Chapter 2

Bells and Bell Founding

High-quality bells are normally made by casting bell metal in a mould appropriate for the intended pitch of the bell. Further fine tuning is performed on a lathe where metal is cut from the inside of the bell in order to produce a true tone with correct harmonics.

Bell founding in Britain, as with other scientific crafts, had its origins with monastic orders. It eventually became a regular trade run by independent craftsmen who set up small permanent foundries in towns. These businesses were not solely restricted to casting bells but frequently engaged in related trades such as metal ware, utensil and arms manufacturing. Some of the early founders were itinerant travelling from church to church to cast bells on site, but businesses later centred around selected towns and cities with London, Gloucester, Salisbury, Bury St Edmunds, Norwich, and Colchester acquiring eminent foundries.

These early bells had tonal discrepancies, a result of differing weight and alloy composition as well as thickness and profile, with the height usually being disproportionate to the diameter. But the 19th century onwards brought advances in all aspects of bell founding where a better understanding of principles of bell design contributed to the introduction of a superior shape. The angles at the crown and sound bow were gradually flattened out and the waist became shorter, flaring toward the mouth of the bell.

Bell metal

Bell metal is an alloy of around 80% copper and 20% tin. Tin and copper are relatively soft metals that will deform on striking. By alloying, a harder and more rigid metal is created but also one with more elasticity than the use of one metal alone. This allows for a better resonance and causes the bell to "vibrate like a spring when struck", a necessary quality as the clapper may strike at speeds of up to 600 miles per hour. The forces holding the tin and copper together cause vibrations rather than cracks when the bell is struck which creates a resonant tone. This metal combination also results in a tough, long-wearing material that is resistant to oxidation and subject only to an initial surface weathering. Verdigris forms a protective patina on the surface of the bell which protects it against further oxidation. The hardest and strongest bronze contains large amounts of tin but too much tin content will make the bell more brittle and susceptible to cracking. This proved to be the nemesis of Russia's third attempt at casting the Tsar Bell from 1733 to 1735. The bell was never rung, and a huge slab cracked off (11.5 tons) during a fire in the Kremlin in 1737 before it could ever be raised from its casting pit. Burning timber fell into the casting pit, and the decision was whether to let it burn and risk melting the bell or pour water on it and risk causing it to crack from cooling it too quickly. The latter risk was chosen and, as feared, because of the low melting point of the bronze and uneven cooling, the bell was damaged. This bell is discussed in more detail in Chapter 11.

Other materials occasionally used for bell casting are brass or iron. Steel was tried during the busy church-building period of mid-19th century England, for its economy over bronze, but was found not to be durable and manufacture ceased in the 1870s. Examples of small decorative glass hand bells are also often seen, but this substance being very brittle is unable to withstand the continued use of the clapper.

Some bell founders were also known to have suggested that the addition of some small amounts of silver would help enhance the tonal quality of the bells being cast in the churchyard. They would collect silver coins from the parish but these are unlikely to have ever been added to the final bell metal itself.

Casting a bell

The craft of casting bells has remained essentially the same since the 12th century. Bells are cast mouth down, in a two-part mould consisting of the core and the shell, or cope, with both parts being clamped to a base-plate.

Standard cores and copes are used to create a bell with the right profile. For a special order the bell founder would need to calculate the precise specifications to create a bell that will resonate with the proper number of vibrations and create the right pitch. The bell pattern is then cut out in two wooden templates called 'strickle boards'. One provides the dimensions of the outer bell (i.e. cope); the other matches that of the inner bell (i.e. core). The boards are used to create the inner and outer moulds of the final bell.

An exact model of the outer bell, sometimes called a false bell, is built on a base-plate lined with porous materials such as coke or brick. It is lined with sand or loam (sometimes mixed with straw and horse manure). This gives a profile corresponding to the outside shape of the finished bell, with any figures and inscriptions required then being added by hand. The false bell is painted over with fireproof clay. A model of the inner bell is also constructed of stone and coated with fireproof clay or cement, before being smoothed to remove any irregularities. The outer bell mould is then lowered over the inner mould and the outer and inner sections are clamped together, leaving a space between them.

The clamped mould is supported by being buried in a casting pit which bears the weight of metal and allows even cooling. The bell metal is heated in a furnace until liquid at a temperature of approximately 1,100 °C (2,010 °F). The liquid metal is then skimmed to remove impurities. When everything is ready, the molten metal is transferred to the moulds using either ladles or a system of brick channels specially constructed in the casting pit, through which the hot metal can then flow from the melting furnace into the space between the two moulds. Holes in the top of the mantle ensure that gases are able to escape. If gas remained in the metal, the bell would be porous and susceptible to cracking. Porousness can also develop if the mould is damp, is not at the proper temperature, or the metal when poured is not hot enough. The bell is allowed to cool for several days. Large bells can take over a week to cool. Small bells, those under 500 pounds (230 kg), can be removed from the moulding pit the following day.

After the bell and equipment have cooled, the mould, containing the newly cast bell, is raised from the pit by the projecting trunnions of the bell case. The core plate is unclamped and the core broken out. The bell is then carefully extracted from the case. At this stage, any remaining loam still attached to the bell is brushed away and flash (excess metal), which may have formed below the bell's rim owing to mould contraction in the presence of hot metal, is trimmed off. This completes the casting process.

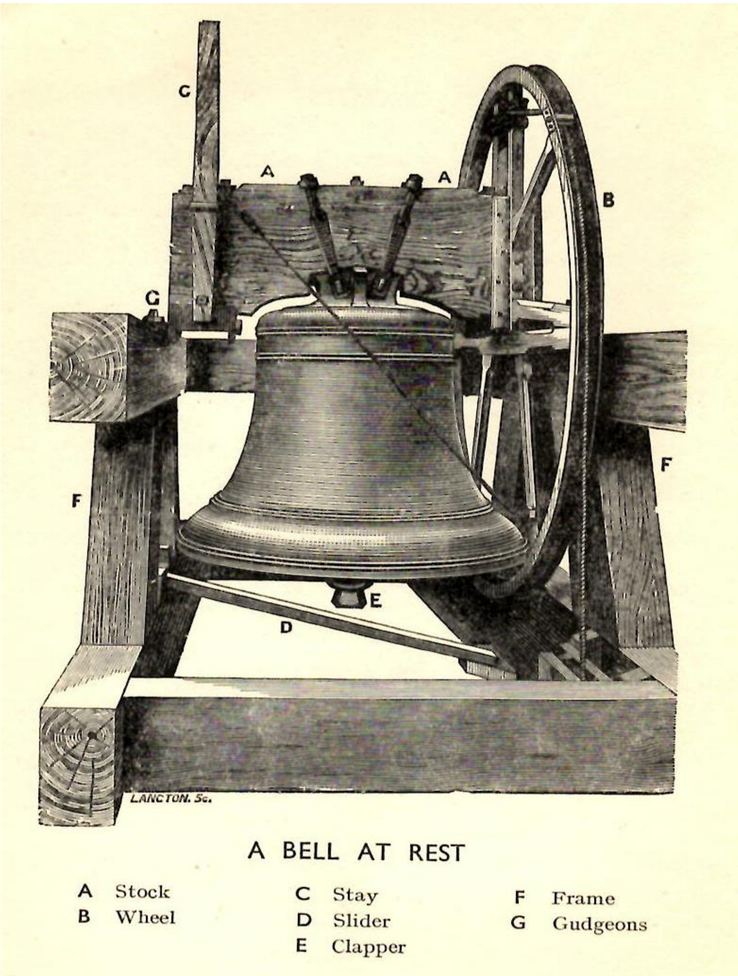
Bell Tuning

Bells are manufactured with exact formulas, so that using the diameter it is possible to calculate precisely every dimension of the bell, and in turn its note or tone. Much experimentation and testing have been devoted to determining the exact shape that will resonate to give the best tone. In general, the smaller the bell the higher the pitch, with the frequency of a bell's note varying with the square of its thickness and inversely with its diameter. The thickness of a church bell at its thickest part, the ‘sound bow’ is usually one thirteenth its diameter. If the bell is mounted as cast without any further tuning, then it is called a ‘maiden bell’.

In the early days of bell founding, bells were tuned using an imprecise method whereby the inside of the bell or edge of the lip was chipped away. With the improvement of machinery this is now done using a lathe. The bell is cast with slightly thicker sides before being inverted and gripped by vices to keep it perfectly firm. The bell is then ground as it rotates on a circular lathe to acquire the precise tone. The bell tuner must be highly skilled as it takes years of experience to know how much metal to remove. By this means, bells can be very accurately tuned. In casting, the tone of the bell is best left sharp because it is much easier to flatten the tone. A bell may readily be flattened one-eighth of a tone or even more, but it cannot be sharpened so much; indeed, any sharpening is to be deprecated and if at all possible should be avoided. The bell tone is tested frequently during the tuning process usually with tuning forks or an electronic stroboscopic tuning device commonly called a strobe tuner, which registers the vibrations as the bell is struck. If the tone is too low, the lathe operator grinds more metal off the lower edge. If the tone is too high, the bell is thinned with a file. The bell's strongest harmonics are tuned to be at octave intervals below the nominal note, but other notes also need to be brought into their proper relationship.

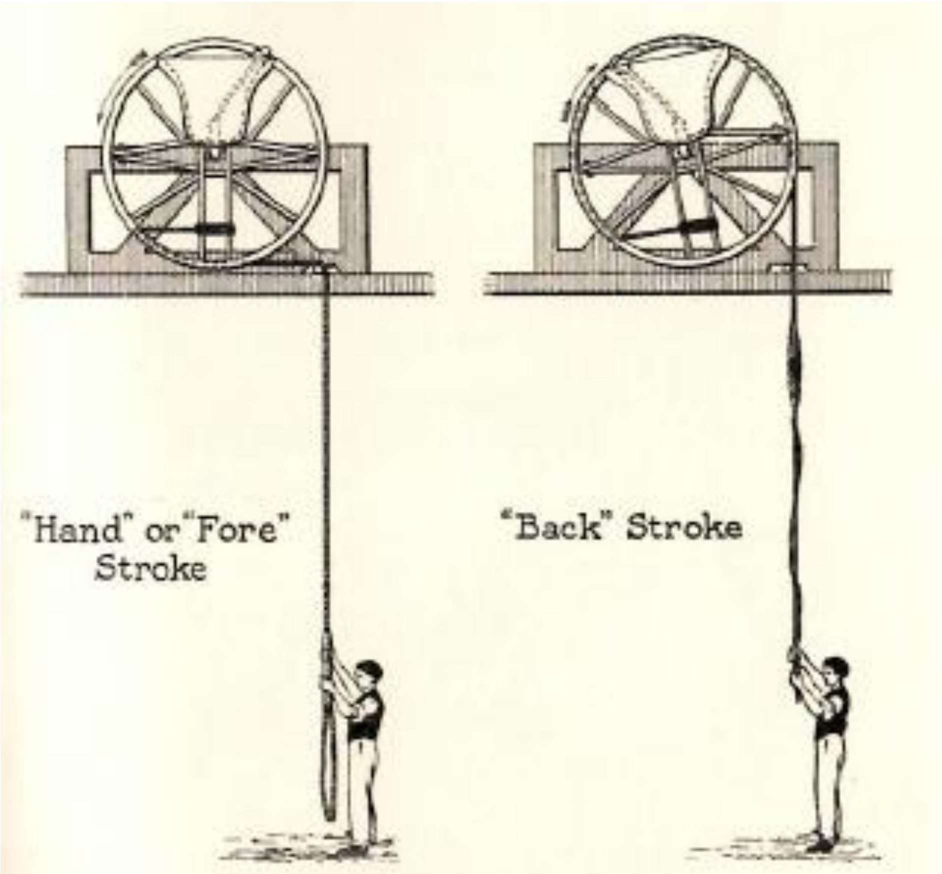
Bell fittings

The clapper strikes the bell as it is rotated through nearly 360° to produce the sound. It is manufactured in a similar process as the bell, typically using wrought iron or steel graphite metal, but in recent times clappers with wooden shafts have been used in some larger ringing bells to achieve a much better strike note. Special care is given to cast the clapper at the proper weight, as a clapper that is too light will not bring out the true tones of the bell and a heavy clapper might cause the bell to crack.



Ropesight - Jasper Snowdon Change Ringing Series: Various editions (14.0cm by 9.0cm)

The bell is fastened to the headstock usually through a series of holes in the top of the bell itself. Older bells can be found with a ‘crown staple’ through which metal straps were then past to fasten the bell to the headstock. It is not unusual to find older bells which have had their crown staple removed and replaced by holes drilled into the top of the bell. The wheel around which the bell rope runs allows the bell to be rotate through nearly a full circle providing the control necessary to bring the bell to a balance on each rotation. On one stroke (i.e. backstroke) the rope is wrapped around the wheel, while at the other stroke (i.e. handstroke) the rope is only partially on the wheel. This gives the ringer below two ringing positions (i.e. handstroke followed by backstroke) which they need to master, by providing just sufficient pull to bring the bell to the balance at each stroke taking account of the momentum of the bell and stretch within the rope. The handstroke has a woollen sally woven into it to provide an element of comfort to the hands of the bell ringer.



Bell position from *The History & Art of Change Ringing* by Ernest Morris, page 17, 1931 edition

At rest the bell takes its familiar profile, but to ring it through nearly a full full circle it is necessary to ring it up so the mouth of the bell points upwards. It remains balanced by the ringer in this position before being fully rotated to an upright position at the next stroke. To avoid having to ring the bell to a downward resting position at the end of each piece of ringing, a stay is fitted to the head stock. When the bell is in an upright position at the balance it can then be gently allowed to rest against the slider under the bell bring the upright bell to a stationary position without the need to hold the rope. This is known as the bell being set. The slider itself is fitted at one end with the other sliding to allow the bell to be set at either the handstroke or backstroke. The stay is normally made of ash wood, which will break if hit too heavy to prevent damage to the bell and other fittings. Such an accident when the bell is beyond the balancing position will cause the bell to continue on a second rotation taking the rope up with it – a reason why all ringers should let go of the rope if they are too heavy handed when learning the techique of ringing a bell.

The historic prints which follow show the various stages of bell founding described in this Chapter.

Bell founding

(i) Fontes des Cloches

Fontes des Cloches or bell casting was published in a variety of versions which involved the use of the same plates. Two sources are:

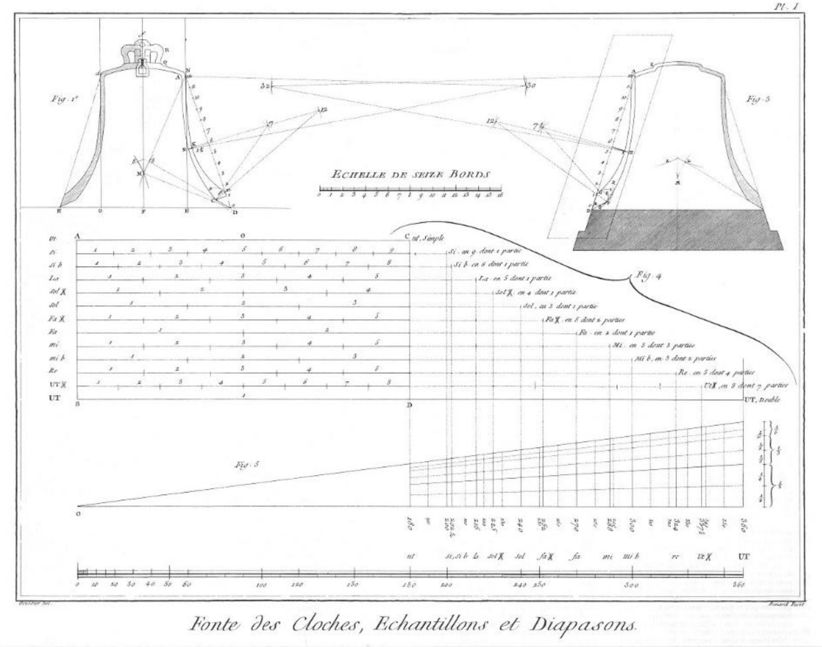
- *Fontes des Cloches*: Encyclopédie, ou dictionnaire raisonné des sciences, des arts et des mátiers (Encyclopedia or Reasoned Dictionary of Sciences, Arts and Crafts) by Denis Diderot and Jean Rond d'Alembert, Volume 5 (1767). Image size is typically 15.5cm by 23.5cm throughout.

- *Encyclopédie méthodique par ordre des matières (Methodical Encyclopedia by Order of Subject* Matter): published between 1782 and 1832 by Charles Joseph Panckoucke. It was a revised and much expanded version, in roughly 210 to 216 volumes, of Encyclopédie edited by Diderot. Copperplate engraving on verge type hand laid paper. Overall size of book is 23.5cm by 32.0cm with image sizes typically 15.5cm by 23.5cm throughout, except for Plate 1 which covers two pages.

The following pages gives examples of the plates taken from *Fontes des Cloches* (left) and the *Methodical Encyclopedia* (right). They can be distinguished from the different headers and footers used. Notably the plates in the former having roman numerals while the plates in the latter have algebraic numbers. The footer text to each plate can also be used to identify the original source of the print.

Variations on the foot notes appearing immediately underneath the print on *Fontes des Cloches* are also known. Some editions show both the artist's (e.g. del.) and engraver's (e.g. fecit names, or else simply page numbers and the initials FF. The artist is known to be Louis-Jacques Goussier (1722 to 1799) who was a French illustrator and encyclopedist – he was the first drawer to be hired on Diderot's encyclopedia in 1747 and he did himself more than 900 plates and directed the drawing of the others. Some call Goussier the *third encyclopedist*, after Diderot and d'Alembert. The engraving was undertaken by Robert Bénard (1734 to circ. 1786) who supplied plates for the Encyclopédie from 1751.

Plate 1: Patterns and Diapasons



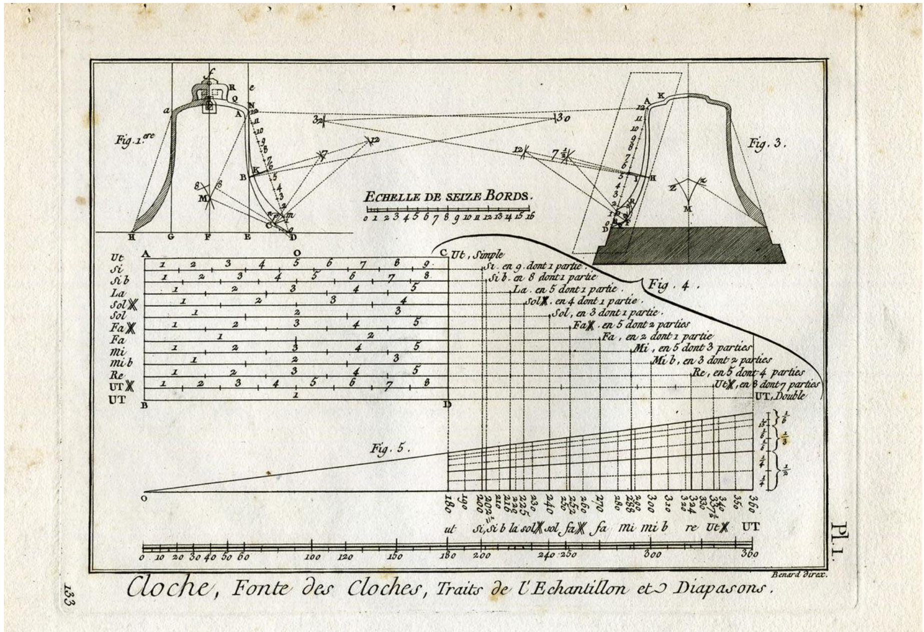
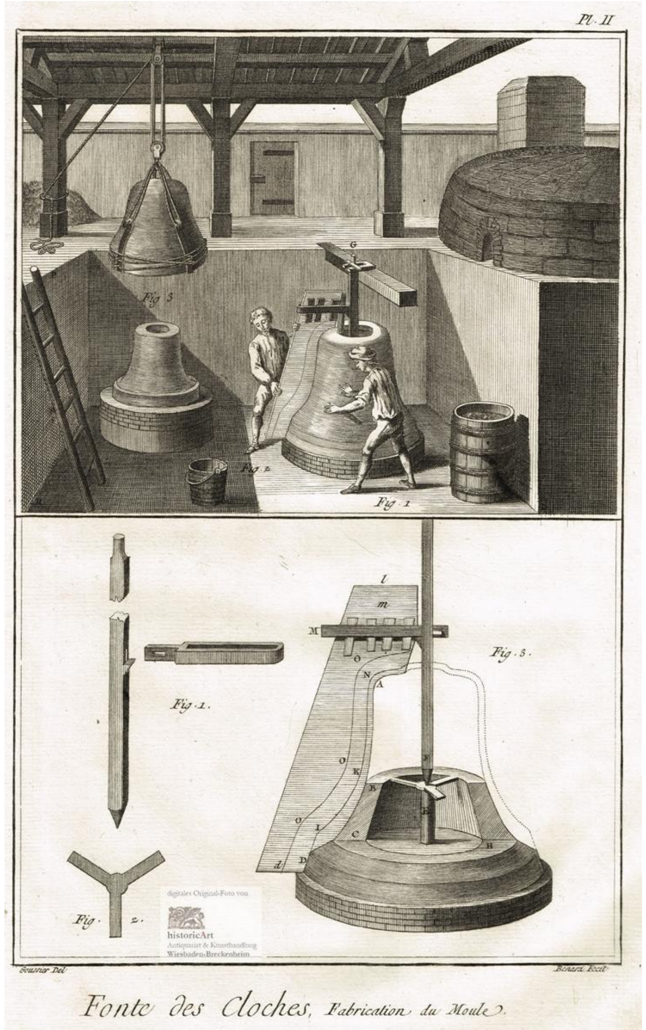


Plate II: Manufacture of Moulds



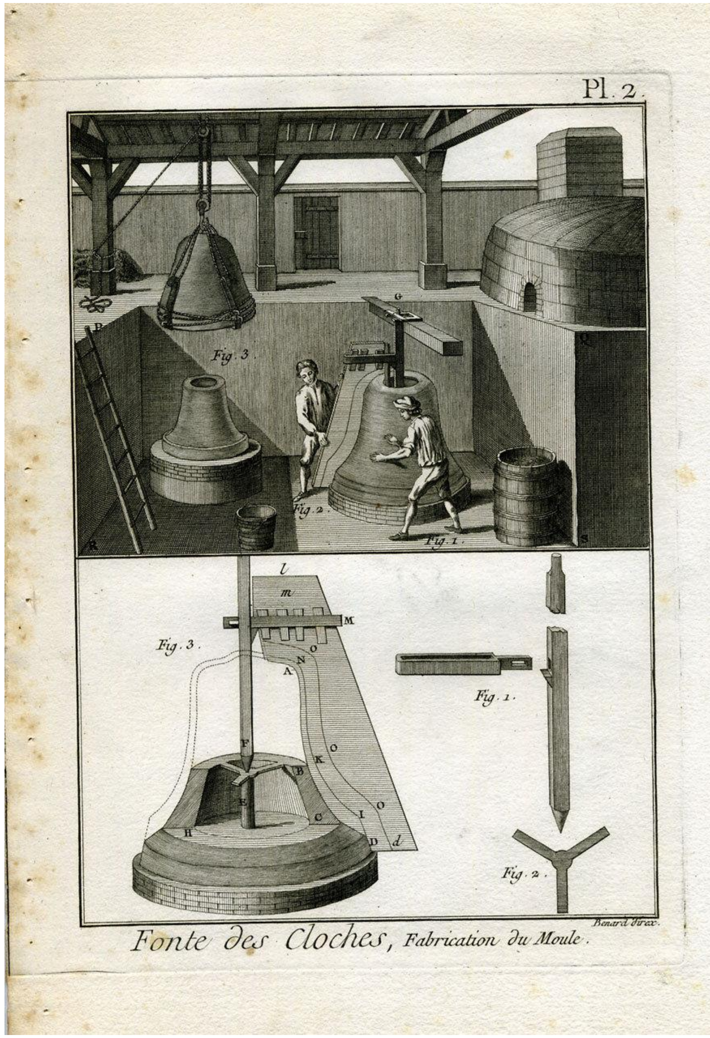


Plate III: Different Steps in the Manufacture of Moulds

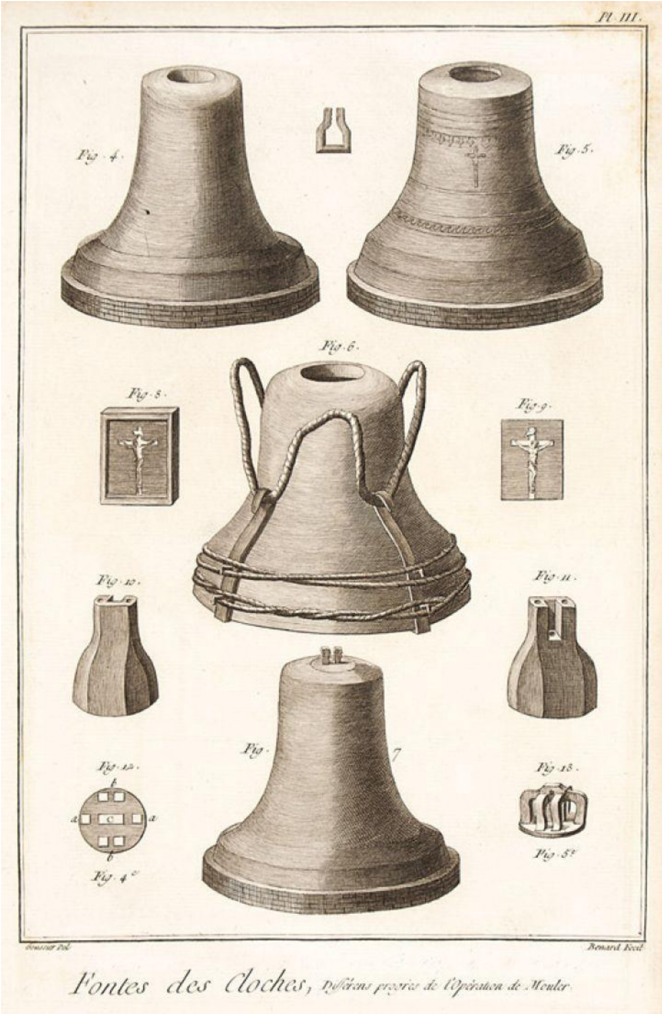
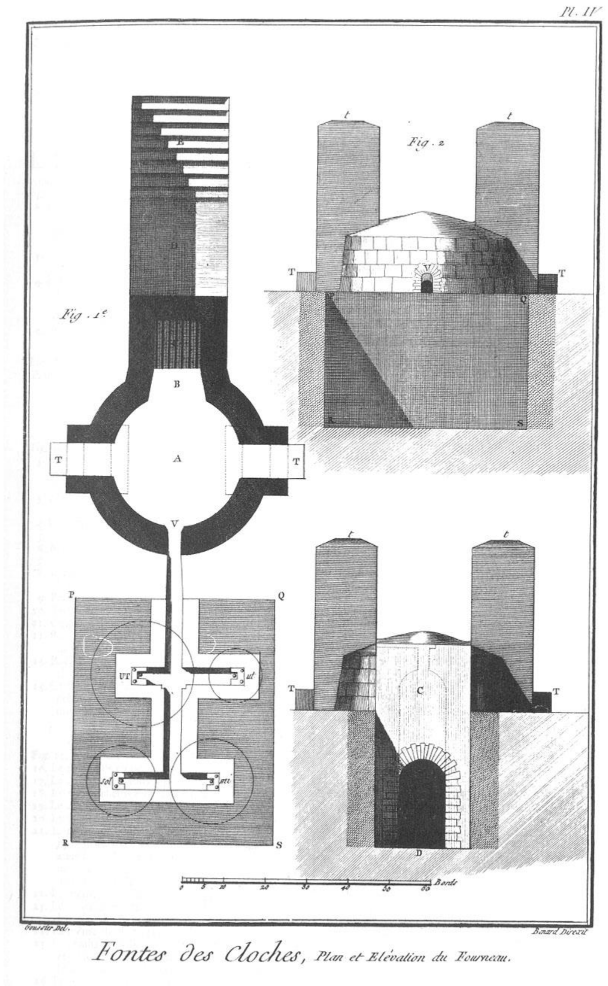


Plate IV: Plan and Elevation of the Furnace



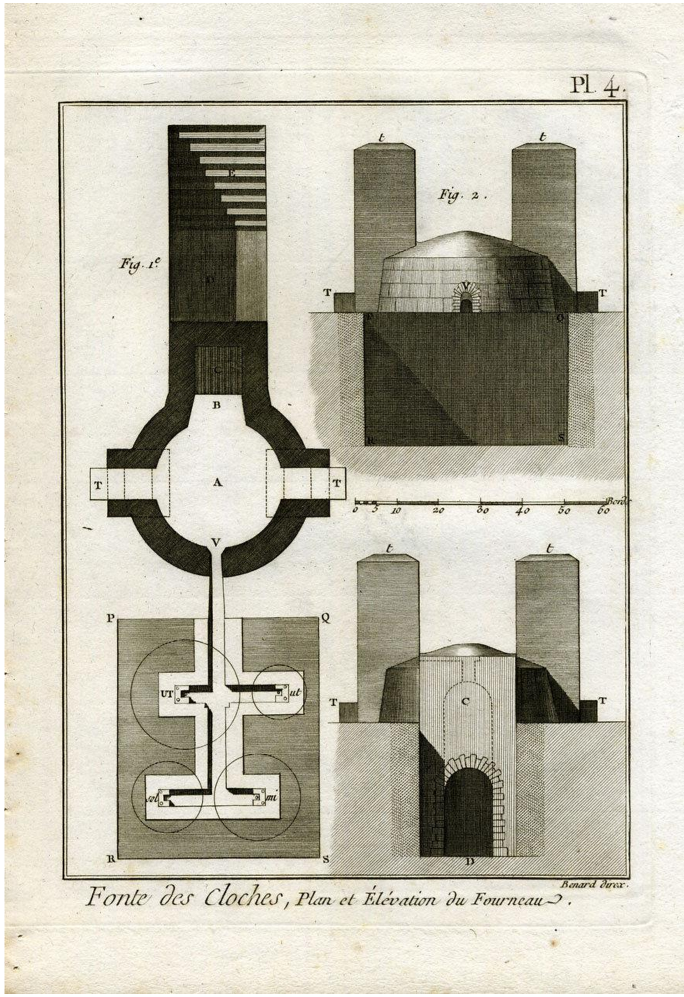
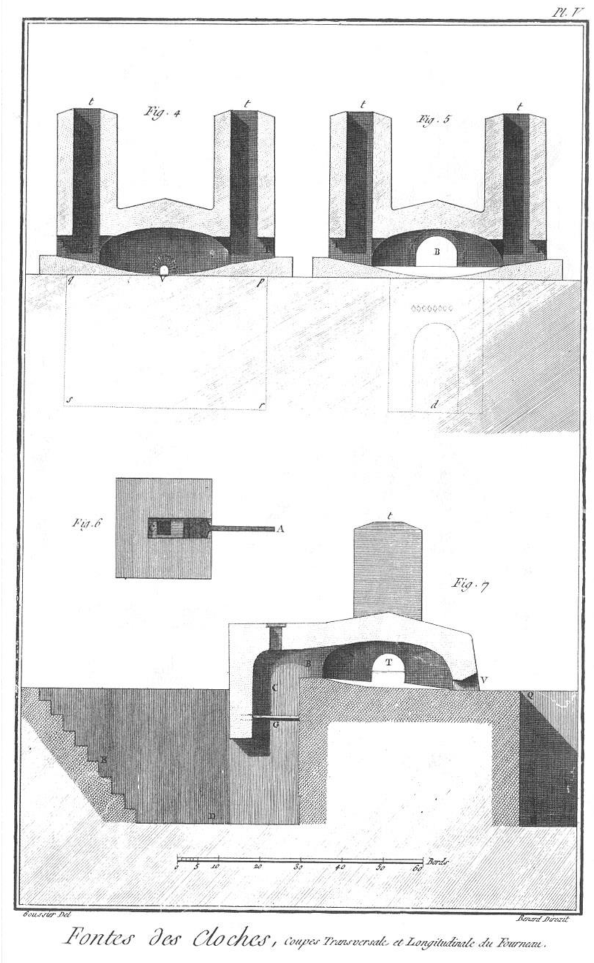


Plate V: Longitudinal and Transversal Views of the Furnace



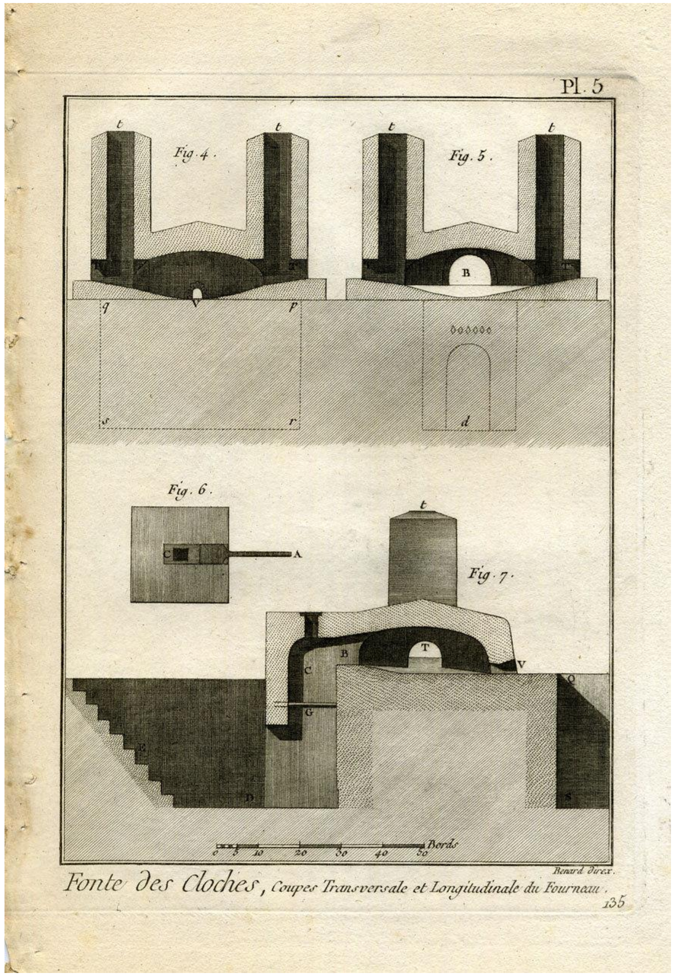
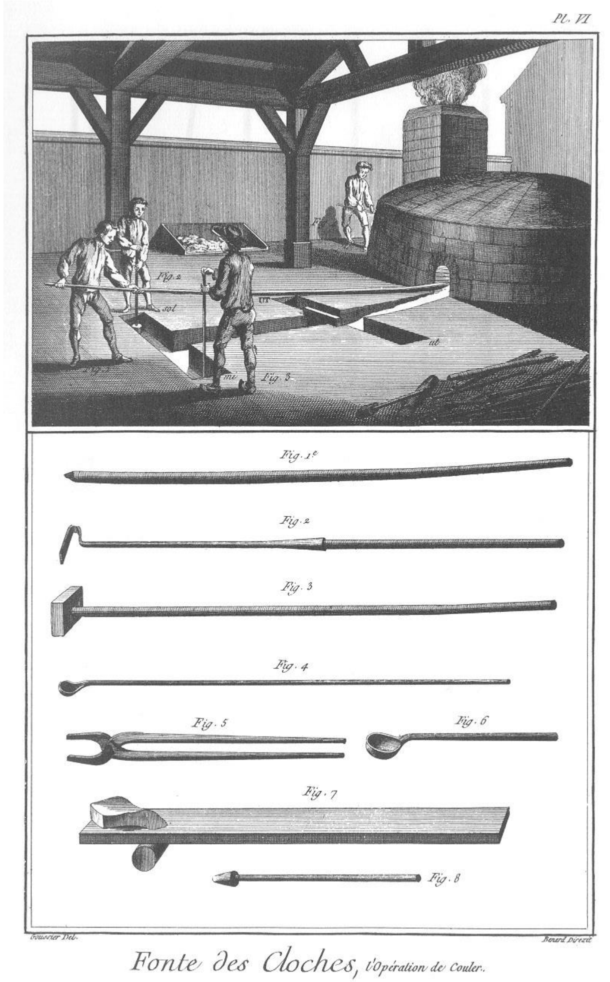


Plate VI: Operation of Casting



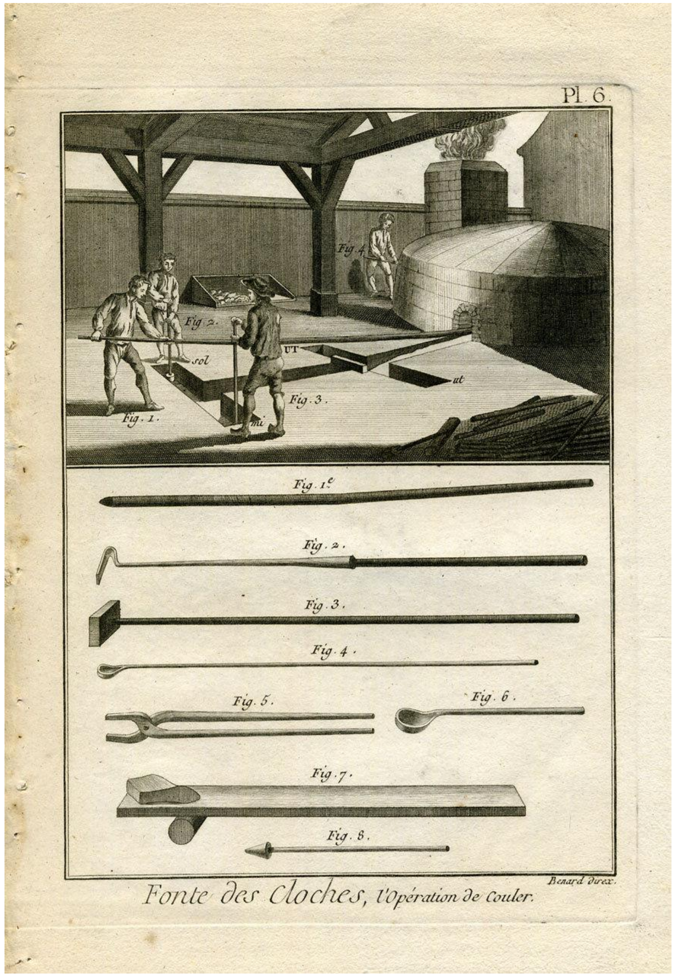
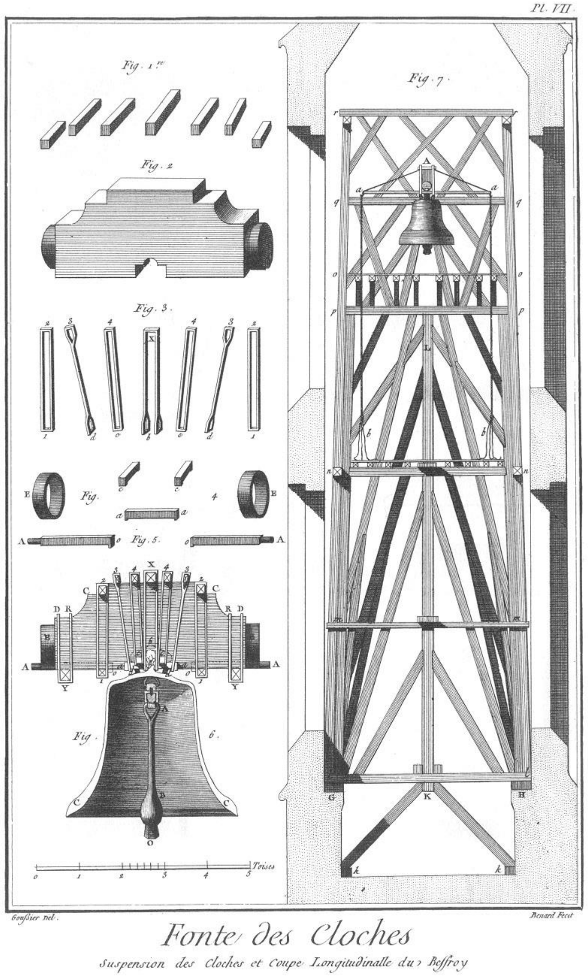


Plate VII: Bell Suspension and Longitudinal Cut of the Belfry



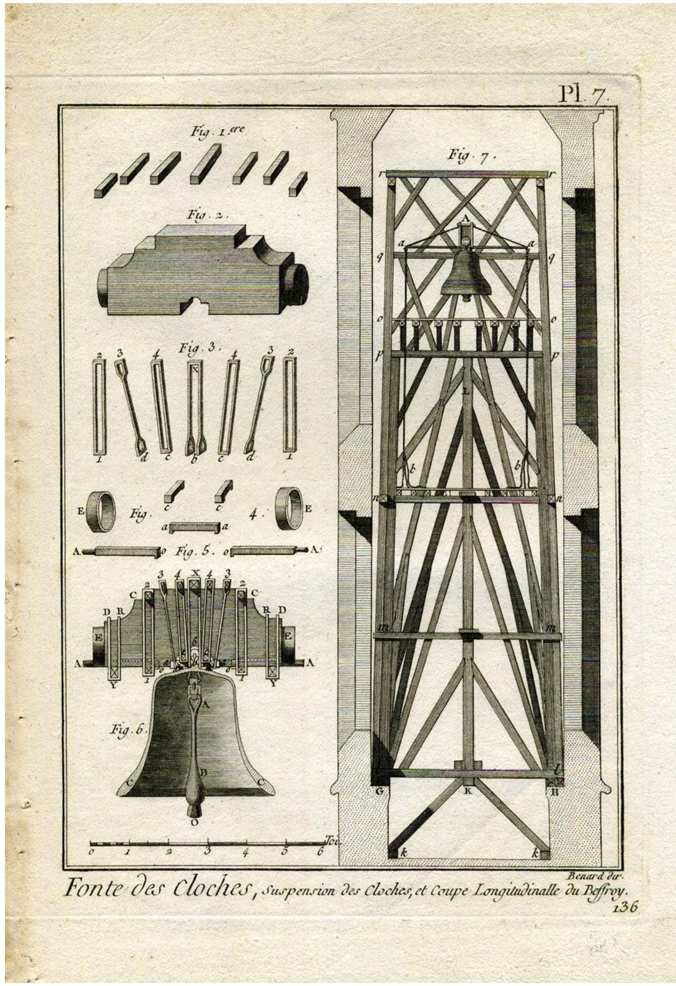
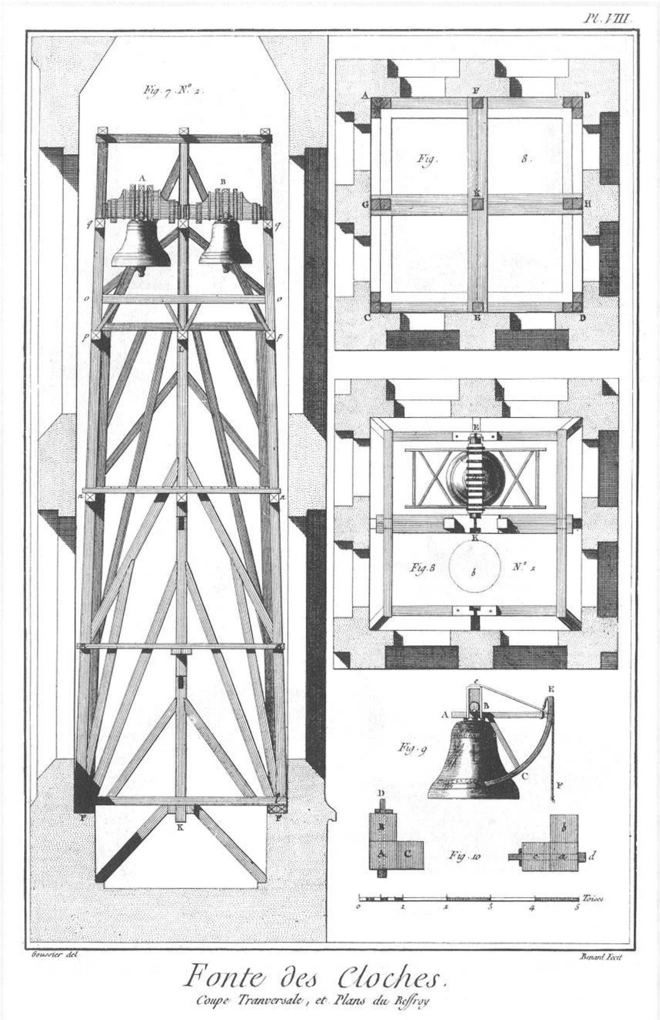
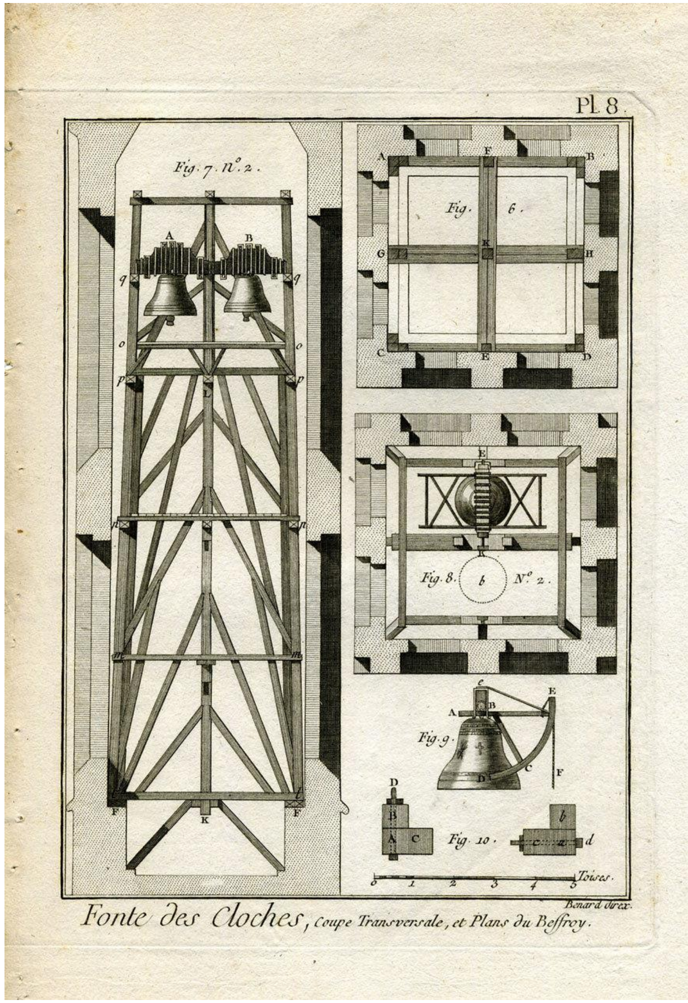


Plate VIII: Bell Casting, Transversal View, and Plans of the Belfry





(ii) Illustrated Magazine of Art

This two volume periodical of 1852 was an illustrated monthly British journal devoted to the visual arts.

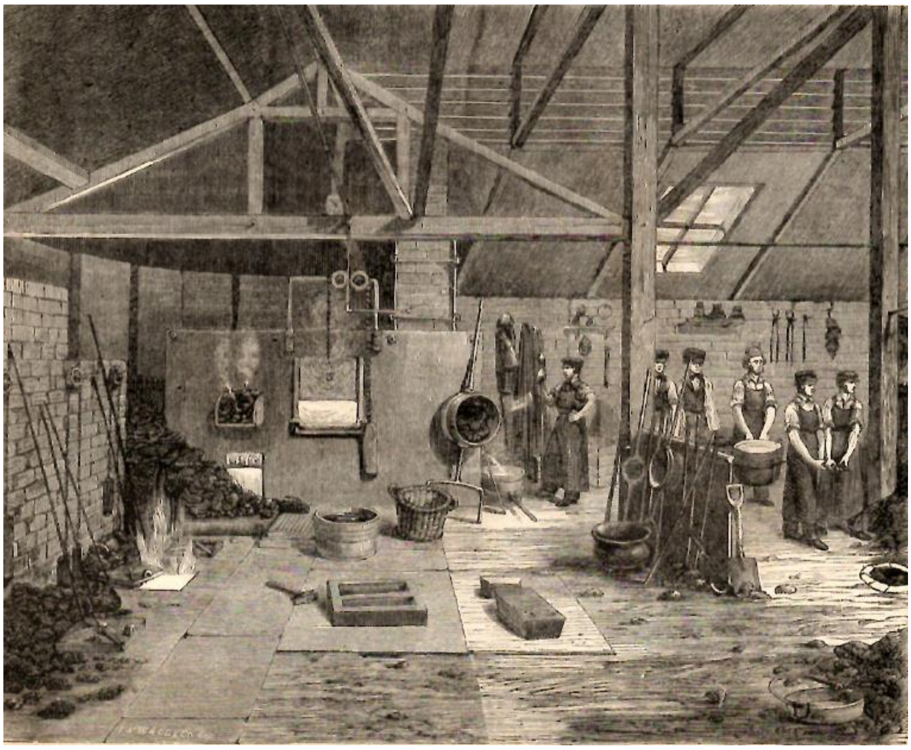


Figure 1: The Foundry: *Illustrated Magazine of Art* (Volume II 1854) page 264: as illustrated by I E Waldeck (15.2cm by 12.5cm)

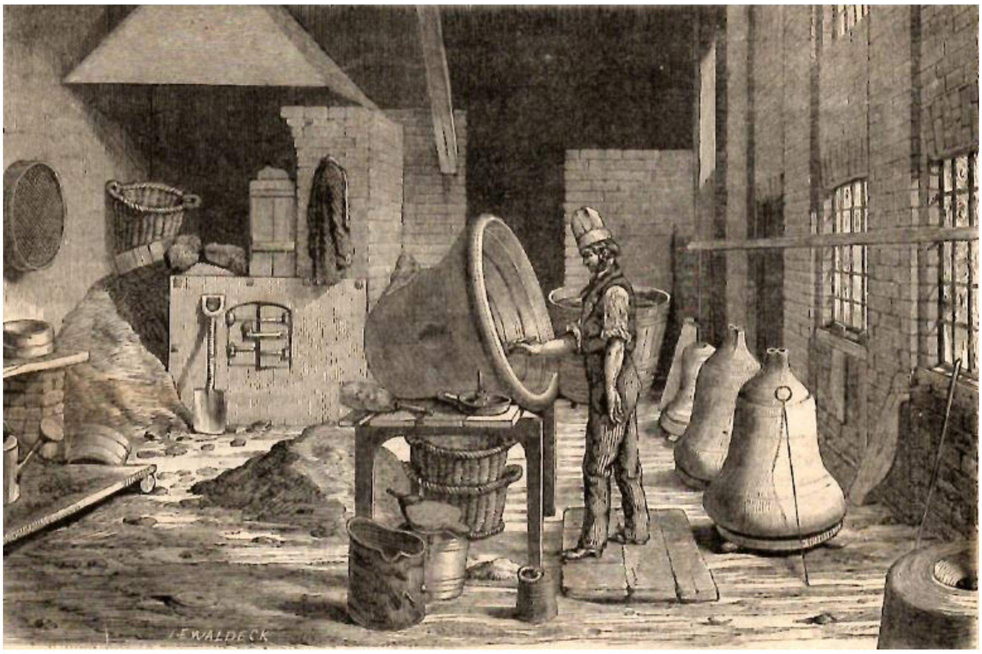


Figure 2: Finishing the Cope: *Illustrated Magazine of Art* (Volume II 1854) page 264: as illustrated by I E Waldeck (15.2cm by 10.0cm)

Figure 3: Finishing the Core - the Crook: *Illustrated Magazine of Art* (Volume II 1854) page 265: as illustrated by I E Waldeck (15.2cm by 10.0cm)

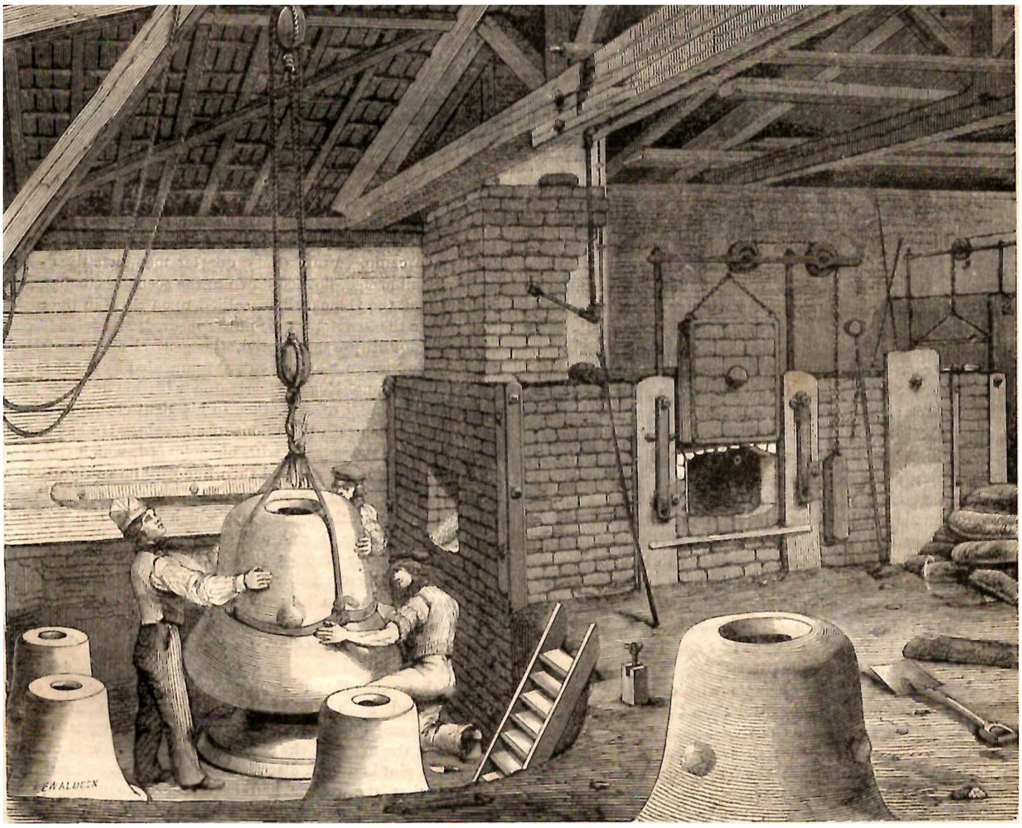


Figure 4: Putting on the Cope: *Illustrated Magazine of Art* (Volume II 1854) page 265: as illustrated by I E Waldeck (15.5cm by 12.6cm)

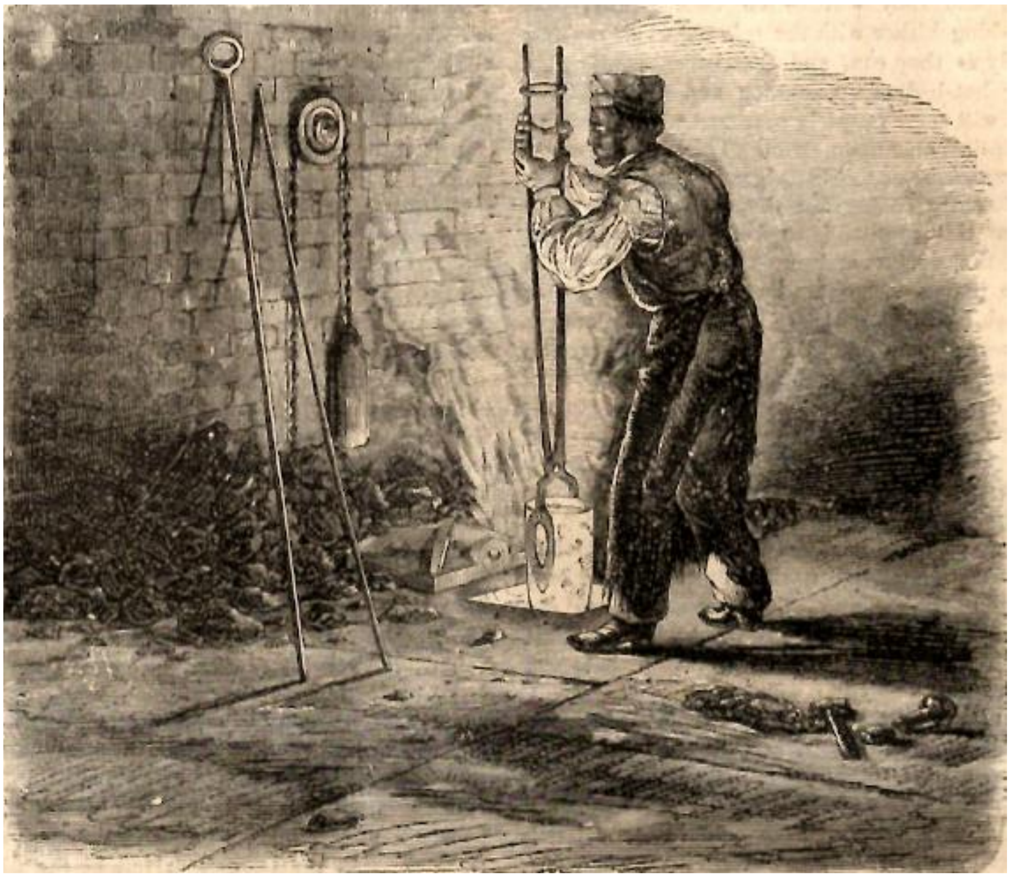


Figure 5: Drawing the Crucible*: Illustrated Magazine of Art* (Volume II 1854) page 292: as illustrated by I E Waldeck (11.3cm by 9.3cm)

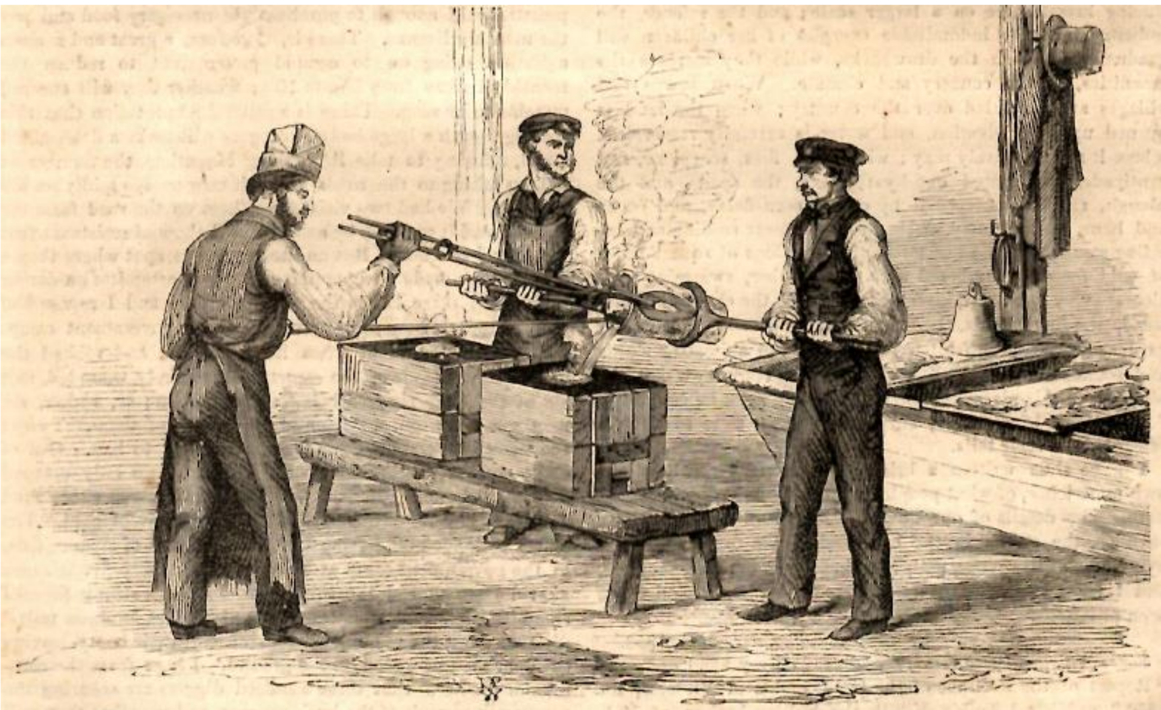


Figure 6: Casting Small Bell: *Illustrated Magazine of Art* (Volume II 1854) page 292: as illustrated by I E Waldeck (15.3cm by 9.2cm)

Figure 7: Pouring the Metal in the Mould: *Illustrated Magazine of Art* (Volume II 1854) page 293: as illustrated by I E Waldeck (15.0cm by 9.8cm)

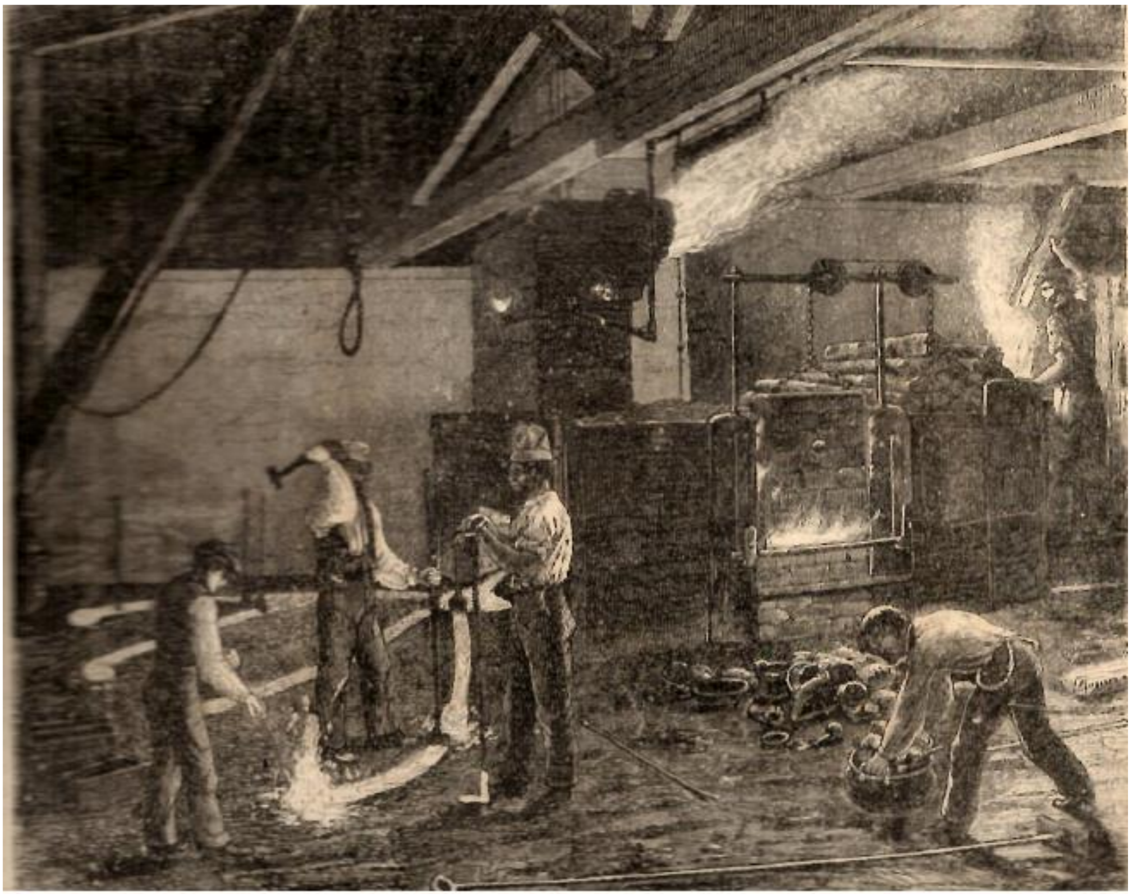
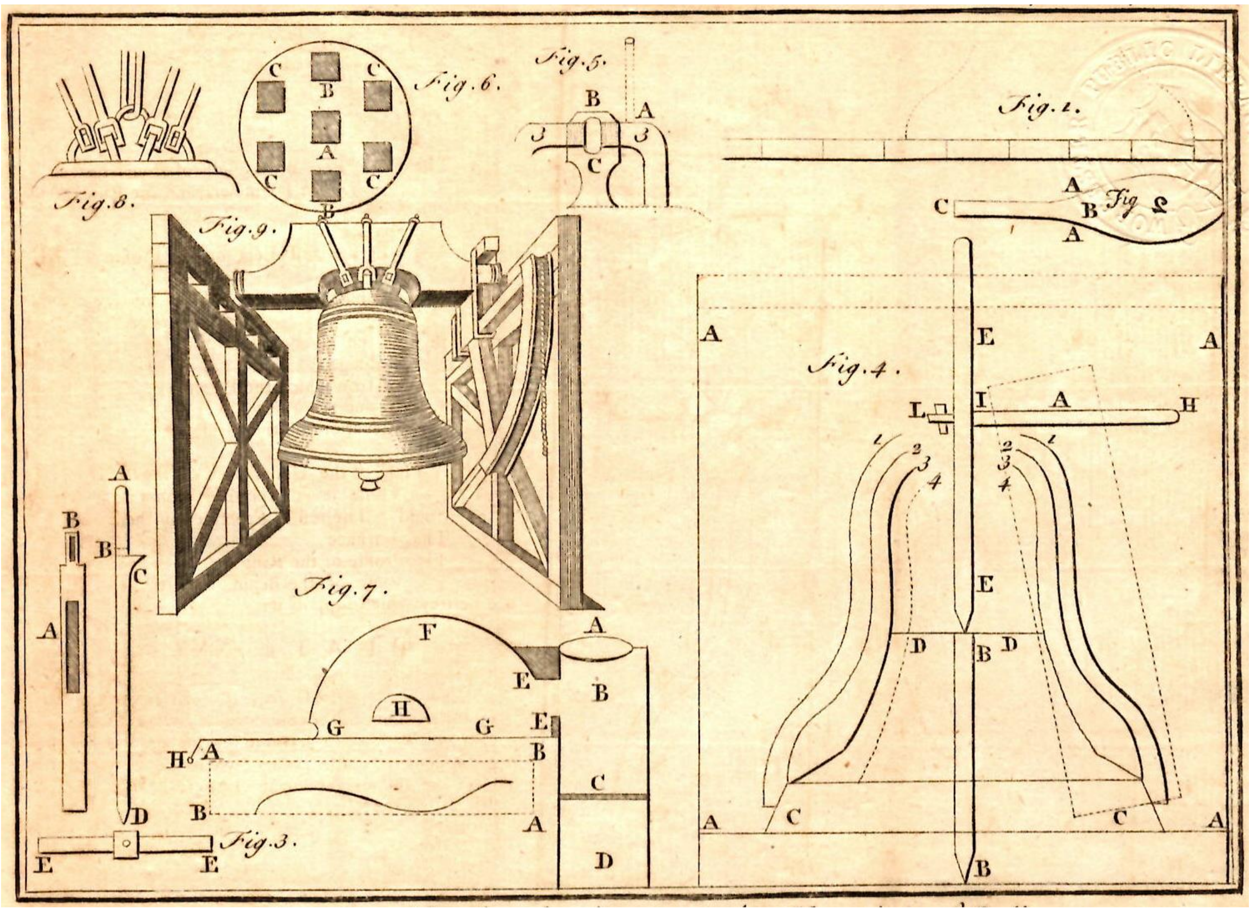


Figure 8: Casting Large Bells: *Illustrated Magazine of Art* (Volume II 1854) page 293: as illustrated by I E Waldeck (15.5cm by 12.6cm)

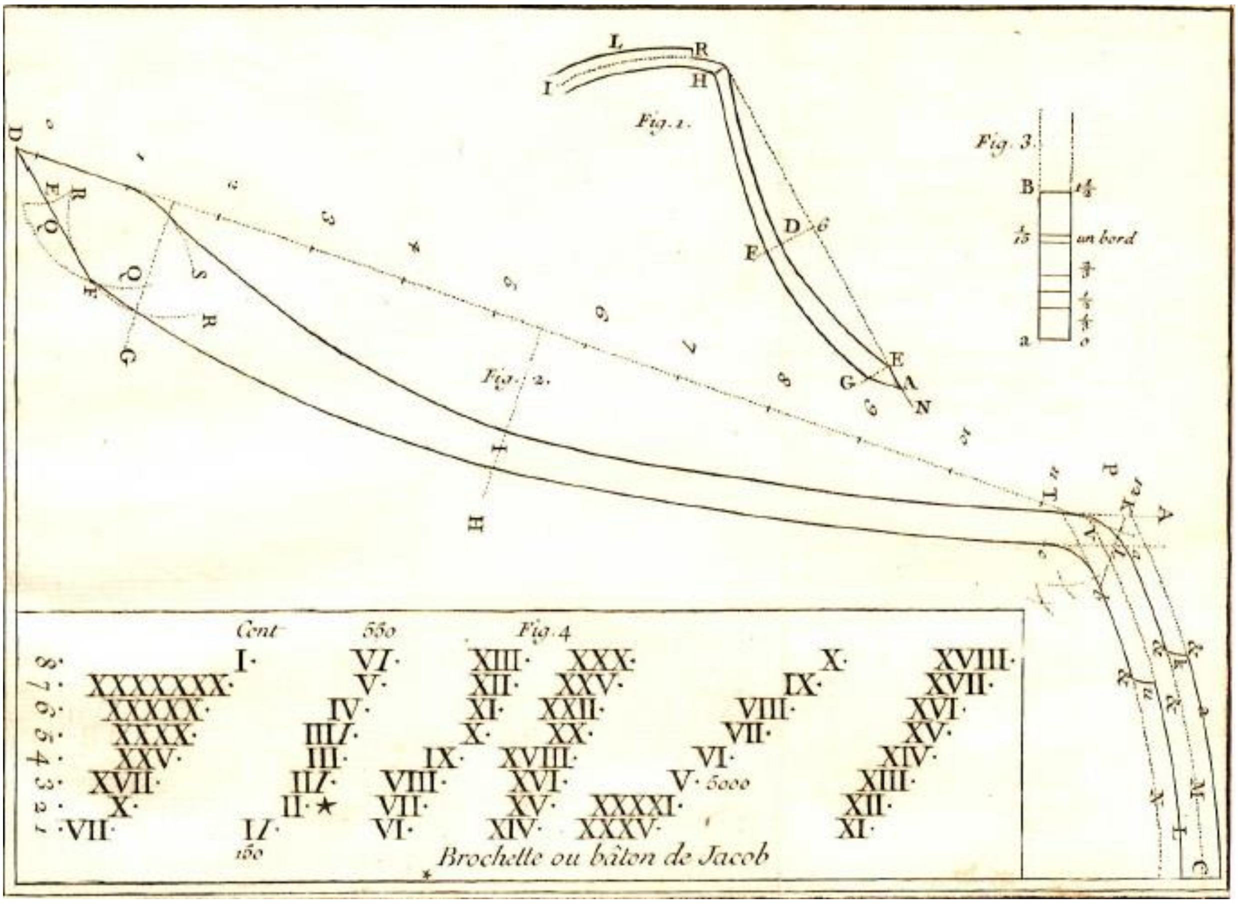
Figure 9: The Tuning Room and Tuning Machine: *Illustrated Magazine of Art* (Volume II 1854) page 296: as illustrated by I E Waldeck (15.0cm by 12.2cm)

(iii) Spectacle de la Nature

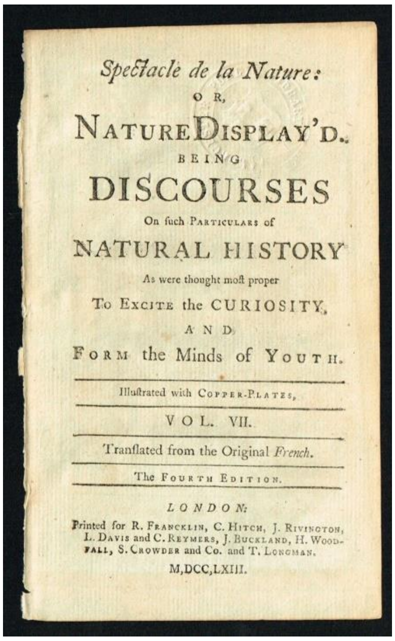
Spectacle de la Nature: or Nature Display'd being Discourses on such Particulars of Natural History as were thought most proper to Excite the Curiosity and Form the Minds of Youth: 1763.



Mould, the Casting and the Hanging of Bells: *(Spectacle de la Nature: or Nature Display'd being Discourses on such Particulars of Natural History as were thought most proper to Excite the Curiosity and Form the Minds of Youth* 1763, Vol VII, Plate XXIX, page 204 - English version / page 349 - French version) (18.5cm by 13.5cm)



Proportions of a Bell


Spectacle de la Nature:

OR,

NATURE DISPLAY'D.

BEING

DISCOURSES

On such PARTICULARS of

NATURAL HISTORY

As were thought most proper

To EXCITE the CURIOSITY,

AND

FORM the Minds of YOUTH.

Illustrated with COPPER-PLATES,

VOL. VII.

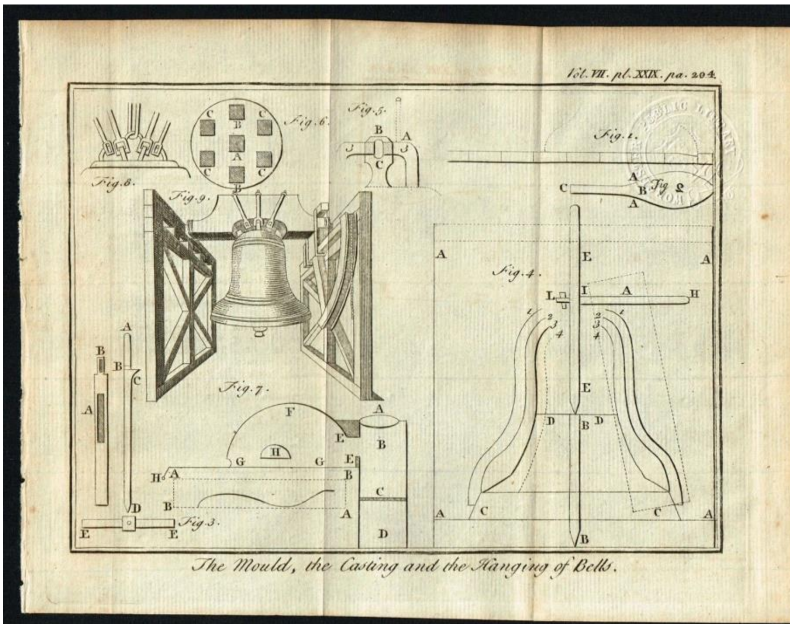
Translated from the Original *French*.

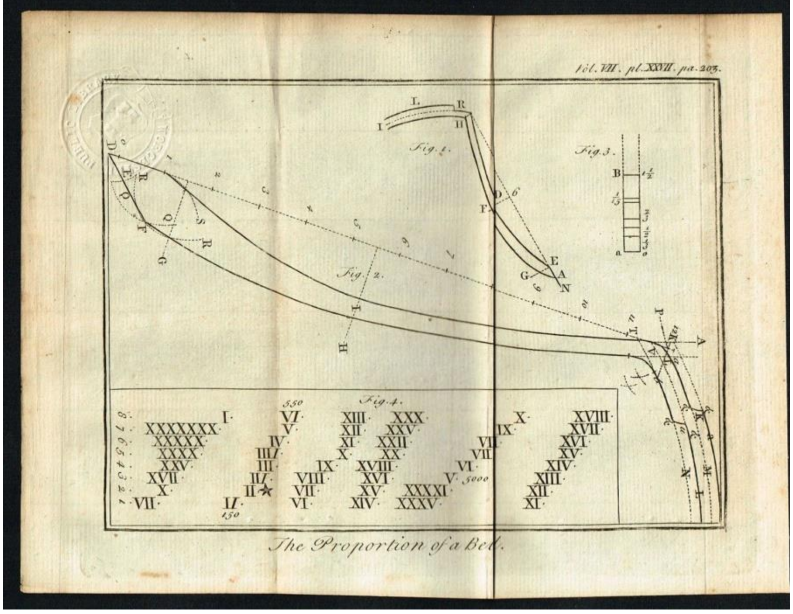
The FOURTH EDITION.

LONDON:

Printed for R. FRANCKLIN, C. HITCH, J. RIVINGTON, L. DAVIS and C. REYMERS, J. BUCKLAND, H. WOODFALL, S. CROWDER and Co. and T. LONGMAN.

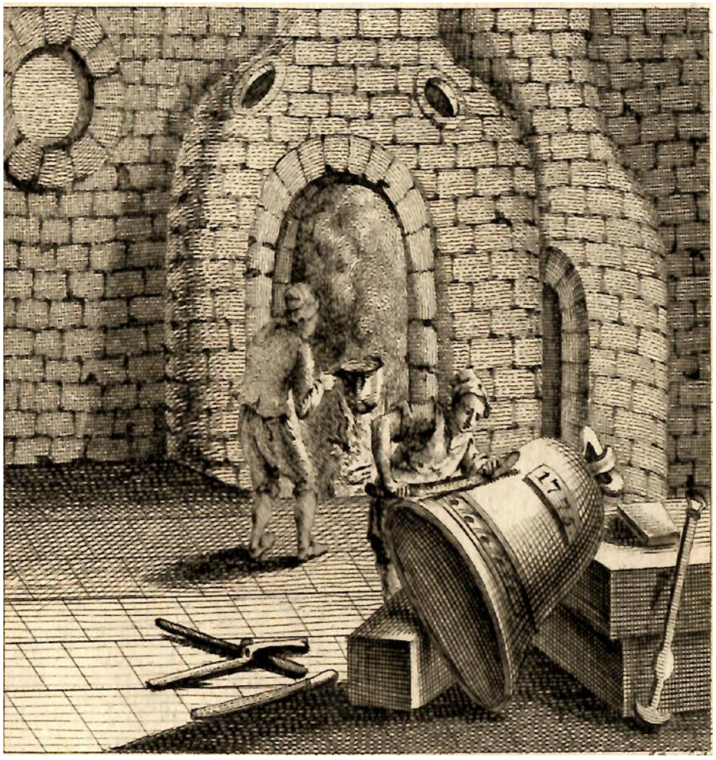
M,DCC,LXIII.



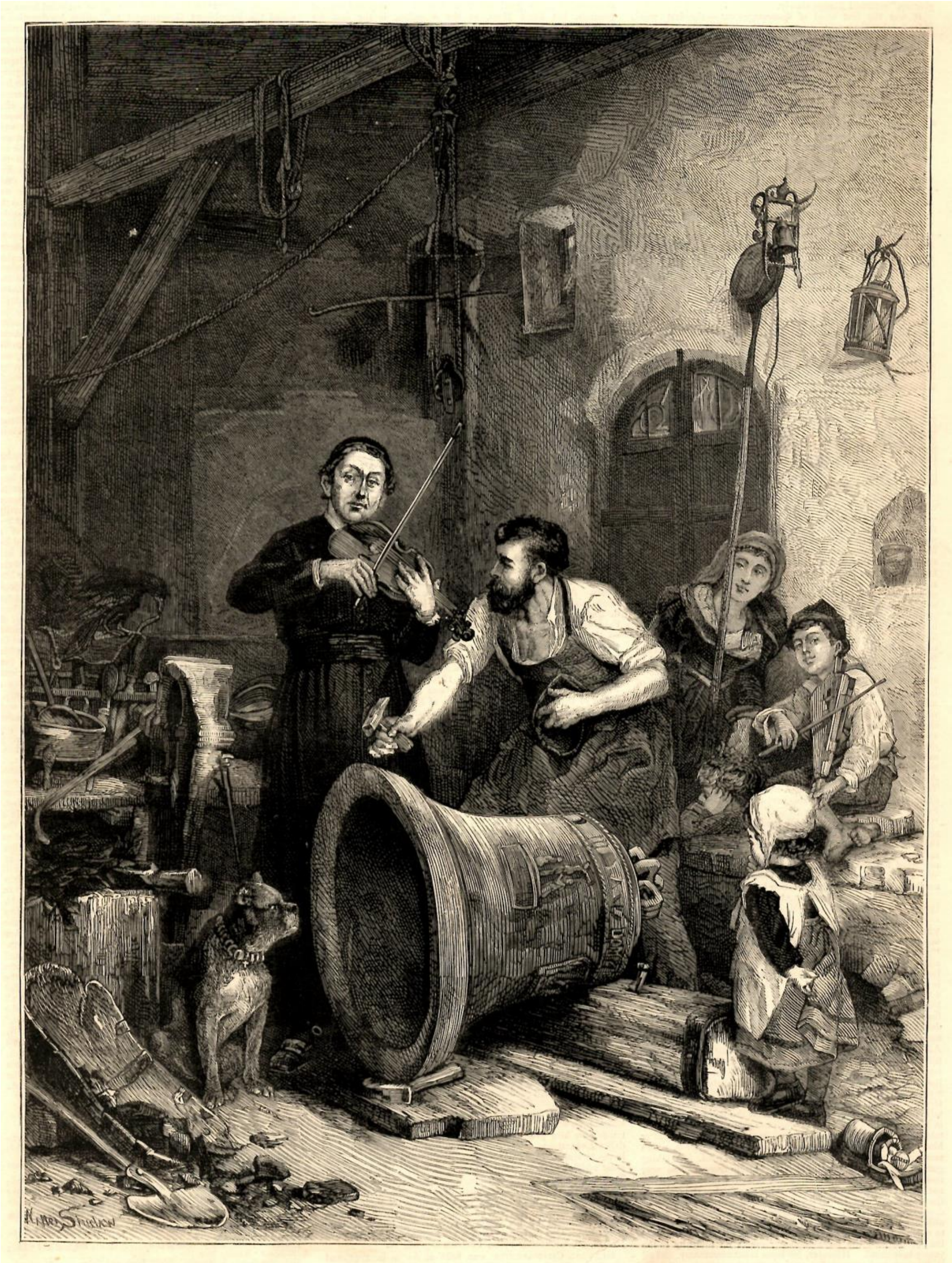


(iv) Other examples

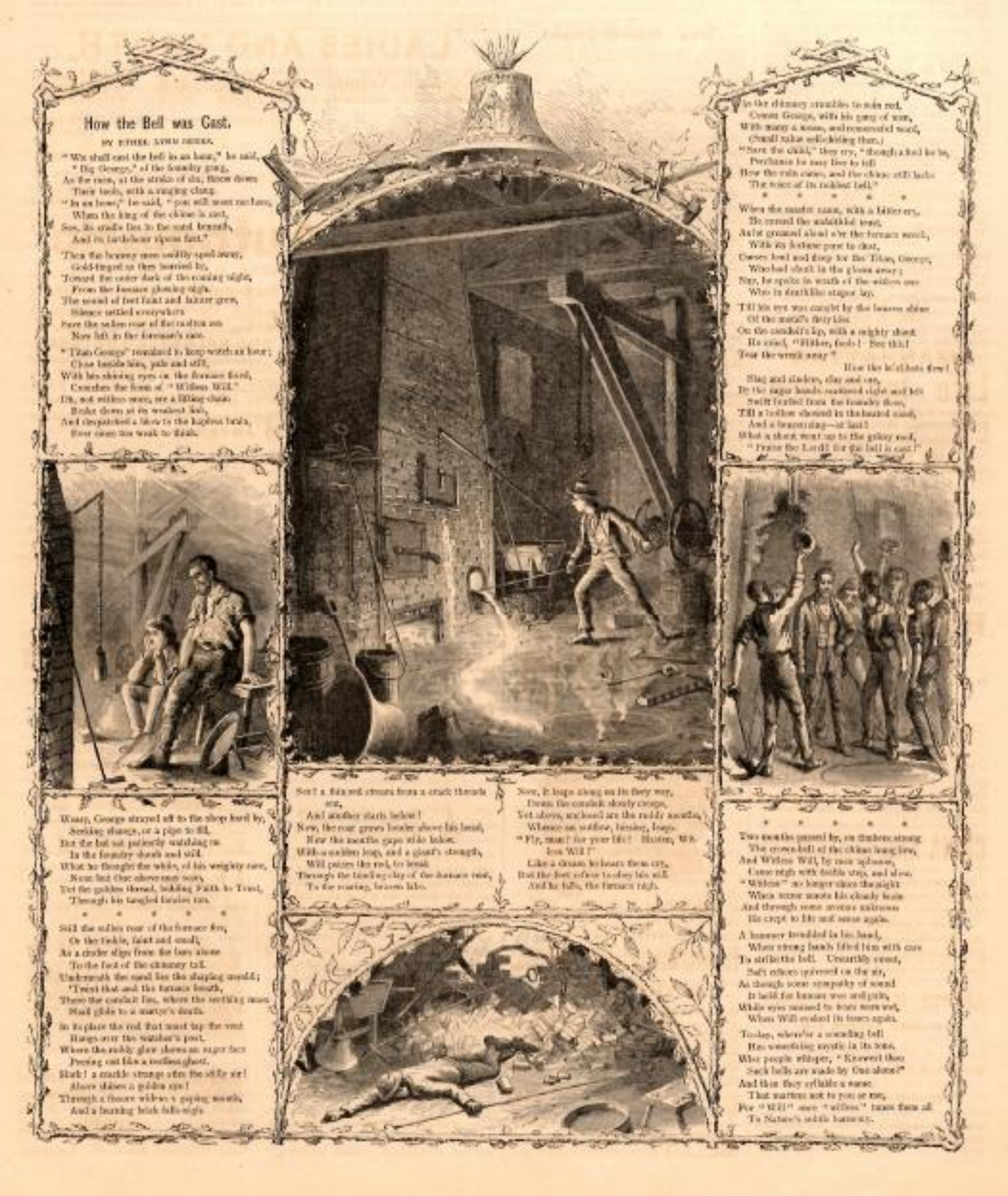
Casting Pit of a Bell-Foundry: Illustration from Knight's *Pictorial Gallery of* Arts, circ 1860 (13.0cm by 10.0cm)



Unknown publication in four languages from 1775 (12.5cm by 9.8cm)

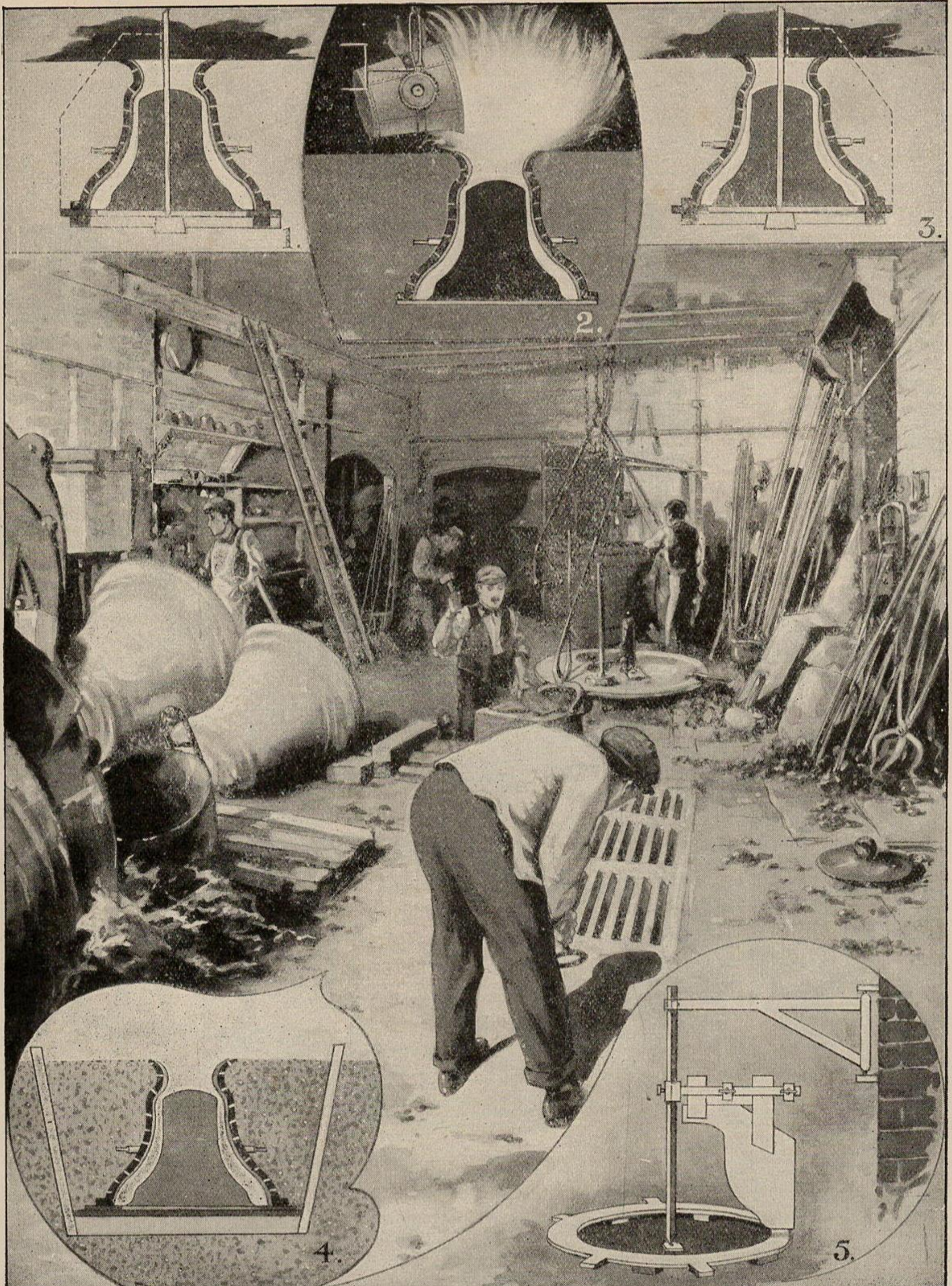


The Toning of the Bell: *The Graphic*, 24 February 1877 page 180, from the picture by Walter Shirlaw (30.5cm by 22.6cm)


How the Bell was Cast.

How the Bell was Cast: *The Illustrated Christian Weekly*: 21 September 1878, page 445 (28.0cm by 23.0cm)

HOW BELLS ARE MOULDED INTO SHAPE



A busy scene in a bell foundry. A core of bricks is built up and covered with soft clay, moulded to the outline of the inside of the bell. Then an outer mould is made, shaped to the outline of the outer surface of the bell, and the molten metal is poured in (2) and left to harden. 1 and 3. Interior surface of bell, the dotted lines showing the loam-board, used for shaping the bell, and shown in 5. 4. Core and hair-loam covering.

For any subject not found in its alphabetical place see information

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How Bells are Moulded into Shape: Source unknown (20.2cm by 14.8cm)

CASTING A CHURCH BELL IN NORMAN DAYS

The English have always been noted for their skilful bell-founding, and some of the finest church bells of the Middle Ages were cast in England. In those olden times the art of bell-founding was in the hands of ecclesiastics, and it is believed that Dunstan, Archbishop of Canterbury, superintended the casting of bells. The bell-founders had no fixed place for working, but travelled about the country and erected temporary foundries at various centres, casting there the bells that might be wanted in the district round. Often the foundry was set up in a churchyard. The reason for the bell-founders moving from place to place was that the condition of the roads made the transport of heavy masses like large bells difficult. The ecclesiastics invoked the blessing of heaven, standing round the furnace in processional order and singing the 150th Psalm, which calls upon people to praise the Lord with musical instruments. After certain prayers the molten metal was blessed and then taken from the crucible and poured into the space between a cap and core previously prepared

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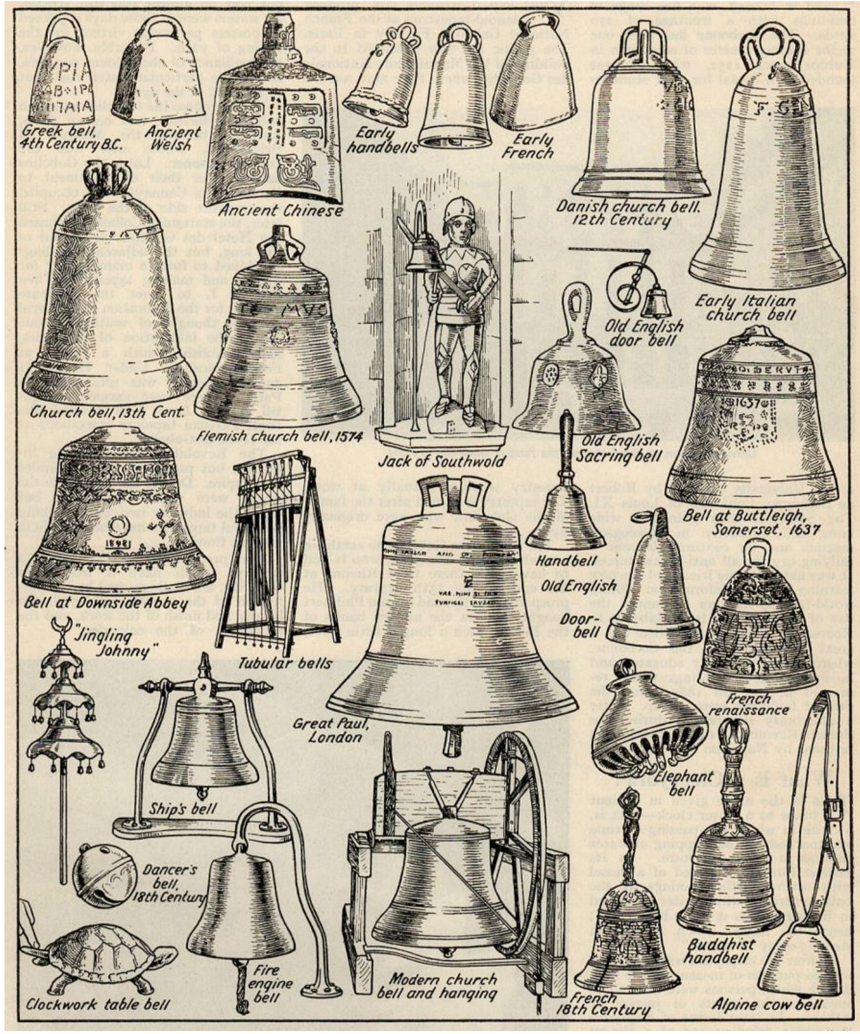
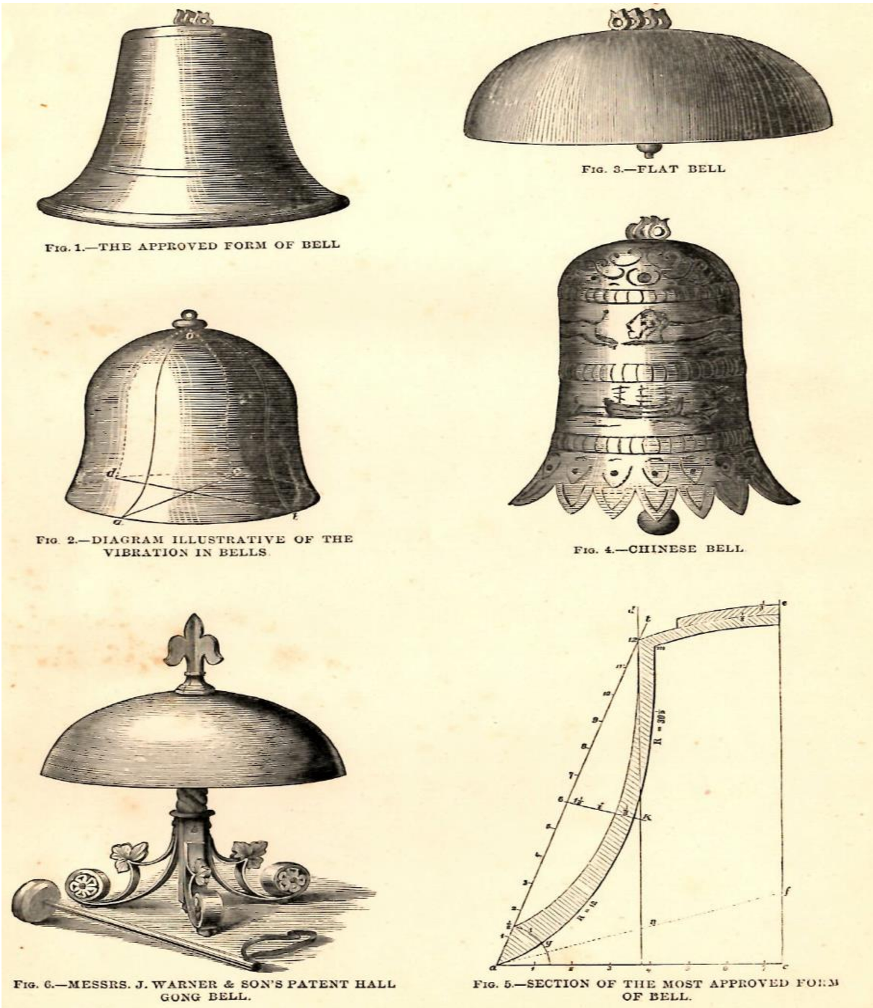
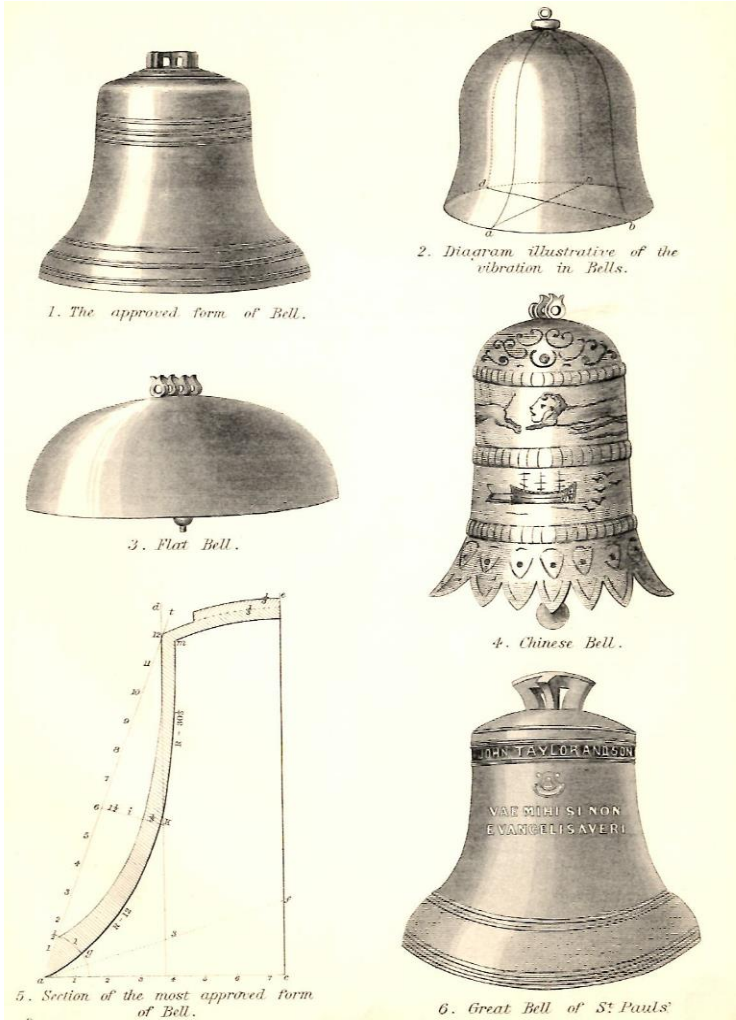
Casting a Bell in Norman Days: Source unknown (17.0cm by 20.5cm)

What Nationality is that Bell: Source not known (17.2cm by 20.7cm)



When and Where was that Bell Used: Source not known (17.2cm by 20.7cm)

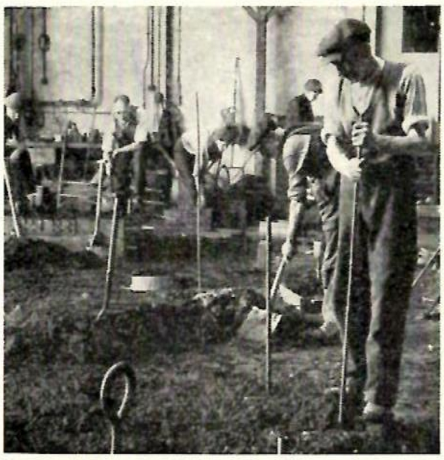




Plates from a Dictionary showing different types of bell. Source *The National Encyclopaedia: A Dictionary of Universal Knowledge* (circ 1890). Left hand side - Vol 3, Plate 1; right hand side – Vol 2. No plate number shown. (16.0cm by 24.0cm)

Stages in the manufacture of a 10-ton bell

Scenes from an English Foundry – Gillett & Johnston: *The Illustrated London News*, 28 October 1950, page 705 (Size: 23.4cm by 32.2cm).

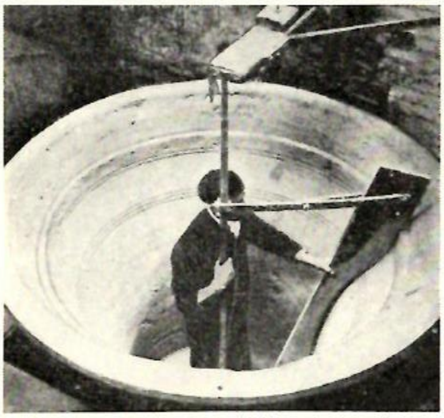


Before a bell can be cast a mould and core must be made from a composition called " foundry loam."

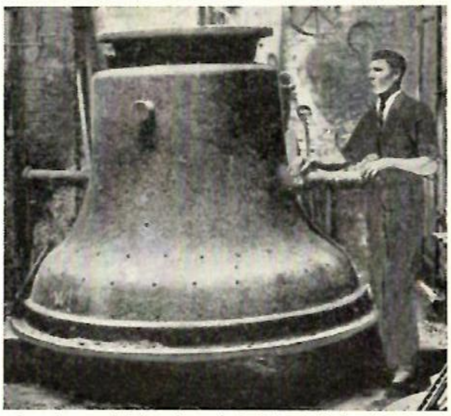
The core, shaped like the inside of a bell, is made from "foundry loam," and here we see the work started.

Gradually the core is built up, being modelled by a shaped board that works round the loam core.

Then the core is baked hard or is dried by means of fires lighted on the top, in an iron pan, as shown here.

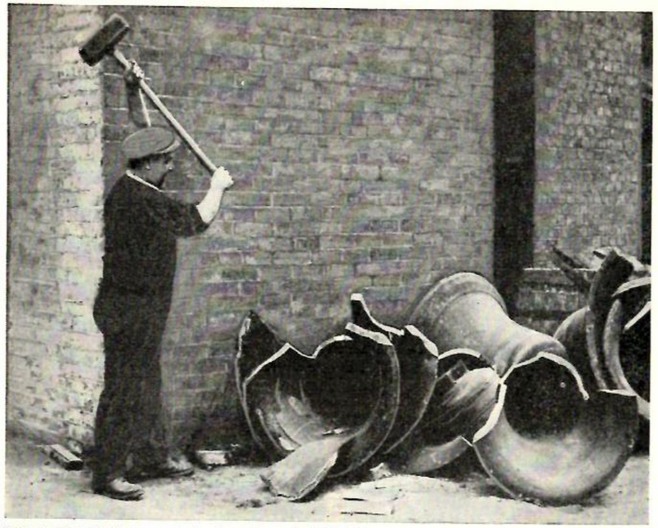


A cast-iron " case " is lined with " foundry loam " and a mould formed by means of a board shaped like the outside of the bell. Here we see the mould being shaped.

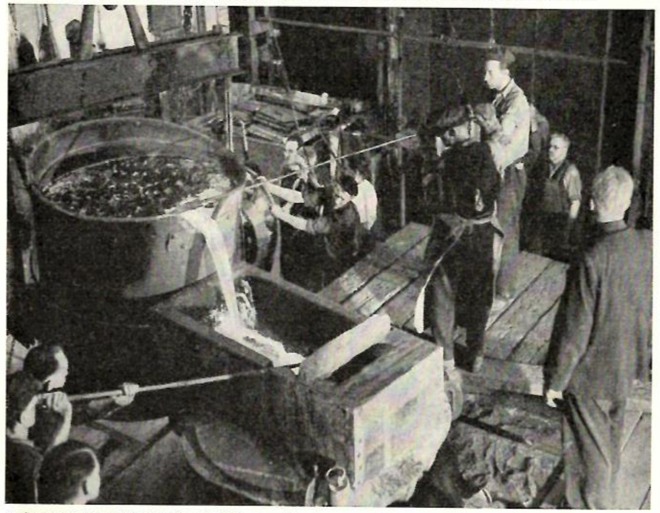


After the mould has been baked hard, it is placed over the core, as seen here, ready for the molten metal to be poured in to fill the space between and so form the bell.

Preparing the Mould (page 2779) (12.5cm by 19.3cm)



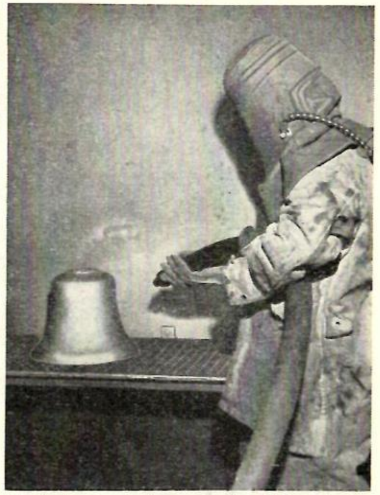
Bells may be made from new metal or from the metal of old bells broken up into fragments, as seen here. Bell metal is valuable, and even in its scrapped condition is worth two-thirds of its original value in bell form.



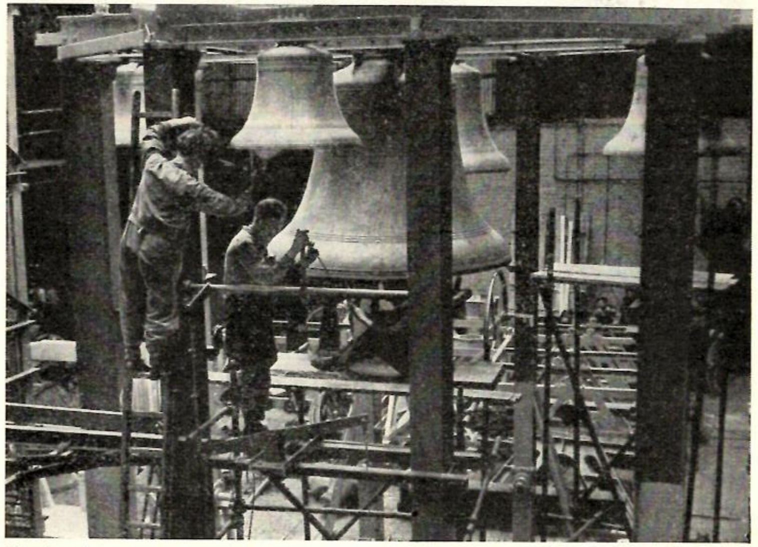
At the present time bells are made entirely from an alloy of copper and tin, the metals being melted in a great furnace and run into a cauldron. The cauldron of molten metal is swung by crane to the spot where the mould and core are ready to receive the metal ; and the cauldron, turned by machinery, pours the metal into the top of the mould, as seen here.

Melting Metal for a Peal of Bells (page 2780) (12.5cm by 19.3cm)

When the metal is cold the mould is removed and the newly-cast bell is taken from the core. The bell is then given its correct tone by the machine seen in this picture.

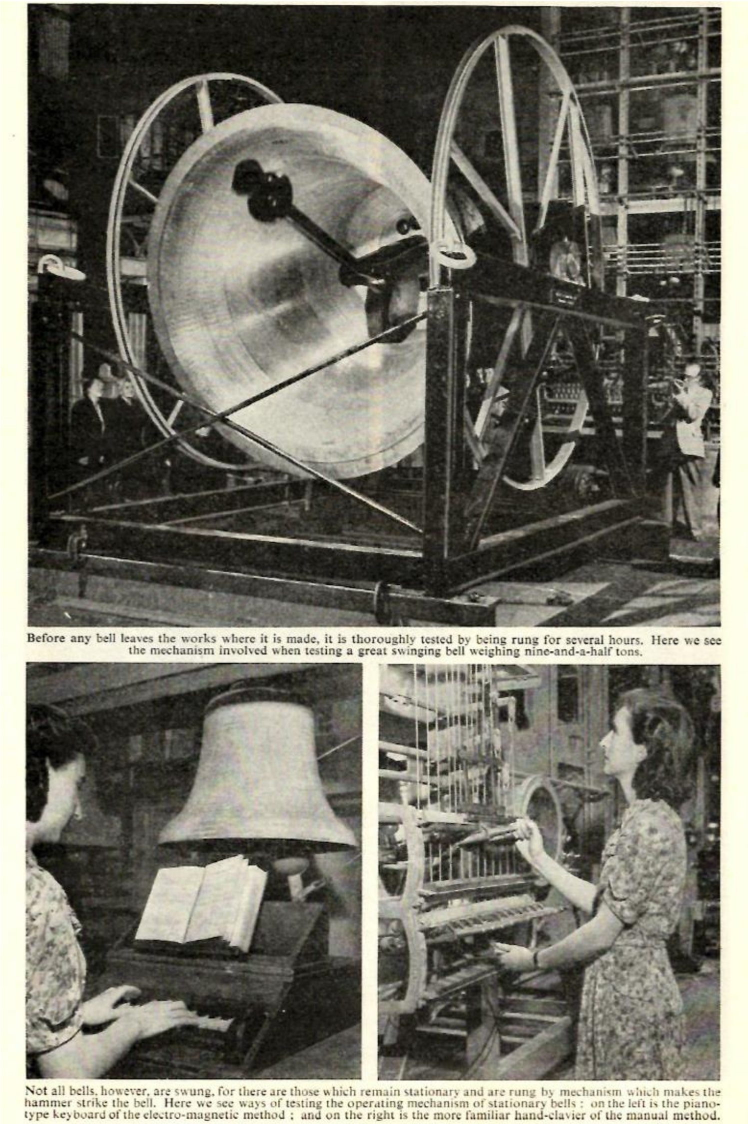


The final process is the smoothening of the surface by sandblasting, and the worker who does this has to be encased in a special dress to protect him from the dust.



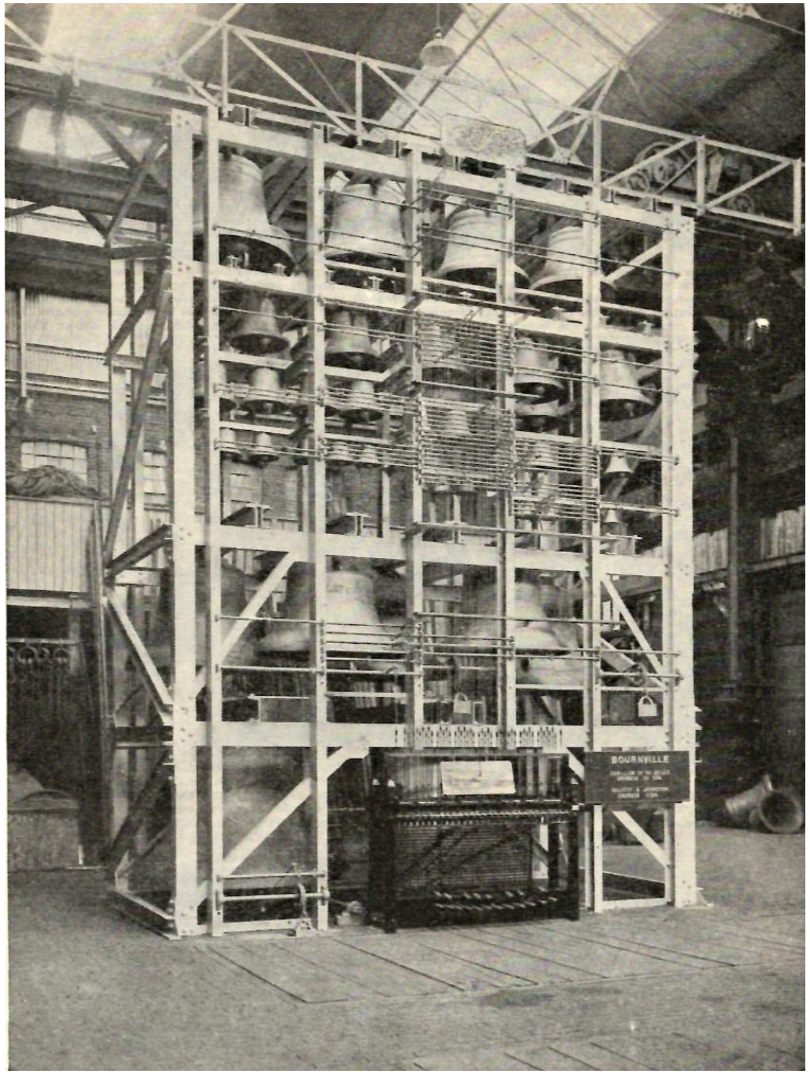
When the bells have been tuned and their surfaces made smooth, the hammers, or clappers, are added. The great framework in the picture holds a carillon of bells while the clappers are being attached.

The Bells receive their Hammers (page 2781) (12.5cm by 19.3cm)



Before any bell leaves the works where it is made, it is thoroughly tested by being rung for several hours. Here we see the mechanism involved when testing a great swinging bell weighing nine-and-a-half tons.

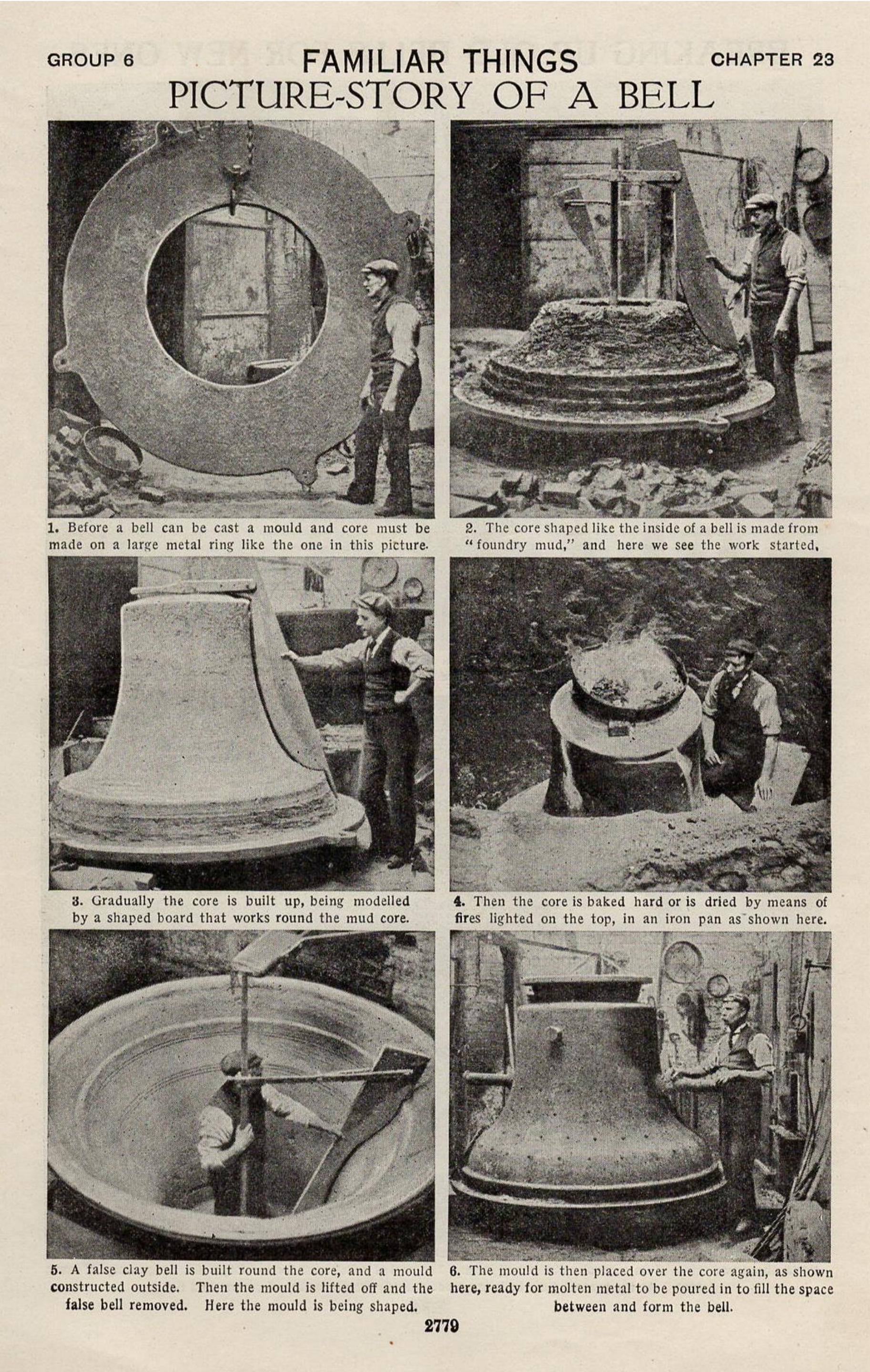
Not all bells, however, are swung, for there are those which remain stationary and are rung by mechanism which makes the hammer strike the bell. Here we see ways of testing the operating mechanism of stationary bells : on the left is the piano-type keyboard of the electro-magnetic method ; and on the right is the more familiar hand-clavier of the manual method.



The Complete Bell is Tested (page 2782) (12.5cm by 19.3cm)

A Wonderful Carillon of Bells (page 2783) (12.5cm by 19.3cm)

As shown above, but with some differences in the illustrations used from an unknown publication.



GROUP 6 **FAMILIAR THINGS** CHAPTER 23

PICTURE-STORY OF A BELL

1. Before a bell can be cast a mould and core must be made on a large metal ring like the one in this picture.

2. The core shaped like the inside of a bell is made from "foundry mud," and here we see the work started,

3. Gradually the core is built up, being modelled by a shaped board that works round the mud core.

4. Then the core is baked hard or is dried by means of fires lighted on the top, in an iron pan as shown here.

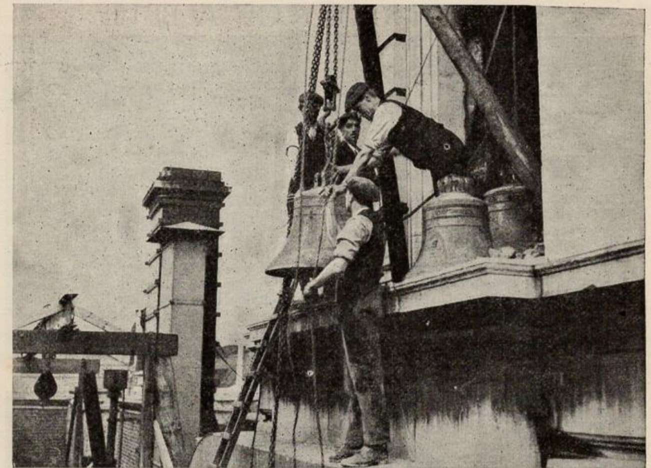
5. A false clay bell is built round the core, and a mould constructed outside. Then the mould is lifted off and the false bell removed. Here the mould is being shaped.

6. The mould is then placed over the core again, as shown here, ready for molten metal to be poured in to fill the space between and form the bell.

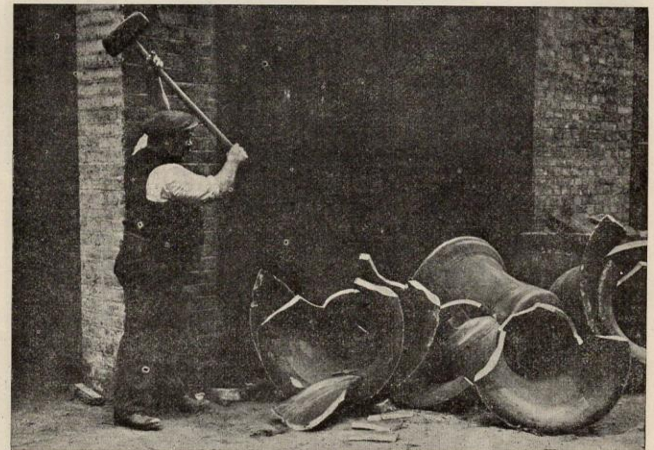
2779

Preparing the Mould (page 2779) (12.5cm by 19.3cm)

BREAKING UP OLD BELLS FOR NEW ONES



7. Bells may be made from new metal or from the metal of old bells broken up into fragments. Bells often become cracked or worn; and here we see the old bells of the Royal Exchange in London being lowered for recasting.

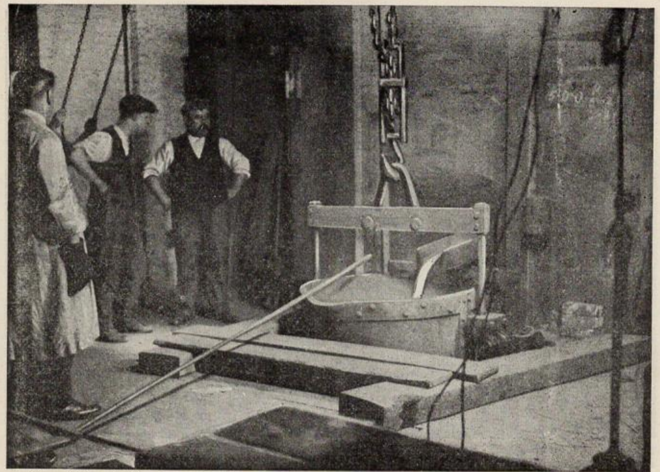


8. This is how the old bells are broken up for recasting. Bell metal is valuable, and even in its scrapped condition it is worth about two-thirds of its original value in bell form. The peal of bells recast for the Royal Exchange weighed seven tons. At the present time bells are made entirely from an alloy of copper and tin.

2780

Breaking Up Old Bells for New Ones (page 2780) (12.5cm by 19.3cm)

MELTING METAL FOR A PEAL OF BELLS

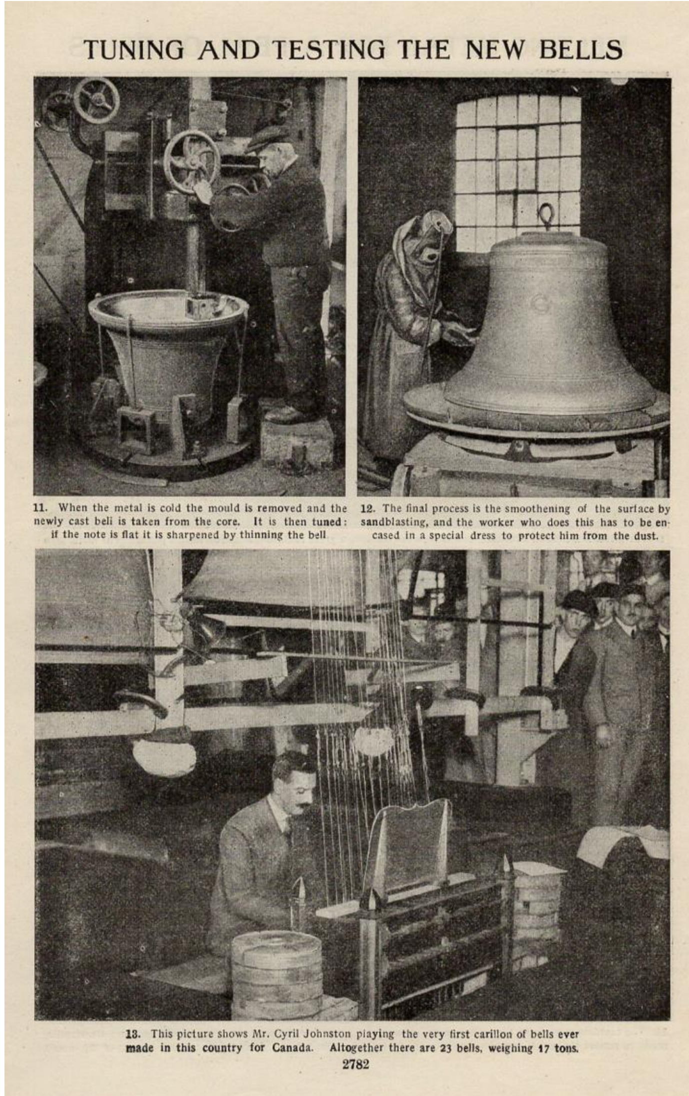


9. The metal is melted in a furnace, and is then run out into a great cauldron, as shown in this picture. The metal seen here was for the making of the bells that now hang in the Royal Exchange and delight Londoners with their chimes.

10. The cauldron containing the molten metal is swung by a crane to the spot where the mould and core are standing ready to receive the metal: and the cauldron, being turned by machinery, pours the metal into the top of the mould.

2781

Melting Metal for a Peal of Bells (page 2781) (12.5cm by 19.3cm)



TUNING AND TESTING THE NEW BELLS

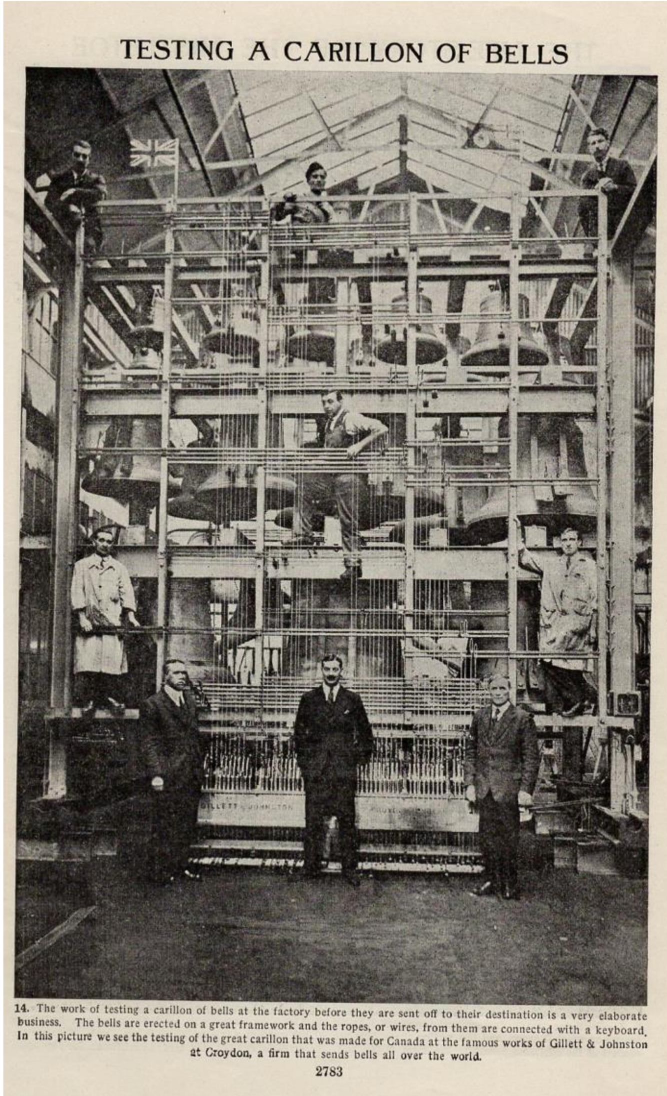
11. When the metal is cold the mould is removed and the newly cast beli is taken from the core. It is then tuned: if the note is flat it is sharpened by thinning the bell

12. The final process is the smoothening of the surface by sandblasting, and the worker who does this has to be encased in a special dress to protect him from the dust.

13. This picture shows Mr. Cyril Johnston playing the very first carillon of bells ever made in this country for Canada. Altogether there are 23 bells, weighing 17 tons.

2782

Testing and Tuning the New Bells (page 2782) (12.5cm by 19.3cm)



TESTING A CARILLON OF BELLS

14. The work of testing a carillon of bells at the factory before they are sent off to their destination is a very elaborate business. The bells are erected on a great framework and the ropes, or wires, from them are connected with a keyboard. In this picture we see the testing of the great carillon that was made for Canada at the famous works of Gillett & Johnston at Croydon, a firm that sends bells all over the world.

2783

Testing a Carillon of Bells (page 2783) (12.5cm by 19.3cm)

Bell Fittings and Ringing the Bell

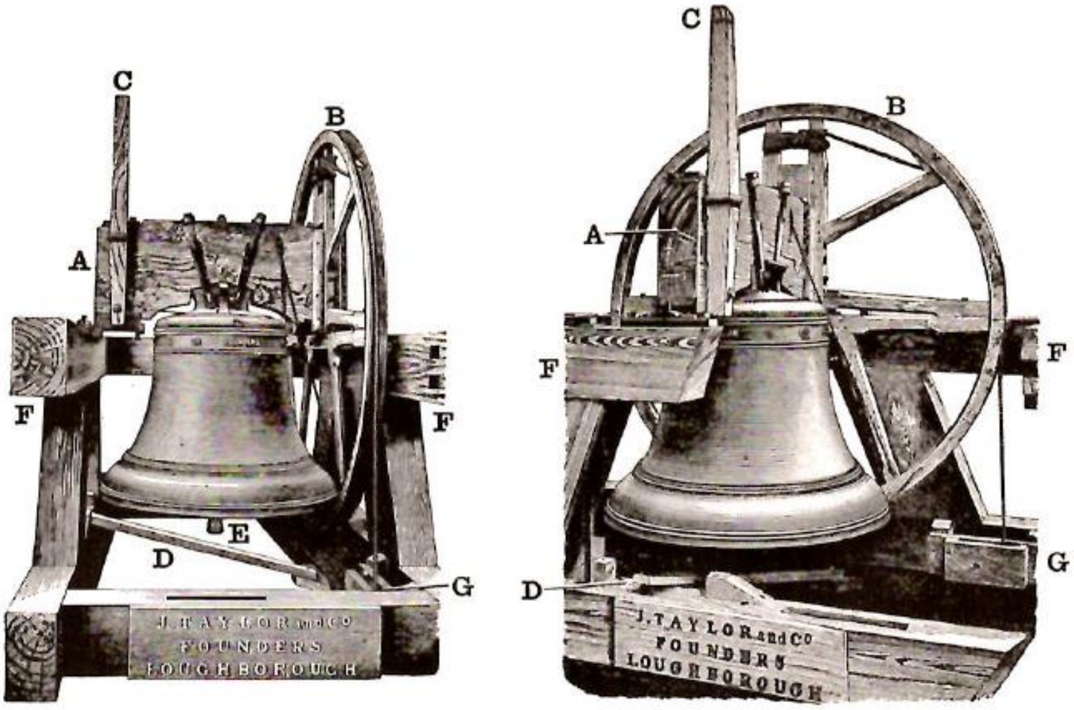
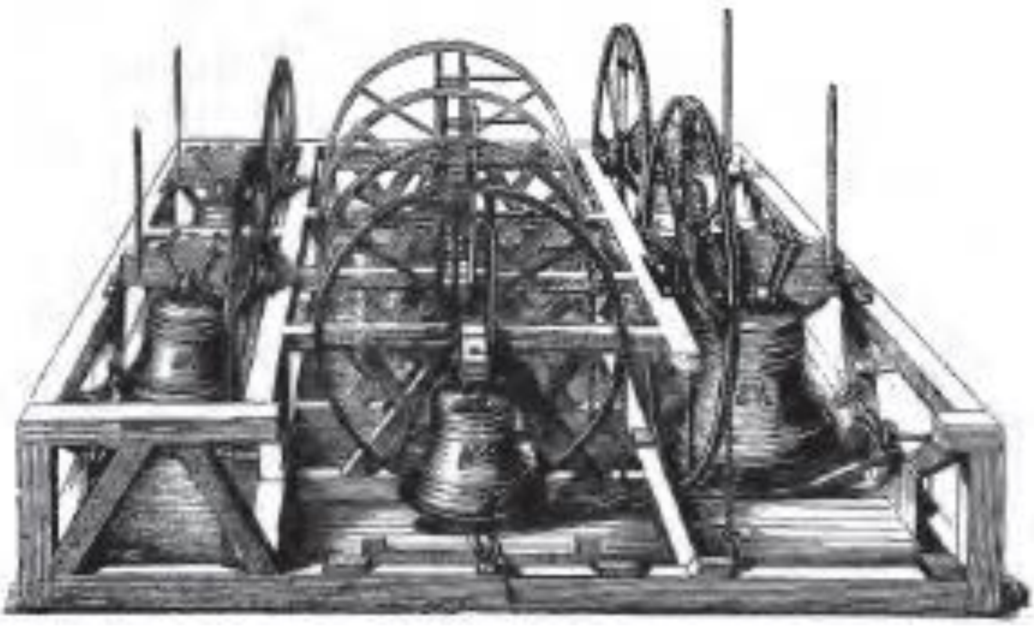


FIG. 12.—Typical English Bell in Wood Frame.

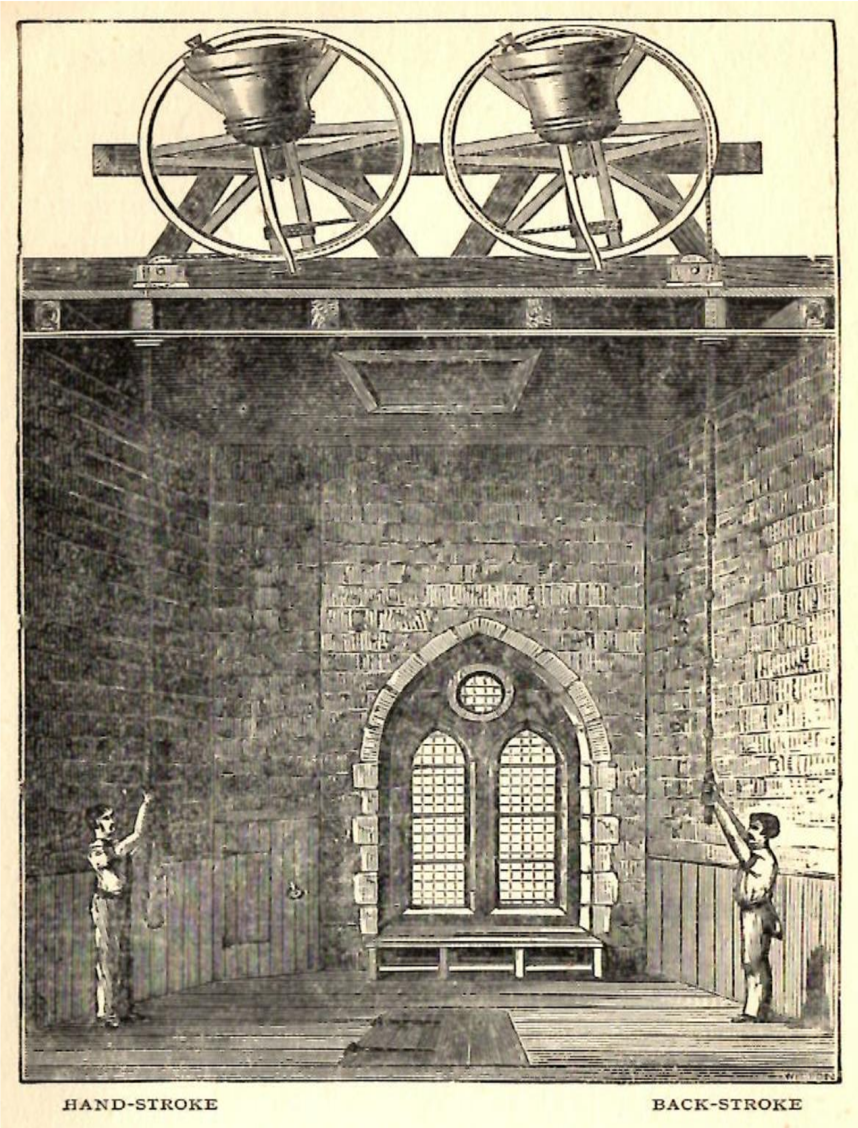
A. Stock.	D. Slider.
B. Wheel.	E. Clapper.
C. Stay.	F. Frame.

G. Roller or Pulley.

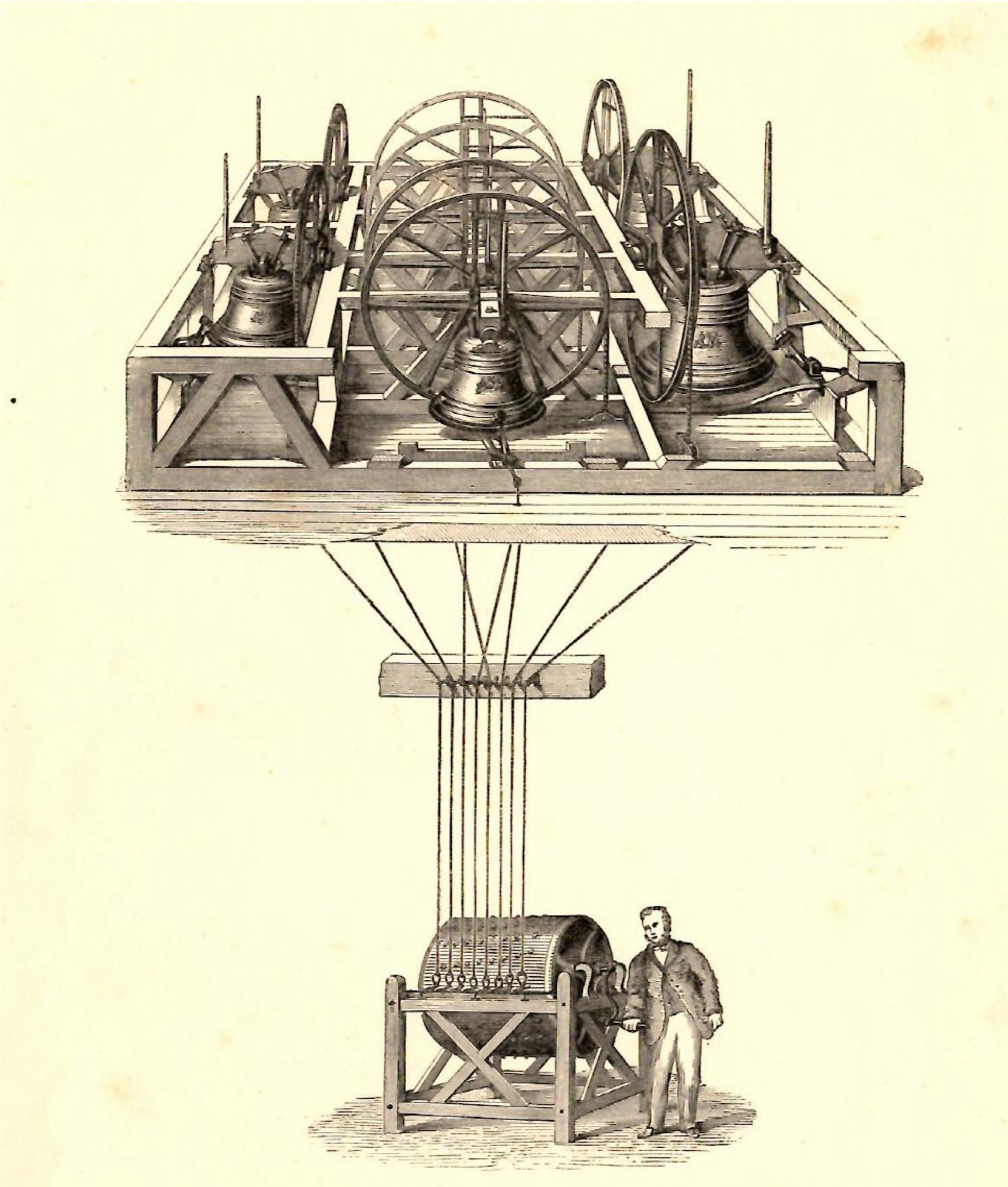
Reproduced in *The History & Art of Change Ringing* by Ernest Morris (page 15a, 1931 edition)



First Steps in Bell Ringing: Samuel B Goslin 1881 (2nd edition)



Ropesight - Jasper Snowdon Change Ringing Series: Various editions (14.0cm by 9.0cm)



As above showing Messrs J Warner & Sons Patent Chiming Machine from *The National Encyclopaedia: A Dictionary of Universal Knowledge* published by William Mackenzie, London circ 1890 - Vol 3, Plate 2 (16.0cm by 23cm)