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COMMONLY USED WIRE FOR AGRICULTURAL FENCES

This factsheet describes wire used for agricultural fences, including single strand wire, woven wire, electric fence wire and special wires. It also has a section on the properties of steel used for fence wire.

BARBED WIRE

During the period from 1790 to 1873, there were 652 U.S. patents issued for fencing-related inventions. However, at a county fair in De Kalls, Illinois in 1873, a patented device of "Wooden Strip with Metallic Points" was displayed. That quickly led to a local farmer, Joseph Glidden, to adapt this "armoured fence attachment" to wire and install the first section (66 feet) of barbed wire fence. Although earlier work was done elsewhere, Glidden is credited with starting the barbed wire industry with his US patent No. 157142 of "The Winner", issued November 24, 1874, of a two strand wire with two point wire barbs. Many other patents on barbed wire followed; close to 400 patents exist with references to more than 700 wire varieties.

Initially it was the homestead farmer who popularized barbed wire and the open range cattlemen who fought against it. However, as settlement continued, cattle ranges were fenced as well. Barbed wire invention and manufacture coincided with the quick expansion of the West in the late 1800s.

Today barbed wire is commonly available as two strands of 12½ gauge wire with four-point barbs of 14 ga. wire spaced 5 to 6 inches apart. This wire is formed from low tensile steel with a breaking strength of about 950 pounds. Commonly the zinc coating is less than or equal to Class l.

Barbed wire is sold in rolls of 1320 feet weighing approximately 80 pounds.

Pretensioning Required. During manufacture, two strands of wire are "twisted" together to form a single, double strand wire but these are not always pulled tightly together. For this reason, when constructing a fence using two strand barbed wire the two strands must be prestretched or pretensioned to ensure the fence wire performs as a single unit, not as two separate wires. This involves tensioning the wire up to about 600 pounds and then relaxing to the normal wire tension of 250 pounds **before** stapling. Failure to pretension two-strand barbed wire will result in loose fence wires a year or two after construction.

High Tensile Barbed Wire

Barbed wire is also manufactured from high tensile (ht) steel in either one or two strands. Two strand 15½ ga. ht barbed wire has the same breaking strength but about one half the weight of common barbed wire.

HIGH TENSILE SMOOTH WIRE (HTSW)

Various types of barbless, smooth wire have been used over the years, many not meant for fencing. In the early 1980s a smooth wire was introduced into BC that was specifically designed for fences. This wire is a barbless (smooth), single strand fence wire produced from a high tensile steel. The standard size is 12½ gauge with a minimum breaking strength of 1,350 pounds. Rust protection is to Class 3 galvanizing for long life. It is available in 100-pound rolls containing about 3,750 feet on a drum suitable for dispensing the wire.

High tensile smooth wire (htsw) is used in fencing to overcome some of the disadvantages of barbed wire, especially that of low strength. With the higher tensile and yield strengths of htsw, there is also a greater amount of elasticity. This produces a fence that can be subjected to greater loads without permanently stretching the fence wires or breaking them. These strength advantages are obtained without increasing the diameter of the wire, only increasing the grade of steel.

As expected, these advantages are accompanied by some disadvantages when compared to low tensile steel wire (common barbed wire). These two wires are compared in Table 1. With experience, workers find htsw is easy and quick to work with but is quite different from low tensile barbed wire.

WOVEN WIRE

Standard wire strand fences are often not effective on small livestock or aggressive predators unless droppers are spaced very close together. To overcome this, wire is available that has been manufactured with vertical wire "droppers" woven into the horizontal line wires. This forms a one piece fence wire fabric that can be rolled out and installed on posts.

Types of Woven Wire Fabric

Six general types of fabric are available, five steel and one "plastic". Steel fabrics are categorized by the method used to secure the joint where the verticals intersect the horizontals.

Steel Woven Wire

These first two steel woven wires are commonly used in agricultural fences:

Hinged Joint The vertical is composed of separate wire pieces that are twisted together at each horizontal. This is a very flexible fabric. Refer to Figure 1.

Knotted Joint. The vertical is one piece and knotted to each horizontal with separate knotting wire. This is a semi-rigid fabric. Refer to Figure 2.

The following three steel woven wires are **not** commonly used in agricultural fences:

Chain Link More expensive and not used for standard agriculture fences.
Soldered Joint This light wire fabric ("chicken wire") is not covered here.
Welded Joint This is a very rigid fabric and not normally used for agricultural fences.

Plastic Woven Wire

Polymer Grid A specialty product with various fence uses (refer to Special Wire, page 6).

Table 1 COMPARISON OF HIGH TENSILE SMOOTH WIRE AND BARBED WIRE		
Wire Description	**High Tensile Smooth Wire**	**Barbed Wire**
Wire type	single strand 12½ ga.	double strand 12½ ga.
Tensile strength of steel	high (to 200,000 psi)	low (60,000 psi)
Breaking strength (min.)	1350 lb	950 lb
Relative brittleness	high	low
Relative elasticity	high	medium
Standard rust protection	class 3	class 1 (class 3 available)
Standard roll weight	100 lb	80 lb
Standard roll length	3750 ft	1320 lb
Wire Characteristics		
Subject to breaking at nicks?	yes	no
Will transfer loads to braces?	yes, through loose stapling	some–but catches on post staples
Requires prestretching?	no	yes
Staple to posts before tensioning?	yes	no
Effort to cut	high	low
Recoil tendencies	high	low
Splicing joints	mechanical splice	knot
Tying–off at end posts	mechanical splice or knot	knot
Effort to knot	high	low
Ease to retension after repairs	easy	difficult–must pull staples
"Wear" on workers	low (smooth)	high (sharp barbs)

Comments:

- htsw is easy to pull out along the fence line; barbed wire catches on "everything"
- htsw is "alive" when cut (high recoil tendency) – use caution; barbed wire has low recoil tendency
- htsw single strand has less visibility than two strand barbed wire
- htsw will not cut workers or livestock as will barbed wire
- htsw load transfer to braces requires good brace construction
- htsw is suitable for multiple strand dispensing to speed construction

Identifying Steel Woven Wire

Steel woven wire is identified by a number system that describes the fabric. For example:

10/47/6 woven wire has
- **10** horizontal wires
- a total height of **47** inch
- vertical wires spaced **6** inches apart

This number may also be written as 1047-6 or 1047/6. Sometimes it is followed by the wire gauge if the horizontals and verticals are the same, as in 10/47/6 12½ for 12½ gauge wire fabric.

Woven wire is available with heavier wire for the top and bottom horizontals (the edge wires). Whereas 12½ gauge is standard for many woven wires, the edge wires are available in larger size of 9, 10 or 11 gauge. Some manufacturers stock a heavy fabric made entirely from 9 or 10 gauge wire or a fabric made with high tensile steel wires.

The vertical wires are available in two standard spacings; 6 inch and 12 inch The choice depends on the size of the livestock. Be sure to consider both adult and newborn sizes; birthing areas for some livestock may require the smaller 6 inch spacing.

The horizontal wires are available in a wide range of numbers of wires and total heights depending on the fence requirements. From 7 to 20 wires are available in heights from 26 inch to 96 inch with most fabrics having a horizontal spacing that becomes progressively wider to the top. This spacing change varies between fabrics and manufacturers. Be sure to know the spacing before purchasing woven wire. Refer to Figures 1 and 2, page 5.

ELECTRIC FENCE WIRE

Electric fences are commonly constructed using steel wire strands (htsw only – barbed wire should not be electrified). This produces an effective fence, one that usually is permanently located. However, one use of electric fencing is for temporary or movable fences, especially in controlled livestock grazing. Although standard gauge steel wire can be used for temporary electric fences, special wires are available.

Steel Wire

Smaller size steel wire may be used for electric fences, especially movable fences. Gauges of 14 to 17 are available. Electrical resistance increases with smaller wires and visibility decreases.

Poly Wire

For movable fences, lightweight, easy to handle wire is an advantage. Poly wire is composed of stainless steel or aluminum conductors woven with brightly colored fiberglass strands. Permanent electric fences are not usually constructed with this type of wire. Poly wire has the following characteristics:

Advantages of Poly Wire:

- lightweight – 300 ft weighs approx. 1 lb
- easy to handle – does not kink; easy to wind up on a drum
- easy to join – simple knots are used (these may be points of high electrical resistance)
- well suited to intensive grazing systems requiring temporary, movable fences

Figures 1 & 2, below, illustrate typical knotted and hinged joint woven wire specifications.
Note the mix of options, for example in Figure 1, the difference between 13/74 and 17/75 knotted joint fabrics.

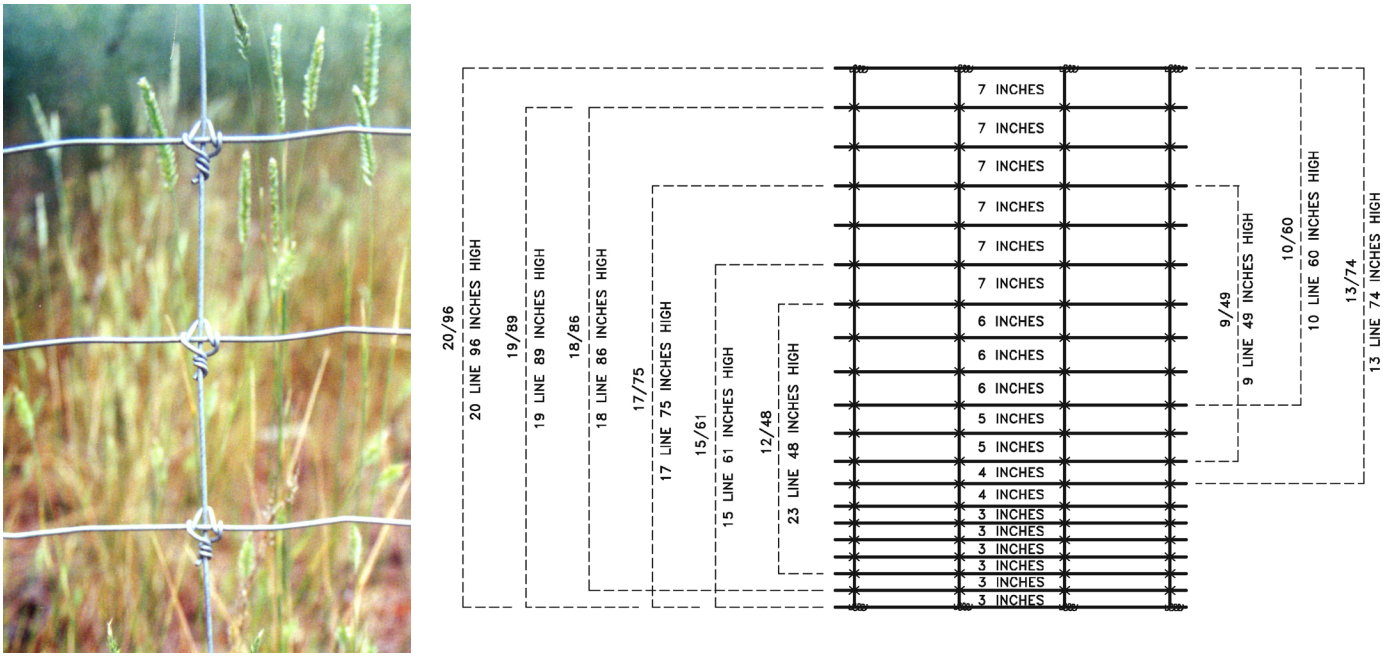

Figure 1 Typical Knotted Joint Woven Wire Specifications

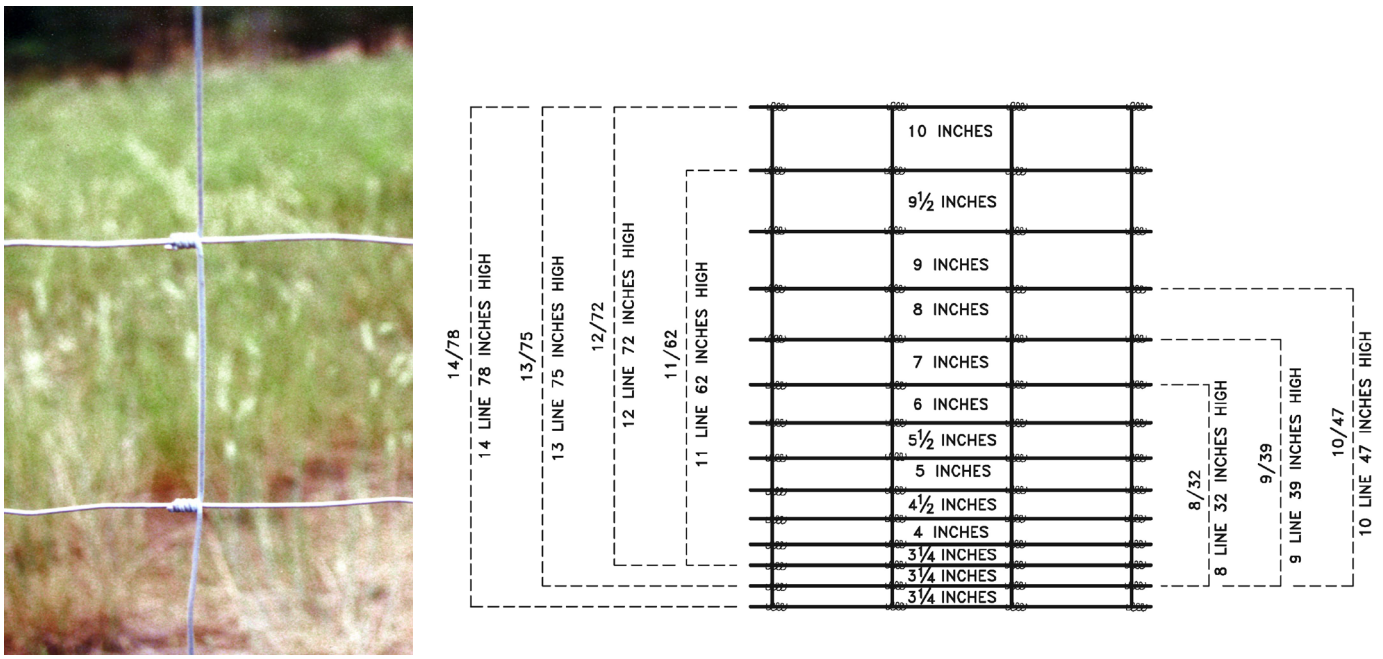

Figure 2 Typical Hinged Joint Woven Wire Specifications

Disadvantages of Poly Wire:

- cost – more expensive than steel wire
- high electrical resistance – due to small area of conductor limits fence to approx. 1000 ft
- low breaking strength – approx. 120 lb
- short life – due to sunlight deterioration; 5 year guarantee by some manufacturers

Poly wire is available as a braided wire (has appearance similar to poly twine) or as a tape (5/8 in. to 1–1/2 in. wide for greater visibility and strength). Poly wire is also available woven to form a net, sometimes used for grazing sheep. One manufacturer makes a net with solid plastic verticals for improved support. Poly wire may be chosen when ease of moving a fence is desirable (for controlled grazing, for example).

SPECIAL WIRE

Numerous special purpose wires are available. These may be more expensive but offer special features.

Aluminum Wire

This wire is used in electric fences for its good conductivity (4 times that of steel of the same gauge). It is more expensive and has lower strength than steel (1/4 of htsw). It is available in a braid form that is very flexible and used in temporary, movable fences.

Polymer Monofilament

This wire is a single strand of white 'plastic' and used mainly in horse fencing. Typically:

- diameter of 0.01575 inch (8½ ga.)
- weights about 1 lb per 100 feet
- breaking strength of 1,140 lb
- roll length of 2,500 feet
- tension not affected by normal temperatures
- good visibility

This wire is stapled tight to line posts or it may be threaded through drilled posts. It is joined or tied off with knots.

Polymer Coated Wire

This 'plastic' coated steel wire is available as a single strand or a two or three wire 'rail' coloured either white or black. It is used mainly for horse fences.

Polymer Grid Mesh

This all 'plastic' product is available in a wide range of thickness and mesh openings. It is used for everything from bird barriers to livestock, snow and safety fences.

This grid material is not nailed directly to posts but is set between the post and a wooden batten and then nailed.

Poly Vinyl Chloride

PVC posts and rails, while not actually “wires”, are available that assemble into a long life attractive fence. It is used mainly for horse fences and has an 'estate' quality that is priced above standard agricultural fences.

PROPERTIES OF STEEL USED FOR FENCE WIRE

Before wire became popular as a fencing material, fences were usually constructed from readily available local material, often wood. The introduction of wire meant that fences could be strung in areas where wood was not abundant. Wire is relatively light and strong; it can be strung at various spacings over rough terrain to suit a variety of livestock and wildlife; it can be re-used if so desired and has a long life.

The type of wire to use is dependent on the fence design. For instance, woven wire is used to contain deer on a deer farm, high tensile smooth wire could be used on a beef ranch and single strand electric wire could be used for strip grazing on a dairy farm.

The following are some properties and common terms that apply to steel fence wire.

Gauge

The gauge (ga.) of a wire is a standard measurement scale that relates to the wire diameter. The smaller the gauge number the larger the wire diameter (i.e. 9 ga. is a heavier wire than 12 ga.). Table 2 gives the wire diameters and weights of common U.S. steel wire gauges used for fence wires.

Table 2 can be useful for determining both the length of wire in a roll of known weight or the weight of a given amount of wire. Note that these figures are for a single strand of wire (smooth/barbless). To account for the weight of the barbs add approximately 10% to the bare wire figure.

Table 2 U.S. STEEL WIRE GAUGE FOR FENCE WIRE

Wire Gauge (ga.)	Wire Diameter (inch)	Weight (Lb/100 ft)
9.0	0.1483	5.87
11.0	0.1205	3.87
12.0	0.1055	2.97
12½	**0.0985**	**2.64**
14.0	0.0800	1.70
16.0	0.0625	1.04

Example **Determining Length of Wire Knowing Weight**

How many feet of wire are on a 100 lb roll of single strand 12½ ga. htsw?

- From table 5.3, 12½ ga. wire weighs 2.64 lb/100 feet
- Length of 100 lb = 100 lb ÷ 2.64 lb/100 ft = 3,788 ft /100 lb roll

(note: manufacturer specification typically lists 3,750 ft per 100-lb roll as minimum)

Example **Determining Weight of Wire Knowing Length**

What does a standard roll of two strand 12½ ga. barbed wire weigh?

- Standard roll length = 1,320 feet
- From table 5.3, 12½ ga. wire (barbless) weighs 2.64 lb/100 ft (per strand); for the barbs, add 10%; 2.64 × 1.1 = 2.9 lb/feet

Weight of 1320 ft roll =1,320 ft × 2 strands × 2.9 lb/100 ft =77 lb

(note: manufacture specification typically list the roll weight at 78 lb.)

Tensile Strength and Breaking Load

The maximum tension for a given area that a wire can withstand is called its tensile strength and it is dependent upon the steel composition of the wire. This strength is calculated by dividing the maximum load or breaking load the wire can resist by the cross sectional area of the wire and is expressed in pounds per square inch. The breaking load is the load that will actually break the wire.

Standard steel used in barbed wire has a low tensile strength. The double strand 12½ ga. wire will break at a load of approximately 950 lb. High tensile smooth wire (one strand, same gauge) will break at a higher load of approximately 1,350 lb because of its higher tensile strength. Common barbed wire has a tensile strength of 60,000 psi versus htsw at up to 200,000 psi.

Fatigue Limit and Brittleness

The disadvantage of increased tensile strength is that the fatigue limit of the steel is lowered. This means the higher tensile strength wire is more brittle and subject to failure if it is bent sharply, kinked or nicked.

Elastic Limit and Yield

The maximum tension which can be placed on a wire, such that when the tension or load is removed the wire will return to its original length, is called the elastic limit of the wire. In fencing, this elastic limit should never be exceeded, otherwise the wires, once relaxed from the excess load, will be loose as the wire will have been permanently stretched. Normally, the elastic limit or yield is approximately 75% (60%–90% range) of the tensile strength. This means that although the breaking load of 2 strand barbed wire is 950 lb, the maximum load that will not cause permanent stretching is about 75% of 950 lb or about 700 lb. This then is the actual useable load capacity of the fence wire. For htsw this yield strength is about 1000 lb.

Elongation and Elasticity

Elongation is the change in length of a wire due to a load. Up to the elastic limit, elongation is proportional to the load and returns to zero when the load is removed. For a given load, a thinner wire will elongate more than a thicker wire, and is said to be more elastic. For instance, for every 100 lb. applied to 330 feet of 9 ga. wire it will elongate about 1 in; 12½ ga. wire (smaller in diameter) will elongate 2 in (the rate of elongation is only dependent on wire diameter, not wire composition). Because elongation can only be “useful” up to the yield strength of the wire, high yield strength fence wires will have more useful elasticity. This is the case when comparing standard barbed wire to high tensile smooth wire; the high tensile wire is more elastic having a higher yield strength. Or in other words, high tensile wire can accept higher loads before permanent stretching occurs.

Zinc Coating

Chemically applied zinc is a rust protective coating used on steel fencing wire. This galvanization is available in three levels or classes, the higher the level of zinc coating, the better the rust protection. For 12½ ga. fence wire refer to Table 3, below.

Table 3 ZINC COATING STANDARD FOR 12½ GA FENCE WIRE

Class	Minimum Weight of Coating (oz/ft$^{2)}$
1	0.30
2	0.50
3	0.80

From: ASTM Standards

The choice of which class of coating is required will depend on the environment the fence will be in; a dry climate requires less protection than a coastal climate. Table 4 indicates the approximate life expectancy of Class 1 and 3 (the two commonly used) galvanized 12½ ga. wire in different climates, and life expectancy once rusting starts.

Table 4 APPROXIMATE LIFE OF GALVANIZED 12½ GA WIRE

Climatic Condition	Galvanized Class	Years until Rust Starts	Years after Rust Starts until Wire is at ½ Strength
Dry	1	11	50+
	3	30	
Humid	1	6	50+
	3	13	
Coastal	1	2	12
	3	6	

From: U.S. Steel "Max-Ten 200"/ASTM Standards

Coefficient of Linear Expansion

This term is used when considering the effects of temperature change on fence wire, and is defined as the change of length per unit length due to a temperature change. Steel wire contracts with temperature decreases and expands with temperature increases at a fixed rate. Contraction causes a force or tension to be exerted on the cross sectional area of the wire and is proportional to that area. The greater the area of the wire the greater the tension created by temperature change; for a given temperature change thin wires will have a smaller change of wire tension than heavy wires. This tension must be resisted by the braces.

For **one strand of 12½ ga. steel fence wire** (regardless of steel composition):

$$F = 2.6\ \Delta T$$

where F = force or tension (lb) as a result of temperature change
ΔT = temperature change (°C)

Note: This formula is an approximation of the force on the cross sectional area of one 12½ ga. strand only.

Example

Wire Forces Generated Due to Temperature Change

A fence with five single strands of 12½ ga wire is built in Kamloops in summer with temperatures at 30°C. The wires are tensioned to 250 lb each. What is the wire tension and total force exerted on the end braces in the winter at -30°C?

- **Change in Wire Tension**

  Wire tension change due to temperature drop:

  F = 2.6 ΔT
  ΔT = -30 to +30 = 60°C
  F = 2.6 x 60°C = **156 lb added tension** (each strand)

  New (winter) wire tension: 250 lb original tension + 156 lb tension due to temperature change = 406 lb tension/strand

Note: This force is well below the wire breaking strength so there are no concerns about wire damage.

- **Change in Brace Forces**

  Wire force on end braces from fence wires when built:
  5 strands x 250 lb per strand = 1,250 lb force (original)

  Increased force from fence wires due to temperature change:
  = 5 strands x 156 lb added tension per strand = 780 lb force (total added)

  Total force at -30°C = 1,250 lb (original) + 780 lb (added) = **2,030 lb brace force**

Note: This example is for five single strands of 12½ ga wire. If five two-strand wires were used (i.e. two strand barbed wire), each wire strand adds 156 lb tension to the braces. Each wire would have a tension of 562 lb (250 + 156 + 156) and the total brace force would be 2,810 lb (1250 + 780 + 780).

SUMMARY OF STEEL FENCE WIRE REQUIREMENTS

A thin steel fence wire is preferred rather than a thick wire because it has greater elasticity and is less affected by temperature changes. However for the same grade of steel, the thinner wire would have a lower strength. To overcome this, a thin wire of high tensile strength steel may be chosen. This is why fence builders are moving towards using 12½ ga high tensile steel wire. A single strand of high tensile wire will out perform two strand low tensile wire and do it at a reduced cost.

However, as shown in Table 1, strength and elasticity advantages come with some disadvantages. In the end, fence wire decisions are made considering all the factors.

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