TECHNICAL GUIDE

Forest Research

Forest Fencing

Forestry Commission

Checklist for planning, constructing and maintaining forest fences

(✔)

1 Assessment of fencing options and data collection

- Identify potential wildlife problems. ☐
- Identify all statutory obligations. ☐
- Take account of ESR and EIA constraints. ☐
- Establish costs and likelihood of grant aid. ☐
- Consult neighbours. ☐
- Assess alternative wildlife management options. ☐
- Evaluate impacts of fencing on target and non-target species. ☐

Confirm whether a fence is appropriate.
Go to Stage 2

2 Fencing strategy and outline design

- Is there a single problem species or more than one? ☐
- Can an existing boundary fence be adapted or should a new fence be created? ☐
- Is permanent or temporary protection required? ☐
- Location of fence end points, e.g. tracks/side roads, water, threats to effectiveness and difficulty to overcome. ☐
- Identify potential problem areas during fenceline construction, e.g. public access points, steep slopes, exposure and hard or soft ground. ☐

Create outline fence specification and plot route on map.
Go to Stage 3

3 Detailed design and fencing specification

- List default fence materials and quantities; consider: ☐
  - the fence height required for target species;
  - the type of mesh required for target species;
  - the supporting structure and cladding material.
- Identify where possible deviations from normal fencing specification are required and quantities needed; consider: ☐
  - the position and type of access gates and styles;
  - whether watergates/roads/grills are needed;
  - local knowledge of ground conditions and exposure;
  - requirements for other wildlife, e.g. grouse;
  - easy exit options for deer.
- Consider whether machinery will be used during construction. ☐

Complete revisions of fence specification and initiate tendering process if appropriate.
Go to Stage 4

4 Implementation

- Obtain materials. ☐
- Agree responsibilities and carry out risk assessments. ☐
- Mark out fenceline. ☐
- Liaise with contractor over fence construction: ☐
  - inspect progess during construction;
  - identify weaknesses and agree remedial actions.
- Final inspection. ☐

Construct fence.
Go to Stage 5

5 Periodic inspection, maintenance and record keeping

- Routinely inspect integrity of fence, noting any weaknesses or failings. ☐
- Identify remedial measures and monitor actions taken. ☐
- Monitor changes in wildlife status. ☐
- Wildlife manager to remove animals inside fence. ☐

Continue periodic inspection and maintenance until trees no longer need protection.
Go to Stage 6

6 Remove temporary and permanent fencing as and when the need ceases

Forestry Commission

Technical Guide

Forest Fencing

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Contents

Preface

Since the publication of Bulletin 102: *Forest fencing*, 14 years ago, forest fencing has advanced considerably and this new publication includes a number of issues previously unaddressed or considered elsewhere. The British Standard EN wire specifications, especially on rabbit netting, have led to some confusion and difficulties in that the mesh size under the EN system is now slightly larger, potentially allowing small rabbits to penetrate; and the change from gauge to millimetre measurements has coincided with thinner wire being adopted by almost all manufacturers. In contrast, the use of a green or gold plastic film on top of the galvanised layer has led to considerable anticipated increases in wire life (if handled correctly during construction) and also has the advantage of being slightly less visible in the countryside. The recent changes of approved wood preservative from the copper/chrome/arsenic (CCA) to the copper/chrome/boron (CCB) preparations has increased the price of woodwork.

Machinery is increasingly being used for fencing purposes, assisting in speeding up fence installation times, clearing a path for a new fence, moving netting rolls and safe removal of old fencelines for correct disposal. Unreeling net or barbed wire can now be achieved more safely and netting dispensed vertically in brash-cluttered or tight locations. Use of heavy mechanical post driving has increased the use of driven straining posts without underground cross members. The ability to drive a post 2 metres into the ground (well beyond any hand digging capability) in a few minutes saves time and may prove able to withstand the continuous tension applied by the spring steel line wires and high tensile netting that is now the recommended norm.

Some aspects of fencing have not changed over the decades; here running out line wire that will support hinge joint netting.

Lifting heavy materials by helicopter allows fencing to take place in otherwise inaccessible locations.

While we have attempted to indicate the minimum specifications required to be fit for purpose, it is for the manager to determine whether a specification for fencing will really achieve the objective within local constraints and we recommend increasing fence height if in doubt. Manufacturers can now make a wide variety of bespoke specifications of rectangular wire mesh netting of hinge or knotted joint for large or specialised jobs, even including different distances between verticals at the upper and lower sections of a one piece deer net. Manufacturers remain keen to provide specifications to order.

The need to produce temporary fencing in some circumstances has been addressed to keep costs low, supplementing the original Practice Note 9: *Recommendations for fallow, roe and muntjac deer fencing: new proposals for temporary and reusable fencing*. The importance of taking account of the rare woodland grouse, which all too frequently fly into unmarked upland deer fences, has also been included.

Information on electric fencing has now been provided. This rather contentious subject has its proponents and critics since similar specifications can work in the short term in some circumstances and can also fail spectacularly in others. It is unclear whether all the critical key aspects to success can easily be met and its general applicability for all circumstances remain unproven.

In this publication we have aimed to provide details on best materials, techniques and practice, but we are always interested in hearing of new developments.

Roger Trout and Harry Pepper
April 2006

1. Introduction

Fencing in forestry is traditionally used to protect young trees from damage by herbivores. Such fencing may also protect the local flora and associated fauna. Fencing against wild animals is an expensive operation, particularly in forest situations in remote areas or where access is difficult. The use of fencing to protect trees from animal damage is only one of the management tools available and a fence on its own may not be sufficient to overcome a particular problem at the local, landscape or landowner scale (Hodge and Pepper, 1998). In contrast, fencing domestic stock is routine. There is a wide range of types and specifications of fence available and it is important that an appropriate choice is made for a particular situation if both the objective and best value for money is to be achieved. For long-term fences this choice may need to take into account future expansion of ranges, e.g. muntjac deer, wild boar. Conversely, removal of fences when the objective has been achieved, e.g. trees are large enough or deer populations have been reduced by other means to acceptable levels, is also an integral part of the process.

The risk of animals breaching a fence is related to both the quality of the fence and the capabilities of the particular species to climb, jump, push through or under, together with the pressure to cross, i.e. the number of animals on one side of a fence and their need to be on the other side. The risk that a panicking deer may jump over or become tangled in a fence that it would never normally attempt to cross may also need to be considered. This is particularly important where fences are next to roads, areas with heavy public access or close to urban areas. Fencing migrating or herding red or fallow deer completely out of traditional forest blocks may create excessive pressure, resulting in regular breaking of the fence. Allowing limited refuge areas or appropriate diversions may succeed in reducing pressure, even though the fencing costs will be higher per hectare (as would a hard, sustained culling programme which would be needed to cover a very large area).

Scope

This publication replaces Forestry Commission Bulletin 102: *Forest fencing,* published 14 years ago (Pepper, 1992). It recommends best practice principles for managers and practitioners as a guide to planning, assessment and mitigation of adverse factors, in choosing the fence design appropriate for the target species and by indicating the key practical steps in construction. It assists in identifying the normal specifications of components required to accommodate typical situations and when taking account of special local circumstances. It assumes that those involved are reasonably familiar with agricultural stock fencing installation, but outlines working with spring steel line wires, hexagonal mesh and high tensile netting products, which together create the recommended generic fencing options against rabbits and deer. Sections on temporary and electric fences are provided, together with tools, safety aspects and maintenance. The publication is not intended as an exhaustive account of all the local variations in style nor does it consider all the finer points of fencing or list materials and suppliers. Such details may be found in Agate (2001), Pepper *et al.* (2006) or the recent update of *Design manual for roads and bridges* (Highways Agency, 2005a and b).

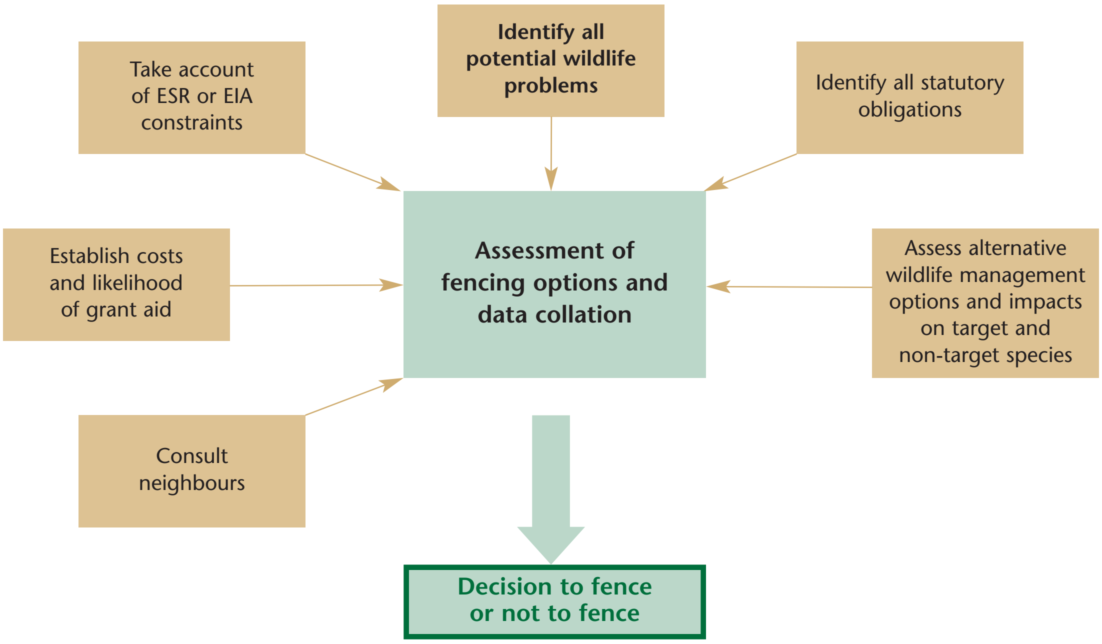
Objectives of fencing

The objectives of any proposed fence in a forestry context must be clearly defined in reaching a decision to install a fence. Often it will be a small part of a pre-planned process within a formal multi-objective forest design plan but sometimes a reaction to an emerging problem.

The intended lifespan of the fence will determine whether it is to be a permanent or temporary structure. This will also influence the type and quality of materials (e.g. wire gauge, need for preservative-treated woodwork) to be used in construction, although minimum fence height and maximum netting mesh size will usually be the same. Planning must include not only the intended target species and any non-target species whose welfare may be affected, but also mitigation highlighted by an Environmental Survey Report (ESR) or Environmental Impact Assessment (EIA) to reduce adverse impacts locally on biodiversity, public access/safety and landscape (Figure 1). Planning approval must be sought before installing an electric fence alongside any road or railway or if the fence is higher than 1.8 m. A checklist to consider when planning, constructing and maintaining forest fences is shown on the inside cover.

Figure 1

Flowchart outlining the factors that must be taken into account when deciding whether a fence is appropriate.



Definitions

Permanent fences are generally classified as those that are required for more than five years. This time scale allows for trees to grow adequately out of the damage-vulnerable stage (usually 5–15 years) or where permanent boundaries between landowners are required.

Temporary fences are generally those that are required for less than five years and are aimed at short-term management problems, e.g. protection of recently cut coppice. They should be dismantled and the materials removed from site for reuse or safe disposal as soon as the fence is no longer needed.

Electric fences are usually, but not always, temporary in nature and require a higher level of maintenance than other forms. They are easy to remove and the expensive components (charging unit, solar panel/wind turbine) can be reused. The principles, components and specifications of these fences are described in Section 8 (page 35).

2. Siting the fenceline

The general area to be fenced is a management decision governed by the objectives of the fence but the ratio of length to area enclosed will have an important influence on the costs per hectare; for example, fencing a linear shelterbelt is more expensive per hectare than a compact woodland. The position of a fence can influence the capital cost, acceptability for any grant, the cost of fence maintenance and the ease of removal of intruding animals by a wildlife ranger. Unless the intention is to fence along a legal boundary, it may be possible to make worthwhile savings by straightening out the line to eliminate one or more corner posts even at the expense of excluding some planted land and perhaps using individual tree guards there instead. Once the objectives are established and the general specification has been chosen, the route of the fenceline needs to be surveyed on a map and on the ground.

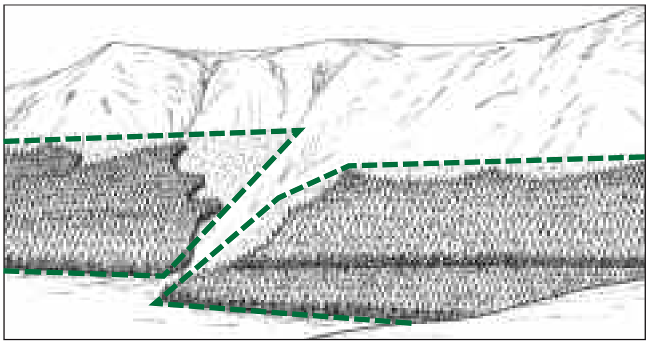
Deciding the position of the fenceline

Factors that need to be considered when choosing the proposed fenceline include:

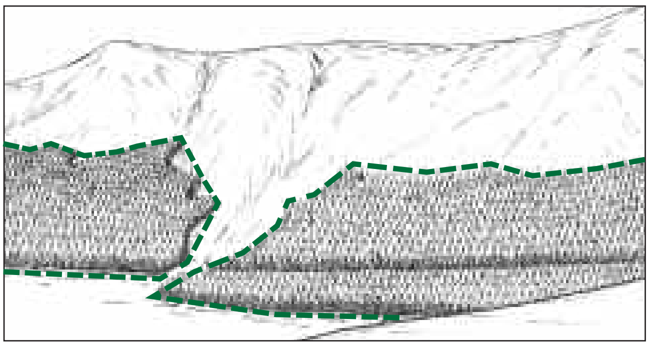
- The visual impact that the fence may have immediately in the landscape or for amenity can be influenced by the chosen route (Figure 2a, b). Growth of the protected vegetation may reduce the visibility of the fence in due course. An alternative style may be less intrusive, e.g. coloured net or marking with wooden pales instead of orange plastic mesh in areas with woodland grouse and where the fence is visible to the public.

Figure 2

Fencelines in the landscape.



(a) A fence with long straight lines may cause a harsh woodland shape that is too prominent in the landscape.



(b) A choice of fenceline that is sympathetic with natural contours will harmonise forest edges into the landscape.

- The suitability of the terrain; the desirability to divert the line to avoid problem areas, archaeological features and waterlogged soils. Situations which may require extra time to be allocated for construction include ease of digging-in and firming straining posts, steepness of slope and shallow soils over rock where it may be difficult to prevent the bottom of the fence lifting and so allowing access by wildlife.

- The impact of fencing on sites important for nature conservation, e.g. Sites of Special Scientific Interest (SSSIs). In the medium to long term, removal of grazing (of stock and deer or rabbits) may significantly alter the vegetation composition and form.

- Ease of access for maintenance and the location and type of access points necessary for forest management and for the public.

- Minimisation of the number of times a fenceline has to cross ditches and watercourses to reduce damage and maintenance requirements, particularly after heavy rainfall, and any impacts on wildlife of water gates.

- Avoidance of fencing across established major wildlife pathways. The local wildlife manager can determine established deer and badger paths and whether fencing will change their pattern of behaviour or result in additional pressure on the fence. A sudden restriction of herding deer that prevents them reaching a historical (seasonal) part of the range may result in undue pressure and potential fence failure.

- Avoidance, wherever possible, of a line that will create a hazard to flying birds, especially grouse species. Consultation with any adjacent pheasant shooting estate is advised.

- Avoidance of a simple endpoint at road edges and junctions, tracks or water bodies by creating deflecting wings. Fencing may increase the risk of wildlife collisions with vehicles. Consider the impact of fencing along one or both sides of a road.

- Avoidance of raised ground close to the outside of the fence to prevent deer or rabbits jumping in.

- Taking account of the local climatic conditions, e.g. a valley or exposed hilltop prone to drifting snow. Moving the fenceline some metres up or down a hillside can reduce the occasions when the fence will fail due to the weight of snow or animals crossing snow bridges.

- Locating areas to assist management of deer, e.g. escape routes such as deer leaps (ramps up to the fence on the inside that enable the deer to jump out) or one-way deer gates, should be planned into the fenceline wherever possible. The local wildlife ranger should also advise on details that assist the culling of animals inside the fence, e.g. small access gates, siting of high seats with appropriate sightlines.

- Future plans for forest expansion or other land uses.

The FC publications *Forest landscape design guidelines* (Forestry Commission, 1994) and *Forest design planning: a guide to good practice* (Forestry Commssion, 1998) address many of these issues.

The amount of material required can be estimated by making a simple map while walking the proposed fenceline and marking on the map the positions of straining and turning posts, the number of struts required by each post, the distance between stakes and any special circumstances affecting the design or construction. Use of a hand-held global position satellite (GPS) receiver to record locations of major turning posts allows subsequent mapping and assists in future maintenance by identifying the location of any observed problems.

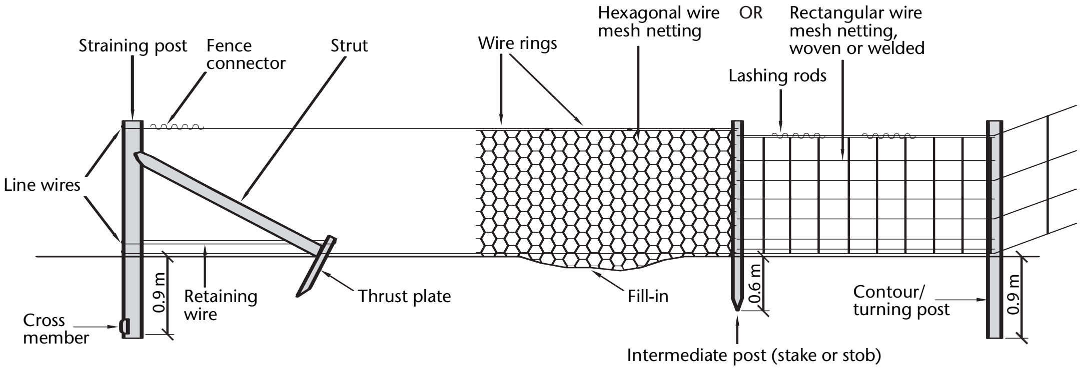
3. Fence components

The two main parts of a permanent or temporary barrier fence are the support structure and the cladding material. The *support structure* is freestanding and usually consists of wooden posts and tensioned steel line wires. The line wires are usually located at the top and bottom of the netting and there may be additional support wires in between. The *cladding* is secured to the support structure and normally consists of mesh or netting of hexagonal woven mild steel, high tensile woven wire, welded wire or occasionally high tensile plastic netting. The majority of forest fences use rectangular woven wire netting and there is a standardised system to identify the detailed specifications – see Section 4 (page 11).

The parts of a typical fence are shown in Figure 3; this also helps to clarify and identify the components as some have synonyms or other interpretations used in different areas of the UK.

Figure 3

Component parts of a post and mesh fence including fixings.



Support structures: timber

Woodwork for the support structures will normally be round softwood. In permanent fences the wood will always be treated with preservative, but need not be in a temporary fence. Table 1 indicates the natural durability of timber from various tree species. Properly treated wooden posts and stakes should outlast the metal cladding components unless a permanent barrier such as an estate boundary fence is required and components are repeatedly replaced over time. The strength and durability of all the components in a fence should be matched to the strength of fence required to deter the target species and the period of time for which the fence is needed. Untreated and undried fencing material of conifer heartwood or hardwood poles may last for 3–5 years and be sufficient for some temporary fencing, for example

Table 1 Durability of untreated heartwood timber.

Very durable (25 years)	Durable 15–25 years)	Moderately durable (10–15 years)	Temporary only
Sequoia	Western red cedar	Douglas fir	Hemlock
Yew	English oak	Larch	Spruce
	Robinia	Pine	Ash
	Sweet chestnut	Turkey oak	Poplar

coppice regeneration, though chestnut and oak will last longer. If the fence is required for a longer period it will be necessary to treat the timber with a preservative or to use durable timber. Under BS EN13183 timber should have a maximum of 20% moisture before pressure treatment; treated wet timber is not recommended. The copper/chrome/arsenic (CCA)-based preservatives have been withdrawn under EU legislation. Their use solely for fencing mammal pests away from trees is no longer allowed. New treatments are being tested and are available, including copper/chrome/boron (CCB) and pressure treated creosote. Treated pine is preferred while spruce and hemlock are probably among the most difficult species to treat. Most other softwood species are intermediate. In general, treated hardwoods do not last as long as similarly treated softwoods.

Round wood posts and stakes are recommended in preference to sawn material because the sapwood allows the pressure treatment to provide a relatively even and complete protective barrier around the post. However, it is impossible to erect a fence without cutting into some of the treated timber and in such instances it is important to renew the protective layer of preservative. There are three types of post that carry the cladding: they have different dimensions, as outlined in Table 2.

Table 2

Recommended woodwork for permanent fences and maximum spacing of stakes; length in metres (m) and top diameter in centimetres (cm).

Target situation	Endposts and turning posts (m x cm)	Struts (m x cm)	Intermediate stakes (m x cm)	Maximum stake spacing (m)
Rabbit/hare	2.0 x 10–13	2.0 x 8–10	1.7 x 5–8	10–14
Rabbit + stock	2.3 x 10–13	2.0 x 8–10	1.7 x 8–10	8
Sheep	2.3 x 10–13	2.0 x 8–10	1.7 x 8–10	12
Cattle, quarry/ mines	2.3 x 10–13	2.5 x 10–13	1.8 x 8–10	6
Roe deer	2.8 x 10–13	2.5 x 8–10	2.5 x 5–8	10
Muntjac deer	2.8 x 10–13	2.5 x 8–10	2.5 x 5–8	10
Red/sika/fallow deer	2.8 x 12–18	2.5 x 10–13	2.6 x 8–10	10
Badger	2.3 x 10–13	2.1 x 8–10	1.8 x 8–10	8
Boar	2.3 x 10–13	2.0 x 8–10	1.8–2.3 x 8–10 (angled)	6

Notes: 1. These sizes are suitable for permanent fences in normal situations where treated timber is used. In particular circumstances (see Section 6) larger diameters or longer lengths are required.
2. End posts and turning posts driven by machine (Figure 4) should be a minimum of 2.8 m for stock or 3.5 m for deer.

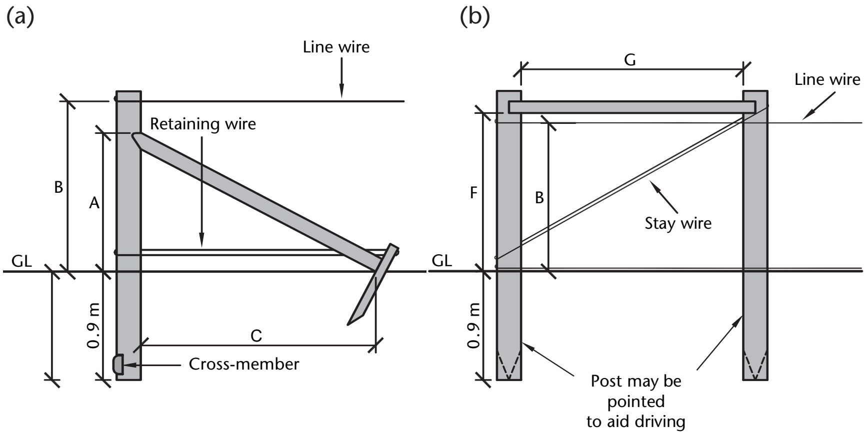
1. **End post assemblies** are anchors that take and retain the tension put onto the line wires and netting and as a result they are usually referred to as straining posts. There are two designs of end post, the *strutted* and the *box* (Figure 5a, b). Both are equally effective at retaining tension when installed correctly. The strutted post has a cross-member underground at the base to increase its holding power and therefore has to be put into a shaped hole that is dug by hand (or initially produced by a power auger) and then rammed firm or set in concrete. The cross-member normally measures 0.5 m but is longer in soils with poor holding ability such as peat or in those where significant movement occurs such as clays. A driven strutted straining post must have at least 1.5 m below ground. The use of two posts in the box section assembly (material costs are thus higher) very rarely requires an underground cross-member and are preferably driven in with a mechanical post-driver (Figure 4). The spacing of end post assemblies will normally be dictated by major changes in direction of the fenceline and ground contours. However, where the fencelines on flat ground are long and straight and the cladding material allows, for example rabbit netting, distances of 1000 m between posts are possible.

Figure 4

Machine mounted post rammers save time and effort.

Figure 5

Types of straining post assemblies: (a) post and strut; (b) box section.



A Height of notch (0.75 of B)
B Height of top line wire
C Distance from post to base of strut (1.25 x A)

F Height of horizontal rail
G 1.5 x F
H Minimum depth in ground
GL Ground level

2. **Contour/turning posts** are posts without a strut. They must have an underground cross member. They are used where there is a minor change of direction in the fenceline (where the internal angle is greater than 110°) or where the fence has to be held down in a depression or gully, as an alternative to a concrete or metal ground anchor. A strut is required if the angle is less than 110°.

3. **Intermediate posts** are pointed and often referred to as stakes or stobs. These are driven into the ground with either a manual or mechanical post driver. Stakes are placed at regular intervals on flat ground or varied to allow for undulations in the ground, but never further apart than the maximum specified in Table 2. The distance may also have to be reduced along certain stretches of a fence that are likely to be subjected to increased pressure from animals or weather (see Section 6). The effectiveness of a fence should not be compromised just to save money by increasing the spacing between stakes.

Support structures: metal

Metalwork and its protection

Metalwork in fences may include mild steel, spring steel and high tensile steel. All metalwork in fences should be protected from corrosion. The protective coating on all steel materials used for forest fencing may be zinc, zinc alloy, plastic or other coating or a combination of two coatings such as a plastic powder coating over zinc. The coating will normally be a sacrificial zinc coat of 230 g m^{-2} conforming with the requirements of British Standard EN 10244-2 (British Standards Institute, 2000). Some manufacturers offer other special coatings that may give extended protection, such as zinc/aluminium alloy or coloured green or gold. Some imported netting may not meet the BS or EU specifications – especially low cost hexagonal netting – and should be carefully checked.

Metal posts and stakes

Metal posts and stakes are normally not used for forest fencing except in rock substrates where T or Y section metal posts may be chosen. Metal stakes may also have a place in temporary fencing (see Section 7, page 32) where they can be recovered and reused.

Wire in support structures

The steel support wire component consists of tensioned line wires or the retaining/stay wire of straining post assemblies. Tensioned line wires are required to support mesh netting between intermediate posts; the tension reduces sagging. The maximum distance between intermediate posts can be achieved by using the recommended 2.65 mm diameter spring steel wire conforming to British Standard 5216 Grade 6. It has a breaking strain of 1490–1690 N mm^{-2}, has no yield point and keeps its tension when strained. This wire has adequate strength to give a safety margin of 100% between the top of the 'normally applied tension' (3000–4000 N), obtained by correct hand operation of wire strainers, and the breaking point. High tensile steel 3.15 mm diameter wire with a breaking strain of 1050 N mm^{-2}, conforming to BS 4102, may be used as an alternative when spring wire is unavailable. However, high tensile is inferior to spring steel wire in weight per metre (approximately double) and may present a higher safety risk as it may snap while tensioning. High tensile wire of 2.5 mm or 2 mm is even weaker and potentially more dangerous. High tensile 3.15 mm line wire with a vanadium component has recently become available but is not significantly stronger. Mild steel wire of 3.15 mm has a breaking strain of only 3510 N but because it has a yield point will also stretch permanently and allow fencing to sag, so is not recommended. Only when using spring steel line wires can stakes and straining posts be most widely spaced.

While spring steel and high tensile wire have great strength for their small diameter, this can be drastically weakened if the wire is damaged or inappropriate joins are made. When spring steel is used, a wire dispenser, appropriate hard-edged cutting pliers and proprietary wire strainers are all necessary to maximise safety and minimise damage and danger. Staples should be used to guide the position of tensioned wires on the woodwork, but *never* to pinch the wire in an attempt to hold the tension.

The use of barbed wire on forest fences is not recommended unless required by neighbouring farmers for protection against cattle. Even in these cases it is preferable to fix it to the top of the net rather than as a separated higher wire. Mild steel barbed wire is not suitable for use with any steel fence as a separate strand where the stakes are spaced 3 m or more apart because it sags, but it can be used when attached to the top of a net. Galvanised or coloured twin-strand high tensile barbed wire is available and is suitable but single-strand high tensile barbed wire is brittle and dangerous, and therefore not recommended.

Multiple line wire fences, even with occasional droppers, rarely provide a fully effective barrier to wild mammals and are not recommended. They may be applicable in very remote agricultural situations with extreme upland exposure against less agile breeds of sheep.

Cladding material

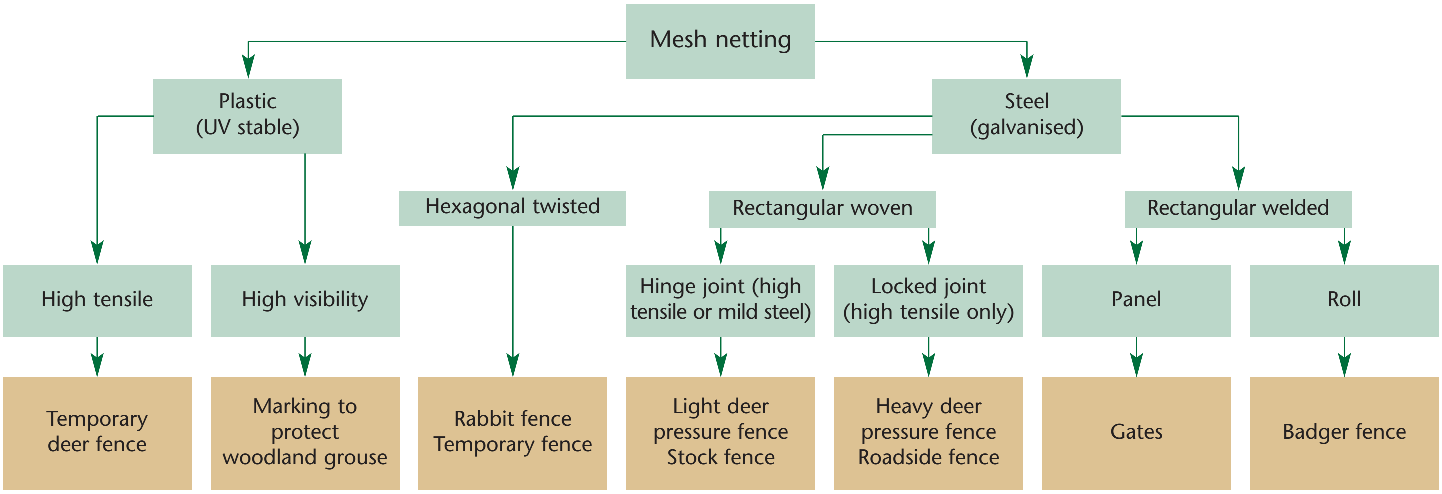
The cladding material is normally netting attached to the support structure on the side facing the direction of approach of the target species (usually the outside of the fence). The netting must be sufficiently strong and positioned to prevent, or at least reduce to an acceptable degree, the ability of the target species to cross the fenceline by:

- climbing or jumping;
- pushing through or under;
- burrowing under;
- breaking/chewing;
- pushing down.

Mesh netting is either plastic or steel. A variety of generic forms of netting are available and in use in forest fencing (Figure 6). Chestnut paling styles of fence cladding may be appropriate for some situations.

Figure 6

Types of netting (green boxes) and their typical uses in fencing (yellow boxes).



- **Plastic net** is most likely, but not always, to be used for temporary fencing or when providing extra visibility in areas with woodland grouse. The net, and any plastic fixings, must be high tensile and highly UV stabilised to prevent rapid disintegration that causes a subsequent litter problem.

- **Steel net** is of three types: hexagonal wire mesh, rectangular woven wire mesh or rectangular welded wire mesh. The wires should be zinc coated and comply with either BS 4102 (1998) or BS 1485 (1983) and be manufactured to BS EN 10223-1.

Hexagonal netting comes in one basic pattern of mild steel wires, traditionally manufactured before galvanising. The selvage (edge) may have one thick wire or two wires of the same diameter as the main net. The modern green coloured 'rabbit' net has both galvanising and protective colouration applied before weaving. Some alternative patterns have additional horizontal wires through some or all of the hexagons to provide extra overall strength and rigidity but this does not alter the ability of animals to bite through thin material.

Rectangular woven mesh should be galvanised to EN 10244-2. Some specifications may be both galvanised and colour coated, e.g. green or gold. Net is available in many mesh sizes, roll widths and combinations which together require a standardised shorthand identification specification – see Box 1 (page 11). It can be either *mild steel* mesh, obtained in medium (C grade) quality in a range of sizes, or *high tensile* mesh which is made from 2.0 or 2.5 mm wire with the breaking strain of the horizontal wires of 1050 N mm^{-2} conforming to BS 4102. It is lighter in weight and stronger than the C grade mild steel netting and can be permanently tensioned but requires wire joiners to join the nets together.

Netting is available in a variety of sizes and meshes. There are two types of join where the wires cross: hinge joint in mild steel or high tensile (Figure 7a) and locked joint patterns in high tensile steel only (Figure 7b). Rolls are usually 50 m or 100 m in length.

Figure 7

Woven rectangular wire mesh netting knots.

(a) Hinge joint.

(b) Locked joint.

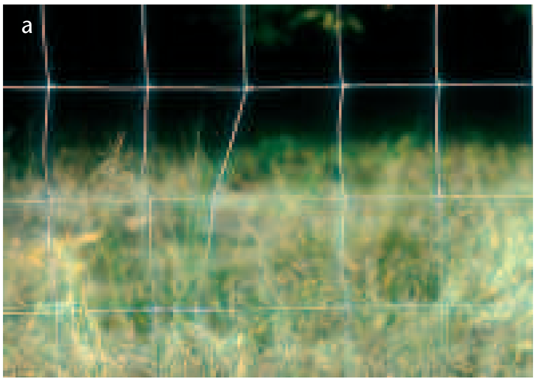
Hinged joint netting has individual vertical lengths of wire between each horizontal line and the ends are simply joined by twisting round the horizontals. It is cheap to manufacture but the joints may be relatively easily slid along the horizontal wire, especially when new, to produce bigger holes (Figure 8a and b). It also has a tendency to concertina vertically when lifted over rising ground or hit by even small branches, and when deer attempt to jump over they sometimes trap a leg or entangle their antlers (Figure 9a and b). Both a top and bottom spring steel line wire are recommended. Extra intermediate stakes are required to lift the netting over the humps to maintain fence height. High tensile material is recommended except locally on very severe frequent changes of slope where mild steel is easier to erect.

Locked joint mesh has a wire clip at each intersection that stops the verticals from sliding. It also has continuous vertical wires that prevent the net from folding up like a concertina. This more expensive high specification is only available in high tensile wire but is preferred, especially in high risk locations. A top line wire is usually unnecessary when using this type of net.

Figure 8

Hinge joint wire mesh netting is cheaper than locked joint but may be opened by wild deer and domestic stock. (a) A roe deer and (b) a fallow deer have passed through the fence.

a



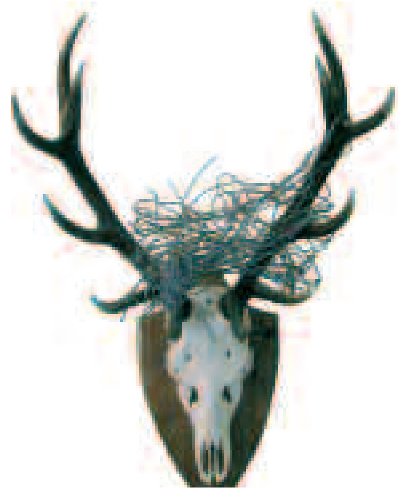
b

Figure 9

(a) Hinge joint mesh should always be suspended from a tensioned top line wire to prevent jumping deer being caught by a back leg. (b) Mild steel netting is not recommended against red deer because it can be easily deformed and may get caught in antlers.

a

b



Welded netting is manufactured entirely from mild steel where the horizontal and vertical wires are welded together where they cross. Lighter gauge is produced in rolls, typically of 6 or 25 m, which can be used for fences or cladding gates; heavier material (3 mm or more diameter wire) is made as panels, which can be used to form gates.

4. Fence specifications

This section details the specification of the fence height and the fencing materials, which will largely be determined by the size, behaviour and abilities of the individual wildlife species to be excluded but other factors listed in Section 6 (page 22) must also be taken into account.

Netting

Identifying the specification of rectangular netting

For most types of steel woven mesh netting the spacing between the horizontal wires may change across the width of the netting. Generally the spacing will increase in stages and when installed on a fence the smallest spacing will be at ground level and the largest at the top.

Because there have been so many individual types of rectangular woven netting, a shorthand descriptive code has been adopted by most manufacturers. The wire diameters and the spacing between the vertical wires of woven wire mesh is usually regular on any given netting pattern. These codes follow a convention that is accepted by European manufacturers and the British Standards Institute, though manufacturers may extend the code to give their own-brand product a specific identity (see Box 1 and Table 3). Wire remains the most durable and economic type of netting available for permanent fences.

Box 1 Coding convention for describing rectangular netting.

Each code has three sections separated by a forward slash, e.g. HT17/190/15.

1. The specification of the wire used in the manufacture – high tensile (HT) or mild steel (identified only by the diameter, e.g. C) and the number of horizontal wires, e.g. HT17.

2. The distance in cm or mm between the selvage (edge) wires which equates to the total height of the netting, e.g. 190.

3. The spacing in centimetres between the vertical wires (see Figure 10), e.g. 15.

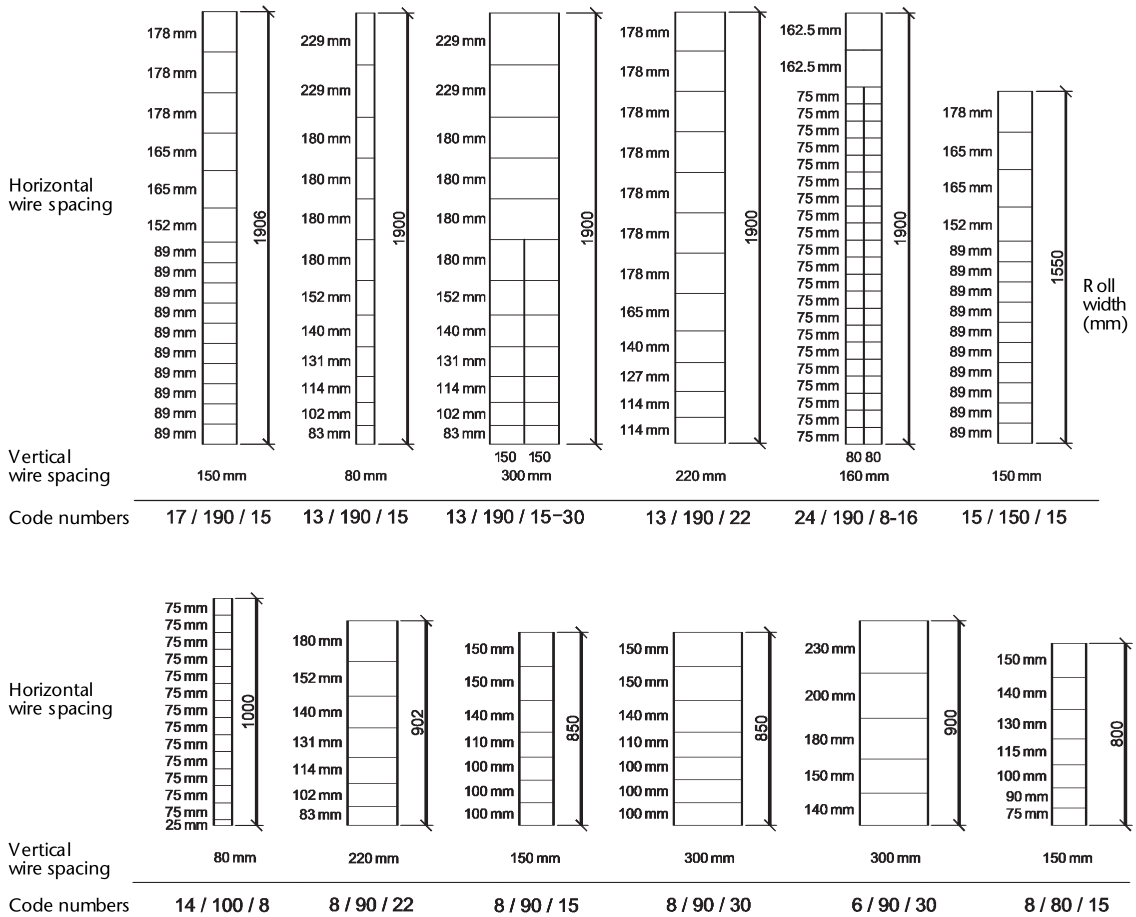
Table 3

European manufacturers' codes and wire diameters for rectangular galvanised mesh. Mild steel net is only recommended in areas with severe changes of slope.

Code letters	Wire weight	High tensile steel wire diameter (mm)		Mild steel wire diameter (mm)		
		Horizonal wires – all	Vertical wires	Horizontal wires		Vertical wires
				Edge	Inner	
HT	Standard	2.5	2.5			
MHT	Medium	2.24	2.24			
LHT	Light	2.0	2.0			
C	Medium			3.15	2.5	2.5

Figure 10

A wide range of rectangular mesh specifications is available and appropriate for different applications. See also Table 4. NB. Some of the possible combinations of horizontal and vertical wire spacing may only be available as a special order.



Netting width and mesh size

The minimum netting requirements (minimum fence height, maximum mesh size) for different wildlife species under normal situations are given in Table 4. The need to increase the specification above the minimum requirements (see page 24) should be considered in situations with:

- severe environmental conditions;
- a high pressure on the fence;
- known site history;
- safety or legal grounds;
- vandalism;
- woodland grouse present.

Where fencing has a planned temporary life, some material specifications may be reduced, but not minimum height or maximum mesh size. Local knowledge can also be very relevant. For example, a wide divergence of effective height requirement has been reported for fallow deer; reports vary from deer not crossing a fence of 1 m around a small farm woodland to deer clearing 1.8 m, well above the normal minimum recommended height. If in any doubt a taller fence should be installed; the requirements of the Highways Agency are for taller fences alongside roads.

Table 4

Recommended minimum fence height and maximum mesh sizes.

	Minimum overall height (m)[a]	Maximum mesh size (mm)	Recommended detail	Typical example of mesh recommended (see note 3)
Rabbit	0.9[a]	Hexagonal 31	Net to BS1485b. Lapped 150 mm; 3 line wires with sheep.	1050 mm or 1200 mm width. 18g or 1.2 mm for high pressure. EN10223 for light pressure[b]
Hare[c]	1.05[a]	Hexagonal 31	EN 10223 lapped 150 mm.	1200 mm. NB there is no definitive work indicating an adequate specification
Muntjac deer	1.5[a]	80 x 80	75 x 80, lapped on ground 15 cm minimum[d]	Heavy rabbit net with LHT4/100/8 above. 1.8 m high tensile plastic or hexagonal mesh. LHT23/167/8
Roe deer	1.2–1.5 or 2.5 ha	150 x 200	150 x 150	2 narrow width or 1 single width net. HT15/1550/15 or HT17/1800/15.
Fallow deer	1.5	200 x 200		2 narrow width or 1 single width net. HT13/1900/22
Red deer/ Fallow deer	1.8–2.0	300 x 220	200 x 300	2 narrow width or 1 single width net. HT17/1900/30 or A/13/190/30; MVHT/13/190/15–30 for deer and sheep
Sheep	0.9–1.0	150 x 150	Smaller lower mesh for lambs	Stock net HT9/80/15 + barbed wire[e]
Cattle	1.0	300 x 300		Stock net HT 8/90/30 + barbed wire[e]
Boar[f]	1.2	200 x 200	Buried 40–60 cm Locked joints	1 piece 17/1900/150. 8/90/15 if barbed wire on top and ground level[e] +150 mm offset electric outrigger 350 mm above ground
Badger	1.45[a]	100 x 50; or 75 x 75	Dug 30–60 cm	100 x 50 Welded 2.5 mm. Locked joint netting HT15/158/8

[a]Excluding turned base of at least 150 cm. For example, for rabbit fence: 0.9 m + 0.15 m = total netting roll height = 1.05 m.
[b]See rabbit fence (page 13 and Figure 11).
[c]No formal data are available to determine minimum fence height against hares.
[d]The head of a muntjac but not the body will pass through a 100 mm x 100 mm mesh. When the head is withdrawn there is a danger of the antlers becoming snagged.
[e]Fallow and roe deer in particular are likely to get caught when jumping fences with a separated top (barbed) line wire. Attach it to the top line wire.
[f]A great variety of specifications are stipulated by district councils to contain boar.

Notes
1 Typical examples illustrated are not exclusive of similar dimensions fit for purpose from various manufacturers. Many fences are now manufactured with gradually increasing mesh size towards the top; ensure maximum mesh size is adequate.
2 It is now possible to manufacture one piece deer net with small mesh at the bottom suitable for sheep and wider mesh at the top, e.g. HT17/190/15-30 (Figure 10).
3 For areas in excess of 5 ha or along roadsides at least 1.8 m height is recommended for fallow, roe or muntjac and 2 m for red and sika.

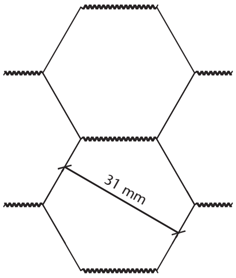
Rabbit fences

Rabbits are capable of burrowing under and climbing over fences. In some situations where permanent fencing is merited, it may still have to be supplemented by other methods of rabbit management.

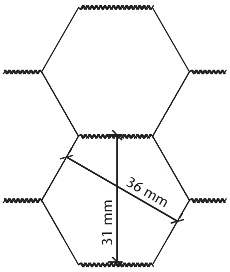
A rabbit fence should be a minimum 0.9 m high. Raising the height of the netting above 0.9 m will not in itself make the fence a more effective barrier. Hexagonal mesh netting, 18 gauge (now usually manufactured as 1.2 mm diameter overall), 1050 mm wide and with a maximum mesh size of 31 mm has been the standard pattern for many years to exclude rabbits. The use of 19 gauge (now manufactured as 1 mm diameter wire) is not recommended where there is a

Figure 11

Measuring the mesh size of hexagonal rabbit netting.



Original BS: mesh size = 31 mm



BS EN: when 31 mm between twists, diagonal = 36 mm

severe rabbit problem because they may bite through it. The manufacturing tolerance of the mesh size for 'rabbit' net (under BS EN 10223–2) should be no greater than ± 2 mm, rather than ± 4 mm for 'ordinary' hexagonal mesh. This is important because some juvenile, but recently independent, rabbits are able to pass through a 36 mm hole which is within the new EU standard (previously known as DIN). EU standard rabbit net may be used, but with caution, because it has a significantly larger aperture (31 mm ± 2 mm between horizontals as opposed to 31 mm ± 2 mm between diagonals; see Figure 11) and may allow very small rabbits to pass through and start to colonise the fenced area. Where protection of infrastructure or the protection of trees from high rabbit populations is required the original BS is recommended. Cheap net from other sources may not meet either the EU or BS standards and therefore not be fit for purpose. Temporary rabbit fences should be of the same mesh. However, welded mesh is easier to remove and reuse.

It is recommended that the netting is turned outwards for a minimum of 150 mm at the base to deter rabbits from digging under the fence. In undulating ground extra horizontal fill-in pieces of netting are recommended to deter burrowing under. The lap of netting is held down with turves or pegs, though some contractors use an extra line wire in the angle. Research indicates that burying the netting 150 mm and then turning it out 150 mm is no more effective. For areas with a more extreme pressure, the use of 1200 mm wide netting to make a taller fence with the top 150 mm turned out at least 45 degrees is recommended; the top edge is clipped to an extra line wire fixed to steel rods or sawn wooden blocks attached to each post (Figure 12a, b). As rabbits can easily run up the struts of strainer posts, these should always be placed on the side of the fence away from them.

Figure 12

A high specification rabbit fence with a 150 mm top overhang. (a) Metal rods or (b) shaped wooden blocks will achieve the required offset.

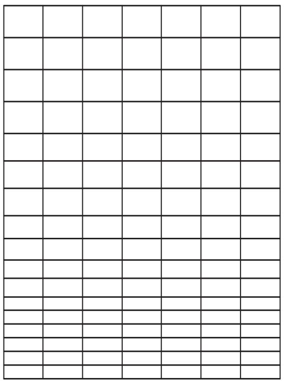
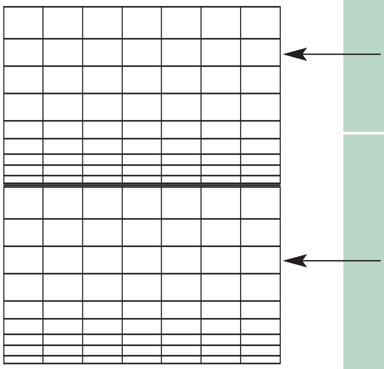
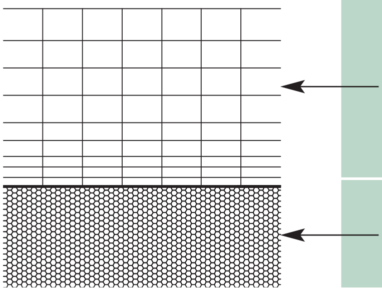
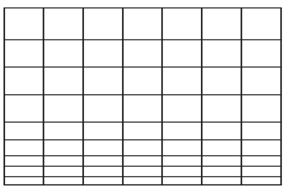
Deer fences

The expected behaviour of deer when meeting a fence varies by species and determines the fence structure required. Roe and fallow deer approach a fence in a consistent and measured way. Males (bucks, stags) will walk up to the fence, measure the height by eye and, if able, jump over. They do not usually attempt to push through. Females (does, hinds) will, again at walking pace, test a fence by prodding and pushing with their head to seek a way through or under. Only if they are unable to pass through or under will they attempt to jump over. Muntjac of both sexes will search for a way under a fence before attempting to push through. If they fail they will attempt to jump over. Where large concentrations of herding red or fallow deer collect, or even if small numbers are panicked, their collective force may break a fence that does not have a stronger than normal specification.

Specifications for the fence support structure and cladding are given in Tables 2 and 4; constructional advice is provided in Section 9 (page 39). Deer fences up to 1.5 m high will normally use single width netting. Taller fences may have either two nets one above the other, giving the option of different mesh sizes on the top and bottom of the fence, or consist of single width netting (Figure 13).

Figure 13

Typical mesh netting specifications for deer fencing.

Deer size	Large		Medium	Small
Species	**Red and Sika**	**Fallow**	**Roe**	**Muntjac**
Minimum fence height (m)	1.8		1.5	1.5
Maximum mesh size (mm)	200 x 300	200 x 220	200 x 150	75 x 75
Single width netting deer fences	Netting code/type			
	17/190/30 13/190/30	13/190/22 15/150/15	13/190/15 15/150/15	LHT 23/167/8 LHT 26/195/8 13/190/22 plus overlay of 1.8 m x 75 mm hexagonal wire mesh netting. 65 mm² mesh HT (heavy) plastic netting.
		13/190/15 15/150/15		
	17/190/15			
			LHT 23/167/8 LHT 26/195/8 65 mm² mesh HT (heavy) plastic. 13/190/22 plus overlay of 40 mm² mesh HT (light) plastic netting or 50–75 mm mesh hexagonal wire netting.	
	26/195/8, 17/190/15 plus overlay of 65 mm² HT (heavy) plastic netting.			
Double width netting deer fences	Netting code/type			
	6/90/30 8/90/30	8/80/22 8/90/30	8/80/15 75 mm mesh x 0.9 m hexagonal wire mesh netting.	50–75 mm mesh x 0.9 m hexagonal wire mesh netting.
	8/90/15	8/80/15 8/90/15	8/80/15 8/90/15	14/107/8
Combination fences (deer plus other wild mammal species)	Netting code/type			
	As shown under double width fences.			
	31 mm mesh x 1050 mm wide hexagonal wire netting where rabbits are present. Additional line wires are required to support the netting where large and medium size deer and/or sheep and cattle are present.			
Stock fences for sheep and cattle	Netting code/type			
	13/190/15–30 (where red deer are present); 8/90/15 or 8/80/15 (sheep only); 8/90/30 or 6/90/30 (cattle only)			
	Note: a single line wire of barbed wire must not be installed 150 mm above the netting when fallow and roe deer are present. Barbed wire must be attached to the top of the netting.			

Nets wider than 1.5 m can be difficult to handle without machinery (a 1.8 m wide roll of high tensile netting can weigh 120 kg), particularly in confined spaces between trees and structures and on difficult ground. For light deer pressure, hinge joint net on line wires is suitable but for heavier pressure or in public safety situations locked joint net is best. Deer attempting to scramble over may concertina hinge joint netting without a top line wire and trap a leg, leading to an agonising death or broken leg; this is almost impossible if locked joint netting is used. A single width combined stock and upper red deer net as a single unit is also available. A wide variety of net sizes and specifications are marketed, or can be made to order, which fit or exceed the basic minimum standards recommended in Table 4 and Figure 13, including for muntjac (Figure 14).

Figure 14

Novel fence mesh designs are becoming available; here a small rectangular 75 x 80 mm locked joint mesh has been tested against muntjac deer and otters.

Fencing against more than one species of deer or other wildlife

Wildlife fences may be targeted at a single species, but frequently there are two or more species present on a site for which fencing is required. It is not good practice to erect two or more parallel fences due to the high cost involved and the poor visual impact on the landscape. In these situations the requirements of the different species are best combined into a single fence specification (Figure 13) that includes a mesh size to exclude the smallest species, a fence height to exclude the most agile jumper or climber, together with the material strength to withstand the most powerful. However, there are some combinations of wildlife species that are not fully compatible with a single fence, for example, when it is necessary to fence against rabbits and muntjac deer but badgers need access (see badger gates, page 26). A rabbit/muntjac fence with *heavy* badger gates would appear to be the obvious choice, but unfortunately there have been several reports of muntjac deer using these gates. A 1 m long pipe sunk at ground level may suffice against muntjac but research needs to find a solution where rabbits are present.

Fences and woodland grouse

Black grouse may be present in northern parts of the Pennines and areas of upland Scotland and Wales. In parts of Scotland capercaillie may be present in or adjacent to woodland. Where there are such grouse, it is critical to assess the need for a fence. In Scotland, Guidance

Note 11: *Deer and fencing* (Forestry Commission Scotland, 2001) and the *Joint agency statement and guidance on deer fencing* (Scottish Executive, 2004) should be consulted. The location of any fenceline and appropriate methods for constructing the fence to make it visible to flying birds should be considered (Trout *et al.*, 2001). Internal woodland fences are considered to be the most dangerous for capercaillie and, if practicable, should be removed rather than marked, and not erected at all unless there is no other realistic option: this needs to be determined in consultation with woodland officers and other agencies.

Putting extra weight and wind resistance on a deer fence frequently necessitates the strutting of stakes and provision of stronger straining posts to prevent fence collapse (Figure 15). See Section 6 (page 28) for further details on fixing marking materials and Table 5 for specifications.

The usual approach is to create a strong support structure for a 'normal' deer fence and then mark it. Trials are in progress for new specifications for deer fences; these comprise a bottom stock net without any steel top net but incorporating manufactured rolls of 1.2 m chestnut paling/chespale or sawn, treated softwood battens of minimum 32 x 32 mm, connected by four sets of twisted wires (see Table 5, page 29). The timber is similar to that used in treeshelter stakes and screened against knots. The rolls are hung on three line wires as the top portion of the fence (Figure 16a and b). An alternative of 1.8 m height with four sets of twisted wires and three line wires is also under trial. A specialist machine in Scotland (Figure 17) can supply the recommended spacing of pales at 150 mm and 250 mm centres for roe and red deer respectively and also insert the twisted wires close enough to remove the risk of bowing of chestnut pales.

Figure 15

A strutted stake assembly for use in exposed locations, sites with a heavy deer pressure or soft soil.

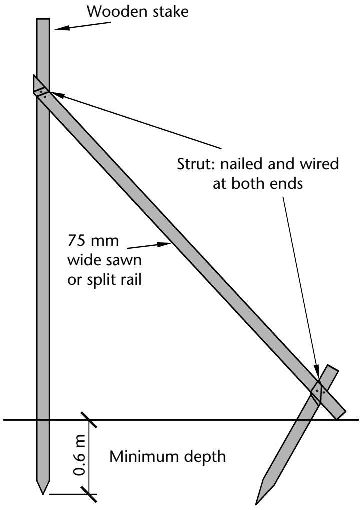


Figure 16

Trial fences using paling style fencing to reduce woodland grouse strikes: (a) a new deer fence without the top net or (b) with no deer net in the specification.

Figure 17

A specialist machine capable of making woodland-grouse-friendly deer fencing from a variety of timber specifications. Spaces can be adjusted for different deer species and twisted wires can be inserted at close enough intervals to prevent bowing of pales.

5. Joining and fixing wires and netting

If the appropriate grades of materials are used in construction, the greatest potential for weakness in a fence occurs when wires are joined without the correct connectors. Figure 18 shows methods of straining and securing wires; Figure 19 shows a range of suitable joiner types used in fence construction.

Joining line wires that are to be tensioned

The join should be as strong, if not stronger, than the breaking strain of the wire. Knotting wire is not recommended. Joining line wires is best achieved by using the correct size spiral wire preformed fence connectors as shown in Figure 19a. The arrangement for termination of a line wire on a fencepost is shown in Figure 18a.

Joining retaining wires on straining post assemblies

The arrangement of the wires in the assembly should be as in Figures 18a–c. Block or spiral preformed connectors are recommended and crimped sleeves if the correct tool is used for crimping (Figures 19a–d).

Figure 18

Methods of straining and securing wires on an endpost assembly. (a) Fence connector terminating a line wire at a post. (b) The position of the wire strainer tool when straining the retaining wire of an end post assembly. (c) Use of a fence connector to secure the strained retaining wire.

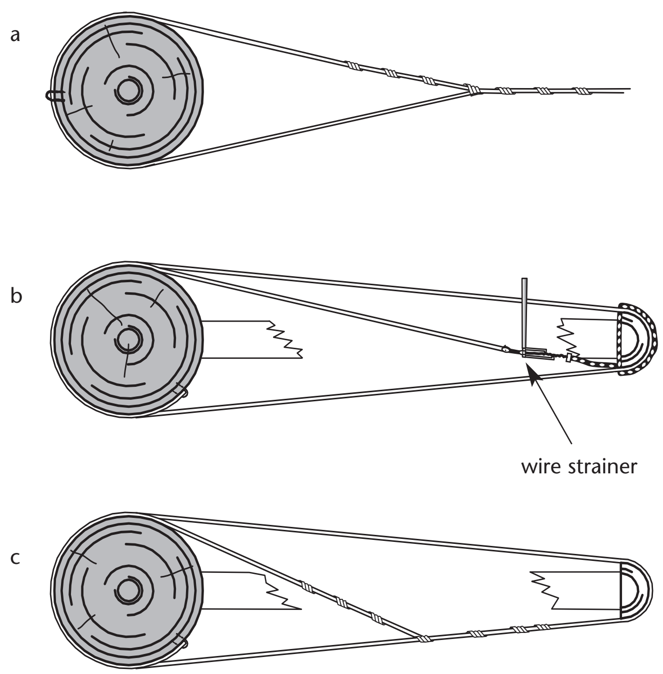
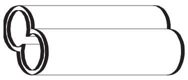
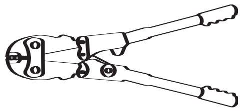
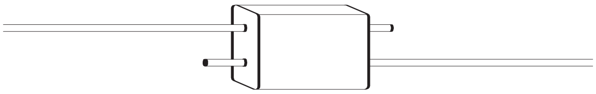
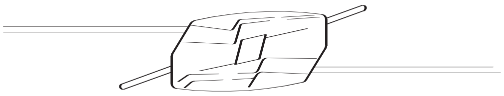
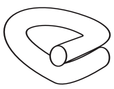
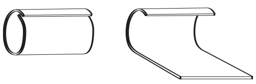


Figure 19

Joining line wires under high tension (A), rolls of rectangular mesh (B) or mesh to line wires (C).

(A) Line wire under 4000 N tension 2.64 mm spring steel or 3.15 mm high tensile	(B) Rolls of rectangular mesh netting
(a) Preformed fence connector (wound spiral)	
 Two connectors are used to join a wire	
✔ The join is always stronger than the joint	✘ A superior join but expensive ✘ Not suitable for mild steel net
(b) Sleeve connector (crimped)	
  Two or more sleeves are crimped around wire	 Tool for crimping sleeves
✔ Join stronger than wire if four sleeves used on spring steel wire. ✘ The only joiner requiring a special crimping tool	✔ Relatively inexpensive ✔ Can be used for mild steel netting
(c) Wire locking joint (push fit)	
	
✔ Join is almost always stronger than the wire	✔ Expensive
(d) Torpedo (push fit)	
	
✘ Join is weaker than wire	✔ Adequate (limited size range manufactured)
(e) Locking joint (push fit with internal wheel)	
	
✘ Join is weaker than wire and wire will creep through jaws when under tension	✔ Adequate
(f) Ratchet winders	
✘ Not suitable ✔ Low tensioned temporary and electric fences	✘ Not suitable

(C) Joining mesh to line wires
(g) Lashing rod (wide spiral)
Line wire Edge of net
✔ For joining net to line wire or the edges of net to net ✔ Stronger than ring gun clips ✘ Not suitable for joining hexagonal netting to line wire
(h) Ring clips CL22 style, galvanised with or without plastic coating

✔ Suitable for joining hexagonal mesh to line wire
(i) Clips for welded mesh

✔ Also suitable for joining paling fence to line wires

Joining rolls of rectangular or welded mesh netting

Proprietary joiners are made in several sizes and can be used to join the horizontal lines of high tensile wire mesh (Figures 19b–e). Each line wire is carrying about 500 N of strain. Twisting high tensile wires to join nets is not recommended because it will damage much of the protective zinc or colour coating and the action of wrapping often causes some wires to break. A proprietary bending tool (twister) can be used for joining the ends of *mild* steel net together because the strain is significantly less and the wire is more pliable. Straining the nets to tension is fully described in Section 9 (page 42 and Figure 45). An example of joined net is shown in Figure 20.

Securing line wires and all types of netting to wooden posts

Zinc-coated staples (40 mm x 4 mm diameter) should be used for fixing line wire to woodwork but to allow the wire free horizontal movement they should not be fully hammered home to pinch the line wire. Staples should be driven into the wood at a slight angle to the vertical to avoid creating a split along the grain of the wood. Some staples are manufactured with a barb on each leg and it is claimed that the barbs prevent the staples from being pulled out when the wood dries and shrinks. Rectangular mesh is stapled to stakes with 30 mm staples. For hexagonal mesh the use of 20 mm staples is sufficient. Plastic netting for temporary fences or marking in woodland grouse areas is not usually stapled to posts, though it can be held to a stake by a nailed batten (Figures 21 and 22d).

Figure 20

A simple way to join high tensile nets together; twisting the wires is not recommended.

Figure 21

Temporary fence mesh may be fastened to a stake by means of a batten.

Fixing netting to line wires

Hexagonal wire mesh netting can be attached to the spring steel line wires with galvanised wire rings dispensed from a magazine. Some plastic coated rings give a tighter hold where vandalism is a consideration. Monel metal pig rings are stronger but more laborious and time-consuming to fix individually.

The preformed lashing rod is stronger than wire rings and is recommended for attaching rectangular high tensile woven wire or welded wire mesh netting to line wires (Figure 19g). It is manufactured in two sizes. Lashing rods are also strongly recommended for tying two deer nets to the central straining wire.

Fixing marking materials in woodland grouse locations

The most critical part of marking a fence in a woodland grouse location is to ensure it is strengthened adequately to take the extra weight and wind resistance of the chosen materials – see Figure 15 and Section 6 (page 28). A variety of forms of marking material are indicated in the Scottish Forestry Grant Scheme including cleft chestnut, sawn wood or specialised UV-stable plastic mesh. If individual wooden battens are used for marking an existing fence, one end of the batten can often be woven behind the mesh before fixing the other end with a galvanised or stainless steel potato sack tie or heavily UV protected plastic cable tie, but two fixings may be necessary where battens are very close together. Orange UV stable plastic mesh should be placed on the windward side, nailed to the stakes, using a batten for added strength (Figure 22d), and attached at the top and bottom at a maximum of 1 m intervals with highly UV stable cable ties fixed *across* the joints and *not* clipped with a ring-gun to the thin strands (Figure 22a and b). Fixing bamboo with cable ties is under trial in very exposed areas. Rolls of chestnut or sawn softwood paling-style fence can be used and should first be hung on partly driven 100 mm nails near the top of each stake and then tensioned by means of a bar inserted behind each fence stake. The fencing is fixed with 100 mm sack ties (galvanised or stainless steel, Figure 22c) or strong metal clips used for welded mesh panels clamped alternately round the top line wire and the twisted wires, and then the bottom twisted wire and a horizontal of the net. The twisted wires should also be stapled into each stake as the nail is removed.

Figure 22

Woodland-grouse-friendly fencing must be strongly attached: (a), (b) heavily UV inhibited plastic cable ties must be placed across the intersections not across the weaker filaments; (c) stainless steel sack ties are suitable for attaching rolls of paling fence onto a deer fence; (d) a batten nailed through plastic netting provides an additional firm attachment in exposed locations.

6. Special situations: adjustments to specifications

Local circumstances, or the need to fence against several species simultaneously, may often dictate changes to the normal specification. Such potential changes should be assessed carefully because failure to do so may jeopardise the objective of the fence.

Ground conditions

Longer posts and stakes may be necessary in soft ground. In areas with heavy deer pressure it may be better to use one size thicker posts and stakes. In stony soils, the use of an auger (Figure 23) to loosen the soil in the hole (taking care to leave the soil in the hole to provide a tight fit) may be useful for driving pointed straining posts to an adequate depth. Metal posts can be used in rocky locations, perhaps using a compressor-driven post hammer.

Figure 23

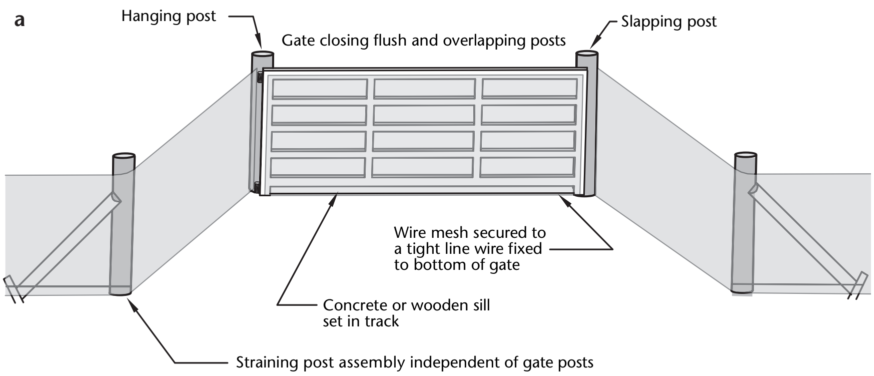
Machine driven augers save time, both for starting the traditional end post with an underground cross-member (see Figure 4a) or for loosening the ground (and leaving the loose soil in the hole) when driving large pointed strainers.

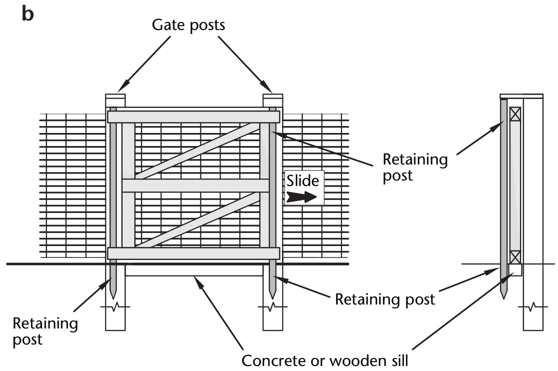
Access points: gates and stiles

The manager must assess the need for a gate against alternatives such as stiles or altering the location of the fenceline. The likely frequency of use of any access point must be determined: a simple hinged or sliding gate (Figure 24a, b) if use is to be infrequent, a stile or some form of self-closing mechanism if it is to be used regularly.

Figure 24

(a) The general form and details of a gate designed to keep out mammal pests showing that straining posts must not be used as gateposts. (b) A sliding gate for occasional use.





The inclusion of any opening mechanism within a length of fence is a potential weakness because of the risk of it being left open and the difficulty in making the gate as secure a barrier to wildlife as the fence. Gateposts should be independent of straining posts to avoid the slight but unavoidable movement of the straining post over time, altering the swing of the gate and the ability to latch it shut. There is a variety of options as shown in Figures 25a–d. Gaps between the bottom of the gate and the sill, the hanging gatepost and the gate, and the gate to the slapping post must be small enough to prevent the target species squeezing through. A single wooden or concrete sill will be required beneath the gate to prevent any burrowing under (Figure 25e) and to be strong enough to prevent wheel ruts from vehicle traffic. Gates should be hung with a reversed top hinge to prevent them being lifted off, and padlocked if there is no public access. Self-closing mechanisms, e.g. special hinges or a spring assembly (Figure 25f), can be used but may not be reliable.

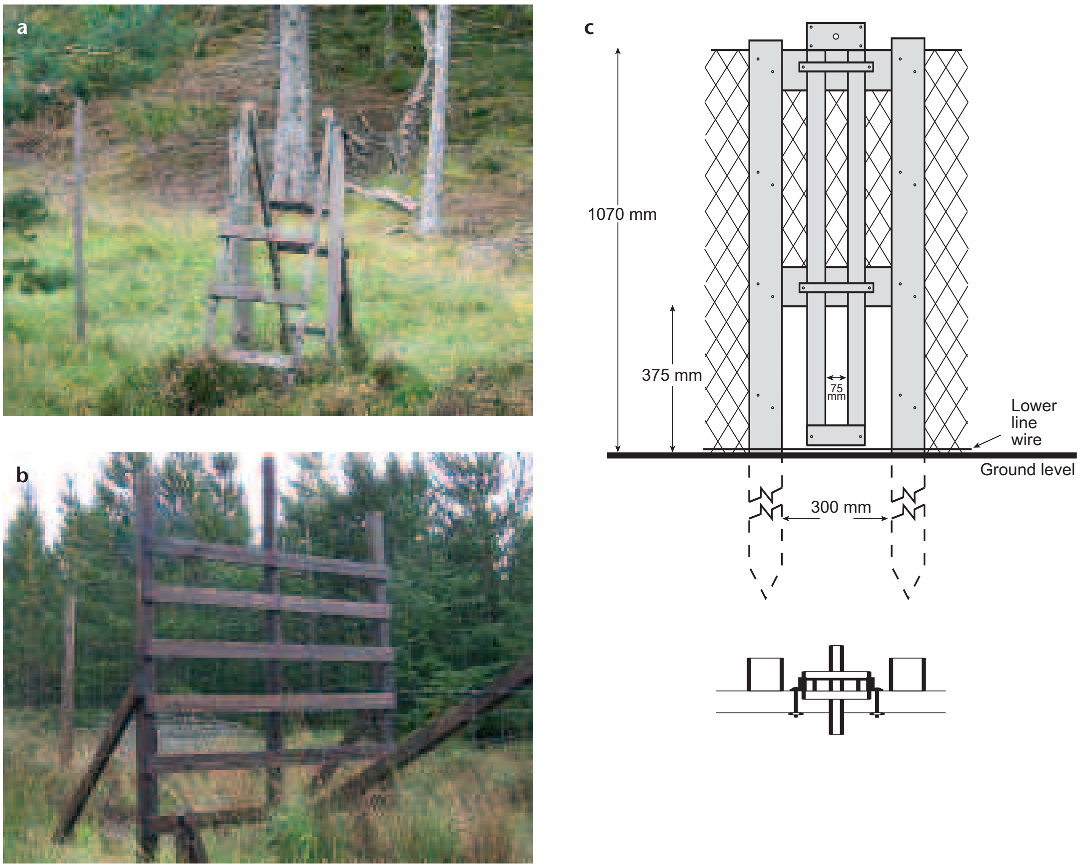
Figure 25

Gates used in fences: (a) and (b) person gates; (c) panel gate for vehicles; (d) full public access gate; (e) lack of a cill has resulted in rabbits gaining access; (f) self-closing hinges and mechanisms are becoming more reliable.

Stiles (Figures 26a–c) can be a useful form of crossing but wide-tread steps over relatively low deer fences can easily be used by sheep and deer. If the fence crosses a right of way a suitable gate/stile or bridle gate must be provided. Since October 2004, service providers also have to make 'reasonable adjustment' to the physical features of their premises to overcome physical barriers to access under the Disability Discrimination Act. Designs specifically for disabled access through fences are available, though there will be many remote locations where the most severely disabled are unlikely to go. The cost of providing and installing a wheelchair accessible gate in a deer fence is considerable. The possibility of siting small integral pedestrian gates within existing deer mesh fences in more remote areas is being investigated (Figure 25b).

Figure 26

(a) (b) Stiles, ladders and (c) dog latches also have a place in easing public access.



Roads, side roads and road grids

The height of forest fencing alongside motorways or main roads should follow the Highways Agency guidelines *Design manual for roads and bridges* (Highways Agency, 2005a). They are higher than the minimum forest fence height given in Table 4. Ungated road, junctions or track entrances are the greatest weakness of long fences. Where these are crossed by roads or tracks that cannot be gated, fenced or gridded, it may be appropriate to construct curved 'wings' from the main fenceline to the side road edge. The curved wings act to encourage the return of the animals back into the remaining cover. The wings should be of at least 50 m for rabbits and up to several hundred metres long to deflect deer away from the gap (Figure 27c). If it is practicable, any cover from the roadside outside the fence should be cleared back – this allows drivers to see deer easily and may deter some deer from entering an open space. This layout is a compromise because no fence conformation can prevent all (especially migrating) deer from finding the gap; it is inevitably a weakness.

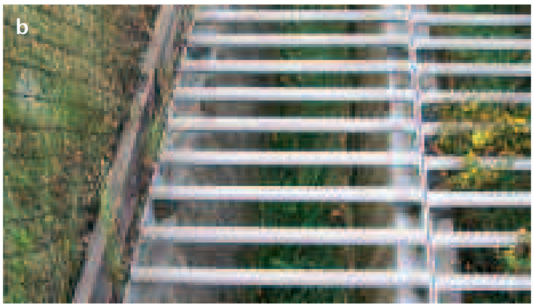
Cattle and horse grids are common in upland areas. Normal cattle grids have too short a span to prevent jumping by deer but may work for enclosed farmed or parkland deer. A minimum 4 m deer grid specification for roads is given by the Highways Agency. The grid should be located within the line of the fencing (Figures 27a, b and c) to reduce the pressure to cross the grid and allow undecided animals to divert at the last moment. Grid construction should include bars of round section pipe or rolled steel bar that is sufficiently strong and supported underneath to take the appropriate weight of traffic (Figure 27b). Positioning of any grid planned to deter horses, sheep or cattle and deer should be near the end of curlback wings (Figure 27c), not at the original fenceline. In this way a hesitating animal has every opportunity to move away along the fence or into adjacent cover and not attempt to jump the grid. An adjacent bypass gate must also be constructed and the barrier must be to the specification of the fence and be able to withstand the abilities of the wildlife species to climb over, push through or burrow under to the same degree as the fence. At each side of the grid there must be side fencing of adequate height, longer than the full span of the grid and tight to its edges to prevent animals jumping across.

Figure 27

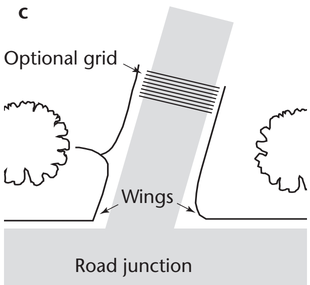
Fencing or gating across frequently used roads is often unrealistic. (a) Inclusion of a deer grid. (b) A road grid using rolled steel bar or round section steel pipe will deter deer crossing only if it creates a sufficiently wide barrier. Normal cattle or pony grids are insufficient to stop a jumping deer. (c) Shaping the fenceline to guide deer away from the weakness formed by the gap.

a

b



c



Deer leaps

Deer trapped inside a fenced area may leave if provided with a suitable exit. Natural features close to the fence on the inside can be enhanced to create a deer leap by use of stone or roundwood timber covered by turf to raise the level by about 1–1.5 m above the surround. The fence height from the outside must not be reduced (Figure 28).

Figure 28

A well-positioned deer leap allows deer to escape from an enclosure.

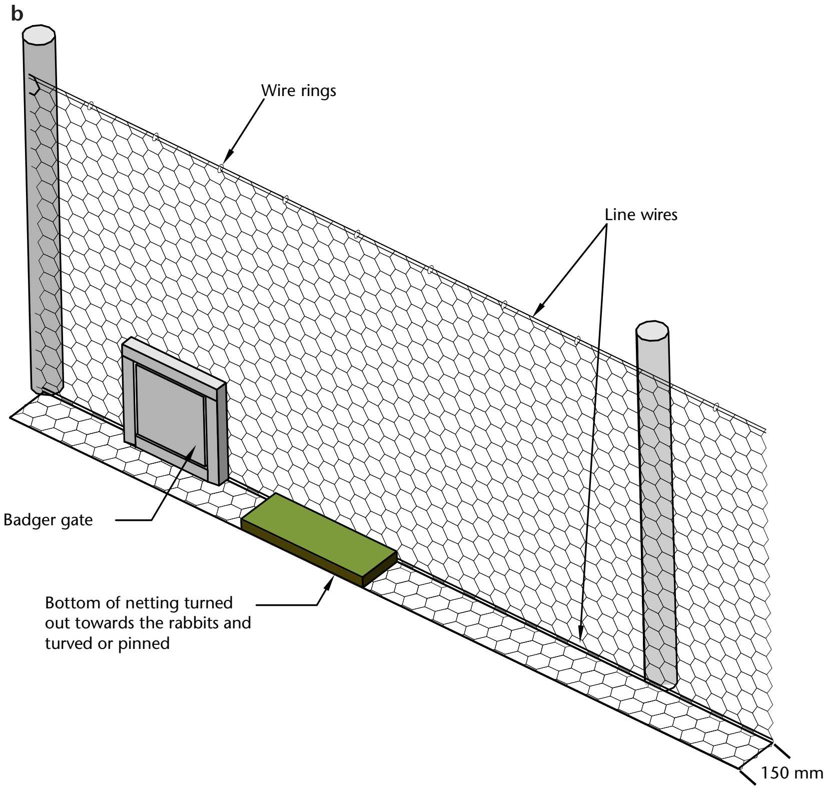
David Whitaker

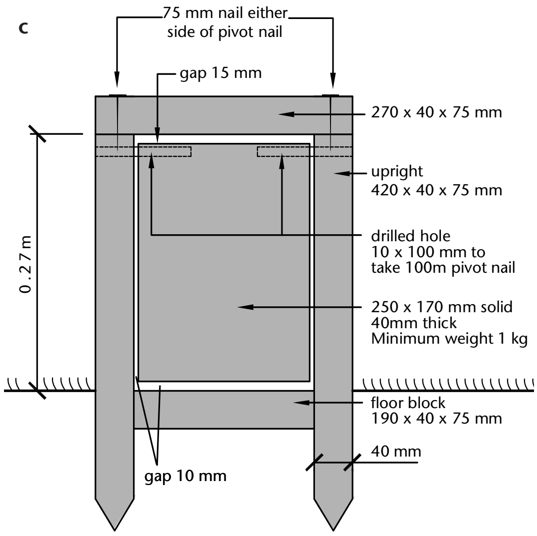
Badger gates

Badger gates are installed in rabbit fences when the fence crosses an established badger run (Figures 29a–c). The gate allows badgers to continue to use the run in the presence of the fence without allowing rabbits to pass through. If a gate is not installed the badgers will tear a hole in the netting or alternatively may excavate underneath the fence. Reports indicate that muntjac are capable of opening metal mesh gates, therefore it is important to use heavy wooden gates where this species occurs.

Figure 29

Badger gate: (a) a heavy timber gate prevents rabbits pushing through; (b) positioning within rabbit fence; (c) specifications.





Watergates and culverts

There are several ways to allow for water passing under a fenceline that crosses a watercourse, drainage gulley or even a small river (Figures 30a–c). It is recommended that straining posts are not installed on the edges of river banks where varying water levels occur. Under conditions of spate a fixed simple grill of fencing net (Figure 31a) may clog with debris and result in the fence being washed away. Watergates are less likely to clog as they are hinged at the top to rise and fall as the water level fluctuates. There needs to be a hard bottom to the watercourse where it is crossed by the gate; if this does not occur naturally it may have to be made of concrete, welded mesh or steel girders. Consultation with the appropriate fisheries and water quality regulatory authority is necessary (Forestry

Commission, 2003). The design and size of a gate will depend on the width and depth of the watercourse to be crossed (Figures 31b, c and d). The use of fixed (multiple) polypropylene plastic culvert pipe (Figure 30c) of appropriate diameter in the stream bed acting as a deer grill is possible for smaller waterways. Minimum guideline pipe diameters of 30 cm have been devised (Scottish Executive, 2000) to aid fish passage at the lowest flow level, though smaller diameter pipes may be placed above.

Figure 30

Fencing across waterways is always at risk from clogging by debris and being washed away. (a) Pivoting gates are less likely to clog than (b) grills or (c) small pipes.

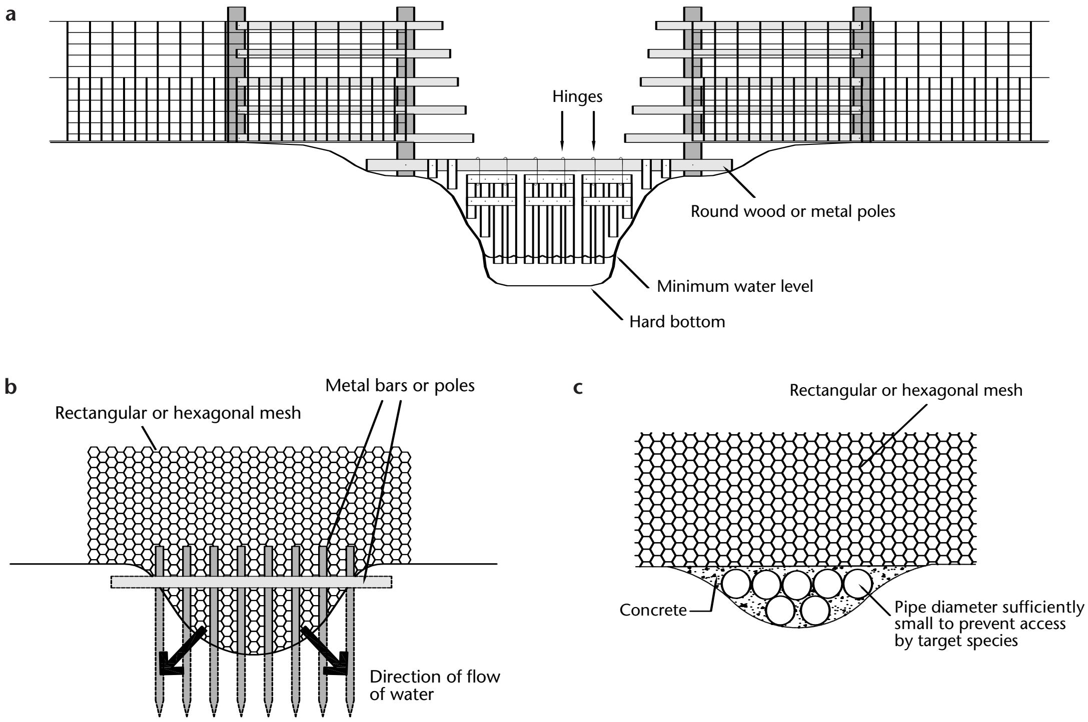


Figure 31

Deer fencing specifications adapted where they cross waterways: (a) an area with only occasional flow; (b) a small ditch; (c) a small river gate hinged on a wooden pole; (d) a large river gate hanging on a substantial steel cable (with woodland-grouse-friendly marking on the fence above).

Areas with high exposure

Hexagonal mesh netting manufactured from pre-galvanised wire always has a degree of flexibility in the twists which may cause metal fatigue and failure when the netting is situated on sites exposed to high winds. For this reason four spaced line wires should be used. Mesh galvanised after manufacture is less prone to this problem.

Bracing struts with ground pegs are sometimes required at right angles to the fenceline to brace deer fence stakes on exposed sites or over shallow soils; these should be 2.7 m x 30 mm x 75 mm and fixed higher than two-thirds of the way up the stakes (see Figure 15, page 17). Where a specific section of the netting is designed to collapse from the support structure under severe snow conditions, smaller staples should be used in construction and consideration given to the use of only partly crimped aluminum sleeves for joining that section of net.

Locations with woodland grouse

To counteract the tendency for woodland grouse to be killed or injured on wire fences, a variety of materials may be attached to the fence to make it more visible to them. The bracing procedure previously outlined (Figure 15), together with checking straining posts, adding extra stakes and top line wire is often essential to counter the extra weight and sail effects of adding such marking material to fences (Figure 32).

Typical marking structures such as lengths of wood or special plastic netting are listed in Table 5 for existing fences and described in Section 4 (page 17) for new fencing. The use of small swinging metal plates or short lengths of rope is not generally recommended. Three levels of priority location are generally agreed by specialists.

1. Within 1 km of lek (breeding) sites marking should be extremely obvious with wooden marking material 15–20 cm apart if vertical or 60–70 cm if set diagonally at 30–45 degrees. In sheltered (internal woodland) areas, UV-stable plastic mesh can be used in 1.2, 0.6 or 0.3 m widths. As exposure increases the width of netting should be reduced.

2. Elsewhere in capercaillie core areas, and in black grouse areas, wooden marking material should be 25–30 cm apart or 50–75 cm if set diagonally, or plastic mesh used as described above.

3. In the most exposed situations, wooden droppers can be placed diagonally at about 75–100 cm spacing, plastic net should be in 30 cm widths (if used at all) and, exceptionally, the use of bamboo or other narrow material can be considered.

Figure 32

Strutted stakes reduce the incidence of grouse-friendly fences collapsing in exposed locations.

Table 5

Materials for marked fences where capercaillie or black grouse occur. Advice should always be sought from the capercaillie project officer or local FC advisor.

Location: sheltered, intermediate or exposed	Material	Specification	Attachment: vertical or diagonal (Figures 22, 33 and 34)
A. Existing net fences			Attachment to existing net or line wires.
• Sheltered	Specialist UV stable plastic mesh positioned against prevailing wind	1.2 m x 50 m rolls. Cut to 1.2, 0.6 or 0.3 m width according to exposure	Heavily UV stabilised cable ties placed across 'knots'. Nailed batten on stakes.
• Sheltered or intermediate exposure	Individual chestnut pales Sawn softwood droppers/battens	1.8 m or 0.9–1.2 m 15–20 mm x 12 mm[a]	Vertical or diagonal: individual fixing with stainless steel or galvanised sackties.
	Manufactured rolls of chestnut or sawn softwood[a] with 2 or 3 sets of twisted wires	9 m rolls of 0.9 m or 1.8 m split pales from paling winding machine	Vertical: stainless steel or galvanised sack ties; heavy duty clips used for welded mesh; staple to each stake.
• Very exposed	Bamboo canes or Sawn battens	1.2 m length 1.2 or 1.8 m; wide spacing	Diagonal: heavily UV stabilised cable ties. Diagonal: sackties.
B. New fences[b] (all situations)			
• If full deer height	Manufactured rolls of chestnut or sawn softwood with 4 sets of twisted wires. Gaps of 120 mm for roe deer, 250 mm for red deer	9 m rolls of 1.8 m chestnut pales of c. 100 mm circumference. If sawn timber, minimum 31 mm x 31 mm treated and inspected for quality.	Vertical: attach to 3 line wires with stainless steel or galvanised sack ties; or clips suitable for welded mesh; staple twisted wires to each stake.
• If lower stock net but no upper mesh	Manufactured rolls of chestnut or sawn softwood with 3 sets of twisted wires as top section of fence	9 m rolls of 1.2 m chestnut c. 100 mm circumference or sawn wood minimum 31 mm x 31 mm treated.	Vertical: attach to 2 line wires with stainless steel or galvanised sack ties; or clips used for welded mesh; staple to each stake. Attach lowest twisted wire to stock net with most pales towards the deer.

[a]Sawmills often have a cheap tile batten specification.
[b]In exposed locations new fences may be treated as 'existing' mesh fences using netting and then marked as in the A section of the table.

Where march (landowner boundary) fences are involved (Figure 33c), the use of split chestnut pales, sawn larch or red cedar droppers/battens is preferable because of their longevity, but otherwise treated softwood is adequate. A single detailed specification of dropper size is unrealistic but a high quality of manufacture is important (Figure 33a). Timber length used varies from 0.9 m placed vertically (Figure 33b) covering the top section of fence to 1.8 m in areas of highest risk. Droppers fixed at approximately 45° to the vertical are very visible for the amount of wood used (Figure 33d). Droppers should be placed at intervals along the fence with the interval varying according to advice on highest collision risk locations or sites with high exposure. One end of the dropper can usually be woven behind the mesh before fixing with a galvanised or stainless steel potato sack tie or heavily UV-protected plastic cable tie (see Figure 22). Where only temporary use is required (less than 8 years) such as marking a fence due for removal in a few years, untreated softwood or orange UV stable plastic mesh may be used. (The orange mesh normally used in association with roadworks is not UV stabilised and is *not* suitable.) Demonstration sites have been constructed in eastern Scotland to show options for marking materials and attachment methods (Figure 34).

Figure 33

Timber attached to deer fences can reduce deaths of woodland grouse. (a) Poor quality manufacturing soon becomes apparent. (b) This newly marked fence will become less obvious in the landscape as the timber weathers. (c) Paling with 1.8 m wide spacing marking an estate boundary fence. (d) Diagonally placed pales, even when widely spaced in this exposed site, are obvious to woodland grouse used to flying through vertical trees.

Figure 34

A demonstration site west of Perth shows options for marking fences to protect woodland grouse.

Fences ending at water or cliff edge

In freshwater lakes where levels are unlikely to alter significantly and, more importantly, there is no water current, a panel of welded mesh (preferably galvanised) of appropriate mesh size can be used. For rivers and sea edges it is not usually appropriate to fence into the water because of the impacts of flotsam or currents on the fence, together with the variation in distance between high and low tide. Since deer swim it may be appropriate to construct wings from the main fenceline parallel to the water's edge for at least 50 m to deflect the target animals away. The visual aspect may also be important, and individual tree protection or pest population management may be more appropriate. In areas of regular heavy flooding and high flow rate, e.g. river flood plains, fencing may not be an appropriate form of management, unless positioned on top of an earth bund or angled to allow deflection of flotsam back into the river during spate conditions. Creating the critically necessary short overhangs at cliff edges requires particular attention to safety (Figure 35).

Figure 35

Contractor safety becomes especially important when fencing at a cliff or rocky outcrop but, as shown here, a short overhang is definitely required.

Vandalism

Dealing with vandalism involves both planning and choosing components on a case by case basis. In extreme instances, trees cannot be protected and there is no point in fencing because any materials used are removed or damaged (Hodge, 1995). More frequently, an increase in component specifications may improve the strength to reduce damage, e.g. plastic temporary net and thin hexagonal wire mesh erected against deer may be rendered useless, whereas a more robust locked joint high tensile metal net could be effective.

Materials may need to be laid out on a daily basis to avoid pilfering. Box section straining stays are prone to being cut; therefore strutted wooden straining posts with extra heavy wooden struts secured by mortice and tenon joints and well-nailed together are preferable. Use of spring steel or heavy high tensile line wires and high tensile types of mesh may reduce casual damage to fences because it cannot be cut with normal pliers. Locked joint rectangular mesh is more difficult to prise apart than hinge joint material. Barbed staples are often less easy to remove.

Welded mesh panel gates, a padlock through predrilled holes in gate pintles or reversing the top pintle should be considered. Where the tensioning nut is designed to break away from the assembly, cone bolts make it more difficult to remove gate hinges or bolted components (Figures 36a and b).

Figure 36

(a) A special breaking nut system for a gate hinge reduces the chances of vandals removing the gate.
(b) The nut automatically breaks after tightening.

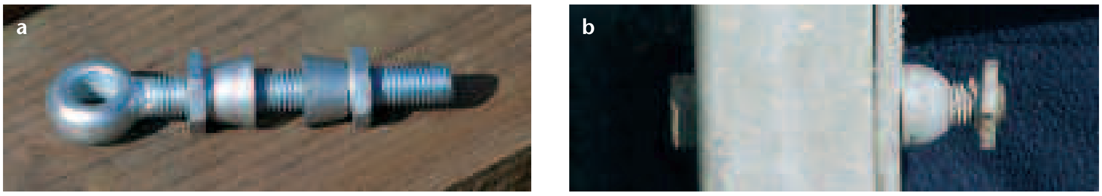


Figure 37

A vandal-proof electric fence box keeps the components safe by remaining 'live' until switched off by a key.

For rabbit fences, even 1.2 mm (18 gauge) net can be kicked through. The use of hog rings or tightly fitting plastic covered ring clips instead of the normal CL22-clip type reduce the ease of removal of the netting from the line wires. Electrified plastic rabbit netting is too insubstantial. Electric fencing installations can be protected by a 'live' vandal-proof box enclosing the energiser placed just inside the fence with a lock, inactivation key and warning sign (Figure 37). Wind generators or solar panel chargers should be placed well within the enclosure or hidden nearby and connected to the battery by an underground insulated cable. Clearly sighted warning signs are compulsory on an electric fence of high voltage electricity where there is public access.

7. Temporary fencing

Temporary netting fences are planned to be in place and active for a specified and relatively short time, e.g. 2–5 years when protecting small coppice coupes or restock sites of less than 1 ha with good growth potential. They should not be considered as a cheap substitute for long-term fencing or for large areas, or against severe deer pressure. Used against deer, they rely on less robust fence support structures and cheaper materials than permanent fencing (Figures 38a–e). There are differences in principle and detail in the support structure and cladding that create considerable variation in costs. Table 6 outlines the types of components and an indicative life of a variety of temporary fences. It may be possible to carefully dismantle and reuse some of the materials from a temporary fence. In other respects the planning and construction processes are the same as for normal fencing, except that large areas (greater than 5 ha) should not be enclosed because deer must easily be able to move round the edge and not seriously challenge the fencing. The minimum height and maximum mesh criteria must still be followed.

Table 6

Generic options for temporary fences.

Structure and status	Corner posts	Stakes	Cladding material	Life
Cheapest, not reuseable	Untreated, cut on site; tie back to stump or pollarded tree	Untreated, cut on site	Light hexagonal or cheap high tensile (HT) plastic	2 years
Reusable	Treated softwood; durable hardwood; steel; box section corner assembly; tie back to stump	Treated softwood; durable hardwood plastic; steel	HT plastic; reinforced hexagonal; light HT metal; chestnut paling; welded mesh panels[a]	2–3 cycles
Electric fence[b] Initial expense of solar panel/ wind generator	Treated or untreated timber with tough insulators	Plastic, with set or adjustable height options; wood	6–7 line wires of braided plastic rope or tape. Multistrand cable wire; 2 mm HT line wires	2–3 years 3+ cycles

[a]For temporary rabbit fencing see Cladding material (page 33).
[b]Electric fence details are given in Table 7 (page 37).

Fence support structure

- Pointed corner posts can be driven in and tied back with wire and stapled to a stump or tied to the base of nearby pollarded or coppiced trees (Figure 38a); the wire must be separated from the live trunk with pieces of wood and ultimately removed.
- Pointed stakes can be used of untreated wood cut on site.
- High tensile (HT) 2 mm line wire can be used since great tension is not required to hold the lighter weight mesh.
- For longer duration, e.g. 5 years, or complete reuse of materials, more durable hardwood or treated timber, plastic recycled or steel stakes are required.
- For electric fences see Section 8 (page 35) and Figure 38d for an example of temporary electric fencing.

Figure 38

Temporary fencing is not designed as a cheap alternative to permanent fencing: (a) a tieback corner post is effective for a couple of years; (b) thin hexagonal mesh fencing; (c) lightweight plastic mesh; (d) electric strand fences appear effective for protecting small coppice coupes for 2 years against low–medium deer pressure; (e) metal security panels as used on construction sites provide a temporary fence against deer in a high value conservation woodland.

Cladding material

- Lightweight rectangular net of HT15/1550/15 or HT 17/200/15 is suitable for all deer except muntjac. The recommended 1.5–2 m wide netting against muntjac is 50–75 mm hexagonal galvanised mesh or high tensile plastic net of 60–80 mm mesh, provided the latter is tensioned (see Figure 38b and c). Any net should be lapped 150 mm on the ground where muntjac are present. Muntjac net of LHT 23/167/8 is available (see Figure 14, page 16).

- High tensile plastic net must be properly strained using straining clamps, not just by hand, but the strain must not reach the level to which high tensile steel net is strained, as it may 'unzip' if damaged later. (Use a hand-held hedge cutter to remove excessive vegetation prior to recovery; a strimmer may result in damage to the net.)

- Soft plastic nets and those composed of loose woven fine filaments are not recommended because they can easily entangle in deer antlers.

- Temporary rabbit fencing has a use around coppiced or short rotation biomass crops, for example welded mesh net (900 x 25 x 25 mm 16g) could be used for the main vertical barrier. A narrow 300 mm roll (created by cutting a 600 mm roll in half) of hexagonal rabbit net as a sacrificial portion comprising both the horizontal lapped and overlapping the lowest part of the vertical structure. The expensive welded mesh is reusable because it has continuous horizontal wires and can be re-rolled but the narrow hexagonal net is removed by pulling up with a tractor and then disposed of safely. Some hexagonal rabbit mesh styles have sufficient strengthening horizontals within the netting width (>4) and may resist excessive deformation during recovery, as long as herbicides have kept vegetation growth to a minimum.

- Durable welded mesh security panels or chestnut paling with four sets of binding wires have been used for small enclosures or in particularly sensitive woods (see Figure 38e).

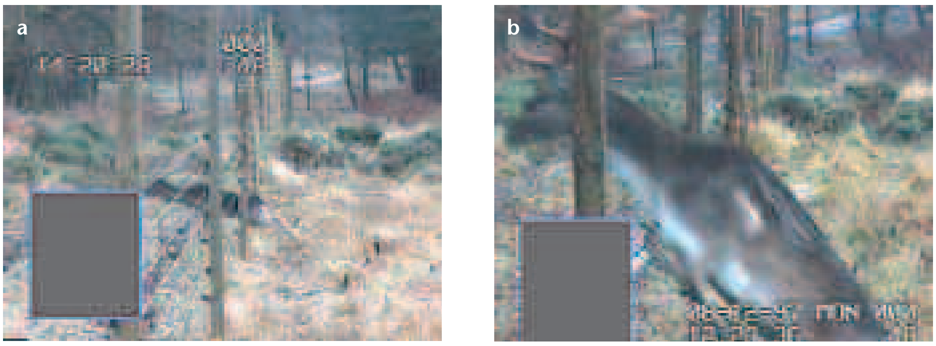
- Reusable gates of welded 75 x 25 mm mesh panels (sited on strong timber cills) are useful for vehicle access (see Figure 25c, page 23).

8. Electric fencing

The principle of an electric fence is to provide a sufficient short pulsed electric shock – ideally 5–9 kV for under 1/1000th of a second – along a wire and through the thorax of any animal touching it. The animal learns to avoid attempting to cross what may be only a very weak physical barrier. Electric fences have been used as permanent or as temporary fences, but opinion is divided on their effectiveness against wild deer, and different species appear to react differently. They consist of line wires supported by stakes but separated by insulators. The exception is for rabbits or sheep where electrified plastic netting containing fine wires is available. Electric fences may be effective for short-term exclusion from small areas, e.g. coppice coupes or established biomass rotation. Research on rabbit fencing has indicated that well-maintained electric netting fences may be less costly in materials and maintenance than traditional fencing for up to 7 years. The long-term effectiveness, such as an alternative to traditional netting fences for deer, is much less certain and lacks data on formal trials. Opinion varies greatly on all aspects: specification, power supply and whether electric fences are fit-for-purpose for wild deer (see Figure 39a and b). The need for the animals to cross has considerable influence on the specification required (if indeed it can work at all) and the same specification on one site may fail on another. Under limited deer or rabbit pressure they may work. Roe deer may be the hardest to contain by electrified line wires. Confusion has also arisen partly because of the tendency to overstretch the capabilities of electric fencing by using long or unmaintained lengths of fence or placing it across major deer movement trails. Enclosing only small areas on a 'divide-and-rule' principle of allowing or diverting access from part of the range appears successful in some lowland coppice trial areas but requires a high maintenance input. The use of electrified outrigger wires or two sets of electrified wire assemblies about a metre apart are claimed by some practitioners to be effective. However, compared to mesh steel fences, electric fences are not as certain a long-term barrier to wild deer (except perhaps red deer) or rabbits over a wide range of site conditions. Protecting small areas in the short term is more appropriate.

Figure 39

Electric strand fences appear less effective against high deer pressure: video shots of fallow deer illustrate that (a) females can push through and (b) males jump over.



Components

Six components form an electric fence system.

1. The **energiser** produces a pulsed electric current which is directed along the fence wires. Many have high and low output voltage settings. For animal welfare and human safety, the current code of practice is that they should not produce more than 5 joules of energy

at 500 ohms. They may be powered by either mains supply or battery. Batteries have to be regularly recharged from a mains supply, or be connected to a wind generator or solar panel (see Figure 40) via a non-switching voltage regulator to prevent overcharging. 'Leisure' or deep-cycle marine batteries are recommended because they are more suitable than tractor or car batteries to withstand the fluctuating and often low state of charge.

Figure 40

Solar panels and wind generators are now relatively reliable for charging battery-powered energisers.

2. An **earthing rod assembly** is an essential requirement to return the electrical pulse of energy to the energiser. It consists of one or more copper covered or galvanised steel rods driven into the ground and firmly clamped to the return wire of the energiser. Very dry soils are poor conductors of electricity and a tensioned line wire placed on or just above the ground along the fenceline and earthed with a metal peg every 50 m will assist in the conducting process.

3. **Fence supports** may be made of wood, metal, plastic or fibreglass. Some proprietary forms have built-in fixed or adjustable insulators. Wooden stakes with strong insulators are needed where tensioned HT wires are used.

4. **Insulators** are a fundamental component, ensuring the pulsed current is not lost to earth but maintained to provide a high voltage shock (recommended at 4 kV or above) to any animal touching the fence. There are many forms and types available suitable for particular situations.

5. **Conducting wires** may be of single or multi-strand steel wire or plastic twine, string, rope or tape containing fine stainless steel wires. Barbed wire must never be installed as an electric fence. Wires may be tensioned by proprietary in-line strainers appropriate to the line wire material. Electrified netting should only be used against sheep, rabbits and foxes; deer, hedgehogs and other wild animals may get entangled as they react to a shock. All electrical connections should use proprietary joining clamps. Conducting wire or mesh must have high voltage warning signs.

6. A **fence tester** is essential during maintenance to show whether the fence is providing sufficient voltage. Reliance solely on a fence 'flasher' unit is not recommended. The inclusion of some appropriately hidden isolating switches can save time during maintenance.

Specifications

Most fences rely on multiple parallel wires, with the number relating to the size and agility of the animal (see Table 7). However, experimental trials using video cameras in a high pressure situation suggest:

1. Roe and muntjac are not permanently deterred by even seven line fences.

2. Roe in particular appear to have a high body resistance to electric shock sensation.

3. Electrified line wire fences become effective against roe only when unelectrified wires give a similar result, suggesting that the physical barrier itself is the key.

In contrast, some local experiences from Scotland indicate that a single high tensile 2.5 mm 'scare-wire' at 1 m height, placed 0.75 m from an existing stock fence or wall, can keep out most red deer if properly maintained. A stand alone double fence of high tensile electrified line wires at 0.5 and 1 m height is also claimed to work against red deer. Trials in East Anglia around small coppice coupes of 0.5 ha suggest that six electrified line wires are effective against low populations of fallow, roe and muntjac for 2 years.

Table 7

Recommendations for electric fences for stock and wildlife (based on McKillop *et al.*, 2003).

Species		Live wires	Earthed wires (E)	Height of wires, each measured from ground level (mm)
Domestic stock				
Cattle (full grown)	(a)	1	0	750–850
	(b)	2	0	350–450; 750–850
Cattle (calves)		1	0	450–600
Pigs (full grown)	(a)	1	0	300–400
	(b)	2	0	200–300; 350–450
Piglets		2	0	150; 350–450
Sheep and goats		5	0	150; 300; 450; 650; 900
Horses		1	0	750–850
Wildlife				
Rabbit		6	1	50(E); 100; 150; 200; 250; 300; 400
Badger		4	0	100; 150; 200; 300
Fox (earth/live)	(a)	4	4	50; 150(E); 250; 350(E); 450; 600(E); 800; 1050(E)
	(b)	1	0	Offset to metal mesh fence by 50–75 mm at 1200–1500 mm high
Boar	(a)	2	0	250, 375 offset from mesh fence by 250 mm
	(b)	4–6	2	2 offsets as above + 100(E); 250; 450(E); 700; optional 950;1250
Red deer	(a)	7	0	(a) 300; 600; 900; 1050; 1200; 1500; 1800
	(b)	1+2	0	(b) scare wire at 900, set 0.75 m forward of second energised fence at 600 and 900.
	(c)	2	0	(c) scare wires at 600 and 1000 set 0.75 m forward of stock fence or wall
Fallow deer		7	0	300; 450; 600; 750; 900; 1050; 1200
Roe deer		5	0	300; 450; 600; 900; 1200 NB: not recommended for high pressure
Muntjac		6	0	150; 300; 450; 600; 750; 900

Notes
1. Most wild animals require more wires than domestic stock.
2. (a), (b) and (c) indicate alternatives used by practitioners and reported as satisfactory.

Construction and monitoring principles

There are five critical principles in the successful use of electric fences.

1. Any length of electric fencing must be constructed *and* made live (including the earthing arrangement) on the same day to ensure any animal touching the fence always receives a shock. A further section can be completed and electrified each day. Rabbits in particular will continue to cross an electric fence if it was not electrified when first encountered.

2. Adequate tension must be provided to prevent a 'dead short' through energised wires touching the ground (or aerial earth wires shorting) which will damage the equipment and render the fence inoperative.

3. Monitoring should ensure the fence remains live and is not allowed to be unpowered for any period; proprietary alarm systems are available to warn of failure for mains powered units.

4. Regular maintenance and inspection is essential, not only to check the voltage but also the integrity of the fenceline posts (for example line fence contour posts across valleys may be pulled up). Broken insulators must also be replaced.

5. Vegetation control is often required. This may be by spraying a herbicide or careful use of a strimmer.

Other points to consider include:

- High tensile or braided steel line wires and plastic rope or tape can be tensioned with cotton reel or ratchet type strainers. In-line springs should only be used with high tensile wire.

- The use of live and earth line wires, as indicated in some of the specifications in Table 7. In theory this can be useful for animals that may jump *through* the fence because an animal off the ground is not providing an earth and will not otherwise receive a shock. However if it is jumping forward it may still continue through the fence through inertia and be trapped inside. Using all live wires is the best option because it ensures any shock passes though the animal's sensitive thorax.

- Corner posts and intermediate stakes require multiple insulator locations. Plastic and fibreglass stakes are self-insulating, some have adjustable fittings.

- Fence and power source must be removed immediately the need for it stops.

The important safety aspects of electric fencing are included in Section 12 (page 48).

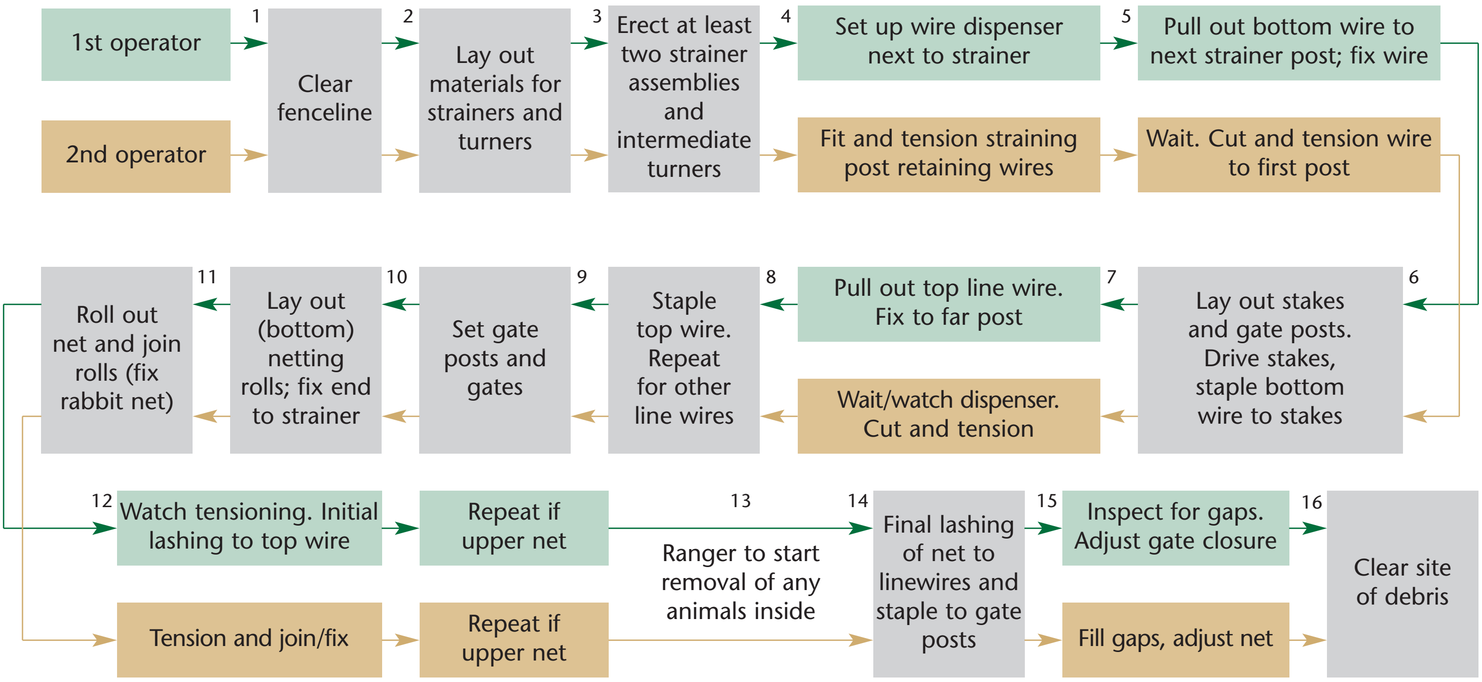
9. Constructing a typical forest fence

Sequence of operations

The detailed method of approach to each operation will vary according to whether the fence is being erected with or without the aid of a vehicle or power tools but the basic sequence of operations (16 in total), as outlined in Figure 41, will remain the same. A team of two, or multiples of two, is usually the most cost-effective.

Figure 41

Sequence of operations for a two-person fencing team constructing a deer fence.



Operations 1–16

1. Clear the general area of the fenceline. Removing vegetation beforehand, using tractor or power equipment can greatly ease subsequent fence construction. This may include the removal of existing fencing. Unless an existing fence has recently been erected it is rarely possible to rely on reusing any existing line wires or barbed wire, for safety reasons. Whether or not high tensile netting is wanted again, when removing an existing fence with the line wires or high tensile mesh still under strain, the fence should *only* be cut equidistant between strainers with all the stakes, fence mesh, rings, lashing rods and staples still attached. This is to reduce the safety hazard resulting from the springback of the tensioned net, which may be several metres per 100 m. It is critically important that any other staff should be immediately behind the cutter, not to one side. Proprietary hand tools are available to assist in lifting stakes out of the ground. Alternatively a machine with a protected cab can be used to release the tension by lifting or breaking the corner posts inwards. The fence net and line wires should then be cut into approximately 50 m sections, rolled up, flattened and removed offsite for disposal. Optionally, the stakes can be retrieved. Both the transporter and the disposal site require licensing under the Waste Management regulations if tanalised timber is being disposed of.

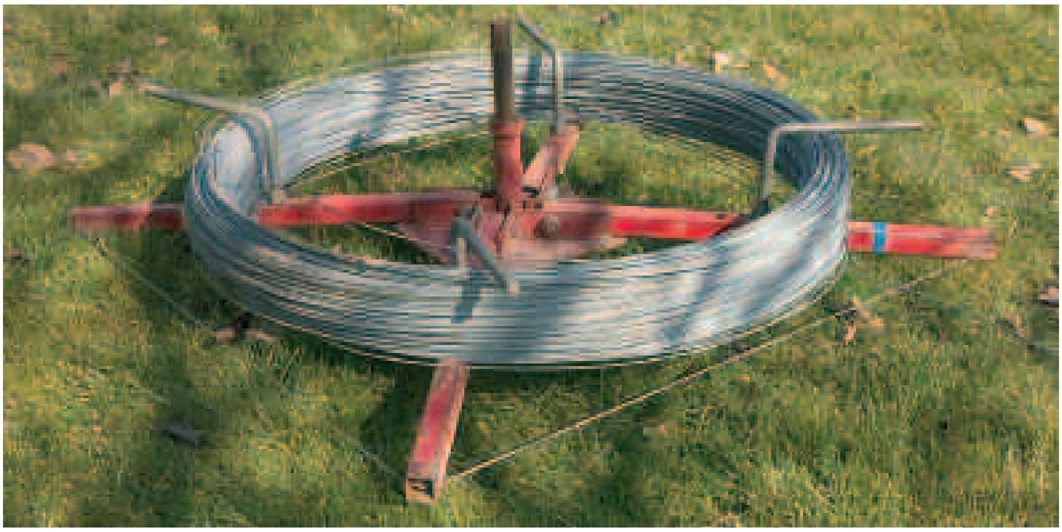
2. Distribute the new materials regularly along the route by manual vehicle, trailer or even helicopter (except where pilfering is likely).

3. Construct at least two end post assemblies (posts dug and set by hand or driven by machine) with intermediate contour and turning posts in between. Both strutted and box strainers require tensioned loops of HT line wire to provide rigidity as shown in Figures 4a and b (page 6).

4. Set up the line wire dispenser. A wire dispenser must always be used when uncoiling line wire (see Figure 42). The starting end is usually marked with a label and this end is placed on the base of the dispenser so that when the wire is pulled out it comes from the *underside* of the roll. The clamps on the dispenser should be secured over the roll of wire *before* the binding wire is cut. The dispenser is located beside post A ready for the wire to be pulled to post B.

Figure 42

A wire dispenser: an essential tool for unwinding line wires.



5. Pull out at least one wire, fix it as a loop with a preformed fence connector (see Figure 19a, page 19) round post B and, after looping the wire around post A, strain up, cut and terminate it with another fence connector; see Section 3 (page 8) for handling spring steel line wire. Staples are used only to guide the position of the line wire, not to pinch and hold the tension. Two dispensers can be used to dispense two wires simultaneously. A second person should assist by raising and lowering the wire over undulations in the ground during straining to ensure a final straight line. Any further vegetation clearance or flattening of ground should be completed before final tensioning to prevent incidental damage to the line wire.

6. After the bottom line wire is tensioned, position the first stake halfway between the straining posts to confirm the line is correct. The precise location of stakes in the line can only be determined by using the bottom line wire as a guide. The wire is held to the position it would take on the stake (ground level or 50 mm). The height of the wire from the ground from this point to the straining post is observed. This will show if the position of the stake needs to be moved to accommodate any rise or dip in the ground while maintaining the minimum required height of fence with the most economical use of stakes; alternatively a netting fill-in or tie-down may be required. When the location is

fixed the first stake is driven in by hand or tractor mounted hammer and the bottom wire stapled to it so the line wire is on the side facing the pressure from excluded animals. The other stakes are placed at regular intervals or varied to allow for undulations in the ground (see Table 2, page 6), driven in and the line wire stapled.

7. Run out other line wires if needed, locate in the correct position, tension round the strainer posts and staple. For joining line wire see Section 5 (page 18) and Figure 19. Remember to keep the top line wire 15 cm lower than the width of the net if a turnout lap is required against rabbits or muntjac deer.

8. Repeat operations for other line wires. The fence support structure is complete.

9. Construct major gateways. Gate posts supporting side-hung gates must be separate from straining posts; see Section 6 (page 22).

10. Distribute the netting along the fenceline on the side of the fence where the line wires are fixed. The netting is attached around the first straining post using wire joiners – see Section 5, Figure 19a, for high tensile mesh or 20 mm staples for hexagonal mesh.

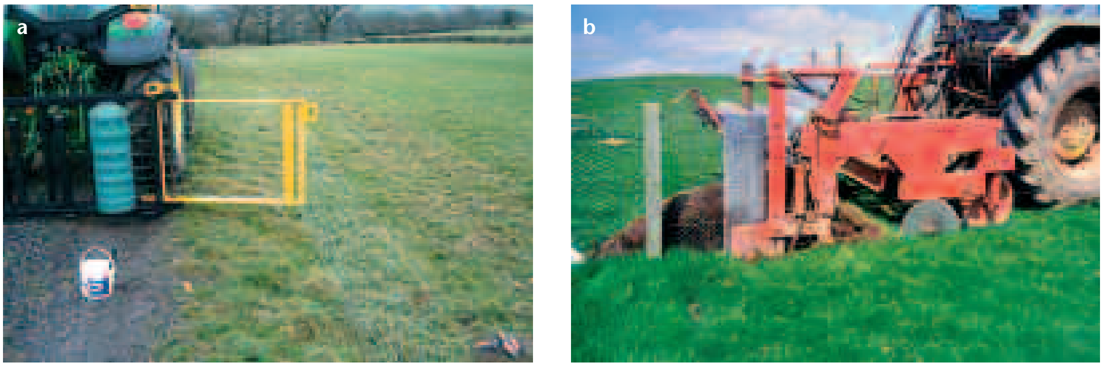
11. Roll out the net using traditional or advanced techniques (Figures 43a–c and 44a,b). This can be done in several ways: horizontally by rolling it along the ground; with two persons carrying the roll on a metal pole; or vertically using a handheld dispenser. Vehicle mounted systems are available, and for buried rabbit net, a proprietary plough mechanism. Hexagonal netting (rabbit or lightweight deer net) is best hung one roll at a time, tensioned by hand, and fixed to line wires by wire rings such as zinc-coated CL22, and stapled to the end posts and all stakes. It is best joined by overlapping the ends of the two nets at a stake. Alternatively a 0.3 m overlap has clipped rings or wire twists at 10 cm intervals to

Figure 43

Unreeling of mesh has developed from (a) the traditional finger and back breaking job to using (b) and (c) hand held devices.

Figure 44

Vehicle mounted dispensers for (a) above ground or (b) partly buried netting can save time.



seal the overlapping rolls. For a rabbit plus deer fence, the deer net is erected first (with lashing rods attaching it to the line wires) and the rabbit netting second. For a deer fence with two layers of rectangular netting the lower net is erected first. The first end is fixed round the straining post. High tensile and welded wire mesh netting is joined with wire connectors (Section 5, page 20, and Table 5, page 29). As many as six 50 m rolls of high tensile net can be joined and then strained together. Before the net is finally strained the top of the net is loosely clipped to the line wire, if one is used, with two wire rings or a lashing rod in each space between stakes or hooked over staples or nails in each stake.

12. Tension the lengths of net using a straining bar of a similar length to the height of the netting and one (for stock net) or two (for one piece deer net) chain strainers. Only chain strainers with the handle supplied should be used to derive the correct maximum tension. During the operation of straining the netting, it is sometimes necessary for the second operator to 'bounce' the net in places to allow it to slide along the top line wire. There are two ways to strain net:

    (a) One end of the net length(s) is stapled to a post and the other end is strained to the next straining post (see Figure 45a). Where the distance between posts is greater than 300 m it is necessary to strain and attach the netting to a stake. A temporary strut must first be fitted to the stake to enable it to hold the tension on the net until the next length is strained and joined (see Figure 45b). When straining high tensile rectangular mesh the clamp type straining bar and boundary (or clamp) strainer is used because all the horizontal wires must be tensioned simultaneously to avoid distorting the mesh. Note that after pulling into line, high tensile mesh that has crimp marks on the horizontal wires may stretch about 1 m in every 100 m and the crimp marks become noticeably less distinct. The net is then strained and stapled to a post before the strainers and straining bar are removed.

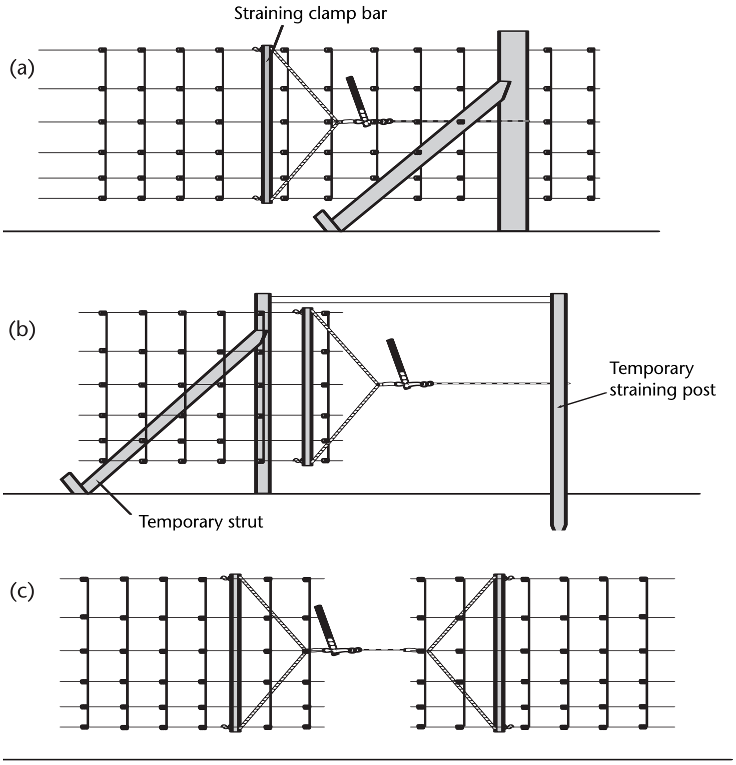
    (b) Sections of netting are attached to both strainer posts and the two netting lengths strained together using two straining bars (see Figure 45c). The ends of the netting are cut to length while under strain and joined by joiners before the clamps are removed.

    Note that specialist badger or boar fences of high tensile net are more difficult to tension as the bottom of the netting must be below ground level in a trench. Rolls of lightweight welded mild steel mesh should be straightened out by hand but cannot be formally tensioned.

13. Before final closure of the last length the wildlife manager should ensure that the fence is not enclosing any animals.

Figure 45

Straining rectangular netting requires one or two tensioning bars and chain strainers depending on whether the net is strained (a) to a post or (b) a temporary straining post (for mild steel only) and (c) from both ends to the middle of the fence.



14. Finally, secure the top and bottom of the netting to the line wires (and then two nets to each other and the central line wire) with preformed lashing rods spaced at approximately 2 m centres (see Figures 46 and 19g, page 19). Hinge joint netting is stapled to each stake to prevent bowing.

Figure 46

A lashing rod is the optimum way of joining the netting to line wire because it will not pull out under a strain, as occurs with most clips.

15. Any gaps under the netting are filled in with extra mesh or an anchor disc is screwed into the ground to hold the fence down. If the bottom 0.15 m is lapped out against rabbits or muntjac deer it must be weighted with sods of earth or pegged every metre. Netting should be fixed from the straining posts to the gateposts. If a fence is erected in sections, the sequence is repeated for each section. It is important that each netted section is completely finished before starting the next. Walk the entire fence to check for construction errors, adjust gate furniture and close any gaps. Make arrangements for maintenance visits.

16. Clear up all surplus materials including offcuts, fixings and old fencing, and take off-site for proper disposal.

10. Tools used for fencing

Many varieties of tools are available for fencing. Over the years several items have become part of the 'standard language' in fencing, e.g. wire dispenser (spinning jenny), C7 type cutter, straining clamp, monkey strainer. However these are actually generic terms for useful tools (Table 8) rather than those of any specific manufacturer. Items must be fit for purpose, rather than cheap alternatives, particularly to prevent compromising damage to the wires or decreasing the safety of operators. A reputable supplier can advise on appropriate choices.

Table 8 Useful tools to assist with fence construction.

Function/purpose	Tools required	Comments
Planning and marking out	Map: scale 1:10 000 or better; measuring wheel; compass.	A handheld GPS may be useful.
Clearing scrub and fencelines	Mattock; slasher; billhook; bowsaw; power clearing saw or chainsaw. In some situations a tracked/wheeled adjustable swipe mower or flail machine. Machine removal of old fences is increasingly used (see Figure 47a, b).	
Constructing straining post assemblies	Narrow strong spade: 'rabbiting spade'; shuv-holer; hand auger or two-man powered or vehicle mounted auger; a rammer for compacting soil around dug posts.	Machines should only be used by trained operators wearing necessary PPE, i.e. safety trousers, boots and headgear.
Driving fencing stakes	Hand-held post driver, mell or maul and a post holder of appropriate size for the woodwork. A vehicle mounted post driver (with integral post holder) speeds up the insertion of stakes and box section strainer posts.	
Handling spring steel and high tensile line wires	Wire dispenser. Wire bending tool to ensure the wire is laid out flat without kinks.	Incorrect bending causes damage. It is essential to make a U-bend with a wire-bending tool rather than a V-bend. Wire that is bent to less than three times its diameter will be weakened.
Cutting spring steel and high tensile line wire	Small, hardened-steel bolt cutters, high tensile cable cutter similar to Type C7 or a small hacksaw are the most satisfactory cutting tools.	The wire is very hard, therefore conventional or fencing pliers are unsuitable.
Straining spring steel and high tensile line wires/barbed wire or straining post assemblies (see Figure 19)	Monkey type with grips are preferable as they do not damage the wire. Fencing pliers, claw hammer or wrecking bar should never be used to tension spring steel or high tensile wire. A vehicle should never be used for straining line wires unless a strain gauge is fitted 'in line' and monitored.	Handle extensions or extra long handles should not be used; the recommended strain of c. 3000–4000 N is attainable without these handles (overstraining may cause a safety hazard).
Straining rectangular netting (see Figure 45)	One or two chain-type strainers in conjunction with a straining clamp bar of c. 1 m or 1.8 m depending on netting width.	Hexagonal mesh is not strained this way because it will deform.
Retaining hand tools	A leather 'fencing belt'.	Enables fencer to have the smaller tools to hand that are most frequently used and most easily lost.

Figure 47

Fencing deconstruction: (a) mechanised deconstruction is much faster and safer than by hand; (b) a skilled operator can roll up old fencing and transport it to the collection point for proper disposal.

11. Fence maintenance

The amount of maintenance required to ensure that a fence is an effective barrier at all times will largely depend on how well the fence was planned initially. Preventative maintenance should be practised through a wildlife management programme that incorporates regular inspections of all fencelines. Major repairs should not be required if the fence specification, route and length was well defined initially and the materials used were chosen to reflect the anticipated length of life and pressure from the target species. However, it is recommended to record (perhaps with a GPS system) the results of regular inspections, and repair as quickly as possible any holes that may have been made under, between or through the netting. Any animal intruders on the wrong side of the fence should be driven out or killed by a specialist ranger; the latter is generally the favoured option because it will eliminate the risk of those individual animals attempting to find or create another entry point. Consideration should also be given to the need to control wildlife populations resident outside the fence because excessive pressure on a fence – especially from migrating deer – can cause serious damage.

Inspection staff should be trained in routine maintenance skills and should arrange a monthly site visit to deal with the following:

- Checking around the base of end posts of post and wire support for movement. In some soil types the post may move slightly, leading to a loss of tension on line wire and netting. Re-tensioning is a relatively simple operation provided the appropriate fixings were incorporated into the fence and inspection staff are equipped with the appropriate tool.

- Checking for straining and intermediate posts (stakes) that have broken or lifted out of the ground, for example, by a tree falling on the fence (Figure 48a), and effecting a repair. A contour post or ground anchor may need to be inserted to hold a fence down in a hollow; alternatively the gap under a lifted fence can be filled in using additional netting well lapped on the ground and extra stakes.

Figure 48

Maintenance inspections are a critical component of fencing to locate and repair problems, especially after a storm. (a) This post has broken off at ground level, at the place indicated by the arrow. (b) Electric fences within a wood require regular inspection as they are generally more liable to be rendered ineffective than permanent netting fences.

- Replacement of any staples that have partially or completely pulled out.

- Repairing holes made by animals, machinery or vandalism by using additional netting clipped over any hole or well lapped on the ground and pinned. Sticks, small stones and turves are not suitable fill-in material as animals can easily rake these out.

- Checking for damage after heavy snowfall or strong winds, removing any fallen trees or branches (see Figure 48b). Inspections during periods of lying snow can reveal the presence of wildlife footprints and indicate animal behaviour at fences. It can also reveal whether there are any animals (including other problem species) on the wrong side of the fence or in the vicinity.

- Checking and adjusting gates and stiles to ensure that they close properly and are fit for purpose, especially where there is public access. The number of key holders should be kept to a minimum. Adjustments to hinges and latches may be necessary and any self-closing mechanisms should be specifically checked especially in the first year. The gateposts of gates that allow access for vehicles are frequently hit and may need to be repaired or repositioned, or the gate re-hung.

- Regularly cleaning debris from grills in watercourses and checking that watergates are operating and closing efficiently.

- Clearing vegetation, e.g. bracken, alongside rabbit fencing to aid inspection for holes.

Fences must not be forgotten and allowed to fall into disrepair. Unmanaged fences are unsightly, act as litter traps and become hazards capable of trapping or injuring larger wild mammals, dogs or the public. Fences must therefore be maintained in good order as an effective barrier for as long as they are required. Once a fence is no longer required it should be dismantled and the materials removed from site for safe disposal or re-use. The option of re-use of some fencing materials, e.g. when protecting young coppice for only two years, should be considered when the fence is being planned.

12. Safety during fencing operations

The Health and Safety at Work Act requires that operators are trained in the use of equipment and for the tasks required of them. Leaflet AFAG104: *Fencing* (HSE Arboriculture and Forestry Advisory Group, 2003a) provides best practice guidance on safe working practices when fencing. This and other relevant leaflets, for example AFAG804: *Electricity and forestry*, AFAG301: *Using petrol driven chainsaws*, can be viewed and printed from the website www.hse.gov.uk under 'Free Leaflets', then 'Forestry' or 'Agriculture'. All fencing contractors should be familiar with the advice and risk assessments.

Netting fences

The following is a summary only of the many clauses in Leaflet AFAG104 and does not replace that full advice.

- Use protective clothing and good quality equipment – strong boots, gloves and eye protection – when cutting wire, stapling and dismantling fences. The risk of injury during the erection of a fence utilising 2.65 mm spring steel wire and high tensile materials is only reduced if the recommended tools are used and staff are trained to follow the methods described and observe the safety precautions.

- Accident statistics indicate that use of chainsaws for adapting woodwork should only be performed by trained operators wearing personal protection equipment, including non-snag outer clothing, safety boots, trousers and headgear as given in the HSE AFAG Leaflet 301.

- Follow best practice on manual handling (Leaflet INDG145: *Watch your back*) including organising mechanical aids for the safe distribution of materials along the fenceline and team lifting of straining posts and heavy rolls of netting.

- Check with landowner for underground pipes and cables or overhead hazards such as power lines. Power companies should be consulted if electric or metal fences are to be erected or dismantled within 40 m of overhead cables. A fence should never be attached to electricity poles.

- Exercise great care when dismantling old fences, particularly when vegetation has grown into them. Wire that is pulled can easily and unexpectedly release or break and recoil. It is appropriate to wear eye and face protection, even if driving machinery involved in dismantling high tensile fencing.

- Rusty wire, particularly barbed wire, will very easily puncture skin and thin gloves.

- Ensure that tetanus immunisation is up to date; this is important for all members of the fencing gang.

- Handle treated timber with gloves.

- Take care when driving posts by hand to stand firm on the ground or on a firm slip-proof platform and use fence stake tongs. Do not allow post-driver to rise too far and use eye protection if using a maul. Always use the post retaining strap/chain when a vehicle mounted post driver is operating.

- Use a wire dispensing reel for line wires. When a length of wire has been cut and the coil is not to be re-used immediately it is advisable to put a U-bend in the end to aid recovery and reduce risk of injury. Alternatively if the end is required within a short space of time it can be pushed into the ground. A considerable amount of time can be lost searching for the end of the wire if it has gone back into the coil. A part-used roll of spring steel wire should not be removed from the dispenser without first being rebound with tying wire.

- Secure either side of the proposed cut when cutting line wire to prevent the ends recoiling. If working alone, this is achieved by placing a foot on one side of the proposed cut and holding the other by hand. The line wire diameter is relatively small and any damage from abuse or using the wrong tools that reduces this diameter, e.g. using a hammer and spade to cut wire, is dangerous and will weaken the wire considerably.

- Fix one end of the line wire round the straining post with a partly driven staple and a preformed fence connector before applying tension. Driving tractors and other vehicles to tension either line wires or wire netting is potentially highly dangerous. Hydraulic technology may be used if a 4000 N tension meter is in-line and being read by a second operator.

- Tension 2.65 mm spring steel (or 3.15 mm high tensile) line wire or high tensile netting using monkey strainers to 4000 N. This allows a safety factor of 100%, provided no additional levers are added. Ensure strainers are properly attached and anchored.

- There are important safety points applicable in HSE leaflet 105 when using power or tractor mounted tools, e.g. hole borers or post drivers.

Electric fences

The HSE AFAG804 leaflet relates to working practice and electricity.

- Electric fences must not be installed parallel to or under power lines.

- It is a legal requirement to display warning signs at least at 50 m intervals on electric fences and on any high voltage equipment.

- Barbed wire must never be electrified.

- Disconnect the power supply when working on the fence. Isolating switches speed up maintenance operations but they should be hidden from the public in areas where vandalism may be a problem.

References and useful sources of information

Agate, E. (2001).
Fencing: a practical handbook. British Trust for Conservation Volunteers, BTCV Enterprises, Doncaster.

British Standards Institute (1993–2000).
See British Standards, page 50.

Forestry Commission (1994).
Forest landscape design guidelines, 2nd edn.
Forestry Commission, Edinburgh.

Forestry Commission (1998).
Forest design planning – a guide to good practice. Forestry Commission, Edinburgh.

Forestry Commission (2003).
Forest and water guidelines. Forestry Commission Edinburgh.

Forestry Commission Scotland (2001).
Deer and fencing. Guidance Note 11. Forestry Commission, Edinburgh.

Highways Agency (2005a, updated annually).
Design manual for roads and bridges, Vol. 10, section 5, parts 3 and 4. Highways Agency, Birmingham.

Highways Agency (2005b).
Manual of contract documents for highway works, Vol. 1, series 300: fencing. Highways Agency, Birmingham.

Hodge, S. (1995).
Creating and managing woodlands around towns. Forestry Commission Handbook 11. HMSO, London.

Hodge, S. and Pepper, H.W. (1998).
The prevention of mammal damage to trees. Forestry Commission Practice Note 3. Forestry Commission, Edinburgh.

HSE Arboriculture & Forestry Advisory Group (2003a).
Fencing. AFAG104. HSE, Edinburgh.

HSE Arboriculture & Forestry Advisory Group (2003b).
Hand held power posthole borers. AFAG105. HSE, Edinburgh.

HSE Arboriculture & Forestry Advisory Group (2003c).
Using petrol driven chainsaws. AFAG301. HSE, Edinburgh.

HSE Arboriculture & Forestry Advisory Group (2004).
Electricity at work: forestry and arboriculture. AFAG804. HSE, Edinburgh.

McKillop. I.G., Pepper, H.W., Butt, R. and Poole, D.W. (2003).
Electric fencing. Central Science Laboratory, York.

Pepper, H.W. (1992).
Forest fencing. Forestry Commission Bulletin 102. HMSO, London.

Pepper, H.W. (1999).
Recommendations for fallow, roe and muntjac fencing: new proposals for temporary and reuseable fencing. Forestry Commission Practice Note 9. Forestry Commission, Edinburgh.

Pepper, H.W., Holland, M. and Trout, R.C. (2006).
Wildlife fencing design guide. CIRIA, London.

Scottish Executive (2000).
River crossings and migratory fish: design guidance. Scottish Executive, Edinburgh.

Scottish Executive (2004).
Joint agency statement and guidance on deer fencing. Scottish Executive, Edinburgh.

Trout, R.C., Quine, C.P., Dugan, D. and Summers, R. (2001).
Alternative deer fences in core capercaillie and black grouse habitats. Forestry Commission/RSPB Interim Guidance Note. Forestry Commission, Edinburgh.

Useful websites

www.efa.fences.org	The electric fencing organisation
www.f-c-a.org	The UK fencing contractors association
www.fences.org	The European fencing industry association
www.forestresearch.gov.uk	Further information on tree protection
www.forestry.gov.uk	Forestry Commission policy and grant advice
www.gatesandstiles.com	Information and access options
www.hse.gov.uk	Health and safety leaflets

British Standards

British Standards on fencing are mainly of interest to manufacturers of fencing materials and components, and to specifiers of fencing for building contracts, road schemes and other works. Fencing which qualifies for grant aid may need to comply with certain British Standards. The Norme Européenne (EN) system also applies to some fencing standards. General information and a list of standards are available on the British Standards website: www.bsi-global.com

The following British Standards are referred to in this publication:

BS 4102 1998	Specification for steel wire for general fencing purposes
BS EN 11722-2 2000	Specification for strained wire and mesh fences
BS EN 10223-1 1998	Steel wire and wire products for fences
BS EN 10223-2 1998	Hexagonal steel wire netting
BS EN 10223-5 1998	Steel wire woven hinged joint and knotted mesh fencing
BS EN 13183-1 2002	Moisture content of a piece of sawn timber
BS EN 61011 1993	Electric fence energisers

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