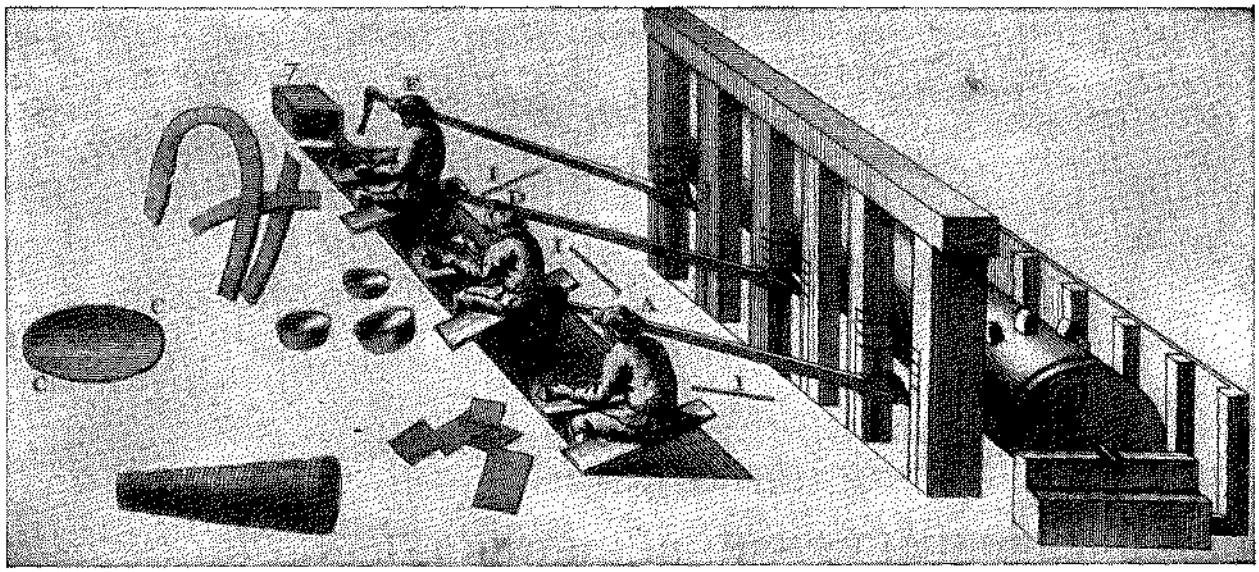


21. Serial Production by Handicraft Workers in the Eighteenth Century: The Art of Converting Red Copper. 1764. *This engraving entitled 'The Artisans at Work' is from the* Descriptions des arts et métiers, *one of our most valuable sources for eighteenth-century mechanization. The large flat trip hammers beat with varying force and speed as the volume of water falling on the wheel is greater or less. Artisans shape the metal into strips, plates, or vessels.* (*Duhamel du Monceau,* L'Art de convertir le cuivre rouge. Descriptions des arts et métiers, *vol. V, pl. X, Paris,* 1764)

THE HAND

Beyond enumeration are the domains of mechanization and all the techniques that bave gone to build up the life we know today. But the method that forms the basis of all mecbanization is amazingly simple.

Tbe human hand is a prehensile tool, a grasping instrument. It can seize, hold, press, pull, mold with ease. It can search and feel. Flexibility and articulation are its key words.

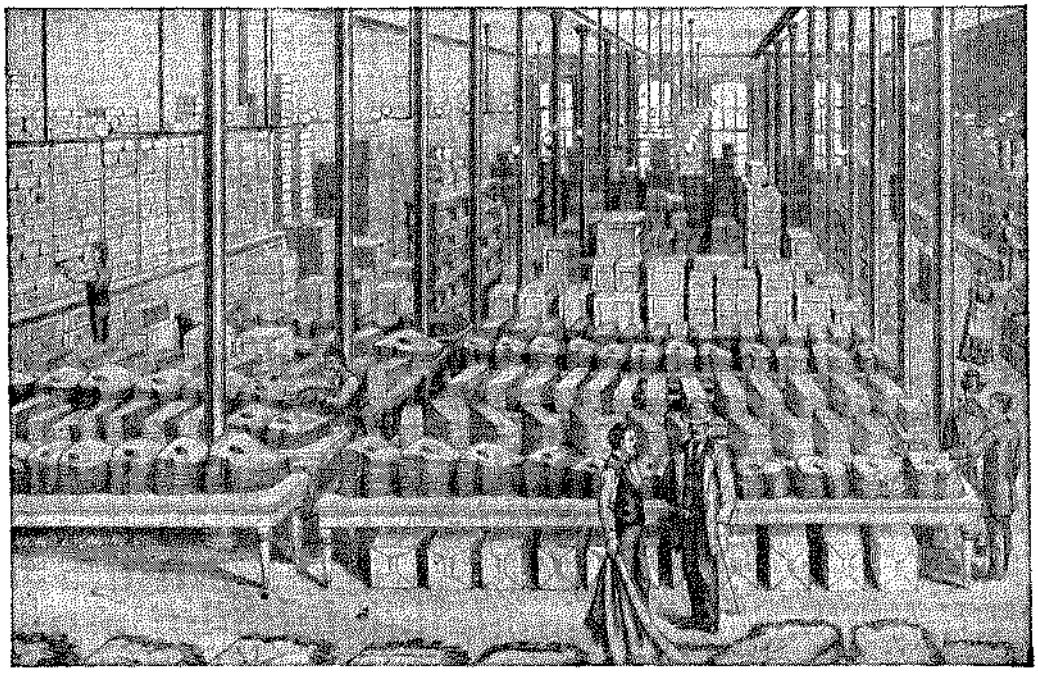
The triple-articulated fingers, tbe wrist, the elbow, the shoulders, and, on occasion, the trunk and legs beighten the flexibility and adaptability of the hand. Muscles and tendons determine how it will seize and hold tbe object. Its sensitive skin feels and recognizes materials. The eye steers its movement. But vital to all this integrated work is the mind that governs and the feelings that lend it life. The kneading of bread; the folding of a cloth; the moving of brush over canvas: each movement has its root in the mind. For all the complicated tasks to which this organic tool may rise, to one thing it is poorly suited: automatization. In its very way of performing movement, the band is ill-fitted to work with mathematical precision and without pause. Each movement depends on an order that the brain must constantly repeat. It wholly contradicts the organic, based on growth and change, to suffer automatization.

Frank W. Gilbreth, the master of motion studies, who probed so deeply the nature of manual activity, stresses once again in his last essay, *A Fourth Dimension for Measuring Skill* (1924), that no movement can exactly repeat another.

The hand can be trained to a degree of automatic facility. But one power is denied it: to remain unvaryingly active. It must always be grasping, holding, manipulating. It cannot continue a movement in endless rotation. That is precisely what mechanization entails: endless rotation. The difference between walking and rolling, between the legs and the wheel, is basic to all mechanization.

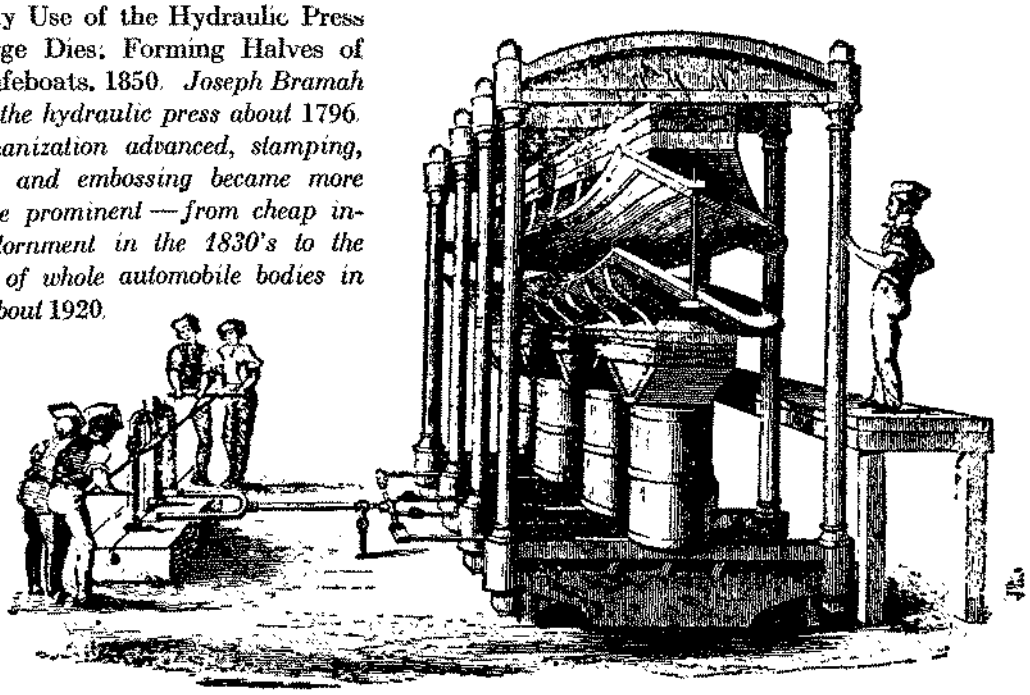
STANDARDIZATION AND INTERCHANGEABILITY

THE first phase of mechanization consists in transforming the pushing, pulling, pressing of the hand into continuous rotation. The second phase concerns the means of mechanization: By what procedures are objects to be mechanically reproduced? As early as the first decades of the nineteenth century, mechanical reproduction was effectuated in diverse ways, by stamping, pressing, embossing, and other methods, as described, for instance, by Charles Babbage, 1832, or



22. Serial Production in the Second Half of the Nineteenth Century: Wholesale Grange Supply House, Chicago. 1878. *Hat and clothing parts cut by mass production methods are stacked on the tables. 'In front is one of our salesmen showing Buffalo Robes. Today America excels in mass-production clothing, especially in cheap and sturdy work clothes made from a minimum number of pieces. These had their beginning in the nineteenth-century endeavor to create satisfactory work clothes.* (*Montgomery Ward*)

23. Early Use of the Hydraulic Press and Large Dies: Forming Halves of Metal Lifeboats. 1850. *Joseph Bramah invented the hydraulic press about* 1796. *As mechanization advanced, stamping, pressing, and embossing became more and more prominent — from cheap interior adornment in the 1830's to the pressing of whole automobile bodies in Detroit about* 1920.

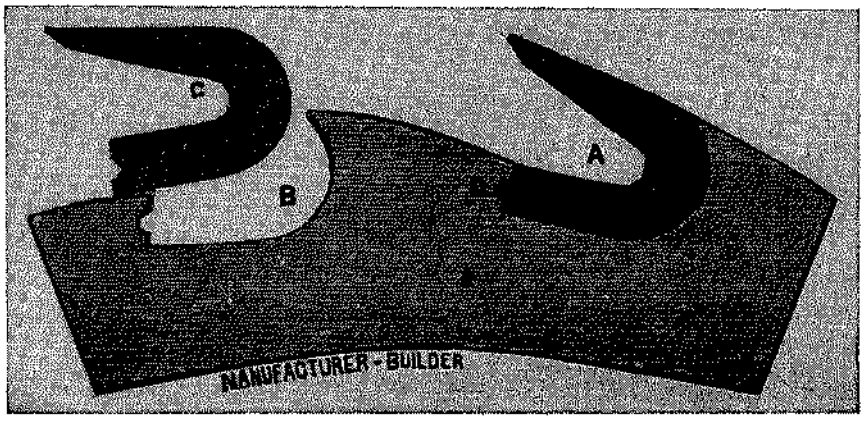


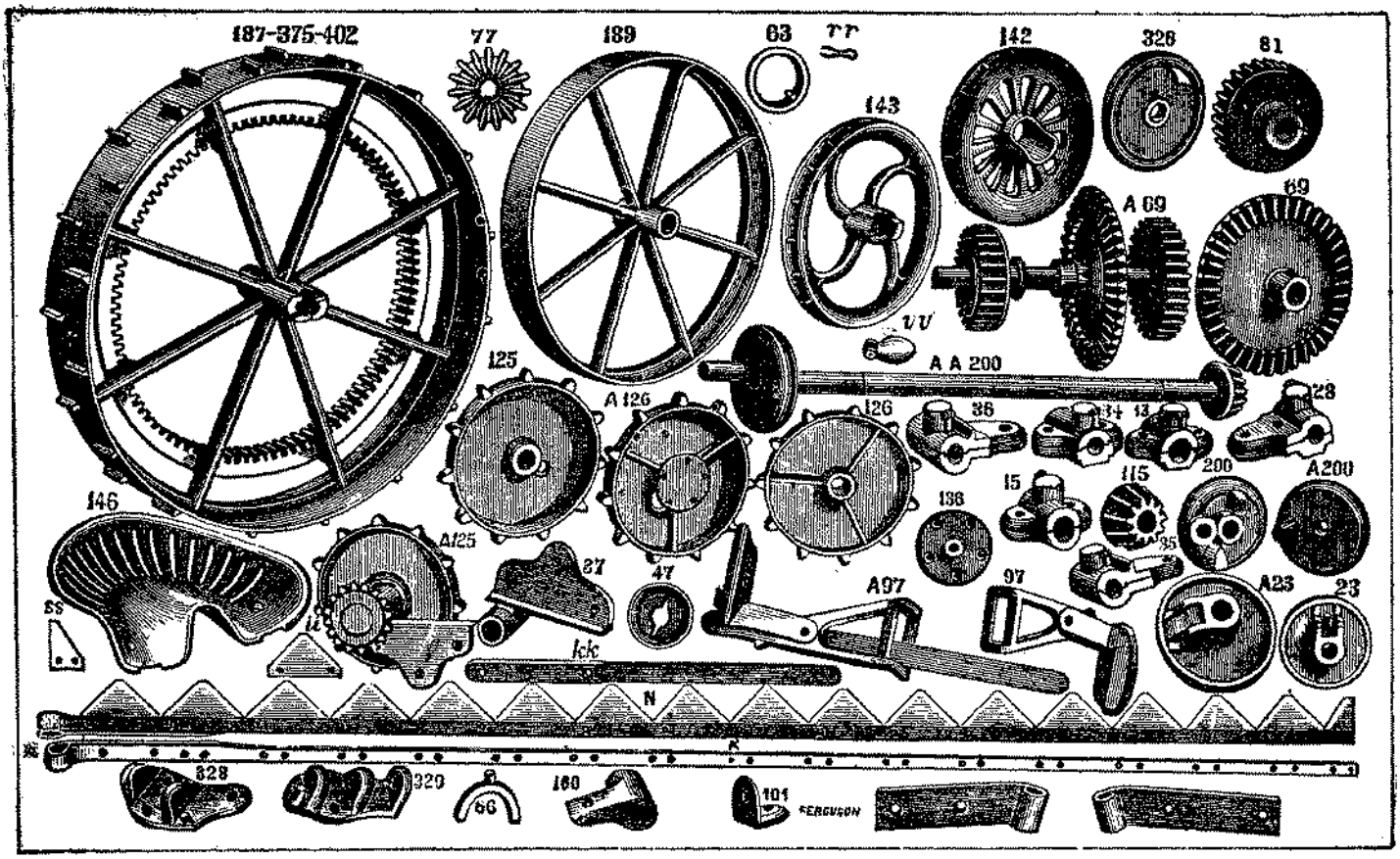
HYDRAULIC PRESS.

The engraving of the Hydraulic Press, is to give the reader some idea of the method of construction. Sheets of Galvanized Iron are laid between the enormous dies, grooved to fit each other, one of which rests upon the Cylinder, and which when brought together by the Hydraulic Pressure of *eight hundred tons*, corrugates the Iron, which gives it great strength, and at the same time the shape and curve of the Boat; the sheets are then riveted together, and finished with the usual gunwale, &c.,

by Peter Barlow, 1836. Dies become of growing importance: from the stamping of coins (fig. 200) to the pressing of metal lifeboat halves, achieved around 1850 (fig. 23). 'Sheets of galvanized iron are laid between enormous dies, grooved to fit each other.' This procedure was not exploited on a grand scale until the time of full mechanization, in the automobile industry. Side by side with the differentiation and reshaping of age-old tools, a simultaneous transformation

24. Interchangeable Parts: Replaceable Saw-teeth. 1852. *A California saw mill superintendent 'realized while engaged in his work how very great are the objections to the use of solid-tooth saws in districts remote from saw factories . . . Circular saws with inserted teeth will do more work with less expense.'* (Manufacturer and Builder, *New York, January* 1869)





25. Early Use of Interchangeable Parts for Large Machines: Reaper Parts, 1867. *Interchangeable parts for small articles — pistols, guns, clocks — had been in use since the beginning of the nineteenth century. But the now rare catalogue of Walter A. Wood, the enterprising designer of agricultural machines, Hoosick Falls, N. Y., shows a broad range of replaceable parts half a century before Henry Ford brought standardization to the automobile industry. (Courtesy McCormick Historical Society, Chicago)*

occurred in their production. It was by dies that hammers, axes (fig. 71), saws, scythes [1] were given their shapes.

Pressing, stamping, casting result in standardization and, closely connected therewith, the interchangeability of parts. Of the early beginnings some facts and fragments are generally known. Eli Whitney, inventor of the cotton gin, is held the first to have introduced interchangeability of parts in gun manufacture at his Whitneyville factory; Simeon North, the pistol maker who had his workshop in near-by Middletown (Conn.), worked on the same principle. That is, the idea was in the air. In France, Thomas Jefferson in an often-quoted letter observed that a mechanic was manufacturing guns from interchangeable parts (1782). We have but scanty knowledge, however, about what late eighteenth-century France accomplished in this sphere, and systematic research is still needed. The machines that Brunel invented or combined with existing ones for the production of pulley blocks based on standardization and interchangeability are described and illustrated in full detail in the early nineteenth-century editions of the *Encyclopaedia Britannica.*

[1] This concomitance of new form with new production methods can be established from the thirties on. The only example we show here is a scythe blade invented in 1834 (fig. 73).

America, for reasons that are not difficult to understand, was a fertile ground for the standardization and interchangeability of parts. But it is still a matter of small dimensions even in mid-century, when clocks assembled from interchangeable parts were manufactured by the Waltham factory. Skilled workmanship was needed for clock repair and the interchanging of clock parts.

Proposals for the interchangeability of larger parts were advanced in various spheres at the beginning of the 'fifties. The idea of saws with interchangeable teeth (fig. 24) arose in a California sawmill extremely remote from any factory where damaged teeth could have been repaired. The inventor subsequently returned to the Atlantic States, where he put his idea into practice.[2] A circular saw of this type, 80 inches in diameter, was exhibited at the Paris International Exhibition of 1867.

This whole field will not be gone into further here, for mainly technical procedures are involved. Besides, to investigate it with the necessary precision demands interrelated research, which will doubtless be accomplished only when American industry has overcome its historical bashfulness.

Only one point need be touched upon here: Interchangeability becomes an interesting question as soon as it is applied to larger machines, and when interchange can be performed independently of skilled labor. One of the very rare catalogues from the 'sixties, the *Circular for the Year* 1867 of the most elegant constructor of agricultural machinery, Walter A. Wood, Hoosick Falls, N. Y.,[3] publishes six 'diagrams of parts' (fig. 25) for his mower and Handrake Reaper, each part being illustrated and numbered, so that the farmer need only write for the necessary part by number. From the first, the mechanically minded farmer was accustomed to assemble the machines himself. McCormick, for instance, sent out his reaper in four numbered crates.

So far as we can yet ascertain, Walter A. Wood, whose name we shall again encounter, was the first to institute the interchanging without technical help of parts for large machines. This catalogue of 1867 gives more space to the representation of interchangeable parts than to the machines themselves. This was half a century before Henry Ford in the automobile industry familiarized the broader public with the same principle.

As we soon shall see, the advent of interchangeable parts for the larger machines and the elimination of skilled labor fall within the same period as the beginnings of the modern assembly line in the meat packing industry.

---

[2] *American Manufacturer and Builder*, New York, Jan. 1869.

[3] The Walter A. Wood Mowing and Reaping Machine Company, Hoosick Falls, New York, *Circular for the Year* 1867, Albany, 1867.

MECHANIZATION OF A COMPLICATED CRAFT

The Craft of the Locksmith

FOR SOME CENTURIES after the late Gothic period, the locksmith was known as the artisan of a most elaborate handicraft. He united mastery of hand with the gift of untiring inventiveness. His work included, besides locks, all sorts of artistically wrought ironwork: gates, grilles, knobs, handles, and the fantastic iron ornamentation of chests.

The Gothic period was very sparing of bodily comfort but felt strongly that imagination should animate the objects of man's surroundings. The woodwork of a door is rough and not highly finished; the craftsman spent all his pains on the sensitive area of the door: the keyhole. He framed it with delicate ornamentation as if he were illuminating a manuscript. And the handle that draws the latch be transformed into an abstract serpentine shape ending in an animal head, as in the lock from a house at Visp, Switzerland (fig. 26). Later, in the eighteenth century, the last period of refined handicraft, craftsmen turned their energy to the creation of large-scale works like the wrought-iron grilles, screening choir from nave in monastery churches, surrounding parks, or forming the gates of public squares. They wove transparent iron veils before the altar or the park. In one case the artist-locksmith binds into the architectonic space his high iron structure, the water curtains of the sculptured fountains, and the green beyond.[1]

The development of this artistry ran parallel with the achievement of eighteenth-century furniture and comfort beginning with the last years of Louis XIV and the Regency.[2]

Louis Sébastien Mercier, the remarkable critic of the end of the *Ancien Régime*, was one of the first to see a city from a sociologist's point of view. It has been said that he described the cellar and the attic but forgot the salon. When he comes to the refined handicraft, the critic is carried away. Mercier describes with the directness of a contemporary the high standard of craftsmanship a few years before the French Revolution: 'Our smith has become an artist. Art has so wrought the metal as to fuse it with architecture; it has been developed into superb grilles which have the advantage of enhancing the view without

[1] It was Jean Lamour (1698–1771) who accomplished this in Nancy, when he adorned the three most elaborate squares of the late Baroque. In one of them, the Place Stanislas (1751–5), he spans the open side between two of its corners with hovering iron grilles. (Cf. Lamour, *Recueil des ouvrages de serrurerie sur la Place Royale de Nancy*, Paris, 1767.)

[2] Cf. the work of the master locksmith, Louis Fordrin, *Nouveau livre de serrurerie*, Paris, 1723, reprinted in facsimile by A. de Champeaux, Paris, 1891. Especially interesting are plates 19, 23, 27, depicting the various parts of great church grilles.

destroying it. Iron has become as supple as wood. It is twisted at will and changed into light and mobile leaves; its coarseness removed, it is animated with a sort of life.'

But it all died out as the Industrial Revolution set in. What the smith had formerly forged hy hand out of iron was then entrusted to the mold. Between 1825 and 1845, as ohserved in the report of the jury of the Paris International Exhihition of 1867, the highly skilled smiths disappeared from the hig cities. Grilles, railings, and halconies had come to he made of cast iron. By the time of Haussmann's transformation of Paris under the Second Empire, large firms had sprung up, offering stocks of cast-iron pieces, from the continuous halconies of the houlevards to cast-iron copies of Michelangelo's sculpture. Their catalogues were like texthooks of art history, and expanded to three or four hundred pages.

But we shall not deal further here with this aspect of mechanization in the locksmith's trade. It was unfruitful from the historical point of view, for it followed the easy way of mechanization, the sole aim of which is to make copies as cheaply as possible. Mechanization in the locksmith's sphere is of historical interest only when it chooses the hard way: when it is achieved hy creating new methods and new aims. There is no creativeness in the mechanical production of cast-iron grilles and ornaments.

To gain an insight into the real nature of mechanization we shall have to confine ourselves to the lock. Nowhere else in this respect did the transition from handicraft to mechanical production take place with such speed and efficiency as in the United States. The steps in this change occurred during the two decades from 1830 to 1850, decades of outstanding importance in the formation of American industry's distinctive features. At first, the European practice of using wrought iron for the various parts of the lock was followed in America, but almost from the heginning a differentiation hegan hy the substitution of 'cast material in place of wrought. . . . This change of material greatly reduced the cost of production, and soon led to changes in design. . . .'[3]

From Handicraft to Mechanical Production

The change from manual to mechanized production has another starting point as well — in hank and safe locks. Out of experience in the construction of these expensive locks, costing from $100 to $400, there evolved in the 'sixties of the last century a new type of efficient and inexpensive mechanized locks. From the late eighteenth century onward, the prohlem of the hurglar-proof lock

[3] Henry R. Towne, *Locks and Builders Hardware, a Hand Book for Architects*, New York, 1904, p.39.

→

26. Late Gothic Lock of a House at Visp, Switzerland. *The woodwork is relatively rough. The craftsman spent his care in accentuating with iron work the significant part of the door, the keyhole.*