



Das lange 19. Jahrhundert (1780–1914)

Teil I: 1780–1850

Stefan M. Holzer, ETH Zürich

Jahrhundert des Eisens:
Die Voraussetzungen

Rot-
eisenstein
(Hämatit)
 Fe_2O_3



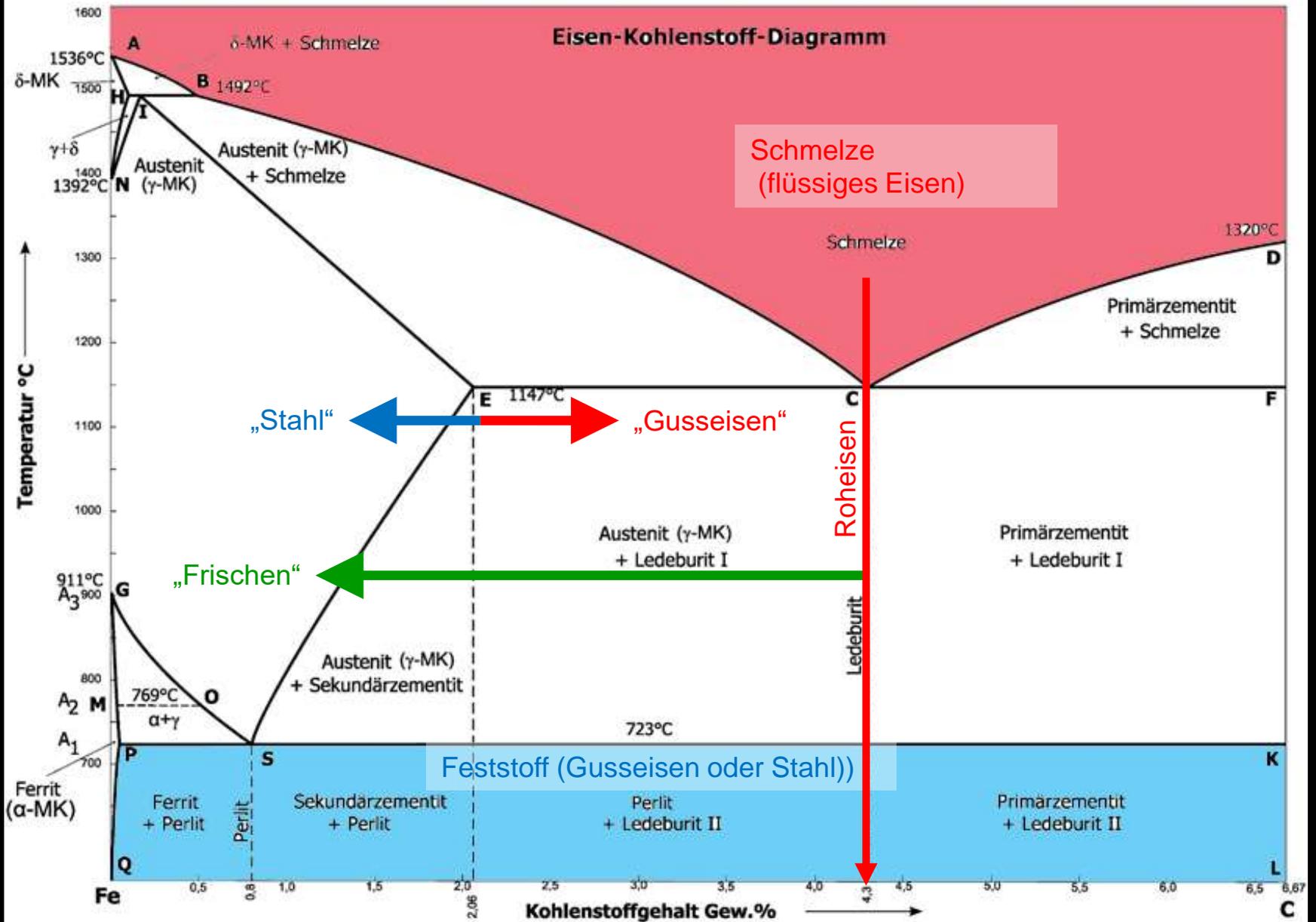
Brauneisen-
stein
(Limonit)
 $\text{Fe}(\text{O})\text{OH}$



Spateisen-
stein
(Siderit)
 FeCO_3

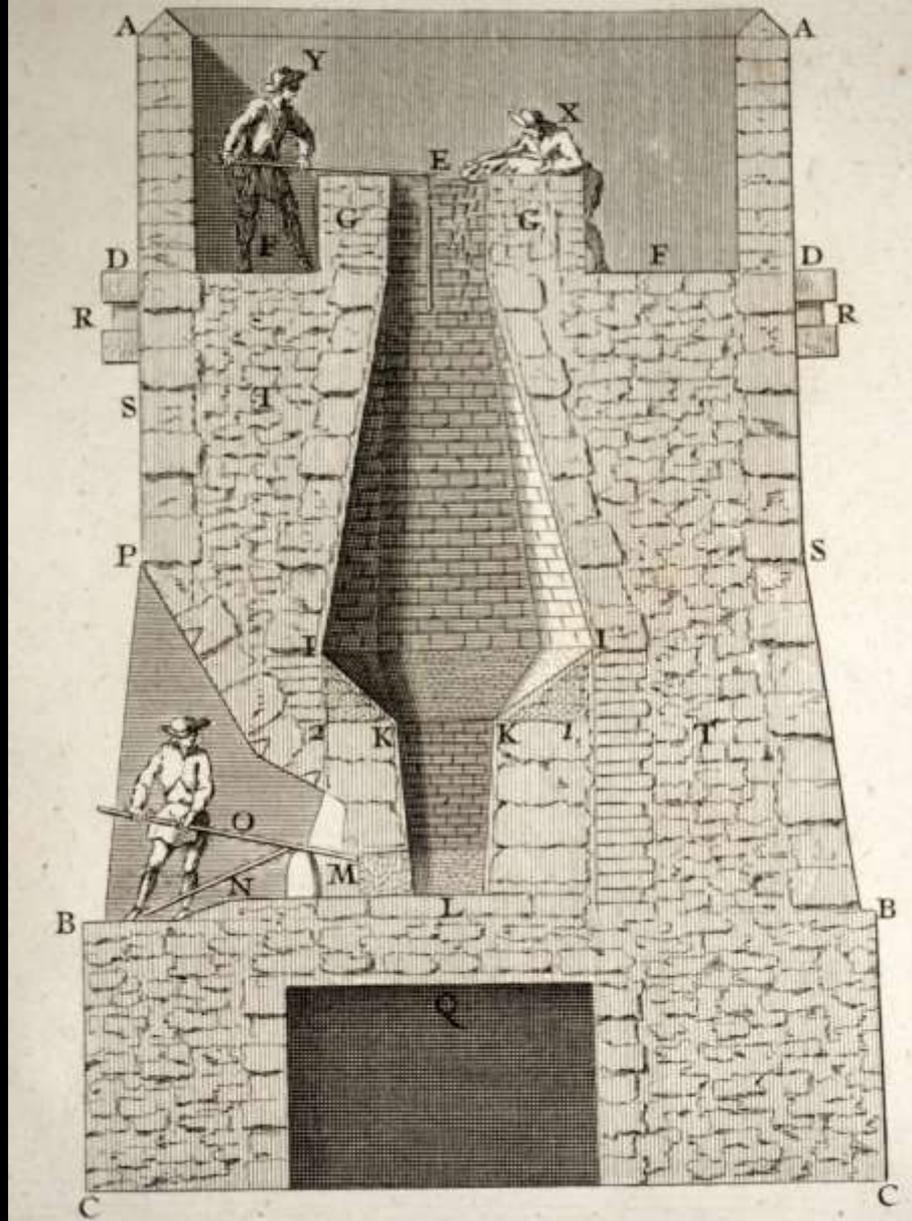
Pyrit
 FeS_2





Eisen-Kohlenstoff-Diagramm und Herstellungsschritte

fig. 1.^{re}



Hochofen, Reduktion des Eisenoxids, ermöglicht Produktion von flüssigem Roheisen etwa ab 17. Jh. allgemein gebräuchlich (Courtivron/Bouchu 1762)



Französische Ofenplatte aus Gusseisen



Bauteile aus Schmiedeeisen, 18. Jh.

Gusseisen vs. Schmiedeeisen



Gusseisen:

- Hoher Kohlenstoffanteil
- Formgebung: direkter Guss in Sandform
- Materialeigenschaften: hart, spröde, hohe Druckfestigkeit (vgl. Stein)
- Ggf. nur einstufiger Herstellungsprozess (Roheisen = Gusseisen)

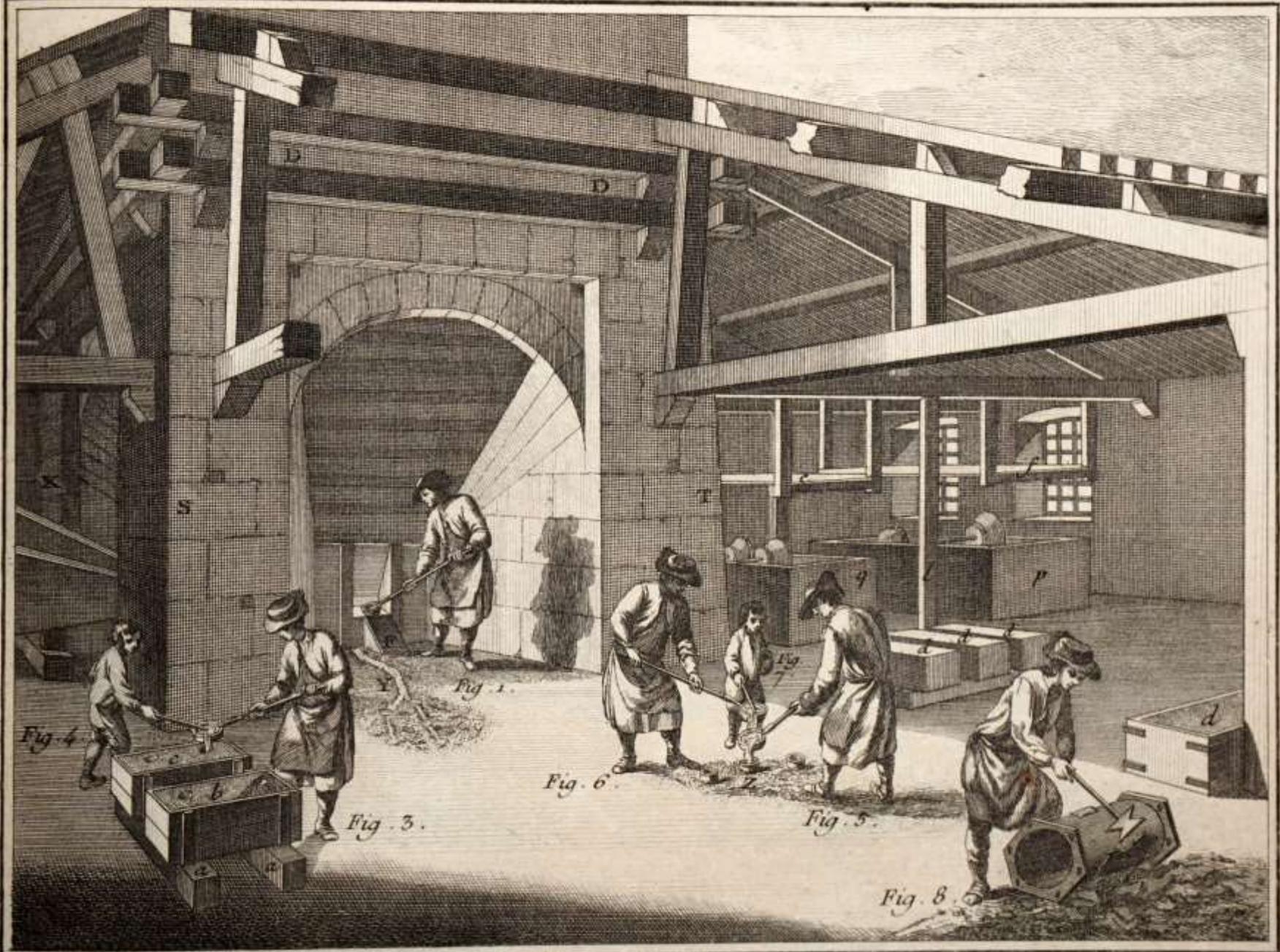


Schmiedeeisen („Stahl“):

- Niedriger Kohlenstoffanteil
- Formgebung: Umformen durch Schmieden
- Materialeigenschaften: zäh, Druck- und Zugfestigkeit gleich hoch (vgl. Holz)
- Zweistufiger Herstellungsprozess (Roheisen -> Schmiedeeisen)



Herstellung von Holzkohle für die Eisenverhüttung in Meilern
(Duhamel du Monceau, *Art du Charbonnier*, 1770)



Direkter Guss von Roheisen aus dem Hochofen
(Encyclopédie 1765)

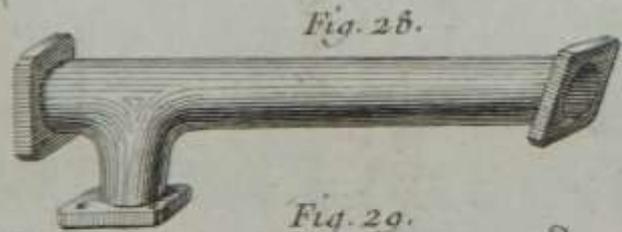


Fig. 28.



Fig. 29.



Fig. 30.

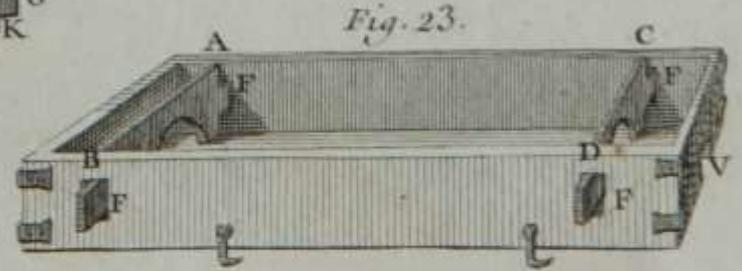


Fig. 23.

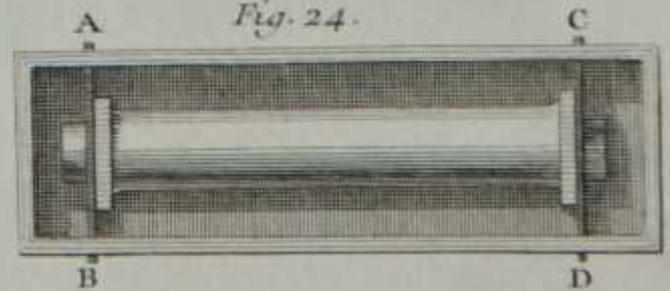
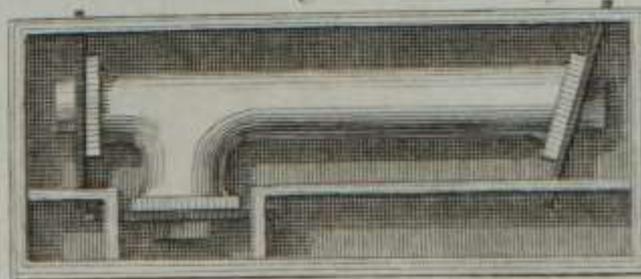


Fig. 24.

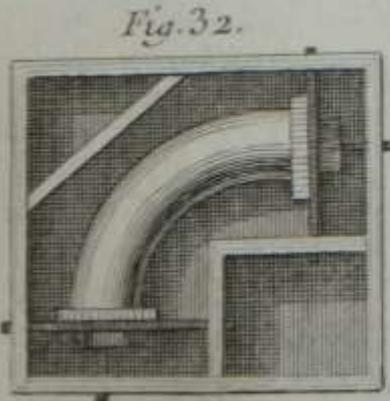


Fig. 32.

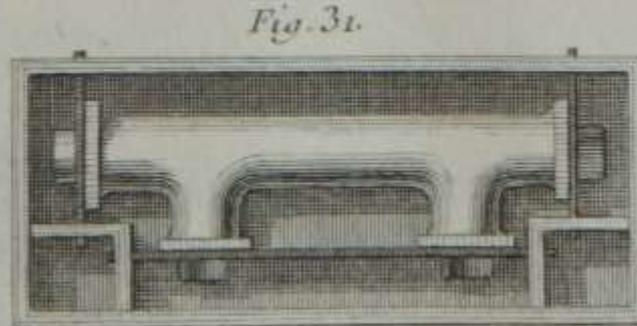


Fig. 31.

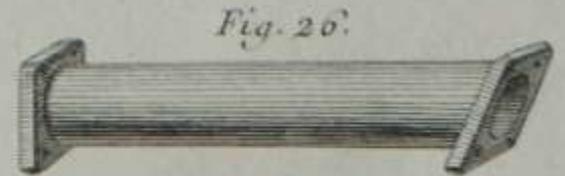


Fig. 26.

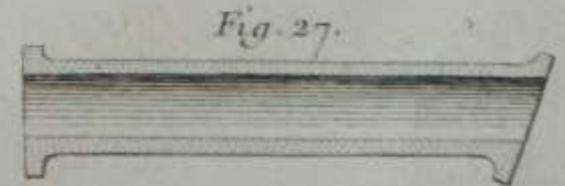
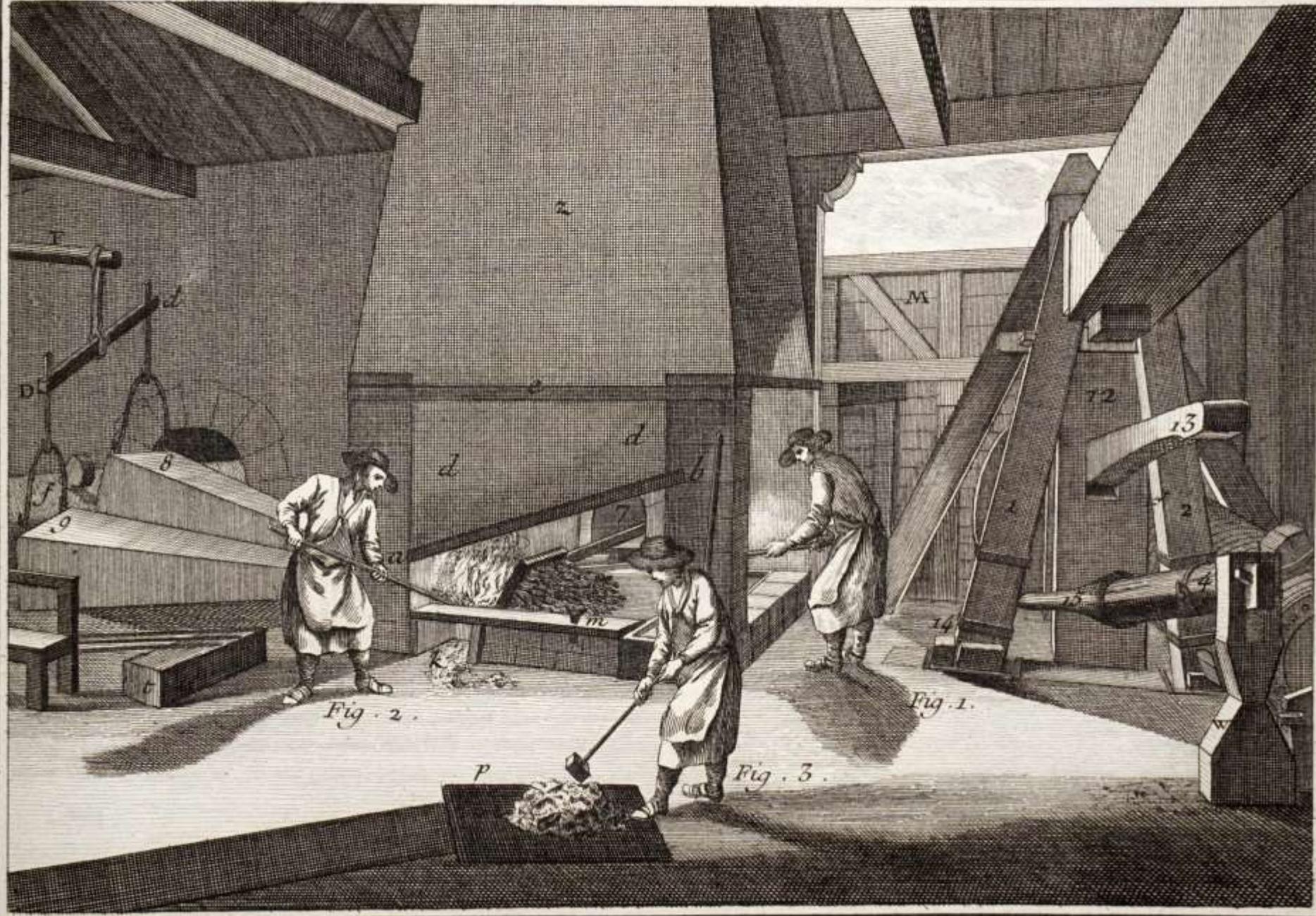


Fig. 27.

Typische Gusseisen-Produkte des 18. Jahrhunderts: Rohre
(Courtivron/Bouchu 1762)



Frischherd des 18. Jahrhunderts: aus Roheisen wird schmiedbarer Stahl („Schmiedeeisen“)
(Encyclopédie 1765)



Typische Schmiedeeisenprodukte: Nägel des 15.-18. Jh.

Industrialisierung der Eisenproduktion

- 1705 Innovationsschritt Kohlenkoks statt Holzkohle
- 1784 Innovationsschritt „Puddeln“ statt Frischherd

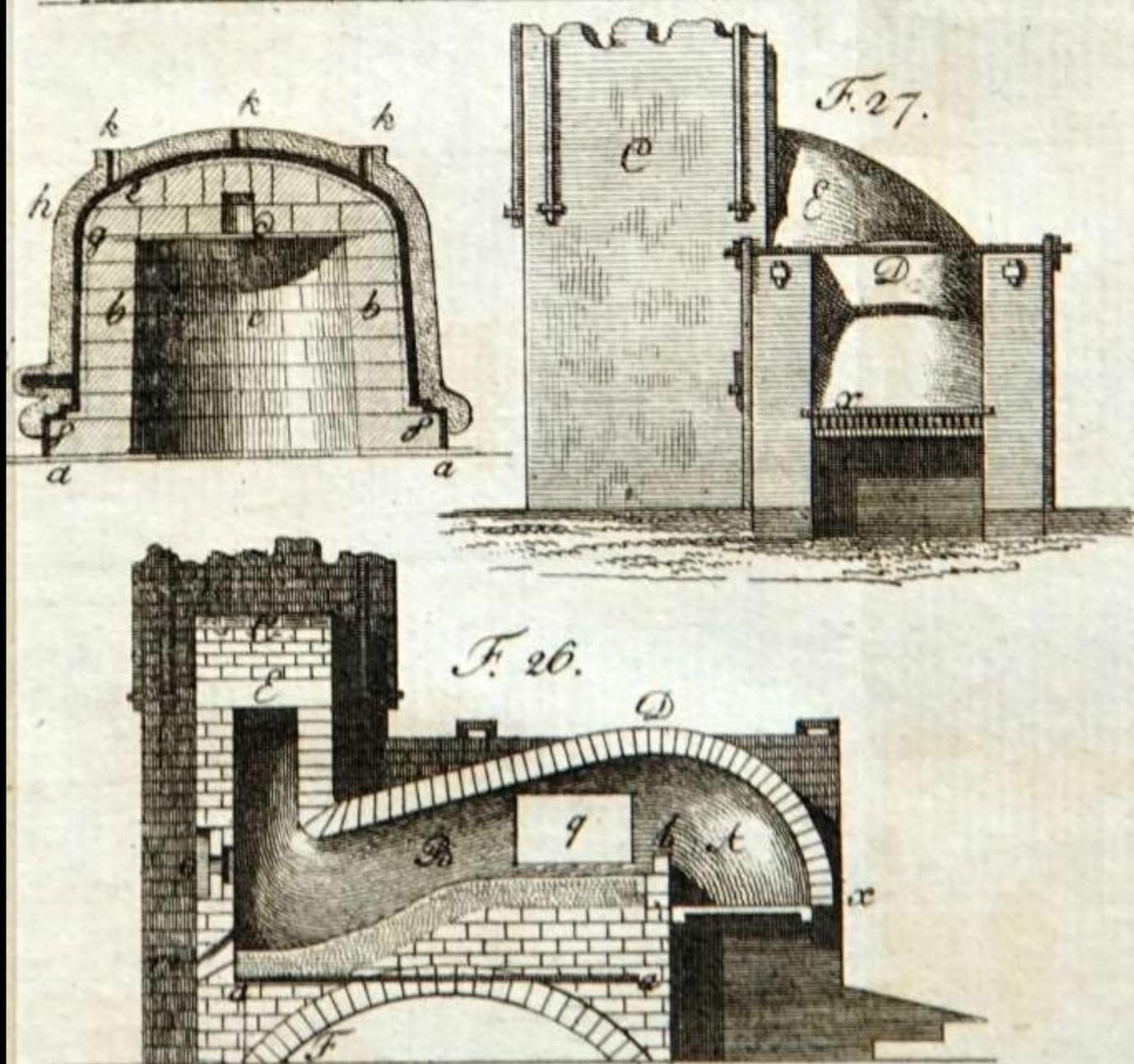


*A VIEW of the Upper Works at Coalbrook-Dale, in the County of Shropshire.
Designed and Published by G. Perry and S. A. P. O. P. T. Smith 1728, according to Act of Parliament.*

Roheisenproduktion mit *Koks* im Hochofen (Abraham Darby I, ab 1705)
(Francis Vivares, A View of the Upper Works at Coalbrook-Dale, Kupferstich, 1758)



Coalbrookdale (Shropshire) um 1800, hier wird 1784 durch Henry Cort das „Puddeln“ erfunden (Ph. J. Lutherbourg, *Coalbrookdale at Night*, 1801; London Science Museum, CC-BY-NC-SA 4.0)



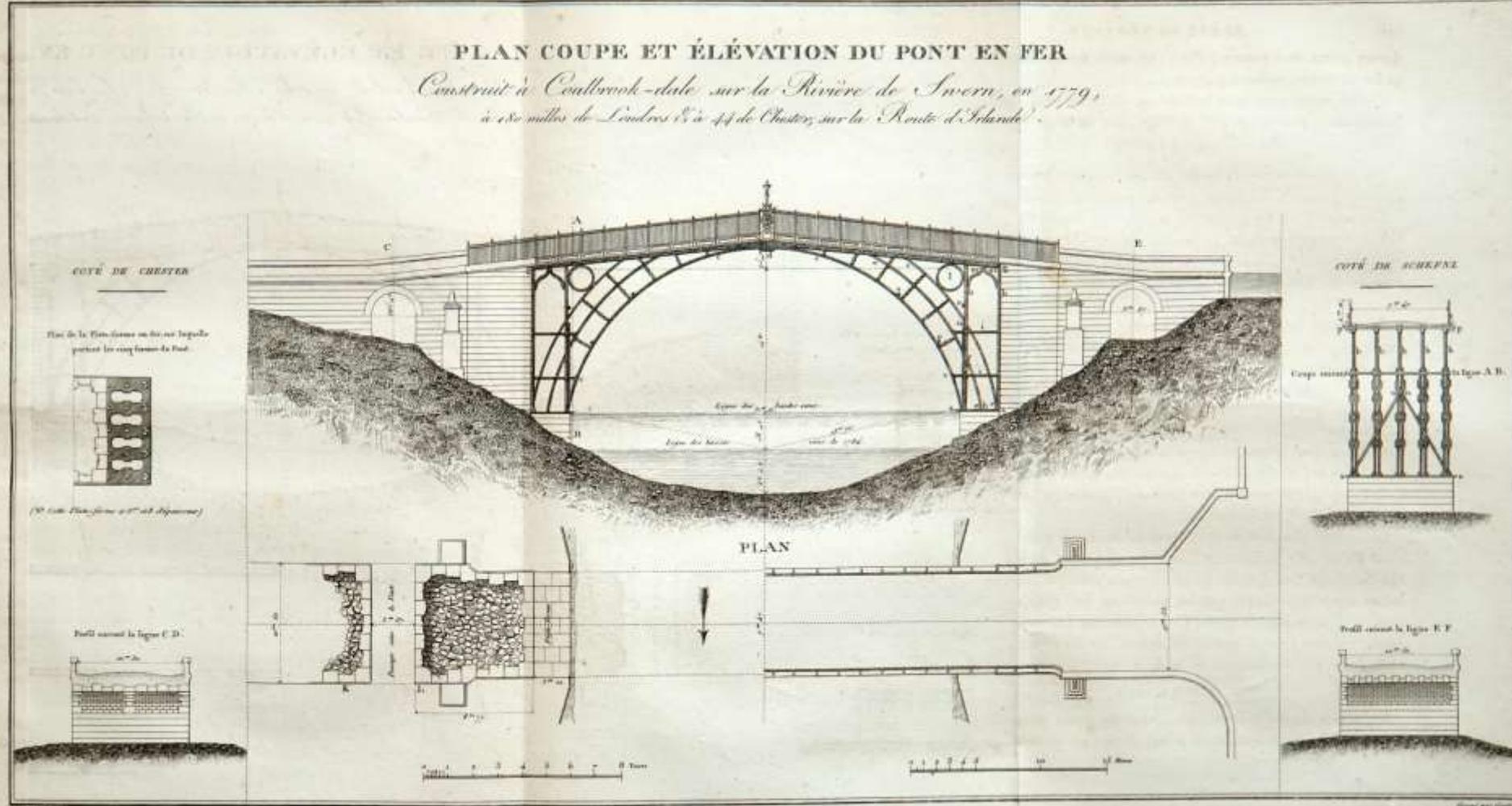
Puddlings-Flammofen: Frischen unter kontrollierten Bedingungen
(Karsten 1816)

England

Bauen mit *Gusseisen*: von der Bogenbrücke zur Industriehalle

PLAN COUPE ET ÉLÉVATION DU PONT EN FER

*Construit à Coalbrook-dale sur la Rivière de Severn, en 1779,
à 80 milles de Londres & à 44 de Chester, sur la Route d'Étandre.*

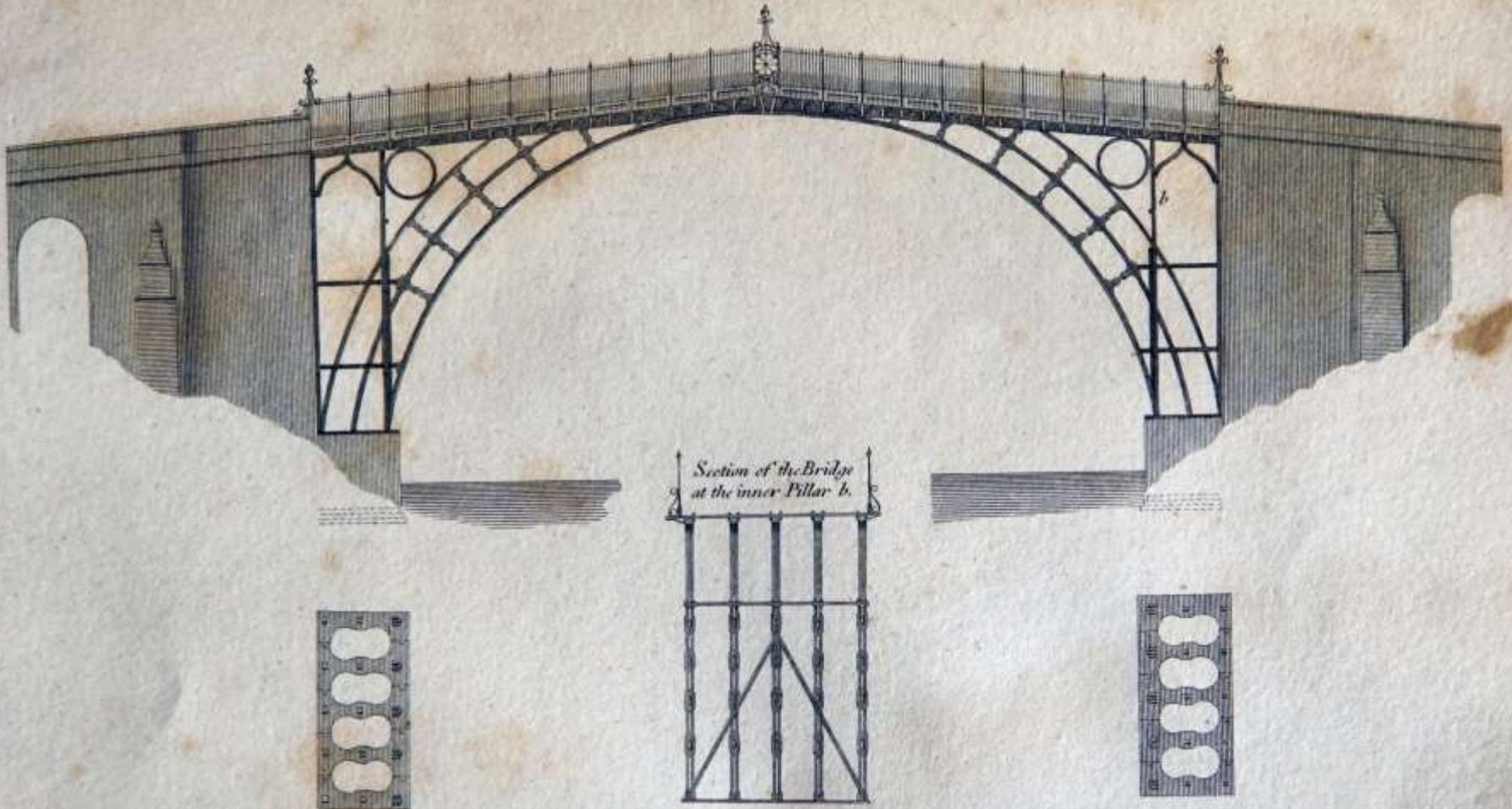


Abraham Darby III, Gusseisen-Brücke über den Severn in Coalbrookdale, 1779
(Lesage 1810)

BRIDGE.

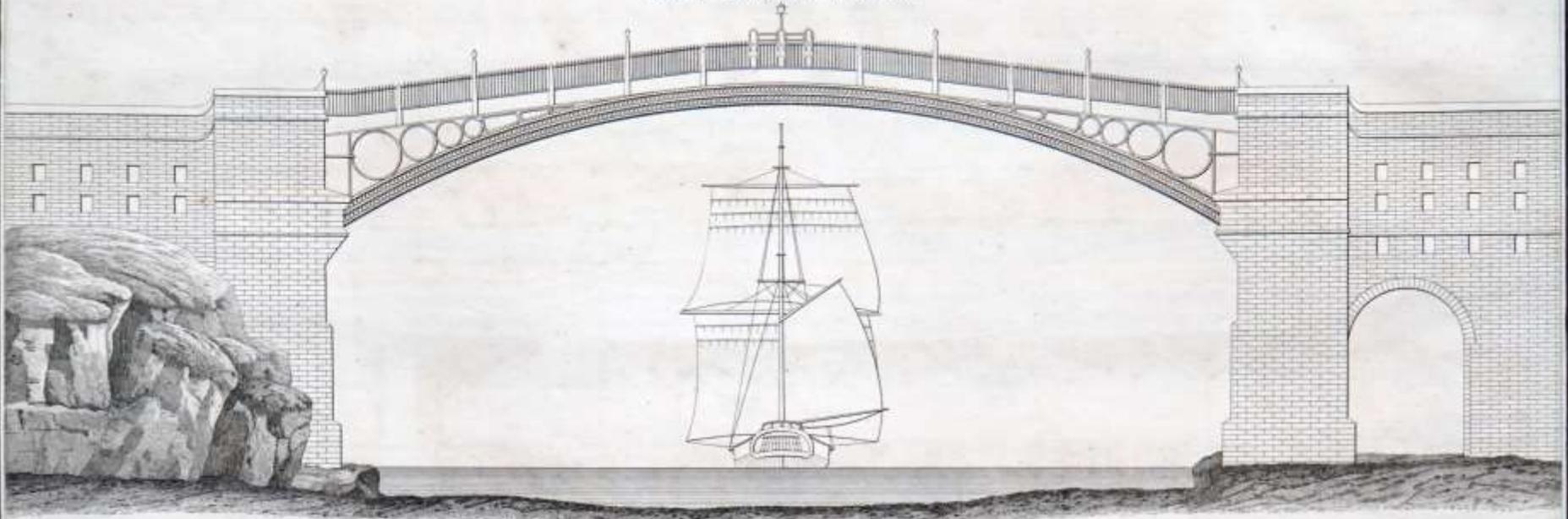
PLATE XCI.

PLAN ELEVATION and SECTION of the FIRST IRON BRIDGE built over the RIVER SEVERN near COALBROOK DALE in the COUNTY of SALOP.



Abraham Darby III, Gusseisen-Brücke über den Severn in Coalbrookdale, 1779
(Telford, Edinburgh Encyclopedia, 1835)

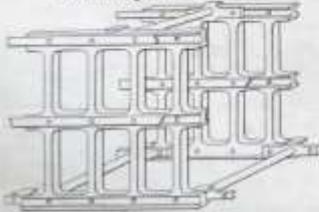
Pont de Sunderland sur le Wear.



Pont de Sunderland.
(Coupe à la Clef.)



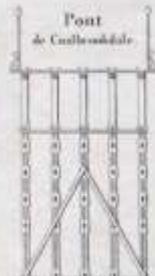
Assemblage des Fermes.



Pont de Coalbrookdale.



Pont
de Coalbrookdale.



Elevation



Plan.

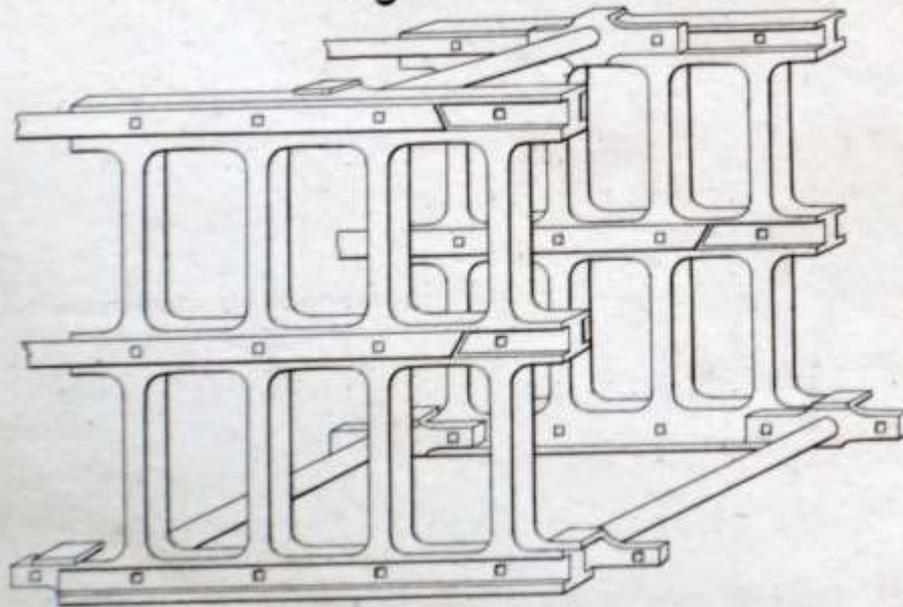
Sunderland, Gusseisen-Brücke über den Wearmouth (Thomas Paine, 1796)
(Dupin 1824)

Pont de Sunderland.

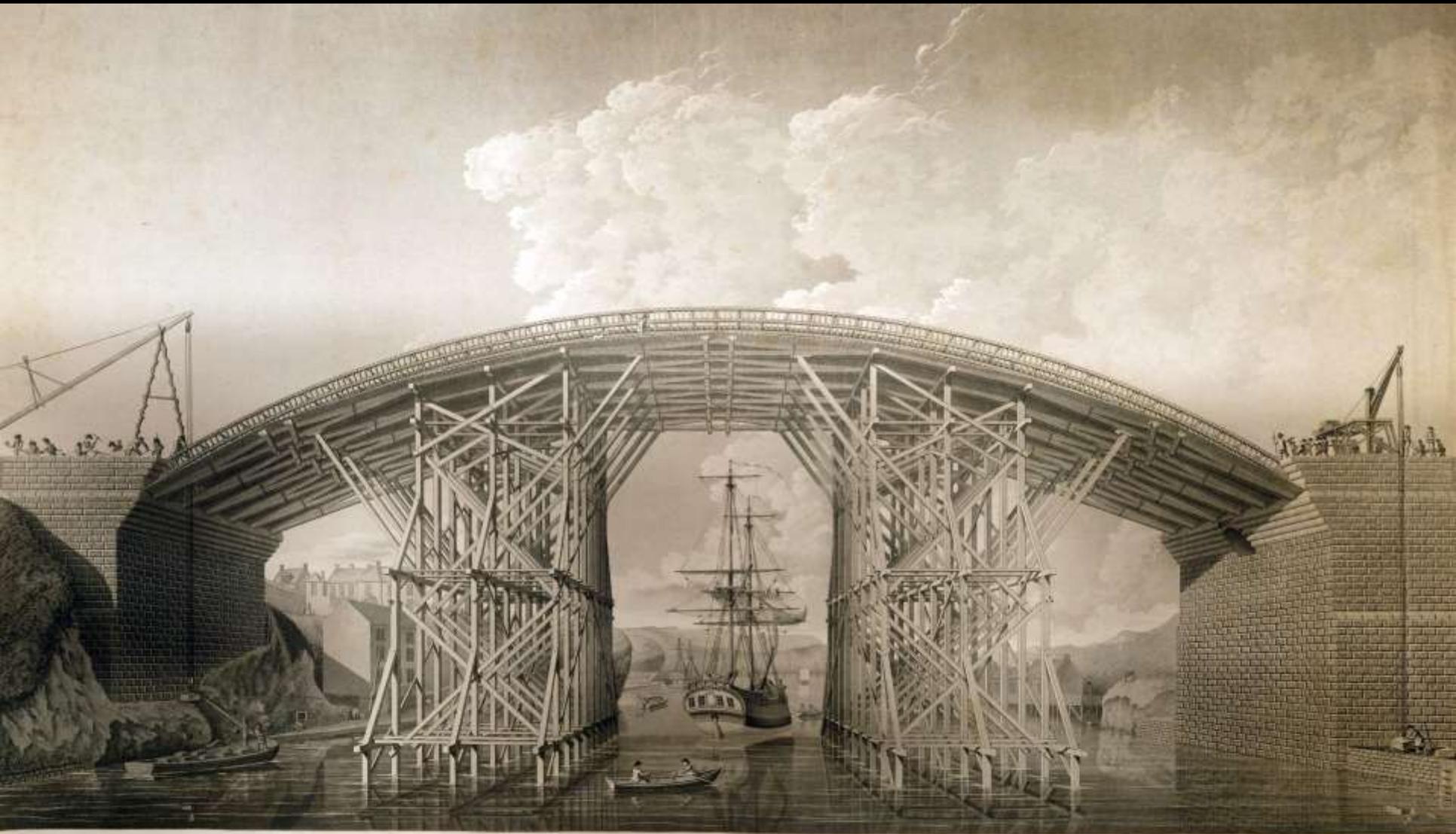
(Coupe à la Clef.)



Assemblage des Fermes.



Sunderland, Brücke über den Wearmouth (1796), Detail der Gusseisen-“Keilsteine“
(Dupin 1824)



To Rowland Burchell Esq. M.P. by whom this Excellent piece
of Mechanism was invented, under whose Patronage it has been carried into Execution
This East View of the CAST IRON BRIDGE over the RIVER WEAR at
Sunderland in the County of DURHAM, previous to the Contracting being taken down.
Is respectfully dedicated by His humble Servant Robert Clarke.

Sunderland, Gusseisen-Brücke über den Wearmouth (Thomas Paine, 1796)
Montage der Brücke auf einem Lehrgerüst (Stich von J. Raffield)



Bath, Gusseisen-Brücke in den Sydney House Gardens (1800)



Bath, Gusseisen-Brücke in den Sydney House Gardens (1800)



Bath, Gusseisen-Brücke in den Sydney House Gardens (1800)
Verbindung der Gussteile im Scheitel



Chepstow, Gusseisen-Brücke über den Wye (1816)



Chepstow, Gusseisen-Brücke über den Wye (1816)



Tewkesbury, Mythe Bridge über den Severn (Thomas Telford, 1826)



Tewkesbury, Mythe Bridge über den Severn (Thomas Telford, 1826)



Tewkesbury, Mythe Bridge über den Severn (Thomas Telford, 1826)



Giesshalle der Sayner Hütte bei Koblenz, Deutschland (1826-30)



Giesshalle der Sayner Hütte bei Koblenz, Deutschland (1826-30)



Giesshalle der Sayner Hütte bei Koblenz, Deutschland (1826-30)



Giesshalle der Sayner Hütte bei Koblenz, Deutschland (1826-30)



Giesshalle der Sayner Hütte bei Koblenz, Deutschland (1826-30)

A

PRACTICAL ESSAY

ON THE

STRENGTH OF CAST IRON,

INTENDED FOR THE ASSISTANCE OF

ENGINEERS, IRON MASTERS, ARCHITECTS, MILLWRIGHTS,
FOUNDERS, SMITHS, AND OTHERS ENGAGED IN THE
CONSTRUCTION OF MACHINES, BUILDINGS, &c.

CONTAINING

PRACTICAL RULES, TABLES, AND EXAMPLES;

ALSO AN ACCOUNT OF SOME

NEW EXPERIMENTS,

With an Extensive Table of the

PROPERTIES OF MATERIALS.

ILLUSTRATED BY FOUR ENGRAVINGS.

BY **THOMAS TREDGOLD,**

CIVIL ENGINEER;

MEMBER OF THE INSTITUTION OF CIVIL ENGINEERS;
AUTHOR OF ELEMENTARY PRINCIPLES OF CARPENTRY; THE
ARTICLE JOINERY IN THE SUPPLEMENT TO THE
ENCYCLOPEDIA BRITANNICA, &c.

—“ The same Truth, which is a Principle in science, becomes a
Rule in art.” *Playfair.*

Taf.

London:

PRINTED FOR J. TAYLOR,
AT THE ARCHITECTURAL LIBRARY, 59, HIGH HOLBORN.

1822.

MEMOIRS

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LITERARY

AND

PHILOSOPHICAL SOCIETY

OF

MANCHESTER.

Second Series.

VOLUME V.

London:

PRINTED FOR BALDWIN AND CRADOCK,

BY HENRY SMITH, 20, ST. ANNE'S-SQUARE, MANCHESTER.

1831.



THEORETICAL
AND
EXPERIMENTAL RESEARCHES

TO ASCERTAIN THE

STRENGTH AND BEST FORMS

OF

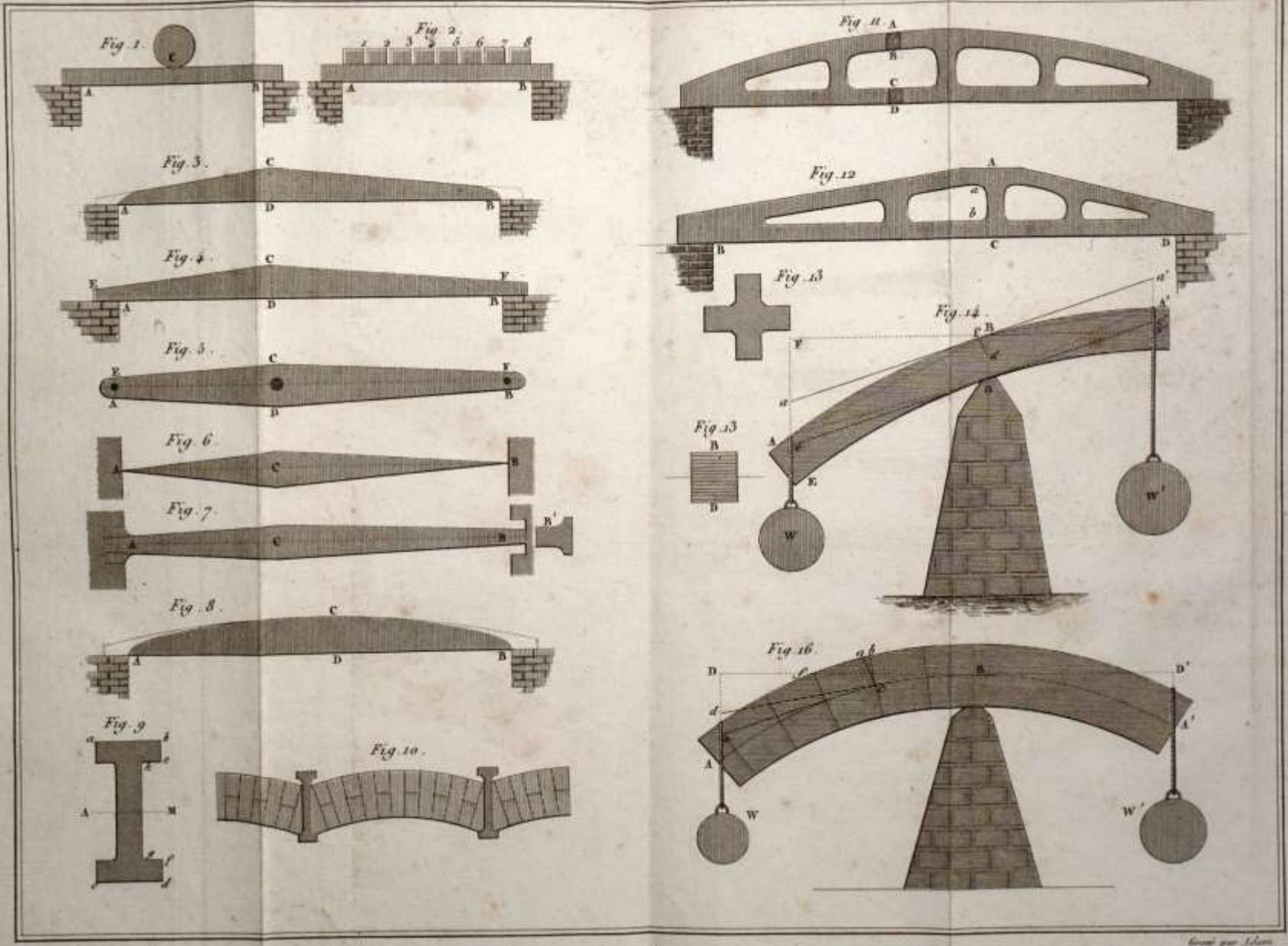
IRON BEAMS.

BY MR. EATON HODGKINSON.

(Read April 30th, 1836.)

THE very frequent use of iron beams for supporting the floors of factories, and of other places crowded with people, renders it extremely desirable that the best information should be obtained with respect to the strength of this material, in order to insure, without a great superfluity of metal, the requisite stability. In a case so deeply involving the loss of life, and where a failure would be attended with such serious consequences, hardly too much research can be applied. The scientific character of the subject also imparts to it additional

Grenzen des Gusseisens und die Suche nach der besten Form
(Tredgold 1822 und Hodgkinson 1831)



Günstige Formen gusseiserner biegebeanspruchter Träger (Tredgold 1822/26)

I. EXPERIMENT.

Beam with equal rib at top and bottom.
Dist. between supports, 4ft. 6ins. Depth of beam, 5½ins.

Dimensions of cross section, at place of fracture, in inches and parts.

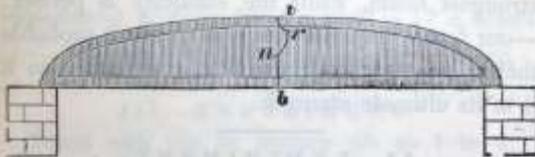
Area of top rib = $1.75 \times .42 = .735$
Area of bottom rib = $1.77 \times .39 = .690$
Thickness of vertical part, between the ribs, } = .29.



Area of above section = 2.82 inches.

Weight of Casting = 36½ lbs.

Breaking weight 6678lbs. = 59 cwt. 70 lbs.



The form of fracture is represented by the line bnr , where $tr = .6$, and $bn = 2.5$, the figure being a side view of the beam.

To find the strength per inch of cross section, we have, dividing the breaking weight by the area, $\frac{6678}{2.82} = 2368$ lbs. per inch. This quantity in each

* All the sections in these experiments are laid down of 1 their real lineal dimensions in order to afford ocular comparison.

Breaking weight = 7368lbs. = 65 Cwt. 88lbs.
It broke obliquely about 4 inches from the middle, the top inclining to it.

The form of fracture at the top of the beam was nearly the same as in Experiment 1; here $tr = .55$ inches: see second figure to that experiment.

To find the strength per inch of section, as in the last experiment, we have $\frac{7368}{2.87} = 2567$ lbs. per inch.

Comparing this as above with the result of experiment 4, gives $2584 - 2567 = 17 =$ defect.
∴ Loss in strength = $\frac{17}{2584} = .0066$ or $\frac{1}{152}$.

III. EXPERIMENT.*

Beam with top to bottom rib as 1 to 4.
Dist. between supports, 4ft. 6ins. Depth of beam, 5½ins.

Dimensions of cross section in inches.

Area of top rib = $1.07 \times .30 = .32$
Area of bottom rib = $2.1 \times .57 = 1.2$
Thickness of } = .32.
vertical part. }

Area of cross section = 3.02.

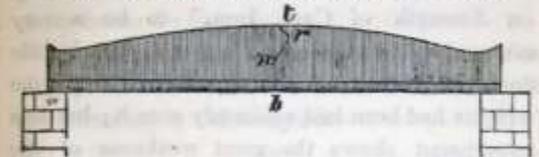
Weight of casting = 40 lbs.



* At the preceding experiments and at several of the latter ones, Mr. John Kennedy was present, as well as Mr. Ewart who attended them generally.

The beam twisted a little before breaking: this however was not usually the case in the other beams from the same model.

Form of fracture as in figure, $tr = .75$.



Hence strength per inch of section = $\frac{6970}{3.2} = 2584$ lbs.

V. EXPERIMENT.

This casting had its top rib a parabolic arch and the top and bottom ribs nearly equal in section, with equidistant ordinates only between them.

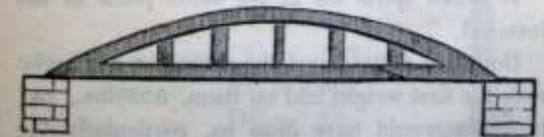
Dist. between supports and depth of beam as before.

Dimensions of ribs in inches.

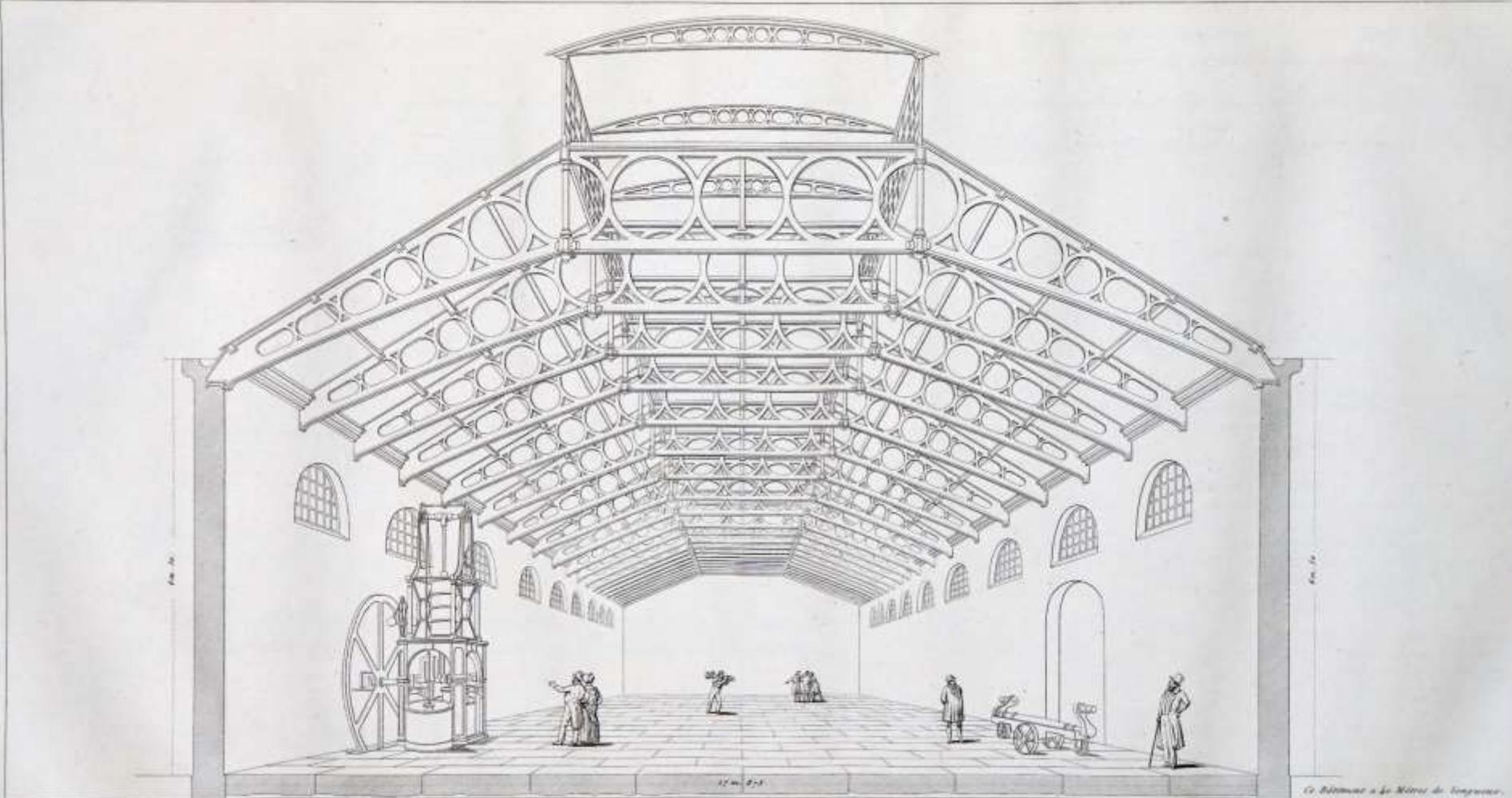
Area of top rib = $2.2 \times .56 = 1.23$
Area of bottom rib = $2.2 \times .53 = 1.17$.

Weight of casting = 41½ lbs.

Breaking weight = 5528lbs. or less: see next expt. This weight however is but $\frac{2}{3}$ of what was borne by the common beam in the last experiment.



It broke by separating, near the first ordinate,



Pl. 29. Eck. Architekt.

La Charpente de ce Comble est en fonte de fer.

Ce Bâtime a 40 Mètres de longueur.

M. Eck.

Fabrikhalle von Henry Maudslay mit Gusseisendach, um 1825 (Eck 1836)

Fazit Gusseisen

- Wegen der Materialeigenschaften Anlehnung an Steinkonstruktion (Bogentragwerke)
 - Keine echte Revolution des Bauwesens

Kontinent

Bauen mit Schmiedeeisen hinter klassizistischer Fassade

Feuersicheres Bauen in Paris – Eisengerippe und Tontöpfe
1784–1827



Vielleicht der erste Versuchsbau der feuersicheren Bauweise mit Eisenskelett und Tontöpfen:
Paris, Théâtre du Palais Royal, um 1784



Vielleicht der erste Versuchsbau der feuersicheren Bauweise mit Eisenskelett und Tontöpfen:
Paris, Théâtre du Palais Royal, um 1784



Vielleicht der erste Versuchsbau der feuersicheren Bauweise mit Eisenskelett und Tontöpfen:
Théâtre du Palais Royal, um 1784

- A. Girelle en bois de charnière.
- B. Tige en fer.
- C. Arbre en fonte (1^r morceau.)
- D. Table en bois.
- E. Arbre en fonte (2^e morceau.)
- F. Pivot en fer.
- G. Caillou avec excavation naturelle pour loger le Pivot F.
- I. Plâtre en ciment.
- K. Banc de l'Ouvrier.
- L. Etabli du Tourneur.
- M. Marchepied.
- N. Vase rempli d'eau.
- O. Fers-balaise.
- P. Régulateur.
- Q. Balaise très-souple.
- R. Sigadon.
- T. Estec avec lame de scie.
- V. Fil de laiton pour enlever le pot creux de dans la girelle.
- X. Serpette.
- Y. Plateau en fer.
- Z. Pot creux ébauché.

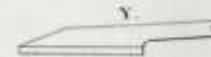
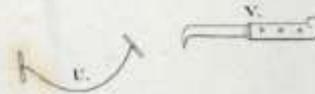
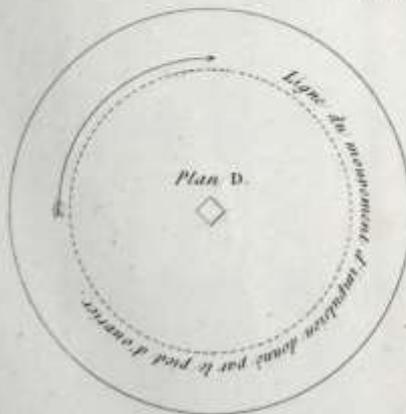
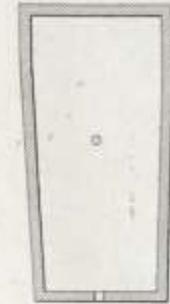
fig. 1.



Ouvrier tournant un Pot creux.

fig. 2.

Coupe d'un Pot creux prêt à être mis au four.



Echelle de

2 Mètres.

Ce Poitrail supporte tout un Mur de refend de 20 Mètres de hauteur sur 6 m. 40 c. de largeur, d'un poids total de 66200^k.

Élévation.

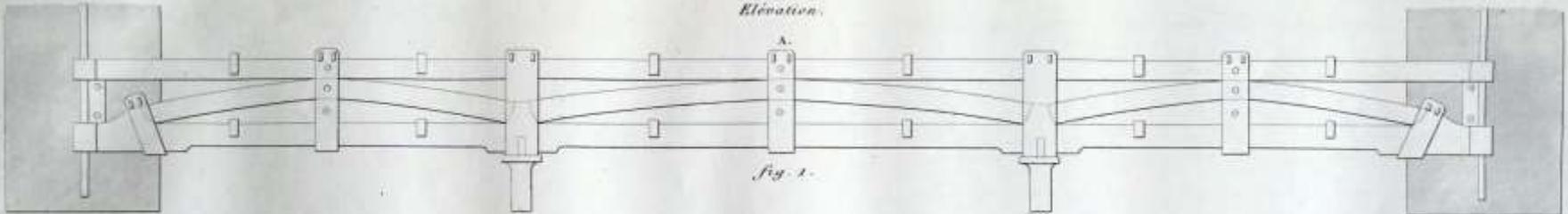
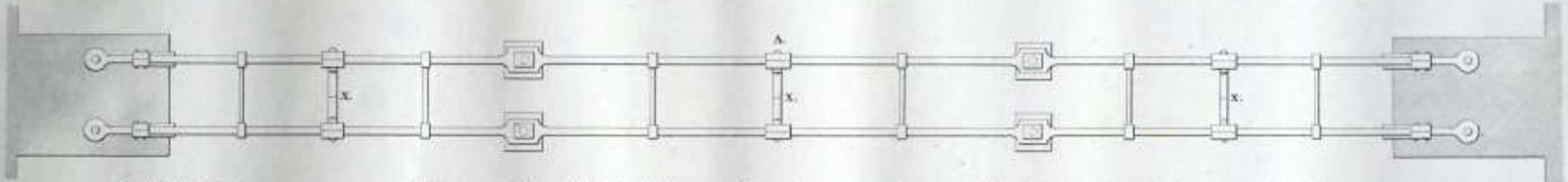


fig. 1.

(Nota.) L'Intervalle entre les deux fermes accolées est banché en briques et plâtre.

Plan.



(Maison particulière. M^r Callet, Architecte.) Deux fermes en fer accolées formant poitrail, dont une fait chaîne.

Élévation.

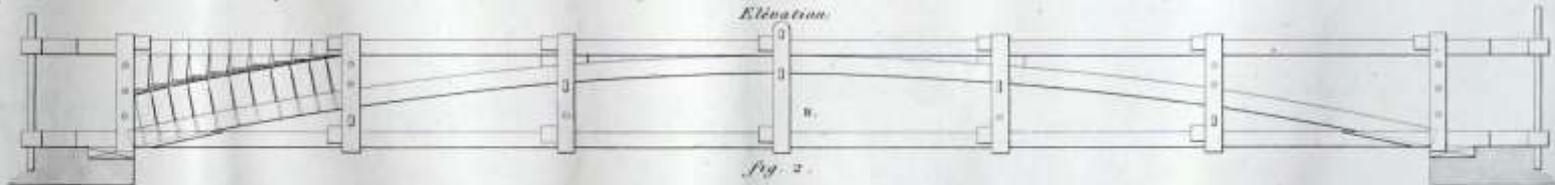
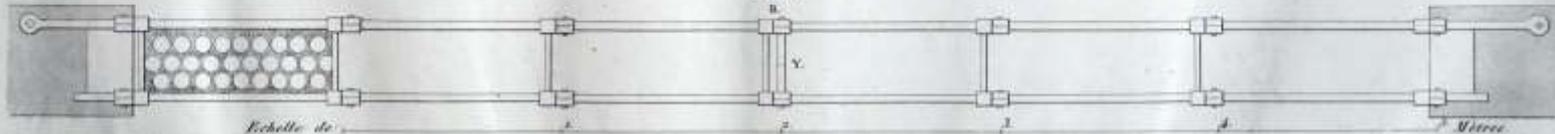


fig. 2.

Plan.



A. Ferronnerie par M^r Roussel.

B. Ferronnerie par M^r Letare.

Blanc 26

Feuersicheres Bauen mit Bandeisen und Eisenstäben

Das Kombinationssystem „Hohlkörper“ + „Eisengerippe“ = sogenannter „Pariser Rost“ nach Angot 1782

(Eck 1839)

Traité de plancher en fer et poteries.

Coupe sur AB.

Ligne supérieure de la Chappe.

fig. 2.

Plan d'une trevise de plancher en fer et poteries.

*Coupe sur la ligne CD.
Ligne supérieure de la Chappe.*

*Coupe d'une Voûte (plein Centre)
bandée en poteries et plâtre (sans fer)*

fig. 1.

fig. 3.

*Coupe de pots creux assemblés et coiffonnés de manière
à servir de Carreaux pour la partie supérieure d'un plancher.*

Echelle de 0 1 2 3 4 Mètres.

*(Nota: Les Carreaux en fer, dans les systèmes de Voûtes autres qu'à plein centre exigent
une portion d'éclaircissement analogue à celle généralement nécessaire aux planchers,
elles doivent donc être noyés dans l'épaisseur de la construction en poteries.)*

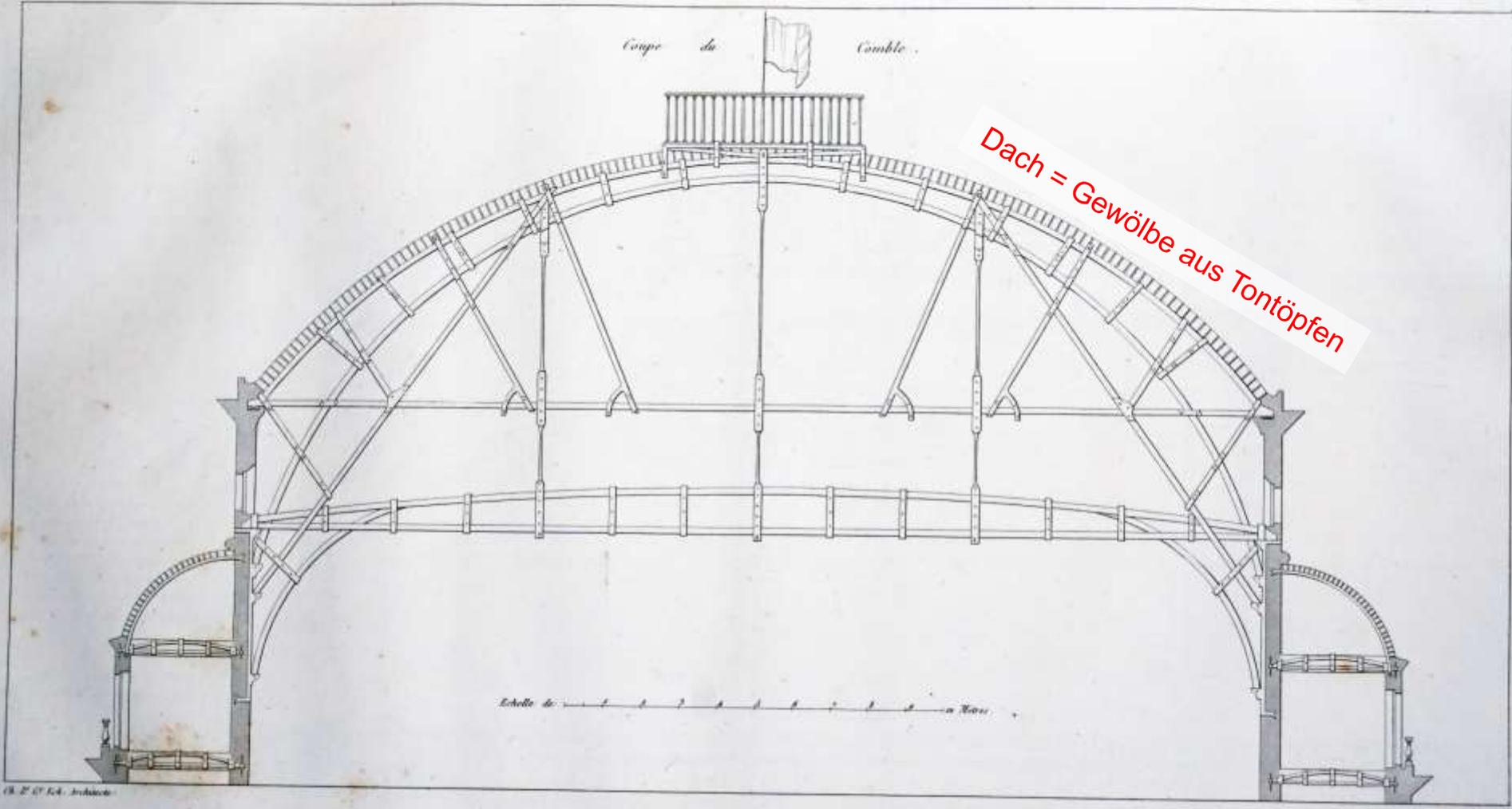
Construction par M^r Lemaire (Nicolas)

Pl. 5

Feuersicheres Bauen mit Bandeisen und Eisenstäben
Das Kombinationssystem „Hohlkörper“ + „Eisengerippe“ = sogenannter „Pariser Rost“ nach Angot 1782
(Eck 1839)



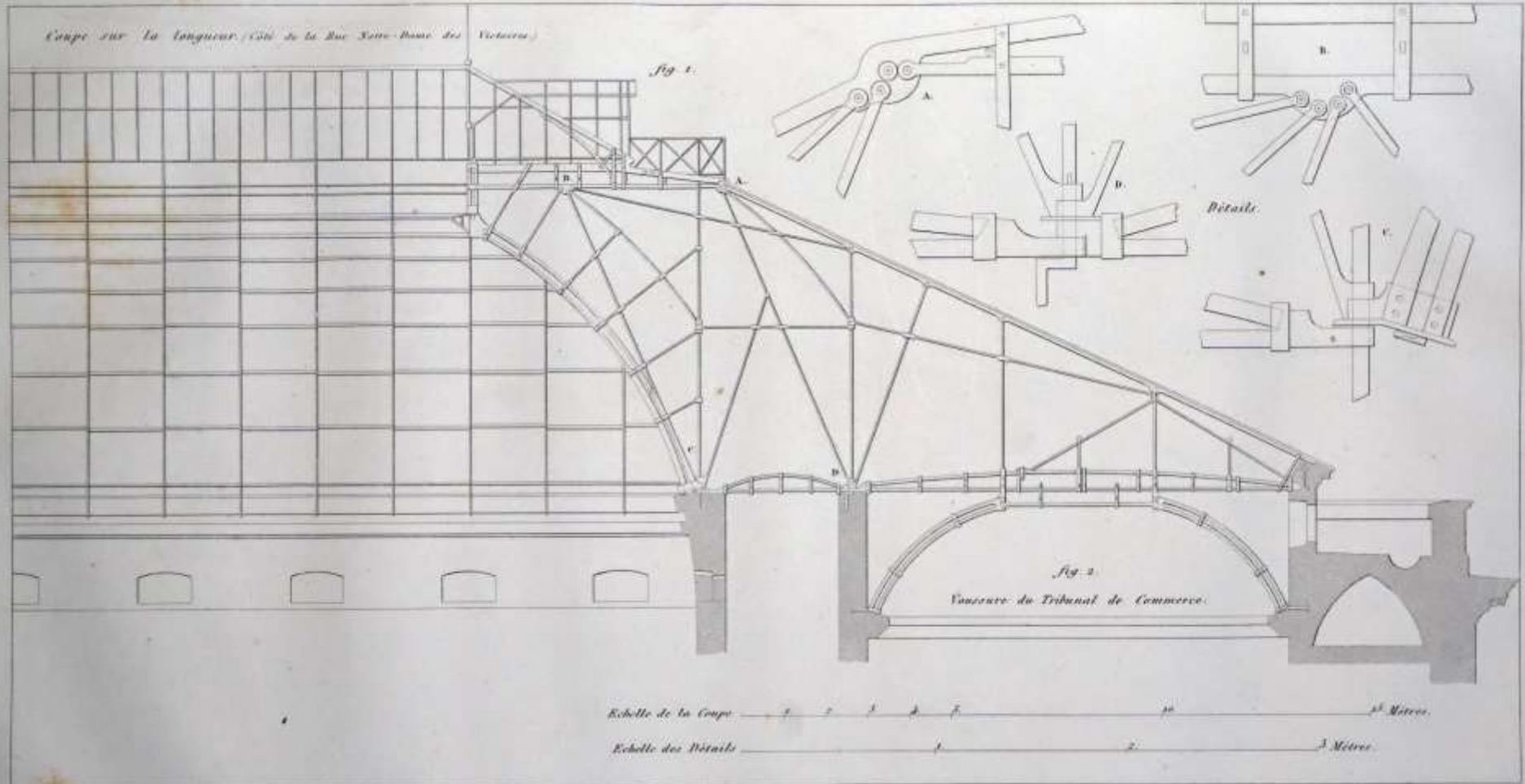
Hubert Robert, Brand des Opernhauses im Palais Royal, 1781 (Paris, Musée Carnavalet)



Paris, Wiederaufbau des Théâtre Français im Palais Royal (Victor Louis, 1786)
(Eck 1836)



Paris, Börse (Brongniart und Labarre, 1821-27)

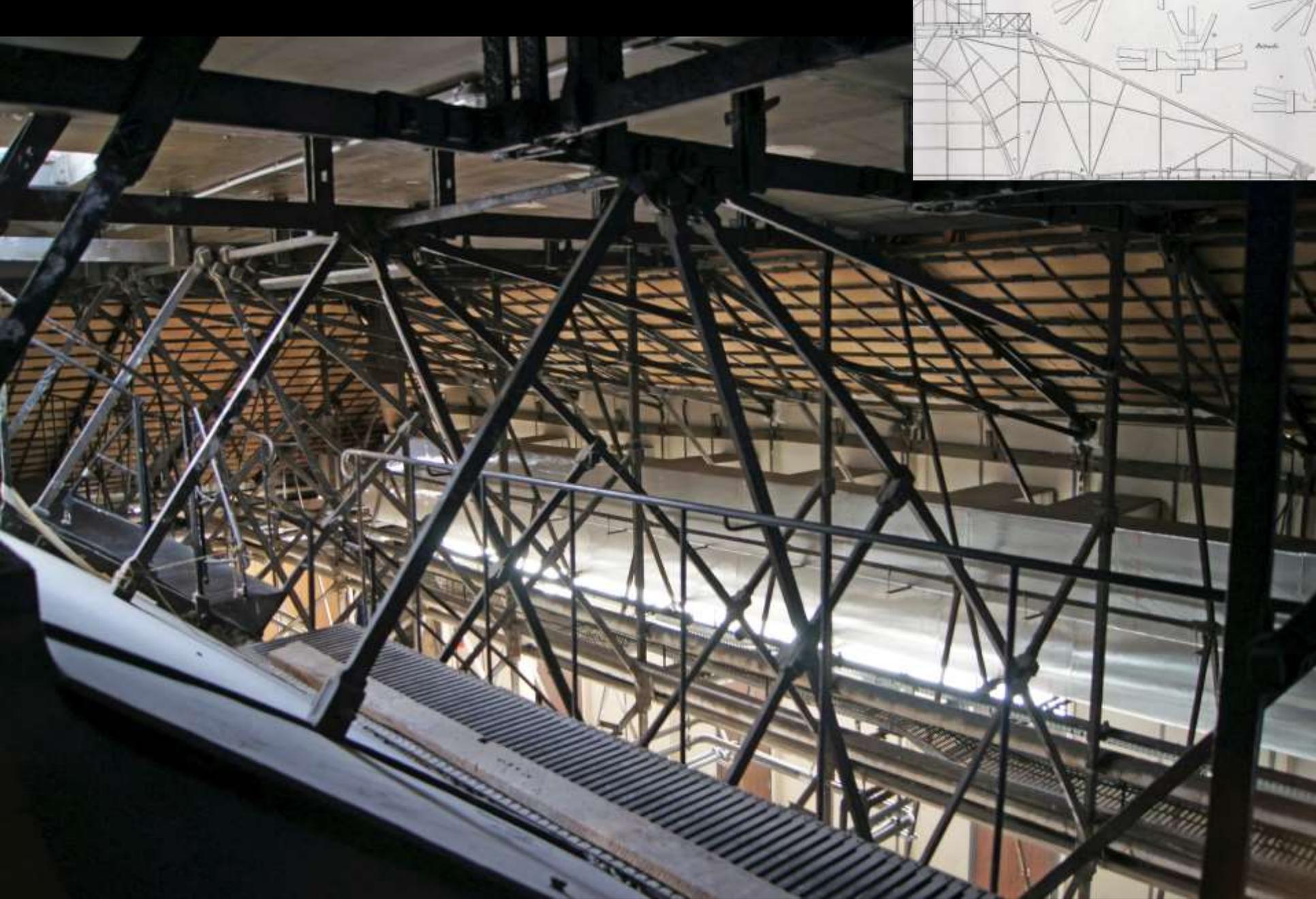


Ch. L. G. Ed. de l'Imprimerie

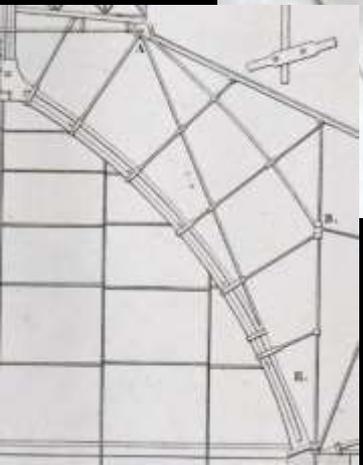
Ferronnerie par M^r Albouy

Albouy

Paris, Dachkonstruktion der Börse (1821-27)
(Eck 1836)



Paris, Dachkonstruktion der Börse (1821-27)
Dachkonstruktion



Paris, Dachkonstruktion der Börse (1821-27)
Detail der radialen Streben



Paris, Dachkonstruktion der Börse (1821-27)
Anschlussdetail mit Quadratmuttern und Montagemarkierungen



Paris, Dachkonstruktion der Börse (1821-27)
Anschlussdetail mit Quadratmuttern und Montagemarkierungen



Paris, Dachkonstruktion der Börse (1821-27)
Anschlussdetails der „Speichen“



Paris, Dachkonstruktion der Börse (1821-27)
Kuppelschale aus Tonhohlkörpern



Walhalla bei Regensburg
(Leo v. Klenze 1836-40)



Walhalla bei Regensburg: Innenraum der Cella
(Leo v. Klenze 1836-40)



Walhalla bei Regensburg: Dachwerk über dem „Adyton“: eisernes „Bogenhängewerk“
(Leo v. Klenze und „Mechanicus Manhard“ 1836-40)



Walhalla bei Regensburg: Dachwerk über dem „Adyton“
(Leo v. Klenze und „Mechanicus Manhard“ 1836-40)



Walhalla bei Regensburg: Dachwerk über dem „Adyton“: Auflager des Bogentragwerks
(Leo v. Klenze und „Mechanicus Manhard“ 1836-40)

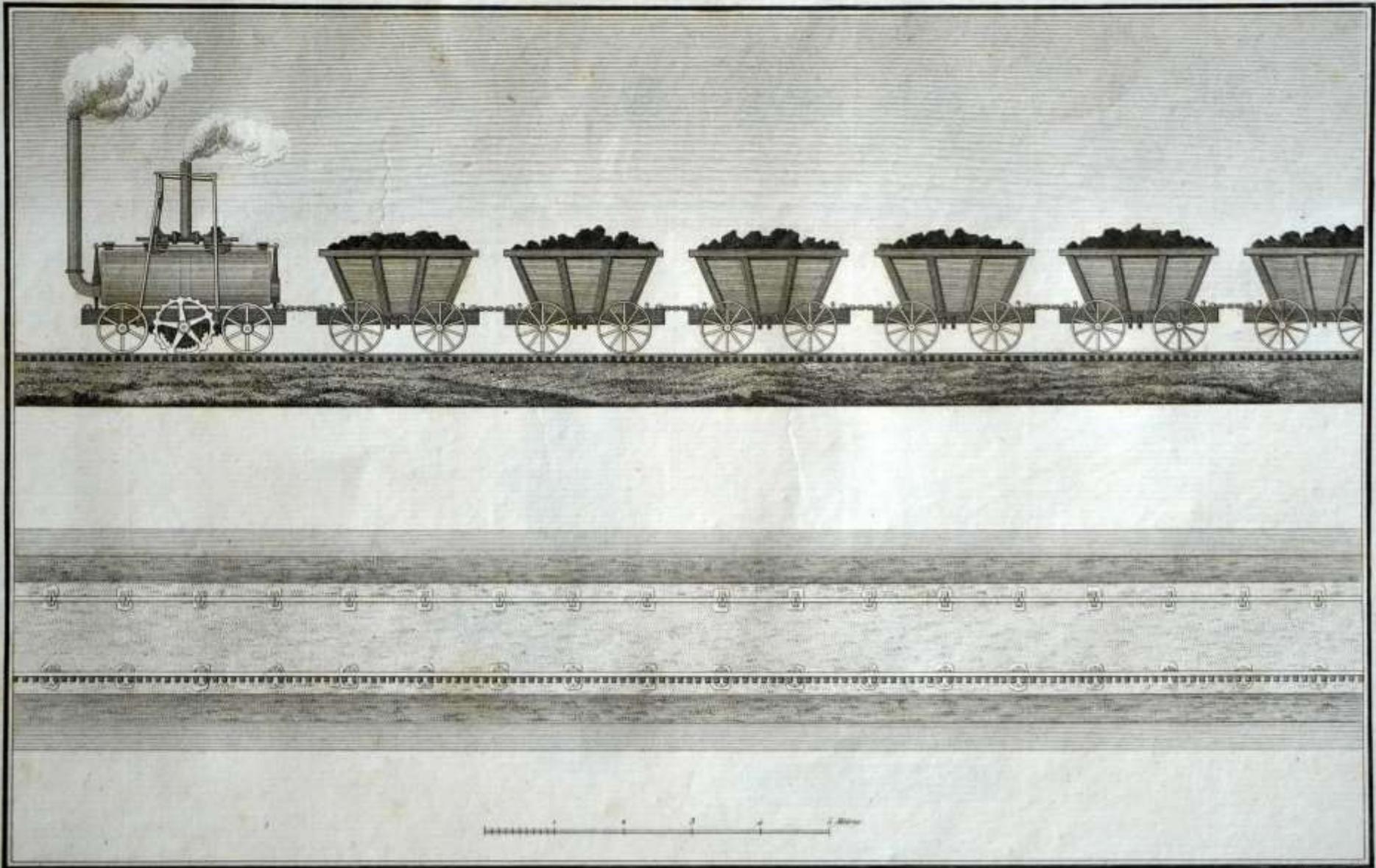


Walhalla bei Regensburg, „Adyton“: Anschlussdetail mit Keil und Gegenkeil, „Abbundmarken“
(Leo v. Klenze und „Mechanicus Manhard“ 1836-40)

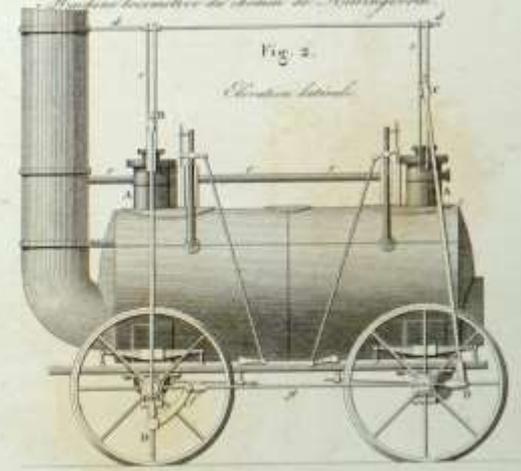
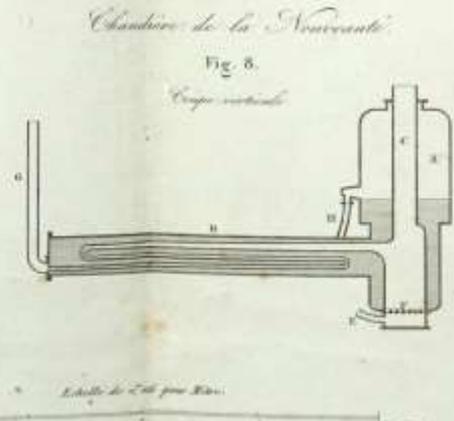
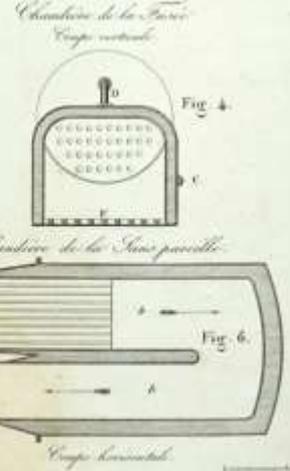
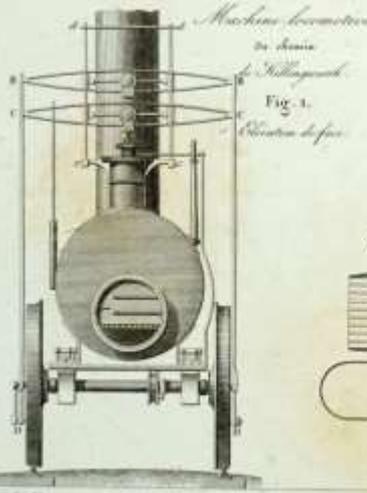
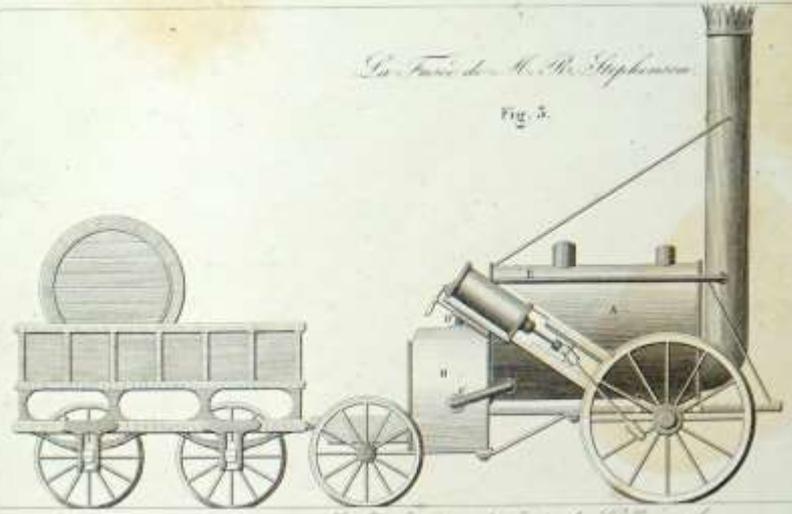
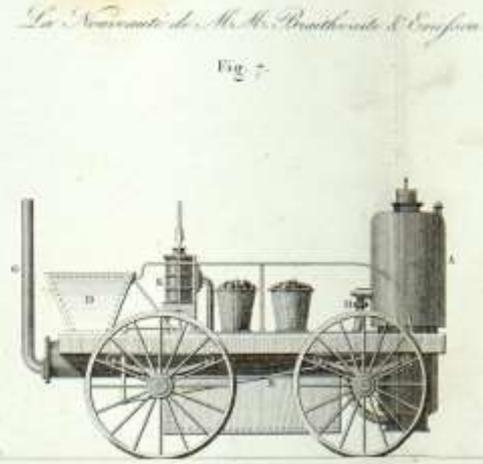
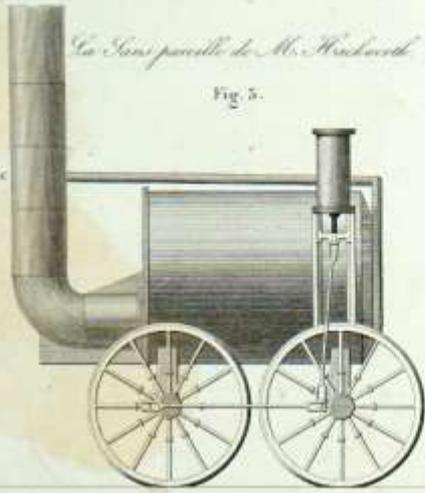


Walhalla bei Regensburg, Dachwerk über dem „Adyton“: abgehängte Eisen-Draht-Putz-Decke
(Leo v. Klenze und „Mechanicus Manhard“ 1836-40)

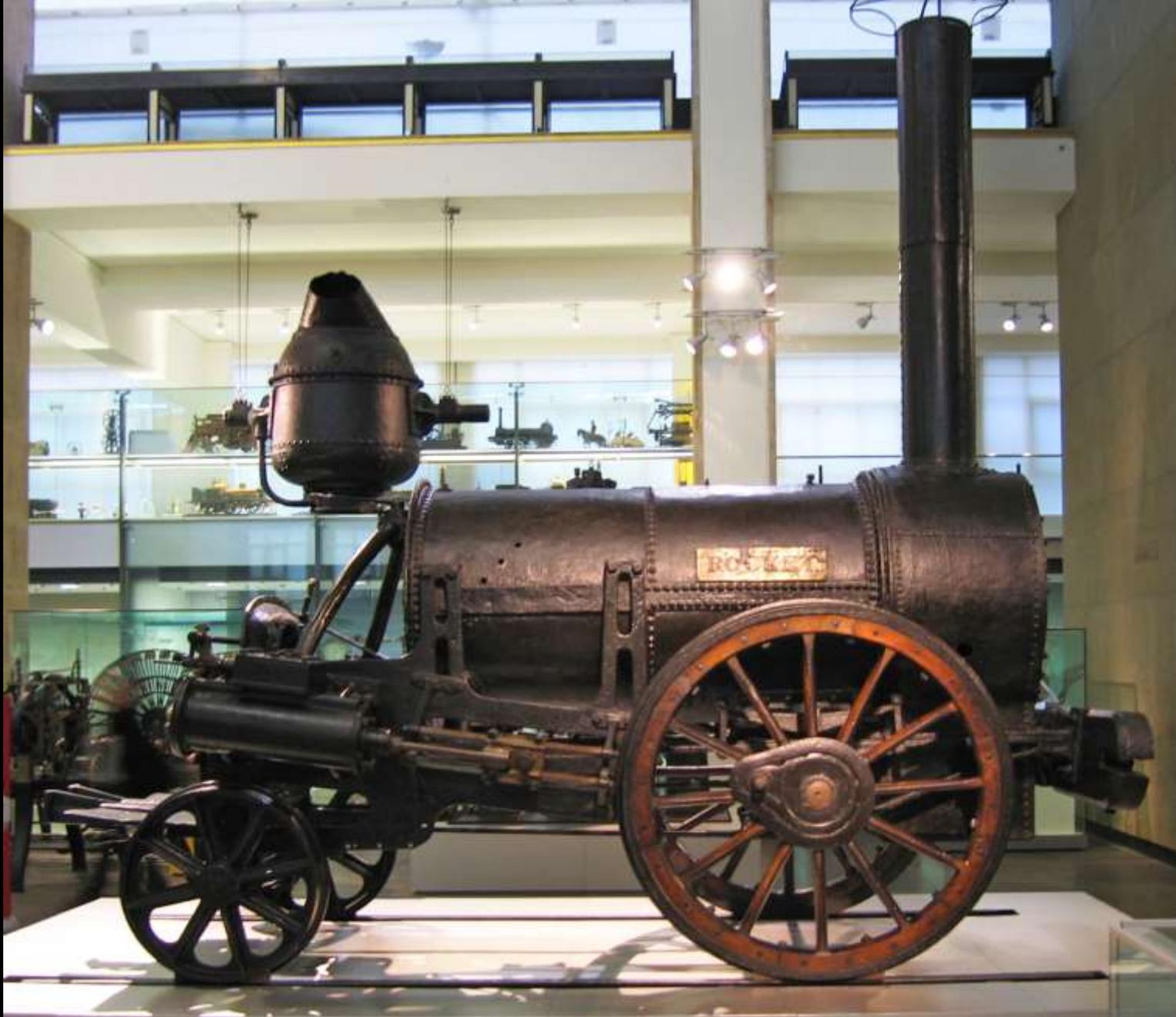
Die Eisenbahn und die Folgen



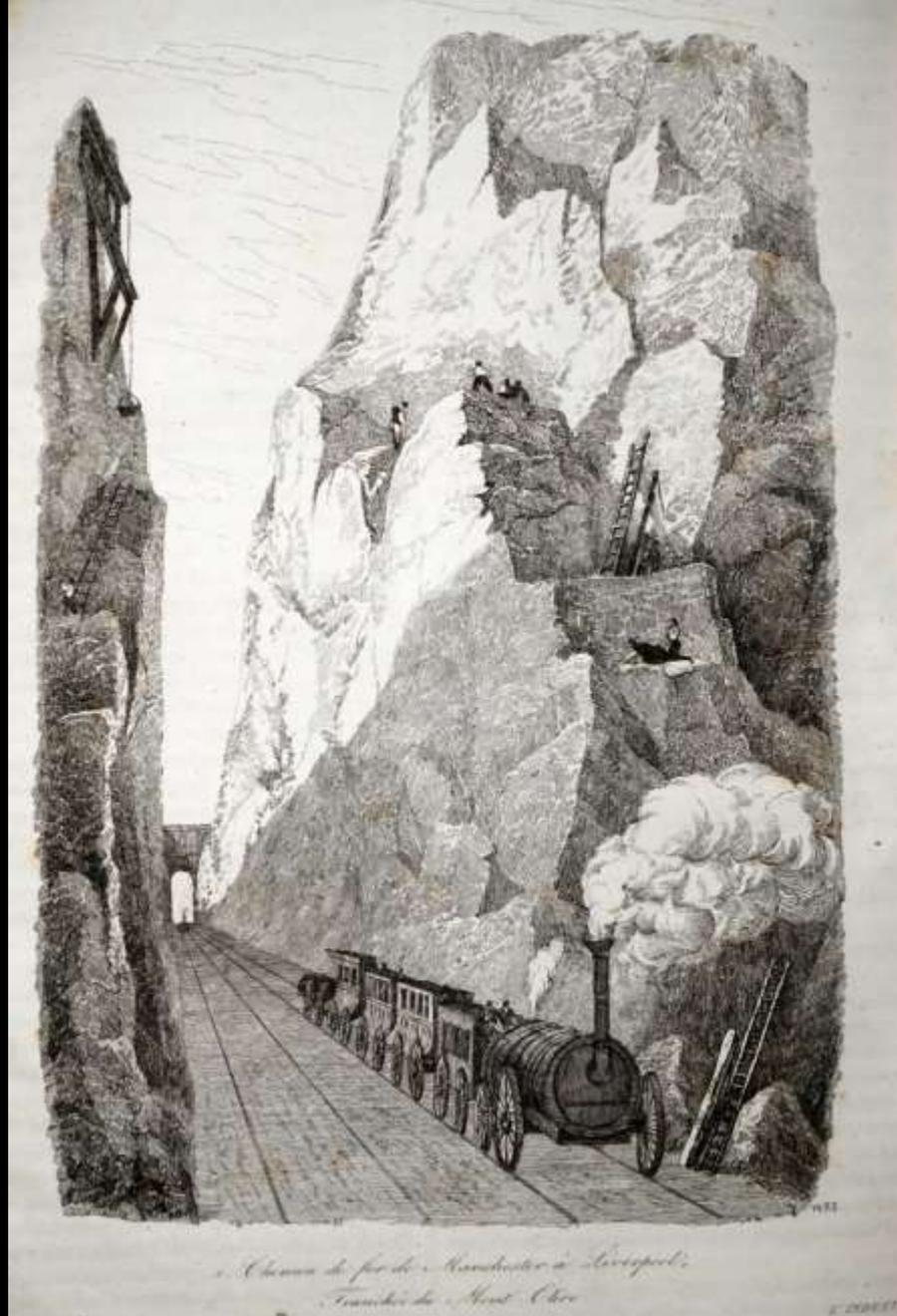
Die ersten Eisenbahnen mit Lokomotivbetrieb: Leeds, Middleton Railway, 1812: Lokomotive „Salamanca“ (John Blenkinsop und Matthew Murray; Abb.: J. Cordier 1823; man beachte den Zahnradantrieb!)



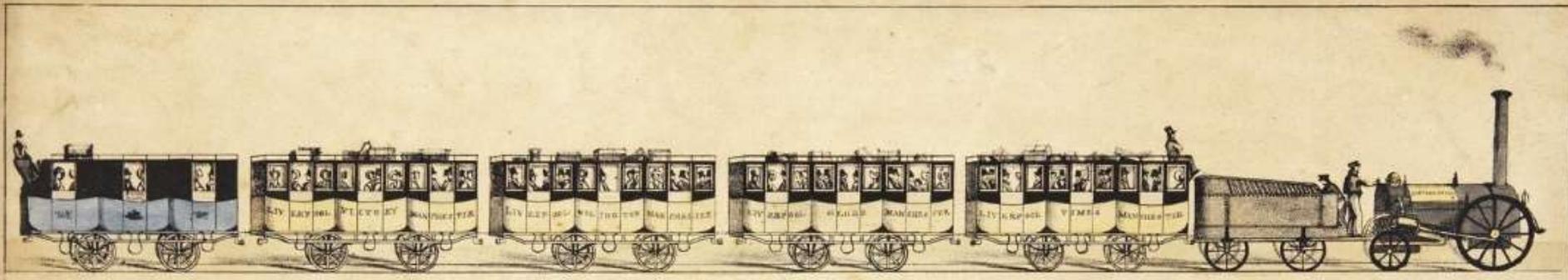
Dampflokotiven der ersten Generationen. Rechts oben Stephenson's „Rocket“ (Wood 1831/1834)



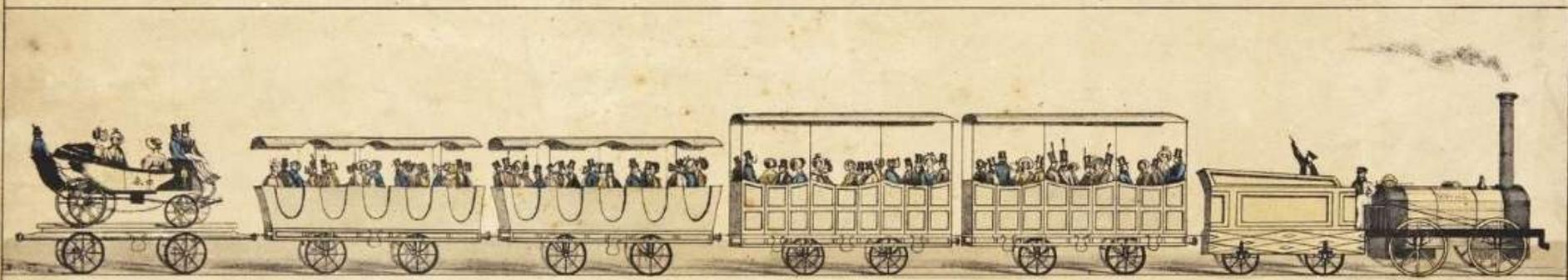
George & Robert Stephenson's „Rocket“ (1829), Siegerin der Rain Hill Competition (London, Science Museum)



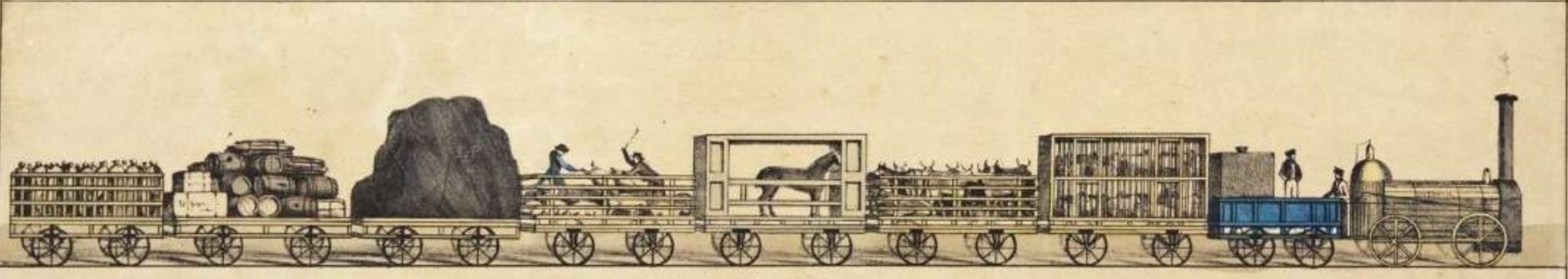
Die Eisenbahn Liverpool-Manchester (1830), erste grosse Personen- und Frachteisbahn (Mount Olive Cutting, S. Flach at 1835)



FIRST CLASS AND MAIL



SECOND CLASS

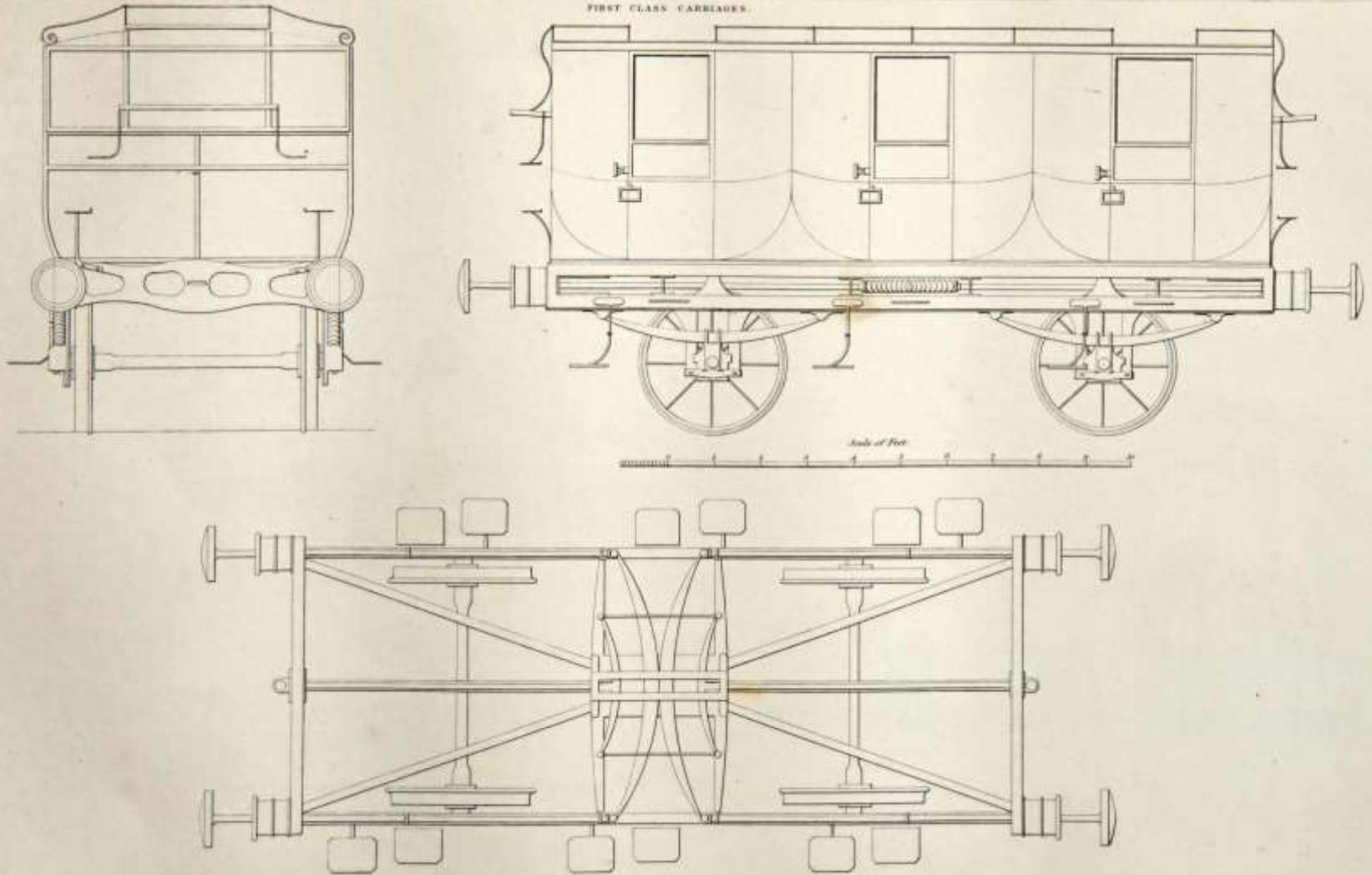


CATTLE AND GOODS

SKETCH OF THE CARRIAGES ON THE LIVERPOOL AND MANCHESTER RAILWAY.

Die Liverpool-Manchester-Eisenbahn (1830)
(Stich von W. Crane, Chester, um 1830; Scan: Science Museum London, CC-BY-NC-SA 4.0)

FIRST CLASS CARRIAGES.



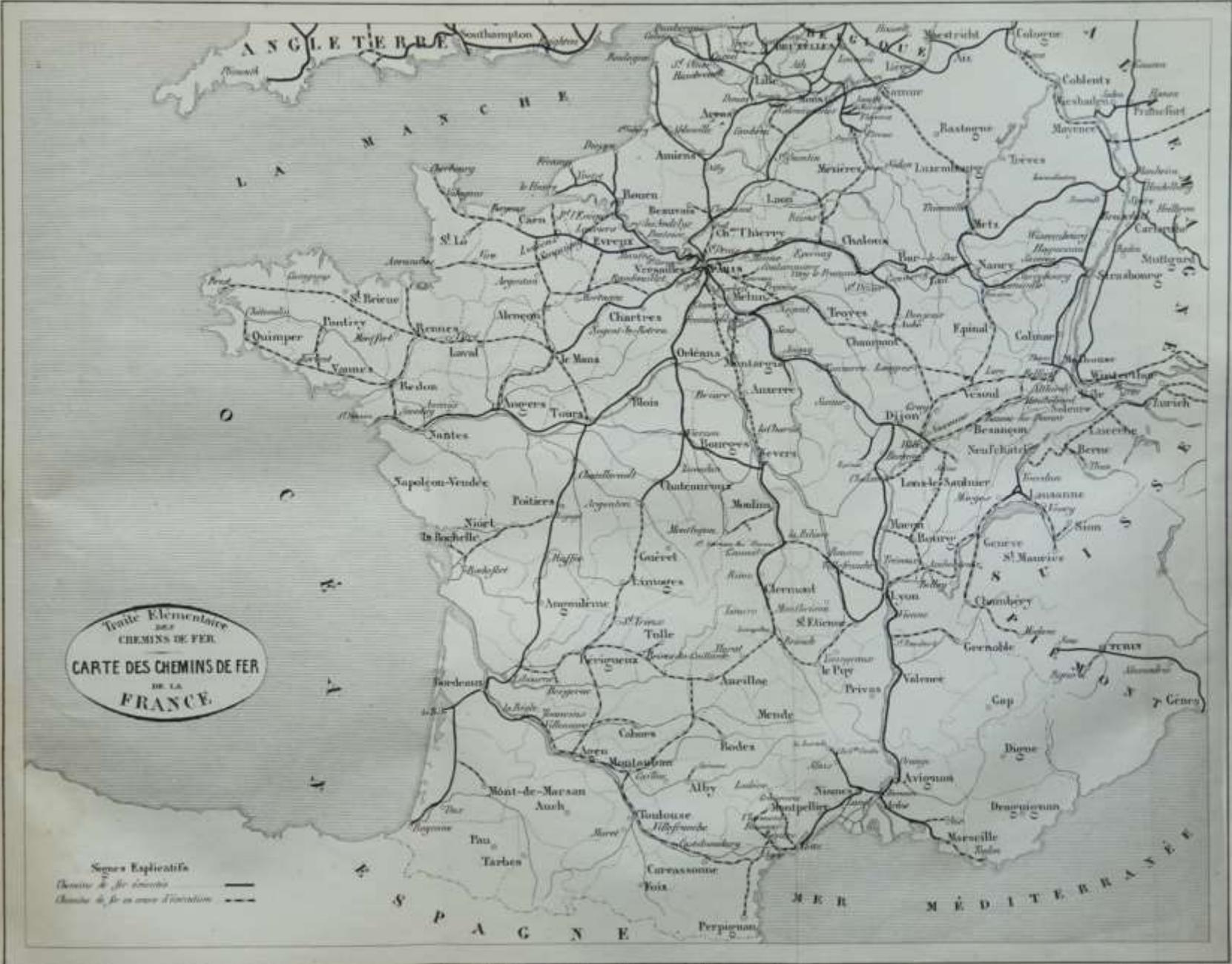
Die Personenwägen der Eisenbahn London-Birmingham (Gesamtstrecke eröffnet 1838)
(Simms 1838)

Traité Élémentaire
DES
CHEMINS DE FER
—
CARTE DES CHEMINS DE FER
DES
ILES BRITANNIQUES



Carte par Perdonnet, 1855. Révisée par...
Édité par R. B. Longman, London & New York, 1855.
Lith. Lacomme & Co.

Eisenbahnen in England um 1855 (Perdonnet 1855)



Paris par Anst. 177 Rue des Beveuglies 18.

Édit. par M. H. Langlois-Leclercq Libraire R. des Mathurins 171 et 173

Lith. Lacomme et Dreyer

Eisenbahnen in Frankreich um 1855 (Perdonnet 1855)



Tome I. 1855. Page 20

Paris par Saint-Denis, 1855. Par des Annonces, et
 Paris par St. Germain-Lancy, 1855. Par des Annonces, et
 Edit. L'Imprimerie de Paris

Eisenbahnen im deutschsprachigen Raum um 1855 (Perdonnet 1855)

Zweckbau – von der Markthalle zur Eisenbahnhalle
Die „eigentliche“ Architektur des 19. Jh.?

(1815–1846)



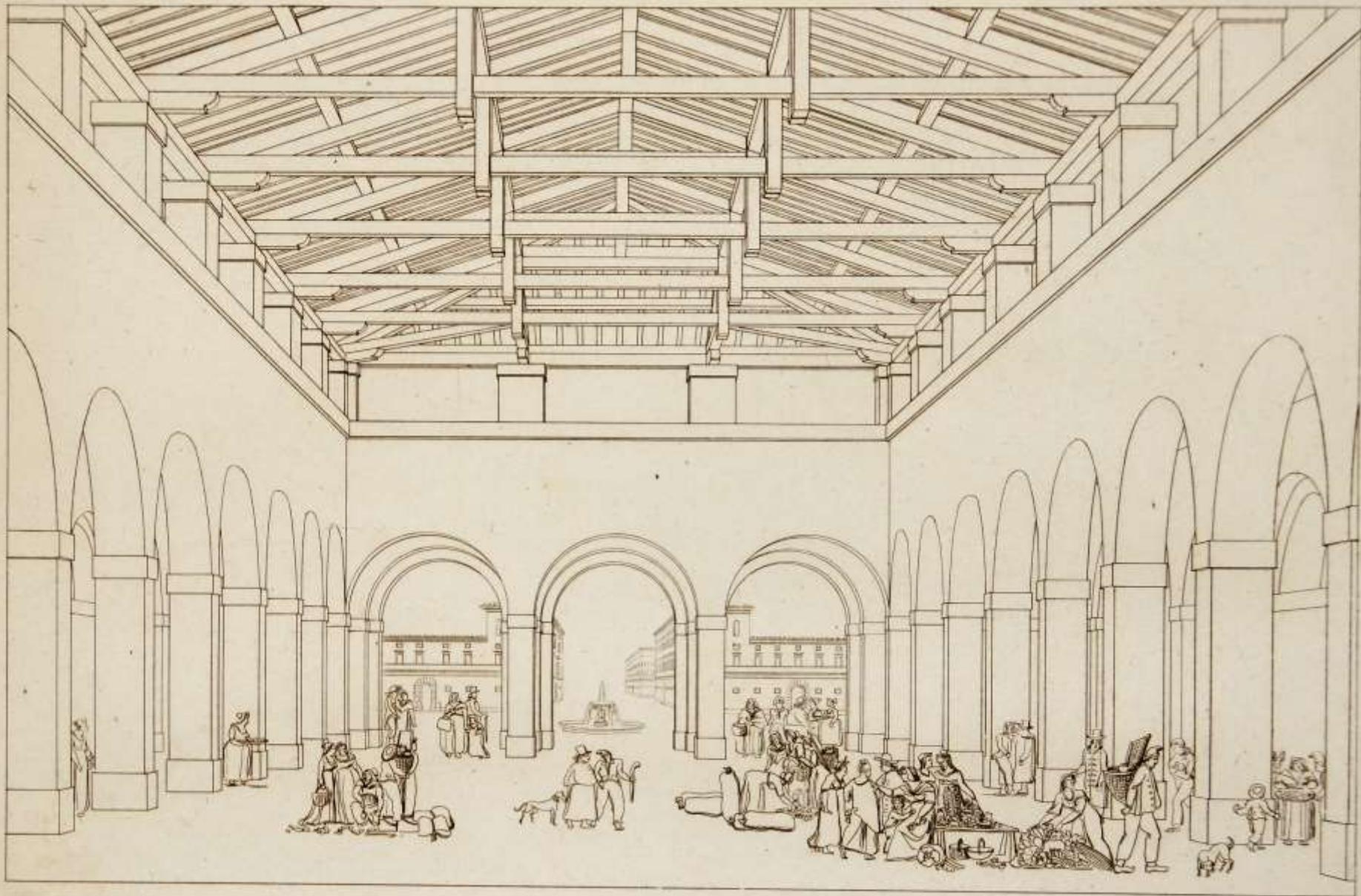
Bourg-sur-Gironde, Waschhaus (1828)



Bourg-sur-Gironde, Waschhaus (1828) mit Pfettendachbinder



Paris, Marché Saint-Germain (1817; heute Rekonstruktion)



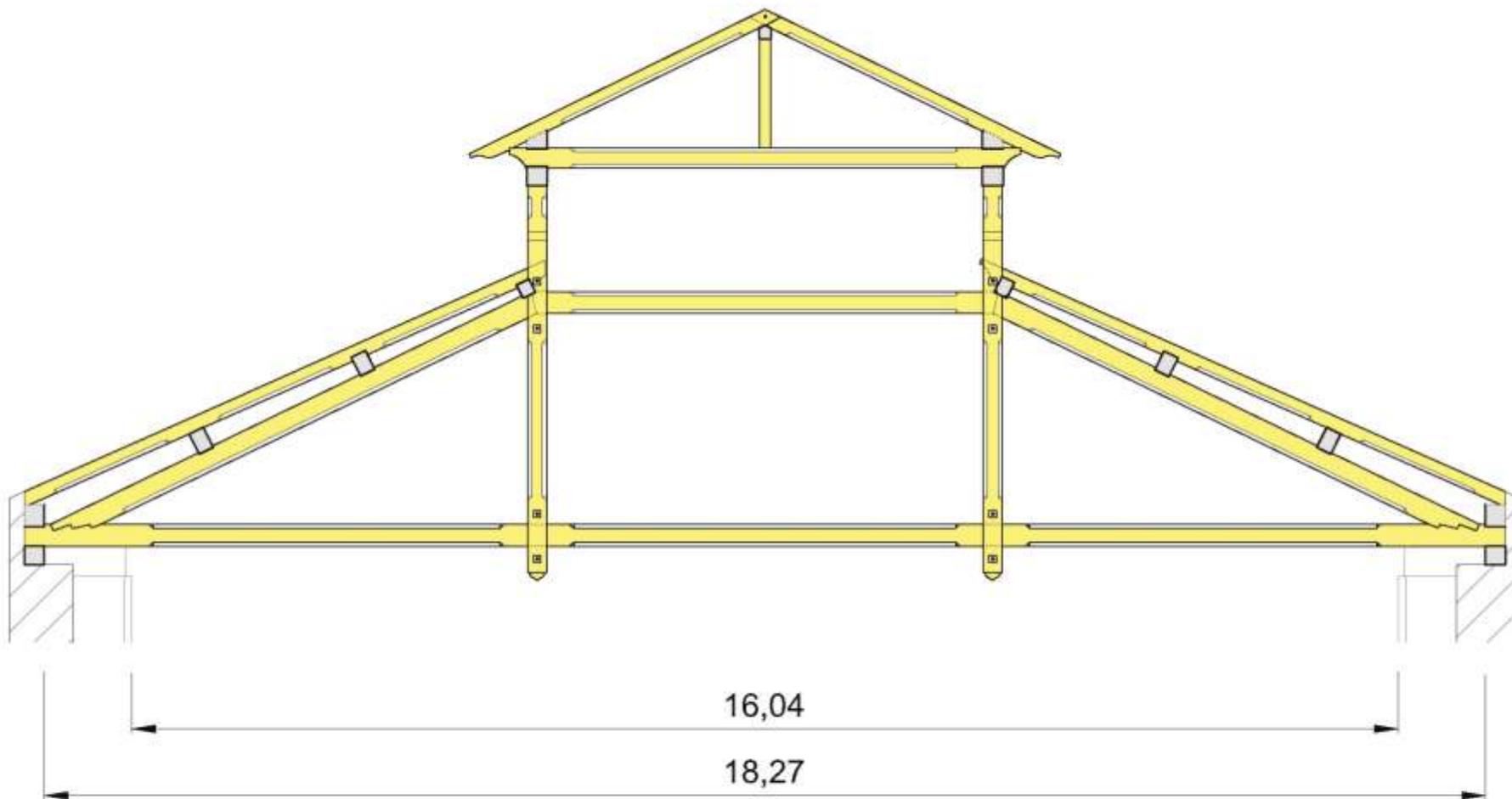
Projets de Marchés.



Augsburg, ehem. Bahnhofshalle (1840)



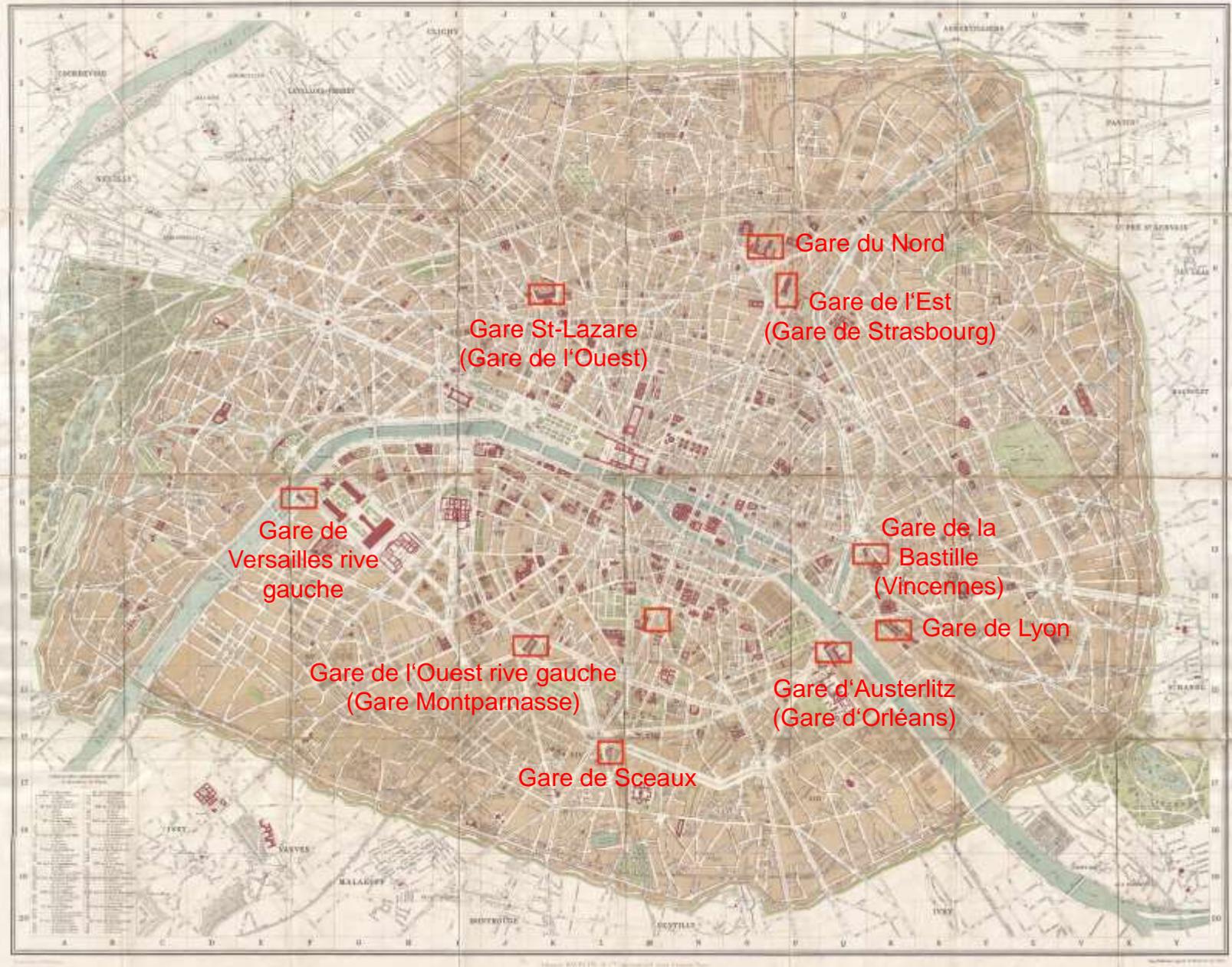
Augsburg, ehem. Bahnhofshalle (1840)



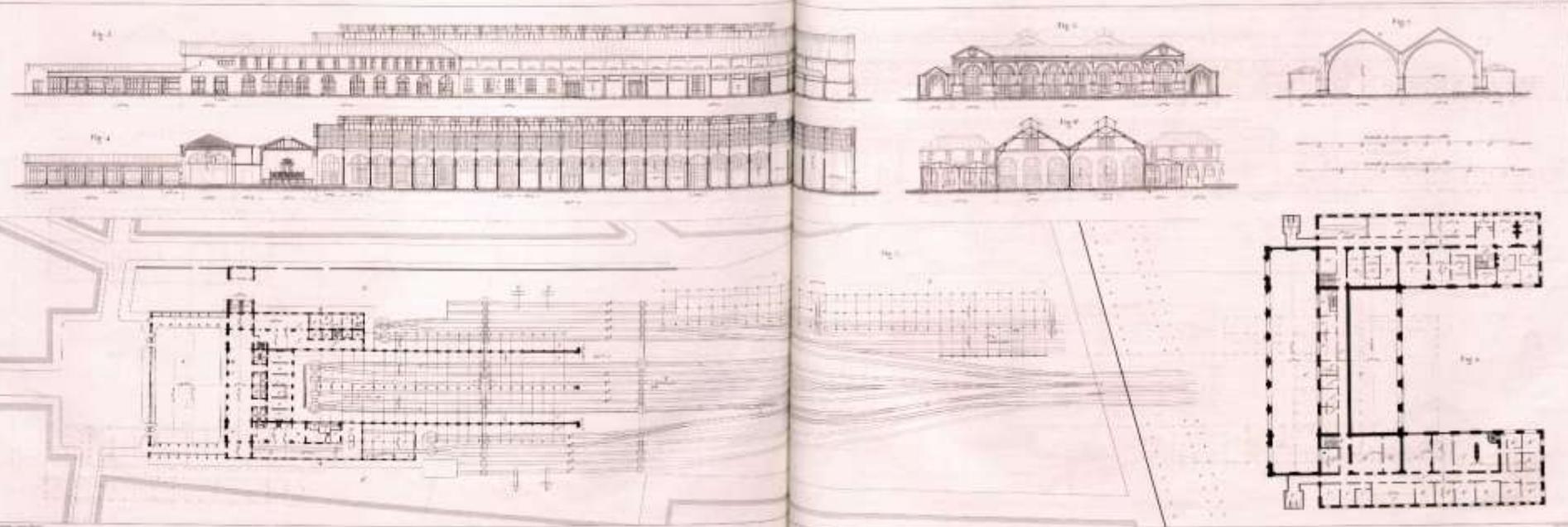
Augsburg, Straßenbahndepot
 ehemaliger Bahnhof (1840) M 150
 Systemskizze, vor Ort gemessen
 Anja Winnemann/ Stefan Hölzer
 Universität der Bundeswehr München

Augsburg, ehem. Bahnhofshalle (1840)

PLAN DE PARIS



Paris, die Bahnhöfe
(Plan v. Vuillemin 1894)

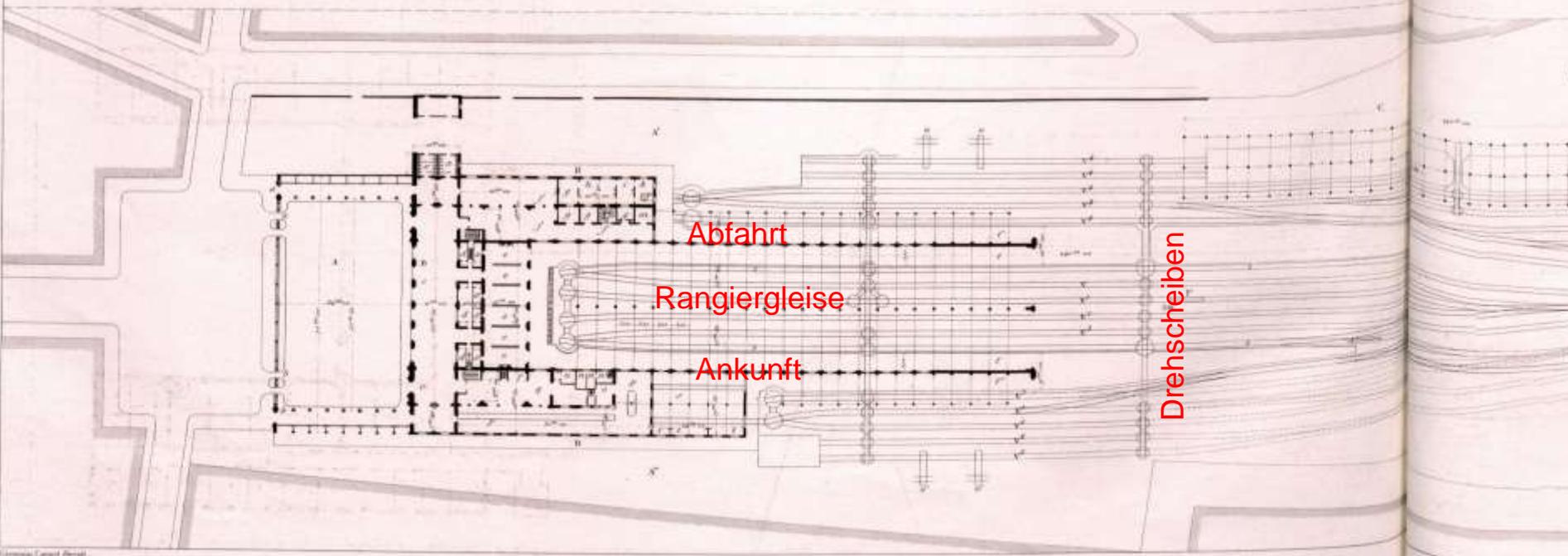
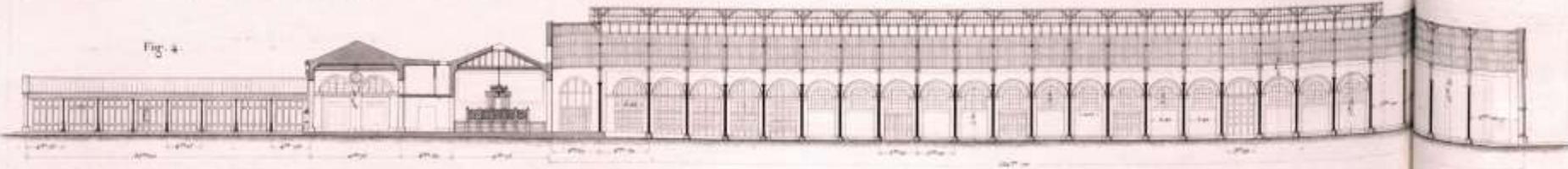


Paris, Gare du Nord (1846)
Gesamtdisposition (Perdonnet/Polonceau 1846)

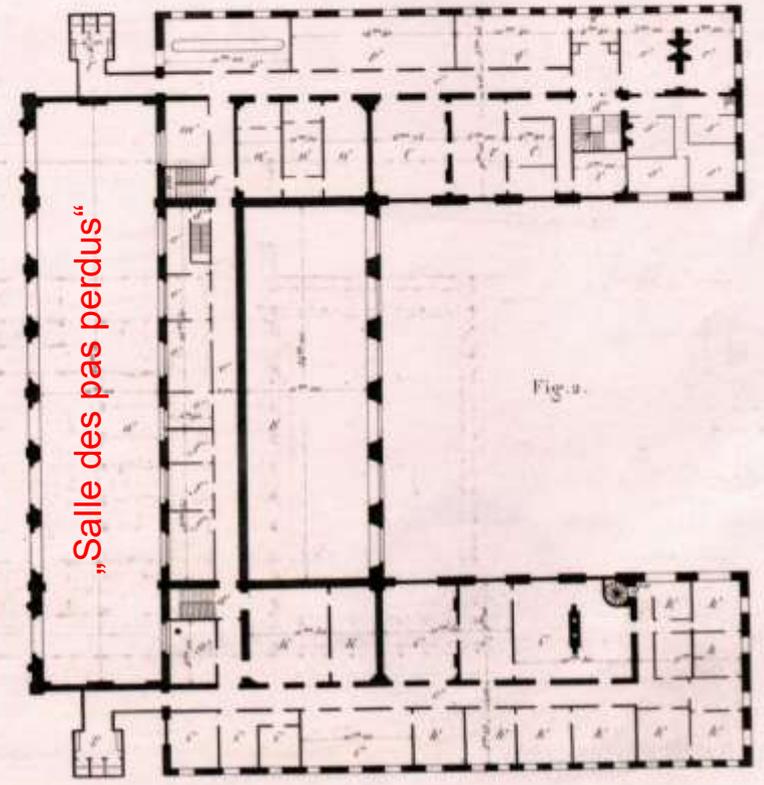
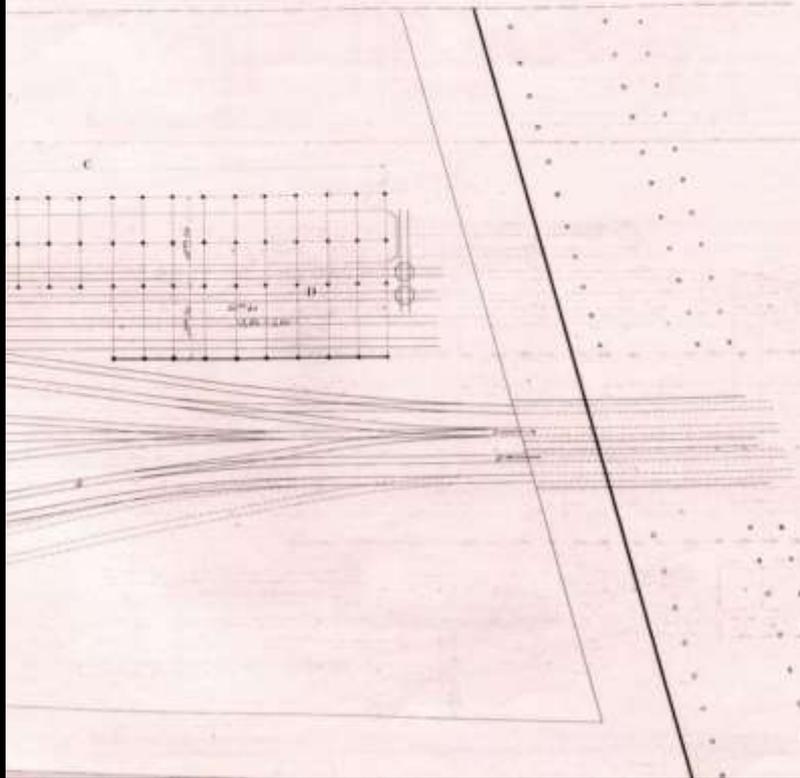
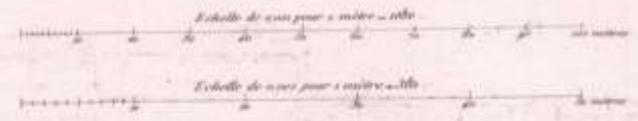
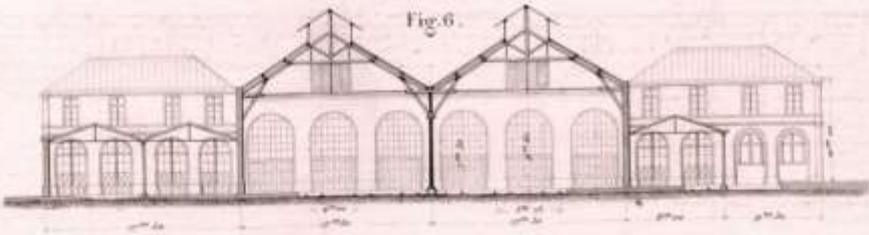
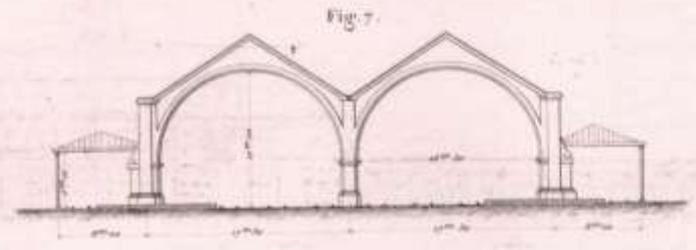
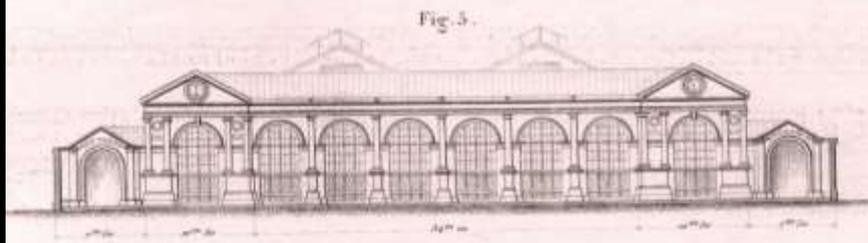
Fig. 3.



Fig. 4.



Paris, Gare du Nord (1846)
Gesamtdisposition (Perdonnet/Polonceau 1846)



Paris, Gare du Nord (1846)
Gesamtdisposition (Perdonnet/Polonceau 1846)

Fig. 5.

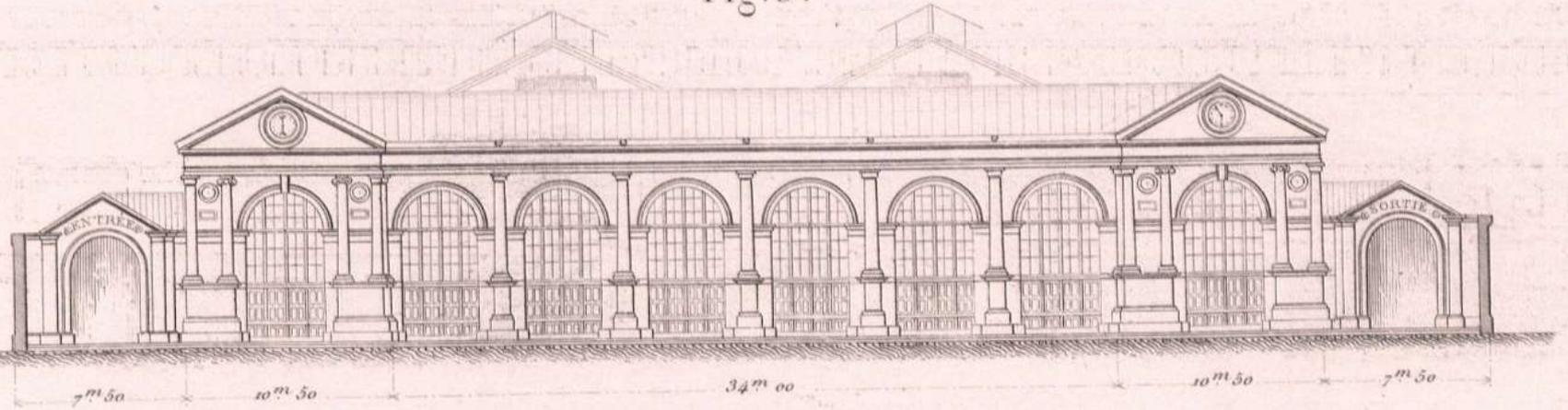
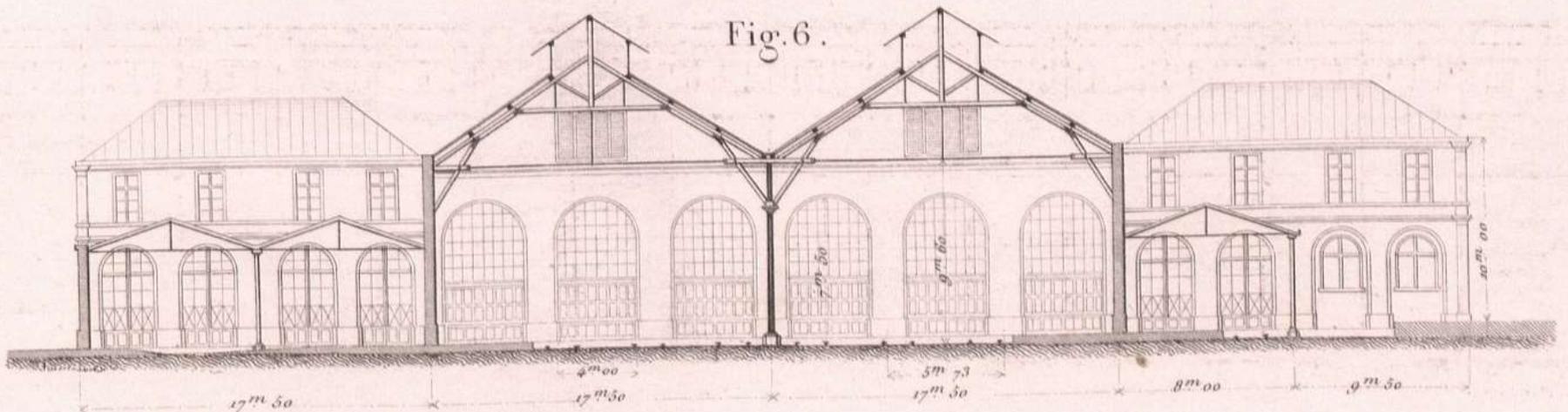
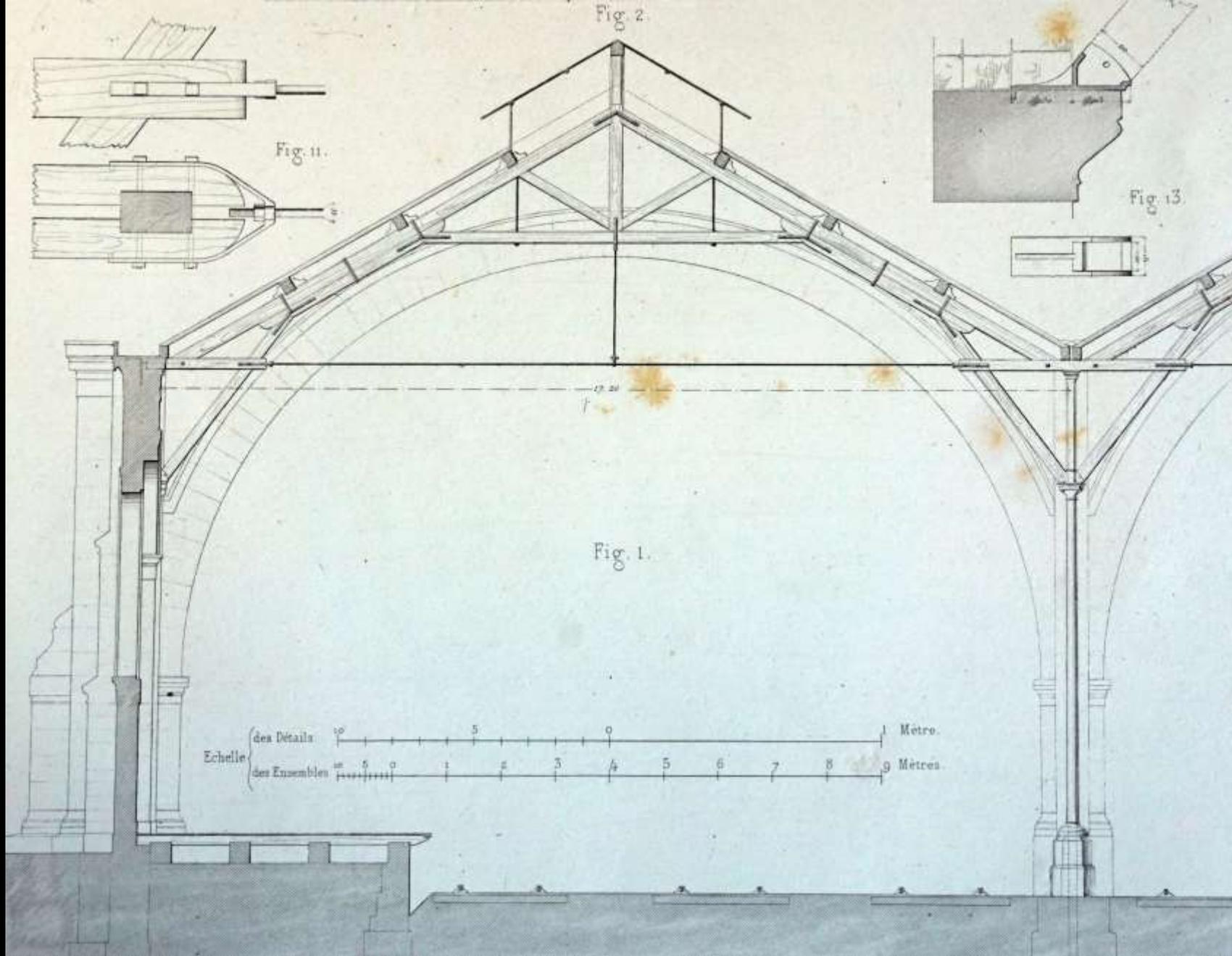


Fig. 6.



Paris, Gare du Nord (1846)

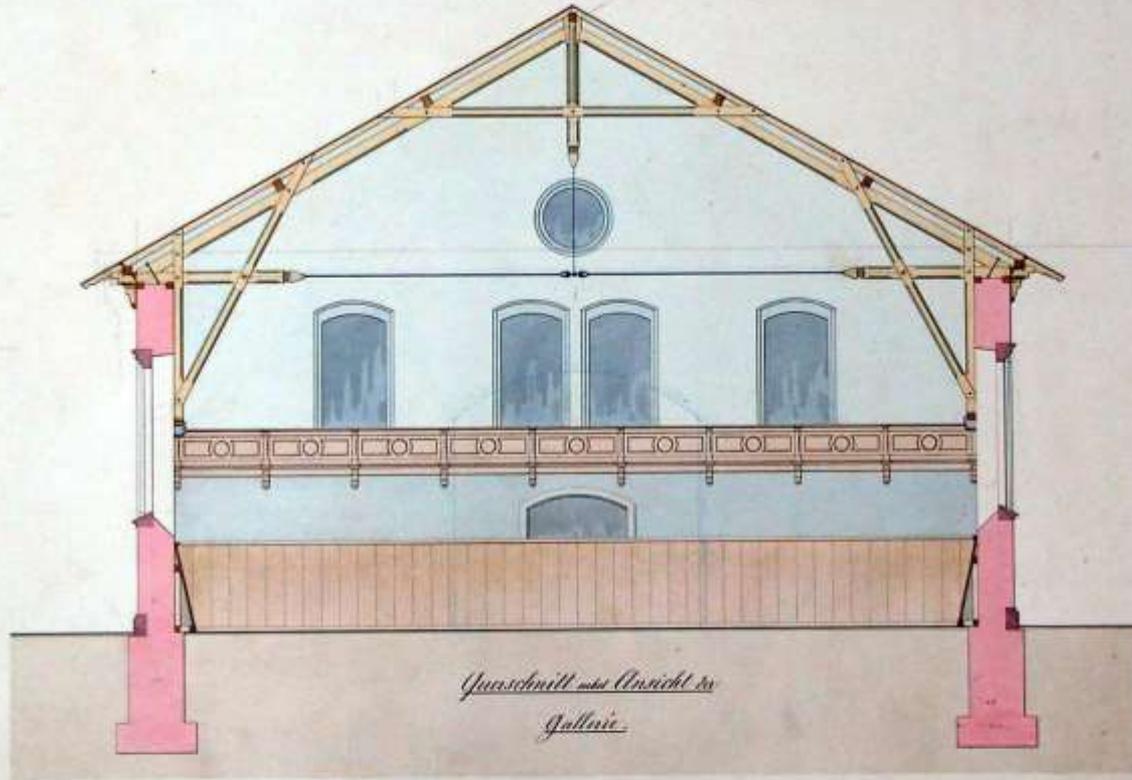
Fassade und Schnitt durch die Einsteighalle (Perdonnet/Polonceau 1846)



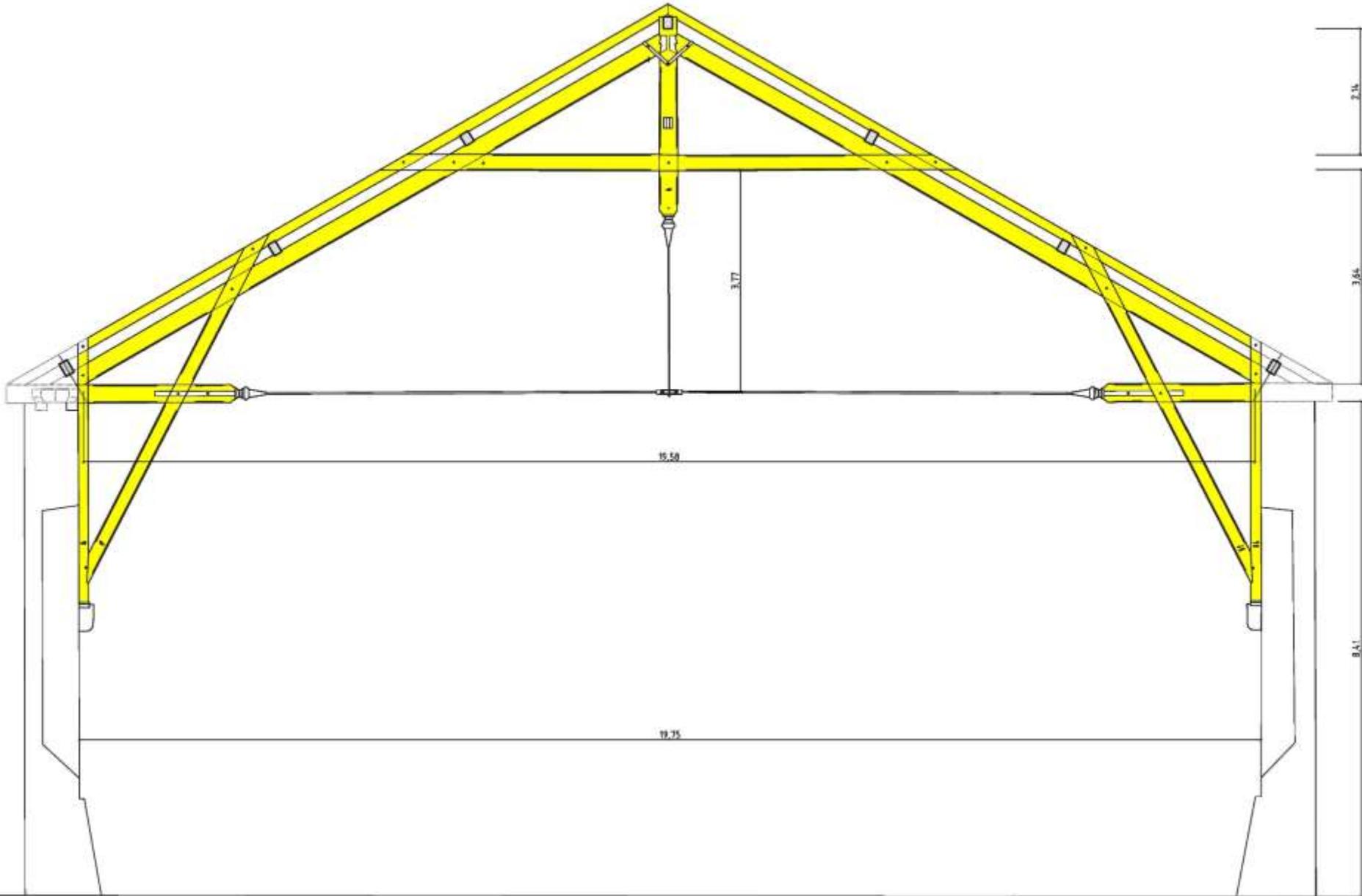
Paris, Gare du Nord (1846), Einsteighalle von Leonce Reynaud (Reynaud 1860)



Paris, Gare du Nord (Leonce Reynaud, 1846-50; zeitgenöss. Modell im Cons. Arts & Métiers, Paris)



C 1123



Aarau, Reithalle (1864)



Aarau, Reithalle (1864)



Aarau, Reithalle (1864)