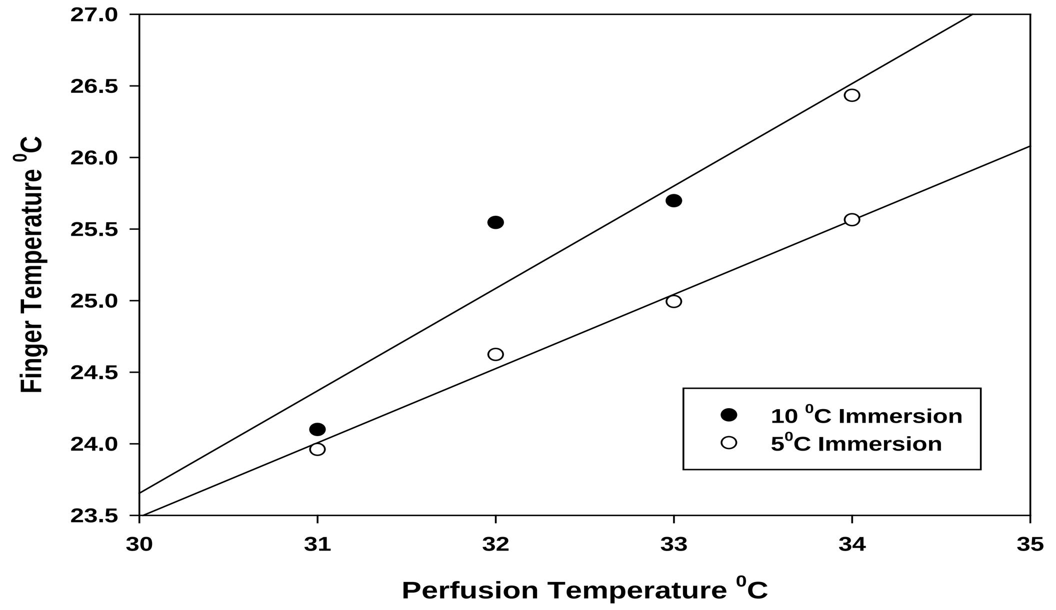
Steady State Core Temperature as a function of Perfusion Temperature



•Core T was decreased with 34 ^oC perfusion T
•Core T with 33^oC, 32^oC, 31^oC decreased linearly, but remained above desired level

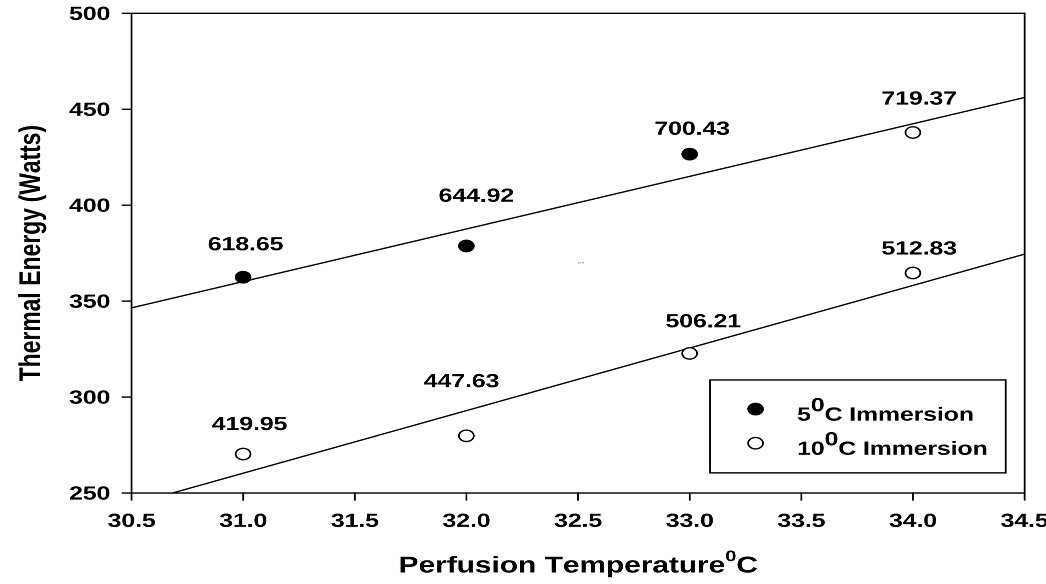
Results

Steady State Finger Temperature as a function of Perfusion Temperature



Finger T decreased linearly with the reduced perfusion T, but remained above the desired level at all perfusion Ts

Thermal Energy Required



Thermal energy to heat the diver is plotted as a function of perfusion T
The numbers above the points are the electrical power requirement
To heat the diver the regression was: = 27.4 – 489 in 5 ^oC and 32.6 – 751 in 10 ^oC
The electrical power was: = 35.8 – 492 in 5 ^oC and 33.7 – 624 in 10 ^oC

Summary

- These preliminary findings:
- Confirm previous studies that keeping skin temperature too warm (34 ^oC) results in a greater drop in core temperature than cooler skin temperatures, potentially causing hypothermia
- Show that perfusion Temperature of 33 ^oC, 32 ^oC, 31 ^oC would appear to keep core and finger T above desired levels
- Show that the power to maintain the diver in the desired skin and core T range is minimized with 31 ^oC
- Perfusion temperature of 31 ^oC would appear to provide protection and use the minimal power, thus be optimal in cold water, but this must be confirmed by additional experiments