Use of
Battery-Operated Equipment in Hyperbaric Conditions

International Marine
Contractors Association

www.imca-int.com

IMCA D 041
October 2006

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.

IMCA D 041

This document – an update of the earlier AODC 062 – *Use of battery operated equipment in hyperbaric conditions* – has been produced for IMCA under the direction of its Diving Division Management Committee.

AODC 062 is now withdrawn, superseded by this document.

www.imca-int.com/diving

Use of Battery-Operated Equipment in Hyperbaric Conditions

IMCA D 041 – October 2006

Appendix

1 Introduction

Until 1993, there was no known legislation or guidance available on the use of battery-operated appliances in hyperbaric conditions and the possible safety implications surrounding the use and/or failure of such equipment (a) within a pressurised chamber and (b) during and following subsequent decompression. To address this, IMCA's predecessor organisation published AODC 062 in September of that year. IMCA has now reviewed AODC 062 and has updated it with this document to reflect battery-operated equipment currently in use.

Divers have for some years introduced items of personal electronic equipment such as calculators, personal MiniDisc players, etc. and, more recently, mobile telephones and laptop computers into a hyperbaric environment.

The purpose of this document is to evaluate the potential hazards of such systems when used in hyperbaric conditions and offer guidance on their application.

This guidance may be applied in any geographic area provided national regulations are adhered to.

2 Electric Fire and Shock

Items developing internal voltages in excess of 30V dc could potentially be a source of electric shock. In practice, very few items of equipment falling within the categories covered here will generate voltages significantly above this figure. The major safety hazard is that of overheating and fire, caused by a partial or complete electrical short-circuit developing across the batteries. This can also lead to leakage of toxic material (see section 4). The factor determining the level of hazard is the value of the current which can potentially be supplied by the battery for a period under short circuit conditions. Even quite small batteries, particularly those of the rechargeable nickel-cadmium (NiCd), lithium, nickel-metal hydride (NiMH) types, are capable of supplying some tens of amps for a short period. This also applies to non-rechargeable primary cells.

All batteries possess a quality termed 'internal impedance' which determines the maximum short circuit current which can flow. The lower the numerical value in ohms of the internal impedance, the higher the short circuit current, resulting in a greater potential to overheat with the consequent risk of inducing a fire. In general, large capacity (A/hr) rechargeable batteries have the lowest internal impedances and small capacity non-rechargeable units the highest. Thus, large rechargeable batteries have the greater potential to produce a hazardous short circuit. Care should also be taken when charging that the correct charger recommended by the manufacturer is used and maintained correctly.

Both rechargeable and non-rechargeable batteries can age at different rates which could give rise to potential problems (see notes on Table 1 in section 6). Temperatures outwith manufacturer recommendations will have an adverse effect on the capacity and life cycle of the battery.

Current literature varies slightly in quoting the level of oxygen required to support combustion viz. 5% (Ref. 1) and 6% (Ref. 2). In order to provide the maximum safety factor this guidance assumes the maximum oxygen level to be 5%. This does not mean that there is greater potential for ignition in an atmosphere with oxygen content in excess of 5%. However, the propagation of any fire which does start will be enhanced by the oxygen in the atmosphere.

The devices considered in this note are all low-energy components. In order to create a serious hazard from such low energy devices, it would require a substantial mechanical accident of such magnitude as to cause a very significant short circuit on the batteries, resulting in ignition of flammable materials which would then be propagated in an oxygen enhanced atmosphere. This combination of circumstances, although theoretically possible, is extremely unlikely and can be further minimised by limiting the amount of power available from the batteries.

In order to assess the intrinsic safety of battery-operated equipment, comprehensive measurements and trials would have to be carried out on each individual item. In the absence of such definitive information, any judgement on safety must be based upon experience of the maximum size and type of battery that can be safely used under hyperbaric conditions in order to limit to a reasonably low figure the energy available to cause serious overheating (see notes on Table 1 in section 6).

3 Pressure-Related Effects

Equipment may fail during compression due to the collapse of one or more internal components. No serious hazard to the user is foreseen due to this factor. However, in the case of equipment containing vacuum devices, there is a risk of implosion.

Rapid decompression, e.g. in a medical lock, may cause failure of the equipment due to the ingress of helium during saturation. This can be a hazard to personnel outside the chamber by equipment exploding due to internal pressure.

It is possible that build-up of pressure due to helium ingress over a period of several days at depth may not be able to be released quickly enough even during routine decompression and could result in an explosion hazard.

4 Atmospheric Pollution

Certain items, such as batteries, contain potentially toxic materials, e.g. lead-acid, lithium sulphur dioxide, lithium etc., which may emit gas within the chamber (see notes on Table 1 in section 6). Subsequent pressure-related-effects resulting from seepage of helium from pressurised components or sealed units during or following decompression may, therefore, release toxic materials into the atmosphere, causing pollution.

5 Recommendations

It is recommended that this guidance, together with that given in Table 1 (Appendix 1) and its associated notes (section 6), be applied by onshore engineering departments in assessing the safety and suitability of equipment for use in hyperbaric environments in order that positive guidance can be given to diving supervisors.

6 Notes Applicable to Table 1

1. All items of equipment should have the prior approval of a competent person in conjunction with completion of a suitable and sufficient risk assessment carried out before use. Examples of categories of competence relevant in this case are 2, 3 and 4, as defined in IMCA D 018, section 3, and repeated below:

   Category 2

   A technician, certificated Class 1 Chief Engineer, or other person, all specialising in such work who may be an employee of an independent company, or an employee of the owner of the equipment (unless specific legal restrictions apply), in which case his responsibilities should enable him to act independently and in a professional manner.

   Category 3

   Normally a classification society or insurance company surveyor, but who may be an 'in-house' chartered engineer or equivalent (unless specific legal restrictions apply), or person of similar standing.

   Category 4

   The manufacturer or supplier of the equipment, or a company specialising in such work which has, or has access to, all the necessary testing facilities.

2. The possibility of explosive decompression due to helium ingress should be taken into account when decompressing equipment. Also the rate at which items are decompressed. In particular, great care should be taken in case of explosion when passing items in and out of the medical-lock, especially battery cases, also all equipment that creates a pressure barrier i.e. battery housing needs to have the seal de-energised to allow equalisation to occur.

3. Items containing potentially toxic materials which may emit gas within the chamber should not be permitted. If there is any doubt about the composition of a battery it should not be used until it has been assessed by a competent person. Where possible an alternative to batteries should be considered.

4. Battery power sources should ideally use cells no larger than 'AA' size (1.5v) NiMH rechargeable or their physical equivalent in non-rechargeable form (500 mA/hr). However, this may not always be practical. Some small equipment may use batteries with other cells of a higher voltage. In all cases a suitable and sufficient risk assessment must be carried out and, where necessary, additional protection may need to be fitted.

5. All batteries in the same pack should be renewed at the same time. When some cells in a battery are exhausted this places stress on the remaining cells with a resulting tendency for them to reverse polarisation.

6. All battery-operated equipment should be maintained in a functional and clean condition to minimise the risk of corrosion. Batteries which are kept in storage must be protected against corrosion and should be stored in a dry environment. Where batteries are likely to be affected by high humidity, they must be kept in suitable dry containers to protect them. Any battery which is affected by moisture or corrosion must be removed immediately from service and disposed of as set out in section 8 below.

7. No form of battery charging should take place within the chamber complex.

7 References

- International Institute of Welding – Commission VII Health and Safety – Hyperbaric Fire Safety
- US Navy Report 0994-LP-001-9020 Rev. 3 – US Diving Manual Volume 2 (Mixed Gas Diving)
- IMCA D 018 – *Code of practice for the initial and periodic examination, testing and certification of diving plant and equipment*

8 Disposal

Care should be taken in the disposal of batteries. It is important that they are discharged and that different types of batteries are separated for disposal. The disposal should be in conjunction with current regulations.

Battery-Operated Equipment in Hyperbaric Conditions – Recommendations for Use

The following list is not exhaustive and is intended as a guide (see notes in section **Error! Reference source not found.**.)

Recommendation for Use/Non-Use	Equipment	Comment
Prohibited	Rechargeable power tools	Potential physical damage to the hyperbaric chamber and its occupants from a tool of this nature renders it undesirable. Battery capacity is almost certain to exceed the set criterion (Note 4).
	Batteries containing potentially toxic materials, e.g. mercury, lead-acid, lithium dioxide, lithium	Potential atmosphere pollution/metal corrosion.
	Mobile telephone	Potential atmosphere pollution/metal corrosion due to type of battery.
	Battery chargers	Potential overcharging of batteries and consequent gas emission.
	Cathode ray tube TV monitor	Possibility of pressure-related implosion.
Potential problem (Suitable and sufficient risk assessment should be undertaken)	LCD monitors/video player	Check battery criteria are in line with Notes.
	Portable computer	Check battery type as part of risk assessment.
	Rechargeable torch (not diver's type torch in a pressure housing)	Check battery type as part of risk assessment.
	iPod, PDA or laptop	Possible pressure related damage to LCD screens. Check battery type as part of risk assessment.
	Calculator	Check battery type as part of risk assessment.
	Camera	Check battery type as part of risk assessment.
	Dictaphone	Check battery type as part of risk assessment.
	Digital analyser	Check battery type as part of risk assessment.
	Electronic clock	Check battery type as part of risk assessment.
	MiniDisc player	Check battery type as part of risk assessment.
	Shaver	Check battery type as part of risk assessment.
	Toothbrush	Check battery type as part of risk assessment..

Table 1 – Recommendations for use of battery-operated equipment in hyperbaric conditions