Lost Bell Survival
Trainers' Guide

International Marine
Contractors Association

www.imca-int.com

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The International Marine Contractors Association (IMCA) is the international trade association representing offshore, marine and underwater engineering companies.

IMCA promotes improvements in quality, health, safety, environmental and technical standards through the publication of information notes, codes of practice and by other appropriate means.

Members are self-regulating through the adoption of IMCA guidelines as appropriate. They commit to act as responsible members by following relevant guidelines and being willing to be audited against compliance with them by their clients.

There are two core activities that relate to all members:

- Competence & Training
- Safety, Environment & Legislation

The Association is organised through four distinct divisions, each covering a specific area of members' interests: Diving, Marine, Offshore Survey, Remote Systems & ROV.

There are also five regional sections which facilitate work on issues affecting members in their local geographic area – Asia-Pacific, Central & North America, Europe & Africa, Middle East & India and South America.

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This trainers' guide and accompanying video have been produced in conjunction with the UK Health & Safety Executive.

IMCA expresses its thanks and appreciation to the various members and those in HSE and MaTSU who contributed towards the preparation of this video and accompanying trainers' guide.

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1 Introduction

The Health & Safety Executive (HSE) and the International Marine Contractors Association (IMCA) recognise that a 'lost bell' diving incident is fortunately a rare occurrence, but one which is life-threatening for the divers concerned. Previous experience tells us that the divers' chances of survival will be enhanced if the divers and their support crews know how to make effective use of the emergency survival equipment provided in each diving bell. This requires training so that divers are familiar with the equipment and support crews recognise their role in deploying and maintaining an effective survival system.

The HSE and IMCA have therefore jointly sponsored the video 'Lost Bell Survival' and this accompanying 'Trainers' Guide'. Together the video and guide are designed to supplement in-house training for dive teams, dive supervisors, life support technicians, maintenance personnel and diving school trainees, in use of the survival equipment provided in a diving bell or welding habitat.

Each diving contractor may have company-specific emergency procedures and equipment which are unique to that company or diving operation. Contractors will therefore wish to take account of these specific requirements when designing their in-house training programme. However, the video and guide will assist by highlighting the basic procedures which should be followed by divers involved in a lost bell incident.

Please watch the video and read this guide before preparing to train your target audience.

2 Objectives of the Training Programme

The aims of the training programme are to:

- enhance divers' prospects of survival in a 'lost bell' incident;
- provide training in the procedures to be adopted in the 'lost bell' incident;
- provide training in the effective use of the survival equipment stored in the diving bell or welding habitat;
- disseminate information on why it is essential to deploy, maintain and use the equipment effectively.

3 Background to 'Lost Bell Survival'

A potential risk of saturation diving techniques involving the use of diving bells is the possibility that the diving bell and its divers cannot be recovered from depth to the surface, either because the lift wire and umbilical are severed or because the bell is trapped. Such an incident is referred to as a 'lost bell' if the supply of breathing gas or heating from the surface are lost.

Some previous lost bell incidents have proved fatal. Fortunately there have been very few such incidents or 'near misses' in recent years; however if an incident does occur, the divers' lives may be at risk. The main threat is severe hypothermia, together with the risk of carbon dioxide poisoning. Therefore thermal survival bags and regenerator units with CO_2 gas scrubbers are provided in all diving bells to protect against these threats.

For this equipment to be effective, it has to be deployed, maintained and used in the optimum manner. Previous experience from incidents and research trials shows that if the equipment isn't used properly, or is damaged, the risk to the diver of life-threatening hypothermia is significantly increased and the time available to organise a successful recovery is reduced.

The purpose of the training programme is therefore to ensure that divers are trained to take the most appropriate actions to assist with their own survival; and that support crews recognise the critical importance of ensuring that the emergency equipment is 'fit for purpose' for every dive.

The type of lost bell incident described here may also occur to divers within an underwater welding habitat. The emergency equipment described here should be provided in habitats, and the key points on use of the equipment are also relevant to divers trapped within a welding habitat.

3.1 Survival Time versus Rescue Time

Under ideal laboratory conditions men have endured cold heliox conditions at pressures equivalent to 150m for 24 hours. In other research trials, tests have been stopped after as little as six hours when the volunteer divers were chilled to a level where it was no longer safe to continue the trial. **Assuming that the survival equipment is undamaged and is used effectively by the divers**, computer predictions of survival in a lost bell vary from about 12 to 24 hours, depending on individual physiology, bell cooling rates, depth, whether the diver is already cold from the dive before the onset of the emergency, and the thermal effectiveness of the emergency equipment. However if other factors work against the diver, for example discovery that the soda lime in the thermal regenerator unit is wet and unusable, or the survival bag is soaked, **predictions of survival time decrease dramatically, possibly to as little as six hours**.

If the body cools to below a core temperature of about 34°C, the diver will become semi-conscious, confused, unable to co-ordinate motor function and lethargic. He will be unable to respond effectively to the emergency or to assist with his own rescue. At around a core temperature of 30°C he will be unconscious. It is difficult to predict how long it may take individuals to reach such an incapacitated state. Once the core temperature falls below a certain point, it will not be possible to rewarm the diver by passive means, e.g. radiant heat or thermal insulation, and his condition will deteriorate even further. It is therefore essential that divers in a lost bell preserve body heat as soon as and for as long as possible. Ideally the diver will then be able to assist with his own rescue, for example by making a wet transfer, or at least should be capable of being rewarmed in the bell.

Rescue time will depend on the nature of the emergency and the time required to mobilise rescue facilities, for example a rescue team operating from a second diving bell. This may vary significantly depending on whether the parent DSV has a twin bell system in operation, or whether another DSV has to be summoned in support. These factors should be considered during the planning of the diving operation. However the divers will need to prepare themselves, mentally and physically, for a potentially long wait. There is little doubt that the chances of survival will be greatly enhanced if all personnel who may be involved in a lost bell incident understand why the emergency procedures need to be followed and have practised with the relevant equipment before an incident occurs.

3.2 Respiratory Heat Loss

In a normal cold environment, receptors in the skin detect low temperatures which trigger the brain to initiate shivering; shivering is the body's response to reduce the rate of heat loss. In the heliox environment, most heat is lost through the respiratory tract, which does not trigger the shivering response. Heat will be removed from the body core without the diver being aware of it. The diver may still feel comfortable, but the slow drain of heat from his body may be life-threatening. If shivering is triggered by low skin temperatures, it cannot be sustained indefinitely; fatigue will set in and this will be followed by a further drop in core temperature.

If the bell is warm when contact with the surface is lost, several hours will pass before the bell gas will cool to nearly the temperature of the sea. However the gas inside the bell will begin to cool below the comfort range before this, and this will result in chilling of divers who breathe in this cold gas without any means of heating it.

To minimise respiratory heat loss and to remove excess CO_2, the survival equipment includes:

- a thermal regenerator unit which acts as a small heat exchanger to conserve the heat of the divers' expired gas;
- a CO_2 scrubber which removes the CO_2 from the divers' exhaled breath and uses the exothermic reaction of the chemicals to heat the inspired gas.

Together the combined unit is very effective in preventing respiratory heat loss. In previous incidents and trials, divers who did not have the benefit of regenerator units became debilitated several hours sooner than others who did use the equipment in an effective manner.

It is therefore essential that the divers know how to use the thermal regenerator unit and appreciate the need to put it on as soon as possible after the start of the emergency.

3.3 Passive Thermal Protection

The rate of heat transfer from the divers' bodies to the environment inside the bell is by convection and conduction. Both can be reduced by increasing the thermal resistance of the garments worn by the diver, and providing insulation between himself and the cold hull of the bell. The emergency equipment provided therefore consists of:

- a thermal undersuit and bag;
- an inflatable mattress*;
- a harness*.

* The individual components of each manufacturer's system vary, but as a minimum all provide some form of undersuit or vest and a survival bag. The manufacturer's system demonstrated in the video also incorporates an inflatable mattress and a harness.

Heat loss will be increased if the diver and the thermal protection are wet, due to evaporation of the moisture and increased conduction of the wet material. The value of the thermal insulation of the survival bag may be reduced by as much as 40% if it becomes wet.

It is important that divers recognise the need to take all possible steps to keep the survival bag dry.

3.4 Other Factors

For the body to continue to generate heat by shivering, it requires sources of carbohydrate as a fuel. The bell emergency kit should therefore contain high-energy carbohydrate bars and fluids.

It is recognised that a bell is a restricted space and that it will be difficult for divers to put on the equipment. It is essential that the divers work as a team to help each other; this is the only way in which it will be possible to unpack and don the emergency equipment.

While the divers are preparing the bell and the emergency equipment they will be working hard and generating CO_2. To avoid a hazardous increase in CO_2 levels, the bell scrubber should be run until the divers are settled inside their survival bags. In addition, the thermal regenerator units should be put on as soon as possible, mainly to preserve body heat but also to reduce CO_2 levels. This is essential if the bell scrubber is not operational.

4 The Training Programme

4.1 Resources

The video 'Lost Bell Survival' is designed to be a key component within an in-house training programme. An effective programme will require the following resources:

- training room or mess room, free from interruptions;
- survival equipment, consisting of thermal survival bag, thermal regenerator/CO_2 unit, towel, emergency rations and any other company-specific kit provided in the bells;
- knowledge of company-specific emergency procedures;
- 'Lost Bell Survival' video;
- this 'Trainer's Guide';
- video player.

The video can be shown offshore on board a DSV or at the onshore base. The video lasts approximately ten minutes; it is likely that about an hour will be required to show the video and to familiarise crews with the survival equipment provided by your company.

4.2 Outline Training Programme

It is recommended that the video is shown first. This will introduce the procedures which should be adopted by divers in the event of an incident and put them in context by explaining the threat to life posed by hypothermia in the unique conditions of a 'lost bell'.

This should be followed by hands-on training for the dive teams in the operation of the kit provided in your company diving bells. There are several designs of survival bags currently on the market or in use within the diving industry. Although the principles on which the various systems work are identical, there are some variations in design. It is therefore essential that your teams have the opportunity to experience your own company kit.

This training should identify the separate components of your survival system e.g.:

- survival bag, undersuit, inflatable mattress and harness;
- towel, if provided;
- regenerator unit with oral nasal mask and CO_2 gas scrubber;
- spare gas scrubber canister or additional supplies of soda lime if provided;
- emergency rations;
- torch;
- means of collecting urine, if provided.

Means of operation should be demonstrated and if possible divers should have the opportunity for hands-on practice in the use of the emergency equipment. Familiarity with the kit will increase confidence and competence in its use.

4.2.1 Procedures

The generic procedures outlined in the video are:

Preparing the bell

- Divers should dump unnecessary gear to create space (invite the divers to consider what they would really need in a lost bell emergency).
- Excess water should be bilged to avoid the survival bag subsequently getting wet.
- The hatch should be closed.
- The umbilicals should be coiled to sit on (unless an inflatable mattress is provided in your survival kit). In doing so, **the bottom hatch should be kept clear so that rescuers can access the bell.**

Emergency equipment – thermal survival bags

- The divers should get dry before opening the survival kits.
- After opening the pack containing the survival bag, the material of the bag should be shaken to distribute the insulation material.
- The diver should urinate if possible before getting into the suit, and should later use the urine collection device provided. If the diver is forced to wet the suit, or has to get out of his suit to avoid wetting the bag, he will experience significant heat loss.
- Insulation should be provided between the diver and the bell hull, either by use of the inflatable mattress built into the survival bag, or by sitting on the umbilical. A net rigged across the bell for the divers to lie on has also been used successfully in research trials to keep the diver away from excess water and condensation on the bell hull.
- The integral harness should be tied off to the bell wall. **In the event of the diver later becoming semi-conscious, being tied on will prevent him collapsing over the bell hatch and impeding access by rescuers. A net will also fulfil the same purpose.**

Thermal regenerator unit and CO_2 scrubber

The key point is that this unit has to be used effectively, which means:

- Keeping the unit on at all times;
- Ensuring that the oral nasal mask is a good seal, preventing cold bell gas leaking into the mask;
- Making sure that the oral nasal mask fits comfortably;
- Knowing how to adjust the gas temperature if the gas becomes too hot, instead of being tempted to remove the unit;
- Knowing that even if the soda lime becomes exhausted, keeping the unit on will still provide some protection from heat loss.

Emergency rations

The emergency rations should include high-energy carbohydrates, preferably in both solid and liquid form. One carbohydrate bar (21g) should be eaten every hour. Dehydration may be prevented by taking 250ml of a carbohydrate drink instead of a solid bar every six hours, or by drinking other fluids provided such as water. Drinks should be kept warm by keeping them close to the body inside the survival bag.

Inspection and maintenance

The importance of regular inspection should be emphasised to both maintenance and dive crews. It is essential that survival bags are inspected in accordance with an agreed schedule for evidence of:

- damage to the protective packaging e.g. broken zips, rips in the packaging material;
- moisture within the bag e.g. wet feel, mould. Ideally, bags should be checked for dampness by using a dampmeter probe inserted into the bag material through the zipper.

Regenerator units should be inspected for:

- damage to the unit and soda lime scrubber, e.g. cracked container, split hoses, spillage of soda lime;
- degradation of the soda lime due to ingress of moisture.

Ideally, kits should be checked prior to each bell run where it is practical to do so. Any damaged kits should be replaced immediately with a fully functional kit.

Company procedures for the regular change-out of kits for return to shore for servicing, maintenance and re-packaging should be explained.

Support crews should recognise that in the event of a lost bell, the divers' survival is critically dependent on the effectiveness of the survival equipment deployed in the bell.

5 Further Reading

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