SFIA Electro-Trawling Trials Onboard MT Boltby Queen

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SEA FISH INDUSTRY AUTHORITY
Industrial Development Unit

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S.F.I.A. ELECTRO-TRAWLING TRIALS ONBOARD
M.T. BOLTBY QUEEN

SUMMARY

The report describes the present state of development of the electrified array system intended to replace "tickler" chains on trawls designed for flat fish capture. The system has been developed over some 7 years and has involved trials with Beam and Otter trawls modified to carry the electrified arrays. The latest series of trials, with a modified version of a Lowestoft C4 Otter trawl, are described in the report.

The results of the trials with the C4 trawl have proved to be disappointing, with potential minor gains in vessel fuel usage and gear replacement costs being swamped by the losses incurred due to reduction in catch rate of the target species. While the problems of catch rate reduction are not necessarily insoluble the study team conclude that the necessary development work would make heavy demands on financial and staff resources and therefore suggest that future work be concentrated on development of electrified beam trawling techniques. Work in this area has already given promising results, with achievement of reduced operating costs in conjunction with equal or even increased catch rates, and with some expectation of extention of the fishing method onto soft grounds, where the traditional chain mat - rigged beam trawl is seen to have serious limitations.

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1. INTRODUCTION

Vessels fishing for flat fish species incur high costs on both fuel and gear replacement, associated with the requirement to tow a series of heavy tickler chains ahead of the trawl. The S.F.I.A. has developed an electrified tickler system which replaces the major portion of the heavy tickler chain rig with savings in towing power requirements. A series of trials has been carried out on a variety of vessels during recent years, initially with modified beam trawls but more recently with a modified version of the C4 Otter trawl used by the Lowestoft Middle Water trawler fleet. For the latter trials the S.F.I.A. chartered the Lowestoft based stern trawler BOLTBY QUEEN. Trials were arranged for two separate periods, in 1981 and 1982. The earlier trials are reported in Field Report 1003. This report covers the activities of the second series of trials and draws conclusions from work done during the whole series of trials to date including beam trawling operations.

The equipment used in the 1981 trials was modified after those trials to incorporate an alternate design of pulser capacitance bank. The work involved re design of the capacitance bank housings and the opportunity was taken to modify the rigging of the pulser system and trailing electrode arrays in order to eliminate handling difficulties which had been noted in the trials.

The 1982 series of trials were set for May 1982, and arrangements were made to loan an underwater video system from DAFS, Aberdeen for use during the trials. In the event it was necessary to postpone the trials in order to resolve leakage problems in the new pulser housings. The trials eventually took place during October 1982; the underwater video equipment was by then in use on another project and was not available for S.F.I.A. trials.

2. BACKGROUND

The flat fish fishery in the U.K. has its base in Lowestoft although more recently there has been a growing fishery from Brixham and Plymouth. The vessels engaged in this fishery range from 50ft beam trawlers, fishing mainly for Dover Sole (Solea Solea), to 170ft stern trawlers fishing as far afield as the Norwegian sectors for Plaice (Pleuronectes platessa).

Traditional methods used in the capture of these species require heavy chain ticklers which, when towed forward of the ground rope 'dig out' the fish buried in sand or mud, to be subsequently captured by the following beam or otter trawl.

In the early 1970's as the industry prospered and there was new investment, vessels grew larger in size (and consequently horsepower) to cater for inevitably larger trawls to cover more ground and catch more fish. This carried with it the need for more chains and considerable increases in drag forces and horsepower to tow gear.

Though energy costs increased with power requirements, these costs were only about 10% of the total running expenditure. However, rising fuel prices during the mid-seventies created many problems for both individual vessel owners and trawler fleet owners alike and fuel now accounts for 45-50% of the total running expenditure during a fishing voyage.

In 1976 the S.F.I.A. performed trials on several beam trawlers fishing for flat fish. Measurements were recorded of the horsepower required to tow these heavy chain rigged trawl gears over the sea-bed. With a view to reducing the drag of these trawls, but at the same time maintaining their fishing performance, the S.F.I.A. commenced development of the electro-trawl system to provide an alternative to the chain tickler systems in common use.

3. BASIC PRINCIPLES OF ELECTRIC FISHING

The traditional heavy tickler chains on the trawl are replaced by a lightweight set of trailing electrodes fed by a series of electrical impulses from a pulse generator controlled from a ship-borne conditioning module. These impulses produce an electric field, over the area bounded by the electrode array, which give fish buried in the sand or mud, or close to the sea-bed, an electric shock. The resulting reaction, termed "involuntary flight" by scientists, causes the fish to dart upward away from this hostile zone into the path of the approaching trawl. Often in practice, the initial elevation of fish from the sea-bed is followed by a secondary pursuit known as 'herding' before subsequent capture of the fatigued specimens occurs.

3.1 Historical Background to Current Studies

Electric fishing is by no means a novelty, however its application to commercial sea fisheries is relatively new.

A bibliography published in 1978 gives a list of some 1200 publications (Meyer-Waarden and Halsband). Many of these describe controlled experiments in fresh water, such as ponds, lakes and rivers. Some of the work dates back to the turn of the century while an important part was done in the late 1920's.

In the more recent past , electronic components developments have given stimulus to technical research and development in this sphere of science. Today, intense currents at high frequencies can be switched with very fast rise times, using thyristor technology. Much research has been done too on mechanisms which cause different reactions in fish, though predominantly with fresh water species. Nevertheless, many of the basic physiological reactions due to the application of varying degrees of electrical impulses on fishes can be shown to be similar, whether in fresh or salt water, the main difference being the water conductivity which can present power problems (See Appendix I).

A vast majority of authors describe the different fish reactions as related to the voltage per unit distance in the water or sea bed substrate (v/m or v/cm) one of the most important reactions being forced swimming towards the anode known as 'anodic taxis' - or galvanotaxis. This reaction is very marked with many round fish species with direct current.

The principle of anodic taxis is used, in reverse, in both sea and fresh water installations of fish deterrent screens. The negatively charged screen reverses the reaction from one of attraction to repulsion from the screen itself. This application is used widely in deterring fish from entering inlets to power plants and factories.

As sea fisheries today are practised on a much larger scale than freshwater fisheries, the potential applications of electricity must be greater. The physical problems, however, are magnified vastly because of the high conductivity of sea water, approximately 500 times that of fresh water. The application of pure d.c. must be immediately ruled out because of the substantial power demands, if realistic electric fields are to be created over a practical area. The solution of pulsed d.c., which has a strong physiological effect on fish and much lower average power consumption, providing the duty cycle is controlled to a sensible economic limit, has been adopted by most institutions currently experimenting in this field.

3.2 SFIA Electric Fishing Equipment Details

The S.F.I.A. electro-trawling system is made up of the components listed below. They are sited and are connected as shown in Fig. 1

(i) A single phase power source of 240v 50Hz 12k.v.a. - provided from a 3 phase to single phase rotary converter.

(ii) A resistive inline ballast unit to control power consumption of the system.

(iii) A bridge control console supplying single or dual outputs for either otter or beam trawl applications.

(iv) Self-tensioning winch fitted with 400m of power transmission cable for ship to trawl pulser link.

(v) Two pulsers mounted on an aluminium raft and fixed to the centre of the trawl headline (see Fig. 2).

(vi) An electrode array consisting of eleven steel wire electrodes 2.7m in length and horizontally separated by a distance of 0.73m. (C4 Trawl only - specification changes for other trawl gears - see Fig. 3).

3.3 Basic System Operation

(see Appendix I for technical details)

The 240v A.C. supply from the alternator is fed to the bridge control console via its associated switchgear and protection. This unit essentially converts the A.C. to a compound continuously pulsed d.c. waveform at the output. Output channels are duplicated when beam trawling.

The compound d.c. output comprising of twenty four positive consecutive sine pulses are fed via the supply power line and its associated self tensioning winch to the trawl mounted pulser.

The electrolytic capacitors contained within the pulser are sequentially charged by the positive series of sine pulses and after the twenty fourth pulse completes the cycle of charging, a negative sine pulse received by the pulser trigger network allows the accumulated energy on the capacitor bank to flood out into the electrode array.

The frequency of this output is called the pulse repetition frequency (p.r.f.) and was 4Hz during most fishing experiments.

The amplitude of the voltage between the electrodes at the initiation of discharge was 230v d.c. peak, producing a peak discharge current of 2,400A at a time constant pulse width of 0.9 milliseconds.

4. ELECTRO TRAWLING TRIALS ONBOARD M.T. BOLTBY QUEEN, OCTOBER 9th 1982 to OCTOBER 21st 1982

4.1 Preparatory Work

The test period from May 1982 to September 1982 involved several modifications, laboratory and field tests on the S.F.I.A. electro-trawling system.

New capacitance bank housings had been manufactured during the spring of 1982. The new housings provided a greater internal volume than before and were provided with removeable plugs for access to the capacitor banks as an alternative to the previous arrangement which had required the grinding away of a welded joint. The new housings were designed against an external pressure equivalent to immersion at 100 fathom sea water depth and when filled with a compressible medium such as air. The units were provided with Cam-Lock plugs on Input and Output leads to allow complete disconnection from the remainder of the system if necessary.

A preliminary trial in July 1982 was curtailed due to immediate ingress of water into the pulser housings. Later laboratory analysis of the failure revealed that the fault was due to perforations in the end cap welds. Critical analysis of the method of mounting the cam-lock input/output connectors led to changes in their mounting.

A purpose built pressure chamber was acquired for full scale pressure tests on the modified housings. They were immersed to a simulated depth of 100 fathoms, approximately twice their expected operating depth, for periods of up to 4 hours.

4.2 Laboratory Trials

The pulsers were initially tested into simulated electrode array loads (dummy loads) of resistances varying from 50 milliohms to 100 milliohms. The voltage developed across the capacitance bank at the end of the charging cycle was adjusted by means of an inline ballast resistance to give a pulse magnitude at the output terminals of 267v peak d.c. (see technical details in Appendix I). The operating periods were limited to 2 hours because of the poor heat sink loading available in the laboratory. However, all four pulsers performed satisfactorily in this limited test environment.

4.3 Field Trials

In order to establish even greater confidence in the operational performance of the system, a second trial took place in Stonehaven harbour. The ease of access, practical tidal depths, and lack of public hampering made this harbour ideal for such measurement trials.

The objectives of these tests were two fold:-

Primarily to subject the S.F.I.A. system to operating periods in excess of minimum commercial towing periods of 2 hours, and to discharge the pulser capacitance banks into the electrode arrays used in practical applications.

Secondly, to measure the resistances of various numbers of electrodes of constant length, diameter and separation comprising an array, subsequently defining the relationship between array resistance and 'n', the number of electrodes. This relationship would establish practical limits of area which can be economically electrified (see Appendix I).

The electrode arrays were laid out and held to the sandy beach using metal tent pegs, which ensured that the electrodes would not be disturbed by undercurrents and therefore keep their parallel configuration.

The running periods of the pulsers was approximately five hours continuous twice daily with an off period of ten minutes. During these tests, values of electric field strength were recorded and array resistances deduced from the time constant of the exponentially decaying discharge pulse.

The impeccable performance of the system throughout its test programme justified revaluation of the S.F.I.A. electro trawling system on a full commercial fishing voyage onboard M.T. BOLTBY QUEEN.

4.4 Sea Trials
October 9th to October 21st, 1982

These trials were performed during a normal commercial voyage on the above vessel. The vessel normally uses an 82ft headline, two panel C4 flat fish trawl, rigged with a series of chain ticklers (see Figure 4). For the purpose of this trial, the C4 was used rigged as normal but with the electrode array replacing the tickler chains.

Following re-installation and commissioning of the electric fishing system a brief deck test of the pulsers into dummy loads was performed, with satisfactory results.

In order to assess the vessels performance and fuel consumption, recordings of shaft-torque, horsepower, vessel speed and warp tensions were made for both chain and electro trawl rigs. Also, comparative fishing trials, though limited by other vessels fishing the same grounds, were conducted to assess the catch effectiveness of the electro-trawl.

4.5 Vessel

The vessel used was the stern ramped trawler BOLTBY QUEEN owned by Talisman Trawlers Limited, Lowestoft. The vessel was built in 1974 by the Goole Shipbuilding and Repairing Company Limited, and her main dimensions are as follows:-

Length overall	37.95m
Length b.p.	31.72m
Moulded breadth	8.3m
Gross tonnage	349.24

The vessel carries wet fish only, i.e. does not have facilities to freeze the catch, and has a crew of seven men including the skipper. Further details of the vessel are given in Appendix II.

4.6 Instrumentation for Otter Trawl Trials on the Vessel

Shaft torque, shaft speed and therefore horsepower, were measured via a four-arm active strain gauge bridge employing the F.M. short range telemetry link system. These parameters, together with warp tensions and propeller pitch, were recorded on the Gould pen recorder. Vessel speed was taken from the vessel's own Kelvin Hughes Sal-log and event marked on the recorder at relevant stages of recording.

The warp tensions were measured using the I.D.U. 10 ton load cells which were attached to the warps by means of chain stoppers. The inboard ends of each load link were shackled into fabricated pads at the rear of each winch.

5. TRIALS RESULTS

5.1 Power and Fuel Consumption Requirements

Performance parameters were recorded over a range of towing speeds for both the electrode array and tickler chain rigged trawl.

5.1.1 Shaft Horsepower

Figure 5 shows shaft horsepower against towing speed for the chain tickler and electrode array rigged C4 otter trawl.

This graph (upper section) shows that at the normal towing speed of 4.5 knots, with the chain rigged trawl 700 S.H.P. was required to tow the gear. At the reduced optimum of 3.5 knots for the electrode array, the power required was 670 S.H.P.

5.1.2 Gear Drag Forces

Fig. 6 shows total warp tension plotted against vessel speed for a chain rigged trawl and electrode arrays. At 4.5 knots the total warp load recorded was 6.8 tonnes, this figure reduced to 6.1 tonnes at 3.5 knots for the electrode array rigged trawl.

5.1.3 Fuel Savings

Fig. 7 shows a histogram of the fuel savings for the two types of fishing gear and indicates a 4.3% fuel reduction in favour of the electrode rigged trawl.

For comparison purposes the fuel savings obtainable on 4m and 8m bean trawls, from results taken from M.F.V. HOMEWATERS (F.R. 1003) and more recently on MFV ZUIDER KRUIS operating from the port of Brixham, have been included for discussion in this report.

5.2 Fishing Performance

Trials with the electro trawling equipment on the otter trawl, first carried out in 1977, were so fraught with handling difficulties that the main technical development of the equipment was carried out on the beam trawl, as it provided a much better platform for this purpose. It was not until this main development work had been carried out that serious attempts to electrify the otter trawl were made and meaningful results were obtained.

Earlier trials results from the same vessel were inconclusive as the electro trawling equipment, owing to technical problems, was operating only spasmodically. However, it was noted that initially the catch rates for plaice were only about 25% of those achieved by nearby vessels fishing with conventional gear. This catch was increased to approximately 50% later in the trial by the addition of a further chain at the front end of the electrodes in order to keep them down on the sea bed. The failure of the equipment half way through the trial lead to doubts as to whether the low catch rates were due to the malfunctioning of the equipment or to the fact that plaice do not react to electrical stimulus in the same way as dover sole.

Better estimates of comparative catch rates have been obtained from the October 1982 trials, when the technical performance of the equipment was uniformly good. The results are shown in Tables 1 to 7 and on Fig. 8.

The electro trawling equipment was in use during the trials for 30 tows, or 71 hours actual fishing time, and during this period caught a total of 1,781.8 kgs of flat fish (mainly plaice) giving a catch rate of 25 kgs per hour, in comparison with the vessels normal chain gear which caught 4,486 kgs of flat fish in 26 tows, or 64 hours of actual fishing time, a catch rate of 70.1 kgs per hour. This represents an effective catch for the electro trawling gear of approximately 35% of that for the normal chain rig.

In addition to the total of 6,267 kgs of flat fish, a further 2,960 kgs of other species were caught, of which approximately equal amounts were caught with electro-trawling equipment and the chains.

It was interesting to note that in both trials, although the catch of plaice was only 30-35% of that usually caught with the chains, the catch of lemon sole, although fairly small, was roughly equal.

During the trials various towing speeds were used to try and establish if there were any significant changes in catch rate, as during the beam trawl trials a speed of 3½ knots was found to be the optimum for dover sole. However, in the case of plaice no significant differences were detected.

Day and night catch rates were compared and again no discernable differences were noted.

5.3 Handling of the Otter Trawl Array

The main difference between the beam and otter trawl gear is that the beam trawl presents a fixed solid platform on which to attach the various pieces of equipment. Otter trawling on the other hand is a dynamic method of fishing so that once the gear comes to a standstill it collapses and thus it is much more difficult to satisfactorily fix the various components of the electro-trawling equipment.

This meant that the various parts of the electrode array and cables frequently became entangled and thus valuable fishing time was lost in rectifying these problems.

One of the main problems on the BOLTBY QUEEN was that the vessel had a relatively narrow ramp and short working deck, due to the net drum being situated aft of the fishroom hatch. Therefore under normal circumstances, when using tickler chains, virtually the whole trawl is wrapped around the net drum leaving only the cod end to be lifted aboard. It was not possible to do this whilst using the electro trawling equipment as the pulser package mounted in the headline is a relatively bulky object and will not go round the net drum. Once the pulsers were hauled up to the net drum the rest of the net had to be fleeted up the deck, with extention of deck handling times.

The fact that all the cables and most of the electrodes were taken onto the net drum every haul (approximately every two hours) tended to cause damage to the equipment and inevitable entanglements.

However, despite these difficulties, with a skilled crew, the trawl can be shot and hauled without extensive time loss. The normal handling time for a chain rigged trawl was 15-20 minutes, and for the electrified trawl was 20-30 minutes, from leaving the sea bed to returning to it.

This additional handling time would mean that, in a normal trip when a vessel could expect to make 80-90 hauls, it would lose 15 hours fishing time, or approximately five hauls.

These handling problems can be compared to use of the electro-trawling equipment on the beam trawl where the difficulties do not exist. The vessel, once it reaches the fishing grounds, usually puts its beams outboard where they remain until the grounds are changed or fishing is completed, the cod end only being brought in board for emptying. Therefore, as long as the array is clear when it is first "shot away", it should remain that way unless damaged whilst on the sea bed.

5.4 Maintenance of the Array

The main problems experienced were due to sea bed abrasion causing the various components of the electrode array to wear away fairly quickly. Some damage was caused when the array was wound onto the net drum after every haul.

Many of these problems could be overcome by the manufacture of items, such as insulators, specifically for the job, and similarly a more suitable arrangement of deck machinery could be achieved if a vessel was to be involved permanently with electric fishing. This would make the shooting and hauling of the gear more efficient and reduce entanglements and damage.

Damage due to sea bed debris, often a problem on the beam trawl, did not seem to pose any particular problems on the grounds worked with the otter trawl.

The initial object of the trial was to prove catching efficiency of the equipment and reduce fuel consumption. The durability of the gear could easily be improved should it ever become commercially viable.

5.5 Comparative Trials Data - MFV HOMEWATERS towing 4m beam Trawls

5.5.1 Shaft horsepower

Fig. 5 shows the variation of shaft horsepower with towing speed for chain mats and electrode arrays.

At 5 knots the chain mat rigged trawl required 265 S.H.P., and at the same towing speed, the electrode rigged trawl required 225 S.H.P. At 3.5 knots, which coincides with maximum catch rates on the electrode rigged trawl, the shaft horsepower demand was 120 SHP.

5.5.2 Gear Drag Forces

Figure 6 shows total warp load plotted against vessel speed for chain mats and electrode arrays. At 5 knots, the total warp loads recorded were 3.3 and 2.9 tonnes for both chain mats and electrode arrays respectively. At 3.5 knots the electrode array towing load had fallen to 2.45 tonnes.

5.5.3 Fuel Savings

The saving of fuel on the MFV HOMEWATERS was found to be of the order of 43% during towing of the electrode rig over the chain mat. This figure was taken from comparisons of the two gears towed at their optimum towing speeds of 3.5 knots and 4.5 knots for electric and chain beam trawls respectively. (See Fig. 7)

Fig. 9 shows the relative catch rates for three types of fishing gear, i.e. chain mats, chain ticklers and electrode arrays.

6. DISCUSSION OF RESULTS, PERFORMANCE AND BENEFITS OF S.F.I.A. ELECTRO-TRAWLING SYSTEM

6.1 Fuel Savings on 3 Vessels towing Chain Rigged Trawls

The histogram (Fig. 7) indicates the relative fuel consumptions for three vessels which employ chain rigged trawls. Sections 7(a) and 7(b) represent the results from commercial fishing trials on board M.T. BOLTBY QUEEN and M.F.V. HOMEWATERS respectively, during which fish catch rates were established. Section 7(c) has been produced from a recent trial onboard M.F.V. ZUIDER KRUIS, a Brixham based 8m beam trawler, to indicate the potential fuel savings achievable by larger beam trawlers using electrode arrays.

6.2 Fuel Savings when Otter Trawling

The application of the electro fishing system to the C4 Otter trawl revealed poor improvements to the fuel economy of the M.T. BOLTBY QUEEN even at the reduced towing speed of 3.5 knots, with the savings limited to some 5 litres per hour, about 4% of the total consumption when towing the traditional trawl. Some potential saving was lost by failure to redesign the otter boards to account for the revised forces which a change in trawl rigging provides; another "lost" element of saving would seem to be associated with the poor towing pull/propulsion power characteristic of the vessel itself. These are discussed briefly below.

6.2.1 Effects of Rigging Changes on Towing Pulls

Two of the most important chains, in terms of catching power, are those attached to the heel of each otter board. The backward drag force produced by these chains creates a turning moment on the doors which reduces their angles of attack and subsequently their drag through reduction in shear. However, the electrode array rigged trawl omits, for obvious reasons, any heavy chains attached to either trawl or otter boards. The effect is to allow the otter boards to take up a new position, due to reduction of back dragging forces, and increase their angles of attack, creating more drag than with the chain rigged system. This is described in more detail in Appendix III.

6.2.2 Towing Pulls and Shaft Horsepower Requirements

The BOLTBY QUEEN is one of a series of fairly modern stern trawlers which utilise propeller pitch variation alone for control of running speed or towing power, the engine and propeller running at a continuous speed during all operations. This form of control is inherently uneconomic in that reductions in propulsive thrust are not matched by reductions in transmitted horsepower; the flatness of the curves in Fig. 5 is a good indication of this. The reasons (and solutions) for this phenomenon are being investigated in a separate section of the Authority's programme and will be reported separately.

6.3 Effectiveness of the Electric Field employed on C4 Otter Trawl

Figures 10 and 11 show the areas enveloped by the electric field for both a C4 otter and 4m beam trawl in relation to the respective areas bounded by their foot ropes. It will be noted that the lateral coverage value for the otter trawl array is lower than for the beam trawl array. This is an unavoidable consequence of the differences in array towing arrangements on the two trawls.

Experimental tests in Stonehaven on electrode array measurements showed that if the same percentage area on the C4 Otter trawl were to be electrified to similar energy densities as that of the 4m beam trawl, then the pulser housings would require a 4 fold increase in volume. This necessary increased volume would encapsulate a 100,000μF bank of capacitors, a totally impracticable situation on both physical size and capital cost grounds.

6.3.1 Relationship between Towing Speed and Effectiveness of Electric Fishing Techniques

The speed at which an electrified array is towed over the sea bed will regulate the effective area and field intensity of the array in the manner described below.

Fish which are buried in sand or mud must be subjected to a minimum number of energy pulses before a reaction will take place. The initial reaction, artificial contraction of fish muscle, will occur in as little as a half second but the desired reaction of movement from the sea bed is likely to occur only after a one and a half seconds exposure to energy pulses. This time delay, the "emergence time" has been shown to vary with physiological factors including size and metabolism of fish.

It will be necessary to relate the length of towed electrode to expected towing speed to ensure that the period during which a fish is exposed to the energy field is not less than the emergence time defined above. In practise the SFIA has used a criteria of period of exposure to the energy field of 1.67 seconds and this has limited the towing speed to 3.5 knots for the configuration used in both otter and beam trawl trials. The layout of the electrified array and its spatial relationship to the trawl footrope must take the "emergence time" factor into account since the fish must react before the footrope passes over it if the fish is to be caught.

Though some increase in towing speed could be accepted if the overall length of the towed array were increased (and if the whole towing arrangement were changed to maintain the correct spatial relationship between array and footrope) it would be necessary to ensure that the design of the trailing electrodes was such that any tendency of the electrodes to lift from the seabed were reduced to the greatest extent possible, since the effectiveness of the field in the mud or sand below the electrode is reduced as the electrode lifts off the sea bed. The "lift off" speed of the electrodes used in the trials is some 4.25 knots and a restriction of towing speed to 3.5 knots thus ensures that the electrode array should maintain good contact with the sea bed.

6.3.2 Combination of Electrical Stimulation and Herding Effects of Trawl Design

The process of capture is usually a combination of physical restrictions to the immediate environment, and the mechanics of trawl doors and bridles which, by the production of visible dust clouds, obscure most of the possible escape routes. The elevation of fish by electrical means, particularly on complex arrangements such as the otter trawl, is usually only the first stage of pursuit before fatigue and subsequent falling back into the trawl occurs. Thus the reduction in towing speed associated with use of an electrode array to replace the chain rig will have affected the geometry of the trawl, in a way which could be predicted in Flume Tank trials and allowed for in the rigging arrangement, and may also have effected the herding characteristics of the system, the latter change being much harder to detect in any model trials. Use of underwater video equipment might have provided some information on this feature but was ruled out for reasons given earlier in this report.

6.4 Catch Rates with the Electrified Array Otter Trawl

Catch rates for the modified Otter Trawl were disappointingly low at about 20-30% of that achieved by other vessels towing traditional trawl gear in the same area. Not all of the possible factors could be checked though the trials staff were satisfied that the electrified array was maintaining ground contact, that the pulse discharge system was operating correctly and that the expected electrified field was being developed. Some reduction in field strength could have been tolerated in any case since the plaice species forming the major part of the vessel's catch are generally larger than the Dover Soles taken by the trials beam trawl and have a greater reaction per unit strength of pulse. The relevance of other factors must be subject to conjecture but it is felt that the towing speed reduction, carried over from beam trials, may have reduced the effectiveness of the otter trawl in a manner not noted with the beam trawl trials. The reasons for this reduction in effectiveness are associated with the increase in size of fish (and therefore endurance speed of fish) on the otter trawl grounds and also the absence of a factor which had been noted during the beam trawl trials. This latter factor, in which the electrified beam trawl had a higher catch rate at a lower speed than its traditional counterpart, has not been fully explained but is felt to be related to the manner of physical design of the electrode arrays and chain mat rigs; the electrode array provides stimulus to fish to move from the sea bed without impeding the path of a fish attempting to do so, while the chain mat rig provides stimulus and barrier, the barrier effect being particularly significant for the larger fish. The electrified beam trawl therefore tended to catch a higher proportion of larger fish than its traditional counterpart, with positive effect on the overall catch rate.

6.5 Comparisons between Otter and Beam Trawling Arrangements and Results

The application of electrode arrays to replace chain mats on beam trawlers is made simple due to the rigid structure of the beam trawl framework. The heavy pulsers - 40lbs weight each in water, electrode distributor cables, and backward drag on feeders to electrodes have no effect on the configuration of the trawl since their weight is taken by the beam itself. The rigging of the electrode array on the beam trawl ensures that the electrodes adhere to the seabed during their forward traverse, and that they remain parallel to each other. This ensures that the electric field between adjacent pairs of electrodes is similar, providing a uniform distribution of electrical energy forward of the ground rope.

The methods of capture by electrode arrays applied to beam and otter trawls is different not only from a physical point of view but further complicated by other differences in gear arrangement which reflect the fundamental differences in the catching systems for the two trawls.

Capture by beam trawl seems to be a simple matter of ejecting the buried fish from the sand or mud in which they are substantially buried. The flight reaction created by the presence of manual 'digging' of chains, or by electric shock is closely followed through by capture by the trawl. In fact the effects of herding by this trawl are minimal, since there is no corridor or boundary forward of the disturbance zone created by the chain mat or electrode array.

Otter trawling utilises a different mode of capture technique, with herding as a secondary though decisive part of the total system. The disturbance zone is not bounded by mesh net, as is the case with beam trawls, and it is necessary to herd the fish into the area of the net opening. If a change in the arrangement of ground gear generates a reduction in the herding efficiency of the door/bridles arrangement then any improvement in the digging out technique can be countermanded by an increase in the fish escape ratio. This has neither been quantified or even proved on the recent trials but is an indication that the range of factors which can effect the efficiency of the trawl system is greater for the otter trawl than for the beam trawl. A greater understanding of the degree of interaction between the different elements of an electrified otter trawl, and of the electric field effect itself, is necessary if progress is to be achieved.

A specific instance of an unexpected effect of the electrode field effect has been noted on the beam trawl trials whereby the catch rates of round fish such as cod or haddock have been higher with the electrified beam trawl than with the traditional trawl. The improvement is believed to be due to a combination of "herding" and "tetanic" effects on round fish, caused by the electric field.

During the charging of the capacitance bank on the trawl, a compound electric field of variable magnitude is produced between the ship and the negative electrodes of the array. Throughout this enormous volume of seawater, electric current is emitted. The strength of the field a few metres in front of the trawl could quite feasibly produce an effect on fish such as cod or haddock which are then 'herded' by the beam trawl. The wave form is shown on diagram E5 in the Appendix section of this report.

It is realistic however to consider only the first and second sine pulses in the exponentially decaying cycle. The rest are well below the minimum electric field threshold levels necessary to contract fish muscle.

The first pulse of 120 v.d.c. peak amptitude is half sinusoidal in nature and of ten milliseconds duration - defined by the power source frequency. Figures 10 and 11 show the variation of field strength at various distances in all planes from the surface of the negatively coupled electrodes. During the charging cycle the negatively coupled electrodes assume positive polarity with respect to the ship's hull. It is only during the discharge of the capacitors into the array that these electrodes are actually negatively charged; the rest of the period they are at positive potential.

The areas subjected to this effect are indicated on Figs. 12 and 13 which show that fish swimming immediately ahead of the ground rope are in areas where the field strength may have a tetanic effect on them.

6.6 Reliability of Electrical Equipment

The equipment performed faultlessly during the whole trials sequence on the BOLTBY QUEEN. This is of particular significance for the Authority's future work with electrode arrays on beam trawls since the equipment is essentially the same for otter or beam trawl installations. Equipment incorporated into the latest trials equipment and not formerly tested at sea included new capacitance banks and housings. The capacitor units have recently become available following their development for onshore use. A particularly useful feature is the low heat dissipation requirement compared with former units. The new design of capacitor is also cheaper than former models of similar performance.

The capacitance bank housings incorporate new and more convenient external sealing and cable coupling arrangements.

The cable used in the trials has now been tested on a number of successive trials and can be recommended for future trials and commercial work. The specification is given in Fig. 14. The introduction of single core cable (with circuit return via the sea) has eliminated much of the complexity of cable couplings and has eased repair problems.

Long term reliability of the system is essential not only to maintain fishing effectiveness of the system but to limit the degree of electrolytic wastage of array components, particularly the electrodes. Some degree of wastage is inevitable during the charging cycle, when the array electrodes become anodic with respect to the vessel. The effect is much less serious than that which occurs if the equipment develops a fault, when electrodes can waste away within 15 hours of operation in such a mode. The expected electrode life in fault free circumstances is expected to be of the order of at least 800 hours, dependent on the degree of mechanical abrasion due to sea bed contact.

7. ESTIMATION OF FINANCIAL VIABILITY OF SYSTEM

It has not been possible to calculate the overall capital investment and operating and replacement costs for the electrified system as applied to the C4 Otter Trawl, since it is by no means clear that the trials installation is representative of the optimum installation for such a trawl. Attempts to optimise the design would almost certainly involve provision of additional electrodes and ground chains, with a reduction in savings to a value less than the £2,000 annual savings estimated for operations with electrified rather than traditional beam trawls.

Fuel savings associated with use of an electrified system on the C4 Otter Trawl are also likely to be of a low order, perhaps £3,000 per year, though the major factor in this case is the poor shaft horse power/thrust relationship of the vessel's propulsion system. Changes to this system could lead to an enhanced value for fuel saving.

The combination of savings noted above can by no means overcome the losses associated with reduced catch rate. Reduction of catch income by a factor of about 3, as noted in the trials voyage, would lead to overall losses of some £250,000 per annum.

There is no possibility that further improvements to the operating efficiency of vessel or electrified trawl can retrieve more than a minor part of this loss unless the improvements restore the catch rate to its former value.

An estimate of the comparable annual gear costs for electric and conventional beam trawl systems is shown in Table 8.

8. CONCLUSIONS ON OTTER TRAWLING TRIALS

8.1 Fish catch rates with the electrified C4 Otter trawl are unacceptably low when copared with catches with the traditional trawl.

8.2 The order of magnitude of catch rate reduction is such that changes in operating or gear replacement costs cannot offset the loss of income.

8.3 Continued development of the electrified otter trawl cannot be justified and future work should be concentrated on development of beam trawling equipment and techniques.

8.4 Handling of electrified otter trawl on board typical fishing vessels creates difficulties which could only be overcome by vessel redesign.

8.5 The trials vessel, which is a typical member of a class of some 12 modern stern trawlers, is seen as having undesirable propulsion characteristics in that reductions in towing pull requirements are not matched by reductions in shaft horse power requirements. (This factor is the subject of a separate study from which recommendations are shortly to be made).

8.6 The trials have provided useful testing and proving of new equipment in the electric field system. The new equipment can be utilised in further work on development of electrified beam trawls.

8.7 Operation of the electrified array in conjunction with the otter trawl has provided useful comparative data (with similar equipment on the beam trawler) and has provided some insights into the operation of the array on the beam trawl which were not apparent from trials with beam trawls.

9. RECOMMENDATIONS FOR DEVELOPMENT OF THE ELECTRIC ARRAY FISHING SYSTEM

9.1 Beam Trawls

The possibilities for further development of electrified array systems are seen to lie in the use of such equipment with beam rather than otter trawls. Work to date has shown that beam trawls equipped with electric fishing systems can achieve catch rates of a similar order to that achieved with traditional trawls, and with reduced power and gear replacement costs for the electric array system. It is seen as having significant potential for integration into the expanding beam trawler fishery of the U.K.

The current U.K. beam trawling fleet comprises about 100 vessels based at Brixham, Newlyn and Lowestoft. The Brixham fleet (of some 60 vessels) is seen as taking particular benefit from the use of electric fishing techniques during the summer fishery in Liverpool Bay, where chain mats trawls are noted as being unsuitable for the soft grounds of the area. There is potential for the same fleet in the English Channel by expansion of its present fishery onto softer grounds.

The adoption of the chain mat by beam trawlers seems, to some extent, to lie in tradition rather than necessity. On severe grounds containing large boulders and stones, it assumes a very useful function in restricting their entry. The chain mat, however, can restrict the physical entry of large flat fish into its trawl due to the limiting dimensions of the chain squares. A recent visit to Brixham highlighted this point, when it was noted that one of the largest beam trawlers, MFV CATEER, (1,400 h.p.) had changed to an 'open fishing gear' which used 'chain ticklers' instead of mats and was achieving some degree of success. Other vessels have tended to retain the heavy chain mat for all fishing requirements to avoid the work and problems involved in changing from heavy to light tickler systems. The electrode array system is seen as having potential use in a wider range of sea bed conditions than a single existing gear and is thus particularly suited for the fishery in the English Channel.

The European flat fishery in Holland and Belgium is almost wholly dedicated to beam trawling and it too provides a potential market for manufacturers of a commercial electrical fishing system.

9.2 Nephrops Fishery

The present SFIA system has been developed from equipment originally designed for the Gulf of Mexico shrimp fishery though not gaining acceptance in that fishery. The equipment is seen as having potential both in the UK and tropical shrimp fishery and particularly in conjunction with the use of double boom trawling techniques. Such techniques are seen as being more amenable to introduction of electric fishing arrays since many of the gear handling problems associated with use of electrified equipment with a "single" trawl are not encountered when handling double boom trawls.

10. FUTURE WORK

Though the technique of electric fishing on the C4 Otter trawl has been shown to be commercially non-viable without extensive work, improvements to the existing gear could be made.

It has been suggested that the otter board drag on these trawls be investigated through flume tank experiments, with the view to improved efficiency. The present Fearnought otter boards have been used for many years and the introduction of new techniques and ideas in determining optimum angles of attack of different otter boards are the obvious areas where drag reduction and therefore fuel saving are possible.

Preparations are currently in hand to perform electro beam trawl trials on the Brixham based trawler MFV ZUIDER KRUIS. The vessel employs 8m beam trawls and is typical of at least 70% of the UK beam trawling fleet. Investigations will be made into the types of ground on which a light electrode rigged trawl can be used to best advantage. The chain mat rigged beam trawl cannot be deployed successfully in very soft muddy grounds because of the excessive drag forces on the gear; electrode arrays should not create such difficulties, and can thus be used on the very grounds on which the best catches of flatfish can be expected.

The Authority is maintaining contact with potential UK suppliers of the technical equipment used in the system and will seek to expedite commercial exploitation of an appropriate system for the UK beam trawler fleet.

R. S. Horton

J. E. Tumilty

TABLE 1 **ELECTRO TRAWLING TRIALS - M.T. BOLTBY QUEEN** FISHING LOG

Date	Tow No	Time Shot/Haul	Position	Depth Fathoms	Warp Length Fathoms	Speed knots	Weather	Bottom	Catch (stones)				REMARKS
									Plaice	Cod	Dogs	Others	
1982													
9/10	Depart Lowestoft 0730 Lay Yarmouth roads to rig gear 1400 hours proceed to fishing grounds												
		2040 2140	Botney Cut	18	150	VAR	NE4	Sand					Hauled after 1hr parted supply cable. Effected repair shot away again
		2250 0100	"	18	125	VAR	NE3-4	Sand	14	-	-	3 ling Skate	Electric fishing gear pulsing correctly
10/10	Vessel returning to Lowestoft to land K. Dye												
		0940	Arrive Lowestoft changed cable on winch depart 1140 for fishing grounds										
11/10	1	1055 1340	Outer Rough	34	150	3.5 4.5	E3-4	Sandy Shells	4		45	3 lemons	Moderate Easterly swell towing with Farnham Queen catch for 2½hrs 45st pl.
	2	1415	"	34	150	4.5	E3	"	-	-	-	-	Parted supply cable
	3	1640 1945	"	34	150	4.0	SE3	"	6½	-	-	-	No electrics Farnham Queen 35st flat fish

TABLE 2

ELECTRO TRAWLING TRIALS - M.T. BOLTBY QUEEN

FISHING LOG

Date	Tow No	Time Shot/Haul	Position	Depth Fathoms	Warp Length Fathoms	Speed knots	Weather	Bottom	Catch (stones)				REMARKS
									Plaice	Cod	Dogs	Others	
	4	2000 2240	Outer Rough	34	150	4.0	SE4	Sandy Shells	12½	-	6½	-	Added door to Dan Leno chain 63ft electro trawling gear OK Farnham Queen 29st flats
		Steamed 1 hour South											
12/10	5	0020 0250	Tail End	28	150	4.0	E4-S	"	7	3	-	7 mixed	Wing end & mid wing chains parted some electrodes loose
	6	0400 0630	"	26	150	3.0	E3	"	6	-	-	7 mixed	Some electrodes loose
	7	0700	"	30	150	3.0	ENE 3-4	"	6	-	-	7 mixed	Array in need of renovation. Lay to effect repairs. Spliced in 60fm cable repaired 3 feeders replaced 2 electrodes
	8	1455	Outer Rough	34	150 at water line	3.0	SE3	Sand	7	-	-	3 lemons 7 mixed	Farnham Queen 30 st Plaice
		Steamed for 20 minutes											
	9	1750 2030	Outer Rough	30	"	4.5	SE5	Sand/ Shells	8	-	-	-	

TABLE 3 **ELECTRO TRAWLING TRIALS - M.T. BOLTBY QUEEN** FISHING LOG

Date	Tow No	Time Shot/Haul	Position	Depth Fathoms	Warp Length Fathoms	Speed knots	Weather	Bottom	Catch (stones)				REMARKS
									Plaice	Cod	Dogs	Others	
	10	2115 2445	Outer Rough	37	150 at water line	4.0	SE6	Sand/ shells	9	7	4	2 lemons	Bunt chain added
13/10	11	0015 0245	"	37	"	4.0	SE6-7	Sand/ shells	6½	-	30	2 lemons	Second tow with bunt chain insitu
	Steamed back to East, unable to tow into wind because of cable snatching												
	12	0700 0900	"	40	"	3.0	E+S 7-8	"	4	-	-	-	Hauled early because of weather electro trawling gear not functioning Worn feeder cable shorting on pulser frame
		1200	Steamed to Clay Deeps										
	13	1915 2145	Clay Deeps	25	150	3.0	SW4	Sand/ shells	12			2 hadd.	Door/Dan Leno and bunt chain in place
	14	2210 0040	"	25	150	3.0	SW4	Sand/ shells	14				

TABLE 4 ELECTRO TRAWLING TRIALS - M.T. BOLTBY QUEEN FISHING LOG

Date	Tow No	Time Shot/Haul	Position	Depth Fathoms	Warp Length Fathoms	Speed knots	Weather	Bottom	Catch (stones)				REMARKS
									Plaice	Cod	Dogs	Others	
14/10	15	0120 0350	Clay Deeps	25	150	3.0	SW3	Sand/ shells	16	1	1	1 hadd. 4pr soles	Underley Queen 60st flat fish
	16	0415 0645	"	25	150	4.0	SW3 VAR	"	17	-	-	-	
	17	0730 1005	"	26	150	4.0	VAR 2	"	15	-	-	-	In bridles to 10fm Remove bunt chain
	18	1145 1415	"	26	150	4.0	VAR 2	"	15	-	-	-	Barnby Queen 30st. Underley Queen 35st. (½hr longer tow) Some renovation of array required
	19	1515 1745	"	26	150	4.0	VAR 2	"	7	-	-	-	Barnby Queen 35st.
	20	1815 2045	"	26	150	3.5	N3-4	"	11	5		½ lemons	
	21	2150 0050	"	26	150	3.5	N5	"	14				Barnby Queen 20st

TABLE 5 **ELECTRO TRAWLING TRIALS - M.T. BOLTBY QUEEN** FISHING LOG

Date	Tow No	Time Shot/Haul	Position	Depth Fathoms	Warp Length Fathoms	Speed knots	Weather	Bottom	Catch (stones)				REMARKS
									Plaice	Cod	Dogs	Others	
15/10	22	0030 0320	Clay Deeps	26	150	3.5	N6-7	Sand/ shells	15	-	-	-	Barnby Queen 30 stone Renewed several insulators
	23	0400 0630	"	26	150	3.5	N6	"	18	-	-	-	Barnby Queen 18 stone flat fish
	24	0700 0930	"	26	150	3.5	N6-5	"	12	3	-	1 turbot	
	25	0950 1230	"	26	150	3.5	N6-5	"	10	-	-	-	Parted supply cable respliced at end of tow majority non-electrified Barnby Queen 45 st flats
	26	1430 1710	"	24	125	3.5	N5	"	3	-	-	-	
	27	1730 2000	"	16	125	4.0	NNW4	"	3	-	-	-	1900 stopped pulsing cable parted between strain bobbin & array large bag of weed
		Steamed for 1½ hours											
	28	2255 0130	Tail End	18	125	4.0	N4	"	9				"T" feeder to 1 pulser parted

TABLE 6

ELECTRO TRAWLING TRIALS - M.T. BOLTBY QUEEN

FISHING LOG

Date	Tow No	Time Shot/Haul	Position	Depth Fathoms	Warp Length Fathoms	Speed knots	Weather	Bottom	Catch (stones)				REMARKS
									Plaice	Cod	Dogs	Others	
16/10	29	0230 0505	Tail End	18	125	4.0	N3-4	Sand/ shells	15	½	4		V/L laid ½hr to change injector
	30	0555 0830	"	18	125	4.0	VAR 2	"	5		7		End of electro trawling trials remove gear. Trawl rigged with bunt chain & mid wing, door/Dan Leno chains & extra SFM bridle
	31	1040 1310	"	24	125	4.5	S2-3	"	10	3		3 hake	
	32	1350 1620	"	24	125	4.5	S3	"	15	7		7 hadd.	Added 1 wing end & 2 Dan Leno chains
	33	1655 1930	"	24	125	4.5	SSE 5	"	20			8 hadd.	Normal chain rig
	34	2205 0040	Coffee Soil	26	150	4.5	SSE 4	"	28			3 mixed	

Vessel completed a further 22 tows with normal chain rig averaging 30-35 stones of flat fish for 2½ hour tow. Returned Lowestoft 2000 hours, 20.10.82.

TABLE 7

SUMMARY OF FISHING RESULTS OF BOTH VOYAGES ON BOLTBY QUEEN

FISHING GEAR	VOYAGE	CATCHES DURING VOYAGE PLAICE KG	LEMON SOLE KG	OTHER FISH KG	HOURS FISHED	CATCH RATES KG/HR PLAICE	LEMON SOLE	OTHER FISH
ELECTRO TRAWLING GEAR	VOYAGE 1	1178	286	3150	51.75	22.8	5.5	60.9
	VOYAGE 2	1782	210	1507	71.0	25.2	2.9	21.2
CHAIN GEAR	VOYAGE 1	9727	656	8142	124.7	78.0	5.2	65.3
	VOYAGE 2	4486	155	1453	64.0	70.1	2.4	23.8

TABLE 8

ESTIMATE OF COMPARATIVE ANNUAL GEAR COSTS FOR ELECTRIC & TRADITIONAL BEAM TRAWLS

1. Capital Expenditure on Shipboard Installations

	£
Alternator Set (if required)	8000
2 off Cable Winches	8000
Control Panel	1000
Ballast Units	500
Shipboard Cables	2000
Installation Costs	4000
Total	£23500

Annual charges associated with repayment of loans etc will depend on grant received, rate of interest etc and are ignored in the comparison table below.

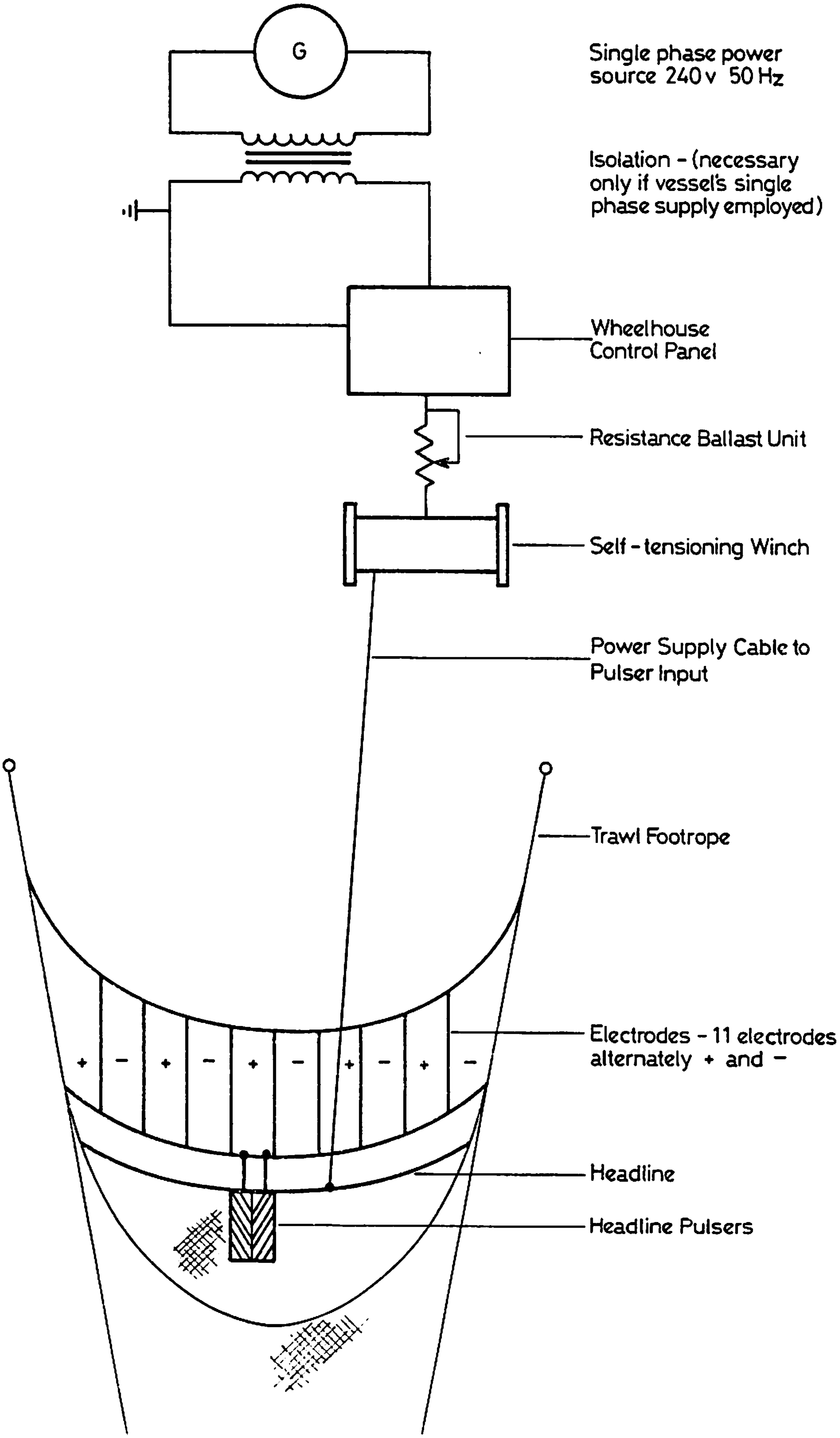
2. Annual Costs Associated with Electric System

Replacement Costs of above items (averaged over 10 yrs)	3800
Ship to trawl cables, replaced annually	1500
Headline pulsers, replaced annually	1600
Electrode Arrays, replaced 5 times per year	3000
	£ 9900

3. Annual Costs of Equivalent items on Traditional System

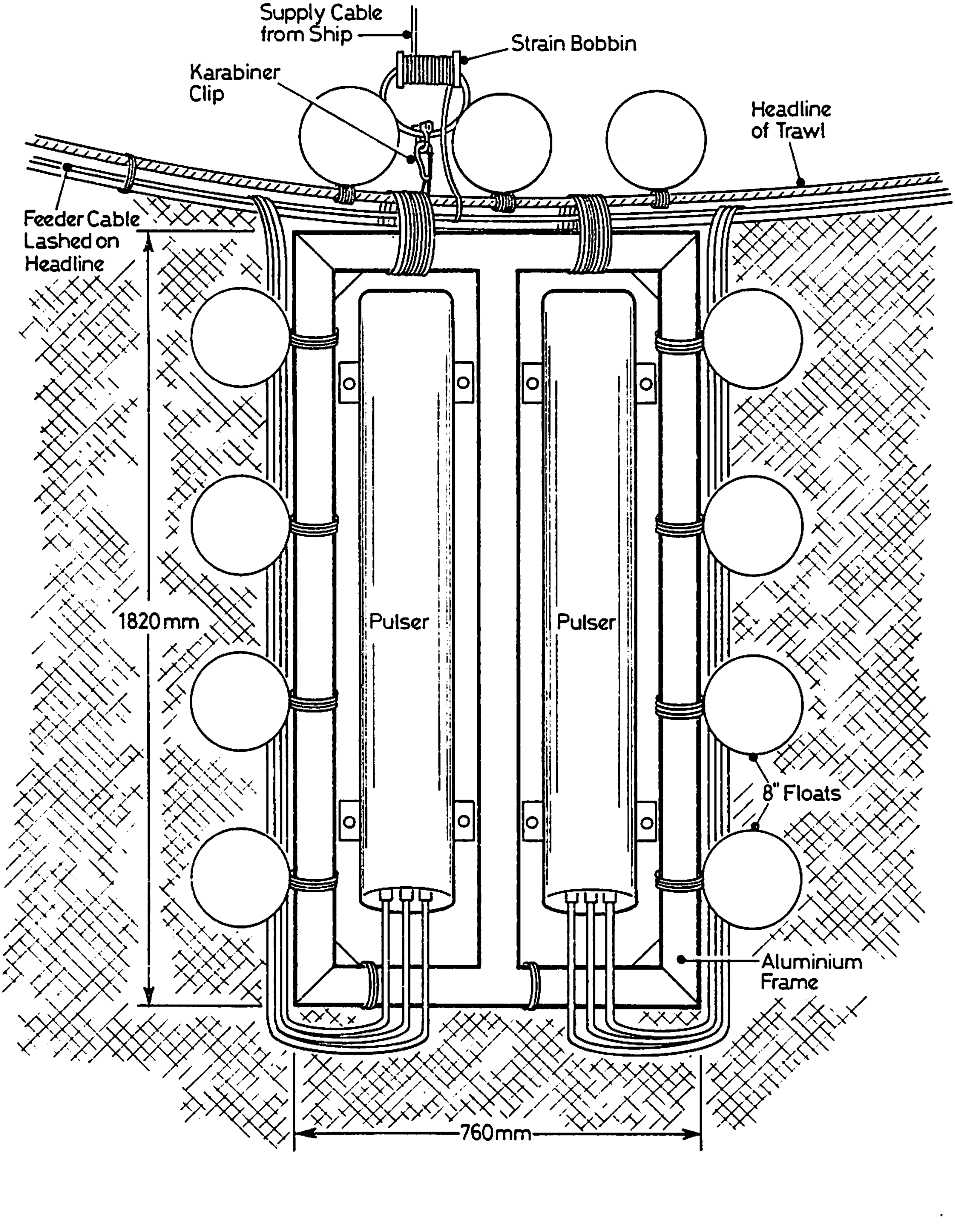
Chain mats replaced 5 times per year	9000
Shackles, 500 per set, replaced 5 times per year	2500
Extra repair costs on gear and sole plates due to use of heavier gear	500
Total	£12000

NOMINAL ANNUAL SAVINGS ≃ £2,000



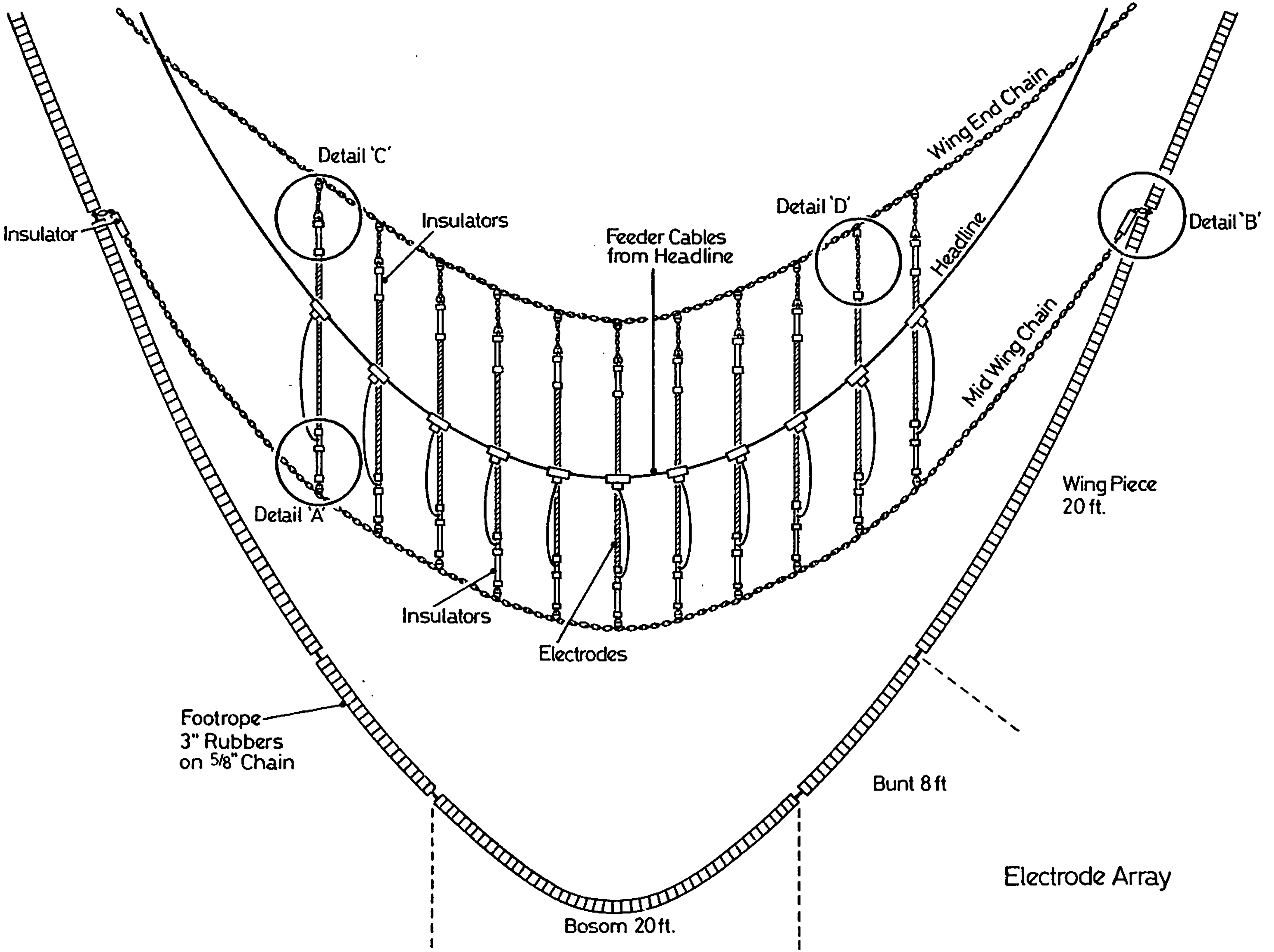
Arrangement of Components of Electro Trawling System

Fig. 1



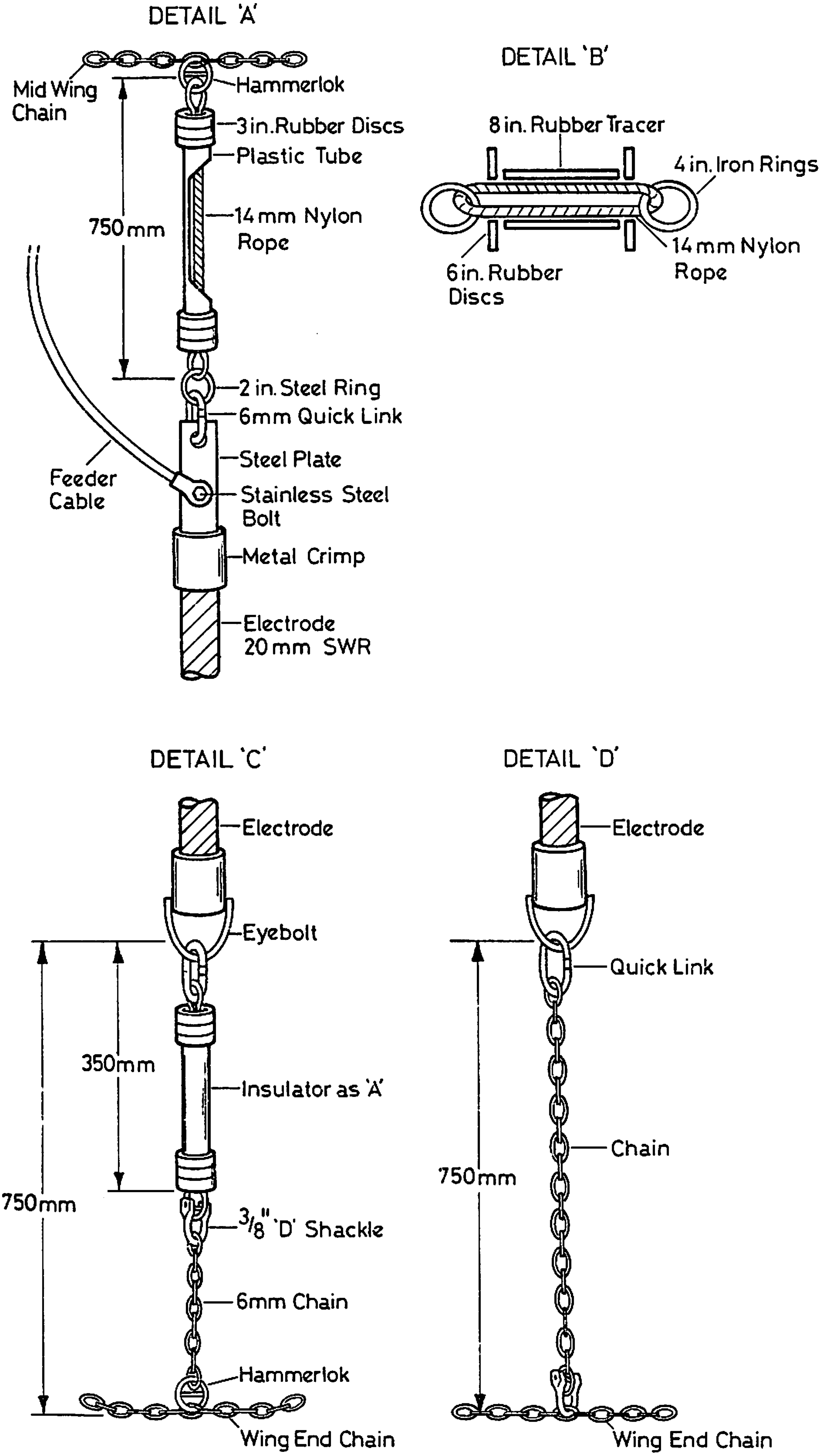
Detail of Pulsers Attachment to Trawl Headline

Fig. 2



Details of Electrode Array on C4 Otter Trawl

Fig.3a



Details of Electrode Array on C4 Otter Trawl

Fig.3b

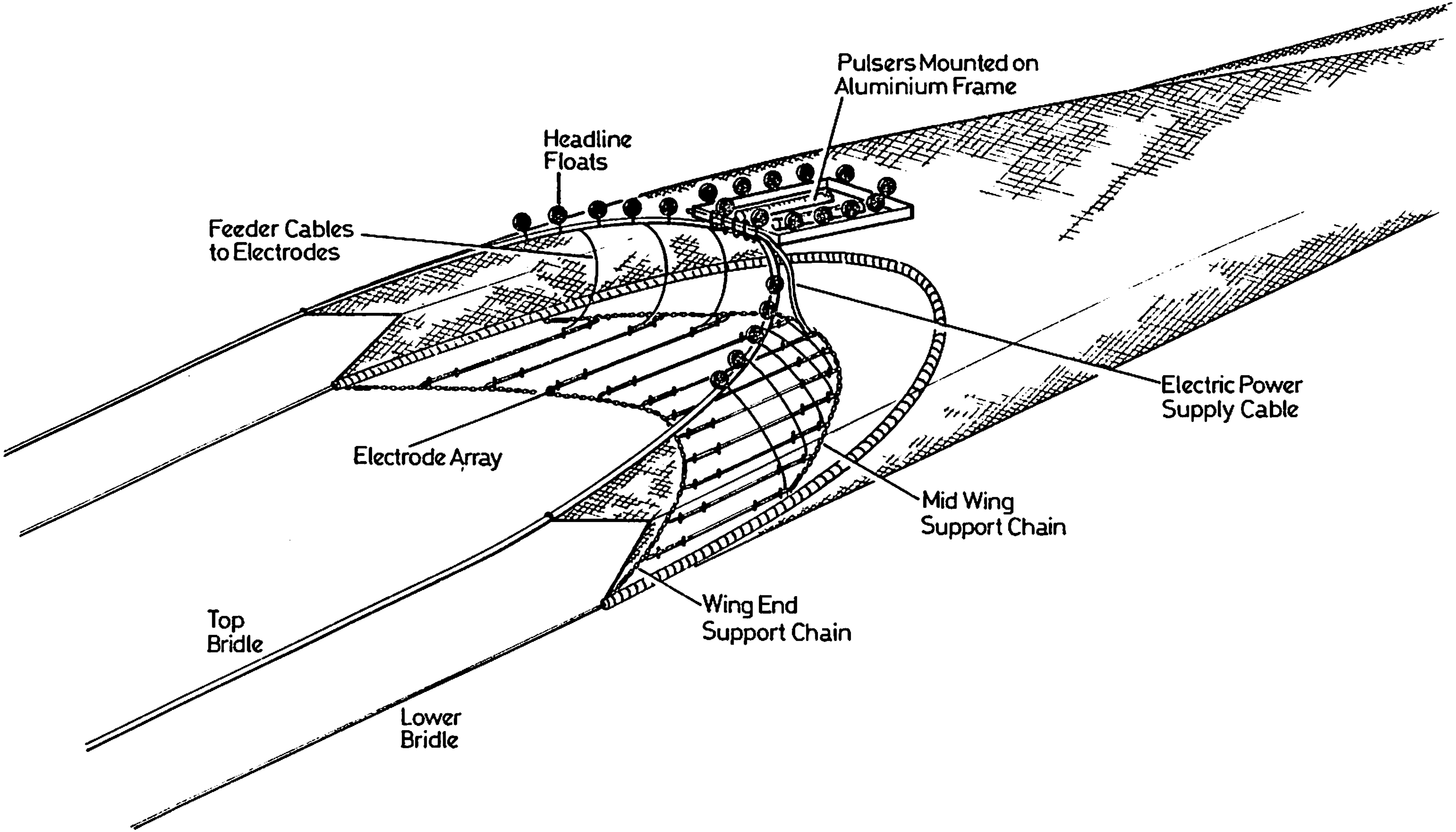


Fig. 4

General Arrangement of Electrified C4 Otter Trawl

m.v. BOLTBY QUEEN

Otter Trawl	Chain Rigged	E/Array
4·5 knots	715 h.p.	700 h.p.
3·5 knots	685 h.p.	670 h.p.

H.P. Reduction 6·4% at Optimum Speeds

2·1% at Equal Speeds

m.v. HOMEWATERS

Beam Trawling	Chain Rigged	E/Array
5 knots	325 h.p.	260 h.p.
3·5 knots	200 h.p.	150 h.p.

H.P. Reduction 54% at Optimum Speeds

20% at Equal Speeds

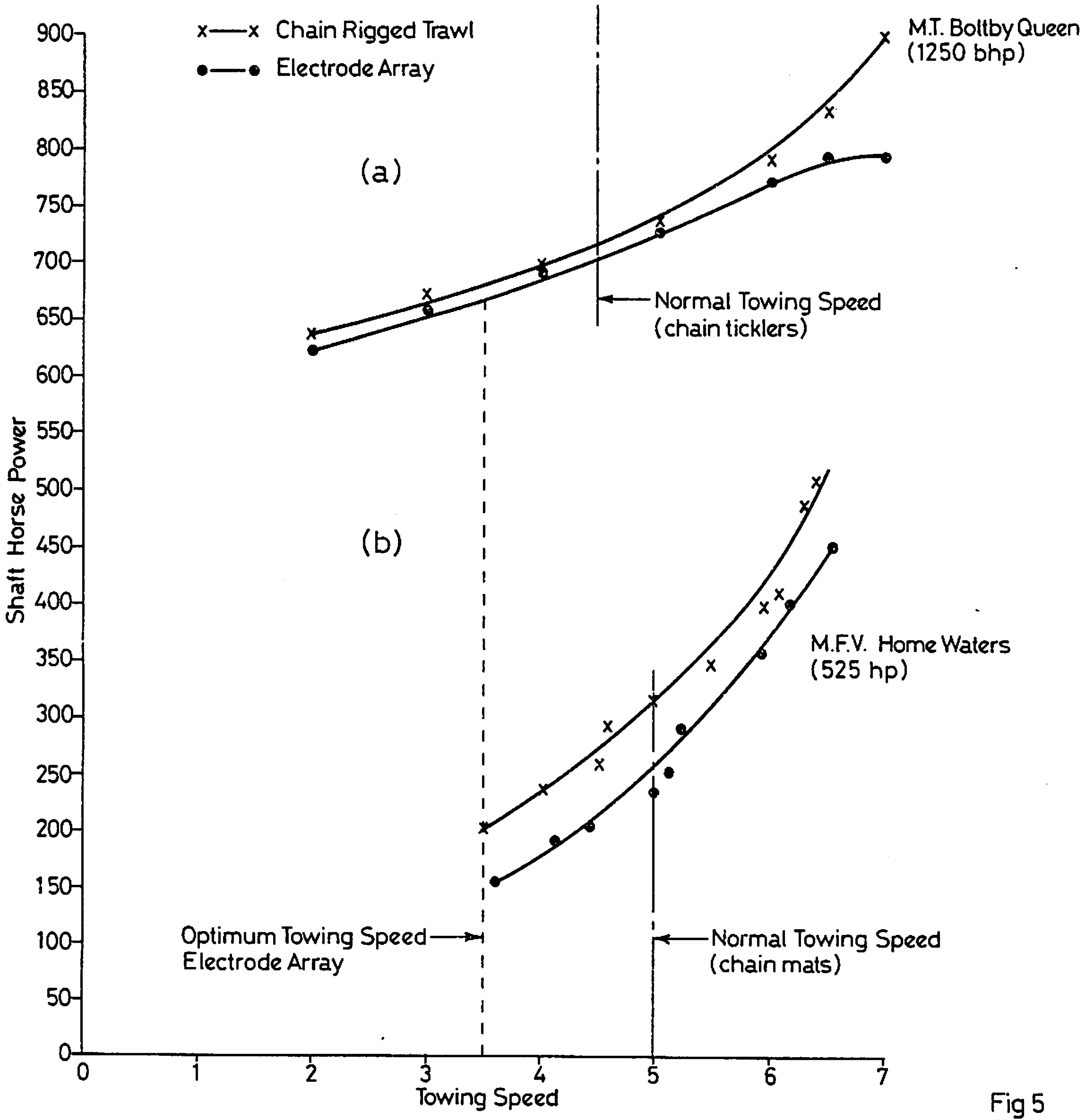


Fig 5

Variation of Shaft Horse Power with Towing Speed for C4 Otter Trawl and 4m Beam Trawl m.v. BOLTBY QUEEN

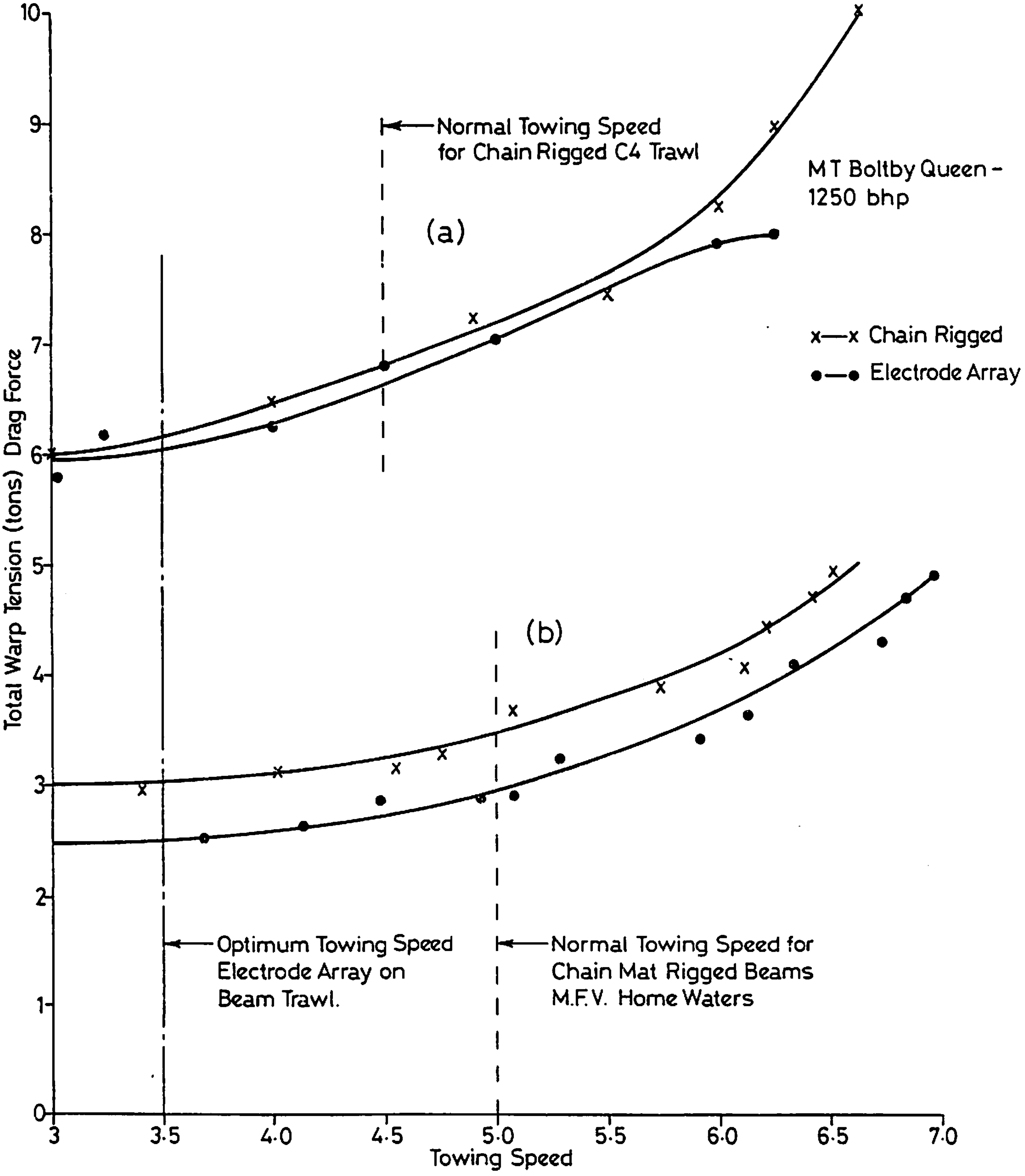
Otter Trawl	Chain Rigged	E/Array
4·5 knots	6·8 tons	-
3·5 knots	-	6·1 tons

Drag Reduction 10%

m.v. HOMEWATERS

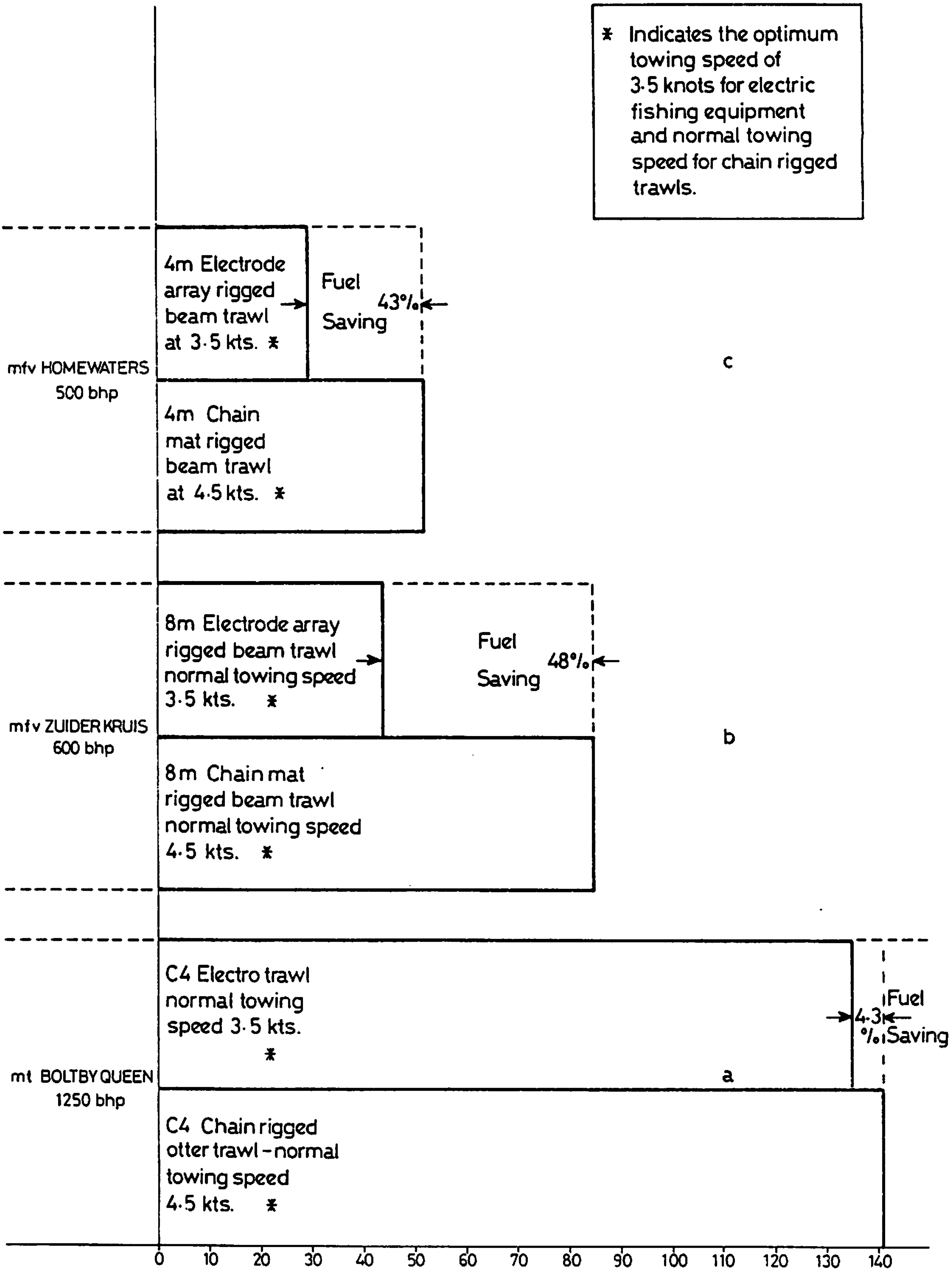
Beams	Chain Rigged	E/Array
5 knots	3·5 tons	-
3·5 knots	-	2·5 tons

Drag Reduction 29%



Variation of Drag Force with Towing Speed for C4 Otter Trawl and 4m Beam Trawl

Fig 6



Histogram showing fuel consumed for 3 vessels towing chain gear in comparison with electrode rigged trawls

Fig.7

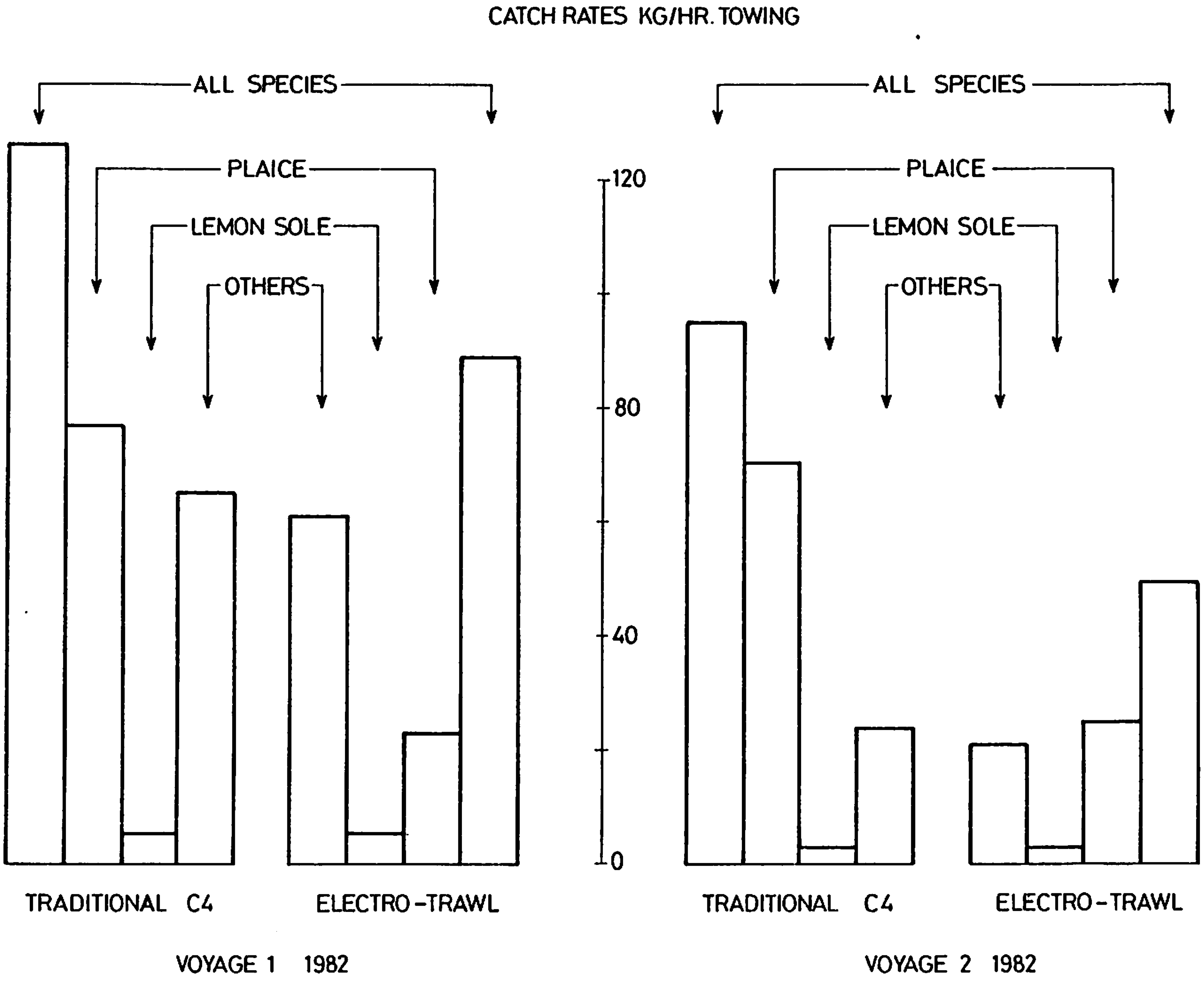
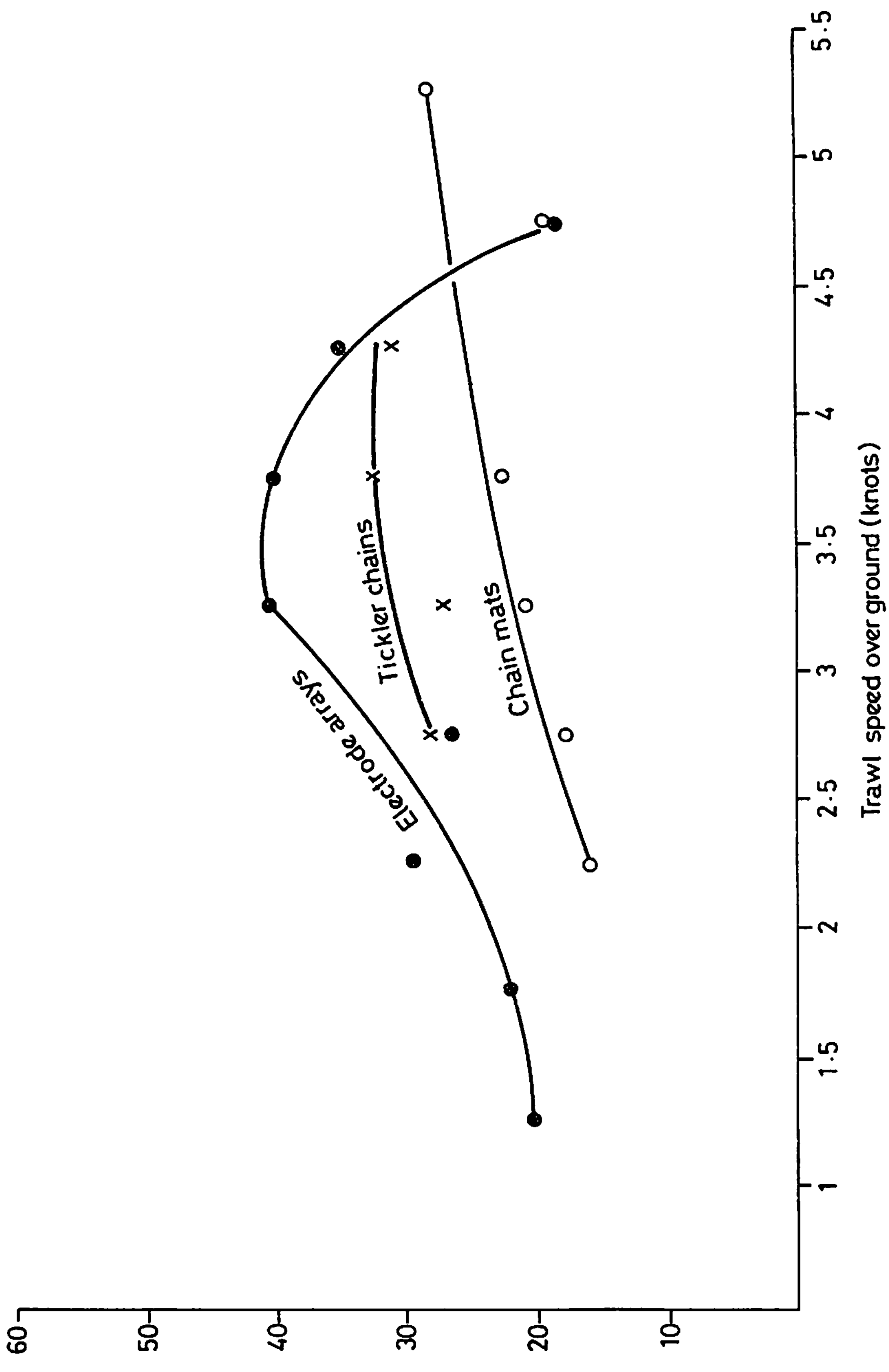


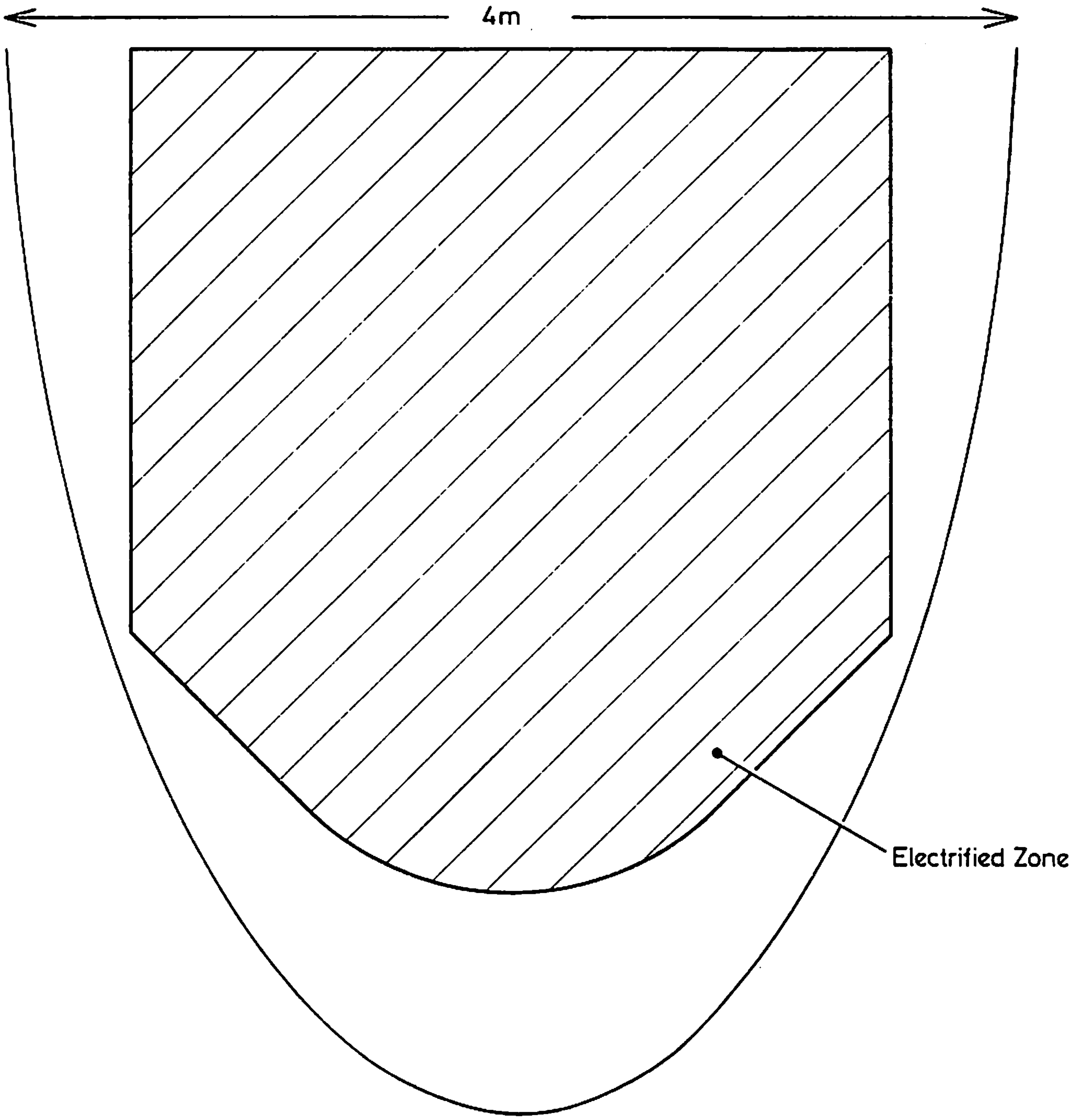
Fig.8

Comparative Catch Rates for C4 Trawl in Traditional and Electro-Trawl Forms



Variation of Catch Rate with Trawl Speed mv. Homewaters
Fishing Gear Beam Trawl 4m, Rigged as indicated

Fig.9



Lateral Coverage Min$^{\underline{m}}$ 75%
Lateral Coverage Max$^{\underline{m}}$ 86%

Scale:
1cm = 0·25m

Ground Rope 11·1m

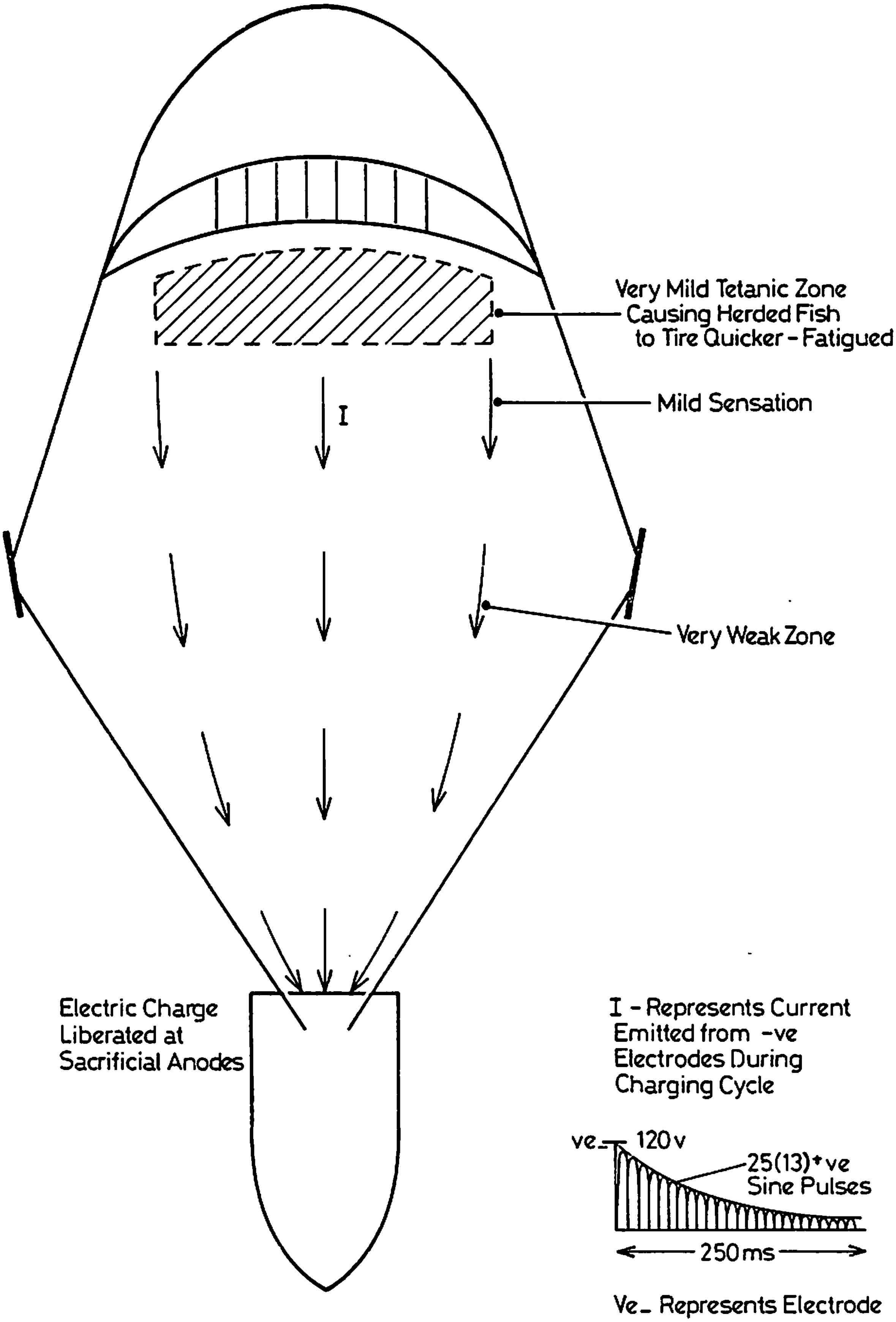
Total Area Bounded by Ground Rope = 12·5m

Total Area of Electrified Zone = 8·4m^2

% Coverage by Electrified Zone = 67%

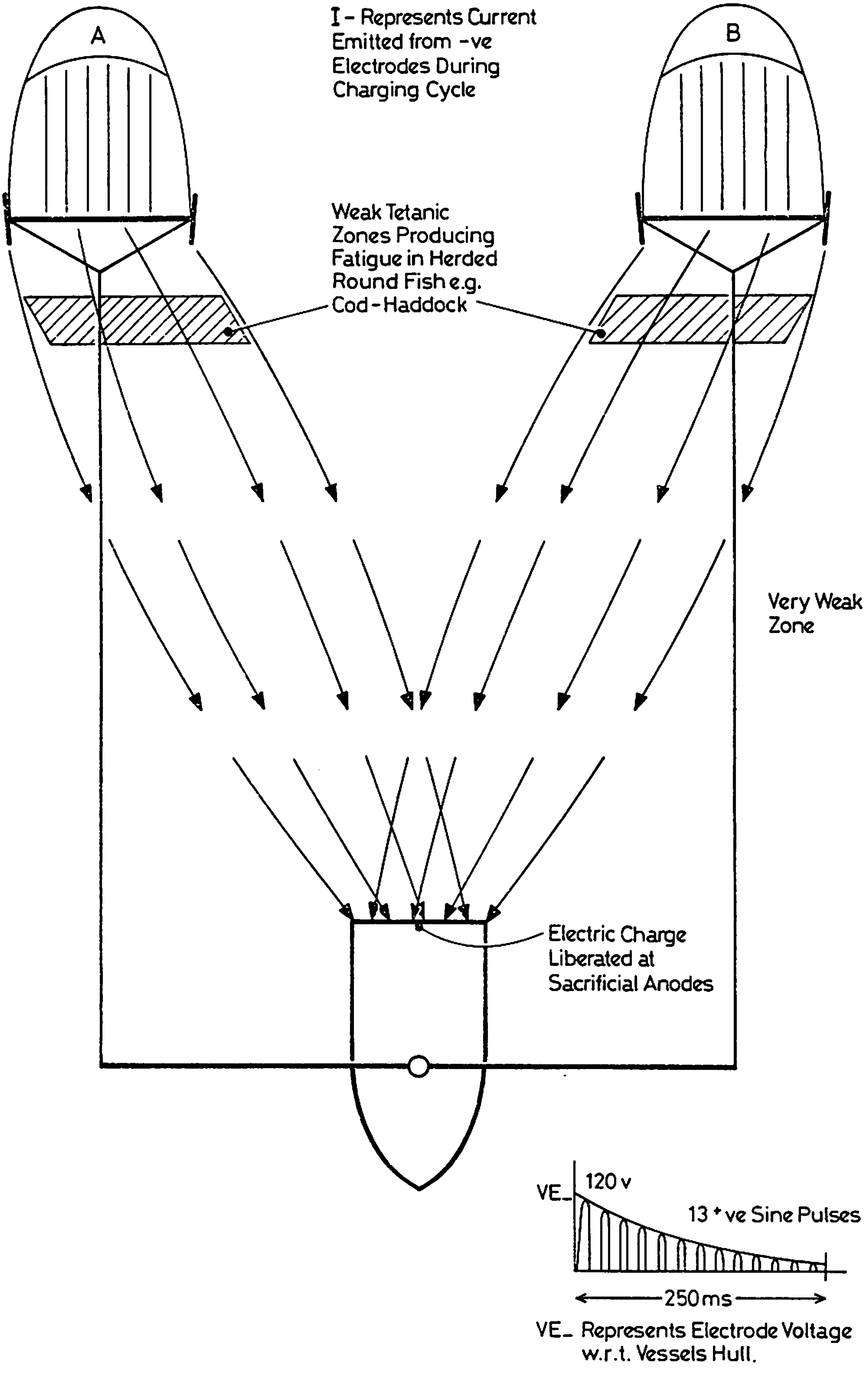
Area of Electrified Zone in Relation to Area Bounded by Footrope for 4m Beam Trawl

Fig 11



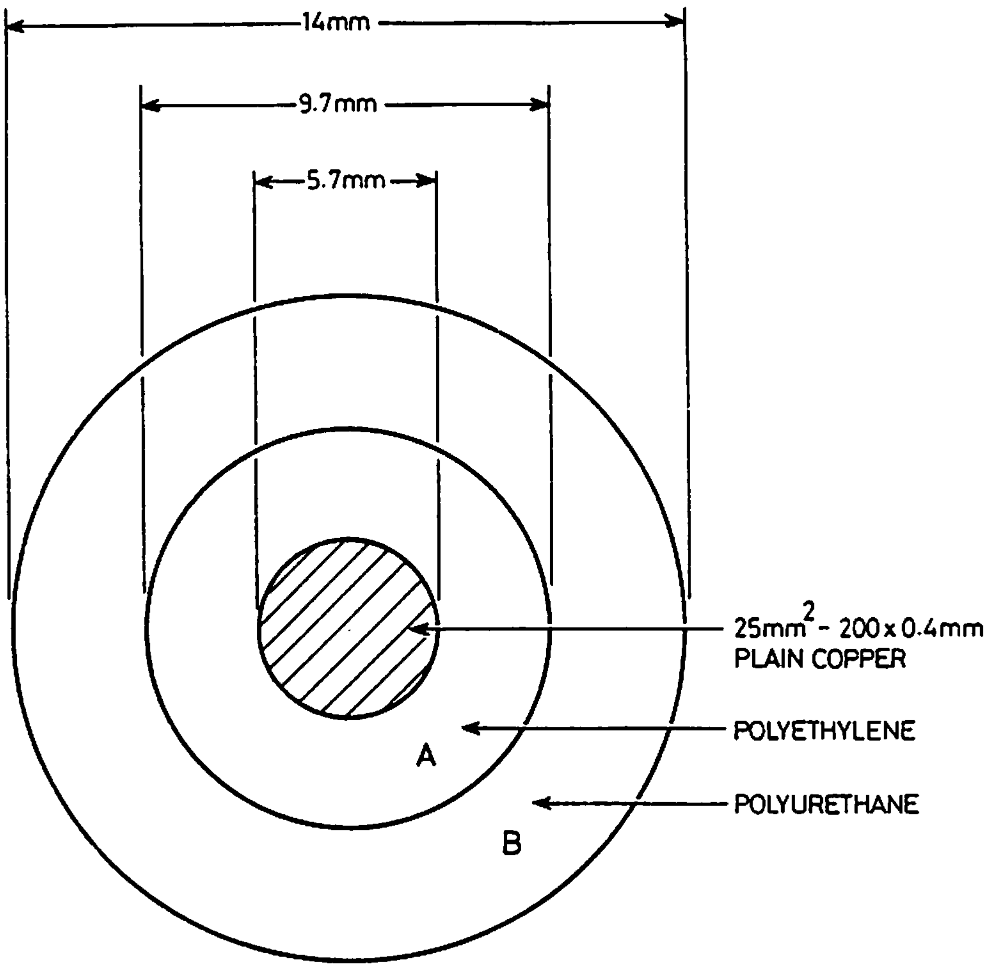
Area of Tetanic Zone associated with Electrified Otter Trawl

Fig. 12



Area of Tetanic Zone associated with Electrified Beam Trawl

Fig.13



CONSTRUCTION :-

CONDUCTOR - 25 mm² - 200 x 0·4mm dia.

A - INSULATION - POLYETHYLENE - 1·6mm thick-wall

B - JACKET - POLYURETHANE - 2 mm thick-wall

OUTSIDE DIAMETER - 14 mm ±0·4 mm

PHYSICAL CHARACTERISTICS :-

D.C. RESISTANCE - 0·75 ohms/km

WEIGHT IN AIR 360 kg/km

WEIGHT IN FRESH WATER 200 kg/km

Underwater Supply Cable for Electro Trawling System

Fig.14

APPENDIX I

ELECTRIC FISHING TECHNICAL DETAILS

APPENDIX I

ELECTRIC FISHING TECHNICAL DETAILS

1. SYSTEM LIMITATIONS

The larger area of the C4 otter trawl, in cmparison to the 4m beam trawl, required a much greater dissipation of electrical power into its respective electrode array.

In order to maintain the electrical field parameters on the C4 otter trawl similar to those successfully employed on 4m beams, the mode of pulser capacitor bank charging required slight modificiations external to the pulsers themselves.

The present design of the system allows universal application from dual 4m beam trawling to otter trawls of the C4 class, and, midway between these, the 9 and 10m beam trawls which now used by about 80% of the flat fishing fleet in the U.K.

In order to create a versatile system, the pulser units are each of 10,000 micro-farads capacity. These would be used singly for all beam trawling applications and two in parallel on the C4 otter trawl due to the much larger area.

2. TECHNICAL DESCRIPTION

The electro trawling system comprises of the following essential items:-

(i) A single phase power source of 240 V rms 50Hz

(ii) A bridge control panel and conditioning network

(iii) A series/parallel combination of power resistors forming an inline ballast unit.

(iv) Two pulsers each containing a 10,000 μF bank of electrolytic capacitors and associated semi-conductor control circuitry.

(v) 400m of power supply cable, providing a power link with between control panel output and the pulser units mounted on the trawl.

(vi) An electrode array comprising of eleven steel wire electrodes 2.7m in length, 20mm diameter and separated by a distance of 0.73m.

System Operation

The bridge control panel contains the following elements:-

(a) Two thyristor controlled bridge modules
(b) A timing unit
(c) Switch gear, protection and monitoring arrangement for input and output control (Described fully in Field Report 1003).

The incoming A.C. supply parallels both the thyristor bridge and inputs to the timing module. By clocking the timing pulse through the logic circuitry and applying them to the thyristor bridge gates, the output into a resistive load appears as 24 (12)* positive sine pulses of amplitude 340v and period 10 milli-seconds (or ½f seconds where f = supply frequency), followed by a single negative sine pulse of similar magnitude and duration. Circuit details are shown in Figs. E1-E4. The Voltage Characteristic is shown in Fig. E5. (*(12) represents half wave charging used only on 4m beam).

This output wave form is applied to the pulser capacitance bank via its single cored supply line and series ballast unit. The negative side of the bridge output is connected to the vessels earth plate or hull (if steel) See Figure E6.

The duty cycle of operation is divided into two halves - charge and discharge and is described below.

2.2 Charging Cycle

Both inputs to the pulser units were paralleled enabling charge of the compound bank of 20,000 micro-farads, through a single conductor power line. In order to achieve this the common capacitor negative was connected to the output negative side of the pulser units which links all negative electrodes in the array. Thus the charging loop was completed through the ballast unit, the supply cable, the compound capacitor, the seawater return resistance between the negative electrodes and the ships hull and the conductive zones of the hull exposed to the seawater, i.e. sacrificial anodes.

Charging of the capacitors continues for a period of 240 milli seconds through a line resistance of 8 ohms; the charging wave form is shown on Figure E7.

The exponential rise represents the capacitor terminal voltage the end of the 240 milli-second cycle, reaches a maximum of 267 V d.c. This level is governed through the time constant of the charging line which is 160 milli seconds. Control of the voltage level can be varied by changing tappings within the ballast resistance unit.

2.3 Discharge Cycle

Upon receipt of the single negative sine pulse the thyristors in each pulser unit conduct, and allow the accumulated charge on the capacitor bank to flood out into the electrode array. For techno-economic reasons the electrode array was divided into two halves but with common negatives. The arrays comprised of 6 positive electrodes and 5 negatives, the positives being isolated at their centres to allow individual discharge of the separate 10,000μ F banks of capacitors through their respective power thyristors. The discharge pulse for is shown in Fig. E8.

Each array presented a d.c. resistive load of 95 milli ohms, and the time difference of each pulser discharge was negligible (depending upon the gating characteristics of the two devices and constituting less than 10 nano-seconds in phased lag delay).

Figure E8 shows the discharge wave form at the pulser terminals. In order to produce a voltage of 230 V d.c. pk discharge across the array the capacitance bank required a terminal voltage of 267V allowing for a 37V drop in the 50mm^2 distribution cable linking the pulser outputs with their respective electrode arrays.

The widths of the exponentially decaying pulses measured at 67% of their decay was one milli-second producing energy per pulse discharged into the array of 264 Joules and a power dissipation of 278 Kw/pulse.

3. VOLTAGE DISTRIBUTION BETWEEN ELECTRODES

Figure E9 shows the variation of voltage between positive and negative electrodes with respect to their separation, and Fig. E5 shows the voltage time relationship.

The electric field distribution produced by electrodes of a finite size in an unbounded medium like the sea is highly non-uniform, with a zone of high electric field strength concentrated near the electrodes. The voltage between two long parallel cylindrical electrodes, radius r_o, at a distance D apart is described by:-

$$V_x = V_o \ \log \ (\underline{D-x})/2.\log_e \frac{(D-r_o)}{r_o}$$

where V_x is the voltage at a point on the line joining the centres of the two cylinders, distance X from one of them, and V_o is the voltage between the cylinders.

In October 1980 the C.K. AMBER was dry-docked for her annual survey. During this period all eight of the hull sacrificial anodes were replaced. This provided the necessary datum for the following year's electro-trawling commercial assessment. During the following year some six months were devoted to electric fishing trials.

The annual inspection of October 1981 highlighted no visible indications of excessive anode disintegration or ill-effects on rudder, propeller or any of the painted surfaces above or below the water line.

As expected the negative electrodes and negatively charged wire experienced minor electrolytic disintegration due to the formation of a galvanic cell, enhanced by the circulation of the charging current. However, no action in this area is contemplated since it appears that the rate of deterioration from abrasion, especially on hard ground comprising shells and hard mud, is the dominant factor governing potential electrode life.

9. Transmission Cable Requirements

The choice of a suitable cable for the ship to trawl link has always created problems through the need to combine acceptable electrical, economic and mechanical characteristics in one cable. The success of the seawater return system and the consequent change to a single core supply to the trawl is of particular advantage.

The polyrethane outer covering particularly resists the effects of abrasion in long commercial usage running over guiding blocks.

Heat dispersion is particularly important for the cable layers remaining on the winch if a variety of cable lengths are to be shot.

The present cable has sufficient mechanical strength to sustain drag forces incurred by its own weight of up to 200 fathoms. Beyond this point the cable strength would be suspect; however, it is known that warp lengths do not usually exceed this value in the U.K. flat fish fishery.

The electric field strength at the same point, Ex is given by:-

$$Ex = \frac{dV}{dX} = V_o \left(\frac{1}{x} + \frac{1}{D-x} \right) /2 \log_e \frac{(D - ro)}{ro}$$

The electric field strength decays rapidly away from the electrodes and at the mid point, where = D/2, is at a minimum value:-

$$E_{D/2} = 2Vo/D \log_e \frac{(D - ro)}{ro}$$

Consider typical values employed in the S.F.I.A. system.

$ro = 10mm \qquad D = 0.73m \qquad Vo = 230V$

$\therefore \quad ED/2 = 147 \text{ V/M}$

In practical conditions, such as that of the sea bed, this value represents the minimum value between the electrodes in the horizontal plane. For points equidistant above and below the horizontal plane, adjoining the electrodes, the field strength varies due to the differences in the conductivities of sea water and the sea bed on which the electrodes lie. Within this phenomenon a distinct advantage of theoretical calculations applies. The lower conductivity of the sea bed causes distortion of the electric flux distributionpattern; the voltage gradients at these points are larger in magnitude than those above the horizontal datum. Briefly, the electric field strength in way of the electrodes has a greater effect on fish below the electrodes (i.e. buried in sand or mud) than those above.

From the formula above it will be noted that field strength can be increased by use of larger diameter electrodes or by use of more electrodes thus reducing separation distance). However, size and numbers of electrodes must be carefully considered in the design, bearing in mind their effects of drag force, mechanical 'tickling' effects and changes in array resistance.

It is for these main reasons that the design of an electrode array bears paramount influence on the success of this technique applied to flat fishing.

3.1 Electrode Array Resistance

The geometric configuration of an electrode array bears considerable effect on the quality and quantity of energy discharged over its area.

The energy discharged into an electrode array of resistance R, by a single pulse of amptitude V_o and of time constant $\tau = C \times R$ (where C is the capacitance of the pulser) is given by:-

$$E_p = Vo^2/R \qquad \int_0^\infty e^{-2t/\tau}\,dt = Vo^2\tau/2R$$

Clearly to minimise the power requirements of an electric fishing system V_o and τ should be as small as possible. Obviously C, the capacitance must not be so large as to create volumetric problems in handling on the deck. The resistance R between the electrodes is relatively complex on practical designs of multiple electrode arrays comprising of n parallel electrodes.

The resistance between a pair Ro in an unbounded medium of conductivity (ρ) is given by Ro = $\frac{\rho}{\pi L}$. loge (D/ro) where ρ is the conductivity of sea water, L the length of the electrode, D the separation distance and ro the radius of the electrode.

The above formula assumes no voltage drop along the electrode, and for this reason the radius and material are an important consideration.

This formula on multiple electrode arrays is modified to give:-

$$Rn = \frac{\rho \quad \log_e D/ro}{\pi \quad L\,(n - 1)} \qquad \text{where}$$

n is the number of electrodes, and therefore (n - 1) is the number of parallel paths taken by the discharge current.

The duration of the energy discharged into the array, (Rn x C) seconds is known as the time constant of the discharge pulse and is defined theorectically by the above formula.

In practical situations where the electrode array lies on the sea bed, obviously not in a static condition due to its forward traverse, several other variables influence its value:-

(i) The difference between the conductivities of sea bed and sea water, again as seen with field strength, govern its value. In fact increase its overall magnitude since sea bed conductivity is several times lower than sea water, making ρ, the resistivity,higher, i.e. Conductivity = $\frac{1}{\text{Resistivity}}$

Practical measurements have shown this wide divergence of theoretically calculated values and practically measured values, e.g.

Consider for instance five trailing parallel electrodes of length 2.7m, separation 0.73m, radius 10mm. The number of parallel current paths (n - 1) is 4, taking ρ for seawater = 0.25 ohm - metres,

Then, $$R_5 = \frac{0.25}{\pi \times 2.7 \times 4} \cdot \log_e \frac{0.73}{0.01}$$

R_5 (theoretical) = 31 milli-ohms

In comparison, the measured value is 95 milli-ohms - a factor of 3 greater. Some of the difference may be accounted for by error in measurement. Measurement of the resistance of such an array must employ certain techniques to eliminate the effects of polarisation, which can strongly influence an apparently high value (discussed later). A certain amount of error involved in the theoretical value amounts to the assumption that the electrodes are cylindrical and perfectly conductive throughout their length. This is why the usage of the theoretical equation serves only to explain the mathematical relationship so that practical measurements of maximum and minimum can be determined.

Exterpolation by graphical means, throughout a series of practical electrode array measurements in Stonehaven showed the limits of electrode numbers, lengths and separation. This determined the maximum possible array size which could be practically electrified with respect to the pulser capacitance, and its maximum liberated charge within practical power demand limits.

4. Effects upon Electrodes, and Seawater Return Concept

Electric fishing in seawater requires the passage of intense current pulses if useful electric field strengths are to be developed through a significant volume. The passage of such currents from metallic electrodes into a concentrated conduction solution like seawater will clearly give rise to physical and chemical effects such as corrosion and polarisation at the metallic solution interface which affects the flow of current. In a static condition these effects give rise to barrier potentials which oppose current flow rather like semi-conductor barriers. The effects however, of polarisation, due to the evolution of gases at the surface of the electrodes are reduced to some extent when the electrodes are dragged over the sea bed which tends to remove not only the impeding barrier but also material particles through abrasion.

The ideal electrode material for electric fishing should be mechanically robust, cheap and expendable. It should not be too rapidly corroded nor too strongly polarised, and the properties of the metal/seawater junction should not distort the shape of any current pulses which it passes.

Several types of electrodes have been used during the S.F.I.A. electric fishing trials . The most important point influencing changes has been robustness and the continuous process of abrasion, especially on harder grounds. Following a short period of using electrodes made up of copper wire wound into the lay of 32mm dia. nylon rope, which proved too light, therefore losing essential ground contact, stainless steel electrodes were tried. The only advantage of this material is its high position in the electro chemical series and therefore anti-corrosive properties in sea water. In fact there were several draw backs in the application of stainless steel to electrode arrays.

a) High cost and poor availability

b) Relatively high resistivity which created larger voltage drops along the length of each electrode reducing the intensity of the electric field between the free ends of the electrodes.

c) To a much lesser extent, though a contributory factor, the poisonous gases given off by stainless steel in seawater may have clouded the electro-physiological effects of electrical discharges on the fish themselves.

The cost and availability ruled out stainless steel in favour of ordinary mild steel warp. The rate of electrolytic corrosion of this material, though relatively high at the anodes was found through other considerations, such as abrasion losses, a cost effective solution.

5. Power Demands of Dual Charging System applied to Beam Trawling

Figure 1 shows the current demand on a single phase generator supply its load to dual beam trawl electric pulser units. As seen, the maximum power demand for individual pulser units occurs at the beginning of each charging cycle when the pulser capacitor voltage is zero. As the charge voltage increases the load demand falls away to a minimum at t_o + 250 milliseconds, where t_o is the time at which charging commences on each bank of capacitors.

In order to produce the necessary field strength between the electrodes (ED/2) of value approximately 150 V/m then the capacitor voltage required is 267-270 volts. This takes into account of the losses between the pulser terminals and the electrodes via the interconnecting distributor 50mm^2 insulated copper cable.

The cumulative current waveform shows a peak current value of 59 Amperes requiring an alternator of minimum capacity of $\frac{59 \times 340}{2}$ = 10.15 k.V.A. (rms).

Since the load is of pulsating quality, specific consideration of the alternator will need to be taken into account.

Clearly an alternator of this capacity would experience problems associated with rotor oscillation (or hunting) unless the stator poles were heavily damped. The ideal source would be; separate to any other machinery loading; at least 20% higher capacity than demand of the electric fishing system; and inclusive of the above mentioned damper windings on the stator core.

6. Safety of System

The bridge control unit houses the overload protection relays for both output channels also providing appropriate visual indications of a fault condition.

The risk of electric shock only exists should the electrode array be handled whilst energised on deck, i.e. following hauling. For this reason, in a totally commercial system, an electro-mechanical interlock with the main winches should be fitted to ensure immediate power shut down on commencing the hauling procedure.

Brief Description of Seawater Return Concept

The resistance to current flow in a highly conductive medium such as sea water is complex and a function of many variables, several of which are listed below:-

(i) Nature of the electrical signal source, i.e. A.C., D.C.

(ii) Area of anode, and surface nature

(iii) Area of cathode, and surface nature

(iv) Potential difference between the two surfaces

(v) The geometry of both surfaces

(vi) The volume and conductivity of the interposing medium

The sea water path, between the conductive zones of the vessel's hull and the area enveloped by the effective negative electrode surfaces, provides a conductive medium in which the charging current passes. During this process the negative electrodes pertaining to the electrode array become anodic with respect to the conductive zones of the vessel's hull which assumes cathodic status.

The value of the sea water return resistance is of paramount importance when designing a system suitable for a particular vessel size or class. To a large extent it influences the size of the source power mechanism. The resistance is an integral part of the total charging line resistance and therefore influences the final charging voltage.

Calculation of this resistance is complex and generally involves use of assumptions of the surface geometry of the conductive surfaces.

The value of the seawater return path resistance has been calculated in two separate practical examples, firstly on the C.K. AMBER and more recently on trials aboard M.T. BOLTBY QUEEN, is seen to be about 3 ohms. The variables of depth and distance, and therefore the volume of medium between the vessel's hull and the negative electrodes, appear to have little influence on the value of return path resistance. In fact it has more recently been resolved that the most influential factor governing Return Path Resistance is the boundary condition of the total area of the negative electrodes.

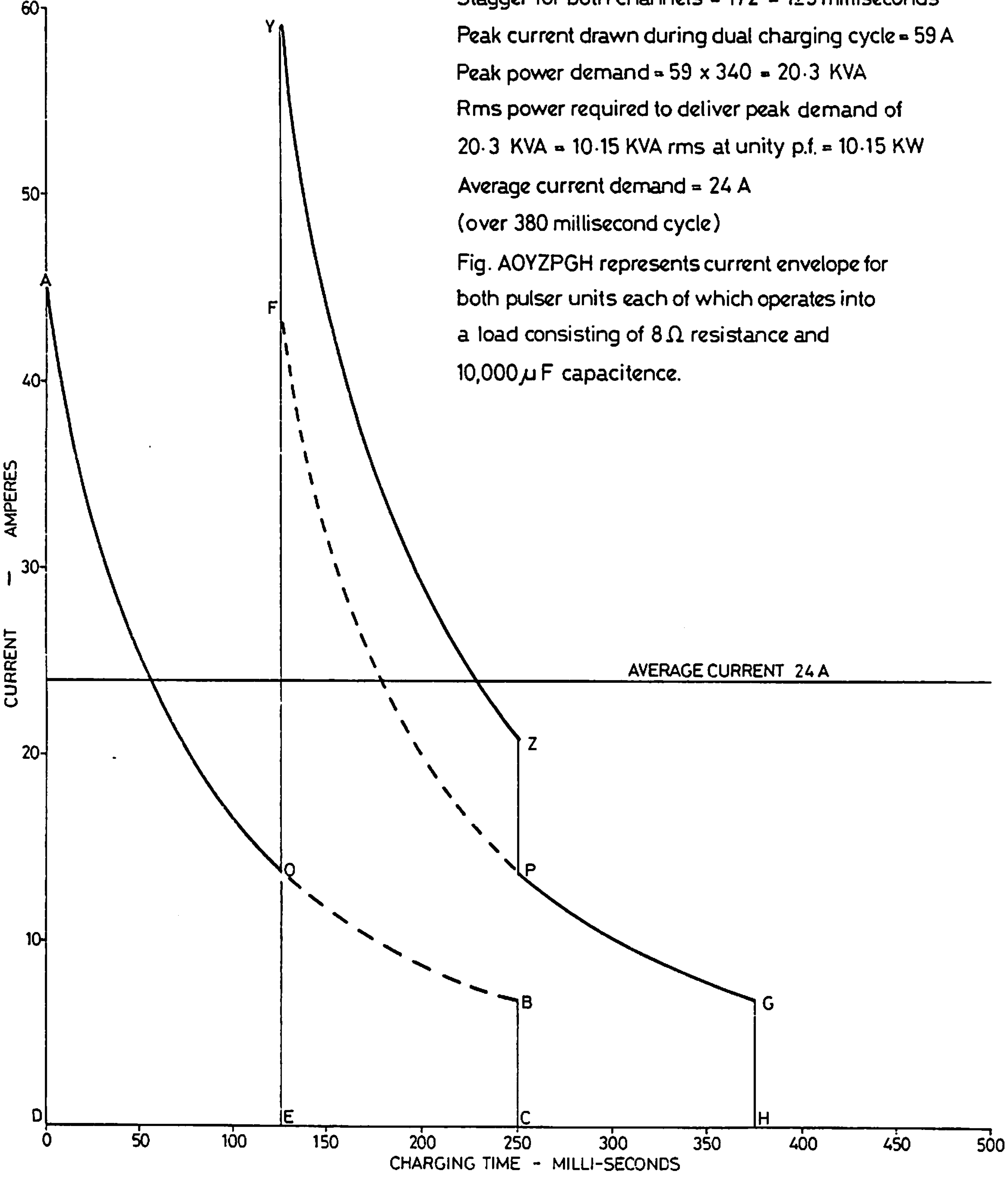
8. Current Flow with regard to Effects of Corrosion

During the charging cycle the electrodes connected to the negative output of each pulser, are positive with respect to the vessel's hull. The system may be considered as two plates oppositely charged and immersed in a conductive medium, this medium being the sea water separating the two. The anode represented by the effective area of the negative electrodes in the array looses ions which, ideally, should be liberated at the hull. In a static instance, this phenomenon would occur, in practice, the efficiency of the process is highly impeded by the influence of water flow and sand or mud particles in the path of the current. The effects of polarisation also serve, by the evolution of salts and gases at the surface of the anode, to increase the effective resistance at this interface.

Long term effects on metals pertaining to both array and vessel's hull have been monitored during the year long association with the C.K. AMBER.

The single core cable currently specified for electric fishing requirements cost some £3 per metre, a saving of £5 per metre over the twin core cable formerly used. Other benefits are seen in the reduction of complexity of plugs and fittings and in ease of repair of the cable following parting or crushing.

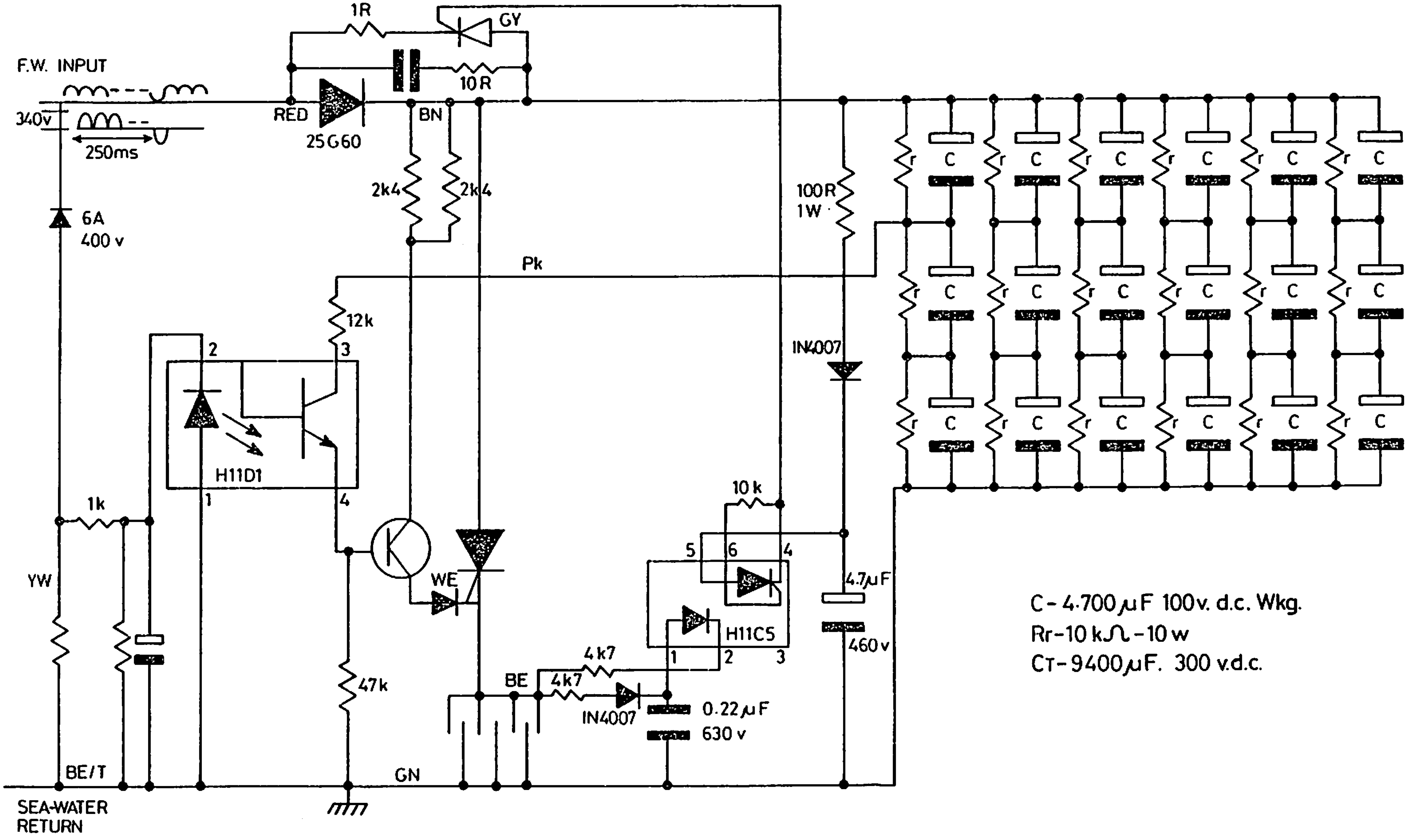
Fig. ABCD represents current cycle for port pulser
Fig.EFGH " " " " stbd "
Period T for each = 250 milliseconds
Stagger for both channels = T/2 = 125 milliseconds
Peak current drawn during dual charging cycle = 59 A
Peak power demand = 59 x 340 = 20·3 KVA
Rms power required to deliver peak demand of
20·3 KVA = 10·15 KVA rms at unity p.f. = 10·15 KW
Average current demand = 24 A
(over 380 millisecond cycle)
Fig. AOYZPGH represents current envelope for
both pulser units each of which operates into
a load consisting of 8 Ω resistance and
10,000 μF capacitence.



Electric Fishing Current (demand) Waveform for Electrified Beam Trawling on mfv. Zuider Kruis

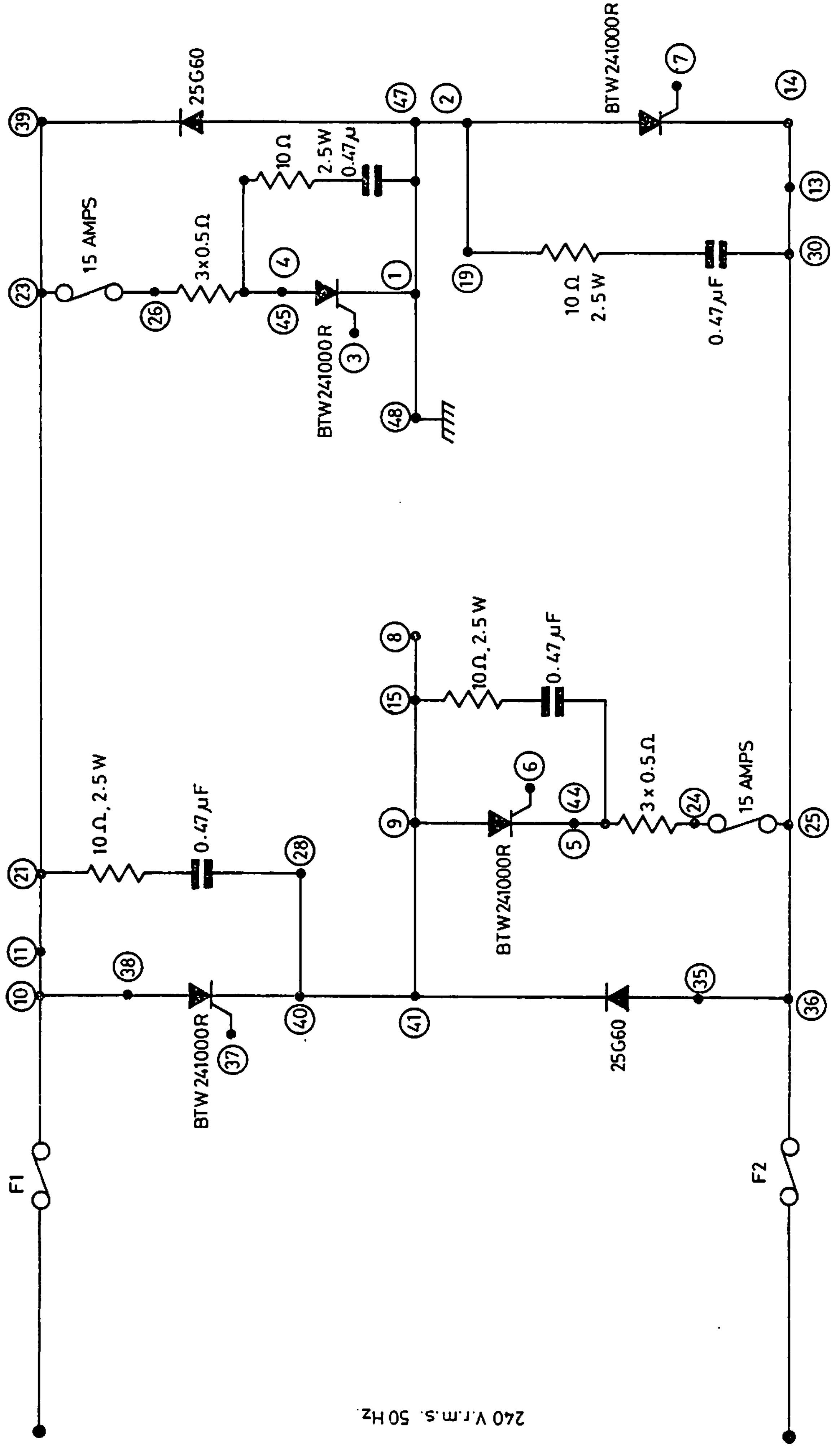
Appendix I Fig 1

Electric Fishing System – Pulser Circuits



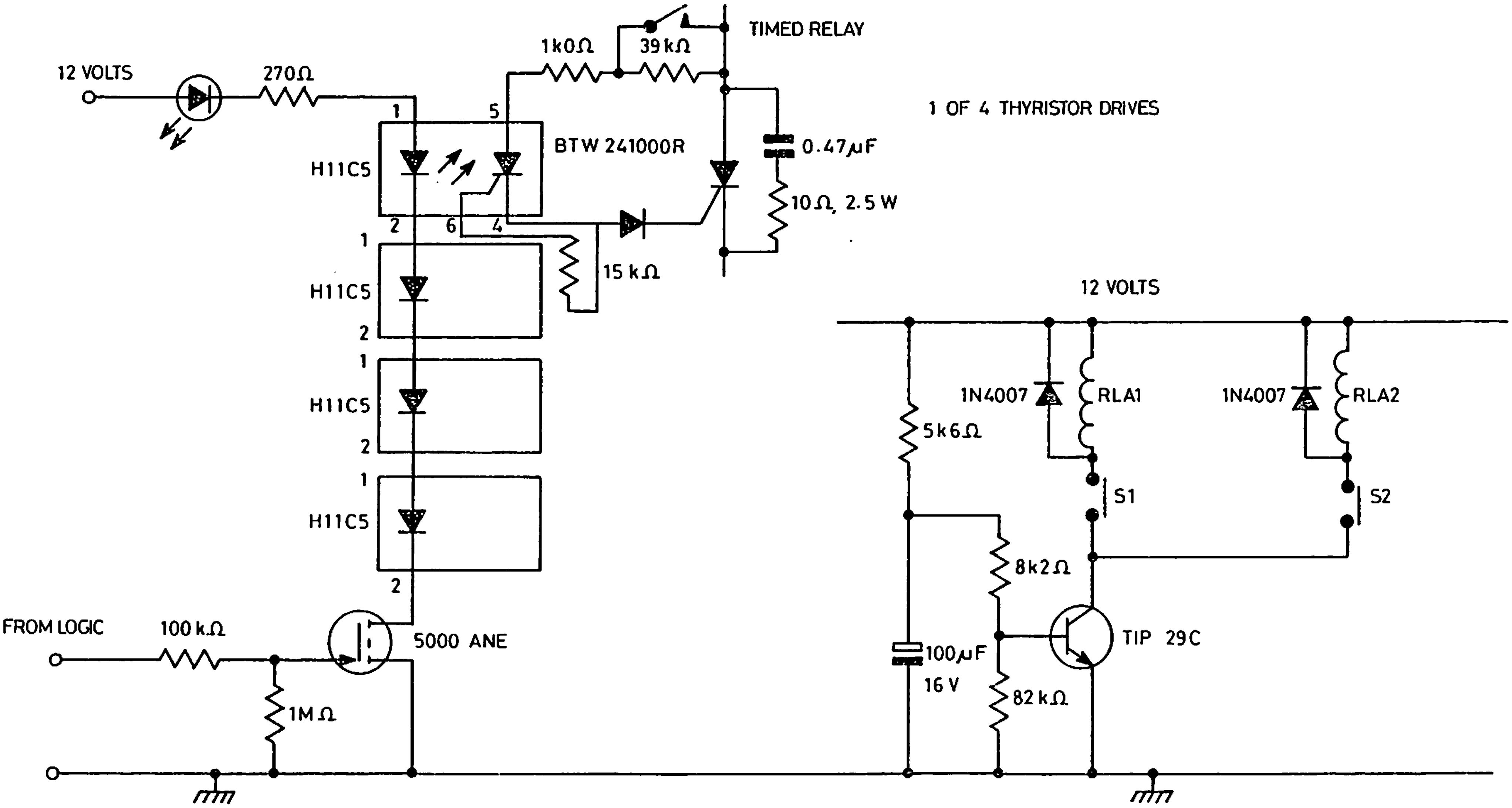
C – 4·700µF 100v. d.c. Wkg.
Rr – 10 kΩ – 10 w
CT – 9400µF. 300 v.d.c.

Appendix I Fig.E1



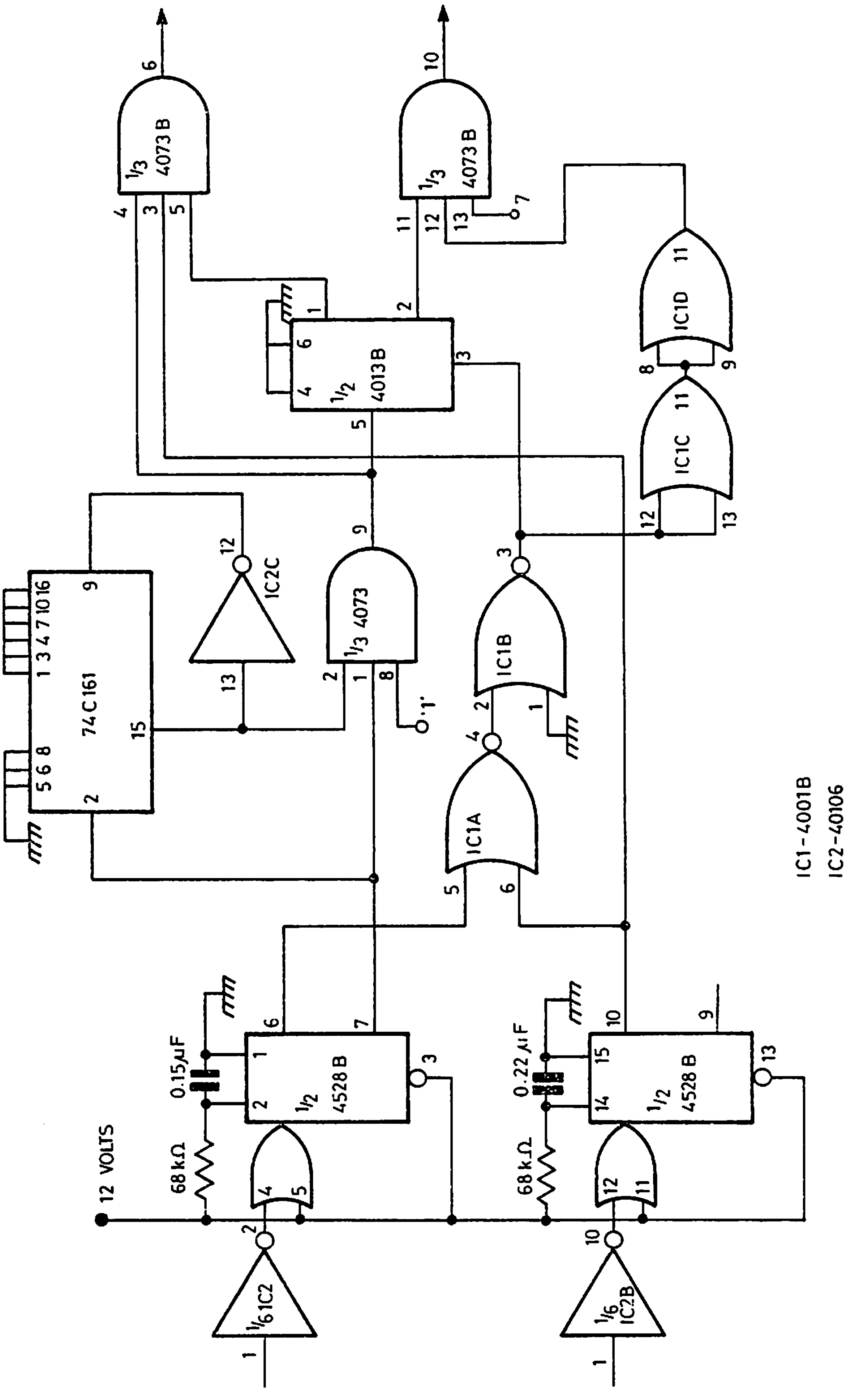
EFS - Bridge Power Module Circuit

Appendix I Fig E2



Appendix 1 Fig. E3

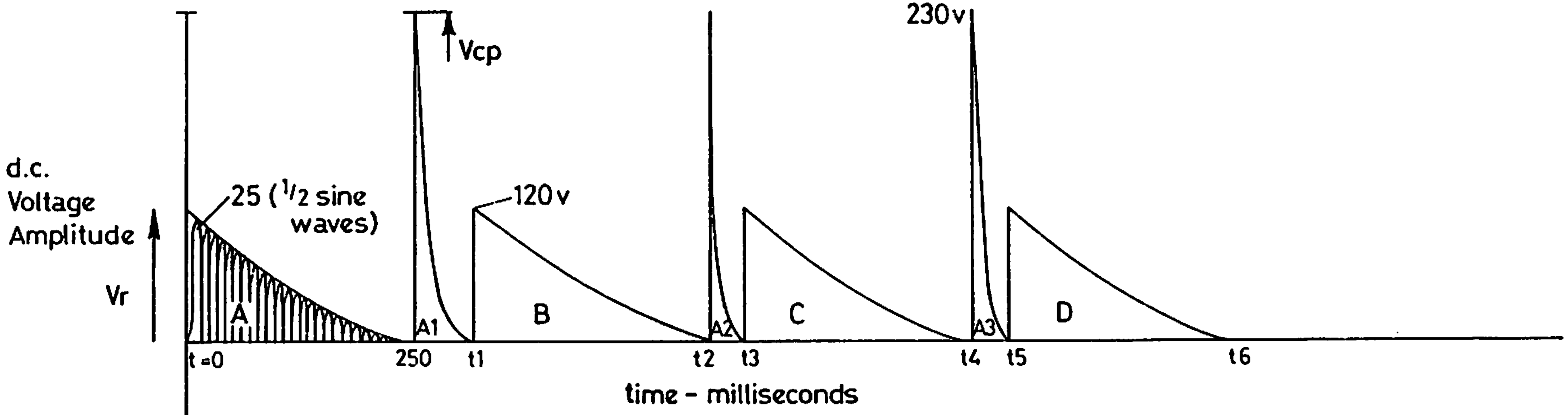
EFT Thyristor Drive Circuit



EFS Logic Timing Control Circuit

Appendix I Fig. E4

Variation of Pulser Output Voltage with Time



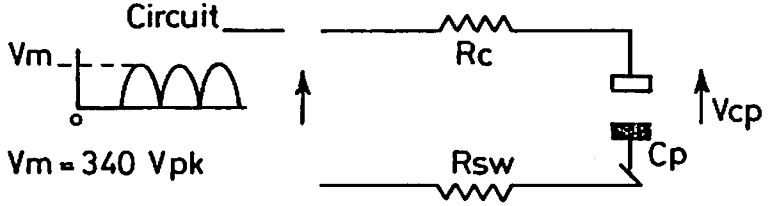
t1→t2 - 250ms = t3→t4 = t5→t6

t2→t3 = t4→t5 = τ = 1ms

A1 - A2 - A3 represents voltage between +/- electrodes

A B C D represents voltage between -ve electrodes and vessel's hull

Equivalent Charging Circuit



Vm = 340 Vpk

Vr = Total Voltage Dropped Across (Rc and Rsw)

Voltage at Neg. Electrodes wrt. hull

$$= (Vm - Vcp) \times \frac{Rsw}{Rsw + Rc}$$

Rc = Total Line Resistance
= (cable resistance and ballast resistance and all contact resistances)

Rsw = Seawater Return Resistance between -ve electrodes and conductive zones of vessel's hull

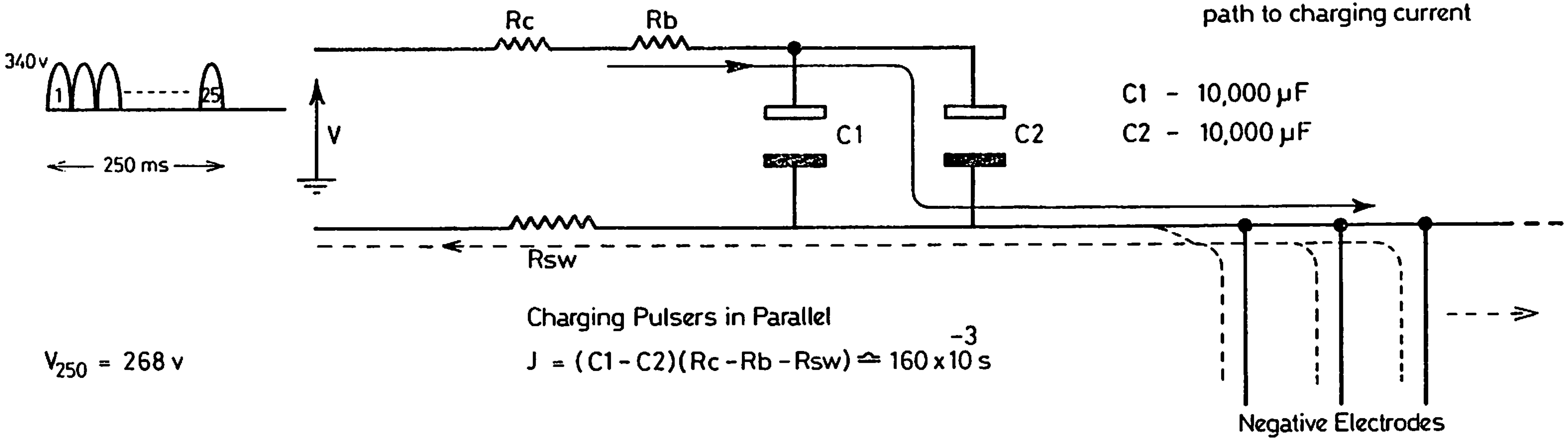
Appendix I Fig. E5

Equivalent Charge / Discharge Circuits

circuit neglects inductance
of -ve electrodes and winch cable

→ charging current
⇠ return to ⏚ source

Rc = transmission line resistance
Rb = ballast resistance
Rsw = simulates resistance of return path to charging current



C1 - 10,000 μF
C2 - 10,000 μF

V_{250} = 268 v

Charging Pulsers in Parallel

$J = (C1 - C2)(Rc - Rb - Rsw) \simeq 160 \times 10^{-3}$ s

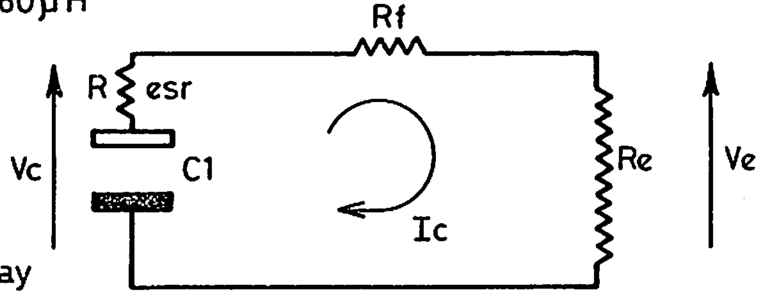
Discharge Circuit

circuit neglects array inductance. L → 60 μH

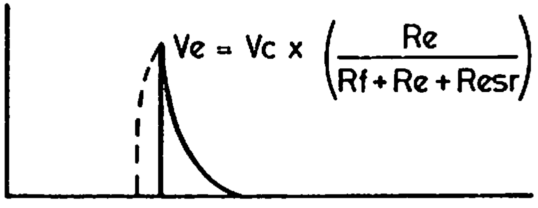
Resr - equivalent series resistance of pulser bank capacitance C1

Rf - feeder cable resistance between pulser output and electrodes

Re - electrode array resistance



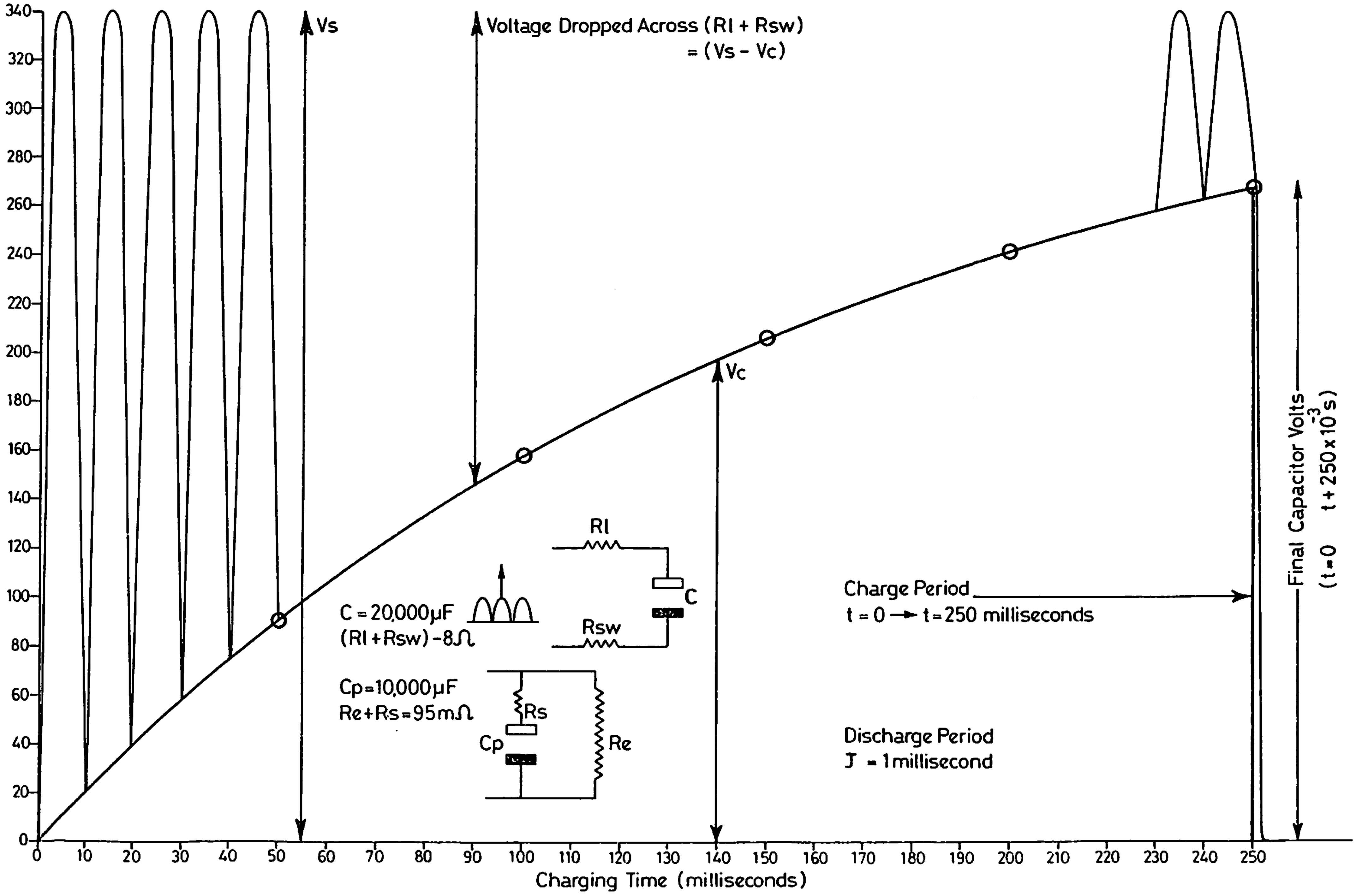
circuit neglects array capacitance (Ce)
C1 >> Ce



$J = C1\,(Resr + Rf + Re) = 950\ \mu s$

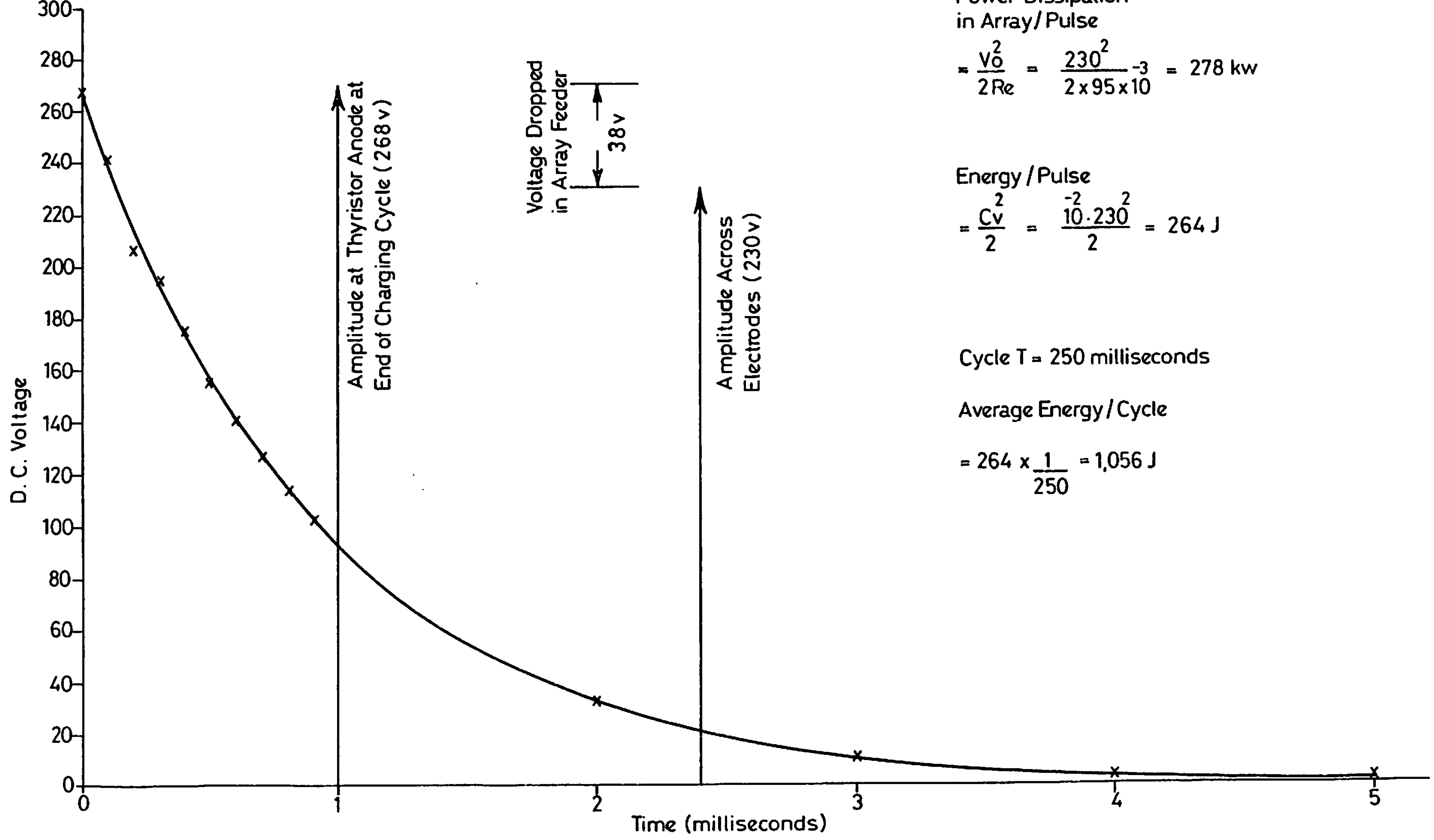
Appendix I Fig E6

Variation of Charging Voltage with Time



Appendix I Fig E7

Discharge Pulse



Power Dissipation in Array / Pulse

$$= \frac{Vo^2}{2Re} = \frac{230^2}{2 \times 95 \times 10^{-3}} = 278 \text{ kw}$$

Energy / Pulse

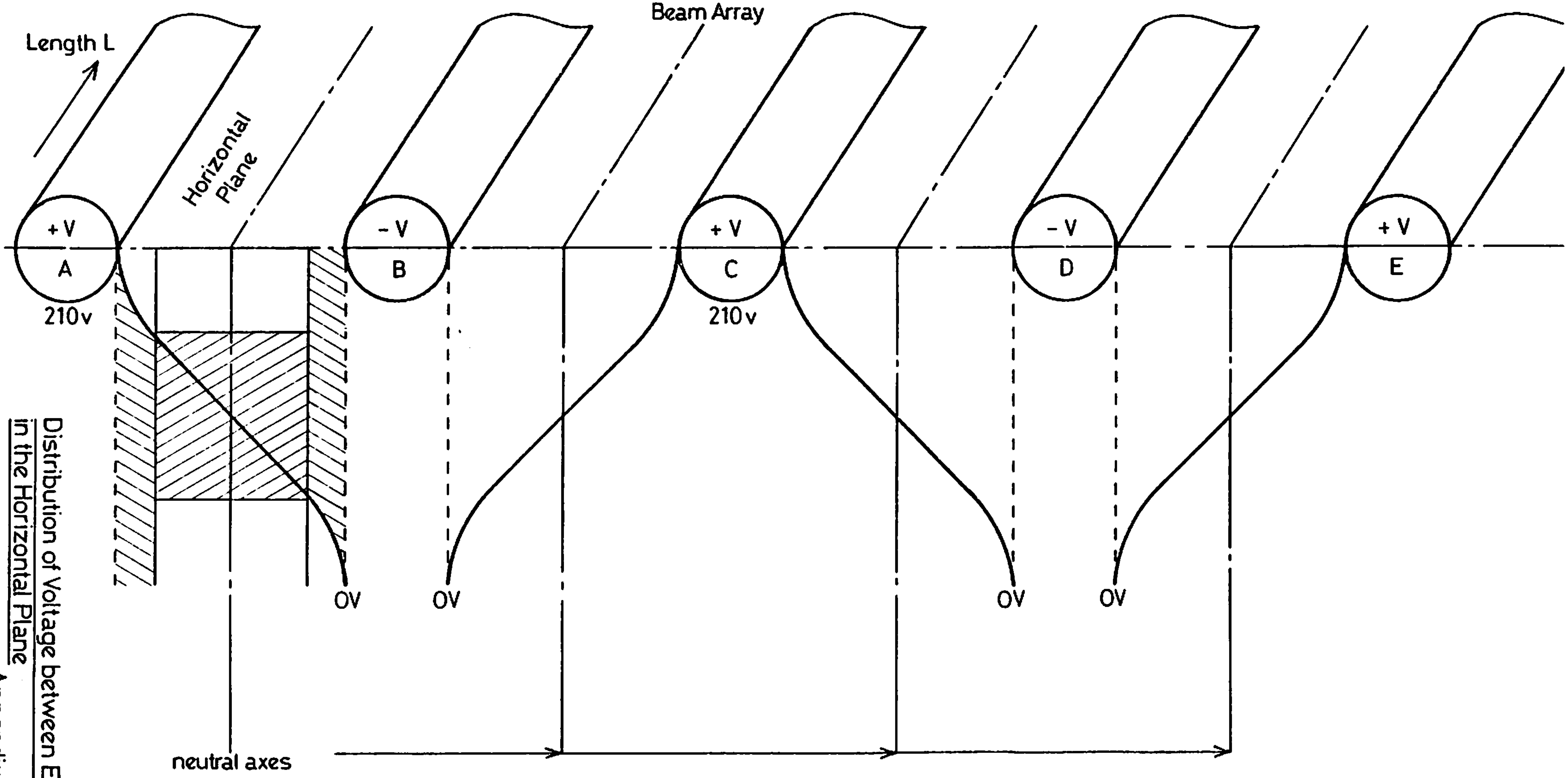
$$= \frac{Cv^2}{2} = \frac{10^{-2} \cdot 230^2}{2} = 264 \text{ J}$$

Cycle T = 250 milliseconds

Average Energy / Cycle

$$= 264 \times \frac{1}{250} = 1{,}056 \text{ J}$$

Appendix I Fig. E8



▨ Ambience – minimum value of voltage gradient constituting approx 90% of electrode lateral separation.

▨ Zone of high voltage gradients increasing to maximum at conductor surface.

Distribution of Voltage between Electrodes in the Horizontal Plane

Appendix I Fig E9

APPENDIX II

M. T. BOLTBY QUEEN

APPENDIX II

M. T. BOLTBY QUEEN

BOLTBY QUEEN LT 121

BRIDGE EQUIPMENT

Kelvin Hughes Type 17 Radar
Koden SRM 658 Echo Sounder & Koden SRM 681A Fish Graph Sounder
Decca Mk 21 Navigator and 350T Track Plotter
Sailor SSB T122 and R105 Radio Telephone
Sailor RT 144c V.H.F., S.B.E. Optiscan V.H.F.
Decca 450 Auto Pilot. SAL Log.

MAIN MACHINERY

British Polar SF8VS 8 cylinder 1250 BHP & 720 RPM main engine
Reintjes WAL 1850 2.5:1 reduction gearbox
3 blade C.P. Propellor by J.W. Berg.

WINCHES

Main trawl winch Norwinch TO-11-38-70 split unit installation
2 Norwinch LF25 outhaul/cod end winches
Norwinch net winch

APPENDIX III

EFFECTS OF DOOR CHAINS IN OTTER BOARD FISHING

APPENDIX III

EFFECTS OF DOOR CHAINS IN OTTER BOARD FISHING

1. Figure 1 shows some of the forces acting on an otter board. The towing pull on the warps is made up of the outward spreading force of the warps themselves; the otter boards, net and gear behind them. The drag of the door tickler chains acts on the after end of the otter board heel. The pull or drag of the chains is in the direction in which the chain leads from the otter board. This total pull comprises of backward drag and inward pull on the board. For the normal length of tickler, the lead of chain from the board is at approximately 20° to the direction of towing. Therefore most of its drag constitutes backwards pull with relatively low laterat forces. Use of heavy tickler chains has a significant effect on the towing pull requirements for the total fishing gear assembly. Typical U.K. practice is to use seven chains, all of which are of heavy gauge with two towed from the board and the remainder towed from Dan Leno, Wing End or Mid Wing.

Dutch skippers use up to 14 tickler chains of which 8 heavy ones are fixed to the shoes and 6 lighter ones are strung across bight of the ground rope, just as otter trawls use mid wing bunt and bosom chains. Successive chains will each disturb only a thin layer of sand. It could well be that the virtue of using many chains lies not so much in their power to 'dig out' fish, as in preventing the fish from burying themselves thereafter, before the ground rope reaches them. If this is so then it may prove beneficial for British vessels to apply similar reasoning. A heavy door chain or even two could be followed by any reasonable number of lighter chains joining the danlenos wing ends, mid wings and bunts.

Any ticklers however will reduce the spread of the gear somewhat. Thus catch rate increase due to more efficient tickling must more than offset the loss due to reduced spread or speed. However, the rig must not be so cumbersome as to impede hauling and shooting nor so fragile as to be in constant need of repair.

The relative importance of door chains to fishing effectiveness is seen when an event such as the loss of door chains by parting occurs. Catch rates plummet to as low as 40% of normal rates. Should a danleno chain or midwing chain part, little change is effected.

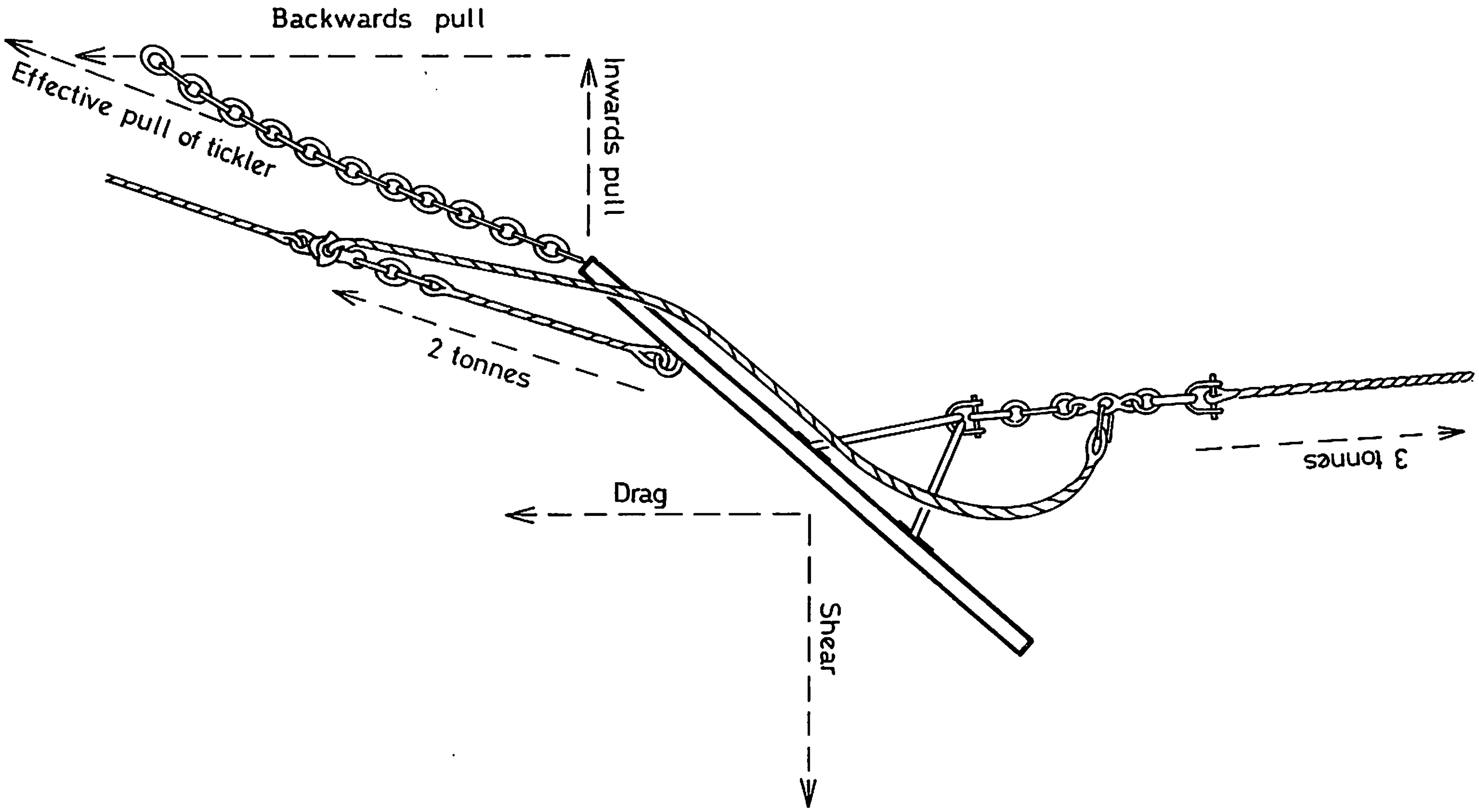
Since inarguably the door chains do the lifting of fish from the sand or mud, and the others prevent re-burying, it seems obvious that if no fish are initially lifted, then only fish already off the sea bed will be caught by the following trawl.

The door chains, however, perform more than one major function in this rig.

i) The transverse bight digs out fish from the sea bed.

ii) The trailing sections of the chain produce a mud/sand curtain which obscures a possible escape route for the herded fish. The effect is compounded by the remaining trailing chains (towed from the danleno and tow leg wires).

In an effort to restore the latter effect to the electrified array system a trailing chain was fitted between otter board and dan leno on each side of the fishing gear; a marginal improvement in catch rates was noted after these chains had been fitted.



Appendix III Fig.1

Forces on the Otter Board when Towing

APPENDIX IV

FISHING GEAR SPECIFICATION

APPENDIX IV

FISHING GEAR SPECIFICATION

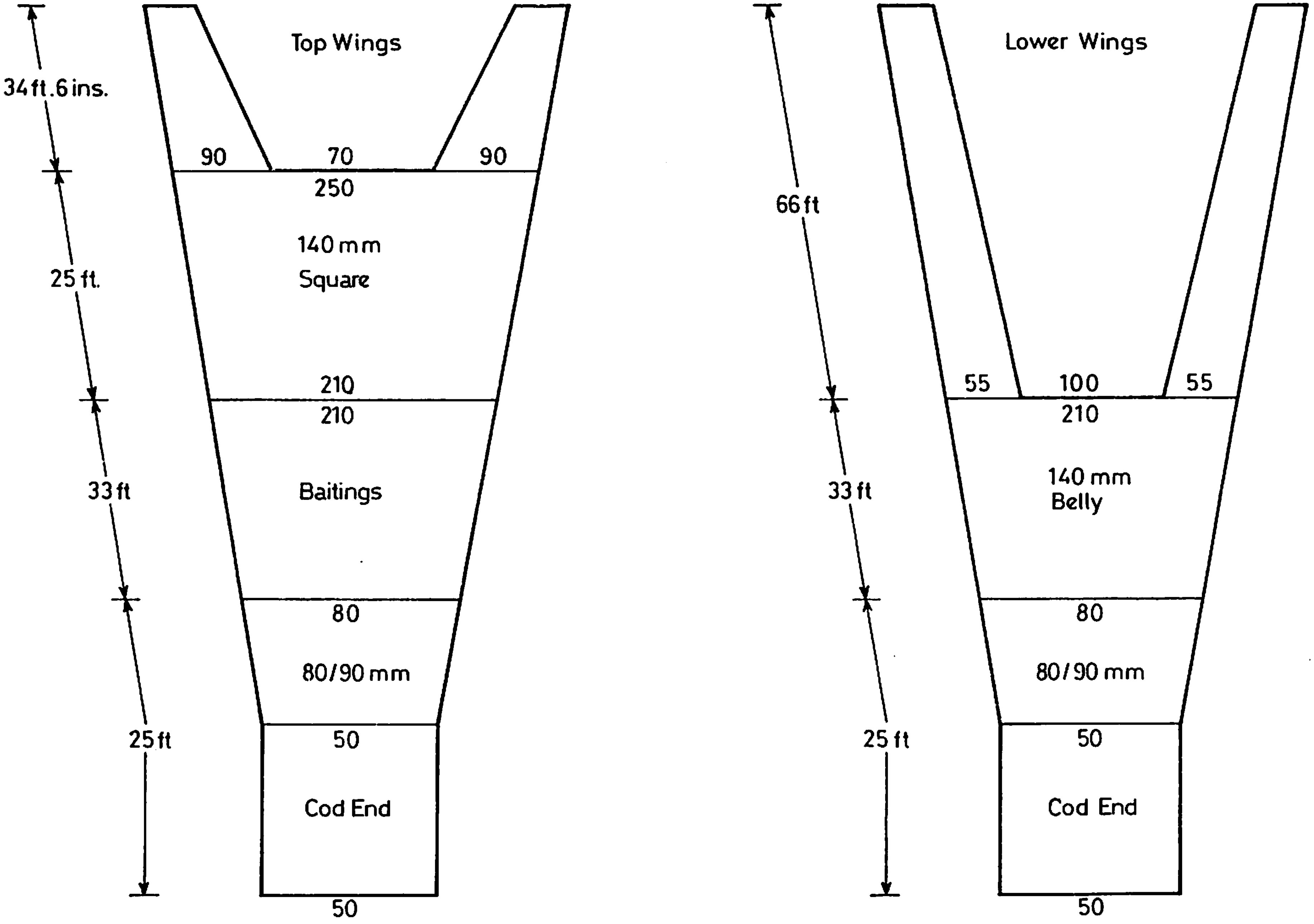
Lowestoft C4, manufactured by J & W Stuart, in braided nylon PN100 3.54mm see Fig. 1 , 2 panel North Sea flat fish trawl.
Headline 82 ft
Fishing lines 122 ft
Ground gear as follows: 3 ins rubber discs on ⅜ in drag alloy chain with Kuplex connectors in the following sections.
20 ft bosom, 8 ft bunts, 2 x 20 ft wing sections
Total length 116 ft
12 ft tow legs upper 2½ ins wire lower in chain
Dan Leno butterfly
Flotation 20 x 8 ins aluminium floats
Bridles 30 ft (with 20 ft extension)
Backstrops 9 ft 6 ins.
Doors 10 ft x 5 ft wooden

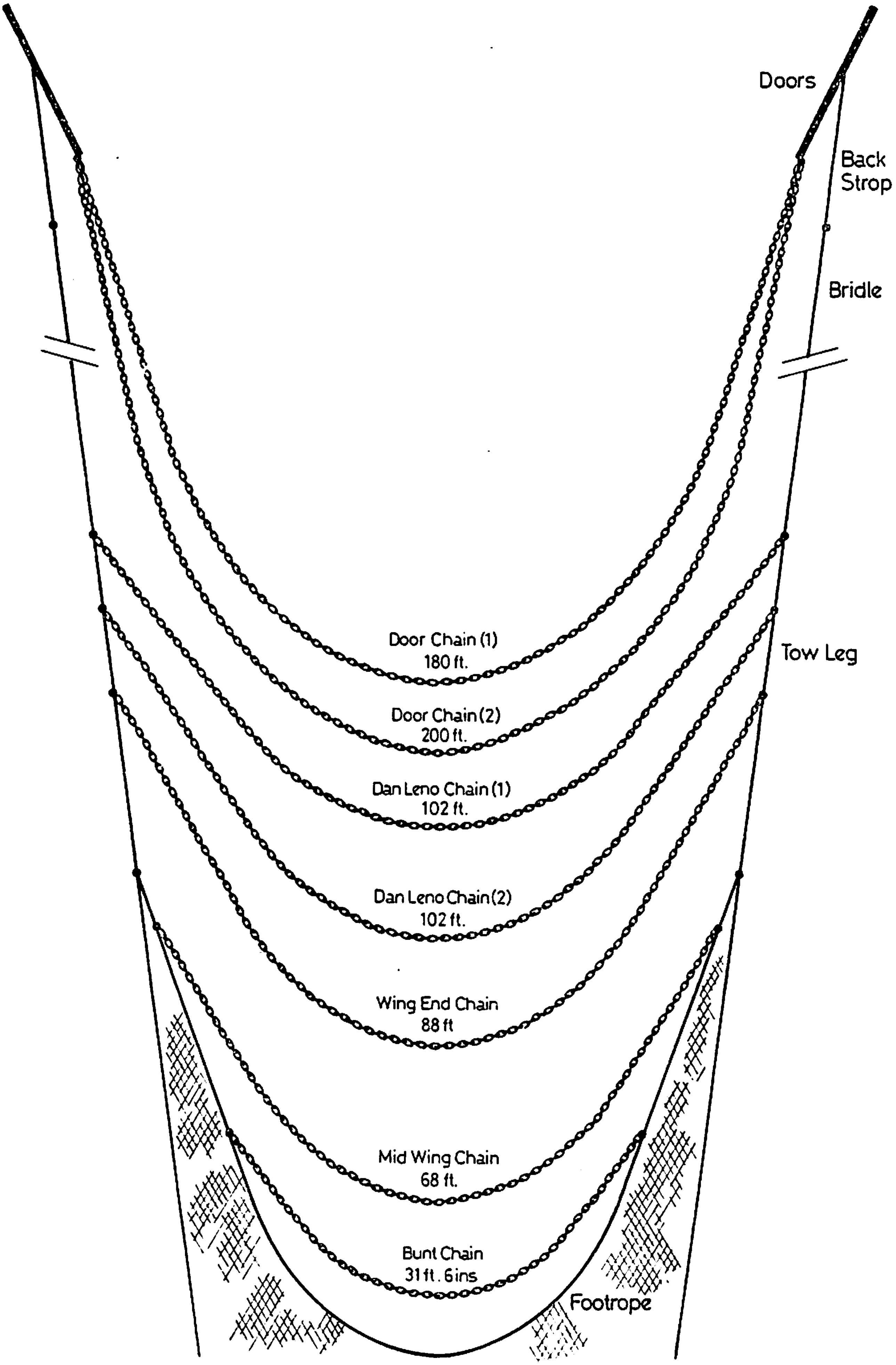
NORMAL CHAIN RIG USED WHILST PLAICE FISHING

¾ in chain (500 ft = 1 ton)
Door chains 204 ft and 180 ft
Dan Leno 2 x 102 ft (attached at Dan Leno and half way along lower tow leg)
Wing end 1 x 88 ft
Mid wing 1 x 68 ft
Bunt 1 x 31 ft 6 ins.

Appendix IV Fig 1

Lowestoft 82 ft. Headline C4 Trawl





Chain Tickler Rig C4 Trawl

Appendix IV Fig. 2

APPENDIX V

HISTORICAL BACKGROUND

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HISTORICAL BACKGROUND

1. DEVELOPMENT OF U.K. FLEET - BEAM TRAWLERS

Beam trawling for flatfish such as Dover Sole (Solea solea) and Plaice (Pleuronectes platessa) in the North Sea has been developed by the Dutch and Belgian fishing fleets into a very effective method of fishing. During the course of development, the size and weight of trawls used has increased in order to improve catch efficiency and this led to a corresponding requirement for more and more powerful vessels. Despite the current high cost of fuel, vessel size has continued to rise and the latest Dutch vessels have engines in excess of 2,000 h.p. and two 12 metre beams rigged with up to 10 tickler chains per side.

Although beam trawling was seen by British fishermen as an effective method of fishing, it was considered that the conversion of the existing otter trawling vessels to utilize beam trawling was not practicable and that purpose built vessels were required. However, during the early 1970's, modernisation of the Belgian and Dutch beamers fleet initiated the supply of second hand vessels, some of which were subsequently purchased by British fishermen. Additional vessels have joined the British fleet during the last ten years. The Lowestoft beamer fleet comprises some 15 vessels ranging from 18 to 28 metres, and the south coast total exceeds ninety; the main proportion of which operate from the port of Brixham. The latter utilize the beam trawl all year round but do not necessarily depend on flat fish such as Dover Sole and Plaice, but rely also on bottom dwellers such as Monk fish.

Vessels fishing from Lowestoft are also unable to operate upon flat fish all year round. Most of the smaller vessels (operating 4m beams) - which operate close inshore have adapted to allow otter trawling from the stern when beaming becomes uneconomic.

The earliest electro-beaming trials carried out by the S.F.I.A. date back to 1977 on board MFV P.G. ISLANDER. With the assistance of Wilbur Seidel of N.M.F.S. (Pascagoula - Mississippi) and equipment supplied by

J.L. Newman of OCEAN HARVESTER CORPORATION, TEXAS, trials commenced in the Summer of 1977. The equipment had been used successfully in the shrimp fishery in the Gulf of Mexico, but early comparisons showed a definite lack of power in inducing a reaction from flat fish. The results suggested that a larger amount of power needed to be discharged into the sea bed forward of the ground rope, also that the ground holding characteristics of the array required improvements.

Further trials were carried out in 1978 on MFV CHANDELLE (FR 678) with a more powerful output into the newly improved electrode array.

These trials which spanned a total period of three months proved most important to future developments. During these trials a variety of electric field strengths and pulse widths were tried over many commercial tows. Finally, through comparative catch rate performance, minimum values of the electrical parameters were determined.

At this stage catch rates during electrical fishing trials were approximately 80% of those using the conventional chain gear.

It was concluded at this time that the more limited ground contact effect of the electrode array, even at the lower towing speed of 3.5 knots, allowed fish escape under the ground-rope, underneath the bosom. To deter this reaction of fish, following electrical stimulation by the array, a light bunt chain was rigged to the ground rope and subsequently electrified by connecting it to one of the negative electrodes through a direct chain link.

This chain produced a dust cloud in front of the ground rope which obscured the fishes vision of it, and effectively extended the electric zone enclosed by the electrode array.

Later trials showed that catch rates were similar for the two types of fishing gear, i.e. electro beam to the traditional chain rigged beam, and, that the former required considerably less towing power.

Through a variety of modifications to the array and changes in levels of output power, these trials revealed the electro mechanical combination of stimulus necessary to produce catch rates comparable with chain rigged beam trawls, and the optimum towing speed at which these results occurred.

A further series of trials were carried out in 1979 on the 26m, 525 BHP beam trawler MFV HOMEWATERS (FR 1003). The object of these trials was to establish the potential power and fuel savings obtainable with electrified trawls as well as assessing catch rates in relation to conventional gears. From the results of the previous trial it was considered that simultaneous comparison of different gears was not completely valid because of the difference in optimum towing speed for electrode arrays and tickler chains. It was believed, and indeed ascertained on the Chandelle trials, that electrode arrays were most effective at speeds of up to 3.5 knots, whereas chain gears were more productive at higher speeds up to 6 knots. Savings in fuel of up to 50% during towing were found to be possible.

A further series of trials were carried out in 1979 aboard the Lowestoft beam trawler C.K. AMBER (22.5m, 240 BHP).

The power transmission cable link between vessel and pulser unit mounted on the beam had posed many problems of one kind or another. These ranged from the electrical loop resistance characterised by manageable twin conductor feed lines, to mechanical strength and abrasion resistance and even to problems associated with repair and water ingress into pulser input connections. All of which were embraced in the most important parameter, economics.

Many of these problems were eliminated by the introduction of the sea water return concept (See App. I for brief description). This system allowed the use of a single cored supply line conductor, and was found to operate successfully during these trials. Its major advantages were as follows:-

i) Easy to handle and repair of a single 25mm^2 multi strand conductor.

ii) Low current density of remaining coils of cable left after shooting on the winch, and therefore less heat generated in these coils.

iii) Input connections to the pulser housing made simpler with less likelihood of water ingress compared with two conductor inputs.

iv) Suitable cable readily available at reasonable cost.

By 1980, sufficient confidence had evolved in the potential of this method of fishing, that a permanent installation of the equipment was made over a period of one year in order to assess catch rates and the ability of the equipment to sustain commercial operations. Analysis of the results showed that the trials vessel had maintained catch rates while reducing fuel consumption by about 40% . A slight saving was projected for gear costs but was not achieved in practise due to the unnecessary wastage of electrodes associated with random equipment faults. The faults were successively eliminated by development of the equipment.

Following success of these trials, it was decided to transfer the parameters and technology onto the C4 Otter trawl and trials commenced in 1981.

APPENDIX VI

ELECTRIC PARAMETERS APPLIED TO C4 ELECTRO TRAWLING SYSTEM

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ELECTRIC PARAMETERS APPLIED TO
C4 ELECTRO TRAWLING SYSTEM

VOLTAGE BETWEEN ELECTRODES - 230 V d.c.
ELECTRODE SEPARATION - 0.73m
VOLTAGE GRADIENT OF AMBIENT ZONE - 160 V/m
PULSER CAPACITANCE - 20,000 F.
PULSE WIDTH - 1.2 milli-seconds
PULSE REPETITION FREQUENCY - 4 Hz
CAPACITANCE ENERGY PER PULSE - 778 J.
ENERGY DENSITY - 25.2 J/m^2
*SEA WATER RETURN RESISTANCE - 2.5 ohms.
TOTAL LINE RESISTANCE INCL.* - 6 ohms.

APPENDIX VII

ELECTRIC PARAMETERS APPLIED TO 4m ELECTRO BEAM TRAWLING SYSTEM

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ELECTRIC PARAMETERS APPLIED TO 4m ELECTRO BEAM TRAWLING SYSTEM

PULSER CAPACITANCE/BEAM - 10,000 micro farads
ARRAY RESISTANCE - 90 milliohms
PULSE WIDTH (to exponential decay of - Vm/e) - 0.9 milli-seconds
ELECTRODE VOLTAGE - 210 volts peak d.c.
PULSER OUTPUT TERMINAL - 246 volts peak d.c.
ARRAY FEED DROP - 36 volts peak d.c.
AMBIENT FIELD STRENGTH - 154 V/m

TRANSMISSION CABLE RESISTANCE - 0.75 ohm/Km

CABLE RESISTANCE/SIDE + CONN^n (250m) - 0.3 ohm

LINE BALLAST RESISTANCE - 3.5 (ohms)

AVERAGE SEA WATER RESISTANCE - 2.5 ohms

TIME CONSTANT OF CHARGING LOOP - 63 milli-seconds

INPUT - ½ WAVE RECTIFIED - 240 V rms 50Hz input

OUTPUT PULSE FREQUENCY - 4 Hz