Designing Hyperbaric Decompression Chambers

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Deep sea divers live and work under extreme conditions. It is not untypical for a diver to spend over 20 days living and working underwater. In such instances they share a decompression chamber with other divers (between 2 and 5) who may be working on different shifts. Given the need to redesign and update this accommodation, a questionnaire survey was undertaken of divers to determine what the main issues were with the accommodation. Issues related to not just the quality of communication with the outside world. The recommendations were fed into a series of concept designs and a prototype build which is currently undergoing client approval.

Introduction

The objective of the work was to improve the current conditions within hyperbaric decompression diving chambers based upon an understanding of the range of different diver requirements. Current chambers are sealable pressure vessels with entry and exit hatches for divers that are used after the end of a dive in order to safeguard against decompression sickness (DCS) more commonly known as the bends. DCS is the name given to the variety of symptoms that are suffered by divers exposed to either a decrease or more often an increase in the pressure around their bodies.

Putting the user at the centre of the design of the chamber involves consideration of the divers living environment in terms of the restricted physical space available for them to be able to conduct everyday tasks as well reducing the cases of potential infection caused by the need to control the atmospheric conditions within the chamber. The divers' cognitive requirements are also necessary to take into account when they are faced with remaining in the chambers for unbroken time periods of over a month. The application of human factors can therefore lead to improvements in health and safety, ease of use, comfort and quality of working life and leisure.

Research

The initial stage of the project was to review how the current chambers were being used by the divers. Due to the unpredictable availability of the diving chambers it was not possible to conduct direct observation, interviewing and task analysis. Instead divers' experiences and the understanding of their living conditions were achieved using a questionnaire approach; the most appropriate method based on published guidance (Boynton & Greenhalgh, 2004, Kirakoski, 2000).

Additionally the physical workplace was assessed by the client and a report compiled based on divers' reviews of the prototype build and compliance with the general guidelines pertaining to diving chamber space and furniture, namely:

- Sintef 'Design Requirements for Saturation Diving Systems: The living chamber'
- Offshore Standard DNV-OS-E402

These Norwegian guidelines give very prescribed recommendations on the internal components for the diving chamber e.g. bunks, seats, tables etc. and are based upon the size and construction of diving chambers that the design aims to satisfy as opposed to British Standards which are not as specific and open to interpretation. Panero & Zelnick (1979) was used as a reference for the design details not mentioned by Sintef in terms of determining seat incline, heights of cabinets and mirrors.

Questionnaire development and design

The questionnaire was designed by third year intern students and the author following a series of meetings with the project manager and client. The meetings flagged up assumptions that might have occurred about the use of the chamber without initial client feedback. Its principal purpose was to provide detailed information about what kind of activities divers would like to do in the chambers, the amount of private space that they have and their working shift patterns that could provide the designers with an insight into the life of the divers in the diving chamber and the problems they experienced. From this a set of user requirements could be devised.

Questionnaire distribution

The questionnaire was distributed in mid July 2006 to the client company and divers currently engaged in deep sea diving who would form the end user population of the chamber. They had a three fold purpose:

1. To enable the Coventry design team to understand more about the nature of the work and leisure time of deep sea divers
2. To provide initial input into early concept designs
3. To understand communication with the outside environment.

Results

Personal details

The results are based on 28 (sometimes partially) completed questionnaires. The age of the divers varied from 30+ to under 60 years of age, with both the modal and arithmetic mean age lying in the 41-50 year age range. The majority of divers in the sample have over 20 years diving experience. This trend indicates that diving has been their main occupation, and they are likely to be highly skilled, used to diving conditions and the decompression chamber. Most of the participants' longest period of time in a decompression chamber was between 26-35 days.

Nature of work

36% of the respondents reported muscular problems, 57% stated they had no problems. Much of the work undertaken was of a highly demanding, physical nature. There was also a general reporting of arm, neck, shoulder and lower back pain, sore wrists and fingers.

Physical fitness – away from work

All respondents rated themselves as having either average (10 respondents) or above average fitness (17 respondents), with one respondent rating himself as having a high level of fitness. When not at work, the hours per week spent exercising varied from under 4 to up to 16 hours, with the average time lying in the 4-8 hour range.

The types of exercises undertaken were varied with most of the respondents undertaking more than one form of exercise. The most popular form of exercise being that related to leg strength; which could be explained by the fact that divers do not use their legs extensively when they are diving and therefore need to make sure that sufficient circulation is maintained in these limbs. The majority of activities undertaken were non competitive. Some of the gym based activities, such as resistance bands were also used in the decompression chamber.

Physical fitness – during work

The amount and type of exercise undertaken changed when the divers were in the decompression chamber, with the majority of divers never exercising inside. However the confined space of the chamber and the conditions of the space where exercise could be carried out (i.e. the shower/wet room) made this difficult to achieve. For some, exercise started when the decompression started. Exercises undertaken required little (e.g. resistance bands, bungee tubes, stepper, dumb bells and light weights) or no equipment (sit ups, press ups, lunges, stretch, lateral raises and bicep curls, crunches). Sit ups and steps were the most frequently mentioned (three occurrences each).

Shift work

It was very clear that having two different shifts operating from one chamber caused disruption to sleep with 87% of the divers commenting upon the affect of noise intrusion from such items as the operation of locks and hatches and teams passing through the chamber when others were asleep. There was also a change in circadian rhythms, with a drift towards shorter days.

Communication patterns

Communication with colleagues outside the chamber was mainly related to instructions about the dive and took place when needed via radio, email via flashcard, fax and intercom. This communication would vary from 5-10 minutes 3 to 4 times a day, once or twice a shift from a few minutes to up to 2 hours.

Everyone communicated with their family and friends with the amount of time, method and frequency of the communication varying. Some of the divers were in contact with their families every day, in some cases 2 or 3 days a week.

Living environment

In the chamber there are essentially three different areas; namely the shower/toilet, living/eating quarter and sleeping space.

Ingress and egress from the chamber is currently through a circular hatch located within the shower/toilet area. Another circular hatch is located from the shower/toilet area into the main living/eating quarters. Approximately 75% of the divers questioned had not experienced problems in this respect.

Only two respondents had no issues about the interior. For the rest of the divers comments were associated with:

- Shower/toilet: privacy within this area
- Living/eating quarter: seats – no support for back and generally a lack of seating with much time being spent on bunks. Moreover the space inside the chamber did not allow for a table. Neither were there any communication facilities such as the internet or e-mail or wi-fi. The lack of integral entertainment facilities meant that many divers had to take their own personal items in with them ranging from the majority taking books, through to personal electronic equipment, food and spare clothes.
- Sleeping space: bunks – considered too small and narrow and mattress uncomfortable, and not enough privacy provided by the curtains.

In terms of responses covering all areas of the chamber, both general and specific recommendations can be made regarding the use and design of space, changes in work pattern down to the design of shaving mirrors and mattresses. The most important areas would seem to relate to:

- Provision of separate chambers for different shifts
- Better toilet, sleeping and sitting areas –spaces, fixtures and fittings
- Better communication facilities
- Noise reduction
- State of the art entertainment facilities, and built in leisure facilities
- Provision of an exercise area

Questionnaire interpretation into design

The detailed report was used to direct design in terms of converting concept sketches into computer generated images generated by Rhino Photoshop and Illustrator, examples given in Figure 1. Original dimensioned information came from the client as Solidworks files, e-drawings, pdf drawings and jpgs. Rhino work was translated into iges files for 5 axis machining to create some of the components to be incorporated in a full sized mockup built by a professional team supported by eight third year intern students.

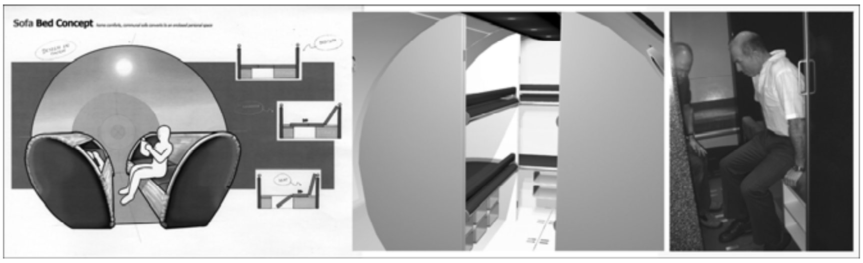

Figure 1. Sketch concept translation into computer file and mockup evaluation

This mockup has been used to facilitate the next development of the chamber design by having eight divers who had all completed the questionnaires and 4 medical experts from Norway further comment upon the suitability of the interior and compliance of relevant standards. These reviews consisted of allowing the divers to test the seating and bunks inside the mockup in terms of sturdiness.

A further visit was made by a retired diver and a Dive System Coordinator who together with a member of the ergonomics teaching staff informing evaluated the design against the requirements that emerged from the questionnaire. This approach provided a more in depth understanding of the scenario of usage associated with the furniture and equipment inside the chamber.

Conclusions

Not all the issues raised by respondents could be addressed directly as some issues related to personnel, management and financial concerns.

However, what emerged from the questionnaire approach was that divers strongly expressed a need to be included and have ownership of the design. The final design needs to be refined by divers' first hand knowledge of the problems they face within the chambers as the design team have no first hand knowledge or experience of the working conditions, the work routine or characteristics of the end user population.

To date the reviews of the prototype build have been favourable and the designers have a better awareness of divers' requirements.

Recommendations

It is recommended that further site visits be conducted with a more structured approach in order for the designers to better understand 'a day in the life of' divers by videoing divers highlighting the current issues with the use of the interior. These would not only provide invaluable information and insight into the design requirements, thereby leading to a better design, but also ensure that the divers are active stakeholders in the design of their new environments.

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