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Techniques to Construct New Zealand Elk-Proof Fence

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Abstract

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An elk-proof fence was built in 1987 at the Starkey Experimental Forest and Range in northeast Oregon. The 25,000-acre research enclosure holds several hundred Rocky Mountain elk *(Cervus elaphus nelsoni V.* Bailey) and Rocky Mountain mule deer *(Odocoileus hemionus hemionus* Rafinesque) year-round. The fence, con structed with high-tensile Tightlock woven wire from New Zealand, is 8 feet high and requires minimal maintenance. Tension curves in the wire, unique to Tightlock deer fence, make it elastic. Injury to animals is minimized by this inherent "shock absorbing action." Techniques for constructing the fence and costs of materials and labor are discussed.

Keywords: Woven wire fencing, high-tensile fence, wildlife fence, deer and elk management, deer and elk research, New Zealand fence, Starkey Experimental Forest and Range.

Contents

Introduction

A 10-year research project on Rocky Mountain mule deer *(Odocoileus hemionus hemionus* Rafinesque) and Rocky Mountain elk *(Cervus elaphus nelsoni V.* Bailey) was begun by the USDA Forest Service (FS) in 1987 at the Starkey Experimental Forest and Range near La Grande, Oregon (fig. 1). Population responses to intensive timber management, cattle grazing, vehicle traffic, and breeding bull age are being studied (Bryant and others 1991, Johnson and others 1991). Research objectives and experimental design required a 25,000-acre research enclosure to contain about 300 mule deer and 560 elk year-round.

Building fences to safely exclude or contain mule deer or elk requires special materials and techniques. Because of the species' adeptness in jumping obstacles and their gregarious behavior, fencing to contain wild ungulates must be strong enough to withstand animal impacts and tall enough to preclude escape by jumping.

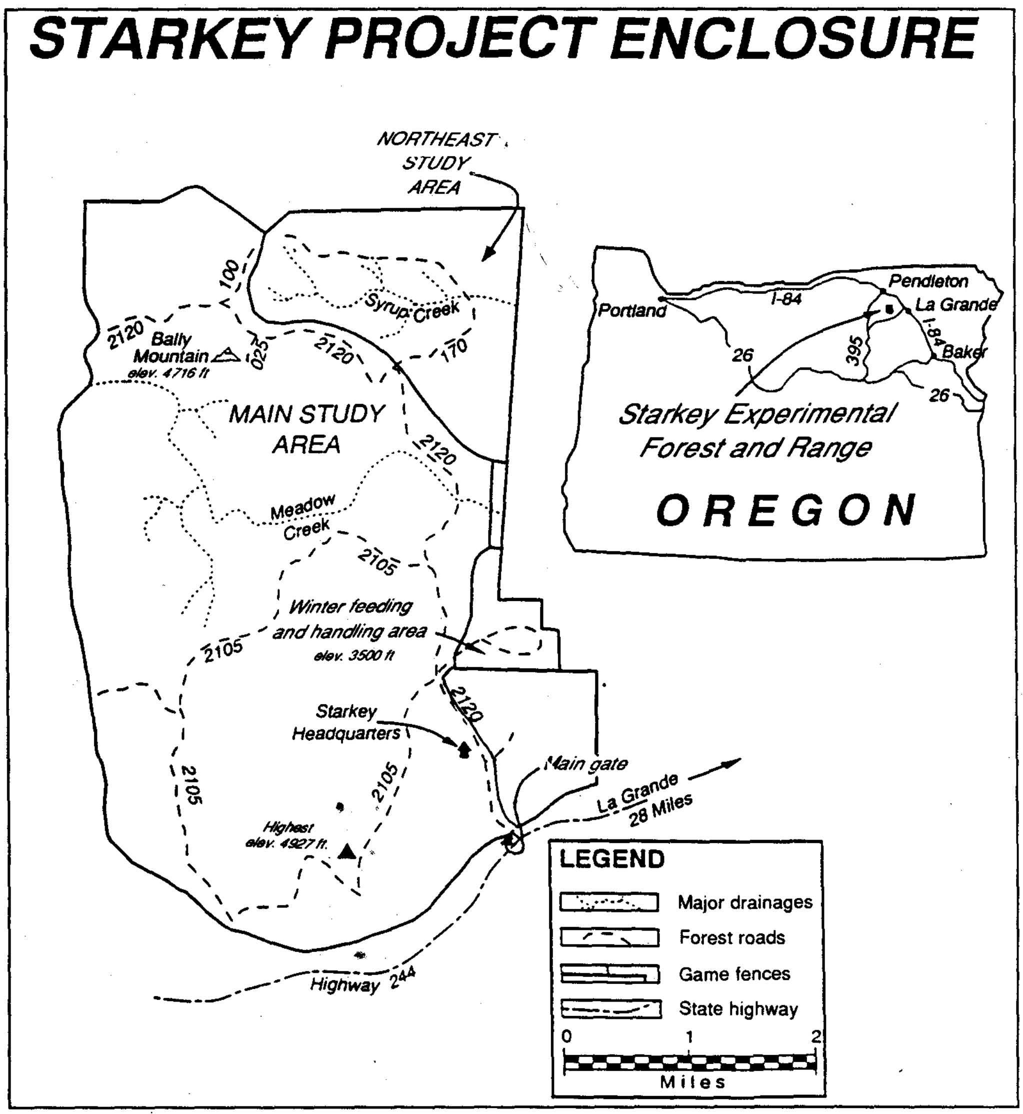

Figure 1—Starkey Experimental Forest and Range. northeast Oregon.

Fencing with woven wire (mesh fence of vertical and horizontal strands, also called hog wire or net fence), topped with smooth or barbed wire, has been used for deer and elk exclusion for many years (USDA Forest Service 1988). In Texas, over 300,000 acres of rangeland were enclosed with deer-proof fence by 1984 (Ray 1985). The standard was an 8-foot fence of two 4-foot panels of 12-1/2-gauge wire, tied together with hog rings. The lower panel was typically 6-inch mesh and the upper panel was 12-inch mesh. Another type of wildlife exclusion fence is 15 strands of smooth, high-tensile wire, spaced 6 to 8 inches apart, and 8 feet high. This fence may or may not be electrified (USDA Forest Service 1988, p. 129).

Fences are built to exclude or enclose large ungulates for many reasons, including to:

- contain research animals
- keep deer and elk away from major highways
- protect research plots
- protect haystacks, agricultural crops, or other plantings
- restrict animal movement in urban areas
- raise animals for commercial purposes (for example, breeding or meat production)

Red deer (C. *elaphus elaphus* Linnaeus) were captured from the wild in Europe and introduced in New Zealand for sport hunting, later becoming a noxious animal. After development of a market in Europe for the meat and antlers, red deer have been successfully raised in New Zealand since the early 1970s. New Zealanders were the first to develop high-tensile smooth wire (USDA Forest Service 1988) and later developed lightweight, high-tensile woven wire (see "Glossary" for all terms used in this paper). This wire, originally designed for livestock fencing, was modified for fencing red deer and has been used successfully since 1975 (Wiremakers Limited, n.d.). The fencing complies with the specifications of the Noxious Animals in Captivity regulations of 1969 for New Zealand (Cyclone 1980); it is the only type allowed in New Zealand for perimeter fencing.

Tightlock deer fence was selected for the Starkey enclosure because of its strength, durability in variable weather conditions, and cost-effectiveness.' The fence at Starkey was the first large-scale use of Tightlock deer fence for wild ungulates in the United States. In addition to its patented knot connecting vertical and horizontal (line) wires, line wires in Tightlock woven wire have unique tension curves (Wiremakers Limited, n.d.; fig. 2). These tension curves give the fence elasticity, thereby minimizing severe body injuries to animals caused by impact with the fence.

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[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

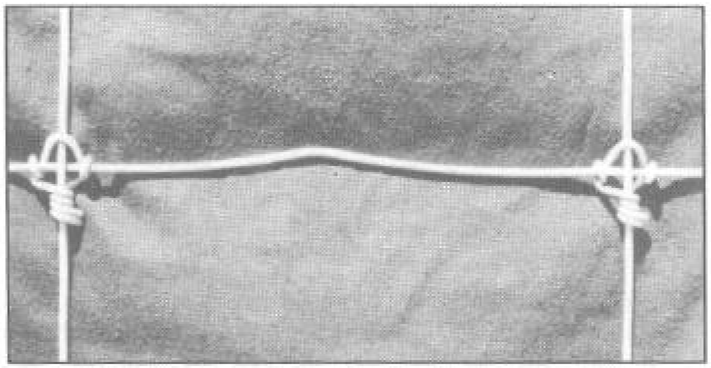

Figure 2—Tension curves and knots in Tightlock deer fence.

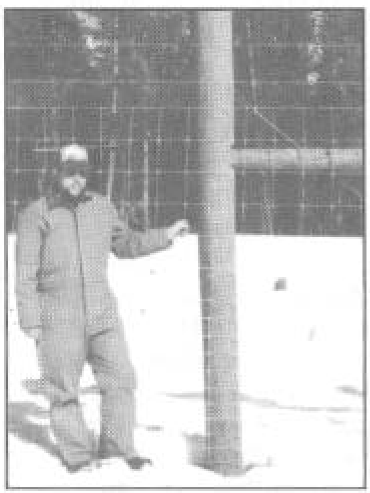

Figure 3—The Starkey fence encloses 25,000 acres and is 8 feet high, with two strands of smooth wire above the woven wire.

Thirty-six miles of Tightlock deer fence was built at Starkey in 1987 (figs. 1 and 3), which included 27 miles of perimeter fence and 9 miles of interior fences. The Starkey fence is 8 feet high, with a single bottom strand of high-tensile smooth wire to discourage animals from crawling under the fence. Two additional strands of smooth wire run above the woven wire. Life expectancy is 30 years or more, with minimal maintenance.

This paper describes basic techniques for construction of the Starkey fence and provides cost estimates for materials and labor. The information could be used by various user groups whenever exclusion or inclusion of deer and elk is warranted.

Construction Costs

Materials

Costs for construction of a hypothetical mile of elk-proof fence at Starkey are displayed in table 1. The total, $10,434.26, does not include labor. Construction specifications (for example, spacing of posts and braces) are those described later in the text. Note that these estimates are based on 1992 prices; the actual cost for materials at Starkey was less than $8,000 per mile in 1987. Total cost for 36 miles of New Zealand elk-proof fencing completed in 1987 at Starkey was about $585,000, including $285,000 for labor. This figure includes gates and other components not part of the mile of fence described in table 1.

Costs of materials for elk-proof fencing range widely. The Oregon Department of Fish and Wildlife (ODFW) supplies materials for game-proof fencing to local ranchers and farmers to alleviate wildlife damage. A 9-mile drift fence built in 1982 near Joseph, Oregon, cost $5,238 per mile (ODFW funds) for materials (Bryant and Feltis 1985). This fence was 8 feet high, with high-tensile woven wire (Hurricane fence) from New Zealand and two strands of smooth wire above, attached to wooden posts. A more typical game-proof fence constructed by ODFW is 84 inches high, with 60-inch-high woven wire (not high-tensile) and three upper strands of barbed wire. Costs in 1992 averaged about $5,000 per mile for materials.[2] In Texas in 1984, a typical 8-foot deer fence cost about $6,000 to $10,000 per mile, including materials and labor but not right-of-way preparation (Ray 1985). In comparison, materials for a livestock fence of woven wire topped with smooth wire are about $5,269 per mile (Broussard and Gates 1988).

Many factors affect the cost of materials in fence construction: quantity of each item purchased-discounts often are applied for large orders; local supplier; distance materials must be transported; and the exact specifications of the fence. For example, the 12-foot spacing of posts at Starkey is closer than that recommended by distributors of Tightlock fencing. Even in hilly terrain, Tightlock deer fence can be erected successfully with 24 feet between posts, or up to 30 feet in some instances. This spacing substantially reduces the money spent on posts, as well as labor needed to drill or dig postholes and hang wire. At Starkey, the configuration (alternating steel and wooden posts every 12 feet) was chosen for two reasons: (1) if a fire occurred, the steel posts would likely keep the fence intact until the wooden posts could be replaced; and (2) to ensure that the fence would remain upright even with heavy snow accumulation.

Other fence specifications that may affect costs include the spacing and type of posts used, number of smooth wires, whether the fence is electrified, the mesh and height of woven wire, and number of gates and water gaps. If an 8-foot fence is needed, two rolls of net wire must be spliced together, because the tallest available is only 60 inches. Tightlock deer fence is available in heights up to 96 inches, thereby eliminating the need to stack two rolls together; this partially offsets the higher cost per roll of Tightlock fencing.

Another factor in construction involving the Federal Government is the Buy American Act (U.S. Laws, Statutes, etc. 1933), which dictates purchasing requirements for construction materials. Because of these restrictions, costs may be higher for Government agencies than those incurred by individuals or private entities building the same fence.

[2] Personal communication. 1992. Jack Melland, wildlife habitat biologist, Oregon Department of Fish and Wildlife, 2111 Adams Ave., Suite B, La Grande, OR 97850.

Table 1—Materials needed and costs for construction of 1 mile of New Zealand elk-proof fence at the Starkey Experimental Forest and Range in northeast Oregon[a]

Item	Quantity	Cost[b] Each	Total
		------- Dollars -------	
Pressure-treated wooden posts, 11 feet by 6- to 8-inch diameter[c]	222	16.15	3585.30
Pressure-treated wooden posts, 12 feet by 6- to 8-inch diameter[d]	6	16.15	96.90
Steel T-posts, 10 feet	220	6.50	1430.00
Pressure-treated wooden posts, 8 feet by 4-inch diameter[e]	6	4.25	25.50
High-tensile smooth wire, 12.5-gauge, 4,000-foot roll[f]	6	55.00	330.00
Tightlock deer fence, 330-foot roll[f]	17	270.00	4,590.00
Plastic snap-on pinlock insulators for steel posts	220	.33	72.60
Plastic insulators for wooden posts	456	.36	164.16
Nicopress sleeves (box of 100)	1	16.00	16.00
Galvanized barbed steel staples, 1.5-inch[f]	2,760	34.00	34.00
Wire clips for steel posts	1,760	.03	52.80
In-line wire strainers	4	2.85	11.40
Tension springs	4	6.40	25.60
Total			10,434.26

[a] Based on construction on gentle terrain, with no gates, rock jacks, or leave trees in the fence line. The hypothetical mile of fence begins with a double-H brace and ends at an 11-foot wooden post.
[b] 1992 prices.
[c] Minimum specifications for wooden posts: pressure-treated (chromated copper arsenate), 0.4 lb/ft3; 1.25-inch penetration, or 85 percent of sapwood, for lodgepole pine *(Pinus contorta* Dougl.); 2-inch penetration, or 85 percent of sapwood, for ponderosa pine (P. *ponderosa* Laws.).
[d] Used in double-H braces.
[e] Cross-pieces in braces.
[f] Shipping costs from New Zealand included.

Labor

Labor costs for fence construction are highly variable. A new section of New Zealand fencing built in 1992 by ODFW at Starkey cost about $5,500 per mile for labor; a Department of Corrections work crew erected the fence and a private company drilled postholes.3 Labor costs for the original fence erected by the FS in 1987 were about $7,900 per mile. The elk-proof fence near Joseph, Oregon, mentioned above, cost about $3,500 per mile for labor in 1982.

3 Personal communication. 1992. Bruce Johnson, wildlife biologist, Oregon Department of Fish and Wildlife, Forestry and Range Sciences Laboratory, 1401 Gekeler Lane, La Grande, OR 97850.

Any construction involving state or Federal agencies is subject to the Davis-Bacon Act (U.S. Laws, Statutes, etc. 1931), which sets standards for wages and other labor provisions. Federal construction contracts also require posting of a performance bond equal to the size of the contract, which at Starkey was $285,000 in 1987. This requirement eliminates many small, local contractors from bidding.

The terrain on which a fence is built, including soil conditions and contour, may greatly influence construction costs; for example, postholes may be drilled with a drilling rig or by hand, or posts may be driven in the ground or set in rock jacks. Because of highly variable but primarily rocky soils (basalt parent material) at Starkey, the decision was made to drill all postholes with a drilling rig. This costs more than driving posts but less than digging postholes by hand.

Any comparison of fence construction costs warrants several caveats. First, the fence must be tailored to the user's needs, and the risk associated with failure of the fence must be considered. For the Starkey Experimental Forest and Range, the cost of losing research animals (representing a substantial investment of time and money) justified building the best available game-proof fence. Davis (1985) recommends building better fences for deer in research enclosures than in other types of fencing (for example, along property boundaries) because the animals are in contact with the fence more often.

Second, long-term maintenance costs must be considered. Tightlock deer fence will not break as easily as hog wire fence and better resists fire and snow accumulation. Thus, maintenance costs should be relatively lower.

A more difficult aspect to assess in economic terms is animal welfare. Tightlock deer fence, with its ability to flex upon impact, is the safest game-proof fencing available. This is especially important at Starkey, where occasionally large numbers of elk are herded in alleys and pastures. Also, deer and elk are hunted on lands surrounding the Starkey Experimental Forest and Range, so an effective fence is required to bar any movements of deer and elk into or out of the enclosure.

Effects of the Fence on Wildlife

Deer and Elk

The entire fence line at Starkey-about 43 miles-is surveyed weekly by personnel on all-terrain vehicles. During hunting seasons, surveys are more frequent, even daily. This frequency ensures that few, if any, fence-related injuries to large animals are overlooked.

New Zealand fencing is designed to exclude and include deer and elk with minimal injury. From completion of the enclosure in 1987 through 1992, losses of one elk and 15 deer were documented as being the result of collisions with the perimeter fence. Deer losses were highest in the first few years after construction; we are not aware of any deer mortalities from collisions with the fence since 1990.

Collisions or contact with the fence should decline after the fence has been in place several years, as animals learn to recognize it as a barrier (Davis 1985). Also, fawns and calves born inside the enclosure will not have the migratory patterns of their parents and should be less likely to try to escape from the enclosed area (Davis 1985).

Two bull elk have been seen escaping from the Starkey fence by jumping between the upper smooth wire and the top of the woven wire. One was in a group of elk being herded toward a gate for movement to another pasture. At least two other elk are known to have escaped from the enclosure, because they were tagged animals harvested outside the fence during the regular hunting season. Also, a group of about a dozen elk, including several large bulls, pushed down a section of fence in an interior alley as they were being herded toward the handling facility. Under normal conditions (that is, without being handled or moved), an elk or deer would be highly unlikely to attempt to jump the fence, unless packed snow along the fence line made the effective barrier considerably lower.

Other Species

At least one American kestrel *(Falco sparverius* Linnaeus) and one blue grouse *Dendragapus obscurus* Say) have been found dead adjacent to the fence. We have no evidence that any species other than deer, elk, and the two bird species has been injured from contact with the fence.

Although New Zealand fencing contains deer and elk, it was not designed as a barrier to other species. Coyotes *(Canis latrans* Say) have been seen passing under the fence with little or no difficulty. Their tracks along the fence line indicate frequent movement into and out of the enclosure, with no apparent harm or deterrence caused by the fence. We also have documented black bear *(Ursus americanus* Pallas) climbing over and under the fence.

Construction Techniques and Materials

Step 1: Clear the Fence Line

Clear a 12-foot right-of-way on each side of the fence alignment with a bulldozer or grader if necessary. The 24-foot swath allows for construction access for crews, equipment, material, and future maintenance; it also functions as a fuel break in the event of fire. Remove rocks, trees, stumps, and debris along the right-of-way to allow better clearance for drilling postholes or pounding posts. Remove trees beyond the right-of-way that are likely to fall on the fence.

Live trees less than 2 feet from the proposed fence alignment and at least 8 inches d.b.h. (diameter at breast height) may be used as line posts, but this is not recommended. Leave trees often must be replaced with rock jacks or wooden posts.

Step 2: Set Fence Posts

Mark 24-foot intervals along the fence line before digging or drilling postholes for wooden posts. Wooden and steel posts alternate every 12 feet for increased stability. The steel posts serve as a visual barrier for animals, maintain fence rigidity when snow pack is high, and provide support if wooden posts are destroyed by fire or destabilized. For in-line construction, we used pressure-treated wooden posts, 11 feet long and 6 to 8 inches in diameter. Steel posts were 10 feet long, T-shaped in cross-section, and "heavy duty" (that is, thicker steel than standard-weight posts). On rocky or steep ground, rock jacks were constructed instead of setting posts (USDA Forest Service 1986; 1988, p. 39, 54).

For strength, install a single H-brace every 0.25 mile and a double H-brace for fence stretching every 0.5 mile. Double H-braces also are built on both sides of water gaps, at gate openings, at corners approaching 90°, and at the bases and ridgetops of steep slopes (USDA Forest Service 1986). High-tensile wire fences in mountainous terrain require stronger braces than barbed wire fences. High-tensile wire also lasts much longer than other wires, and thus the braces are in place for many more years (USDA Forest Service 1988, p. 139).

Spacing of posts in all H-braces is 8 feet. Posts used for single H-braces are identical to in-line wooden posts; double H-braces should use 12-foot posts. Cross pieces on all braces are treated wooden posts, 8 feet long by 4 inches in diameter. In suitable soils and moisture content (that is, soft soils with no bedrock close to the surface), both wooden and steel posts can be driven into the ground. Otherwise, postholes must be drilled or dug. Holes should not be more than 9 to 10 inches in diameter for 6- to 8-inch-diameter posts. Depth of the hole depends on the type of post used. Holes for wooden posts are drilled at least 34 inches deep for in-line posts and H-braces and 42 to 46 inches for double H-braces; holes for steel posts are drilled a minimum of 14 inches.

For improved compaction, mix water with soil and rock spoils from digging holes and shovel the moist soil into the holes around the seated posts. Do not add too much water, or compaction will be hindered. If the soil contains a high ratio of soil to crushed basalt, the mixture will set the posts firmly, as in setting with cement. Tamp the fill firmly around the posts with a tamping rod.

Step 3: Install Woven Wire

Tightlock deer fence-The high-tensile woven wire used at Starkey is Tightlock fawn fence, 75 inches high, with 17 line wires and 6 inches between vertical stays. The spacing between the line wires differs, with the lower wires more closely spaced (about 3.5 inches) than the upper strands (about 7 inches). This configuration discourages fawns and calves from trying to get through the fence (Wiremakers Limited, n.d.). The line and vertical wires are 12.5-gauge, heavily galvanized steel, with a tensile strength of 170,000 pounds per square inch in the line wires. The wire is rust-proof and fire-resistant.

The tension curves in Tightlock fencing, mentioned above, prevent the fence from losing tension when pushed by animals. Because of this property, Tightlock deer fence does not require stretching as tightly as do net wire and high-tensile smooth wire, which usually stretch upon impact (Cyclone 1980). With less tension on the fence, it is less likely to break when hit, thereby reducing long-term maintenance costs. It also is less likely to injure an animal that runs into it. The elasticity makes Tightlock fencing very useful in heavy snowfall areas, unlike net wire.

Hang woven wire-Lay out a roll of Tightlock fencing near the posts, keeping the more closely spaced wires (that is, the smaller mesh) at the base of the posts. Typically, the wire is stretched from and tied off at double H-braces, so about eight rolls of fencing (330 feet per roll) must be spliced together before stretching the wire on level terrain.

Fencing is placed on the side of the fenceposts that will receive the most pressure from animals, to reduce strain against the staples and wire clips attaching the fencing to the posts. In a typical enclosure, this would be the interior side; aesthetics or other considerations (for example, location of an electrified wire) may determine placement of the woven wire. At Starkey, the woven wire was hung on the exterior side of the enclosure, because more long-term pressure was anticipated from deer and elk outside the enclosure than inside. Regardless of the placement of the wire, where the fence line makes a turn of more than 10° from a straight line, bring the fencing to the outside of the post so that tension is against the post rather than the staples. Initiate turns on wooden posts, not steel posts.

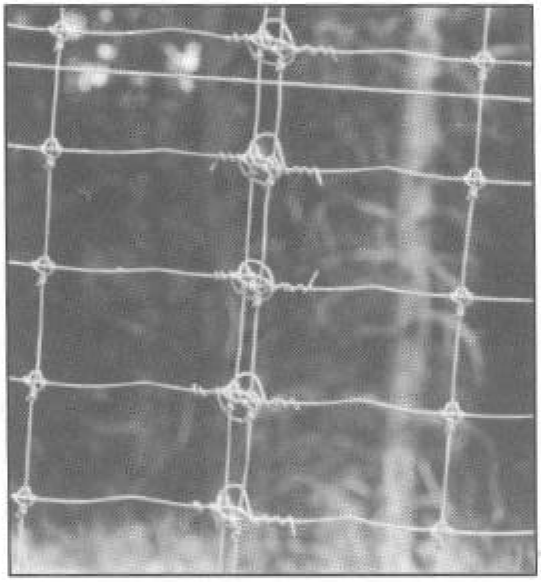

Figure 4—Spliced section of New Zealand Tightlock fence; note location of splice near vertical stays.

Splicing-Remove the vertical stays and Tightlock knots at the roll ends to allow adequate line wire for splicing or tying off end wires. The first two vertical stays should be removed at the roll end adjacent to the brace from which the fence will be stretched.

Attach the cut line wires to the anchor post of the double H-brace with a simple loop knot and splicing key (Cyclone 1980). Fasten with temporary staples through the Tightlock knots. Keep the stay wires leading to the brace vertical by standing the roll upright close to the brace posts.

Unroll the next roll of woven wire and remove the stays and Tightlock knots as described earlier. Splice the rolls together with double-eye splices (fig. 4). Make splices by forming two loops, or eyes. Wrap the end of one line wire back around itself to form a loop. Using the splicing key, twist the wire end around the line wire at least three times; keep the twists as close together as possible to form a tight , knot. Next, thread the end of the opposite line wire through the loop and wrap it back around itself, twisting with the splicing key as before. If possible, make the join where two vertical stays meet.

Continue splicing the rolls together until a double H-brace is reached. Attach the end of the last roll to the strainer board (also called a stretcher board or straining clamp), leaving ample room (about 3 feet) for splicing to the next roll or tying off on the brace post. Metal or wooden strainer boards may be purchased from the manufacturers of Tightlock deer fence (Wiremakers Limited, n.d.) or may be constructed with 2- by 4-foot boards and bolts. Keep the strainer board parallel to the vertical stay. Woven wire must be stretched as one unit; do not stretch the line wires individually (Cyclone 1980). One advantage of using Tightlock woven wire is that it does not pull out of shape when stretched, unlike hog wire fence.

Figure 5—Stretching New Zealand woven wire with a strainer board attached to a tractor bucket.

Stretching-Attach the strainer board with two chains to a vehicle such as a tractor or pickup truck (fig. 5). Begin pulling the fence up gradually against the line posts, while easing the fence around any corners. Lift the woven wire 6 inches above ground level to allow for uneven soils, frost heaving, and the single strand of high-tensile smooth wire installed below it later.

Stretch the fence by pulling on the strainer board until the tension curves in the line wires are reduced to half of their original depth, or about 220 to 250 pounds of tension on each line wire (Wiremakers Limited, n.d.). Stretching Tightlock woven wire too tightly decreases its ability to dissipate and absorb the impact load of an animal (Wiremakers Limited, n.d.).

Double staple the stretched woven wire to the double H-brace. Depending on terrain, the fencing sometimes may be stretched from or tied off on a single H-brace or a leave tree. The roll end is either tied to the brace post, as described earlier, or it is stapled, with the excess line wire left for splicing to the next roll. The staples should be barbed and 1.5 to 2 inches long. Drive the staples at a slant to the grain of the wood to prevent splitting of the posts and causing the staples to pull out. Leave 0.125- to 0.25-inch gaps between the inner edges of the staples and the wire to permit movement of the wire in response to climatic changes and for re-stretching the fence, which may be necessary. Under no circumstances should the wires be stapled tightly to the posts. This can weaken the wire and make it more likely to break if hit by an animal.

Position the staples on a post so that they are not in one vertical line. As the posts weather, surface cracks may develop, which could cause an entire vertical line of staples to pull out. Only every other wire on a given post is stapled, with the line wires that are stapled alternating from post to post (USDA Forest Service 1986).

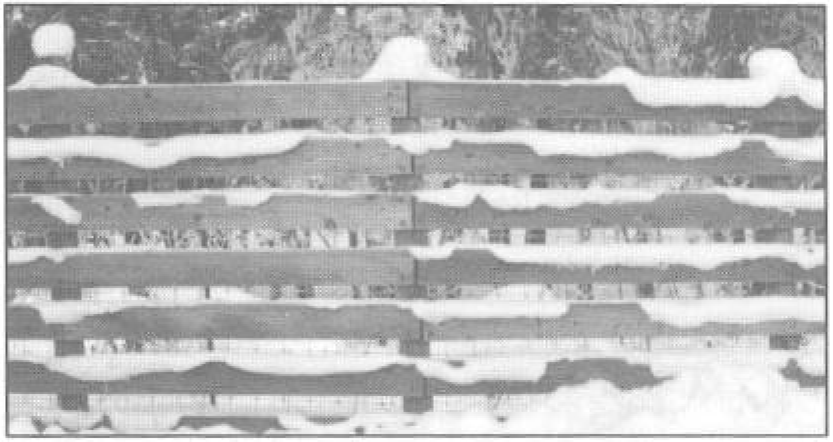

Figure 6—Boarded sections of the fence protect the Tightlock woven wire in areas of potential pressure from groups of elk.

Staple the line wires to the wooden in-line posts between the braces and, at the same time, keep the bottom of the fence about 6 inches above ground level. Attach the woven wire to the steel posts with wire fence clips on every other line wire; affix the wire that was not stapled on the previous wooden post.
Continue hanging the remaining rolls of woven wire. At breaks in the fence line, such as at water gaps and gates, tie off the line wires to the brace posts as discussed previously.

In sections of the fence where elk may be concentrated (for example, near gate openings into alleys), we attached 2- by 8-inch boards to the wooden posts with lag bolts and left a 4-inch gap between boards; the boards are parallel to the ground (fig. 6). With the woven wire covered in these sections, it is protected from large numbers of elk pushing against it. These boarded sections extend away from gate openings various distances, depending on anticipated pressure from animals at those points. Do not sever or nick the fence wires while placing the boards.

Gullies-Maintaining an even tension across gullies may be difficult. If the gully is dry, place a post in the low point and staple the woven wire to the post. Tighten the loose section of fencing in one of the following ways:

1. For a small amount of slack, remove one-half to two-thirds of a vertical stay and the knots from the line wires. Take up the slack in each line wire with a wire strainer (USDA Forest Service 1988). Join the wires with a double-eye splice or Nicopress sleeve and turn the wire ends back to prevent slippage.

2. With significant slack in the fence, cut a "V" from the top of the fence to about two-thirds down. Stretch the line wires with a fence strainer and tie off each wire as above. Use this method (that is, cutting a "V") only in extreme cases; the removal of a section of the woven wire decreases its effectiveness (Wiremakers Limited, n.d.).

Step 4: Install Smooth Wire

Four strands of high-tensile smooth wire were used in the fence at Starkey; two are equipped to carry an electric current. The other two, which run along the top of the fence, heighten the fence to prevent deer and elk from jumping over it. The wire is 12.5-gauge, heavily galvanized steel, with a tensile strength of 170,000 pounds per square inch.

Begin with the top wire, which is hung 96 inches above ground level (or about 14 inches above the woven wire). Tie off the end by wrapping it twice around a brace post at the proper height and twisting the end of the wire back around itself, at right angles, about six times. Smooth wires should be tied off on gate, corner, angle, and in-line brace posts and at water gaps. When splicing is necessary, use a double-eye splice.

Staple the wire with barbed staples or clip the smooth wire to posts at the appropriate height before stretching. Leave a 0.125- to 0.25-inch gap between the staples, and the smooth wire, as with the woven wire. Avoid nicking the wire, because that will decrease its tensile strength.

The smooth wire is stretched with in-line strainers or Rapid Wire tighteners (figs. 7 and 8) to about 220 to 250 pounds. The ratchet action of the in-line strainer allows the tension to be set to the desired level; a pin locks ratchet movement. If in-line strainers are used, the wire is spliced once to the tool and once to the strainer handle. The Rapid Wire tightener requires no splicing but uses a handle and ratchet action tool to stretch the wire (Gallagher, Inc., n.d.). Both types of strainers are left in the fence line.

Repeat this procedure for the second wire down, which is 88 inches above ground level (or about 6 inches above the woven wire).

The bottom two lines of smooth wire can be electrified-one is 3 inches above the ground and the other 42 inches. The ground-level wire prevents animals from crawling under the fence, and the other deters animal contact with the fence.

Attach snap-on, ultraviolet-resistant plastic pinlock insulators 3 inches up on the outside (that is, the side facing away from the enclosure) of the steel posts. The smooth wire at 42 inches is not hung on the steel posts. On the wooden posts, use 1.5-inch barbed staples, driven at a slant to the grain, to attach plastic insulators to the wooden posts at both 3 inches and 42 inches. The insulators at 3 inches above ground are outside the enclosure, whereas the insulators at 42 inches are fastened inside the enclosure. Porcelain insulators are used at gates and other locations where an electric wire is tied off.

Install the two lower strands of smooth wire by running them through the insulators. Attach in-line strainers, and stretch to about 220 to 250 pounds. See USDA Forest Service (1988) for additional details about electric fence construction and safety precautions.

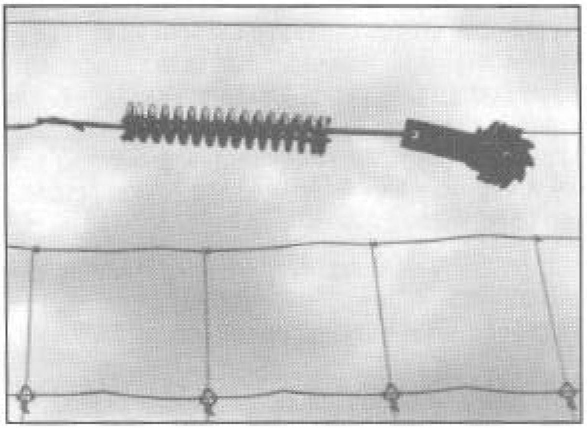

Figure 7—Typical in-line strainer.

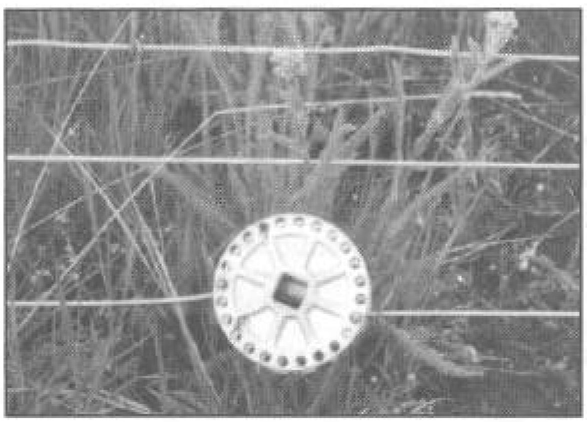

Figure 8—Rapid Wire tightener in place.

Step 5: Hang Gates

Widths of gate openings in the fence depend on their intended use; gates at Starkey are either 12 or 24 feet wide. Gates should swing freely to 180° for vehicle passage and should be hung no more than 4 to 6 inches above the road to prevent animals from crawling under them (USDA Forest Service 1986).

Hinge type differs with gate type; be sure to order the proper hinges when ordering gates. Attach hinges to wooden posts according to the manufacturer's directions. At Starkey, Cyclone gates were used, which have a galvanized tube frame and chain link netting (Wiremakers Limited, n.d.). These gates are less likely to injure animals than are pipe frame or wire mesh gates.

The top hinge hook usually is inverted to lock the gate on the post; however, in areas of heavy snow accumulation, it may be best to leave the top hinge hook upright so that the gate can be lifted off the hinges. This allows the gate to be raised as snow accumulates, and is an alternative to plowing snow away from gates along infrequently traveled roads.

Step 6: Electrify Smooth Wire

Choose a suitable energizer for the smooth wire. Battery- or solar-powered (direct current) fence chargers, manufactured in the United States, generally power 6 miles of fence and last up to 4 years. Some of the New Zealand-designed, solid state chargers can electrify up to 100 miles of fence and last 10 to 15 years (Gallagher, Inc., n.d.). A Gallagher 220-volt (alternating current) solid state energizer is in place at Starkey and produces relatively short, strong pulses. Solar-powered chargers also have been used successfully at Starkey.

A recurring problem with charging the lowest wire is electrical shorts caused by rocks and debris contacting it and by vegetation growing along the fence line. An electric current at ground level may not be necessary for all fences.

Recommendations

With the fence in place for over 5 years, several modifications have become apparent that will improve the effectiveness or longevity of the fence.

- Leave trees-Although trees can function as in-line wooden posts, their growth and eventual death can reduce fence stability and strength. They must be replaced eventually. Nearly 400 leave trees were left in the fence at Starkey; however, many of these have now been replaced with treated wooden posts or rock jacks. We recommend using leave trees only when absolutely necessary.

- Smooth wire-A third smooth wire has been hung above the Tightlock fencing in some new sections of interior fence. The overall height of the fence was not increased; the three wires are closer together than the previous two. There was evidence that elk occasionally were jumping between the two upper strands of smooth wire. The third wire should further discourage jumping over or through the top of the fence.

- Braces-If at all possible, follow the spacing for braces recommended in the text. In sections where braces were more widely spaced, the fence has needed more repair.

- Stapling-Rather than stapling only alternate line wires on the Tightlock fencing, staple the top three wires; then begin alternating wires that are stapled. The top of the fence is the part most likely to be hit by running animals and requires more support than the lower portion of the fence.

- Electrifying the fence-Problems with electrical shorts have made electrifying the lower two smooth wires impractical. These problems were due primarily to vegetation growing along the fence line and also to rocks rolling into the lower wire. If the lower wires are to be energized, the surrounding area must be kept free of vegetation and debris. In some new sections of fencing at Starkey, only the upper strands (that is, above the woven wire) of smooth wire were hung; there are no lower strands of smooth wire, and none is energized.

Sources of Additional Information

The following sources can provide additional information about techniques, materials, and costs for constructing deer- and elk-proof fencing:

- Gallagher Power Fence, Inc., P.O. Box 708900, San Antonio, TX 78270. Telephone: (512)494-5211 or (800)531-5908.
- Live Wire Products, Inc., 1127 "E" Street, Marysville, CA 95901. Telephone: (800)272-9045. Distributors of Tightlock deer fence and associated supplies.
- USDA Forest Service, Pacific Northwest Research Station, Forestry and Range Sciences Laboratory, 1401 Gekeler Lane, La Grande, OR 97850. Telephone: (503)963-7122.
- USDA Forest Service, Missoula Technology and Development Center, Building 1, Fort Missoula, Missoula, MT 59801. Telephone: (406)329-3900.
- Wiremakers Limited, Export Division, P.O. Box 22-198, Auckland, New Zealand. Telephone: 0064-9-276-1949. Manufacturers of Tightlock deer fence.

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References

Broussard, Kevin R.; Gates, Roger N. 1988. Comparative costs for fence construction. Rangelands. 10(5): 224-226.

Bryant, Larry; Feltis, Scott. 1985. Elk fence project, Joseph, Oregon. 3 p. Unpublished report. On file with: Pacific Northwest Research Station, Forestry and Range Sciences Laboratory, 1401 Gekeler Lane, La Grande, OR 97850.

Bryant, Larry D.; Thomas, Jack Ward; Johnson, Bruce K.; Noyes, James H. 1991. Hunter and Rocky Mountain elk *(Cervus elaphus nelsoni)* interactions in the Starkey Experimental Forest and Range. In: Christensen, A.G.; Lyon, L.J.; Lonner, T.N., comps. Proceedings of the elk vulnerability symposium; 1991 April 10-12; Bozeman, MT. Bozeman, MT: Montana State University: 168-173.

Cyclone. 1980. Field fences. [Brochure]. [Place of publication unknown]: Wiremakers Limited. [Not paged]. Available from: Wiremakers Limited, Export Division, P.O. Box 22-198, Auckland, New Zealand.

Davis, Donald S. 1985. Game-proof fences-my personal experience. In: Roberson, Sheila F., ed. Deer-proof fencing. Proceedings of a workshop; 1984 June 26; Kingsville, TX. Kingsville, TX: Caesar Kleberg Wildlife Research Institute: 27-30.

Gallagher, Inc. [n.d.]. Power fence catalog. [Brochure]. [Place of publication unknown]. 10 p. Available from: Gallagher Power Fence, Inc., P.O. Box 708900, San Antonio, TX 78270. 10 p.

Johnson, B.K.; Noyes, J.H.; Thomas, J.W.; Bryant, L.D. 1991. Overview of the Starkey project: current measures of elk vulnerability. In: Christensen, A.G.; Lyon, L.J.; Lonner, T.N., comps. Proceedings of the elk vulnerability symposium; 1991 April 10-12; Bozeman, MT. Bozeman, MT: Montana State University: 225-228.

Ray, M.E., Jr. 1985. Fence types and placement. In: Roberson, Sheila F., ed. Deer-proof fencing. Proceedings of a workshop; 1984 June 26; Kingsville, TX. Kingsville, TX: Caesar Kleberg Wildlife Research Institute: 21-23.

U.S. Department of Agriculture, Forest Service. 1986. Starkey elk fence construction. [Not paged]. FS contract 50-04H1-6-0181 C, dated 1986 September 3. On file with: Pacific Northwest Research Station, Forestry and Range Sciences Laboratory, 1401 Gekeler Lane, La Grande, OR. 97850.

U.S. Department of Agriculture, Forest Service. 1988. Fences. Pub. 2400-Range, 8824 2803. [Location of publisher unknown]: U.S. Department of the Interior, Bureau of Land Management; U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 210 p. Available from: Society for Range Management, 1839 York Street, Denver, CO 80206.

U.S. Laws, Statutes, etc.; Public Law 428. [H.R. 13520, Title III], Buy American Act of 1934. Act of March 3, 1933. [Making appropriations for the Treasury and Post Office Departments for the fiscal year ending June 30, 1934, and for other purposes.] In its: United States statutes at large, 1931-1933. Vol. 47, Part 1: 1489.

U.S. Laws, Statutes, etc.; Public Law 798. [S. 5904], Davis-Bacon Act of 1931. Act of March 3, 1931. [An act relating to the rate of wages for laborers and mechanics employed on public buildings of the United States and the District of Columbia by contractors and subcontractors, and for other purposes.] In its: United States statutes at large, 1929-1931. Vol. 46, Part 1: 1494.

Wiremakers Limited. [n.d.]. Tightlock deer, game, and livestock fence. [Brochure]. [Place of publication unknown]. 7 p. Available from: Wiremakers Limited, P.O. Box 22-198, Auckland, New Zealand.

Glossary

Brace: a constructed support within a fence line.

Double-eye splice: a splice formed by creating a single loop in one wire, then threading the second wire through that loop and tying off the second wire by creating another loop. The finished splice resembles a horizontal figure "8" or a "double-eye."

Double H-brace: a brace consisting of two H-braces sharing a vertical post in the center.

H-brace: the most commonly constructed brace, consisting of two vertical posts and one shorter post placed horizontally between the two uprights to form an "H." Also called a "horizontal brace."

High-tensile woven wire: woven wire fencing constructed of 12.5-gauge, high-tensile wire.

In-line strainer: a ratchet-action tool for stretching smooth wires; remains in the fence line.

Nicopress sleeve: a fitting for permanently tapping feed and ground wires into line wires, or splicing cut line wires together; must be crimped with a special tool; available in various sizes.

Pinlock Insulator: an insulator, often plastic, for attaching electrified smooth wire to, fenceposts; uses a pin that is pushed through two holes in the insulator, parallel to the post.

Rapid Wire tightener: a type of in-line fence strainer that does not require splicing.

Rock jack: a support in the fence line that is constructed from posts, lumber, and rocks. Usually built on steep slopes or where the ground is too rocky to support a post.

Splicing key: a tool used to bend or twist wire strands during splicing.

Tension curve: a crimp, or bend, in the horizontal strands of Tightlock high-tensile woven wire that allows flexion if an animal pushes against the fence.

Tightlock fencing: high-tensile woven wire fencing with a patented knot (Wiremakers Limited, n.d.) at the junction of horizontal and vertical wires.

Vertical stay: wire in the fence that is vertical,. or perpendicular to the ground; separates line wires in a woven wire fence.

Water gap: a section of the fence that ends at the bank of a water channel, then begins again on the opposite side of the channel.

Bryant, Larry D.; Thomas, Jack W.; Rowland, Mary M. 1993.
Techniques to construct New Zealand elk-proof fence. Gen. Tech. Rep. PNW-GTR-313. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 17 p.

An elk-proof fence was built in 1987 at the Starkey Experimental Forest and Range in northeast Oregon. The 25,000-acre research enclosure holds several hundred Rocky Mountain elk (Cervus elaphus nelsoniV. Bailey) and Rocky Mountain mule deer (Odocoileus *hemionus hemionus Rafinesque)* year-round. The fence, constructed with high-tensile Tightlock woven wire from New Zealand, is 8 feet high and requires minimal maintenance. Tension curves in the wire, unique to Tightlock deer fence, make it elastic. Injury to animals is minimized by this inherent "shock absorbing action." Techniques for constructing the fence and costs of materials and labor are discussed.

Keyword: Woven wire fencing, high-tensile fence, wildlife fence, deer and elk management, deer and elk research, New Zealand fence, Starkey Experimental Forest and Range.

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