

# Story of the Saw

**P. d'A. Jones and E. N. Simons**

---

**Spear & Jackson Limited 1760-1960**

---

*Published to mark the second centenary of  
the world's oldest sawmakers*

*Published in 1961 by Newman Neame (Northern) Limited  
Manchester, Birmingham and London  
for Spear and Jackson Limited, Aetna Works, Sheffield*

*Printed in England  
by James Cond Limited, London*

Scanned by The Traditional Tools Group Inc 2009  
for the benefit of members and others interested in  
the history of tools

# Contents

<i>Acknowledgements</i>	9
<b>Prehistoric, ancient and medieval times (to about 1450)</b>	11
The coming of the wheel	13
Saws of the Roman Empire	15
Medieval saws	21
<b>Modern times (1450 to the present)</b>	23
Sawmills	23
Handsaws	27
Circular saws	42
Brunel's statement of November 1811	44
Other inventions	44
Stone-working saws	48
Bandsaws	49
<b>Saws of 1960</b>	53
Short saws and long	53
Specialised circular saws	58
Wide and narrow bandsaws	70
Shaping history	73
<i>Selected bibliography</i>	74
<i>Index</i>	76

# Illustrations

- 1 Prehistoric flint saw
- 2 Two Mesolithic flint saws
- 3 Two mounted flint saws
- 4 Two modern primitive saws from Western Australia; they are made from stone and glass flakes set in gum. *University College, London*
- 5 Mesopotamian sawyers on the way to work
- 6 Egyptian handsaws. XVIIIth Dynasty, c. 1450 BC, tanged, of bronze or hardened copper with unraked, unset teeth. *British Museum, London*
- 7 Cabinet Makers. Egyptian: painting on clay dating from the end of the XVIIIth Dynasty – from *Temples and Treasures of Egypt*
- 8 Minoan bronze saw from Crete
- 9 Late Bronze Age saw (c. 800-400 BC) – found in Priory Farm Cave, Monkton, Pembrokeshire, Wales. *National Museum of Wales, Cardiff*
- 10 Siberian bronze saw, 6th to 3rd century BC. Krasnoyarsk district, River Yenisei, Siberia. *Minusinsk Museum, USSR. By courtesy of Mme V. P. Levashova, Moscow*
- 11 Roman iron frame-saw, used in Egypt; the wood frame is a replica. *Science Museum, London*
- 12 Roman carpenters at work; no toggle is shown on frame-saw. *By courtesy of Joan Liversidge, M Litt, FSA. From Antiquarium Comunate, Rome*
- 13 Roman handsaws; example on the right, from St Germain, is possibly an early back saw
- 14 Early Iron Age open handsaw. *Landesmuseum, Zurich*
- 15 Iron Age saw, c. 100 BC. Glastonbury lake village
- 16 British Iron Age saws, found in London
- 17 Saxon saw dating from the 10th century – found at Thetford in Norfolk. *Ministry of Works, London*
- 18 Medieval pit-sawyers. *British Museum, London*
- 19 Death by saw. *British Museum, London*
- 20 Sawmill from Villard de Honnecourt's sketchbook (c. 1250)
- 21 The Windcliff push saw. The earliest British example yet found of a push saw
- 22 11th-13th century Russian handsaw (knife-like) from Novgorod. Right: method of setting teeth. *B. A. Kolchin, Metalworking in Medieval Russia, Moscow, 1952*
- 23 A Virginian sawmill of 1650
- 24 Mechanical frame-saw as used in the 15th and 16th centuries
- 25 Sheffield saw-makers organise, 1797. *By courtesy of the Sheffield Sawmakers Protection Society*
- 26 15th century carpenters – from *History of Technology*
- 27 'Les Carpentiers' by Richard Tassel, 1580-1660. *Musée des Beaux Arts, Strasbourg*
- 28 English saw yard. *MS Diccionario de Construcción Naval*, first half of 18th century. *Museo Naval, Madrid*
- 29 Elementary mechanisation. *Bergeron, Manuel de Tourneur, Paris, 1816*
- 30 St Simon with M-toothed cross-cut saw. *Chasse de St Hippolyte, c. 1477. Unterlinden Museum, Colmar*
- 31 Early 15th century saw. *Poems of Christine de Pisan. British Museum, London*
- 32 Noah building the Ark. *Bedford Book of Hours. British Museum, London*

- 33 Baslow (Derbyshire) inn sign from 'The Joiner's Arms' (demolished some 200 years ago). The handle of the saw was originally open as evidenced by the rivet marks in the cross-bar
- 34 Holy Family. Saenredam, c. 1590. *Collection of J. M. Greber, Trier*
- 35 The earliest dated evidence of a closed handsaw handle. A carpenter's gravestone in the churchyard of St John-sub-Castro, Lewes, Sussex, 1747
- 36 18th century Swedish handsaws. *Nordiska Museet, Stockholm*
- 37 Early 18th century Dutch saws from the Peter the Great collection. Above: hacksaw. Below: handsaw. *State Hermitage, Leningrad*
- 38 18th century Swedish hacksaw. Another example, the blade much worn by repeated sharpening. *Nordiska Museet, Stockholm*
- 39 Early 19th century handsaws. *Smith's Key to the Manufactories of Sheffield, 1812*
- 40 Backsaw used in the 1770s by Samuel Crompton, inventor of the spinning mule. *Science Museum, London*
- 41 Shop sign showing crossed saws and gridiron, London, c. 1780. *Sir Ambrose Heal, Signboards of Old London Shops, Batsford, London*
- 42 Swedish compass saw, 19th century
- 43 18th and early 19th century Swedish tenon saws
- 44 Late 18th century shoulder saw. Swedish. *Nordiska Museet, Stockholm*
- 45 French *scie a araser* (1751-1769). *Diderot Encyclopédie*
- 46 18th century Dutch floorboard saw, used for cutting floorboards in position. *Stedelijk Museum, Leyden*
- 47 St Joseph and the Holy Child, c. 1525. *Museo National, Trento*
- 48 Buck saw with fixed blade favoured by the French in the 18th century. Buck saws and bow saws are still widely used, especially in Scandinavia. *Diderot Encyclopédie*
- 49 French carpenter's sign, 18th century. *Musée des Arts Décoratifs, Louvre, Paris*
- 50 18th century French coping saw. *Diderot Encyclopédie*
- 51 Felloe saw, used by wheelwrights and chairmakers. *Museum of English Rural Life, Reading*
- 52 18th century veneer sawing *Roubo: L'art du menuisier ébéniste, Paris, 1774*
- 53 Sabot maker's saw. *Musée Ducal, Bouillon, Belgium*
- 54 Sir Marc Isambard Brunel, 1769-1849, by James Northcote. *National Portrait Gallery, London*
- 55 Spear and Jackson price list of circular saws, March 1845
- 56 Industry in Sheffield: saw-making in the 19th century. *The Working Man, 1866*
- 57 Sheffield's name for quality in saws is of long standing. The Cross of the Legion of Honour was conferred on Samuel Jackson at the Paris Exhibition of 1855
- 58 Another decoration bestowed in 1873: Joseph Burdekin Jackson is honoured by the Emperor Francis Joseph of Austria. These honours and awards were typical of many earned by Sheffield cutlers and saw-makers at this time
- 59 Early form of inserted-tooth saw showing holder and wedge-fitted tooth. Original hoe patent registered in the USA c. 1870 was for a solid tooth insert, later developed into a two piece spring shank and a bit or tooth
- 60 An obsolete Slack's machine knife grinding machine with tilting table and fixed wheel occupies the foreground. Behind it is the saddle type machine on which the grinder sits astride. Such machines were formerly employed for grinding saws
- 61 William Newberry's bandsaw, 1808
- 62 A Robinson 6-foot vertical bandmill with log carriage installed, in 1923, in the North Western Railway workshop, Moghalpura, Lahore. This bandmill was the first on the Indian sub-continent to convert timber in log form by endless band blades
- 63 A modern tenon or back saw, fitted with brass or steel back
- 64 Nest of saws
- 65 Grecian pruning saw
- 66 Pit-sawing in Ghana. Saws up to ten feet long are used frequently. *Ghana Information Service, Accra, Ghana*

- 67 Tubular frame or log saw. Example shown incorporates a patented adjustable straight-pull tensioning device
- 68 Automated production of log saw blades or webs. Lines of file-sharpening machines are shown
- 69 Rolling steel sheet for short saws
- 70 The Spear and Jackson *Double Century* handsaw with rosewood handle. Diagram below illustrates the effect of radial taper-grinding
- 71 Setting the teeth of a best quality handsaw. No machine yet devised duplicates the flexible wrist and sensitive touch of a craftsman
- 72 Typical circular saws for ripping and cross-cutting, showing manufacturer's standard tooth shapes
- 73 Hardening the heated blade by quenching in oil. A 72-inch diameter solid tooth saw at red heat is quenched
- 74 Smithing: putting the tension into a saw blade. An 84-inch diameter solid tooth saw is shown
- 75 Not every customer agrees with the manufacturer's tooth shape. A saw is given a shark's tooth form
- 76 Sheffield companies cater for the needs of the Canadian west coast lumber industry. The new Spear and Jackson (BC) Limited factory at Burnaby, Vancouver
- 77 Modern sawmill, showing multiple trimmer fitted with saws supplied by the Spear and Jackson Vancouver factory and made from Sheffield rolled plate
- 78 Fitting the teeth and holders in an inserted-tooth circular saw
- 79 Standard type holder and tooth of a modern inserted tooth circular saw. See also 59
- 80 Re-sharpening the teeth in situ by flexible drive jockey grinder
- 81 Cutting cold metal by segmental circular saw
- 82 Fitting high-speed steel segments to a metal-cutting cold saw
- 83 Cutting aluminium plates 57 feet long by 10 feet wide by 6 inches thick. A comparative newcomer to the saw family, the tungsten carbide-tipped saw here takes on a mammoth task. *Northern Aluminium Company Limited, Banbury*
- 84 A close-up of the tungsten carbide-tipped circular saw in use on the Wadkin machine shown above. *Northern Aluminium Company Limited, Banbury*
- 85 Final lapping by diamond impregnated wheel of a 50-inch diameter tungsten carbide-tipped saw
- 86 The world's largest saw is this giant 11 feet 7½ inch diamond-segmented saw employed in cutting rough-hewn blocks of Portland stone at the South Western Stone Company's quarries on Portland Bill in Dorset
- 87 A Spear and Jackson team of three smithers prepares to tension the largest saw ever made
- 88 The latest development in circular saws: an internal tooth tube saw. Segmental in construction, taper-ground and of high-speed steel, this unique saw operates within the eccentric head of a machine patented in 1960. Its purpose is to cut ferrous and non-ferrous tube without 'fash'
- 89 A Stenner 42-inch band rack with hand operated carriage. *Stenners of Tiverton Limited, Devon*
- 90 A modern band re-saw made by Thomas Robinson and Son Limited of Rochdale
- 91 Abattoirs use bandsaws for cutting carcasses. Smaller bandsaws, such as this Wadkin-Bursgreen machine with 16-inch wheels, are found useful by retail traders for cutting the meat into small joints
- 92 Recent development of friction discs provides the engineer with a new tool. Here one is employed for rapid cutting of tubes in the Spear and Jackson tubular frame saw department
- 93 A few links of Oregon chipper saw chain. The replacement of two-man cross-cuts by powered cross-cuts has revolutionised logging methods. The inventor of the Oregon chipper saw chain illustrated had studied the larvae of *Ergates spiculatus*, the timber beetle, in developing the design of the left and right hand cutters of his chain
- 94 Felling in the forest by power-operated saw chain

# Acknowledgements

Research for this history was carried out at the institutions listed below, and the authors would like to take this opportunity of thanking the respective staffs for their help.

Brighton Museum  
British Museum  
Eastbourne Reference library  
Edgar Allen library, Sheffield University  
Imperial College of Science and Technology  
London School of Economics: British Library of Political  
and Economic Science  
London University: the library and senate house  
Manchester Central Reference library  
Manchester University: the Arts library and the Christie library  
Museum of English Rural Life, Reading  
Patent Office library  
Public Record Office  
Science Museum library  
Sheffield Central Reference library: the Local History library

The material from Spear and Jackson archives is to be deposited in the Sheffield Central library. We should like to thank the Museum of English Rural Life at Reading for permission to publish photographs of saws in their collection, Mr W. L. Goodman of Bristol for the loan of a large number of photographs from his collection and Mr E. K. Rowles of Drabble and Sanderson Limited for technical assistance on the modern section of the *Story of the Saw*. Dr W. H. Chaloner of the Economic History department of Manchester University was kind enough to check the manuscript; but any errors are the sole responsibility of the authors.

# Prehistoric, ancient and medieval times

## (to about 1450)

More than half a million years ago, man took a tremendous step. That step helped to distinguish him forever from the less intelligent and un-selfconscious animal world: he began to make hand tools.

Because they were of such great antiquity, many of our familiar hand tools had already attained a late stage of development in classical or medieval times. The very thing that surprises people today when they first see four or five hundred years-old axes, planes, hammers, chisels and saws is that they all look so 'modern'.

The basic principle of sawing was first devised in the pre-metal age. Neolithic man adapted as tools the objects he found around him; he cut crude and uneven notches or serrations in the edges of flint flakes. The principle of abrasion man understood from his fire-saw or sawing-thong. This was a system of rubbing one piece of wood, bamboo or thong (saw) against another (hearth) so that the sparks from the friction fell into the sawing dust and made fire. It was a technique common all over Europe, India, Australia, South-East Asia and the Pacific Islands.

Archaeological excavations in Southern France have provided some very early examples of flint saws from what pre-historians call the Magdalenian culture of the Upper Palaeolithic period (reindeer period). Many such saws were still being used countless years later in the so-called Bronze age, and were being copied in metal. Saws six or seven thousand years old made from a black vitreous lava called obsidian were uncovered in the great excavations at the ancient Sumerian capital, Ur of the Chaldees in Mesopota-

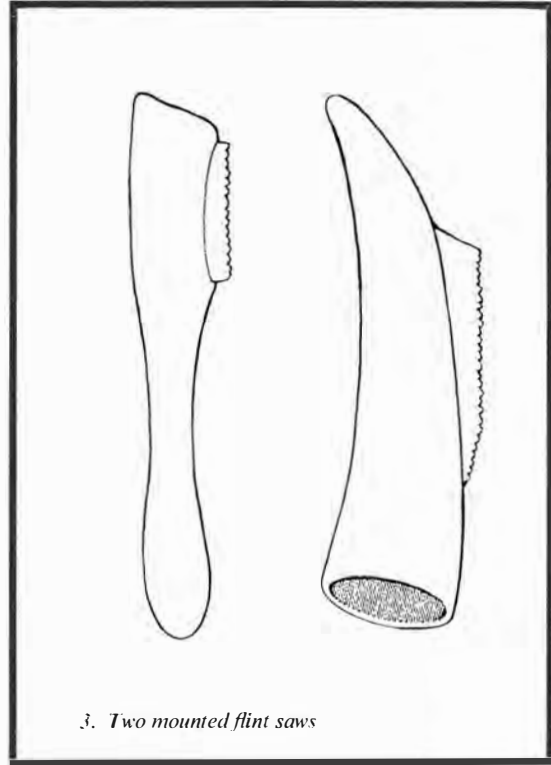
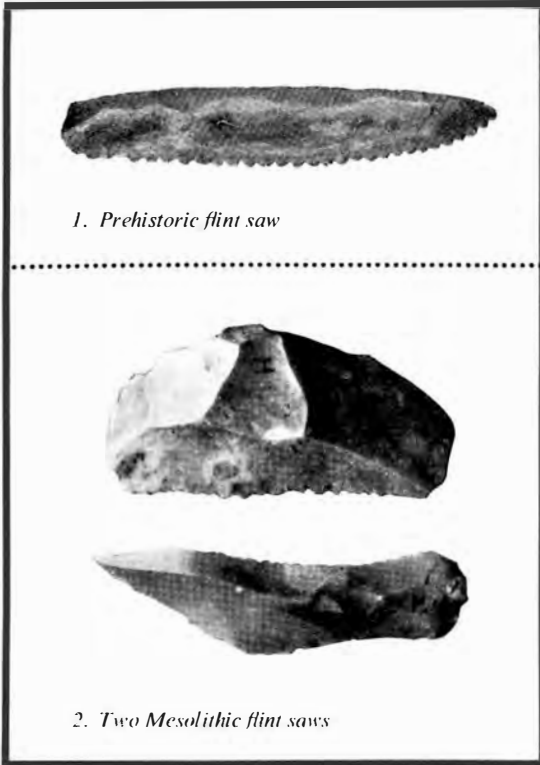
mia. These small, two inch-long blades (now in the University of Pennsylvania Museum at Philadelphia in the United States) were the tools of Sumerian craftsmen in the legendary lands of the Garden of Eden between the rivers Tigris and Euphrates, two thousand years before the birth of Abraham.<sup>1</sup>

Prehistoric saws which were found in the tumuli or burial mounds of Northern England, in French caves, in the stone-heaps or Kjekken-Moddings of Sweden and Denmark and in former lake-dwelling sites in Switzerland and Italy have an average length of about three inches and vary in length from one and a half inches to nine inches. Many flint artefacts were not true saws but sickles, and these very tiny saws were used to cut bone, wood and horn in the making of ornaments. Flint was favoured, being hard and chipping into a keen, straight cutting-edge. It is even thought that the best kinds of flint for this purpose were used in prehistoric trade. But the flint saw was thick and easily wedged in the cutting groove. The problem was not solved at this stage of history, despite the more sophisticated models like those found at Palada, Northern Italy, and Vinelz, Switzerland, on which serrated flint flakes are mounted with natural asphalt in a grooved wooden or stag horn handle.

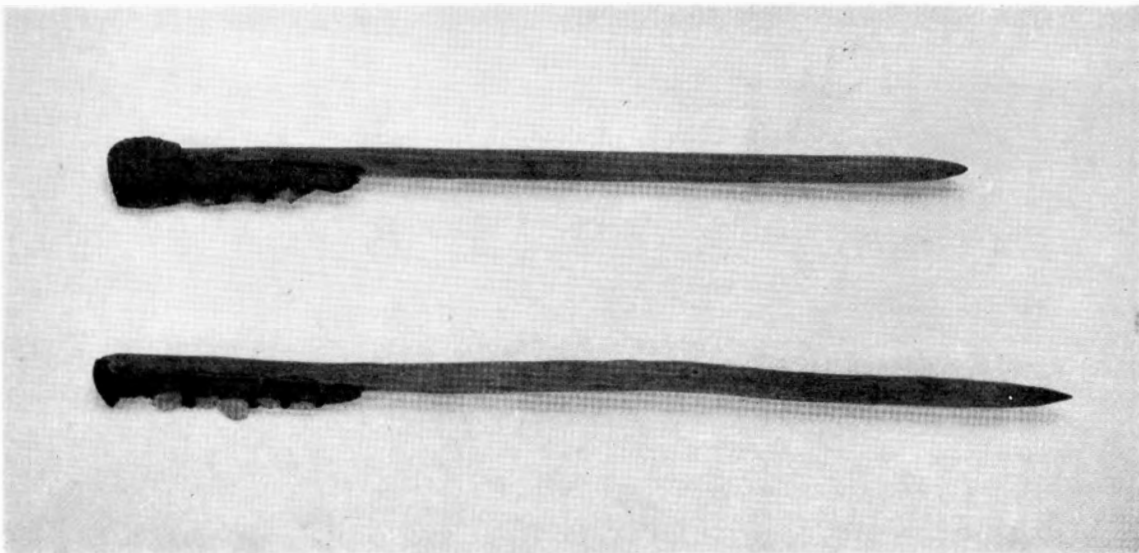
The length and shape of pre-metal saws were determined largely by accident. Man merely adapted what he found at hand and had little choice of design.

<sup>1</sup> Disston, H. and Sons Inc, *The Saw in History*, 8th ed, New York, 1925, p 6





4. *Two modern primitive saws from Western Australia; they are made from stone and glass flakes set in gum*





5. *Mesopotamian sawyers on the way to work*

Pacific islanders used sharks' teeth saws, the aborigines of Madeira favoured the snout of the saw-fish, while the Caribbean Indians notched shells and the Aztecs (like the Sumerians long before) used obsidian, found in quantities on the volcanic slopes of Mexico. They all had to accept the dictates of local geography. With the coming of metals man could himself design and determine the kind of saw he wanted.

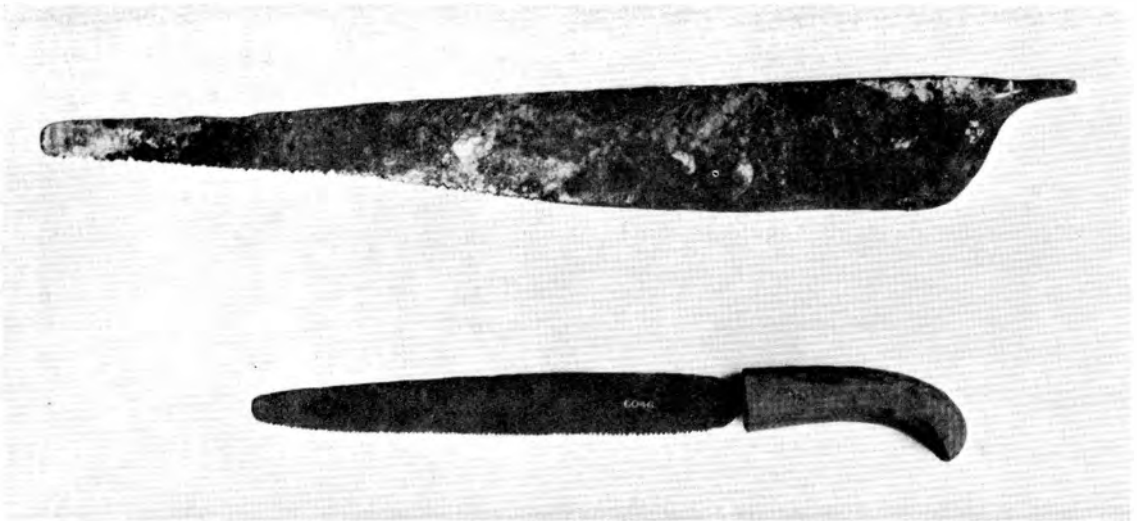
## The coming of the wheel

One of the greatest single events in the history of mankind – the invention of the wheel – may well not have been possible without the earlier invention of the metal saw. It was well-nigh impossible to make a wheel without a saw, and really effective timber saws had to be made of metal. So, copper, bronze or iron deposits were the essential condition for the evolution of the wheel.<sup>2</sup>

An extremely early example of a metal saw was found in the hearse graves at Kish in Mesopotamia – that cradle of technical civilisation which also yielded up the very early obsidian saws. Egyptian metal saws were made of copper, bronze, and more rarely of iron. The earliest of these saws were made of hardened copper, and date back as far as the IIIrd Dynasty (or roughly 4900 to 4700 BC). They began as large, round, crudely serrated copper knives with the teeth sloping in no particular direction, not raked, and therefore cutting in both directions. The examples found were used for the lugubrious task of cutting up coffin boards.

In later Egyptian dynasties the saw teeth were made larger and the uses to which the saws were put widened. The Vth Dynasty witnessed unraked four-

<sup>2</sup> Singer, C. et al, *History of Technology*, 4 Vols, London, 1954–58, Vol I, p 207



6. Egyptian handsaws. XVIIIth Dynasty, c. 1450 BC, tanged, of bronze or hardened copper with unraked, unset teeth

foot long open saws with large triangular teeth, and the VIth Dynasty longer eight-foot saws, used, like most Egyptian saws in the early period, for stone-cutting. Fed with sand or emery, or set with emery teeth, these saws cut huge limestone blocks seven or eight feet long over 4000 years before the birth of Christ.<sup>3</sup> In later dynasties too, bronze began to replace copper, the use of saws as woodworking tools was greatly extended and the handsaw began to take on something of its modern appearance, with wooden pistol-grip handle (XIIth Dynasty) and made to average modern size.<sup>4</sup> In the British Museum there is an XVIIIth Dynasty open handsaw found in 1853, with other tools, in a tomb at Thebes; this find dates back to about 1450 BC. Its blade is bronze or hardened copper and its wooden handle under five inches long fits, like a modern table-knife, over a metal tang which is of a piece with the blade. Its teeth are unraked, unset and V-shaped; and so its ten and a half inch blade cuts both ways.

Egyptian workmen even had bronze saws with jewelled teeth for difficult stone-cutting operations and, in later years, iron saws. A wedge of iron was found in the masonry of the Great Pyramid which was built in 3500 BC. Despite this, Egyptian craftsmen were beset by several grave difficulties. Copper and bronze saws were both laborious and inaccurate,

and all work done by them needed finishing with an adze or a rasp. Saws remained merely abrading tools as long as their teeth were not raked. And although the bronze saws were superior to flint ones because they were thin and wedged less easily in the kerf (cut), bronze was admirably suited for making other edge tools.

In some cases these tools actually supplanted the saw. For instance, where wood was abundant, forest timber was 'converted' by being split with wedges and hewn.<sup>5</sup>

In the Old Testament are three well-known standard references to the saw. Two of these references relate to events that took place in the 10th century BC. The earliest described David's gruesome treatment of Ammonite prisoners-of-war from the captured city of Rabbah

And he brought forth the people that were therein, and put them under saws, and under harrows of iron, and under axes of iron, and made them pass through the brick-kiln: and thus did he unto all the cities of the children of Ammon.

Second Book of Samuel, XII, 31

In the next generation Solomon, David's son and successor, built a great Temple, a palace for himself and another for his wife, Pharaoh's daughter.

<sup>3</sup> *ibid*, p 570 <sup>4</sup> *ibid*, p 613 <sup>5</sup> *Disston op cit*, p 10

All these were of costly stones, according to the measures of hewed stones, sawed with saws, within and without, even from the foundation unto the coping . . .

First Book of Kings, VII, 9

Two hundred years or more later, in the 8th century BC, Isaiah, preaching his message in what are obviously homely and everyday images, asks

Shall the axe boast itself against him that heweth therewith? or shall the saw magnify itself against him that shaketh it?

Isaiah, X, 15

It is claimed by later Church writings that Isaiah suffered death by being sawn apart, and in the New Testament, Paul, casting a backward glance, says of many of the prophets

. . . they were stoned, they were sawn asunder, were tempted, were slain with the sword.

Epistle to the Hebrews, XI, 37

Both uses of the saw mentioned in the Bible – the one for stoneworking and the other for torture – were to have an even longer history, and they re-enter the story of the saw many centuries later.

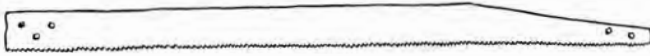
## Saws of the Roman Empire

In Europe examples of Bronze Age saws are comparatively rare, and have come from Scandinavia, Central Europe and Siberia. The Greeks were not great technical innovators. Greek architecture introduced little in the way of new methods of enclosing space. It was left to the Romans to do this. The Greeks simply adapted known methods superbly well. It is thought unlikely that the Greeks wrought any changes in saw-making or sawing technique. There is evidence that they used traditional copper and bronze saws for wood and stone conversion.

Real changes in the manufacture and use of saws

7. *Cabinet Makers. Egyptian: painting on clay dating from the end of the XVIIIth Dynasty from Temples and Treasures of Egypt*





8. *Minoan bronze saw from Crete*



9. *Late Iron Bronze Age saw (c. 800-400 BC)–  
found in Pioroy Farm Cave, Monkton, Pembrokeshire, Wales*



10. *Siberian bronze saw, 6th to 3rd century BC. Krasnoyarsk district,  
River Yenesei, Siberia*

came only with the introduction of iron production. Hesiod's reference to 'bright' iron and 'black' iron in the 9th century BC and further references in the 5th century BC have led writers to place the first use of steel some time between these two centuries; but even this evidence is inconclusive. Before the birth of Christ, the making of steel could be accomplished only in two ways. First, by the direct production of 'natural' steel from manganese bearing iron ores or, second, by the surface carburisation of wrought iron.

The latter, called the 'cementation' process, involves

placing wrought iron at red heat in contact with carbonaceous material. Iron absorbs carbon, and a grade of steel is thus formed. It is possible that when converting bloom into wrought iron, early craftsmen may have superficially carburised the iron by continual charcoal heatings between the hammerings, and made steel this way. There is some evidence that quenching (plunging the metal at heat into cold water) was practised as early as 1200 BC. Quenching makes the metal hard but brittle, and further heat treatment is needed in order to counteract this. Tempering is one way of furnishing further heat treatment, but it is

not believed this was practised until the Roman era.<sup>6</sup>

The steel made by quenching would in any case have been costly both in time and material. It would have been impure and not very homogeneous in composition. Much doubt still remains about the first use of steel. This arises from the imprecise distinction between iron and steel and the special difficulty of identifying wrought iron. However, metal technology has always been recognised as very important to the saw-maker. For instance Love and Manson (the parent firm of Spear and Jackson) who started their business in 1760 chiefly to make the new crucible steel, soon found themselves making saws for a living. Even then they recognised that the quality of a saw is to a great extent the quality of its metal.

The Iron Age (from about 500 BC to 50 AD) brought definite improvements at the time quite apart from that of future development in steel. First, the Iron Age saw the general introduction of the raking of teeth to give a cut in one direction only – on the pull

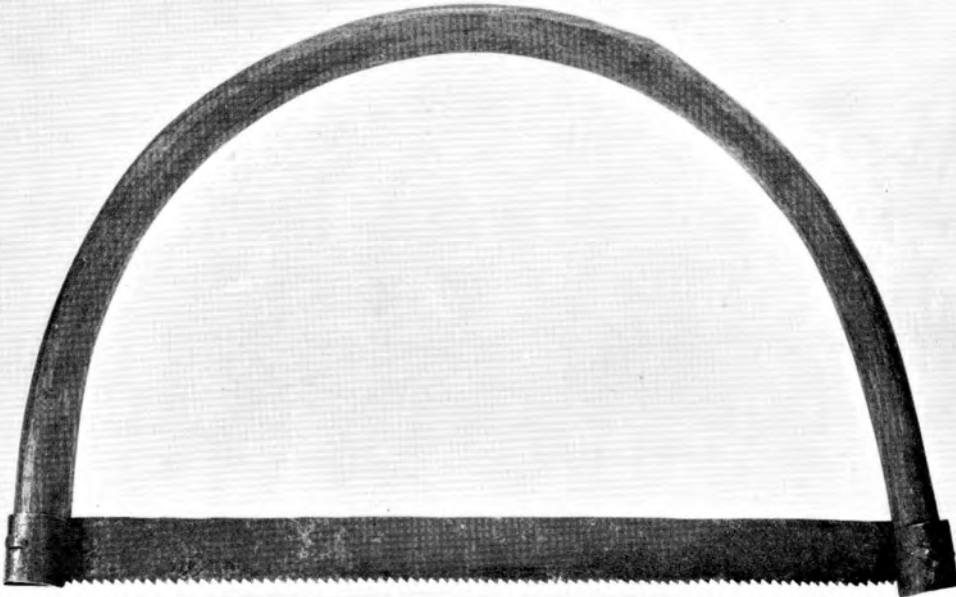
stroke, so the teeth were raked towards the handle. This was a great advance on haphazard unraked teeth, even though pull strokes are much weaker actions than the push strokes of modern saws. Push stroke saws could not be used successfully until some means had been discovered for overcoming the tendency of weak metals to bend. High quality steel and tensioning have overcome this problem, but even as late as the time of the Roman Empire, push stroke saws were still unsuccessful.

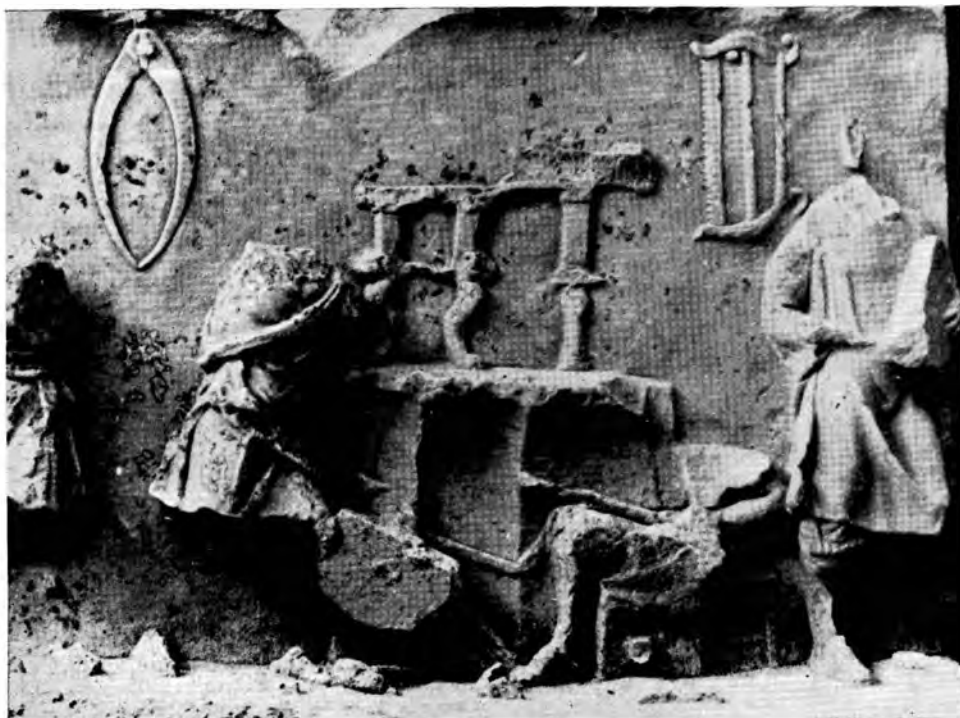
The American scholar, Dr H. C. Mercer dates the first clearly raked saws to about 900 BC.<sup>7</sup> These saws must have been of copper or bronze as the Egyptians did not generally switch to iron saws until about 660 BC. One type of saw remained unraked, because

<sup>6</sup> Schubert, H. R. *History of the British Iron and Steel Industry* (from c. 450 to AD 1775), London, 1957, pp 29–30

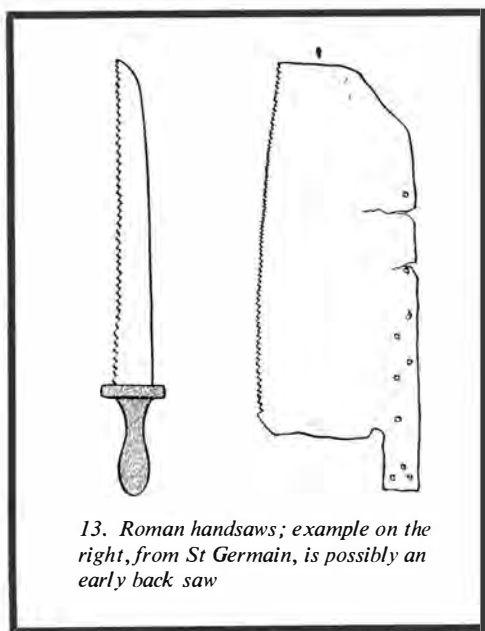
<sup>7</sup> Mercer, H. C. *Ancient Carpenters' Tools*, Doylestown, Pa, 1929, p 144

11. Roman iron frame-saw, used in Egypt; the wood frame is a replica





12. Roman car penters at work; no toggle is shown on frame-saw



13. Roman handsaws; example on the right, from St Germain, is possibly an early back saw

of its particular function; this was the cross-cut or thwart saw. The raked pull stroke handsaws were all rip saws, made especially for cutting down the grain.

Some Iron Age saws even had their teeth almost correctly set so as to allow working clearance in the cut or kerf. For unless the kerf is wider than the blade the saw will clog. In any case there must be some provision for continuous removal of dust, whether stone or wood. Three ways are known of tackling this problem: first, the kerf can be expanded with wedges (a method of the old pit-sawyers and of tree-fellers); second, the back of the saw blade can be made thinner than the toothed edge (as in 19th century compass and keyhole saws); and third, the teeth can be set or bent very slightly to right and left alternately. We owe the final practice to the Romans. The Egyptians had simply used wedges and greased the blade hopefully.<sup>8</sup>

<sup>8</sup> Singer, op cit, Vol II, p 229; Mercer, op cit, pp 159-160

The other major innovation of the Iron Age, developed but not invented by the Romans, was the frame-saw. This was an ingenious way of avoiding the bending and buckling of soft metal blades by setting the blade either centrally in a frame or as one side of a frame. Previously all saws had been open and unframed, with a handle at one end or occasionally at both ends of the blade. As early as the Iron Age the frame-saw began to look very much the same as the modern hacksaw. In the type where the blade is one side of the frame itself, strained between two wooden arms and held apart by twisted cord, it cannot be stated for certain whether the Romans could vary the tension on their blades by means of a toggle-stick twisted in the centre of the cord. The absence of a toggle-stick device would be a considerable disadvantage, but much worse was the fact that Roman iron blades were still too soft for cutting either effectively or readily on the push-stroke, even in frames. A Roman open saw of the 1st century BC in St Germain-en-Laye, France, has its handle extended along the top edge of the blade, similar to the modern tenon saws, in order to prevent bending on the forward stroke.

Like the Etruscans before them, the Romans had long two-handed saws for converting felled timber

and, like the Egyptians, used saws for stone-conversion. The Egyptian influence was a direct one, for the Romans themselves had quarries in Egypt. Jewish prisoners taken by Emperor Claudius (41–54 AD) worked with copper saws to cut stone in the Eastern desert, their blades being fed with sand and emery in the traditional Egyptian way.<sup>9</sup>

Granite blocks are known to have been cut with handsaws in the Roman quarry at Odenwald (in the province of Hesse in Germany). Used for altar stones, these granite blocks were worked with great accuracy and the German scholar, Dr A. Neuberger, has written about them:<sup>10</sup>

The saw blade used must have had a length of at least fifteen feet, and have produced cuts only one-sixth of an inch wide, that is, not wider than the modern frame-saw.

This description presents a very great achievement, but what is even more impressive is that by the end of the 4th century AD the Romans were successfully employing machine-saws in their German quarries. Ausonius, in his poem about the Moselle countryside entitled *Mosella*, hailing a tributary stream near Trier

<sup>9</sup> Singer, op cit, II, p 29

<sup>10</sup> Neuberger, A. *Technical Arts and Sciences of the Ancients*, trans H. L. Brose, London, 1930, pp 402 ff

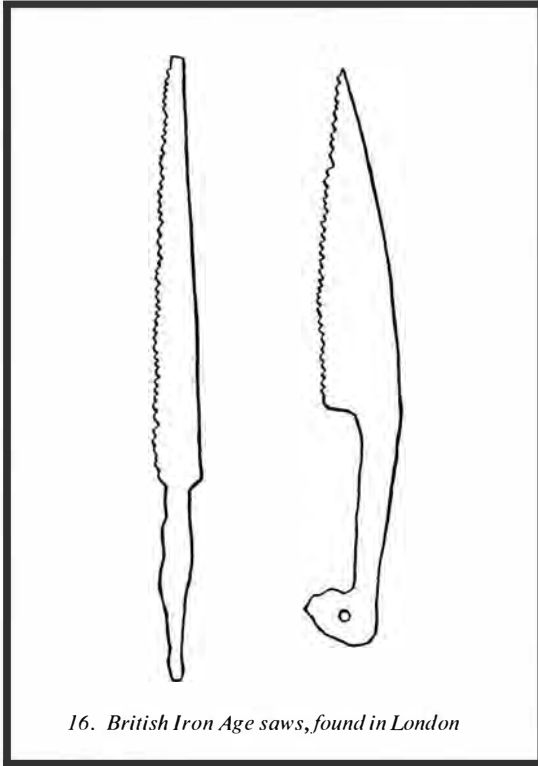


14. Early Iron Age open handsaw



15. Iron Age saw, c. 100 BC. Glastonbury lake village



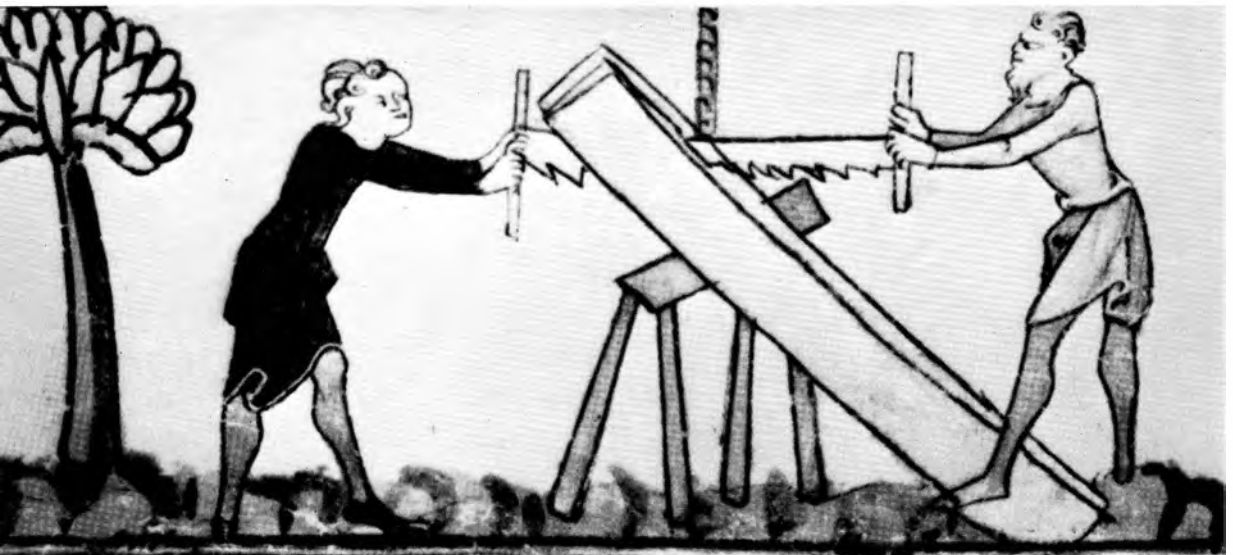


16. *British Iron Age saws, found in London*



17. *Saxon saw dating from the 10th century – found at Thetford in Norfolk*

18. *Medieval pit-sawyers*



(near the border of modern Luxembourg) which was famed for marble, says:<sup>11</sup>

He turns his millstones in furious revolutions and drives the shrieking saws through smooth blocks of marble, and so hears from either side a ceaseless din.

The poem was written in about the year 370 AD.

While Roman advances were without doubt exceptional, examples of saw craftsmanship in other parts of the continent of Europe are not hard to find. Indeed, before the era of the Roman Empire excellent raked iron saws were being made in Britain and Switzerland, examples of which can be seen in the Glastonbury Museum and the Zurich Landesmuseum. A late Celtic saw found in Glastonbury in the year 1892 actually has set teeth. A Swedish late Iron Age handsaw has teeth set in groups of five on alternate sides of the blade. The handle of the saw is on a tang, which goes right through it and is clinched at the end.

It was, however, the need to subjugate, administrate and defend a great continental Empire stretching over the face of Europe that stimulated the Romans to the greatest technical achievements of the age.

## Medieval saws

The Middle Ages witnessed no significant advances in the technical evolution of the saw other than the

introduction of sawmills. These, though they were exploited mainly in the early modern period, actually date back to at least the 13th century.

Throughout medieval times the use of saws became much more general all over Europe, and a considerable variety of them was developed. The saw became, next to the axe, the most symbolic of tools. There were five main types of medieval saws, open handsaws, two-handled saws, frame-saws, pit-saws and machine saws.

Open handsaws, sabre-like and cutting on the push stroke like those of today, needed to be thick-bladed. Two-man saws could always be kept in tension, if used correctly. Frame-saws had by this time definitely acquired adjustable tension: a 12th century Italian mosaic in Monreale cathedral depicts a startlingly perfected instrument<sup>12</sup> of which the blade could be turned out of line with the frame, to cut a board down its length if necessary.

Pit-sawing, previously performed by the Romans, was a method for converting logs into boards and planks, especially for flooring. The cut to be made was marked by placing a stretched string dipped in

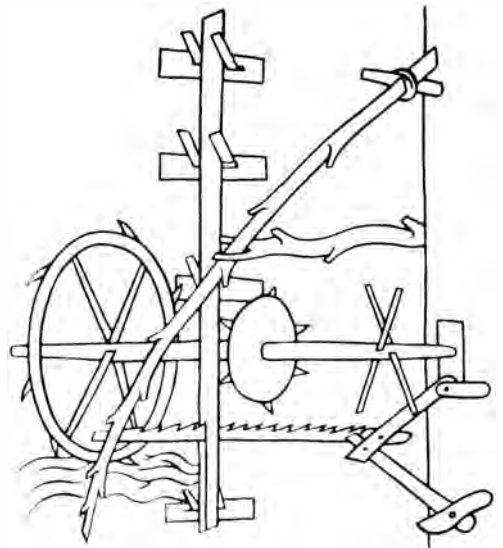
<sup>11</sup> Ausonius, trans H. G. Evelyn White, *Loeb Classics*, London, 1919. Vol I, pp 252-3

<sup>12</sup> Singer, *op cit*, II, p 391

19. *Death by saw*



20. *Sawmill from Villard de Honnecourt's sketchbook (c. 1250)*



chalk or pigment over the necessary cutting line, and simply flicking it against the timber. The technique of pit-sawing will be described in a later section.

As for medieval machine saws, they depended for their motive-power, like all other machines of their age, on the treadmills, windmills or water-mills which gave a continuous rotary action. The difficulty in the use of the camshaft idea, when applied to sawing, was that saws were not in themselves heavy enough objects to make the return motions. In Villard de Honnecourt's now well-known machine of about 1250, however, the return motion was made by the simple relaxation of a bent pole.<sup>13</sup>

Britain and Russia have provided interesting examples of handsaws. The earliest saw in England to cut on the push stroke was dug out of a 13th century midden at Windcliff, near Niton, and was reported in the *Isle of Wight Archaeological Society Proceedings (1939)*.<sup>14</sup>

The teeth are crosscut and very large, there being only four teeth to the inch. Alternate teeth are slightly set to opposite sides, so that the cut made by the saw itself is wider than the saw. The points of the teeth all slope away from the handle, which shows that this is a push saw. The saw is 0.2 of an inch thick at the teeth and tapers gradually almost to an edge along the back . . .

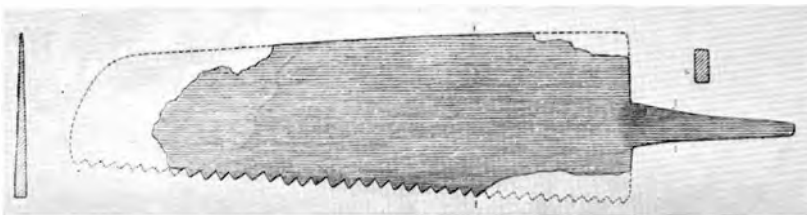
This 13th century saw embodies most of the advantages required. These advantages were tapered blade, teeth raked and set, cutting on the push. Several

British 14th and 15th century church paintings depict push saws, but little other evidence is yet available for earlier years. It seems very likely that the change over from pull to push blades took place gradually during the 12th century, or even in the late 11th century.

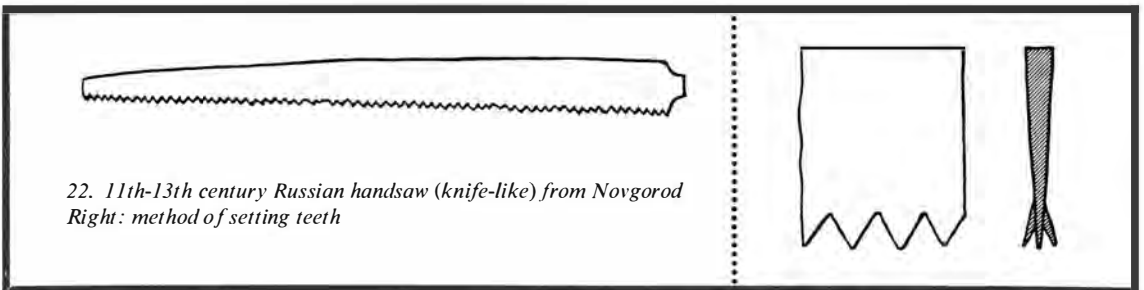
In Russia, however, some blades of the 10th to 13th centuries have luckily survived. They are open handsaws and two-man frame bow saws. The handsaws were knife-shaped, over a foot long and one and a half inches wide near the handle. The teeth were graded, more to the inch towards the point of the blade, and they were set, every third tooth being flattened. The bow saws had unset teeth, but the blade tapered towards the back edge. It was during the 10th and 11th centuries that Viking invaders took over control of the Slav tribes on the river Dnieper, created a great trade route connecting the Baltic with the Black Sea and Mediterranean and established the first centre of Russian civilisation – the Principality of Kiev. These Russian saws and others like them must have played a great role in the forest industries, in the building of river ports and in the construction of the trading ships which were the basis of economic life in Kievan Russia.

<sup>13</sup> *ibid*, pp 643–4

<sup>14</sup> *Proceedings, Isle of Wight Natural History and Archaeological Society, Vol III, Part II, 1939: G. C. Dunning, A Thirteenth Century Midden at Windcliff, near Niton*



21. *The Windcliff push saw. The earliest British example yet found of a push saw*



22. *11th-13th century Russian handsaw (knife-like) from Novgorod*  
 Right: *method of setting teeth*

# Modern times

## (1450 to the present)

In the history of the saw the characteristic feature of the early modern period was undoubtedly the adoption of the sawmill in many parts of Europe and, later in the 17th century, in the New World. Coming into use were blast-furnaces; and the actual casting of iron (a technique learned by the ancient Romans from the Chinese) was introduced in Britain somewhere between the years 1490 and 1500, under the reign of Henry VII, the first of the invigorating Tudor dynasty.

### Sawmills

We have already noticed two remarkable examples of sawmills long before the mid-15th century – one Roman and one medieval. But like many other technical innovations sawmills were adopted only very gradually, and even as late as the 18th century the pit-saw was still in more general use.<sup>15</sup> It was the advent of the steam-engine, in the late 18th century, that was the chief stimulus to the widespread employment of woodworking machinery.

Among the earliest known sawmills was one near Augsburg in Germany. The 15th and 16th centuries are full of examples of sawmills:<sup>16</sup> from 1420 the Portuguese built mills in Madeira to exploit the timber resources of the island; mills were constructed in Silesia, at Breslau (1427), at Erfurt (1490), in Norway (1530), in Holstein (1545), in Ratisbon (1575 – a very early gang-saw), in Holland (from 1596) and in Sweden (from about 1653).

The first Norwegian sawmills to practise what con-

temporaries called the ‘new art of manufacturing timber’ was opened in about 1530 to meet the demands of the expanding export trade in deal (and later, of the deal tax imposed by Christian III in 1545).<sup>17</sup> In 1555, Queen Mary’s ambassador to Rome described a sawmill he saw on his journey through France at Lyons. He wrote that the waterwheel:

... hath a piece of timber put to the axle-tree end, like the handle of a brooch (sic), and fastened to the end of a saw . . . Also the timber lieth as it were upon a ladder, which is brought little by little to the saw with another vice.

Despite the ambassador’s report<sup>18</sup> England was remarkably conservative and slow to accept sawmills. Although they were used extensively by the Dutch, French, Scandinavians, Germans and Poles, and in every new town in the British colonies of New England in the 17th century, the English consistently refused to employ them.

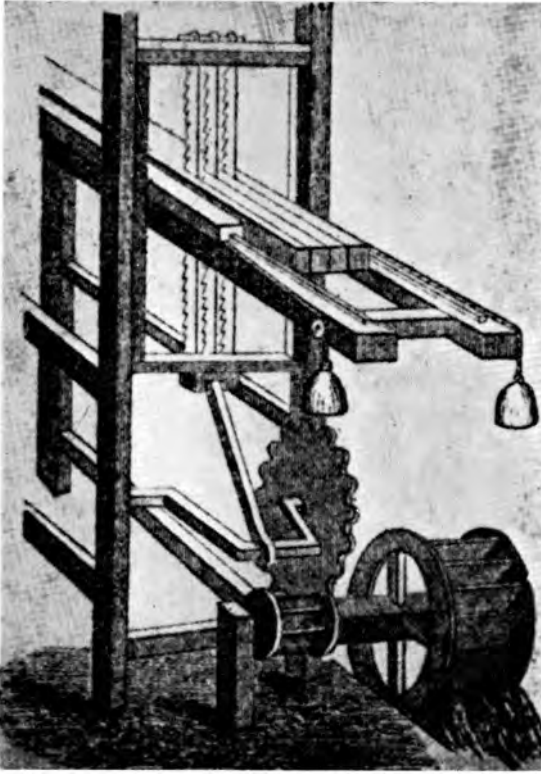
An attempt by a Dutchman to start a mill near London was prevented by violence from hand sawyers

<sup>15</sup> Mercer, *op cit*, p 16

<sup>16</sup> Note Disston, *op cit*, p 13, says 1322, but gives no particular evidence. M. Powis Bale, *Woodworking Machinery*, 3rd ed, London 1914 (1894), pp 4–6, says 1337 and bases it on Stetten: *Kunst und Handwerks-geschichte der Stadt Augsburg, 1779*

<sup>17</sup> *Sawmill Magazine*, Sheffield, Vol I, No 4, Nov-Dec. 1925, p 112

<sup>18</sup> Hardwicke Miscellaneous State papers, 1501–1723, p 71



23. *A Virginian sawmill of 1650*

in 1663, and as late as 1767-68 John Houghton's Limehouse sawmill was destroyed by an angry mob of artisans fearing loss of employment.

Thirteen years later Walter Taylor of Southampton was turning out ships' blocks for the Royal Navy from a sawmill on the river Itchen using a new circular saw, with which he was quite successful. It is surprising that the Navy, despite its great need, did not adopt the use of sawmills until the late 18th century, and even as late as 1862 – when the first iron-clad warship was launched – half the Navy's timber was hand converted. The pit-saw method was so costly and laborious that few deals or boards were in fact cut in England. It was found to be cheaper to import them from Danzig, where they were made cheaply with the help of windmills. The thriving Baltic and Dutch ports all had sawmills.<sup>19</sup>

The first American sawmill was probably the one built by Captain W. Gorges in what is now York,

Maine, in either the year 1623 or 1624. Subsequently every town acquired a mill – in fact the sawmill followed the frontier line in its westward advance across the continent of North America and was the mainstay of the economy of Maine and New Hampshire. In 1803, a steam-powered sawmill in New Orleans was destroyed by hand sawyers, and about two years later they smashed a mill in Natchez, higher up the great Mississippi river. This was in spite of the fact that unlike Britain with its acute unemployment problems the United States had a long-term labour shortage. The total number of lumbering establishments in the United States in the year 1810 was 2,541 (2,016 of them were in Pennsylvania), and immediately before the Civil War, in 1860, there were ten times that number: 20,658.<sup>20</sup>

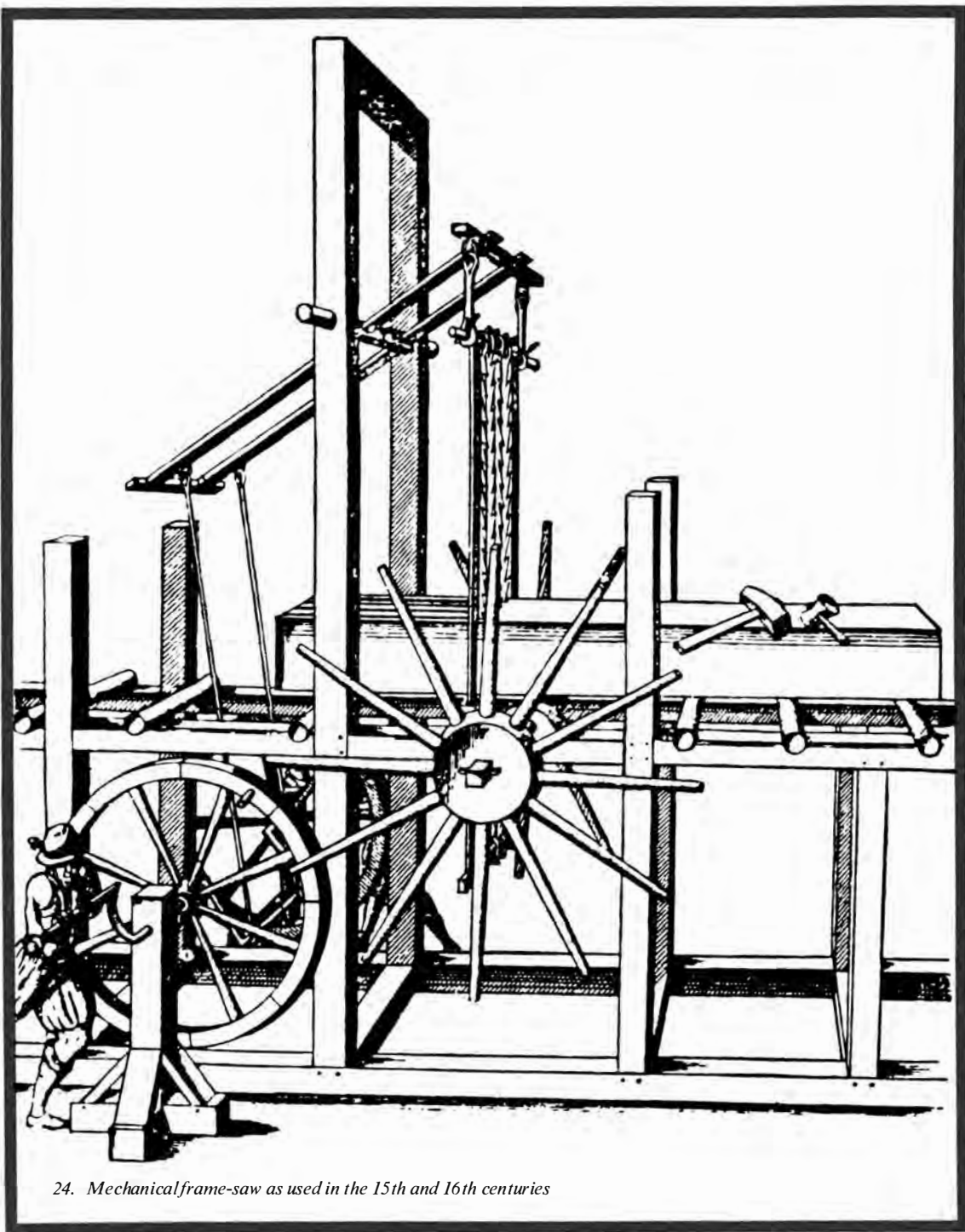
As early as 1790, when England was only beginning to adopt sawmills, one Massachusetts factory was turning out up to 250 mill-saw blades a year for gang-saws. The effect on American productivity was immediate: a man and a boy could cut 4,000 feet of timber, fifteen feet to twenty feet long and one inch thick in ten hours.

Even so, the early mill-saw in the United States was only a single, vertical, reciprocating blade saw, so slow that a sawyer had ample time to squat on the log and eat his lunch. Wind, river and tides turned the mill-wheels. Saw blades were held in tension in tough wooden frames, driven up and down by cranks on a revolving shaft attached through cogs to the ever-turning mill-wheels. Later models, gang-saws, had several blades together. The saw frames were themselves inside further frames secured to the mill foundations.

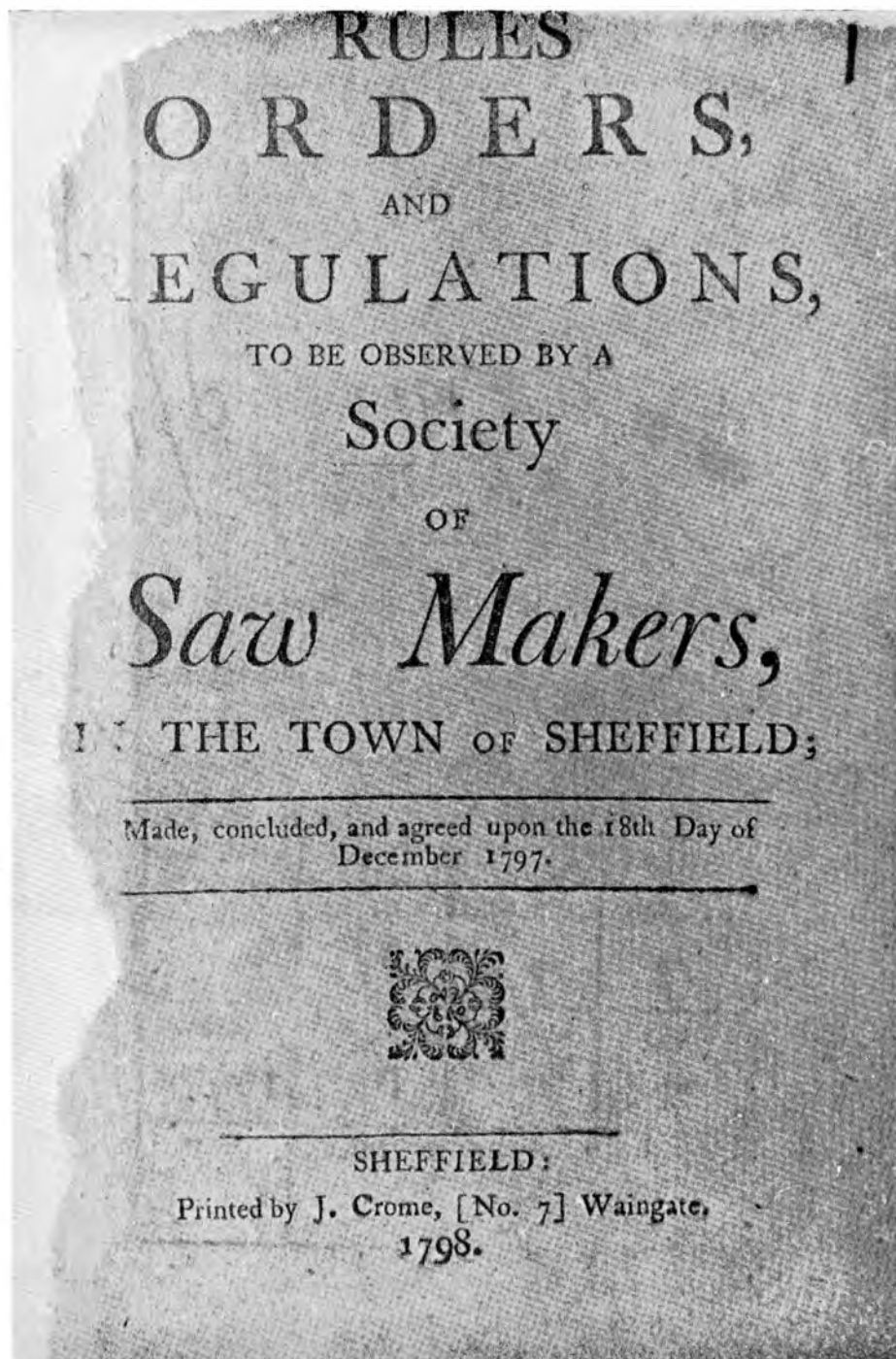
From the Middle Ages onwards many variations in sawmill mechanics evolved. Log carriages could be moved on rollers, by cogwheels, in greased channels by windlass ropes or by suspended weights. In 19th

<sup>19</sup> Albion, R. G., *Forests and Seapower* (Timber Problem of the Royal Navy, 1652–1862), Cambridge, Mass, 1926, pp 70, 102–3; Wood, Sir H. T., *History of the Royal Society of Arts*, London, 1913, p 247; Bale, op cit, p 6; Beamish, R., *Memoir of the Life of M. I. Brunel*, 2 Vols, London, 1862, Vol I, p 112; *Sawmill Magazine*, op cit, pp 112–13

<sup>20</sup> Defenbaugh, J. E., *History of the Lumber Industry in America*, 2 Vols, New York, 1906, Vol I, pp 477, 491, Vol II, p 6; Albion, op cit, p 233; Mercer, op cit, p 16



24. Mechanical frame-saw as used in the 15th and 16th centuries



25. *Sheffield saw-makers organise, 1797*

century mills the horizontal carriage slid along the mill floor, driven by rack and pinion which was itself moved through ratchet wheels driven by the motion of the saw-frame. The mill-wheels were of many sizes – flutterwheels, overshot and undershot wheels, tubwheels – adapted to achieve the correct velocity from varying volumes of water. One basic principle was common to sawmills of all ages: the timber moved against the saw, never vice versa.<sup>21</sup>

The 19th century witnessed the application of steam and gas power to sawmills, to circular saws and later to bandsaws. Mill men were fairly slow to use electric power because of its initial cost and also because it was at first abused:

... through the erection of motors not sufficiently powerful for their work or to sustain the occasional heavy overload to which they are subjected.

As late as 1910 an English mill expert wrote:<sup>22</sup>

Steam and gas are still the powers chiefly used in sawmills.

However, the electric motor, with its constant standard speed and great adaptability (for working isolated machines or machines with intermittent duty for instance) inevitably came into its own.

The significance of these changes in sawmill technique for the history of saw-making itself is obvious. The much greater speeds and strains and the higher productivity constantly demanded by sawyers from their saws meant continuous pressure for improvement in quality and design. Old, romantic, backwoods reciprocating sawmills have long since gone; cheaply built and cheaply run, they remained a profitable proposition until the early 19th century, when the vast increase in demand for boards and planks was met by steam-powered circular saws.

## Handsaws

Complete monopoly of timber conversion was never asserted by reciprocating gang-saw mills. Laborious, slow and wasteful, ancient pit-sawing methods showed remarkable persistence and staying power. Towards the very end of the last century (1894) an English observer stated:<sup>23</sup>

In isolated districts . . . these pit-saws are in considerable use, even at the present time.

Even in the United States handsawyers were ripping boards until the 1820s. Pit-sawing thus long outlived the sawmill that once had threatened to supersede it.

Saw pits in 19th century England were up to fifty



26. 15th century carpenters. From *History of Technology*

feet long, four to six feet wide and five or six feet deep. Two strong timbers ran the whole length (side-strakes), with cross-pieces at either end (head-sills) and intermediate cross-pieces, shifted under the log while sawing (transoms). These strakes, sills and transoms were all replaced in sawmills by the moving log carriage.<sup>24</sup> One man worked down below in the pit, very uncomfortably, and his partner in the more favourable position on top. The appellations 'top-sawyer' and 'pitman' survived for many years.

The framed, two- or three-man pit-saw used in primary timber conversion, had a thin, narrow blade,

<sup>21</sup> Mercer, *op cit*, pp 25–6, 28; Bale, *op cit*, p 36

<sup>22</sup> *ibid*, p 139

<sup>23</sup> *ibid*, p 36

<sup>24</sup> Holtzapffel, C., *Turning and Mechanical Manipulation*, 2 Vols, London, 1846, Vol II, p 703



flexible and adjustable – large toothed for ripping down the grain, and finer toothed for shipyard and joinery work. Two men could cut full length sixteen-foot boards by placing logs on the transom. American shipyard workers of the last century used a version with all the teeth raked downwards and with no pit. Instead, the logs were sawn Chinese fashion; that is, the top Sawyer stands on one end of the log, which is rested against a trestle. The pitman does all the real work, pulling on the downward stroke. In China and Korea before the Communist revolution an American-type bucksaw with two toggles was used. An Italian fresco in Pisa (Campo Santo) shows this kind of pit-sawing as early as 1350.<sup>25</sup>

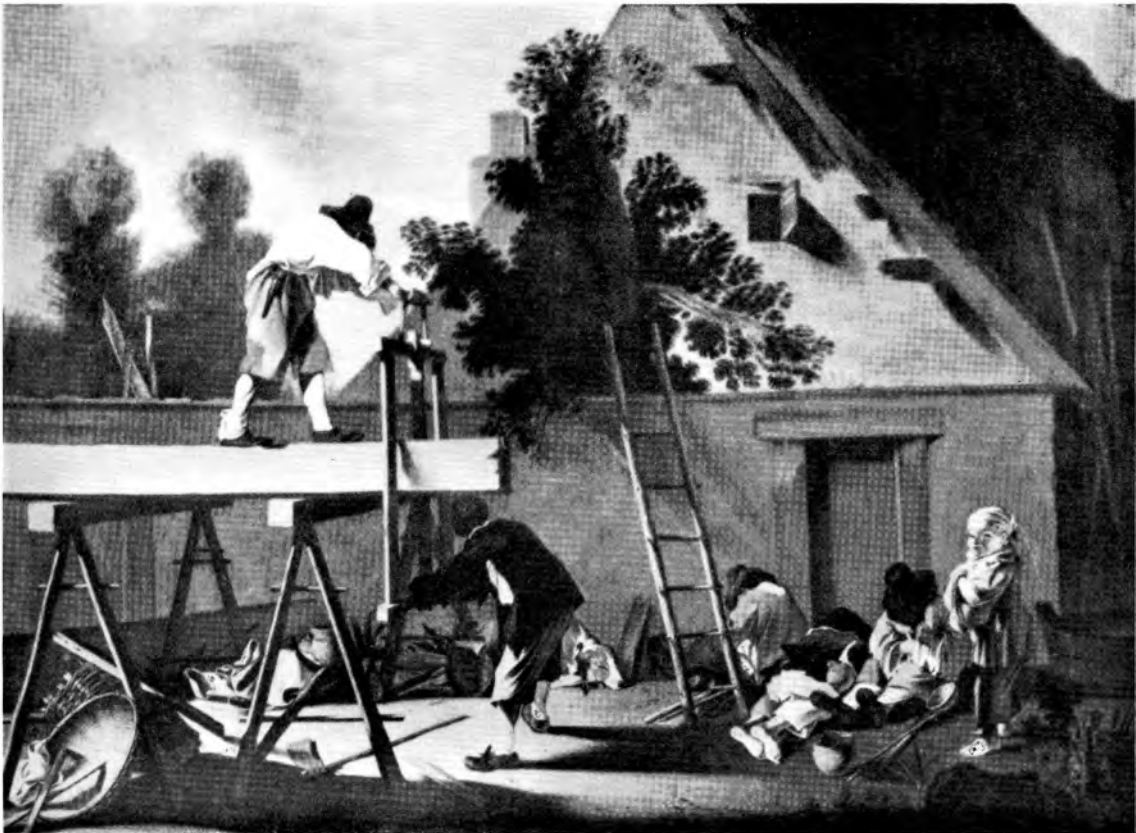
Open, as opposed to framed, pit-saws were probably not extensively employed until the 1780s, because their manufacture demanded smooth, broad steel

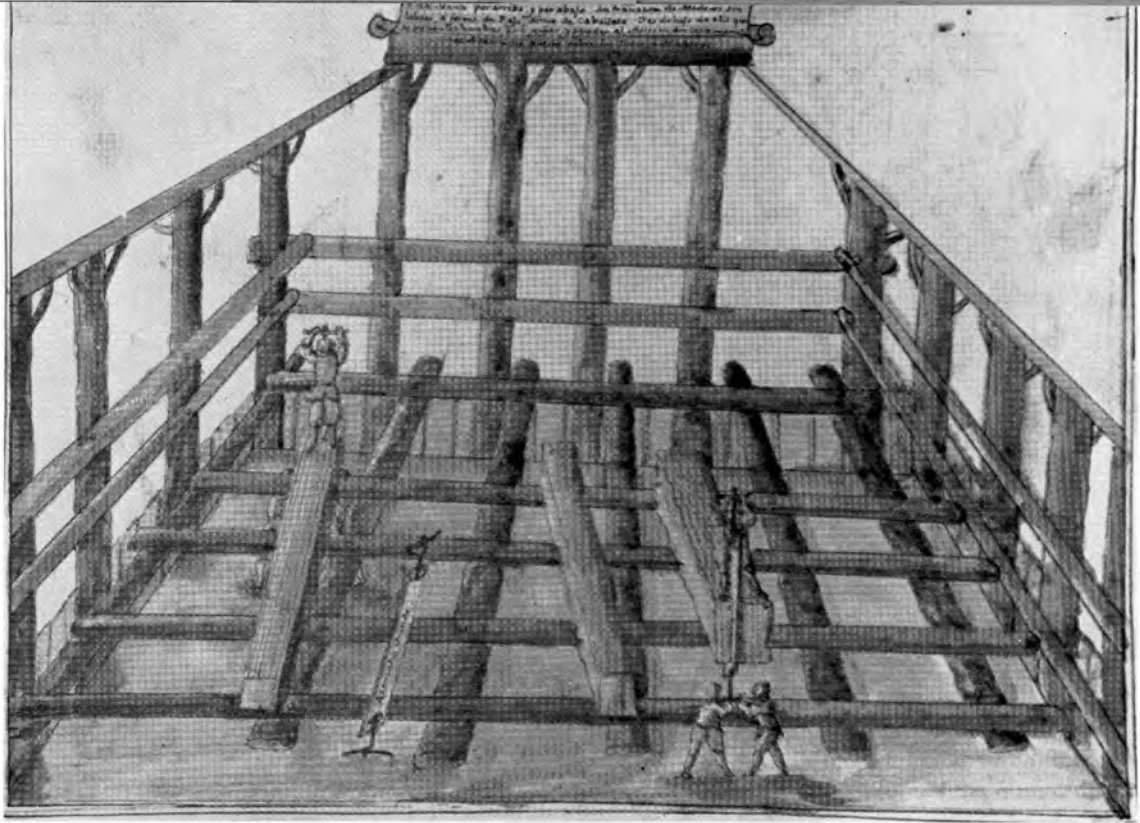
plates of good quality – not easy to produce in a blacksmith's forge, or even with a water-powered trip-hammer. Rolling and slitting mills were known in the 16th century in what later became Belgium (Liège) and also in Germany. In 1588, the Elizabethan engineer Bevis Bulmer was licensed to build the first in England. Their development was very slow and by the 18th century there were still not more than twenty rolling mills capable of making quality open pit-saw blades in the country. It was steam-power that altered the picture in the 1780s.<sup>26</sup> By the mid-19th century open pit-saws had generally replaced the

<sup>25</sup> Mercer, *op cit*, pp 17, 24

<sup>26</sup> *ibid*, p 34. Note Dr Mercer's claim that the rolling mills were altering the situation in the 1760s seems twenty years too soon. See for instance, Schubert, *op cit*

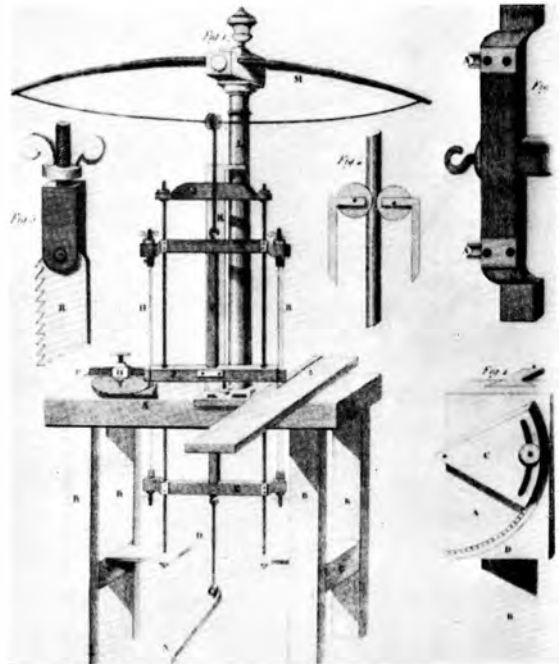
27. *'Les Charpentiers'* by Richard Tassel, 1580-1660





28. *English Saw Yard.* MS Diccionario de Construcción Naval, first half of 18th century

29. *Elementary mechanisation.* Bergeron, Manuel du Tourneur, Paris, 1816



framed variety in American and British shipyards – though not in Europe and not in the lumbering industry.

Open pit-saws were thick, long, tapered two- or three-man saws, with upper handle (tiller) fixed and lower (box) adjustable. A rare copper engraving of the 16th century by Antonio Tempesta of Florence depicts an open pit-saw in use Chinese fashion in a satire on building called *The Age of Brass*. Several references to it as a whipsaw occur in 17th century Massachusetts records, though mistakenly, and in 1915 a United States manufacturer revived them for the Russian market.<sup>27</sup>

Primary timber conversion demanded another kind of saw, the cross-cut or thwart saw. Not used for making boards, they played a less vital but important part. Two-man thwart saws had vertical handles at each end at right angles to the blade. Single models had a hollow grasp handle, as on general saws today. The long and very unsteady blades had unusual

<sup>27</sup> Mercer, op cit, pp 21, 23, 28. Essex County (Mass United States) Probate records, 1654: 'one Whip-saw, 5 shillings; one Crosscut saw, 3 shillings'



30. *St Simon with M-toothed cross-cut saw.*  
Chasse de St Hippolyte, c. 1477

teeth, widely spaced to avoid clogging in the kerf, and set at right angles to the blade without any hint of rake, thus cutting either way. One type had double (M-shaped) teeth raked in both directions.

Thwart saws must have been the principal open, two-man saws in use for many decades before the late 18th century when the successful manufacture of open pit-saws became feasible. Certainly, open cross-cut saws did yeoman service in Britain and Europe from the early 15th century onwards. County records in Massachusetts refer to them often in the 17th century, and after about 1880 they began to replace the axe in the United States as the major tool for tree-felling.<sup>28</sup>

So much for timber conversion. The basic shaping and fitting tools of the 18th and 19th centuries were the Anglo-American open handsaw and its deriva-

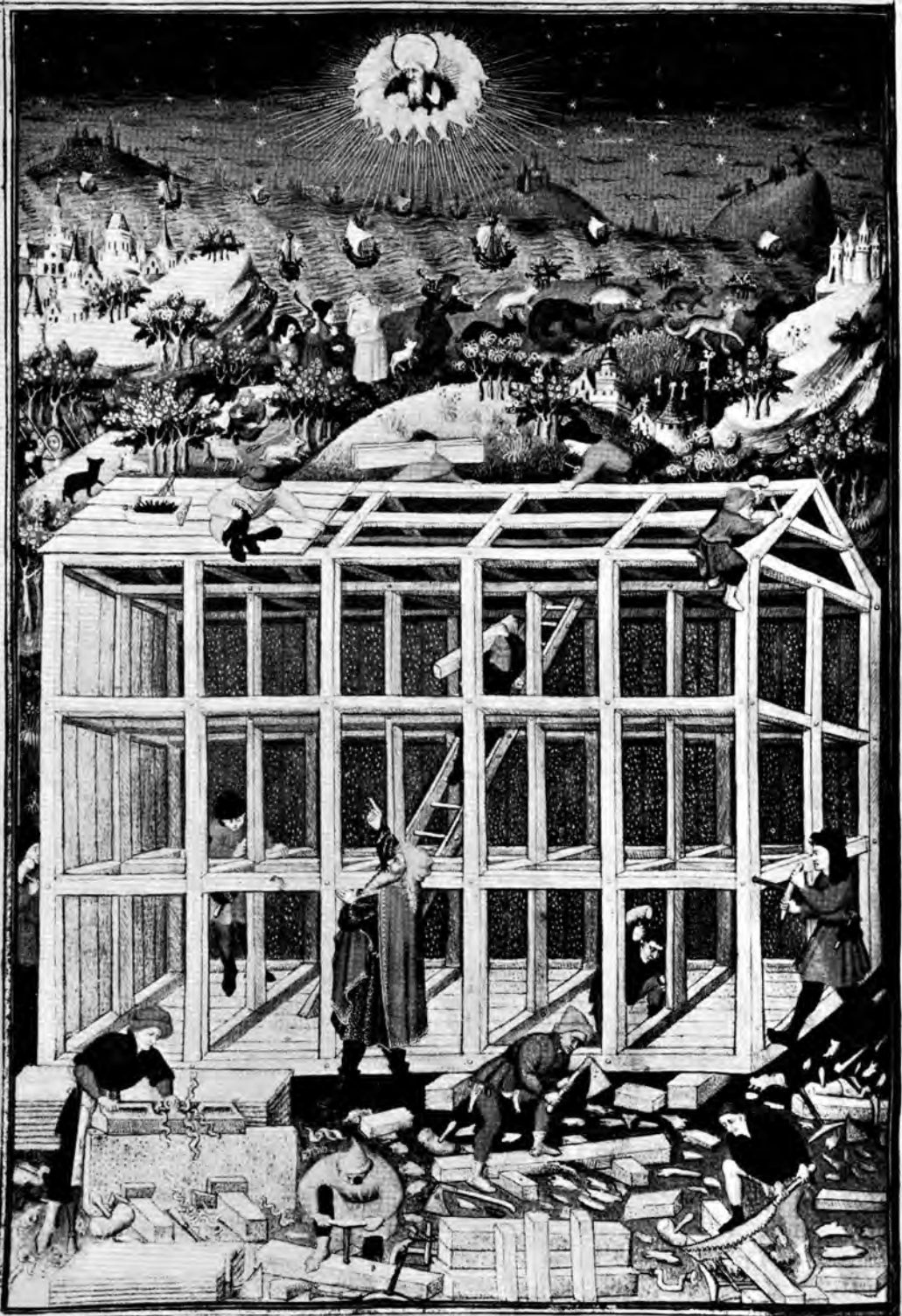
tives, the keyhole saw and the tenon saw. Significant in the building of material civilisation in the New World was the open handsaw; it was exported from Britain (chiefly from Sheffield) even long after the 1830s when local producers were firmly established in the United States.

Shipping bills in the Spear and Jackson archives in Sheffield show that the firm, having successfully weathered great financial troubles in 1820–21, was exporting saws to the continent of Europe (Calais, Hamburg, Antwerp) via Hull and to the United States (New York) via Liverpool.

In July, 1826, three casks valued at £75 went to France at a cost of £3 7s 7d (duty 16s 6d). In November  
<sup>28</sup> Mercer, *op cit*, pp 31–4

31. *Early 15th century saw.* Poems of Christine de Pisan





Comme nre seigr comenda a noel faire vne arce et y mettre vne paire de touz bestes pour le deluge.

32. Noah building the Ark. Bedford Book of Hours

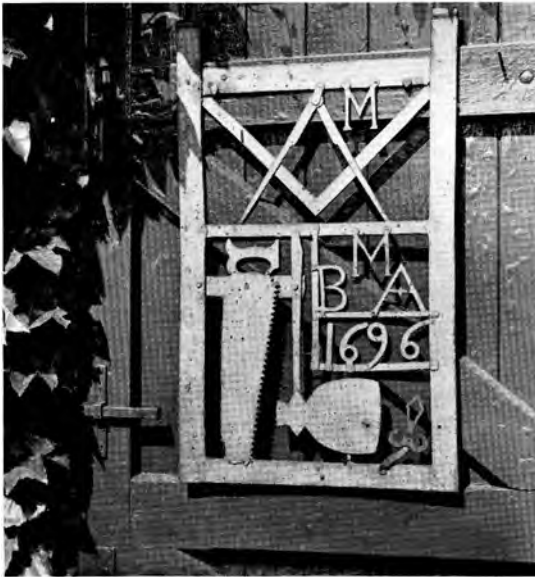
of the same year a single cask valued at £100 went to New York for £1 1s 8d (duty 10s) and again in December another cask went to J. S. Rousevelt and Sons for 16s 3d (duty 8s). The casks of blades were about five feet high and four feet diameter and they were very securely packed. Until railways were built, the casks went to Liverpool by packhorse over the Pennine Moors, and then to New York or by clipper round the Horn to San Francisco. From these distributing centres they served settlers of the entire Far West in the mid-19th century.

Usually, though not always, Americans fitted their own handles to Sheffield blades. These were wide, smooth-ground crucible steel blades, often about two feet by ten inches, with triangular, pointed, raked teeth, cutting on the push.

Some time in the early 18th century ancient pistol-grip open handles on tangs began to be replaced on saws as well as planes by closed handles common today, of which the American pattern was slightly different from the British.

Keyhole, compass and tenon saws are essentially special smaller varieties of one-man open handsaws,

33. A Baslow (Derbyshire) inn sign from 'The Joiner's Arms' (demolished some 200 years ago). The handle of the saw was originally open, as evidenced by the rivet marks on the cross-bar



34. Holy Family. Saenredam, c. 1590

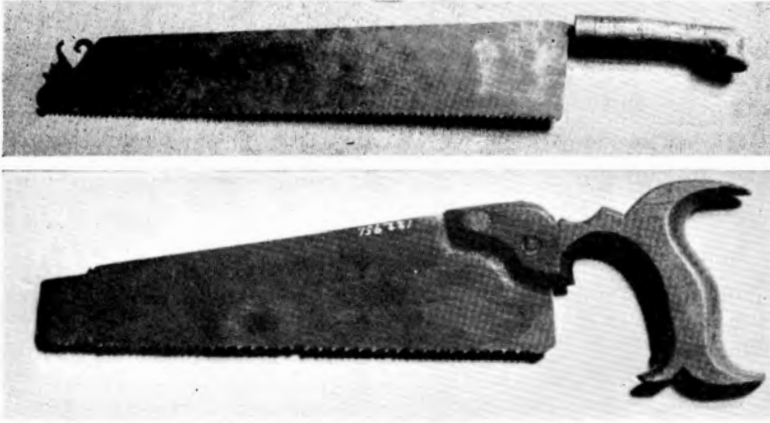
and were evolved in early modern times. They share the same characteristics: being extra stiff or extra wide because they are all unframed, and cut on the push stroke. (There are Chinese, Japanese and Turkish open handsaws that cut on the *pull*.)

Keyhole saws have straight, bread-knife type handles, riveted to the blades, which are extra narrow for fine carpenter's work and therefore extra thick for stability. Their teeth are not set. A good example is shown in Dürer's picture *Melancholia* (1514). A larger variety of keyhole saw is the compass, sometimes called a locksaw with unset teeth and pistol-grip handle.

Tenon saws and their derivatives have short, rectangular, thin blades with teeth slightly set, and strengthened by a stiff metal strip along the top edge. This prevents them from entirely penetrating the wood. (From which they earn the name back saws.) Since the 18th century they have had hollow grasp handles, slotted and riveted on the blade. In 1960s as in 1760, tenon saws serve these same purposes: to cross-cut

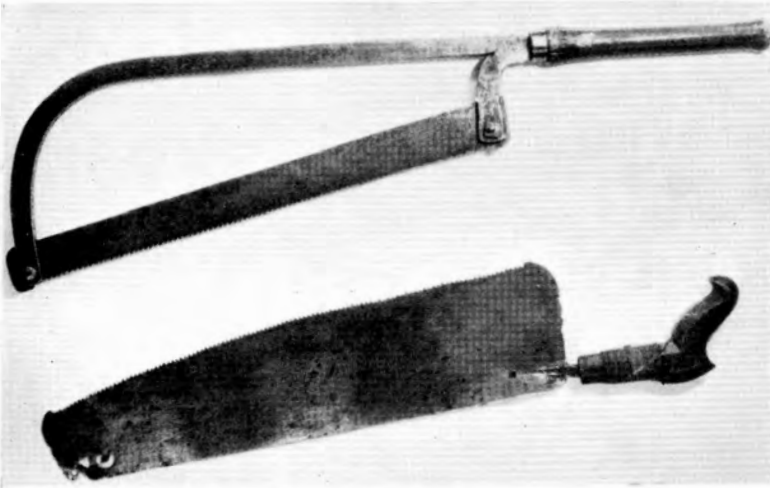


35. The earliest dated evidence of a closed handsaw handle. A carpenter's gravestone in the churchyard of St John-sub-Castro, Lewes, Sussex, 1747



36. 18th century Swedish hand saws

37. Early 18th century Dutch saws from the Peter the Great Collection, Leningrad.  
Above: hacksaw. Below: hand saw



38. 18th century Swedish hacksaw. Another example, the blade much worn by repeated sharpening



# SAWS

N<sup>o</sup> 591

*Hand Saw.*



22 24 26 28 30 Inches

598 *Gentleman's*



10 12 14 16 18 20 in<sup>s</sup>

596 *Grafting*



10 12 14 in<sup>s</sup>

600 *Dovetail*



8-9-10 in<sup>s</sup>

605 *Carcase*



12 in<sup>s</sup>

610 *Sash*



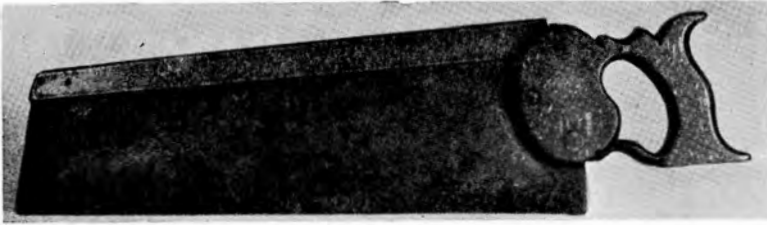
14 in<sup>s</sup>

615 *Tenon*

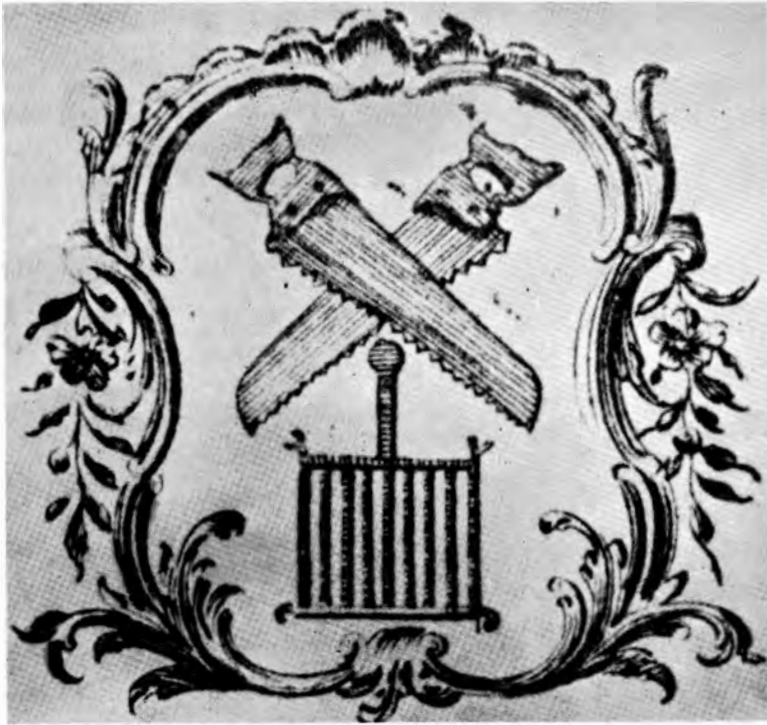


16-19 in<sup>s</sup>

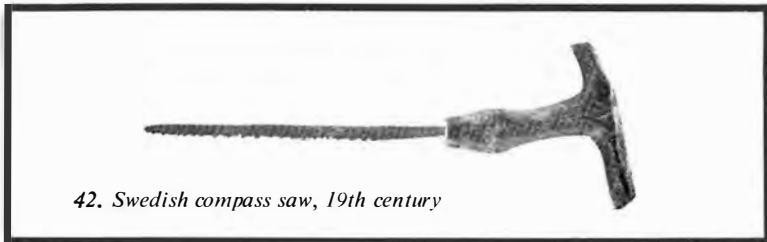




40. Backsaw used in the 1770s by Samuel Crompton, inventor of the spinning mule



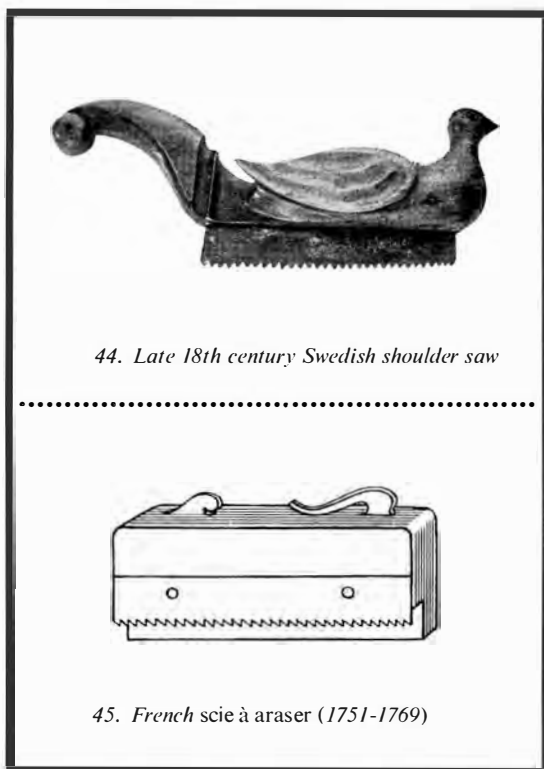
41. Shop sign showing crossed saws and gridiron, London, c. 1780



42. Swedish compass saw, 19th century



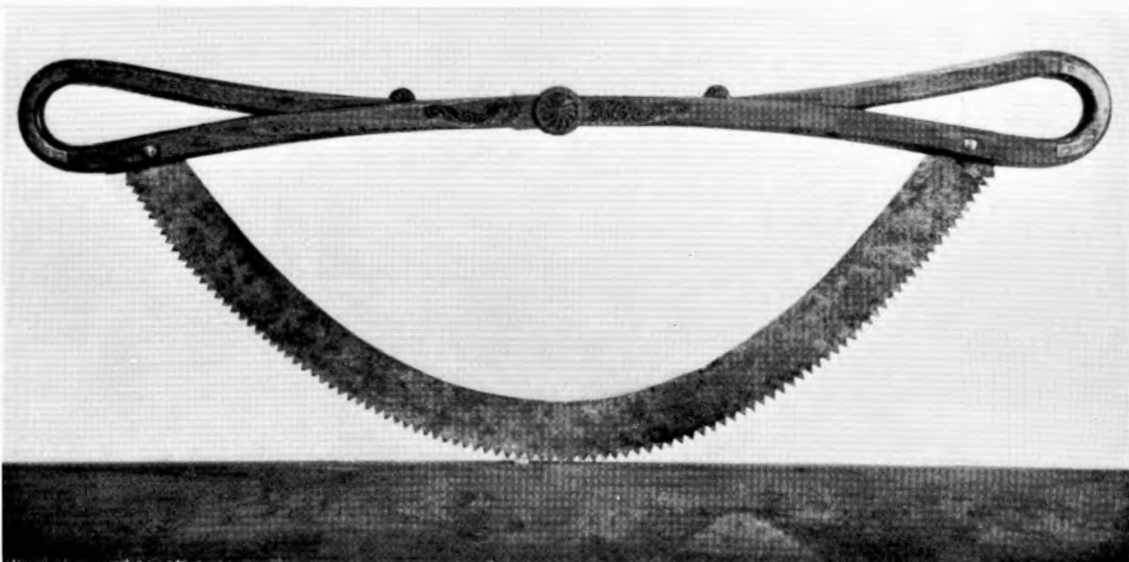
43. 18th and early 19th century Swedish tenon saws



44. Late 18th century Swedish shoulder saw

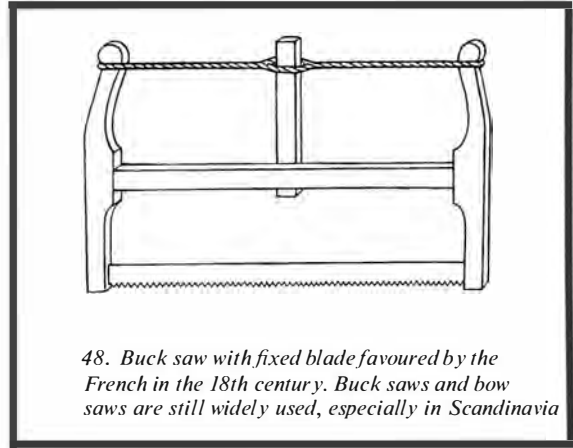
45. French scie à araser (1751-1769)

46. 18th century Dutch floorboard saw, used for cutting floorboards in position





47. *St Joseph and the Holy Child, c. 1525*



48. *Buck saw with fixed blade favoured by the French in the 18th century. Buck saws and bow saws are still widely used, especially in Scandinavia*

generally, and to cut smooth edges of tenon and dovetail joints and mitre fittings. Dovetail saws and sash saws are specific types of tenon or back saw, the latter usually backed with brass.<sup>29</sup>

Like primary conversion saws, shaping and fitting saws have also evolved a framed species – they are bow saws and their family.

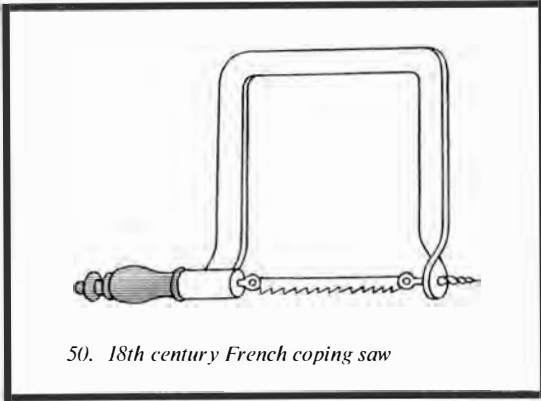
In essence bow saws are thin, narrow, slightly raked blades strained between the lower ends of two wooden arms, the top ends of which are joined by twisted cord; constant pressure from the cord (variable by adjusting the toggle-stick) tends to prise open the lower ends of the frame thus straining the blade. As we have seen the Romans had a version, but whether they could vary the tension is unknown. Buck saws are similar to bows, and the two co-existed throughout the Middle Ages and down to the 18th century; these two types are often confused in historical prints and paintings. The chief distinction is that bow saws have an adjustable blade to cut in any direction and out of the plane of the frame. The depth of cut of bow saws was thus not limited by the cross-brace impeding movement. Buck saws on the other hand were strictly limited with the fixed blade to the cross-cutting of narrow, thin articles – although according to Diderot's *Encyclopédie*, they were favoured by French 18th century carpenters.

In North, Central and Eastern Europe, China and Korea, woodworkers preferred bow saws to open handsaws for cross-cutting and ripping alike. A

<sup>29</sup> *ibid*, pp 111, 139



49. French carpenter's sign, 18th century



50. 18th century French coping saw

complete early illustration – with toggle-stick and adjustable blade – is in a Venetian woodcut of 1482.<sup>30</sup>

In the same saw family are the Buhl saws, named after a 17th century craftsman of Italian extraction – an inlayer of brass and tortoiseshell – who worked at the time of Louis XIV. (A. C. Boule, 1642–1732.) He designed his saws for specialised, delicate work and throughout the following two centuries they were used for marquetry, clockmaking and scrollwork. Modern fretsaws, all metal and mass produced, with very fine adjustable blades fastened by screws, are the direct progeny of these Buhl saws

<sup>30</sup> *ibid*, pp 145–51



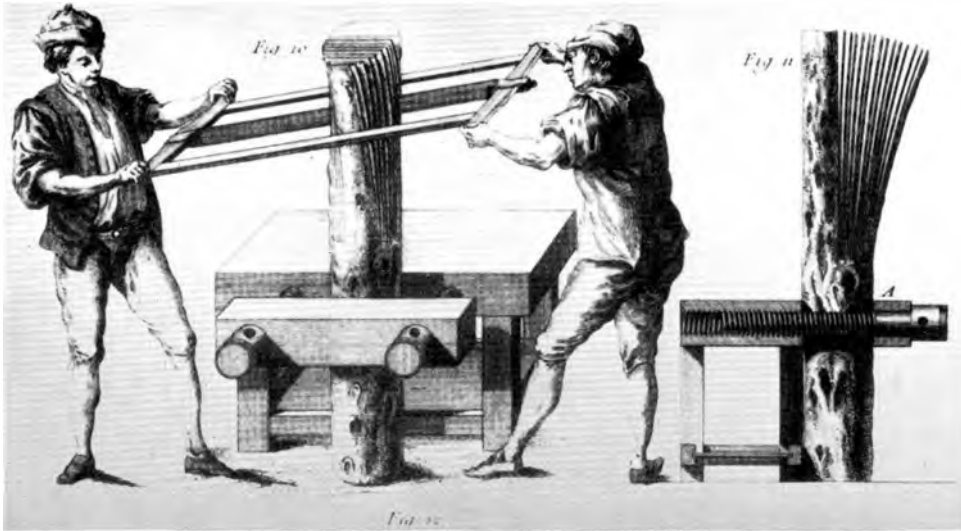
51. Felloe saw, used by wheelwrights and chairmakers

A frame-saw well over a century old, one of many of its kind, used in a California Gold Rush in 1851, has been discovered in a gravel-pit of a worked-out goldmine at Yreka Creek, and is now in the Siskiyou County Museum in California. The blade bears a Sheffield manufacturer's stamp (Spear and Jackson) and is in an excellent condition; but unfortunately the tough oak handle had begun to rot. The green oak branch was bent in a half-circle to provide the spring that held the blade in tension – not at all unlike the modern tubular steel frame-saws or log saws.<sup>31</sup>

The 18th century veneer saws were heavy two-man frame-saws easily confused with pit-saws except for their fine blades. These saws became obsolete in the

1820s with the adoption of Brunel's powered circular veneer saw (patented in 1806) which could cut fifteen to twenty veneers to the inch (as opposed to six to twelve by hand) and this gave birth to the fashion in veneers for interior decoration during the first half of Queen Victoria's reign. One of the most specialised of all the handsaws, and probably totally extinct, were felloe saws (wheelwright's or chairmaker's saws). Felloe saws were very much lighter, small one-man frame-saws with no handles; they were used at least until the 1890s.

<sup>31</sup> *Forest and Mill, Vancouver BC, Vol II, No 8, 27 April 1948, p 8*



52. 18th century veneer sawing. Roubo: *L'art du menuisier ébéniste, Paris 1774*

53. Sabot maker's saw



## Circular saws

Changes in handsaw design were comparatively minor steps in the story of the saw compared with the invention and adaptation of circular saws. The underlying principle of circular saws to cut by *continuous action* instead of merely reciprocal action, was quite revolutionary. Perhaps it was even of greater significance than the invention of sawmills, for once the principle of continuous *rotary* action was established in the use of circular saws, this, in turn, led inevitably to that of continuous non-rotary action in the bandsaws. Gang-saw (reciprocal) mills, circular saws and bandsaws are the three greatest innovations in the evolution of the saw since the Iron Age.

According to the latest evidence available, the first Englishman who 'mastered the inherent difficulties of making the circular saw into a workshop tool',<sup>32</sup> was a Southampton carpenter named Walter Taylor (1734–1803). He was, in fact, preceded in the *invention* of the circular saw by a sail-maker from his home town, Samuel Miller.

Miller's patent (No 1152) was registered on 5th August, 1777, for 'an entirely new machine for more expeditiously sawing all kinds of wood, stone and ivory; and the saws are made of a circular figure'. The saw was to be driven by a horizontal windmill, and an automatic log carriage of sorts was provided for.<sup>33</sup> There is nothing to show that Miller ever constructed his machine, and it seems that Taylor's claim remains valid. An earlier type – in reality a milling cutter used for making clock teeth and watch wheels – was used in England by Robert Hooke in about 1670. Also in the Netherlands, C. C. Jonge Calff patented something like a circular saw on 25th June, 1645. But circular saws proper were nurtured in Royal Navy shipyards, by Taylor, Bentham and Brunel.

Walter Taylor was fortunate in his natural inheritance because he came from several generations of skilled artisans. In 1762 he took the opportunity of a Royal Navy contract for the manufacture of ships' blocks at Southampton to apply mechanisation. He used a horse-drawn mill for sawing, but as the demand for blocks increased, he switched first to a watermill (at Weston on the river Test) and then to a better mill with more summer water, an ex-Norman cornmill, on the river Itchen (Wood Mill). Here, in 1781, four years after Miller's patent, he used circular saws. According to local opinion the saws:

... proved of ineffable use in expeditiously cutting timber for any purpose, particularly lignum vitae shivers, to an exact thickness . . . formerly done in a tedious way by the manual labour of the workman with the axe, mallet and chisel.  
*Hampshire Repository, 1801*

It is very likely that Sir Samuel Bentham (1757–1831) visited Taylor's mill once or twice between completing his apprenticeship in 1778 and taking out his own great comprehensive patent, No 1951, for labour saving devices in naval dockyards. In April, 1793 Bentham himself admitted:

Working by a rotative motion has already been used, as I understand, in a few instances such as cutting timber into boards, or in cutting logs for firewood, cutting mortices for ships' blocks, cutting the teeth of cog wheels and other slight indentures in metal.

His own contribution was segmental circular saws, later developed in the 20th century, to a great art and science. Saws of 'considerable diameter' he wrote,<sup>34</sup>

... may be more advantageously composed of annular segments, fastened on the face of the flaunch.

Brother of the more famous Jeremy Bentham, Samuel possessed great administrative talents. The story of his work as Inspector-General of Naval works, is to some extent the administrative history of the Napoleonic war. He designed and built warships in the Crimea for Catherine the Great of Russia. He was sent to Russia again in 1805, partly to build British ships there and partly because his flood of ideas and efficiency were too much for his seniors to stomach. His patent specifications have amazingly wide range, including machines for planing, moulding and dovetailing and crown and cylinder saws as well as the segmental circular saw. Yet he had the *extra* talent necessary to recognise talent in others – and in Brunel particularly.

Sir Marc Isambard Brunel (1769–1849), the builder of the first Thames tunnel (not to be confused with his equally famous son, Isambard Kingdom Brunel, the shipbuilder, bridgebuilder and railway engineer), was thirty-two years of age when, in 1801, he designed ships' block-making machinery for Bentham at Portsmouth. Brunel was not yet Vice-President of the

<sup>32</sup> Dickinson, Dr H. W., *The Taylors of Southampton* in *Edgar Allen News*, Vol 35, No 404, Feb 1956, pp 38–41

<sup>33</sup> *Sawmill Magazine*, op cit, p 113; Bale, *Stoneworking Machinery*, 2nd ed, London, 1898, p 25

<sup>34</sup> Dickinson, op cit

Royal Society, but he had travelled extensively in the United States (1793–1799) and had the chance to see many frontier sawmills. In 1802–3 his designs were accepted by Bentham on behalf of the Royal Navy and the machines were built by yet another great figure of the Industrial Revolution – Maudsley. The Brunel operations at Portsmouth dockyards are one of the earliest examples of the use of machine tools in mass production. By 1808 he was turning out 130,000 blocks a year, enabling ten unskilled men to do the work of one hundred and ten skilled artisans. He saved the Admiralty £17,000 a year at a time of crisis in British naval history during a large-scale war in which there were chronic supply shortages. Elm logs, from which the blocks were made, were cut into required lengths by two cross-cutting machines, one circular and one reciprocal – in a combination that an expert of a century later said ‘would not do discredit to a designer even of the present day’.<sup>35</sup> Circular saws were fixed to move around the logs and cut timber almost their own diameter. The blocks were then cut to rough shape on circular saw benches. The very heart of Brunel’s labour-saving scheme was clearly the circular saw.

In 1805 Brunel advanced a very futuristic scheme for bending timber under heat, and several minor improvements in sawing machinery to do with log carriages; while in 1806, as we have already noticed, he patented a highly successful veneer-cutting machine. Two years later he was asked to design special sawmills for Woolwich by the Ordnance department. His own sawmill at Battersea was opened in the spring, then he had patented a circular saw.

Brunel’s circular saws of 1808 were intended ‘to cut out thin boards or slips with as little waste as appears practicable’. The two essentials were, that these saws should be very thin and very stable. In 1812–13 two more Brunel patents were sought for minor improvements in frame-saw mills, and in the same year he was asked to improve Chatham Docks too.<sup>36</sup> An extremely modest man, he wrote; ‘I cannot claim the merit of original invention in sawmills’.

Brunel was justly admired for all his achievements by his contemporaries. Maria Edgeworth said of his block-making:

Machinery so perfect appears to act with the certainty of instinct and the foresight of reason combined.

The Russian government wooed him, as it had Bentham, and he received from the Tzar a ruby en-



54. Sir Marc Isambard Brunel, 1769-1849,  
by James Northcote

circled with diamonds which still remains in the family.

Brunel’s machines cut timber at ten to twelve feet a minute (tended by a single man). He cut the price of sawing straight timber to one-sixth (from 3s a hundred to 6d) and of cutting iron pins (gun-carriage axles) to one-twelfth (3s to 3d). This was a startling result,

<sup>35</sup> Bale, *Woodworking Machinery*, p 6; Singer, *op cit*, IV, p 427

<sup>36</sup> Note Edlin, H. L., *Woodland Crafts*, London, 1948, p 19, says Brunel was at Chatham in 1799, which is unlikely, as he only returned to England from the United States in March of that year



even for the Industrial Revolution. For his work at Woolwich Arsenal he received a grant of £4,500. His own mill at Battersea was unfortunate and became a less happy affair. He greatly reduced the price of furniture but lost most of his fortune, and the mill was even gutted by fire in 1814.

There was much opposition to Brunel from hand sawyers and others. Brunel was vilified as a 'foreigner' (he was born in France) who received government finance, for his 'expensive, strapbreaking, crank-breaking' machinery. It did not matter that later on a mill was erected at Rotherhithe by a Scot (Rennie) which proved much less efficient, while Brunel's designs were used in Trinidad (1821) and British Guiana (1824). The fairest conclusion on Brunel is in his own statistics, submitted in November, 1811, to the Navy Board in favour of mechanising the dockyards. A summary is given here.<sup>37</sup>

## Brunel's statement of November 1811

- 1 Brunel claimed that four sawmills would supply all the needs of Portsmouth, Plymouth, Chatham, Woolwich, Sheerness and Deptford yards.
- 2 He took an average works of 600 men (300 pairs of sawyers) whose average datal wages would be 6s 4½d per day a pair (3s 6d for top-sawyer, 2s 10½d for pitman), but whose piece-work averaged higher at 10s per day.

One pair could cut 220 feet of timber per day

220 × 300 = 66,000 feet per day

Of this total three-fifths was 'of a type fit to be cut by a sawmill' (i.e., 40,000 feet)

- 3 He then analysed the cost of cutting this 40,000 feet a day by machine

a mill of eight frames (average thirty-six saws) could cut 1,260 feet per hour i.e., 10,000 feet per day

four mills would thus be needed

Cost of one mill	£11,400
yearly expenses (interest on capital, wear and tear, and running etc) at 23¼ per cent of the above	= £2,650
average cash value of sawn timber at 4s 2d per 100 feet for 10,000 feet (one day's work) =	£20 16s 8d
for one year (300 days) =	£6,250

deduct yearly expenses

£2,650

profit:

£3,600 per year

Thus, profit on four mills would be four × £3,600 = £14,400 per annum.

- 4 Brunel thus hoped to make a government profit of £14,400 a year on the cutting of this 40,000 feet of timber by machine.

## Other inventions

Meanwhile inventors elsewhere had not been idle. In France, L. C. A. Albert patented an 'endless saw' (*scie sans fin*) in 1799. This was a disc with toothed segments attached. In England, George Smart's patent circular saw for cutting the staves of soldiers' wooden canteens was registered (No 2415) in June, 1800. The chief advances of the century in circular saw design were in the quality and tensioning of steel and the use of inserted and diamond impregnated teeth.

Manufacturing and tempering a thin disc of steel of 18 inches diameter or more, with higher speeds of revolution for wood than for metal, and the design of high-speed bearings, presented early 19th century craftsmen with thorny problems. The rim speed of 4,000 feet per minute, although less than half that of modern saws – was very fast for badly-balanced, unground, untensioned, flat, heavy plate, with roughly punched teeth.

It was in the United States that the first successful inserted tooth circular saw was invented. America's first circular saw was hammered out in about 1814 in a blacksmith's forge at Bentonville, in the State of New York, by Benjamin Cummins (1772–1843). Six years later, on 16th March, 1820, R. Eastman and J. Jaquith (Brunswick, Maine) patented a normal circular saw, and in 1824 Eastman alone secured a patent for a 'false tooth' saw. Instead of continuous teeth around the rim, this had four cutting sections of two inserted teeth each fixed at equal distances.<sup>38</sup>

It has been claimed that from the end of the Napoleonic war (1815) to about 1835 circular saw engineering in England suffered a standstill. However, things were certainly different in the 1840s. A price catalogue from the Spear and Jackson archives, of March, 1845, advertises 'patent engine turned, cast steel circular saws' of diameters from 2 inches to 48 inches (price range, 2s 6d to £12), with considerable variety and spacing of teeth.

<sup>37</sup>Frere, E. *Notice historique sur la vie et les travaux de Marc Isambard Brunel*, Rouen, 1850, passim; Beamish, op cit, pp 99–103, 105–107

<sup>38</sup>Bale, op cit, p 9; Disston, op cit, pp 14–15



Sheffield.

### Prices of Saws and Files.

#### CAST STEEL CIRCULAR SAWS.

2	3	4	4½	5	6	7	8	9	10	12	14	16	18	20	22	24
2s6d	3s0d	4s0d	4s6d	5s0d	6s6d	8s0d	9s6d	11s0d	13s0d	16s0d	20s0d	24s0d	30s0d	36s0d	42s0d	48s0d
26	28	30	32	34	36	38	40	42	44	46	48					
Inches Diam.																
56s0d	66s0d	76s0d	86s0d	104s0d	120s0d	150s0d	160s0d	176s0d	190s0d	210s0d	240s0d	Each.				

Best Cast Steel 3-Square, Frame Saw, Oval, & Gulletting Files.			
Inches.	3sq. Taper Files,	3sq. Blunt Files,	Frame Saw, Oval, & Gulletting, 2nd Cut Single.
	2nd Cut Single.	2nd Cut Single.	2nd Cut Single.
	Per Doz.	Per Doz.	Per Doz.
	l. s. p.	l. s. p.	l. s. p.
1 to 3	0 2 9	0 2 9	0 3 2
3½	0 2 9	0 3 0	0 3 4
4	0 3 0	0 3 4	0 3 7
4½	0 3 4	0 3 9	0 4 0
5	0 3 9	0 4 3	0 4 6
5½	0 4 3	0 5 3	0 5 3
6	0 5 0	0 6 0	0 6 0
6½	0 6 0	0 7 0	0 7 0
7	0 6 9	0 8 0	0 8 0
7½	0 7 9	0 9 0	0 9 0
8	0 8 6	0 10 0	0 10 0

#### MILL SAWS & GANG SAWS.

	4	4½	5	5½	6	6½	7	7½	8 Feet.
Cast Steel...	18s	22s	26s	28s	30s	33s	37s	42s	48s Each.
German Steel	14s	18s	22s	24s	26s	29s	33s	38s	44s do.

#### MILL WEBS & VENEERING WEBS.

	3	3½	4	4½	5	5½	6 Feet.
Cast Steel.....	8s	10s	12s	14s	16s	18s	20s Each.

#### CAST STEEL MILL SAW FILES, (Single Cut.)

	7	8	9	10	11	12	13	14	15	16 In.
Bastard.	4s3d	5s3d	6s6d	8s0d	9d6d	11s6d	14s0d	17s0d	21s	25s6d Doz.
2nd Cut.	5s0d	6s3d	7s6d	9s6d	11s6d	13s9d	17s0d	20s6d	25s6d	31s6d do.

If Double Cut, 6d. Per Doz. Extra to 11 Inches inclusive, and all above 9d.

#### BEST CAST STEEL TOPPING FILES, (2nd Cut.)

	4	4½	5	5½	6	Inches.
	3s6d	3s9d	4s2d	5s0d	5s6d	Dozen.

All Quarter Inches same price as Size above.  
Double Cut Hand Saw Files, 4d per doz. extra.  
Do. Frame Saw, Oval, & Gulletting, 6d. per doz.

# THE WORKING MAN:

A Weekly Record of Social and Industrial Progress.

ALL RIGHTS OF TRANSLATION AND REPRODUCTION ARE RESERVED.]

[REGISTERED FOR TRANSMISSION ABROAD.

VOL. I.—No. 5.]

SATURDAY, FEBRUARY 3, 1866.

{FACE 2,  
{STARRED, 3c.

## THE WORKSHOPS OF THE WORLD.



### Sheffield Saw Manufacture.

THE saw is of great antiquity. It was known to the Egyptians and other early nations, and traces of its early use have been discovered in nearly every country where the arts and sciences

have made the least progress. In England, Sheffield—the metropolis of our manufactures in steel—has had the saw-making almost entirely to itself, many hundreds of skilled and intelligent artisans being continually employed in this important branch of industry.

In former times, there was little variety in the

shape of the saw, which in general appearance strongly resembled the *hans-saw* used by the carpenters. At the present day, however, the different kinds of saw—such as the *cross-cut-saw*, *pit-saw*, *france-saw*, *egyptian-saw*, *hand-saw*, *pond-saw*, *compass-saw*, and *saw-saw*—are almost endless; the making of each kind of saw forming, as it



57. Sheffield's name for quality in saws is of long standing. The Cross of the Legion of Honour was conferred on Samuel Jackson at the Paris Exhibition of 1855



58. Another decoration bestowed in 1873: Joseph Burdekin Jackson is honoured by the Emperor Francis Joseph of Austria. These honours and awards were typical of many earned by Sheffield cutters and saw-makers at this time

In 1851 at the Great Exhibition, Spear and Jackson were awarded a Gold Medal for, in the official words of the citation:<sup>39</sup>

... a cast steel circular saw, of the large size of five feet diameter and of such signal beauty and perfection that it stands far above comparison with any other in the building.

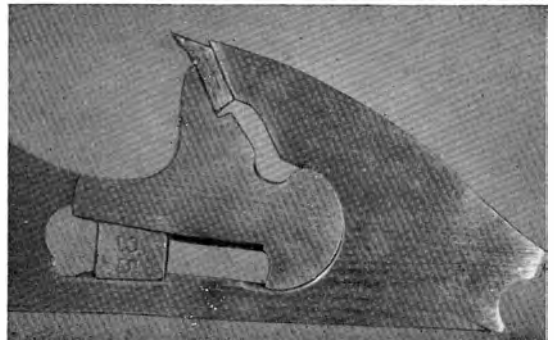
The mere excellence of its quality and workmanship however would not, the jury are aware, have enabled them to distinguish it by a council medal, if they had not been able to satisfy themselves that its merits are the result of a new and peculiar process of manufacture.

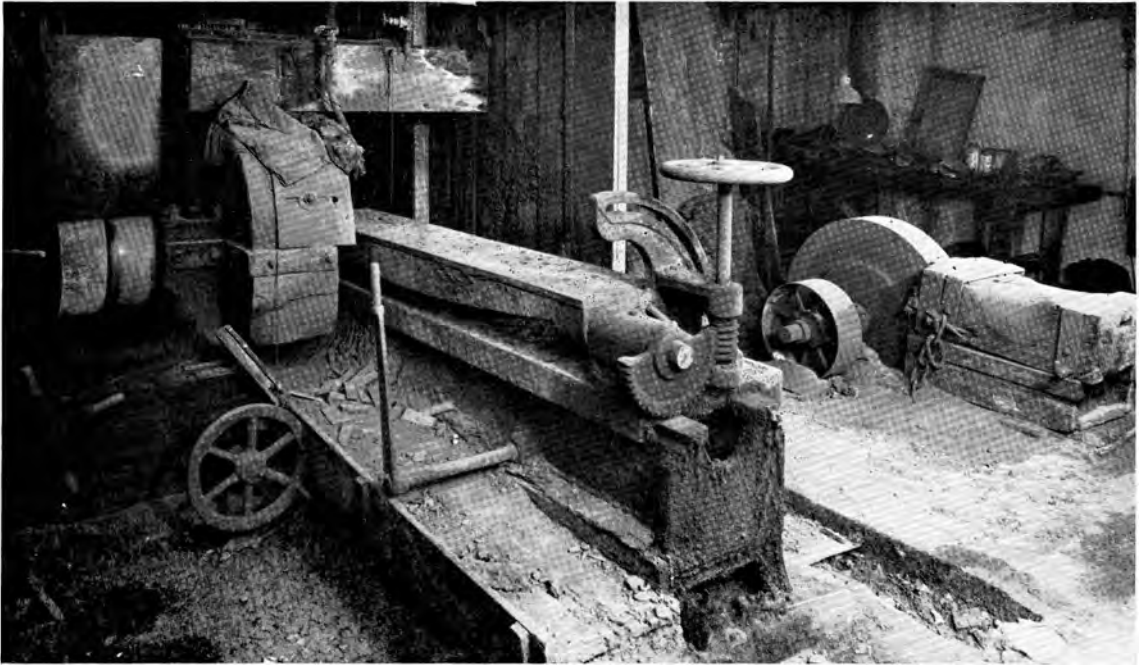
During the 1850s machines and ideas in the United States were introduced and adapted to English needs. For instance, in 1859, Spaulding of Sacramento, California, solved the vexed problem of holding inserted teeth firmly in place, with his curved sockets. This discovery contributed much to the increased popularity of inserted tooth saws. But on the other hand, inserted tooth saws for stone-cutting were developed in Britain by George Hunter (1865). The leading firm in the United States, Henry Disston and Sons, Inc (founded by a man who had previously worked at Spear and Jackson's in Sheffield), were making huge inserted tooth saws at the turn of the century for stone and timber conversion.

Why was so much effort and imagination put into inventing inserted tooth circular saws? Chiefly, because their diameter remains always constant, they

<sup>39</sup> Spear and Jackson archives; also *Yorkshire Evening News*, 5 May 1953, p 2

59. Early form of inserted-tooth saw: holder and wedge-fitted tooth. Original hoe patent registered in the USA c. 1870 was for a solid tooth insert, later developed into a two piece spring shank and a bit or tooth





60. An obsolete Slack's machine knife grinding with tilting table and fixed wheel occupies the foreground. Behind it is the saddle-type machine on which the grinder sits astride. Such machines were formerly employed for grinding saws

run for years and keep their cutting edge. Teeth, being carbon steel or chrome plated stay sharp longer yet are easily file sharpened.

## Stone-working saws

The ancient Egyptians had used bronze saws with jewelled teeth for difficult stone-cutting operations, but 19th century stone-cutting demanded the evolution of the diamond-tipped circular saw. Some of the honour goes to a Frenchman named Jacquin, who perfected a working saw in 1885. Previously, a model which was exhibited by a compatriot in Paris in 1854 led to nothing. The use of industrial diamonds for tipping the teeth of circular saws developed in the late 19th century, mainly in the United States, superseding the older frame-saws. The diamonds were black ones from Brazil. The difficulty was to hold the jewels in position.<sup>40</sup> In the two largest diamond stone-cutting saws in the world at present (1960) which were made in the late 1950s by the Scots firm, Anderson-Grice of Carnoustie, and by Spear and Jackson of Sheffield,

the segments heavily faced with industrial diamonds are brazed to the perimeter of the steel body.

The long story of the saws as a stone conversion instrument dates from the building of the Pyramids. After many centuries of evolution metal saws began to take an important part in cutting and shaping hot and cold metals also. A machine saw was used in an English cannon foundry in England in 1603, for cutting off the gunhead after the cannon had been cast.<sup>41</sup> Granite was being machine-sawn in Aberdeen in 1739, and marble (by waterpower) in Ashford, near Bakewell, in 1748. Samuel Miller's patent of 1777, which has already been mentioned, was for a circular saw to cut, among other things, stone. Sir Samuel Bentham in 1793 and Joseph Bramah in 1802 patented stone-working machinery, and in the United States Oliver Evans of Philadelphia had in 1803 a 'double-acting high-pressure steam-engine' driving 'twelve saws in heavy frames, sawing at the rate of 100 feet of marble

<sup>40</sup> Bale, *Stoneworking Machinery*, p 36

<sup>41</sup> Singer, *op cit*, III, p 365

in twelve hours'.<sup>42</sup> An English made marble-sawing machine of the early 19th century at Kilkenny on the river Nore in Ireland, had a 10 feet diameter, twelve-foot water-wheel driving two frames, one of twelve and one of eight saws, and a frame of five polishers. The saw blades were of soft iron and had to be replaced weekly.

The 'real father of stoneworking machinery' however is said to be James Tulloch (Millbank, London) who built the most complete stone-working plant with reciprocal and circular saws in 1824. Also in that same period of alleged stagnation in circular saw design, G. W. Wilde patented a friction disc in 1833. A smooth circular metal plate for marble sawing, it was fed with sand and water, but was without teeth.

The early circular saws for stone were the ripping-bed variety. This consisted of several saws mounted on one rising and falling spindle to regulate their depth of cut, with the stone on a moving carriage fed forward by screw or counterpoise. During the last two decades of the 19th century improved machines were introduced with large diameter blades for sawing, facing and edging stone, and with fitted teeth. The inventor of stone cutting fitted teeth saws, George Hunter, worked closely with Sir W. F. Cooke on all sorts of improvements in stone-cutting machinery. Hunter claimed in 1865 that his teeth were especially suited for cutting thick rock slabs (Bath, York or Portland), for undercutting stone, slate and coal *in situ*, and for facing stone. The teeth were made from a bolt of best rod steel, the head forged like a trumpet shape, turned at the edge and hardened, and set in steel sockets. Saw shafts had a diameter of 15½ inches and the whole apparatus stood some seventeen feet from the floor, as blades had a thirteen foot diameter. Hunter designed two of these monster saws for the Tyne Navigation Commission, which were built by Powis, James and Company, under the supervision of M. Powis Bale, a leading authority and author of later years.<sup>43</sup>

In 1898, Powis Bale predicted some possible future use of bandsaws – perhaps even diamond tipped – at slow speeds (say, 250 feet per minute) for curved stone-cutting such as Gothic arches. The nearest thing to bandsaws used in 20th century quarries had been wire-saws. Their principle is as old as the Stone Age – simple abrasion. They are in essence endless, three-stranded (0.16 inch to 0.22 inch) steel cables, driven by ordinary 10 hp engines. They have been used

with success since 1926 in the United States slate quarries (the US Bureau of Mines issued reports to encourage their use in marble quarries too, in 1930–31). They have also been used with success in slate, marble and limestone quarries in Italy, France and Belgium.<sup>44</sup> Yet despite such inventions, old folkways persist with charming though inefficient disregard: operators of reciprocating swing-saws and wire-saws refusing to recognise the advent of circular saws (with or without inserted teeth and diamond tips), are still faithful to these older ways in at least one British quarry.

## Bandsaws

The first man to use band or ribbon saws for cutting metal was General Tulloch, who introduced bandsaws into Woolwich Arsenal after being very impressed by one he saw at a French exhibition in 1855.

Bandsaws had been invented half a century before by William Newberry, (patent No 3105) London, 1808. Specified as 'machinery for sawing wood, splitting or paring skins . . .' they were basically an 'endless' serrated steel ribbon, stretched around pulleys. Newberry's patent is an example, unusual in history, of the birth of an idea almost 'full-grown'. A later inventor, W. S. Worssam, wrote<sup>45</sup> about this bandsaw:

Newberry appears not only to have conceived the principle of the bandsaw and the details of the mechanism for operating it, but also to have foreseen nearly all the various purposes to which the creation of his mind might be applied.

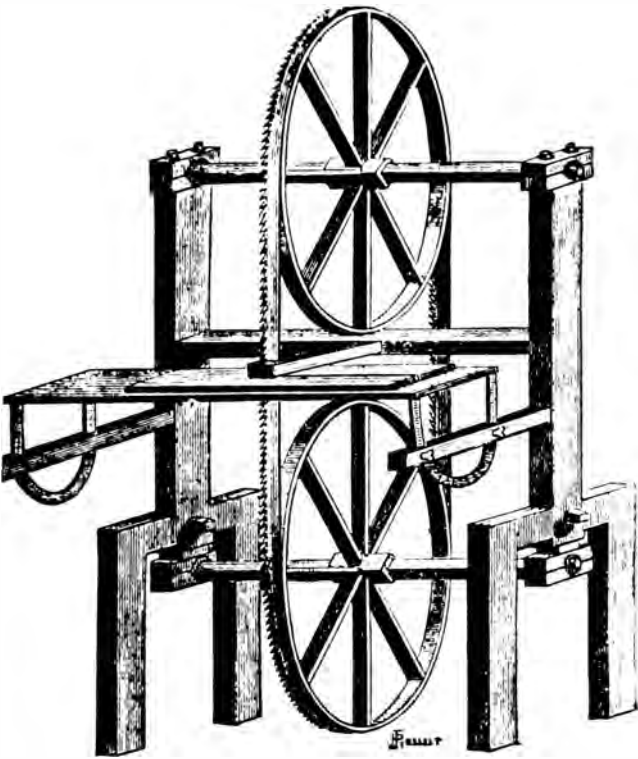
Newberry did not anticipate metal-cutting. His plan included: bandsaw ribbon with flanged pulleys to carry it; support guides to maintain the line of cut; wedge devices for tension; a canting table (adjustable table angle) for sawing material; roller-feed for straight pieces; and even a radial arm for cutting wheel felloes.

<sup>42</sup> Bale, *op cit*, pp 25–7

<sup>43</sup> *Society of Arts, Journal*, Vol XV, p 19; Bale, *op cit*, pp 43–4, 51

<sup>44</sup> Bowles, O., *Significant Features of Wire-Saw Operation in Europe*, Information Circular No 6483, US Dept of Commerce, Bureau of Mines, August 1931; also his Technical Paper No 469, *The Wire-Saw in Slate Quarrying*, US Dept etc, 1930; (both publ in Washington, DC); Weigel, W. M., *Application of the Wire-Saw in Marble Quarrying*, American Inst of Mining and Metal Engineering, Tech. Publ No 262, New York, 1930

<sup>45</sup> Worssam, W. S., *History of the Bandsaw*, Manchester, 1892, pp 7–8



61. William Newberry's bandsaw, 1808

It had two defects only: the web (blade) was difficult to remove, and the pulley rims were not cushioned to protect the blade.<sup>46</sup>

This remarkable and revolutionary invention, which could totally transform the sawing process, never got beyond the patent and model stage.

Four years later, in September 1812 – the year of Napoleon's disastrous march on Moscow and of Luddite machine-smashing riots by the unemployed in Britain – a French civil servant developed a new type bandsaw. He worked as a sub-engineer in the Highways department, and was called Touronde. His plan, which he did not patent, provided cloth tyres to cushion the pulley rims. Then followed an apparent hiatus of about thirty-five years, at the same period as the alleged setback in circular saw engineering. Bandsaws were simply not good enough. Steel was not of sufficient quality, and above all, the webs snapped too easily. The technique of brazing metal joints was still not properly understood. Early bandsaw webs were

narrow (not over one inch wide) and the machines were treadle-operated and wooden-wheeled.

In 1842 another French engineer, Thouard, submitted a forty-two page patent specification for a bandsaw to cut two pieces (stone or wood) simultaneously, one piece by the up and one by the down blade. The web was jointless, made from a ring; its productivity ratio to reciprocating saws was 1 : 30; but when built in 1846 it snapped too readily. Thouard's failure did not deter a female compatriot, Mademoiselle Crepin, 'a lady with mechanical proclivities of no mean order',<sup>47</sup> from patenting her own version of Newberry's machine in the same year. In this machine the pulley rims were covered in leather and the guides improved. (French patent No 22382 in the *Brevet d'Invention*, IX, p 84, 1846.)

The leading Frenchman to develop Newberry's idea quicker in France than Britain was the Parisian veneer expert, Périn. It was his machine at the Palais d'Industrie in 1855 that impressed General Tulloch so much. Périn snapped up Mademoiselle Crepin's patent, to develop her machine for light work (for which, ironically in the light of its later history, bandsaws were originally intended). His use of spring steel as well as a simple but effective method of rejoining in case of fracture, was patented in 1853. He achieved power-saving, continuous and therefore economical sawing, and (for his day) great speed – 5,000 feet per minute. That bandsaw performed feats 'impossible by any other known mechanical means'.<sup>48</sup>

A series of British bandsaw patents followed, between 1855 and 1876. Two of those in 1856 suggested treatments of blades: James Barbour (London) said the web should be hammered before mounting to make it spring into shape after rounding the pulleys; William Exall (Reading) said the blade needed heat-treatment (by blow-pipes, lamps or ordinary fire), and tempering between steel rollers.

Henry Wilson in 1858, invented spring bearings to allow movement in the pulleys on expansion and contraction, and thus prevent fracture of the web. Thomas Greenwood of Leeds exhibited a patented model adapted to curvilinear cutting (ships' ribs) in 1862, and in the 1860s and 1870s special designs to make bandsaws a heavy instrument were evolved, including

<sup>46</sup> *Sawmill Magazine*, Vol II, No 5, Jan-Feb 1926, pp 7–9; Worssam, op cit

<sup>47</sup> *ibid*, p 9

<sup>48</sup> *ibid*, p 10

Finnegan's horizontal bandsaws for heavy logs (1868) and McDowell's triple machines mounted in one bed for mass-production (1876). A cloth-cutting bandsaw was patented in 1874. This was a toothless, self-sharpening steel band.<sup>49</sup>

By 1900, bandsaws were an accepted tool in most large engineering works for metal-cutting operations. One such bandsaw employed at Woolwich Arsenal, could cut cold metal to a depth of 12 feet. Combination machines for sawing both wood and metal already existed, geared for the necessary speed change. A catalogue of Spear and Jackson for 1900 advertised cast steel bandsaw webs for wood at various prices according to width, with a net additional charge per saw for brazing. For instance, Spear and Jackson advertised a 1½ inch web 24 feet long (unbrazed) costing 22s (11d a foot). Brazing cost a further 1s 9d. Périn's prices of four years previously, advertised by Worssam, were very similar – 23s 3d. Webs for metal-cutting were considerably dearer; a similar length cost at that time £3 12s, excluding any trade discounts. In 1903, after three years further production, Spear and Jackson found themselves able to reduce the cost of wood bandsaw blades by well over a third (1½ inch width down to 8d per foot). This was proof of the increasing popularity of these machines in face of strong opposition in England to their use for heavy, straight timber work.

Worssam claimed in 1892 that the chief causes of the opposition were first and foremost, the strong hostility of British workmen, and their failure to learn the great care and dexterity needed to manage bandsaws, as opposed to the simpler circular and reciprocating saws; and secondly, the imperfectly flat and inaccurate cut of bandsaws compared with orthodox machine-saws, especially into hard and expensive woods. It was said that they were easily deflected vertically and longitudinally by knots, cross-fibres and stiff-heart. Worssam complained that Sheffield manufacturers were allowing the French to capture the bandsaw market and, moreover, to use British steel to do it. He was pessimistic, finding 'insurmountable obstacles' impeding the spread of the bandsaw for log-conversion.<sup>50</sup>

Nearly twenty years after Worssam's pessimistic findings, Powis Bale took a more cheerful view (1900). He admitted that the lack of wide saw blades of high quality and the prejudice of users had delayed the progress of bandsaws in Britain, but dismissed this as an aberration of the past. Because they were rapid,

economical of timber and adaptable, bandsaws would inevitably become more general for primary log conversion.<sup>51</sup> It was certainly a Sheffield firm that opened the Canadian market for bandsaw blades; but in the United States, where the bandsaw had been independently invented in 1849, by Lemuel Hedge, blades were much wider than in England. Disston's made a 6 inch blade for a Philadelphia Exhibition of 1876. The English inventor Worssam had visited the United States himself at the outbreak of the civil war, 1860–61, and had found no bandsaws working at that time.

Between the two world wars smaller bandsaw machines (blades ½ inch – 2 inches wide) were employed universally in English mills for curvilinear and irregular sawing. Two larger machines were band re-saws (blades 4 inches to 6 inches wide), replacing the old frame and circular saws for resawing deals and fitches into thin boards, and the bandmills (blades 6 inches to 18 inches wide) for general log conversion with a fast rate of cut.<sup>52</sup>

The battle of the bandsaw had been won, although in one respect it was not yet over.

In this battle the mechanical problems for all their complexity had proved less intractable than the human problems associated with economical, trouble-free running. Bandsawing demanded blades capable of withstanding exceptionally severe tensional and torsional strains and constant rolling and bending around the pulleys. Spring-tempered, tenacious, lively steel was indispensable; but so also was the 'saw doctor' or 'filer', the man with knowledge and experience enough to maintain at concert pitch the larger blades on ever more elaborate, permanent-site installations now coming into general use.

Worssam, in his day, characteristically declared it impossible to tell by ordinary examination if a wide blade were evenly tempered. He advocated entire dependence on the name of a good manufacturer. Worssam further declared that blades must be absolutely parallel in width and thickness, that joins must be perfectly brazed. Tensioning, or the spreading of the centre of the band by rolling and hammering (a technique developed in the 1860s), was an absolute

<sup>49</sup> *ibid*

<sup>50</sup> *ibid*, pp 13–14

<sup>51</sup> Bale, M. P., *Handbook of Sawmill and Wood Converting Machinery*, London, 1919 (1899), p 70

<sup>52</sup> Todd, R. W., *The Practical Saw Doctor*, London, 1926, pp 1–2



essential to ensure smooth, stable running and minimise cracking. And these improved bandsaws required for their successful manufacture and operation a number of auxiliary machines for rolling in the tension, brazing and scarfing, automatic sharpening and setting and the grinding of pulley wheel faces.<sup>53</sup>

What advantages were to be derived from all this effort? In a word – economy. Used in metal-cutting, cabinet-work (giving severe competition to old frame-saws for the contour sawing of chair backs, tables, barrel ends) and timber conversion alike, whatever the size or scale of the work, bandsaws reduce costs in time and power. In the timber industry they were able to give more boards from the log because they cut a less wasteful kerf; and their smooth rapid and

continuous action proved to be even more economical than circular saws.

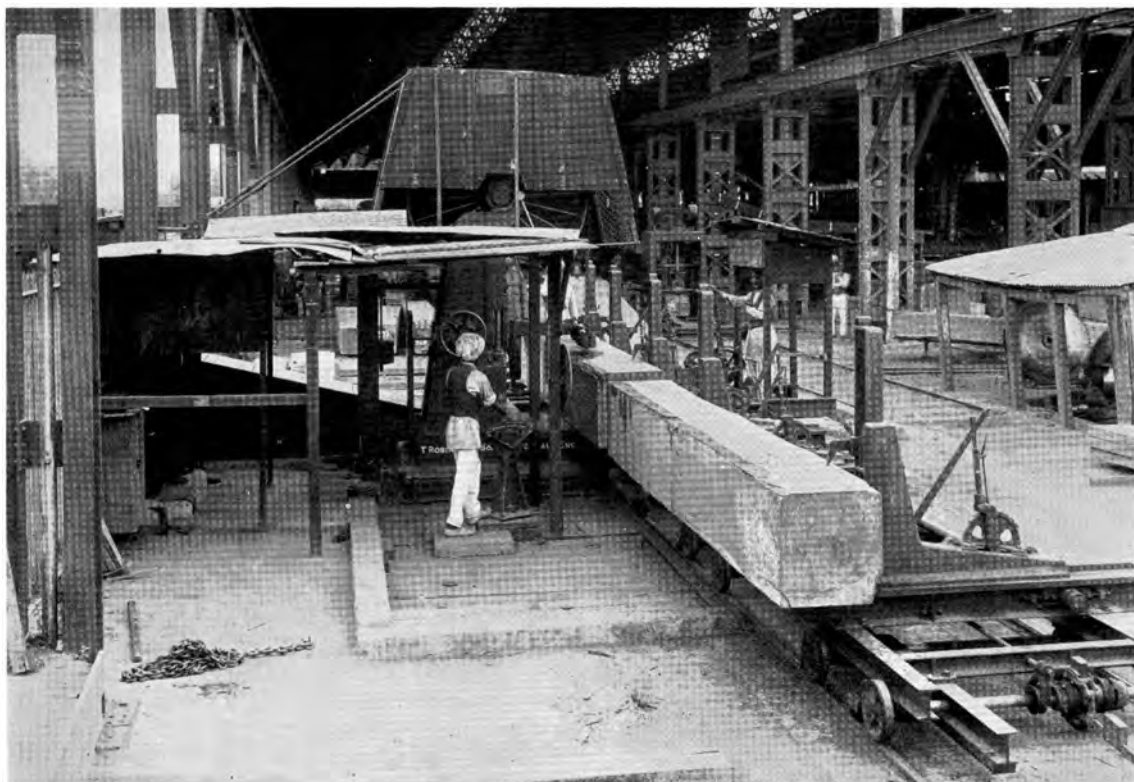
Modern vertical bandmill machines are able to convert miles of timber with great economy at speeds up to 400 feet a minute. The slower band re-saws and horizontal bandmills may also be classified as high production machines. Comparative statistics of circular saws and bandsaws are indicative:

<i>Depth of cut approximately</i>	<i>Width of cut approximately</i>	
	<i>Circular saw</i>	<i>Bandsaw</i>
6 inches	0.135 inch	0.075 inch
12 inches	0.160 inch	0.085 inch
24 inches	0.250 inch	0.100 inch

This considerable saving can be improved further by cutting 24 inches depth with a bandsaw of, say, 19 gauge – only 0.042 inch thick.

<sup>53</sup> Patents by Orton, Robinson, Panhard-Levasseur

62. *Robinson six-foot vertical bandmill with log carriage installed in 1923, in the North Western Railway workshops, Moghalpura, Lahore. This bandmill was the first on the Indian sub-continent to convert timber in log form by endless band blades*



# Saws of 1960

Leaving out of this account surgical saws, the major change in which has been the production of a totally aseptic instrument, and omitting musical saws (the so-called singing saws) which had a short music-hall life and were simple, inexpensive handsaws played with a bow or padded drumstick, the blade being flexed to produce changes in pitch – we now have a fairly well-balanced picture of the story of the saw from the earliest times. What general conclusions may be drawn?<sup>54</sup>

Saws of any period fall into two general categories: reciprocating or continuous action.

Reciprocating saws may be rip or cross-cut saws, and may be open-bladed or framed, manual or mechanised. Reciprocating saws of many degrees of specialisation and sophistication have existed at least since the New Stone Age.

Continuous action sawing, either rotary or by endless band, has existed only since the late 18th century.

The salient features of the evolution of the saw since its conception as a serrated flint artefact have been the invention of copper and bronze saws, probably in Mesopotamia, and their role in the emergence of the wheel. Iron saws with raked and set teeth, the framing of blades and first mechanisation of reciprocating saws – all belong in the Iron Age and Roman period.

The spread of the sawmills, the appearance of push saws and improvements in metal technology took place in the medieval and early modern period. The Industrial Revolution and modern age witnessed the proliferation of design, the invention of continuous

action saws, both circular (including those with teeth of inserted pattern, segmental or hard-tipped) and band, and the use of high quality carbon crucible steels, alloy steels containing nickel, chromium and vanadium, separately or in conjunction one with another, and high-speed steels. In modern times the employment of nickel chrome strip for bandsaws became general, hard chrome plating of solid plate saws and of inserted teeth was introduced as a means by which the 'life' between sharpenings could be extended three or more times and, in cases where continuous cutting of abrasive materials was the problem, the employment of tungsten carbide tips for the teeth of circular saws provided an economic solution despite high initial costs.

It is a far cry from nickel chrome strip and tungsten carbide tips to traditional pit-saws and the folk-lore of the 'most strenuous of all trades', the sawyer's:

Strip when you're cold, And live to grow old.

## Short saws and long

Yet the demand for handsaws remains. Made in Sheffield are short saws of every description and long saws, including even the perennial pit-saws: handsaws of open and framed construction, backsaws including the delicate dovetail saw, compass saws not unlike those of the 18th century, coping and fret and

<sup>54</sup> Guthrie, D., *History of Medicine*, rev ed London, 1953, p 149; *Grove's Dictionary of Music and Musicians*, ed Dr Eric Blom, rev, London, 1954, Vol VII, p 425



63. A modern tenon or backsaw, fitted with brass or steel back

---

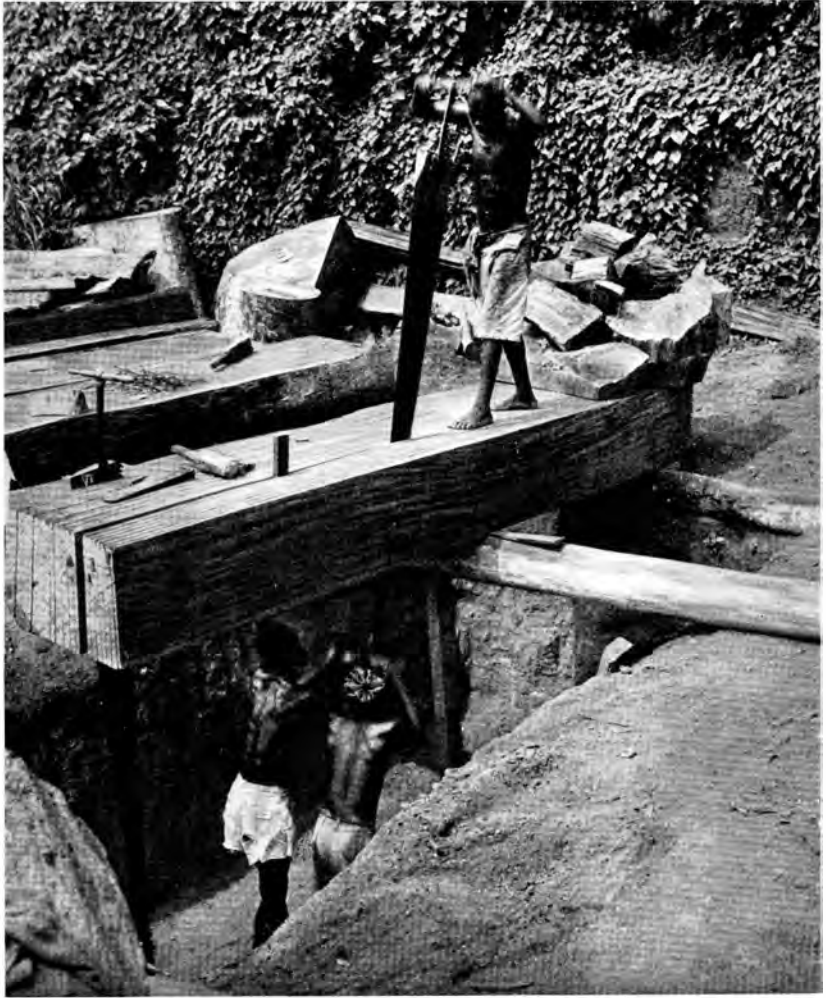


64. Nest of saws

---



65. Grecian pruning saw



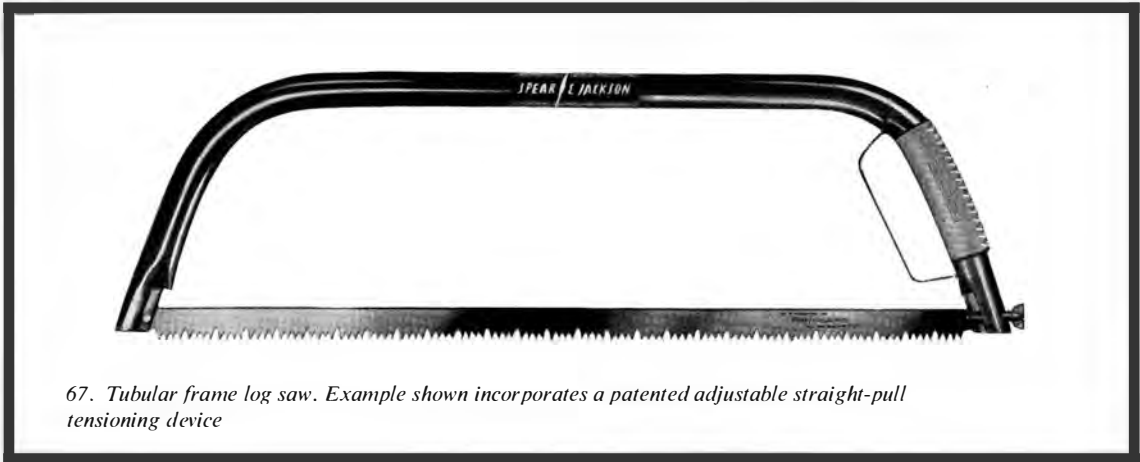
66. Pit-sawing in Ghana. Saws up to ten feet long are used frequently

a variety of pruning saws; and long saws such as the exactly-tempered, hand-sharpened cross-cut saw and mill webs strongly reminiscent of 'two dozen of mill webbes eache with twentyeight teeth' supplied by the founder of Spear and Jackson, John Love, to a sawmill in 1776.

Also centred in Sheffield is modern plant for the production of another type of handsaw, the metal-cutting hacksaw. They are made in two qualities: high-speed steel and low tungsten steel, the former being essential for continuous sawing as well as for cutting

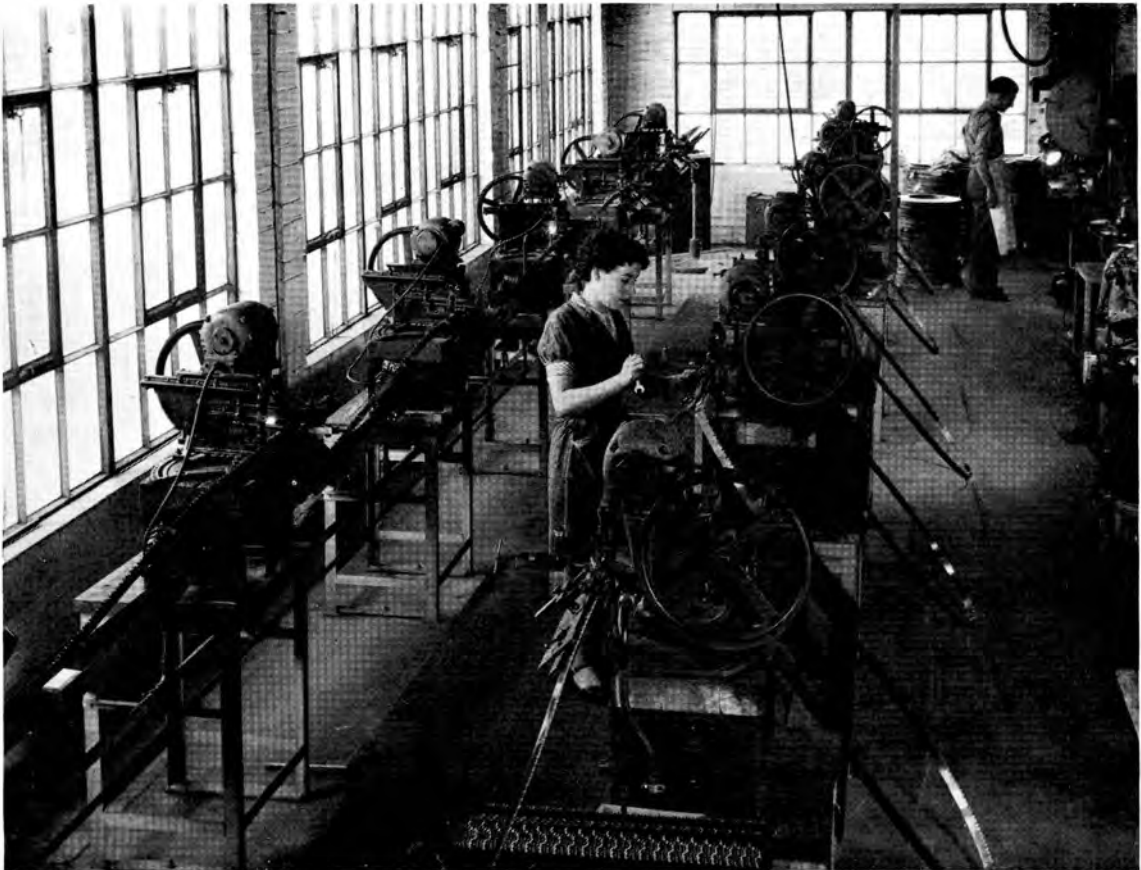
high tensile stock and the more difficult highly alloyed metals such as stainless steel, nickel chrome and manganese steels and Nimonics, whether sawn by hand or machine. Low tungsten blades for hand use may be either 'all-hard', preferred by the skilled worker for their rigidity; or 'flexible', these being hardened on the teeth only are practically unbreakable and are recommended for use by semi-skilled operators or where work cannot be held firmly.

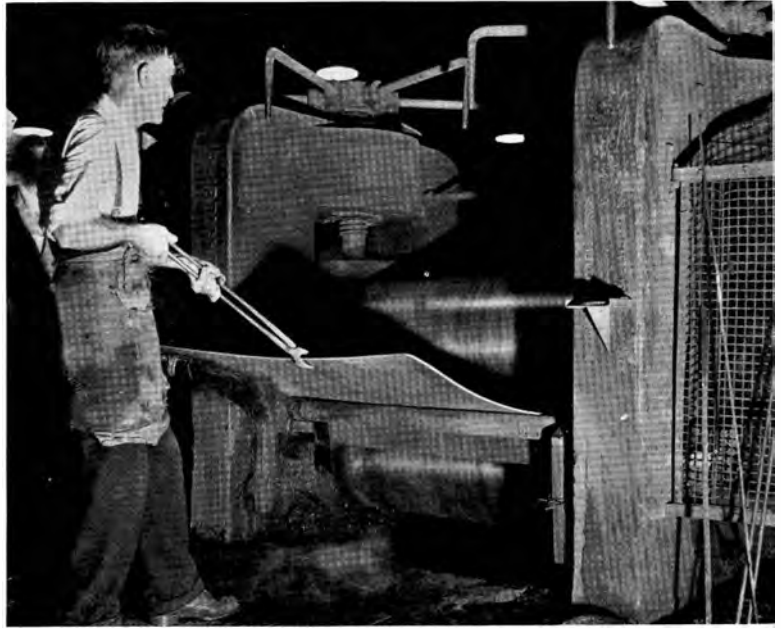
Choice of the correct blade is a matter for care and reference to trade literature. In general, the softer the



67. Tubular frame log saw. Example shown incorporates a patented adjustable straight-pull tensioning device

68. Automated production of log saw blades or webs. Lines of file-sharpening machines are shown





69. Rolling steel sheet for short saws

material and the heavier the desired cut the fewer the teeth per inch of blade. Conversely, the smaller the workpiece or diameter of rod or tubing and the lighter the cut the more teeth per inch.

Of all this variety in handsaws, perhaps the most unusual is the tubular frame or log saw, the blade of which is now made by automated process at the Aetna works of Spear and Jackson. Saws have again scooped the other edge tools in being the first to be so produced. The blade or web is fed from rolls of steel strip, continuously and at controlled tension. (It is this element of 'feed-back' that justifies the description, automation.) Tothing, setting and sharpening – all are done by automatic production line. The most recent development at this plant is the hard chromium plating of teeth – chromium-armoured teeth for lasting sharpness and rust-resistance.

Tubular frame saws are used by the forester for felling and lopping and are beginning to take the lead as the householder's saw for outdoor use. However, this handy log saw, and in particular the older cross-cut saws, in their turn face competition from the power-operated chainsaw, a necessary adjunct to the

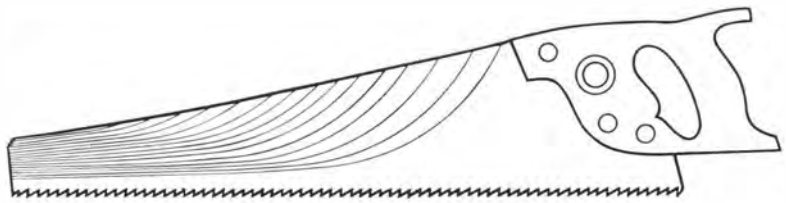
equipment of the nation's foresters, the smaller woodland owner and the farmer.

The manufacturing sequences involved in the making of best quality handsaws still demand here and there the skill of the hand craftsman.

In Sheffield, at Spear and Jackson's Aetna works, *Spearior* quality hand and tenon saws and *Mermaid* quality circular saws are all made from steel melted in electric arc furnaces. The ingots to controlled analyses and free from impurities are hammered or roll-cogged to slabs (or 'cheeses', as circular saw slabs are called in the trade), cross-rolled to plates in a sheet mill and passed through blanking press or paring shop in an annealed or soft state, and then go to the particular production department. The handsaw blank is toothed by rotary or reciprocating punch, hardened and tempered, tested, hammered flat and tensioned by highly skilled smiths, before going forward to be ground and glazed. A delicate, highly skilled craftsman's job follows – setting the top third of each tooth by hand, using a special hammer. No machine yet devised gives just the right amount of curving offset to the tooth cut in the highly tempered chromium-vanadium



70. *The Spear and Jackson Double Century handsaw with rosewood handle. Diagram below illustrates the effect of radial taper-grinding*



or other special analysis steel blade. The teeth of the saw are then file-sharpened. The blade is now ready for acid etching, after which process it is stiffened by immersion in hot oil, cleaned in trichloroethylene and finally dry lacquered for protection against rust. Kiln dried hardwood handles have meantime followed a separate manufacturing journey from the initial routing process through slitting and boring to sanding and cellulosing, to be united with the blade in assembly and packing bays.

Quality handsaws are taper-ground. This is a modern way of performing an 18th and 19th century operation – it will be remembered that compass and keyhole saws of that period had thinner back edges than toothed edges. This taper-grinding produces a blade, say, four gauges thinner on the back edge nearest the point, thickening towards the handle end, than along the whole length of its cutting edge. Saws that are radial ground to a taper in this way will not bind

in a deep cut. Their teeth in consequence require less set.

The production of a handsaw for the skilled tradesman of the 1960s or the enthusiastic amateur woodworker, requires a manufacturing journey some twenty-seven processes long in which traditional skills mingle with metallurgical control and machine operation. Just such a product of this fruitful union of hand skill and mechanisation is the *Double Century* panel saw, a 22-inch ten point handsaw with rosewood handle, pictured above, which was selected to mark the bicentenary in 1960 of Spear and Jackson Limited.

## Specialised circular saws

The variety and size ranging of modern circular saws is enormous. Types include ordinary plate saws (in standard sizes ranging from 4 inches to 84 inches

in diameter); inserted tooth saws; swage and hollow ground saws; segmental cold saws and the so-called hot saws for metal-cutting; tungsten carbide-tipped saws for cutting wood and non-ferrous metal; and diamond saws for stone-cutting.

Within this extensive range are saws indispensable for all stages of timber conversion as well as for work in the plastics, ferrous and non-ferrous metal industries. Among the more unusual jobs such saws perform—performances that would probably surprise Walter Taylor or Brunel—are cutting Ivorine for cameo brooches in Devonshire and buffalo horn in Warwickshire, sawing frozen stockfish in Nigeria, tearing cotton in the Sudan, slitting slabs of salt in Peru and shaping brake-linings in Canada.

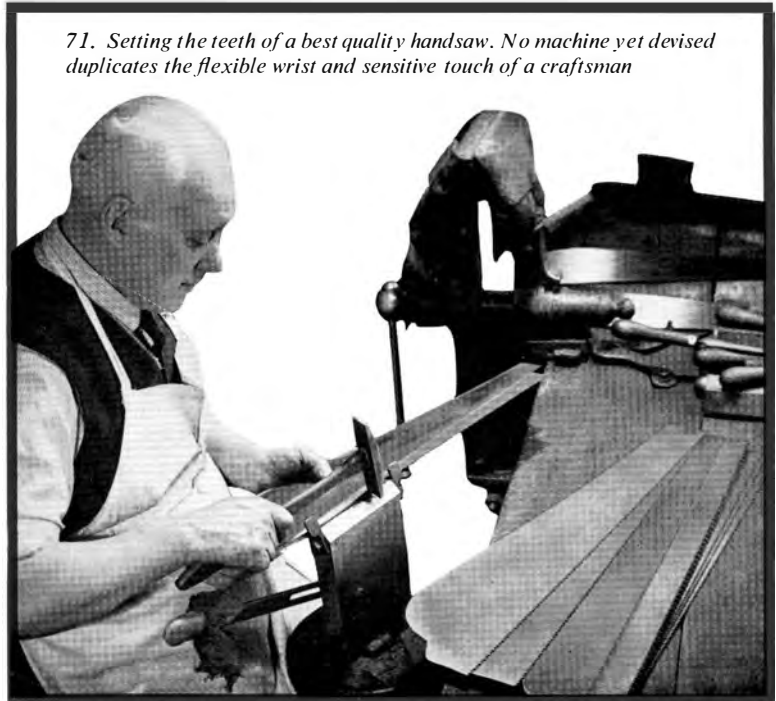
In the 1920s, after a series of earthquakes in Japan, circular saws and mill webs were exported in hundreds from Sheffield for reconstruction work. The skill of the mill operator in some eastern countries is of long-standing and thin-bladed saws and special tooth forms are demanded and successfully employed. Meanwhile, the smaller swage saws developed essen-

tially for box-making meet requirements of a special kind, as for instance in East Africa where this is a basic tool of the industry cutting cedar for pencil slats.

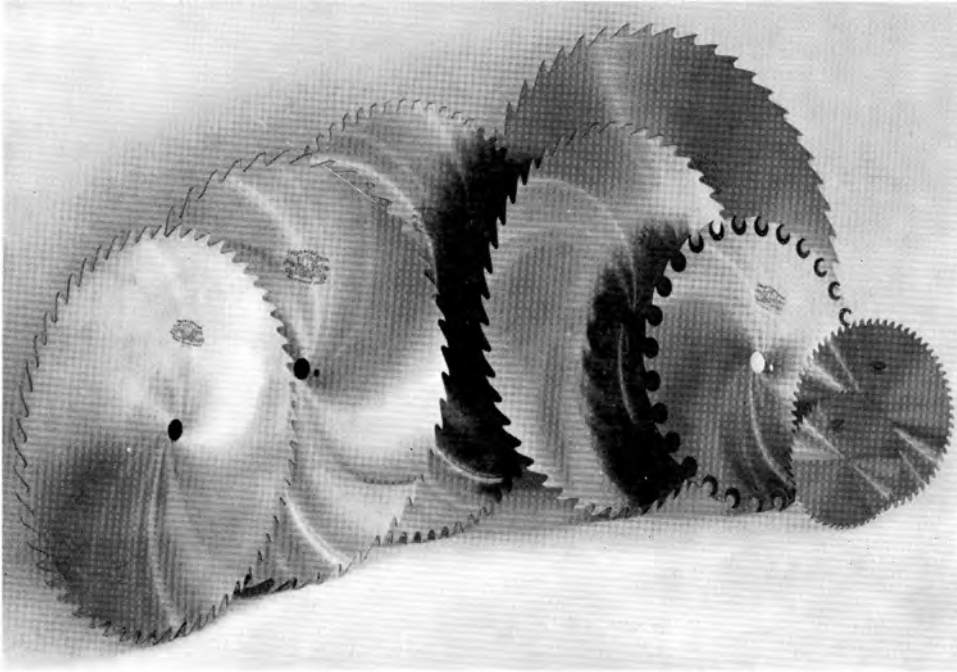
It is this very universality of the saw, its successful employment for tasks so varied in conditions so diverse over so long a period of time, that has complicated the manufacturing problem. For there can be no effective standardisation of product when the product itself is so traditional and its successful employment in exacting conditions often more an art than a science. Local prejudices and preferences have grown up and it is as true of mill men as of professors of economics that, to paraphrase, when six saw doctors are gathered together there will be seven opinions! Local knowledge and experience should be given due weight for a saw must operate successfully on timbers the structure of which varies enormously.

This is why attempts to reach agreement on standard toothings are usually frustrated. Yet in the manufacture of circular saws—as has been noted already in the making of handsaws—a sequence of

*71. Setting the teeth of a best quality handsaw. No machine yet devised duplicates the flexible wrist and sensitive touch of a craftsman*







72. Typical circular saws for ripping and cross-cutting, showing manufacturer's standard tooth shapes

operations is followed, albeit for small batch production.

The pared plate is given a batch reference number and is flattened before being individually toothed to specification. Its centre hole and, if required, pin holes, are trepanned or bored out to be subsequently reamed. Next follows a most important and formative stage in the making of a saw: the toothed plate or blank is placed in a temperature-controlled furnace and when brought to correct temperature is quenched quickly in oil, being held in a press to prevent distortion. Brittleness must be overcome and so the blank is transferred to a rotary circular press and tempered in a gas-fired furnace maintained at a known temperature. Brinell hardness tested, the saw blank moves to the smithing shop where any small distortions are hammered out by expert artisans and some tension hammered in.

Smithing or tensioning demands a further word of explanation. Old fashioned though the spreading of the metal of a blade by beating with hammers

may appear, this art resembles setting in that it did not become common until less than a century ago. Even today it cannot be fully explained in terms of engineering and metallurgy, of stresses and strains. Broadly speaking, a handsaw or bandsaw cuts better for having its centre in compression and its cutting edge in tension. Similarly, a circular saw runs truer with a static internal stress cancelling out the centrifugal dynamic strains experienced when its teeth are cutting at the normal peripheral speed.

The processes can be considered complete only after surface grinding has provided a uniform blade thickness and a surface free from oxide scale, for the heat generated by grinding may have varied the amount of tension present in the blade. Checking and final adjustment of tension, the highly skilled blocking operation, using light hammers with slightly crowned heads, is now necessary to make certain that the blade is sufficiently loose at the centre, that it has the right amount of tension for its running speed. Present practice is to tension saws according to their

type for speeds up to 12,000 feet per minute (over 135 mph) at the rim.

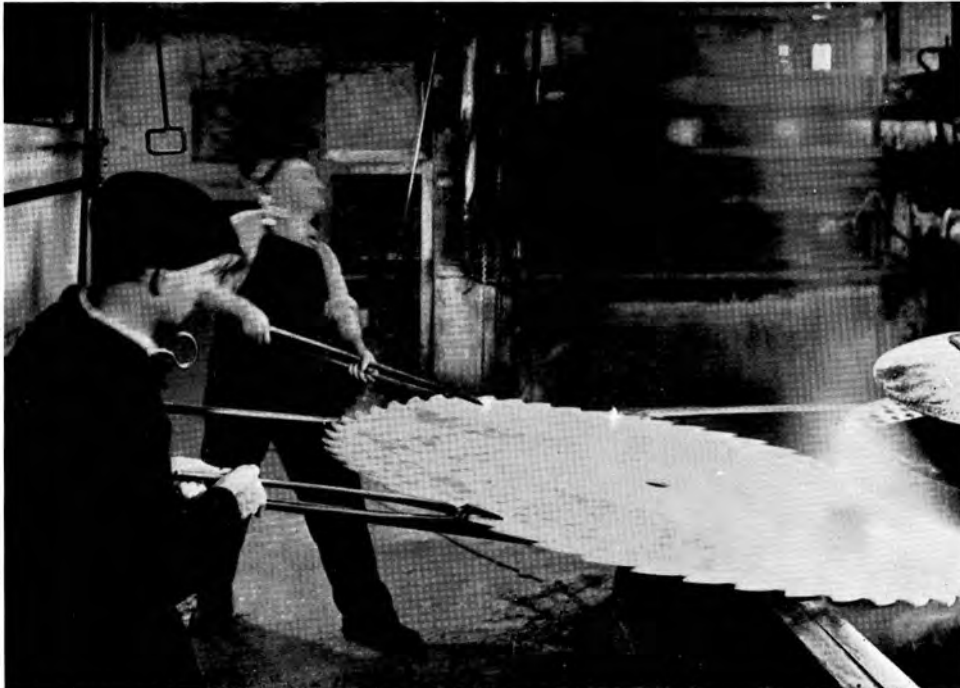
Setting and sharpening are further important processes in the making of a circular saw. Only when these operations are completed is the blade ready for balancing and etching.

The service life of the saw will depend on many factors. An electrically-melted alloy steel saw will retain its tension because of its greater uniformity and consequently will run true for a longer time than a saw of cast steel. Similarly, a saw that has teeth hard-chromed will blunt less quickly and the intervals between re-sharpening will be longer. These are important considerations for the sawmill operator.

The Vancouver factory of Spear and Jackson Limited catering for the lumber industry along the west coast of the North American continent produces saws of up to 108 inches in diameter and was the first to manufacture cut-off saws for pulp mills having inserted teeth tipped with stellite. Pared plates – no longer finished saws – are shipped from Sheffield.

Circular saws for cutting metals including high tensile steels must be viewed in shorter perspective. It was not until the second and third decades of this century that segmental circular saws (foreseen in Bentham's great patent of 1793) became a reality, superseding saws with high-speed steel inserted teeth which hitherto had been satisfactory only for lighter steel sections and non-ferrous metal. The new type segmental saw, originating in Germany, was for heavy or light duty, having riveted segments interlocking around its periphery, each segment being formed with roughing and finishing teeth of a pitch to suit the type of work. Such saws proved to be capable of withstanding the high rates of feed and speed of hydraulic machines developed at this time. The particular virtue of such saws is the replacement segment of high-speed steel. It reduced costs; if damaged it was quickly replaced; and worn teeth could be sharpened repeatedly, all segments eventually being replaced with a new set. Normally, re-sharpening is carried out by the user and full re-segmenting by the

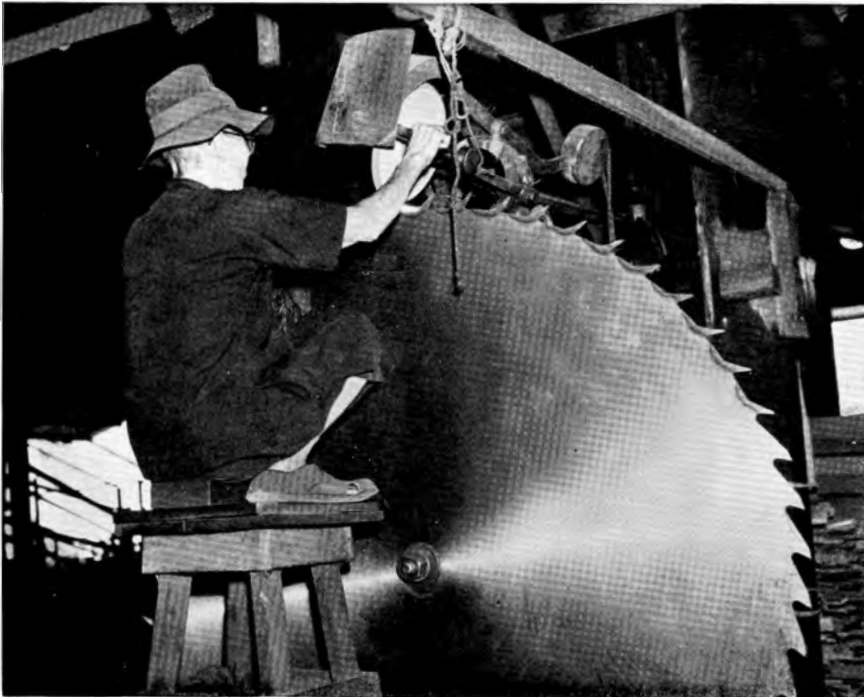
73. *Hardening the heated blade by quenching in oil. A 72-inch diameter solid tooth saw at red heat is quenched*





74. *Smithing: putting the tension into a saw blade. An 84-inch diameter solid tooth saw is shown*

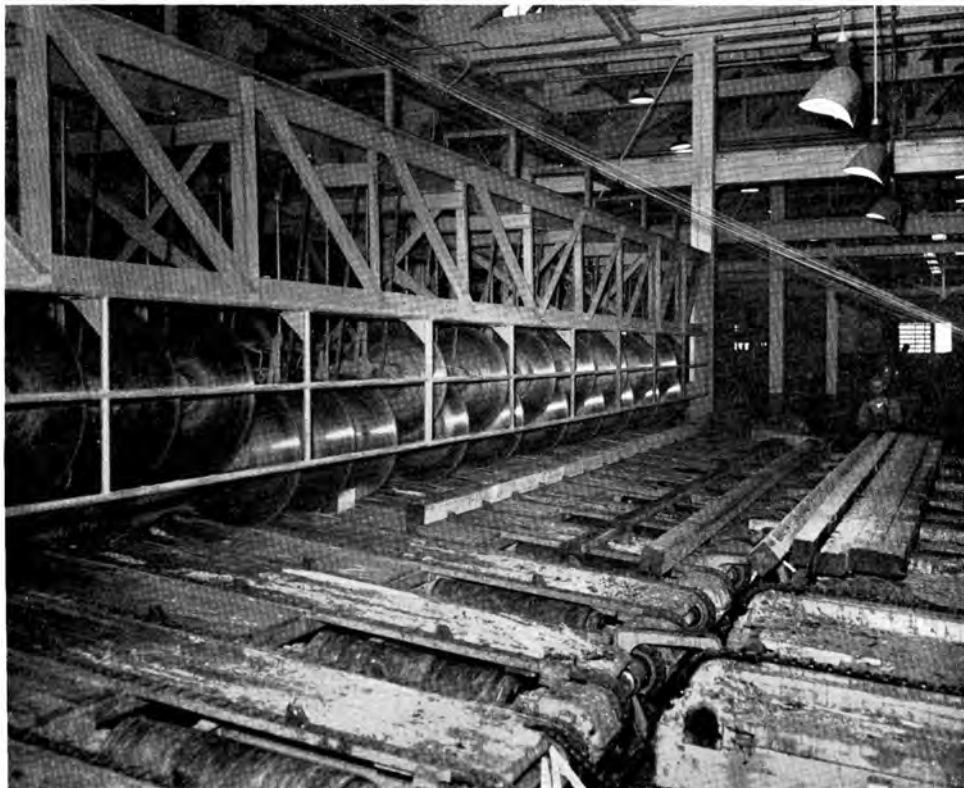
75. *Not every customer agrees with the manufacturer's tooth shape. A saw is given a shark's tooth form*





*76. Sheffield companies cater for the needs of the Canadian west coast lumber industry.  
The new Spear and Jackson (BC) Limited factory at Burnaby, Vancouver*

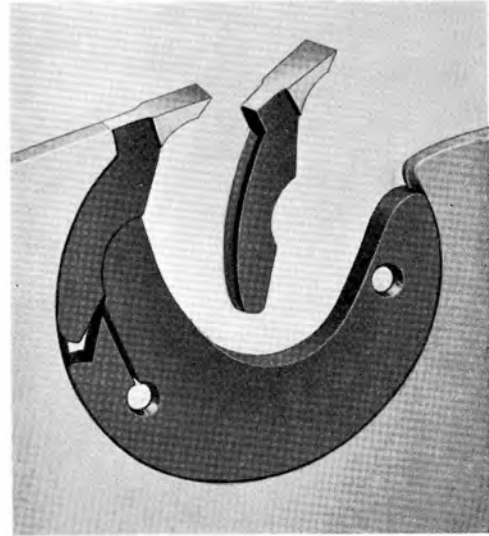
*77. Modern sawmill, showing multiple trimmer fitted with saws supplied by the  
Spear and Jackson Vancouver factory and made from Sheffield rolled plate*





78. *Fitting the teeth and holders in an inserted-tooth circular saw*

79. *Standard type holder and tooth of a modern inserted-tooth circular saw. See also 59*

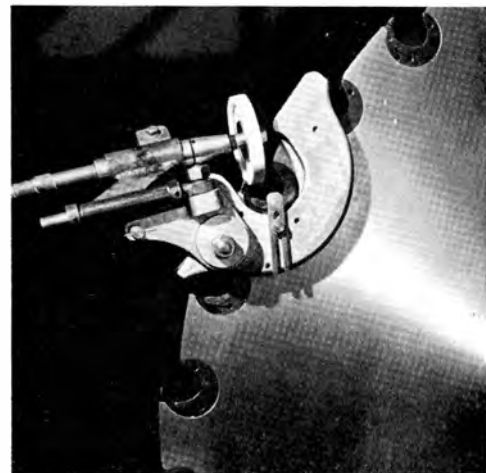


original maker of the saw. These so-called cold saws are, to a degree unusual, continuously in motion, for besides heavy duty sawing they are consigned to and from the maker or service repairer for re-fitting, the centre or body being re-fitted a dozen times or more.

For cutting ingots, billets, tubes and bars, the segmental saw has as yet no equal. Improvement in the design of segments has however been possible and a patented segment having no intermediate rivets to link the segments has been successfully tried, its principal merit being the greater economy resulting from its use. Teeth can be re-sharpened until the gullet is ground down much closer to the tongue of the segment than was previously possible. New tooth shapes have also been found of practical advantage. Spear and Jackson engineers have pioneered both these advances.

It is appropriate here to record yet another and more recent development: the high-speed steel inter-

80. *Re-sharpening the teeth in situ by flexible drive jockey grinder*



nal tooth saw of segmental construction. This saw is new in that the teeth are milled on the internal diameter. Each toothed segment, taper-ground for clearance, is dowelled and screwed into position on an annular ring to form the saw. The sawing machine developed and patented by Sir James Farmer Norton and Company of Manchester, incorporates an eccentric head within which this unusual saw is located. The combined movement of saw and head accomplishes the objective of cutting ferrous and non-ferrous tube without 'fash' formation. Consequently the need for de-burring is avoided.

The blade's construction provides for re-sharpening, repair and re-fitting of segments simply and quickly. It is expected that the saw will have a longer life between sharpenings owing to the machine's peripheral sawing action – the feed of the blade is through the tube wall thickness only and not through the tube diameter.

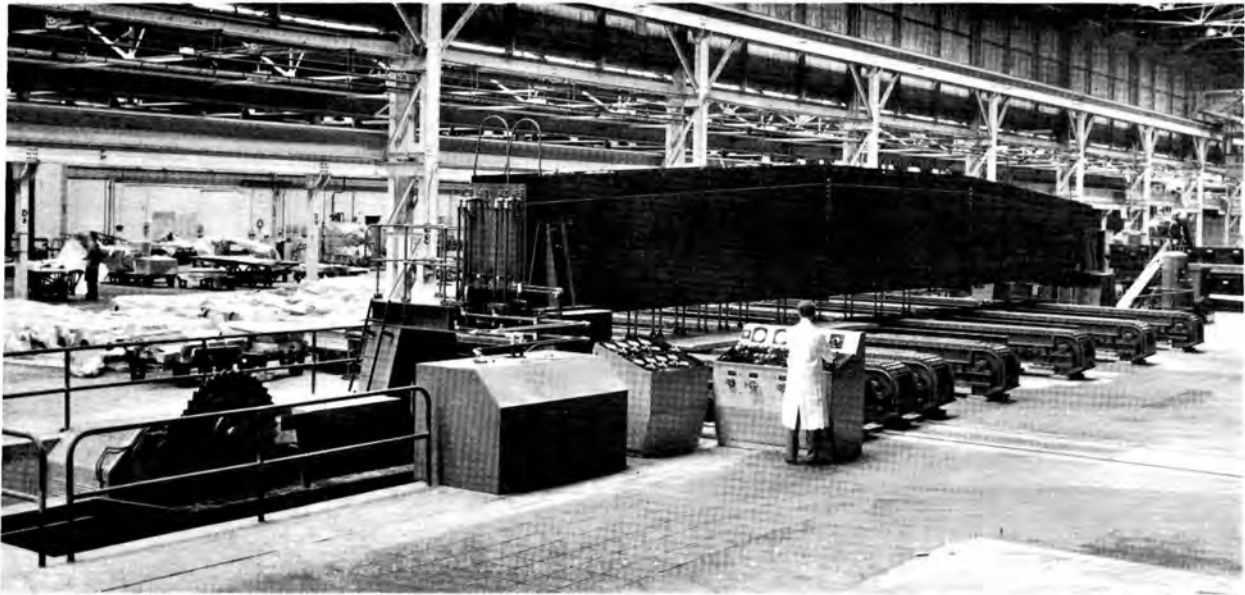
Milling cutters, although in some respects similar to the segmental saw, do not form a part of the saw's



81. Cutting cold metal by segmental circular saw

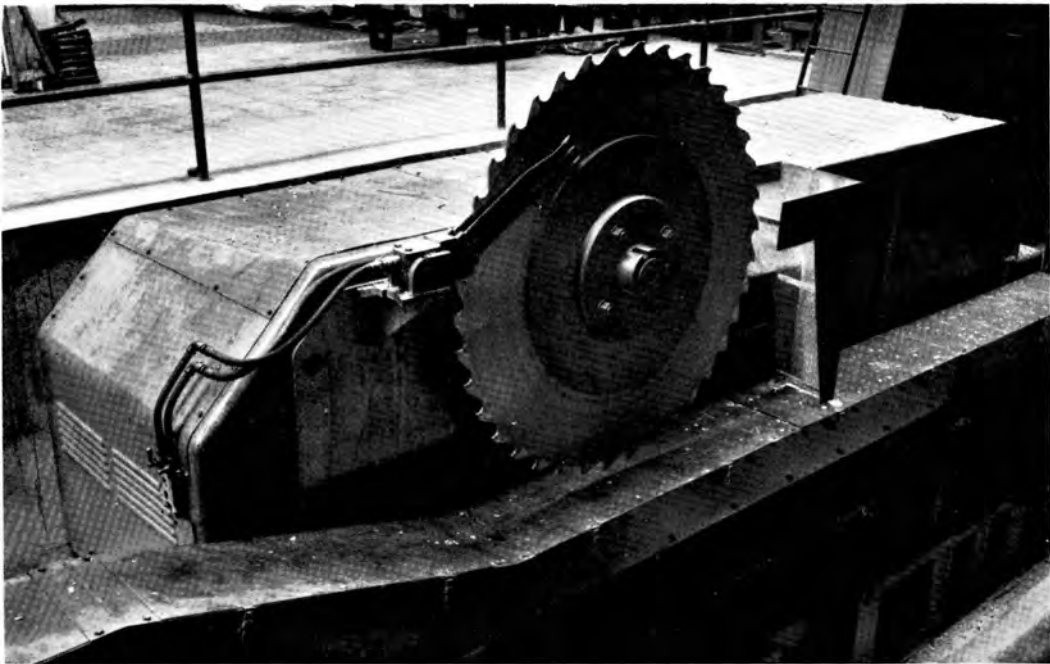
82. Fitting high-speed steel segments to a metal-cutting cold saw





83. Cutting aluminium plates 57 feet long by 10 feet wide by 6 inches thick. A comparative newcomer to the saw family, the tungsten carbide-tipped saw here takes on a mammoth task

84. Close-up of the tungsten carbide-tipped circular saw in use on the Wadkin machine shown above



history. Hot metal sawing, as distinct from cold sawing, is however a part of this story – and a somewhat unhappy chapter, since the high standard of maintenance so essential for full operating efficiency is not easily secured under shift working conditions in the large rolling mill.

The circular hot saw is manufactured from carbon steel in diameters up to 72 inches. Saws of this type are supplied in the 'as-rolled' black condition or are bright ground. They are run at faster speeds than wood saws and are often put to severe and exacting duty. The machines on which these saws operate must therefore be robust and efficient, and they require adequate maintenance as do the saws used on them. Hot saws are of heavier gauge than any employed on timber break-down and conversion and have strong cross-cut type teeth. There is no set to the teeth; for the saw cuts easily through the already red hot metal, the kerf being always wider than the nominal thickness of the saw.

In the universal beam mill at Lackenby, Durham, Dorman Long and Company use saws of the largest diameter for cutting to length beams 36 inches wide. The problem here as elsewhere is the rapid cooling of the work with the likelihood of damage to the teeth of the saw.

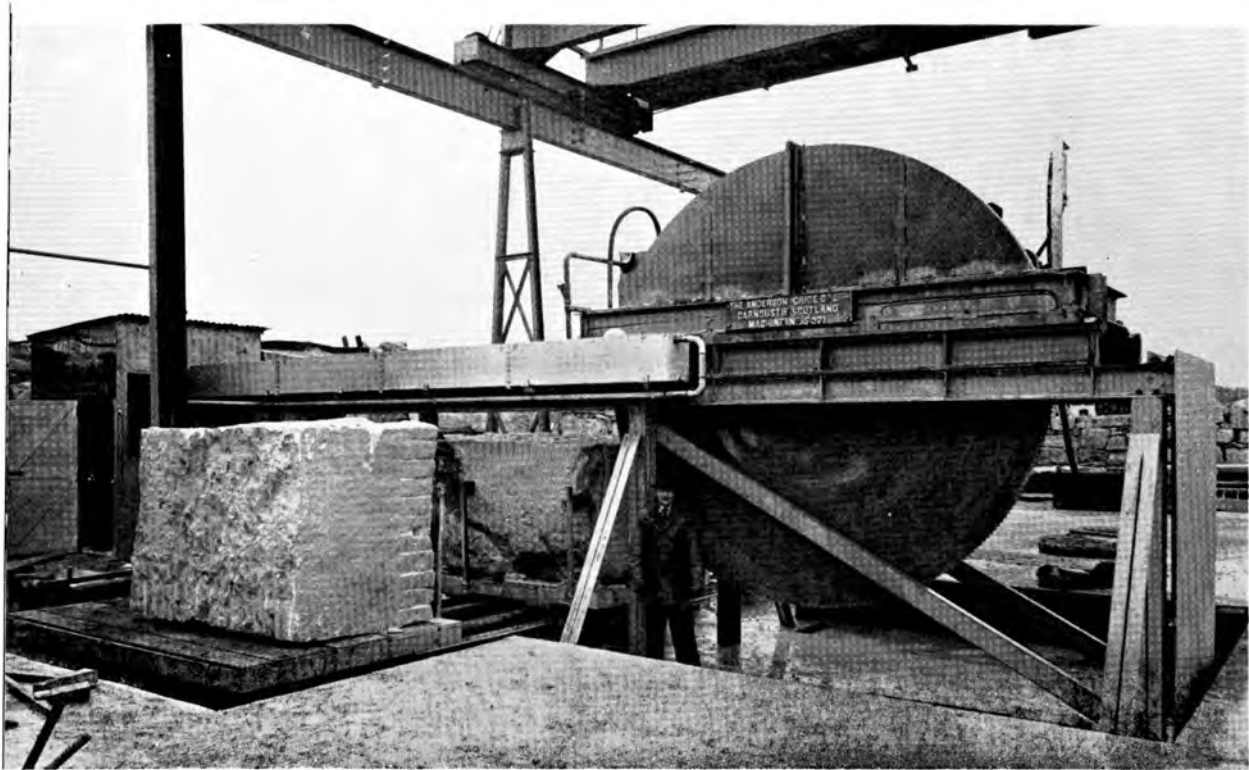
A new pattern tooth with flat top evolved after extensive study promises a solution to some of the problems of hot sawing in modern integrated mills, and progress has also been made with hot saws having swaged and tip-hardened teeth.

Tungsten carbide circular saws of 50 inches diameter able to cut aluminium plate up to 57 feet long, 10 feet wide and 6 inches thick are successfully operating at the Monmouthshire works of the Northern Aluminium Company. A specially built sawing machine, the first of its kind, has been installed there by Wadkin and Company of Leicester. The saw carriage of this machine alone weighs eight tons. The saw, driven by a 75 hp motor, travels beneath a 20-ton, 68 feet long

85. Final lapping by diamond impregnated wheel of a 50-inch diameter tungsten carbide-tipped saw

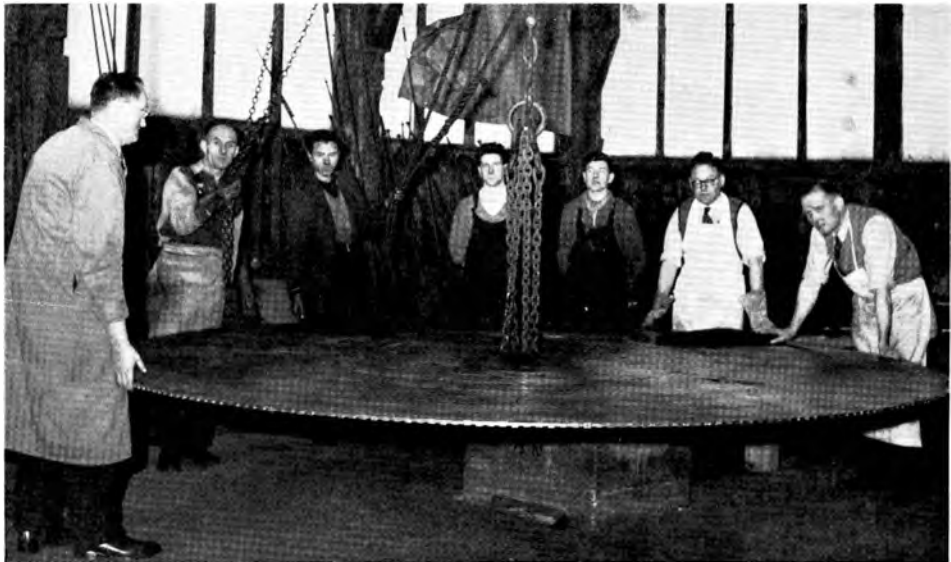


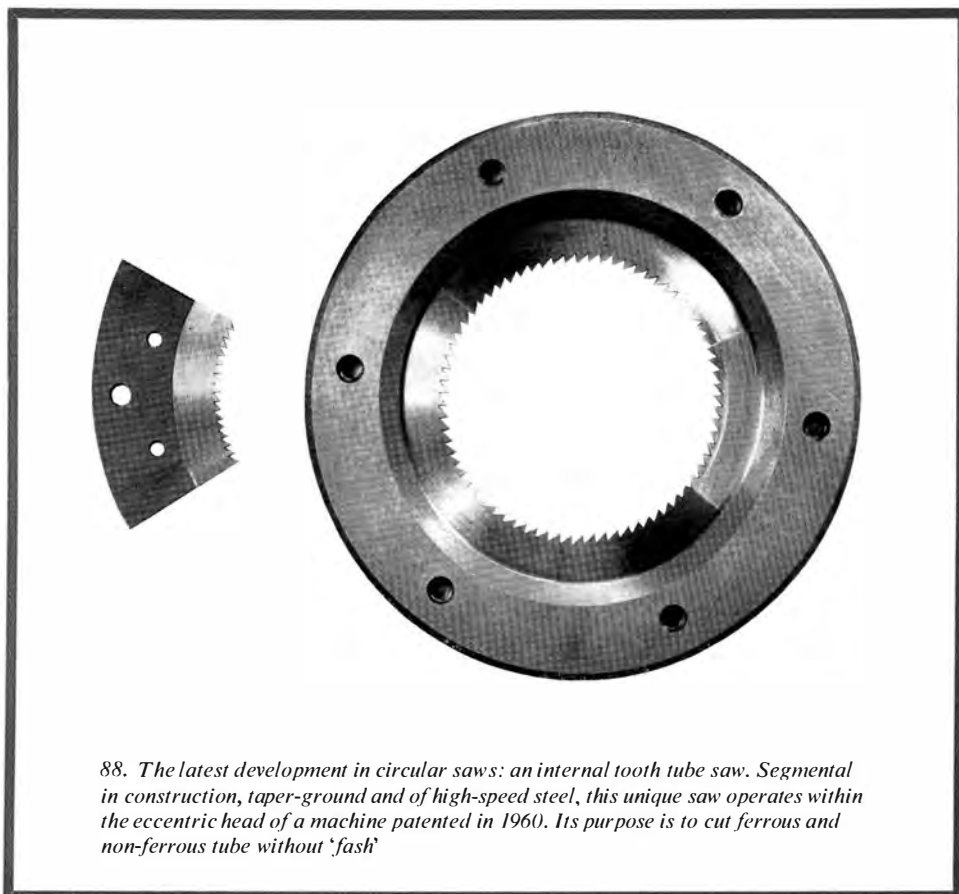




86. The world's largest saw is this giant 11 feet 7½ inch diamond-segmented saw employed in cutting rough-hewn blocks of Portland stone at the South Western Stone Company's quarries on Portland Bill in Dorset

87. A Spear and Jackson team of three smithers prepares to tension the largest saw ever made



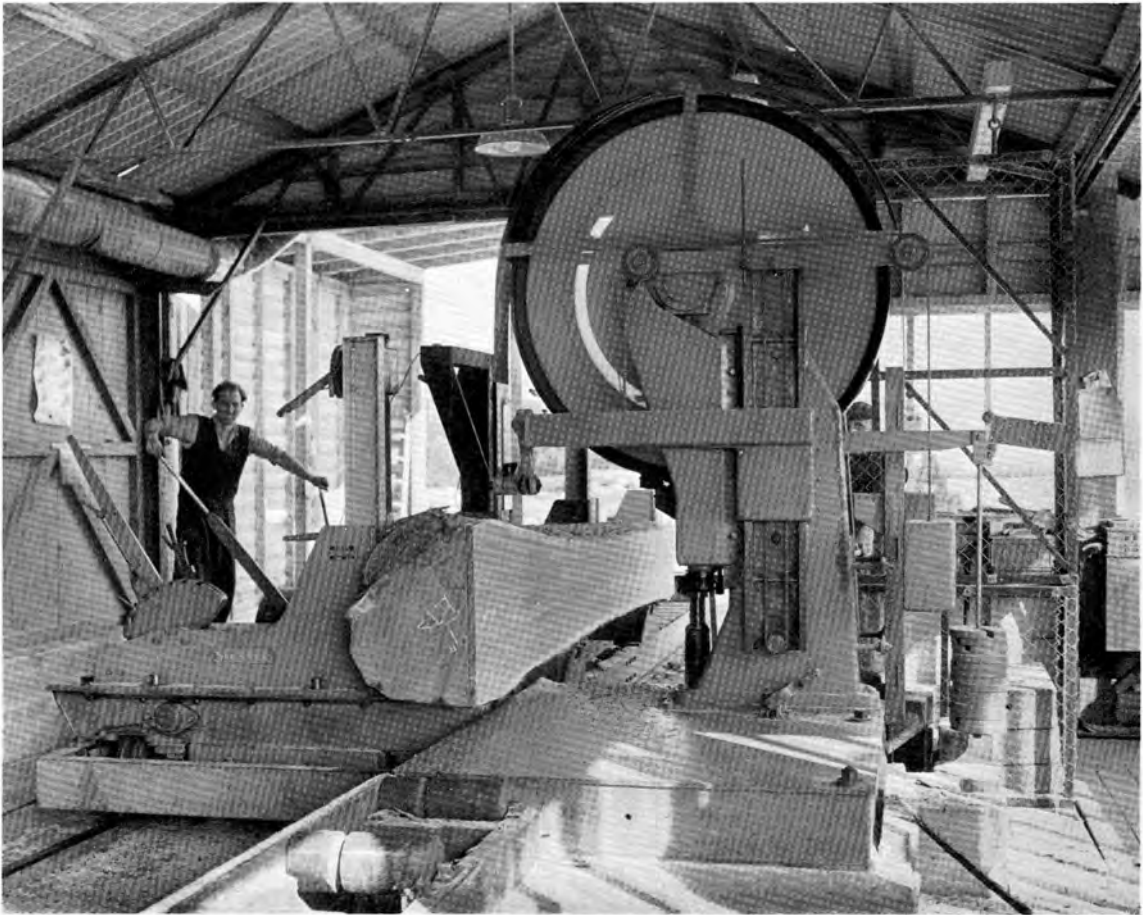


*88. The latest development in circular saws: an internal tooth tube saw. Segmental in construction, taper-ground and of high-speed steel, this unique saw operates within the eccentric head of a machine patented in 1960. Its purpose is to cut ferrous and non-ferrous tube without 'fash'*

beam holding the material to be sawn by means of eighteen hydraulic jacks. These particular saws supplied by Spear and Jackson are believed to be larger than any previously made. They are tensioned to run at rim speeds of up to 13,500 feet per minute. The teeth enter the cut at full operating feed speed of 180 inches per minute without damage to the tungsten carbide tips. Smaller cemented carbide saws had already proved their suitability for non-ferrous metal cutting and such saws are extensively used in the aircraft industry, for instance, and in the furniture trades for cutting especially abrasive timbers and the many synthetic and composite materials.

The record of modern saws having specialised applications would be incomplete without referring

again to the world's two largest diamond stone-cutting circular saws. Around the perimeter of the 11 foot  $7\frac{1}{2}$ -inch diameter blade are some two hundred sockets each containing three carats of diamond held within a sintered matrix. Successfully run by the South Western Stone Company on Portland Bill, in Dorset, these saws cut rough quarried blocks of Portland stone 5 feet deep and 6 feet wide. Their manufacture was a joint enterprise by the Anderson-Grice Company of Carnoustie, Scotland, Spear and Jackson and the giant concern, The Steel Company of Scotland. Successful completion of the project meant enthralling but exacting work for a team of Sheffield sawsmiths. These saws reduced sawing time from sixteen hours to forty minutes.



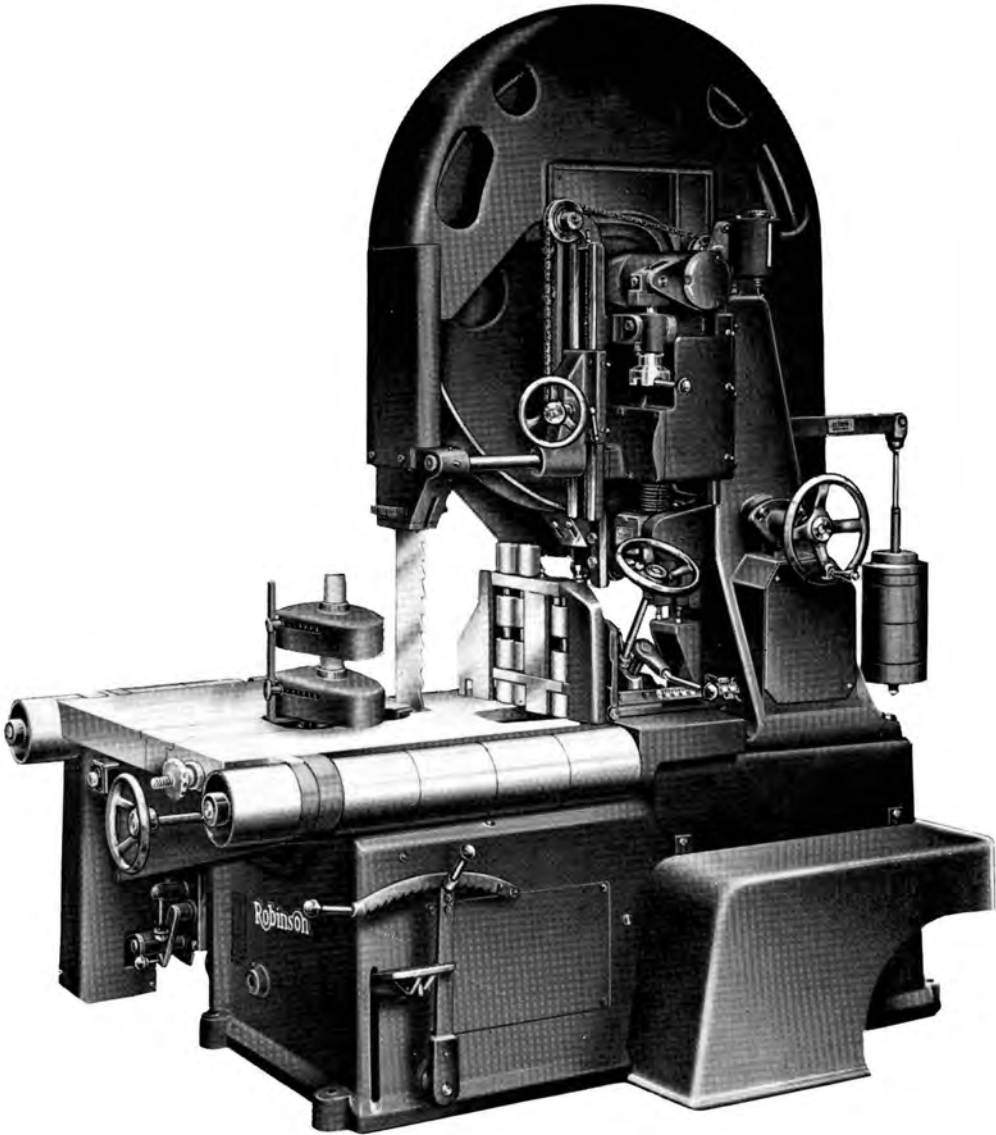
89. *Stenner 42-inch band rack with hand operated carriage*

## Wide and narrow bandsaws

As mentioned already in the last chapter, modern bandsaws have advanced far since the days of Worssam, mainly owing to steel-making discoveries and the development of the modern strip mill. The nickel chrome strip of today's bandsaws can bend through 180 degrees and re-straighten eight times a second. Steel strip of, say, 10 inches width is no more than one sixteenth of an inch thick; yet, electrically-driven with pulleys 6 feet in diameter, such toothed bands may be driven at up to eight thousand feet per minute on modern log mills and re-saws.

Narrow bandsaws for straight and contour sawing

of wood are operated on efficient machines to give accurate results such as are required in pattern shops. The bandsaw is nothing if not versatile and may be employed for re-sawing, for sawing large radius curves, cross-cutting with a mitre gauge, and bevel sawing. There are machines available today fitted with electric blade-welding equipment suitable for continuous operation in woodworkshop and furniture factory as well as many small machines designed for blades ranging in width from an eighth to three-quarters of an inch and intended for schools use and home workshops. Besides the bandsaw for wood there is the hard-toothed, flexible back blade for metal-cutting with raker set or wavy set teeth and the alternative



90. A modern band re-saw made by Thomas Robinson and Son of Rochdale

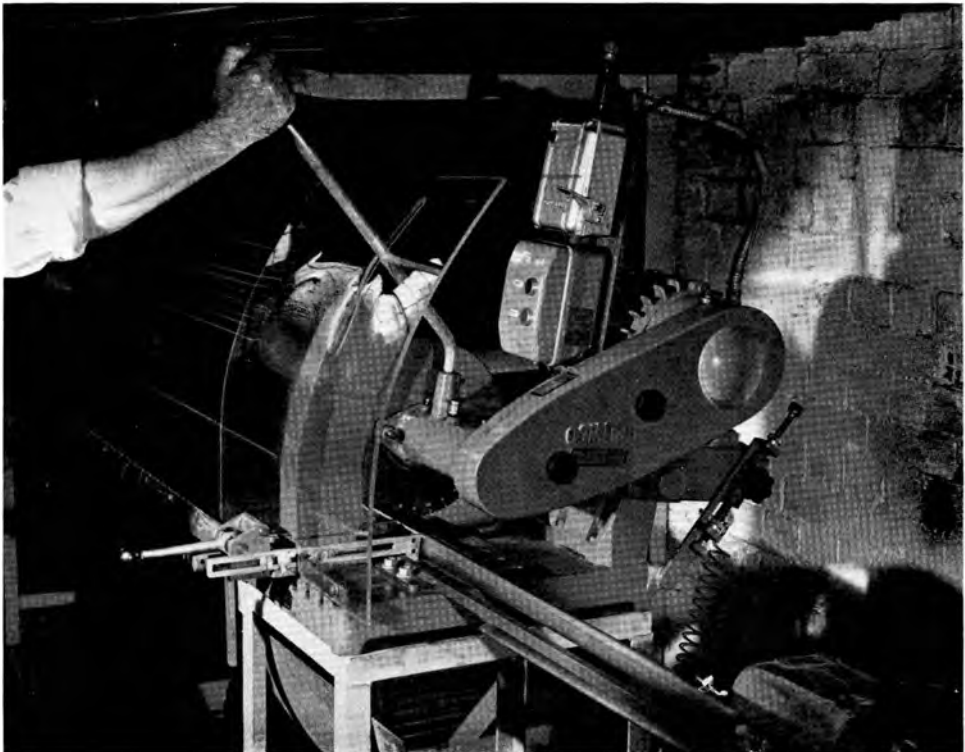


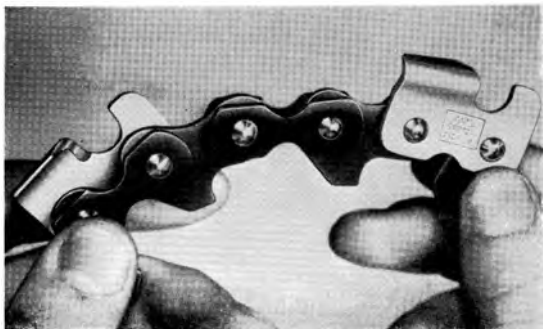
91. Abattoirs use bandsaws for cutting carcasses. Smaller bandsaws, such as this Wadkin-Bursgreen machine with 16-inch wheels, are found useful by retail traders for cutting meat into small joints

skip or buttress type tooth recommended for cutting most plastics, the softer non-ferrous metals, bone, meat and frozen foods.

In cold sawing of steels also, bandsaws have not been left behind by their circular cousins. On the contrary, fusion bands run at surface speeds of 20,000 feet per minute and over and melt their way through the steel. All previous saws have been mechanical in their action and the fusion bandsaw presents the industry with a new cutting principle, more akin to the oxy-acetylene flame. Circular fusion saws – friction discs – have also had success at rim speeds of fifteen to twenty thousand feet per minute. More durable than abrasive discs, their extended use in burning through tubes, steel sections and bars, is guaranteed.

92. Recent development of friction discs provides the engineer with a new tool. Here one is employed for rapid cutting of tubes in the Spear and Jackson tubular frame saw department





93. A few links of Oregon chipper saw chain. The replacement of two-man cross-cuts by powered cross-cuts has revolutionised logging methods. The inventor of the Oregon chipper saw chain illustrated had studied the larva of *Ergates spiculatus* the timber beetle, in developing the design of the left and right hand cutters of his chain.

## Shaping history

The saw of today is a tool of many sizes, shapes and functions, made out of a variety of materials. From its very birth it asserted its authority over the world of tools.

Outranging the edged tools . . . because potent in cutting metal and stone as well as wood, the all-important saw as a master tool . . . has outrivalled the axe and outclassed the wedge from the beginning of time.

The facts bear out this judgment by Dr Mercer.

From the origins of Russia to those of the United States; from the primitive forests of 10th century Kiev to the virgin lands of the equally harsh New World colonies of the 17th century; and from the pyramids of Egypt to Portland stone of Dorset in England, the saw has been a creative influence in the economic and social history of the world. The saw enabled pioneers to carve our forests, subjugate continents, construct material civilisation.

The saw indeed enabled Man to master and shape his physical environment. To a great extent it is still doing so.



94. Felling in the forest by power-operated saw chain

# Selected bibliography

This book list is in no sense comprehensive and merely indicates works used in writing this *Story of the Saw*.

- Albion, R. G.** *Forests and Seapower: the Timber Problem of the Royal Navy, 1652–1862* (Cambridge, Mass, USA, 1926)
- Ausonius** *Works* (trans H. G. Evelyn White, *Loeb Classics Library*, London, 1919, Vol I)
- Bale, M. Powis** *Woodworking Machinery, its Rise, Progress and Conclusion* (3rd edition, London, 1914, (1894))
- Bale, M. Powis** *Stoneworking Machinery* (2nd edition, London, 1898)
- Bale, M. Powis** *Handbook of Sawmill and Wood Converting Machinery*, (London, 1919, (1899))
- Beamish, R.** *Memoir of the Life of M. I. Brunel* (2 Vols, London, 1862)
- Bible, The** The Book of Samuel, Kings, Isaiah, and The Epistle of Paul to the Hebrews
- Bowles, O.** *Significant Features of Wire-Saw Operation in Europe* (Inf Circ No 6483, US Dept of Commerce, Bureau of Mines, August, 1931)
- Bowles, O.** *The Wire-Saw in Slate Quarrying* (Tech PublN No 469, US Dept of Commerce, Bureau of Mines, 1930)
- Defenbaugh, J. E.** *History of the Lumber Industry in America* (2 Vols, New York, 1906)
- Dickinson, Dr H. W.** *The Taylors of Southampton*, in Edgar Allen News, Vol 35, No 404, February 1956, pp 38–41
- Disston, H. and Sons, Inc** *The Saw in History* (8th edition, New York, 1925 (1915))
- Dunning, G. C.** *A Thirteenth Century Midden at Windcliff near Niton*, in Proceedings, Isle of Wight Natural History and Archaeological Society. Vol III, Pt II, 1939

- Edlin, H. L.** *Woodland Crafts* (London, 1948)
- Frere, E.** *Notice historique sue la vie et les travaux de Marc Isambard Brunel* (Rouen, 1850)
- Goodman, W. L.** *History of Woodworking Tools* (Part 3 'The Saw', Practical Education, December 1956 – April 1960)
- Greber, J. M.** *Geschichte des Hobels* (Zurich, 1956)
- Grove** *Dictionary of Music and Musicians*, Vol VII (London, 1954)
- Guthrie, D.** *History of Medicine* (London, revised edition, 1953)
- Holtzapffel, C.** *Turning and Mechanical Manipulation* (2 Vols, London, 1846)
- Kolchin, B. A.** *Work of the Medieval Russian Blacksmith* (Moscow, 1952)
- Mercer, Dr H. C.** *Ancient Carpenters' Tools* (Doylestown Historical Society, Doylestown, Pa, USA) 1929
- Neuburger, A.** *Technical Arts and Sciences of the Ancients* (Trans H. L. Brose, London, 1930)
- Sawmill Magazine** Drabble and Sanderson Limited, (Sheffield, 1925, 1926)
- Schubert, H. R.** *History of the British Iron and Steel Industry* from c. 450 BC to AD 1775 (London, 1957)
- Singer, C. (Editor)** *History of Technology* (4 Vols, London, 1954–58)
- Spear and Jackson Limited** Material from archives: Bills of Lading, Catalogue of 1900, *Mermaid* manual, etc.
- Spear News** House Magazine of Spear and Jackson Limited, Sheffield, No 3, September 1957
- Todd, Sir H. T.** *History of the Royal Society of Arts* (London, 1913)
- Weigel, W. M.** *Application of the Wire-Saw in Marble Quarrying* (American Inst of Mining and Metal Engineering, Tech Pubn No 262, New York, 1930)
- Wood, R. W.** *The Practical Saw Doctor* (London, 1926)
- Worssam, W. S.** *History of the Bandsaw* (Manchester, 1892)



# Index

## A

Abattoir bandsaw, 72  
Abraham, 11  
Albert, L.C.A., 44  
Aluminium plate cutting, 66  
Ammonites, killing of the, 14  
Anderson-Grice Company, 48, 69  
Ark, building of the, 31  
Ausonius, 19, 21  
Australian aboriginal saws, 12  
Automatic production, 57

## B

Backsaw, 32, 36, 53, 54  
Bale, M. Powis, 49, 51  
Band rack machine, 70  
Bandsaw, 49-52, 53, 70, 72  
    advantages of, 52  
    cloth-cutting, 51  
    compared to circular saw, 52  
    cut depths and widths, 52  
    economy of, 52  
    meat cutting, 72  
    metal cutting, 49, 51, 70  
    wood cutting, 70  
Barbour, James, 50  
Bentham, Sir Samuel, 42-44, 48, 61  
Bevel sawing, 70  
Bible, references to saw, 14-15  
Blades, hacksaw, 55, 57  
Blast-furnace, 23

Blocking, 60  
Boule, A.C., 40  
Bow saw, 38, 40  
Bramah, Joseph, 48  
British Iron Age saws, 20  
Bronze Age saws, 11, 53  
Brunel, Sir M.I., 41, 42-43  
Buck saw, 38  
Buhl saw, 40  
Burial mounds, 11

## C

Cabinet makers, Egyptian, 15  
Calf, C.C. Jonge, 42  
California gold rush, 41  
Carcass saw, 35  
Carpenters, 15th century, 27  
    French 17th century, 28  
    gravestone, 18th century, 33  
    Roman, 18  
    sign, 18th century, 39  
Celtic saws, 21  
'Cementation' process, 16  
Chain saw, 57, 73  
Chain saw links, 73  
Chairmaker's saw, 40, 41  
Chatham Docks, 43  
Chrome plating of teeth, 53  
Chromium, 53  
Circular saw, 27, 42-49, 52, 53, 58-69  
    Asiatic requirements, 59

brake lining shaping, 59  
 buffalo horn cutting, 59  
 compared to bandsaws, 52  
 cotton tearing, 59  
 cut depths and widths, 52  
 frozen fish cutting, 59  
 ivory cutting, 59  
 manufacture of, 59-61  
 metal cutting, 59, 61, 64, 65, 66, 67, 69  
 salt slab slitting, 59  
 stone cutting, 48, 59, 68, 69  
 Circular fusion saw, 72  
 Claudius, 19  
 Compass saw, 32, 53, 58  
 Compass saw, Swedish 19th century, 36  
 Continuous action saws, types of, 53  
 Contour sawing, 70  
 Cooke, Sir W. F., 49  
 Coping saw, 40, 53  
 Copper saw, 53  
 Crepin, Madame, 50  
 Crompton, Samuel, 36  
 Cross-cut saw, 18, 29-30, 55  
 Cummins, Benjamin, 44  
 Cut-off saw, 61

**D**  
 David, 14  
 Diamond impregnated teeth, 44  
 Diamond inserted teeth, 48, 59, 68, 69  
 Diderot, 38  
 Disston and Sons, Incorporated, 47, 51  
 Dorman, Long and Company, 67  
*Double Century* handsaw, 58, 65  
 Dovetail saw, 35, 53  
 Dürer, Albrecht, 32  
 Dust removal methods, 18

**E**  
 Eastman, R., 44  
 Egyptian bronze saws, 14, 17  
 copper saws, 13-14, 15, 17  
 iron saws, 14, 17  
 Etruscans, 19  
 Evans, Oliver, 48  
 Evolution of the saw, 53  
 Exall, William, 50  
 Execution by saw, 21  
 Exports of saws, 19th century, 30, 32

**F**  
 Farmer, Norton and Company, 65  
 Felling by chain saw, 73  
 Felloesaw, 40, 41  
 File sharpening machines, 56  
 'Filer', 51  
 Finnegan, 51  
 Fire-saw, 11  
 Fish teeth saw, 13  
 Flint saw, 11, 12, 53  
 Floorboard saw, Dutch 18th century, 37  
 Frame saw, 17, 18, 19, 21, 22, 41, 53  
 mechanical, 25  
 tubular, 56, 57  
 Fretsaw, 40, 53  
 Friction discs, 72, 73  
 Fusion bandsaw, 72

**G**  
 Gang- saw, 24, 27  
 Grafting saw, 19th century, 35  
 Greeks, 15  
 Greenwood, Thomas, 50  
 Grinder, jockey, 64  
 Grinding machine, saw, 48

**H**  
 Hacksaw, Dutch 18th century, 34  
 Hacksaw, metal-cutting, 55, 57  
 Hampshire Repository, 42  
 Handles, saw, 32, 33, 58  
 Handsaws, 19th century, 35  
 20th century, 53-56  
 Chinese, 32  
 Dutch 18th century, 34  
 Japanese, 32  
 manufacture of, 56-57  
 pull, 32  
 Swedish 18th century, 34  
 Turkish, 32  
 Hearse graves, 13  
 Hebrews, Epistle to the, 15  
 Hedge, Lemuel, 51  
 Hesiod, 16  
 Holder, 64  
 Hollow-ground saw, 59  
 Hooke, Robert, 42  
 Hot saw, 59, 67  
 Hunter, George, 47, 49

**I**

Inn sign, 17th century, 32  
 Inserted tooth saws, 44, 47-49, 53, 59, 64  
 Internal tooth tube saw, 65, 69  
 Iron Age, 16, 17, 18, 19, 20, 21, 53  
 Iron casting, British, 23  
 Iron casting, Chinese, 23  
 Iron casting, Roman, 23  
 Iron production, 16-17  
 Iron saw, 53  
 Isaiah, Book of, 15  
 Isle of Wight Archaeological Society, 22

**J**

Jackson, Joseph Burdekin, 47  
 Jackson, Samuel, 47  
 Jacquin, 48  
 Jaquith, J., 44

**K**

Kerf, saw, 18  
 Keyhole saw, 30, 32, 58  
 Kings, First Book of, 15

**L**

Lapping, diamond wheel, 67  
 Log saw, tubular frame, 56, 57  
 Love and Manson, 17  
 Love, John, 55

**M**

McDowell, 51  
 Machine saw, 21  
 Magdalenian culture, 11  
 Manufacture of modern handsaws, 57-58  
 Meat cutting bandsaw, 72  
 Mercer, H. C., 73  
 Mesolithic flint saws, 12  
 Mesopotamia, 11, 13, 53  
 Metal cutting, 48, 49, 51, 55, 57, 59, 61, 64-65,  
 66, 67, 69, 70, 72  
 cold, 48, 65  
 hacksaw, 55, 57  
 hot, 59, 67  
 Middle Ages, 20-22, 23  
 Miller, Samuel, 42, 48  
 Mill webs, 55  
 Minoan bronze saw, 16

Multiple trimmer, 63  
 Musical saw, 53

**N**

Naval Board, 44  
 Neolithic tools, 11, 53  
 Nests of saws, 54  
 Neuburger, A., 19  
 Newberry, William, 49  
 New Testament, 15  
 Nickel, 53  
 Nickel-chrome strip, 53  
 Northern Aluminium Company, 66, 67

**O**

Obsidian saws, 11, 13  
 Old Testament, 14-15  
 Open handsaws, 21, 22, 30, 53

**P**

Palæolithic saws, 11  
 Perin, 50, 51  
 Pit-sawing, 21-22, 55  
 Pit-saws, 20, 21, 23, 24, 27-29, 53  
 framed two-man, 27-28  
 open, 28-29  
 Pit-sawyers, medieval, 20  
 see also Saw pit  
 see also Sawyers  
 Plate saw, 58  
 Powis, James and Company, 49  
 Pre-historic saws, 11-13  
 Pre-metal saws, 11-13  
 Price list, 19th century, 44, 45  
 Pruning saw, 55  
 Grecian, 54  
 Pull saw, 32  
 Push saw, 22

**Q**

Quenching, 16, 17, 60, 61

**R**

Radial taper grinding, 58  
 Rakerset teeth, 70  
 Raking of teeth, 17, 53  
 Reciprocating saws, types of, 53  
 Re-sharpening teeth, 64  
 Rip saw, 18

- Robinson band re-saw, 71  
 Robinson vertical bandmill, 52  
 Roman era, 15-21, 53  
 Roman handsaws, 18  
 Roman iron frame-saw, 17, 18  
 Roman machine-saws, 19, 21, 53  
 Royal Naval shipyards, 42  
 Russian handsaw, 22
- S**
- Sabot maker's saw, 41  
 Saint Paul, 15  
 Samuel, Second Book of, 14  
 Sash saw, 19th century, 35  
 'Saw-doctor', 51, 59  
 Saw-making, 19th century, 46  
 Sawing-thong, 11  
 Sawmills:  
   Brunel's plan for, 44  
   history of America, 23, 24  
   history of British, 23-24  
   history of European, 23  
   medieval, 21, 22, 23  
   modern, 27, 51, 52, 63  
   spread of, 53  
   technique, development of, 24, 27  
 Saw pit, 18th century, 29  
 Saw pit, 19th century, 27  
 Sawyers, Ghana pit, 55  
 Sawyers, medieval pit, 20  
 Sawyers, Mesopotamian, 13  
 Saxon saw, 20  
 Segmental cold saw, 59, 61, 64  
 Segments, fitting of, 65  
 Service life of circular saw, 61  
 Set of teeth, 18, 53  
 Setting handsaw teeth, 59  
 'Shark's tooth' form, 62  
 Shop sign, 18th century, 36  
 Shoulder saw, Swedish 18th century, 37  
 Siberian bronze saw, 16  
 Slack's knife grinding machine, 48  
 Smart, George, 44  
 Smithing, 60, 62, 68  
 Society of saw makers, 26  
 Solomon, 14  
 South Western Stone Company, 68, 69  
 Spaulding, 47  
 Spear and Jackson (BC) Limited, 61, 63  
 Spear and Jackson Limited, :  
   Aetna Works, 58  
   automated processes, 58  
   bicentenary 1960, 65  
   California gold rush, 41  
   catalogue 1900, 51  
   H. Disston and Sons, Incorporated, 47  
   *Double Century* handsaw, 58, 65  
   exports to continent 19th century, 30  
   exports to North America 19th century, 32  
   Gold Medal 1851, 47  
   handsaw manufacturing, 58, 64-65  
   John Love, founder, 1776, 55  
   largest saws, 48, 67, 68, 69  
   log saw blade production, 58  
   *Mermaid* circular saw, 58  
   parent firm of, 17  
   price catalogue 1845, 44, 45  
   price reductions, 51  
   steel production, 58  
   *Spearior* quality saws, 58  
   tensioning largest saw, 68  
   world's largest saw, 48, 67, 68, 69  
 Steam engine, 23  
 Steels, alloy, 53  
 Steel blanks, manufacture of, 57  
 Steel, carbon crucible, 53  
 Steel Company of Scotland, 69  
 Steel, high speed, 53, 55  
 Steel, low tungsten, 55  
 Steel sheet, rolling, 57  
 Stellite tipped teeth, 61  
 Stenner band rack, 70  
 Stone cutting:  
   Biblical times, 13-15, 19, 48  
   Roman, 15, 19, 21  
 Stonecutting saws, Egyptian, 13-14  
 Stonecutting saws, modern, 48-49, 50, 59, 68, 69  
 Sumeria, 11  
 Surgical saw, 53  
 Swage saw, 59
- T**
- Taper-grinding, 58  
 Taylor, Walter, 42  
 Teeth, chrome plated, 53, 57  
 Teeth fitting, 64  
 Teeth, inserted, 64  
 Tempering, 16-17, 60

Tenon saw, 30, 32, 38  
 Tenon saw, 19th century, 35, 54  
 Tenon saw, Swedish 19th century, 37  
 Tensioning, 44, 51-52, 60, 62, 68  
 Thouard, 50  
 Thwart saw, 18, 29-30  
 Tooth setting, 57-58  
 Tooth: see also Teeth  
 Tothing, 57  
 Touronde, 50  
 Tube saw, internal tooth, 65, 69  
 Tulloch, General, 49, 50  
 Tulloch, James, 49  
 Tumuli, 11  
 Tungsten carbide, 53  
 Tungsten carbide-tipped saws, 59, 66, 67  
 Two-handled saws, 21, 22  
 Tyne Navigation Commission, 49

## U

Unraked teeth, 13, 17-18  
 Ur of the Chaldees, 11

## V

Vanadium, 53  
 Veneer saw, powered circular, 41  
 Veneer saw, two-man, 41  
 Villard de Honnecourt, 22

## W

Wadkin and Company, 66, 67  
 Wadkin-Bursgreen machine, 72  
 Wavy set teeth, 70  
 Wheel, emergence of, 13, 53  
 Wheelwright's saw, 40, 41  
 Wilde, G. W. 49  
 Wilson, Henry, 50  
 Windcliff push saw, 22  
 Wire-saw, 49  
 Wood conversion:  
   Egyptian, 13, 14, 15, 18  
   medieval, 20, 21-22, 23  
   modern, 23-47, 49-52, 53-55, 56, 63, 70, 73  
   Roman, 15, 18, 19, 17, 21-22, 38  
 Woolwich Arsenal, 43, 44, 49, 51  
 World's largest saw, 48, 67, 68, 69  
 Worssam, W. S., 49, 51