ELECTRIC FENCE REFERENCE MANUAL

ELECTRIC FENCING

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DEFRA

Department for
Environment,
Food & Rural Affairs

**Research and Development
Surveillance Report 607**

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INTRODUCTION

Background

An electric fence usually consists of several conductors of bare wire, supported on insulators and connected to a fence energiser which in turn is connected to a power source and earth rod(s). Electric fences were first used in World War I to contain prisoners of war. These fences carried alternating current (a.c.) and were designed to kill anyone coming into contact with them. It was not until the late 1930s that non-lethal fence energisers (also called controllers or fencer units) producing direct current (d.c.) were developed to manage stock or wildlife. Nevertheless, these early energisers were still dangerous, unreliable and easily short circuited. Then, in the late 1930s, better units were developed, making the technique more successful and acceptable.

Over the last 30 years, improvements in energiser technology have continued to be made so that now, in the early 2000s, a large range of energisers can be purchased. They are powered either from a mains electricity supply or, where this is not available, by battery. In remote areas, wind and solar power can be used to charge batteries. Energisers of varying power output, ranging from less than 1 joule to over 20 joules, can be purchased. (A joule (J) is the unit of energy used by manufacturers to specify the energy level of pulses produced by their products).

Electricity flows as a result of electrical pressure which is measured in volts (V). Energisers produce brief, high voltage pulses of electricity between the conducting wire and earth when the circuit is closed by animal contact. An animal standing on the ground and touching the electrified wire completes the circuit and receives intermittent but regular shocks to deter it. The pulsed nature of the electricity enables animals to move away from the fence, so preventing electrocution, although lethal fences still have a limited use in the Far East for control of rodents.

Temporary or permanent?

The main value of electric fencing is as a temporary fence to contain stock or exclude wildlife. The relatively low cost of the labour and materials required to erect this type of fence, and its high adaptability compared with the equivalent requirements of a standard post and wire fence, makes it especially suitable for this purpose. For example, electric fencing enables large fields to be easily subdivided to allow their more efficient use by grazing stock.

Electric fencing can also be used as a more permanent fence, particularly where failure would not result in serious consequences. For example, it can be used in this way to keep stock away from ditches, to control cattle in farmyards or to create access routes for cattle between milking parlours and fields. It is, however, less suitable as a farm boundary fence where failure could result in stock gaining access to neighbouring properties or roads.

Aims and scope

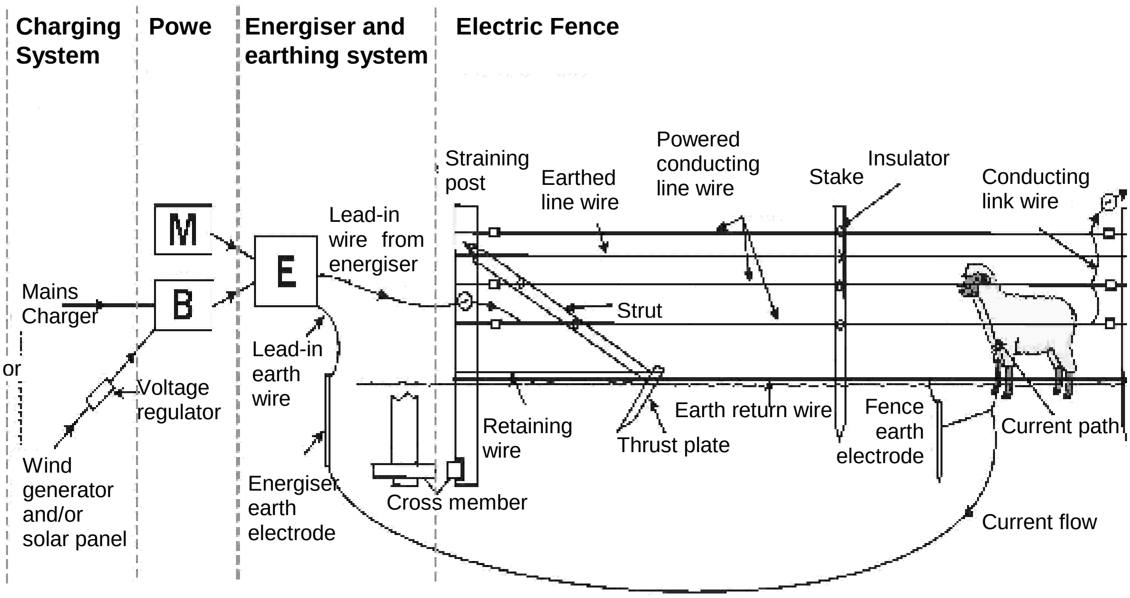
To obtain the maximum benefit from electric fencing, it has to be used safely and efficiently. The aim of this book is to provide guidance on how this can be done. The book is divided into seven chapters. Chapter 1 provides information on fence energisers, insulators, conducting wire and earthing. Chapter 2 examines the compatibility of fence energisers, batteries and charging systems. The third chapter provides guidance on appropriate fence specifications to manage a range of domestic stock and wild mammals. Chapter 4 considers safety aspects from the perspective of the user and humaneness from the perspective of the animal being managed. The last three, Chapters 5, 6 and 7, look at fence construction, siting and maintenance. Note that electric fencing used for security purposes around buildings to prevent potential criminal intrusion is not considered in this guide.

CHAPTER 1

Equipment

This chapter describes the range of fence components available and can be used as a guide to making choices when preparing a fence specification for a particular situation. Definitions of the terms used are given in Table 1. Many of them have synonyms or sometimes other interpretations which are used in different parts of the UK. The main components are shown in Figure 1 which outlines the principles and construction of an electric fence. Table 2 gives guidance on the suitability of the components for either temporary or permanent fencing.

Figure 1 Principles of Electric Fencing



Key:

B Battery
M Mains
E Energiser
Cut-out switch
In-line insulator
Post insulator
Wire staple

Table 1 - Common electric fence terms and units

Terms

Alternating current	Abbreviation a.c.
Direct current	Abbreviation d.c.
Dropper	A rigid vertical component used to keep line wires apart.
Electric fence	A barrier which includes 1 or more electric conductors, insulated from earth, to which electric pulses are applied by an energiser.
Electric animal fence	An electric fence used to contain animals within or exclude animals from a particular area.
Electric fence energiser	An apparatus which is intended periodically to deliver voltage impulses to a fence connected to it.
Insulator	A non-conductive material or a device made with the intention of preventing current flow.
Leakage	A small energy loss from the fence line to earth.
Line wire	A single fence wire, which may be either single strand or multi-strand.
Polythene wire (Polywire)	Polypropylene or Polyethylene twine incorporating one or more stainless steel or tinned copper strand(s).
Polythene tape (Polytape)	Polypropylene or Polyethylene woven tape incorporating stainless steel or tinned copper strands.
Post	Posts are placed in a hole dug in the ground and firmed. They may be used as: 1. a straining post to tension line wires to and from; 2. a contour post to hold a fence in depression or valley; 3. a turning post when the fence line changes direction and the internal angle is greater than 110°.
Short	A large energy loss from the fence line to earth.
Stake	A post that is driven into the ground.
Strut	An angled support to a straining post.

Units

Ampere	A unit of electrical rate of current flow. SI unit symbol: A
Joule	A unit of electrical energy. SI unit symbol: J
Ohm	A unit of electrical resistance. Symbol: Ω
Volt	A unit of electrical pressure. SI unit symbol: V

Table 2 - Electric fence component use

Component	Temporary fence[a]	Permanent fence
Energiser (mains powered)		✓✓
Energiser (battery powered)	✓✓	✓✓
Battery charging system (wind solar)		✓✓
Battery charging from mains	✓✓	✓✓
Non-rechargeable battery	✓	
Straining post - wood	✓	✓✓
Contour post - wood		✓✓
Turning post - wood	✓	✓✓
Strut - wood	✓	✓✓
Stake - wood, plastic, metal or fibreglass	✓✓	✓✓
Insulators integral with stake	✓✓	
Porcelain insulators		✓✓
Plastic insulators	✓✓	✓✓
Tube insulators		✓✓
Off-set insulators		✓✓
1.6 mm and 2.00 mm medium-tensile steel and aluminium wire	✓✓	
2.5 mm high-tensile, 2.65 spring-steel and 3.15 mm mild steel wire		✓✓
Multi-strand steel cable	✓✓	✓
Polythene and stainless steel wire ‘Polywire’ and ‘Polytape’	✓✓	✓
Polywire electric mesh netting	✓✓	
Barbed wire/mesh	**xx**	**xx**
Copper coated steel earth rod	✓	✓✓
Zinc coated steel earth rod	✓✓	

[a] Temporary fences are considered to be those required for less than 3 years.

✓ occasional use ✓✓ principle use **xx** not to be used

Introduction

The objective of any electric fence must be clearly defined before any consideration is given to its detailed specification and certainly before any construction is begun. Therefore knowledge is required about:

1. The species and sometimes breed of animal which is to be managed and its capability to scale, burrow or just force its way through a fence.
2. The pressure on the fence which is related to the number of animals on one side of the fence and their need to be on the other side.
3. The length of time an effective fence is required.
4. The maximum permitted level of financial expenditure.

Electric fencing, to be effective, must have its conducting wires totally insulated and effectively isolated from the ground. The fence structure must be of sufficient strength and capacity to deliver an electric shock sensation to an animal when touched.

If an animal is to receive an effective shock upon contact with the bare electrified fence wire, current must be able to flow through its body to the ground. This can only happen by establishing a very sound earthing area system which must be connected directly to the energiser. The degree of shock sensation experienced is directly related to the level of the current which can pass through the animal's body and the time it takes to do so: the higher the current and the longer it takes to pass through, the greater the shock sensation. Current level is regulated by electrical resistance which opposes the flow of current: the higher the resistance the lower the current and the less the shock sensation experienced. A good earthing system will help to minimise resistance, but current flow will still be affected by the resistance between those parts of the animal's body which come in contact with the fence and with the ground and by the resistance of the ground itself. A higher level of voltage produced by the energiser will help to overcome a high resistance path through the body, but will be of little consequence if the earthing system is not soundly constructed.

Energisers

The centre of any electric fence system is the energiser. There are two types: mains operated and battery operated. The energiser converts a.c. or d.c. voltage, respectively, into repetitive high voltage pulses of d.c. voltage which are delivered along the entire length of a fence connected to it. Each pulse lasts for a very short time (approximately 500 microseconds) and is produced at one second intervals. Thus, fence energisers are constantly switching on and off, and it is this characteristic which is responsible for preventing a fatality under normal operating conditions. The voltage peak of each consecutive pulse can rise to a limit of 10,000 V; values exceeding this limit are considered unsafe by present international safety standards.

Voltage is not the only aspect to be taken into consideration where safety is concerned. Each pulse will contain a potential quantity of electrical energy. This quantity of electrical energy is measured in joules (J). Energisers with an output in excess of 5 J are not recommended under UK Health and Safety codes of practice, although those producing up to 20 J are nevertheless available on the market.

Each of the mains operated and battery operated energisers are sub-divided into the two categories of high or low power. Many of the energisers available allow the choice of either low or high energy outputs. These outputs are usually available from colour coded terminals on the energiser. A red coloured terminal will usually identify the higher output and a yellow coloured terminal the lower output. The earth terminal, common to either output, is green. The most recent designs of energisers have digital liquid crystal display providing certain characteristics of the output on the fence, such as fence voltage and earth leakage.

There are three important factors to be considered when choosing an energiser:

- fence location
- animals to be controlled

- fence length.

Under most circumstances, fence location will dictate the selection between a mains or battery powered energiser. For example, in remote areas where no mains supply is available, the only option will be a battery powered unit. When a battery powered energiser is selected, consideration must be given to replacing or recharging the battery which, with a higher powered energiser, may be as frequently as every two weeks. Thus, where there is a choice, mains operated energisers are preferable to avoid the problems of battery charging and maintenance.

Different species of animals vary in their susceptibility to electric fence shocks. Some, such as pigs, are relatively easy to control: as little as 300 millijoules (mJ) of energy on a well-insulated fence with a sound earthing system will deter them. Animals with fur generally require more energy capacity on the fence to receive an effective shock. Body size is also important. Generally the larger the animal the greater the energy capacity needed. For example, rabbits and foxes require less energy (they need about 1.5 J) than sheep and deer. Deer generally represent one of the most difficult animals to control by electric fencing and high powered energisers are essential.

The fence manufacturer will usually specify the maximum length of fence that their energiser will power effectively. The length of fence, for multi-strand fences, is the total length of conductor wire used. Thus, an energiser capable of powering a 4 km (2.5 miles) length of fence can be used on either a 2 km (about 1.2 miles) fence of 2-line wires or 1 km (about 0.6 miles) fence of 4-line wires.

Batteries

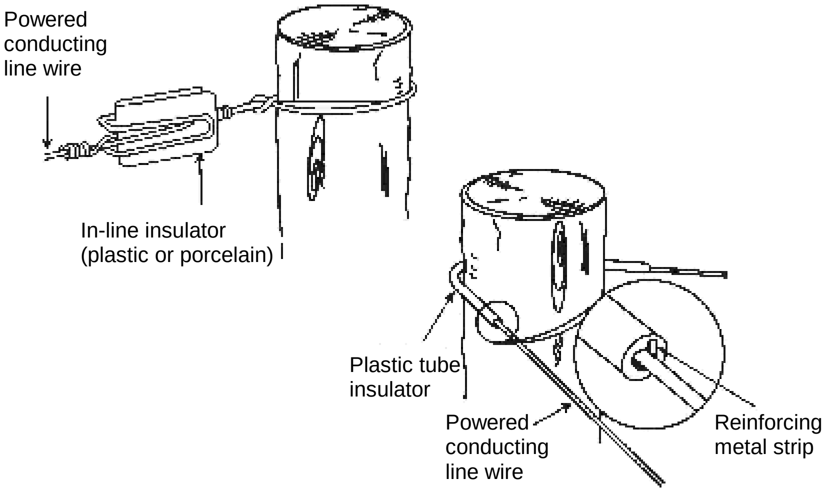
Some low power energisers can be used with dry cell batteries which are designed to be used and discarded. However, most energisers require rechargeable lead acid batteries. The required voltage of the battery will be specified by the energiser manufacturer and the capacity of the battery can be determined from the proposed usage and method of charging. Batteries that are not designed for cyclic discharge and recharge (car starter batteries, for example) will deteriorate rapidly if not maintained at or near full charge. Leisure batteries (for example, those used in caravans) are more appropriate.

Insulators and switches

Insulators are a fundamental component of any electric fence. They are made from a non-conductive material, usually either porcelain or thermoplastic, and form a barrier between the electrified wire and its support material to prevent current leakage to the ground. Good quality insulators should have a smooth surface and be impervious, so that they will drain and dry rapidly, to prevent moisture collecting in any cracks or splits and water accumulating on their surface.

The total amount of energy in each pulse delivered by an energiser is relatively small but, as already stated, the voltage peak of each pulse may be as high as 10 000 V. This high level of voltage will 'jump' from any accumulated moisture on a poor quality insulator to any point that is effectively earthed. This leaking of electrical discharge may be in the form of an 'arc', which can be heard as clicking from as far away as about 50 metres (55 yds), and can on occasion be visible to the eye as sparking. Leakage of this nature will result in a reduction of the effectiveness of the fence. Not all leakage of electric current is detectable without the aid of instrumentation. It is therefore important to select the correct type and quality of insulator. The quality of some types of insulator is variable. Therefore, experience gained from the use of insulators from particular suppliers can help to guide future purchases. Choice of insulator will also depend to some extent on whether the fence is to be permanent or temporary.

Figure 2 Insulating conductor wires from straining posts

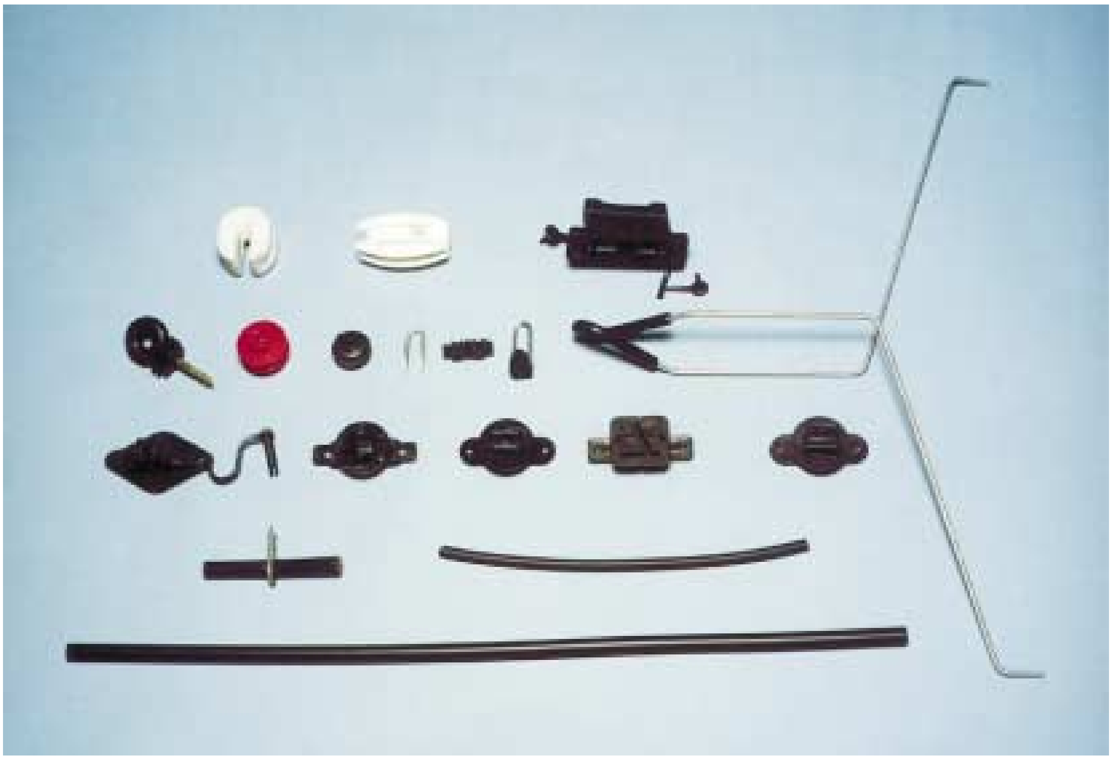


Porcelain insulators
Porcelain insulators (Plate 1) have the best insulation properties and, if of good quality, are the strongest. They are therefore particularly suitable to insulate tensioned line wires from straining and turning posts (Figure 2). They are fire resistant and can prevent any electrical arcing causing a fire. Their main disadvantage is their relatively high cost and, as a result, they are mainly used on permanent fencing. Poor quality porcelain insulators may be fragile under tension; they may also crack allowing absorption and retention of moisture giving rise to conductive deposits.

Plastic insulators
Moulded from either polythene or polypropylene, plastic insulators are the most common type in use today. They are cheap and because they can be moulded into any suitable shape (Plate 1) they are easy to fit. The more basic and smoother designs are better as they have fewer ledges, cavities or holes to gather moisture. The most durable plastic insulators are fully ultra-violet (UV) light inhibited, normally with carbon black, to prevent degradation in sunlight.

Plastic tube insulators
These insulators are designed to enclose the electrified wire to allow it to be held against and stapled to a post (Plate 1). Plastic tube insulators are particularly useful for taking a line wire around a turning post or terminating it at a straining or gate post, particularly when the wire is made of high-tensile or spring-steel (Figure 2). Some have a reinforcing metal strip inside the tube to prevent the tensioned wire splitting the plastic. Various types of plastic tube including garden hose pipe are utilised on a 'make do' basis. However, it is recommended that only plastic tube manufactured and supplied specifically for electric fencing is stipulated for use. Even these can collect conducting agents (e.g. dead insects and acid rain) which may reduce their insulation properties.

Plate 1 - Examples of the range of insulators currently available



Off-set insulators
Off-set insulators (Figure 3 and Plate 1) are used to attach a conductor wire to a new or existing non-electric permanent fence. The off-set wire will reduce animal pressure on the fence and can be used either to increase the barrier effect of the fence or to extend the life of an ageing or dilapidated fence.

Stakes with insulators
These are designed or manufactured as an integrated unit (Plate 2) and are principally available for specific applications of temporary fencing. The stakes may either be metal with plastic insulation or all plastic and will carry single or multiple line wires or plastic mesh netting. The positions of the insulators may be either fixed or adjustable.

Self-insulating posts
Made of eucalyptus wood, these self-insulating posts have been used to support fences in the UK. However, the wood is becoming scarce and is unlikely to be readily available in the future. It is of such high density that it does not conduct current. Therefore, no insulators are required and the conducting line wire is fixed directly on to the post.

Figure 3 Off-set insulators in position

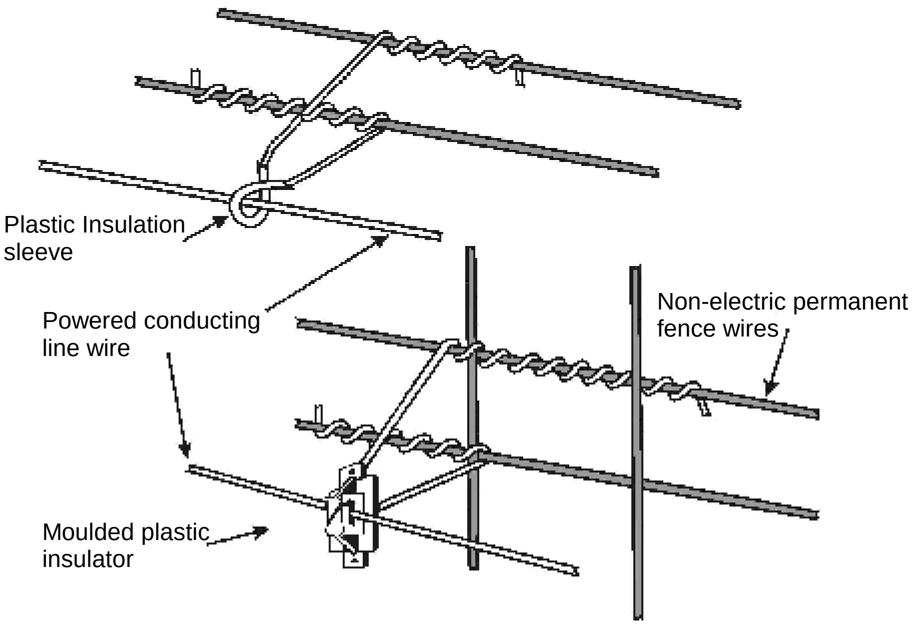
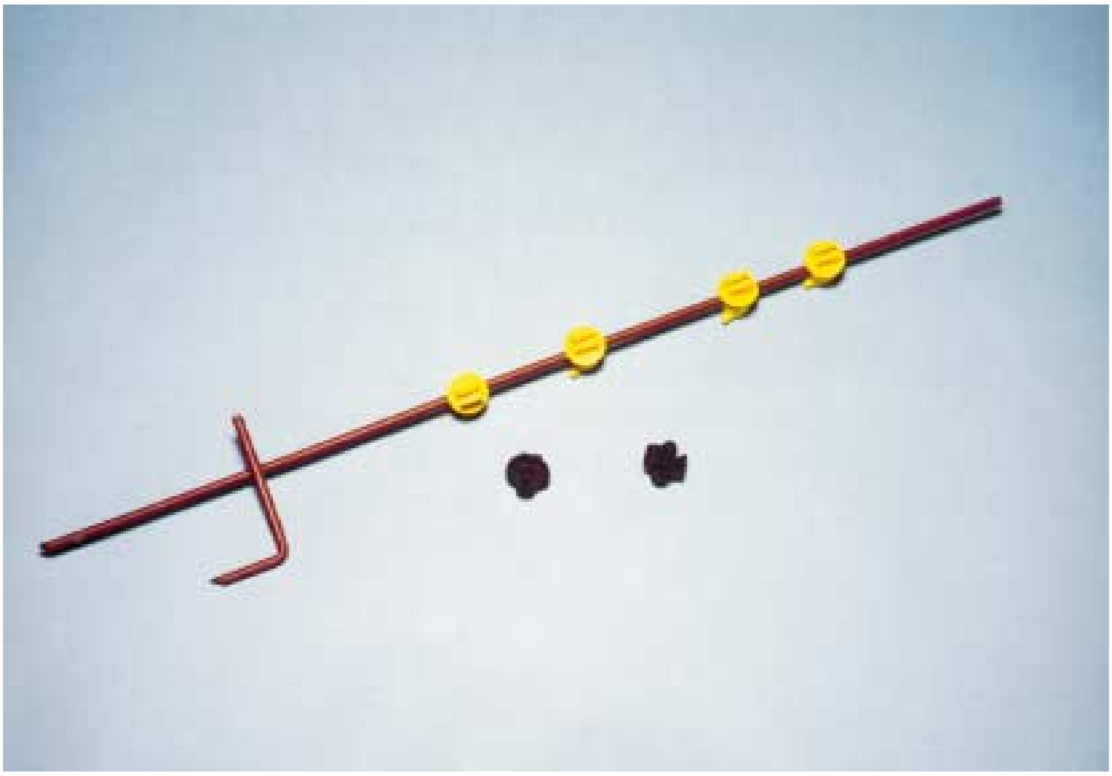
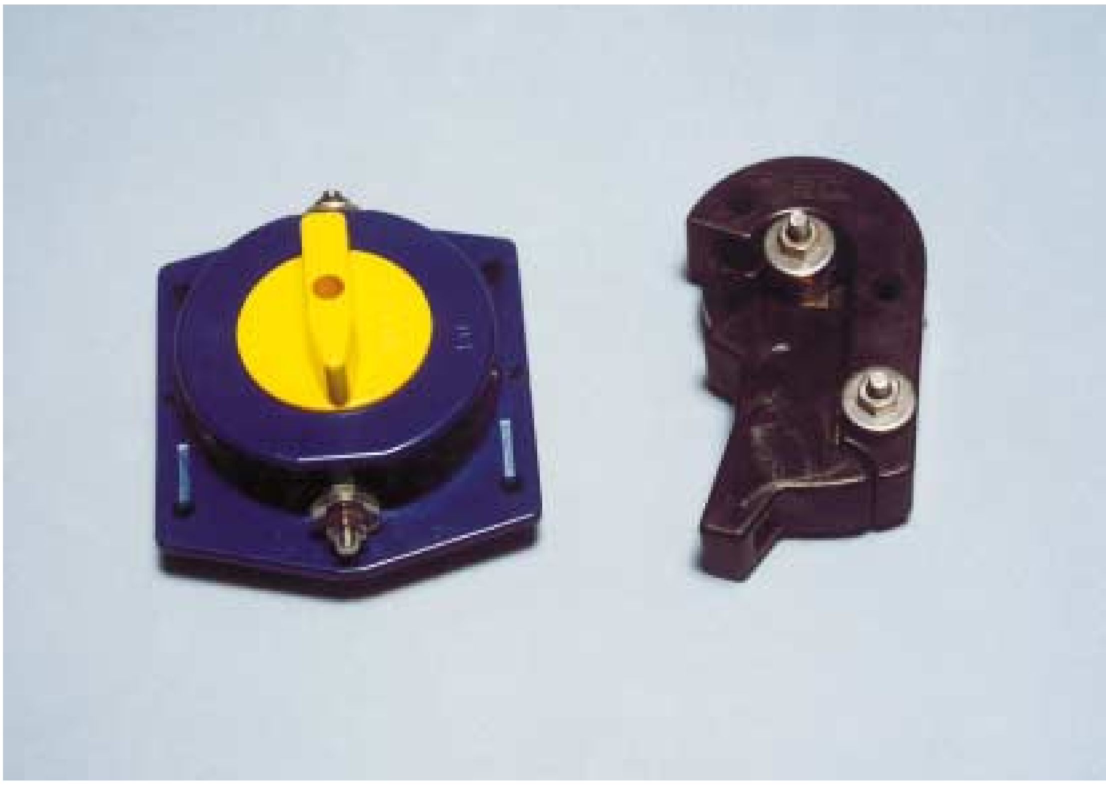


Plate 2 - Metal fence stake with adjustable insulators



Cut out switches
Cut out switches (Plate 3) are used to isolate parts of a fence without the need to turn off the energiser. Switches must be protected to an IP44 classification and be capable of isolating and insulating a voltage level of 10 kilovolts (kV): suppliers should be able to advise.

Plate 3 - Cut out switches



Supporting posts

Materials
Metal or plastic-coated metal stakes and fibreglass stakes or posts are used to support temporary electric fences. As there is usually no sustained, direct pressure from animals leaning against an electric fence, these stakes, which are made of relatively lightweight materials and therefore easy to move, are well suited for temporary fencing. More substantial and durable materials such as timber posts are required for permanent fences which may have to withstand many years of adverse weather conditions, vegetation and blown or fallen debris.

Timber can, however, be used to support both temporary and permanent fences and some or all of the components listed in Table 3 may be used in any one particular situation. Wood without a preservative treatment will normally be used on temporary fences whereas treated wood will be required for permanent fences. Timber must be without bark to enable preservative to penetrate the wood. It must also be seasoned to a moisture content of 25% or less before it is treated as a moisture content greater than 25% will inhibit preservation.

Preservation
The preservative treatment should either be with copper/chrome/arsenic (CCA) or creosote. Preservation should be either by pressure impregnation or by a full length hot-and-cold open tank treatment with creosote; there is little difference between the life of creosote-treated and CCA-treated wood of the same species. Treated round fencing material lasts longer than treated half-round material as the surrounding layer of absorbent sap-wood provides an all-round protective barrier of treated timber compared with half-round material where this barrier

is absent over half of the timber. In general, preservative treated hardwoods do not last as long as similarly treated softwoods.

Table 3 - Fence post sizes for permanent electric fences

Sawn timber fence posts, struts and stakes

Fence height m (ft)	Posts length m (ft)	Posts Section mm (inches)	Struts Length[a] m (ft)	Struts Section mm (inches)	Stakes Length m (ft)	Stakes Section mm (inches)
0.6 (2'0")	1.45 (4'8")	100 x 100	1.20 (4'0")		1.30 (4'3")	
0.8 (2'6")	1.65 (5'5")	(4 x 4)	1.40 (4'6")	75 x 75	1.50 (5'0")	75 x 75
0.9 (3'0")	1.75 (5'8")	125 x 125	1.50 (5'0")	(3 x 3)	1.60 (5'3")	(3 x 3)
1.05 (3'5")	1.85 (6'2")	(5 x 5)	1.60 (5'3")		1.70 (5'6")	
1.15 (3'8")	2.00 (6'6")		1.75 (5'8")		1.80 (6'0")	

Round timber fence posts, struts and stakes

Fence Height m (ft)	Posts Length m (ft)	Posts Top diameter (min.)[b] mm (inches)	Struts Length[a] m (ft)	Struts Top diameter (min.)[b] mm (inches)	Stakes Length m (ft)	Stakes Top diameter (min.)[b] mm (inches)
0.6 (2'0")	1.45 (4'8")	100 (4)	1.20 (4'0")	80 (3)	1.30 (4'3")	65 (2.5)
0.8 (2'6")	1.65 (5'5")	100 (4)	1.40 (4'6")	80 (3)	1.50 (5'0")	65 (2.5)
0.9 (3'0")	2.00 (6'6")	100-130 (4-5)	2.00 (6'6")	80-100 (3-4)	1.70 (5'6")	65-80 (2.5-3)
1.05 (3'5")	2.30 (7'6")	100-130 (4-5)	2.30 (7'6")	100-113 (4-5)	1.80 (6'0")	80-100
1.15 (3'8")	2.30 (7'6")	130 (5)	2.30 (7'6")	100-113 (4-5)	1.90 (6'3")	(3.0-4.0)

[a] These lengths are suitable for struts fixed at an angle of 45° on level ground. If site conditions make the use of struts of these lengths unsuitable the length may need to be specified.

[b] Dimensions are under bark measurements. If cleft or quartered timber is used, this is the diameter of a circle that fits inside all parts of the perimeter of the top of the post or strut.

When not set in concrete, the lengths of posts specified in the table should be increased by 300 mm (about 9 inches) and set 300 mm (about 9 inches) deeper in the ground.

Sizes

The required length of posts and stakes will vary according to the height of fence to be erected, which is dependent on the species of animal to be excluded. In addition, they will vary according to the depth to which the posts or stakes have to be sunk into ground and this is dependent on soil texture and whether the post is to be set in concrete.

Conducting wire

The conducting wire of an electric fence can be of steel, aluminium or aluminium alloy. Steel wires are either of medium-tensile strength, high-tensile strength or spring-steel. All have a coat of zinc or zinc/aluminium alloy to protect them against corrosion. Conducting wires can be either single or multi-stranded and range in diameter from 1.6 mm to 3.15 mm (0.06 - 0.12 inches). Choice of wire will depend on a number of factors.

Medium-tensile steel wires
Along with aluminium wires, medium-tensile steel wires have the smallest diameters (about 2 mm or 0.1 inches) and are used on temporary fencing where ease of handling and little tension are required. The smaller the wire diameter, the greater is its resistance to current flow. Therefore, it less suitable for long permanent fences, especially where more than one wire is required. Also, medium-tensile wire has a yield point which is the point at which it stretches plastically. This point is reached before the wire breaks which means that, when strained in a fence, it will not retain its tension over long periods. It therefore requires a large number of support stakes and posts to prevent it sagging. When used on permanent fences, it should have a minimum nominal wire diameter of 3.15 mm (0.12 inches) and a protective zinc coat weight of 275 g/mm^2 to BS443 and EN10244.

High-tensile steel wire
This wire has a high carbon content, does not have a yield point and when tensioned does not slacken. However, as it is more brittle than other wires it can cause a hazard as it may fracture during tensioning. High-tensile steel fencing wire is only available as a single strand wire. It should only be used on permanent fencing, because of the fracturing hazard. It should have a minimum diameter of 2 mm (about 0.1 inch) and a protective zinc coat of 200 g/mm^2.

Spring-steel wire
This is a single strand steel wire, has no yield point, retains its tension and is also more resistant to breakage. It should only be used on permanent fencing, because its springiness can cause a hazard. It should have a minimum diameter of 2.5 mm (about 0.1 inches) and a 230 g/mm^2 zinc coat.

Multi-strand cable wire
This is made from 6-12 strands, normally of medium-tensile zinc coated steel wire. It is mainly used for temporary fences. However, it can also be used for permanent fences where one or more high-tensile wires can be included to give strength and rigidity.

Aluminium wire
This small diameter, single strand wire is very soft and pliable and is only suitable for use on temporary fences.

'Polywire'
This UV stabilised polythene twine has three or more strands of stainless steel wire woven into it. 'Polywire' is designed for temporary fencing although a similar but more substantial 'polyrope' is available for permanent fences.

Electric mesh netting
Electric mesh netting is manufactured using Polywire in a range of mesh sizes suitable for managing, for example, sheep, goats, rabbits and poultry. The horizontal strands of the netting are Polywire, except the bottom one, and the vertical strands are plain polythene twine or rigid plastic filaments.

Polythene tape
Known as *'Polytape',* this consists of stainless steel wires and polythene strands woven into a ribbon. 'Polytape' is available in a range of widths and colours.

Remember ... Barbed wire should not be used as a conducting wire in an electric fence or used in conjunction with any fence which has part of it electrified. There is a risk of serious injury from prolonged exposure to electric shocks to any animal or person that becomes entangled in the barbed wire, particularly as an electric shock received through a puncture wound will be more severe than by contact with unbroken skin.

Earthing

The earth rod, spike or stake is technically termed the electrode. It is recommended that, as copper is a very good conductor, a 20 mm (about 1 inch) minimum diameter copper coated steel electrode is used in conjunction with pvc insulated multi-strand copper earthing cable and brass bolt clamps.

There are two types of earthing systems (Figure 1):
1. earth electrode(s) only, sometimes referred to as an all live wire system;
2. earth electrode(s) plus earth wire return system.

Earth electrode only system
This system consists of an earth electrode driven into the ground alongside the fence and connected to the energiser's earthed terminal. It is used on the most favourable electric fencing sites i.e. consistently wet and highly conductive soils which are covered by green vegetation for most of the year. It is also the system most commonly used on temporary fencing.

Earth electrode(s) plus earth wire return system
This is similar to the earth electrode only system but with the addition of an uninsulated bottom line wire, which is connected to the earth electrode and the energiser earth terminal. This earth line wire should be along the entire length of the fence and should be connected directly into the ground at about 50 m (50 yd) intervals by a series of galvanised steel pegs, or short electrodes, driven approximately 350 mm (1 ft) into the soil. The effectiveness of the earthing system can be improved further by the addition of several 1.8 m (6 ft) copper earth electrodes placed at equal intervals and connected directly to the uninsulated line wire.

This type of system provides a more effective and reliable earth system on unfavourable electric fencing sites. Unfavourable sites can be defined as those having poor soil conducting properties, for example, dry sandy soil and those in areas of low average rainfall. It is the earthing system recommended for permanent fences. One or more earthed line wires which alternate with the conductor line wires may be added, particularly when dealing with animals such as foxes which may try to jump between the wires. The addition of these wires means that the animal will receive a shock, even when all its paws are off the ground, as a consequence of simultaneously contacting a live and an earthed wire.

Fence testing equipment

It is important to know that the fence is operating properly. Several instruments can be used to check its operation:
- *An electrostatic voltmeter* measures the voltage pulses of electricity produced by the energiser. It is particularly useful to detect if performance is deteriorating which will be reflected by a drop in voltage. It is the most commonly used type of fence tester.
- *A joulemeter* measures the level of electrical energy of each pulse on the fence. The severity of shock sensation experienced by an animal is related to the level of electrical energy present. Therefore, it gives a better measure of fence performance than a voltmeter.
- An *electrical insulation* tester measures the electrical resistance of the insulation of fence components such as insulators and the complete fence.

CHAPTER 2

Compatibility of components used with battery operated energisers

When using a battery powered energiser, it is important to choose the correct type of battery, charging system and charging regulator.

Batteries

It is not uncommon to find that most battery powered electric fence energiser systems are powered by conventional car batteries known as traction batteries. These batteries are not ideally suitable for an electric fence energiser installation. They have a fairly high internal resistance which arrests the charging rate under low current conditions and, as a result, increases the time taken for them to become fully charged. Car batteries also have a higher inherent battery drain current and therefore discharge more quickly than more appropriate types under all conditions, even when disconnected. They also produce a relatively unstable output terminal voltage and at 0°C and temperatures below freezing their efficiency can drop by up to 50%.

The most suitable and compatible battery is the deep-cycle marine or leisure battery containing low levels of antimony. These batteries are more expensive but are maintenance free, do not have the disadvantages of car batteries and last longer. Data on the average current drawn from the battery by an energiser is available from the supplier and this, together with the number of hours of use between charges, will determine choice of battery capacity.

Charging systems

There are three types of battery charging systems: mains, solar and wind powered:

- *Mains operated charging systems* can be used to charge most types of batteries because the power supply is reliable and stable. However, batteries and chargers must be compatible. Battery chargers for lead acid systems are designed to charge the battery up to a specified voltage, with the charge current reducing as full charge is achieved. Nickel cadmium battery chargers often charge at a constant current, with the voltage varying to suit. It is unlikely that a charger designed for one battery type will operate satisfactorily with the other. Overnight charging of a battery removed from a fence may not be adequate to guarantee full charging in any 24 hour period.
- *Solar operated charging systems* convert light directly into electricity when rays of the sun are incident on the solar panels. The amount of electric current generated is dependent on the strength of the sun's rays and their angle of incidence. For example, in December a 5 ampere (amp/A) panel may only give an output of 0.5 A whereas in July it may produce its full 5 A capacity. Also some solar panels are very susceptible to shade and in the poorest conditions their output may fall to nearly zero.
- *Wind operated generators* are usually more suitable for charging electric fence energiser batteries in the UK than solar panels. Their output is directly related to wind speed and so it is important always to connect a wind generator to a battery via a regulator and never directly to the energiser.

Regulators

A battery charging regulator, located between the charger and battery, is a necessary component of all battery charging systems. Its main function is to prevent too high a charge rate or overcharging of the battery, as an overcharged battery will give off hydrogen, which is explosive, and its internal plates may also suffer permanent damage.

Some of the more expensive charging regulators use integral switching relays which in themselves can use more current than is fed into them. Under these conditions, the regulator will further drain the battery. These regulators are therefore suitable only for use with mains chargers and high output wind generators. Cheaper and more simple regulators without switching relays are therefore more suitable for use with most wind generators and solar panels.

Careful consideration should be given to the siting of a regulator since it may become hot as any excess energy is dissipated. Therefore it should be mounted where it will not be a fire hazard.

CHAPTER 3

Fence specifications

Introduction

Electric fences are cheaper to construct than conventional fences because they do not have to be robust impenetrable barriers which require considerably more time and materials to erect. Electric fences instead operate by modifying animal behaviour: animals are repelled by the shock sensation received from fences and learn to avoid them. Thus, for a fence design to be successful, it must take account of animal behaviour. Until recently most designs appear to have been developed largely by trial and error, particularly those deployed to try to manage wild mammals, as the main aim was to use as little fencing material as possible to keep costs low. The specifications given in this chapter, particularly for fences to manage wild mammals, have been obtained from scientific reports where animal behaviour has been of crucial importance in designing the fence.

Encountering the fence for the first time

An electric fence encountered for the first time by a wild mammal is an unfamiliar object which the animal will investigate, usually by touch, using its nose. Domestic stock familiar with electric fencing are also likely to investigate new fences by touch with their nose. By contrast, stock unfamiliar with electric fencing are more likely to try to push through the large spaces between wires, thereby touching the wires with their neck, back or chest. Wild animals may also make this type of contact if they do not see the fence before touching it, which can often be the case with nocturnal species.

The intensity of the shock felt by an animal determines its subsequent reaction to the fence. Different species, as well as individual animals within a species, may react differently. An animal which touches a wire with its nose, which is poorly insulated and highly innervated, usually receives a severe shock which is likely to deter it from crossing the fence. By contrast, an animal which touches a wire with a less sensitive area, such as its neck, back or chest, may not even receive a shock and may cross the fence. Furthermore, if an animal is moving swiftly and has almost crossed before the electrical pulse is generated, it is likely to complete the crossing. Similarly, if an animal jumps through and is off the ground when it contacts live wires it will not receive a shock. A danger is that any animal that passes through or over a fence will be retained within the fenced area.

Principles of effective fence design

In designing an effective fence the factors discussed above need to be taken into consideration.

Number and positioning of wires

The number of wires in the fence and their positioning also depend on the size and agility of the species being managed. For example, fences designed to exclude smaller, agile species, such as wild rabbits, require more wires than fences designed to contain larger, less agile animals such as cattle. The number and positioning of wires should be sufficient to stop animals being easily able to push through the wires or jump over them. Jumping over, however, has not been recorded as a method of crossing as often as might be expected, considering that the heights of the fences are generally less than the species concerned can jump. For example, a height of 45 cm (1.5 ft.) has been used successfully to exclude foxes and a height of 50 cm (about 1.5 ft) to exclude rabbits. Therefore, it would appear that receiving a shock deters animals from attempting to jump fences. All species of deer in the UK, however, provide an exception as they have regularly been recorded jumping over fences up to 1.1 m (about 4 ft.) high.

Alternating live and earthed wires

Earthed wires can also be added to the system so that they alternate with live wires in such a way that animals pushing through the fence touch both live and earthed wires simultaneously. This earthing design is likely to result in a more severe shock being received by the animal than that received when the animal is earthed solely through its paws or hoofs. However, the closer the wires, the less the shock sensation that will be felt, as it is proportional to the distance the current travels through the animal's body.

For animals trying to jump through fences, the use of alternating live and earthed wires can also ensure that the animal will actually receive a shock which would not be the case if it was off the ground when it contacted an all live wire fence. The main drawback to the use of earthed wires is that it increases the likelihood of a dead short if live and earthed wires were to come into contact. Therefore, adding extra live wires should always be considered first.

For smaller animals, such as rabbits, which may try to crawl under the lowest electrified wire, insertion of an earthed wire close to the ground is often the only feasible way to prevent them crossing in this way. Inserting an additional electrified wire so close to the ground is usually impracticable as inevitably it would result in the fence being short circuited by touching the ground or vegetation. The earthed wire is positioned close to the ground so that the animal must pass over it, forcing it up and into contact with the lowest electrified wire.

Surprisingly, digging under electric fences is not a serious problem. Rabbits and badgers, for example, both dig under wire netting fences and could be expected to burrow under electric fences but this has rarely been recorded. Therefore, it appears that receiving shocks deters these animals from spending the time required near to the fence to dig under it.

Planning the fence perimeter

Fences will normally encircle an area either to contain animals or exclude them. The electric fence may form the complete circle or it may just be part of the circle and be in combination with a standard post and wire or mesh fence. On the occasions when the fence is not required to encircle an area, wild animals have been recorded going round the ends of the fence. For example, foxes went around a fence erected across a peninsula to protect sandwich terns, and rabbits have gone around fences extended 50 m (about 50 yds) past their burrows. One solution, which is particularly applicable where animals have relatively small home ranges in relation to the area being protected, is to extend the fence so that the ends are located outside the home ranges of the individuals being excluded. For example, rabbits rarely move more than 150 m (about 170 yds) from their burrows and so any fence extended to this distance from their harbourage is likely to be effective. Another solution is to cull the individuals which are circumventing. This was done in the case of the specific foxes which were going round the ends of the fences protecting the sandwich tern colony and has been used to prevent 'rogue' stock animals crossing fences.

Animal training and management

Animal behaviour can be modified to ensure fences are effective. Domestic stock can be taught that an electric fence is different from a conventional fence. This can be done by putting the stock inside a small enclosure, usually of <1 ha (about 2.5 acres), formed by a stout conventional wire fence to which an electrified wire is attached on the inside as an out-rigger. Animals are kept in this training yard at high stocking rates to maximise the likelihood of contacts with the electrified wire, but are prevented from pushing past it by the conventional fence. Trained animals have subsequently been shown to touch electric fences enclosing fields less often than untrained animals. Another training method is to tether the animals close to the fence so that they can touch but not cross it.

Stock can be encouraged to investigate an electric fence by attaching unfamiliar and highly visible objects to it. This method also makes a fence more conspicuous and, therefore, animals which otherwise may have run through the fence can be encouraged to investigate it. Strips of plastic, luminous hazard warning tape and plastic bottles have been used for this purpose. Food items, such as kale or hay, have also been used in this way which makes the fence not only unfamiliar, but also attractive. However, this general approach has the disadvantage that animals may associate the shock received only with fences to which objects are attached.

Another possibility for stock management is to erect parallel electrified wires, so that the vegetation growing between them forms a more conspicuous, attractive barrier. This combination is usually referred to as a 'grassfence'. However, it has disadvantages in that it uses grazing land, is slow to establish, and can encourage the spread of weeds from the grass strip.

Additional techniques
The severity of the shock can also be increased by sheering domestic stock, such as sheep or goats, immediately before they are first released into a field enclosed by electric fencing.

Electric fences can also be designed, using material other than wire to carry the current, to make the fence look unfamiliar and therefore encourage investigation. For example, polytape twists and moves in the wind when loosely tensioned between posts. These tapes have been successfully used to contain horses but are relatively expensive and not very durable.

Remember ... the use of electrified barbed wire, which would increase the severity of an electric shock by penetrating animals' insensitive hide or fur, is illegal in Great Britain as there is a danger that animals or people could become caught on the barbs, receive shocks repeatedly and possibly be killed.

In conclusion, the best solutions to prevent fence crossing are:

- for *domestic stock*, training them to investigate the fence
- for *wild animals*, the addition of extra wires either live or, where necessary, earthed.

Specifications for domestic stock

Electric fencing has been successfully used to manage most types of livestock and usually one or two line wires is sufficient. Polywire is usually an adequate alternative to steel as the conductor. In addition, a range of commercially available polywire electric netting fences are available to manage most stock. Details of suppliers are given in Appendix 1. Irrespective of the type of conducting wire used, good straining is important to avoid variation in the height of the wire due to sagging and to ensure good contact when the animal pushes against it. On uneven ground, additional supporting posts will be needed to ensure that the wire is at a reasonably uniform height. The specification for each species is given in Table 4.

Table 4 - Specification of electric fencing to manage domestic stock.

Stock	Number of live wires	Number of earthed wires	Height of wires, each measured from ground level mm/(inches)	Electric netting commercially available
Cattle (full grown)	1	0	750 to 850 (30 to 35)	No
Cattle (full grown)	2	0	350 to 450; 750 to 850 (14.5 to 18; 30 to 35)	No
Cattle (calves)	1	0	450 to 600 (18 to 24)	No
Pigs (full grown)	1	0	300 to 400 (12 to 16.7)	No
Pigs (full grown)	2	0	200 to 300; 350 to 450 (8 to 12; 14.5 to 18)	No
Piglets	2	0	150; 350 to 450 (6; 14.5 to 18)	No
Sheep and goats	5	0	150; 300; 450; 650; 900 (6, 12 , 18; 26; 36)	Yes
Horses	1	0	750 to 850 (30 to 35)	Yes

Cattle
A single wire is usually sufficient but a second wire can be added if any difficulty is experienced in containing particular individuals. The height of the wire should be varied according to the height and age (i.e. full grown or calf) of the breed being managed. The specification for a ‘grassfence’ is two parallel fences 60 cm (2 ft) apart, each with wires at about 350 and 650 mm (1 and 2 ft) above the ground.

Pigs
As with cattle, a single wire is usually sufficient for full-grown pigs but a second can be added if any difficulty is encountered. Piglets can be more of a problem and the lower electrified wire must be closer to the ground to try to contain them.

Sheep and goats
Four or five wires are generally recommended to manage sheep and goats.

Horses
One wire is usually sufficient to manage horses. Polytape is being used more frequently as the conductor, mainly because it is highly visible and because the chance of injury to horses is less than with the use of galvanised wire.

Specifications for wild mammals

Electric fencing has been used to manage many wild mammals, with rabbits being the smallest of the species targeted. Some species, mainly deer, appear to be very resistant to electrical shock, because of the poor conductivity of their hooves and insulation properties of their coat. Therefore the use of electric fencing to deter these species appears to be limited at present. More wires are needed to manage wild mammals than domestic stock and metal wire is preferable to polywire. However, a range of commercially available polywire electric netting fences are also available to manage some species and all have been found to be effective. Details of suppliers are given in Appendix 1. It is extremely important to ensure that the wires are sufficiently well strained to avoid variation in wire height and to ensure good contact when animals push against them. The specification for each species, including deer, is given in Table 5. The decision to use electric fencing will, of course, involve comparing the cost-effectiveness of this and other methods of wildlife management, including conventional unelectrified fencing, with the estimated costs of any damage being caused. In doing these comparisons, it should be remembered that fencing materials are likely to last between 5 and 10 years if well maintained.

Rabbits
A series of enclosure and field trials has been conducted to develop the recommended specification (as shown in Table 5). The earthed wire has been found essential to prevent rabbits crawling under the fence. Rabbits have only rarely been found to dig burrows under electric fences.

Table 5 - Specification of electric fencing to manage wild mammals.

Wildlife	Number of live wires	Number of earthed wires	Height of wires (E: earthed wire), each measured from ground level mm (inches)	Electric netting commercially available
Rabbits	6	1	50 (E); 100; 150; 200; 250; 300; 400 (2 [E]; 4; 6; 8; 10; 12; 16)	Yes
Badgers	4	0	100; 150; 200; 300 (4; 6; 8; 12)	Yes (use rabbit netting)
Foxes	4	4	50; 150 (E); 250; 350 (E); 450; 600 (E); 800; 1050 (E) (2; 6[E]; 10; 14[E]; 18; 24[E]; 32; 42[E])	Yes
Red deer	7	0	300; 600; 900; 1050; 1200; 1500; 1800 (12; 24; 36; 42; 48; 60; 72)	No
Fallow deer	7	0	300; 450; 600; 750; 900; 1050; 1200 (12; 18; 24; 30; 36; 42; 48)	No
Roe deer	5	0	300; 450; 600; 900; 1200 (12; 18; 24; 36; 48)	No
Muntjac	6	0	150; 300; 450; 600; 750; 900 (6; 12; 18; 24; 30; 36)	No

Badgers
A series of field trials has been run to develop the recommended specification which has been used to exclude badgers from small plots and entire fields. Again, badgers have rarely been recorded digging under electric fences.

Foxes
As for rabbits and badgers, enclosure trials have been conducted to develop the recommended specification. The use of alternating live and earthed wires was found necessary to prevent foxes crossing fences by jumping through the wires.

Deer
Again, to test the effectiveness of electric fencing against roe, fallow and muntjac deer, a series of enclosure trials has been conducted. The electric fence specifications found to be most effective against each of the three deer species were all less successful than the best non-electric wire mesh netting deer fence specifications. Therefore, the potential use of electric fencing to control these deer is limited and is not recommended except where conventional fencing cannot be used. There have been no successful UK field trials of the red deer fence specification developed in New Zealand and currently used in some areas in the UK.

CHAPTER 4

Safety Aspects

All electric fences must be installed and operated in a way that ensures there is no electrical hazard to people, animals or their surroundings. The fence construction must not risk the entanglement of animals or people.

Animal welfare

The main animal welfare issues concern the use of electric netting fences. Firstly, the lowest electrified wire, particularly of electrified rabbit netting, is close to the ground. Consequently, animals such as hedgehogs, frogs and toads can come into contact with these wires and this can, on occasion, result in them receiving repeated shocks and being killed. Rabbits can also become entangled in these fences which results in their death. Details of the occurrence of fatalities in field trials with rabbit electric netting fences are given in Table 6. No fatalities have so far been recorded in field trials of wire fences used to manage badgers or rabbits.

Table 6 - Details of rabbit electric netting study sites and fatalities

Number of sites	63
Average length of electric netting erected at each site	750 m (850 yds)
Average length of time each netting fence monitored	4 months
Total number dead rabbits found alongside fences at all sites	27
Mean number found/site/ 4 month period	0.4
Total number dead hedgehogs found at all sites	16
Mean number found/site/4 month period	0.25
Total number frogs and toads found dead at all sites	63
Mean number found/site/4 month period	1.0

The data on dead rabbits are not straightforward to interpret. The majority were found alongside the fence, unlike the hedgehogs, frogs and toads which were all found in or on the fence. It appeared that most dead rabbits were dropped at the fence by foxes which received a shock from the fence as they tried to cross it with a rabbit in their mouths when returning to the cover of the adjacent woodland.

Farmers would probably erect these netting fences for a maximum of eight months a year. Thus, based on this large data set, on average it would be expected to find, over a one year period in a fence 750 m (about 850 yds) long, fewer than one dead rabbit, one dead hedgehog and about two dead frogs or toads. Therefore, in general, the welfare issues do not appear to be too serious. The exception could be if fences were erected close to ponds, as large numbers of frogs and toads could potentially be killed. Therefore, the use of wire rather than netting fences would be advisable at these locations.

Human safety

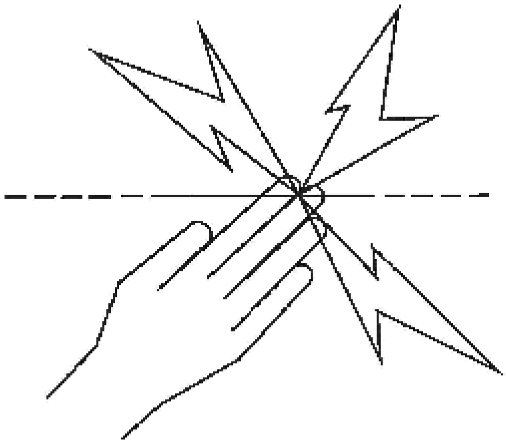
All energisers and fence installations must comply with the present regulations and standards. People are generally more susceptible to an electric fence shock sensation than stock or wildlife and so extreme care should always be taken when installing, testing or maintaining an electric fence. A healthy person will not suffer any serious or permanent injury from an electric shock sensation received from a fence under normal conditions. However, it can prove to be an unpleasant and memorable experience.

Safety precautions

The following safety precautions must be observed when installing or maintaining an electric fence:

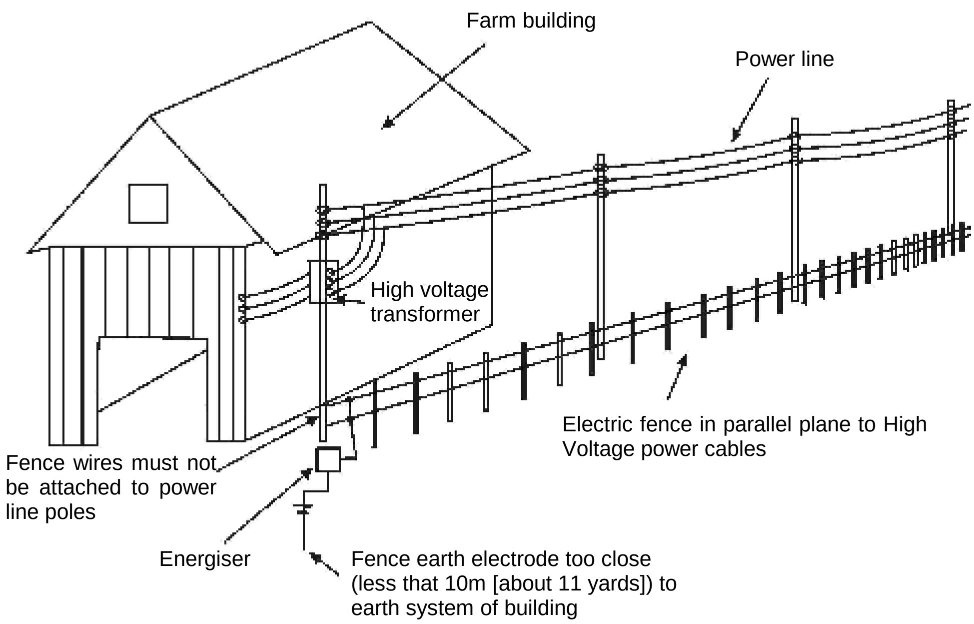
- Always seek planning approval from appropriate authorities before installing a fence alongside any road, railway or telecommunication line.
- Always display warning signs (Figure 4) at no greater than 50 m (about 50 yd) intervals along a fence where there is public access.

Figure 4 Symbol for warning sign



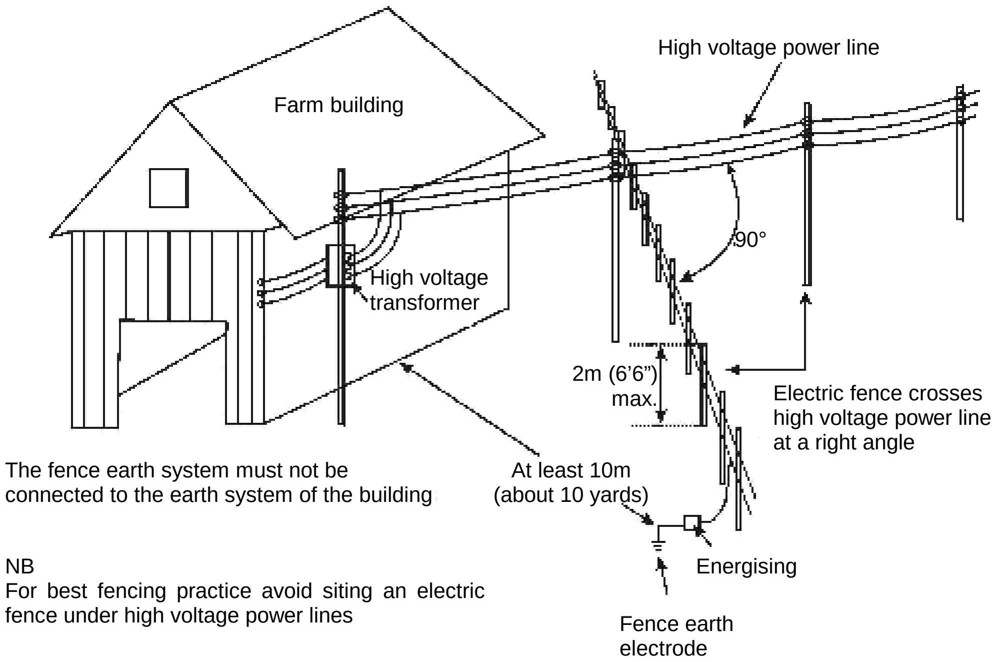
- Always ensure the fence is well insulated, to prevent fence posts or any other structure becoming electrified.
- Always consider the risk of an animal or person becoming entangled in live fence wires.
- Always charge the battery in a well ventilated area and in accordance with manufacturer's instructions.
- Always disconnect the battery from the fence energiser when charging from the mains.
- Always disconnect the power supply before working on the fence.
- Never site an energiser earth electrode within 10 m (about 10 yds) of any mains earthing system (Figure 5).

Figure 5 Unsuitable line of an electric fence in relation to a high voltage power line



- Never connect more than one energiser to the same fence.
- Never electrify barbed wire.
- Never install a fence under and parallel to an overhead power line as the induced voltage generated on the electric fence conductor wire may be hazardous (Figure 5); if crossing a power line, do so at right angles (Figure 6).
- Never install an electric fence above the recommended height (currently 2 m [6.6 ft]) when crossing a power line.
- Never attach electric fence wires to mains power line poles (Figure 5).
- Never overcharge the battery.
- Electric fence wires when crossing a public highway must be at least 5.45 m (about 6 yds) above the ground.

Figure 6 The line of an electric fence in relation to a high voltage power line



International and National Standards

There are a number of International and British Standards concerned with energiser safety. Publication 1011 1989 of the International Electro-Technical Commission (IEC) is the reference set of documents on which the design principles for electric fence energisers are based. Details of how to obtain copies are given in Appendix 1.

There are three relevant British Standards:

1. BS EN 61011:1993 Electric fence energisers. Safety requirements for mains-operated electric fence energisers.
2. BS EN 61011-1:1993 Electric fence energisers. Safety requirements for battery-operated electric fence energisers suitable for connection to the mains supply.
3. BS EN 61011-2:1993 Electric fence energisers. Safety requirements for battery-operated electric fence energisers not for connection to the mains supply.

CHAPTER 5

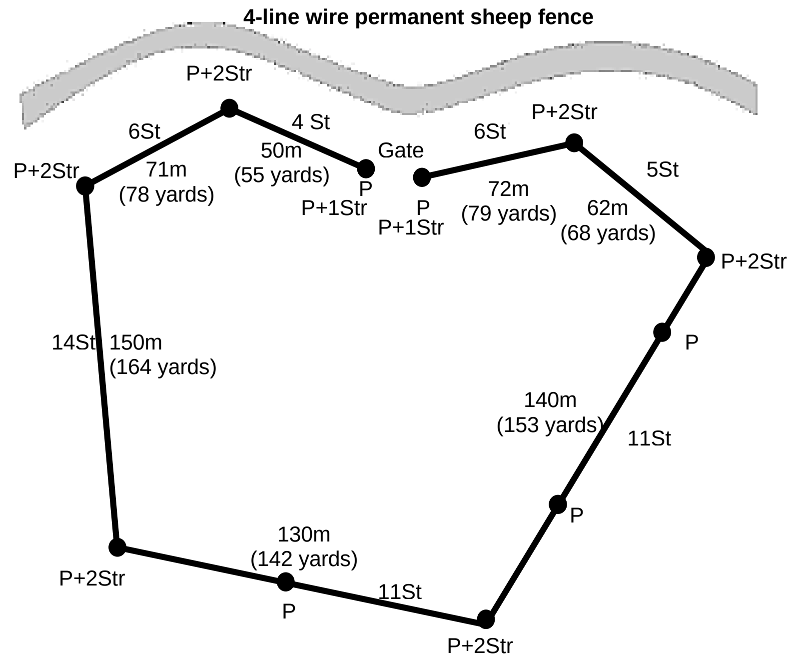
Fence construction: techniques and best practice

This chapter describes construction techniques and best practice for all the components that are needed to achieve fencing suitable for the chosen site. The materials to be used to construct the fence can be selected from those described in Chapter 1 and listed in Table 2, once the line of the fence has been decided and the general fence specification chosen. Factors to be considered in the specification are: height, mesh or line-wire, number of wires and spacing, the distance between stakes and whether the fence is to be a temporary or permanent structure.

Pre-construction work

- *Estimating requirements*. The amount of material required can be estimated by making a sketch map while walking the chosen fenceline and marking on the map the number of stakes needed and, for permanent fences, the locations of straining posts, turning posts and the number of struts required by each post (Figure 7).

Figure 7 Sketch map used when estimating quantities of material required on a fence line



Total Requirements
(P) Posts 13
(STR) Struts 14
(St) Stakes 57 maximum spacing 10m (about 11 yards) average spacing 8m (about 9 yards)
Spilt rail 15m (16.5 yards)
Gate 1
Total length 675m (about 740 yards)
Length of wire = 4x675=2,700m (about 3000 yards)
56 in-line insulators and 28 in-line ratchet winders
or
32 tube insulators and 8 in-line ratchet winders
228 insulators

- *Distribution of materials.* The next operation, the distribution of the materials along the fenceline, should be done with a vehicle. Where this is not possible, carefully sited dumps of materials should be placed within easy reach of the fenceline to reduce the distance the material has to be carried by hand. A single dump at the beginning of a fenceline should be avoided. If possible, the distribution of materials should be done by those who are going to erect the fence. A two-person fencing team is recommended as the most efficient.

Fence construction principles

The construction of the fence should be based on the principles illustrated in Figure 1. An *earth electrode only system* is a fence that does not have either an earth-returning wire or earth line wires and relies on the current flow to the energiser earth being passed through the ground (see Earthing in Chapter 1). These systems are generally associated with temporary fencing and are only used with permanent fencing on sites where the soil remains damp throughout the year. Temporary fences will generally be powered by battery-operated energisers.

It is recommended that permanent fences are constructed as *earth electrode plus earth-return wire systems*. The addition of earthed line wires is an option and will depend on the species being managed.

Setting-up the energiser and charging system

Installing the energiser

Permanent fences may be powered by either mains or battery powered energisers. *Mains powered energisers* should be installed under cover, near to the mains supply and out of reach of children. They should also be sited away from flammable materials and away from the risk of mechanical damage. *Battery powered energisers* are sited close to the fence, at any convenient place along the fence line and on the opposite side of the fence to the animals being managed. The energiser should be installed off the ground to protect it from insects and moisture. Small dry cell battery energisers may be clipped directly on to the fence. Wet cell batteries should be housed in a ventilated, locked weatherproof box to provide security from vandalism and theft, and protection against extreme temperature changes and corrosion.

Siting batteries, charging systems and regulators

When batteries are to be charged from the mains supply, access for a vehicle to and from the fence is desirable. Carrying heavy, wet cell batteries any distance by hand, particularly over rough ground, may result in backstrain, acid spillage or both and should be avoided.

Wind and solar power charging systems should be located in open areas close to the battery. Solar panels should face south and be angled towards the sun and away from any possible shade. The angle of incident light on to the solar cell array is critical for maximum output. The optimum is 90° to the sun. Wind generators must be located so that they are exposed to the prevailing winds.

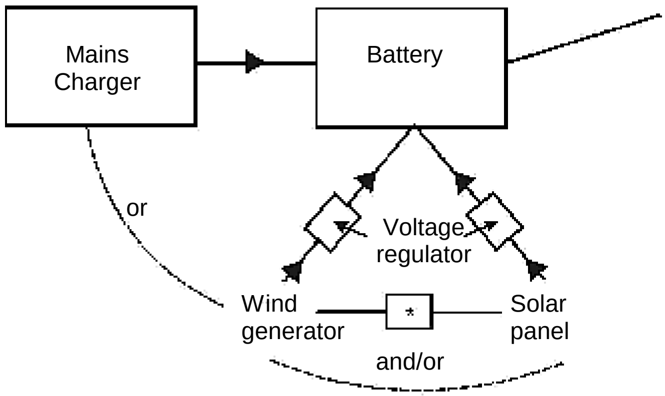
A *battery charging regulator* must be fitted between a wind generator or solar panel and the battery (Figure 1). Expert advice should be obtained before selecting a regulator to ensure that it is compatible with both charging system and battery and, when a solar panel is to be used, to ensure that the regulator does not consume more power than the panel produces. When charging rates are too high for the battery, a particular occurrence when using wind generators, or when the battery is fully charged, the regulator dissipates the excess energy in the form of heat. Therefore the regulator should be mounted where there is free movement of air to prevent heat build-up.

Under some site conditions, it may be necessary to install both wind and solar charging systems in order to provide adequate charging for an energiser battery throughout the year. When both systems are used, controlling diodes must be placed in the two independent charging systems (Figure 8). It is recommended that a qualified person should be consulted before the installation of diodes. Care must be taken to observe the correct polarity when interfacing wind generators, solar cells and regulators.

Lead-in wires: insulating and positioning
The lead-in wire from the energiser to the fence and from one fence to another fence should be insulated and fitted with a cut-out switch. Energisers produce output pulses of several thousand volts and low density polythene or equivalent of 1 mm wall thickness is an adequate insulating material. Either copper or steel wire may be used as the lead-in wire and should be at least 4.0 mm^2 (about 0.2 inches^2) cross sectional area to ensure adequate strength and conductivity. A cable lug should be fitted, crimped or soldered at the energiser end of the lead-in wire. Where lead-in wires pass underground, double insulation is required which can be achieved by using single insulated cable in a plastic tube or conduit. The effects of cattle hooves and tractor wheels sinking into the ground should be taken into account when deciding the depth to which these tubes should be buried.

The provision of *lightning conductors* should be considered where there is historical evidence of lightning strikes or where strikes are anticipated. A proprietary device should be used at the fence/lead-in wire junction.

Figure 8 Battery charging options



* If both wind and solar are to be used together controlling diodes are required but a qualified person should be consulted before installation.

Installing an effective earthing system
The efficiency and effectiveness of any electric fence is dependent upon an adequate and properly installed *earthing system*. Many electric fence problems are avoided when good earthing is provided. One major manufacturing company quotes that surveys have shown that the earthing systems on 80% of electric fence installations are ineffective.

The earthing system of an electric fence ***must never be connected to the main earth system of the mains supplies.*** Also, every earth rod (electrode) connected to the electric fence must be situated at least 10 m (11 yds) away from any earthing system for the protective earthing of buildings to ensure it is outside the resistance area of the building's system.

A ground earth electrode should be connected via a brass bolt clamp to the earth terminal of the energiser with 10 mm^2 (about 0.4 inches ^{2}) PVC insulated multi-strand copper cable with a cross-section area of not less than 4.0 mm^2 (about 0.2 inches^2). The energiser should be located as near to the fence as is practical to ensure the copper connecting cable is the minimum possible length. The electrode (copper-coated steel of 20 mm [about 1 inch] minimum diameter) should be driven into the ground to a depth of approximately 2 m (about 6 ft), if possible, but not less than 1 m (about 3 ft). It should be positioned as close as possible to, but certainly within 5 m (about 5 yds) of, the fence. Galvanised steel electrodes may be used on temporary fencing and for the earth electrode on earth return wire systems. The earth electrode of the fence should be installed, if possible, where the soil is damp to ensure a good contact. On ground with low moisture retaining properties, two electrodes screwed together may be necessary to enable the earth electrode to be driven to a greater depth. An inadequate earth attached to a battery powered energiser may result in a proportion of the fence pulse appearing on the battery terminals.

Erecting the fence: post, wires and insulators

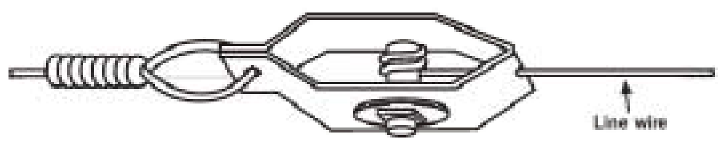
The *posts* and *stakes* of an electric fence function to support the conducting line wires or netting. It is the shock sensation felt by the animal when it touches a conducting wire that makes the barrier effect and not the physical strength of the fence.

Temporary fences
When constructing *temporary fences*, which are generally erected in relatively short and straight lengths, the posts only need to be strong enough to withstand the weight of the conducting wires or netting and the tension put on them.

Posts and stakes. The posts and stakes of a temporary fence are driven into the ground; there is often a pre-marked point on stakes to indicate the depth to which this should be done. Their spacing will depend on the holding ability of the soil and the number of conductor wires present, but as a general rule they will be between 3 and 5 m (about 3-5 yds) apart.

Conducting wires. The conducting wires will be either 1.6 mm or 2 mm (about 0.1 inches) steel or aluminium, polytape or polywire or polywire net. Polywire and polywire netting are hand tensioned. The other types of conductor wires are tensioned using wire strainers or ratchet winders (Figure 9 and Plate 1) to a strain that is just sufficient to keep the wires taut.

Figure 9 In-line rachet winder in position



When a conducting wire has to be joined, it is essential to ensure that there will be a good current flow through the connection. Two ends of either polywire or polytape are joined by exposing the metal strands using a match or lighter to melt a 50 mm (about 2 inches) length of the plastic at each end to be joined. Both ends are then tied with a reef knot and the exposed strands are twisted together. Steel and aluminium wires are joined with either a double 6 knot or reef knot. A double-loop knot is not recommended because the point of contact is too small (Figure 10).

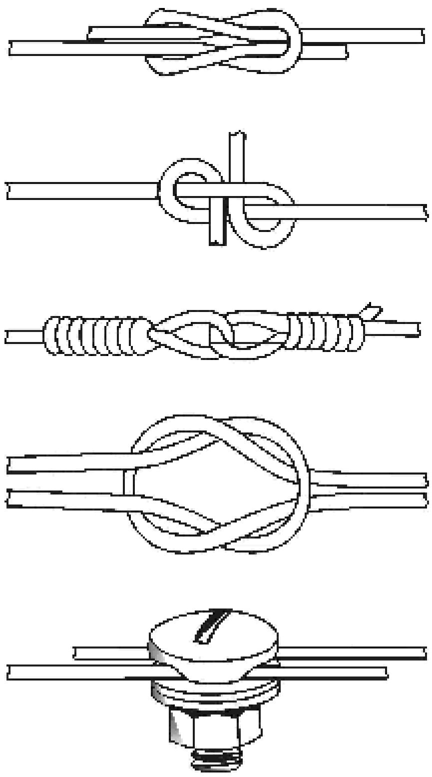
Permanent fences
The supporting posts and stakes of permanent fences need to be more robust to withstand the rigours of the weather and resist pressure from vegetation and fallen branches over a period of many years. Permanent fences are generally multi-strand fences. Their line will normally follow field and woodland boundaries and a farm or estate may be managed with a network of fences. To enable current flow along the full length of the conducting wires, 2.5 mm (about 0.1 inch) diameter wire or more must be used. The construction techniques used to erect permanent electric fences are similar to those for conventional non-electrified fences.
Posts and stakes. Posts, stakes and struts should be of square sawn or round timber which has been treated with a wood preservative. Posts are placed in a hole dug in the ground to a depth of at least 0.9 m (3 ft) and then firmed with soil. The post hole is either dug out by mechanical auger or hand using a shuv-holer and long-handled spade.

Straining posts, to tension wires are strutted. The strut is located in a notch in the post. The notch is cut between one-half and two-thirds up the post and facing the direction of strain.

The distance between straining posts will be dictated by the shape and size of the area to be fenced.

Intermediate posts or stakes are driven into the ground to a depth of at least 0.6 m (2 ft). The maximum distance between stakes will be 3 m (about 3 yds) when 3.15 mm (about 0.1 inch) medium-tensile steel conducting wires are to be used and 10 m (about 10 yds) for 2.5 mm (about 0.1 inch) high-tensile and 2.65 mm (about 0.1 inch) spring-steel wire.

Figure 10 Wire joining



Double-loop knot

Double-six knot

Open double loop is unsuitable for joining conductor wires (insufficient contact between the two wires)

Reef-knot

Nut and bolt clamp

Conducting wires. The conducting wires are tensioned between two straining posts. First, the wire should be uncoiled from the roll using a wire dispenser. If a dispenser is not used, the wire can be damaged and, as a result, may subsequently fracture. The wire is terminated at and insulated from a straining post with either an in-line insulator (Figure 2) or a tube insulator with a reinforcing metal strip. The metal strip must be positioned between the wire and the post. The wire is then strained to a second post using a hand-operated wire strainer. It is important that the type of strainer used does not damage the wire. For example, the 'Monkey' type strainer is particularly suited to straining high-tensile and spring-steel wire but not medium-tensile wire. Experience will tell the fence erector how much strain has to be put on the wire to allow it to be raised and lowered over undulations in the ground and also to ensure that not too much stress is left on the insulators. When the wire is strained to the required tension, it is secured to and insulated from the straining post. An in-line ratchet winder (Figure 9) may be fitted into each line wire to assist future fence maintenance operations.

Joins in the wire should be made either by knotting (Figure 10) or with a double crimp sleeve joiner.

Insulators

The conductor line wires should be secured to and insulated from wooden intermediate posts or stakes with *insulators* to prevent current leakage to earth. Insulators are not required if the stakes are plastic or glassfibre. It is recommended that only insulators that are designed and manufactured specifically for electric fencing (see Chapter 1) should be used and that materials such as hose pipe and empty fertiliser bags should be avoided. Care must be taken when securing insulators with nails that the hammer does not strike and damage the insulator.

The fence erector can test the quality of the insulation using an electric insulation tester between the secured conductor wire and the supporting post. A measurement of resistance is taken from the wire to a point on the post 150 mm (6 inches) from the wire and a reading of 25–200 megaohms is required.

Existing fences
Conducting wires can be added to new, unelectrified fences and walls to improve their effectiveness and to existing, and often ageing, unelectrified fences to extend their life. Wires added to fences are generally attached with off-set insulators (Figure 3) or insulated brackets. The wire should be fixed at about two-thirds the height of the animal being controlled and the brackets should be spaced about 10 m (10 yds) apart. These off-set wires are sometimes called scare wires.

Existing fences and walls should be inspected prior to the addition of electric fence wires. Any straining point not appearing to be strong enough for the proposed tension on the wires should be strain-tested to 150% of the expected tension. The wires on an existing fence should be inspected for corrosion. Sections of fence where there is significant corrosion and consequently a risk of fracture, which would short the electric fence, should be removed and replaced.

Remember ... the addition of electric fence wires to an existing barbed wire fence is not recommended.

Gates

Gates are required for access and where electric fences cross bridleways or public pathways. A non-electrified gate (Figure 11a) may be incorporated into the fence line. Underground feed wires at gateways are preferred to overhead wires as they cannot be knocked down or blown over. Stiles may also be built over fences which cross public paths as an alternative means of access. Warning signs must be erected on either side of gateways or stiles on public rights of way.

Electrified gates (Figure 11b) may be used where public access is not a consideration. The simplest electrified gate consists of an insulated handle attached to a high-tensile spring of sufficient size to stretch across the gateway (Figure 11c). Spring gates should be wired so that they are not live when unhooked.

Figure 11 Gates

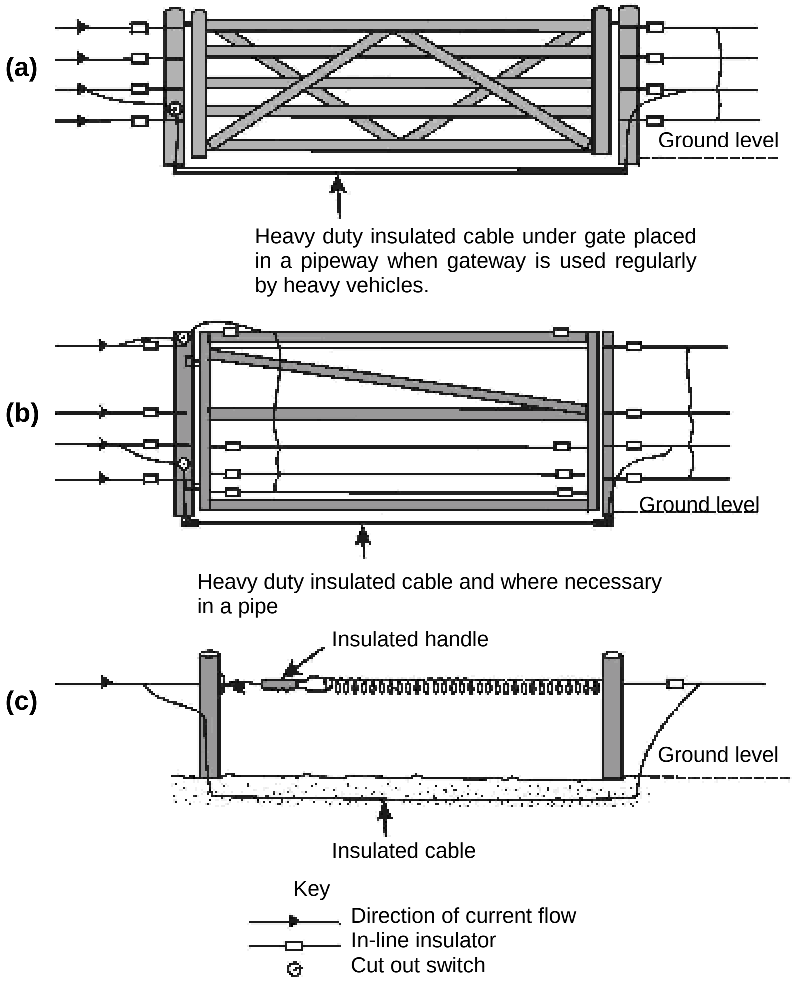
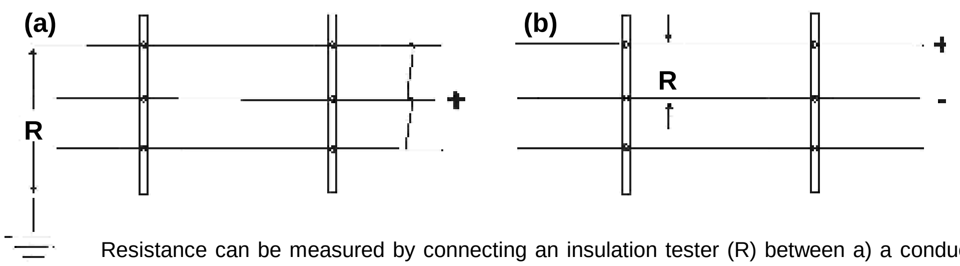


Figure 12 Fence resistance measurement



Resistance can be measured by connecting an insulation tester (R) between a) a conducting live wire and earth electrode or b) between a conducting live wire and an earthed live wire

When the fence erection is complete, the total insulation resistance of the fence should be measured with the energiser disconnected (Figure 12). A reading on the insulation tester in excess of 2 megaohms indicates an acceptable level of insulation between the conducting wires and earth.

CHAPTER 6

Fence siting

Before a final decision can be made on the actual siting of the electric fence, the following main issues have to be taken into consideration:
- planning aspects
- geography of the area
- ratio of fence length to area enclosed
- seasonal and climatic influences

Planning aspects

When planning the line of an electric fence, there are a number of aspects that need to be taken into account, particularly in relation to power lines and telephone lines. The issues of power lines, electric fencing and safety have already been discussed in Chapter 4. Electric fences can cause interference on telephone lines and it is the legal responsibility of the landowner to prevent any interference occurring. Therefore, fences should not be sited under telephone wires or parallel to underground telecommunication cables. Similarly, electric fences should be sited away from radio aerials. It is recommended that when new, permanent electric fences, and particularly boundary fences, are being planned, all interested parties should be consulted to ensure that the proposed fence line is acceptable to all.

Geography of the area

The line a permanent fence may be required to take is often rigidly defined by law or the geography of the area, and allows for little subsequent variation. Where this is not so, it may be possible to make worthwhile savings by straightening out the line to eliminate one or more corner posts. The ease of digging-in and firming the straining posts should also be considered and waterlogged areas and shallow soils over rock avoided. Where possible, avoid fencing on excessively undulating ground, where it may be difficult to prevent a multi-strand electric fence lifting off the ground.

Ratio of length to area enclosed

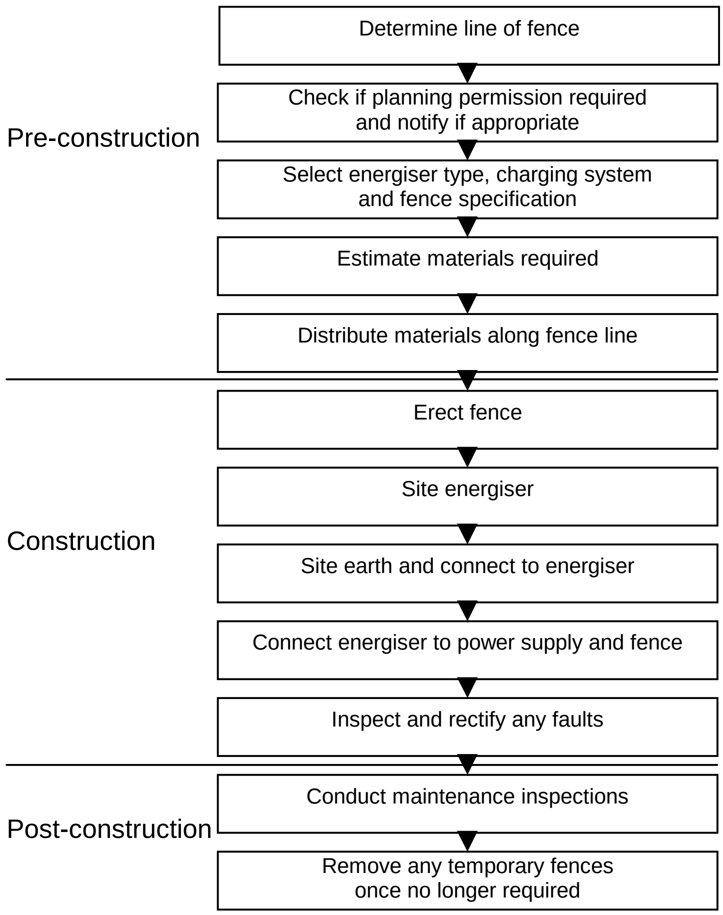
The length of fence in relation to the area to be enclosed must also be taken into account. The best practical shape, to give the lowest ratio of fence length to area enclosed, is a square and the larger the area fenced, the lower the cost per hectare. However, very large areas may be unmanageable if animals break through the fence.

Seasonal and climatic influences

Climatic conditions should also be considered. For example, in a valley that is subjected to regular drifting snow, a fence placed some yards up the hillside, rather than in the valley bottom, may miss snowdrifts. However, care should be taken when fencing along a steep slope that animals approaching from the higher side are not able to jump over the fence.

Remember ... every opportunity must be taken to gather and consider all the available relevant local knowledge before a fence line is agreed and the fence is erected. Relocation of a permanent electric fence after completion is expensive. A flow chart to act as a guide and checklist on the order of tasks to be undertaken is given in Figure 13.

Figure 13 Flow chart to act as a guide and checklist on the order of tasks to be undertaken



CHAPTER 7

Fence maintenance

Once erected, electric fences cannot be forgotten. Routine inspections are required to ensure that they continue to operate effectively. Inspections are required to check, for example, fence power in order to decide when it is appropriate to change batteries and to examine the fence for any problems which could reduce its effectiveness, such as sagging wires, debris or vegetation growing against it. This chapter provides recommendations on the frequency of inspections based on studies of behaviour at fences, as well as the items to be checked at each inspection, and concludes with some important advice on out-of-use fences.

Animal behaviour at fences

Most animals learn to avoid objects associated with unpleasant experiences: this is called conditioned avoidance (see also Animal training and management in Chapter 3). If the experience is sufficiently unpleasant, then the effect can be immediate and long-lasting and this can be the case with mammals receiving a shock in a sensitive area such as the nose. In studies with cattle, sheep and goats most shocks were received during the first few days of enclosure. Thereafter, very few were received. Some cattle avoided the fences without ever having touched them, presumably by copying others or by witnessing their reactions after having touched the fence: this is called socially learned avoidance. There have been suggestions that cattle may not touch an electric fence because they can sense when it is operating, possibly by detecting an odour, the electromagnetic field, or ozone generated around the wires. However, at present, there is no conclusive research evidence in support of these views.

In studies undertaken to exclude wild, nocturnal animals such as rabbits, foxes and badgers, most shocks were again received during the first few days after fence erection. Thereafter, most animals altered their ranging behaviour to avoid the fences and far fewer shocks were received. In those studies where individuals have been marked, all received shocks. Therefore, there was no evidence of socially learned avoidance, as would be expected for these animals as they do not move around at night in groups.

Implications of behaviour for the frequency of maintenance inspections

Since most contacts with fences appear to occur shortly after fence erection and some animals learn to avoid fences without receiving shocks, it follows that animals may continue to avoid the fence even if the power were to be accidentally cut off. Therefore, daily inspections, which are sometimes recommended to forestall crossings as a result of power failure, may be essential only during the first few days after erection. For example, when power was disconnected to a fence containing 24 cattle in a 10 ha (about 25 acres) enclosure after three weeks of electrification, it took about a further week before cattle crossed the fence. When power was disconnected after only one night's electrification to a fence containing different groups of five wild rabbits in a 0.1 ha (about 0.25 acres) enclosure, all crossed on the night power was disconnected. By contrast, when the fence had been electrified for one week prior to power being disconnected it then took a further week before rabbits crossed. Extending the period of electrification to three weeks, prior to disconnection, made no difference as it still took a further week. Similarly, electric fences used to exclude free living badgers for two weeks from plots containing an attractive food on commercial farms continued to exclude them for up to three weeks after power was disconnected.

These results confirm that a conditioned avoidance reaction is not immediately lost when power to a fence is cut off and that daily inspections should not be necessary after an initial period of conditioning. More research would be required, however, before species-specific recommendations could be made for the timings of maintenance inspections of electric fences. This would involve, for example, determining the duration of the initial training periods for stock and investigating factors which could influence it and the time taken for conditioning to be lost. When managing domesticated mammals, stocking density will obviously be an important factor; when managing free-living wild mammals, ranging and territorial behaviour, and social structure will be important factors. Results obtained from these kinds of experiments, combined with recent developments in automated fault detection equipment which can be attached to the fence, could further contribute to considerable reductions in maintenance costs.

Fence inspections: when and what to check

It is recommended that electric fences should be inspected daily during the first week after fence erection to ensure that they are continuously electrified. This will ensure that animals have the maximum opportunity to encounter the live fence and receive a shock during this period. Thereafter, inspections should be at least at weekly intervals. However, more frequent inspections may be necessary if the consequences of animals crossing the fence are considered to be serious.

At each inspection, the connections between the battery and energiser, the energiser and earth rod and the energiser and fence should be checked. The electrical pulse should be checked at each end of the fence and on each conductor wire on multi-wire fences. If the system contains earthed wires, the connection between these wires and the earth rod should be checked and the voltage between live and earthed wires should also be measured. The fence line should be walked to check for physical damage to insulators or evidence of ‘arcing’ (charring of the insulation material) which indicates a break-down of the insulation. If the energiser is switched on, the arcing may be heard and in low light conditions, the sparks generated may be seen. In an electric netting fence, each horizontal wire should be checked at intervals of about 100 m (about 100 yds) to ensure that no wire has been bitten through at more than one point in each roll; if this does occur, the section of wire between the two breaks will not be carrying current. Connections between adjoining rolls of netting should also be checked. The entire fence should be inspected and any debris removed. The need for herbicide applications should be considered when vegetation begins to grow against the fence, causing leakage and hence a reduction in voltage.

Monitoring electrical efficacy

The following two meters are very useful for determining electrical efficacy. An *electrostatic voltage meter* calibrated in kilovolts (kV), usually 0 to 10 kV, provides an indication that the fence is in working order, and can be used to monitor levels of deterioration. Therefore, the aim should be to obtain the highest output possible from the energiser being used. As a guide, the voltage should be maintained at between 4 and 6 kV. If it drops below that level, the battery should be changed, if appropriate, and the fence line inspected to rectify any faults. Voltage meters do not indicate the energy available to deliver an effective shock.

A joulemeter calibrated in either millijoules (mJ) or joules(J), usually 0–1000mJ or 0–10J, is used to measure the energy available on the fence. This measurement provides a clearer indication of the shock sensation that will be experienced by an animal contacting the conductor wires and therefore the efficacy of the fence.

Identifying and rectifying faults

The following systematic approach should be adopted to identify and rectify faults.
First check the energiser. If it is not ticking it may be because:

- it is not switched on;
- the mains supply has failed;
- the fuse has blown;
- the battery needs charging; or
- there is a lose or broken connection between the power supply and the energiser.

If no fault is found the problem will be *in* the energiser. This can be confirmed by substituting with another.

If the energiser is ticking but there is no output it may be because:

- the battery needs charging;
- the lead-in wire to the fence has a loose or broken connection; or
- the energiser is faulty.

If the energiser is found to be at fault it must **be returned to the manufacturer for repair**. Do not attempt to repair it yourself.

If the energiser is found to be operating satisfactorily, then check the fence for:

- a loose or broken connection to earth;
- a leakage of current to earth which may be due to vegetation or debris touching the conductor wires or to damaged or poor insulators (it may be necessary to check each insulator in turn for evidence of arcing or for any wire that has been dislodged); or
- a short to earth which may be caused by a broken conductor wire or a foreign object of low electrical resistance bridging the gap between the conductor wire and earth.

All components found to be faulty, such as insulators, should be replaced and discarded to ensure they are not inadvertently used again. Fault finding on extensive permanent fence systems can be eased at the time of fence erection by breaking the fence into sections separated by isolating switches. The section with the fault can then be identified more easily.

Out-of-use fences

Temporary electric fences should not be left unelectrified in the field for long periods of time, once the need for them has passed. Wild mammals in particular can become so accustomed to crossing such a fence that when it is switched on again, it may be less effective. Electric netting fences can also become severely damaged by animals biting through the wires so that sections of the netting may have to be replaced. Furthermore, there is a danger that wild mammals can become entangled in the netting and may die as a consequence. Unelectrified temporary fences can also easily be damaged by machinery or stock. Vegetation can grow through electric netting fences, making them more difficult to remove when this eventually becomes essential. Materials such as fence posts left on the ground can become overgrown very quickly, be easily lost and may eventually damage tyres, harvesting equipment or other types of machinery.

Remember ... Once the fence, either temporary or permanent, has served its purpose, it should be removed completely. This avoids any future hazards and makes way for better working practices in the future. In addition, many of the components, if carefully stored, will be available for future use.

APPENDIX 1

Further reading

British Standards on electric fencing:

BS EN 61011:1993 Electric fence energisers. Safety requirements for mains-operated electric fence energisers;
BS EN 61011-1:1993 Electric fence energisers. Safety requirements for battery-operated electric fence energisers suitable for connection to the mains supply; and
BS EN 61011-2:1993 Electric fence energisers. Safety requirements for battery-operated electric fence energisers not for connection to the mains supply.

British Standards information can be obtained from:

BSI,
Customer Services,
389 Chiswick High Road,
London,
W4 4 AL
(Tel: 020 8996 9001)
www.bsi-global.com

Useful contact addresses

Suppliers of electric netting

Bramley & Wellesley Ltd.
Unit C, Chancel Close Trading Estate,
Eastern Avenue,
Gloucester
(Tel: 01452-300450)

Euronets
Capel Farm
Capel-le-Ferne
Folkestone
Kent
(Tel: 01303-250736)

Electranets Ltd.
31 Westfield Ave.
Brockworth
Gloucester
(Tel: 01452-864320)

Renco Ltd.,
Bath Road Trading Estate,
Stroud
Gloucester.
(Tel: 01453-752154)