winding-drum, worked by water-power, pumped up for the purpose; the winding-drum, coupled direct to the steam-engine; an automatic collision-preventing arrangement for slowing the wicker-baskets when they passed each other in the shaft, rendered necessary by the increased speed of winding; next, the introduction in 1833, by Mr. T. Y. Hall, of South Hetton Colliery, of guides and cages to convey the waggons to the surface; and lastly, we come to the improved winding-engines of to-day.

The invention of wire-rope, by Oberbergrath Albert, in Clausthal, in 1833, rendered deep mining possible. Before that date, the cost of hemp-ropes for deep shafts was very serious, and often as much as 6d. per ton of output was required for their maintenance. The ropes at Wearmouth Colliery cost £550 per pair. They weighed 5¾ tons, and only lasted 10 months. Iron wire-rope has now been superseded by steel. At the deep shafts at Przibram, crucible cast-steel, with a tensile strength of 76 tons per square inch, was used up to 1885. Since then, special crucible cast-steel, with a tensile strength of 114 to 120 tons per square inch, has been used with most satisfactory results. At these mines the advantage of using tapering ropes is especially noticeable.

Flat steel ropes are in use in Belgium, at the Providence shaft at Marchiennes. They are made of eight parallel four-stranded ropes, tapered by reducing the number of wires in the strand from 12 to 11 and 10, the wire which is of crucible cast-steel, of a tensile strength of 89 tons per square inch, being of the same diameter (0·08 inch) throughout. The breadth of the rope varies from 7·87 inches at the thick, to 6·69 inches at the thin end, and the average weight is 8·2 lbs. per foot. The winding engines of 2,000 horse-power have cylinders 43 inches in diameter, and 78 inches stroke, and draw a load of 12½ tons (6½ tons for the cage and tubs, and 6 tons of coal) from a depth of 3,117 feet. The life of the rope is about 12 months.

At another deep Belgian colliery, the Sainte Henriette shaft of Produits Company, at Flenu, aloe ropes are used to lift a load of 6½ tons from a depth of 3,937 feet. They are of flat section, with ten strands, tapering in breadth from 16·5 inches to 8·6 inches, and in thickness from 1·93 inch to 1·14 inch. The average weight per foot is 7·4 lbs. The life of these ropes is about 24 months.

At the deep mines of the Lake Superior copper region, machinery of a very high-class is employed. The following interesting particulars, for which I am indebted to Mr. John Birkinbine, Past-President of the American Institute of Mining Engineers, will serve to illustrate this.

In the case of one pair of quadruple engines at the Calumet and Hecla Mine, each engine has its four cylinders, 18 inches, 27¾ inches, 48 inches, and 90 inches in diameter, with a stroke of 60 inches, driving through gearing conical winding-drums 14 to 24 feet in diameter, and 12 feet wide, which lift cages carrying 6 tons of ore at the rate of a mile in 1½ minute.

At the Tamarack Mine, an average winding speed of 3,200 feet per minute has been obtained by a direct acting engine, having 42 by 84 inch steam cylinders, driving winding drums 30 feet in diameter. At the same mine a 32 by 84 inch engine, driving a double conical drum 13 feet 6 inches to 36 feet in diameter, lifts a cage carrying 2½ to 3 tons 4,500 feet in 1½ minutes. These are vertical shafts.

At the Quincy Mine, there are two principal shafts. No. 6, on a slope of 51° 44′, has a total depth of 3,680 feet, the weight raised being about 6 tons. No. 2 shaft, with the same dip, has a total depth along the slope of 3,954 feet, the weight raised being 10 tons.

It is interesting to compare results obtained at these three mines with those obtained at English collieries. Three illustrations which are given on good authority may be cited. In the "Encyclopædia Britannica," 1877, Mr. Bauerman selects as a good example of modern winding, such as is required to draw 1,200 tons in 10 hours, that at Shireoaks Colliery, Nottingham. There the cage with a load of 34 cwt. in five tubs is raised from a depth of 1,548 feet in 45 seconds, an average of 2,100 feet per minute. Mr. Emerson Bainbridge cites as an illustration of swift winding a North Derbyshire colliery, where in June, 1890, as much as 6,309 tons was raised from a depth of 1,527 feet in 8½ hours. Figures of cage speed published by the North of England Institute of Mining Engineers in 1876 show that the greatest maximum speed of the cage in the shaft recorded was at Rose Bridge Colliery, where it reached 5,100 feet per minute, or about 57 miles an hour.

The selection of the best form of drum is a matter of importance in winding from great depths. It appears best to replace large and expensive drums by small ones, and to have more revolutions for each journey. This object is attained in the system of winding engines patented in 1866 by Mr. S. B. Whiting, the manager of the Culumet and Hecla Mine. In this system, there are two grooved drums, one directly in line with the other, coupled by two connecting rods. The rope from one compartment of the shaft winds round both of these drums for three turns and is then led to the other compartment of the shaft. In order to allow of winding from different levels the rope is led back round a sheave on a tension-carriage running on rails, and a steam winch is connected to it so as to adjust its distance from the shaft. The following are particulars of a winding plant of this type at the Red Jacket shaft:—

Depth of shaft	4,900 feet.
Size of shaft	13½ by 23 feet.
Diameter of rope	1¼ inch.
Diameter of drums	7 feet.
Cage speed per minute	1,900 feet.
Weight of cage	2,500 lbs.
Weight of load	3,000 lbs.

Remarbable economy in fuel and winding efficiency has been attained with the machinery designed by Mr. L. I. Seymour for the De Beers Diamond Mines, Kimberley, and built by Messrs. James Simpson & Co., of London. The plant consists of a pair of inverted vertical tandem compound condensing engines driving two reels, which are capable of carrying flat wire ropes 3⅝ by 13-16 inch. The winding is from the 1,200-foot level. Two automatically discharging skips are used, each weighing 4,400 lbs. and holding 9,600 lbs. of mineral. According to Mr. W. McDermott, on one occasion during a single shift of 11 hours 43 minutes, the weight of blue-ground raised was 3,665 tons. The engines have been in use for over 3 years, and consume only 2¼ lbs. of coal per horse-power per hour.

For highest speeds, vertical shafts and wire-rope guides are absolutely necessary. In metal mines time is saved by adopting vertical shafts and cages instead of inclined shafts and skips. The number of loading places should be reduced to the lowest limit. A great deal of the ore obtained from the upper levels could be dropped down winzes by balance cages, as is done in working inclined coal seams. In the Niddrie Collieries, near Edinburgh, experience shows that it pays better to drop coal 100 yards down a staple pit than to wind it from an intermediate landing.

The best method of increasing the speed of winding appears to be to slightly increase the size of the engines, and to greatly increase the steam pressure. Small engines start easily, get up speed quickly, and can be stopped more conveniently. Consequently time is saved at the bottom and at the top of the pit. This is important, as it is on stopping and starting that time is lost. In many cases endeavours have been made to obtain a combination of swift winding and econ-