ENVIRONMENT AGENCY

Development of Lightweight Backpack Electric Fishing Gear – Phase II

W.R.C. Beaumont , M.J. Lee & M. Rouen

Progress Report To: Environment Agency
IFE Report Ref. No: RL/T11068K7/1

NATIONAL R&D PROJECT W2009

RESEARCH AND DEVELOPMENT
PROGRESS REPORT

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Report Date:	July 1998
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1. EXECUTIVE SUMMARY

Progress on Phase II of the Backpack Electric Fishing Project is reported. Some delays in the proposed timing of the WAVE experiment have been caused by the necessity to obtain Home Office licences for the project (under the Animals (Scientific Procedures) Act. All other aspects of the project are progressing on schedule.

KEY WORDS

BACKPACK ELECTRIC FISHING EQUIPMENT

2. INTRODUCTION

The use of backpack electric fishing (BEF) gear is extremely useful and effective for sampling fish populations in small streams, particularly where access is limited. In addition, it reduces manpower requirements and therefore leads to more cost-effective sampling strategies. Equipment currently in use in the Environment Agency however is considered to have usage and ergonomic drawbacks.

Phase I of this project assessed the current usage and needs of BEF equipment within the Agency, reviewed the current operational Health and Safety requirements and Environment Agency's Code of Practice for Safety in Electric Fishing Operations (CoP EFO) and assessed whether gear manufactured in the UK or other countries met or could be adapted to meet the CoP EFO. Recommendations were made regarding both the specifications for BEF equipment detailed in the CoP EFO and future research direction regarding the assessment of electrically efficient waveforms.

Phase II of the project will seek to address the issues raised in Phase I

Objectives of the study (as detailed in the project schedule) are as follows:

1. To review BEF compliance with all current UK equipment legislation.

2. To make detailed representation regarding amendments to the CoP EFO.

3. To carry out trials to assess the merits of different waveforms.

4. To build a prototype BEF unit to incorporate design and construction details determined above.

The following sections of this report give details of the progress made to date on objectives 1, 2 and 3.

3. REPORT OF VISIT TO SOCIÉTÉ GÉNÉRALE DE SURVEILLANCE (SGS) LABORATORIES

The meeting took place at 1200 on 5 May 1998 at the SGS Laboratory, Bowburn.

Present: Alex Dobie (SGS Consultant)
Jim Hogg (Electrical Adviser, Environment Agency)
Mike Lee (Electronics Engineer, IFE).

The meeting commenced with a brief introduction to the SGS group with particular reference to the Bowburn facilities.

The operation of Electric Fishing equipment was explained, boom boats, bankside, and backpack operation described.

The partnership between the Environment Agency and IFE was explained and an outline of the work undertaken in Phase I was described and illustrated with photographs of representative equipment. An overview of the work to be undertaken within Phase II was given, with emphasis on the production of a prototype to demonstrate the feasibility of the manufacture of "safe", compliant (with legislation), equipment from which a tender specification will be derived.

Safety

Issues of safety were discussed with reference to the Environment Agency COP. AD agreed IEC335 is an appropriate standard and that, although part 2 is not yet published, it would be reasonable to design to it in the absence of any harmonised or national standard. Subsequent discussions confirmed that there is no obligation to meet standards, but that Article 6 of the Low Voltage Directive (72/23/EEC) implies that equipment, which conforms to an appropriate IEC standard will be regarded to conform to the provisions of Article 2 (i.e. that it is safe). If we wish to deviate from the standard (e.g. swap tilt switch for immersion switch, or use 24 V controls) it could be acceptable provided that we can justify it, ultimately, in a court of law. Such an argument is strengthened if it is supported by a report from a notified body (for LVD).

Electro Magnetic Compatibility Regulations

AD enlisted support from an SGS EMC engineer to look at the equipment. He suggested that the generic standard for light industrial equipment may be appropriate, with tests for emissions, susceptibility, and ESD. Susceptibility may be a particularly safety critical test if the system can be switched on through a solid state switch. If claiming compliance by the standards route, then the equipment must fully meet all relevant standards claimed. If full compliance with all elements of the claimed standards cannot be demonstrated then the only route to conform with the requirements of the EMC Directive is the Technical Construction File route, for which a technical report or certificate issued by a competent body is mandatory. There was some concern as to how representative tests could be arranged (i.e. with a distributed electric field).

Conclusion

The meeting concluded with a brief tour of the facilities at SGS Bowburn site. Facilities include Electrical testing for transients, physical, environmental, EMC susceptibility, conducted emissions, and harmonics. The site contains SGS's only UK open field RF test site.

Actions

AD (SGS) will estimate costs involved in inspecting our prototype unit and make pre-compliance measurements as appropriate. Costs will be broken down into component elements and sent to MJL

MJL will contact Michael Kinnersley-Taylor (SGS) with address for correspondence.

Work will continue to produce a prototype. Approximately one month's notice will be required for any test/inspection with expected equipment retention time by SGS of one week for EMC, two weeks for safety.

Comments

Notified Bodies

The essential requirements of the Low Voltage Directive (LVD) are that the equipment is constructed in accordance with good engineering practice in safety matters and that it does not endanger the safety of persons, domestic animals or property when properly installed, maintained, and used in applications for which it was made. A report from a notified body is not a legal requirement under the Low Voltage Directive, however it would add substantial weight to any argument against compliance with the directive.

In implementing the Low Voltage Directive in the UK, the Electrical Equipment (Safety) Regulations 1994 paragraph.8 states:-

> "Where the conformity of any electrical equipment with the requirements of regulation 5(1) is called into question (whether in any proceedings or otherwise) any report prepared by a body notified in accordance with the procedure set out in Article 11 of the Low Voltage Directive for the purpose of Article 8.2 of that directive may be relied upon and due regard shall be had to any such report by any person or court by whom the question of conformity falls to be determined."

Competent Bodies

Under the EMC Directive, a body is considered to be competent if it fulfils the criteria set out in Annex 2 of the Directive. These criteria include the availability of personnel and of the necessary means and equipment to carry out work; technical competence and professional integrity of personnel; independence in carrying out tests; preparing reports and performing verification functions provided for in the directive; maintenance of professional secrecy; and

possession of civil liability insurance. A body can be recognised as competent either by an accreditation body recognised as such by the competent authority of a member state, or by a body representing the supervisory authority of a member state (DTI in UK).

If compliance with EMC is claimed by Technical construction file, the file must contain a certificate from a competent body. It is possible under the EMC legislation to claim compliance under the standards route without a report from a competent body, provided that the equipment can be demonstrated to comply fully with an appropriate harmonised standard.

Summary

While neither piece of legislation necessarily forces tests to be carried out, or reports to be prepared by an independent third party, it would almost certainly be in our interests to have the support of such an independent body for any design specification, which we propose. In the case of the Low Voltage Directive, for example, the only appropriate standard that we are aware of is IEC335 (2), which specifies the use of a tilt switch. If we do not wish to incorporate a tilt switch (and hence cannot claim to fully meet that standard), the support of a notified body would add great weight to an argument to justify such non-compliance. It would be expected that in order to gain such support, the third party would need to be satisfied that appropriate alternative measures had been put in place (e.g. immersion switches).

In the case of the Electromagnetic Compatibility Directive, unless we can fully meet all appropriate standards, a certificate or report from a competent body is mandatory to declare compliance by the Technical Construction File route. However even if we choose to self certify compliance to standards it may still be necessary to enlist assistance for tests such as immunity to electromagnetic radiation for which we are not equipped and which may have serious safety implications.

Although not unique, SGS are well suited to consult on this project as a notified body under low voltage directive and a competent body under EMC directive. They are within reasonable travelling distance of the Windermere Laboratory and have laboratory capacity within reasonable lead times. Before any final decision regarding the selection of a test laboratory, one or more alternative organisations will be contacted to obtain alternative opinions and, possibly, quotations.

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4 REVIEW OF CODE OF PRACTICE FOR SAFETY IN ELECTRIC FISHING OPERATIONS (COP EFO)

Objectives

The objective of this review is to examine the Environment Agency Code of Practice for Safety in Electric Fishing Operations (CoP EFO) with particular attention to its application to Backpack Electric Fishing Equipment. Proposals for amendments to the existing code of practice will be made where appropriate.

It is proposed, after discussion, to construct an Annex to the CoP (Annex C), which specifies the safety principles to be incorporated into the design and construction of backpack electric fishing equipment. A draft of the proposed content of this annex is included at the end of this document. It is intended to be a discussion document and comments are welcomed.

Background

The Environment Agency Code of Practice for Safety in Electric Fishing Operation sets out a framework within which the potentially hazardous operation of electric fishing can be carried out safely. It is applicable to a range of electric fishing techniques including boom-boat, bank-side and backpack equipment. It is comprehensive and sets very high standards for the design, construction, maintenance and operation of the equipment. However in covering such a wide range of equipment it is necessarily general in its application and has been criticised for being excessively prescriptive in its specification. This removes freedom from the designer to incorporate new or novel techniques and equipment, which could provide major improvements to the equipment from the point of view of the operator. Experience has shown that backpack equipment, which is claimed by the manufacturer to have been designed to meet this specification, often does not meet the detailed requirements of the specification. Moreover it is heavy, cumbersome, and ergonomically unsatisfactory, which makes the equipment generally unpopular with its operators. It is generally agreed among the users of the equipment that discomfort and intermittent or unreliable operation of the equipment can themselves represent significant hazards to the safe use of the equipment.

Phase I of the project included a review of the equipment available world-wide and a survey of the users of the equipment within the Environment Agency to determine their requirements and preferences regarding operational and safety features.

The current CoP includes two annexes: Annex A "Electric fishing equipment specification for the design and construction of fishing machines using hand held electrodes", and Annex B "Electric fishing maintenance specification and schedule for fishing machines using hand held electrodes"

It should be noted that the purpose of the CoP is to ensure adequate safety standards for the design, operation, and maintenance of the equipment. Design restrictions should not be imposed by the CoP unless they are necessary to ensure safe operation of the equipment.

One of the aims of the CoP would appear to have been to specify a common interconnection system for all types of electric fishing equipment including backpack equipment. This gives the advantage that it is not possible to inadvertently cross connect inappropriate electrodes and control units. Industrial connectors having a current rating of 16A in a range of specific pin configurations and colours are specified. However it is generally agreed that the types of industrial connector so specified are unsuitable for BEF equipment due to their size and weight. If the connection types are to be changed for BEF equipment this will be done as part of the design review, but it will not then be possible to maintain a common test procedure or equipment interchangeability between all types of electric fishing equipment.

Review of Main Document: Environment Agency CoP for Safety in Electric Fishing Operations

Section 1 Introduction

Backpack electric fishing equipment will come under the provisions of The Electrical Equipment (Safety) regulations 1994 and The Electromagnetic Compatibility Regulations 1992, and the CoP should make reference to them.

Section 2 Personnel

No amendments

Section 3 Equipment Design Criteria

This section duplicates, to some extent, the detailed specification contained in Annex A and the proposed Annex C. There is a case for simply referring to the annexes to define the equipment design criteria. If the section is to be retained it is important that it is written in language sufficiently general so as not to preclude detail design differences between the different types of equipment.

***Electrical Equipment*:**

Reference should be made to annex C for BEF equipment.

***Protection*:**

IPX7 = Protected against harmful ingress of water when immersed to a depth of 1 m.
Marking for backpack equipment should be defined in Annex C. There is no requirement for additional description here, particularly under the category of *protection.*

Power Supplies:

No amendments.

Batteries:

No amendments.

Generators:

Not applicable, no amendments.

Mains Electricity:

No amendments.

Control boxes:

This could define an IP rating and an insulation specification, but omit the requirement for non conductive material. This would enable suitably rated metal clad components such as connectors to be used where appropriate. If appropriate connectors are used, the requirement for power cables to be permanently glanded to the box is unnecessary and should be deleted.

Cables and connectors:

Since it is likely that backpack equipment will utilise different types of connectors to other types of equipment, the connector colour coding and pin configurations should be defined in the appropriate Annex and deleted from here.

Electrodes:

The requirement for the electrode to have a stud fixing to the handle is not a necessary condition for safety, and this requirement should be removed.

Back Pack Equipment:

The requirement for a tilt switch is probably the most controversial requirement of the CoP. The results of Phase I of the project clearly demonstrated that the most common reason for dissatisfaction with the operation of the equipment is the spurious operation of the tilt switch. In discussing the problems described by users it is apparent that many of the problems arise because of the environment in which electric fishing commonly takes place. When using BEF equipment it is common to have to stoop to fish under overhanging vegetation, or to move suddenly to capture fast swimming fish. Either movement can, in practice, cause spurious operation of the tilt switch causing the unit to shut down. This can cause frustration and irritation to the operator and thus can itself be a serious hazard to safety.

Since the purpose of the tilt switch is to protect the operator in the event of falling into the stream, it may be argued that alternative systems may provide an equivalent degree of protection without the disadvantages experienced with a tilt switch system. Systems such as contact immersion switches, which operate on contact with water, can be used. Such a switch, possibly fitted to the anode handle (which is often the first piece of equipment to be immersed in the event of a fall), in addition to the control unit could provide a very high degree of protection while avoiding spurious operation.

If a tilt switch is deemed to be necessary, a system to reduce spurious operation will be required. Such a system could be a damping mechanism, or may use accelerometers. The current requirement for operation at 45° (60°) seems to be somewhat arbitrary and may give rise to unnecessarily sensitive systems.

Under any circumstances, there can be no justification for insistence upon the use of mercury tilt switches if other types of tilt switches may be considered to be preferable by the designer.

It should be noted that IEC335-2(22.102) specifies a requirement for a tilt switch to operate at 45°, hence it will be necessary for any equipment, which claims to meet this standard in full to have such a switch fitted.

It is proposed, therefore, that the requirement for a tilt switch is moderated, by allowing appropriate alternative safety measures, which give equivalent or greater protection to the operator.

Boats:

No amendments

Ancillary Equipment:

No amendments

Manuals:

No amendments.

User options:

The reference to Annex A will need to be modified to accommodate the additional Annex C for backpack equipment.

Section 4 Protective Clothing, Safety Equipment, and their Use

No amendments

Section 5 Hazards Associated with Electric Fishing

No amendments

Section 6 Recommended Working Procedures

Any equipment MUST be operated in accordance with the operating instructions and maintenance schedule supplied with it by the equipment manufacturer. This should be emphasised in the Maintenance section in lieu of the reference to Annex B. The requirement that the checks must be performed by suitably qualified personnel, and the requirement for maintenance records should be retained.

Section 7 Emergency and Accident Procedure

Although not applicable to BEF equipment, item 3 includes stopping the generator. In practice it would be important to stop the generator and thus remove the power source before attempting to remove any electrodes from the water.

Review of Annex A: Electric Fishing Equipment Specification

This document contains the engineering specification criteria for the design and construction of Environment Agency fishing equipment for use with hand held electrodes. This review highlights areas, which are not applicable, or not necessary for the safety of BEF equipment, with a view to forming an Annex C to the CoP, which relates solely to BEF equipment.

Introduction and General Conditions

1.1 Materials and Workmanship:

Additional legislation includes The Electrical Equipment (Safety) regulations 1994 and The Electromagnetic Compatibility Regulations 1992.

1.2 Equipment Design:

Minor amendments

1.3 Quality Assurance:

No amendments

1.4 Drawings:

Minor amendments

1.5 Operations and Maintenance manuals:

Four-ring loose leaf binders is probably over prescriptive and not essential for safety!

(1.5.1) Technical data sheets listing each component type/supplier are unlikely to be supplied by any manufacturer interested in protecting his design.

Electric Fishing Control Unit Construction

2.1 General:

In view of the possibility of the operator of BEF falling in the water IP57 may be more appropriate than IP55 (2.1.2). If IP55 is retained then there must be a condition of use that in the event of immersion the equipment is not used before it has been serviced, or preferably that an engineered control such as a moisture operated trip, which prevents operation after such an event. Suitable connectors may provide an alternative to permanently glanded cables (2.1.3). The Emergency Stop button should not rely on the mechanical latching mechanism of the button itself (2.1.4)

2.2 Control Box Enclosure:

No amendments

2.3 Internal control box wiring

(2.3.1) References to wire colour relate to common industrial voltage levels, and may not be appropriate to specific BEF equipment. The specification should not preclude the use of colour coded multicore cable or ribbon cable where appropriate.

(2.3.3) 1.5 mm^2 may be adequate for the current levels anticipated within the secondary currents associated with BEF equipment. Conversely, 6 mm^2 or greater may be required on the battery supply wiring for a 12 V system. PCB interconnections, to a display for example, may be quite adequate as flexible printed wiring or ribbon cable, which often has a cross-sectional area (csa) of less than 0.5 mm^2. Thus the broad statement that power wiring should have a minimum cross-sectional area of 1.5 mm^2 is somewhat inadequate.

(2.3.4) Ring type ferrules are frequently used on industrial equipment wiring but may not be appropriate for the wiring systems used in BEF equipment where weight is at a premium Manufacturer defined colour coding and interconnection identification would be adequate.

(2.3.6) Wires may be terminated in connectors, and could be ribbon cable or co-axial, for which lugs or sleeved connections would be inappropriate.

(2.3.8) The 20 wire limit for harnesses seems to be arbitrary. There are many cases in modern electronic equipment where harnesses with many more conductors are used with no safety hazard. IEC335-1 (section 23) sets standards for internal wiring, which are adequate.

2.4 Socket Outlets

(2.4.1) Sockets should be IP57 rated and rated for their working current and voltage. 16 A is far in excess of the output current expected for BEF equipment.

(2.4.2) Colour coding aids identification of appropriate connectors. However, provided that the connectors are not interchangeable it is not necessary to define the pin numbers here.

(2.4.3) The requirement for two separate sockets for the Anode circuit and the Control circuit forces the requirement for a Y junction ("Trouser Joint") in the main anode lead. It could be argued that this requirement conflicts with (2.13.4) "All cables shall be installed in continuous lengths" since such a joint, by definition, forms a discontinuity. Experience has shown that it is a vulnerable part of the lead and invariably leads to a cable, which is mechanically weakened and very difficult to seal at its junction with the connector due to the fact that it is not round in cross section. A more rugged solution for backpack equipment would be to use a single connector, provided that it is adequately rated for the voltage and current, gives adequate isolation between Anode and Control circuitry, and is sufficiently rugged for use in the field. The CoP should not preclude this solution.

(2.4.4) Connector pin-outs should be re-defined to accommodate new connectors exclusively for BEF equipment, or the pinout should be left for the designer to specify.

(2.4.5) Connectors are not normally given a power rating. They do normally have a voltage and current rating, which must not be exceeded.

2.5 Control switches and push buttons

(2.5.1) It is envisaged that future designs for BEF equipment may utilise modern techniques such as membrane switches, which may provide a high degree of waterproofing while minimising weight and cost. Such techniques should not be precluded from use.

(2.6) A condition of any design is that all the components should be capable of sustaining the operating conditions at all times. The insistence upon devices designed for industrial power equipment leads to the use of large and heavy devices where they may not be necessary. The requirement for 10% unused movement at either end of the travel is not necessary.

2.7 Instruments

This paragraph inevitably forces a design solution, which uses an industrial type moving coil meter mounted behind a polycarbonate cover. This solution is invariably large, heavy, and not well suited to lightweight equipment. Moreover the specification does not accommodate more novel instrumentation solutions, which have been suggested such as an arm mounted or anode mounted remote control unit. It is envisaged that a modern design may use low power digital display such as LCD rather than the analogue meters referred to in paragraph (2.7.3). A requirement that the instrument has a specified accuracy (e.g. better than 5%), is clearly visible in all anticipated light conditions, and maintains the IP rating of the enclosure would be more appropriate.

2.8 Indicators

(2.8.1) The specification of a preference for LEDs doe not preclude alternative solutions. LED's are certainly preferable to filament bulbs. However other indicator solutions could be considered, such as LCDs, which may be equally suitable for some tasks without compromising safety in any way.

(2.8.2) The requirement for a minimum illuminated diameter of 10mm forces the use of large industrial type bezels, which are not well suited to portable equipment because they are large and heavy. High intensity LEDs are available, which are clearly visible, but far smaller. The function of the indicator also contributes to the necessity for visibility. For example, if the function is to indicate that the anode is energised, then high visibility is very important. However if the function of the indicator was simply to warn of a partially discharged battery, then a less visible indicator may be considered to be acceptable.

2.9 Locks

(2.9.2) Barrel type locks can contribute a significant weight to the unit. Equivalent safety assurance with far less weight and cost could be provided by using "tamper proof" fixings on the enclosure.

2.10 Carrying Handles

(2.10.1)This should be amended to make the use of carrying handles optional since backpack equipment can normally be easily carried by the straps or the frame.

2.11 Legends

The requirement for adequate labelling is essential, however the insistence upon using laminated labels affixed by impact adhesive is more appropriate to industrial plant than lightweight portable equipment. It is envisaged that labels could be constructed, which conform to the specifications defined in (2.11.7) at moderate cost having lower weight and better durability. The legend in 8.5(d) relates to a 230 V AC generator and is not relevant to BEF equipment. (c) refers to charged capacitors and should be included.

2.12 Fixings

Self locking nuts cannot necessarily be relied upon to prevent unfastening from the outside. A requirement to use fixings, which cannot readily be unfastened from the outside of the unit states the requirement and gives more freedom for the solution.

2.13 External cables

The general requirement that all cables should be installed in continuous lengths, have high visibility and protection at the cable entry are necessary requirements. IEC335 (2) requires 0.75 mm^2 for battery circuit external cable. In practice, for a 12 V system, this is unlikely to be adequate. Although it may be adequately rated for the current requirements in the output circuit, the use of cable having a larger cross sectional area would probably improve the durability of the system. Note BS requirements (BS6500, BS6346) have not been checked, and may have been superseded.

2.14 Testing

Type testing of a design for conformance with its IP rating is necessary but, provided adequate quality control is implemented, type testing of each production unit is not required.

Electric Fishing Control Box Circuit Requirements

3.1 General

Figure 8.6 is confusing and implies a circuit topology and complexity, which may not be relevant to BEF equipment. A general requirement for the equipment to be designed to be, wherever possible, fail-safe is reasonable. All components must be selected to operate within their specified operating parameters under worst-case conditions.

3.2 Power supply input

The reason for the requirement of a permanently connected cable with a fitted plug is unclear. Alternative connections to a battery could be considered, such as a socket arrangement on the battery pack or fixed terminals, which mate on installation of the battery. Figure 8.1 defines a

plug pinout, which is not appropriate for BEF equipment as discussed previously. The use of the industrial type mushroom head "stop" button as a means of latching the supply off is not in itself adequate. Experience has shown that these buttons can fail to latch when lightly struck, and can be inadvertently released if knocked from the side. They are suitable only if used in combination with a relay, contactor, or other trip mechanism.

A requirement for the battery to be fused within the battery assembly would be reasonable.

3.3 Control Circuit

The requirement for 12 V or less seems to be rather unclear. If it is a maximum limitation it would seem to be a somewhat conservative specification for the safety of the control circuit. It could be interpreted as meaning 12 V rms. or less derived from a transformer, in which case a peak to peak voltage of 33.9 V could be expected. There is a reasonable case for arguing that less than 30 V would be quite safe subject to appropriate isolation from the high voltage circuitry as described in IEC335. This would enable a 24 V primary circuit to be used (i.e. 24 V battery, and control system), which could give significant advantages in the power conversion circuitry as it would reduce the requirement for heavy conductors by reducing the current requirements and could improve the conversion efficiency.

The multiple fuse arrangement specified for transformer, semiconductor, and instrumentation is not appropriate for BEF equipment. Fusing for the control circuit would be adequate within the control box, the external battery having its own fuse at the source.

3.4 Power Circuit

Voltage and current capacities should be specified by the manufacturer. It is not normally possible to reliably protect the semiconductors in power converters by means of thermal fuses since, in general, they cannot interrupt a fault condition with sufficient speed. Modern power conversion techniques often provide self protection for semiconductors by means of current limiting control to force semiconductors to switch off before their maximum current is exceeded. The function of fuses should be to protect the system wiring in the event of a fault condition.

This section requires a 2 pole contactor to switch power to the anode/cathode electrodes when the requirements for safety switch operation are satisfied. Such a contactor is necessarily large and heavy because it must have a high voltage and current rating. It is possible to imagine more modern circuit techniques, which would provide equivalent safety by implementing the control on the primary side of the converter, possibly with a "crowbar" device across the output to provide additional safety. Such innovation should not be precluded simply by specification of circuit techniques, which are suited to mains powered industrial equipment. Provision is made for primary side isolation within IEC335-2 (22.102) and this option should not be precluded by the specification. It would be reasonable to specify that backpack equipment must only have one anode and one cathode.

Capacitors should discharge to less than 30V within two minutes of disconnection of the battery, and the warning notice of Figure 8.5 (or similar) should always be fitted in a prominent position on the outside of the enclosure.

3.5 Safety Control Circuit

Notwithstanding the requirement for a control circuit isolator as mentioned above the following requirements are needed:

a. The manual safety switch on the anode must be operated.

b. The manual safety switch must comprise a dual series arrangement so that if one of the switches fails to open at the same time as the other, then the power circuit is to be inhibited.

c. Unused hand held electrodes are not applicable in the case of single hand held electrode BEF equipment.

The specification remains open to innovation such as wireless operation of the safety control circuit, subject to suitable fail safe mechanisms.

3.6 Voltage Control

The specification insists on the use of a rotary potentiometer for voltage control. A system, which uses a multi-position switch, a rotary encoder, or digital push buttons to increment or decrement the voltage setting would be adequate and would not degrade the safety specification.

A specification that voltage must be controlled within a given tolerance (e.g. 5%?) (unless in a current limited state, in which case it should be indicated) would be appropriate.

3.7 Output Frequency Control

The specification insists on the use of a multi-position rotary switch or a rotary potentiometer for frequency control or a switch in the case of two frequency units. A system, which uses a rotary encoder, or digital push buttons to increment or decrement the frequency (pulse repetition rate) setting would be adequate and would not degrade the safety specification.

A specification that frequency must be controlled within a given tolerance (e.g. 5%?) would be appropriate.

3.8 Indicator lamps

Clearly visible indicators can give an effective warning of potentially hazardous instrument states. However it must be borne in mind that the equipment will normally be operated in conditions of high ambient light, so that an illuminated warning lamp, which is sufficiently bright as to be clearly visible could represent a significant additional load upon the batteries. Novel techniques for power reduction such as the use of high efficiency LED's or pulsing the light should not be precluded. The current requirement is for indicator lamps to show the following states:-1) Input power available, 2) Fishing circuit mode (e.g. DC, Pulsed), 3) Fishing circuit live, 4) Hand held electrode safety control switch failed. Of these 1) 3) are necessary. 4) May be replaced by a "Unit Tripped" indicator, which could represent operation of any of the safety mechanisms.

3.9 Instrumentation

The specification requires meters for input voltage, output voltage, output current and, where it is continuously variable, output frequency. Such instrumentation, in the form of analogue meters, contributes significantly to size and weight and cost. In the case of backpack equipment they are generally not visible by the operator and thus have limited value.

In the case of input voltage, an indicator (visible and / or audible) to warn of low voltage would be adequate.

In the case of output voltage, provided it is controlled to a given tolerance (e.g. max deviation of 10% is specified in IEC335-2 section 10.101) and a current limit indicator is provided, the set voltage can be relied upon.

In the case of output current, some form of indicator visible by the operator is useful. This could be audible or visible, possibly in the form of a bar graph indicator. Indication of a current limited state is essential.

Reducing the instrumentation requirements in this way could make a major contribution to reducing the size and weight of the unit without affecting its function.

3.10 Connections

Connections to the plug and socket pins must be defined when the connectors have been specified.

3.11 Tests

(a) Type tests are specified on one example of each design variant.

The requirement for tests to be carried out "using a 50 Hz mains supply" is not relevant to BEF equipment and should be removed. Indeed the Main Document states that "Electricity supplied direct from the mains must never be used to energise a control box..."

However it is unclear as to what the purpose the test specification serves here. The purpose of a type test should be to ensure that the equipment meets the safety requirements, and the manufacturers performance specification. Thus it should be sufficient to require that the system is type tested and certified. Any type testing of this form should be carried out by an appropriately qualified independent test facility.

The tests as specified are:

Voltage waveform. This test appears to be seeking thermal stability. The requirement, in the case of pulsed DC, for an instantaneous rate of rise in voltage to 50% is plainly absurd, and could never be measured even if it could be produced!

Current waveform. It is unclear as to what this test is attempting to achieve. If the equipment is resistively loaded it will simply produce a waveform, which is analogous to the voltage waveform measured above. Since electric fishing equipment

is normally voltage controlled, the "current waveforms available from the electric fishing equipment" will be infinite and will be load dependent.

Heat test. Overload thermal tests are a reasonable requirement.

Semiconductor protective device effectiveness. A short circuit test is reasonable but this test implies that semiconductors will be protected by a replaceable fuse. The test should be sufficiently broad to encompass the use of current limited supplies. In order to simulate a short circuit in operation, the test could specify that the equipment must be both switched on into a short circuit and shorted out when energised without sustaining damage.

(b) Production tests

Flash test and insulation resistance test. The requirements for Leakage current and electric strength are well defined in IEC 335 and should be followed. The general safety feature check list as described includes many features, which are design specific (e.g. Electro-mechanical extra-low-voltage switching system, all power switching double pole) and are quite inappropriate as production tests. Any production tests should be to confirm that the product functionally meets its specification and would be better defined for specific equipment. The requirement in the CoP should be that production units are tested to ensure that they meet their specification.

Additional Special Requirements for Battery Powered Back Packs (Electric Fishing Control Box Construction)

4.1 General

This section relates entirely to BEF equipment and will be replaced by the proposed Annex C.

4.2 Batteries

The current specification does not call for fusing within the battery circuit. However since the nature of the equipment means that it is likely to be transported, perhaps accompanied by one or more fully charged spare batteries, it would be wise to specify that the battery unit should be fused in both poles, as close as is practical to the battery itself, and there should be no exposed conductors on the battery side of the fuse.

(4.2.1) The specifications for batteries should not preclude the use of modern (or future) high energy density batteries where appropriate. The current specification assumes the use of sealed lead acid batteries (which are often described as maintenance free although they do require regular and careful charging when used in cyclic mode). A more general requirement that they should be non spillable would be more appropriate.

(4.2.2) The requirement for batteries to be in an enclosure, which is sealed to the same specification as the control unit may conflict with the battery venting requirements.

Advice is currently being sought from battery manufacturers regarding this application.

4.3 Battery Charger

(4.3.1) The battery charger should be appropriate for the type of battery used, thus a requirement for a constant voltage charger is inappropriate.

(4.3.2) It should be emphasised that it must not be possible to operate the BEF equipment if the battery is connected to the mains system in any way (e.g. by the charger) ref. IEC335-2 (22.103).

4.4 Safety Switches

This section states that a tilt switch and float switch must be fitted to the control box. It is possible that the tilt switch, if required, could be fitted to the anode electrode. As stated previously it is not clear that this is a necessary requirement for safe operation.

(4.4.1) Tilt switches are required to operate at 45° from the vertical, although the vertical reference line is not defined. It is possible that a shallower angle (e.g. 60°) or additional damping on the tilt switch mechanism could be acceptable.

(4.4.2) Float switches are also specified as a requirement. The reason for insistence upon a float switch (with a device to prevent spurious operation, which is unclear) is not apparent. A disadvantage with the types of float switch normally seen is that they operate in a single axis, and rely upon moving parts for their operation. A more satisfactory solution may be to use a conductivity sensing solid state immersion switch. This could also be lighter, cheaper, not orientation specific and, possibly, more reliable. Moreover more than one could be mounted on the control box(s) and/or anode pole to provide additional protection.

4.5 Safety control circuit

(4.5.1) 45° Specification for the tilt switch. The comments in (4.4.1) above apply again.

(4.5.2) This paragraph implies that the purpose of the float switch is to detect immersion, in which case an immersion switch should provide an appropriate alternative.

(4.5.3) The requirement for the trip circuit to be latching with a manual reset provides good protection. The requirement for the reset to be by external push button is unnecessary.

4.6 Audible sounder

The two modes of operation of the sounder described in the CoP could be combined to provide the user with more operational feedback as follows.

The sounder could operate a pulsed tone when the anode is energised, and to increase the pulse repetition frequency, or the pitch, or the amplitude as the anode current is increased. A continuous tone could warn of a "tripped" state e.g. in the event of operation of an immersion switch or an emergency stop switch.

4.7 Carrying frame

It is preferable for the carrying frame to be of insulating material since it is large and could under fault or abnormal operating conditions, come into contact with live parts. Experience has shown that many manufacturers have used aluminium based frames probably because they are strong light and commercially available. On balance the requirement for a non-conductive frame is probably achievable and undoubtedly in the best interest of safety. The Main Document calls for a quick release mechanism for rapid removal from the operator, and this would certainly be beneficial in an emergency. Only one of the systems tested in Phase I had a quick release mechanism that was separate from the normal rucksack attachment fastenings.

Electric Fishing Hand Held Electrodes and Associated Cathodes

5.1 Hand held electrodes - General

(5.1.1) Electric fishing electrodes may be far smaller than 380 mm diameter. Phase I of the project revealed that anodes as small as 200 mm and as large as 600 mm are currently used within the Environment Agency.

Point sampling, for which BEF equipment is ideal, may use smaller anodes.

(5.1.4) Since a fault condition in which the plug end of the electrodes becomes immersed is easy to imagine, an IP57 rating for the connectors should also be recommended.

(5.1.5) In the case of BEF equipment a current rating of 4 A and a voltage rating of 1000 V would be adequate.

(5.1.6) Dual series switches provide a high degree of protection against a s/c fault, which would cause the electrode to become inadvertently energised. The switch rating must exceed 12 V. A control current of far less than 400 mA could be envisaged, and a 100 mA DC rating would be adequate.

(5.1.7) The requirement that the operating switch cannot be operated by any part of the hand being wrapped around the switch lever and handle together is similar to the requirement in IEC335-2 (22.113). It is unclear how a switch can be specified to "always fail safe i.e. open".

(5.1.8) This section refers to Figure 8.8 and specifies a grade 304 stainless steel M12 stud fixing to hold the electrode to the electrode handle. Examination of fig 8.8 shows that for the dimensions shown, M12 is not an appropriate size of stud to maintain the proportions shown on an 18mm diameter pole. Indeed in the survey of Phase I the largest fixing stud used by any of the manufacturers was M8. M12 would seem to be an inordinately large stud for the purpose, and does not enable a lightweight anode pole to be used. Any weight added to the electrode end of the pole adversely affects the ergonomics of the system, many of the systems evaluated utilised much lighter assemblies. The safety requirement should be that it is securely fastened.

5.2 Cable and Sockets for Hand Held Electrodes

(5.2.1) The cable length for backpack equipment should be long enough to allow free movement of the electrode but sufficiently short to prevent any tripping hazard.

(5.2.2) The types of connectors to be used for BEF equipment will be specified in due course.

5.3 Electrode head for hand held electrodes

(5.3.1) The appropriate tube diameter will depend upon the required geometrical characteristics of the electrode. Phase I of the project yielded an example of equipment, which used several small cross-sectional diameter electrodes bunched to give a larger effective cross sectional diameter while providing low weight, low resistance to flowing water and a flexible, rugged solution. It is important for the electrical characteristics of the electrode that the surface of the electrode does not become oxidised thereby increasing the anode resistance since this will reduce the magnitude of the potential gradient within the water. Stainless steel is probably the most suitable material although some of the equipment evaluated in Phase I used aluminium.

(5.3.2) The stud fixing was discussed in section (5.1.8)

(5.3.3) The anode should be fixed to the pole so that it cannot rotate relative to the axis of the pole. Further specification, such as adjustment of the angle between the plane of the electrode and the axis of the pole, should be open to the designer.

5.4 Cathode

(5.4.2) Cable length need not be specified in the CoP but measures must be taken to prevent moisture ingress into the cable.

(5.4.3) The connectors to be used will be defined in due course

Electric Fishing Generator Specification

(6.3.1) Not relevant to BEF equipment.
Electric Fishing Control Box: User Options Selection Form
The CoP is not an appropriate place for an order form.
Electric Fishing Equipment Diagrams

Connector Specifications Figures 8.1 to 8.4

These will be different for BEF equipment and will be defined in due course

Electric Fishing Equipment Labels

(8.5.a) This label refers to a generator and is not appropriate for BEF equipment.

(8.5.b) The purpose of this label is unclear.

(8.5.c) Should refer to disconnecting battery before removing cover.

(8.5.d) This label refers to a generator and is not appropriate for BEF equipment.

(8.5.e) The reference to a 230 V supply is not appropriate for BEF equipment.

Control box circuit requirements

(8.6) The diagram shown is complex, confusing, and assumes a topology, which is not necessarily appropriate for BEF equipment.

Trouser junction

(8.7) This is used in order to separate the connectors for the high voltage circuit connectors and the control circuit connectors. However in practice it is far from satisfactory. In slitting the cable to extract the high voltage cable, the sheath carrying the remaining cables is no longer packed, and therefore does not seal on a circular gland. The high voltage conductor is too small in diameter to fit its sheath properly, and the junction becomes weakened. In view of the fact that the integrity of the anode cable is essential to maintain adequate insulation it is recommended that the use of a trouser joint is avoided and properly rated high voltage connector is used to carry both the power and the control conductors.

Anode Stud

The anode stud design illustrated is dimensionally inconsistent (i.e. an M12 thread together with a 5mm key would have a radial dimension greater than the 18mm diameter tubular handle shown. Such a design does not yield a lightweight design. The evaluations in Phase I showed that reducing the weight of the anode can significantly improve the ergonomics of the system.

Electric Fishing Glossary

(9.1) Cathode. No amendments.

(9.2) Control box. Change to control unit.

(9.3) Control box enclosure. The IP rating should be as specified in annex A. This category is unnecessary in a glossary.

(9.4) Control circuit. No amendments

(9.5) Control switch. No amendments

(9.6) Electrode head. No amendments

(9.7) Replace ... "head (and cathode)" with "electrodes"

(9.8) Fishing circuit output. No amendments.

(9.9) No amendments

(9.10) Power circuit. Change to "Circuitry within the control box, which delivers current to the electrodes".

(9.11) Power supply. No amendments

(9.12) Safety control circuit. That part of the control unit circuitry, which ensures that the fishing circuit produces output only when all safety switch mechanisms are activated.

(9.13) Safety control circuit switch. No amendments

Review of Annex B: Electric fishing maintenance specification and schedule

This annex covers all electric fishing equipment but includes within its Appendix 1 a section entitled "Maintenance check list electric fishing back-pack". Sections 3, 4, and 5 describe test procedures for hand-held electrode, cathode, and control box respectively, which specify insulation, continuity and load tests, which are quite specific regarding connector colour and pin configuration. Tests such as 500 V Megger tests, as in section 3, may be inappropriate on an anode electrode, which included control or indicator electronics. Section 5 refers to "older" and "newer" type control boxes, and suggests connecting mains power to the input socket. This conflicts with the Main Document Section 3 (mains electricity), which states that mains must never be used to energise a control box.

Appendix 1 of Annex B gives example maintenance checklists and equipment test certificate. It is envisaged that in the specification of new backpack electric fishing equipment that some of these tests will be inappropriate or inapplicable, and that the maintenance specification and schedule for backpack equipment may be better separated from other types of electric fishing equipment. It can be seen from the existing specification that it is difficult to produce a general specification for test procedures without referring to design details of particular equipment.

It is, therefore, likely that a more satisfactory route would be for the CoP to require that any BEF equipment supplied MUST include an appropriate maintenance specification and schedule within its accompanying documentation. An operational requirement within the CoP that any equipment MUST be operated in accordance with the maintenance schedule supplied with it by the equipment manufacturer e.g. in the Main Document Section 6 (Maintenance) would ensure that this was adhered to. This would then place a responsibility on a manufacturer to specify appropriate tests and maintenance with due regard to safety, while leaving sufficient design freedom to produce equipment of differing design details.

References

Beaumont W.R.C., Lee M.J. and Rouen M.A. (1997). Development of lightweight backpack electric fishing gear. Final Report. BEF Phase I report

Environment Agency CoP SEFO

IEC Standard 335-1 Safety of household and similar electrical appliances Third edition 1991-04 Part 1: General requirements

IEC Standard 335-2-86 Particular requirements for electric fishing machines. Committee draft .

Health and Safety Guidelines No. 6. Safety in electric fishing operations. National joint health and safety committee for the water service April 1983 ISBN 0 90190 66 2

Proposals

The code of practice should have a title page, which states the following: title, version, date of issue, issuing authority

Section 4 of Annex A should be removed, and be replaced by Annex C.

It will be necessary to re-title the existing Annex A and Annex B documents to distinguish their target equipment from backpack equipment, which will be covered in a new Annex C.

The requirement for a tilt switch is defined in Main vol. Section 3, Annex A section 4.4, and Annex A section 4.5. Such multiple specification could lead to confusion and should be replaced by a single requirement for a tilt switch or appropriate alternative safety measures.

5 DRAFT PROPOSAL FOR ANNEX C: ELECTRIC FISHING EQUIPMENT SPECIFICATION (for the Design and Construction of Backpack Electric Fishing Machines)

Introduction and General Conditions

This document contains engineering specification criteria for the design and construction of Backpack Electric Fishing Equipment for use by, or on behalf of, the Environment Agency. It includes all types of Electric Fishing Equipment, which is designed to be carried by the operator during operation. The manufacturer of the equipment shall be responsible for the design, construction, and supply of equipment in accordance with this specification.

Materials and Workmanship

The design and all materials used in the construction of the unit shall be of appropriate quality and suitable for the intended purpose of Backpack Electric Fishing Equipment. The equipment must comply with all relevant legislation including the Health and Safety at Work Act 1974, the Electrical Equipment (Safety) Regulations 1994 and the Electromagnetic Compatibility Regulations 1992 and be to the entire satisfaction of the Regional Electrical Adviser.

All equipment and materials supplied shall be new and in current production.

Items of equipment and components shall be selected to minimise different types and sizes in accordance with good engineering practice. Items of the same type and size shall be completely interchangeable without modification or addition. Spare parts shall be manufactured from the same materials as the originals and shall fit the equipment without modification or addition.

All materials, which come into contact with water shall be resistant to corrosion and organic growth.

Equipment Design

Backpack Electric Fishing Equipment must be battery powered. Engine driven generators are not permitted.

The backpack equipment must be mounted on a quick release harness to enable rapid removal from the operator in an emergency.

All equipment shall operate with minimum unwanted noise and vibration.

All parts of the equipment should be chosen to have a minimum operational life of 3 years, and should maintain their properties without undue ageing due to the passage of time, exposure to light, or any other cause. All parts that are subject to wear in service shall be

readily accessible and provision shall be made, where applicable, for adjustment or replacement of these parts.

The total weight of any Backpack Electric Fishing System shall be less than 15 kg
All equipment shall be suitable for use within an ambient operating temperature range of -5 C to +40°C.

Quality Assurance

The Environment Agency encourages the provision of equipment from suppliers with BS EN 9001 (Manufacture and Design) certification.

Drawings

All drawings provided by the supplier shall be of standard size (A3 or A4). Drawing practice and symbols shall be in accordance with BS 5070. The standard used shall be stated on all drawings. All dimensions shall be in ISO metric.

All drawings shall have a drawing number, title, date, and issue number and date.

The supplier shall submit the following drawings:

a) Detailed general arrangement drawings of all the main items of equipment to a scale not smaller than 1:20.

b) A detailed wiring diagram showing all connections to printed circuit board level. Printed circuit board details need not be included but all external connections to the board must be referenced.

c) Detailed schematic diagrams to enable fault finding and diagnostic operations to be carried out.

Operation and Maintenance Manuals

Operation and maintenance manuals should be of A4 size. Prints of drawings within the manual shall be A3 or A4 size.

The manuals shall have contents sheets at the front and a comprehensive index at the back. A full list of all relevant drawings shall be included.

The manual shall contain the following:

- Title page giving the name and address of manufacturer, Model number and type of equipment to which the manual relates, serial number (or range of numbers) to which the manual relates, date of issue.

- A copy of the Certificate of Conformance relating to the equipment.

- Equipment specification to include the following information:
    1. Manufacturer's name and Address
    2. Manufacturer's model and serial number (or range of serial numbers)
    3. Range of rated output voltage
    4. Maximum rated output current
    5. Details of waveforms available
    6. Maximum and minimum rated input voltage
    7. Maximum rated input current
    8. IP rating

- Safety instructions and pre-start check list

- Operational instructions including details of all available controls, instruments, and indicators.

- Maintenance schedule

- Fault finding and diagnostic guide.

Backpack Electric Fishing Control Unit

Construction

General

All external components of the Backpack Electric Fishing Control Unit shall be suitable for use in a wet outdoor environment. Particular attention should be given to robustness of construction, weight, protection of components and terminations.

The finished control box shall have an ingress protection rating of at least IP55 (with internal moisture protection fitted) or IP57 (without internal moisture protection). All cables entering or leaving the unit must be properly terminated in glands or connectors with appropriate strain relief mechanisms.

At least one double pole mushroom headed latching "Emergency Stop" button shall be mounted on the control box in a position easily accessible to the operator and/or an assistant. The button(s) shall be red in colour and mounted on a yellow escutcheon and clearly marked "Emergency Stop". The function of this switch is to de-energise the electrodes in an emergency. When activated, the supply should enter a "tripped" state, which should not be reliant upon the mechanical latching mechanism of the stop switch(es). This state should be indicated by an audible and/or visible warning. Resetting the state of the machine to an operational mode shall require releasing the mechanical latch and operating a separate "start" switch or sequence of switches.

All controls used for adjusting and resetting the state of the machine during normal operation must be accessible from outside the control box.

Enclosure

The enclosure shall be manufactured from a corrosion resistant non-conducting material. The enclosure shall be fitted with a hinged door having a minimum door opening of 135° or a lid with screw type fixings. In either case, unauthorised entry to the box shall be prevented by means of a lock, tamper proof seal or security fixings, which require the use of a special tool.

Wiring

The specifications for internal wiring described in IEC335-1(23) should be adhered to. Power circuit conductors shall have a minimum cross sectional area of 1.5 mm^2 and shall be adequately rated for their worst case maximum voltage and current.

Connectors

All connectors shall have an IP57 rating when mated and shall be rated for the worst case voltage and current, which the unit is capable of sourcing. Connectors shall be supplied with sealing caps so that their IP rating can be maintained even when they are not mated.

(A recommended connector system and pinouts will be specified in due course.)

Controls

Control switches and push buttons shall be manufactured from heavy-duty plastic or similar non conductive material. All switches and push buttons and other controls shall be secured to the enclosure in such manner that they cannot turn or work loose during normal operation or maintenance.

Instruments

Instruments shall be flush mounted and fitted with impact resistant covers. Instruments must be clearly visible in all anticipated ambient light conditions. They shall be clearly labelled and shall have an accuracy better than 5%. Ammeters and their associated circuitry must be capable of withstanding fault currents without damage until the circuit protection operates.

Indicators

Indicator lamps shall be provided to indicate the following states: Power Available, Electrodes Energised, Current limit, Unit Tripped. Their function shall be clearly labelled.

The use of flashing indicators is not precluded provided that their duty cycle is adequate to maintain clear visibility under all anticipated conditions of ambient light.

Security

The enclosure shall be secured with tamper proof fixings.

Portability

Where fitted, carrying handles shall be constructed from non-conductive material and shall be secured by corrosion resistant fixings.

Markings

Identification labels shall comprise black text on a white background.

Warning labels shall comprise black text on a yellow background.

All controls, indicators, and instruments shall bear a label to indicate their function.

All labels shall be clearly visible.

A nameplate shall be fixed to the unit giving the following minimum information:

1. Manufacturers name and Address
2. Manufacturers model and serial number
3. Month and Year of manufacture
4. Maximum rated output voltage
5. Maximum rated input voltage
6. Maximum rated input current
7. IP rating

Fixings

All fixings, hinges, catches, locks and similar hardware shall be made of corrosion resistant material. Where fixing screws are used they should not be readily unfastened from the outside of the unit.

External Cables

All external cables shall have high conductivity stranded copper conductors with a cross sectional area of at least 1.5 mm^2 for power conductors and 0.5 mm^2 for signal conductors. Cables shall be adequately rated for the worst case voltage condition under normal operating conditions. All cables must be installed in continuous lengths.

At their termination with the enclosure or connector, cables must be sealed with the correct size cable gland. Cables shall be suitably protected at terminations to prevent excessive bending.

High visibility cables shall be used, which have suitable over-sheath to prevent damage due to abrasion, scuffing, or tearing and should be resistant to water, U-V radiation and organic growth. The cables should be coloured as follows:

Battery to control unit: Blue
Control unit to hand held anode: Orange or Yellow.
Control unit to Cathode: Orange or Yellow.

Carrying Frame

The carrying frame should be made of non-conductive material.

It should be fitted with adjustable fittings to enable the equipment to be fitted to the operator.

It should be able to be released and removed from an operator in an emergency.

Tests

A sample unit shall be independently type tested by an appropriate test authority to certify its IP rating.

A sample unit shall be independently tested and certified by an appropriate test authority to ensure that where the equipment is claimed to meet the requirements of published standards, that these standards are met.

Production control procedures shall demonstrate compliance of subsequent units, or appropriate tests will be undertaken on each before it is supplied.

Circuit Requirements

General

All components shall be selected to operate within their specified operating parameters under all conditions of operation. The unit shall not be damaged in any way as a result of any value of resistive load placed across the electrodes with any combination of control settings. Wherever possible, circuits shall be designed to be "fail-safe"

Batteries

Batteries must be housed in a separate enclosure to the Control Unit. The battery enclosure should be rated to IP54 or better. Batteries should be non-spillable and rechargeable.

Power Input

Interconnecting cables between the battery enclosure and the Control Unit shall pass through appropriate glands or be terminated in connectors rated to IP55 or better. Both poles of the incoming power shall pass through an isolating switch or contactor.

Charging System

The charging system should be supplied as part of the overall system and should be appropriate for the type of battery used. It must not be possible to operate the equipment if the battery is connected to the charging system.

Control Circuit

The peak voltage in any part of the control circuitry shall be less than 30 V. The control circuitry should be protected by at least one fuse.

Power Conversion Circuit

The manufacturer shall specify the maximum output voltage, output current and output power for the unit. A two-pole switch or contactor shall be fitted, which isolates both poles of the output circuit from the power source. Note: this does not preclude the disconnection being on the input side of a converter supplying the output circuit.

All capacitors shall be associated with circuitry to ensure that they are discharged to less than 30 V within 2 minutes of the power supply being removed.

Safety Circuit

The safety circuit shall be designed wherever possible to ensure that in the event of any component failure the electrodes cannot be energised. The safety circuit shall include a manually operated control switch on the anode electrode, one or more immersion switches on the control unit, and one or more emergency stop switches. It may also include tilt switches or remote switches designed to be operated by secondary operators, etc. The manually operated safety control switch shall comprise two series connected single pole switches. Both of these switches must be closed to enable the output to be energised. To ensure that the either of the switches has not failed to a short circuit condition the two switches are to be continuously monitored. If either of the switches fails to open at the same time as the other, the power supply should enter a "Tripped" state.

The safety circuit shall ensure that the electrodes cannot be energised until the following conditions have been met:

1. The emergency stop switches are in a Reset state.
2. The "Trip" circuit is in a Reset state.

3. Immersion switches are not activated.
4. Any other safety device fitted to the equipment is in a Reset state.

Nothing in the above precludes the development of novel techniques for operating the safety circuit such as the use of wireless techniques, subject to full compliance with fail safe and monitoring techniques described above.

Voltage Control

The equipment should maintain its output voltage within 5% of its set value for any value of resistive load placed across the output electrodes, unless the supply enters a "current limit" state, in which case a clear warning should be available to the operator.

Pulsed output control

Where the output is pulsed the unit shall maintain the pulse duration and repetition rate to within 5% of its set value.

Indicators

Visual

The use of Light Emitting Diodes is preferred where practicable to provide high efficiency and reliability.

Indication of the following states shall be provided

1. Input power available
2. Electrodes Energised
3. Current limit
4. Unit tripped

Audible

An audible sounder should be provided to provide a pulsed tone when the electrodes are energised. The pulse repetition frequency, or the pitch, or the amplitude may be increased as the anode current increases. A continuous tone shall warn of a "Tripped" state. The sounder may have a user adjustable volume.

Electrodes

General

Backpack Electric Fishing Equipment utilises two electrodes. The anode is generally held in the water by the operator by means of a long insulated pole, which is connected to the control

unit by means of a flexible cable. The assembly comprising the metallic electrode, the insulated handle and the associated cable is referred to as the Anode.

The cathode is generally trailed in the water behind or alongside the operator. It comprises a length of insulated cable connected to an uninsulated section, which may itself be flexible cable or braid.

No part of the electrode assemblies may be constructed of wood or any material liable to absorb moisture.

Anode

The flexible cable must enter the hand held electrode tubular handle at least 1m from the electrode head. The anode pole shall be equipped with a control switch assembly as described above having a single actuator. The design of this actuator shall be such that it cannot be held in an "On" position by the hand, or any part of the hand, being wrapped around the lever or button and the handle together.

The minimum distance from the actuator to any part of the uninsulated electrode head shall be 1metre. A means of fixing the electrode head to the handle, which prevents any movement or rotation of the head during operation, shall be provided. This does not preclude the provision of a method of adjusting the angle between the plane of the electrode and the axis of the handle. The anode assembly, including its connector when mated to the appropriate socket, must be rated to IP57.

Cathode

An appropriate strain relief mechanism shall be provided to ensure that any strain caused by pulling on the trailing end of the cathode is not transmitted to the connector. Measures must be taken to ensure that moisture does not migrate within the insulated section of the cathode cable due to immersion. The cathode cable shall be terminated in a connector rated to IP57.

Diagrams

Simplified Electric Fishing System Block Diagram
To be defined

Connector Specifications and Pinouts
To be defined.

Warning Labels
To be defined

6. WAVEFORM AND VOLTAGE EVALUATION (WAVE): INVESTIGATION PROTOCOL

Introduction

Electric fishing gear is an extremely useful and effective tool for sampling fish populations in small streams. As early as 1949, however, papers were being published claiming or detailing the harmful effects of electric fishing (Hauck). Subsequently, fish biologists (mainly in the USA) have conducted several research projects studying the effect of electric fishing on injury rates to fish. Research has shown that fish exposed to electric fields can suffer a wide range of short and long-term changes and damage ranging from minor behavioural modification to death. However, many evaluations have suffered from poorly designed experimental procedure and uncertainty over the "actual" as opposed to "intended" waveform being tested and few have provided accurate diagrammatic representations of the waveforms being evaluated.

One of the most noticeable factors highlighted by a literature search on injurious effects of electric fishing is the disagreement and conflicting ideas over the "ideal" pulse shape or frequency to use for electric fishing. The merits, or otherwise, of Pulsed DC (PDC), Smooth DC (SDC) and different waveforms of PDC (1/4 sine, square, exponential discharge *etc.*) have all received varying criticism in many research papers (see Phase I report for full discussion of this topic).

The type of pulse shape used has considerable and particular bearing upon Backpack Electric Fishing (BEF) equipment, as different pulse shapes and frequencies will result in significantly different power requirements. For example, it is interesting to note that as well as the findings of Sharber and Carothers (1988) that exponential discharge pulses "may be the least damaging to fish", its use would also seem particularly applicable to battery powered units, because of the power savings which may be made *(c.* 25% of the power required by square wave).

Objectives

The purpose of this study is to identify which of the three most commonly used voltage waveforms used for electric fishing is the most power and capture efficient, waveform for use in BEF equipment concomitant with acceptable injury and mortality rates to fish affected.

Methods

Three waveform types will be assessed: square wave, exponential decay and gated burst. An assessment will be made of capture efficiencies of these waveforms, both at constant voltage and constant power level (based upon the maximum power usage of the square wave pattern). The research will note factors associated with injury, and help identify electric fishing procedures that will optimise efficiency of electric fishing while minimising injury to fish.

The investigation will focus on salmonid species as these are often targeted with backpack electric fishing. Due to their availability Rainbow Trout will be used for the evaluation. Fish size will be standardised at around 20 - 25 cm.

Water conductivity plays a large part in both the efficiency and injury rates resulting from electric fishing. The questionnaire in phase I of this project found that BEF equipment was used in a conductivity range of 20 to 1200 μS^{-1}. In this regard the use of mid-range (550 μS^{-1}) conductivity water for the evaluation will enable results to be applicable to most systems in the UK. However, because electric fishing is practised by fishery workers nation-wide, the results will be of use in a broad geographical area.

Many non-electrical factors can have an effect upon the incidence and extent of electric fishing-induced injury. Environmental conditions (e.g., conductivity of water, water depth, substrate type, interspersed objects), fish species and size, equipment configuration (e.g., electrode size, shape, and position), affect electrical intensity and thus electric fishing efficiency and injuries (Vibert 1967; Reynolds 1983). For this reason, as many conditions will be kept constant as is possible. The only variables will be the behaviour of the individual fish used, the electrical waveform and the current/voltage used.

Anode dimensions will be that found to be in greatest use in the EA regions from the questionnaire in phase I (25 cm). Voltage gradient and field will be plotted for the anode used. Movement of the anode/cathode array will be kept constant, and duration of fishing will be constant between all evaluations. An oscillograph will be recorded for each waveform type and voltage evaluated in order to ensure that waveforms comply with expected shapes.

Many of the experimental designs used for waveform and voltage evaluation studies have used very artificial systems (plastic tanks etc). The results obtained from these studies therefore may not be applicable or valid when applied to natural streams. The WAVE design will have the advantage of being carried out in earth channels that will have all the electrical characteristics of a natural stream. Results therefore are likely to be directly applicable and valid for actual equipment use.

Waveform shapes and voltages will be generated from commercially available equipment. In the case of the exponential decay waveform, this will be from Deka backpack electric fishing equipment already owned by the IFE. In the case of the square wave and gated burst waveforms, Smith-Root (USA) will be approached for either the loan, or if necessary the purchase, of their equipment.

The UK Home Office will be contacted to see if the evaluation requires licensing under the Animals (Scientific Procedure) Act 1986. Appropriate licensing or exemption will be obtained.

The following waveform shapes and electrical values will be evaluated.

Waveform	Constant Voltage	Constant Power
Square wave	✓	✗
Exponential decay	✓	✓
Gated burst	✓	✓

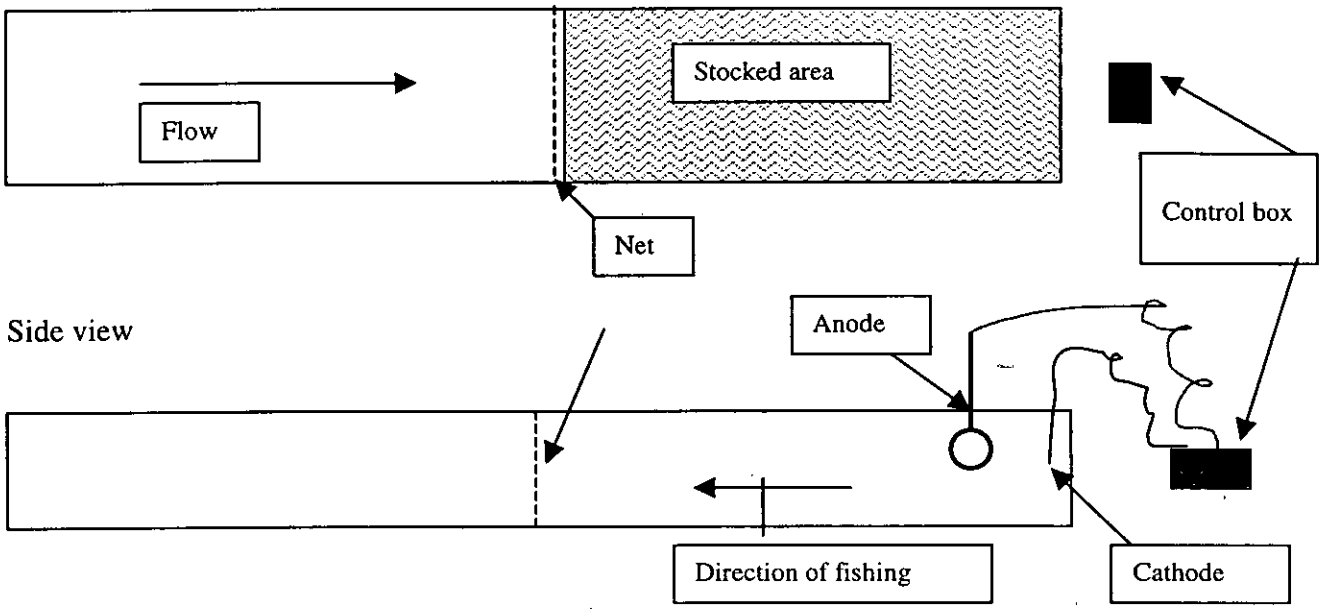
Five replicates will be carried out for each of the above variables.

In all cases pulse repetition will be kept at 50 Hz (or in the case of the gated burst the burst of pulses will have a 50 Hz repetition). The voltage for the constant voltage will be set at 200 volts. For the constant power category, the power usage of the square wave pulse will be

ascertained and the voltage of the exponential decay pulse and gated burst pulse shape increased until the same power usage is achieved. In this way the effect of both constant voltage and constant power will be evaluated. As the square wave shape will provide the bench mark power use for the other two waveforms it will not need to be included in the constant power assessment.

The layout of the evaluation channel is as follows:

Plan view



Channel dimensions are: Length 25 m
Width 5 m
Depth 1.5 m
Cross section shape – shallow "U"

Evaluation Protocol

For each waveform type to be evaluated the following protocol will be carried out:

The area of the channel to be fished will be stocked with 50 standard size rainbow trout. This stocking density equates to roughly one fish/m^2.

Fish will be batch marked according to the waveform/voltage evaluation being performed.

After a period for acclimatisation (30 minutes) the fishing equipment will be energised and moved at a constant rate from the downstream end of the channel towards the upstream end. The anode and cathode will have a fixed distance between them (1 m).

During the electrode travel one operator on each side of the channel will attempt to net any immobilised fish.

When both electrodes have passed over the upstream retaining net the power will be shut off and the evaluation terminated.

All netted fish will be counted and retained in an oxygenated container. The fish in the channel will then be left to recover for a 30-minute period.

The fishing process will then be repeated.

At the end of all the fishings all fish remaining in the channel will be netted out and put in a recovery channel. The mortality of any fish will be recorded and these fish will be retained for further pathological examination.

Fish netted out will be retained in oxygenated holding tanks for a period of one hour to allow for any immediate post-fishing mortality to occur after which they will be put in the same recovery channel as the non-caught fish.

Recovered fish will be kept for a minimum of 5 days to assess any longer term mortality which may be associated with the waveforms or voltage/power combinations.

Any fish that die during the evaluation will be examined for obvious tissue and skeletal damage. Dependent upon facilities being available a sample of fish will be X-rayed for skeletal damage.

Dependent upon Home Office requirements all fish will be killed at the project termination. No fish will be used for more than one evaluation.

Safety

At all times staff will be fully briefed regarding safe working practice and a staff member will be positioned next to the control box with responsibility for implementing emergency off procedure.

Emergency off systems will be positioned on the pulse box in order to enable a rapid/ instantaneous shut-off of the equipment.

Results

The efficiency of capture will be calculated for each of the waveforms/voltages evaluated. In addition a measure of the variation in efficiency between fishings will be ascertained.

Statistical tests will be carried out to determine the significance of any variations in efficiency or mortality between waveforms and voltage/power combinations.

Conclusions

The evaluation outlined above should allow a rapid evaluation of the three most commonly used waveforms for electric fishing. The evaluation does not encompass a total "roots-up" evaluation of electric fishing waveforms and voltages but concentrates on those criteria which experience shows to be the most efficient or commonly used. The use of only one fish size and one water conductivity, whilst reducing the scale of the evaluation, should not unduly inhibit the results from being broadly applicable throughout all the Environment Agency regions. The results will enable informed decisions to be made regarding the most fundamental aspect of electric fishing theory (waveform type), and will have particular importance in regard to the further design and use of lightweight battery-powered electric fishing equipment. The work will also provide a precursor for any further work involving a more fundamental review of the characteristics of the waveforms used for electric fishing.

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7. WAVE: PROGRESS REPORT

Anticipated progress in the evaluation has been delayed by the requirement to obtain a licence for the experiment (under the Animals (Scientific Procedures) Act) from the Home Office. Both project and personal licences will be required for the evaluation. Whilst the principal investigator (WRCB) had the qualifications required for a personal licence, additional training was required in order to qualify for holding a project licence. This further training has now been completed and applications for both licences submitted.

Administrative delays within the Home Office (6-weeks) make granting of the licences unlikely within the time scale initially envisaged for the evaluation. This delay may affect the possibility of using the channel facilities at the fish farm. However, alternative channels (albeit smaller) can be used at the IFE River Laboratory. If these smaller channels are used it may be necessary to use smaller fish and lower numbers, however a full reassessment of the requirements for the evaluation will be made prior to any work commencing.