Presented to Mr Patrick

by

Mr Walter Lightowler

Lowmoor Company.

A RECORD

OF THE

ORIGIN AND PROGRESS

OF

LOWMOOR IRON WORKS

From 1791 to 1906.

LOW MOOR, BRADFORD,

YORKSHIRE, ENGLAND.

1906.

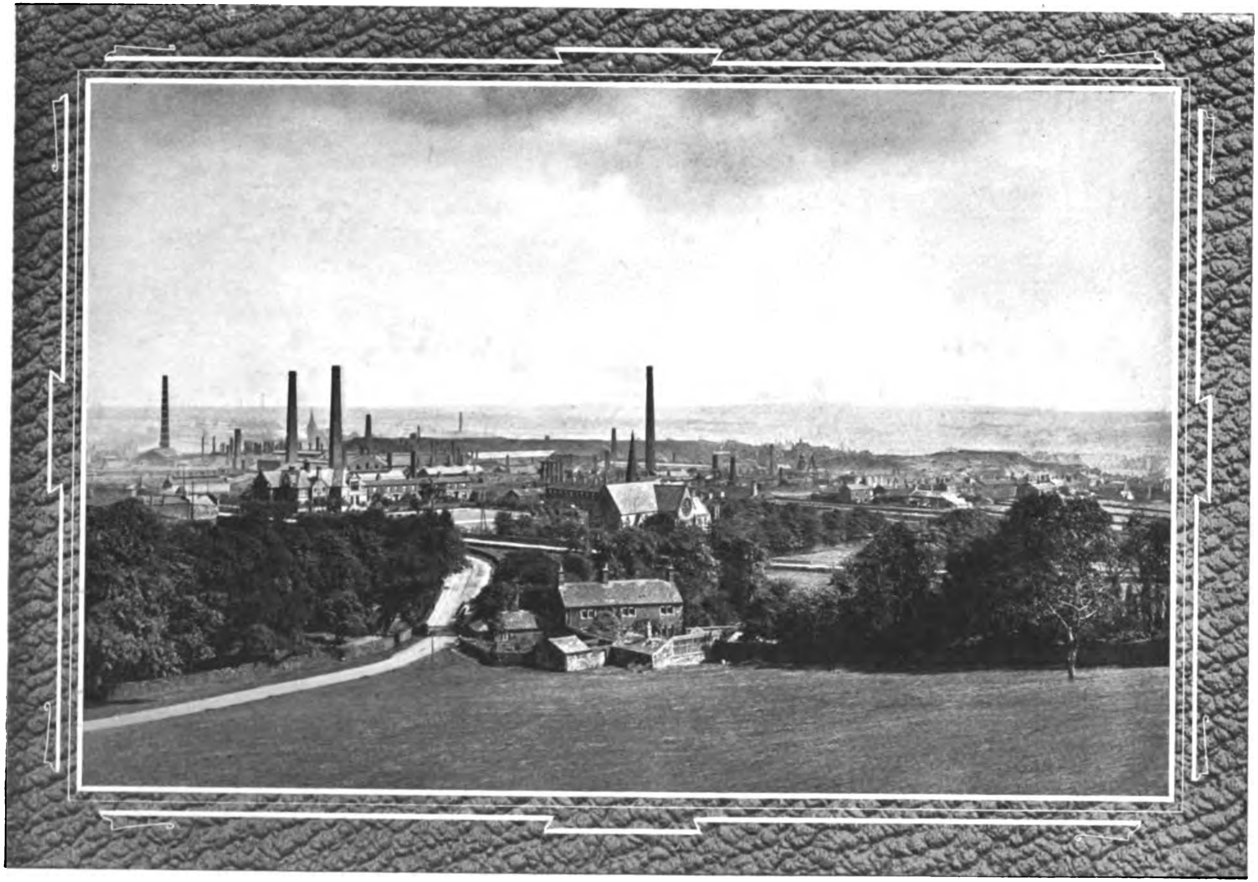
BRADFORD:

Illustrations by T. C. Bridges & Son,
Photographic Artists;

Printed & Engraved by W. H. Brocklehurst,
High-class Printer.

1906.

View of Name Plate, with date 1790 attached,—taken from the front of one of the original Blast Furnaces at Lowmoor Iron Works. The initials represent the names of the first partners in the Lowmoor Company, viz.: HIRD, JARRATT, DAWSON & HARDY. Ultimately Messrs. Hird, Dawson & Hardy became possessed of the entire property, and the representatives of the same three families still comprise the entire proprietary of the Lowmoor Company Limited.



VIEW OF LOW MOOR.

LOW MOOR.

THE Manors of North Bierley and Wibsey originally comprised several hundred acres of low-lying moorland,—and it was upon the lower portion of this moorland that the Lowmoor Iron Works, and the village surrounding them, were first established.

A view of the village of Low Moor, which is now a suburb of the city of Bradford, is shewn on the opposite page. The view gives a good representation of the position and extent of Lowmoor Iron Works, which are situated three miles from the central part of the city.

The Centenary of the Lowmoor Iron Works was celebrated in 1891, but the inception of this great industrial undertaking goes back to the year 1789, when the Manors of Royds Hall and Wibsey were purchased from the assignees of one Squire Leedes who, having lived beyond his means, had come to grief the previous year. An interesting reminiscence of this transaction is preserved in the reproduction in fac-simile of the original advertisement announcing the sale, shewn on page 6.

The entire estate, with all its valuable rights and accessories, came into the possession of the firm of "Hird, Dawson & Hardy," and the proprietary therein is still held by representatives of the families so named.

Low Moor is served by the Great Northern and Lancashire and Yorkshire Railways, the Lowmoor Company having siding connections with both lines.

Fac Simile

of the

Advertisement

in

The Leeds Intelligencer.

Printed by THOMAS WRIGHT, at NEW-STREET END.

[Price THREE-PENCE.] TUESDAY, *DECEMBER* 23, 1788. Vol. XXXV No. 1793]

To be SOLD,

THE MANOR and CAPITAL MESSUAGE of ROYDS-HALL.——Alfo the COLLIERY and feveral FARMS and WOODS, within the faid MANOR, late the ESTATES of EDWARD LEEDES, Efq., deceafed.

☞ Particulars may be had by applying to Nathan Jowett, Efq; of Manningham: John Hodgfon, Efq; of North Bierley or at Mr Hardy's Office, in Bradford.

A good service of Electric Trams pass through Low Moor, close to the Works, on the main road leading from Bradford to Huddersfield.

Some years ago about twenty acres of land, forming a portion of the surrounding Commons adjoining the Works, and containing one of the Company's large reservoirs, were enclosed and laid out as a public park, and opened by the Earl of Cranbrook in 1885. This is called "Harold" Park, and is named after His Lordship's youngest son, the Hon. Harold Gathorne Hardy, who had been the chief promoter of the enclosure of the surrounding Commons in the district. A prominent feature in the park is a granite monument, erected by public subscription, commemorating the interest which that gentleman took in the formation of the park.

"Harold" Park is considered quite an aquisition to the neighbourhood, and is much appreciated by the workpeople in the district.

VIEW OF ROYDS HALL, LOW MOOR.

ROYDS HALL, LOW MOOR.

THE old Manor House of the lords of North Bierley, a view of which is given herewith, is situated on high table-land, about 700 feet above sea level.

The venerable and interesting mansion of Royds Hall commands an extensive prospect from the front, looking over a portion of the Yorkshire and Derbyshire Hills. History relates that in 1377, a mansion-house, the residence of the lords of North Bierley, stood on this spot. Sometime during 1509 the ancient family of "Rookes" were resident here as Lords of the Manor, and it is recorded that a member of this family rebuilt the mansion during 1640, as shewn by the date over one of the doorways.

Royds Hall is a very fine specimen of one of the substantial country residences in existence at that period. Externally it is massively built, with many mullioned windows. The internal arrangements, comprising the entertaining rooms and passages connecting them with the Great Hall, are remarkably good, and quite in accordance with the style of architecture prevailing about the above period.

The Lesser Hall portion of the building bears the date 1651; the west end that of 1656. The eastern end was added about the year 1770 by the then Lord of the Manor, Edward Rookes Leedes, Esqr., familiarly known in the district as "Squire Leedes." He was a justice of the peace and a "*bench in himself.*" His Court Room at Royds Hall still exists in the grounds attached to the Hall, and there are unmistakable indications

in the broad flight of steps outside, and the stone "seat of justice" within, as to its ancient use.

At the back of the Hall, and in front of the domestic offices, is a spacious court-yard, surrounded by the necessary farm and other buildings, thus forming a quadrangle, similar to those often seen attached to large country mansions of that period.

Formerly a considerable Park stretched away to the south of the Hall, and a large portion of this, with the interesting old Lodge at the eastern end, still exists. In this Park is situated a large reservoir, which contains the chief source of water supplied to the Works.

Royds Hall stands about a mile distant from Lowmoor Iron Works, and is at present occupied by Mr. Reginald W. Wickham, the General Manager of the Works.

"HIGH MOOR LANE" COAL PIT, HARTSHEAD.

THE LOWMOOR COMPANY'S COLLIERY.

IT was well known that there was abundance of Coal upon the estate which the Lowmoor Company had purchased, but the late owner had no conception of the fact that beneath his broad acres there was an almost inexhaustible supply of Iron Ore.

It was left to the enterprising firm who had purchased the Manor, to develop the estate, and utilize the mineral treasures to their full extent.

The Company was not long in doing this. They soon extended the coal pits which the late Lord of the Manor had been working, and established a Colliery of their own designing, and as soon as they had got the first Blast Furnace erected, were quite in readiness to put into actual practice the smelting of the iron ore which they now possessed in such abundance.

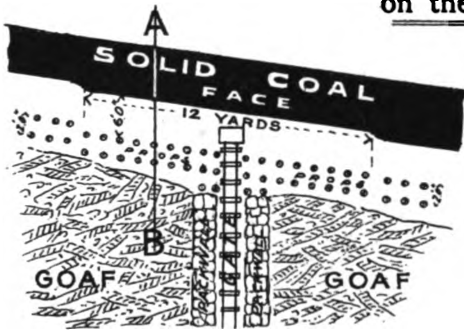
Since that period the Company's Colliery has extended a considerable distance from the Works, and now covers an area of about 8,000 acres, lying in the districts of Low Moor, Bierley, Cleckheaton, Scholes, and several other adjoining hamlets,—all of which are connected by a network of tramways 22 miles long, and in direct communication with the Works.

The Company also own Ironstone Collieries in the townships of Beeston, Churwell, Hunslet, Osmondthorpe, and other districts in the neighbourhood of Leeds. They have 73 miles of underground roads laid with rails, and employ close upon 2,000 hands in

THE LOW MOOR CO'S. COLLIERIES.

No. I.

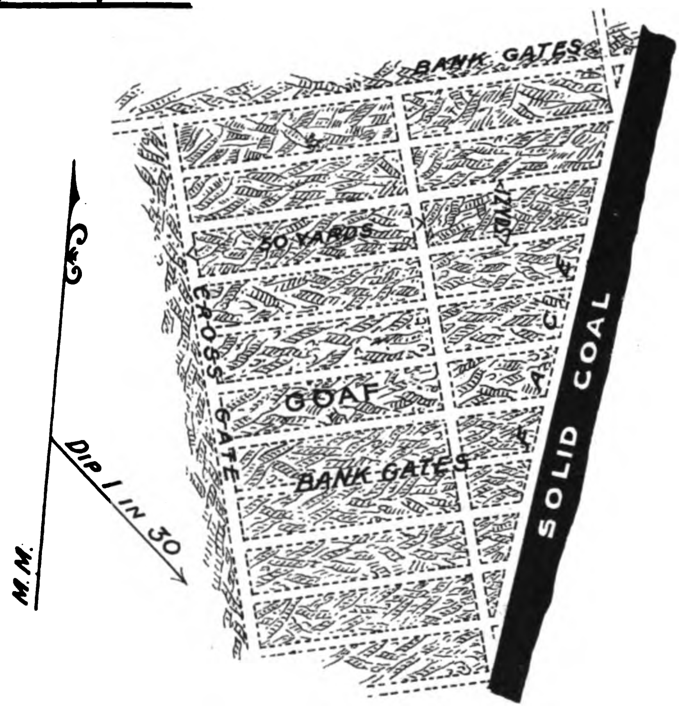
Sketches shewing the method of working the Better Bed Coal on the Longwall System.



PLAN OF WORKING PLACE

SECTION ON A.B.

Scale 8 Yards to 1 Inch.

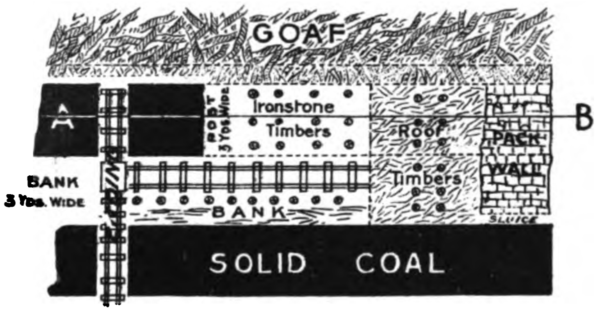


PLAN OF WORKING DISTRICT

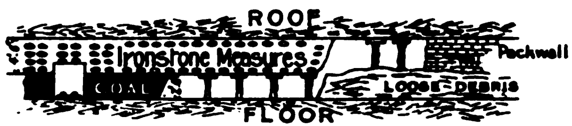
Scale 2 Chains to 1 Inch.

The Low Moor Co's. Collieries. No. 2

Sketches shewing the method of working the Black Bed Coal and Ironstone.

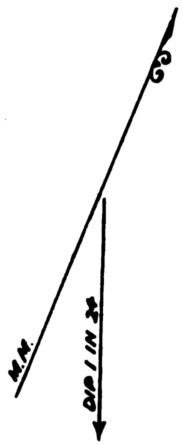


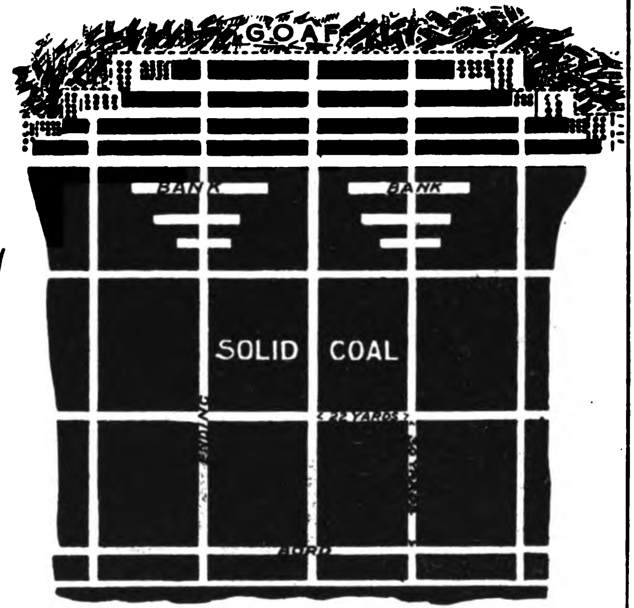
Plan of Posting Hole



Section on A.B.

Scale 8 Yards to 1 Inch.



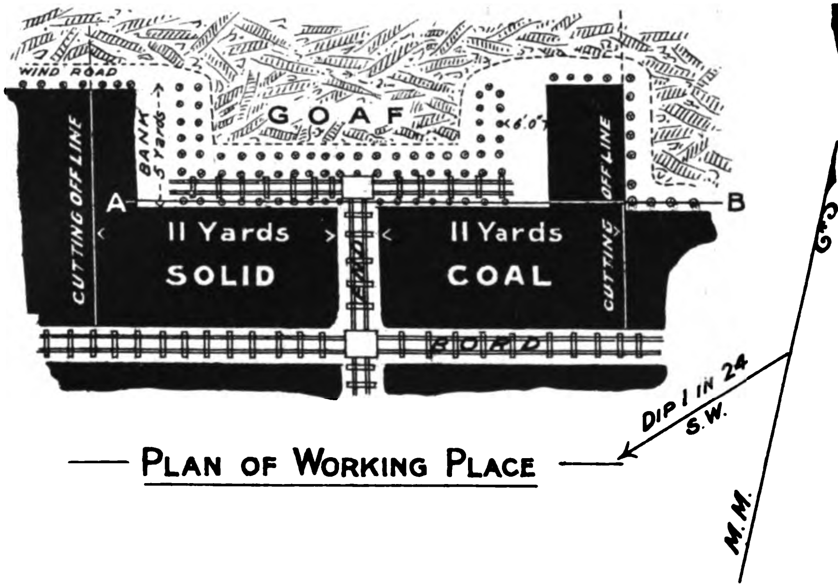


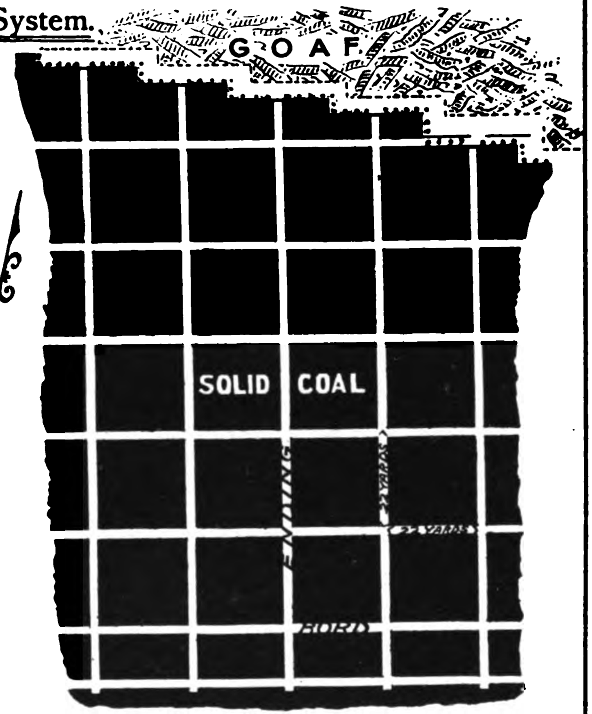
Plan of Working District.

Scale 2 Chains to 1 Inch.

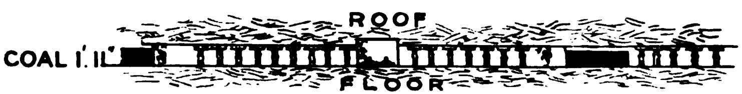
THE LOW MOOR CO'S. COLLIERIES. — No. 3

Sketches shewing the method of working the Better Bed Seam of Coal on the Bord and Pillar System.





PLAN OF WORKING PLACE



SECTION ON A.B.

Scale 8 Yards to 1 Inch.

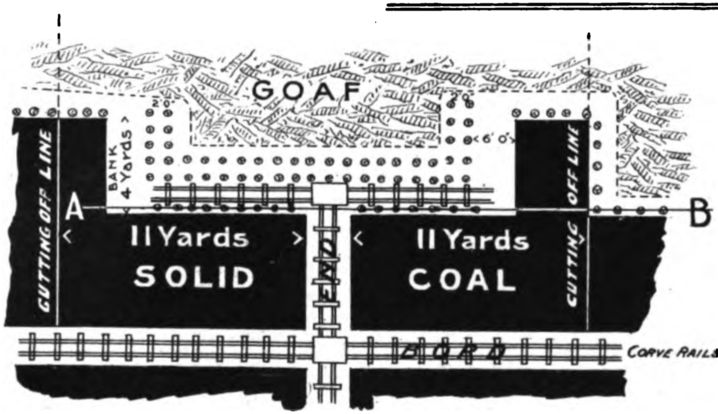
PLAN OF WORKING DISTRICT

Scale 2 Chains to 1 Inch.

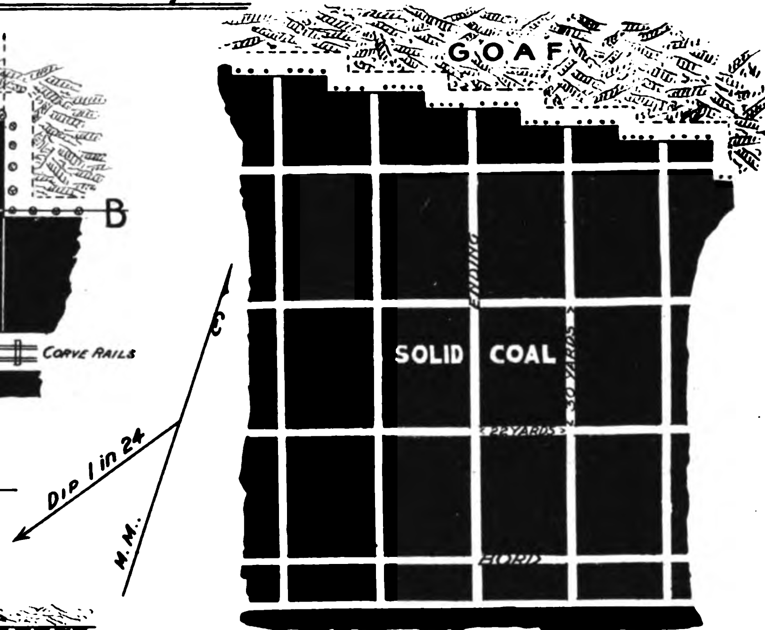
The Low Moor Co's. Collieries.

No. 4

Sketches shewing the method of working the Black Bed Coal on the Bord and Pillar System.



— PLAN OF WORKING PLACE. —



— PLAN OF A WORKING DISTRICT —

Scale 2 Chains to 1 Inch.

— SECTION ON A. B. —

Scale 8 Yards to 1 Inch.

their collieries. They have by purchase and lease secured large tracts of minerals, and thus can supply themselves with all their raw materials.

The Ironstone is worked in conjunction with the "Black Bed" Coal, an excellent steam coal, just above which it lies; while the "Better Bed" Coal, lying about 40 yards below the "Black Bed," is, judging from the following analysis, which shews particular freedom from sulphur, the very best coal obtainable for producing a superior class of coke, specially suitable for cupalos, and the manufacture of Iron generally.

The thickness of the "Better Bed" Coal varies from 14 to 24 inches.
" " "Black Bed" Coal " 22 to 34 inches.

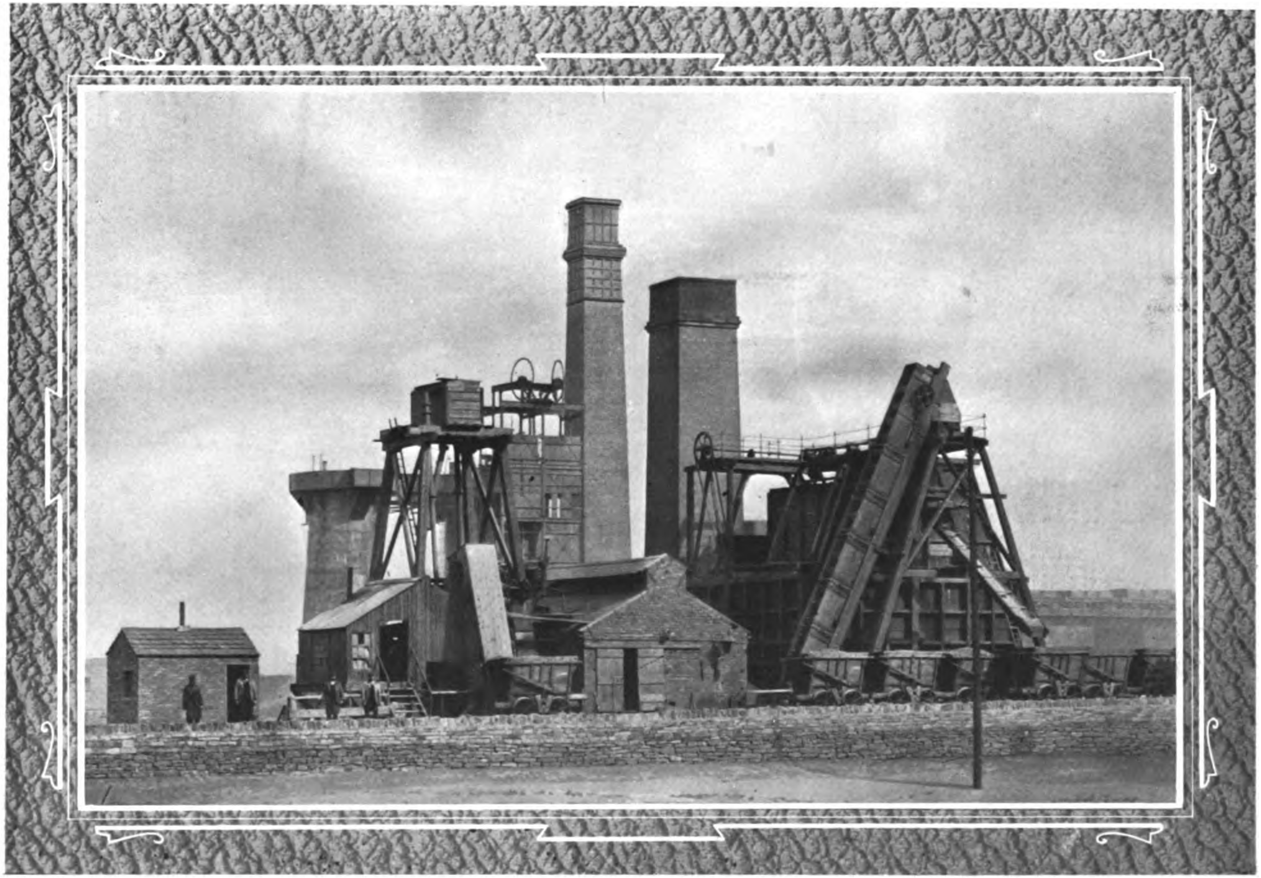
ANALYSIS

OF

HARD AND SOFT LOWMOOR "BETTER BED" COAL.

	Hard.		Soft.
Fixed Carbon	83·45	...	84·03
Sulphur	·41	...	·41
Ash	1·08	...	1·75
Moisture	2·08	...	1·72
Hydrogen	5·35	...	4·98
Oxygen and Nitrogen	7·63	...	7·11
	100·00	...	100·00
Per cent. of Coke	66·80	...	69·20

The Gases evolved on treating in a closed vessel, burnt with a yellow smoky flame. The Ash was light greyish red in each case.



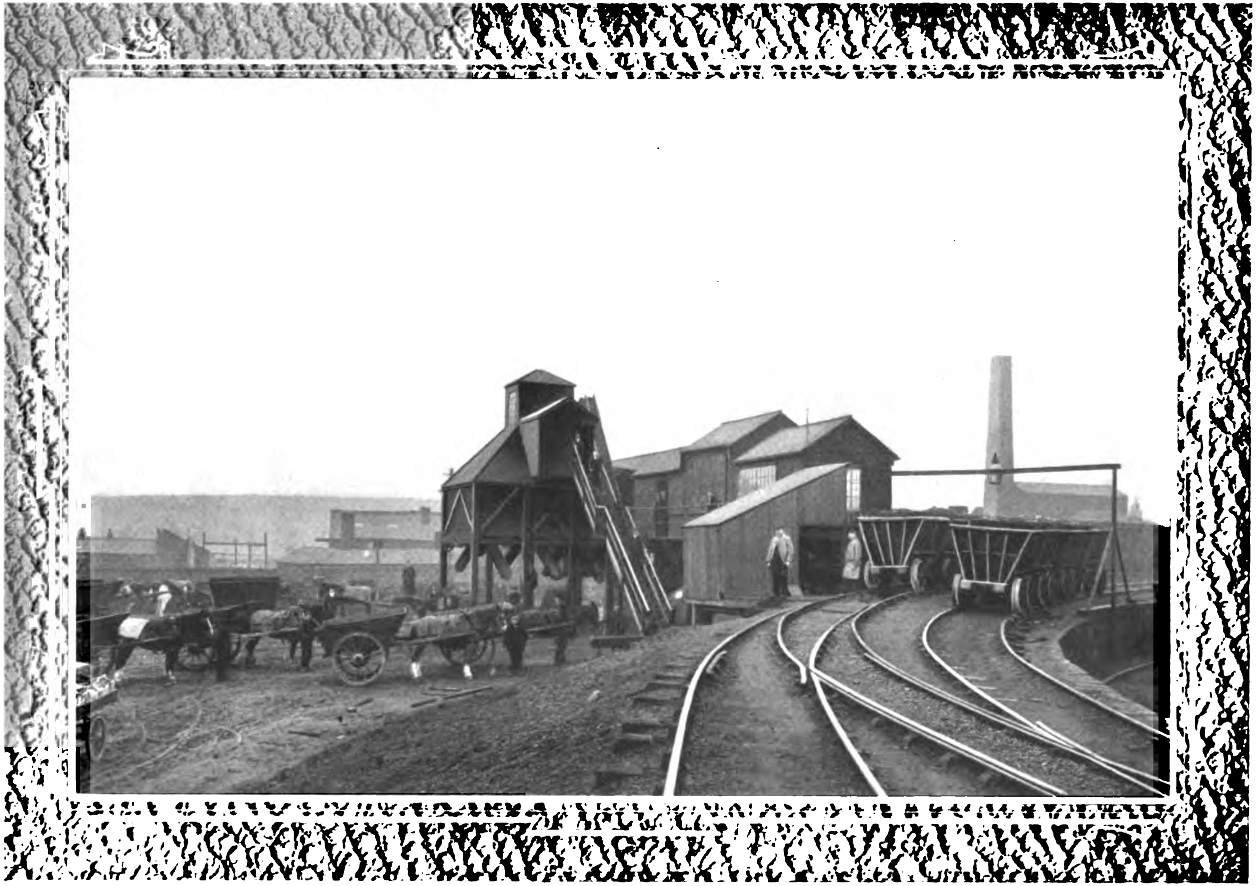
COAL WASHER, LOWMOOR IRON WORKS.

COAL WASHER.

THE Lowmoor Company have a special plant for producing Coke of a very high quality, great care being taken to extract everything of a deleterious nature.

The "Better Bed" Coal is brought in suitable wagons from the Colliery to the Coal Washer, emptied down a "Shoot" to the breaker, or disintegrator. The pulverised Coal is then conveyed by an elevator to the washing apparatus, where the dirt is released and separated, and the pure Coal is carried in small wagons to the "Beehive" ovens, and made into high-class Coke, for smelting, cupalos, and other purposes where fuel of the purest quality is required.

The Coal Washer is closely adjoining the Company's Blast Furnaces, as will be seen by the annexed illustration.

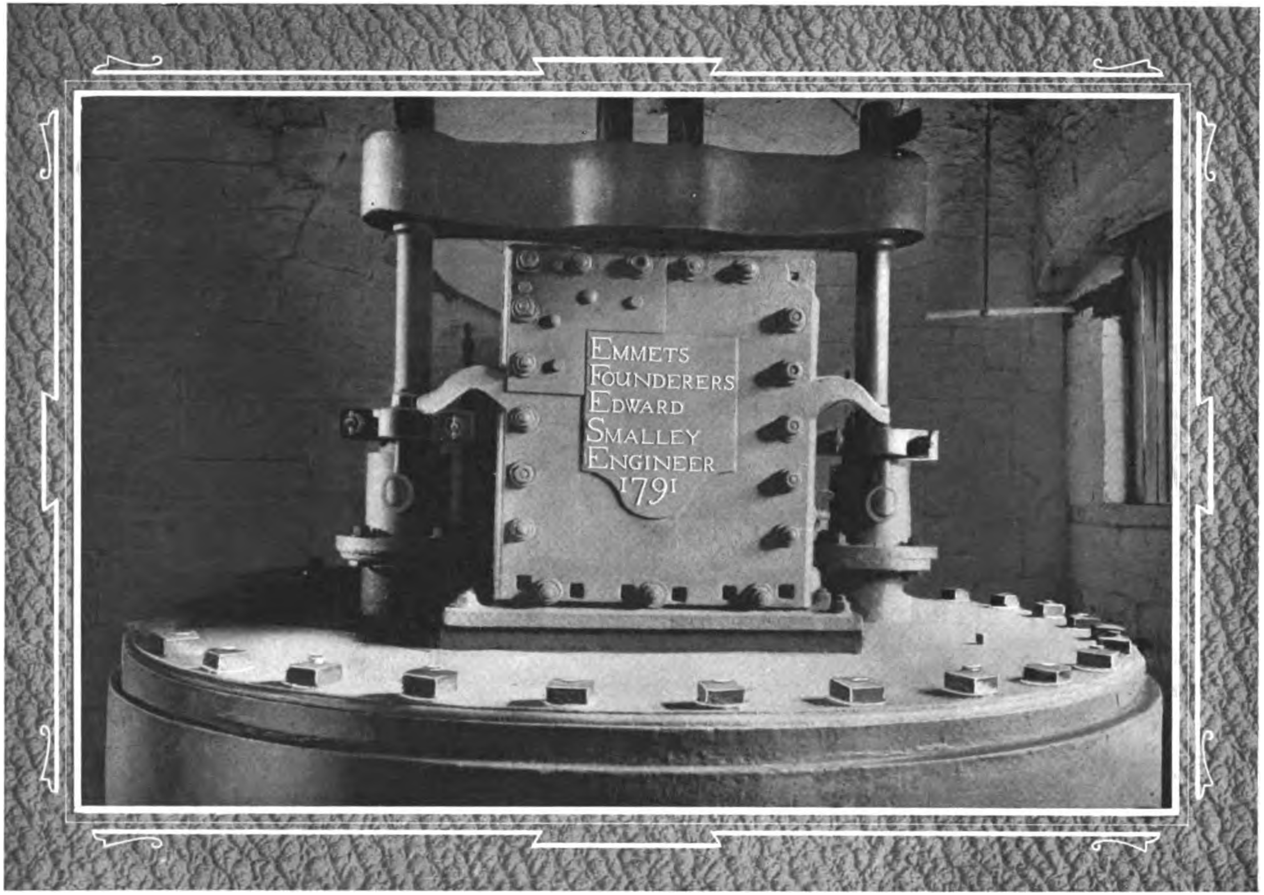


COAL SCREEN, LOWMOOR IRON WORKS.

COAL SCREEN.

THE "Black Bed" or Steam Coal is brought from the Colliery by locomotives to the Coal Screen.

The Coal is dropped from the wagons into a "well," from which an elevator lifts it to the picking and conveying belts, and from there it is discharged into the various shaking screens, each having different sized grates for separating the various sizes of Coal, viz., from large or "all round" Coal, to very small "pea nuts" and smudge.

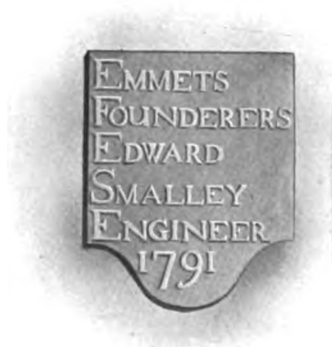


OLD BLOWING ENGINE, LOWMOOR IRON WORKS

THE OLD BLOWING ENGINE.

THE original "Trevithick" or "Boulton & Watts" Blowing Engine, which supplied blast to some of the old furnaces at Lowmoor Iron Works, is still in existence, but not working.

This is one of the oldest engines in England, and is unique in its quaintness and design. It was designed by Mr. Edward Smalley, the Company's then Engineer, and made by Messrs. Emmets, of Birkenshaw, near Bradford, as shewn by the following inscription in front of the air cylinder :—

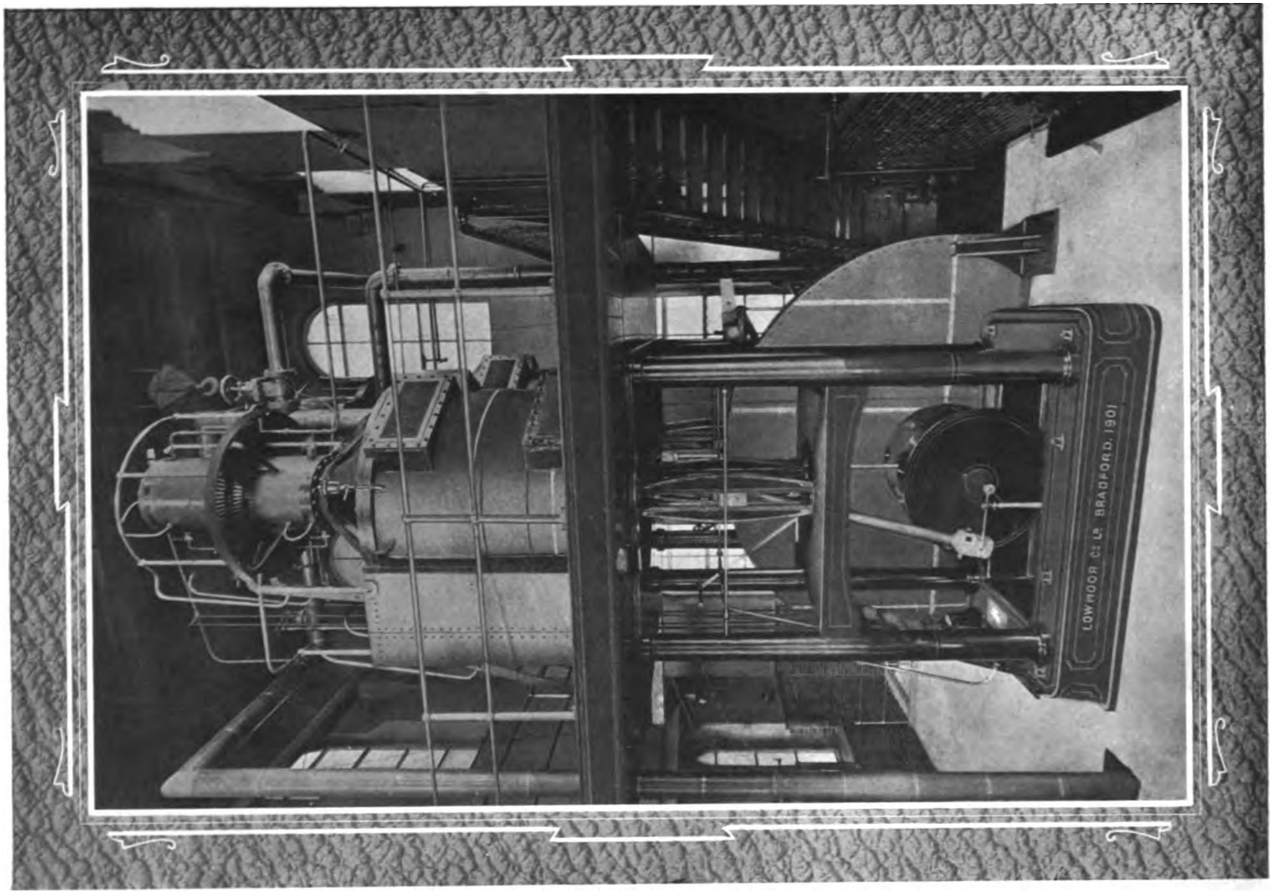


This is what is termed an Atmospheric Engine, having an open top steam cylinder 5 ft. inside diameter. The piston worked with a covering of water on the top, which assisted in maintaining the vacuum. The valves were worked by the original "handgear" motion, with wheel tappets on the air-pump rod. These could be adjusted to regulate the steam admission and cut-off, to suit the return stroke of the piston. All the necessary appliances—most of which are considered original—for condensing purposes, are still attached.

The air cylinder, which is 8 ft. 5 in. inside diameter, is open at the bottom, there being four valves in the piston for admitting and discharging the air into the receiver, which was placed underground, and made of thick stone flags, carefully jointed and made airtight with cement. This receiver was in use for many years, and served for two Blowing Engines and three Blast Furnaces. Ultimately, from the vibration caused by the large Forge Hammers adjoining, the cemented joints begun to leak, and the stone receiver was eventually abandoned, and a wrought iron one, placed aboveground, substituted.

There are two piston rods, placed 4 ft. 3 in. apart, working from a crosshead from which the air piston is suspended.

There are no wheels, cranks, or shafts in connection with the Engine: all balancing arrangement is done by a metal weight bolted to one end of the engine beam. This allows means of adjustment to meet any variation in weight between the steam end of the beam and that of the air.



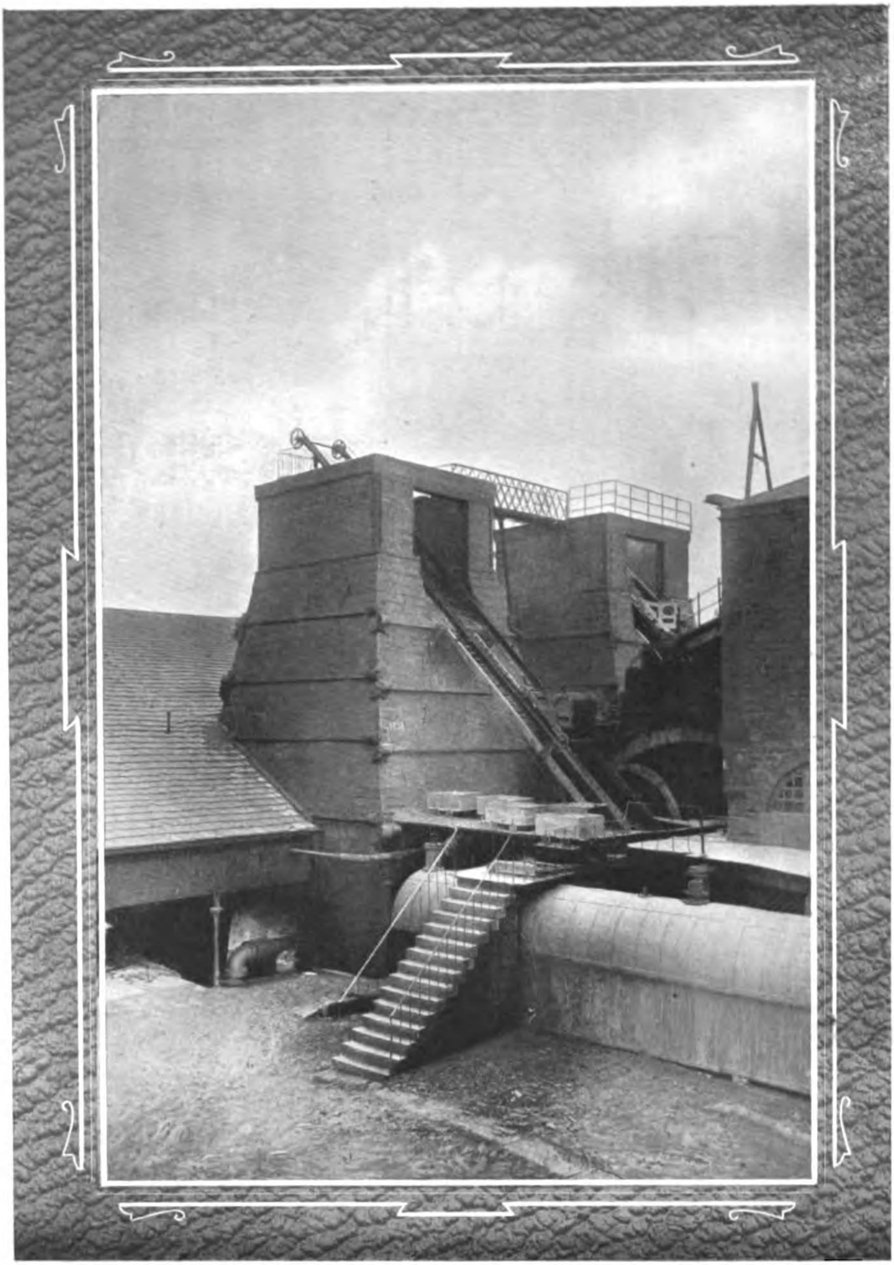
NEW BLOWING ENGINE, LOWMOOR IRON WORKS.

The New Blowing Engine.

This Engine was erected in place of one of the old ones, which was afterwards dismantled. It is a Vertical High-Pressure Compound Engine. High-pressure cylinder 17 inches, low-pressure $28\frac{1}{2}$ inches, air cylinders 77 inches; 4 feet stroke; worked with 100 lbs. steam pressure; air pressure about $2\frac{1}{4}$ lbs. The valves are so arranged that the Engine can be worked high or low pressure, condensing, or compound condensing.

The Engine is placed on a strong baseplate, on the floor line, with a fly-wheel on crank shaft as shewn on the annexed view. An upper metal frame fixed on pillars, supports the steam and air cylinders, and keeps the whole of the parts perfectly rigid. It is well designed, and is capable of supplying the blast required for Refineries, Cupalos, and smiths' fires. The whole of the Engine and attachments were made by the Lowmoor Company during 1901.

In the same building and alongside the Blowing Engine, are two Horizontal Ram Pumps, the rams being 9 inches diameter and 18 inches stroke. Each Pump has high and low pressure steam cylinders, which materially assist in supplying most parts of the Works with water at a very high pressure. The water is drawn from a culvert connected with one of the Company's reservoirs closely adjoining the Works.



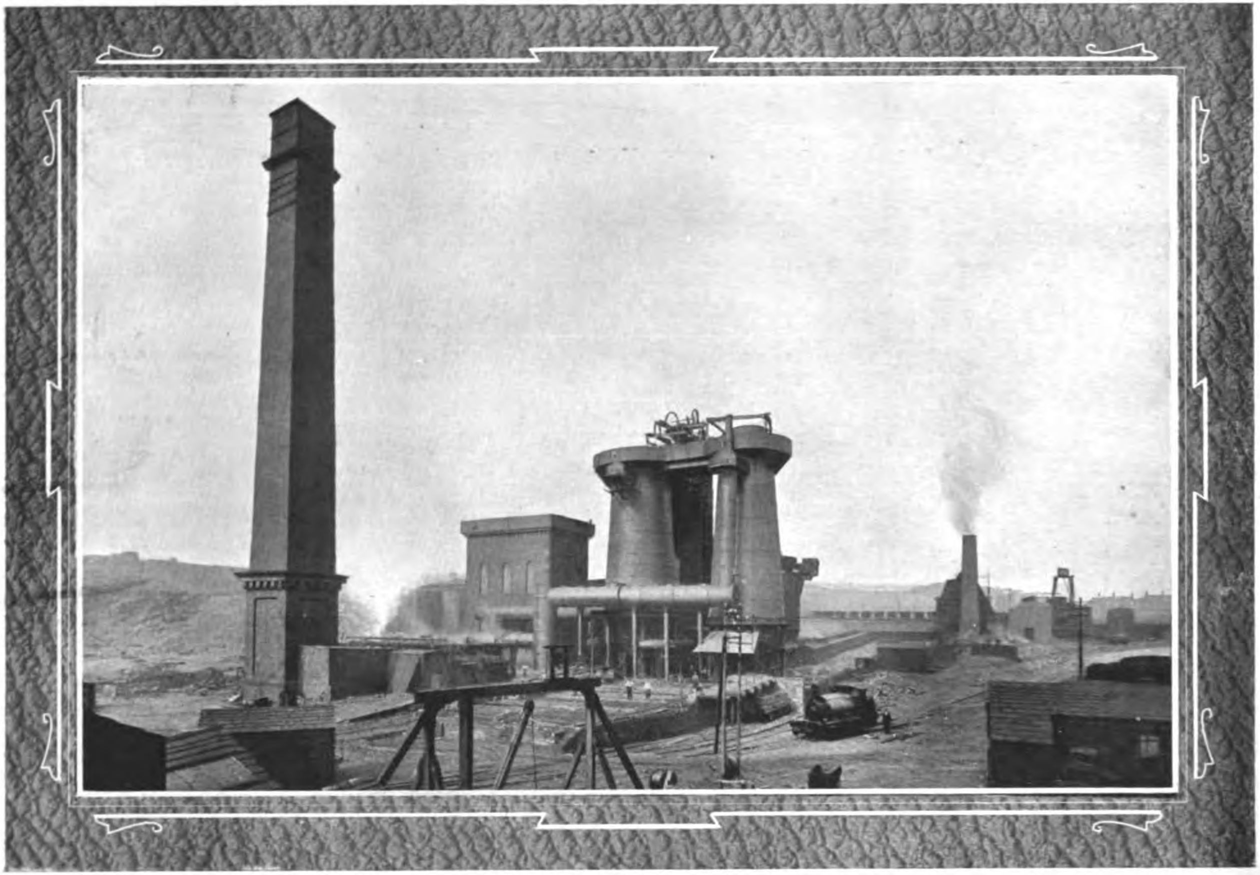
ORIGINAL BLAST FURNACE (1791), LOWMOOR IRON WORKS.

THE ORIGINAL BLAST FURNACE.

THE work of excavating the foundation of the first Blast Furnace at Lowmoor Iron Works was commenced at Christmas 1789, the foundation stone being laid in March 1790. The exterior of the Furnace was stone built of square form, and about 50 feet high.

The original method of feeding the Furnace was by hand labour. Baskets containing coke, ironstone, and limestone were carried or wheeled on a platform level with furnace top, and the contents were dropped or thrown into the Furnace. This system of feeding was abandoned in the year 1800, when the method of filling was changed to that of adopting a water wheel, driving a chain pulley, which hauled the carriages, enclosed in an iron frame, and containing the ironstone, coke, &c., up an inclined plane *(see view opposite)*. An automatic arrangement at the top tilted the carriage and emptied the contents into the Furnace, and by disconnecting a clutch at the bottom, the empty carriage, by its own weight, resumed its position and descended to the loading floor.

During this period and long after, the calcining of the ironstone was done in stone-built kilns lined with fire-brick, and built in rows close to the Furnace, with a tram road over the top bringing the stone direct from the Colliery. After a while these kilns were not capable of producing sufficient ironstone to supply the furnaces, and large quantities were then calcined on the ground in the open air. Subsequently both these methods were abandoned, and "Gjer's" Continuous Kilns were erected close to the furnaces, and the same type are now in operation.



NEW BLAST FURNACES, LOWMOOR IRON WORKS.

The New Blast Furnace.

The Low Moor Furnaces having been in "blast" for over a century, the time had arrived when the Company considered it necessary to erect a new plant, and put into operation a Blast Furnace of larger dimensions.

The New Furnace has a bosh 18 feet diameter, 8 feet hearth, 15 feet throat, and a height of 70 feet. This furnace commenced working in November 1892.

The Blowing Engine is of the vertical direct acting type, having a 40 inches steam cylinder, 84 inches air cylinder, 5 feet stroke; steam pressure 80 lbs.; blast up to 6 lbs. This Engine has been duplicated to meet emergencies.

The Kilns for calcining the Lowmoor Ironstone are 40 feet high, and 24 feet diameter. A complete system of locomotive haulage is arranged for conveying the ironstone to the kilns.

This Furnace is equal to a weekly production of about 340 tons of cold blast pig iron.

An additional Furnace has been erected, closely adjoining the one above described, of rather less capacity, having a bosh 14 feet, hearth 7 feet, 11 ft. 6 in. throat, with a similar height to that of the larger furnace—viz., 70 feet,—so as to utilize the same lift and landing stage. The output of this Furnace is equal to about 240 tons per week,—all cold blast pig iron.

The above being Closed-top Furnaces, the gases are conveyed through downtake tubes

to the boilers, and generate sufficient steam for supplying Blowing Engines, Coal Washer Engine, and also the engine for driving the Electrical Generator.

These two Furnaces are erected on the same site as two smaller Open-top Furnaces which were erected during 1836, each of which had a weekly output of about 70 to 80 tons.

The above Furnaces are situated about half-a-mile from the general Works, and the pig iron is hauled by locomotives to the Refineries.

ANALYSIS OF LOWMOOR PIG IRON.

Combined Carbon	·550
Graphite	3·060
Silicon	1·335
Sulphur	·049
Phosphorous	·367
Manganese	·808
Iron *(by difference)*	93·831
	100·000

OLD FOUNDRY, LOWMOOR IRON WORKS.

FOUNDRY.

The commencement of the Foundry at Lowmoor Iron Works would be contemporary with that of the Blast Furnace—viz., at the latter part of the year 1791. During the first few years the output consisted chiefly of miscellaneous articles, such as coal wagon wheels, cast-iron rails, pillars, and other hardware for building purposes; but within a comparatively short time, the Lowmoor Company began the manufacture of guns for artillery purposes. It is recorded that guns were made at Lowmoor Iron Works during 1795, and doubtless cast-iron shot were also made at that time, as these formed part of the same branch of trade. This business the Company energetically carried on for many years, for in 1854, the weekly output of shot, shells, guns and mortars, amounted to several hundred tons.

The Foundry during these years was also occupied in making castings for the Colliery and Engines, such as beams, cylinders, bedplates, &c., and also castings for forge purposes, many large castings being required for the latter purpose, especially when the various extensions were made in the Forge.

Another branch of trade which the Company was extensively engaged in was the making of sugar mills of various sizes, some being heavy machines requiring fairly heavy castings. This class of work was carried on at Lowmoor Iron Works for many years.

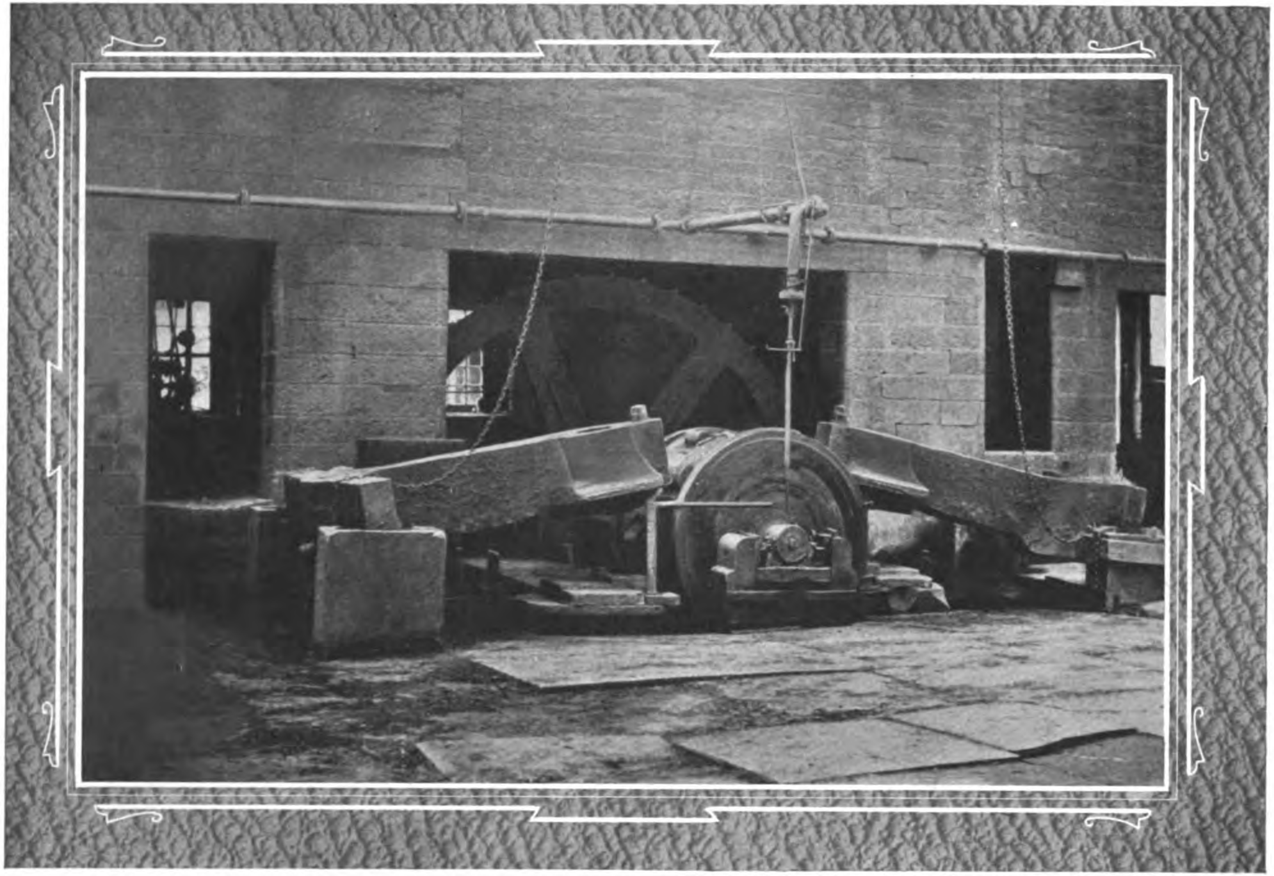
A view of the interior of the Old Foundry is attached hereto, shewing the original crane erected for lifting heavy weights. This crane would be erected during, or very shortly after, 1791.

ORIGINAL OCTAGON OFFICE. LOWMOOR IRON WORKS.

The Original Octagon Office.

This was built at the commencement of the Works during 1791, and is still used as a pay office. It was built in the octagon form, as many buildings were at that period. The upper room was the Company's Private Office; the lower one was the Clerks' Room.

It was occupied as the sole General Office until December 1842, when the present Offices at the entrance gates were opened. Prior to this date, however, the Colliery office-work was chiefly carried on in a separate building.



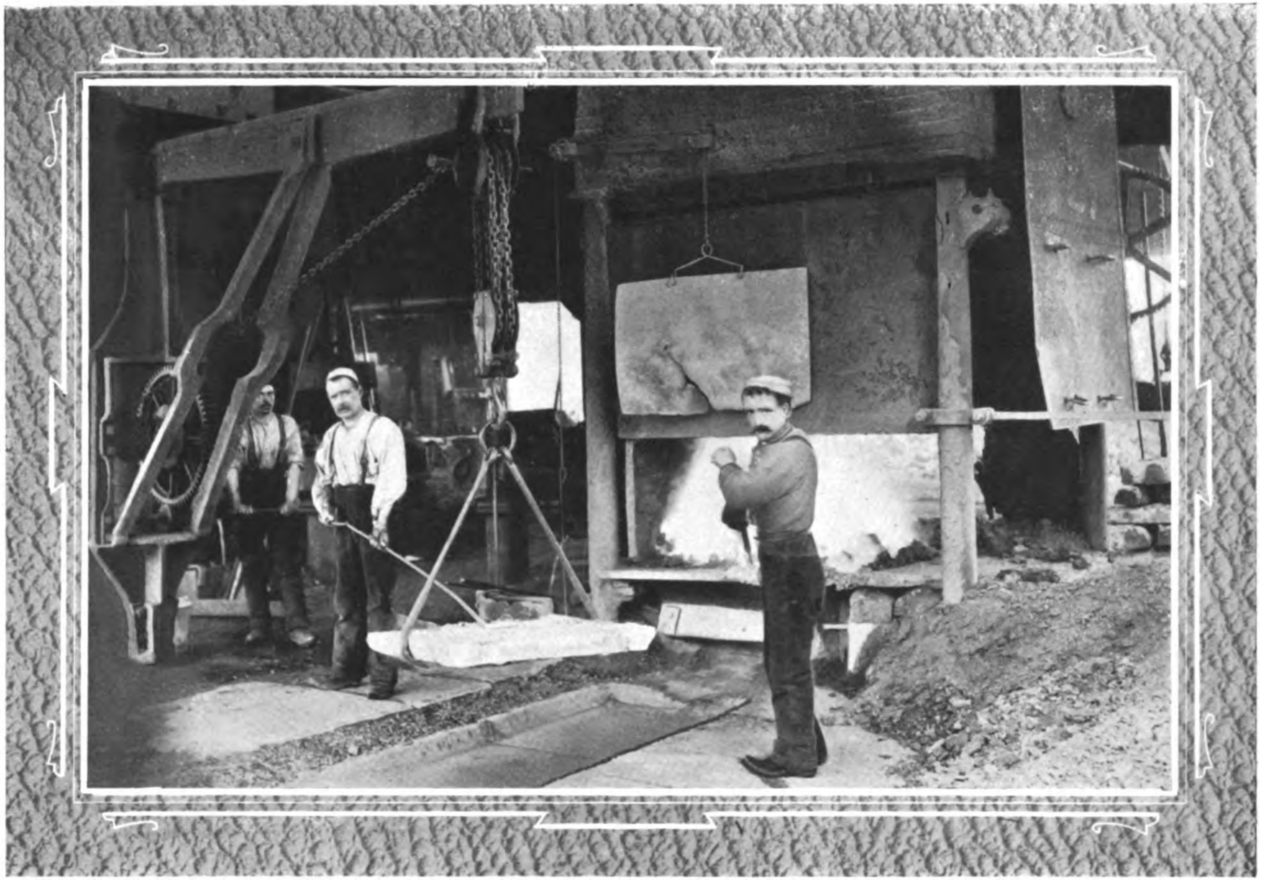
ORIGINAL TILT HAMMER, LOWMOOR IRON WORKS.

FORGE.

THE first record in connection with the Forge is found during the year 1801. There would be no Puddling Furnaces at Low Moor at this time. Charcoal fires were used, with a Slitting Mill attached, for producing nail rods, and very small flat and square bars.

During 1802, Forge Hammers were erected, a view of the original one being shewn on the opposite page. This hammer, or rather two hammers combined, was driven by a Low-Pressure Reversing Condensing Engine.

The reversing arrangement was by means of revolving tappits bolted to the air-pump rod which regulated the valves. The hammers—one on each side of the cam shaft—could, by reversing the engine, be worked alternately. One was generally used for making rough blooms; the other used for forgings, shafting, &c.



REFINERY, LOWMOOR IRON WORKS.

REFINERY.

REFINERY FIRES were first commenced at Lowmoor Iron Works during 1803. These fires are composed of cast-iron boxes, so arranged that during work a continuous stream of water is flowing through each box. This is necessary, so as to resist the effect of the blast impinging against the sides. These iron boxes were adopted many years ago, in place of fire bricks, which often required renewing.

The internal space of the Refinery is 4 feet by 3 ft. 4 in. by 18 inches deep, and supplied with blast from two tuyres, placed at an angle on one side of the fire.

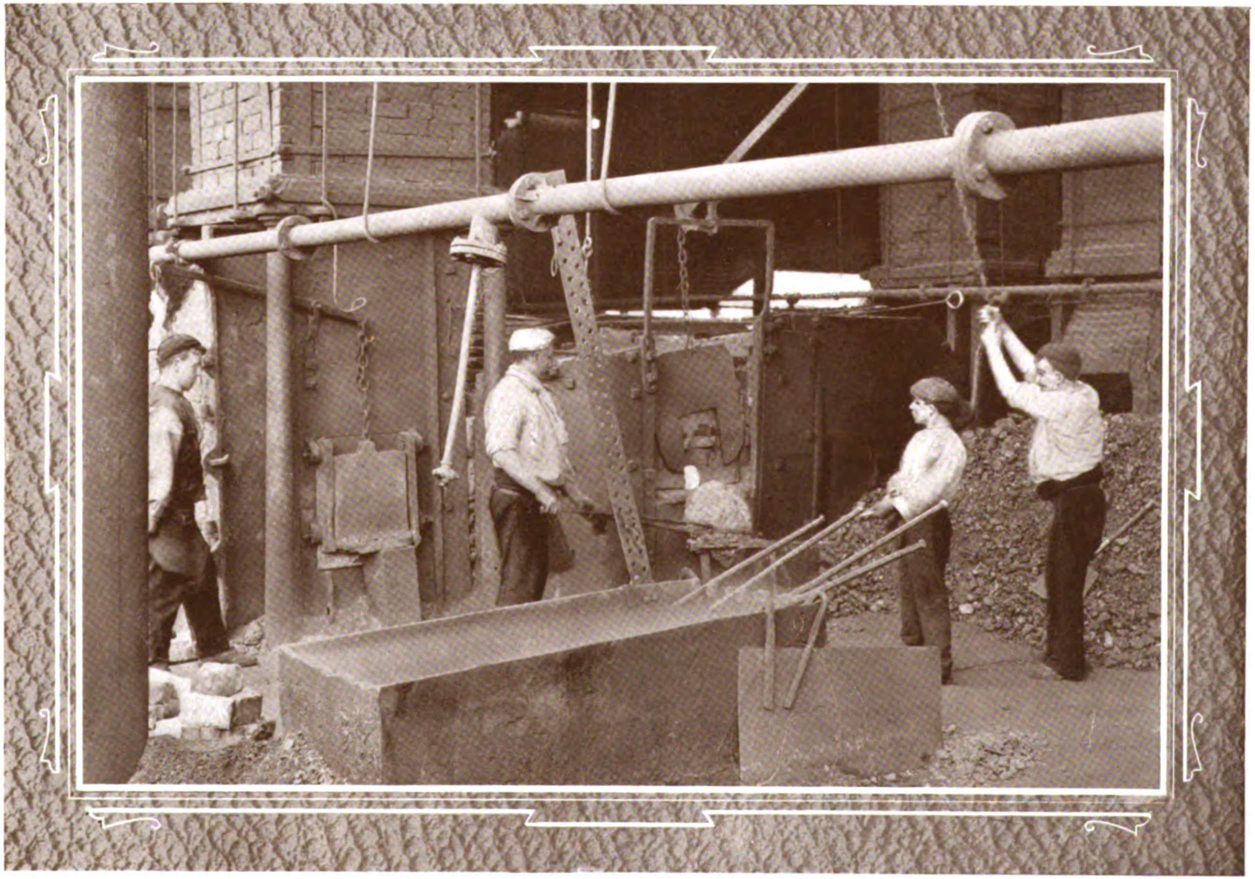
The charge consists of about 30 cwts. of pig iron, with coke as fuel. The refined metal when tapped runs into a shallow metal trough, or mould, about 3½ inches deep. The refined iron is broken when cold into suitable pieces, in readiness for the Puddling Furnace.

ANALYSIS

OF

LOWMOOR REFINED IRON.

Combined Carbon	3·100
Graphitic Carbon	·400
Silicon	·253
Sulphur	·038
Phosphorous	·244
Manganese	·720
Iron	95·200
	99·955



PUDDLING FURNACE, LOWMOOR IRON WORKS.

PUDDLING.

The first reference to Puddling at Lowmoor Iron Works is recorded in a written agreement dated 11th May 1803, in which John Davis agrees to serve the Lowmoor Company as puddler for the term of three years, upon certain conditions—viz., prices per ton, house rent and coal free, and expenses of family's removal allowed.

Only a small number of Puddling Furnaces were built during the first few years, the number being increased as demand required.

The method of puddling as now carried on at Lowmoor Iron Works differs only slightly with that of former years, with the exception, that originally sand bottoms were used for the working part of the furnace, in place of metal ones as now in general use.

The form of intermediate heating also differs somewhat from the original design. The charges of refined iron are placed in a small chamber, at the end of the furnace, and directly under the bottom of the chimney. The flame, after passing through the working part of the furnace on its way to the chimney, passes over the refined iron, heating it to a good red heat. It is then placed in the body, or working part of the furnace, melted, and continually worked, until the mass begins to granulate and form itself into small particles, which, with increased heat, begin to adhere to each other.

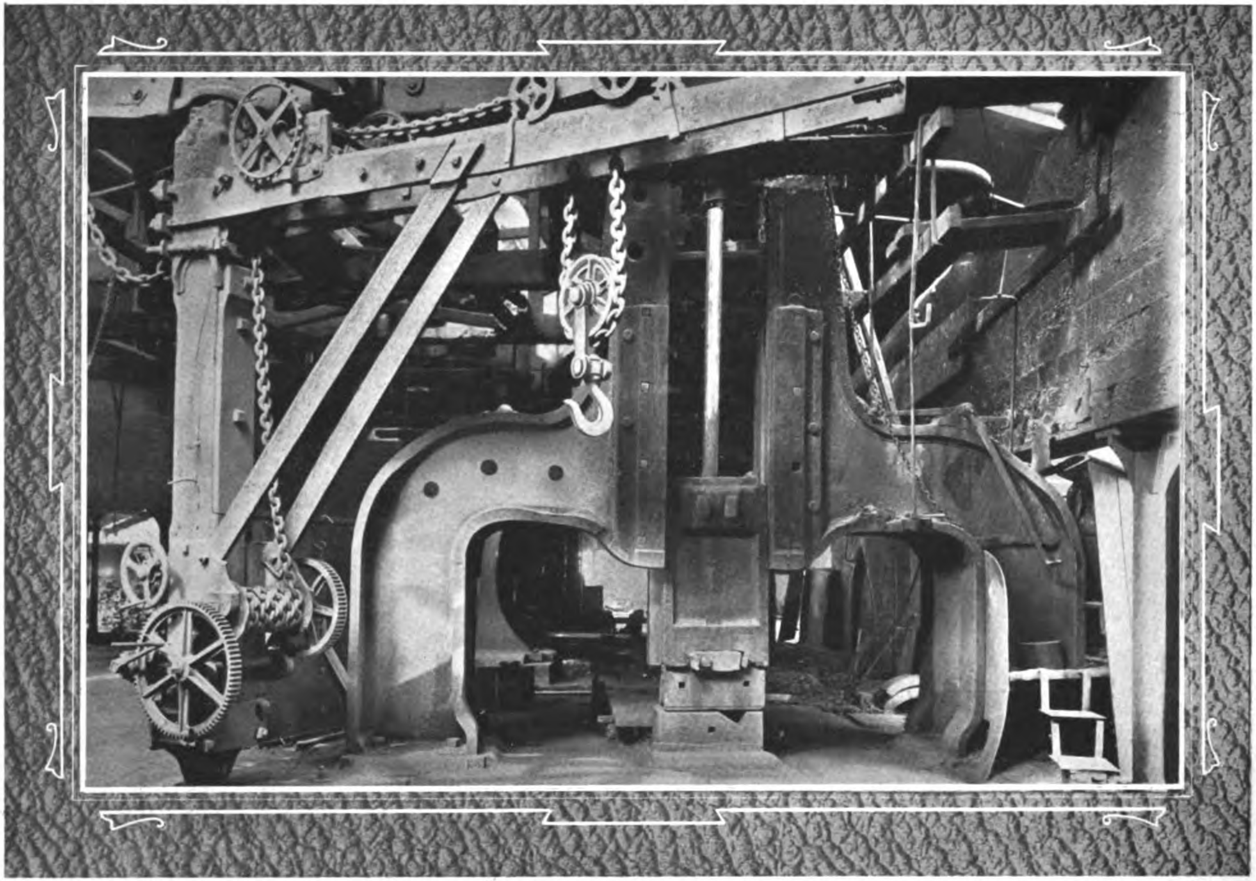
The puddler is careful to expose each part of the charge alike to the action of the flame, so as to ensure uniformity in the whole; he then divides the mass into three or

four portions, as required. Each portion is formed into a puddled ball, brought out and "shingled" under steam hammers into rectangular pieces, or slabs, about 12 inches by 10 inches—the thickness varying according to weight, special care being taken that each piece, or slab, bears the puddler's private mark for identification during subsequent working. The weight of refined iron charged per heat is about 3 cwt., the puddler getting ten heats per day or night.

The whole of the puddled iron at Lowmoor Iron Works had been made, up to 1846, in what is still called the "Old Forge," at which date the present New Puddling Forge was erected.

ANALYSIS OF LOWMOOR PUDDLED IRON.

Iron	99·010
Carbon	·420
Silicon	·039
Sulphur	·008
Phosphorous	·240
	99·717



ORIGINAL 4-Tons STEAM HAMMER, LOWMOOR IRON WORKS. Erected in 1844.

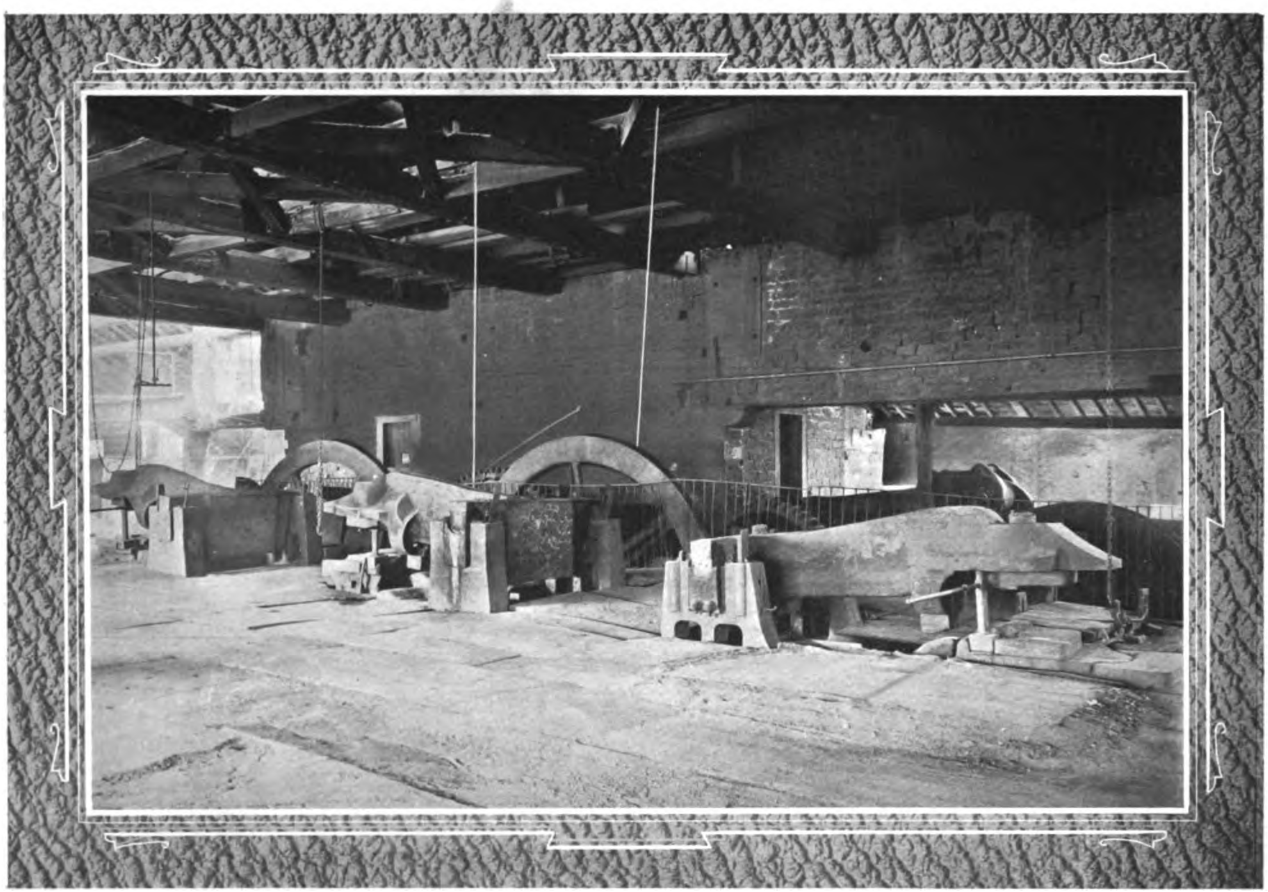
ORIGINAL 4-TONS STEAM HAMMER.

THE year 1843, and probably a little before that, was a period when Steam Hammers were being introduced, and Mr. Nasmyth, of Patricroft, the inventor, was very wishful for the Lowmoor Company to adopt them, he being very sanguine that eventually (as has since been proved) this class of hammer would supersede all others previously used.

The Company, however—not yet being convinced as to their general utility for forge work,—were deciding in 1843 and 1844 to put down several additional hammers of quite another design. These were named "Helves," as a distinction from the old Tilt Hammers, and were driven by a 30 h.p. Low-Pressure Engine, with very powerful gearing attached. They were suspended at one end, and lifted near the centre by a three-armed revolving cam, keyed on the driving shaft. A view of one of the forges where three hammers of this class were situated is shewn on page 50.

These hammers were considered quite up-to-date, and did good service, especially for blooms, slabs, and other plain work. They had been tried for making locomotive cranks, but were not a success; still they were used for other purposes until 1904, when seven of them were dismantled, and Steam Hammers substituted.

During 1844, however, Mr. Nasmyth prevailed upon the Company to try (almost as an experiment) a 4-tons Steam Hammer, this being the largest attempted to be made up to that date. The hammer was erected, and for a time was worked under great

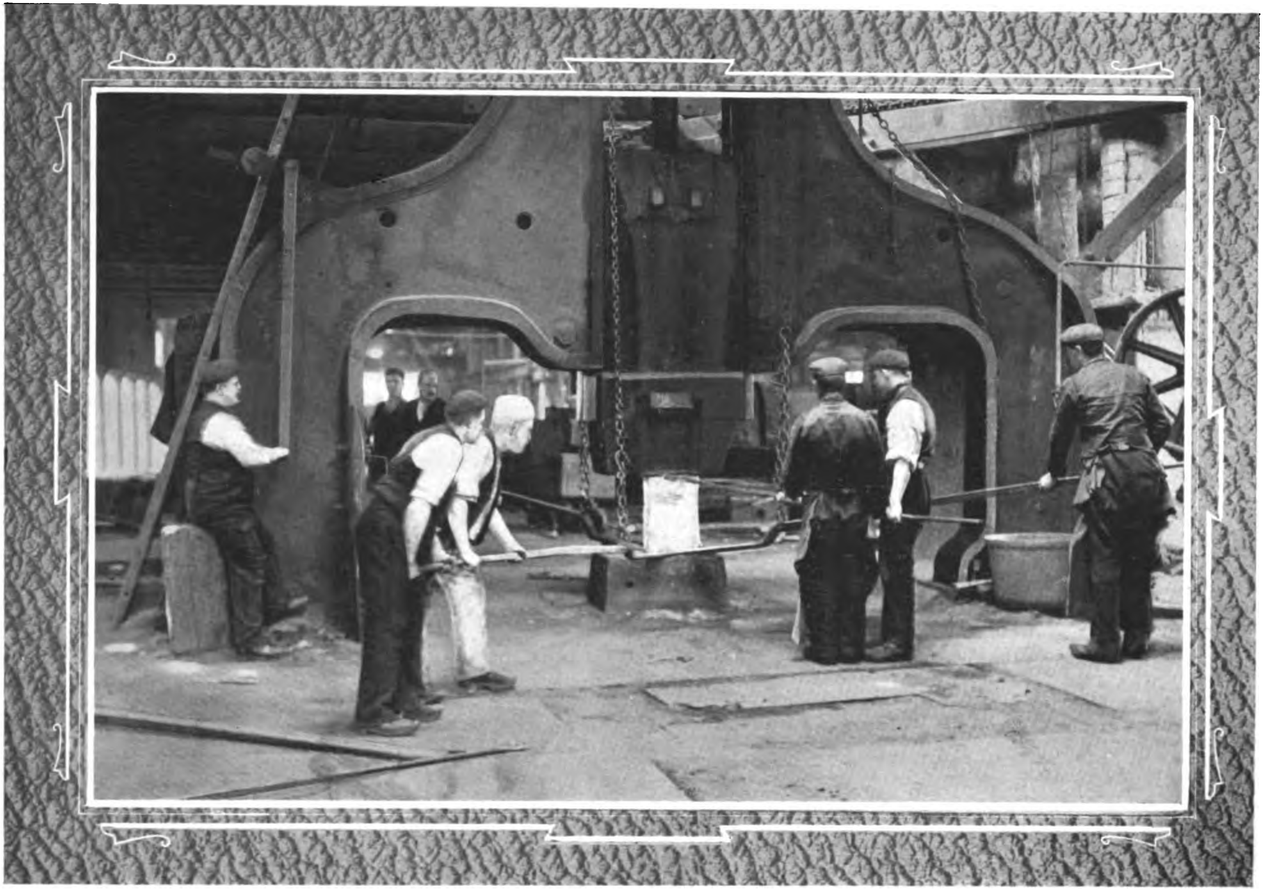


SLAB FORGE HELVES, LOWMOOR IRON WORKS. Erected 1844 Dismantled 1904.

difficulties, partly owing to complication in valve and motion arrangement, and partly to forgemen's prejudices. It is recorded, too, that those who had the supervision of the hammer were not satisfied with its working, and informed the maker that he had erred on the heavy side, and that a 2½-tons, instead of a 4-tons Hammer, would have been more suitable for general purposes. In the course of years it was proved otherwise, and in 1864, a Steam Hammer double the weight—viz., 8 tons—was erected for a heavier class of work. A view of this hammer is shewn on page 52.

The difficulties in connection with the original Steam Hammer, however, were eventually overcome, and the hammer became most useful in making fairly heavy and difficult forgings. All the piston rods, connecting rods, crank pins, and several other forgings for the "Great Eastern" Steamship, were made under this hammer.

The hammer was worked continuously until 1864, when it was found that, owing to its single action (working by gravitation), it was too light for the work required. It is still in existence, however, and is frequently at work.

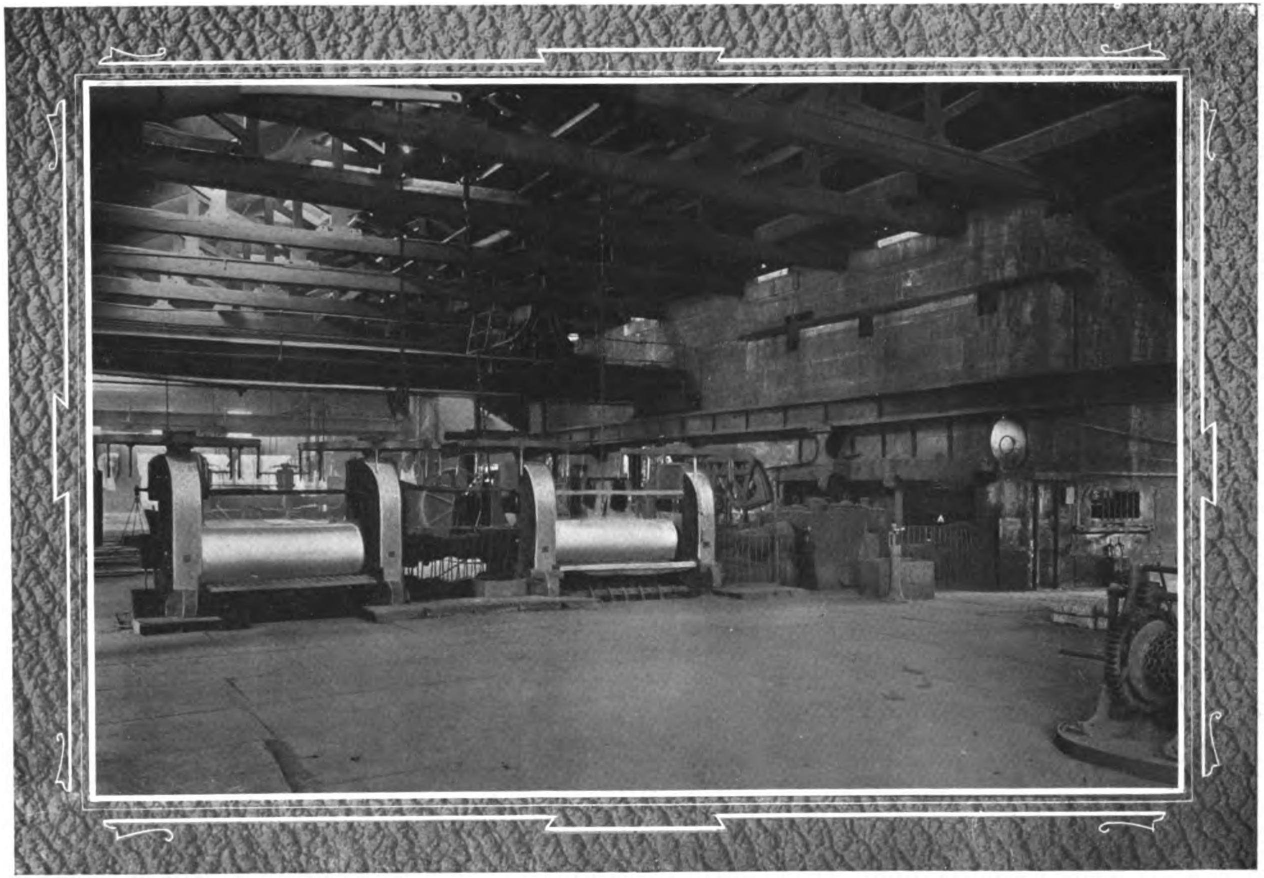


8-Tons STEAM HAMMER, LOWMOOR IRON WORKS. Erected in 1864.

BARS, PLATES, AXLES, AND OTHER FORGINGS.

THE Puddled Iron is brought to the re-heating Furnaces, heated and hammered into blooms, then rolled into bars, and cut into short pieces or faggots. These are piled lengthway or crossway as required, and again heated and hammered, and afterwards rolled into finished bars, or made into slabs for plates, and blooms for axles and forgings. Great care is taken during each process that no deleterious matter is allowed to get mixed up with the iron. This has special reference to boiler plates, which require every precaution to ensure the inside welds being kept clean, and thoroughly united. Rolling across the grain, to get width of plate, is a severe strain upon the joinings or weldings, and any small unsoundness in the slab is soon developed and made larger during rolling,—sufficiently so, to cause serious defects or laminations.

Much attention is also given during rolling, to keep the surface of the plates free from scale; and to render them smooth when finished, jets of water are used as the plate passes and re-passes through the rolls. This not only assists in keeping the surface clean, but often enables the man in charge to detect an occasional defect, which the use of water makes more apparent.



24-Ins. PLATE MILL, LOWMOOR IRON WORKS. Erected in 1867.

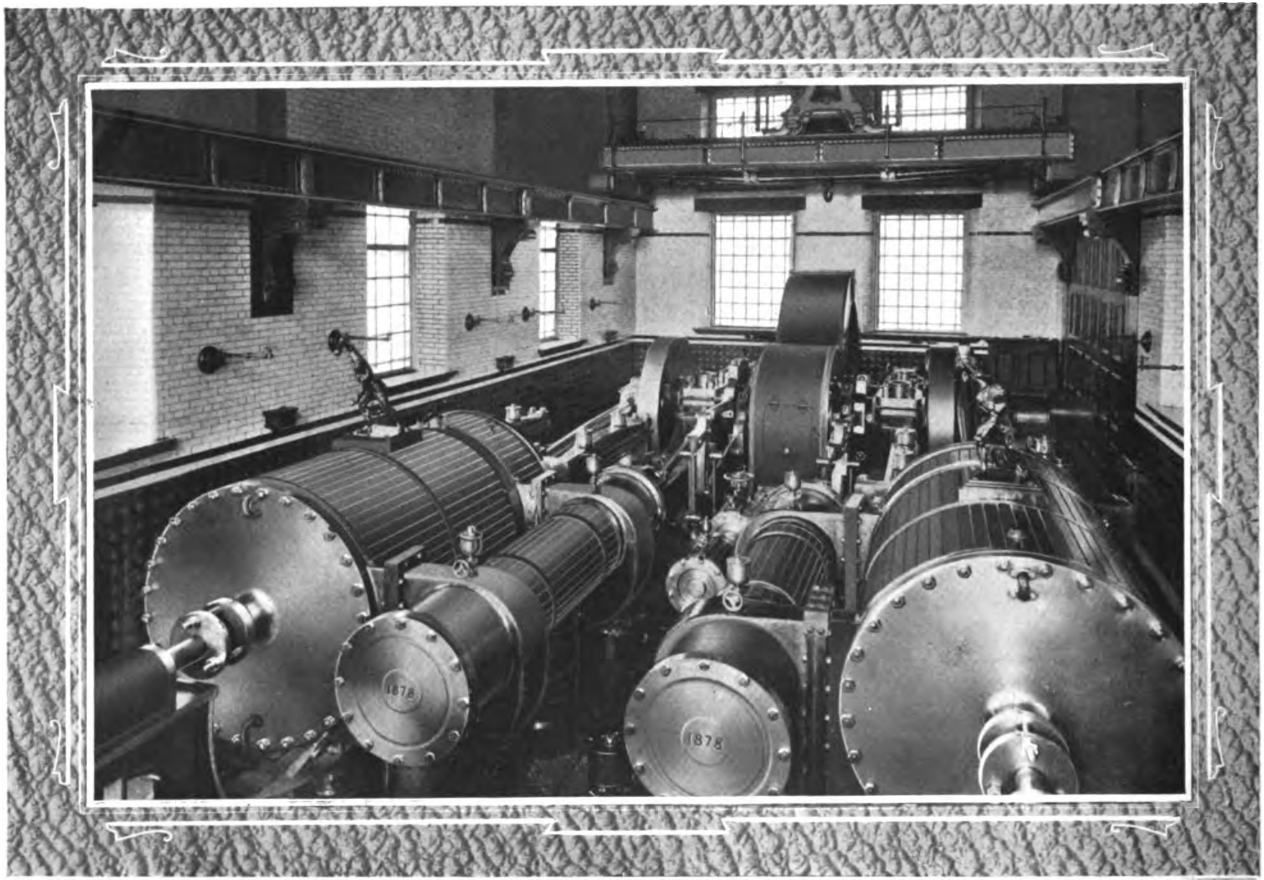
24-INS. PLATE MILL.

In 1867, the Company finding their original 18-inches Plate Mill was not equal to the increasing demand, put down a 24-inches Plate Mill, 7 ft. 6 in. rolls, driven by two 60 h.p. (nominal) Low-Pressure Beam Condensing Engines, coupled. These develop with full load, close on 200 indicated horse-power, having 41 inches cylinders, 7 feet stroke; the spur wheel on crank shaft is about 20 feet diameter, and pinion on fly-wheel shaft about 8 feet diameter; pitch of teeth 6 inches; the diameter of fly-wheel is 24 feet, and weighs about 30 tons. A reversing gear is attached, driven in the usual manner by a series of wheels, so arranged that two of them run in an opposite direction on the same shaft, having a sliding wrought-iron clutch in the centre, and worked by a reversing lever, which is moved to the right or left by steam, and is controlled by a special arrangement to stop the clutch in the centre, and then move it slowly into gear.

Spring buffers are arranged in boxes on face of wheel bosses to receive the sudden strain when the rolls are started and reversed. This arrangement has been very successful in preventing breakages, and thus prolonging the life of the reversing wheels.

An additional 7-tons Steam Hammer, for supplying this Mill with slabs, was erected during 1871.

This Plate Mill, although considered quite up-to-date (as regards size and arrangement) at the time of its erection, only sufficed for a few years, as in many instances larger plates were required than this Mill could roll. The Lowmoor Company therefore decided in 1878 to erect a larger and more powerful Plate Mill, of such proportions as would meet trade requirements for many years.



LARGE PLATE MILL ENGINES, LOWMOOR IRON WORKS. Erected in 1878.

LARGE PLATE MILL.

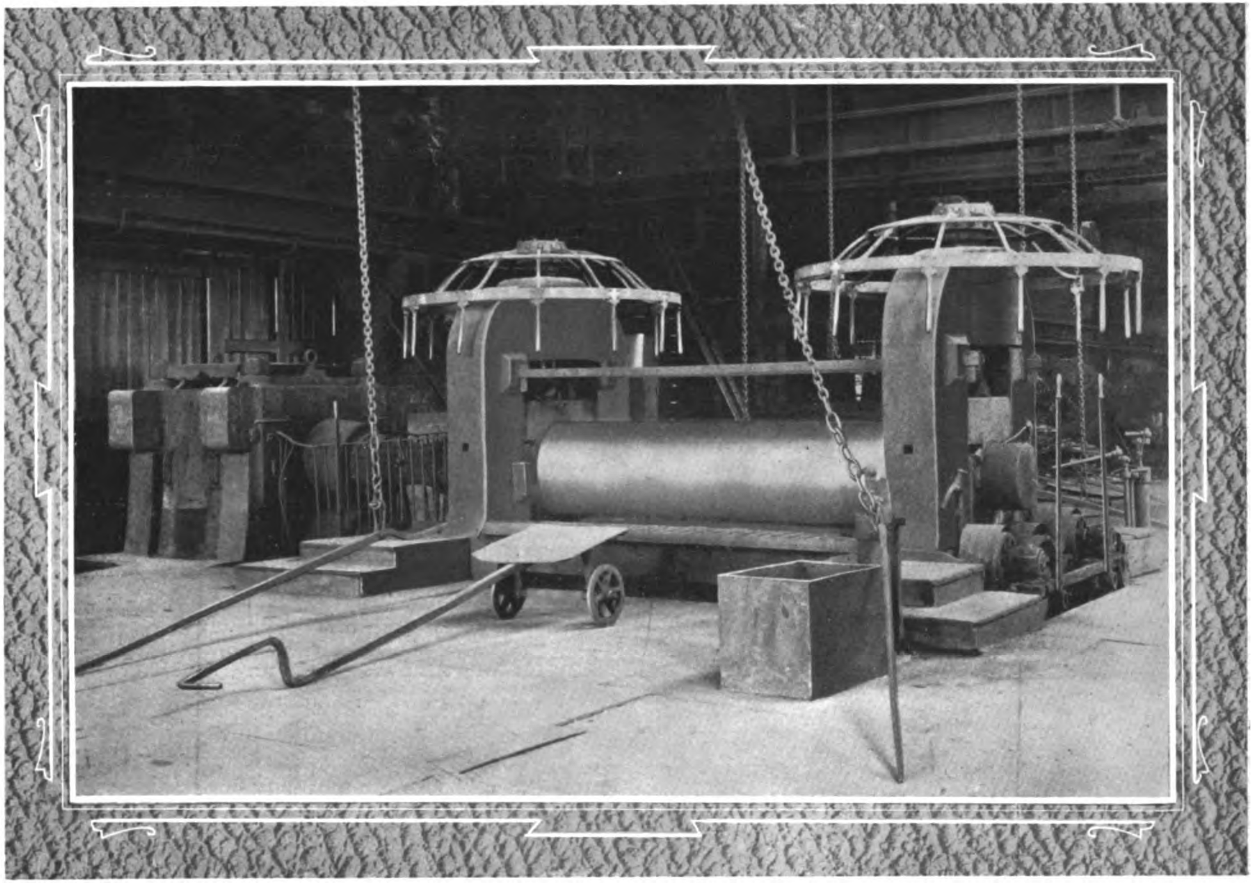
THE Engines for this Mill are a pair of Horizontal High-Pressure Reversing Engines, 50 inches cylinders, 5 feet stroke, arranged to work at 50 revolutions per minute, with an initial steam pressure of 60 lbs. per square inch. The valves are of the piston type, having loose linings 20 inches diameter.

The crank shaft bearings are 18 inches diameter, 2 ft. 3 in. long, while those of the second motion shaft are 21 inches diameter, 2 ft. 3 in. long. Both these shafts were made at Lowmoor Iron Works, the weight of the forgings being 12 tons and 6 tons respectively. The pinion on crank shaft is 5 ft. $5\frac{1}{4}$ in. diameter, and spur wheel 13 ft. $7\frac{1}{4}$ in. diameter, pitch of teeth 8 inches, and 24 inches across the face.

The Engines are reversed by a steam cylinder and oil "cataract." The reversing lever, and that for regulating the valves, are placed outside the engine-house, in order that the man in charge may have the rolls in sight when in operation.

The foundation and housings for this Mill (a view of which is shewn on page 58) are very massive. The plate rolls are 32 inches diameter, and 11 feet long. Friction rolls and feeding gear is attached, both front and back of rolls, to assist in passing the plate backwards and forwards during rolling.

This Plate Mill, being one of the largest in the country, merits special attention.



LARGE PLATE MILL ROLLS AND HOUSINGS, LOWMOOR IRON WORKS.

Rivet, Stay Bolt, and Chain Iron.

Rivet making is carried on at Lowmoor Iron Works, both by machines and by hand. An extensive variety of shapes and sizes are produced, as is shewn by the list attached hereto. "Lowmoor" Iron is specially adapted for this class of work, and is in general demand, the rivets being sent into all parts.

Stay Bolts for fire boxes require a similar material to rivets, and "Lowmoor" Iron is much used for that purpose.

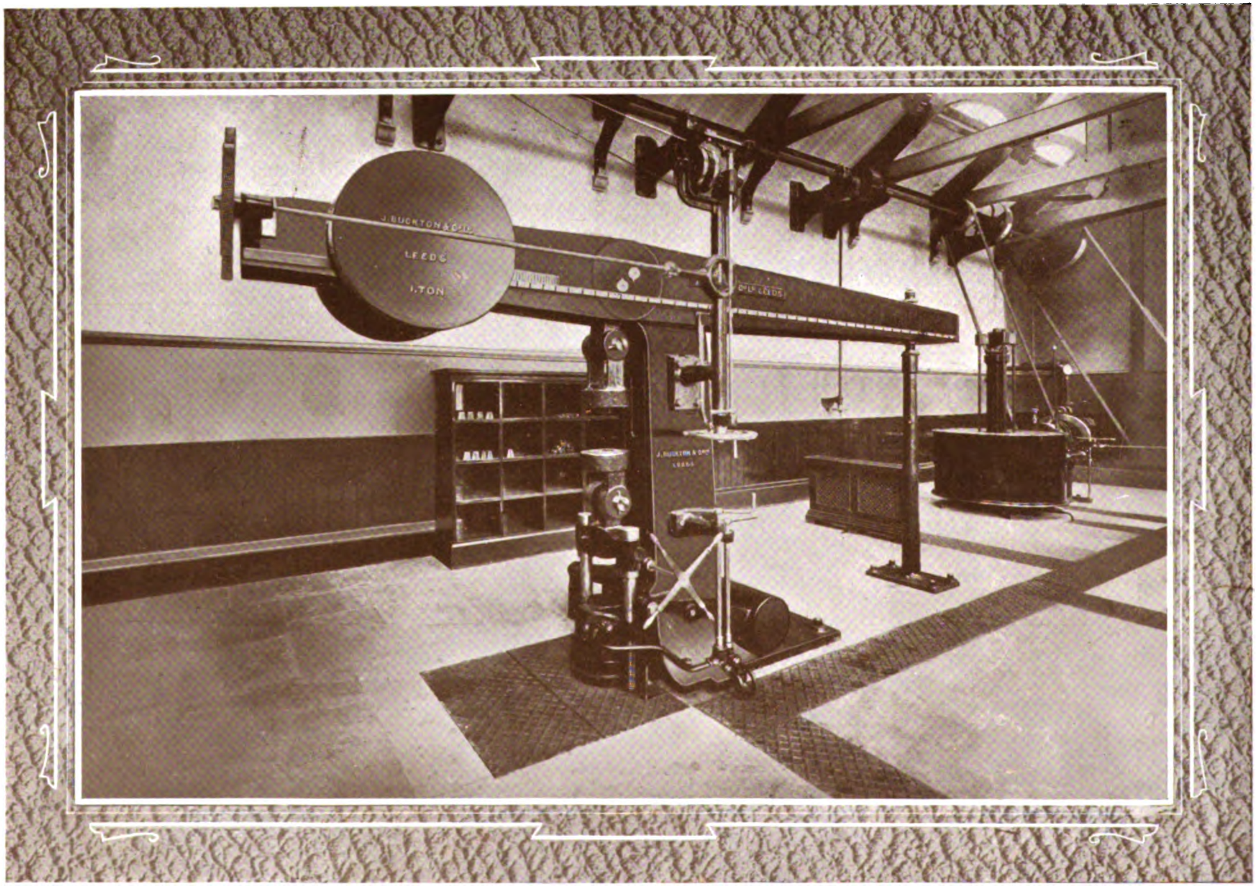
"Lowmoor Chain" Iron also forms a considerable part of the output of the Works, being extensively used, not only for ordinary chains, but for railway coupling chains, carriage and wagon draw gear, and colliery work. Where ductility is of vital importance for endurance and safety, much depends on a reliable material being used for such important purposes.

ANALYSIS

OF

LOWMOOR FINISHED IRON.

Combined Carbon *(by colour determination)*	·081
Silicon	·104
Sulphur	*traces*
Phosphorous	·041
Arsenic	·008
Manganese	*traces*
Iron *(by difference)*	99·766
	100·000



50-Tons TESTING MACHINE, LOWMOOR IRON WORKS.

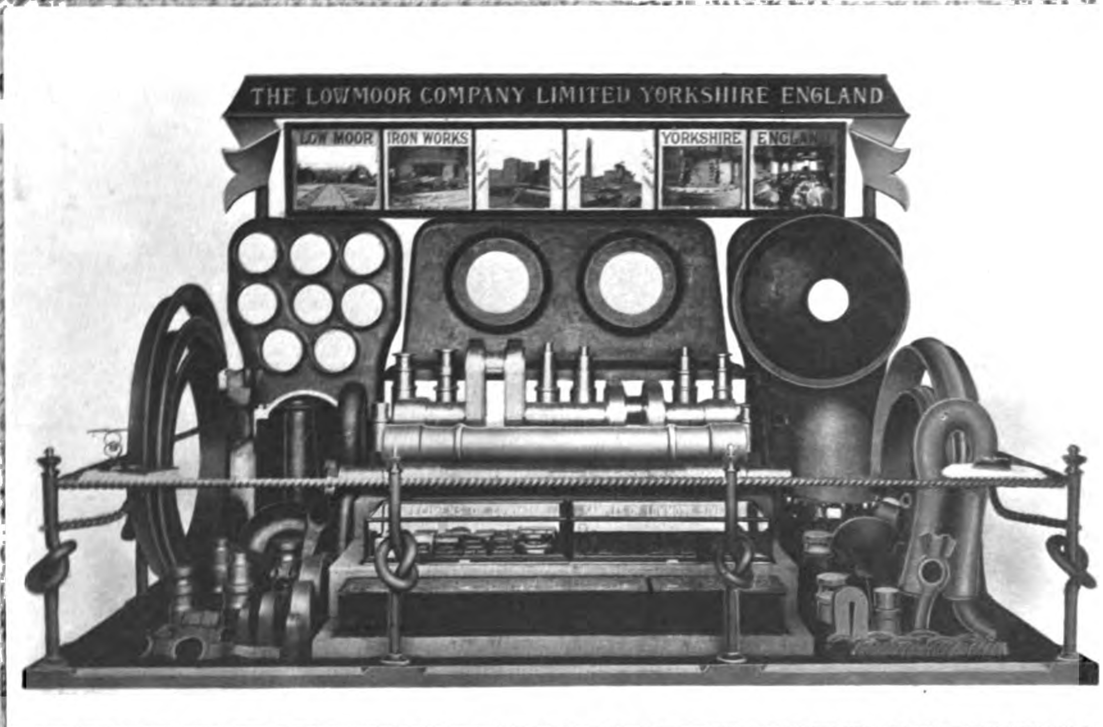
TESTING HOUSE.

The Testing House contains one of Messrs. Buckton's 50-tons Single Lever Testing Machines. The lever is graduated to indicate tons, tenths and hundredths of tons, and is fitted with knife-edged fulcrums at 3 inches centres, to work up to 50 tons.

The machine is made with a Hydraulic Straining Cylinder 10⅝ inches diameter and 6 inches stroke, and fitted with hydraulic valves for admitting and exhausting water from the accumulator, which works at 1,500 lbs. pressure, with a 4 inches ram, and 4 feet stroke.

All exhaust water from the strain cylinder after a test has been made returns to the "well" of the pump. The pumps are belt-driven and self-contained.

Steel-hardened Clips are provided for testing up to 1½ inches diameter, or sizes of equal area; larger sections are turned down to meet capacity of machine.



COLLECTION OF PRODUCTS FROM LOWMOOR IRON WORKS.

"LOWMOOR" IRON.

"Lowmoor" Iron has attained its high reputation by commencing the manufacture with an uniform and well-known raw material, combined with the use of the Company's "Better Bed" Coal of exceeding purity. Both these materials are found locally, and are quite distinct stratas from those found in other parts of the country.

Users of "Lowmoor" Iron, acquainted from long experience with the careful methods of its manufacture, often place more reliance upon the ductility of the material in actual practice, and its capability to withstand exposure to extreme variations of heat when in work, than upon bare mechanical tests. Although these may be very interesting, and probably sometimes assist in shewing some of the virtues and otherwise of the material, yet they do not always represent what is most essential—viz., its power to withstand sudden shocks without fracture, and its reliability and welding properties.

Manufacturers who have to furnish material subject to exceedingly varied requirements, have often cause to complain of those who, unfortunately, do not avail themselves of the experience and knowledge naturally possessed by the Manufacturer. Orders are often given out containing sizes of wide range, both in bars and plates, which have all to be subject to, and expected to fulfil, the same requirements. This, as all iron makers know, is quite contrary to general practice, and no system of difference in manipulation would meet the difficulty.

COLLAPSED BOILER FLUES, LOWMOOR IRON WORKS.

In some few instances, a graduated scale, according to sectional area, is specified, which is much more reliable than a fixed rule for all sizes.

Then the elongation requirement is a very important factor in mechanical testing. The length of piece under test varies very much in fact, viz., from 2 inches up to 10 inches, or perhaps more, in some cases are specified. And, as is inevitable in practice, the local extension on each side of fracture tells in a greater ratio on a short piece than on a longer one; hence the necessity of having a scale of elongations, diminishing with the increase in length.

Many Engineers make tests only on such a number of plates and bars in an order as are, in their opinion, sufficient to ascertain if the quality is in accordance with the specification.

Scale of Tests

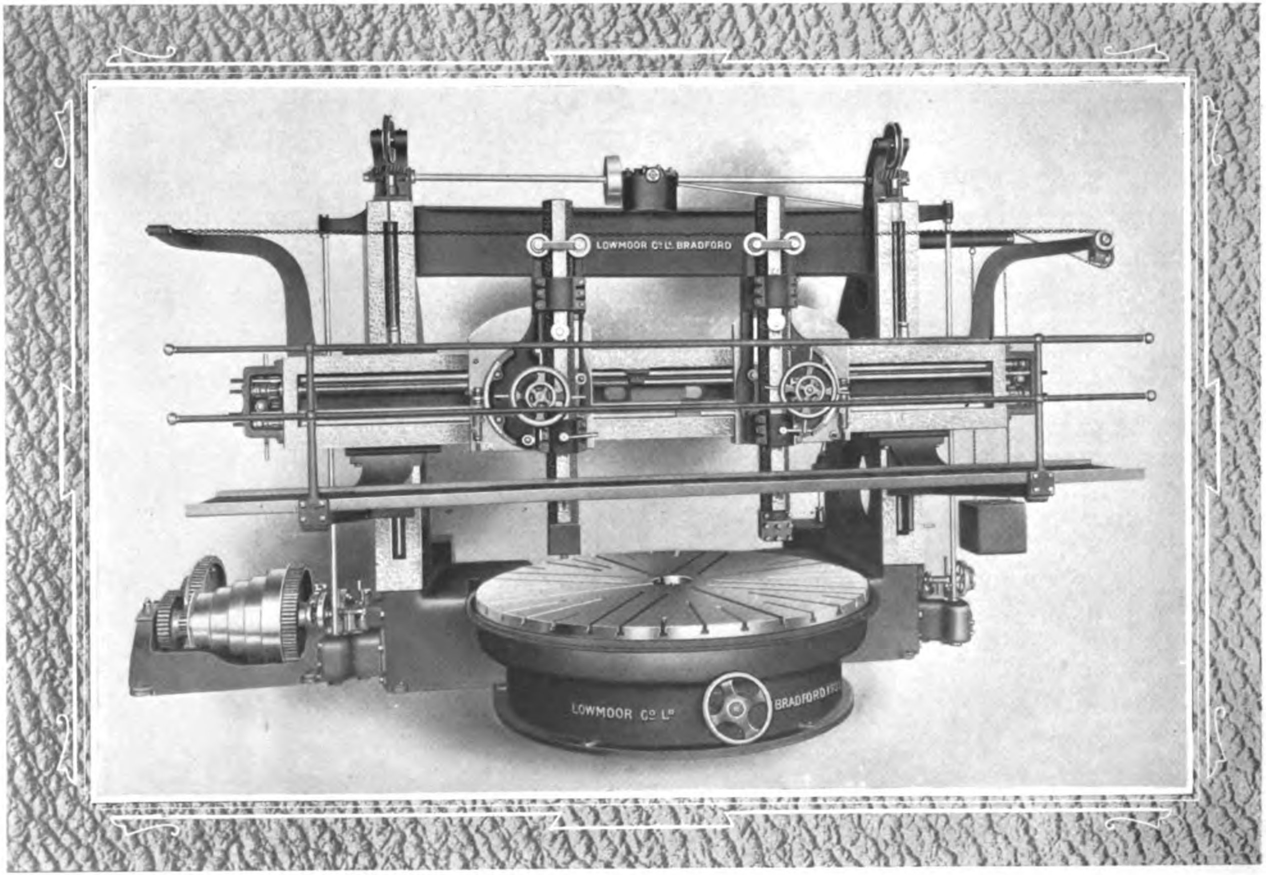
According to the Sectional Area generally in use.

	Contraction per cent.	Tons per square inch	Elongation per cent. in 8 inches
Bars 1 inch and under in Sectional Area ...	50%	23	27
„ from 1 inch to 4 inches „ ...	45	22	25
„ from 4 inches to 8 inches „ ...	40	22	23
„ 8 inches and above „ ...	40	21	22
Plates with the grain	20	22	17
„ across the grain	15	20	12

Regarded as a factor in the production of Iron suitable for all purposes where ductility and strength are required, Lowmoor Iron Works rank among the chief workshops in the world, their output having acquired a standard of quality which is well known throughout every habitable part of the globe. Any departure from the long successful lines of manufacture, in order to meet special mechanical requirements, would doubtless result in producing a material differing from that which has heretofore gained a world-wide reputation, and which can only be maintained by the use of the purest raw materials, combined with the utmost possible care in all the numerous processes of manufacture.

The Lowmoor Company have invariably kept this view prominently before them, feeling sure that they have obtained their great success by the regular observance of all necessary requirements, and in the determination that quality shall be—as it has been heretofore—their first consideration.

Lowmoor Iron Works will always hold a prominent place in the history of the iron trade in England, which it has assisted so much to develop for more than one hundred years.



BORING AND TURNING MILL, made at LOWMOOR IRON WORKS.

ENGINEERING DEPARTMENT.

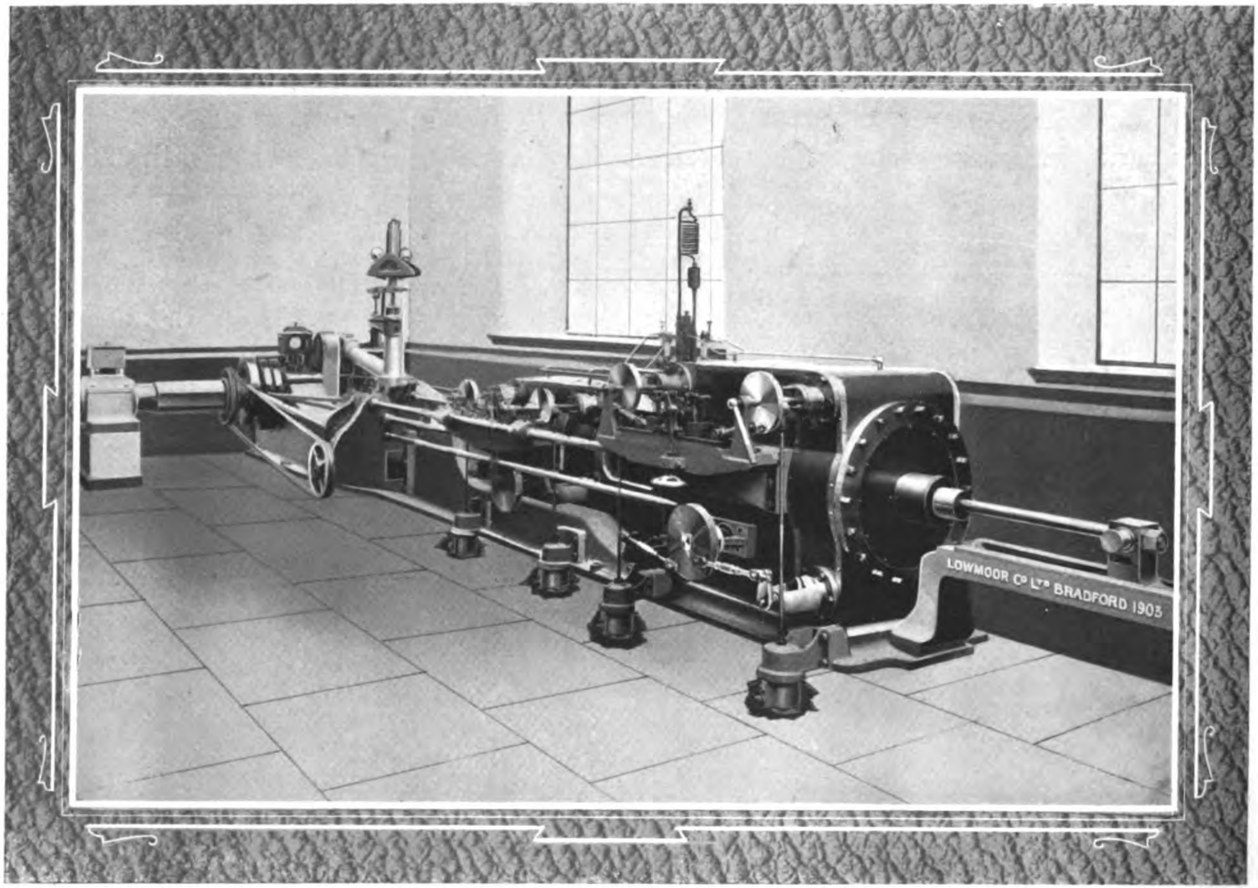
ENGINEERING in several branches has been carried on at Lowmoor Iron Works for many years, originally for making Cast and Wrought Iron Shafting, general millwrights' work, and afterwards, Stationary Engines—of which many were formerly turned out; and this branch of business has been added to by putting down a Steam Boiler-making Plant.

The Lowmoor Company have also gone into Machine Tool making, such as Turning Lathes, Planing, Boring, and Drilling Machines in great variety.

A view of a Boring and Turning Mill, made at Lowmoor Iron Works, is here shewn. This is a very powerful and useful machine, being well adapted for general work in large shops where heavy machinery is constructed.

The following leading particulars will shew its size and capacity :—

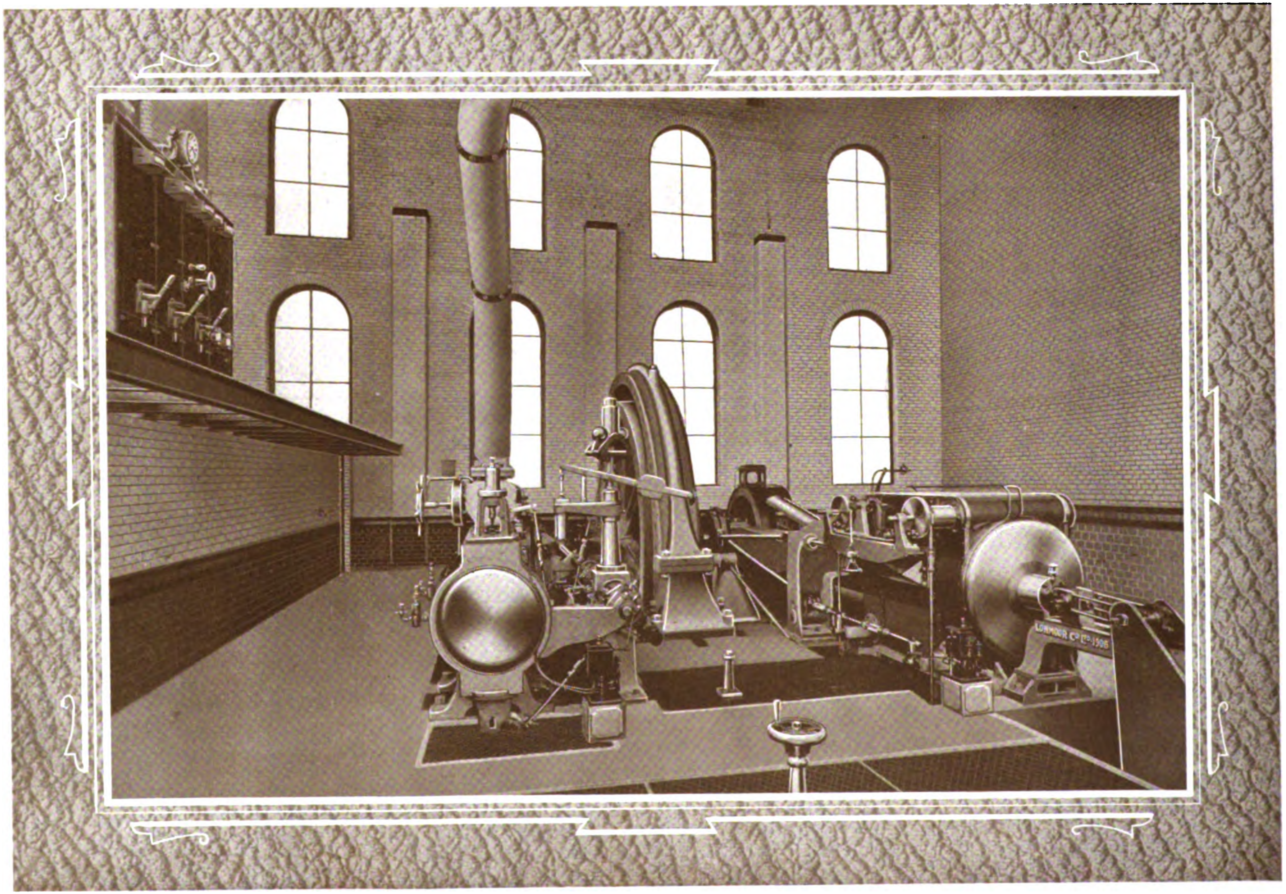
Diameter of Table on working face	9 ft. 0 in.
Will admit in diameter	12 ft. 0 in.
Vertical and angular traverse of Rams	3 ft. 6 in.
Will admit in depth under Tool Holder	6 ft. 0 in.
Will admit in depth under Cross Slide	6 ft. 10 in.
Revolutions of Countershaft	240 to 280 p. m.
Width of Rams across flats	8 inches
Approximate finished weight	34 tons



CORLISS ENGINE, made at LOWMOOR IRON WORKS.

Many other kinds of Machines and Engines are produced, and designs are submitted and estimates given for any class of machinery not included in the Company's list.

A view is here shewn of a Horizontal Tandem Compound Condensing Corliss Engine, made at Lowmoor Iron Works during 1903, having cylinders 14 and 28 inches diameter, by 42 inches stroke, developing 300 indicated horse-power at a piston speed of 500 feet per minute, with steam pressure of 160 lbs. per square inch, and driving direct on main shaft. This was a fine and interesting piece of engineering workmanship, combining the latest improvements in Compound Steam Engines.



VIEW OF ELECTRICAL PLANT, LOWMOOR IRON WORKS. 1906.

Electrical Installation.

Present-day competition necessitating the lowest cost of production, the Lowmoor Company recently obtained a report on the power and driving arrangements in the Works. Subsequently they decided to improve upon the existing arrangements, replacing the more wasteful and inefficient steam drives by electric power. A large Electrical Installation has been laid down, a view of which is shewn on opposite page.

The site of the Generating Station is at "New" Works. Here the necessary boiler plant is installed, arranged for firing by gases from the Blast Furnace plant.

The Station adjacent contains primarily—

One combined unit, consisting of a Cross Compound Horizontal Condensing Engine, with Cornish drop valves for high-pressure cylinder, and also Cornish valves on low-pressure cylinder, and when running at 96 revolutions per minute will develop 550 indicated horse-power, with a steam pressure of 155 lbs. per square inch. The steam is superheated to 500° at stop valve, and the high-pressure exhaust is re-heated, entering the low-pressure cylinder. The Engine is coupled to a Three-phase Alternator of 350 kilowatts normal capacity.

The Alternator is placed between the lines of cylinders, with its Magnet Fly-wheel mounted on the crank shaft.

The distance over which the main of the power is transmitted is about half-a-mile, and the voltage selected is 1,000 to 1,050.

The Main Switchboard embodies the latest safety devices, and all high tension apparatus is mechanically remote controlled.

The transmission of energy to the Lowmoor Works is by bare overhead cables where advisable; but where public roads intervene, 3-core cables, laid underground, are used.

A Sub-Switchboard in the "Old" Works controls the electrical supply to the various departments.

The first installation consists of 24 Motors ranging from 3½ to 50 brake horse-power. Twenty of these are for individual and departmental drives. Two overhead travelling cranes absorb the four remaining.

The total brake horse-power of the Motors is 479. The Generator, however, is capable of dealing with approximately a total of 550 brake horse-power in Motors, together with the lighting.

The various drives have been arranged with a view to obtaining the highest economy, and embody such as—

(*a*) Departmental Line Shafting, groups of Tools, Engineering Shops;

(*b*) Individual Tools, Shears, Hot Metal Saws, Rivet-making Machines, Haulage, Testing Machine, &c.;

(*c*) Also a Guide, or Rod Rolling Mill.

The Motors, with the exception of a 3½ brake horse-power and the Crane Motors, are placed direct on the 1,000 volts system. Suitable Static Transformer plant gives a 250 volt system for the above exceptions, and also for lighting.

The Lighting Installation consists of approximately 550 incandescent lights and 80 arc lights, and will entirely supersede gas lighting in and about the Works.

The plant has been designed with a view to ready and economical extension at any future date, keeping in view that a total of 1,000 kilowatts may be efficiently absorbed in the Works.

LIST OF

ANGLES, TEES, AND OTHER SECTIONS OF IRON.

MANUFACTURED BY

THE LOWMOOR COMPANY LIMITED,

LOW MOOR, BRADFORD, YORKSHIRE.

SKETCHES SHEW ACTUAL HALF-SIZE.

Special Sections of Iron made at Lowmoor Iron Works.

The following list of Angles, Tees, and other Sections represents what are made at Lowmoor Iron Works, and comprise those which are chiefly used for Locomotive, Stationary, and other Boiler work. Sketches shew actual half-size.

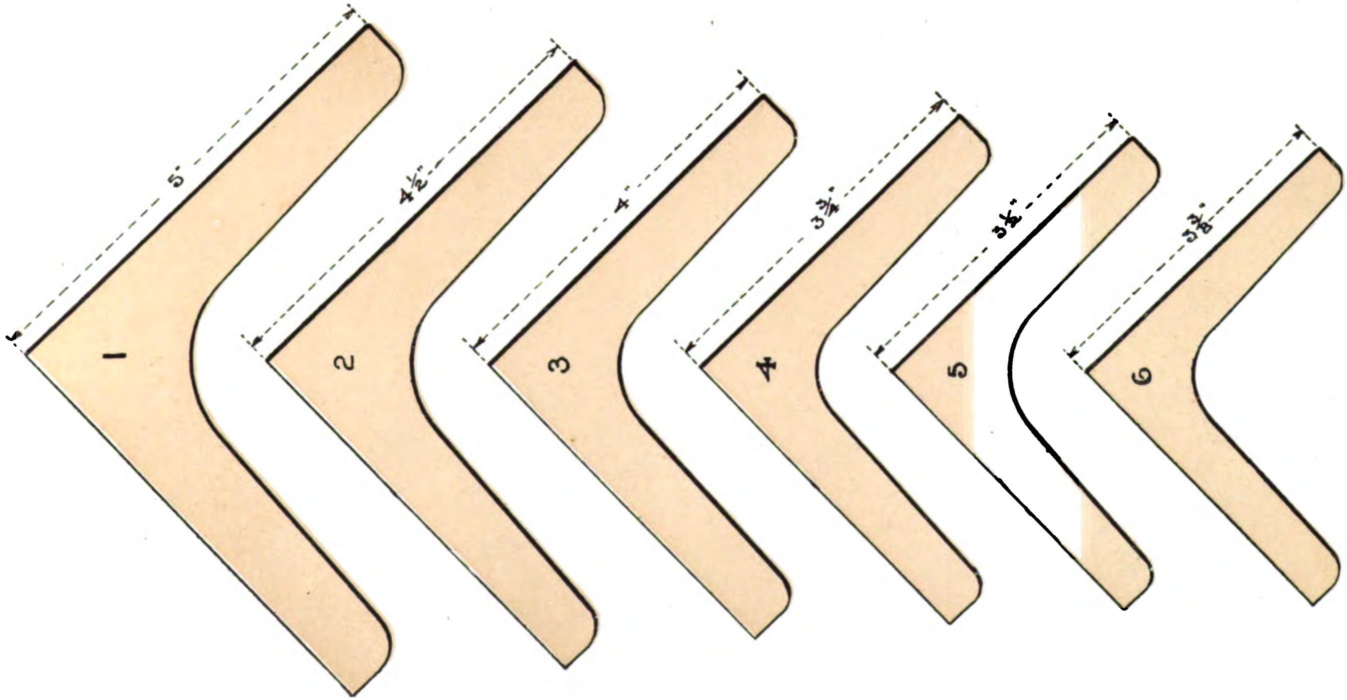
The larger wide sections are mostly used for Manhole Rings, Dome Seatings, and for forming part of Welded Locomotive Domes.

The intermediate sizes are generally used for connecting Boiler Barrels to Fire Boxes, and Smoke Box Ends.

The lighter and lesser sections are much used for Pit Cages and Colliery work generally. This class of work is considered to require first-class material as a precautionary measure for safety.

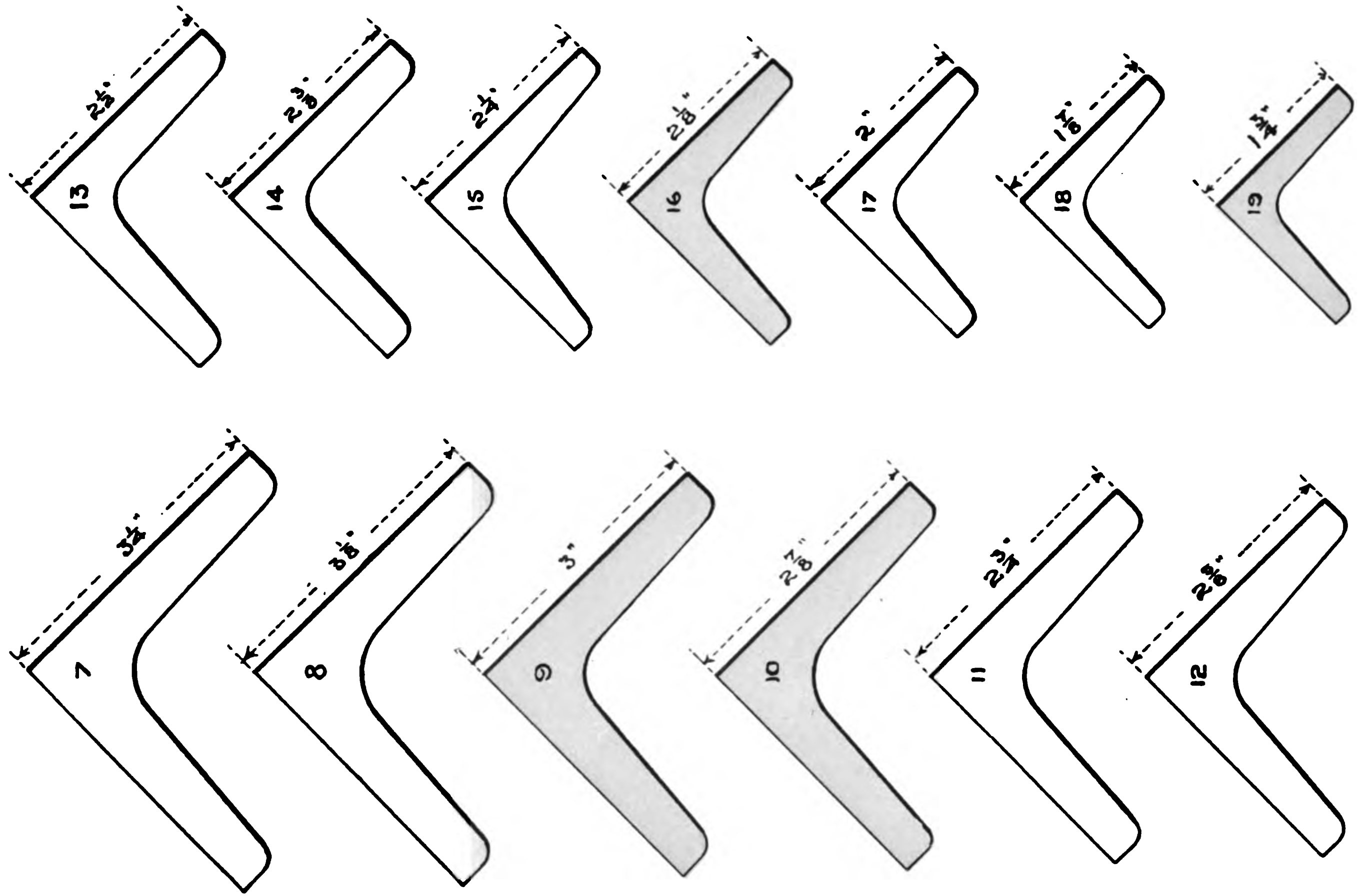
Other sections shewn are generally ordered for Water Space Bars, Fire Box Roof Stays, and Tee Bars, the latter being in frequent demand.

Although it is possible to vary the thickness of Angles to some extent, and consequently differing slightly from the dimensions given, yet it is advisable to adhere as near as possible to the sections, to ensure the bars being rolled near the shape shewn on the printed engravings. This especially applies in the case of Tee Bars, a very small margin only can be allowed for variation in thickness, and this should be confined to the top or table part of the bar.



SECTIONS HALF-SIZE. THE THICKNESSES CAN BE VARIED.

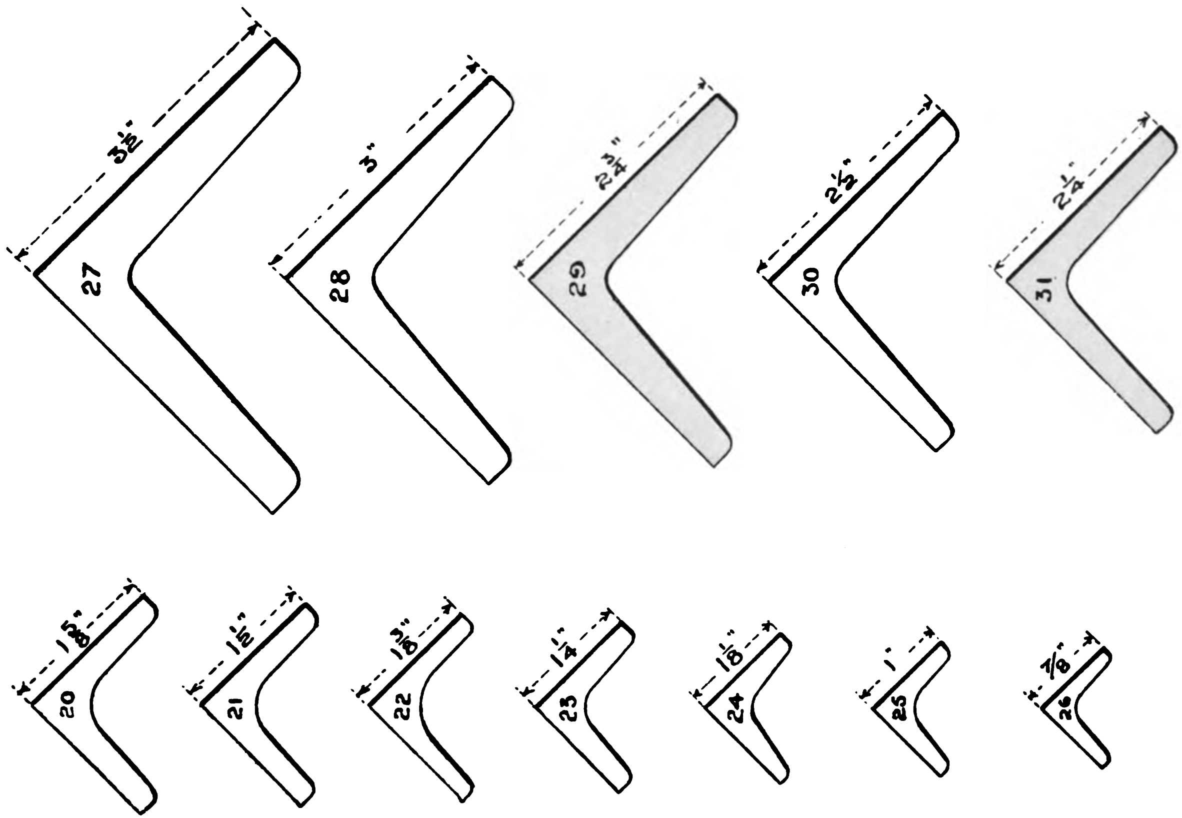
THE LOWMOOR COMPANY LIMITED,



SECTIONS HALF-SIZE. THE THICKNESSES CAN BE VARIED.

LOWMOOR IRON WORKS, BRADFORD, YORKSHIRE.

THE LOWMOOR COMPANY LIMITED,

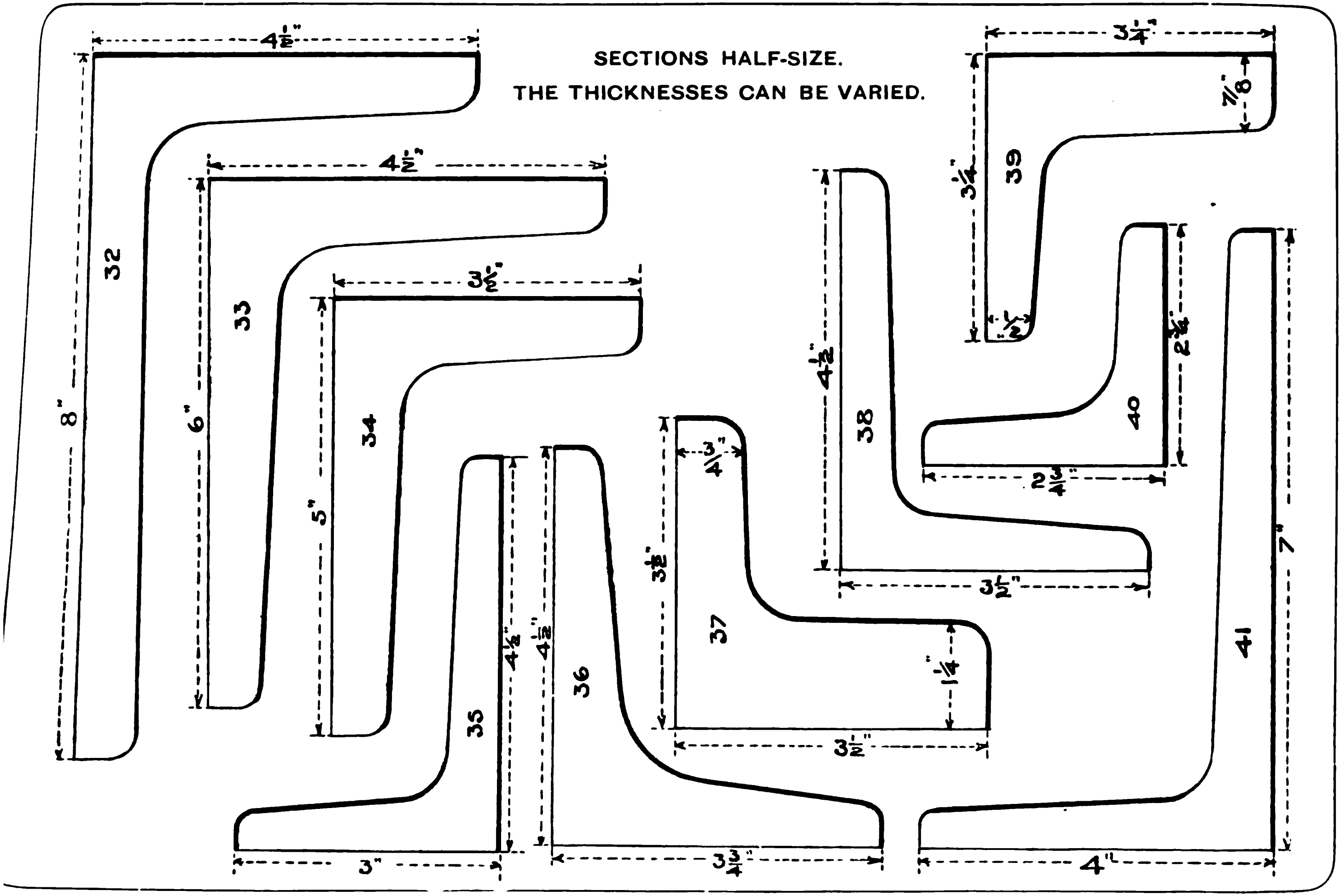


SECTIONS HALF-SIZE. THE THICKNESSES CAN BE VARIED.

LOWMOOR IRON WORKS, BRADFORD, YORKSHIRE.

THE LOWMOOR COMPANY LIMITED,

SECTIONS HALF-SIZE.
THE THICKNESSES CAN BE VARIED.



LOWMOOR IRON WORKS, BRADFORD, YORKSHIRE.

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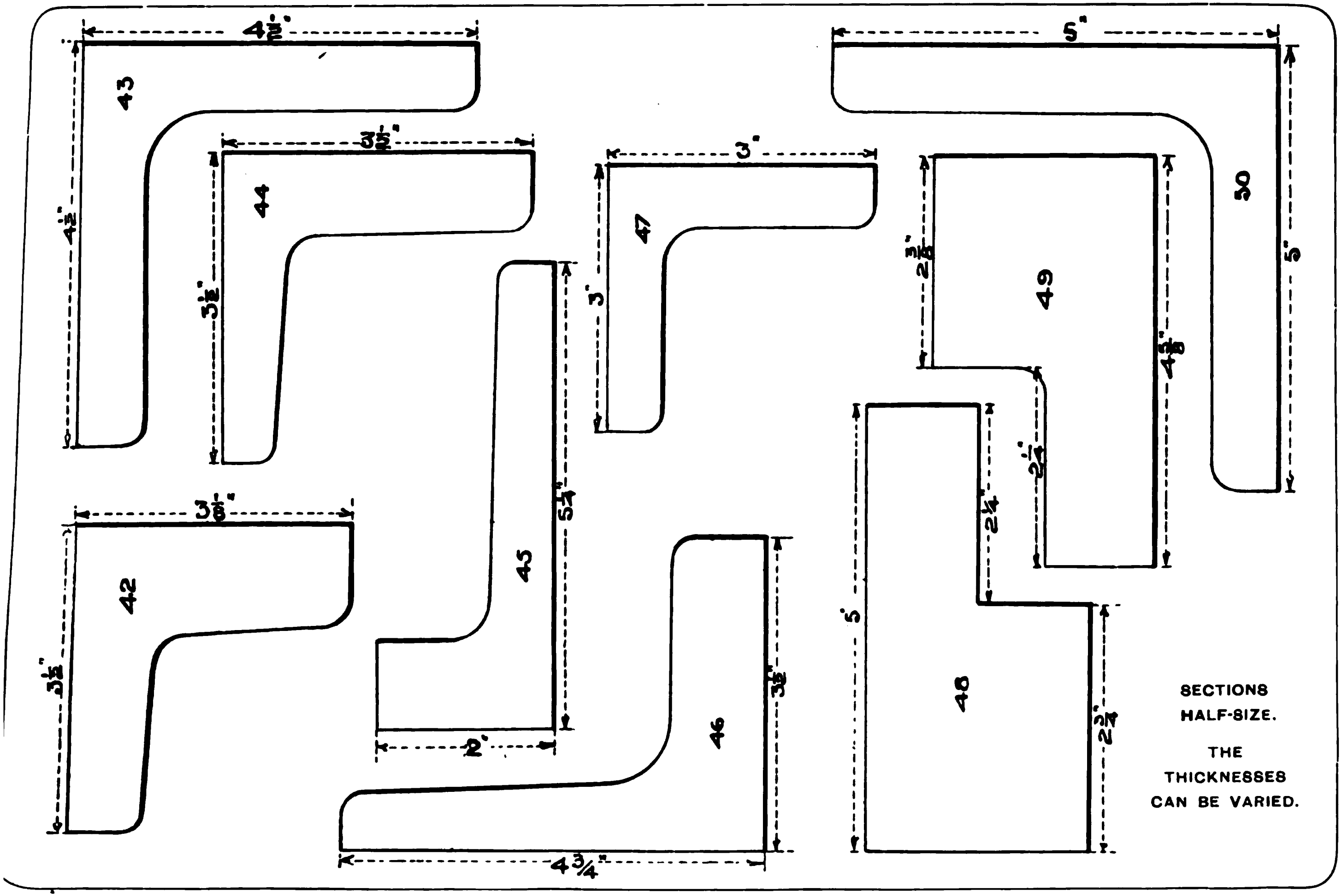

LOWMOOR IRON WORKS, BRADFORD, YORKSHIRE.

THE LOWMOOR COMPANY LIMITED,

SECTIONS
HALF-SIZE.

THE
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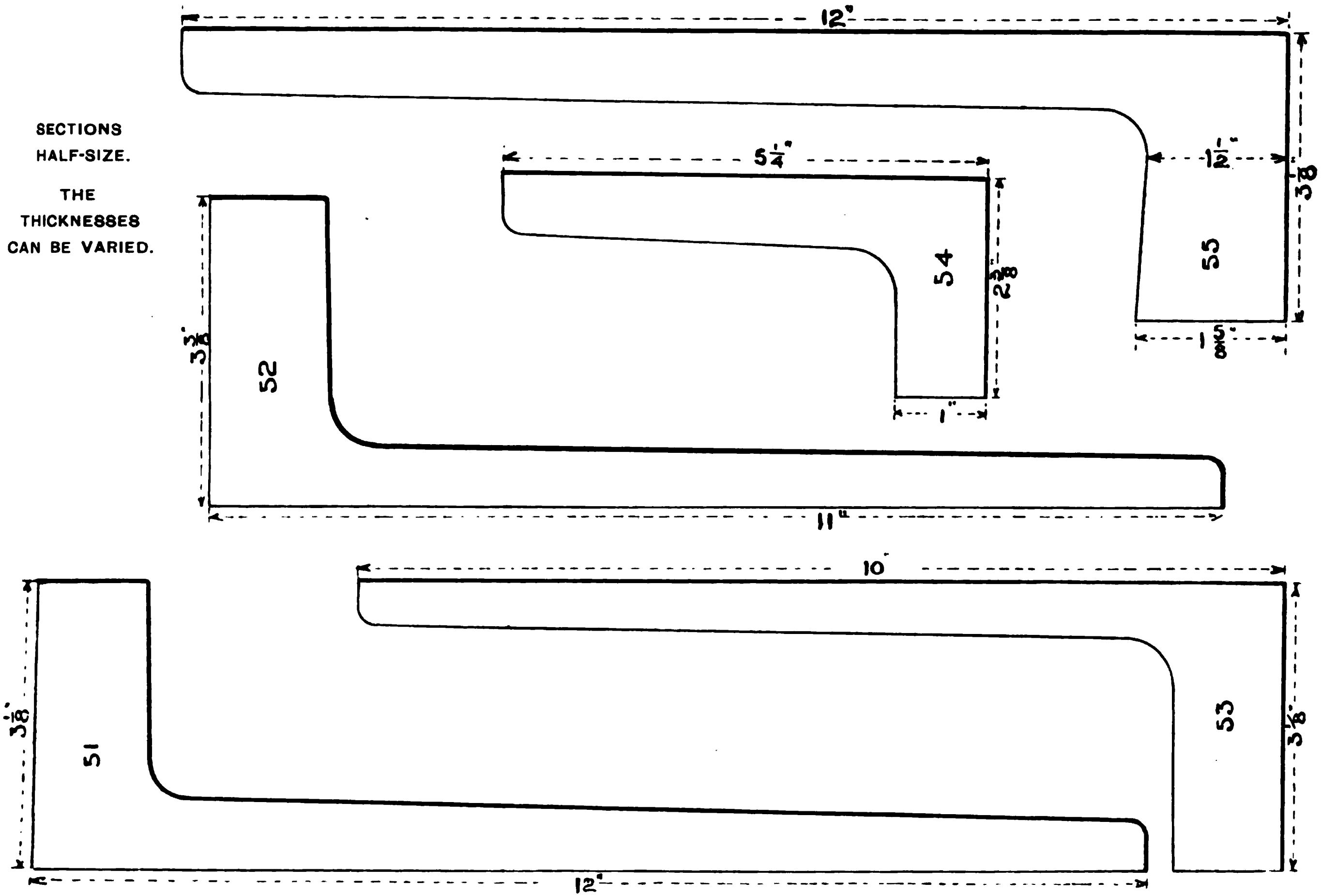
CAN BE VARIED.



LOWMOOR IRON WORKS, BRADFORD, YORKSHIRE.

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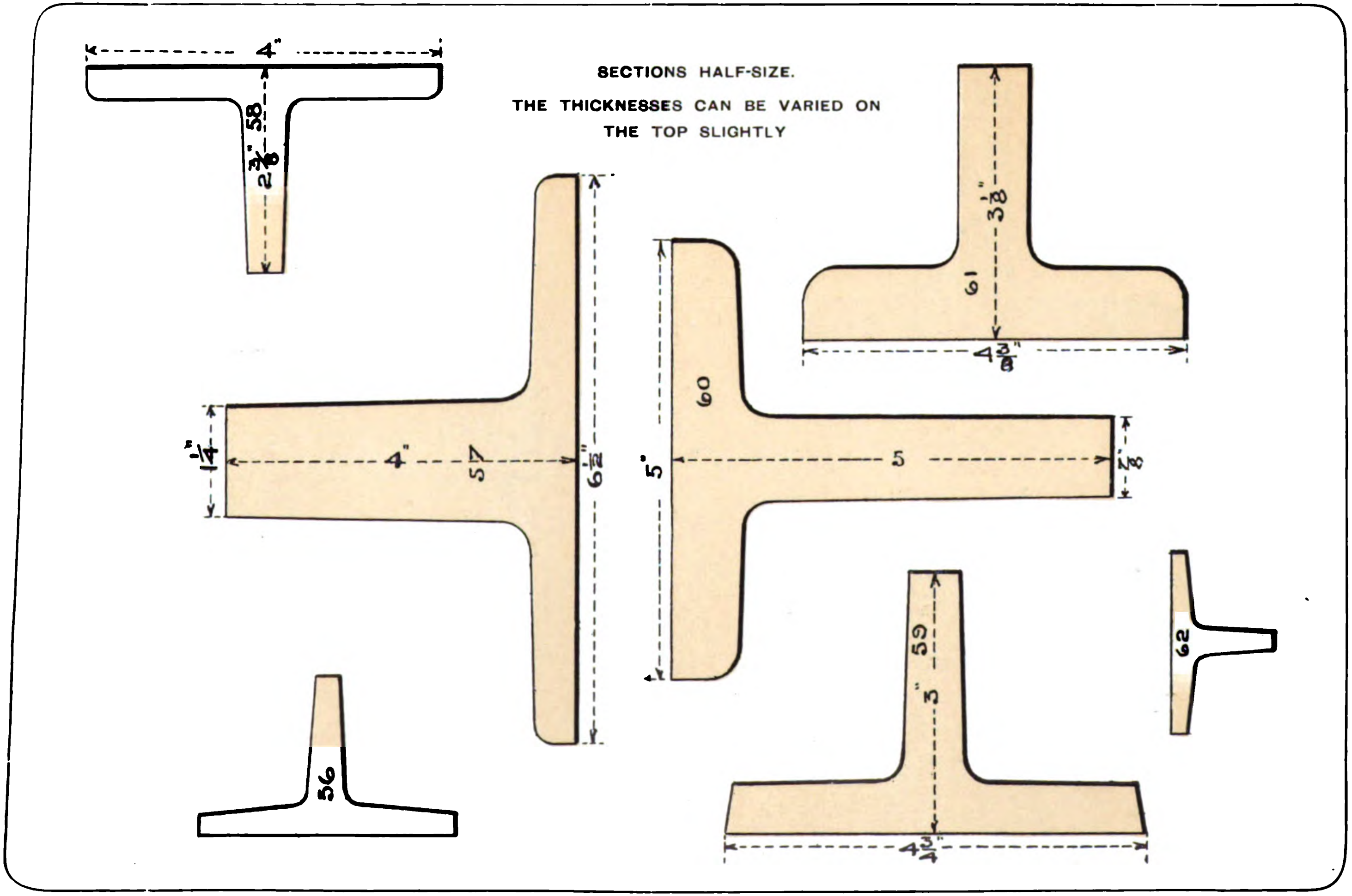
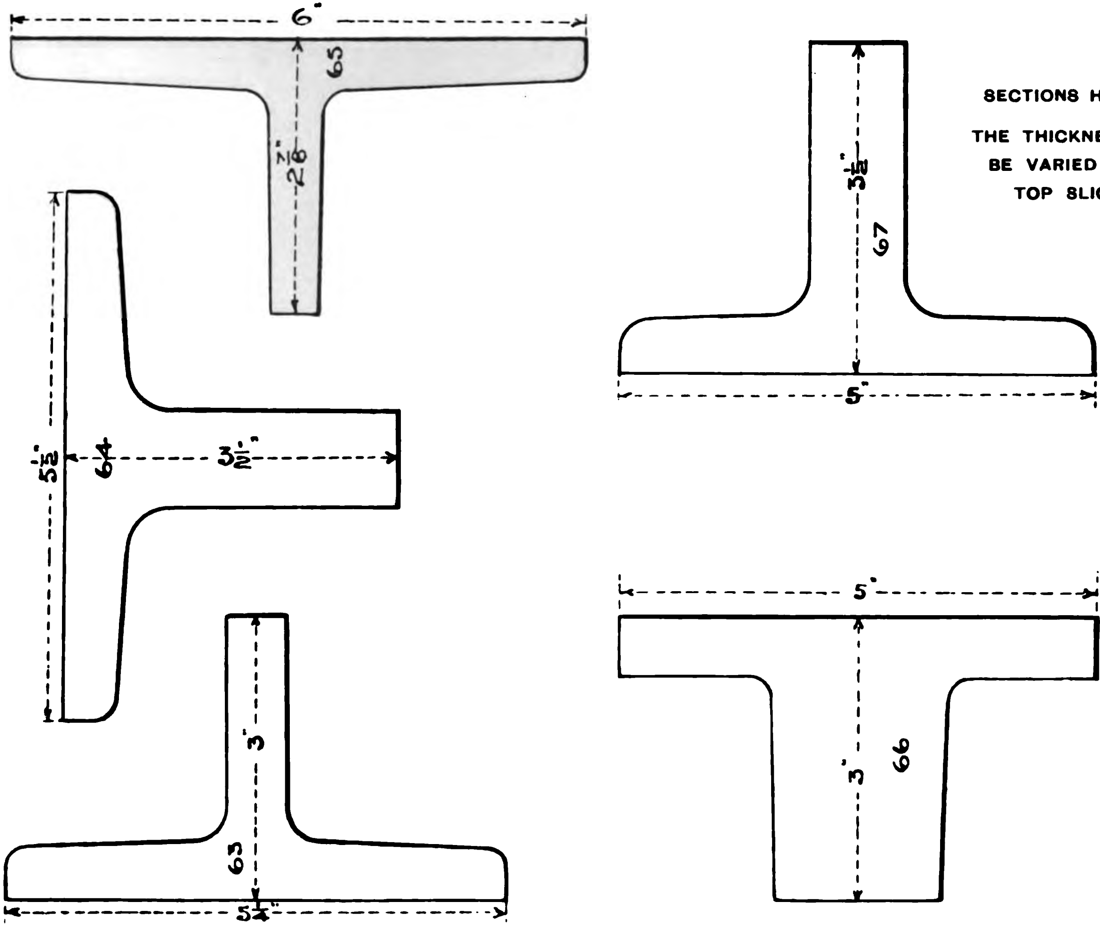


LOWMOOR IRON WORKS, BRADFORD, YORKSHIRE.

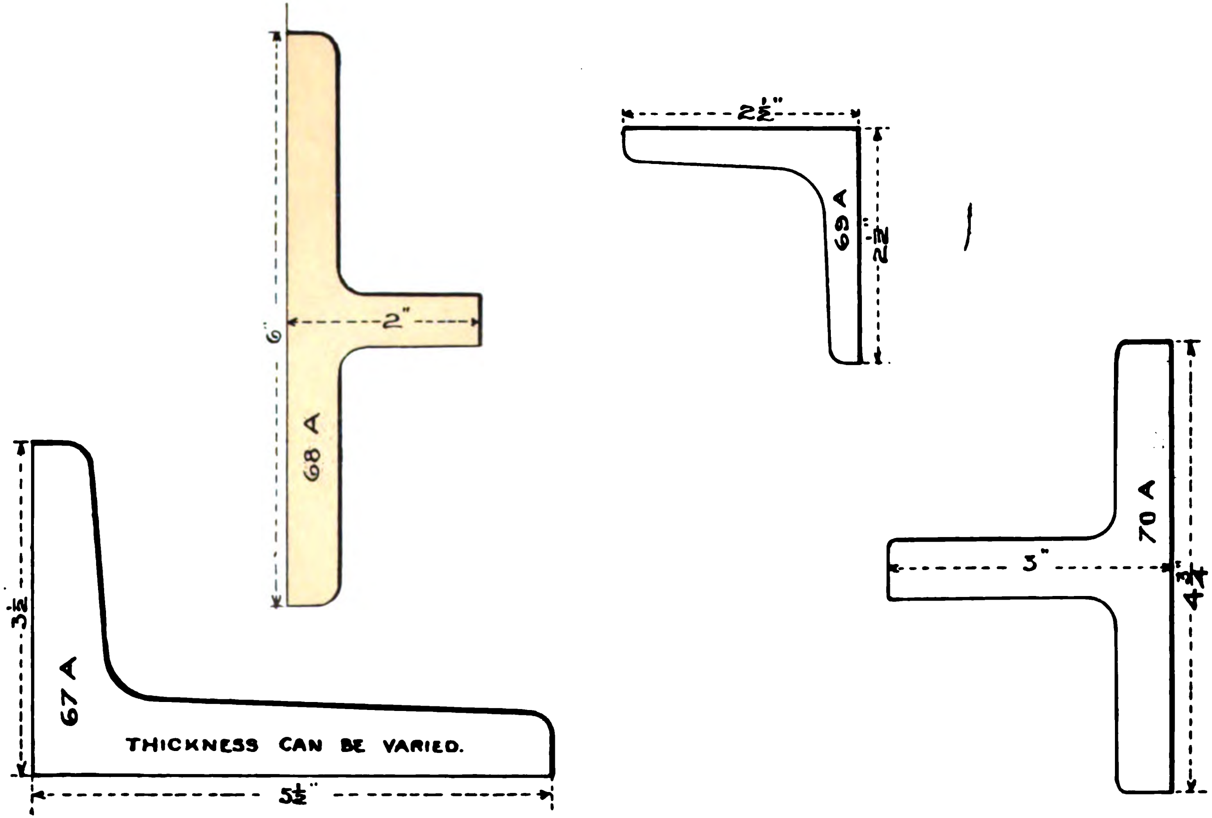
THE LOWMOOR COMPANY LIMITED,



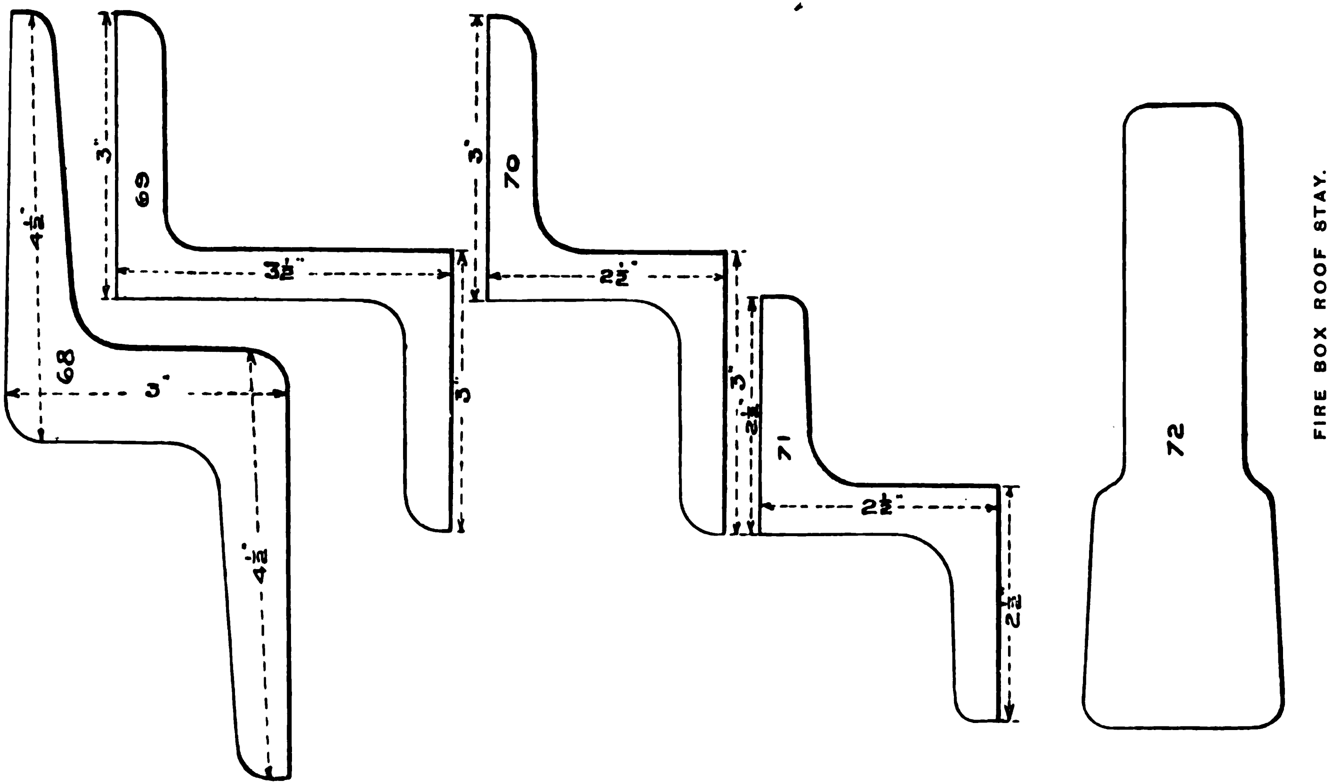
SECTIONS HALF-SIZE.

THE THICKNESSES CAN BE VARIED ON THE TOP SLIGHTLY.

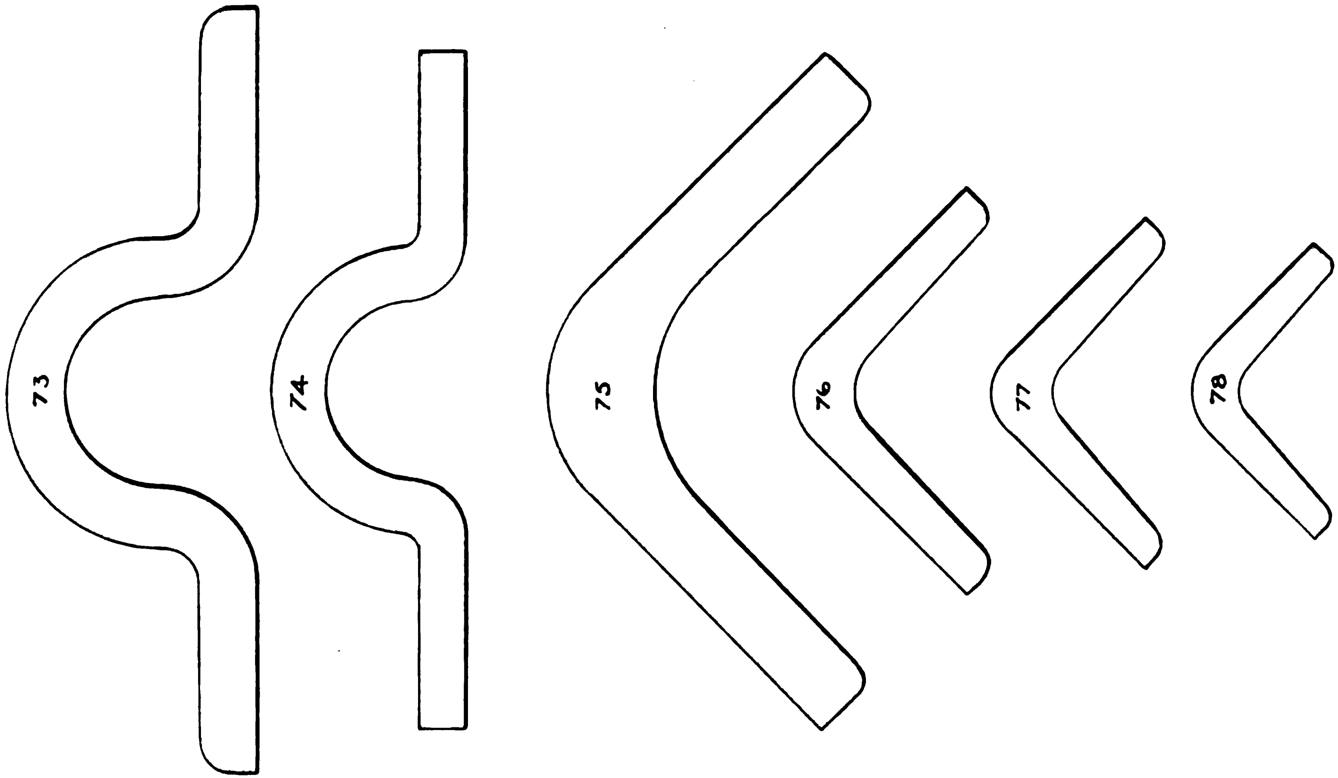
LOWMOOR IRON WORKS, BRADFORD, YORKSHIRE.



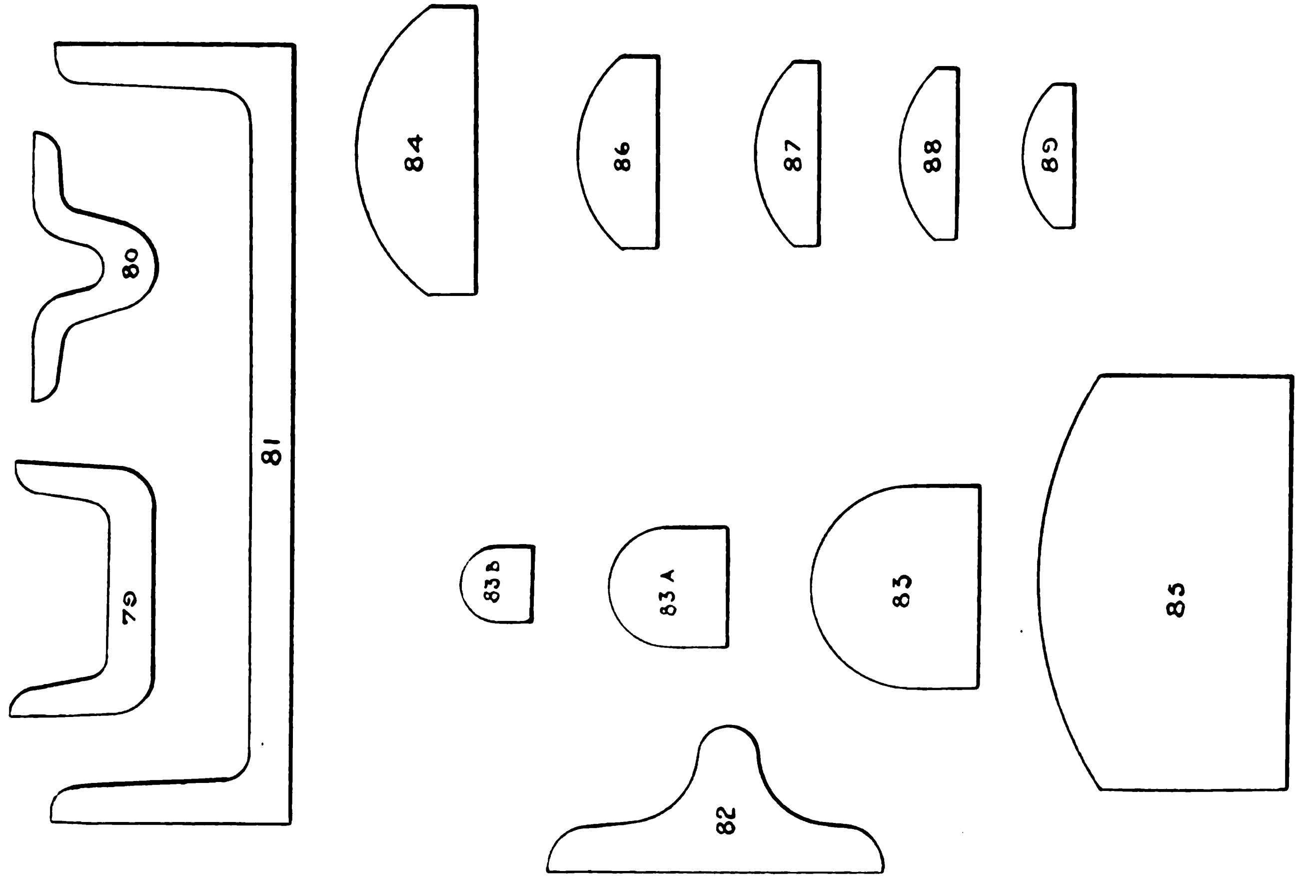
SECTIONS HALF-SIZE. THE THICKNESSES CAN BE VARIED ON THE TOP SLIGHTLY.



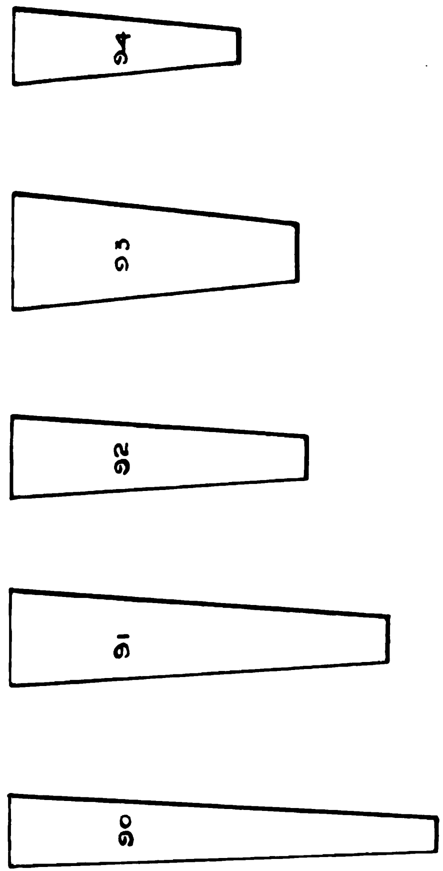
SECTIONS HALF-SIZE. THE THICKNESSES CAN BE VARIED.



SECTIONS HALF-SIZE. THE THICKNESSES CAN BE VARIED.

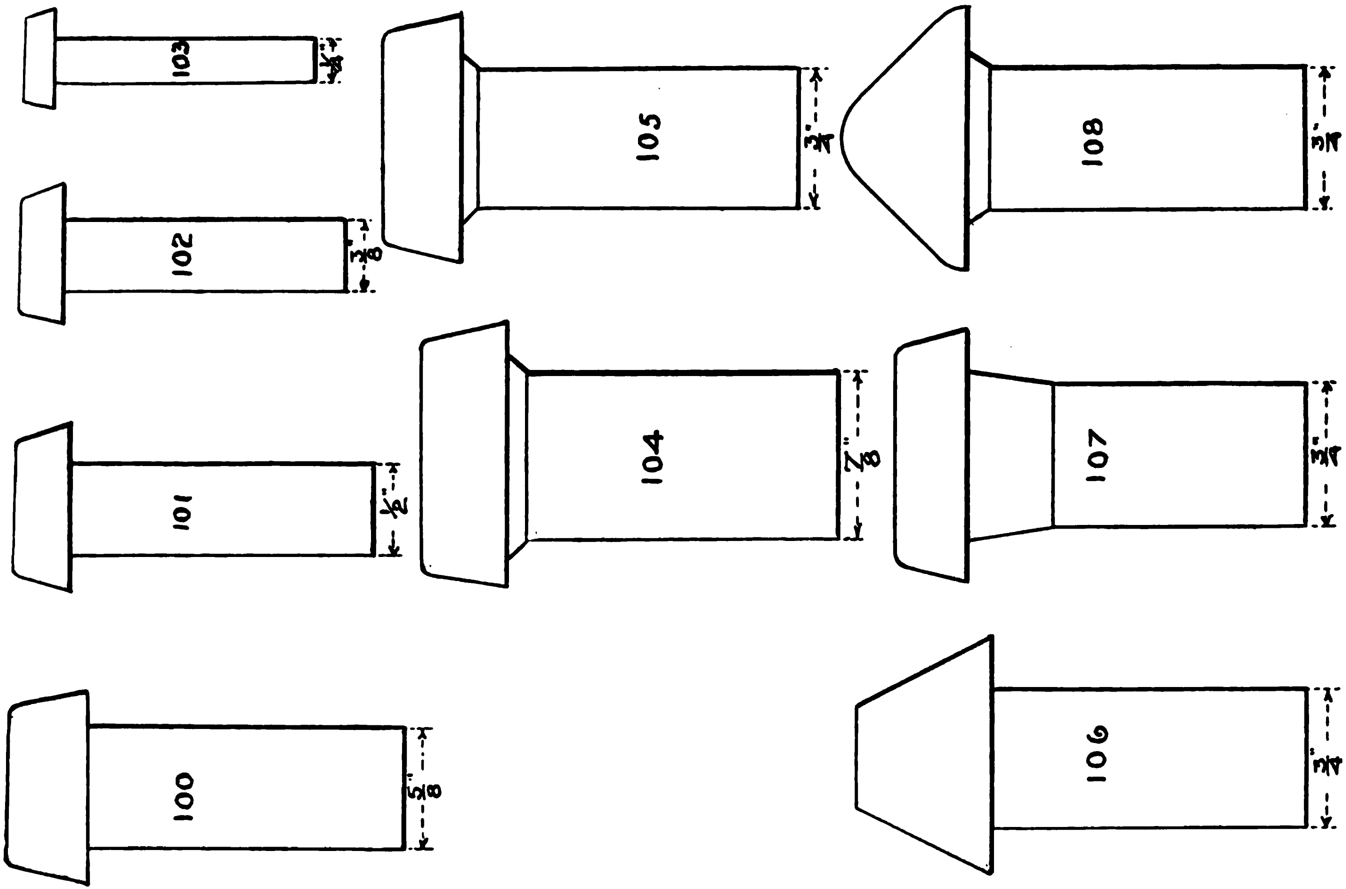


SECTIONS HALF-SIZE. THE THICKNESSES CAN BE VARIED TO FEATHER EDGE, IF REQUIRED.



FIRE BARS.

SECTIONS SHEWN HALF-SIZE.



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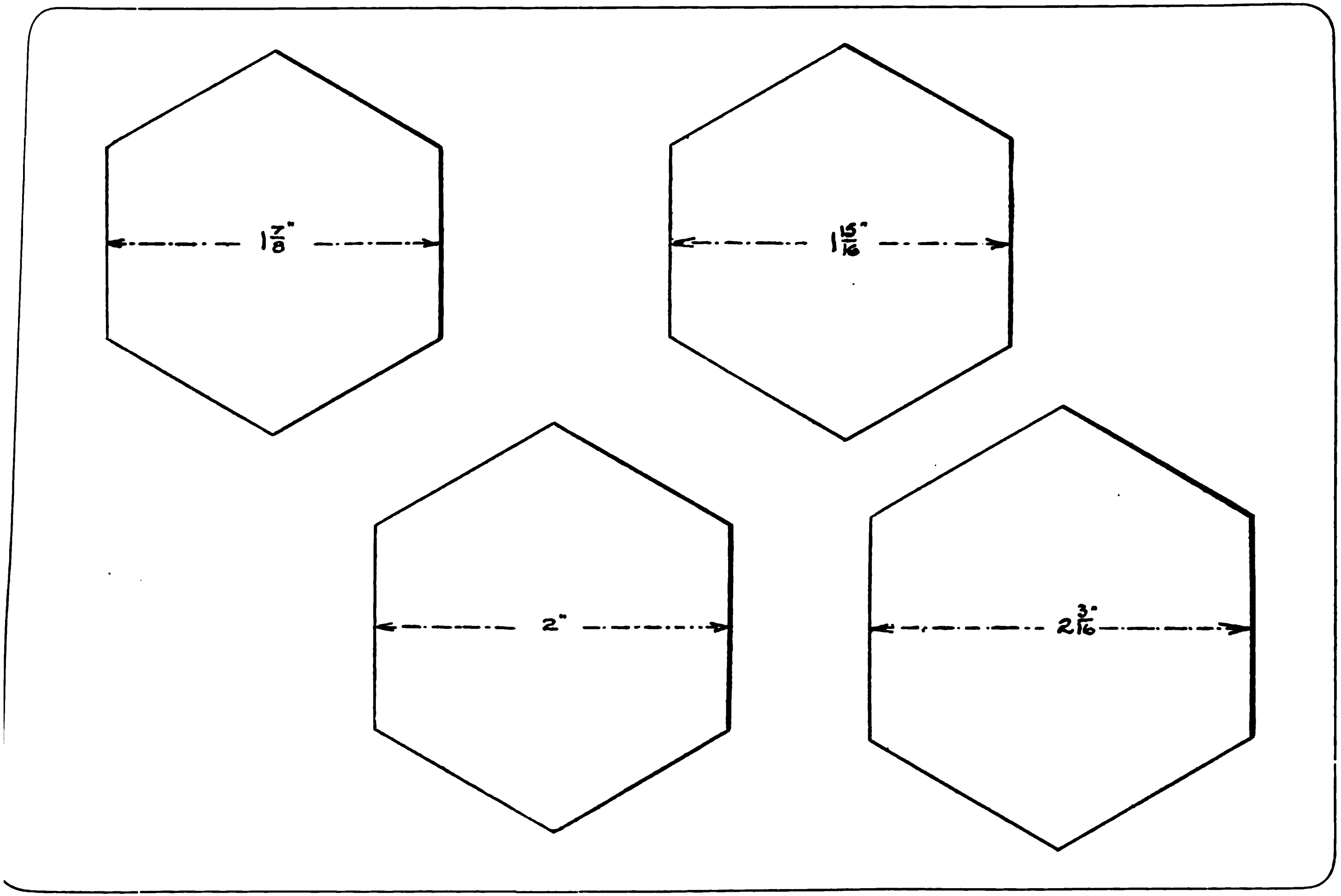
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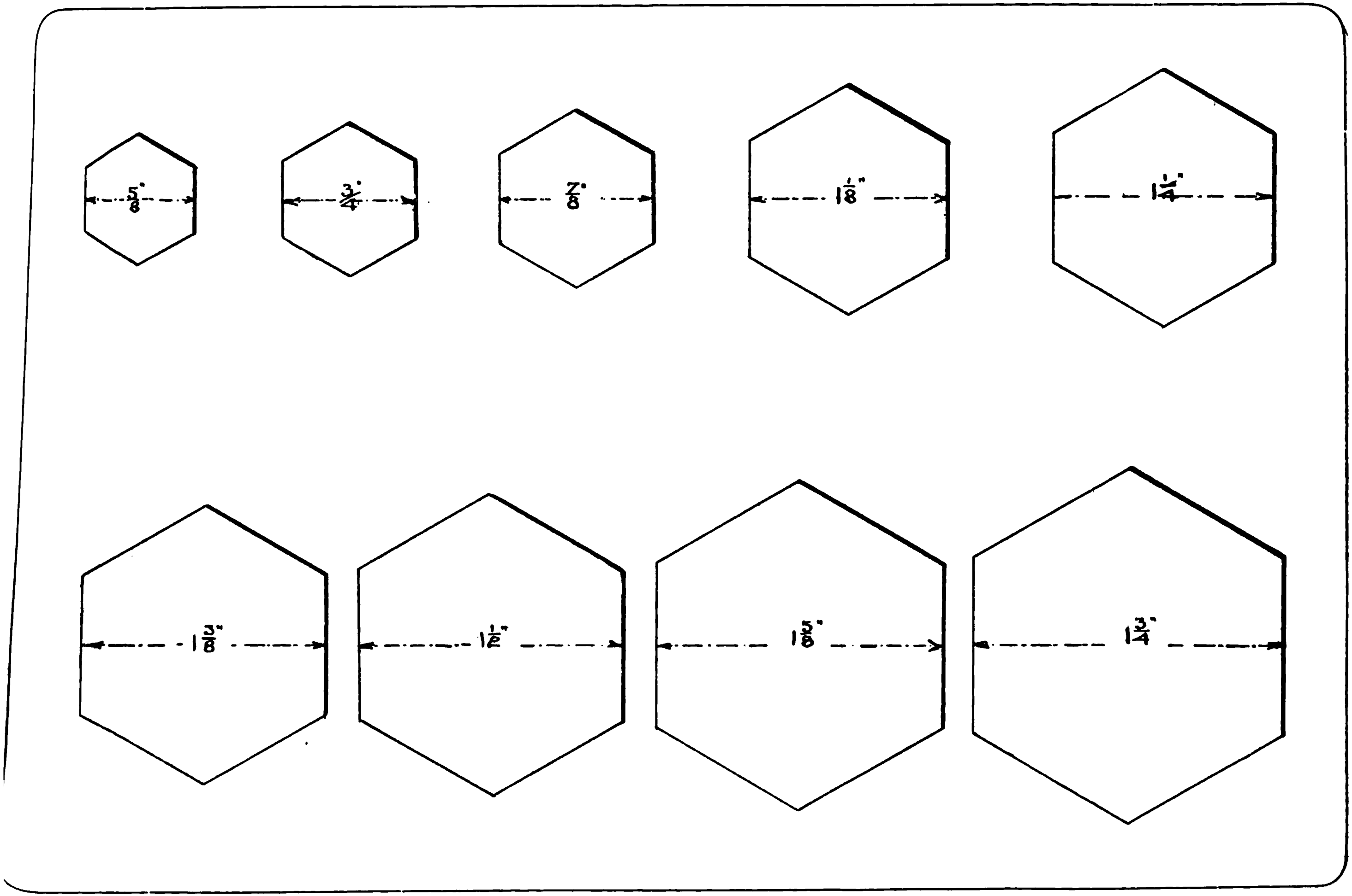
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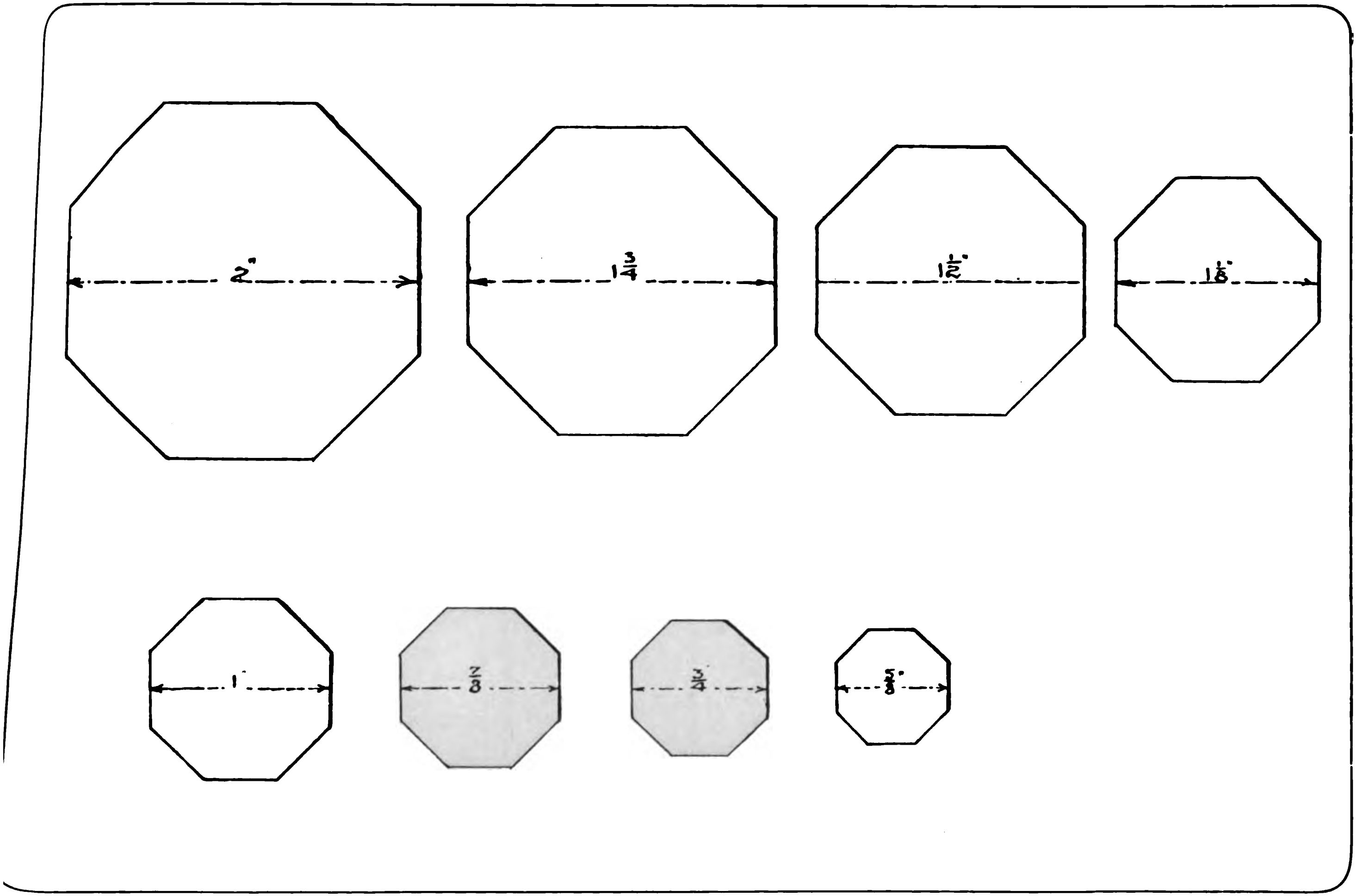

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AN ESSAY

ON

THE EFFECT OF AIR AND MOISTURE ON BLAST FURNACES.

Delivered at Bradford, June 11th, 1800,

BY MR. JOSEPH DAWSON,

OF ROYDS HALL, LOW MOOR,

One of the Founders of Lowmoor Iron Works, 1791. Born May 12th, 1740; Died December 11th, 1813.

Reduced Facsimile of Title Page of Pamphlet reprinted on succeeding pages.

MINUTES,

MADE AT

A MEETING,

of the

PRINCIPAL

Iron Masters,

IN THE

Counties of YORK and DERBY;

At BRADFORD, June 11th, 1800.

No. II.

BRADFORD:

PRINTED BY R. SEDGWICK.

1800.

ESSAY I.

Delivered at Bradford, *June* 11*th*, 1800,

By the President, Mr. Dawson, of the *Low-Moor* Iron-Works.

"Gentlemen,

"YOU will remember, that the subject of the present Essay is, the effect of Air and Moisture on Blast Furnaces. In order to understand the business, it will be proper to consider the nature of each of these substances separately, that from hence we may the more distinctly point out their joint or separate effects on the furnace.

"By air we mean that elastic substance which surrounds this globe, and constitutes what we call the atmosphere. Like all matter, it is heavy, and possesses besides, the property of being elastic. In consequence of this, either by its own weight or by any compressure, it can be made more or less dense. This fact is pointed out to our daily observation by the Barometer.

"Like every other substance air is expanded by heat and contracted by cold. It has an affinity also to a vast variety of substances. By means of this principle the odoriferous perfumes of every plant, flower or shrub, are widely defused in the air and regale our nostrils. And on the same principle the disagreeable stench arising from putrid carcases, stagnant pools, oil, tallow, and a variety of other substances, convey their pestilential effects to all within the sphere of their influence.

" But that substance to which air has an affinity, which particularly claims our attention at this time, is, moisture. It has always been a matter of curious enquiry how it happened that moisture, which is a body so much specifically heavier than air, should ascend in it ? And how it came to pass, that clouds of water should be formed in the airy regions above the earth and supported there——that they should now be spread out in their variegated colours and then be dispersed——at one time descend in rain, hail or snow, and immediately after be elevated in water ?

" Various have been the hypotheses that have been formed, from the first dawn of philosophy to the present day, to account for the appearances ; but no one has succeeded so well in these conjectures as Dr. Hamilton, who ascribes them to a mutual attraction or affinity which takes place between air and water.

" This attraction is affected by the rarity or density of the air. Common atmospheric air placed within a close receiver on an air-pump, will be perfectly transparent——the sides of the glass receiver will be clean and free from moisture,——but a single stroke or two of the piston, by rarifying the air, causes it to deposit moisture upon the sides of the receiver. Let the air return and the moisture is immediately absorbed.—On the other hand, damp the sides of the receiver belonging to a condenser, inclosing air of the common density of the surrounding atmosphere and the moisture will remain. Throw into the receiver a quantity of air, and the dense air will immediately take up the moisture and the whole will become transparent. The rairer therefore the atmosphere, the less moisture it contains, and the denser, the more.

"But this attraction between air and moisture is further modified by heat and cold. Heat enables the air to dissolve more moisture, and cold disposes it to throw it out ;—consequently heat increases the attraction between air and moisture, and cold diminishes it.—Hence in a morning when a thick fog covers the earth, it is immediately dispersed as soon as the sun warms the air and enables it to dissolve the water which lay intangled in it, and spread it upon the surface of the ground.—Hence too evaporation is generally more abundant in proportion to the heat of the weather, and hence a thousand appearances, which daily strike our eyes, depending on this principle, were it our present business, might easily be explained.

"We have said before, that the attraction between air and moisture is diminished by its being made rare, and increased by its being made dense ;—We have also said, that heat increases that attraction and cold diminishes it :—Now it is evident, that when heat is applied to such an elastic body as air, it must rarify it, and consequently at the same time that the attraction between air and moisture is increased by heat it will be diminished by the rarefaction it occasions. What proportion these two circumstances bear to each other in increasing or diminishing the affinity between air and moisture, has, I believe, never yet been determined. But the prevalence of each principle in different circumstances has been matter of observation to every Philosopher, and abundantly sufficient to establish the sentiment.

"You will give me leave further to remark concerning the attraction between these two substances ; that in proportion as the air takes up moisture, its attraction for it seems to diminish, and *vice versa*, its attraction for it increases as the quantity it contains is less. This is consonant to the laws of elective attraction in every instance. Hence in the summer season when the weather has been for a considerable time dry, evaporation does not proceed with its usual vigour, notwithstanding the temperature of the air is considerably high ; and in the winter, when a considerable descent of water has taken place, evaporation proceeds rapidly, notwithstanding the weather is remarkably cool. Perhaps it may be owing to this, that in frosty weather evaporation is very quick, and hence the practice and phraseology of the Laundry Maids when they hang out their new washed linen in a winter's evening to let the frost *nip* the water out.——Be it owing to whatever cause it may, it is a certain fact, that in frosty weather the air is particularly greedy of moisture; and, what is remarkable, it will take it even from ice. Dr. *Boerhaave* hung up a piece of ice in a frosty night, and found in a small space of time it lost considerably of its weight.

"Water, or what we have thus far called moisture, was formerly esteemed an elementary substance. But later experments have found it to consist of two, what modern chemistry calls oxygen and hydrogen. Subject water to a red heat in an iron vessel and the decomposition takes place. The oxygen part of the water is seized by the iron and it becomes oxygenated and the hydrogen part assumes a gasseous form and flies off in hydrogen gas, or what Dr. *Priestley* calls inflammable air. Put hydrogen and oxygen gas into a receiver, and either by an electrical spark, or flame from any inflamable body, set the hydrogen gas on fire, and as it burns it absorbs the oxygen gas and the product is water. This proof is both analytic and synthetic of the composition of water. From water we can make hydrogen and oxygen gas, and from the union of these two gasses by combustion we can form water. This is the doctrine of the French Chemists, and it is pretty generally received as a just explanation of the facts.

"Give me leave to make one general observation more, and we shall then be able fully to understand every thing that will be said on the principles to be advanced on the effects of air and moisture on blast furnaces. From a vast variety of experiments the Chemists are led to conclude, that all bodies in different degrees of temperature and under different pressures may be made to assume the state of a solid, a fluid and an elastic vapour. Under the common temperature of this climate and the common pressure of the atmosphere, we find different substances assume very different states. Metals and a variety of other substances are commonly solid. Water, quicksilver, spirits of wine, &c. are commonly in a fluid state, while air is an elastic vapour. But all these bodies under different temperatures and different pressures are made to change their appearances and assume a different nature. An additional quantity of heat will melt metals and make them fluid, and a still greater degree of heat will cause them to fly off in vapour. Water, quicksilver, and spirits of wine are rendered solid by being deprived of heat, and can easily be made elactic vapour by a sufficient addition of the same element. And even the air itself, by pressure and a degree of cold sufficiently intense, may, by parity of reasoning, be brought into a fluid and even into a solid state.

"But what I mean particularly to remark, as applicable to our present subject, is, that in all these different states under the same temperature, each body contains within itself a very different quantity of heat; and in passing from one state to another, they either give out, or take in, a very considerable portion of heat, which, before this change, could not be discovered by the thermometer. Let us take for an example, to illustrate what we have said, water, one of the most familiar substances we have. In the act of being changed from ice to water, it takes up a large quantity of heat to make it fluid, and which does not at all increase the temperature of the water into which the ice is changed. When it is changed again from a fluid to steam, after the water comes to the boiling point, it absorbs a large quantity of heat in being changed into steam, without any alteration of temperature in either the water or the steam. Reverse these circumstances and the direct contrary effects take place. Change steam into water and water into ice, and at each change a large quantity of heat will evolve, which becomes discoverable by a Thermometer. Dr. *Black* first discovered this important fact and he called this heat, latent heat, because in its different states it lay concealed in the body that absorbed it without being discoverable by the thermometer.

"Take a small piece of candle and put it on a small piece of wood and it will swim on the top of a trough of water. Light it and place over it a close receiver, which will be full of air of the common density and quality of the atmosphere. The candle in these circumstances will burn a considerable time and as it burns the water will keep rising into the inside of the receiver, till the air is considerably diminished in quantity and then it will go out. If a fresh lighted candle be put into the same air it is immediately extinguished. This experiment shews, that, whatever it was in the air that supported the combustion of the candle, it is spent, and it further shews, that it is entirely taken out of the air and has disappeared.

"Upon examining closely into experiments of this kind, it was found that the common atmospheric air consisted of two parts or kinds of air, one called oxygen, which supports combustion, and which is absorbed by the burning body and rendered solid ; the other called azote, which is incapable of supporting combustion, and when united together in the proportion of one of oxygen to three of azote, constitute atmospheric air. Good atmospheric air contains about 27 parts of oxygen and 73 of azote to make 100.

"The oxygen, you will observe, always disappeared as the body burnt, and was fixed in the inflammable body in a solid or concrete state. If this be the case, according to the principles just laid down, the air by combustion being changed from an elastic fluid to a solid, must necessarily give out a large portion of heat, and hence arises the heat which issues from the burning body.

"It is the same process that supports combustion in the blast furnace. The fuel absorbs the oxygen out of the large quantity of air that is thrown into it, and, from an elastic fluid, changes it to a solid concrete. This process, throws out a large quantity of heat and raises the furnace to the temperature that is necessary to make the several ingredients in it act one upon another, by which the metal is deposited, and the refuse goes off in dross.

“ Hence it appears that a certain degree of oxygen air is necessary to be thrown into the furnace, to raise it to a proper degree of temperature ; that, by the action of the several materials one upon another, metal may be produced. It follows, then, that when there is a deficiency of oxygen, the furnaces will not only work slowly, but the decomposition of the materials will be imperfect, and the metal produced not only less in quantity, but inferior in quality. These facts are certain ; the experience of every Iron Master, and the cause from whence they arise is equally manifest. But what are the particular circumstances that contribute to produce this cause, and how to effect an adequate remedy are matters of serious concern, but of difficult solution.—Perhaps the following thoughts may a little elucidate the subject.

“ If combustion depend upon the quantity of oxygen thrown into the furnace in proportion to the air that actually enters, it will follow, that any operation, either of nature or art, that lessens the quantity of oxygen in the air, will be injurious, while every operation that has a tendency to increase it, will be beneficial. The investigations of Philosophers have discovered, that every burning body on this globe, every animal that breathes, every putrid substance, and a vast variety of other operations and substances, which have an attraction for oxygen, daily devour large quantities of this kind of air. If this be true, it is astonishing that all the oxygen in the whole atmosphere is not long since destroyed. But it is a matter of rejoicing, that in all the works of our Almighty Creator, there is an antidote for every poison, and a remedy for every defect. Thoughts like these led Philosophers to enquire, what operations in nature counteracted this baneful distruction of this necessary principle.

“ Their enquiries have found out some, and no doubt there are many more yet to be discovered. From Dr. *Priestley*'s experiments on vegetation, it is highly probable, that every vegetable that grows, every plant, shrub and tree, from the moss on the barren rock, to the towering cedar on

Lebanon, daily sends forth pure oxygen air to renovate the atmosphere, defiled by so many natural operations. Nay, that even the simple agitation of air, and particularly the agitation of air with water, produces the same effect.——Hence the great importance of the herbage of the fields, the trees of the forest, the tempestuous winds, and the large reservoirs of water spread over the face of the whole globe.

" But besides these purifiers of air, which I have here enumerated, I am persuaded there is a greater source of purification than even all these processes put together ; I mean the action of air and moisture on one another. I am fully persuaded, that air does not in the act of spontaneous evaporation attract and absorb water in its compound state, as is commonly supposed, but that in this absorption, by some law of nature never yet investigated, the water is actually decomposed and one or both of its constituent parts converted into air, as circumstances require. The air, I apprehend, in its different circumstances, acquires a different affinity for the oxygen or hydrogen part of the water, and converts it into air according to the necessity of natural operations, and this beautiful chain of cause and effect manufactures such air as these operations require, and supports the exact harmony which universally reigns in all the works of the great governor of the universe.

" Is not the hypothesis here laid down, confirmed by Dr. *Priestley*'s observations respecting the purification of air, by water ? According to him, air, that has been rendered foul, either by an inflammable body burning in it, or by an animal breathing in it, or by any other process, is renovated merely by standing over water, and, it is very soon purified, if the air be agitated in the water. Does not this shew in the most convincing manner, that foul air can readily take from water, that principle which is necessary to restore it to its former purity, and can, at the same time, convert this principle into air ? Now, this principle we know to be oxygen, and we also know, that oxygen is contained in water. If then foul air, or azotic gas, by mere agitation in water, can take from the water as much oxygen, and convert it into air, as it requires to make it atmospheric air; it follows, that, when the atmosphere, by any natural or artificial operation, is deprived of its oxygen air, it can readily supply the defect from the lakes, rivers, and seas, that are interspersed over the face of the whole globe, and, by the agitation of the wind, this necessary ingredient can readily be restored.

" In reflecting on these circumstances, I had no doubt in my own mind, with respect to the truth and importance of the hypothesis; but one objection struck me very forcibly. If the component parts of water and air had been the same, they would at once have supplied each others wants in a direct and easy way. But unhappily water was said to consist of oxygen and hydrogen, and air of oxygen and azote. Now atmospheric air will perhaps be as injurious to be deficient in azote as in oxygen. Supposing this deficiency to occur, how shall it be remedied?

" While in this uncertainty the Philosophical Magazines for *March* and *April*, came to my hands, and there it is said, that Dr. *Girtanner*, had discovered that atmospheric air, did not consist of oxygen and azote, as the French chemists maintained, but solely of hydrogen and oxygen, and that in azotic air, there were 21 parts out of 100, of hydrogen, and 79 of oxygen.——That when these two substances were compounded in these proportions, they formed azote, but that when more oxygen entered into the composition, the compound became atmospheric air, of more or less purity according as the oxygen part abounded.

" Consistent with this discovery, Dr. *Priestley*, had long since found that inflammable or hydrogen air, merely by standing over water, in some instances lost its inflammable principle, and in others became pure atmospheric air; and that this process was greatly accelerated by agitation. He also found, that pure oxygen air, by the same process, was reduced in its quality to atmospheric air. These facts, to the Doctor at that time wholly unaccountable, by Dr. *Girtanner*'s discovery, meet with an easy solution. The hydrogen air, by being agitated in water, unites to the oxygen of the water, and converts it into air, sometimes in such exact proportion as to form azote, and sometimes in such increased proportion as to form atmospheric air ; and by the same process the oxygen air takes the hydrogen part of the water, converts it into air, and so becomes atmospheric air. These facts do not only mutually explain one another, but, I apprehend, give a high degree of probability to the hypothesis above laid down concerning spontaneous evaporation.

" There are also some experiments mentioned in the same Magazines, as made by *Humboldt*, which will be easily explained by the principles here laid down, and which will at the same time tend to elucidate and confirm the hypothesis here maintained. This chemist, by experiments with the Eudiometer, is said to have discovered,

" FIRST. That the quantity of oxygen contained in atmospheric air, decreases, according to the abundance of clouds, fogs, rain and snow, but that it increases during dry and serene weather. These facts, I apprehend cannot be explained on the common hypothesis respecting spontaneous evaporation. A dry air, according to this hypothesis, is always exhibited when the water supposed to be contained in it, is in perfect solution with the air, This complete solution of the water in the air, be the quantity dissolved more or less, always protects the water from the hygrometer, and therefore it is called dry. But as soon as the water is precipitated in clouds, fogs, rain or snow, it then affects the hygrometer, and is called moist. But on the common principles of spontaneous evaporation, what difference in the quantity of oxygen air, can water held in solution, make in atmospheric air, in the different situations in which it is placed ? Water is not oxygen air ; and therefore, whether it is dissolved in the air or only intermixed with it, it still retains its distinct characteristic qualities, and can neither increase nor decrease the quantity of oxygen air in the atmosphere.

" It was reflecting on this very circumstance, that led me to adopt the hypothesis which I have above attempted to establish, and upon which the solution is perfectly easy. If evaporation consists in decomposing water and converting it into air ; and if the air, in this act of decomposition, converts only such part of the water into air as is necessary to make it of a proper degree of purity ; and if a deficiency in the oxygen part is generally experienced, it will follow, that a dry air will have its oxygen part increased, and that this increase will generally depend upon the degree of evaporation. And for the very same reason, as soon as this dry air, by the common laws of nature, is decomposed, and forms clouds, fogs, rain or snow, a deficiency in the quantity of oxygen must of course take place ; which is at once discovered by its effects on animal and combustible bodies.

" SECONDLY. The same author also discovered, that in the summer season, or from *April* to *November*, there was a deficiency of oxygen in atmospheric air, in different proportions, varying from 290 to 236, This observation also precisely corresponds with fact. It is sometimes experienced in a very high degree in our blast furnaces.

" But admitting this fact, there will be a difficulty to reconcile it to the principles of evaporation here attempted to be established. In hot weather it is generally believed, that evaporation proceeds with vigour, and consequently, if it consists in converting such of the component parts of water into air as at the time are necessary to render it of a proper quality for the purpose of life, how comes it that at this season of the year, the equilibrium is destroyed and that atmospheric air contains less oxygen than usual ? The objection, made by my friend Mr. *Mushet*, of the *Clyde* Iron Works, is very fairly urged, and it will be proper to meet it in its full force. Perhaps the following thoughts may have a tendency to reconcile the appearances.

" Heat always rarifies air, and consequently, as far as this effect goes, as we have formerly observed, will prevent evaporation. Tho' therefore evaporation, be promoted by heat, yet, on account of the rarity it produces in the air, the quantity may not be so great as is generally supposed, and the scarcity of water at this time may probably arise as much from the want of a supply, as the actual quantity taken away.

"Besides it seems conformable to appearances, that atmospheric air, when it is rare, has actually a less proportionable attraction for the oxygen part of the water, than the hydrogen, and the contrary, when it is dense. Perhaps too, a difference in temperature may have some effect.—Hence the air being rarified by the summer's heat, may attract a greater proportional quantity of hydrogen, from the water, than oxygen; and the dense air of the winter, a greater proportional quantity of oxygen than hydrogen.—And for the same reason, when the air in the superior regions deposits moisture, it will form that moisture with a greater proportional quantity of oxygen than hydrogen. The hydrogen air which is said to abound in these regions, will easily attract oxygen from air thus circumstanced, and by a process yet unknown, the two substances will unite and form water. Consistent with this observation, when *Garnerin* ascended in a balloon over *Paris*, to the height of 669 toises, he brought down with him, a bottle of the air, with which he was there surrounded; and *Humboldt*, in examining it by the Eudiometer, found it to have considerably less oxygen in its composition than even the air in Paris. *Philo. Mag. vol.* 1. *p.* 333.

"Water formed in the superior regions, seems to be in a perfectly neutral state, with respect to the air from which it comes. It descends in it without imparting its oxygen, notwithstanding the air in which it descends, is well known to be deficient in this principle.——If these suppositions be true, they assign the most satisfactory reason, why the air in winter, whatever be the state of evaporation, should be more oxygenated than in summer; and consequently more friendly to combustion and the breathing of animals.

" Add to these observations, That the heat of summer promotes putrefaction both in animal and vegetable substances, and in this state, it is well-known these substances send forth a considerable quantity of azotic, carbonic acid, and hydrogen gasses, each of which, even in small quantities, will considerably diminish the purity of the air.——An increase of temperature also increases the attraction of those substances which have an affinity for oxygen. Oil, tallow, and all unctuous substances, become sooner and to a greater degree rancid, in warm than in cold weather, which is caused by their greater attraction for oxygen, which enables them the more readily to take it out of the atmosphere. But in winter time all these circumstances are changed, and their effect upon atmospheric air is apparent.

" Give me leave further to remark, That the greatest deficiency of oxygen is experienced in the summer season, when the weather is calm and little circulation of air takes place. In these circumstances, tho' evaporation may proceed with vigour, on account of the heat of the weather, yet the atmosphere in general, will not so readily partake of its effects. The fact will be, that the air over lakes, rivers, and especially seas on account of their extent of surface, will be highly oxygenated, but for want of circulation, it will hang over the waters without being able to communicate, in a beneficial degree, its salutary influence to the surrounding air; and, being itself confined over the water, by the calmness of the weather, the surrounding air cannot approach to receive purification. But we all know, that as soon as the circulation of the air takes place, the circumstances change, and the air becomes more pure.

" From some or all these causes, I apprehend, evaporation in the summer season, may be equal or even superior to what takes place in the winter, and yet the comparative quantity of oxygen in the air may be very different. If therefore in the summer season there be actually such a proportionable deficiency in the air as *Humboldt* discovered, it accounts at once, in the most satisfactory manner, for the working of our furnaces, and the various appearances in the state of our metal, which we all experience.

"THIRDLY. It is further remarked by the same writer, That the air is more full of oxygen on the sea than over the land. This, at the same time that it confirms the sentiment just advanced, is easily explained by the theory here attempted to be supported. The sea is the great source of evaporation. Its constant motion, extent of surface and distance from contaminating causes, afford to the air the best opportunity of supplying itself with this revivifying principle. Hence, in a dead calm, the air must hang over the sea highly loaded with oxygen, and hence too the salutary effects of sea breezes.

"FOURTHLY. It is yet further observed in the same paper, That the air on elevated situations contains less oxygen than over low grounds. This is perfectly consonant to the theory above stated. Lakes, rivers and seas, from whence the air derives its oxygen, are generally on a low level. As soon as the air is oxygenated, it becomes specifically heavier, and consequently has a tendency to remain in the valley. Hence a dry air always raises the barometer, and a moist air causes it to fall. Hence too the difficulty of breathing, of which every one complains, in a moist season, and on the tops of very high mountains.

"These experiments were made with the Eudiometer, and the different proportional quantity of oxygen in the air, circumstanced as above stated, exactly ascertained by this instrument, and this difference being considerable, corresponding exactly with our experience, and directly accounted for on the principles of evaporation above stated, at once confirm the facts, and give a high degree of probability to the sentiments here advanced.

" Now, if the above experiments be true, you will easily see that azotic gas, atmospheric air and water, consist of hydrogen and oxygen, differently proportioned, and that these two substances are thus capable of being united without at all destroying the compound ; and that being united in these different proportions, we can easily account for the different appearances which in our operations daily take place. We can assign a very good reason why air is generally so much more advantageous to a blast furnace when it is dry than when it is moist—why it should be better in vallies than on the tops of mountains—In winter than in summer—At sea than on land. Now, in all these different degrees of purity, the air is exactly the same in all its essential properties, differing only in its use according to the proportion of its component parts.

" Experiments respecting water have never yet been made with a particular view to the sentiments here advanced, and, for this plain reason, because I do not know they were ever advanced before. But I have no doubt but water under different degrees of evaporation, and in different circumstances, will be found to contain in its composition, different proportions of its two constituent parts. When much moisture, for instance, has fallen, experiments may discover that the proportion of oxygen will be increased. When evaporation has being long continued, the hydrogen will be more abundant ; and perhaps a difference will be found in the proportion of oxygen, under a long continued evaporation in the summer season, to what it will be under the same circumstances in the winter. At least, these are direct inferences from the above method of reasoning, but experiments are wanting to confirm or confute the supposition.

" The facts however are rendered probable from the different results that have arisen from the several experiments that have been made on the composition of water. The proportion of hydrogen and oxygen, as component parts of water, has frequently been found variable. The experimentalists have never once thought that the composition might be different in different circumstances; but whatever exceptions to preconceived notions have been found, they have always been applied to the inaccuracy necessarily attendant on experiments of so delicate a nature. A closer investigation may perhaps shew that the experiments were accurate, and the difference lay in the component parts of the water examined.

"I would only further remark, that in the argumentation above adopted, the hydrogen and oxygen differently compounded, so as to form the different substances here mentioned, are in all their different states supposed to be in a perfect degree of combination. When they are united in such proportion as to form azotic gas, every particle of the air is supposed to have its just proportion of oxygen and hydrogen in perfect solution. When any quantity of oxygen gas is added, the whole mass is supposed to be improved, and that every part gets its respective share; and, when any part is taken out, the dificiency is supposed to be diffused through the whole. Exactly in the same manner, when a quantity of oxygen is carried by a descent of moisture into water, the whole becomes intimately combined with the water into which it falls; and, when either hydrogen or oxygen is taken out and converted into air by evaporation, every part of the water connected with it, will suffer its due proportion. So that when either hydrogen or oxygen is either taken out or put in from either air or water, no actual decomposition takes place; so as that when either of the component parts of the substance is in part abstracted, the other must of course be separated also. The bodies are so constituted that they will easily give out a portion of one of their constituent parts, without being under the necessity of giving up either the whole or part of the other. What remains is diffused through the whole mass, and the compound is only, as it were, weaker in proportion of the part that is taken away.

"Nor is this a singular property of these bodies. Water can be united to acids, and perhaps to every other fluid for which it has an attraction, in any proportion you please, and yet every particle of water will have a particle of acid united to it, and the whole will form a perfect compound. If you take 10 or 100 gallons of water, and add to it a small quantity of sulphuric acid, this small quantity will be diffused through the whole mass, and every particle of water will have a particle of acid united to it. You may add acid to the same quantity of water in any proportion you please, the same effect will follow. Every particle of water will have an additional quantity of acid united to it, and, in every stage, the compound will be compleat. I need not add, that when such additions or dimunitions are made, that without agitation it will require some time before a perfect diffusion can take place. You see this, in mixing a little sugar with a cup of tea. But if no agitation was used, the same effect in time would follow. By the common laws of nature, an equal diffusion would of necessity ensue.

"I have taken the liberty, gentlemen, to illustrate this principle at considerable length, not only as it is new, that you may fully understand it, but that I might view it in all its consequences, and submit the whole to your consideration. If it appear to be a philosophical whim, I trust there will be no harm. Our time may be worse spent than in being employed in philosophical trifles. If it be found true, sure I am, it will lead to great practical utility.

"Give me leave, now, to enquire how these principles respecting air and moisture, will explain the several appearances that take place in our blast furnaces.

"In the summer season we all know that the furnaces never work quite so well as at any other time. We also know that this has been applied to the rarefaction which the air experiences by the heat it receives from the sun. The late Mr. *Wilkinson*, to prevent this, actually made a long subterraneous passage, through which he caused all the air to go that went into his furnace, in hopes, that by this contrivance, it would be cooled, and thereby condensed before it entered the tuyere pipe. How this experiment succeeded with him, I cannot say. But in the year 1793, impressed with the same idea, I reasoned in this manner. If our furnaces work thus slowly, and make such bad metal, in consequence of the air being rarefied by the sun ; any mode, by which this air can be condensed equal to such rarefaction, will correct the evil. Our safety valve was loaded at that time with two pounds upon one inch, and I laid upon it half a pound more. This would cause a degree of condensation of the air much superior to the rarifaction it had received by the heat of the sun. The engine worked well, and, for five or six days, lifted up the valve. The furnaces run faster, but the metal was not at all improved.

"I then varied the experiment, and, instead of throwing air into the furnaces in a condensed state, under the same pressure, I suffered it to enter in greater quantity. I took the half pound on every inch from the safety valve, and enlarged the tuyere pipe. From $2\frac{1}{2}$ inches in diameter, I made it 3, and continued it for a number of days without any effect at all upon the metal. From hence I was fully convinced that the furnaces were not injured with the air being rarified by the summer's sun.

"Disappointed in this experiment, I reflected with attention on the circumstances that accompanied it. It perfectly accorded with my observations, that, in the summer time, when there was a pretty constant circulation of air, attended with brisk breezes with now and then a shower, notwithstanding the heat of the weather, the furnaces were never much injured. But when a dead calm continued for a considerable time, the heat sultry, and no rain, the furnaces suffered much indeed. In these circumstances, the heat of the weather promotes putrefaction, and the union of oxygen with oil, tallow and other substances that have an attraction for it. The dryness of the season stops vegetation. The stillness of the scene never agitates the air or disturbs the water, and the same contaminated atmosphere is circulated again and again through the furnaces, panting, as it were, for want of breath. Thus every operation that attracts oxygen out of the air, acts in its full force ; and every circumstance that produces it, is greatly obstructed, and evaporation itself, which, I apprehend, is the great cause of renovation to the atmosphere, from the calm state of the air, must be very much impeded. The heat of the weather has a tendency to promote it ; but then, as the air is rare and has no circulation, the particles next to the water, tho' loaded with oxygen, not being removed from their situation by circulating breezes, can neither communicate with the surrounding atmosphere, nor permit other particles in succession to receive purification. If in this situation, as we have hinted above, the air has a stronger than usual attraction for the hydrogen of the water, it will be pretty manifest, that when all these circumstances combine, the atmosphere must be considerably impure, and therefore that the injury done to the furnaces at this season, principally arises from a deficiency of oxygen in the air. This sentiment received a strong confirmation in my mind from observing that the furnaces in this state always worked cool, and that the metal had every appearance of an imperfect regulus.

" Knowing that water contained a considerable quantity of oxygen in its composition, and that, upon being exposed to a red heat in connection with any substance that had an attraction for oxygen, the water was decomposed and formed oxygen and hydrogen gas ; it occurred to me, that if steam could, in the situation supposed, be thrown into the furnace, the red hot coaks would decompose it, absorb the oxygen gas as it rose into the higher regions of the furnace, and thereby increase the temperature of the furnace. Not having an apparatus ready for this purpose, and, recollecting that some old cinders that had been long exposed to the weather, had been very effectual in melting metal in the cupola, I determined to throw water upon the coaks before they were put into the blast furnace. The water put upon the coaks in this manner, would, undoubtedly, in a great degree, evaporate and fly out of the top of the furnace in the form of steam, before it could be raised to a red heat. But apprehending that some part of the water, which was received into the more internal part of the coak, might remain and be changed into air, I determined to try the experiment. The trial was attended with some success. The temperature of the furnace was raised, and the metal improved. But the experiment was not long continued. In a few days a little rain fell, the air met with a pretty brisk circulation, its temperature was lowered, and that refreshing vigour, which always accompanies an increase of oxygen, remedied all defects and caused the furnaces to work well and make plenty of good metal.

"Upon a future occasion, to try the effect of steam on the furnace circumstanced as above, I placed a boiler by its side, made an opening into the furnace 8 or 10 Inches above the Tuyere, and through this opening sent in a quantity of steam, at the same time the usual quantity of air was going in at the Tuyere. This effectually raised the temperature of the furnace; but the heat which the steam took from the lower part of the furnace, to be converted into air, so cooled the furnace in this part, as in a great measure to scaffold it over, and prevent its working. You will see this experiment in sufficient detail in the Philosophical Magazine, page 114. Vol 6th, therefore it is needless to repeat it here.

"In the autumnal season the descent of vapour is commonly great, and, either now or at any other time when rain is abundant, it is always detrimental to the blast furnace. A change from dry to moist air, has sometimes reduced our charges four or five in 24 hours, and changed the metal from rich No. 1, to very indifferent No. 2.—This is easily explained on the principles before laid down. When the air descends, the atmosphere parts with a considerable quantity of oxygen, and the loose particles of moisture, entering the furnace along with the air, act precisely in the same manner as steam, and therefore materially injure the furnace.

"But as soon as ever the rainy season is at an end, the atmosphere, having parted with too much of its oxygen, is eager to receive it from every river, lake or sea. Evaporation proceeds briskly. The roads swimming with water, are quickly dried up, and every reservoir contributes its portion. Cold succeeds, the circulation of the air is quick, and becomes highly oxygenated, and does its office in the furnace with increased vigour.

"This give us a faint idea of frosty weather, frequently so abundant in the winter season, and shews the happy effects of it on the blast furnace.

"At last the spring arrives in all its gaiety. Plants, flowers and shrubs throw out their shoots, and with them plenty of oxygen gas. Evaporation takes place precisely as it is wanted. The air is pure. Every animal rejoices in the sensation, and every combustible substance manifests the aid that it receives, by its remarkable brilliancy. Our furnaces work well, and metal is made good in quality and abundant in quantity.

"Thus in every season and in every state of the weather, the principles we have here advanced, directly apply, and give an easy solution to every appearance. The air produces good effects on blast furnaces by means of oxygen, and a deficiency of this principle in the atmosphere is highly injurious. The cause of irregularity is evident and certain. It would be happy under every injurious change to be able to correct. But this is a real difficulty, for which at present, it is not in our power to point out an adequate remedy. Nature, you see, relieves herself with perfect ease. She produces a wind, she agitates the water by the air, or the descent of gentle showers, and converts that part of the water into air, in which the atmosphere is deficient, exactly to suit the exigencies of the case. But this is not within the compass of human nature.

"I have always thought a water receiver did this in part, and think so still. The air in a compressed state, lies exposed to the surface of the water in motion, and therefore I apprehend, will in part, renovate itself, by converting such part of the water into air, as circumstances require. It might do this more effectually, if all the air that goes into the blast furnace, was made to pass through water before it entered the tuyere. I mean to try this experiment, and am not without hopes of success.

" A more complete remedy however would certainly be, if we could, either by means of heat, or some chemical solvent, extract oxygen air directly from water. If the process was cheap and could be carried on to any extent, we might easily produce that quantity of oxygen gas which would exactly suit our purpose, and throw it into the receiver in such proportion as would make it beneficial.

" Black Calx of Manganese abounds with oxygen, and can easily be set at liberty in the form of oxygen gas, by sulphureous acid and heat. This will amend any small quantity of air injured by any natural process. But the quantity in the blast furnace, will, I fear, much exceed, what in this way, we can possibly produce.

" We know if steam be thrown into an iron vessel made red hot, the iron attracts the oxygen and sets the hydrogen loose in the form of hydrogen gas. Did we know of any substance that would act directly contrary to this—that would attract and absorb the hydrogen, and set the oxygen at liberty in the state of gass,—it would answer our purpose completely. But of such a substance, I am entirely ignorant. It is, however, one point gained,—that we know our wants. Our future enquiries may perhaps effectually relieve them.

" R. Sedgwick, Printer, Market-Place, BRADFORD.—1800."

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