A

DESCRIPTIVE CATALOGUE

OF THE

GEOLOGICAL, MINING, AND METALLURGICAL MODELS

IN THE

MUSEUM OF PRACTICAL GEOLOGY.

BY

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LONDON:
PRINTED BY GEORGE E. EYRE AND WILLIAM SPOTTISWOODE,
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.
FOR HER MAJESTY'S STATIONERY OFFICE.

1865.

Price 2s. 6d.

10434.

NOTICE.

In issuing this Descriptive Catalogue of the Geological, Mining, and Metallurgical Models in the Museum of Practical Geology, I gladly express the opinion that the work is highly creditable to the skill of Mr. Bauerman.

The visitor to the Museum will find in it a lucid explanation of the models illustrative of the Sciences of Geology, Mining, and Metallurgy.

The models being distributed according to the available spaces in the Museum, it has been found impossible to notice them in the order in which they are placed. A systematic order has therefore been adopted, and the heads of this arrangement are set forth in the opposite table of contents. The second and more detailed list, contains the name of each model according to its position in the Museum.

RODERICK I. MURCHISON,
Director.

Museum of Practical Geology, Jermyn Street,
March 29th, 1865.

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TABLE OF CONTENTS CLASSIFIED ACCORDING TO POSITION.

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CATALOGUE

OF

THE GEOLOGICAL, MINING, AND METALLURGICAL MODELS.

The articles comprised in this division of the Museum are, with a few exceptions, placed in the model rooms and galleries, and are arranged according to the following scheme:—

ON THE FIRST FLOOR.

EASTERN MODEL ROOM, OR ROOM A., entrance from the principal floor of the museum, contains mining tools, pumping and winding engines, boring machines, ropes and chains, and man engines; in addition to which a crusher, a blowing engine and blast furnace, and the sectional model of Dolcoath mine are placed here, being too large to go with the models of the same classes in other parts.

ROOM B., OR WESTERN MODEL ROOM, entrance from room A., contains models illustrative of the workings of collieries, the Upleatham inclined plane, and a series of pit frames, cages, and guides for collieries, and safety catches.

ON THE SECOND FLOOR.

THE SMALL ROOM C. contains illustrations of mine timbering, masonry, and tubbing, geometrical models illustrating geological phenomena, such as denudation, faults, contortion, the formation of mineral veins, &c., an old model, showing the different operations of mining as carried on in Saxony in the last century, a model of the surface workings of a small Cornish mine, and a hand crusher used in the smaller lead mines in Derbyshire.

THE EASTERN GALLERY D. is almost entirely filled with models of smelting and foundry furnaces, the only foreign objects being the large water pressure engine in the corner above the staircase and the crystallographical models in the entry from the lower front gallery.

THE WESTERN GALLERY E. includes safety and other lamps, surveying instruments, ventilating machines and furnaces, ore crushing and dressing machines, with the exception of those too large to be introduced, as already mentioned, and Gay Lussac's apparatus for silver assaying.

ON THE PRINCIPAL FLOOR OF THE MUSEUM ARE PLACED,

ON THE EASTERN SIDE, the large pumping water wheels from Devon Consols mine.

ON THE WESTERN SIDE, the model of a North of England colliery, the workings of Holmbush copper mine, and an Australian quartz crushing and amalgamating works.

FACING THE PRINCIPAL ENTRANCE OF ROOM A. is a model of a steel converting and casting works, and on the left of the entry of the room is a condenser for lead smoke.

The detailed notices of the models are arranged according to the following order :—

GEOLOGICAL MODELS.

SOPWITH'S MODELS OF STRATIFIED MASSES.
MODEL OF NENTSBERRY MANOR, ALSTON MOOR.
MODEL OF THE DEAN FOREST COAL BASIN.
MODEL OF THE EBBW VALE COLLIERIES AND IRONSTONE MINES.
GENERAL MODEL OF A COAL MEASURE DISTRICT.
MODEL OF THE LANDSLIP AT AXMOUTH.
MODEL OF THE LANDSLIP AT AUCHENGRAY.
MODEL OF THE VOLCANIC MOUNTAINS OF AUVERGNE.
MODEL OF THE PASS OF MONT CENIS.
GEOLOGICAL MODELS OF THE ISLE OF WIGHT.
GEOLOGICAL MODEL OF THE ISLAND OF ARRAN.

SPECIAL MINING MODELS.

MINING TOOLS.
FUZES AND CARTRIDGES.
TIMBERING AND MASONRY.
BORING MACHINERY.
LAMPS.

DRAWING ENGINES, INCLUDING,—
- WINDLASSES AND HAND WHIMS.
- HORSE WHIMS.
- WATER WHIMS.
- STEAM WHIMS.
- COAL DRAWING ENGINE AND SCREENS.

PIT GUIDES AND SAFETY CATCHES.
ROPES AND CHAINS.
INCLINED PLANES.
CRANES, HOISTS, AND DROPS.
MAN ENGINES.
METHODS OF WORKING AND VENTILATING COLLIERIES.
TYROLESE METHOD OF WORKING SALT MINES.
PUMPING ENGINES (water and steam power).
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GENERAL MODELS OF MINES.

SURFACE MODEL OF A SMALL TIN MINE.
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SURFACE MODEL OF THE CLUNES GOLD QUARTZ MINES.
MODEL OF MINING OPERATIONS AS CARRIED ON IN SAXONY IN THE LAST CENTURY.

METALLURGICAL MODELS.

MODELS ILLUSTRATIVE OF GEOLOGICAL PHENOMENA.

Nos. A. I. to A. XII.

A series of 12 models by T. Sopwith, Esq., F.R.S., illustrating by geometrical construction the principal phenomena connected with the denudation or dislocation of stratified rocks, as follows:—

A. I. MODEL TO ILLUSTRATE THE EFFECTS OF DENUDATION.

On a scale of 1 inch to 50 feet.

It represents the general character of the Carboniferous or Mountain Limestone formation of Alston Moor, in the county of Cumberland, consisting of alternations of thin coal seams with beds of sandstone, limestone, and shale. As all the beds are parallel to each other, it is obvious that only the uppermost one would have been known to us had the original surface of the ground been preserved. By subsequent denudation, however, a deep valley has been furrowed out of the mass, the effect of which is seen by removing the upper part of the model; the lower rocks coming to the surface in the cliffs on either side are exposed in long sinuous lines, called outcrops or basset edges, which, when undisturbed by dislocations, form V-shaped curves, pointing up or down the valley, according to variations in the inclination of the rocks on the bottom of the valley, as shown in Nos. VIII. and IX.

A. II. Model of Coal Strata near Newcastle-on-Tyne.
Scale, 5 chains or 110 yards to an inch.

The undulating surface shows the basset or cropping out of an upper seam of coal, completely circumscribed by denudation.

The successive beds of coal are represented by laminæ of ebony, as follows:—

Names of Seams in descending order.	Depth from Surface.	Thickness of Seam.	
	Yards.	*ft.*	*in.*
1. Monkton and Hebburn Fell seam -	40	2	10
2. Three-quarter coal - - -	204	1	2
3. High-main coal - - -	264	6	0
4. Metal-coal seam - - -	278	3	0
5. Stone-coal seam - - -	292	0	8
6. Yard-coal seam - - -	312	3	0
7. Bensham seam - - - -	336	4	8
8. Six-quarter coal - - -	366	2	6
9. Five-quarter coal - - -	374	2	8
10. Low-main coal - - - -	386	6	0
11. Crow coal - - - -	406	0	10
12. Ryton five-quarter coal - -	425	0	5
13. Ryton Ruler coal - - -	433	0	8
14. Beaumont seam - - -	470	3	5

Making a total thickness of 37 feet 10 inches of coal interspersed through 1,410 feet of other measures.

The model is divided into two parts at the level of the Bensham seam, the depth of which at Walls-end is about 870 feet, and upon it are shown the workings of a colliery on the pillar and stall system.

A. III. Model showing the Dislocation of Carboniferous Limestone.

This model is in four parts, which may be separated, and thus exhibit, 1st, the original position of strata; 2nd, the shifting and vertical displacement; 3rd, the appearance of the surface after the inequalities are removed. The line of displacement illustrates the nature of mineral veins, which are fissures in the strata, attended with more or less vertical movement of adjacent rocks.

A. IV. Model to show the fallacious Appearances caused by successive Dislocation.

Representing a part of the mountain limestone strata, with three thin seams of coal, which, by successive *faults* or dislocations, throwing them down in a direction contrary to their dip, are made to basset or crop several times on the surface, the three beds having ten outcrops, and thus, on a cursory view, a fallacious idea of the strata beneath may be formed, for though several beds of coal appear at the surface, there is no considerable quantity beneath. An excellent illustration of these faults is given in Mr. Buddle's Section of Jarrow Colliery, inserted in De la Beche's "Sections of views illustrative of Geological Phenomena," plate 7.

The same kind of repetition of beds at lower levels by down-throw faults is often well seen in the oolitic valleys of Gloucestershire and Oxfordshire.

A. V. Model showing Dislocations of Coal Strata.

This is similar in principle to No. IV., being a piece of ground in which the rock is separated by parallel faults; all the coals are, however, deep, and do not come to an outcrop, owing to the line of erosion of the valley being parallel to the strike of the beds; the lines of outcrop of the rocks are straight; but the effect of the faults is to bring the highest dark-coloured bed of sandstone to the surface of the ground three times on the same side of the valley. The rocks in the bottom of the valley form a wedge shape mass, let down by what is known as a trough fault, that is, it is bordered by dislocating planes which incline towards each other. In all these cases it will be seen that the rocks are thrown down on that side of the dislocating plane that makes the greatest angle with the horizon, illustrating a rule that is generally but not invariably true.

A. VI. Model showing the Intersection of Mineral Veins.

In this model the surface of a dislocated seam of coal is shown as it would appear if the superincumbent strata were to be removed. The vein represented by *white* wood, following a direction from W. of S. to N. of E., is the first-formed vein; it *hades* or inclines with the bottom to the east, and the strata on the east side are thrown down 40 feet. Subsequently a second vein, crossing the first one obliquely, has been formed and a further dislocation ensued, by which the rocks on the east side of the newly-formed vein have been thrown up 70 feet; and hence the seam of coal, which was originally a regular plane, like that shown in Model No. 2, is separated into four parts, and taking the highest portion marked A, for a datum, one part B, is 40 feet, another C, 70 feet, and another D, 110 feet below it.

A. VII. Model to illustrate the Phenomena of Mineral Veins.

This is the same as the preceding model No. VI., brought to a natural surface by denudation, the top coal has been entirely removed in the sections A. and D., and is now represented by the triangular patches in the parts marked B. and C.

A. VIII. Model of Overcut Strata.

If the strata had remained in the nearly horizontal position in which they were deposited, any subsequent grinding away of the surface of any stratum would have worn off the upper portion, and denuded first the upper, then the lower strata, which may in such case be said to be overcut, as shown in this model. In every case where the strata are overcut, they form a V-like shape, *pointing up the valley;* the *highest* rocks *appear to be the highest,* and the seams of coal are to be worked above the place where they *basset* or crop out.

A. IX. Model of Undercut Strata.

It frequently happens that the strata are inclined at a steeper angle with the horizon than the surface of the country, in which case they may be said to have been *undercut* by the process of denudation, as shown by this model. The V-like form of the strata now points *down* instead of *up* the valley, as in the model No. VIII. The *highest* rocks appear the *lowest*, and the coal is to be worked *below* where it crops out. These terms of *overcut* and *undercut* apply to plane surfaces as well as to valleys; but steeply undulating surfaces have been selected, as affording the most striking illustration of these features, which are of general practical use in the observation of a mineral district.

A. X. Model showing Denuded Basset of Inclined Strata.

The models hitherto explained have been either cases of horizontal strata or of strata inclined in the same direction as that of the surface. In this model the strata are inclined in the opposite direction to the descent of the valley, and in every such case they are *undercut*—hence the V-like form tends upwards. The four models, Nos. I., VIII., IX., and X. form an epitome of the conditions under which stratified rocks are exposed by denudation when not disturbed by faults, and of the characteristic marks by which their relative inclination, as regards the surface, may be ascertained.

A. XI. Model to illustrate the Vertical Intersection of Mineral Veins.

The strata represented in this model are dislocated by four mineral veins, and the plane surfaces of the model afford a clear view of the geometrical relations of the several rocks. Two sides show the original horizontal deposition, the other two sides the subsequent disturbance or dislocations; on one of these may be observed the *intersection of two veins on a vertical section;* by removing the upper part of the model the same intersection is shown on the *oblique plane*, and again a horizontal surface on the base of the model, as it would be represented by the ordinary ground plan of a mine.

The four faults or veins are of two different ages; two of them, those in white wood, incline and throw down the rocks to the westward; the other two, in dark wood, dip to the east, throwing down the rocks on the same side, and are of newer date. The centre of the ground is affected by one of the latter series crossing the plane of one of the faults.

A. XII. Model showing Denudation of Mineral Veins.

This is the same piece of ground as No. XI., the faults and lower beds being exposed by denudation.

No. A. 13.—Model of Ebbw Vale and Sirhowy Iron Works, in the County of Monmouth.

Scale, $\frac{1}{4752}$, or 1 inch to 6 chains.

This model is by Mr. Sopwith; it comprises nearly four square miles of ground. The upper surface being taken off, *the black-pins mine*, a bed of ironstone, with the workings in it, appear. Below this the *three-quarter coal, Modellwg,* or *Bydylog coal*, and *red vein mine* are exhibited by removing successive trays which represent the intervening strata. The outcrop of the strata forming a circuitous bend round the hill, and the V-like forms pointing down the valley, are worthy of observation, and the favourable position of these vast and rich deposits of coal and ironstone may be readily understood by inspection. The ground over which the coal has been worked out is coloured bright red; the lines of the surface boundaries and enclosures are projected on the surface of each seam.

No. A. 14.—Model of the Forest of Dean, in the County of Gloucester.

Scale $\frac{1}{6336}$, or 1 inch to 8 chains 176 yards.

This model was constructed by Mr. Marcus W. T. Scott, some twenty to thirty years ago, on a principle laid down by Mr. Thomas Sopwith. It represents a tract of country comprising the principal coal field of the Dean Forest, the superficial area being 24 square miles. Various colours represent planted enclosures belonging to the Crown, roads, reservoirs, &c. Railways are shown by black lines, streams of water by blue lines, and buildings by a bright red colour. The *outcrops* or *basseting* of the principal beds of coal are shown on the surface, and vertical sections of the strata are painted on the sides of the model. These comprise the *coal measures* or strata, the seams of coal being represented by black lines; below these are the strata of the *carboniferous* or *mountain limestone*, resting on the *old red sandstone* forming the base of the model, and is at least from 6,000 to 8,000 feet in thickness. In order to show similar vertical sections in the interior of the Forest, the model is made in compartments, placed on a sliding table, so as to be easily separated.

The upper surface of the model, or face of the country, is made to lift off, in order to show the position and extent of the *Park End* or *Lowery vein* of coal. This may again be lifted to show the workings in the *Churchway High Delf*, and by a third removal a view is obtained of the

Coleford High Delf vein. (Thos. Sopwith, F.R.S., G.S., on Mining, Record Office.) Ground worked out is coloured red on the surface of the coal seams; old workings from the outcrop now filled with water, blue or purple. Three contour lines are traced on each seam; the first, coloured yellow, is the level of free drainage, the other two are the levels of 100 and 200 yards below it.

No. A. 15.—MODEL OF PART OF THE LEAD MINING DISTRICT OF ALSTON MOOR, IN THE COUNTY OF CUMBERLAND.

Scale, $\frac{1}{792}$, or 1 inch to 66 feet.

The manor of Alston Moor, belonging to the Commissioners of Greenwich Hospital, was surveyed upwards of 200 years since, and its mines were reported to be nearly exhausted. In 1821 it was stated by the Secretary of Greenwich Hospital to be "the most valuable and interest-" ing part of the landed property of Greenwich Hospital," the mines then yielding an annual produce of 100,000*l.*, nearly one-fifth of which was received as rent or royalty from the mines.

The produce of the mines of Cumberland, which are mainly comprehended in the important district of Alston Moor, belonging to Greenwich Hospital, was, in 1863, as follows:—

Lead ore.		Lead.		Silver.
Tons.	*cwt.*	*Tons.*	*cwt.*	*Ozs.*
6,690	18	4,949	4	41,304

This model, which was constructed by Mr. T. Sopwith, represents part of the mining district adjoining the river Nent. It exhibits the thickness and inclination of the strata of limestones, hazels (or sandstones), and argillaceous beds. In the front of the model is shown the celebrated "Nent-force Level." This work was projected in 1775, by Smeaton, and being judiciously carried out, it has been of the greatest advantage to the district. "Nentsberry engine " shaft, represented on the model, is sunk down to Nent-" force Level, 3½ miles from the entrance. The whole of " this distance, which was then navigable in boats, was " surveyed by the author in 1826; it has since been con-" tinued, as shown in the model, on the top of the stratum " of limestone called the *Scar limestone.* The usual mode " of entrance to the lead mines of Alston is by means of " adits or water levels, made sufficiently large for a horse " to travel in. The entrance or *level* mouth of Nentsberry "greens mine is shown on the model, and the several *rises* "by which access is gained to the veins of ore in the *great* "*limestone*."—(*Sopwith.*)

The *mineral veins* are seen on the sides of this model descending in nearly a vertical direction through the various laminæ. It will be observed that those layers are not opposite each other, on either side of the vein. The cause producing the *fissure* in which the mineral matter has been deposited has occasioned the subsidence of all the strata on one side of the *lode*. Hence the mineral vein may have limestone on one side and sandstone on the other, or sandstone and clay may be opposite. It has been observed that the metalliferous character of the vein is in a great measure dependent upon the arrangement of the strata on either side of the lode. In this district the lead is usually found in the limestone, and when limestone forms both *cheeks* or sides of the vein it is generally there the most productive.

Old Carr's cross vein in the model has, to use the miner's phrase, *thrown down* the strata 25 fathoms, whereas at *Wellgill cross vein* the amount of vertical disturbance is only 3 fathoms. *The great limestone* is 9½ fathoms thick, consequently it follows that the last-named vein has limestone sides for 6½ fathoms (39 feet). (Much of the information connected with this and some other of the models has been derived from an "*Account of the Museum of Economic* "*Geology and Mining Records Office*," by T. Sopwith, F.G.S., published in 1843.) An isometric plan of Nentsberry and a section of another portion of the lead mining district of Northern England, ALLENHEADS, the property of Wentworth Blackett Beaumont, Esq., M.P., hangs in the MINING RECORD OFFICE. The produce of Allendale, East and West, and Weardale in 1863 was—

Lead ore.	Lead.	Silver.
10,728 tons.	8,482 tons.	44,613 ounces.

No. A. 16.—MODELS ILLUSTRATING THE COAL FORMATIONS.

This model is intended to represent the physical appearances and the geological conditions of a coal district. The beds of coal are shown as they *crop out* to the surface on the sides of the hills. An examination of the conditions will prove that the coal has been formed, as is now universally admitted, from vegetable matter, at different periods, and after the deposition of the carbonaceous mass the bed has been covered up with sand or mud to a certain thickness, upon which again a similar process of growth and decay has gone on; this has again been submerged and buried in the detrital matter from the neighbouring hills.

"In the section of the British coal measures between the Avon and Cromhale Heath, there were no less than fifty periods during which the conditions for soils obtained, and roots (*stigmaria*) were freely developed in them, these soils topped by a growth and accumulation of plants, apparently requiring contact with the atmosphere for their existence. The general thickness of that series is about 5,000 feet, and it is based upon an accumulation, chiefly sandy, about 1,200 feet thick. The Glamorganshire coal field gives a still greater deposit to mud, silt, sand, and gravel, intermingled with soils, in which roots of some at least of the plants of the time spread out freely, most frequently, though not always, covered by beds or seams of coal, the thickness of which necessarily depended upon the duration of the conditions needful for the growth and accumulation of their component plants.

"The mass of these various beds in the neighbourhood of Swansea may be estimated at about 11,000 feet; so that if accumulated by subsidence, horizontal beds piled on each other, it would have to be inferred that in this part of the earth's surface, and at that geological time, there had been a somewhat tranquil descent of mineral deposits, sometimes capable of supporting the growth of plants requiring contact with the atmosphere, but most commonly beneath water, for a depth by which the first-formed deposits became lowered more than two miles from their original position." —(*The Geological Observer, by Sir Henry de la Beche.*)

The *Horizontal and Vertical Sections* of the coal measure districts will show at once the manner in which the beds of coal and ironstone, with the sandstones and shales, are found lying one above another.

The want of uniform horizontal direction in the beds of coal and ironstone will be noticed; some parts of the same set of beds being seen upon the higher and on the lower levels. This arises from disturbances which have taken place subsequently to the deposition of the coal beds, by which large tracts of country have been moved. The effects of these movements will be visible in *faults, troubles, dykes, throws*, or *heaves* (as in different localities they are named). These are represented on the Geological Map by white lines, and it will be seen in reference to it that all these lines have a considerable degree of uniformity in their main direction, showing that they have their origin in the same general disturbance. The conditions shown in this model, which is a representation of the existing natural appearance, will be understood by supposing a subsidence of a few square miles of country, leaving the surrounding portions in their original position, or nearly so. This would, of course, produce abrupt precipices on all sides, and sections of the strata would be apparent. After this, the action of floods would wear down the elevations, and eventually rounded hills would be left rising from the valleys, which had been filled in with their débris. The surface soil being removed, the *outcrops* of the beds of coal would be seen at different elevations, as shown in the model. Coals are sometimes worked at the *outcrop*, but, as from the atmospheric influences to which they are exposed, these portions are considerably altered, and of inferior quality, containing an undue quantity of ash-giving matter, and are only suited for brick making, lime burning, &c. In order to determine the quality of the coal, it is therefore necessary to commence workings at some distance from the surface.*

No. A. 17.—Model of the Pass of Mont Cenis.

Scale, $\frac{1}{1000}$, or 1 inch to 83·3 feet.

This model represents about 20 square miles of the country adjacent to the summit level of the pass on the main road from France to Turin. The surface is covered with circuitous lines drawn at equi-distant vertical intervals of 50 metres (about 162½ feet), the alternate ones representing complete hundreds, being drawn in strong lines; all the heights are referred to the sea level. The Hospice near the lake marks the summit level of the road, at a height of about 6,400 feet above the sea level. The road descends on the northern side about 3,000 feet in six miles, the greater portion of this being effected by a series of zigzags near the edge of the printed map attached to the model.

The railway tunnel on the Susa and Chamberi railway, now in course of construction, is about 12½ miles further west; the height of the southern end is about 4,500 feet above the sea level. It is about 8 miles long, and crosses the mountains in a nearly due north and south line.

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* The notices of the models Nos. A. 1—16, are taken with very little alteration from Mr. Hunt's descriptive guide.

No. A. 18.—MODEL OF THE ALPS AND PLAINS OF LOMBARDY, BY MR. BRUNNER.

Presented by the late Dr. Fitton, F.R.S.

Scale, $\frac{1}{518000}$, or nearly 1 inch to 8 miles.

This model is based upon Jomini's map illustrating the wars of Napoleon, and includes a large portion of Switzerland and Italy, with part of Baden, Wutemberg, Bavaria, Tyrol, and Salzburg. The towns nearest to the corners are, on the N.W., Dole and Besançon; on the N.E., Traunstein, near Salzburg; on the S.E., Venice, and on the S.W., Antibes and Nice, with the Italian peninsula down to Spezzia on the West side and Ravenna on the East. The mountains include the Alps, from the sea nearly up to the end of the Rhetian chain, the whole range of the Jura, and part of the Appenines. The rivers include the whole drainage area of the Po, and parts of those of the Rhine, Rhône, Saone, and Danube.

No. A. 19.—MODEL OF THE LANDSLIP ON THE AUCHENGRAY PEAT MOSS, BY MR. THOMAS GIBB.*

Scale for horizontal distances, $\frac{1}{1200}$, 1 inch to 100 feet.
„ vertical „ $\frac{1}{240}$, 1 inch to 20 feet.

The model represents an area of about 70 acres of a peat moss, situate near Slamannan, on the boundary of Lanarkshire and Stirlingshire, which was moved by landslips on the 12th and 13th of August 1861. The moss is about 27 feet deep, and is composed of brown fibrous peat at the top, passing into a black pulpy moss without visible fibres at a depth of 12 feet below the surface; the substratum is formed of stiff blue boulder clay. At the point marked A. was situated a blind loch or overgrown pool, in which water accumulated and made its way beneath the surface to the lower ground, reducing the under peat to a fluid state, which acting by hydrostatic pressure burst up the surface at the lower end near the road B. and flowed downwards until it abutted on the rising ground and plantation at C., which forming a dam retained the mass of peat and water until a sufficient quantity had accumulated to overcome the resistance offered by the plantation, when it rushed in a torrent through the course of the burn D., overflowing the Limerig colliery railway,

* See a more detailed notice in the Proceedings of the Philosophical Society of Glasgow, vol. v. p. 160.

and followed the ordinary drainage channels of the country until it reached the River Avon at Slamannan. A deposit of peat of about 2 feet in thickness, with occasional masses of turf 4 or 5 feet in thickness was left by the torrent over considerable breadths of the courses of the burns. The surface around the blind loch A. fell to a depth of 27 feet, and the water draining from the higher end of the moor has cut a new channel through the bottom of the gully so formed, into the burn at D., the underlying boulder clay being exposed in the lower part of its course.

A section across the dotted line *a*, *b*, is attached to the northern face of the model. It shows the parallel fissures produced in the broken surface of the moss, the vertical heights being, as in the model, increased five times as compared with the horizontal scale.

No. A. 20.—Model of the Volcanos of Auvergne, presented by G. Poulett Scrope Esq., M.P., F.R.S.

Scale, $\begin{cases} \frac{1}{20000}, \text{ about 3 inches to 1 mile horizontal.} \\ \frac{1}{10000}, \text{ 1 inch to 833·3 feet vertical.} \end{cases}$

This model represents the chain of Puys or volcanic cones in Auvergne, which rise from a plateau of granite that separates the Valley of the Allier on the east from that of the Sioule on the west. The extent of surface covered by the cones of scoriæ, pumice, and other loose materials is shown by special colouring, as are also the lavas both basaltic and trachytic of modern date, as well as the older one which flowed from the same heights, and from the higher centre of Mont Dore.

The position of the older lava flows, now forming isolated terraces elevated from 100 to 1,000 feet above the adjoining valleys, shows in a striking manner the large amount of erosion that has taken place since the commencement of the volcanic activity in the Miocene period, such erosion having been entirely produced by the action of rain and running water.

The ground coloured light pink on the eastern side of the model represents the ground occupied by the Miocene fresh water formation. This, together with the alluvium coloured light blue, makes up the fertile plain known as the Limagne of Auvergne, and marks an area that formed a great lake during the older Tertiary period.

The index numbers attached to different points of the model refers to the corresponding numbers on a series of illustrative rock specimens, presented by Mr. C. Le Neve Foster, which are placed in the drawers below. Those brought from the eastern side of the Puy de Dome and the Limagne are in the drawer at the N.E. corner. The specimens formerly among the volcanic collection in the top gallery, noticed at p. 219 of the Rock Catalogue, are incorporated with them. The opposite or S.W. corner drawer contains specimens brought from the district of Mont Dore les Bains, which is beyond the limits of the model.

No. A. 21.—Model of the Isle of Arran, by Professor A. C. Ramsay, F.R.S.*

Scale, $\frac{1}{31680}$, or 2 inches to 1 mile.

The vertical heights in this model are somewhat exaggerated. The best idea of the form of the more mountainous part may be obtained by bringing the eye to the level of the model at the S.E. corner. These mountains consist of granite, forming a circular mass at the north end of the island, about 8 miles wide in all directions. The highest point (Goatfell) is 2,959 feet above the level of the sea, and rising directly from the shore it looks even higher. This mass is surrounded by clay slate, chlorite slate, gneissic and other metamorphic rocks, and it is possible that the granite itself may only be the result of extreme metamorphic action. In turn the gneissic rocks are overlaid by the Old red sandstone, on the east at Glen Sannox, and on the south between Brodick and the west coast north of Mauchrie Water. It is in great part conglomeratic, and pebbles of the underlying metamorphic rocks are contained in it, showing that they were altered before the deposition of the Old red sandstone.

The coal measures (lower coal measures) rest on the Old red sandstone at Brodick bay, and south of Glen Sannox, but between these points they rest, first on the slaty rocks, and then on the granite, showing that they lie on the older strata unconformably. They are also found about 3 miles off the N.E. coast of the island, lying on metamorphic slaty rocks. The limestones, which are interstratified with the sandstones and shales, contain the usual carboniferous fossils. Coal measure plants are found in the sandstones and shales, and thin beds of coal occur near the salt pans. On the S.W., coal measures also appear in the valleys

* Communicated by Professor Ramsay.

where the trap rocks have been removed by denudation. The rocks coloured New red sandstone, according to the original classification of Sedwick and Murchison, are now believed to belong to an upper part of the coal measures. The major portion of the south part of the island consists of felspathic traps and greenstones, which have broken through the stratified rocks indiscriminately and overflowed them, so that in general it is only in the valleys that the underlying strata of coal measures, &c., have been exposed by denudation.

No. A. 22.—Model of Landslip at Axmouth.

Scale, $\frac{1}{1584}$, or 1 inch to 132 feet.

At Christmas 1839 this great landslip took place. The model represents a mile and a quarter of the country over which the subsidence took place. The length of the great chasm caused by this subsidence was 1,000 yards, the breadth 300 yards, and the depth varied from 130 feet to 210 feet. Twenty-two acres were sunk in the chasm. The Rev. W. D. Conybeare thus describes the phenomenon :—

" On the morning of Tuesday the 24th, about three o'clock a.m., the family of Mr. Chapple, who occupied the farm of Dowlands, about half a mile from the commencement of the disturbances which ensued, was alarmed by a violent crashing noise; but nothing farther was observed through that day, On the following night, however, about the same hour, some labourers of Mr. Capple, the tenants of cottages built among the ruins of the adjoining undercliff, hurried to the farm with the information that fissures were opening in the ground around, and the walls of their tenements rending and sinking. Through the course of the day following (Christmas) a great subsidence took place through the fields ranging above Bendon Undercliff, forming a deep chasm or rather ravine, extending nearly three-quarters of a mile in length, with a depth of from 100 to 150 feet, and a breadth exceeding 80 yards. Between this and the former face of the undercliff extends a long strip exhibiting fragments of turnip fields, and separated from the tract to which they once belonged by the deep intervening gulf, of which the bottom is constituted by fragments of the original surface, thrown together in the wildest confusion of inclined terraces and columnar masses, intersected by deep fissures, so as to render the ground nearly impassable.

The insulated strip of fields also which has been mentioned is greatly rent and shattered. The whole of the tract which has been subjected to these violent disturbances must be estimated on the most moderate computation, as exceeding three-quarters of a mile in length by 400 feet."

The tract of downs ranging along the coast is here capped by a stratum of chalk; this rests on a series of beds of consolidated sandstone, alternating with seams of that variety of flints, called chert; beneath these more than 100 feet of loose sand, locally (from an obvious etymology) termed *fox mould*, belonging to the upper green sand formation. This bed was the principal cause of the disturbance. It imbibes all the moisture falling on the surface, and as it rests upon retentive beds of clay, the lias clay, this water softens and wears away the *fox mould* so as to render it incapable of supporting the weight of the superincumbent mass. The support being withdrawn, or proving insufficient, it is easy to conceive that cracks would from time to time be formed, and the undermined portions of the superstrata precipitated into the hollows prepared beneath them. (See *Extraordinary Landslip and great Convulsion of the Coast of Culverhole Point, near Axmouth.* By the Rev. W. D. Conybeare. *The Edinburgh New Philosophical Journal*, 1840.)*

NO. A. 23–24.—GEOLOGICAL MODELS OF THE ISLE OF WIGHT.
Presented by Captain L. L. B. Ibbetson, F.R.S.

Scale, $\frac{1}{1760}$, or 36 inches to 1 mile.

No. A. 23. represents the eastern edge of the chalk ridge traversing the Isle of Wight, showing the succession of the rocks from the lower green sand on the south to the Hampstead beds on the north. The chalk and part of the tertiary beds are nearly vertical, as shown by the lines of the flints, the upper part of the tertiary rocks is nearly horizontal.

No. A. 24. represents the high ground at the south-eastern end of the island, formed of nearly horizontal cretaceous rocks, the chalk forming the high ground of Shanklin over Boniface downs and the lower green sand forming the coast line; the slipped and tumbled cliff of the upper green sand forming the well known undercliff, which extends for about six miles to the westward of the ground shown in this model.

These models are more particularly described in Bristow's Memoir on the Geology of the Isle of Wight, p. xi.

* Notice taken from Mr. Hunt's guide.

MINING TOOLS.

The following list includes the leading dimensions and weights of the mining tools exhibited in the wall cases in room A.:—

The whole of the dimensions are given in inches and tenths, to the nearest tenth.

The weights are those of the tools mounted for use, except where otherwise stated.

Cornish Mining Tools.

No. B. 1–3. **Gads.**

	Length.	Breadth.	Thickness.	Weight.
	"	" "	"	oz.
B. 1.	5·0	0·8 at end	0·5	8½
„ 2.	6·0	0·9 tapered to 0·8	0·6	10
„ 3.	5·5	1·0 tapered to 0·9	0·6	11

No. B. 4–11.

Eight gads arranged in a star. They are made with a central swell in breadth, but taper uniformly in thickness from poll to point.

No. B. 12. **Pick.**

Length.	Width.	Thickness (depth).	Weight.
"	"	"	lb. oz.
12·5 pick end.	3·1 over eye.		
3·0 poll end	1·2 poll end	1·2 poll end	4 8
2·2 eye	1·1 pick end	1·1 pick end	
26·0 handle.			

For hard ground, point set at 85° to handle, poll end eight sided.

No. B. 13. **Pick.**

17·5 pick end	1·0 over eye	0·8 poll end	2 10
3·0 poll end	0·8 poll end	0·9 pick end	
2·1 eye	0·8 pick end.		
26·5 handle.			

For use in soft ground, set of handle 83°.

No. B. 14. **Single Hand Boring Hammer.**

Length.	Breadth.	Thickness.	Weight.
"	"	"	lb. oz.
4·0 head	2·3 over eye	1·4 greatest	2 14
1·9 eye	1·3 face.		
9·5 handle.			

Rectangular at the central section, tapered arms, with edges bevelled, and circular striking faces.

No. B. 15. **Double Hand Boring Hammer or Mallet.**

Length.	Breadth.	Thickness.	Weight.
"	"	"	lb. oz.
4·4 head	3·0 over eye.		
2·2 eye	1·6 clear of striker face	1·9 greatest	8 4
24·0 handle.			

Similar in form to preceding.

No. B. 16. **Stone Tooling Hammer.**

Length.	Breadth.	Thickness.	Weight.
"	"	"	lb. oz.
6·0 head	1·2 over eye	1·2 greatest	5 2
1·2 eye.			
23·4 handle.			

Square section straight arms, each face carries 81 blunt pyramidal points.

No. B. 17. **Picker or Peeker.**

27·5 total	0·9 haft	0·5 blade at top	3 14
14·0 haft	1·0 top of blade	0·3 cutting face.	
11·5 blade	0·8 top of point.		
2·0 point.			

Haft of round iron, blade, rectangular, or slightly tapered with chisel-faced point, used in the St. Just district for workiug in jointy ground.

No. B. 18. **Picker.**

29·0 total	0·9 haft.		
14·0 haft	1·0 top of blade	0·5 blade at top	4 0
13·5 blade	0·8 top of point.		
1·5 point.			

Same form as preceding, except that the blade is worked to a point.

No. B. 19. **Poker.**

25·0 total	0·9 haft	0·6 blade greatest	4 3
22·5 haft	0·9 base of point.		
2·5 point.			

Strong stout form with curved sided point, used in St. Just district for working in jointy ground.

Borers.

No. B. 20.

Length.	Breadth.	Thickness.	Weight.
"	"	"	lb. oz.
33·5 total	1·3 cutting face	0·9	5 15
1·2 tapered part.			

Irregularly eight-sided, drawn from a square bar.

No. B. 21.

23·2 total	1·4 cutting face	0·9	4 4
1·5 tapered part.			

Similar form, drawn in on striker face to 0"·7

No. B. 22.

27·8 total	1·25 cutting face	0·9	4 14
1·8 tapered part.			

Made from a round bar.

The cutting edges of these borers are formed by the junction of two planes at an angle of 90°.

No. B. 23. **Scraper.**

Length.	Diam.	Weight.
"	"	lb. oz.
30·5 total	shaft 0·4	1 6
24·0 shaft	scoop 0·3.	
6·3 scoop	scraper 1·0.	

A thin rod of iron with a round disc turned at right angles at one end, used in cleaning out the bore hole; the other end is provided with a semicircular scoop for carrying powder to the bottom of the hole.

No. B. 24. CLAYING BAR.

Length.	Breadth.	Thickness.	Weight.
"	"	"	lb. oz.
29·0 total	2·8 over eye	1·3 clear, top of shaft	8 7
24·0 shaft	1·0 poll end	0·8 „ end of shaft.	
5·0 poll.			
1·2 diam. of eye.			

Bar with a round tapered shaft ending in a stout hammer head, through which passes a socket hole for the turning bar. It is used for lining bore holes with clay in fissured or wet ground.

No. B. 25. SHOOTING NEEDLE.

Length.	Breadth.	Thickness.	Weight.
"	"	"	lb. oz.
24·8 total	2·3 over eye	0·33 shaft greatest	0 11
22·0 shaft	-	0·3 eye plate.	

No. B. 26. SHOOTING NEEDLE.

44·0 total	2·3 over eye	0·45 shaft greatest	1 5
41·0 shaft	-	0·3 eye plate.	

These needles are made of copper, the handle is formed by a ring of rectangular section. The first is for single hand, the other is for double hand bore holes.

No. B. 27. TAMPING IRON.

	Length.	Weight.
	"	lb. oz.
Tamping iron	23·2 total	3 2

Round bar of iron used for driving in the tamping, tapered from 0″·8 at the top to 0″·9 at the lower end.

TOOLS USED FOR DRESSING ORES.

No. B. 28.

Ellipsoidal hammer, used occasionally for geological purposes. The origin and use of this tool is not known.

No. B. 29.—BUCKING IRON.

An oblong rectangular plate of iron, 5″·15 long by 3″·9 broad, and 0″·8 thick; the handle 15″·4 long, is attached by a stirrup or eye, 3″·2 high by 1″·0 in width; the striking face is flat. Weight, 6 lbs. 2 oz.

No. B. 30.—BUCKING IRON.

A similar tool to No. B. 29. The striking plate measures 4″·9 long, 4″·1 broad, and 0″·7 thick; the stirrup is of the same dimensions as that in No. 29; the handle 16″·1 long. Weight, 6 lbs.

No. B. 31.—Bucking Iron.

The striking plate is nearly square, measuring 3″·6 in length and 3″·4 in breadth; it is, however, tapered in thickness from 0″·5 at the centre to 0·25 at the corner.

No. B. 32.—Cobbing Hammer.

A hammer with arms curving upwards from the centre. Head 13″·1 long, with elliptical eye or socket 1″·1 long; the breadth across the eye is 1″·6; the striking faces are rectangular, 1″·7 deep by 0″·6 broad; the depth at the centre is 1″·3. The arms taper in breadth from 0″·8 at the centre to 0″·6 at the faces. Handle, 9″·0 long. Weight, 4 lb. 11 oz.

No. B. 33.—Cobbing Hammer.

A similar tool to No. 32. Length of the head 9″·4, of the eye 1″·0, of the handle 7″·3, breadth over the eye 1″·6, striking faces 1″·7 deep, 18″ broad. The arms are more strongly curved than those of No. B. 32, the depth of the curve at the centre being 0″·7. The arms are of the same breadth throughout. Weight, 3 lb. 8 oz.

No. B. 34.—Cobbing Hammer.

This tool is smaller than the preceding ones, and the arms are less curved. Length of the head 8″·1, handle 8″·5, eye 0″·9, breadth across the eye 1″·5; the faces are 1″·1 deep and 0″·6 broad. The depth of the curve of the top surface is 0″·3. Weight, 2 lb. 4 oz.

Tools from the Alport Mines, Derbyshire.
Presented by the late S. Barker, Esq.

No. B. 35.—Pick.

A double-headed pick with short points, used in either rock or vein. Head, 15·4 inches long. Handle, 29·0 inches long. Weight, 4 lbs. 6 oz.

No. B. 36.—Pick (Slitter).

A double-armed pick, one side worked up to a point, the other having an horizontal cutting edge 0″·4 wide; used for slitting out the vein. Head, 15·7 inches long. Handle, 29·0 inches long. Weight, 3 lbs. 10 oz.

No. B. 37.—Poll Pick (Maundril).

Single-armed pick with a short bluff point, used for hard veins and working into rock where the slitter is too slight. Head, 10·7 inches long. Handle, 28 inches long. Weight, 4 lbs. 6 oz.

No. B. 38.—Single Hand Boring Hammer.

Head, 5 inches long. Handle, 15·2 inches. Weight, 4 lbs. 6 oz.

No. B. 39.—Double Hand Boring Hammer.

These hammers are square in the centre with tapered 8-sided arms, the striking faces are circular. Head, 6 inches long. Handle, 26·7 inches. Weight, 8 lbs. 12 oz.

Single Hand Borers, "Augur or Noger."

Made of round cast steel, 0″·85 diameter, with strongly curved cutting edges; the striking ends are drawn to a diameter of 0″·6.

	Length.				Weight.
	″			″	lb. oz.
No. B. 40.	18·5 total	- -	cutting face	1·25	- - 2 14
No. B. 41.	25·0 „	- -	„	1·2	- - 3 14
No. B. 42.	31·2 „	- -	„	1·1	- - 4 15

No. B. 43.—Double Hand Borer or "Noger."

Made of round cast steel, 1″·35 in diameter, drawn to 1″·0 at the striking end; total length, 42″·8; cutting face, 2″·1 wide. Weight, 17 lbs. 10 oz.

No. B. 44.—Scraper.

For clearing the powdered material out of the bore hole. 27·3 inches long, pointed at one end, with a circular scraper 0″·84 broad at the other end. Weight, 12 oz.

No. B. 45.—Pricker.

For keeping open a channel for the priming rush or straw through the tamping when filling up the hole, 27″·7 long, tapered to a point from a maximum thickness of 0″·4. Weight, 10 oz.

No. B. 46.—Claying Iron.

Used for lining bore holes with clay when bored in porous or wet ground, 25 · inches total length, made up of a round shaft, 0 · 8 in diameter, with a broad poll pierced with a hole, 1″·2 in diameter, for inserting a key bar. Weight, 8 lbs. 8 oz.

No. B. 47.—Ramming Bar.

Used for ramming down the tamping or filling above the charge of powder; the lower end is elliptical, 0 · 8 in greatest diameter, with a small shallow groove in which the point of the pricker rests; the striking end of the bar is 6-sided. Total length, 21″·8. Weight, 2 lbs. 12 oz.

Tools from Allenhead's Lead Mines, Northumberland.

No. B. 48.—Gad.

Made of 8-sided iron, the lower part near the point is of rectangular section, the breadth increasing towards the centre, the thickness diminishes uniformly from the point to the striking end. Length, 6″·7. Weight, 15 oz.

No. B. 49.—Pick.

A double straight-armed pick; the arms are thickened in the middle, resembling two gads joined horizontally. Length of the head, 18″·9. Handle, 25″·0. Weight, 4 lbs. 6 oz.

No. B. 50.—Single Hand Boring Hammer.

8-sided in section, the striking faces, also 8-sided, and flat. Length of head, 4″·0. Handle, 13″·6. Weight, 3 lbs. 2 oz.

No. B. 51.—Double Hand Boring Hammer.

Resembles the preceding. Length of head, 5″·2. Handle, 24″·2. Weight, 5 lbs. 5 oz.

No. B. 52.—Borer.

Made of cast steel, 8-sided in section, 0″·75 in diameter; breadth of cutting edge, 1 · 0. Length, 29″·7. Weight, 3 lbs. 15 oz.

No. B. 53.—Scraper.

Shaft, 26″·0 long, has a circular scraper at each end, set at 135° to its length. Weight, 6 oz.

No. B. 54.—Clayting Iron.

Length, 27″·2. Eye, 1″·3 diameter. Weight, 6 lbs. 0 oz.

No. B. 55.—Shooting Needle.

Total length, 21″·5; shaft made of copper, tapered from a greatest thickness of 0″·45, which is brazed into an iron ring handle. Weight, ·15 oz.

Tools used in the Lead Mines of Flintshire. Presented by the late Captain Ishmael Jones, Tal-ar-Goch Mine.

Gads.

Made from 8-sided bars, the tapered portion about half the total length, with a central swell in breadth.

	Length.	Weight.
	″	lb. oz.
No. B. 56.	5·5	0 10½
No. B. 57.	6·7	1 2
No. B. 58.	8·3	2 0

No. B. 59.—Pick.

Single pointed pick with short 8-sided poll. Length of head, 15″·2. Handle, 29″·0. Weight, 5 lbs. 2 oz.

No. B. 60.—Pick.

Double-armed pick, with one wedge point arm, the other has a horizontal chisel edge, 0″·1 wide. Length of head, 21″·0. Handle, 29″·0. Weight, 5 lbs. 14 oz.

Hammers.

These hammers are straight-armed with 8-sided striking faces. The lower sides are furnished with cheek pieces.

	Length of Head.	Handle.	Weight.
	″	″	lb. oz.
No. B. 61. Single hand	5·0	13·0	3 8
No. B. 62. Double hand	6·0	25·0	5 8
No. B. 63. Sledge	7·4	29·2	8 5

No. B. 64.—Crow Bar (Mod.).

A round bar, 0"·83 in diameter, one end is ground to a blunt point, the top is strengthened by a short 8-sided striking head, 1·0 in diameter. Length, 29·4. Weight, 5 lbs. 6 oz.

No. B. 65.—Borer

round, 0"·9 in diameter; head, 8-sided, 1·0 in diameter; cutting face, 1"·15 wide, nearly straight; length, 30"·0. Weight, 5 lbs. 10 oz.

No. B. 66.—Scraper.

A rectangular iron bar, 22"·0 long, with a round scraper bent at 115° at the lower end. Weight, 0·10.

No. B. 67.—Clay Stamper.

Used for lining bore holes with clay; the shaft has a square head, upon which the wrench is fitted like a spanner. Length, 24"·5. Square of head, 1·0. Weight, 5 lbs. 14 oz.

No. B. 68.—Wrench.

A bar of rectangular iron bent up to fit upon three sides of the square of the stamper. Weight, 2 lbs. 6 oz.

Tools used in the Abercarne Coal Company's Collieries, at Abercarne, near Newport, Monmouthshire. Presented by the late E. Rogers, Esq., F.G.S.

This collection comprises double-hand blasting gear, coal picks, and wedges, as well as some tools used in quarrying.

Hammers.

The Abercarne hammers are straight-armed, the section of the arms are octagonal, springing from a square block in the centre; the striking faces are circular and flat.

	Length of Head.	Handle.	Striking Face.	Weight.
	"	"	"	lb. oz.
No. B. 69. Tamping hammer	7·32	12·1	1·2	2 14
No. B. 70. Double hand boring hammer	8·7	27·2		7 2
No. B 71. Sledge	8·8	35·9	2·0	10 1

Coal Sledges.

These are used for driving wedges in bringing down coal; the arms are straight, and reduced by an uniform taper from a square central section to an 8-sided one at the extremities, upon which rest low conical striking faces.

Coal Sledge.

	Length of Head.	Handle.	Striking Face.	Weight.
	"	"	"	lb. oz.
No. B. 72.	6·2	21·0	1·4	4 11
No. B. 73.	10·1	29·5	1·5	10 5
No. B. 74.	11·0	28·0	1·2	8 0

Coal Wedges.

These wedges are used in bringing down masses of coal with the sledge; the penetrating side forms a slender rectangular pyramid; the striking side is of an irregular 8-sided section, tapered from the base of the wedge, and resembles one arm of a coal sledge; when seen in side view the breadth diminishes uniformly from the striking face to the point.

Coal Wedge.

	Length.	Central Section.	Striking Face.		Weight.
	"	"	"		lb. oz.
No. B. 75.	11·5	1·75 breadth 0·75 thickness	1·0 0·7	elliptical	2 15
No. B. 76.	13·2	1·9 breadth 0·8 thickness	1.1 0·9	"	3 13
No. B. 77.	14·2	2·0 breadth 0·9 thickness	1·2 1·0	"	4 14

Quarry Wedges and Bits.

The arrangement used for separating large blocks of stone of a rectangular figure, known as the "Plug and Feather," is shown in Nos. 78-80. A series of shallow

to be detached, into which the feathers are tapered half-round, ◡ shaped pieces of steel are inserted in pairs. The plugs are a graduated series of blunt wedges, which are driven between the feathers.

	Length.	Breadth.	Thickness.		Weight.
	"	"	"	"	lb. oz.
No. B. 78.	7·0	1·9	1·1 top	0·5 bottom	2 8
No. B. 79.	6·0	—	—	—	2 9
No. B. 80.	11·3	1·8	1·8		7 0

No. 78 is of an oblong section ; No. 80 is square at the thickest section.

Picks.

The Abercarne picks or maundrils are all double-armed ; the slighter ones, for working in coal, being straight, while those for cutting into harder rock are more or less curved.

		Length of Head.	Handle.	Weight.
		"	"	lb. oz.
No. B. 81.	Cutting maundril	17·0	19·1	2 12
No. B. 82.	"	17·0	20·4	2 14
No. B. 83.	Holing maundril	19·0	33·3	3 5
No. B. 84.	"	19·0	33·8	3 5
No. B. 85.		18·0	33·3	3 8

The cutting maundrils taper directly from the centre to the points, the holing maundrils are somewhat stronger and bluffer.

Sadding Axe.

	Head.	Handle.	Weight.
	"	"	lb. oz.
No. B. 86.	15·8	23·3	9 7

This is a stone dressing tool used for bringing up rough blocks of stone to a smooth face by the process known as "axe dressing."

Curved Picks.

	Head.	Handle.	Weight.
	"	"	lb. oz.
No. B. 87.			
Bottom maundril	22·3	30·0	6 6
No. B. 88.			
„	21·3	30·5	7 3
No. B. 89.			
Rock maundril	24·0	30·7	9 5

No. 87 is pointed at each end; No. 88 has two chisel faced arms, 1″·1 wide, one edge being horizontal, the other vertical; No. 89 has 8-sided arms with wedge pointed and one chisel end arm.

Borers.

		Length.	Face.	Weight.
		"	"	lb. oz.
No. B. 90.	Quarry jumper	42·2	1·65	13 9
„ B. 91.	Round borer	45·5	1·9	7 8

The quarry jumper, No. 90, has a straight cutting edge at either end. The middle of the shaft is thickened to 1″·9; the thinnest diameter is 1″0. The shaft of No. 91 is 0·9 in diameter, and drawn in at the striking end to 0·6.

Eight-sided Double Handed Borers.

These bars are of an exceptionally large size, being used for blasting with heavy charges; they are made from regularly 8-sided rolled cast steel bars, and have long conical striking heads.

	Length.	Diam. of Shaft.	Diam. of Striker.	Length of Cutting Face.	Weight.
	"	"	"	"	lb. oz.
No B. 92.	47·0	1·3	1·1	2·0 slightly curved	18 0
„ 93.	47·7	1·2	0·8	1·8 „	14 5
„ 94.	48·0	1·1	0·9	1·6 „	12 15
„ 95.	48·5	1·0	0·8	1·6 „	10 0
„ 96.	38·6	1·3	0·8	2·25 strongly curved	14 11
„ 97.	41·0	1·2	0·8	2·0	13 10
„ 98.	41·0	1·5	0·9	2·5	22 0
„ 99.	36·4	1·1	0·75	1·5 straight.	9 4

Quarry Bars.

		Length.	Diam.	Weight.
		"	"	lb. oz.
No. B. 100.	Round bar	55·5	1·4 conical point	21 4
„ 101.	Crow bar	60·0	1·7 width of face	27 7

No. 101 has a chisel edged face, the lower 23 inches is rectangular in section, 1″·65 in diameter, succeeded by an 8-sided length of 7″·5 of 1″·5, the remainder at the upper end, 28″·5, being circular of 1″·25 in diameter. No. 100 has a conical point.

Scrapers.

		Length.	Diam. of Disc.	Shaft diam.	Weight.
		"	"	"	lb. oz.
B. 102.	Double scraper	40·0	1·3	0·4	1 5
„ 103.	Singlé scraper and scoop	41·5	1·6	0·5	2 6
„ 104.	Single scraper	39·2	0·6	0·25	0 1

No. 102 has a scraper at either end set at 105° to the shaft; No. 103 has a scraper at one end, set at 90°, and a scoop for loading the hole, 9″·6 in length at the opposite end; No. 104 has the scraper set at 95° to the shaft.

No. B. 105.—Needle.

Length, 41″·5, in addition to the usual ring shaped handle it is provided with a poll 3 inches long, the greatest diameter is 0″·85, which diminishes regularly to the point; the ring is formed of a strong flat plate. Weight, 2 lbs.

No. B. 106.—Tamping Bar.

Length, 38 inches; the ramming head is elliptical, 8 inches in length, 1·1 by 1·0 in diameter, with a semi-circular groove, 0″·5 in diameter, for the needle; the striking end of the bar is round, 0·9 in diameter, intermediate between it, in the elliptical part, is a length of 9 inches of half round section. Weight, 6 lbs.

No. B. 107.—Filling Rake.

It has 10 teeth, each 5 inches long and 1″·8 apart, set into a wooden D shaped bar. The handle is 37 inches long, and 1″·2 in diameter. Weight, 3 lbs. 12 oz.

No. B. 108.—Tram Wheel.

Made of cast iron, 8 inches in diameter; axle bearing 1″·0 diameter; breadth of tire, 1·6; number of arms, 4. Weight, 7 lbs.

Tools used in the Flintshire Collieries. Presented by Mr. William Thomas of Bagillt.

Hammers.

	Length of Head.	Handle.	Weight.
	"	"	lb. oz.
No. B. 109.			
Blasting sledge	7·7	22·0	6 7
No. B. 110.			
Coal sledge	11·4	27·3	6 15

The blasting sledge is drawn in from an irregular octagonal (bevelled rectangular) section, to a regular octagon, with flat striking faces. The coal sledges resembles those used at Abercarne.

	Length.	Greatest section.	Weight.
	"	"	lb. oz.
No. B. 111.			
Coal wedge	11·4	1·7 width 0·8 thickness.	3 8
No. B. 112.			
Coal wedge	13·0	1·8 width 1·1 thickness.	4 13

The tapering sides of these wedges are bounded by curved lines instead of straight ones, as in the Abercarne wedges. The smaller one is blunted by a rectangular plane, about 0·1 in the side, at the point.

Picks.

	Length of Head.	Handle	Weight.
	"	"	lb. oz.
No. B. 113.			
Metal driving pick	17·2	27·6	3 10
No. B. 114.			
Holing pick	18·0	28·3	2 10
No. B. 115.			
Heading pick	16·3	27·5	3 0

All these picks have tapered V-shaped cheek pieces.

No. 115 is slightly curved at the top, the arms taper regularly from the central boss. No. 114 has chisel edged arms, 0″·1 width of face, with strongly curved top surface.

Auger.

	Length.	Width of Cutting Face.	Shaft.	Weight.
	"	"	"	lb. oz.
No. B. 116.	33·0	1·66	1·0	7 3

With long conical striking head like the South Wales borers.

No. B. 117.—Auger with Stamper.

41″·4 long; width of cutting face, 1″·7; the opposite end has an elliptical stamping head, 1″·2 by 1″·0, with a semicircular groove for the needle, 0″·5 deep and 4″·7 long. Weight, 7 lbs. 10 oz.

No. B. 118.—Scraper.

42″·6 long; shaft, 0″·45 diameter, with ring handle and one circular scraping disc. 0″·9 in diameter, set at 100° to the shaft. Weight, 1 lb. 14 oz.

No. B. 119.—Churn or Ramming Bar.

37″·0 long, with elliptical ramming head like that of No. B. 117; shaft made of round iron, 1″·0 in diameter; the opposite end is worked up to a tapered striking face for driving with a sledge. Weight, 8 lbs.

No. B. 120.—Pricker.

48″·0 long, including ring handle 2·0 in diameter; the needle end is tapered to a point from a diameter 0″·6 in a length of 39″·8. Weight, 1 lb. 5 oz.

No. B. 121.—Crow Bar.

Length, 30″·0; diameter of shaft, 1″·25; one end has a short chisel face, the other end is turned over at right angles into a taper wedge-shaped arm. Weight, 15 lbs. 6 oz.

No. B. 122.—Cleaning Shovel.

Blade, 12″·0 long; 11″·4 broad; handle, 24″·0 long, set at 155° to the blade; the blade has a curvedsided point, with a straight top edge slightly turned up. Weight, 4 lbs. 3 oz.

No. B. 123.—Filling Shovel.

Blade, 15″·0 long, 16″·0 broad; handle, 23″·0 long, set at 147° to the blade. Weight, 7 lbs. 14 oz.

Tools used in the North of England Collieries, from Towneley and Garesfield Collieries.

Picks.

No. B. 124.—Coal Pick, Towneley Colliery.

Length of head, 17″·8; handle, 32″·0; the lower edge is horizontal, the top edge forms two inclined planes. Weight, 4 lbs. 5 oz; in plan the head is a regular lozenge-shaped figure, diminishing regularly from the centre to the points.

No. B. 125.—Coal Pick, Garesfield Colliery.

Resembles the preceding, except that the arms are bent or anchored, meeting at the top at an angle of 155°. Length of head, 18″·0; handle, 32″·0. Weight, 4 lbs. 5 oz.

Both of the above are distinguished from the stone picks by small semicircular cheek pieces.

No. B. 126.—Stone Pick, Towneley Colliery.

Head, 19″·7 long, slightly anchored, with tapered V-shaped cheek pieces. The arms are bevelled to an 8-sided section, with 4-sided pyramidal points. Weight, 7lbs. Handle, 30″·0.

No. B. 127.—Stone Pick, Towneley.

23″·0 length of head; resembles the preceding, but is somewhat stronger and more anchored. 30″·0 length of handle. Weight, 8 lbs.

No. B. 128.—Stone Wedge.

Length, 6″·4; the wedge end 3″·6 long, drawn in from a rectangular section 1″·6 wide and 1″·1 thick; the opposite end drawn in by a tapering 8-sided section to a striking face 0″·9 diameter. Weight, 2 lbs. 2 oz.

No. B. 129.—Coal Wedge.

Length, 12 inches; the sides are straight like those used in South Wales. The greatest section or the base of the wedge, 6″·0 distant from the point, is a rectangle 2″·2 broad by 0″·9 thick; the striking face an irregular octagon 1″·0 broad by 0″·7 thick; the point is cut off to a rectangle 0″·1 in the side. Weight, 4 lbs.

Hammers.

The north of England colliery boring hammers are chiefly of small weight and short armed, of nearly square section at the centre, with flat striking faces.

	Head.	Handle.	Weight.
	″	″	lb. oz.
No. B. 130. Single hand coal boring hammer	4·5	7·75	2 14
No. B. 131. Single hand stone boring hammer	4·10	10·1	3 6
No. B. 132. Double hand stone boring hammer	5·0	24·6	4 14
No. B. 133. Coal sledge, Towneley	—	30·5	6 4
No. B. 134. Stone mallet or sledge	—	30·0	11 6

Borers or Drills.

	Length.	Cutting Face.	Weight.
	″	″	lb. oz.
No. B. 135. Coal drill, No. 1	22·2	1·5 straight	2 8
„ 136. „ No. 2	41·6	1·4 „	4 10

The shafts of these drills are made in lengths of different section, 8-sided above and round below, but with a general taper towards the point.

	Length.	Cutting Face.	Weight
	"	"	lb. oz.
No. B. 137. Single hand stone drill, No. 1	- 22·1	- 1·5 curved	- 3 10
„ 138. „ „ No. 2	- 35·6	- 1·4 „	- 6 4
„ 139. Double hand stone drill, No. 1	- 18·4	- 1·8 „	- 4 4
„ 140. „ „ No. 2	- 27·0	- 1·66 „	- 6 0
„ 141. „ „ No. 3	- 39·5	- 1·6 „	- 9 4

The stone drills are all of 8-sided section, and taper regularly from the striking faces to the points. The cutting faces are for the most part strongly curved.

No. B. 142.—Coal Scraper.

Length, 37″·0; diameter of shaft, 0″·25; has a circular scraper at either end, 0″·75 in diameter, set at 96° to the shaft. Weight, 8 oz.

No. B. 143.—Stone Scraper.

Length, 37″·0; diameter of shaft, 0″·3; at one end has circular scraper, 1″·0 diameter, set at 90° to the shaft; and a screw worm 1″·0 long at the other end. Weight, 12 oz.

No. B. 144.—"Bull," or Claying Iron.

Length, 35″·0 in all; poll, 8″·5; eye, 1″·5 diameter; shaft, 1″·3 diameter; tapered to 1″·0. Weight, 12 lbs. 8 oz.

No. B. 145.—Pricker for Blasting in Coal.

41″·2 total length; shaft, 0″·4 greatest diameter; tapered to a point in 36″·0; with elliptical ring handle. Weight, 1 lb. 2 oz.

No. B. 146.—Pricker for Blasting in Stone.

Total length, 38″·6; shaft, 0″·55 in greatest diameter; tapered to a point in 32″·0; elliptical ring handle. Weight, 1 lb. 14 oz.

No. B. 147.—Rammer for Coal Blasting.

Total length, 39″·5, with a short crescent shape ramming head 1″·0 in greatest diameter; the shaft is 8-sided at the striking end for a length of 16″·0, the remainder being of a tapered half round section. The groove for the needle is 5″·0 in length. Weight, 4 lbs.

No. B. 148.—Rammer for Stone Blasting.

Total length, 35″·7; 8-sided part of shaft, 16″·0; tapered half round part, 18″·7; groove for needle, 4″·0 long;

greatest diameter of crescent-shaped ramming head, 0″·8. Weight, 5 lb. 13 ozs.

No. B. 149.—Beche for Drawing Broken Drills.

8-sided bar with a conical socket at the lower end. Total length, 34″·0; the socket is 4″·6 long inside, and 7″·0 outside; the greatest internal diameter being 1″·33. Weight, 3 lbs. 14 oz.

No. B. 150.—Cartridge for Blasting in Coal.

6″ long; 0″·9 diameter; 3 oz. charge.

No. B. 151.—Filling Shovel.

Blade nearly circular, with a short point, the edges turned up, forming a shallow hand. Length, 16″·0; breadth, 14″·0 on the bottom; the handle is 24″·0 long, and set on to the blade at an angle of 142°. Weight, 7 lbs. 14 oz.

The following is the arrangement of the various sets of blasting gear.

Set of coal blasting gear:—

1 hammer.	B. 130.
2 drills.	B. 135, 136.
1 beater or rammer.	B. 147.
1 pricker.	B. 145.
1 scraper.	B. 142.

Set of single hand stone blasting gear:—

1 hammer.	B. 131.
2 drills.	B. 137, 138.
1 beater.	B. 148.
1 scraper.	B. 143.
1 pricker.	B. 146.

Set of double hand stone blasting gear, or for two men:—

1 hammer.	B. 132.
3 drills.	B. 139, 140, 141.
1 beater.	B. 148.
1 scraper.	B. 143.
1 pricker.	B. 146.

Extra tools:—

Stone mallet and wedge. B. 134, 128.
"Bull," or claying iron for wet ground. B. 144.
Beche for drawing broken drills. B. 149.
Set of tallies used by colliers. B. 152.

GADS.

NOS. B. 153–4–5.—GAD OR EISEN.

The Saxon gad resembles a long slender hammer, it is furnished with a narrow rectangular eye, when in use it is held by a handle inserted into the socket, and is driven by striking the poll end. Length of the iron, 6″·2; eye, 0″·86; handle, 14″·0; breadth across the eye, 0″·95. Greatest depth 0″·7; the point is formed by a short bluff pyramid, the striking end is also contracted suddenly. Weight, 10 oz.

NO. B. 156.—SET OF GADS.

In this set 15 gads are connected into two series by upright iron stays passing through the eyes, the two sets are united by swivels to a yoke for carrying across the shoulder. Weight, 9 lbs. 15 oz.

NO. B. 157.—FIMMEL.

A large hammer-like gad, mounted similarly to No. 1. The head is 10″·2 long; the handle, 12″·6; greatest breadth across the eye, 1″·5; the greatest thickness, 0″·9; the poll side is of a square section tapered to a face of 0″·9 in breadth; the wedge side is of an 8-sided section. Weight mounted, 2 lbs. 8 oz.

NO. B. 158.—SCHRAM HAMMER.

A small heavy poll pick, very similar in form to the preceding. Length, 13″·5; handle, 19″·8; eye, 1″·8; breadth over eye, 2″·3; greatest depth, 1″·5. Weight, 7 lbs. 12 oz.

NO. B. 159.—KEILHAU OR PICK.

A single-armed pick of tapered octagonal section without a poll; the head is 13″·6 long; the handle, 27″·7; greatest thickness, 1″·5; breadth over eye, 2″·12; the head is set at angle of 85° to the handle. Weight, 5 lbs. 6 oz.

HAMMERS.

NO. B. 160.—SINGLE HAND HAMMER (EINMÄNNISCHER FAUSTEL).

The head has two curved arms. Length, 5″·7; the striking faces form angle of 16° with each other, section nearly square, with the edges bevelled, forming an irregular 8-sided figure. Handle 13″·2 long, fitted into a rectangular socket. Weight, 4 lbs. 4 oz.

No. B. 161.—Double Hand Hammer (Zweimännischer Faustel).

The arms are straight. Length of the head, 7″·1; handle, 27″; breadth over eye, 3″·0; breadth of faces, 2″·3; the cross section of the arms is diminished between the centre and the striking faces. Weight, 10 lbs. 9 oz.

No. B. 162.—Gang Faustel, Large, Sledge.

Used for breaking up large masses of rock, &c. Head, 9″·3 long; handle, 26″·4; thickness of the head, 3″·1 at centre, tapered to 2″·5 at the faces; the faces are strongly curved. Weight, 21 lbs. 2 oz.

BORERS.

Single Hand Borers (Einmännischer Bohrer).

A set of six borers for single-handed bore holes; they are made of steel bars of irregular 8-sided section, 0″·64 in diameter, drawn in to 0″·54 at the striking end; the tapered or spreading portion of the bar is 0″·7 long in each case.

	Length.	Breadth of Cutting Face.	Weight.
	″	″	lb. oz.
No. B. 163.	10·4	1·13	1 2
„ 164.	11·6	1·1	1 4
„ 165.	18·8	1·0	1 15
„ 166.	20·5	1·0	2 1
„ 167.	30·0	0·9	2 10
„ 168.	29·5	0·9	5 0

Double Hand Borers (Zweimännischer Bohrer).

A set of three double-handed borers made from 8-sided tapered bars.

	Length.	Breadth of Face.	Diameter.	Weight.
	″	″	″ ″	lb. oz.
No. B. 169.	22·35	2·1	1·3 tapered to 1·05	8 4
„ 170.	35·5	1·85	1·2 „ 0·93	10 3
„ 171.	47·0	1·8	1·14 „ 1·0	14 11

No. B. 172.—Schramspies or Picker.

A bar with a wedge-shaped point. Total length, 25″; thickness, 0″·7; the wedge is terminated in a straight cutting edge, 0″·25 wide. Weight, 3 lbs. 1 oz.

No. B. 173.—Schramspies or Picker.

Resembles the preceding, only it is somewhat shorter, being 23″·8 long. Weight, 2 lbs. 14 oz.

No. B. 174.—Scraper for Single Hand Boring (Einmännischer Kratzer).

Total length, 29″·3, made of rectangular iron 0″·4 by 0″·2; has a scraper 0″·8 diameter at one end, and a rectangular eye or loop at the other end. Weight, 13 oz.

No. B. 175.—Scraper for Double Hand Boring (Zweimännischer Kratzer).

Total length, 44″·5; shaft made of square iron, 0″·4 in the side; the scraper is 0″·95 diameter; the opposite end has a rectangular eye 1″·0 long. Weight, 1 lb. 12 oz.

No. B. 176.—Einmännischer Stampfer (Tamping Bar for Single Hand Boring).

Length, 29″·5; the shaft is made of irregularly 8-sided iron 0″ 6 in diameter; the tamping head is elliptical, the greatest diameter is 0″·9, with a semicircular groove 0 36 in diameter for the needle. Weight, 2 lbs. 12 oz.

No. B. 177.—Zweimännischer Stampfer (Tamping Bar for Double Hand Boring).

45″·3 long; diameter of the 8-sided shaft, 0″·9; greatest diameter of the elliptical head, 1″·4; groove for the shooting needle, 0″·53. Weight, 9 lbs. 8 oz.

No. B. 178.—Filling Shovel (Berg Kratzer).

A small scraper or hoe. The blade is trapeziform, 15½″ wide at the base, and 6″·8 high; the handle is 27″ long, and is set at 130° to the blade.

No. B. 179.—Single Hand Needle.

A slender wrought-iron needle 24″ long, with flat ring handle.

No. B. 180.—Double Hand Needle.

Similar to the preceding, but somewhat stronger, 29″ long. In the Saxon mines the needle is used with a reed casing, as shown in No. 180; the hole is tamped with sun-dried clay carefully freed from quartzose pebbles or grains. When the needle is withdrawn, the reed remains in the hole, and the priming, consisting of a smaller reed filled with fuse composition, is inserted; the fuse is fired by a match, formed by dipping a cotton thread into melted sulphur.

No. B. 181.—Timber Man's Axe (Kaukamm).

A straight-edged small axe; length of blade 7″·6, breadth of face 2″·3, handle 20″·0 long; a notch for drawing nails is cut into the lower side of the blade.

HUNGARIAN MINING TOOLS.

Schemnitz District.

Gads.

The Hungarian gads are similar in form to the ordinary German berg eisen, but are stronger and more hammer like than those of Saxony. The striking faces of all the Hungarian tools are circular, and of very small diameter.

		Total Length.	Poll.	Point.	Weight.
		″	″	″	lb. oz.
No. B. 182.	Steel gad	6·0	2·4	3·1	0 13
„ 183.	„	5·9	2·4	3·0	0 14
„ 184.	„	5·7	2·3	2·6	0 14
„ 185.	Common gad	6·6	3·2	2·7	2 6

All of the above have rectangular eyes for receiving the handle, and are nearly square in section at the poll end. No. 182 is for use in ordinary ground, No. 183 for moderately hard, and No. 184 for hard ground. No. 185 is square at the greatest section, 1″·3 in the side.

Hammers.

The hammers are not mounted, and the weights are those of the heads only. All have rectangular eye sockets.

No. B. 186.—Single Hand Hammer.

Length of head, 6″·9; section, 1″·35 square. Weight, 3 lbs. 4 oz.

No. B. 187.—Curved Double-Armed Hammer.

Forming 44° of a circle of 12″·0 radius. The striking faces are circular planes 0″·5 in diameter.

No. B. 188.—Berg Kluftel.

A short straight-armed hammer; head, 4″·8 long. The section is a square of 1″·4 side; striking faces flat. Weight, 2 lbs. 4 oz.

No. B. 189.—Sledge.

Arms straight; length of head, 6″·6; section at centre of arms 1″·65 broad by 1″·5 deep, swelling out to 1″·85 breadth, and 1″·6 depth at the striking faces. Weight, 4 lbs. 10 oz.

No. B. 190.—Poch Putzka.

A straight-armed hammer used for breaking up ore. Length of head, 6″·0; central section, 1″·7 broad, 1″·25 deep; section at faces, 1″·3 broad, 1″·2 deep. Weight, 2 lbs. 14 oz.

No. B. 191.—Picking Hammer.

It has one straight arm of square section, and the other inclined and wedge shaped. Total length of head, 6″·5; section of the straight arm, 1″·35 deep, 1″·3 broad; the sides of the wedge arm make angles of 137° below and 145° with the straight arm. The wedge terminates in a rectangular plane 1″·22 deep and 0″·25 broad. Weight, 2 lbs. 8 oz.

Borers.

The Hungarian borers are all single hand, of round section, thickened up near the striking faces. The points are short and bluff, formed by the meeting of two rectangular planes at an angle of 70°.

No. B. 192.—First Borer.

Total length 11″·3; 0″·7 diameter of shaft, increasing to 0″·9 at 0″·25 distance from the striking face. The striking face is the frustrum of a flat cone, of 0″·9 base, 0″·25 altitude, and 0″·33 in diameter at the striking face. The cutting edge is nearly straight, 1″·33 broad. Weight, 1 lbs. 6 oz.

No. B. 193.—Second Borer.

Length, 17″·4; diameter, 0″·7; length of cutting edge 1″·2. Weight, 1 lb. 13 oz.

No. B. 194.—Third Borer.

Length, 23″·7; diameter, 0″·64; cutting edge, 1″·0. Weight, 2 lbs. 4 oz.

No. B. 195.—Half Moon Borer.

Length, 23″·6; diameter 0″·64; the cutting edge is strongly curved, 1″·2 long. Weight, 2 lbs.

No. B. 196.—Scraper.

Made of round iron, 0″·3 diameter, with a circular disc 0·85 diameter, turned at right angles to the shaft. The opposite end has a rectangular loop similarly placed, the length is 22″·0, which can be increased to 42″ by a pair of spring tongs which slip through the loop. Weight, 11 oz.

No. B. 197.—Tamping Bar.

Length, 21″·8, has an elliptical ramming head the groove for the needle is 6″·0 long, 0″·7 in greatest diameter. The shaft is similar in dimensions to those of the longer borers. Weight, 2 lbs. 4 oz.

No. B. 198.—Crow Bar.

This is a model of the real tool in half linear dimensions. Length, 5″·6 with round shaft, 1″·68 diameter; one end is worked to a short 4-sided pyramidal point, the other end has a slightly recurved arm with a chisel edge of 2″·3 breadth of face. Real weight, 25 lbs. 6 oz.

No. B. 199.—Wedging Bar ("Stecheisen").

Length 26″·8; a plain round shaft of 0″·7 diameter, slightly reinforced below the striking head with a short 4-sided point like that of No. 198. Weight, 2 lbs. 12 oz.

No. B. 200.—Claying Iron ("Letten Staucher").

Length, 23″·2; has a tapered 8-sided poll, 3″·7 long, tapering from 1″·2 to 0″·84 in diameter. The ramming shaft is round, 0″·7 broad at the point, and tapered from an elliptical section of 1″·3, in the greatest diameter of the long axis. Weight, 5 lbs. 8 oz.

No. B. 201.—Shooting Needle.

Length, 25″·0; has an iron ring handle shrunk on to a copper needle 20″·7 long, tapered to a point from a greatest diameter of 0″·33. Weight, 13 oz.

No. B. 202.—Shovel.

It has a nearly rectangular steel blade 5″·7 broad below, 6″·0 broad above, and length 5″·0; socket 1″·1 diameter; handle set at 152° to the blade. Weight, 1 lb. 8 oz.

No. B. 203.—Filling Shovel.

A pointed scraper or hoe blade 9″·6 long, 7″·35 broad at top, with curved sides dished to a depth of 0″·75 on the top edge; socket, 1″·8 diameter; handle set at 60° to the blade. Weight of blade only, 2 lbs. 10 oz.

No. B. 204.—Zeug Gurte.

A belt or strap for carrying tools, made of hemp webbing 2″·2, 34 inches long, joined up with a loop with iron eyes. Weight, 9 oz.

No. B. 205.—Wire Rope with Chain for hanging Kibble.

Rope of three strands, each of four wires No. 11 gauge; the loop for the chain is formed by an eye splice lined with an iron chafing thimble, the splice is served with wire over all; the chain is 27″ long, formed of long elliptical links of 0″·4 inch iron; the kibble is hung to two hooks which open in opposite directions, forming a loop when closed.

Wire Rope.

No. B. 206. Wire Rope of 12 Wires No. 11 gauge.

„ 207. Do. 18 „ „

No. B. 208.—Loop with Hanging Chain.

RUSSIAN MINING TOOLS.

Presented by H.I.H. the Grand Duke Constantine of Russia.

No. B. 209.—Pick.

Head 15″·4 long, has only one slender curved arm, which tapers to a point in 12″·8 from a greatest diameter, of 0″·7. The eye socket for the handle is circular; length of handle, 20″·5. Weight, 4 lbs. 3 oz.

No. B. 209.—Pick for Gravels.

Head 12″·5 long; handle, 20″·5. Has a single curved arm; the blade broadens out into a spoonbill shape near the point. Weight, 3 lbs. 6 oz.

No. B. 210.—Single Hand Borer.

Length, 28″·0, made from an 8-sided steel bar 0″·70 diameter. The cutting edge is nearly straight, 1″·0 long, formed by the meeting of two planes at 90°. Weight, 3 lbs. 6 oz.

No. B. 211.—Double Hand Borer.

Length, 55″·3; diameter, 0″·8; cutting face, 1″·125; 8-sided in section similar to the preceding; edge formed by two planes intersecting at 100°. Weight, 9 lbs. 8 oz.

No. B. 212.—Scraper.

Length, 23″·5; shaft rectangular, 0″·5 broad, 0″·15 thick; disc at one end 0″·6 diameter, set at 105° to shaft. The opposite end has a loop for holding tow for wiping out the hole. Weight, 8 oz.

No. B. 213.—Tamping Bar.

Length, 24″·5; the shaft at the striking end is 8-sided, 0″·7 in diameter, tapering down to a half round section 0″·33 diameter; the ramming head is crescent shaped, 0″·8 greatest diameter, and is faced with copper. Weight, 2 lbs. 14 oz.

No. B. 214.—Bar with Scoop.

It is made of copper. Length, 24″·0. A plain round shaft tapered from 9″ diameter to ·62″; has a semicircular scoop 12″·5 long, 0″·75 internal diameter. Weight, 2 lbs. 7 oz.

No. B. 215.—Copper Needle.

Length, 24″·5, tapered to a point from an elliptical section 0″·7; 0″·62 diameter in 22″·5. Weight, 12 oz.

No. B. 216.—Powder Measurer.

A cylindrical copper measure with ring handle, 6″·2 long 0″·75 inside diameter. Weight, 5½ oz.

No. B. 217.—Single Hand Hammer.

A strongly curved double-armed hammer. Length of head, 6″·8; length of handle, 8″·7; angle between the striking faces, 35°. Section 8-sided, 1″·3 diameter. Weight, 4 lbs. 1 oz.

No. B. 218.—Shovel.

Blade, 9′·3 long, D shaped, the curved part in front; breadth at top edge, 9″·3; set at 155° to the handle. Weight, 3 lbs. 4 oz.

No. B. 219.—Scraping Shovel.

It has a trapeziform blade, 8″·2 broad at lower edge, 7″·35 top edge; height, 6″·0, dished, 0″·65 deep. The blade is attached to the eye by two rivets. Handle, 20″·5 long, set at 85° to the blade. Weight, 3 lbs. 9 oz.

MEXICAN MINING TOOLS.*

Presented by Captain Vetch, R.E.

No. B. 220.—Cuña (Wedge or Gad).

It is made of round iron 9″·5 long, tapered to a point from a greatest diameter of 1″·7 in a length of 8″·9. The striking head is a short truncated cone with a face 0″·6 in diameter. Weight, 3 lbs. 15 oz.

No. B. 221.—Socket Wedge.

It is made of round iron like the preceding. Total length, 13″·5; the solid part 1″·37 in diameter. The socket is 5″·0 deep, 1″·77 internal diameter. Weight, 3 lbs. 7 oz.

No. B. 222.—Timberman's Hammer, "Martillo de Palero."

It has a long curved head of rectangular section, 1″·3 diameter, length of head, 16″·3; length of handle, 7″·6. Weight, 8 lbs. 15 oz.

No. B. 223.—Boring Sledge.

A heavy double straight-armed hammer of 8-sided section, 1″·75 deep, and 2″·3 broad at the centre. The

* These tools have been named by Mr. J. H. Clement.

striking faces are 0″·6 diameter; length of the head, 8″·2; the handle is an elastic hazel rod 22″·5 long, set at 110° to the head. Weight, 7 lbs. 2 oz.

No. B. 224.—BORING SLEDGE (Head only).

Straight-armed head, 7″·8 long; the central section 1″·87 deep, 2″·3 broad; striking faces flat, 1″·7 broad and 1″·57 deep. Weight, 6 lbs. 10 oz.

No. B. 225.—LARGE SLEDGE.

For breaking up large masses of rock? Double unequal armed head, 9″·0 long; 8-sided irregular section with flat striking faces, 1″·7 diameter at one end, and 1″·2 diameter at the other; handle, 26″·2 long. Weight, 15 lbs. 10 oz.

No. B. 226.—SMALL SLEDGE.

Similar in character to the preceding, but somewhat smaller. Length of head, 7″·0; faces, 1″·8 and 1″·0. Weight, 10 lbs. 7 oz.

No. B. 227.—BORER, "BARRENA."

Length, 26″·4; diameter of shaft, 1″·2; diameter of striking face, 0″·45; length of crescent-shaped cutting face, 1″·95. Weight, 8 lbs. 13 oz.

No. B. 228.—BORER.

Length, 41″·4; diameter of shaft, 1″·3; striking face, 0″·5; length of crescent shaped cutting face. Weight, 13 lbs. 8 oz.

No B. 229.—CROW BAR (CUÑA LONGA OR LONG WEDGE).

A straight bar 69″·0 long; 1″·13 diameter with a tapering conical point. Weight, 17 lbs. 8 oz.

No. B. 230.—SWALLOW TAILED BAR (BARRENA A DOS ESCOPLAS).

Length, 26″·7; diameter of shaft, 1″·2, with two cutting edges, with a V-shaped point 1″·9 broad. Weight, 8 lbs. 14 oz.

No. B. 231.—SWALLOW TAILED BAR.

Length, 41″·5; diameter, 1″·25; head similar in character to that of the preceding, No. B. 230. Weight, 13 lbs. 10 oz.

No. B. 232.—Pointed Bar.

Length, 23″·0; diameter, 1″·2, with tapering point like that of No. 229. Weight, 7 lbs.

No. B. 233.—Chichara, Scraper.

Total length, 41″·0; diameter, 0″·6. One end has a chisel face 1″·15 wide, the other is worked into a spoon 3″·0 long, 1″·45 broad. Weight, 3 lbs. 8 oz.

No. B. 234.—Cargador or Ramming Bar.

37″·5 long, 1″·25 diameter. A plain bar with reinforced head and conical striker. Weight, 12 lbs. 14 oz.

No. B. 235.—Descargador.

A bar used for drawing charges. Length, 43″·3; diameter of shaft, 1″·25, with a conical socket 4″·8 long and 1″·4 internal diameter at one end.

No. B. 236.—Timberman's Axe (Hacha de Paleros).

A combination of an ordinary axe with a semicircular gouging edge; the axe face is line in with the handle, the gouge at right angles to it. Length of head, 10″·0; length of axe face, 3″·2; length of handle, 27″·0. Weight, 6 lbs.

No. B. 237.—"Azuela."

A double-headed trimming adze, having two strongly sloped blades, with the cutting edges horizontal; the length of the head is 8″·0; the handle, 9″·5; the eye, 1″·6; the breadth across the eye is 2″·2; the blades are set at an angle of 70° to the handle, and widen out to 5″·0 at the faces. Weight, 1 lb. 10 oz.

No. B. 238.—Vara de Paleros, or Timberman's Measuring Rod.

A wooden rod 33′·0 long, with an iron spike head.

No. B. 239.—Vara or Measuring Rod.

A slender wooden rod 33″·0 long, with intermediate divisions cut on it. An officer's walking stick.

No. B. 240.—Wooden Tamping Bar (Cargador).

A wooden shaft 24″·2 long, with an iron ring ferrule 1″·4 diameter and 1″·2 deep. Weight, 1 lb.

No. B. 241–2.—Powder Cases (Costalitos Polvereros).

Cylindrical covered cases made of raw hide, similar to the cartridge cases used for large ordnance. No. 241 is 3″·0 in diameter and 27″·0 high; No. 242 is 6″·0 in diameter and 12″·0 high.

No. B. 243.—Gourd water bottle.

No. B. 244.—Hat, sombrero.

No. B. 245.—Horn Spoon (Cucharo de Cuerno.)

Used for assaying silver ores by washing. A similar implement is used as a scraper underground.*

No. B. 246.—Chiquihuite.

A wicker basket covered with raw hide.

No. B. 247.—Trecho de 20 Hilos. Whim Rope. Sojo Major.

A rope of 20 strands, made of aloe fibre.

No. B. 248.—Sack for carrying Ore (Saca de Tenatero).

No. B. 249.—Head Strap (Mecapal).

This used in carrying heavy loads, the strap passes round the forehead, while the load is supported on the miner's back by the rope.

SAFETY FUSES AND BLASTING CARTRIDGES.

No. B. 250–6.—Safety Fuses by Messrs. Bickford, Smith, and Davey.

This is the original form of safety fuse, invented in the year 1833; it consists of a flexible cord covered with waterproof materials, having a central core of gunpowder, surrounded by hempen yarns twisted up into a tube, known as the "countering." The outer casing is made of different

* Karsten's Archiv. für Mineralogie, &c., vol. X. p. 781.

materials, according to the use for which it is intended. The case contains the following varieties :—

No. B. 250.—Common miners' fuse, with single waterproofed yarn covering.

No. B. 251.—Fuse for dry soil, with white yarn covering not waterproofed.

No. B. 252.—Fuse for wet ground, with a second coating of yarns heavily pitched.

No. B. 253.—Fuse for extra wet ground, with a strip of linen covering the yarn casing.

Nos. B. 254–5.—Fuse for blasting in deep water, having one yarn coating and two of linen, all well waterproofed.

The safety fuses now made by Bickford & Co. have a central touch thread passing through the centre of the powder core.

No. B. 256–8.—Safety Fuses by Messrs. E. H. Hawke & Co.

These differ from Bickford's fuses in having the core of gunpowder enclosed in a strip of linen three-quarters of an inch in width, lapped over into a tube. The varieties are similar to those of Bickford's fuses, viz. :—

B. 256.—Common fuse, with two casings of white yarns.
„ 257.—Ordinary waterproof fuse, with a single yarn casing made up of nine parallel strands waterproofed.
„ 258.—Fuse for wet ground, having a double casing of water proofed yarns and varnished.

No. B. 259.—Copeland's Blasting Cartridges.

These have the charges done up in paper cases, strengthened by a covering of hempen yarn wound spirally about them; lengths of safety fuse are attached to all but the largest size, which has covered copper wires, for igniting the charge by electricity.

No. B. 260.—Ridley's Coal Cutting Machine.

Presented by the Patentee.

This machine is intended to supersede manual labour in undercutting or "holing" in coal. It is very similar to a horizontal steam engine, in which the crank is replaced by a bent lever, whose outer arm carries a pick. The whole of the mechanism is mounted on a truck, which can be moved along a line of rails by means of the hand wheel at the top acting upon the axles of the truck by a combination of bevil gearing. The engine is worked by air at a pressure of about 35 lbs. to the square inch, which is carried from a blast reservoir at the surface through the main roadways in cast-iron mains, while wrought-iron pipes are used in branch roads, and vulcanized india-rubber tubes along the working faces. Several modifications of the machine on the same principle have been made; they differ in the construction of the driving engine, and in the arrangement of the axles with respect to the working face. In the present instance the piston has a trunk or tubular piston rod, the two faces of the piston being of different areas; the smaller one is used for drawing back the pick, and the blow is given by the action of the larger face. The slide valve requires to be moved by hand on the back stroke, but is returned by a roller attached to the parallel guides of the engine. The pick holder is mounted on a square centre, and is provided with a movement for varying the height of the cut above the floor of the coal seam within small limits. In working the machine, three picks are used—the first cuts to a depth of 18 inches, the second about 10 inches, and the third from 6 to 8 inches, making a total depth of 32 or 36 inches; the working speed is from 60 to 100 strokes per minute. At Balaclava Colliery, West Ardsley, near Leeds, an oscillating cylinder machine, working in soft household coal, cuts a groove one yard deep, and 1¼ inches high, at the rate of 20 yards per hour.

BORING MACHINERY.

No. C. 1–20.—Full-sized Boring Rods and Tools.

No. C. 21.—Shear Frame for Boring.

No. C. 22.—Boring Tools, with Free-falling Cutters.

No. C. 23.—Tools for Drawing Tubes out of Bore Holes.

These are all in the large room A., near the fire-place.

Boring tools, full size, made by Clinton and Owens, London.

No. C. 1. Swivel head boring rod, 1 inch square.
„ 2. 10 feet boring rod, 1 inch square.
„ 3. Pair of tillers for turning rods.
„ 4. Scotch or hand dog for screwing up rods.
„ 5. Pair of lifting dogs.

No. C. 6. Spring hook.
„ 7. Flat chisel for $2\frac{1}{2}$ inch bore hole.
„ 8. Tee chisel do.
„ 9. Clay augur. do.
„ 10. Worm augur do.
„ 11. Spiral worm do.
„ 12. Shell with steel shoe, for lifting sludge.
„ 13. Crow's foot for lowering tubes.
„ 14. Bell screw for driving broken rods.
„ 15. Spring dart.
„ 16. Pipe tee for lowering tubes.
„ 17. Pair of pipe tongs.
„ 18 Pair of pipe clambs.
„ 19. 3 feet length of lining pipe, 3 inch bore, with tee clutch.

No. 20. 3 feet length of lining pipe, 3 inch bore, with steel driving shoe.

No. C. 21.—Shear Frame employed for Boring.
Scale, $\frac{1}{8}$th, or $1\frac{1}{2}$ inches to 1 foot.

This represents the surface arrangements used in sinking deep bore holes where hand power is employed. There are two pairs of shear legs, with top cross bars at a height of about 35 feet above the ground. The legs of the two shears rest on strong timbers laid along the ground, and have a slight slope towards each other; the distance between the two adjacent beams on the same side being 3 feet 8 inches below, diminishing to 14 inches at the top. The two frames are maintained at their proper distances apart by horizontal wooden struts placed at intervals of three feet, and fixed by wooden keys. The top cross bars carry a horizontal axle, with two independent guide pulleys of cast iron running loosely upon it. Over these guides are led the ends of two ropes coiling in opposite directions upon the barrel of a windlass moved by spur gearing, and having a ratchet stop which is attached to a pair of diagonal timbers connected with the right-hand legs of the shears near the ground. These ropes are used for raising or lowering the lengths of the boring rod during the lowering or lifting the tool.

About eight feet below the bearings of the top roller a second pair of horizontal traverses is fixed across the frame, supporting a smaller pulley mounted on a cast-iron frame capable of motion between horizontal wooden slides. Over this pulley is led a rope coming from a plain windlass fixed to the left-hand legs of the frame, to be used for raising or lowering the spoon or shell, an iron cylinder, with a valve at the bottom, by which the sludge or pounded rock is removed from the bottom of the bore hole. When in use, the head of the rod is attached to a chain working on a sector head at the end of the shorter arm of lever, which is carried on a framing formed of two pairs of upright legs, with cross bars at top, placed within the principal shear frame; the moving power, whether manual or otherwise, being applied to the longer arm. The relation of the load arm to the power arm is as 1 to 4, the former being 3 feet 8 inches, and the latter 17 feet 6 inches in length. Two kinds of rods are represented; the ordinary ones are made of wrought iron, in lengths of 15 feet, of a square section, $1\frac{1}{4}$ inches in the side, with a cylindrical boss at the lower end, into which a screw is cut, forming a socket for the corresponding screwed plug at the top of the next length below. The second set of rods, intended for use in deeper sinkings, are made of wood, of a cylindrical form, $2\frac{1}{2}$ inches in diameter, terminated at either end by wrought-iron ferrules, having screwed sockets. The connexion between the lengths is effected by means of short cylindrical connecting pieces, made of wrought iron, having a thread cut at either end to fit into those at the end of the rods, and squared heads for receiving a key, by which they are screwed up. A wooden tube is fixed over the mouth of the bore hole, having two wrought-iron shutters fixed on the top, which, when closed, completely stop up the mouth of the hole, with the exception of a small square passage for the boring rod, and thus all danger of the hole being stopped by stuff falling from above is prevented.

No. C. 22.—Boring Apparatus with Free-falling Cutters.

Scale $\frac{1}{12}$th, or 1 inch to 1 foot.

This model represents two kinds of boring tools with free-falling cutters, such as are employed in very deep borings, where the weight of the rods is so great that the tool would probably be bent or broken if the whole mass were to be allowed to fall together. The cutting tool is therefore made of considerable weight, and is mounted in such a manner that it is lifted by the rods during the up stroke, and detached when at the top of the lift, and falls alone, so that whatever may be the depth of the hole, the force with which the cutting edge strikes against the rock is always the same owing to the constant weight of the falling mass. The rods which are alike in both examples are made of wood of rectangular section tapered towards the ends, having the iron sockets for their union connected to them by two pairs of long cheek plates rivetted through on the opposite sides. The method of mounting and lifting the tool is also similar in both cases. The shaft of the cutter is square, and moves in a frame or cage of corresponding form enveloping it. The opposite sides of the cage have each a long slot pierced through them, in which a pin projecting from the shaft of the cutter travels, forming at the same time a guide and a stop for limiting the down stroke. The top of the shaft has a triangular head, with a deep notch cut on either side of it, the sharp corners of the notches being carefully rounded off. The cutter is lifted by a pair of hinged clips, whose points take hold of the notches during the up stroke of the rods, and the method of releasing it differs in the two systems. In A., Mr. Kind's plan, the clip hooks have elliptical eyes moving on a round centre bolt, giving them sufficient play to shake clear of the notches when the rod is stopped. In Mr. Degousée's plan, that marked B., the clips move accurately on the centre bolt, and project slightly beyond the edges of the cage. A vertical iron rod rests at the bottom of the hole, having two square rings at the top, through which the tool carrier passes freely until it comes to the top of the stroke, when the projecting sides of the clip hooks come in contact with the ring on the rod, and are driven in; this causes their outer ends to diverge and let go their hold on the shaft, which immediately falls, its path being confined to a true vertical line by the pin working through the slots. In both examples a guide, formed of bows or loops of wrought iron broad enough to fill up the bore hole, is placed at the end of the line of rods, immediately above the point of attachment of the tool carrier.

No. C. 23.—Tools for Drawing Tubes out of Bore Holes, by Andrew Reid, Newcastle-upon-Tyne. Full size.

In boring through soft ground it is customary to line the hole as it descends with wrought-iron tubes, to prevent the work being destroyed by the falling in of the sides. This tool is intended for withdrawing the tubes in cases where the bore hole is no longer required to be kept open. It consists of a common wrought-iron boring rod, having an enlarged boss at the end tapered down to a fine point. The greatest diameter of the boss is somewhat less than that of the tube to be withdrawn; it has a bent spring, with a straight bar at the top, exactly similar to the locking spring of an umbrella, fixed to one side, and a projecting cast-iron stud covered with triangular teeth opposite to it. When the rod is lowered the spring is passed back, giving room for the enlarged part to pass freely down the tube until it reaches the bottom, when the spring flies out and the toothed part is brought in contact with the tube and takes a sufficiently tight hold on it to drag it out when the rod is drawn up. Specimens of tubes of 2½ inches and 3 inches diameter are shown, which have been taken out by the two tools adjoining them.

LAMPS.

These are all in case 5, Gallery E.

Nos. D. 1 to 13.—Open Miner's Lamps.

The open lamps used in the principal continental mines are mostly very near in form to that employed in Roman times, consisting of a flat cylindrical, or fiddle-shaped box, with a hole for the wick at one end, and another hole covered by a sliding or hinged door for putting in the oil, with the addition of a curved upright bar, to which is fixed a carrying hook and chain. No. D. 1 is an open lamp, with a pedestal and handle, made of unglazed pottery, of reputed Roman origin, which was found in a lead mine in the Sierra de Gador, near Almeria, in Spain, it is almost identical in form with the common household lamp, No. D. 2, made of glazed ware, still in use in the island of Sardinia, which is placed by its side. These were presented by Professor D. T. Ansted. Nos. D. 3, 4, 5, 6, are various forms of Hungarian mining lamps. No. D. 3 is an open form to be used with tallow, the others are for burning oil. All have forceps for trimming the wicks and hooks for carrying attached to short lengths of chain, with the exception of the brass lamp, which has a long wire handle, with two hooks at different heights. The lamp from Siegen, No. D. 7, presented by Mr. W. W. Smyth, differs from the Hungarian ones by the shape of the body, which is cylindrical. The two lamps, Nos. D. 8, 9, used in the Ayrshire collieries, and No. D. 10 from the copper mines of Mansfield, presented by Mr. C. Foster, are distinguished by the use of curved or cylindrical guards round the wickholders, for collecting any oil that may overflow from the wick, and leading it back into the reservoir. Nos. D. 12, 13 are lamps with spiked handles, that may be supported by driving the point into the rock. No. D. 12 is used in the collieries of the Grand Hornu, near Mons, in Belgium. No. D. 13, presented by Mr. John Hunt, is from the lead mines of Pont Péan, near Rennes, in Brittany.

Nos. D. 14, 15.—SAXON MINER'S LANTERNS, OR BLENDE.

This lantern is in general use both in collieries and metallic mines in the kingdom of Saxony; it is a square based wooden box with an arched head, open in front, and having a long hook fixed to the back, which is passed through a loose leather strap buckled round the miner's neck. No. D. 14 is the working miner's lantern, it is lined with tin plate, and carries a small globular brass lamp, with a tube for the wick projecting diagonally from the top. The foot of the lamp is a hollow socket, which fits on to a wooden plug in the base of the lantern; the carrying hook is made of wrought iron. No. D. 15 is the form used by officials and surveyors, it is somewhat larger than the preceding one, is lined with steel, and has a copper carrying hook, and a socket for candles instead of a lamp; the use of iron being avoided in the construction of this variety in order that the compass needle may not be affected by it when it is used by diallers underground. A third variety is sometimes used, having a hollow space behind the inner metal lining at the back, forming a case for a glass shutter, which can be used for closing the front, as a protection to the flame when the lantern is used above ground at night.

No. D. 16.—MEXICAN CANDLE LANTERN, OR LANTERNILLA.

This is a combination of a plain wooden lantern, covering the flame with an open case, in which the body of the candle is carried, so that the flame is nearly at the level of the floor of the box, which is lined with a protecting metal plate. The candle is supported by a leathern thong, and can be raised as it burns away. A similar case at the back of the slide is closed by a hinged door, and serves as a receptacle for spare candles. This lantern is carried by a transverse wooden handle at the top.

No. D. 17.—CANDLE HOLDER USED IN THE SOMERSETSHIRE COLLIERIES.

This is a pair of forceps, made by rivetting two T-shaped blades of copper together at one end, the cross pieces of the other end are curved to fit the outer circumference of the candle.

No. D. 18.—Tinder Box presented by Miss Julia Hawke.

This is the old domestic tinder box that was used for obtaining light before the introduction of lucifer matches. It comprises a piece of steel with a handle, a flint, and a cylindrical box containing tinder made from charred linen rags, which was ignited by sparks struck with the flint and steel; a flame was obtained from the glowing tinder by a narrow match tipped with sulphur. The top of the box carries a socket for a candle, and the tinder was extinguished by a close fitting iron plate. Although not specially a mining contrivance, it has been thought worthy of preservation, as there are but few examples remaining, owing to the complete disuse into which they have fallen.

No. D. 19–20.—Steel Mills.

This contrivance was used for illuminating the dangerous parts of fiery collieries before the invention of the safety lamp. It consists of a steel disc mounted on a horizontal axis carrying a pinion, which is kept in rapid rotation by a large spur wheel with a crank handle. One man holds the machine and turns the handle, whilst a boy presses a flint against the edge of the revolving disc, a stream of sparks is thrown off, giving a feeble and uncertain light, which is not altogether free from danger, as several explosions have been recorded where the gas has taken fire from the sparks of the steel mill. No. D. 19 has a disc 5½ inches in diameter, making five revolutions for every two of the driving handle. No. D. 20 is 3¾ inches in diameter, and makes six revolutions for each one of the driving wheel.

The steel mill was introduced into the north of England collieries in the latter part of the eighteenth century, and disappeared almost immediately after the introduction of the safety lamp in 1815, and they are now very rarely to be met with even by collectors of mining curiosities.

Safety Lamps.—Gallery E.—Case 5.

The safety lamp, as originally introduced by Sir H. Davy in 1816, consists essentially of a common oil lamp, whose flame is isolated from the external atmosphere by a metallic envelope perforated with numerous small holes, a cylinder of wire gauze being generally employed. The holes are large enough to allow air to pass in to the flame, and the products of combustion to flow out freely; but owing to the cooling effect of the wire bars or walls of the apertures no gases in a state of ignition can pass through, the temperature being reduced by the metal below that necessary for the production of flame, so that in fiery mines, where carburetted hydrogen gas is present in the air in sufficient quantity to form an explosive mixture, only such portions as may be brought into direct contact with the flame of the lamp can be ignited, the explosion being confined within the wire cage if the apertures be sufficiently small. The limit of safety for gauze of iron wire is placed at 28 parallel wires to the inch, or 784 apertures to the square inch, or about $\frac{1}{5000}$ of a square inch surface for each hole.

Various modifications of the above principle have been adopted from time to time with the intent of obtaining more light or greater safety, several of which are represented in the 23 specimens in the collection. They are divisible, according to the method in which the air for feeding the flame is introduced, into three heads, as below:—

1. Lamps with plain gauze cylinders and no forced draught.
2. Lamps in which the air is brought in by special channels below the flame.
3. Lamps in which the feed air is taken above the level flame and drawn downwards, acting first as a refrigerating medium for the external envelope.

Nos. D. 21, 22.—The Two First Safety Lamps ever used in a Coal Mine.

They were sent by Sir H. Davy in 1816 to the Rev. John Hodgson, at the time vicar of Heworth, and were presented by him to Miss Emma Trevelyan. They are of small size, having cylindrical copper oil vessels surmounted by chimneys of thin brass wire gauze of a much finer mesh than has been employed subsequently. The gauze is protected by a cage of three vertical bars of stout iron wire fixed to a flat brass roof, into which the carrying ring is secured by a swivel joint. These are not to be confounded with Sir Humphrey Davy's first experimental lamp, which is in the possession of the Royal Institution.

No. D. 23.—Common Davy Lamp.

This is one of the simplest forms of safety lamp. It has a cylinder of black iron wire gauze of 28 apertures to the inch, set in a brass ring, which screws on to the top of the lamp. Three upright wires are fixed to the ring, and are

drawn into a loop at the top, through which the carrying link is secured. The top portion of the gauze chimney is made of two overlapping cylinders; this is rendered necessary by the destructive effects of the hot gases on the iron wire, a single thickness being liable to be burnt into dangerously large holes at this point.

No. D. 24.—Davy Lamp, by H. Watson, Newcastle-on-Tyne.

This resembles the preceding one, with a few slight modifications. The carrying link is attached to an arched brass roof, which protects the miner's hand from being scorched by the escaping products of combustion. The common method of locking the Davy lamp is also shown. This consists of a simple screwed bolt pointed at one end, with a square head fitted with a key resembling a common watch key, which passes through a nut cut in a square boss attached to one side of the oil vessel, until the point is received in a hole drilled through the lower brass ring of the cage carrying the gauze. The bolt is of such a size, that when the lamp is locked the key end is sunk level with, or a little below the outer face of the boss, so that it cannot be unscrewed by the mere use of the fingers. In all cases a vertical wire hooked at one end is provided for trimming the wick; it slides through a tube passing through the body of the lamp.

No. D. 25.—Davy Lamp for Burning Gas.

This is an extra large lamp, which was for experimental purposes for the use of the Royal Commission on Mines. It has no special peculiarities, beyond the substitution of a common single jet gas burner, for the oil lamps of the preceding examples. The gauze case is doubled through a considerable portion of its length, only about one inch immediately above the flame being single.

No. D. 26.—Davy Lamp with Condenser, by Newman.

The gauze of this lamp is doubled in a similar manner to that of No. D. 27. The single part is covered by a plano-convex or bull's-eye lens set in a square brass frame, attached to two of the stay bars of the cage for the purpose of concentrating the light.

No. D. 27.—Davy Lamp from Hetton Colliery.

This is more slightly built than the preceding lamps, and is almost entirely made of brass. A curved horn shade is arranged so as to slide on two of the stay bars; it is added to protect the light from being directly acted on by currents either of air or gas. Many accidents have taken place with Davy lamps when exposed to sudden discharges of gas from the coal; when the gauze becomes red hot, and if the flame is blown to one side, the wire network is no longer capable of preventing the external atmosphere from taking fire, as the flame will under these circumstances pass through the holes.

No. D. 28.—Dr. Clanny's Safety Lamp.

This differs from the Davy lamp in having the lower portion of the gauze cylinder, the part immediately above the flame, replaced by a stout glass tube for the purpose of giving more light. The glass is of larger diameter than the gauze cylinder; it is mounted between two brass rings connected together by six vertical stays, and is attached by one locking bolt to the lamp below, and by a second, to the cage carrying the gauze above. The air for feeding the flame enters through the lower part of the gauze and has to travel downwards, but there is no special contrivance for directing it or for forcing the draught. The advantage of the glass in this lamp is more apparent than real, as on account of the great thickness of the glass envelope, a notable proportion of the light is absorbed, and the illuminating power is not much greater than that of a plain Davy lamp.

No. D. 29.—Self-extinguishing Lamp, used at the Earl of Lonsdale's Collieries at Whitehaven. Presented by Peter Bourne, Esq.

This lamp is so contrived as to become extinguished by the act of opening, in order to prevent the miner from converting his lamp into a naked light, as is not unfrequently done with the common locked lamp by men who have obtained possession of private keys. Externally it resembles a common Davy lamp, but the lower ring or cap of the cage is unusually deep. On the inner side of the cap, above the thread of the screw by which it is attached to the lamp, is a thin shelf or plate of iron cut through in two places opposite to each other, leaving two notches about half an inch in width, which are filled by two wedge-shaped arms moveable about fixed centres. The tube holding the wick is also cut through, having two narrow slits also opposite to each other extending through its entire height. To the top of the oil vessel are attached two unequal-armed levers bent in such a manner that the arms make an angle of about 100 degrees with each other; the longer ones are tapered to a narrow chisel edge somewhat less in breadth than the slits in the wick holder, and are maintained by steel springs in a nearly vertical position when not in use, the shorter arms being at the same time horizontal. The latter have peculiarly shaped tails, forming transverse wedge-shaped blocks, the thickened ends having the corners rounded off. When the cap is screwed on the long tapered wedges attached to the cap pass over the upper surfaces of the wedge-ended arms of the angle levers without moving them, but on reversing the motion, the points of the hinged wedges come in and pass underneath those on the shorter arms of the levers, so that the longer arms are depressed and drive the wick downwards in its tube. The action of the springs bring the longer arms back to the vertical position, as soon as the notched parts of the plate arrive opposite to them, but they are immediately driven down again by the second hinged wedge, the result being an irregular jerking pressure on the wick, which extinguishes the flame before the cap and gauze cage are completely unscrewed from the lamp.

Nos. D. 30, 31.—Self-extinguishing Lamps. By Mr. Dubrulle, Lille, France.

These lamps are similar in principle to that last described but are differently constructed. The oil vessels are urn-shaped and are made of zinc; that of No. 30 has three equidistant studs projecting from its outer surface, which fit into three corresponding clutches in a covering plate forming the lower part of the cage. The locking bolt is a bent iron wire contained within the oil vessel, with a straight portion at the upper end which passes through a hole in the top of the lamp, and is received into a hollow boss lined with brass in the covering plate. The bolt is maintained in position by a curved copper spring, also within the oil reservoir. The wick, formed of a single thickness of flat cotton plait, is held at the lower end by an iron clip with a short projecting arm carrying a screwed nut or collar, through which passes a vertical screw for raising or lowering it. The iron locking bolt is also provided with a projecting arm with a round socket or eye, through which the vertical rod passes loosely, and it is only when the lower edge of the collar on the wick holder is brought in contact with this arm, that the bolt can be withdrawn; but this can only occur when the flame is extinguished by the withdrawal of the wick within its case. In putting the cage on, when the lamp is trimmed, the open parts of the clutches are brought over the studs, sufficient pressure being exerted to press back the locking bolt; the cage is then turned through a small angle to make the clutches take hold of the studs, and when the latter are in position the bolt springs up into its seat and cannot be again withdrawn without screwing down the wick as already described. No. D. 31 is constructed on the same general principles, but has only one clutch instead of three.

No. D. 32.—Stephenson's Safety Lamp.

This lamp was invented by the late George Stephenson, Esq., almost at the same time as that of Sir Humphrey Davy. The air is admitted through a number of small holes pierced through the under side of the lower brass ring of the cage, the wire gauze cylinder is lined with a close fitting glass chimney, surmounted by a cap of sheet copper perforated with numerous holes, which are a little larger than those of the wire meshes. This lamp is said to be safer than the common form of Sir H. Davy's, as the gauze is kept from coming in contact with the flame by the glass lining, and cannot become red hot. Owing to the small size of the air holes they require to be very carefully cleaned before use in order to make the light burn steadily.

No. D. 33.—Howdon and Thresk's Safety Lamp.

This resembles a Davy lamp of extraordinary size and has a tubular wick, with a special contrivance for admitting air to the inner side of the flame. The foot of the lamp is a hollow cone prolonged below the base of the oil vessel, and is pierced with a ring of air holes at the bottom. A slightly conical tube passes up through the body of the lamp; it is covered at the lower end by a double disc of wire gauze, formed of two single thicknesses kept about a quarter of an inch apart by a brass packing ring. The wick is raised or lowered by an upright screw working through a nut in the end of an arm which projects horizontally from the wick holder.

No. D. 34.—Upton and Roberts' Safety Lamp.

The air in this lamp is admitted through a vertical ring pierced with square holes, covered on the inner side with a flat disc of gauze, and is supplied to the flame by a conical argand cap. The wire gauze chimney is contained within an outer glass cylinder, which bears at the bottom against the lower ring of the cage, and at the top against a strong coiled spring of iron wire, in order that it may not be broken by a sudden jar. The top of the lamp is formed of a double brass cap with parallel walls, the outer one is pierced with a series of large round holes for destributing the gases generated by the flame. It is said to be a very safe lamp, but is inconvenient on account of the facility with which the flame is extinguished if it be subjected to a jerking motion when carried.

No. D. 35.—Eloin's Safety Lamp.

The air is admitted in this lamp through a short upright cylinder of wire gauze, and is distributed to the flame by an argand cap. The light is surrounded by a short stout glass cylinder, whose outer surface is shaped to a hyperboloid curve for diffusing the light. The glass is set in a cage with seven stay bars, six of which are solid, and one is hollow, the latter serves as a case for the locking bolt, which is vertical instead of horizontal, as in all the preceding examples. A conical brass reflector slides on the stays; it is used for concentrating the light on the floor of the workings when the lamp is suspended. The wire gauze chimney is replaced by a solid brass tube covered by a gauze disc at the top. No. D. 36 is another example of this lamp, manufactured under the English patent by Messrs. Thornton and Sons of Birmingham. No. D. 37 is a modification by Messrs. Thornton and Sons, in which the glass is protected by an outer casing of mica.

No. D. 38.—T. Y. Hall's Safety Lamp.

This combines the peculiarities of several of the preceding lamps. The cage is made in two parts, the lower part being longer and of greater diameter than the upper one. The air is admitted through holes in a brass ring, as in Stephenson's lamp; the amount necessary for feeding the flame is drawn by a glass argand chimney, which is surrounded by a cylinder of silver wire gauze, with a second glass outside. Another part of the air passes up through a number of holes in a flat portion of the lower ring of the cage, and out through a corresponding series of holes in the upper ring, thus establishing a cooling current between the inner and outer glasses. The amount of air passing by this channel is regulated by a ring, which can be screwed over the upper series of holes so as to contract their apertures at pleasure.

No. D. 39.—Boty's Safety Lamp.

This is one of four patterns of safety lamps recommended for use by a Royal Commission appointed by the Belgian Government, the others being Mueseler's, Eloin's, and the simple Davy. The admission of the air is effected on a similar principle to that adopted in Eloin's lamp, namely, through a perforated copper ring made slightly conical, and placed a little below the level of the flame. The light is covered by a short stout glass cylinder, the top of the lamp is formed by an ordinary gauze chimney.

Nos. D. 40, 41.—Mueseler's Safety Lamp.

This lamp is extensively employed in the collieries of Belgium and the north of France. It has a very thick glass cylinder covering the light, with a gauze chimney made slightly conical, placed above it. An inner conical tube of smaller diameter, terminating below in a trumpet-shaped mouth reaching to within a short distance of the flame, is fixed within the gauze, the space between the two tubes being closed by a wire gauze disc. The feed air enters through the lower part of the gauze chimney, and passes through the disc along the inner side of the glass, whereby the latter is kept cool. No. 41 has the chimney made of brass wire gauze.

No. D. 42.—Dr. Glover's Safety Lamp.

This is similar in principle to the preceding one, but has a shorter draught hood over the flame. The light is covered by two concentric glass tubes, the space between them is in connexion with the external air above and the interior of the lamp below, both sides being covered by a plate of wire gauze. The whole of the feed air has to pass between the two glasses, serving at the same time as a refrigerating current, the upper gauze chimney serving only as a means of discharge for the products of combustion.

No. D. 43.—Mr. H. Mackworth's Safety Lamp.

This lamp is almost identical in construction with the preceding one, the chief difference being, that the upper gauze covering the space between the two glasses, is placed within the outer gauze chimney, and instead of being flat, is made of a conical form. The lower one in like manner is curved to the shape of an argand hood, and placed immediately above the wick. The system of locking is also different, as instead of the usual screw bolt and key, a soft metal rivet made of lead or pewter is employed. The rivet is passed through a hole in two perforated plates projecting from one side of the oil vessel, and is clinched by a pair of pincers having a device engraved on one of its jaws. The soft metal completely fills up the space between the two plates, and takes an impression of the device, so that it is impossible to open the lamp without defacing the impression. A curved metal reflector is placed within the inner glass for concentrating the light on one side.

No. D. 44.—Biram's Safety Lamp.

This has a silvered parabolic mirror placed behind the light, and a flat plate of mica with a narrow slip of gauze below it, set in a copper frame in front, which slides between the grooved edges of the body of the lamp, and can be replaced by a similar frame made of gauze only. The chimney is like that of Eloin's lamp, a solid cylinder with a short gauze cap at the top.

Nos. D. 45–47.—Crane's Safety Lanterns and Lamp.

These include two large square lanterns, and a small Davy lamp. Of the former, one has plain gauze sides, and one is partly glazed, with narrow opening covered with gauze below. They are too weakly constructed to be really safe, as there is no protection for the large flat surfaces of glass, and the holes in the top cowl, by which the hot gases from the flame are discharged, are dangerously large and unprotected by gauze stoppings. The small lamp is also very slight in construction, and the trimming wire is inserted through the mesh of the gauze at the level of the flame, an arrangement that would most probably work a large hole into it after having been used a short time. A lantern similar in character to No. D. 47 is used in some of the collieries in the vicinity of Leeds by men working trains of trucks on the principal road-ways. The gauze screen is of a much more open mesh than that used in safety lamps, and is intended only to screen the flame against currents of air, and not as a protection against explosion.

SURVEYING INSTRUMENTS.

Nos. D. 48–50.—Miners' Dials.

The compass or dial used in underground surveying is essentially the same instrument as the circumferentor used by land surveyors. There are three examples on the lower shelf of case No. 5. No. D. 48 is a plain dial, with a compass needle 5 inches long, the circle being divided to single degrees. The sight vanes are divided into two parts, the upper one on one side having a fine slit cut throughout, the corresponding division of the opposite one carries a plain wire, the relative portions of the slit and wire being changed in the lower divisions. The compass box is attached to the tripod stand by a socket fitting on to a corresponding plug, an intermediate ball and socket joint furnishing the means of levelling the instrument.

Nos. D. 49 and D. 50 are examples of Philipps's underground dial. This instrument is a combination of the circumferentor, with an arrangement for measuring vertical angles. The larger one, No. D. 49, has a 4 inch needle, playing in a circle divided to single degrees, the space between the divided limb and the centre point containing tables for the resolution of the azimuth lines observed into their north and south, and east and west parts. A semicircular vertical arc is fixed across the central line of the compass, provided with a moveable limb, carrying a horizontal bar, with a pair of sight vanes, on which is fixed a long spirit level. The semicircle is divided to single degrees, which are pointed from 90° in the centre to 0° on the horizontal line on either side. A corresponding series of tables for reducing the lengths of inclined lines to those of their bases and perpendiculars are engraved below. The compass box can be turned slowly in azimuth by a spur wheel and pinion, but there is no fine adjustment for the vertical limb. No. D. 50 is a smaller dial, constructed on similar principles, with the addition of a larger bar carrying the level and sight vanes, which is moved by toothed gearing in a similar manner to the slow motion of the compass.

No. D. 56.—Biram's Anemometer.

This instrument consists of a vertical wheel, made of a light copper framework, carrying ten oblique blades or arms, made of oiled silk, with a registering apparatus attached to the axis for marking the number of revolutions made by the wheel. It has three dials, giving a range from 0 up to 10,000. The observation is made by holding the frame of the instrument at right angles to the current, after having read off the index. The wheel is then allowed to revolve freely during one minute, the time being determined by a sand glass. At the end of that time, the wheel is stopped by pressing the hand against the tire, and the index is read off; the difference between the two readings gives the number of revolutions made by the wheel during the period of observation. From this quantity, the velocity at which the air in the gallery is travelling may be determined by the application of a simpler series of constants, which should, however, be determined by subjecting the individual instrument to the action of a current of known velocity, or by comparing it with another instrument whose constants have been determined, as a standard. From the velocity of the stream so obtained, and the area of the cross section of the gallery, the cubic volume of air passing per minute is determined by calculation.

TIMBERING AND MASONRY.

No. E. 1.—Timbering for Shaft and Level, used in Cornwall.

Scale, $\frac{1}{12}$, 1 inch to 1 foot.

No. E. 2.—Level, with Round Timbering, Ulverstone Iron Mines.

Scale, $\frac{1}{12}$, 1 inch to 1 foot.

No. E. 3.—Timbering for Levels, Saxon Mines.

Scale, $\frac{1}{16}$, $\frac{3}{4}$ inch to 1 foot.

No. E. 4.—Shaft Timbering, Saxon Mines.

Scale, $\frac{1}{16}$, $\frac{3}{4}$ inch to 1 foot.

No. E. 5.—Timbering in Ordinary Levels, Harz Mines.

Scale, $\frac{1}{16}$, $\frac{3}{4}$ inch to 1 foot.

No. E. 6.—Timbering in Large Levels, Harz Mines.

Scale, $\frac{1}{16}$, $\frac{3}{4}$ inch to 1 foot.

No. E. 7.—Shaft Timbering, used in the Harz Mines.

Scale, $\frac{1}{16}$, $\frac{3}{4}$ inch to 1 foot.

No. E. 8.—Shaft Timbering employed in Australia.

Scale, $\frac{1}{6}$, 2 inches to 1 foot.

Nos. E. 9, 10, 11.—Masonry for Levels used in the Saxon Mines.

Scale, $\frac{1}{16}$, $\frac{3}{4}$ inch to 1 foot.

No. E. 12.—Cast-iron Colliery Tubbing.

Scale, $\frac{1}{12}$, 1 inch to 1 foot.

The whole of the above are in the small room on the upper floor.

The methods of employing timber for the support of underground excavations vary according to the different degrees of cohesion in the rock. In the most unfavourable cases, a complete and continuous casing of strong beams is necessary, whilst in a more stable material simple frames, placed at longer or shorter intervals, and lined with rough sheeting boards or small poles, are sufficient. In England, where the bulk of the timber employed is imported from foreign parts, squared balks are commonly used; in the Harz, Saxony, and other well-wooded districts the trees are used in the round state. In collieries small round pine or larch trunks, called pit props, cut to six feet lengths, are used in cutting coal, stripping pillars, and other places where only a temporary support is required. Another method used in long-wall collieries consists in building hollow pillars with short pieces of squared timber called "chocks." More recently metal pit props have been introduced.

No. E. 1 is the common method of timbering employed in Cornwall in moderately secure ground. The frames on the levels are formed of three pieces of squared timber, namely, two inclined side pieces, and a horizontal cross piece or cap, which rests on shallow notches on the tops of the side pieces; they are placed at intervals of one to three feet, the space between their outer faces and the rock is lined with a casing of boards or "laths." The frames in the shaft are made of timbers of a rectangular section, the longest side being placed parallel to the vertical line. The points are formed by halving the pieces together at the corners; the interval between the frames is 2 to 3 feet. They are maintained at that distance apart by short supporting pillars called studdles, at the corners. The face of the rock is lined with spilling boards in a similar manner to that employed in the level. The intermediate space between the bottom of the shaft and the mouth of the gallery is a place in which the ore from the workings is stored, and from which the ores are filled into the kibbles. It is timbered in a similar manner to the level, with larger frames.

No. E. 2 is the system of timbering employed in the hematite mines of the neighbourhood of Ulverstone. The shaft is lined with frames of square timber halved together with an overlap at the corners, piled closely one above another into a solid casing, two continuous longitudinal planks are fixed to each of the sides, forming conductors or guides to the vessels in which the ores are drawn. The levels are timbered with frames having two inclined sides and a horizontal cross piece as in the preceding example, with this difference, that round beams are used instead of square ones. The cap pieces rest in shallow curved notches cut in the top of the side beams. At the contact of the levels with the shaft and at the points of junction with other levels, the frames are placed nearly in juxtaposition, at other places they are 2 to 3 feet apart. The walls are lined with poling boards in lengths equal to the distance between three consecutive frames, half the length is placed above the caps of two adjacent frames, the remaining portion is bent downwards and bears against the under side of the cap of the third frame. A plank placed along the floor of the level, forms a roadway for the wheelbarrows in which the ore is brought from the workings to the filling place at the bottom of the shaft.

No. E. 3 is a system of combined or double timbering used in the Saxon mines. The frames are made of round timber in three pieces, with upright side pieces. The cap pieces are cut half way through, and the flat surfaces so produced rest on the end of the uprights. The frames are of three different sizes, the largest are 9 feet high and 5½ feet broad, the smallest, 8¼ feet high and 4 feet in width, are placed within the former, the space between them being filled by lining boards, fixed tight with small wooden blocks. These double frames are placed at intervals of six feet, the lining boards being supported midway between them by the frames of intermediate dimensions, which are 8½ feet high and 4½ feet wide. The effect of the whole arrangement is that of a series of short rectangular based funnels stuck one within the other. Horizontal cross pieces or bearers resting on the upright legs of the frames, are fixed across the level about 15 inches above the floor, to which a continuous plankway is fixed, along which the hand-waggons for conveying the ore are run. The space below the plank serves as a channel for conveying the mine waters to the reservoirs feeding the pumps.

No. E. 4 is a model of a shaft of a rectangular horizontal section, measuring 8 feet in length by 6 feet 4 inches in breadth, timbered on the same system as that employed in the model No. E. 1, but with round instead of squared timber. This plan is known in Germany by the name "Bolzen-schrot Zimmerung." Horizontal bearers are placed across the shorter sides at intervals of six feet from each other, upon which the alternate shaft frames are carried. The frame next above each one that is so carried, is supported by four struts at the corners and two on the long sides; the latter are placed so as to divide the length into two unequal parts, and a corresponding transverse piece paralled to the shorter sides divide off about one third of the shaft, in which the ladders are fixed, the remainder being reserved for a drawing shaft. A lining of planks is fixed on one side, that of the foot wall or under side of the lode, to prevent the kibbles from striking against the timbers and chafing them. The ladders are made entirely of wood; the sides are half round or D-shaped pieces with the flat sides placed outwards; the staves or rounds are pieces of rectangular section, with the top edge horizontal forming the head, the lower one being fish-bellied or thickened in the middle, giving an extra substance immediately under the point where the greatest wear takes place, by the chafing of the men's boots against the wood.

No. E. 5. represents three different methods of timbering a level of the ordinary trapeziform section adopted in the mines around Clausthal in the Harz, when the gallery is of a moderate size. The two outer frames show the plan adopted when one of the walls is firm enough to stand without support, one side piece is used, surmounted by a cap, whose opposite end bears against a square socket cut into the hard rock of the other wall. The space between the wall and the roof and the timbers is filled with a packing, formed by dressing down small poles into rough planks. The centre of the model shows three frames of a system of complete timbering, with two side pieces, and a cap, carried on a foot piece extending transversely across the floor; the lining boards are similar in character to the preceding. The two frames at the opposite end, represent a system in which the side parts are carried on longitudinal floor pieces running along the sides of the gallery; the lining boards of this part are the rough outer slabs obtained in sawing up large trees; they are placed with their flat sides in contact with the rock. Throughout the model the frames are kept at their proper longitudinal distances by horizontal thrust pieces bearing against notches cut in the sides of the timbers.

No. E. 6 shows several systems of timbering employed in the Harz, in galleries of extra size, in which the inclination of the side walls corresponds with that of the walls of the lode. No. 1, the simplest plan, is a single cross beam, butted against the hanging wall, and resting in a socket on the foot wall. No. 2 has a similar bearing for the lower end of the cross piece, with a side post on the side of the cross. In No. 3 there is a side post on the lower wall, as the cross beam bears against the face of the rock on the other side. The remaining system, No. 4, is that in which side posts are used on both walls, in conjunction with an overhead cross piece. In all the above instances longitudinal thrust pieces are used to preserve the verticality of the frames as in the preceding model, No. E. 5. The cross pieces are cut to fit the curvature of the side posts on the upper side, but rest against flat surfaces with a top bearing notch on the lower side. The system of lining boards adopted is that of the small dressed poles, also used in No. E. 5.

No. E. 7 shows the method of timbering adopted in the large inclined shafts in the Harz. The section of the shaft is a rectangle, 30 feet in length on the course of the lode, and about 10 feet in breadth, equal to the thickness of the lode. The frames are made of round timbers, the longer ones are cut into flat notches at the end, which form bearing surfaces for the shorter or cross pieces. The lowest frame rests on three cross bearers, one at each end and one in the centre, all those above being maintained parallel to it at regular vertical intervals by upright struts, placed at the corners, and in the centres of the long sides. The long timbers are stiffened by three transverse diaphragms, each formed of a pair of longitudinal beams parallel to the side walls, kept apart by struts carried in a zigzag or V shape order. By the central diaphragm the shaft is divided into two equal portions, one of which is reserved for the winding, the other contains the foot ways and pumping machinery. Four different sizes of timber are employed, as follows :

The lower bearers, 24 inches in diameter.

The longitudinal beams of the diaphragms, 19 inches.

The V pieces of the truss work, 16 inches.

The frames and their supporting struts, 12 inches.

The interval between the frames in height is 3 feet 4 inches.

No. E. 8 is a system of continuous shaft timbering adopted in the auriferous quartz mines of Australia ; it is formed of rectangular frames made of thick planks, placed with their longest sides upright, the sides are not jointed together, the shorter planks being kept in position by wooden pegs driven into holes bored through the longer ones acting against the uneven surface of the rock. A central wall divides the shaft into two parts.

Nos. E. 9, 10, 11, are three different systems of securing levels by masonry, employed in the Saxon mines. No. E. 9 is a small sized gallery with the walls in hard rock, and a flat segmental arched roof of dressed stone. No. E. 10 is a large gallery on an inclined lode, with one solid wall, the opposite one and the roof, being spanned by a segment of a cylindrical arch, giving an irregular triangular profile to the level. No. E. 11 is a portion of a large adit or water gallery completely walled; the arch is of an elliptical form, the water is carried off by a deep channel cut into the solid rock, whose depth is somewhat greater than the height of the level above the plankway laid for the passage of wagons, at the foot of the arch. In all the above instances the arch stones are made of the gneiss of the district dressed to shape and set in cement.

No. E. 12 is a model of cast iron tubbing employed for securing colliery shafts in water-bearing beds; it consists of a series of cylindrical rings built up in segments which are piled one above another, forming a closely fitting case. The rings are 30 inches in depth, and are divided into eight parts, each of which is flanged at the edges and strengthened by projecting cross ribs and feathers behind. In putting the segments together a thin wooden sheeting is inserted between the flanges, and there is a hole bored through the centre of each piece, which is stopped with a plug as soon as the ring is in its place. The lower end of the tubbing rests on a stout cast-iron ring or curb, also put together in segments, which is forced into a place cut out for it in the first hard ground below the water-bearing stratum. In the upcast shafts of collieries where ventilating furnaces are placed underground, it is advisable to line the interior of the tubbing with a casing of fire brick, in order to protect the iron from destruction by the hot gases from the fire. An accident arising from this cause occurred at Monkwearmouth colliery in the year 1862, when the cast iron wall was found to be reduced to a spongy graphitic mass, owing to the oxidization of the iron by the sulphurous vapours from the ventilating furnace. At Hetton colliery, the tubbing is made with an inside projection for carrying a fire-brick lining.

DRAWING MACHINERY.

This section includes all the machines used for drawing minerals in shafts, whether by manual, steam, or water power. They are all in the model room A., except No. F. 12, which is in the museum.

No. F. 1.—Saxon Windlass (Haspel).

Scale, $\frac{1}{8}$th, $1\frac{1}{2}$ inches to 1 foot.

This is used for drawing, by manual power, in small underground shafts or during sinkings from the surface, before the workings have attained any great depth. It is a simple cylindrical shaft or barrel, 6 feet long and 10 inches in diameter, running on two wrought-iron bearings at the ends, which are prolonged into cranks. The framing is of the simplest character, consisting of two uprights stepped into mortices on two horizontal cross timbers, and stayed by short diagonal struts below. Two inclined planks resting against the outer faces of the diagonal timbers, close up the mouth of the shaft, leaving an opening of the width of the uprights for the ropes to pass through. A fixed horizontal rail runs parallel to the barrel; it serves as a hand-rail for the workman to hold on by, when lifting the loaded bucket out of the mouth of the shaft. The kibbles generally employed in Saxony for windlasses, are wooden tubs formed of straight staves, and of an elliptical plan, the base measuring 15 inches by 9 inches, whilst the mouth is 18 inches by 11 inches; the height is 15 inches. The estimated weight of the amount of broken stone in one filling, under ordinary circumstances, is about 92 pounds. The average quantity of work done by two men at the windlass, in the shift of eight hours amounts to 40 loads of the above net weight, drawn from a depth of 20 Saxon fathoms (130 feet). The mean speed of the load is about 45 feet per minute.* Small round wire ropes are more generally used in preference to hempen ones. A strip of wrought iron is fixed along the horizontal bearer on the receiving side, to prevent it from being chafed by the iron binding hoops of the kibble. The trap-door by the side of the windlass covers the mouth of the ladder way.

No. F. 2.—Saxon Geared Windlass (Vorgelegehaspel).

Scale, $\frac{1}{8}$th, $1\frac{1}{2}$ inches to 1 foot.

The barrel in this case is somewhat larger than that of the preceding example, being 15 inches in diameter and

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* Weisbach Ingenieur und Maschinen Mechanik, III., p. 517.

64 inches long. The men work a pair of crank handles at the ends of a wrought-iron shaft, carrying a pinion with 24 teeth, which drives a larger wheel with 72 teeth on the rope barrel. The latter, therefore, makes only one-third of a revolution during each revolution of the crank shaft.

No. F. 3.—Saxon Hand Whim and Hungarian Waggon.

Scale, $\frac{1}{12}$th, 1 inch to 1 foot.

The hand whim is now nearly extinct; it resembles an ordinary horse whim of small size, having two cylindrical rope drums on a vertical shaft, the brake works on a disc attached to the bottom of the lower drum. The power is applied by means of three projecting arms, called "Schwengel." Each of these arms is formed of three pieces, a central one morticed into the vertical axle, braced by two outer ones, which overlap the axle and fastened to the central piece by screw bolts. The ores are drawn in small wooden tubs moving on rollers between guides. The tipping apparatus at the surface is formed by a pair of sliding rods of wrought iron, which are drawn back as soon as the tub has passed up. The rods form rests on which the rollers on the tub are supported when the whim is reversed. Single-strand wire ropes are usually employed, almost to the entire exclusion of round hemp ropes.

The waggon is the so-called Hungarian "hund" mounted on two pairs of cylindrical wheels of unequal diameter; it is used on plank roads underground, but has almost gone out of use since the introduction of railways into the principal levels.

No. F. 4.—Cornish Horse Whim.

Scale, $\frac{1}{12}$th, 1 inch to 1 foot.

This is the form of applying horse power in general use in England. The horses are yoked to the ends of two radial arms, formed by a large horizontal beam of timber passing through a mortice in the upright axle. These arms are strengthened by two longitudinal straps or fishes applied through about two-thirds of their length. The rope barrel is a plain cylindrical cage formed by nailing straight boards to the outsides of three horizontal wooden rings, placed at different heights, and supported by arms morticed through the axle. The lower ring is carried by the top of the long beam, and another intersecting it at right angles, and the two upper ones by similar cross arms set at an angle of 22½ degrees to each other. The whole cage is further supported by diagonal struts below the lower ring and resting against the sides of the axle near its lower end. The shaft is square at the intersection of the long cross bar, and is chamfered down to an octagonal section, above and below, with cylindrical ends, the cylindrical parts being tired with wrought-iron rings for securing the hold of the pivots. The framing is formed of two short inclined standards, united by a long transverse bar, to the centre of which is affixed the bearing of the top spindle. The guide pulleys over the top of the shaft are of small diameter, the framing giving a clear head room of about 8 feet only; the axis of one is placed a little higher than that of the other, in order that the rope may lead to its proper place on the drum. The diameter of the path described by the horses is 36 feet, that of the drum being 12 feet; the depth or height of the drum, or the receiving surface for the ropes, is 56 inches. The kibbles for horse whims are estimated to carry $2\frac{1}{2}$ cwt. Round hempen ropes, of 6 or 7 inches (circumference), or chains of $\frac{7}{16}$ths to $\frac{1}{2}$ inch iron are employed. For depths of less than 40 fathoms, one horse is sufficient, but two are employed for drawing from any greater depth. The speed at which the load moves in the shaft is from 75 to 100 feet per minute, the horses during the same time passing over about three times that space, or at the rate of about $3\frac{1}{2}$ to 4 miles per hour.*

No. F. 5.—Horse Whim with Skips.

Scale, about $\frac{1}{8}$ of full size.

The drum or cage of this whim is divided into two parts by projecting arms or horns, which serve to confine the flat hempen rope to a particular part of the surface, so as to wind on a cylinder increasing in diameter at each revolution by an amount equal to double the thickness of the rope. The whim shaft is square; the arms carrying the cage are united by iron straps into a frame overlapping the axle, and are not morticed through it as in the preceding example. A short diagonal strut is placed between the inner end of the arm and the next one at right angles to it. From the centre of these diagonal pieces the intermediate arms project. The outer ends of the drum horns are supported by

* Moissenet, Annales des Mines, 6 Ser., vol. II., p. 155.

diagonal beams resting against the axle immediately above the ground. The ropes are made of four hempen strands two with right-handed and two with left-handed twists, placed alternately side by side. The dimensions of the flat ropes, used in Cornwall, vary from 5 inches to 7 inches in breadth, and from $1\frac{1}{4}$ to $1\frac{7}{8}$ inches thick.

No. F. 6.—German Horse Whim (Pferdegöpel).

Scale, $\frac{1}{24}$, $\frac{1}{2}$ inch to 1 foot.

The vertical shaft in the German horse whim is of considerable length; the rope drums are placed near the top, and are carried on a platform formed by four arms overlapping the shaft, supported at the ends by struts, which are nailed to the axle at about one-third of its height above the bottom bearing. The lower drum is fastened to the shaft, the upper one is loose, and can be connected with the lower one by a wooden coupling pin. The brake works on a projecting part of the upper drum, and serves either to stop the whim when both drums are connected, or the top one only when the pin is taken out, which is done when altering the amount of rope out in changing the draught from a higher to a lower level, or the reverse. The upper drum in this case runs on friction rollers on the upper surface of the lower one. The bearing of the foot spindle rests upon a pair of adjusting wedges on a short pillar of masonry; to the top bearing is attached a horizontal beam, carried by two diagonal struts called spiessbaum, which also support a conical roof covering the rope drums and a gallery projecting from the house above the shaft. The horses are attached to a turning bar attached to the lower end of a projecting diagonal arm (schwengel) fixed at the upper end to the shaft and lower drum, and also supported at about half its length by a horizontal strut, which are hung by staples to the lower end of the shaft. Two poles with spiked ends (schlepspieise) are used to prevent the horses being dragged back by the weight of the loaded tub when the whim is stopped. The tubs are of a prismatic form, resting on rollers between wooden guides on the shaft, and are drawn by round wire ropes. The capacity of the tubs is about 2,000 cubic inches; the radius of the path of the horses, 19 feet; the core of the drums, 6 feet; depth of the soil, 13 inches; the vertical shaft is 23 feet long and 17 inches square.

No. F. 7.—Water Whim with Underground Wheel, used in the Harz Mines.

Scales, $\frac{1}{18}$ for the wheel.
„ $\frac{1}{12}$ for the winding gear.

This model represents the ordinary arrangement adopted for a direct acting water whim in the Harz and other German mines. The rope drums are on the same shaft with the over-shot water wheel, which is provided with two systems of buckets opening in opposite directions, each of which is provided with a separate sluice, not shown in the model; the buckets are formed of wood, in two pieces, set in wooden shroudings and backings. The framing of the arms is that usually adopted in Germany for large wooden wheels known as "Dutch framing;" the ring is carried up either side by four principal arms laid in pairs at right angles to each other, and overlapping the sides of the square shaft, and eight intermediate diagonal arms or struts (hilfs armen) which are arranged in pairs forming V's, the apices of the V's resting on the centres of the sides of the shaft. One of the rope drums, that nearest to the water wheel, is fixed to the shaft; it is made entirely of wood, the framing of the arms being similar to that of the wheel. The outer rope drum is loose on the shaft; it is carried by six cast-iron arms on either side, which turn on a pair of cast-iron rings keyed on to the shaft. Each of these rings has four square holes sunk into it to receive the points of the locking hooks, which turn on a shaft attached to the inside of the cage formed by the two sets of arms. These hooks are turned by a handle projecting from the outside of the drum, the coil of which fits into a catch. There are two brakes; one stops the loose drum when adjusting the amount of rope to be paid out; the other, which is used for stopping the wheel, works on a wooden disc placed between the rope drums and the water wheel. The journals of the main shaft project from a cross formed by two plates of cast iron intersecting at right angles, and surrounded by a ring; the arms of the cross are sunk into mortices in the wood, the ring forming an outside tire. This kind of journal is called a "kreuzzapfen."

Diameter of wheel, 29 feet 3 inches.
Breadth of face, 5 feet 6 inches.
Diameter of rope drums, 8 feet 6 inches.
Diameter of brake wheel, 12 feet.
Square of shaft, 1 foot 11 inches.
Diameter of journals, 6 inches.

No. F. 8.—Cornish Water Whim.

Scale, $\frac{1}{12}$th. 1 inch to 1 foot.

This is driven by an overshot water wheel, carrying a spur wheel of 36 teeth, which gears into a pinion with 16 teeth on an intermediate shaft, whose journals are made to slide laterally in their bearings. Two bevil wheels are fixed on to this shaft at a distance from each other, somewhat greater than the diameter of the horizontal mitre wheel on the upright shaft of the whim. By means of the reversing lever, the horizontal shaft can be moved sideways, so as to cause one or other of the two lower mitre wheels to drive that on the drum shaft, the left-hand one producing forward, and the right-hand one backward motion. The drums are intended for flat ropes, which are guided by a frame or cage with six wooden arms, set in cast-iron seating rings resembling those of the water wheel. The vertical shaft carries a second mitre wheel, which gears into a smaller one on a shaft carrying a small fly wheel, serving as a brake drum. A strap on the brake shaft drives a pulley on a small shaft close to the ground, which lifts a weight passing over a roller at the top of a signal board. The path of the weight is proportional to that of the kibble in the shaft, so that the position of the latter is constantly shown by the place of the weight on the board. The buckets of the water wheel are made of a single board, an imperfect construction giving cells of small capacity and now rarely employed. The load drawn at each ascent of the kibble is about $3\frac{1}{2}$ cwt.

No. F. 9.—Saxon Turbine Whim.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

This model represents the system of winding adopted at the mine of Oberes Neues Geschrei, near Freiberg in Saxony. The engine driving the whim is a turbine on Schwamkrug's principle, which differs from the earlier wheels of this class by having the water admitted through a small part of the circumference only, instead of all round, as well as being placed vertically, or with a horizontal shaft, instead of the vertical one which is generally employed for turbines. The effect of these alterations is to increase the size of the wheel, as compared with those in which the water is passed through all the buckets at once, and to diminish the amount of intermediate gearing necessary for reducing the speed of the wheel to that of the rope drum. The wheel has two rings of buckets, which are curved in opposite directions, each ring having an independent sluice box; the right hand one produces forward motion, the left one backward motion of the rope drum. The water is admitted to the wheel in a single jet in a direction tangential to the curve of the bucket. The mouth of the sluice is formed of two curved plates, the front one which is moveable about a fixed centre, forming a lip which is in contact with the hinder plate when the water is shut off, but is nearly parallel to it, when the sluice is fully open. The ring of buckets is attached by one side to a cast-iron wheel with a broad cylindrical tire, forming the brake drum, which is supported by six arms on a hollow cast-iron shaft. This shaft carries a pinion with 29 teeth, which drives a spur wheel with 108 teeth on an intermediate shaft, having a pinion of 27 teeth on it gearing into a wheel with 103 teeth on the whim shaft. The rope drums are cylindrical, with cast-iron frames, the ropes wind on a thin wooden packing. The right-hand drum is not keyed fast on the shaft, but is connected with it by a coupling bolt passing through an eye in the frame, into one of three sockets on a triple-armed crank fixed to the shaft.

The loose drum has a special brake, to be used when adjusting the amount of rope out, which can be varied by any quantity not less than one-third of the circumference.

The whole of the machinery is underground, the motion of the wheel being governed by the banksmen at surface by three rods, of these—

No. 1 is the forward sluice rod.

No. 2 the backward sluice rod.

No. 3 the brake rod, for the wheel.

No. 4 works the tipping gear for emptying the tubs.

The brake on the loose drum can only be applied from the engine room underground. The direction of the ropes is reversed by a pair of cast-iron guide pulleys at the surface. The shaft is sunk on the vein, dips at an angle of 70°; the tubs run upon rollers between wooden guides; they carry a load of about 8-cwt. when filled.

The wheel is worked by a column of water 97½ feet in height, with a discharge of 75 cubic feet per minute.*

* Jahrbuch für den Sächs, Berg and Hullermann, 1856.

No. F. 10.—Impact Water Whim. By Capt. Samuel Reid.

This is a project for a small wheel, with flat radial blades, to be driven by the shock of a column of water. The axle is horizontal, and furnished with six radial paddles or float boards. The water is laid on at two points of the circumference, 45° on either side of the vertical line, through two branches from the vertical pressure column, the stream being directed through one or other of these passages by a cock at the base of the main pipe. The right-hand passage serves for forward; and the left hand for backward motion. The shaft of the wheel carries a spur wheel with 50 teeth, which gears into another with 100 teeth on the whim shaft. This kind of wheel is occasionally used in the western states of America for driving small saw mills, and economises but a very small proportion of the entire mechanical effect of the water.

No. F. 11.—Steam Whim at East Wheal Crofty Mine, Cornwall.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

This model shows the arrangement commonly adopted in Cornwall in winding from shallow shafts by steam power. The engine-house is placed near the centre of the ground, the outer end of the beam, the connecting rod, and the crank, being the only exposed parts of the machinery. The drums on which the drawing chains are received are fixed horizontally on a vertical shaft which receives motion from the engine by a horizontal bevil wheel at the lower end gearing into a similar wheel of equal diameter placed vertically and at the end of the fly wheel shaft. The load is drawn by single link iron chains. The receiving surface of the drums is packed with wood, forming a cylinder of 4 feet in diameter.

The chains are in single lengths, one for each shaft; the ends are carried over guide rollers and hang down the shafts, having the kibbles attached to them by hooks and yokes. Each chain is carried twice round its own section of the drum, but is not made fast to it. The diameter of the path of the crank, probably equal to the length of stroke in the cylinder, is five feet. The wooden drum is surrounded by a skeleton cast-iron frame or cage with projecting horns, for keeping the chains in their proper places. The actual distance of the two shafts from the engine, are 35 fathoms, and 24 fathoms respectively.

The ores are brought up in wrought-iron buckets or kibbles, which are drawn through the shafts without the use of guide rods. The mouth of each shaft is closed by two trap doors with narrow channels in the middle for the passage of the chains; they rest against inclined seats, and are lifted by the ascending kibble when it comes to the surface. The average diameter of the round iron bars of which drawing chains employed in Cornwall at the present time are made is about $\frac{9}{16}$ of an inch, for deep mines with steam whims, or tapered chains are sometimes used, in which part is of $\frac{1}{2}$ inch and part of $\frac{11}{16}$ of an inch diameter; the larger size of three-quarters of an inch is but rarely used. The average weight of the kibble when empty is from 6 cwt. to 10 cwt.; the load is from 5 cwt. to 7 cwt. The working speed in shafts of varying inclination sunk on the vein is from 150 ft. to 170 ft. per minute; a much higher speed may be allowed in shafts where skips or boxes travelling on wooden rods are employed.

No. F. 12.—Model of the Surface Arrangements of a Newcastle Coal Pit. Presented by Mr. John Wales.

Scale, $\frac{1}{24}$. Half an inch to 1 foot.

This model represents the drawing engine and the arrangements for screening and loading the coals usually adopted in the large collieries in Durham and Northumberland, where the coals are sent away by railways, either directly to market, or to the shipping places on the rivers. The different parts are distinguished by letters corresponding with those on the engraved plate on the table.

A is the winding engine, it is direct acting, with a vertical cylinder, worked by high pressure steam without condensation, having the fly wheel and rope drum shaft placed above it. The piston rod is guided by Watt's double lever or grasshopper parallel motion, in which the head of the rod is articulated to the centre of a short moveable link frame, whose outer ends are connected to two beams oscillating about fixed centres on opposite sides of the engine house. A vertical rod, with tappets for working the slide valve, is attached to one beam while the rod of the feed pump occupies a corresponding position on the opposite beam. The cylinder is supported on a cast-iron pillar at a considerable height above the ground. The exhaust pipe is carried through a cistern from which the feed pump draws its supply, in order to economize a portion of the heat of the exhaust steam. Flat wire ropes are used for drawing; they are guided by flat cast-iron cheeks on the sides of the drums. The same shaft carries a conical drum outside its bearings which works a wagon for lifting the small coal to the screening apparatus. The fly wheel has a wrought-iron band brake extending over nearly half its circumference, which is applied by the pressure of the engine-driver's foot on a treadle projecting above the floor of the engine house.

B, the boilers, two in number, each 30 feet long and 5 feet in diameter, with two parallel fire tubes inside, on Fairbairn's principle.

C, top of the pit. This is a timber platform carried on pillars about 16 feet above the natural surface of the ground. The guide framing of the pit is prolonged for a certain height above it, forming two rectangular divisions for the cages; each side has a pair of catches or keeps for supporting the cages when they are at the surface. The platform for some distance from the pit is covered with cast-iron plates, forming a smooth surface for moving the tram waggons on.

D, the cages. Each of these is formed of three wooden platforms maintained at a fixed distance by wrought-iron pillars at the corners, making two divisions, each holding one of the small railway waggons or tubs, in which the coal is brought from the face of the workings, to the surface. The tubs are locked in position by catches attached to the roof above them.

E, hydraulic apparatus at the bottom of the pit. This is a water balance formed of two vertical cylinders with pistons, standing in communication with each other by a tube. The piston rods are surmounted by platforms for supporting the cages when at the bottom of the pit; the pistons are further counterbalanced by weights, in such a manner, that either platform of the cage may be brought to the level of the floor, without moving the drawing engine at the surface.

F, teaming cradles. These are wrought-iron cages mounted on trunnions, which hold the tubs when their contents are tipped over into the screens.

G, tubs or underground waggons, carrying 8 cwt. each.

H, chaldron wagon, of the capacity of 53 cwt. This is the common pattern in use, on the north-eastern colliery railways, and dates from the time when horse-power was employed for drawing, and the waggons required to be slung for loading ships alongside the so-called drops or staiths; latterly, however, three ton waggons and the large six ton straight-sided trucks, common in the midland districts, have to a certain extent replaced the older form.

J, J, J, J, screens. These are inclined rectangular riddles or grates of parallel iron bars ⅝ inch apart, about 18 feet long, and 6 feet broad; a short length at the lower end is hinged to allow of the slope of the discharging surface being varied. The descent of the coal is regulated by a rectangular door which closes the passage when shut down, and is governed by a handle sliding on an inclined bar attached to the vertical pillars of the staging. The round or large coal is discharged directly into railway waggons; the small coal is collected in hoppers below, the whole of the screens communicating by shoots with the discharge place at K.

J. This is a stage for loading coals not requiring to be screened; they are passed directly into waggons on the railway below through square apertures covered with sliding doors when not in use.

K, small coal box. It has a sliding door with counterbalance weight; the refuse from the screens is loaded into an iron waggon running on an inclined railway, which is lifted by the chain passing over the conical drum on the drawing engine shaft.

L, small coal screens. The waggon discharges its contents through a hinged door in the lower end, which is unlocked as the waggon passes up, by a catch placed immediately below the screens. The second screening establishes three sizes of small coal, which are discharged through the shoots M, N, O, and are designated according to their sizes, as nuts, seconds, and duff or slack, the latter is used for patent fuel or coke making when sufficiently clean.

Since the introduction of machinery for cleaning small coal the price of slack has considerably increased in the northern collieries, as the power that it possesses of caking or binding together when heated renders it available for the manufacture of coke.

PIT FRAMES FOR COLLERIES.—CAGES, GUIDES, AND SAFETY CAGES.

No. F. 12*.—Model of Cages at Cowden Colliery.

No. F. 13.—Model of Pit Frame and Cages, by Mr. T. Y. Hall.

No. F. 14.—Flat Rope Pit Frame, Newall & Co.

No. F. 15.—Round Rope Pit Frame, W. H. Jordan.

NO. F. 16.—FORSTER'S CAGES WITH IRON GUIDES.

NO. F. 17.—WHITE & GRANT'S SAFETY CATCHES.

NO. F. 18.—OWEN'S SAFETY CAGE.

NO. F. 19.—SAFETY CAGE.

NO. F. 20.—SAFETY CAGE AND DISCONNECTING CATCH. J. K. HAMPSHIRE.

NO. F. 21.—CALLOW'S SAFETY CAGE.

NO. F. 22.—PAULL'S SAFETY CAGE.

NO. F. 23.—VAN DER HECHT'S PARACHUTE DES MINES OR SAFETY CAGE.

NO. F. 24.—BLEE'S SAFETY BUCKET.

NO. F. 25.—BENNETT'S SAFETY SKIFF.

The greater number of the models under the above heading are arranged along the northern wall of Room B. The safety bucket used in Cornwall, No. F. 25 is in the other room. No. F. 12* is under the same case with the model of a Newcastle coal pit bank in the museum. Pit frames of the simplest construction are represented in the models of the steam whim at East Wheal Crofty, No. F. 11, the common horse whim, No. F. 4, and the improved horse whim, No. F. 5; in each of these instances the guide pulleys for changing the direction of the ropes from the horizontal drum to the vertical line of the shaft, are attached to a cross bar on the top of a pair of simple shears or door post frames, no trussing or diagonal bracing being necessary, in consequence of the small elevation of the guide pulleys above the surface of the ground. In the Saxon mines, where a house with walls of solid masonry is usually built over the mouth of the shaft, the guide pulleys are carried on transverse timbers, resting on the horizontal beams of the roof trusses. In collieries however, more complex arrangements are necessary, as greater head room is required, partly from the fact that the guide rollers are of larger diameter, and partly from the greater speed at which the load is drawn up, requiring a certain extra height for stopping and reversing the motion of the cage. This gives rise to shear frames, built up of trussed beams with diagonal bracings, with various systems of stiffening and bracing between the uprights. In collieries where direct acting engines, with vertical cylinders, having the rope drums overhead are used, the upright legs are tied back by diagonal beams to the engine house wall. Examples of this construction are shown in the model of the Newcastle coal pit, No. F. 12, and Shipley colliery, No. 2. In a few instances a further precaution is adopted by the use of striking off and supporting catches, which disconnect the cage from the drawing rope in case the engine is not stopped in time, and leave the load suspended on the guides by the action of safety catches.

No. F. 13.—Model of Pit Shaft with Cage and Guides. By Mr. T. Sopwith.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

This model was made from a design by Mr. T. Y. Hall and represents the earlist kind of cage introduced in the North of England collieries, to replace the older system of loose tubs or corves. The cage is a square frame of wrought-iron, stiffened by rectangular cross bars on the top and on two of the sides, with a wooden floor laid with tram rails for holding the underground waggon or tub. The drawing rope, a flat hempen one, is fixed by a spring hook to a piece of single link chain, to which the cage is attached by four shorter chains attached to the top corners. The pit guides or conductor rods are plain iron bars attached to the faces of continuous upright beams, bound together at intervals by transverse pieces, upon which the cage is guided in its passage by channel irons of ⊔ section projecting from opposite sides. The guides are continued on a lighter framing above the surface, but are placed on the sides alternating with those to which they are affixed in the pit. The ropes are led over cast-iron guide pulleys to the drums or cages on the fly-wheel shaft of the engine. The framing carrying the pulleys is formed of a pair of tall shear legs, slightly inclining towards each other, and united by transverse bars at the top, and at the ground level. The bearings of the pulleys are placed on short horizontal pieces which project at right angles from the top of the frame and are supported at their extremities by diagonal struts whose inner ends bear against a transverse bar parallel to the top one, and a short distance below it. The whole frame is tied back by two long diagonal beams, stayed at about mid-length by a pair of shorter inclined beams.

No. F. 14.—Pit Frame with Flat Rope Pulley. Presented by Messers. Newall & Co.

This is a frame to be used with flat wire ropes in a colliery having two shafts with a single cage in each, similar to those of Shipley colliery, No. 2. The guide roller is of considerable size, whose rim is a deep channelled ring of cast iron, with rounded bosses at the back, into which are fitted the ends of twenty-four wrought-iron arms, springing from a central boss of a dumb bell-shaped section. The shaft is eight-sided, fitting into a socket of corresponding form in the boss of the guide wheel, which is lined with a wooden packing, and is secured by four wedges driven in on alternate faces of the octagon; the journals run in brass bearings. The framing is distinguished by having no top transom or cross bar to the principal shear frame. A cross bar, uniting the two inclined legs at about one-third of their height from the ground, carries two parallel vertical beams, with horizontal longitudinal bearers projecting at right angles from their tops. The horizontal pieces carry the bearings of the pulley, and are supported on the outer side (in front of the frame) by diagonal struts springing from the faces of the uprights, immediately above a pair of transverse horizontal bars, which bind the whole of the standing parts together, placed about midway between the top of the frame, and the cross bar carrying the two uprights. The whole of the upright part above described is braced back by two long inclined bars fixed, at the top to the sides of the inclined legs, and at their lower ends to a transverse horizontal beam, which is supported on struts a few inches above the ground, at a distance of several yards from the pit.

No. F. 15.—Pit Frame. By Mr. W. H. Jordan.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

The principal legs and long back rods in this model, are united together into two triangular frames by horizontal beams laid on the ground parallel to the line of the rope leading from the pit to the drum. The bearings of the two guide rollers are carried on four parallel horizontal beams, united into a kind of grating by cross pieces at either end; this grating being supported under the centre of each bar, by the apices of the principal triangular frames, and two shorter intermediate frames, the latter being carried on horizontal bars, uniting the principal legs and the back braces together transversely; these intermediate bars are supported on a bracing of diagonal pieces. The top frame is tied to the large hinder braces by wrought-iron tie rods, acting against short diagonal struts. The guides or conductor rods for the cages are carried up to the top of the frame, and a striking-off piece for the disconnecting catch is fixed to the under side of the front cross bar. The guide rollers have deep V grooved rings, being intended for use with round wire ropes, supported by wrought-iron arms arranged in two series, one comprising plain straight rods springing from the centre of the cylindrical boss, which alternate with the others, formed of pairs of rods inclining together from the opposite sides of the boss, and meeting under the centre of the back of the ring. The pit is of an elliptical form, giving room for two cages, which are made of wood, closely boarded on two sides, with semi-cylindrical arched heads or bonnets; and of sufficient size to carry one small tram waggon. The safety catches, placed immediately below the guide channel-irons, consist of levers with plain gripping jaws on the shorter arms, which are kept away from the conductor rods, as long as the chains by which the cage is attached to the rope are drawn taut; and are pressed home against the sides of the rods by the action of vulcanized india-rubber springs, as soon as the chains slacken, whether from breakage of the rope, or any other cause. The roof over the cage is intended to protect the contents from being damaged by the falling rope if a breakage takes place. A cylindrical rope drum is placed within the engine house attached to the model, but no special details of the construction of drawing mechanism are indicated.

NO. F. 16.—CAGES. BY MR. G. B. FORSTER.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

This is a system to be used in drawing large loads; the cages carrying four tram waggons on two floors, are made of flat wrought-iron bars with diagonal bracings, with wrought-iron roof and platforms, and are suspended by six short chains, one from each of the four corners and two from the centres of the long sides. These chains are united together by a wrought-iron eye bolt, to which the end of the drawing rope is made fast. The conductor rods are applied on one side of the cage only, that is on the outer long side; instead of wooden rods, a pair of single-headed or broad foot rails are used; they are kept parallel by cross bars or sleepers, with chairs or clips holding the lower flanges, fixed to wooden bearers placed 6 feet apart through the entire depth of the pit. The cage is guided on the top webs of the rails by three pairs of curved or crescent-shaped slides, rivetted on to the side bars at the levels of the roof and the two platforms respectively. A round iron-wire rope is used, capable of drawing a load of about 95 cwts.

No. F. 17.—White and Grant's Patent Safety Catch, with Disconnecting Hook.

Scale about $\frac{1}{6}$ of full size.

The cage in this model is a simple stirrup frame, with a platform laid with rails for carrying two wagons side by side. The top cross bar is of a double T plan, the central part of the transverse webs forming a guide against the inner faces of the rectangular conductor rods, while the projecting ends are bored through, forming sockets for a pair of horizontal shafts, to which the safety catches are fixed. Each of these shafts has a grooved wheel keyed on to it at the centre, over which runs a chain for turning it outwards when the engine is drawing; a coiled steel spring turns it in the opposite direction. The catches are attached outside the bearings of the shaft; they are eccentric discs, prolonged in to curved smooth tails; a portion of the circumference near the greatest diameter is scored with a number of sharp teeth parallel to each other. When the rope is drawing, the chains turn the catches outwards, the counter springs being compressed, and the smooth tails guide the cage on the sides of the conductors; but when the traction ceases, the springs expand, and, turning the catches, bring the toothed parts of the discs into contact with the rods, and taking firm hold, bring the load to rest immediately. The chains for lifting the catches are attached to a square bar, passing through a guide socket of corresponding section fixed above the top bar of the frame. The end of the rope is fixed to a plug with a rectangular slot cut through it, which fits into a similar socket above the guide bar. The plug is locked in position by a hook with a projecting tail. The disconnection of the cages in case of overwinding, is effected by the projecting tail striking against the top of the framing, when the hook is drawn backward in a manner exactly similar to the lifting of the hammer of an ordinary gun lock.

No. F. 18.—Owen's Patent Safety Cage.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

In this model the cage is a simple frame of four upright bars, united by transverse pieces carrying two plain channel guides on each of the conductor rods. A pair of wrought-iron plates, 11 inches deep and half an inch thick, are attached to the sides of the cage midway between the guides; each carries two levers, whose shorter arms are terminated by edges or combs of fine teeth, for fitting into the conductor rods. The longer arms of the levers are connected by means of a system of jointed rods with the drawing rope; the teeth are forced into the rods when the rope slackens by the action of bent springs, which press down the longer arms. The distance through which the levers move is determined by curved guard plates with stops covering the longer sides. This apparatus has been adopted in several collieries in Lancashire. In one case a load of two tons, moving at the rate of 10 feet per second, was brought to rest in a distance of three feet, after the breaking of the rope; in another case loads of 15 cwt. and 41 cwt. were stopped after a fall of 1½ and 2½ inches respectively.

No. F. 19.—Safety Cage and Disconnecting Hook.

This cage is very similar to the last, having a pair of toothed catch levers on each side, which are lifted by the rods to which the rope is attached, and are brought into action by a curved bar spring placed transversely and below the roof of the cage. The disconnecting hook by which the rope is attached to the cage, is formed of two hinged plates, increasing in width from above downwards, and terminated by straight pieces with studs projecting at right angles. The top of the cage carries a square link, into which the straight ends of the hook are fitted; a spring between the two plates keeps the projecting studs pressed out into notches cut into the sides of the link. The drawing rope passes through a ring fixed to the top of the pit framing, whose diameter is not sufficient to allow of the plates passing through, as long as they are pressed asunder by the spring; but if the engine is not stopped in time, the plates are driven together by the pressure of the ring, which compresses the spring, and the link falls off, leaving the cage disconnected, to be supported by the catches.

No. F. 20.—Safety Cage, with Disconnecting Catch. By James Kaye, Hampshire, Whittington Collieries, near Chesterfield.

The cage in this model has two platforms for carrying tram waggons, the catches are of the lever form similar to those in Nos. F. 18, 19, but they have plain cutting edges instead of teeth, the springs for applying them are plain curved bars fixed below the upper platform. The disconnecting hook is a very simple arrangement, which is kept closed when in use by the weight of the cage; it consists of two bars of wrought iron jointed together like a pair of scissors; the lower ends are connected by rings with the drawing bars of the cage; the upper ones are bent round into hooks, with overlapping jaws, which pass through a link at the end of the rope, forming a loop when closed. Each hook has a projecting tail, which, when the rope is overwound, strike against the top of the framing, and drawing the two sides apart, disconnect the rope from the cage.

No. F. 21.—Calow's Safety Cage, with Disconnecting Catch.*

This cage is distinguished by the peculiarity of the catches not coming into action during any temporary slacking of the rope, but only when the load is actually falling. The disconnecting hook is similar in principle to that of No. F. 19; to the end of the rope is attached a pair of hinged bars with notched ends; these notches bear against the sides of a curved link frame, by means of an inner pair of similarly hinged bars attached to the top of the cage, which are pressed outwards against the former ones by an india-rubber spring. The cage has a tall pyramidal roof, underneath which the mechanism of the catches is placed. They are worked by a coiled spring, which is compressed between a loaded cap and the cross bar carrying the top pair of guides, when the rope is drawing; but expands, and drives out the toothed arms of the catch levers, when the rope is disconnected.

No. F. 22.—Safety Cage. By Mr. Paull, Moor-master, Alston.

This cage differs from all the preceding ones by the absence of springs from the safety apparatus, the catches being applied by the weight of the loaded tub. The framing to which the guides on the conductor rods are affixed, is united by transverse round bars, serving as the centres for the catch levers; the loaded waggon or tub stands on a platform, which is suspended by rods from the longer arms of the catch levers, as are also the drawing chains.

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* Smyth in Johnson's Record of Exhibition of 1862, p. 163.

When the rope is drawing the levers are turned upward, the wagon being lifted into its highest position. When the rope breaks the platform falls and brings the cutting ends of the lever against the rods.

No. F. 23.—Van der Hecht's Safety Cage or Parachute.

This model represents an early form of safety cage constructed in Belgium. The catches are two jointed wooden beams, with toothed pieces of steel fixed in grooves at their outer ends; they are pressed out by two bar springs, fixed one on each side, which act on a central bolt, and are lifted by a long link at the end of the chain which draws on the same bolt. The ends of the top cross bar of the cage are provided with friction rollers, which run on the inner faces of the conductor rods, instead of the channel guides used in all the preceding examples.

No. F. 24.—Safety Bucket for Mines. By Robert Blee, Redruth.

In this model, which was exhibited at the Exhibition of 1851, a rectangular bucket or kibble is represented, having two arms with triangular heads or crooks projected from a cross bar at the top. The crooks are driven outward by springs when the rope slackens, so as to take hold on the staves or rounds of two continuous ladder ways fixed opposite to each other on the shorter sides of the rectangular shaft. The opposite side of the model shows a modification of the same principle, in which a series of triangular steps corresponding in form to a reversed position of the crooks are substituted for the ladder ways. This system is not known to have been adopted in practice.

No. F. 25.—Bennet's Patent Safety Skiff.

Scale, $\frac{1}{5}$. 2·4 inches to 1 foot.

This is an application of the safety catch, to the bucket or kibble employed in metalliferous mines, in which the shafts are sunk at irregular inclinations. The skiff is a wrought-iron box of rectangular section, obliquely cut off at the mouth, with the bottom also put on obliquely and nearly parallel to the mouth, giving it a rectangular front and back, and sides of a trapeziform figure. Two cross bars with projecting ends are fixed to the back of the skiff, forming guides in the vertical parts of the shaft; in the in-

clined parts, it is supported by two pairs of large rollers, which run on the faces of the conductor rods. The drawing chain is fixed to a wrought-iron crutch with forked ends, which are connected with the skiff, by cross bolts passing through elliptical holes in two pieces projecting above its top edge. The safety catches are toothed levers, working on the same centres, as the top pair of guide wheels; they are drawn off the conductors by connecting rods articulated to the centre bolts of the drawing crutch, and are made to take hold, by a pair of coiled springs bearing against two pieces of angle iron projecting from the centre of the sides. The front of the skiff is divided into two parts, which are hinged together by a transverse bolt; the lower part forms a door opening outwards, giving an aperture for discharging the contents equal in area to the mouth; by this system the necessity of tipping the bucket for discharging the load is avoided. This system is in use at South Wheal, Frances' mine, in Cornwall. The same class of skiff is shown in the horse whim, No. F. 5, but without the safety catches.

No. F. 26.—Underground Winding Machine. By Mr. Anthony Rouse.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

This contrivance has been in use at the mine of Wheal Friendship, near Tavistock, since the year 1841, for drawing materials from one level to another, the power being taken off the main pump rods, which are moved at an uniform velocity by a water wheel. The drawing chain is received on a cylindrical reel or drum with projecting flanged sides; a spur wheel with 24 teeth is fixed on the same shaft. One of the beams carrying the bearings is moveable about an hinge joint at one end, so that the drum may be lifted by a system of levers in order to bring the outer flange or cheek in contact with a fixed brake-block attached to a cross timber over head. The large spur wheel, No. 1, on the drum shaft forms the uppermost of a train of three, placed in the same vertical plane, the lower ones, Nos. 2 and 3 being equal in diameter, and somewhat smaller than the top one; they are supported on horizontal axes, to which they are connected by ratchet couplings placed within their bosses. The same shafts carry two other wheels, Nos. 4 and 5, which are moved by a rack fixed to the pump rod. The ratchet wheels have each three spring catches or pauls, and are arranged to work in opposite directions, so that the upper wheel turns with its shaft forward, but runs loose

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when the racked wheel is turned backwards, and the reverse holds good with the lower one. The effect of these arrangements is as follows:—When the rod makes its up stroke the top outer wheel No. 4 carries No. 2 round with it, which acts on the large wheel No. 1 on the drum shaft, at the same time No. 3 is being turned by No. 2 in the direction in which it revolves loosely, and therefore moves independently of No. 5, which is moved by the racked rod in the opposite direction. At the change of the stroke on the descent of the rod the lower wheel No. 5 becomes the driver, carrying No. 3 round with it. No. 2 now runs loose, but from its position forming the intermediate wheel in the train, and drives the large wheel on the drum in the same direction that it did during the up stroke. It will thus be seen that whatever wheels are in gear the drum always turns in the same direction, so that the machine cannot be made with two kibbles to wind in both directions, one being raised while the other is falling. It is therefore necessary to sling the drum, and to provide disengaging gear for sliding the outer wheels out of gear with the rack; the kibble is then lowered with the help of the brake. There are three of these machines in use, placed between 180 and 190 fathoms below the surface; they draw a net load of about 5 cwt. through height of from 40 to 60 fathoms.

Nos. F. 27–43.—Drawing Chains used in South Staffordshire.

The chains in this series are of three different characters, viz., with long links of a rectangular section throughout, as in No. 1; with long links, partly of rectangular and partly of circular section, as in Nos. 2 to 6; and ordinary oval link chains of round iron, as in Nos. 7 to 16. No. F. 27 is called a flat rivet chain; it resembles a watch chain, in which rings are substituted for plate links; it is made of alternate series of three and two links placed side by side, each link is $4\frac{1}{4}$ inches in extreme length, and $1\frac{1}{4}$ in breadth, and is made of rectangular iron $\frac{9}{16}$ of an inch broad and $\frac{1}{4}$ inch thick; the latter series are covered by side plates, giving bearings for the rivet heads on the bolts, by which the two series are articulated together, the weight of the chain is 21 lbs. per yard, and its breaking strain is $21\frac{1}{2}$ tons. Nos. F. 28, 29, 31, and 32, are wood and stub flat chains made of three long link chains placed side by side, the inside of each link being filled up with a piece of hard wood secured by nails driven in at the edges. The sides of the links are flat, their ends are of circular section, the stubbed parts are joined together by links of a similar form, but only about half the length, the narrow part of the iron being turned outwards, the broad part forming the thickness of the chain; they are all precisely similar in construction, but vary in dimensions as follows:—

No.	Breadth of flat of Link.	Breadth of Chain.	Thickness of Chain.	Weight, per yard.	Breaking strain.
	"	"	"	lbs.	tons.
F. 29	$\frac{5}{8}$	$4\frac{3}{8}$	$1\frac{5}{8}$	28	30
" 30	$\frac{9}{16}$	4	$1\frac{1}{2}$	23	23
" 31	$\frac{1}{2}$	$3\frac{5}{8}$	$1\frac{3}{8}$	18	$18\frac{1}{2}$
" 32	$\frac{7}{16}$	$3\frac{1}{4}$	$1\frac{1}{8}$	15	$12\frac{1}{2}$
" 33	$\frac{3}{8}$	3	$\frac{7}{8}$	10	$10\frac{3}{4}$

The following are the dimensions of the round chains:—

No.	Diameter of Iron.	Thickness. of Link.	Weight, per Yard.	Breaking strain.
	"	"	lbs	tons.
F. 34	$\frac{5}{16}$	1	$2\frac{1}{2}$	$2\frac{3}{4}$
" 35	$\frac{3}{8}$	$1\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{1}{2}$
" 36	$\frac{7}{16}$	$1\frac{3}{8}$	6	$5\frac{3}{4}$
" 37	$\frac{1}{2}$	$1\frac{5}{8}$	8	8
" 38	$\frac{9}{16}$	$1\frac{3}{4}$	10	10
" 39	$\frac{5}{8}$	2	12	$12\frac{1}{2}$
" 40	$\frac{11}{16}$	$2\frac{3}{16}$	14	$14\frac{1}{2}$
" 41	$\frac{3}{4}$	$2\frac{7}{16}$	17	19
" 42	$\frac{7}{8}$	$2\frac{11}{16}$	21	22
" 43	1	$3\frac{3}{16}$	27	$26\frac{1}{2}$

The working load of a chain is from $\frac{1}{4}$ to $\frac{1}{6}$ of its breaking strain. By the Act 23 & 24 Vict. c. 151, single link chains are not allowed to be used as drawing chains in collieries.

Hempen drawing ropes—

Round ropes:

No. F. 44	4 inches (circumference),	weight	$4\frac{1}{2}$ lbs. per fathom.
" 45	5 "	" "	$5\frac{3}{4}$ "
" 46	$6\frac{1}{2}$ "	" "	$9\frac{3}{4}$ "
" 47	$7\frac{1}{2}$ "	" "	13 "

Flat rope:

No. F. 4. 85 inches wide, $1\frac{1}{2}$ " thick } " 25 lbs. "

No. 49. Wrought iron cap and coupling bolt for flat hempen rope.

Flat wire rope:

No. F. 50. $3\frac{3}{8}$ inches broad, $\frac{5}{8}$ " thick } weight $15\frac{1}{2}$ lbs. per fathom, working load 93 cwt.

No. F. 51.—Wire Ropes, made and presented by Messrs. R. & S. Newall & Co., Gateshead-on-Tyne.

This series is fixed on a large board placed above the fire-place in the large room A. It includes examples of all sizes of round ropes from the smallest signal cord to the largest suspension-bridge cable, together with two flat colliery ropes, and several kinds of splices and eyes adapted for ships' standing rigging. In addition there are specimens of the principal telegraph cables made by this firm, and three remarkable wire-rope rings or grummets.

No. F. 52.—Model of Self-acting Inclined Plane at Upleatham, in Yorkshire, presented by Messrs. J. & J. W. Pease, & Co.

Scale, about $\frac{1}{18}$ of full size.

The Upleatham mines are situated near Guisborough, in the North Riding of Yorkshire, in one of the lower northern escarpments of the Cleveland hills. The ore, which belongs to the Middle Lias or Marlstone series, is a carbonate of iron containing from 25 to 35 per cent. of metallic iron, with a proportion of silica larger than is usual in the class of argillaceous ironstones; it also contains large quantities of fossil shells of the genera Pecten and Avicula, and is coloured green, probably by the presence of a hydrated silicate of protoxide of iron. Under the name of the Main Cleveland seam the deposit has been traced over a large extent of country with a variable thickness. At Upleatham (as is shown in the section placed above the case) it forms a bed of from 12 to 14 feet in thickness, divided into two unequal parts by a parting from 6 to 7 inches in thickness, containing a large quantity of iron pyrites known as the sulphur band, which is used for the manufacture of sulphuric acid. The upper bed having a thickness of 3 feet is left to form the roof of the workings; the remainder of the seam, measuring from 8 to 10 feet, is taken away by a kind of pillar working, as shown in the part of model nearest to the wall. The headways or galleries are driven 9 feet wide and 90 feet apart, from which at intervals of 30 feet boards, or cross levels 15 feet wide are excavated, giving rise to a series of pillars 90 feet long by 30 feet in width, which are subsequently removed with a loss of only 10 per cent. of their contents; so that under the most favourable circumstances the whole of the stone, to within 7½ per cent., can be brought away.*

At Upleatham the outcrop of the bed extends in a nearly straight line east and west along the face of the hill

* J. T. Bell History of the Trade, &c., of the Tyne, Wear, and Tees, p. 62.

for more than a mile, the principal headways being driven at right angles to the cliff towards the dip of the seam, The ore is drawn to the surface in small railway waggons called "waggonettes," marked M. in the model, by single strand iron wire ropes, winding on to vertical drums worked by a high-pressure engine at H.

—There are two of these engines on the mine, they are placed about three-quarters of a mile apart, and are united together by a railway, along which the waggonettes are drawn by locomotives to the head of the incline; these lines are all of 20 inches width of gauge.

The loaded waggonettes after passing over the weigh-bridges at A are taken to the tipping cages C and D; these are fixed on either slope of a deep level cutting at the head of the incline. The cage is a shallow pan of wrought iron closed in from slipping on a central pivot, and having a brake drum and strap brake on one side below it; the one is discharged into an inclined wooden trough lined with wrought-iron plates, and closed at the lower end by a door turning about a horizontal axis. Each trough is capable of containing the contents of several of the small waggons, and supplies the larger three ton waggons marked M, on the railway, below. The door at the lower end is opened by the pressure of the masses of ore acting against a counterbalance weight at the end of a lever; the amount of opening is regulated by a drum with a brake strap similar to that on the tipping cradle, which is worked by a handle from above. The loaded waggons are formed into trains and lowered on the inclined plane by the drum F, which has a pair of cast-iron cylindrical barrels, with deep cheeks at the side, forming the discs for the brakes, which are wrought straps applied by a handle in front; the rope drawing the ascending train of empty waggons winds on to one drum at the same time as that lowering the full train, is paid off from the other. The incline is connected by a short line of about a mile in length with the Saltburn branch of the Stockton and Darlington Railway, near Redcar, giving access to all the iron works on the shores of the Tees in the neighbourhood of Middlesborough, and with those on the Tyne by the North-Eastern system of railways.

The amount of Cleveland ore carried on the Stockton and Darlington railway for the consumption of the furnaces in the immediate vicinity of Middlesborough exceeded 500,000 tons in the year 1863.

CRANES, HOISTS, AND LIFTS.

This section includes examples of machines for lifting or lowering weights through small heights.

No. F. 53.—Model of a Crane for Shipping Large Blocks of Stone.

This crane is used at the sandstone quarry of Redhall, near Edinburgh, for loading large blocks of stone into barges on the Edinburgh and Glasgow canal. It is of a very simple construction, being made up of two parallel wooden frames, each having an upright pillar, with a long projecting horizontal arm at the top, which is stayed underneath, at about mid length, by a diagonal strut resting against the upright pillar. The parallel beams forming the pillar are joined at the top by a block of wood with a projecting part, into which the upper journal is bedded. At the outer end of the horizontal arm is fixed an arched piece of iron, carrying the bearing for one end of a long horizontal screw, the opposite end being supported by a framing attached to the pillar. A line of rails is laid along the top of the horizontal beams, upon which a carriage travels whose motion is governed by the horizontal screw above it. The lifting chain is made fast to a hook on the cross bar at the end of the horizontal arm and passes down in a loop with a loose block and hook through two guide rollers on the carriage; the load being lifted by winding the inner end on to a plain windlass barrel, fixed to the inner side of the pillar near the ground. The load is moved along the horizontal arm by the top horizontal screw, which is connected with an upright shaft passing up the middle of the pillar, having a horizontal bevil wheel at the top gearing into one or other, of two vertical wheels by means of a sliding clutch, so as to produce either forward or backward motion. The upright driving shaft is moved by a screw and worm wheel at the bottom. The whole crane is turned about its upright axis by bevil gearing wheels fixed to the lower end of the pillar below the ground level. All the three motions are worked by steam power, by means of the projecting horizontal shafts which in the model have their driving pulleys removed.

Nos. F. 54-55.—Models of Apparatus for Shipping Coal. Presented by Messrs. Vivian and Son.

These are used in loading ships with South Wales steam coal for export, a material which it is necessary to deliver as free as possible from small fragments. In No. F. 54 the railway wagon is run out on to a stage, slung by flat ropes at the four corners, capable of being moved perpendicularly, and guided by slides, fixed to the face of the quay wall. The ropes run over guide pulleys on the top framing, and wind on to cylindrical drums, having other flat ropes on them connected with balance weights, which coil in the opposite direction. The weight of the loaded wagon being somewhat in excess of the counterbalance, the platform descends, winding up the weights as it falls; when the wagon is emptied the preponderance is on the inner side, so that the weighted ropes unwind from their drums, and, by so doing, bring back the platform to the level of the fixed railway above. A pair of large spur wheels fixed to the drums, gear into a pinion on a shaft, carrying two fly wheels, which are provided with wrought-iron brake straps, for regulating the speed of the descending load.

No. F. 55 is a somewhat similar apparatus, in which the coal is contained in a rectangular wrought-iron box, with hinged doors at the bottom, slung at the end of a crane with an expanding jib, which can be drawn up to a vertical position for taking the load off the railway truck, and lowered out over the wharf wall by chain tackles, governed by a combination of balance weights, and a geared windlass, with clutch couplings, fixed below. The latter is used for lifting the load from the truck to a sufficient height to clear the wharf, and the former are used in lowering it into the hold of the ship. There are also fly wheels, with strap brakes, provided for moderating the speed of the descent, as in the former example.

Nos. G. 1–2.—MODELS OF SHIPLEY COLLIERY.

PRESENTED BY MESSRS. WOODHOUSE & JEFFCOCK.

No. G. 1.—General Model of the Underground Workings at the Woodside Pits, Shipley Collieries.

Scale, $\frac{1}{120}$, 10 feet to 1 inch.

No. G. 2.—Model of Surface Arrangements at the Woodside Pits, and Details of the Method in which the Coal is cut.

Scales { for workings, about $\frac{1}{20}$ of full size.
for surface, about $\frac{1}{30}$ of full size. }

The larger model represents a portion of the workings of Shipley colliery, which is situated in the southern part of the Derbyshire coal field, about seven miles north-east of Derby, on the western side of the Erewash valley. The topography of the surface is shown in minute detail. The whole of the ground above the plane of the seam worked is suspended by balance weights at the four corners. The position of intermediate coal seams and other measures being represented in the sections along the edges. The surface represented includes about 500 acres, over which the beds are arranged in a flat basin-shaped form, dipping gently from either side towards the centre, the levels being slightly altered by four nearly parallel faults, crossing the model in a nearly north and south line. The reservoir in the centre supplies the Millbrook branch of the Erewash canal, by which the colliery communicates with the Trent navigation, near Long Eaton. A branch railway from the pits also communicates with the Erewash Valley branch of the Midland Railway.

The coals worked in these pits are the seventeenth and eighteenth seams in descending order, called the "Bottom soft," a house coal, and the "Bottom hard," a locomotive and smelting coal; the former is 3 feet 4 inches thick, at a depth of 227 yards below the surface, the latter is 3 feet thick, and is reached at a depth of 234 yards. The ground is worked from two parallel shafts placed about 40 feet apart, near the northern boundary, and on the lowest part of the basin. A principal road or level, divided by pillars of solid coal on either side from the goaves or waste ground which has been wrought out, extends to the northern extremity of the ground, from which numerous roads diverge at intervals on either side. A road, partly protected by pillars of a smaller size is carried for a short distance along the northern edge of the ground. The coal is got along working faces parallel to the main roadway, and at varying distances from it, the faces being joined together by other faces at right angles to them, and parallel to the subsidiary roads through the goaves or wastes, giving a step-shaped outline to the edge of the whole coal when seen in plan. The coal nearest the shafts has been taken away on one side up to the eastern boundary fault; on the other side a pillar of an irregular form has been left to support the dam of the canal reservoir. A constant circulation of fresh air is maintained through the workings by the exhausting action of a furnace placed near the bottom of the northern pit, which draws air from the surface down the southern or downcast pit. The air so drawn is carried in a principal current passing along the main roadway to the southern, where it is split into two branches, going right and left, after several subsidiary currents have been taken off at intermediate points. The first of these branch currents diverges opposite to the stables, passing through the goaf, till it reaches the pillar under the dam head, where it divides into three branches, which pass by nearly parallel roads to the most distant western faces, returning, as shown by the red arrows, partly by the road along the north-western boundary, and partly along the line joining the westernmost working face, with that next in advance, with a return through a diagonal road, also carried through the dam head pillar, with a crossing about mid-way, by which the intake air is passed above it. The remaining works on the western side receive air from three subsidiary currents, as well as from the final split at the end of the main road; the whole of the return air is passed through the diagonal road last mentioned. The eastern workings are ventilated by two parallel currents, and the main split at the extreme end. The latter passes round the extreme edge of the whole coal, the former are carried by parallel roads through the goaf, and uniting at the edge of the working face they are returned by a zigzag road through the goaf, passing for a short distance of the latter part of its course parallel to the main roadway. A part of the ground worked out near the eastern boundary fault is left without direct air circulation. The furnace is placed on the north side of the upcast pit, communicating with it by a short steep flue or drift; it is fed with air from the downcast. The return air from the western side is carried out through a longer drift of less inclination; that from the east side is brought in by a corresponding drift on the other side. The mode adopted for taking away the coal is shown in the left-hand part of model No. 2; it is to a scale of three-eighths of an inch to a foot. The seam is 40 inches in thickness, between a floor of fire-clay, and a roof or cover of black shale. The whole of this thickness, however, is not taken away. An upper part of 6 inches, called the roof coal, not being worth working, is left behind. A triangular groove, having a base of 30 and a height of 9 inches, is cut into the lower part of the seam along the working face, the overhanging part being supported during the cutting, by timber props, placed diagonally, which are removed when the cut has been carried along the face to be brought down; the coal falls, either by its own weight or by wedging or blasting in the higher part. The roof of the excavation is kept up by pack walls, made of the waste material, in front of which a double row of timber props is placed temporarily along the working face. The rows are about 2 feet apart; the props in each row being about 5 feet from one another, and placed in alternating series with those of the other row. The coal is carried in waggons, running on a way of 20 inches gauge, laid with light bridge rails; horse-power being employed for the traction underground.

The surface arrangements are shown in the second part of model No. 2, on the scale of half an inch to the foot, or $\frac{1}{24}$ of the real size. The pits are placed 30 feet apart, near the centre of a platform about 90 feet square, raised from 5 to 8 feet above the surface of the ground, formed of the spoil from the sinking, protected by retaining walls at the edges. The platform is laid with several parallel lines of rails with turn tables and reversing plates for conducting the wagons brought from underground, to the places for filling the large trucks on the surface. The line with sidings running parallel to the long edge of the model is the branch from the Erewash Valley section of the Midland Railway; the other one which crosses it at right angles, is a short railway for carrying coals to the shipping place at the head of the canal (see model No. 1). The pits are of circular section, 10 feet in diameter, and lined with brickwork, with a single pair of parallel wooden guides in each. The cage is a rectangular platform or grating of parallel iron bars, capable of carrying one of the small underground wagons, with two vertical side bars, which are strengthened by diagonal struts, and united together by a cross bar at the top, to which is attached a short V chain hanging from the end of the flat hempen drawing rope. The side bars carry channelled iron guides which run on the conductor rods. The motive power is supplied by a high pressure non-condensing lever engine of a similar pattern to that in the Newcastle model. The steam cylinder is sunk below the level of the engine-house floor, in order to lower the height of the walls and framings for carrying the winding machinery; it has two eccentrics and a link motion for working the slide valve when drawing coals, as well as a hand lever which is employed when raising or lowering men. The rope drums or cages are fixed to the same shaft as the crank and fly wheel; their diameter when empty is about 10 feet, increasing by the double thickness of the rope at each lap to about 15 feet when filled; each is provided with six pairs of projecting arms called drum horns, for holding the rope when wound up. A balance chain winds on a drum of smaller diameter between those of the drawing ropes; this is a flat link chain with a heavy weight attached to it, laying in a pit at the back of the engine-house; it serves the double purpose of easing the load on the engine when the full cage is starting from the bottom of the pit, and checking its velocity when the weight of the empty cage and rope paid out is in excess of that required for counterbalancing the load during the last part of its ascent. The guide pulleys over the mouth of the pits are of cast iron, 8 feet in diameter, and supported upon simple timber frames 24 feet high, which are connected by diagonal bracings extending back to the walls of the engine-house. The mouth of each pit is surrounded by a protecting fence, or guard wicket, supported on the part of the guides that projects above the surface; it is lifted by the top of the cage to allow of the truck being run out, and falls back again when the empty cage descends. The boiler-house is placed in the lowest part of the ground, and the front wall is united by two short side walls with the face of the retaining wall of the spoil bank of the pit; the space enclosed between them forms a capacious hutch for coals, which are tipped over from the edge of the bank above. There are six arches in the front wall, each being opposite to one of the furnaces. There are six boilers arranged parallel to each other on the same bed; they are cylindrical, with hemispherical ends, and fired from the outside; each is provided with a single loaded safety valve, a float gauge, and a blow-off cock. The steam is collected in a steam pipe running transversely, and connected by a stop valve with each boiler; a parallel pipe with similar valves brings in the feed water. The return air and smoke from the furnace passing through the upcast shaft, is taken off by a short drift below the surface into a parallel pit, and discharged into the atmosphere through a chimney about 30 feet high. A weigh-bridge is placed midway between the two pits, and all the coal is passed over it immediately it comes to the surface.

No. G. 3.—Model of the different methods of Working and Ventilating Coal Mines, constructed and presented by Mr. C. L. Wood, Hetton Colliery, Durham.

This model represents a plain surface of coal without faults, which is in process of removal on four different systems, which are distinguished by the open letters, A, B, C, D.

A is the old method adopted in the Newcastle district, in which the whole of the ground to be taken away is divided into two series of parallel galleries intersecting at right angles, and divided from each other by rectangular pillars of solid coal. This is the so-called board and pillar system, the boards or galleries having been carried up to the boundaries of the ground, the pillars are then taken away in reverse order, that is, from the extremities back towards the shaft. The pillars are left of comparatively small size as compared with those in the next division B; this often gives rise to a creep, or thrusting up of the floor, from the sinking of the pillars under the pressure of the overlying rocks. B is an improved method of working, practised in the mines in the vicinity of Newcastle-on-Tyne, in which a portion of the pillars are taken away at the same time that the whole coal is cut in the advanced workings, a sufficient distance being kept between the two districts, in order that they may be kept isolated, the air in the whole coal workings allowing candles to be used, while safety lamps are necessary in taking away the pillars. The proportion of coal taken away in driving the boards is less than in the former system, as larger pillars are left, which on account of their solidity, are less liable to be injured by creeps.

C is the long wall method of working, in which the coal is taken away in one breadth without leaving any solid pillars. The roadways upon which the coals are conveyed to the shaft are carried through the waste or goaf, the sides being kept up by walls made of the fallen stone left behind in the workings.

D is a modification of the long wall method, in which, instead of taking away the coal along the whole face, transverse lines of pillars are left at intervals, through which the roadways are carried, thus giving a solid support instead of the stone walls used in the former case. It will be seen that in both C and D the working faces are not continued in one line, but are divided by short intermediate faces at right angles, the face nearest to the shaft being kept a little in advance of the one next in succession, and so on with the others.

The area is supposed to be worked from two adjacent shafts placed near the centre; one of these serves as the downcast, for bringing in fresh air from the surface, the other is the upcast, and is provided with two furnaces for drawing the vitiated air out of the workings; the currents follow the direction of the feathered arrows, and are kept to their courses by stoppings inserted in the mouths of those lateral galleries, through which they are not intended to pass. These stoppings are solid barriers (shown by slips of mahogany), in parts of the workings not used as a means of communication, and moveable double doors (marked D D) fitting air-tight in the levels, and forming a kind of air sluice in such roadways as are used for conveying the coal to the shaft. The points where currents of air passing in opposite directions cross each other, are shown by the arched cards C C. The wire pins in the front of the workings, are the timber props employed during the cutting of the coal.

No. G. 4.—Model of a Newcastle Coal Mine, illustrating Mr. Buddle's System of Double or Compound Ventilation for Fiery Collieries, by W. Olliver, Wallsend.

Scale, $\frac{1}{792}$. 66 feet to 1 inch.

This is an example of the older class of pillar working in which the pillars are taken away after the whole coal has been worked up to the boundary of the ground, as in the section A of No. G. 3. The seam is an inclined one, dislocated by a downthrow fault near the centre, the inclination being the same on both sides. The shafts are sunk at the lowest point, and the workings are carried on towards the rise; the pillars are set out at regular intervals, the whole area being divided up into districts by parallel ribs of whole coal. The workings on either side of the fault are independent of each other, but are put in communication by a single pair of drifts in each district, which are driven through the dislocating plane. The stoppings in the galleries are so arranged that the return air from each district is kept isolated from the adjacent currents; the ventilating furnace is placed a short distance from the upcast shaft towards the rise, in a short gallery in the centre of a rectangular block of coal, bounded by two parallel inclined drifts and two transverse horizontal ones. There are six doors marked *a, b, c, d, e, f,* in these four galleries, so arranged that the return currents may be sent over the furnace, or into the upcast shaft by the parallel, inclined or dumb furnace drifts, without passing over the fire, by closing or opening them in different combinations. The currents from the districts D and G, under ordinary circumstances, pass over the furnace along the upper transverse level, those from E and F being fiery, are passed by the dumb furnace or inclined drifts to the bottom of the upcast shaft, so as to be kept from direct contact with the fire. If the air in D becomes fiery it is thrown on to the dumb furnace, by opening the doors *a* and *b*, the effect of which is to shut the passages marked H and I on the left of the upcast, and the air from E is now sent over the furnace. If it is desired to pass both D and E by the dumb drift, the doors *a* and *b* are laid flat back against the wall and *e* is shut, which gives an uninterrupted communication between the left-hand incline and the lower transverse level, whilst the top transverse level, through which alone the furnace is supplied, is closed by the door at *e*. In like manner the air from the right-hand districts G and E is managed by opening or shutting the doors *c*, *d*, and *f*. The direction of the currents is shown by the arrows; the crossings and stoppings in a similar manner to those in No. G. 3.

TYROLESE METHOD OF WORKING SALT MINES.

No. G. 5.—Model of the Salt Mine at Hallstatt, in the Duchy of Salzburg.

No. G. 6.—Model of the Salt Mine at Hall, in Tyrol.

No. G. 7.—Model of the Salt Mine at Hallein, in Salzburg.

By Bergmeister Ramsauer.

The whole of the above models are to a uniform scale of $\frac{1}{4800}$, or 400 feet to 1 inch; the surface of the ground is represented on an approximately true scale, and central transverse and longitudinal sections are drawn on the sides of each model. On removing the tops of the models, the workings on the different levels are seen, laid down on plates of glass, fixed at the proper height, one above another.*

In all three instances, the workings are carried on in peculiar and irregular deposits, intercalated in rocks, supposed to be of Upper Triassic age, the so-called St. Cassian and Hallstatt beds. The saliferous rock is not pure, but consists of an intimate mixture of a blackish blue clay, with more or less of salt, interspersed with occasional masses of rock salt, and

* Keller. Ann. des Mines, 6 Ser., vol. ii.

veins and thick bands of anhydrite and gypsum. The other minerals occurring in smaller quantities are sulphate of soda, magnesite, muriacite, and polyhalite. The enclosing rock is a dolomitic limestone, fragments of which, as well as of a coarse quartzose sandstone are occasionally found in the salt marl. The latter is surrounded by a complete case of argillaceous shale, nearly free from salt but rich in gypsum and anhydrite. The working of these mines, especially that of Hallstatt, has been carried on from a very early age, the present system having been introduced in the year 1311. A series of main galleries or levels, with an inclination of about 1 in 40, are driven from the hill side at regular vertical distances of about 20 fathoms, from which small branch levels are driven obliquely into the chambers or workings proper. These are large ponds, which are produced by putting a cross dam in the mouth of the branch level, and laying out an elliptical base of about 200 feet in greatest length and 65 feet in breadth, by driving a great number of smaller galleries intersecting at right angles. The whole of these reticulating passages are then filled up with fresh water, brought in through an inclined shaft or sinkwerk from the level above. The first effect produced by the water, is the erosion of the lateral surfaces, whereby the pillars between the small galleries are removed, and the whole elliptical base is laid bare; by filling up the chamber to the top, and maintaining a constant pressure of a few inches, the solvent power of the water is mainly exerted against the roof, which disintegrates rapidly, the salt passes into solution, while the clay falls down to the floor, protecting it against further erosion; the saturated brine, from its great density, also subsides, giving a further protection of the same character; the floor of the chamber will therefore rise simultaneously with the roof, but at the same time there will be a certain amount of lateral action, by which the diameter of the basin increases upwards, the transverse section of the chamber, when in full work, being nearly a trapezium with the shortest horizontal side for a base, the sides inclining at an angle of 45° to the vertical representing the walls. The fresh water is got from springs that rise at the contact of the clay with the limestone. The process of working is either continuous or intermittent, in the latter or older method, the salt water is allowed to remain in the chamber till it contains about 27 per cent. of saline matters in solution, of which amount 25 per cent. is chloride of sodium, when it is run off to the boiling houses, which are situated at a considerable distance from the mine. At Hallstatt one operation is completed in 15 days, during which time the roof of the chamber is raised about 16 inches; after the water is run off the chamber is left empty for a period which should not exceed six or eight months. The mud deposited on the floor is dug out and thrown down through a winze to the next level below, whence it is lifted by a hydraulic balance, to be used in filling up the exhausted workings in the higher levels. The dams in front of the chambers are formed by driving a short cross level, which is then filled with clay rammed in to a very compact condition. A channel is kept through the centre of the dam for drawing off the brine, whose inner orifice is raised together with the dam at each successive washing. The continuous process of working is of later date, and is chiefly employed at Aussee, where the clay contains an average of from 80 to 90 per cent of salt, without interspersed poorer parts, the foreign matters being confined to occasional masses of gypsum. The chambers are originally of a circular plan, the fresh water is introduced from the centre of the roof, and the discharge takes place through the middle of the floor. As soon as the first filling is saturated, it is run slowly off, and is replaced by fresh water, the operation being regulated in such a manner that the roof is continuously moistened with salt water, nearly but not completely saturated. The advantage of this modification is shown by the diminished inclination of the walls, the chamber being nearly cylindrical, a form that gives rise to supporting pillars of smaller volume, and consequently allows a larger portion of the deposit to be removed. The process is however much slower, the erosion of the roof proceeding at the rate of only 1½ inches per week, or about one-sixth of the amount produced in the same time by the discontinuous process. Masses of rock salt, free from clay, are occasionally met with, and are removed by a species of pillar working, so as to obtain the salt in blocks. In driving the levels, blasting with gunpowder is employed in penetrating the harder rocks, that is, in limestone, hard marls, rock salt, and anhydrite. The latter substance is extremely tenacious, so that bore holes cannot be sunk in it to a greater depth than 10 inches. In the softer argillaceous beds picks of three and four pounds weight are alone employed. In preparing the chambers, in sinking winzes in the salt marl, and holing in the rock salt, the accessory levels are driven by allowing a stream of water issuing under pressure, from simple jets or perforated spreading roses, to act on the rock on the forward end. In all cases the most powerful jet is the horizontal one at the level of the floor, which undercuts the ground in a manner exactly similar to that in which coal is holed with the pick. Small shafts or winzes of communication between the different levels are also driven in a similar manner, either from above downwards or from below upwards. Any insoluble masses of gypsum or anhydrite that may remain sticking out from the walls are afterwards dressed off by hand with the pick. This curious method of driving was introduced in 1841 by Bergmeister Ramsauer, the author of the models. The principal galleries are kept open by walls of dressed limestone masonry set in cement, in other cases simple door frame timbering is employed. The roofs of the chambers stand extremely well if they are not allowed to become too dry, the salt appearing to impart a considerable degree of tenacity to the argillaceous rock in which it is contained. The conveyance of fresh water to, and of brine from the working is effected in wooden pipes, made of pine trunks in about 10 feet lengths, fitted together with socket joints. The greatest distance through which the brine is conveyed to the boiling house is about 10 miles. The loss of salt by leakage during the passage is estimated at about 12 per cent.

The colors of the workings on the glass plates, correspond with those of the named levels on the longitudinal sections. The outer line, drawn in discontinuous bars, shows the extent of the saliferous mass at each level. The chambers that are worked out are those covered with small colored circles, those in course of working are bordered with white dots, whilst those which are being laid out are shown as coloured elliptical rings, covered with cross bars intersecting at right angles, which represent the small galleries by which the process is commenced. The passages shown in plan with cross bars like ladders, are the sinkwerke or inclined winzes through which the fresh water is introduced. The dams in the mouths of the chambers are shown by single transverse lines. The different levels are distinguished by particular names, those at Hallstatt are called after the Emperors and Empresses of Austria. The lowest named level in the model is that of the Empress Maria Theresa, another one is, however, shown below it without a name; this is called the Francis Joseph level, the drivage of which was commenced in 1856, but no working chambers had been opened out in it when the model was made.

The annual production of the mine of Hallstatt is nearly 38,000 tons from brine, and only about 500 tons are raised in the form of rock salt.

PUMPING ENGINES.

No. H. 1.—Models of Water-wheels at Devon Great Consolidated Copper Mines, near Tavistock.*

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

These wheels, which are driven by the water of the River Tamar, work the pumping machinery in three shafts placed at a considerable distance from the river by lines of rods carried on guide rollers over the side of the hill. The construction is somewhat modified from that of the wheel at Wheal Friendship. Each wheel has 112 buckets formed of two deal boards whose ends rest in sockets formed on the cast-iron rings or shroudings. The inner platforms or backing of the buckets are also formed of deal boards. The axles are made of oak, tired in the centre with a cast-iron ring, and terminated at either side by cast-iron cylinders carrying the "bosses" or radial sockets for the arms. The outer sides of these castings are flanged, and to the flanges covering plates carrying the journals are secured by screw bolts. The ring of the wheel is supported by arms arranged in four series; those forming the two outer series are socketed at their outer ends into seatings on the shroudings, and at their opposite extremities rest in sockets on the axles. The arms of the other two series incline inwards from the seatings on the axle and unite midway below the centre of the backing, where they are bolted to a cast-iron ring, so as to form a support for the ring of the wheel equidistant from both shroudings. The power is transmitted from a crank at either end of the axle by a wooden connecting rod. These connecting rods are kept at their proper distance apart by a cast-iron transverse beam. The forked ends of a line of round wrought-iron rods, $3\frac{1}{4}$ inches in diameter, carried upon guide rollers. The water is laid on to the wheels at a point about 20° below the summit.

Principal dimensions:—Height of wheels, 40 feet; breadth of face, 12 feet; breadth of feed launder, 10 feet; diameter of oak axle, 5 feet; diameter of journals 15 inches; length of crank arm, 3 feet 6 inches and 4 feet (each crank has two sockets for varying the length of the stroke). The actual lengths of the lines of rods are 360 fathoms for one wheel and 396 fathoms for the other. The usual working speed is four revolutions per minute, or a velocity of rather less than $8\frac{1}{2}$ feet per second at the circumference. The weight of

* Mining Journal, vol. xxx., p. 518.

the cranks and connecting rods are balanced by a pair of balance bobs placed behind each wheel. Those parts of the model that are made of brass represent cast iron in the original; those in copper representing wrought iron.

No. H. 2.—Vertical Water-wheel at Wheal Friendship, Devonshire.

Scale, $\frac{1}{24}$. ½ inch to 1 foot.

This wheel is employed for pumping; it drives two lines of rods, one from each side of the axle. The diameter of the ring is 50 feet, with a breadth of face of 10 feet. The axle is a hollow cast-iron cylinder with flanged ends, to which are attached the covering plates carrying the journals, which rest in cast-iron bearings supported upon wooden frames and secured by wrought-iron stay rods. The ring is provided with 180 wrought-iron buckets, which are supported by a wooden shrouding at either side and a third in the centre. Each of the three shroudings is supported by 18 tapered radial wooden arms resting in sockets on the seating rings or rosettes attached to the main axle. The power is transmitted by two cranks, making an angle of 180° with each other; each drives a pump rod by a line of wrought-iron rods carried over guide rollers. The weight of the rods is compensated by a pair of balance bobs working in pits placed behind the wheel.

No. H. 3.—Horizontal Water-wheel or Turbine on Fourneyron's System.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

The wheel is divided by curved blades into passages of a rectangular section, through which the water is discharged from the centre outwards; the pressure of the water against the inner side of the curved buckets causes the wheel to rotate in the opposite direction to that taken by the stream. The direction of the entering water is given by a number of curved blades in form similar to the buckets, attached to a disc placed between the inner circumference of the wheel and its shaft. The admission of the water takes place through all the buckets at once. The regulator is a ring sluice which forms a sliding gate in the mouths of the guide passages; it is raised or lowered by three vertical rods, each working in screwed sockets at the ends of three projecting arms. Each of the three rods carries a large spur wheel at its upper end gearing into a central wheel of equal diameter, which receives motion from a regulating pinion. The wheel revolves in a shallow chamber of cast iron, pierced with holes at the bottom for discharging the waste water. The chamber containing the guide curves is carried on four vertical cast-iron columns; it is of cylindrical form; the driving water is admitted through the large tube at the side; the main shaft of the wheel passes through a stuffing box at the top cover; the ring sluice passes through a similar joint in the lower cover. The construction of the wheel and its guide curves is shown on a large scale in the wooden model; the model does not show the self-acting greasing apparatus which is generally employed for the lower bearing of wheels of this kind. The date of the introduction of these wheels was about the year 1827; they have since been considerably modified and improved in France, England, Germany, and the United States.

The construction of this wheel is almost exactly similar to that at St. Blazien, in Baden, which is 26 inches in diameter, and works under a head of 354 feet of water, at the enormous speed of 2,300 revolutions per minute.

No. H. 4.—Water Pressure Pumping Engine at the Alport Mines, Derbyshire.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

This engine was erected by Mr. Darlington in the year 1842, and worked till 1852, when on the opening of the mine it was removed and re-erected at Talargoch mine. It is remarkable for simplicity of construction as well as for its unusual dimensions. The piston rod passes through the bottom of the cylinder, and is attached directly to the pump plunger by a wooden rod in the shaft; the distribution gear consists of a pair of cylindrical valves, with feather-edged beating faces, the inner one, that nearest the gallery, serving for the admission and the outer one for the discharge of the driving water; a pair of sluice valves or slides are placed, one in front of the admission valve, and the other behind the discharge valve, for regulating the speed of the engine by checking the velocity of the water. The pair of small pistons placed between the main valve boxes and the cylinder are auxiliary valves for continuing the admission and exhaust through reduced apertures after the main valves are closed, in order to prevent the shock caused by the sudden closing of the large valves. These relief valves are worked by enlarged gearing placed below the valve nozzles. The pump plunger is loaded at the top, the weight of the rod not being sufficient to press the water out of the pump cylinder.

DIMENSIONS.

Diameter of cylinder, 50″; diameter of pump plunger, 42″; stroke of piston and pump, 120″ = 13 feet.

Height of driving column, 132 feet; height of pump lift, 140 feet.

Pressure on the piston, 112,500 lbs., or about 60 lbs. per square inch.

Average working speed, 4 strokes per minute; with a maximum speed, 7 strokes per minute.

Effective horse-power, 168 H. P.

The volume of driving water per stroke, 852 gallons; discharged by the pump per stroke, 600 gallons.

The pump valves are tubular beat valves, similar to those used in town water works engines.

NO. H. 5.—TAYLOR'S ENGINE AT THE UNITED MINES.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

This model represents the surface arrangements of a pumping engine of the largest class employed for draining deep mines in Cornwall. The engine called Taylor's engine, was erected in the year 1840 at the United mines in Gwennap, now included in the Clifford Amalgamated Mines, and is worked with high pressure steam, with expansion and condensation. It is single acting, that is, the steam is only employed for lifting the pump rods and filling the pump barrels in the shaft; the return stroke, which drives the water out of the pump barrels into the rising pipes, being effected by the fall of the shaft rod, as soon as an equilibrium is established in the cylinder, by opening a communication between the two faces of the piston. The steam piston moves vertically in a cylinder formed of two concentric tubes, the inner one forming the cylinder, and the outer one a protecting case or jacket; the small annular space between the two is constantly filled with steam at the maximum pressure produced in the boilers, in order to keep the walls of the inner cylinder at a uniform temperature. In practice, it is customary to surround the cylinder with other non-conducting envelopes; thus, a shell of brickwork enclosing an air space is first placed round the jacket, which is further enclosed with coatings of felt, lagged with wood; these outer envelopes are not shown in the model. The piston-rod is attached by Watt's parallel motion to the end of a beam oscillating about a horizontal axis, whose bearings are carried on the outer wall of the engine house. The beam is formed of two parallel cast-iron plates of [section, bolted together, the two plates being kept a fixed distance apart by wrought-iron pins. The two arms of the beam are of unequal length, the steam piston and mechanism for working the valves are attached to the longer arm, which works within the engine-house, the main pump rod and rods of the air and feed pumps are attached to the shorter arm, which works in the open air, a gallery projecting from the wall of the engine-house gives acess to the bearings on the out-door side of the beam.

The engine has four valves for the distribution of the steam, three of these are placed near the top of the cylinder and the other one is at the bottom. One of them is a plain disc valve, with a single conical beating face, and is independent of the engine; the other three are of the kind known as the double beat or Hornblower's valve, a construction in which the bearing faces opposed to the pressure of the steam are reduced to a pair of narrow conical rings, the valve and its seat being so formed as to present a very large steam passage when open. Of the three upper valves, that on the right hand side (as seen when facing the cylinder from the outside), is the governor or regulator valve, it is a plain disc valve, which is maintained at a fixed opening by means of the setting screws on the rod attached to the right hand pillar of the valve gear framing. By this valve the steam is admitted from the main steam pipe through the large hollow column on the right into the top steam chest. The central valve is the admission valve, it commands the passage whereby the steam at full pressure enters and leaves the cylinder above the piston, and is governed by a system of levers attached to the uppermost of the three horizontal shafts, which are attached to the two vertical pillars or standards in front of the valve cases. The left hand upper valve is the equilibrium valve; it is placed at the top of a hollow column, through which the steam passes from the upper to the lower face of the piston, in order to establish an equality of pressure at the end of the steam stroke; the movement of this valve is effected by the central arbor. The bottom or exhaust valve, which controls the passage of the exhaust steam from the cylinder to the condenser, is attached to the lower horizontal arbor.

The valves are opened by falling weights, and closed by the action of tappets on the plug rod, acting on curved handles projecting from the front of the horizontal shafts.

The sector-shaped cams and catch levers outside the bearings of the horizontal arbors keep the valves locked in position during the repose of the engine.

The engine is intermittent in its action, a pause being made after the descent of the main rod in the shaft, varying in duration according to the amount of water to be lifted; this is effected by a simple hydraulic regulator, known as the cataract.

The cataract, which is placed in the well below the floor of the engine-house, is a square wooden plunger box, open above and closed at the bottom, with the exception of a small conical hole which can be stopped by a plug attached to a vertical rod; the plunger moves in a square cistern of water a little larger than itself, and is attached to a vertical rod passing through a collar projecting from the right-hand frame pillar; it is further attached by a chain rolling on a sector head, to a double-armed lever which oscillates about a horizontal axis; the shorter arm of this lever is pressed down by a roller at the lower end of the plug rod, during the upstroke of the engine, a balance weight being fixed to the end of the opposite arm, which raises the shorter arm when the pressure of the rod is taken off.

The action of the cataract is as follows:—When the indoor side of the beam makes its down stroke, during the lifting of the main rod in the shaft, the cataract plunger is driven down in its cistern, displacing the water in bottom of the latter, which consequently rises above the open top of the plunger box and fills it up; this water afterwards flows out through the small hole in the bottom of the box with more or less rapidity according to the position of the conical plug, and during this time the valves are closed, and locked by their catches, the steam piston is at the top of its stroke with a slightly compressed cushion of steam above it, and the expanded steam of the preceding stroke below it. As soon as sufficient water has flowed out of the cataract plunger to establish the preponderance of the balance weight on the longer horizontal arm of the lever, the box rises, and the rod attached to it opens the exhaust valve, by striking against the catch lever and releasing the balance weight. The steam below the piston flows away to the condenser, and a vacuum is formed in the cylinder. The catch on the steam valve is formed by the vertical arm of an angle lever, whose horizontal arm is parallel to the exhaust valve catch, and is connected to it by a parallel bar with a slotted link at the top, which works on a pin at the end of the horizontal arm of the upper catch. When the bottom of the link strikes the pin, the steam valve is opened in a similar manner to that already described for the exhaust valve. The piston descends under the full pressure of the steam in the cylinder until the link frame at the back of the plug rod closes the valve, by pressing against the handle which projects from the top arbor; the sector on the arbor in turning gradually lifting the catch lever, which falls into its place as soon as the end of the cam has passed the notch. The steam is now cut off, and the remainder of the stroke is effected by the expansion of the steam already in the cylinder. The length of the full steam stroke is determined by the position of the link frame on the plug rod, the proportion of expansion is diminished or increased by raising or lowering the link by the setting screw on the front of the rod.

The exhaust valve is closed by the plug on the right-hand side of the rod shortly after the closing of the steam valve; the equilibrium valve is opened at the end of the stroke by its balance weight; this establishes a communication between the upper and lower faces of the piston, equalizing the pressure on both sides, when the piston is drawn up in the cylinder by the excess weight on the outer side of the beam. The equilibrium valve is closed by the left-hand plug during the rise of the rod; this confines a small quantity of steam above the piston, which forms a cushion by compression, and brings the moving mass to a state of rest.

The condenser and air pump are connected with the out-door side of the beam. The latter is surmounted by an open hot well of large capacity. The feed pump draws its supply directly from the hot well, and forces the water through a double U tube, passing four times through the exhaust pipe, where it is heated by the waste steam on its passage from the cylinder to the condenser. The feed water is further heated by circulation through a system of horizontal pipes in a flue at the back of the boilers. The steam from the six boilers is collected in a cylindrical steam chest, with hemispherical ends, cast in two pieces, which are united by a wrought-iron expansion joint. The main steam pipe passes from the chest, under the floor of the engine-house, and terminates in the right-hand vertical column, at the top of which the governor valve is placed. The main rod which works the pumps in the shaft, is formed of two square balks of timber placed side by side, and united by wrought-iron fish plates and bolts. The excess weight of the rod, above that necessary to drive the water out of the pump barrels, is balanced off by five balance bobs, of which, three are placed under ground, and two are at the surface. The latter are cast-iron beams, constructed in a similar manner to the beam of the engine, one end being connected by a wooden rod with the main rod on the shaft, the other carries a wooden box, which is loaded with masses of rock, acting as a counterbalance.

Catch pieces or stops are fixed to either side of the beam, to prevent it going beyond its proper distance in case of breakage on either side. The in-door catch is formed by an iron cross piece fixed above the beam, which is received on a pair of spring beams, carried on horizontal balks crossing the upper part of the engine house. The out-door catch is formed by two pieces of timber strapped on to the front of the main rod; the lower end of these beams, which are of the same size as the main rod, are caught by a mass of timber formed of horizontal balks piled one above another in the shaft. This bed of timber is not shown in the model.

The large capstan and shear frame over the shaft lead the rope by which the pump barrels, &c. are lowered in the shaft, it is worked by manual power.

The following are the dimensions of the more important parts of the engine:—

Diameter of steam cylinder - - -	85 inches
Length of stroke of piston - - -	132 „
Diameter of regulator valve - - -	10·8 „
„ admission valve - - -	15·0 „
„ equilibrium valve - - -	18·5 „
„ exhaust valve - - -	25·0 „
„ main steam pipe - - -	18·0 „
„ exhaust pipe - - -	24·0 „
„ condenser - - - -	30·0 „
„ air pump piston - - -	37·0 „
„ „ valve - - -	30·0 „
„ hot well - - - -	55·5 „
„ feed pump - - - -	6·0 „
Length of main beam - - -	34 feet 2¼ „
Height of „ at centre - -	7 „ 1½ „
Length of beam steam side - -	17 „ 10½ „
„ out-door side - -	16 „ 4 „
Length from centre of beam to point of attachment of air pump rod -	9 „ 7½ „
Length of feed pump rod - -	6 „ 8 „
Length of stroke of main rod - -	10 „
Section „ - -	24 inches broad. 12 „ deep.
Diameter of piston rod - - -	7½ „
„ air pump rod - - -	3½ „
„ feed pump rod - - -	2¼ „
„ axis of main beam - -	20 „
„ journals - - -	16 „

Boilers.

4 of 30 feet length,	5 feet diameter of outer shell.	
	3 ft. 4 in. „	inner tube.
2 of 34 „	5 ft. 10 in. external diameter.	
Steam chest - - - -		30 ins. diameter.
Feed pipe - - - -		5½ „

The engine was started in December 1840; its performance was continuously reported in "Lean's Engine "Reporter" up to the end of 1851. The most economical condition of working was reported in September 1842. The mine was then 201·2 fathoms deep; the load on the piston amounted to 75·362 lbs., or 12·05 lbs. per square inch of surface. The engine making five strokes per minute, developed a quantity of work equal to 114·2 horse-power. The quantity of fuel consumed showed an effect of 107,494,580 foot lbs. per bushel of coal of 94 lbs., equal to 1·74 lbs. per horse-power per hour.

The last return in December 1851 shows a duty of 62 millions of foot lbs. per bushel, or 2·9 lbs. per horse-power per hour. The depth had increased to 239 fathoms; the load per square inch to 15·8 lbs., giving a duty of 165 horse-power at a speed of 5·5 strokes per minute. The greatest working speed attained appears to have been in December 1849, when the engine made 7·5 strokes per minute, showing 221 horse-power, with a consumption of 2·4 lbs. per horse-power per hour. The method by which the above duties is computed consists in comparing the amount of coal burned with the theoretical volume of water discharged by the pumps during the period of observation. The actual volume is, however, somewhat smaller, the discharge of the best mining pumps, being from 2¼ to 2½ per cent. less than the theoretical amount for each lift.*

PUMPING MACHINERY.

No. H. 6.—Arrangement of Pumps in a Mine Shaft.

No. H. 7.—Jordan's Pumps, with Wire Rope Rods.

Nos. H. 8, 9.—Common Mining Pump Bucket and Leather for ditto.

No. H. 10.—Lower Clack of Drawing Lift.

No. H. 11.—Kennedy's Patent Metal Packed Pump Bucket.

* Jordan. Karsten's Archiv, vol. x., p. 316.

No. H. 12.—Heaton's Patent Gutta-percha Packed Pump Bucket.

No. H. 13.—Different Systems of Valves adopted to Mining Pumps.

The machines most generally used for lifting water out of deep mines, are the hollow piston or lifting pump, and the solid piston, plunger, or forcing pump. The former is sometimes used alone, more especially in collieries, but generally the two systems are used in combination, the lowest pump of the series in a deep shaft, being a drawing lift, whilst those above it have solid pistons. The whole of the models in the above list are in the East Room A., on the principal floor.

No. H. 6.—Model of Pumps used in Cornish Mines.

Scale of pit work, $\frac{1}{12}$th. 1 inch to 1 foot.

This is a somewhat generalized representation of the arrangement of the pumps adopted in Cornwall. The respective parts are indicated by numbers engraved on them. No. 1, the engine house, and the shears, No. 2, at the top, are on a smaller scale than the pit work. The main rod, No. 5, is attached by a parallel motion to the outer end of the main beam of the engine No. 3, an arrangement that is not usual, the common method of attachment being similar to that shown in the large model of Taylor's engine, in the centre of the room. No. 4, the signal lever, has an iron plate at the end of the longer arm; the other end has a wire attached to it passing down to the bottom of the shaft, and is used for signalling the men at the capstan to hoist or lower, when the pumps are being placed in position. No. 6 is the balance bob for counterbalancing the weight of the main rod in excess of the amount necessary for forcing the water out of the pump barrels. Nos. 7 to 11 are parts of the upper plunger lift; No. 7 is the rising column, 8, the door piece of the top clack or valve, 9, the H piece and lower clack, 10, the wind bore, 11, the plunger and barrel. The remaining Nos., 12 to 15, refer to the lower or drawing lift, 12 being the rising column, 13, the working barrel, 14, the clack door piece, and 15, the wind bore. Of these parts, the wind bore is a tube perforated with a number of round holes, which is placed in the feed cistern, in which the water from the different levels is collected, and acts as a strainer, keeping back the coarser impurities in the water. The clack pieces are the parts next above, they contain the valves and their seats, and are provided with doors secured by screw bolts, so that the valves may be replaced when worn out without disarranging the heavier parts of the machinery. The working barrels and rising pipes are cast-iron tubes, strengthened with mouldings, and flanged at the ends; they are united by screw bolts passing through the flanges. In the drawing lift, the piston or bucket is a hollow cylinder attached to a wrought-iron rod or spear passing down the centre of the rising pipe, it moves air-tight in the barrel by means of a leather packing, and is closed by a hinged leather valve or clack opening upwards, the fixed clack below moving in the same direction. As the bucket is lifted by the rod, its valve is closed by the weight of the water standing above it, and a portion of the latter, corresponding to the volume of the working barrel is carried over the top of the rising pipe into the cistern of the lift next above, at the same time a vacuum is formed behind the lower edge of the bucket, and the water in the lower cistern, by the pressure of the external air, is passed through the lower valve and fills up the empty space. At the change of the stroke the bottom clack closes, and the bucket is pushed back through dead water, so that when at work the pump is always filled with water. It is a necessary condition that the height of the lower valve above the water level in the cistern must be somewhat less than that of a column of water of one atmosphere pressure, or not more than 30 feet. The plunger lift has a wind bore and feed cistern similar to those of the lower one. The H piece is formed of two short upright tubes, united by a transverse horizontal one. One of the vertical limbs containing the lower clack and its door piece is placed above the wind bore; the other one supports the working barrel or plunger case. The plunger is a wooden pole covered by a brass tube, whose outer surface is turned smooth; it is somewhat smaller than the barrel of the pump, but moves air-tight through a stuffing box at the top. The water drawn on the up-stroke of the plunger fills up the barrel, and is driven out during the down-stroke, passing back through the horizontal part of the H piece; it rises in the column through the top clack; the working part of the pump being only filled during the up-stroke.

No. H. 7.—Pumps with Continuous Tension Rods. By Mr. T. B. Jordan.

This represents a system of establishing mine pumps, in which the heavy wooden rods commonly used are superseded by a wire rope carried over two large guide pulleys, placed one at the top, and the other at the bottom of the shaft. There are two plunger pumps placed at the bottom of the shaft having a rising pipe placed between them common to both. The plungers are connected by short projecting arms to the rope, one on each side, so that they move uniformly, but in opposite directions, producing a continuous discharge of water at all parts of the stroke. The valves are plain discs, faced with plates of vulcanized india-rubber, a material which gives a very perfect contact between the valve and its seat when closed.* The plungers are continued above the points of attachment with the rod, into cylindrical guides, which are kept vertical by passing through holes in a pair of transverse wooden guide bars. The method by which the pumps are moved in the model is not such as would be really used; the proper place for applying the power being the axis of the top pulley, which should be connected by a link rod and angle lever, with the fly wheel shaft of a double-acting rotatory steam engine, a water wheel, or any other machine producing uniform rotatory motion. In great lengths of rope, such as would occur in deep mines, it would probably be necessary to insert rigid pieces with screw joints at intervals, so as to be able to restore the tension to the rope in case of its becoming slack. The plan of replacing the upper part of a line of pump rods by a strained wire rope has been adopted in the Harz and in Sweden.

No. H. 8.—Bucket of a Common Drawing Pump.

This is the hollow piston of an ordinary lifting pump; it is made up of a hollow wooden cylinder closed at the top by a hinged leather valve faced with wrought iron on either side. The rod or sword is attached to two forked ends passing through mortices in the wooden body, and secured by cross wedges passing through eyes, which bear against the under side of the wood. The packing is formed of a conical leather collar, tapered in thickness, the top part being formed of two thicknesses united together by copper tacks clinched on the inner side; the thinner part fits closely on the outer side of the wooden cylinder, and is covered by a wrought-iron ring. The forked limbs of the sword are thickened on their inner sides for a short distance above the top of the bucket, the projecting parts have diagonal edges below, so as to form stops for confining the upward movement of the valve within proper limits. The construction of the leather collar is seen in the detailed example No. H. 9.

No. H. 10.—Lower Clack of a Lifting Pump.

This is a plain leather disc, strengthened by wrought-iron plates on either side, mounted on a conical wooden tube; the hinge is formed by a projecting piece of leather fitted on to a corresponding projection on the wooden seat, and is secured by a wrought-iron strap, the ends of which pass through the leather and are made fast by screw bolts. In large pumps it is common to have the clack seat made of wrought iron, with a ring handle for the convenience of lifting it.

No. H. 11.—Kennedy and Eastwood's Patent Pump Bucket.

This bucket is entirely constructed of metal; the fixed parts are the top and bottom guards and the valve seat; the former are two rings of cast iron with their external faces turned smooth, supported by four arms radiating from the central rod; the latter is a plate of cast iron somewhat less in diameter than the barrel, fixed a short distance above the bottom guard; whose upper face is turned smooth, and carries four radial arms, forming a bearing surface and guides for the valve. The packing is a brass ring sawn through diagonally, resembling those that are used for high-pressure steam engines; it rests upon the top of the valve, which is a similar ring not cut through, and having four studs projecting from its upper side, which keeps the packing ring in its place. When the valve is open a free communication is established for the water through the apertures of the lower guard round the outer edge of the seating plate into the barrel of the pump through the top guard.

No. H. 12.—Heaton's Patent Gutta Percha Packed Pump Bucket.

The bucket is formed of a hollow cast-iron cylinder, having the central aperture divided into two parts by a straight cross bar, which is perforated with a slot for holding the rod or sword. The outer face of the cylinder has a flat groove turned out of its surface for receiving the packing, which is an open ring of gutta percha with overlapping tapered ends, and possessed of sufficient elasticity to expand

and come into close contact with the inner wall of the pump barrel when the bucket is in a working position. There are two half-round or D shaped leather clacks, strengthened with wrought-iron in the usual manner, hinged to the central cross bar. The top edge of the bucket inclines inward from the outer circumference to the centre, giving two oblique bearing surfaces, against which the valves rest when closed. In addition to the full size example, a small model of this bucket is placed in the case of model No. H. 13.

No. H. 13.—Model of Various Systems of Valves adopted in Mine Pumps. By Mr. T. B. Jordan.

This is a large model of a force pump with a loaded plunger, having eight rising pipes arranged round, each having a different kind of valve, as follows:—

I. Double leather or butterfly clack.
II. Clack having six triangular flaps opening outwards.
III. Harvey and West's single beat tubular valve.
IV. Hosking's many-tubular slide valve.
V. Darlington's double beat valve.
VI. Jenkyn's ring-shaped clack.
VII. Hoskyn's single beat valve.
VIII. Palmer and Perkins' elliptical clack.

The greater number of the above are intended for use in pumps of large size, where flat valves made in a single piece are objectionable, owing to the shock produced by their fall against the valve seats when the upward pressure of the water is taken off at the change of stroke. Some of the principal methods for obviating this inconvenience are:—1. Forming the valve of several small pieces, as in I., II. 2. Forming the clack of several concentric rings, each serving as a face for the next smaller one, as in IV. and VI., of which the former shows the application of the principle to sliding, and the latter to hinged valves. In VIII. the valve is an elliptical disc suspended by a central axis placed a little above a line passing through the centre of gravity, which bears against a seat of similar form. The disc is so balanced that is opens easily, and falls back quietly against the seat, and when open gives a very large water-way. Nos. III., V., and VII. are examples of the single and double valve, such as are employed in large steam engines, applied to pumps. They consist essentially of tubes of large diameter contracted above and below to flat or conical rings, forming the so-called beating faces, which bear against rings of a corresponding form on the valve seats. The single beat valve has only one beating face, while the double beat form has two. The seat in the latter form is usually a ring turned to the proper shape for the lower bearing surface, which carries a circular plate with a similar edge, for the top bearing face, by a series of radiating arms. When the valve is opened the water passes through the apertures of the lower ring between the arms into the broad part of the valve, and round the edge of the top plate into the rising pipe.

The difficulty of preserving an accurate contact between the valve and its seat, when the water to be lifted is dirty or sandy, renders the double beat form of valve less applicable for mine pumps than it is for towns' water works engines, where the water is clean or filtered before entering the pump. One of the best materials for large valves working under moderate pressure, is vulcanised india rubber, which closes perfectly and is very durable when kept free from grease.

In the same case are placed a common metal-faced leather clack, and a small model of Heaton's pump bucket with gutta percha packing.

MAN ENGINES.

No. J. 1.—Cornish Double Rod Man Engine.

No. J. 2.—German Double Rod Man Engine.

No. J. 3.—Man Engine at Fowey Consols.

These models are in the doorway of the principal entrance of the model room from the first floor of the Museum.

The man engine is a machine in use in a few of the deep mines in Cornwall, Saxony, the Harz, and Hungary, as well as in some of the deep collieries in Belgium and the North of France, but although it was originally introduced in the Harz in 1833, the whole number of mines in which it has been adopted in Europe up to the present time probably does not exceed thirty. In its original form, it consists of two vertical rods placed parallel to each other, and extending through the whole depth of the shaft; the heads of the rods are connected with the crank shaft of a rotary engine, by a long connecting rod and two reversed angle levers, by which a reciprocating motion is imparted to them, one rod rising while the other is falling, and *vice versâ.* A series of small platforms project from the face of the rods, the distance between them being equal to the length of the stroke. The miner wishing to ascend steps on to the lowest platform of one or other of the rods at the moment that it commences its upstroke, and is carried up during the time that the other rod is descending; at the moment when the rod stops at the change of the stroke, he has arrived opposite to the next higher platform on the opposite rod, and stepping across to it, he is lifted through the same amount before stepping back to the rod on which he started, and so on until he arrives at the top; the amount of lift during each revolution of the driving shaft being equal to twice the single length of the stroke in the shaft. In the newer forms adopted in Cornwall a single vibrating rod only, is used, and the miner who is travelling up at the end of the stroke steps off the rod on to a fixed platform, and waits until after the next change; the rod again moves in an upward direction. In either case the method adopted in descending is the reverse of that adopted in coming up.*

No. J. 1.—Double Rod Cornish Man Engine.

Scale $\frac{1}{24}$. Half an inch to 1 foot.

This is a generalized model of a portion of a double rod man engine; the rods are connected by link rods to the horizontal arms of a pair of levers, whose two limbs are bent at right angles to each other, which are supported on a braced timber framing placed above the mouth of the shaft. The ends of the vertical arms are firmly connected together by two flat wrought-iron rods. The motion of the driving crank is transmitted by a long wooden beam linked to the vertical limb of the left-hand angle lever. The rods are guided by broad rollers of cast iron with projecting flanges at the sides in the model; these are placed alternately in front and at the back of the rods, which would necessitate changing the side on which the platforms are attached; this arrangement is not used in practice. A resting place or platform is provided at every 10 fathoms. The guide rollers are placed at 8 fathoms distance apart. The diameter of the path of the crank is 10 feet.

Two double rod man engines have been built in Cornwall; the first was put up in the year 1843 at Tresavean, a mine which is now abandoned, the other at the United mines was put up in 1845, and is still at work.

* Moissenet, Ann. des Mines, 5 Ser., vol. xv.

The Tresavean engine was carried down to a depth of 290 fathoms; it was driven by a steam engine of 36 inches diameter of cylinder and 6 feet stroke, making 15 revolutions per minute, which was reduced by spur gearing to $\frac{1}{5}$, or three strokes per minute on the rods; the latter were uniformly 8 inches square throughout. The speed at which the men were lifted was 72 feet per minute, 24 minutes being requisite for the entire journey of 290 fathoms.

The United mines engine has the section of the rods tapered, varying from 7½ inches square in the upper 60 fathoms to 7 inches in the next length of 100 fathoms, and 6½ inches in the last 50 fathoms. The driving power is furnished by a steam engine of 32 inches cylinder diameter and 6 feet stroke, which also works a pair of crushing rollers; the speed is reduced by gearing wheels to $\frac{1}{6}$th of that of the engine, which runs at 18 revolutions per minute, the rods making three oscillations during the same period. The time required for travelling the whole distance of 200 fathoms is 17½ minutes.

No. J. 2.—Man Engine at Himmelfahrt Mine, near Freiberg.*

Scale, $\frac{1}{16}$. ¾ inch to 1 foot.

This double rod engine was put up in the year 1857; it is driven by a water wheel placed at the level of the adit, about 40 fathoms below the surface, and extends to a depth of 190 metrical fathoms (about 206 statute fathoms) below that point. The rods are about 8½ inches square; the driving mechanism of angle levers and connecting rods being very similar to those of the Cornish model No. J. 1.; the length of stroke is 5 mine feet, Saxon measure (about 56 inches). The guides on the rods are formed by projecting wrought-iron bars, which run between grooves of corresponding section in wrought-iron plates screwed down to the cross timbers in the shaft, placed at intervals of 48 feet. Catch pieces are fixed to the backs of the rods at intervals of 18 feet; they are pieces of cast iron with short arms projecting horizontally, which are intended to be received on horizontal cross bearers in case of any breakage taking place. An elliptical ring with its long axis placed horizontally, fixed above each platform, serves as a handle. The rods are connected together at intervals by

* Jahrbuch fur den Sächs, Berg and Hüttenmann, 1858, p. 69.

chains running on a cast-iron pulley or sheave placed between them; when this occurs, there is necessarily a break in the series of platforms owing to the cross timbers which carry the bearings of the sheaves being in close contact with the face of the rods; at these points, therefore, the men have to leave the rods and travel by the ordinary ladderway for a space of 24 feet; this inconvenience is common to nearly all the German forms of this machine. In the deep mines of the Upper Harz eight man engines have been constructed at different ti mes, the earlier ones are made with double solid rods, but afterwards skeleton frames made of thinner wooden bars, or wrought-iron rods, or ladders slung together with chains were introduced, and in the deepest mine, the Samson shaft, near Andreasberg, the rods are entirely replaced by ladders, whose sides are made of tapered iron wire ropes, diminishing in thickness from 36 wires above, to 2 at the bottom. It is customary in the Harz not to allow the men to descend by the engines, so that a continuous ladderway is necessary; this is either placed between the rods, or at one side of the shaft in the usual way.

No. J. 3.—Man Engine at Fowey Consols Mine, Cornwall.

Scale, $\frac{1}{8}$. $1\frac{1}{2}$ inches to 1 foot.

This, the first of the single rod man engines, was built in the year 1851; it extends from the surface to a depth of 280 fathoms, the shaft being vertical throughout. The rod is 8 inches square, and is driven by an overshot water wheel of 30 feet diameter and 6 feet face, making from 5 to 6 strokes per minute; the crank in the axle of the wheel being connected directly with the large balance bob at the surface, by a round wrought-iron rod $3\frac{1}{2}$ inches in diameter. The bob in its turn is connected to the rod of the man engine by a similar wrought-iron rod, linked to a flat tail, and secured by wrought-iron strapping plates, to a packing piece at the back of the rod. The beams of which the latter is built up average about 36 feet in length; their ends are simply butted together, and the joint secured by long wrought-iron fish or strapping plates placed in pairs opposite to each other on alternate faces, in a manner exactly similar to that employed in pump rods. The length of the plates is usually about 12 feet, giving room for eight bolts of $1\frac{1}{4}$ inches in diameter. At intervals, cross or T pieces are attached to the back of the rod; the ends of these pieces run between grooves in two vertical timbers 14 feet long, forming guides for preserving the verticality of the path of the rod, acting in a similar manner to those of an ordinary horizontal steam engine. The platforms are made of oak planks 1¼ inches thick and 12 inches square, carried upon triangular wrought-iron brackets. Handles made of ¾ inch round iron are fixed 4 feet above the platforms; they are plain staples 2 feet long, placed vertically, with the ends turned over at right angles and driven into the iron. Similar handles are placed above the stationary platforms on which the men run during the alternate strokes; they are attached to a fixed vertical wooden rail. The excess weight of the rod is counterbalanced by three balance bobs, one of which is at the surface and the other two are underground. The mass of the water wheel not being sufficient to produce a sufficiently uniform velocity of rotation, a fly wheel weighing 14 tons has been added; it is driven by gearing wheel at three times the speed of the original engine. There are other single rod engines in Cornwall, at Levant, Dolcoath, Carn Brea, and Huel Reeth; of these, the first is 200 fathoms long, making 4 strokes per minute; the second is 220 fathoms long, and makes 3½ strokes; the length of the stroke being, as is the case in all the Cornish engines, 2 fathoms.

VENTILATING MACHINES AND FURNACES.

No. K. 1.—Harzer Air Machine (Wettersatz).

No. K. 2.—Saxon Ventilating Fan.

No. K. 3.—Fabry's Ventilator, or Pneumatic Wheel.

No. K. 4.—Lemielle's Ventilator.

No. K. 5.—South Wales Colliery Ventilating Furnace.

No. K. 6.—Ventilating Furnace at Hetton Colliery.

No. K. 7.—J. M. Paull's Patent Ventilating Furnace.

No. K. 8.—Patent Self-closing Trap Door for Airways.

The whole of the models enumerated above are in Gallery E., Case 6, adjacent to the case containing the lamps.

The methods of ventilating the workings of mines fall primarily into two classes, viz., those in which mechanical agents are employed, and those where heat alone is used for setting up a current. The former class is again divisible into machines used for compressing and those for exhausting the air, the latter kind being employed almost to the exclusion of the former. In furnace ventilation, of course, the action is always an exhausting one. In the newly invented coal-cutting machines, compressed air of from 2½ to 3 atmospheres pressure is employed as the driving power; this may prove a great incidental advantage to the process, as the air escaping from the cylinder will aid the ventilation, and will also serve to cool the workings by the absorption of heat consequent on its expansion. The use of mechanical ventilators is, in England, generally confined to supplying fresh air to a single level, the whole of the workings of a large mine being but rarely dependant upon a machine for a constant circulation; they are, however, more used in the collieries of the North of France and Belgium, where pneumatic engines of considerable size and power are commonly seen. The great ventilating agent employed in English collieries is the underground furnace, which can be made sufficiently large for the requirements of the most extended workings. Permanent furnaces at the top of the up-cast pit were formerly employed to a certain extent, but are now rarely seen. The details of the method of passing air through the ramifications of a large mine, together with the position of the furnaces and drifts for fiery currents, have been noticed in the account of the workings in the North of England and Derbyshire at pp. 95 and 100.

No. K. 1.—Air Pump of the Harz (Harzer Wetter Satz.)

Scale, $\frac{1}{6}$. 2 inches to 1 foot.

This contrivance is employed in Cornwall and in the German mines for ventilating the ends of levels, and other places where the air is stagnant, by exhaustion; as it is usually of but small size and requiring little power it is generally attached to the rod of the pumping engine. It consists of a wooden box of a square section, open below and closed at the top, attached by a wrought-iron rod to a cross arm projecting at right angles from the main pump rod, by which it is moved up and down in an outer case of a similar shape partly filled with water. A pipe in communication with the level to be ventilated passes up through the bottom of the outer box to within a short distance of the top, it is covered with a plain clack or valve opening outwards; two similar valves are fixed to the top cover of the inner box. As the rod ascends a partial vacuum is established within the box, as communication with the outer air is prevented by the water joint, and the top valves are kept closed by the pressure of the external air; the valve on the pipe inside therefore opens and the air from the workings flows in until the change of stroke, when by the descent of the box the air is compressed and opens the two top valves, through which it passes freely into the atmosphere.

The same principle has been applied in Belgium to the construction of large ventilating machines for collieries. At Marihaye, near Liege, a pair of wrought-iron bells or cylinders are employed, each of 144 inches diameter and about 9 feet stroke; they are suspended by chains over guide rollers, and are driven by a direct-acting horizontal steam engine. There are 16 suction, and an equal number of exhaust valves, which, owing to the small difference of pressure produced, require to be counterbalanced with weights, in order that they may open and shut freely at the change of the stroke. The amount of air drawn by this machine is about 11,500 cubic feet per minute.*

NO. K. 2.—VENTILATING FAN USED IN THE SAXON MINES.

Scale, $\frac{1}{8}$. $1\frac{1}{2}$ inches to 1 foot.

This fan is of the same kind of construction as that employed for blowing ironfounders' cupolas; it has five radial arms with flat rectangular blades, which revolve about a horizontal axis within a cylindrical case or drum, having a circular aperture about 20 inches in diameter in the centre of each of the sides; the outside diameter of the fan is about four feet. The air taken in at the centre is discharged through a rectangular tube of 15 inches in breadth and 10 inches in height at the bottom of the drum, and is conveyed through pipes of a similar section, made of wooden planks or sheet zinc, into the forward end of the level to be ventilated. The fan is driven by a wheel 64 inches in diameter, connected by a strap with a spindle of four inches, giving 16 revolutions of the blades for one of the driving wheel. The strap is kept at a proper tension by a friction roller, attached to a board, which slides on a pair of horizontal cross timbers, an arrangement which allows the machine to be put out of work without stopping the driving wheel or

* Annales des Travaux Publiques de Belgique, vol. iii.

disconnecting the strap in cases where it is only required to be used intermittently. By putting the central apertures in communication with the air tubes, the fan can be used for establishing a circulation by exhausting the bad air. By surrounding the fan with spiral guide plates or diffusers, the air, instead of being discharged at a useless velocity against the walls of the drum, may be led off to the discharge pipe more conveniently and economically. Small ventilators on this principle, constructed by M. Schwamkrug, are now used in the Saxon mines; they have six arms, with blades 8½ inches square and 30 inches in diameter, and can be worked by one man at a maximum speed of from 400 to 450 revolutions per minute, with a pipe of 6 inches square; 60 cubic feet of air can be drawn in that time from a distance not exceeding a quarter of a mile. The quantity of fresh air required by a man at work in the end of a level, is estimated at six cubic feet per minute.*

No. K. 3.—Fabry's Ventilator, or Pneumatic Wheel.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

This machine is employed to a considerable extent in the Belgian collieries. It consists of two fans, each having three broad rectangular blades, arranged radially and at equal distances a part, around a horizontal axis, connected together by spur gearing wheels, so as to revolve at equal velocities in opposite directions. The fans are hung in a chamber of masonry, which covers about two-thirds of their circumference, the remaining parts moving in the open air. The chamber is rectangular in plan, with vertical side walls; the end walls are segments of horizontal cylinders, whose centre lines coincide with the axes of the fans. These cylindrical walls correspond to the drum in the ordinary fan blower; they are coated with cement dressed up to a smooth face, so as to give the smallest possible interval between the ends of the blades, without actually touching. The foul air from the mine is brought in through an arched passage in one of the side walls. The space intermediate between the two axes is kept isolated from the external air by a peculiar contrivance, each of the blades has a shorter blade projecting from either face at right angles, which carries a plate curved to an epicycloidal form; these cross arms are fixed at about two-thirds of the dis-

* Jahrbuch für den Sächsische, Berg and Hüttenmann, 1855.

tance from the centre of the blades towards the circumference. As the two fans turn towards each other on the inner side (between the axes), a pair of the curved heads, one on each wheel, are continually in contact, preventing any communication between the interior of the chamber and the outer atmosphere. The blades, as they rise, scoop up a quantity of air and deliver it at the outer edges of the chamber, the volume included between two contiguous blades being somewhat less than that contained in a segment of 120° of the cylinder bounded by the curved wall. A quantity of air is, however, carried in by the cross arms from without, this is in form, an irregular five-sided prism, whose bases are enclosed by those parts of two of the blades that lie between the centre and the intersection of the cross arms, the cross pieces on one side of these blades and the cross arms on the intermediate blade of the opposite fan. The volume of this prism is, however, but little greater than that of a cylinder whose radius is equal to the length of the blade between the centre of the axis and the intersection of the cross arms with the blades of the fan. The effective volume removed by each fan, per revolution, therefore, is nearly equal to that of a hollow cylinder whose longer radius is equal to the length of the blade, the smaller one being the point of intersection of the cross arms. These machines are usually made with arms 46 to 48 inches long and about 115 to 120 inches broad. The effective volume removed per minute is equal to rather more than 25,000 cubic feet, at a pressure of from 1¾ to 2 inches of water, the wheels making from 36 to 40 revolutions during that time; this requires a disposable effect of 14 steam horse-power, about one-half of which represents the useful mechanical effect.*

No. K. 4.—Lemielle's Ventilator.

This machine has a vertical cylinder, within which revolves a second cylinder or drum, also vertical, but whose axis is placed eccentrically with regard to the outer one. Two portions of the circumference of the inner drum are truncated and replaced by flat sides, to which a pair of hinged leaves or doors are articulated. The section of the inner cylinder approximates to that of a barrel, the heads representing the flat surfaces to which the doors are fixed. These doors are kept continually in contact with the inner

* Ann. des Travaux Pub. de Belgique, vols. xi. and xv.

surface of the outer cylinder by means of rods attached to an elbow or crank formed on the vertical shaft on which the drum revolves, the arrangement being similar to that of the feathering float boards adopted in paddle-wheel steamers. The central line of the aperture by which the air is introduced makes an angle of about 150 degrees with that of the discharging orifice. The folding door as it advances pushes the air taken in at the feed aperture before it, the contact with the cylinder wall being kept up by the eccentric rod, which causes the door to open out further, making a constantly increasing angle with the side of the drum, as the distance between the inner and outer cylinders increases, this goes on until the crank has passed its centre, when the door is again gradually drawn in, as necessitated by the diminishing distance between the cylinders, until it reaches the discharging aperture, where it occupies the same angular position with respect to the side of the drum that it did at starting. The volume of the air carried through the machine by each door, as it revolves, is equal to that of a crescent-shaped solid, with truncated points, whose horizontal section is equal to that part of the base of the outer cylinder, that is truncated by a chord, joining the admission and discharging passages, diminished by half the area of the base of the drum.*

No K. 5.—Colliery Ventilating Furnace, used in South Wales.

This is the commonest class of underground furnace; it consists of a plain rectangular fire-grate placed at the lower end of a level or drift, which rises at an angle of about 15° towards the up-cast shaft. The level is driven in the solid coal and is lined with brickwork, the roof forming a continuous cylindrical arch or vault. The furnace is covered by a similar arched gallery of smaller dimensions constructed in fire-brick, the intermediate space is divided by arched diaphragms into cellular air passages, in order that the outer arch may not become unduly heated by the fire. A funnel mouthed pipe is placed on one side of the lid in front, it communicates with a transverse pipe perforated with small holes placed across the back of the grate, which serves to introduce air for the more perfect combustion of the smoke and inflammable gases produced by the fire. The section of the flue is somewhat diminished at the

* Ann. des Travaux Pub. de Belgique, vol. xvi.

upper end. The section of the up-cast shaft is a four-sided figure with curved sides, formed by two pairs of circular arcs of different length and curvature.

No. K. 6.—Ventilating Furnace at Hetton Colliery, Durham.

Scale, $\frac{1}{24}$. Half an inch to 1 foot.

This is a furnace of the largest class, and it is so arranged that the amount of grate surface at work may be varied according to the necessities of ventilation. It stands in a rectangular chamber, opened in the solid coal and lined with brickwork, having a flat segmental vaulted roof. The fire-grate is level, it measures 25 feet in length by 5 feet breadth on the bars, giving a total surface of 125 square feet; there are four pairs of feeding doors in the front longitudinal wall arranged like those of the furnaces of a marine steam boiler; other doors are placed above these for drawing air above the fire. The top of the furnace is arched in firebrick; the hinder wall is placed within two feet of the wall of the enclosing gallery; on the firing side there is a clear space of seven feet for the stokers, in addition to which there are two rectangular recesses for storing coals in the wall of the chamber, which are four feet square. The up-cast shaft is circular in plan, measuring nine feet in diameter, and is lined with firebrick. There are two furnaces in connection with this pit, producing a draught of 104,000 cubic feet of air per minute at a pressure of one inch of water.

No. K. 7.—Paull's Patent Ventilating Furnace.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

Presented by the Patentee.

This furnace was patented in the year 1857, it is intended to be used in fiery collieries where the air may be drawn through the furnace without coming into contact with the flame. The fire-grate is placed at the bottom of a square shaft, with an arched roof, terminated by an upright and slightly conical chimney. A number of metal tubes are placed across the furnace in horizontal rows, somewhat similar to those of a locomotive boiler. The outer surfaces of the tubes are exposed to the direct action of the fire, which expands the air in the inside, and as the ends of the tubes are in free communication with the air, a current is established passing the air from left to right, the discharging side being in direct communication with the atmosphere. The products of combustion from the fire are only brought in contact with the up-cast air at the top of the chimney, where the temperature is considerably reduced. The patentee recommends that the length of the tubes should not be reduced below six feet, and that they should be tapered, increasing in diameter from the in-take to the discharging side. The limits of diameter recommended are between six and nine inches.

No. K. 8.—Patent Self-closing Trap Door for Air-ways. By Mr. Thomas Heaton, Bolton.

This is intended for preserving the ventilation in galleries which are used for drawing coals. The pressure of the front of the tram waggon against a pair of bent levers turning upon centres attached to the walls, causes the doors to slide apart. As soon, however, as the waggon has passed a corresponding pair of levers on the opposite side, the doors, which are suspended by rollers to a slide, whose upper edge forms a double inclined plane, are brought back to their former position by the fall of the rollers on the slide.

MACHINES EMPLOYED FOR THE DRESSING OF MINERALS.

This division includes all the appliances required for crushing and separating ores and coals from intermixed worthless materials, under the following special classes:—

A. CRUSHING.

1. Crushers.
2. Stamps.

B. SIZING.

3. Sizing Sieves and separating Drums.
4. Slime Sizing Apparatus.

C. SEPARATING.

5. Trunks and Cases, Tyers, &c.
6. Slime Washing Tables, Round and Rotatory Buddles.
7. Jigging Machines.
8. Shaking Tables.

CRUSHERS.

The models belonging to this division are in the west gallery, with the exception of two crushers which are too large and heavy to be exhibited in their proper places; one of these is in the east room, and the other No. L. 3. in the small room communicating with the eastern gallery. The drawings of Berard's coal dressing machinery are hung on the walls of the principal entrance of the galleries from the second story of the museum.

No. L. 1.—Crusher at Tywarnhaile Mines.

No. L. 2.—Cornish Crusher, by Jordan.

No. L. 3.—Derbyshire Hand Crusher.

No. L. 4.—Mackworth's Ironstone Crusher.

No. L. 4*.—Stonebreaking Machine.*

The crusher is a machine used for breaking down minerals into a coarse powder, suitable for treatment by jigging or other dressing processes; it is also employed for reducing clean ores into powder for the smelter. For all substances of medium richness and hardness, especially in the case of lead ores, it possesses great advantage over the stamps when combined with a proper classifier, as its work is done dry, and therefore the loss by the diffusion of finely divided ore through large quantities of water in the form of slimes is avoided. The crushers usually employed at the present time consist of a single pair of cast-iron cylinders placed horizontally and nearly in contact, coupled together by spur wheels of equal diameter, so that their surfaces revolve towards each other at an equal velocity. Rollers with projecting teeth are employed in a few instances but are by no means as common as the plain form.

No. L. 1.—Crusher at Tywarnhaile Mines, Cornwall. Presented by the late John Taylor, Esq., F.R.S.

Scale, $\frac{1}{6}$, or 2 inches to 1 foot.

The rollers of this machine are of unequal length, the driver being 24 inches and the follower only 18 inches, both are of the same diameter, namely, 27 inches; they are formed of thick cast-iron shells keyed on to cylindrical bosses, on a pair of plain shafts, which have couplings out-

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* For description of No. L. 4. see page 199.

side their bearings connecting them with a pair of lighter shafts, carrying the gearing wheels. The bearings of the shorter roller slide between parallel guides, and are kept in position by round bars passing through holes in the frame which are pressed against by the shorter arm of an unequal armed bent lever, whose longer arm carries a loaded box; the relation of the two arms to each other is as 1 to 9. The object of this arrangement is to save the rollers from fracture in case any unyielding substance should get between them, for when the resistance of any fragment is greater than the horizontal thrust exerted by the loaded arms on the bearings, the shorter roller slides apart from its fellow and opens a passage for the unbroken substance to pass through. The broken material passes into a tubular or drum sieve, 42 inches in length and 24 inches in diameter, whose axis is set at an angle of 25° to that of the driving roller, with which it is connected by a pair of bevil wheels, the smaller wheel on the sieve shaft having 11 teeth receives motion from a larger one of 40 teeth. The gauze has six apertures to the square inch; the particles passing through are received in a box, closed by a door, through which they are loaded into a truck on the railway below; the coarse fragments are thrown out into the buckets of the raff wheel or lifting wheel, which resembles a reversed water wheel, being closed on its outer circumference, but provided with a ring of buckets opening inwards; it is 15 feet in diameter, and being coupled to the driving roller makes the same number of revolutions; it discharges its contents on a floor immediately adjacent to the feed hopper to which they are returned to pass a second time through the rollers.

A crusher of this size makes from 30 to 50 revolutions per minute, requiring an effective driving power of from 12 to 20 horse power, and will break down a quantity of ores, varying from 40 to 60 tons per day, according to the hardness of the associated gangues.

No. L. 2.—Cornish Crusher for Copper Ores.

Old Pattern.

Scale, $\frac{1}{12}$, or 1 inch to 1 foot.

This is a small crusher, driven by an over-shot water wheel, with an intermediate train of spur gearing. A cross bar is inserted behind the bearings of the loose roller to receive the pressure of a single balance lever in the centre, instead of using a special weight for each end. The broken stuff is discharged sideways down an inclined shoot into the drum sieve, whose axis is placed at right angles to that of the rolls, and is driven by a special train of gearing wheels. The coarse fragments are thrown into a rectangular box or kibble, which moves between wooden guides, and when filled it is lifted by a rope winding on to a windlass barrel fixed above the rollers; the shaft of this windlass is slung to the end of a lever, by which it can be lifted out of gear. A coiled spring attached to the plummer block of the loose end keeps it in position when in use. The rollers make four revolutions for each revolution of the water wheel.

No. L. 3.—Derbyshire Hand Crusher.

This is used in the small lead mines of Derbyshire when only a few hands are employed. It has two plain rollers of cast iron, 2¾ inches in diameter, and 8 inches long, geared together by spur wheels in the usual manner. The loose roller is not balanced by weights, but is kept in position by setting screws acting on the outer face of the bearings. The ore is supplied through a hopper 12 inches square at the top, to which is hinged a shallow inclined tray with two projecting arms, terminated by convex bosses at the lower end; these bosses rest on the outer faces of the gearing wheels of one of the rollers, and are set in vibration by the teeth as they pass, this gives a jerking motion to the tray, bringing a fresh supply of ore continuously to the roller. The broken stuff falls down an inclined plane into a dish made of sheet iron placed for its reception below.

No. L. 4.—Ironstone Crusher.

This is a pair of rollers studded with coarse blunt teeth, arranged in a spiral form around their circumferences; it is intended for breaking ironstone into coarse fragments in order to facilitate the separation of intermixed argillaceous matter.

STAMPS.

No. L. 5.—Steam Stamps, Carn Brea Mine.

No. L. 6.—Tin Stamps, Par Consols.

No. L. 7.—Saxon Wet and Dry Stamps.

No. L. 8—Australian Stamps.

No. L. 9.—Ironstone Washing Machine.

The stamping mill is the machine generally employed for reducing minerals to a state of division sufficiently fine to allow of the classification of their component parts by the action of water. It consists essentially of a series of vertical beams shod with masses of wrought or cast iron, called stamps, which are lifted by cams fixed on the circumference of a rotating barrel and allowed to fall on the fragments of ore beneath them. The powder or coarse sand produced by the stamp is removed by a current of water passing through the stamp box or cofer, the discharge taking place either through a perforated metal plate, a grating of bars, or by the swell of the water over a thin edged board or weir; this last form of stamp is known as a "flasher."

No. L. 5.—Cornish Steam Stamp, Carn Brea.

Scale, $\frac{1}{12}$, or 1 inch to 1 foot.

This is the original arrangement of the stamps at Carn Brea Mine, Cornwall, but it is no longer in existence, having been replaced by a more powerful set. The stamp heads are 72 in number, divided into two lines of 36 each; the steam engine is placed between them, and drives the cam barrels by a pair of short shafts, each carrying a fly-wheel, which are coupled together by the pin of the driving cranks. The stamps work in sets of three, divided from each other by upright pillars, to which are attached thick oaken planks forming a closed box or cofer to a height of about 20 inches above the ground. The ores to be stamped are introduced, together with a stream of water, through a square hole in the hinder wall of the cofer, whilst the finely divided materials is carried out by the stream through perforated metal plates on the front wall. The stamp head is a mass of white cast iron of an irregular prismatic form, furnished with a tapered projecting tongue at its upper end, which is sunk into a corresponding socket at the lower end of a vertical timber beam called a lifter, and is secured in place by two narrow wrought-iron bands. The lifter moves vertically between two pairs of parallel guides, which are attached to transverse bars uniting the dividing pillars of the sets together, a wooden tongue projecting at right angles from it about midway between the guides receives the action of the rotating cam shaft. Each head is lifted five times in every revolution of the engine. The cams are made of cast iron, shaped to an involute curve, having wedge tails, by which they are keyed into their sockets on the cam barrels; the latter are hollow cast-iron cylinders with flanged ends, united together by screw bolts; the journals are attached by covering plates similar to those of the large Cornish water wheels. A simple disengaging clutch is introduced in the middle of each line, dividing it into two parts, each of 18 heads; the ends nearest to the engine are connected with the driving shaft by ratchet couplings, an arrangement which allows the engine to be run independently of the stamps if necessary; its chief object, however, is to prevent the possibility of the cam barrels being turned in the wrong direction, if by mistake the engine should be reversed by the driver at starting. The bed on which the stamps work is formed of a hard quartzose stone, stamped in a dry state to a depth of eighteen inches between longitudinal walls of masonry. The ores broken into lumps of about two cubic inches volume, are brought in waggons along a railway raised about ten feet above the ground, running parallel to the whole line, and a short distance behind it, and are received in large hoppers with inclined bottoms leading into the backs of the stamp cofers. The descent of the lumps is effected partly by their own weight, partly by the general shaking set up by the falling stamps on the framing, and partly by the action of the water which is introduced near the outlet of the hopper.

In the year 1857 the Carn Brea stamps included 96 heads, divided into sets of four, each one weighing 660 lbs., and striking 44½ blows per minute with a fall of 9 inches, the driving shaft making 8½ revolutions in the same time. The motive power is furnished by a single acting high-pressure condensing steam-engine, with an unequal armed beam; the steam piston is 32 inches in diameter, making a stroke of 9 feet; the radius of the crank is only 4 feet. The two fly-wheels are each 20 feet in diameter. Each head will stamp about 200 tons of ore per annum, or about 13 cwt. daily (in 24 hours); the amount of water consumed is about three gallons per head per minute. The discharging grates are plates of copper perforated with holes of $\frac{1}{30}$ or $\frac{1}{40}$ of an inch in diameter. The weight of the stamps employed in other tin mines in Cornwall varies from 3½ to 7½ cwts, the lighter ones being usually employed where water is the motive power. The height of lift is from 9 to 10½ inches.

No. L. 6.—Stamps at Par Consols.

Scale, about $\frac{1}{6}$ of full size.

This model represents a set of four heads without the cam barrel. The lifters are made of rectangular balks of Norway for with wrought-iron tongues and guides; the latter are formed by two pairs of triangular prisms of an equilateral section, one edge being turned outwards, they rub against planks of soft wood attached to the cross bars of the framing. The shorter sides of the cofer, as well as the front, are provided with discharging grates, formed of perforated iron plates, each of these rest against an iron backing, lining the aperture on the inner side of the box, and is kept in position by a wrought-iron pressure frame, secured by a cross bar resting on two arms projecting from the outer side of the cofer. The front grate is of extra large size, measuring 23½ inches in length by 7 in height. The weight of the stamp head complete is 5¾ cwts.; the lift is 10 inches; the number of strokes per minute 50. A double cylinder engine on Woolf's principle of about 50 effective horse-power, is employed, it moves 76 heads, of which 68 are worked on tin, and the other 8 on copper ores, 20 are flashers, and the remainder stamp through grates. The ore stamped by each head is 265 tons per annum, or about 27 per cent. more than the yield per head at Carn Brea; the ore contains chlorite in considerable quantity, yielding about 1·25°/₀ of metallic tin. The sandy mud passing out through the grates is received in a rectangular channel called a strip, there are two of these for every set of four heads, which are in use alternatly, one being cleared out while the other is filling, they are of the following dimensions, 12 feet long, 14 inches broad, and 12 inches deep, with a forward slope of $\frac{1}{72}$, or 2 inches in the length. The reputed density of the material collected is 1·3, this would give a weight of about half a ton for the contents of one strip when filled, or 14 cubic feet at 80 lbs. The filling takes place in twelve hours, during which time the four heads in the set will have worked through two tons of the ore; the sand deposited in the strip amounts therefore to about 17½°/₀ of the weight of the ore originally treated. The finer materials retained in suspension by the water are collected in large basins called slime pits.*

No. L. 7.—Stamps used in the Saxon Mines.

Scale, $\frac{1}{20}$. ⅗ of an inch to 1 foot.

In the dressing floors in the neighbourhood of Freiberg, stamps driven by water power are exclusively employed. The weight of the head is smaller, and the number of heads

* Moissenet, Ann. des Mines, 5 ser., vol. xiv.

combined together at one spot are fewer than is usual in the Cornish steam stamps. In the model before us we have a series of nine stamp heads, six of which form a set for stamping over with water (Nasspochsatz), while the other three are employed instead of a crusher for pulverizing dry lead ores to fit them for the smelter. The lifters are square beams of alder wood, the tongues being made of the same material; the stamp heads (poch schühe) are of wrought iron. The ores are supplied to the wet sets out of a large hopper, a separate shoot being provided for every three heads; it is of a semicircular section with a vertical wooden pole attached to its lower end, which is struck by a hinder tongue, called the knocker, on the back of the lifters of the stamps, Nos. 5 and 2 in each set of six, these heads are distinguished on account of their office as feeders (unterschürer), the blow of the knocker on the upright pole communicates a jolting motion to the launder, and brings a fresh supply of ore continuously into the stamp box. The discharge of the stamped stuff is arranged on the "flasher" principle by a narrow aperture extending along the front of the set at a height of 10 inches above the floor. The water is introduced by a semicircular wooden launder, with regulating cocks on the front of the cofer, and is not brought in with the ore as is the case in Cornwall. The floor on which the wet stamp heads work is formed of hard vein stuff closely beaten in between a framing of longitudinal wooden bars. The dry heads work on a cast-iron anvil supported on upright beams placed close together, there is no special arrangement for feeding, the ore being usually shovelled in by hand and removed in the same manner, a vibrating riddle or sieve is usually employed for sizing the grain of the crushed ores. The cam shaft is a single piece of oak, it carries an overshot water wheel at one end; the cams are made of alder wood shaped to the proper curvature and bedded into mortices on the shaft. Each head when new weighs 300 lbs., and is lifted three times in the revolution, the height of the lift is 14 inches for the wet, and 9 inches for the dry heads. The lifters are guided on all four sides by transverse bars and thin wooden intermediate plates; the frame pillars dividing the sets are placed at intervals of six heads, and not at every three or four as is customary in England. The water wheel is a plain wooden overshot wheel of the common German pattern, with the arms framed over the axle, but having cast-iron buckets of a kind very generally employed in the Saxon mines, and not common elsewhere. Each bucket is formed of a single thin plate, the outer part forms a straight wall set at an angle of 75° to the circumference, terminating in a bevelled lip, below which is a curved portion forming an arc of nearly 90° of a circle of small radius; the inner edge is thickened by the addition of a triangular prism, which forms a projection for the support of the backing planks, the sides are imbedded in grooves of a corresponding form, cut into the wooden shroudings.

The usual working speed is from 42 to 45 strokes per minute, twelve heads working dry will crush per shift of 8 hours,—

3·5 tons of clean galena.
2·4 tons of pyrites or pyritic ores.
1·5 tons of ore containing carbonate of iron.

The top edge of the discharging board of the wet stamps is laid from 9½ to 11½ inches above the floor. Each head works through about 20 cubic feet of poor ore (about 16 cwts.) in 24 hours, requiring about 1,200 cubic feet of washing water during the same period.*

No. L. 8.—STAMPS USED IN THE GOLD MINES OF AUSTRALIA.

The stamps in this model are cylindrical; having cast-iron heads secured by moulding them on to the forked tail of a wrought-iron rod, which forms the lifter; a small cylinder is keyed on to the lifter in place of the ordinary tongue; the cams act on the lower face of the cylinder on one side of the upright rod, causing the latter to rotate between its guides as it rises, performing nearly one-third of a turn at each lift, the object of this arrangement is to equalize the wear of the cast-iron head by continually bringing a fresh surface in contact with the rock below; the discharge takes place through grates in the common Cornish manner. The stuff carried out passes first over a shallow trough containing mercury, and next on to a series of inclined tables, broken at intervals into low steps which are covered with coarse blue serge; the gold becomes entangled in the fibres of the cloth, and is removed by washing the latter from time to time in a tub of water. The product is a highly auriferous sand, containing magnetic iron ore, &c. which can be cleaned either by amalgamation or hand washing. In some instances a second mercury trough of large capacity is used below the blanket tables. The cams are cast with central bosses, which are hollowed out to receive the shaft,

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* Delvaux de Feneffe. Revue Universel, vol. iv., p. 302.

which is a plain wrought-iron cylinder, connected by spur gearing with the shaft of the driving engine.

The stamps now in general use in the Clunes gold mines near Port Philip have heads made of Bessemer steel, weighing 4½ cwt., but the weight of the newest ones is increased to about 7 cwt., they are united to the lifters by dovetailed wedges in a similar manner to that used for the attachment of the faces of heavy forge hammers. The discharging grates are pierced with 81 holes to the square inch; the working speed is 76 strokes per minute. The amount of stuff stamped per head per day in August 1854, at the works of the Port Philip and Colonial Gold Mining Company, varied according to the hardness of the rock from 34 to 86 cwts., the average being 54 cwts. The rock contains about half an ounce of gold in the ton, about 30 per cent. of which is lost in dressing. Of the amount saved, 66 per cent. is collected under the stamps, 22 per cent. is intercepted by boxes of mercury, and twelve per cent. is retained by the blankets.*

No. L. 9.—Ironstone Dressing Machinery.

This is a combination of stamps with a washing apparatus; there are seven heads, arranged in two sets placed one above the other, working on a cast-iron floor. The crushed material is received in a conical tub, in which revolves a vertical shaft with projecting knives resembling the common brickmaker's pug mill. A force pump at the side maintains a continuous current of water through the tub. The shale and lighter impurities are discharged at the top, whilst the cleaned ironstone collects at the bottom, and is removed through a hole in front, which is stopped by a covering plate when not in use. This arrangement is figured in French works on iron smelting under the name of Bocard and patouillet.

SIZING MACHINERY.

No. L. 10.—Saxon Sizing Sieves.

No. L. 11.—Saxon Drum Sieve for Stamps Sands.

No. L. 12.—Slime Separator.

No. L. 13.—Conical Slime Cleaner.

This is a division including such arrangements as are used for classifying sands according to grain, preparatory

* Dicker's Mining Record, vol. iii., p. 166.

to their treatment in the separating machines proper, *i.e.*, those that produce finished ores; it includes stamps, catch pits, and sifting machines, as well as the newer slime classifiers, where a current of water in mechanical saturation is made to deposit the stuff held in suspension either by an opposing current, or by sudden alterations in the sectional area of the channel.

No. L. 10.—Sizing Sieves (Rätter Maschine) used at Freiberg.

Scale, $\frac{1}{8}$. $1\frac{1}{2}$ inches to 1 foot.

This machine is employed for classing the ore into sizes after it has passed through the crusher, instead of the drum sieve used for the same purpose in England. It has a series of rectangular sieves suspended one above another, receiving a jerking motion from a rotating cam shaft. The sieves are all of the same breadth, but are of dissimilar lengths, decreasing from above downwards; the size of the apertures of the meshes of the wire gauze also diminishes in the same manner; they are hung parallel to each other with a forward slope of eleven degrees from the horizontal line. The cams are attached to cast-iron rings encircling a vertical wooden shaft, which is turned by a mitre wheel near the top, they act upon wrought-iron tongues projecting at right angles from a series of wrought-iron bars, attached one to each sieve at the hinder or upper end. These bars, which are of considerable length, have their ends supported on guide rollers; other rollers are also employed to prevent the sieves from moving laterally. The ore is supplied from a large hopper to the higher end of the top sieve; the particles that pass through are received on the second, and so on; those that remain on the gauze are continually urged forward by the jolting, until they fall over at the lower end into a special compartment of the receiving hutch. The number of classes produced is one more than the number of sieves employed. The model has four sieves, but a larger number, generally six, is preferred in practice. The following are the dimensions of one employed at Thurmhof, near Freiberg.

Nos. 1 and 2 are each 10 ft. 8 in. long, the gauze having apertures of 0·37 and 0·23 in.
No. 3, 8 ft. 4 in. long, the gauze having apertures of 0·18 in.
No. 4, 8 ft. 0 in. „ „ „ 0·12 in.
No. 5, 6 ft. 7 in. „ „ „ 0·09 in.
No. 6, 5 ft. 2 in. „ „ „ 0·06 in.
The breadth of the gauze is 4 ft. 4 in. in each sieve.

Fragments too large to pass Nos. 1 and 2 are returned by a raff wheel to the crusher; those from the remaining ones are treated apart on jigging machines of different fineness. The fine stuff passing through No. 6 is fit for washing on the flat tables described at p. 146. The same machine is also employed for cleaning the dirt from small mine ores (grubenklein), to fit them for hand picking. In this case a small quantity of water is passed through with the ore.*

NO. L. 11.—SIZING DRUM (SEPARATIONS TROMMEL).

Scale, $\frac{1}{8}$. $1\frac{1}{2}$ inches to 1 foot.

This is a plain drum covered with wire gauze of different finenesses, placed horizontally, and receiving a slow motion about its axis by means of a driving strap on the stamp shaft. The sands from the stamps are introduced through a launder on the left-hand side, and passed slowly along by a spiral plate extending along the whole length of the drum to the other end, where the particles which are too large to pass through the gauze are discharged through a rectangular opening of about one foot in surface. The drum is $5\frac{1}{2}$ feet long and $49\frac{1}{2}$ inches in diameter; the gauze is divided into three unequal parts, whose relation to each other is as 2 : 2 : 1. The first division has 150 holes to the square inch, the second 75, and the third 30. The surface is kept clean from adhering particles by a series of small jets of water dripping from a launder placed above. The sands are conveyed by plain launders to the collecting pits, the larger particles kept back going with the coarsest division separated by the gauze. The sieve makes seven revolutions per minute.

NO. L. 12. SLIME SEPARATOR.

Scale, $\frac{1}{12}$th. 1 inch to 1 foot.

Nos. L. 12, 13, 20, 21, and 29 are combined in the model presented by Mr. Whitton Arundel.

This is a modification of the apparatus called the Spitzkasten, or pointed slime pit, originally introduced by Rittinger in 1844, in which a classification is effected by the interposition of large pyramidal boxes or square funnels in the course of the shallow launder conveying the stuff from the stamps. The heaviest matters are deposited in the first box, whilst the lighter parts remain in suspension, passing on to a second box of the same kind, whose sides slope at

* Revue Universel, vol. iii., p. 252.

a different angle, which removes a fresh portion of the stuff kept back, being discharged through a small channel at the bottom. In the model the slime is passed through a drum sieve covered with perforated copper plate, into a launder about 10 feet long and 13 inches broad, at the upper end of which it encounters a parallel stream of clear water, introduced through a vertical pipe provided with a regulating valve. The separating funnels are four in number, placed one behind the other; they vary in length and in the slope of the sides, but are all of the same breadth and depth. No. 1, the uppermost, is 5 inches, No. 2, 8 inches, and No. 3, 11 inches, and No. 4, 15 inches in length at the top, the depth being 12 inches, and the breadth 13 inches. Discharging pipes are inserted at the apices of the funnels, leading off the separated materials to a series of rotatory buddles, where they undergo a final cleaning. The higher divisions, Nos. 1 and 2, supply buddles with concave tables, whilst the finer stuff from Nos. 3 and 4 is treated on convex ones. The fine stuff which remains in suspension after passing the fourth funnel is discharged through the waste pipe at the lower end of the trough.

No. L. 13. Conical Slime Separator Presented by Mr. W. Arundel.

Scale, $\frac{1}{12}$th. 1 inch to 1 foot.

This machine consists of a conical plug supported by a foot spindle at its apex, surrounded by a cast-iron case of a similar form, but of somewhat larger dimensions, the intermediate space forming a narrow funnel-shaped passage for an upward current of water, which is introduced through two branches from a pressure pipe; the top of the plug is an upright cone somewhat more obtuse than the lower one; it acts as a spreader for the slime which is introduced above it, and is provided with a loose lid whose position can be regulated by setting screws. When at work the downward current is regulated in such a manner that the bulk of the earthy material is stopped and immediately removed by the upward flow of the clean water, while the heavier particles fall through and are discharged at the bottom of the lower funnel. A machine differing very slightly from the above was introduced in the lead mines of the North of England in 1859 by Mr. Borlase.*

* Ure's Dictionary, vol. iii., p. 333.

SEPARATING MACHINES.

Under this head may be included all the contrivances giving merchantable ores or highly concentrated substances as finished products. They are divisible into classes according to their method of operation, as follows :—

1. Machines in which the ore is washed by a simple flow of water, the ore collecting in a deep box or pit; this includes the various classes of buddles and cases used in tin dressing and the trunking apparatus No. L. 15.
2. Machines in which the ore is washed on an inclined surface in a thin layer by a stream of water, and removed by the same agent. This includes the so called sleeping or flat tables and the round frames.
3. Machines in which the action of water is combined with constant or intermittent vibratory motion, as in the various forms of jigging machines, the shaking table and the dolly tub.

No. L. 14.—Hunt's Mineral Washing Case. Presented by Mr. John Hunt.

Scale, $\frac{1}{10}$th. $1\frac{1}{5}$ of an inch to 1 foot.

This machine was employed in washing the waste heaps from the old workings at the mine of Pont-péan, near Rennes, in Brittany. The ore to be dressed is mixed with water in a shallow trough at the upper end, and is constantly swept with brooms on to copper plates perforated with conical holes $\frac{1}{15}$ of an inch in diameter at the upper surface, increasing to $\frac{1}{10}$ of an inch below; the stuff that passes through is conveyed by two narrow channels into a trunk or chest $9\frac{1}{2}$ feet long, $4\frac{1}{2}$ feet wide, and 2 feet deep, the floor having an inclination of 8°, being first diffused evenly in a thin sheet by means of heading boards furnished with distributing studs. The best ore is found at the head of the trunk, the deposit diminishing in value downwards. The speed with which the material descends can be varied by fixing the point of discharge for the tail water at a higher or lower level, a series of holes placed one above another being prvoided for this purpose in the bottom board of the trunk; those not in use are stopped with conical plugs. The surface of the deposit requires to be kept even towards the lower end; this service is performed by a child with a broom, sitting on a cross plank, who also superintends the discharge of the tail water, by shifting the plugs when necessary.

The stuff remaining behind on the perforated plate at the top is fit for treatment by the jigging machine.

No. L. 15.—Slime Trunking Machine. Presented by Mr. M. Attwood.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

This arrangement was introduced by the inventor in the lead mines at Alston Moor, Northumberland, in the year 1849, it consists of three similar machines, placed side by side, each having a rectangular chest or trunk, in which the separation takes place by subsidence, combined with a mixing apparatus for effecting a thorough incorporation of the slimes with the washing water. The stuff to be dressed is first thrown into a chest at the upper end, where it receives a supply of clean water through two holes in the front wall. The tougher part of the slime is then subjected to the action of a wheel with projecting knives, which cuts it through, and passes it to a breaking wheel, with four plain blades, extending over the whole breadth of the chest; this wheel agitates the water charged with ore, after the manner of a shovel; the properly incorporated material passes through a curved plate, perforated with holes, the coarse particles, chiefly chips and dirt, remaining on the plate are continually swept off by a rotating bar, carrying besoms, into a launder of a V-shaped section, which is cleaned out from time to time. The stuff passing through the grating is received on a sleeping table or plain inclined board, where it meets a stream of clean water, and after undergoing a further incorporation by a second paddle wheel, falls into the trunk, which is rectangular, 28 inches broad, 15 inches deep, and 7 feet 4 inches long. The floor has a forward inclination of about 2°, the usual provision being made for altering the depth of the tail water by a series of holes at different heights in the bottom board. The heads of the deposit in the trunks, are treated in the dolly tub adjoining. This is a plain wooden tub, in which a certain quantity of ore is agitated with water by a revolving paddle, attached to a vertical shaft, while at the same time a series of blows are struck on the outside by a vibrating bar or knocker; by this treatment the ore is packed into layers of different densities, the best ores depositing at the bottom in a sufficiently pure condition to be sold. The top skimmings give waste material, and the middle part is reserved for further treatment. The tub is mounted upon wheels, and runs on a railway for the convenience of manipulation. The rotating paddle is attached to a horizontal cross bar, moving between parallel iron guides, so that it can be lifted out of the tub, when the latter is ready for removal. The whole of the moving mechanism is turned by a small overshot water wheel, the trunking paddles being driven by spur gearing and the dollying apparatus by straps. The knocker is driven against the tub by a wheel with projecting cogs, and is brought back by a spring to its former position.

No. L. 16.—Saxon Slime Washing Table (Einkehrheerd).

Scale, $\frac{1}{12}$. 1 inch to 1 foot.*

This is an old machine of the class known as sleeping tables or frames. It is employed for the treatment of very finely divided ores, such as the hutch work or tub ore passing through the perforations of the jigging sieves. In the treatment of poor slimes of extreme fineness it has, however, been replaced to a considerable extent by the rotatory buddle. The material to be treated is introduced into the slime box, where it is reduced by the addition of clean water to the consistency of a very fluid mud, and after passing through a fine sieve, which keeps back any chips, leaves, or other extraneous matter, it is received on a head board provided with distributing buttons or studs, by which it is delivered in a thin uniform stream on to the table. The latter is a rectangular wooden platform, 14½ feet long and 3¾ feet broad, with a slight forward inclination. The surface is made of hard wood planks, brought up to a perfectly true surface, and then slightly roughened by the action of strong sulphuric acid. The flow of the slime is continued until a layer of about an eighth of an inch in thickness is formed over about three-quarters of the surface; the supply is then stopped off, and the deposit is subjected to the cleansing action of a gentle current of water, which removes the lighter parts of the earthy impurities, and carries them over the end of the table into the tail-waste launder below.

* From a description accompanying drawings published by the Academy of Freiberg; also in the Revue Universel, vol. iv., p. 287.

As soon as the washing is complete, which is recognized by the darkening of the colour of the deposit, it is classified into three parts, which are removed from the table into different divisions of the ore box below. A small moveable launder, resting on a stirrup below the frame, is employed to bridge over the intermediate space, and leads the different products into one or other of the divisions according to its position. The lowest division is considered as waste, and is swept off by brooms of pine branches, or brushes made of hogs' bristles, into the inner or nearest division of the tail box. The middle portion, consisting chiefly of iron pyrites mixed with some uncleaned slime, is sent into the front box, passing first through a sieve; the uppermost division, occupying from one-third to one-fourth of the whole length, is good ore, and is passed, by reversing the tail bridge, into an ore box or unterfass below the table, The removal is aided by a stream of water, the strength of which is increased towards the end of the operation, in order to clean the surface in readiness for the next charge. The entire process lasts about 20 minutes. The working of four tables can be superintended by a boy of 13 or 14 years of age. The lower end of the table is supported on a trestle, provided with adjusting wedges for varying the inclination according to the nature of the ore. The yield of the cleaned ore varies with the nature of the substances treated. The best is obtained from the hutchwork of the finer jigging sieves, it contains from 60 to 70 per cent. of lead and from 70 to 80 ounces of silver per ton. This is known as best glance. The fine slimes produced in the treatment of the small mine ores (gruben klein) yield, after a second washing, an ore containing only from 15 to 20 per cent. of lead, and 18 to 20 ounces of silver per ton.

ROUND BUDDLES AND FRAMES.

No. L. 17.—Cornish Round Buddle.

No. L. 18.—Zenner's Rotatory Buddle.

No. L. 19.—Saxon Rotatory Buddle.

Nos. L. 20, 21.—Concave and Convex Rotatory Buddles (with Metal Tables, Mr. Whitton Arundel's).

No. L. 22.—Rittinger's Rotatory Concave Frame, (Drehheerd.)

The round buddle which was first used in the lead mines of Cardiganshire, has of late years been extensively introduced into other mining districts, both in the United Kingdom and on the continent of Europe, as a means of dressing finely divided ores of a low per-centage; it has at the same time undergone several modifications, more especially in the Harz, Rhenish Prussia, and Hungary, which may be classed under the following heads, with examples of each kind:—

I. Round buddles with fixed floors.

a. Outward flow or convex buddle, Cornish round buddle.

b. Inward flow, concave or funnel buddle, Borlase's or Hunt's buddle.

II. Round buddles with rotating floors or rotatory buddles, more properly termed frames.

c. Rotatory convex buddle. Schell's or Zenner's buddle.

d. Rotatory concave buddle. Rittinger's rotatory frames.*

Each of the above classes is represented by a model, with the exception of No. I. *b.*

The principle of action is the same for all of the above-named forms; the metalliferous slime, which is brought to a very thin mud by the addition of a large quantity of water, flows over the surface of the conical platform or table, where it deposits the matters held in suspension, in order, according to their specific gravity, the heaviest subsiding first. An advantage is claimed for the concave forms in which the stream flows from the outer to the inner circumference of the table; the scouring power of the water is increased as it descends, owing to the contraction of the surface over which it passes, so that the lighter earthy matters are said to be more completely removed than is the case in the earlier or convex forms of construction. The first-class or fixed round buddles are intermittent in action, the ore accumulates on the table and requires manual labour for its removal; in the second or rotatory class the finished product is removed continuously either by brushes or by the action of a stream of water.

* Notices of the whole of the different forms of round and rotatory buddles, together with reference to other publications on the subject, are to be found in a paper by Von Rauen, in Rittinger's Erfahrungen for 1861, p. 22.

No. L. 17.—Round Buddle.

Scale, $\frac{1}{6}$, 2 inches to 1 foot.

Presented by the late John Taylor, Esq., F.R.S.

This model represents a round buddle which formerly was employed in dressing poor copper ores or "halvans" at the Tywarnhaile mines, in Cornwall, and was exhibited at the Great Exhibition in 1851. The separation is effected on a conical wooden floor, with a smooth surface about 18 feet in diameter. The apex of the floor carries a smaller and more acute cone, which serves both as a distributor and as the bearing for the foot of a vertical spindle, with two projecting horizontal arms, carrying brushes extending over the entire diameter of the floor. The stuff to be dressed is worked up to the proper consistency with water by a tormenter, or cylinder with projecting iron knives, which revolves in a chest at the upper end (right hand); it is attached to an inclined shaft which also moves a drum sieve for sizing the mixed slime, and turns the brushes by a bevil wheel at its lower end. The sieve has eight holes to the linear inch; the coarse particles and chips kept back by it are discharged through an inclined channel and vertical shoot on to the outer edge of the wooden platform below. The sized slime passes by another inclined launder into a narrow conical funnel surrounding the shaft carrying the brushes, from which it flows over the central spreading cone on to the inclined floor, depositing in its course the various substances held in suspension, the heaviest being precipitated first are found nearest to the top, while the lightest settle down nearer to the outer circumference. The revolving brushes keep the surface constantly swept smooth, especially preventing the formation of gutters or ridges in the case of any irregularity in the distribution of the supply; they are attached to the arms by cords passing over pullies, with counterbalance weights to allow of their inclination being varied to accommodate them to the diminished slope of the surface as the stuff accumulates. The tail-water is discharged through a sluice board, pierced with several holes in different heights, all of which, except the one in use, are stopped with wooden plugs, the higher ones being required as the thickness of the deposit on the floor increases. As soon as a depth of about six inches has accumulated, the supply is stopped and the deposit is removed. The arms make from two and a half to four revolutions per minute, and one and a half to two tons of stuff are treated per hour. About three-quarters of the solid contents of the slime are deposited, the upper half of the layer is washed again, the remainder is thrown away; ultimately the finished ore is concentrated to about one twentieth part of the volume of original material.

In the dressing of tin ores the round buddle is employed for treating the middle division of the sands deposited in the first pit or "strip" in front of the stamps. The products are three in number, of which No. 1, or the head, is passed on to the higher classifying machinery; No. 2 is the middle, washed a second time; and No. 3, the tail, is sent to the long strip or pit for treatment with products of a lower class. Thus sands containing 10 °/o of tin yield heads of 18·5 °/o; middles of 2 °/o; and tails of ½ to 1 °/o.*

ROTATING BUDDLES OR FRAMES.

SCHELL'S, NO. L. 18. SAXON, NO. L. 19. RHENISH CONVEX AND CONCAVE. MR. ARUNDEL'S, NO. L. 20, 21.

All on the scale of $\frac{1}{12}$. 1 inch to 1 foot.

This machine was invented in the lead mines of the Upper Harz by Mr. Schell of Clausthal, in 1854, and was subsequently patented in England by Mr. Zenner, of Newcastle-upon-Tyne; it is represented nearly in its original form in the model, No. L. 18, presented by Mr. Zenner. The washing of the ore is effected on a conical wooden platform similar to that of the round buddle, but which is attached to a vertical shaft, and receives a rotatory motion from any appropriate mover, usually a small water wheel, by a screw gearing into a large worm wheel. In the first instance the slime is worked up in a box by an agitating wheel with eight beating arms; a coarse grating keeps back the larger particles, and the stuff is rendered more uniform in texture by passing through a grate with smaller holes before it enters the launder which conveys it to the machine. The distributor is a ring-shaped launder or trough of sheet iron of a V-shaped section, perforated with numerous fine holes at the bottom, one-fourth part of it is divided off for the slimes, through the remaining three-quarters jets of clean water are continually supplied to the table. A curved launder, perforated in a similar manner and covering a segment of about one-third of the table, furnishes a further supply of water, which impinges on the surface in small jets, at points varying in height from about

* Moissenet, Ann. des Mines, 5 ser., vol. xiv.

one-third of the distance from the apex nearly down to the extreme edge. A fixed brush covers the outer part of the table extending upwards for a short distance; it is attached by a wooden bar to the pillar which carries the bearings of the driving shaft. The various substances in suspension reach the edge of the table at different times according to their densities, the lightest arriving first; the heavier ores are less affected by the wash of the water, therefore they require a longer continued action and move much slower, only reaching the edge after the table has turned through a considerable arc, while the best ore adheres so firmly as to require a special set of brushes for its removal. A ring launder, placed immediately below the outer circumference, receives all the stuff washed over, it is divided into partitions of unequal size, each having its own discharge pipe; the first and largest takes the waste, the second the pyritic part, while the third and smallest is reserved for the clean ore. The brushes by which the latter is removed are made of hogs' bristles; they are attached to a wooden bar supported on a guide at one end, while the other receives a backward and forward motion from an eccentric which is driven by an intermediate strap and pulley on the main shaft. A series of experiments was made at Clausthal in the year 1854 to determine the relative values of the rotatory buddle and the shaking table. Two quantities, each weighing 15½ tons, of fine slimes from the stamps, containing a small amount of argentiferous galena were treated, one on either machine, with the following results:—

1. By the rotatory buddle 15½ tons were concentrated, to 33½ cwt. in 86 hours; the enriched ore contained 61°/₀ of lead and 28 oz. of silver per ton.
2. By the shaking frame the same quantity required 609 hours to reduce it to 38½ cwts., with 52°/₀ of lead, and 25 oz. of silver per ton.

The saving of lead appears to be about 1½ per cent. more by the first than the second method, the work being done by the former in one-seventh part of the time required by the latter.

No. L. 19 is a model of Schell's buddle slightly modified, which was erected at the mine of Himmelsfürst, near Brand in Saxony, in the year 1855; no distributing apparatus is employed, the slimes being laid on to the table at one point only; the top ring launder for the washing water only extends for two-thirds of the distance round the shaft. The water issues through perforations in the side, and passes over a spreading cone before reaching the table. The curved launder in Mr. Zenner's model is replaced by a curved tube similarly perforated, and two other perforated tubes projecting radially, enclosing a segment of about 35° of the surface of the table between them, are employed in addition to the reciprocating brushes for removing the cleaned ore. The tail ring, which is not a complete circle, is without divisions, the separation of the materials falling into it is effected by stopping the bottom in opposite directions, forming two streams, each of which flow towards its own discharging aperture at the end, and passes into a box or pit placed for its reception. A small overshot wheel about 6 feet in diameter drives the machine by a screw gearing similar to that already described.

A later modification of the rotating buddle is shown in Mr. Arundel's model, No. L. 20; it has the conical table made of cast iron, the slimes are laid on at one part only. The washing water is supplied through a perforated ring connected at several points with the main supply by short union pipes fitted with cocks; by opening or shutting the latter the force of the jets may be varied at different parts of the table. The spiral launders and brushes are replaced by perforated tubes, which are attached to the ring by spherical joints to be used for sweeping off the last adhered particles. The tail launder is divided into three parts, the largest includes about 240° of the circumference, the second 90°, and the third, in which the ore is collected, only about 30°, each is furnished with its own discharge pipe and catch pit. Two tables of the same construction are shown, each working with a special fineness of material from the separator.

The same model, No. L. 21, contains two examples of the concave or inward flow rotatory buddle, also known as the funnel frame (Trichterheerd). This variety was first introduced in Rhenish Prussia in the year 1861, and is said to be based upon Rittinger's machine, which is described at p. 153, but has little in common with it except the shape of the table. As originally constructed, the slimes were introduced through $\frac{5}{6}$ths of the circumference of a distributing ring, but in the models before us the feeding takes place at one point only. With the exception that the flow of slime and water is from the outer to the inner circumference of the funnel-shaped table, the method of washing is exactly similar to that of the rotatory buddles last described. The details of the washing pipes and driving mechanism are the same in both cases. The funnel tables are supplied with coarser grained slimes than the conical ones.

By experiments made at Kalk, near Cologne, it was found that a funnel table of 6 feet in diameter, moving with a circumferential velocity of from 30 to 60 feet per minute, equal to from 100 to 200 revolutions per hour, will work up from 60 to 100 cubic feet of prepared slimes, probably from four to six tons, according to their toughness, in a day of twelve hours. The consumption of washing water is from 30 to 50 gallons per minute. One man can superintend the working of six tables. A perfect separation may be effected by this machine when only one heavy mineral is present in the ore mixed with earthy matters; but the result is only a preparatory classification when the ore contains two or more heavy substances, as for example, blende and galena, which cannot be separated from each other at one washing.

No. L. 22.— Rittinger's Concave Rotatory Frame. Stetigwirkender Drehheerd. Presented by Ministerialrath Rittinger.

Scale, $\frac{1}{12}$, 1 inch to 1 foot.

This machine was introduced at Schemnitz, in the year 1860, for dressing poor slimes containing gold and silver in combination with galena and iron pyrites, as an experiment, instead of the shaking tables in general use at that time. After undergoing several modifications, the pattern represented in the model was finally adopted. The frame is an obtuse wooden funnel about 16 feet in diameter, attached by 16 arms radiating from a cast-iron seating ring of 5 feet in diameter to a vertical wooden shaft, which is slowly turned from left to right by a screw gearing in the ordinary manner. The surface of the frame is divided by strips of wood three-quarters of an inch high into 32 segments. Eleven distributing tables, or heading boards, occupying an arc of about 320°, are fixed above it, sloping in the opposite direction, so as to discharge their contents on to it close to the outer circumference of the funnel. Eight out of the above eleven distributors are similar in size; the three hinder ones are smaller, having their outer edges, over which the water falls, cut back into a series of steps. The orey mud to be dressed is mixed up with water by a rotaing paddle in a box at the left hand side, from which it is passed into a spiral launder of rectangular section fixed above the heading boards; the water for washing is brought in by a parallel launder of larger sectional area at the back.

The slimes are supplied to the frame over the heading board, Nos. I., III., V., and VII., while the alternate ones, Nos. II., IV., VI., and VIII., as well as the shorter ones, Nos. IX., X., and XI., are reserved for the washing water. The action of the machine is as follows :—As the frame revolves it receives a layer of ore from the first board, this coating is washed by the water coming from the second board; the earthy materials are carried off by the stream, the heavier ones remain on the table; this segment receives a fresh supply of raw material from No. III., which is washed by the water from No. IV., and so on till the original segment has passed No. VIII., when a concentrated schlich of galena and pyritic substances remains. The latter are cleansed out by the water coming from the three hinder boards, the streams from which strike the frames with an increased force from each step, owing to the greater fall obtained by cutting back the edge; the cleaned lead ore remains in four concentric rings or layers near the outer margin. Each of the 32 segments of the frame is terminated by a square wrought-iron shoot, through which the substances removed by the water are passed into two parallel ring launders below. The slime waste from the feeding boards is immediately discharged into the outer ring, which is directly below the shoots. The drainings from the table during the washing periods are diverted by tail boards into the inner ring, and led off into particular receptacles if it is considered necessary to save them for further treatment. The pyritic stuff also passes to the inner ring, while the clean ore is removed into a special compartment of the outer one, by a jet of water which issues from a vertical pipe on the right hand side of the machine. Each of the divisions of the lower rings is provided with a special channel leading to a receiving box, which is not shown in the model.

A long continued series of experiments was made at Schemnitz in order to determine the most favourable conditions of working, as well as the loss of metal by this machine. The best results were obtained when the velocity of rotation did not exceed six revolutions per hour, at which speed a quantity of finely divided ore from the stamps containing 7·2 per cent. of lead, weighing 10,234 lbs., was cleaned up in 158 hours, the stuff being mixed with water in the proportion of 1·4 lbs., of solid matter to the cubic foot, this slime is supplied at the rate of two-thirds of a cubic foot per minute. The above quantity was reduced to an enriched schlich weighing 1,728 lbs., yielding 35·3 per cent. of lead by assay, or a saving of 629 lbs. out of the original contents of 738 lbs., equal to 85·5 per cent., distributed as follows :—

1. Concentrated ore	17·4 %	of original quantity	with	85·5 %	of original amount of lead.
2. Pyritic sand	- 5·2	"	"	1·7	"
3. Waste in dressing	37·3	"	"	2·5	"
4. Tail slimes	- 40·2	"	"	10·3	"
	100			100	

In practice it is found better to neglect all the above products except the first, the loss will therefore stand at 14·5 per cent., or about 5 per cent. less than that of the shaking table. Twenty frames can be driven by an engine of one-horse power, and the amount of finished material produced in a given time is twice as large as that obtained by the use of the shaking table.*

JIGGING MACHINES.

Nos. L. 23, 24.—Hand Sieves.

No. L. 25.—Hand Jigging Machine.

No. L. 26.—Hutching Machine.

No. L. 27.—Cornish Power Jigging Sieves.

Nos. L. 28, 29.—Hydraulic Jigging Machines.

Nos. L. 30, 31, 32.—Berard's Coal Dressing Machine.

No. L. 33.—Mackworth's Coal Dressing Machine.

No. L. 34.—Rittinger's Continuous Jigging Frame.

The process of jigging or hutching (criblage or setzarbeit) is chiefly employed in the dressing of minerals in fragments of a comparatively large grain, such as those obtained from the crushing machine. The charge of ore is placed in a sieve or frame with a bottom of wire gauze, or a perforated metal plate, and receives a series of small lifts or jerks in rapid succession from a column of water forced through the perforations, by which the specifically lighter earthly fragments are gradually brought to the top, while the clean ore is found immediately above the plate. In coal dressing machines the valuable portion, however, is the uppermost or lighter part. The jigging motion can be produced either by shaking the sieve in a cistern of water by hand or machine power, or by driving the water through the holes in a fixed

* Rittinger's Erfahrungen, 1861, p. 27.

sieve by forcing or lifting pumps. The process is generally an intermittent one, the sieve being usually charged and cleared by hand; it has, however, been made continuous by the addition of feeding and discharging apparatus, in Rittinger's jigging frame and certain classes of coal-dressing machines.

Nos. L. 23, 24.—Hand Sieves.

These are the common Cornish hand sieves, used for tin dressing. No. L. 23 has a bottom of iron wire gauze with holes of $\frac{1}{8}''$ square, it is 18″ in diameter and 5″ deep. No. L. 24 is $18\frac{1}{2}''$ in diameter and $5\frac{1}{2}''$ deep; the bottom is a copper plate perforated with holes $\frac{1}{10}''$ in diameter and $\frac{1}{10}''$ apart; the frame is made of thick oak staves, bound together with two iron hoops.

No. L. 25.—Hand Lever Jigging Machine.

Scale, $\frac{1}{12}$, or 1 inch to 1 foot.

This is a double lever jigging machine, or brake sieve, of the kind usually employed in Cornwall; the sieve is rectangular, having a pair of vertical iron bars attached one to each of the short sides; these bars are perforated at their upper ends with three long holes, through which a pair of bolts are passed linking them to the two parallel arms of an oscillating frame. By altering the holes through which the suspension bolts pass the sieve is made to hang at a greater or less depth in the rectangular water cistern or hutch in which it is worked. The suspension frame is an unequal armed lever, the sieve is attached to the shorter side, while the longer arm is terminated by a slotted part, in which works a T-headed fixed link or connecting rod attached to the shorter arm of a second lever placed below it. The motive power is supplied by a boy, who jerks the longer arm of the second lever, moving it through a height of 48 inches, while the sieve is only moved through eight inches. Clean water is introduced through a square pipe on the left hand side of the cistern to replace the muddy waste which is carried off through a similar pipe fitted with discharging apertures at different depths on the opposite side. The sieve is emptied by scraping out the contents with an iron scraper or limp; they are usually classified into three parts, the uppermost being thrown away; the middle, containing mixed ore with earthy matter, requires a further treatment, while the bottom is clean ore fit for sale. The hutch work or fine stuff passing through the sieve collects in the cistern, and is subsequently treated on the round buddle or some other slime-washing machine. The sieve is 57″ long and 24″ broad, and 10″ deep, the hutch measuring 90″ in length, 43″ long, and 45″ deep. The power arm of the jigging frame is four times as long as that to which the sieve is attached, while the relation of the same parts in the second lever is as 1½ to 1.

No. L. 26.—Hetherington's Hutching Machine. Presented by W. B. Beaumont, Esq., M.P.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

In this machine, the sieve is suspended to a pair of horizontal levers carrying counterbalance weights on the opposite arms; the sides to which the suspension bars are affixed are prolonged in front, forming tongues, which are acted on by a pair of wheels, each having fourteen cylindrical cogs projecting on one side. Each of the cogs in passing, presses on the tail of the lever opposed to it, thereby sinking the sieve in the hutch; as soon, however, as the pressure is taken off, the counterbalance on the outer arm lifts the sieve back again, thereby bringing the tongue in contact with the next highest cog, ready for the following stroke. The sieve can be thrown out of gear by sliding the axis of the levers sideways in its bearings, whereby the tongues are disengaged from the cogs, and then it is immediately brought up to the level of the top of the hutch by the counterbalance weights. The suspension bars are provided with several holes for varying the depth at which the sieve hangs. The length of stroke can also be altered within small limits by a similar series of holes in the levers. The sieve is a plain riddle of parallel bars, strengthened at intervals by cross bars.

No. L. 27.—Cornish Machine Jigging Sieves.

Scale, $\frac{1}{24}$. ½ an inch to 1 foot.

These sieves are similar to that of the hand lever machine, and are attached to frames of the same character, they receive a jigging motion by means of a pair of rods connecting the ends of the longer arms of the frames to a small double crank shaft, carrying a pinion which gears into a toothed ring on the circumference of the water wheel. Each sieve has its suspension bars united together by a cross head, and is attached by a flat linked chain to an arch headed lever, by which it is lifted out of gear for filling or clearing. The sieves are confined to a vertical motion by a pair of projecting pins working between parallel guides, attached to the top of the hutches; these pins and their guides also serve as a means of supporting to the sieves when they are disconnected from the suspension bars.

No. L. 28, 29.—Hydraulic Jigging Machine (Hydraulische Setz Sieb).

Scale, $\frac{1}{8}$. $1\frac{1}{2}$ miles to 1 foot.

The plan of using a force pump for driving water through the holes of the jigging sieve, instead of employing moveable sieves, was introduced in Cornwall by Mr. Petherick, in the year 1831, and has of late years been extensively applied in foreign mines. The same principle receives another important application in the machines employed for cleaning small coal from earthy and other impurities. The model represents the machine now in general use for dressing argentiferous lead ore in the Saxon mines; it is composed of a rectangular wooden case or hutch, divided into two parts of equal size, in one of which is fixed a perforated zinc plate with apertures about one-eighth of an inch in diameter, on which the ore is placed, the separation of the different minerals being effected by rapidly alternating jets of water forced through it by a solid piston working in the other division. The aperture in the side wall dividing the two compartments is provided with a sliding door for regulating the current, which is shut down during the process of filling or clearing the sieve. The hutch work collects in the bottom of the jigging hutch, and is removed in the usual way. The piston is a square box somewhat smaller than the cistern in which it works, attached by a wrought-iron rod to a wooden lever; it is lifted by a rotating cam shaft, and falls again by the action of a loaded box affixed to the outer arm of the lever. The sieves are 27 inches square; the piston is of the same size, and makes a stroke of 3 inches in length. The machines generally employed at Freiberg have two sieves, placed one on each side of the piston; one man superintends the working, usually clearing and refilling one side while the charge on the other side is in process of separation.*

The material subjected to the jigging process is the rough ore broken down by the crusher and sized in the sizing sieves; it contains from 9 to 10 °/₀ of lead, being a mixture

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* Revue Universel, vols. iii. and iv.

of galena and precious silver ores, with more or less of blende, copper and iron pyrites, besides earthy minerals. According to the prevalence of one or other of the above-named sulphurets, the ore is sorted into three classes: No. 1 containing chiefly blende; No. 2, iron pyrites, and No. 3, copper pyrites. Only the three coarsest sizes from the upper sorting sieves are treated in the hydraulic machine, the finer numbers being reserved for the moveable sieves. A charge of the coarsest grained ore of the No. 1 or blende class is dressed clean with 120 or 130 strokes of the piston, yielding the following products:—

1. Earthy matters, waste.
2. Poor ore for the wet stamps.
3. Blende fit for zinc smelting.
4. Seconds lead ore, containing galena, blende, iron, arsenical and copper pyrites; it is crushed or stamped dry and then delivered to the smelting works; it contains from 15 to 20 % of lead.
5. Galena in coarse fragments, containing from 60 to 65 % of lead and silver; requiring to be crushed before delivery to the smelter.
6. Hutch work or tub ore (fass erz), which is washed on the fixed slime dressing table.

The products from the other kinds of ore are of a similar character, with the addition of a class of copper ore.

An improved hydraulic jigging machine is represented in Mr. Arundel's model, No. L. 29; the hutch is a cast-iron syphon or U tube of rectangular section, the sieve being fixed in the upper part of one limb, while the other contains the piston, which is a hollow iron box, carrying a projecting tubular socket. A toothed eccentric fixed to a horizontal shaft, which receives a rotatory motion by a strap and pulley, turns within a loop or stirrup attached to the upper part of a loaded box. The latter has a rod fixed to its lower side, fitting loosely into the socket on the piston. When the support of the cam is taken off the stirrup, the weight box falls and drives the piston down in its chamber, forcing the water through the sieve on the opposite side; as the shaft turns the loaded box is lifted by the eccentric, and the pressure is taken off the piston, which is then lifted back to its original position by the column of water and the opposite limb. The hutch work is discharged through a hole at the bottom of the U tube into a sloping trough, which conveys it to a collecting pit. The waste water is replaced by a pipe on the right hand side of the sieve. A slide valve is interposed between the two limbs of the syphon, serving both for regulating the force of the current and for stopping off the water during the clearing of the sieve.

Nos. 30, L. 31, 32.—Berard's Continuous Coal Dressing Machinery.

This apparatus is represented in three drawings on the scale of $\frac{1}{20}$th of the real size. No. L. 30 is a longitudinal elevation, No. L. 31 a transverse elevation, and No. L. 32 a horizontal projection. It is employed for purifying small coal and slack, or large coal of an inferior quality, from earthy and other impurities, in order to render it suitable for the manufacture of patent fuel or coke.

The coal as soon as it is brought to the surface is thrown upon a screen; the small stuff that passes through is the subject of treatment; it is lifted by an elevator or chain of buckets into the feeding hopper of a classifying machine, which is a box divided into compartments containing a number of perforated plates arranged in a step-like series, the perforations being finer in the lower ones. These plates are kept in a state of rapid oscillation by a strap attached to the main shaft of the driving engine, which is usually a horizontal high-pressure steam engine of from 8 to 10 horse power. The number of sizes separated by the classifier is one more than the number of sieves employed. The dust that passes the lowest sieve goes to the bottom of the classifier, while the fragments that will not pass through the top sieve are passed through a pair of crushing rollers, and when broken down are returned into the supply box of the elevator.

The assorted sizes, other than those noticed above, are passed over into a series of washing boxes; these are jigging machines with fixed sieves and round plunger pistons where they are washed in the ordinary way. The coal being lighter than the waste with which it is associated, comes to the top, and is carried off by a stream of water into waggons placed for its reception, and can be removed immediately.

The perforated plates on which the separation takes place are inclined, and have no projecting edges, so that the waste remaining on them is continuously travelling towards their lower ends, where it falls over into a hutch, from which it can be discharged by simply opening a valve.

The fine dust is passed into a labyrinth catch pit, where the coal in it, is separated by the action of running water only, without the aid of any mechanical contrivance.

From 10 to 12 tons of small coal can be cleaned per hour by this machine at a cost of from 1*d.* to 1¼*d.* per ton.

No. L. 33.—Mackworth's Coal Dressing Machine.

This is a special modification of the hydraulic jigging machine combined with a discharging apparatus. The perforated plates are placed at the bottom of a deep hopper-shaped box, with a discharging door for the waste at the lower end. The force-pump piston works in a rectangular chamber at the other end. As the cleaned coal is worked upwards by the water, it meets another perforated plate placed at a small angle from the vertical; this establishes a classification according to size among the purified fragments, the smaller ones passing through on one side, while the larger pieces are kept to the opposite side; both are alternately scooped out by projecting blades on the surface of an endless belt, which passes them to the discharging shoot. The fine dust made by the rubbing of the particles against each other in the original feeding spout is drawn away by a fan blower, and not allowed to come into the water.

No. L. 34.—Rittinger's Continuous Jigging Machine (Stetigwirkender Setzheerd). Presented by Ministerialrath P. Rittinger.

Scale, ⅓ of real size, or 4 inches to 1 foot.*

This machine is distinguished from the older forms of hydraulic jigging machines, by the substitution of a suspended vibrating plate for the fixed sieve, and the use of a lifting pump for driving the water through the ore instead of a force pump. The piston is a rectangular frame with four iron clacks having leather bearing faces; it works in the hutch below the sieve, and is attached by two rods united by a wooden cross head, and a wrought iron connecting rod, to a crank pin on the driving eccentric The bottom of the box has four foot valves similar to those of the piston; one of its sides is moveable for the convenience of examining the foot valves, and is maintained in place by screw bolts. The jigging frame is a perforated plate suspended at the corners by four plain wire links; it receives a reciprocating motion from the large angle lever on the left hand side, which pushes it outwards, and a wooden counter spring

* This account from a MS. description by the inventor.

on the opposite side, which brings it back to its former position. The ore to be treated is contained in a hopper on the left hand side, and is supplied to the sieve by an inclined feeding trough, which receives a vibrating motion from a smaller bent lever on the right hand, both motions being worked by a large eccentric with a single tooth on the driving shaft; which carries a small fly wheel. The hutch is filled with water, the whole arrangement forming a simple lifting pump; the water lifted by the piston passes through the sieve plate, and returns into the hutch by another channel. The ore, in addition to being sorted by the water, is urged continuously forward by the shaking motion of the frame, and on arriving at the end of the principal sieve the deposit is cut into three parts by the edges of three sorting sieves placed one above another; the lowest takes the best ore and passes into the box No. 1, the second quality goes in like manner from the middle sieve to No. 2, while the lightest is discharged by the top sieve into the compartment No. 3. The sorting sieves are provided with setting screws for adjusting the intervals between them in order to render the machine available for different classes of ores. The fine stuff passing through the sieve is discharged by two mud holes at the bottom of the hutch. The water lost during such removal is replaced by supply from a pipe on the opposite side.

The pump works at the rate of from 70 to 75 strokes per minute; the length of stroke varies from 2 to 3 inches. The size of the fragments treated must not be less than two lines (one-sixth of an inch) in diameter. If the ore is of good quality, it is concentrated up to a product containing from 50 to 60 °/o of lead at one operation, but coarse substances will require to be worked over a second time, as it is not found possible to diminish the distance between the sorting sieves to less than half or three-quarters of an inch, and therefore a thinner layer of purified ore would necessarily be delivered in a mixed condition from the bottom sieve. From 25 to 30 cubic feet, probably equal to a weight of from 1¼ to 1½ tons, are worked up hourly by the machine, which requires a motive power of one half or three-quarters of a horse power.

SHAKING TABLES. STOSSHEERD.

No. L. 35.—Saxon Shaking Table of 1792.

No. L. 36.—Saxon Shaking Table, Modern Pattern.

No. L. 37.—Stagg's Shaking Table, with Paddles.

No. L. 38.—Rittinger's continuous Shaking Table. Stetigwirkender Stossheerd.

The shaking table is an old machine, which is still extensively employed in the mines of Germany, Bohemia, and Hungary, and other parts of the continent, for the concentration of the sands, resulting from the operation of stamping poor ores, although it has in some cases been replaced with advantage by the rotatory buddle. The model No. L. 36 represents the form of stossheerd generally employed in the Saxon mines. It has a rectangular table, about 14 feet long, and six feet broad, bordered by raised edges on the long sides. The upper surface is formed of two thicknesses of pine planks, secured to a strong framing of squared beams; it is suspended in an inclined position by chains, attached to the four corners. The hinder or shorter pair of chains are hooked into long staples, with several notches, they are in a more or less inclined position when at rest, and by altering the points of suspension their tension may be varied. The forward pair hang vertically when at rest; their upper ends are attached to a windlass barrel, with a ratchet stop; this arrangement serves for adjusting the slope of the table, which must be diminished when finely divided and poor ores are under treatment. The shaking motion is communicated by a horizontal wooden bar, attached to the outer arm of a small angle lever or V-bob which strikes against the front edge of the moveable table. The other arm of the bent lever carries a projecting tongue, which is acted on by the cams on a rotating horizontal shaft (not shown in this model). The tongue slides between guides on the arm which carries it, and is provided with an adjusting screw for the purpose of varying the length of stroke by altering the amount of protrusion, and throwing the table out of gear by screwing it back altogether. When the pressure is taken off the tongue after the passage of the cam, the table is brought back to its former position by the tension chains. The stuff to be washed is mixed in a slime box, and passed in a uniform stream over a distributing board on to the table in the usual way, where under the combined influence of the shaking motion and a stream of clean water, the component particles are deposited in order according to their specific gravities, the heavier ones subsiding first, those of medium density, such as iron pyrites, taking a lower position. The lightest or earthy part is removed altogether by the waste water which falls over the lower edge of the table into a launder placed immediately below. It can, however, if necessary, be saved for further treatment in the box in front, by bridging over the intermediate space with a tail board (unterfass tafel). The tail launder (fluthgerinne) has a very slight inclination, and it is necessary to flush it out by a current of water from an auxiliary channel, carried on the standards to which the suspension chains are attached, in order to prevent its choking up by the accumulation of waste. The supply of stuff is continued until a layer of about six inches in thickness has accumulated. The table is then thrown out of gear by screwing back the tongue, and the deposit is dug out with shovels, and divided in several parts for further treatment.

The amplitude of the stroke varies with the nature of the ores, from 7½ inches to 9½ inches, and the number of strokes per minute is from 30 to 40 for the coarser sands, and from 35 to 45 for the finer slimes. The volume of water requisite is in the latter case from 1½ to 2½ times that of the ore, while in the former it is from eight to nine times as much.

The concentration of poor substances takes place very slowly, and merchantable products are only obtained after several repetitions of the operation. The coarser sands from the stamping of ores of the pyritic class are washed from three to five times, yielding,—

1. Galena, with 40 to 45 per cent. of lead, and 44 to 50 oz. of silver to the ton.
2. Seconds lead ore, with 15 to 20 per cent. of lead, and 16 to 18 oz. of silver.
3. Pyritic ore, with a small quantity of silver, called Zuschlags erz; this is melted to a regulus, which, after calcination, furnishes iron for the reduction of the galena in the smelting process.

Fine sands and the coarser slimes from the middle divisions of the long catch pits are washed five times, yielding similar products; the galena, however, contains three or four ounces more silver in the ton. Slimes from the lowest divisions of the long catch pits are washed four times over, and yield no galena, but only seconds ore and pyrites of a low content of silver.

The stamp ores of the division containing blende yield in addition to the above products two classes of zinc ores.*

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* Revue Universel, vol. iv.

The small model No. L. 35, presented by the late Thomas Weaver, Esq., represents the form of stossheerd in use at Freiberg in the year 1792. It will be seen on inspection that it differs but very slightly from the form now in use. In a few of the newest dressing floors cast-iron standards for carrying the table have been introduced instead of wooden ones.

No. L. 37 is a shaking table by Robert Stagg, with two rotatory paddle wheels, for mixing and distributing the slimes uniformly with the washing water, to be used in the dressing of very finely divided materials. It was used in the mines of the London Lead Company in Northumberland in the year 1828.

No. L. 38.—Rittinger's Continuous Shaking Table (stetigwirkender Stossheerd). Presented by Ministerialrath P. Rittinger.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

This machine differs from the ordinary stossheerd in the disposition of the shaking apparatus, the table being drawn out sideways, at right angles to the flow of the washing water, instead of being moved in the direction of its length; it is suspended with a slight forward inclination by four wrought-iron links, and receives a jerking motion from right to left from a lever which is acted on by a rotating eccentric with a single tooth, the return stroke being effected by the counter pressure of a wooden spring beam on the opposite side. The surface of the table is similar to that of the ordinary stossheerd, but the left hand and lower sides are without raised edges, giving two discharging sides instead of one, and both have boxes for receiving the washed products placed close to them. There are two distributing or heading boards, the ore in the form of slime is introduced from a mixing box over the left hand one covering one half of the table, the other half receiving a stream of clean water from the second board. The heavier particles contained in the ore by reason of their friction against the surface are but slightly affected by the downward motion of the washing water, and are chiefly moved by the percussive action of the lever and spring, sideways towards the left; the lightest substances on the other hand are carried forward by the stream with a very slight lateral deviation, following a course mainly parallel to the long sides of the table; particles of intermediate densities will of course describe paths varying in their inclination to the long sides, according as one or other of the above influences prevail. The best ore passes over the left-hand edge of the table into the lower part of the long box in front, while the seconds and waste are collected in the box below the lower edge.

The construction shown in the model was adopted in the first experimental machine made in the year 1858. The table is six feet in length and three feet broad, with a length of stroke of two inches. It has, however, been found that the principle of discharging the ores sideways presents great practical difficulties, as only small quantities of stuff could be worked through in a given time, the lateral motion of the ore being very slow and not being susceptible of any sensible increase by increasing the violence of the shocks. A modified construction has been adopted in which the proportion of washing water to slime has been largely increased, and the discharge is confined to the lower edge, the best ore being received on the side of the tail-box farthest away from that on which the slime is admitted to the table. The following are the leading dimensions of these machines adopted at Ohláhláposbánya in Hungary:—The table is eight feet long and four feet broad; the slime board is one foot broad and the washing board three feet; the inclination of the table is, for coarse sandy substances, $\frac{7}{8}$ths of an inch per foot in length, or about one in 13; for fine muddy slimes, half an inch per foot, or one in 24. The number of oscillations per minute and their length is, for coarse sands, 55 of $2\frac{1}{2}$ inches; for fine mud, 65 of one inch. The pressure of the spring is 200 lbs. for coarse and 180 lbs. for fine slimes. The coarser stuff is dressed at the rate of 0·2 of a cubic foot, containing 16 lbs. of solid matter to the foot per minute; the finest contains 4 lbs. of solid matter to the foot, 0·12 of a cubic foot only being treated in the same time; the expenditure of clean water varies between 1·0 and 1·6 cubic feet per minute. Two tables of the above dimensions are combined in one frame, the first receives stuff from the stamps szed by a pointed separating box (spitzkasten); the other is worked with the imperfectly cleaned middle product of the first table; the feeding being effected by an elevator, which scoops the stuff out of the tail box, and discharges it into the mixing box of the second table. Four pairs of tables, each in connexion with its own separator, work up from 10 to 12¼ tons of ore daily.*

By experiments of a later date, the quantity of stuff worked up has been increased to 20 tons daily, 8 men only being required to watch the machines, instead of 70, who were formerly employed, when the same quantity of ore was dressed on flat tables.†

GENERAL MODELS OF MINES.

No. M. 1.—Model of the Clunes Gold Quartz Mines in the Colony of Victoria, Australia.

The parts of this model are lettered in correspondence with explanatory legend in the case as follows :—

1. Deep shaft, intended to cut all the reefs or veins in the north part of the workings at 200 feet below the surface, by three east and west levels.
2. Main shaft on Robinson's reef, 35 feet deep.
3. Shaft on the western reef, with windlass for drawing, 70 feet deep.
4. Drum and brake of the self-acting inclined plane, whereby the wagons with ores from the high ground are lowered to the dressing floor.
5. Storage tank for holding the water pumped up from the deep shaft, which is used for feeding the upper engine boiler.
6. Channel conveying the water brought up from No. 3 shaft, the feed water cistern of the stampers.
7. Mouth of the southern tunnel, a level by which the ores from the south part of the workings are brought to the surface in tram wagons.

8, 8. Tramways.

9, 9. Turntables.

10. Kiln in which such portions of the quartz as may be too tough to be stamped directly are rendered friable by calcination with wood.
11. Tipping place and shoot for filling wagons with ore fit for the stamps without previous calcination.
12. Tipping place for waste.

13, 13, 13, 13. Tanks for the stamps feed water; they are partly supplied from the higher ground, and partly by the launder No. 14, from the engine pump No. 25.

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* Rittinger's Erfahrungen, 1862, p. 32.
† Do. do. 1863, p. 24.

15. Hoppers containing the ores to be stamped.
16. Stamps. They are arranged in four series or batteries, numbered from north to south, as under:—

No.	1.	12 heads in	4 sets of	three heads each.
,,	2.	12 ,,	3 ,,	four ,,
,,	3.	8 ,,	2 ,,	four ,,
,,	4.	12 ,,	3 ,,	four ,,

17. Blanket tables for collecting the gold. (See large model, No. L. 8 in Gallery E., for details.)
18, 18. Barrel amalgamators in which the enriched sand from the blankets is treated with mercury.
19. Shaking frame in which the contents of the barrels are washed in order to separate the fluid amalgam from the exhausted residue.
20. Launder or channel leading the waste water from the dressing floors to the slime pits.
21. Dam across the brook or creek called Cresswill's creek, No. 22, forming a head of water for the pump, No. 25, with which it communicates by the passage No. 23.
24. Circular saw bench for cutting fire-wood into billets for the boiler fires.
25. Lifting pump supplying water to the cisterns of the stamps Nos. 3 and 4.
26. Chinese pump or chain or buckets. This is extensively used in alluvial gold workings for draining shallow excavations.
27. Saw pit.
28. Gold escort. The mounted man in the rear leading the pack-horse carrying the gold.
29. Cradle used for working up the stuff collected under the stamps.
30. Method of filtering the solid amalgam from the fluid mercury by pressing it through buck skin.
31. Edge mill amalgamator or Chilian mill.
32. Man washing the blankets in water to separate the gold entangled in the fibres.
33. Underground chamber for water tanks, storing supplies to be used in time of drought.
34. Upper level of the first drive from No. 1 shaft.
35. Police station.
36. Outcrops or backs of the quartz reefs or veins.
37. Waste heaps from former workings on the backs.
38. Channel conveying water from the deep shaft to the alluvial workings in the valley.
39. Pit and shear frame of the deep shaft.

40. Wrought-iron quartz case (skip or bucket) running on slide guides in the shaft, in which the ore is brought to the surface.

The whole of the machinery is worked by high pressure non-condensing steam engines, distributed as under:—

The stamps in the central sieves Nos. 2 and 3 are driven by a single cylinder horizontal engine with two fly wheels of Mr. Jordan's pattern (a larger model of the same being exhibited in the lower part of the same case).

The boiler is of the kind known as the retort boiler. It is formed of seven horizontal tubes resembling gas retorts, placed transversely in the fire-place, united by a large steam chest crossing them at right angles.

A strap on the end of the cam barrel of the stamps No. 3 works one of the amalgamating barrels and its shaking frame.

The series of stamps No. 1 are driven by a single cylinder fixed on the top of a cylindrical high-pressure boiler with one hemispherical end. The furnace is set in masonry, and also serves to heat the pots in which the mercury in the amalgam is distilled off from the gold. The same engine works the second amalgamating barrel, and a lathe placed behind the stamps hoppers.

Stamps No. 4 are worked by a double cylinder agricultural engine with multitubular boiler in which the steam cylinders are fixed within the smoke box.

Another double cylinder agricultural engine works the lower pump No. 25, the edge mill, and the circular saw.

At the deep shaft there is a single cylinder engine with multitubular boiler, which draws the ores by working a flat rope, and also moves two lines of pump rods.

The whole of the dressing floors are covered in by a roof of corrugated galvanized iron plates supported upon a light wooden framing.

No. M. 2.—Model of a High-pressure Non-condensing Steam Engine. By Mr. J. B. Jordan.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

This is an enlarged model of the engine employed for driving the stamps in Clunes gold quartz reduction works, No. M. 1. It is constructed on the so-called self-contained principle, that is, all the parts that require particular stability, including the cylinder, slide guides, and shafts bearings, are united into a single casting with the bed plate; so that there cannot be any error in setting up. There are two fly wheels of small diameter, with broad rims turned to a proper figure to be used for transmitting the power by driving belts; they may also be used as travelling wheels for taking the engine along difficult roads, the rims, of course, being protected by proper coverings.

No. M. 3.—Model of the Workings of a Small Tin Mine.*

The metalliferous districts of Cornwall are generally hilly, consequently when a trial upon any lode is to be made, the miners are enabled to avail themselves of the character of the ground by driving an adit some distance down the hill, by which the water is drained from above, and hence they are enabled to sink their shaft without the expense or inconvenience of machinery to pump the water to the surface, As the works extend they may drive a lower adit, hence frequently we hear of the shallow and the deep adits; but when the shafts are sunk below these levels, they are compelled to adopt some system of pumps for removing the water. The mouth of the adit is shown on the side of the hill. In trial operations the ordinary windlass is first used, but when the depth of the working increases, then the horse whim is required. This model represents the surface of a Cornish mine up to this point. The ores are brought to the surface in kibbles by the windlass or horse whim, and sujected to the action of the stamps, of which two sets are shown. Taking advantage of the hill, the water, which has done its work at the first stamps, is conducted by launders to flow over the second wheel; and in some cases many sets of stamps are set in motion by the same stream. The pits are for washing and dressing the ores raised to the surface.

No. M. 4.—Sectional Model of the Workings of Dolcoath Mine.

Scale, 1 inch to 48 feet, or $\frac{1}{576}$.

This model affords a perfect view of the general arrangements of this extensive tin and copper mine as it appeared in the year 1839. The red wood represents *granite*, and

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* This description is taken from Mr. Hunt's Handbook.

the white the killas or clay slate of Cornwall. The lode is shown in all its variations of thickness by the black layer which extends over both those rocks. It should be understood that the spectator is to suppose the granite and slate are entirely removed from the side of the lode nearest to him, and that he looks upon a vertical section of the lode, and the workings by which the metalliferous portions have been removed.

Commencing at the left hand of the surface are shown the heaps of refuse, or *deads* or *attle,* brought out of the mine. In the small valley are *the dressing floors,* where the ores are *stamped* by water power, and prepared for the market. From the recent extensive discovery of tin ore in this mine, the dressing floors have been very much extended; new machinery has been added, and the valley is altogether a remarkably busy scene of mining industry. The *stamps* or stamping machinery worked by a water-wheel, and a steam-engine working a *whim,*—a machine for raising the ore to the surface,—are represented, as well as two *burning houses,* in which the ores are roasted to decompose the arsenical iron pyrites contained in them previously to the final dressing processes. The small round heaps represent ore prepared for the market. In the centre of the model is the *steam engine* employed for pumping water from the mine; this water is pumped to the *adit level,*—the level nearest the surface,—through which it escapes. Around the pumping engine are the *coal yard and smithery,* and behind on the right hand are the sheds in which women are employed to break the ore, the adjoining reservoir retaining the water required in the processes of *dressing* or cleaning it. The double lines show the railroads, at the end of which is a *crushing machine,* in which the poorer ores are broken down between rollers in addition to the one in the valley.

Three steam engines are employed to draw ores from three shafts on the lode, as shown in the model.

The vertical lines from the surface are the *shafts* sunk into the rock, directly upon or near to the *lode;* the greatest depth from the surface of the mine is about 1,620 feet, the mine having increased in depth since the model was constructed. The length of the *lode* or *mineral vein* represented is 3,312 feet, not quite two-thirds of a mile. From the *vertical shafts* horizontal galleries, called *levels,* are driven on the lode at tolerably regular depths beneath each other. These levels are connected by shorter underground shafts called *winzes.* These are sometimes worked from above, downwards, and are then called *sinkings;* but not unfrequently they are worked from the lower to the upper level.*

No. M. 5.—Model of Holmbush Mine. By Mr. T. B. Jordan.

Scale, $\frac{1}{720}$. 1 inch to 10 fathoms.

This model is constructed on the same principle that is employed in drawing mine plans; that is, the whole of the excavations made, whether shafts, wing, or levels, and the portion of the lode taken away are represented in colours, while the solid ground is left blank, being the reverse of the method adopted in the model of Dolcoath mine, where the ground removed is shown in a natural manner.

The succession of the levels in depth is shown by projecting them upon frames placed at the proper vertical interval of 10 fathoms, covered with cross wires, which represent the lines of easting and westing, and northing and southing, which are commonly drawn on ground plans of mines.

The workings on each lode are distinguished by a special colour, as follows:—

On the Holmbush lode - -	red.
„ Flapjack lode - -	yellow.
„ Lead lode - - -	blue.
„ Cross courses - - -	green.

No. M. 6.—Model of Mining Operations as Carried on in Saxony, at the End of the Eighteenth Century.

This case contains a complete epitome of the processes of mining, drawing, and dressing lead ores, divided into the following sections:—

I. Stamps.
II. Schlammkasten or tye.
III. Flat table or Einkehrheerd.
IV. Einkehrheerd, with layer of ore, first part of process.
V. Do. second part of process.
VI. Do. with finished ore, third part.
VII. Stossheerd or shaking table.
VIII. Process of hand jigging or "setzarbeit."
IX. Surface buildings with picking house for ores.
X. Scheidehaus or cobbing house for hand breaking ores.

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* Account taken from Mr. Hunt's Handbook.

XI. Bank house or "Huthaus" at the mouth of shaft and winze.
XII. Overshot water whim ("kehrrad") and house.
XIV. Surface buildings with picking house, Scheide bank.
XV. Do. with cobbing house, Ausschlags zimmer.
XVI. Windlass and frame for small shafts.
XVII. Timbering of level with plankway for wagon.
XVIII. Method of driving levels by pick and gad work.
XIX. Level on an inclined vein, timbered with half-frames.
XX. Level on an inclined vein, timbered on one side only.
XXI. XXII. } Method of working away ore by stopping, filling kibbles, ladderways, &c.
XXIII. Bank of small drawing shaft, with lean-to house, and two men at the windlass.
XXIV. Timbering of a winze and footway shaft.
XXV. Timbering of a winding footway and pumping shaft, large scale.
XXVI. Overshot water wheel, with line of travelling rods or "Feldgestänge."
XXVII. XXVIII. XXIX. } Shaft with direct acting overshot water wheel, pumps, and pitwork complete, ladderway, plankway for the kibbles (tonnenfach) in drawing shaft, and windlass.

The smaller figures have reference to a detailed MS.

METALLURGICAL MODELS.

The collection of models of furnaces is contained with only a few exceptions in the gallery of the eastern model room, occupying both the wall cases and the table space. The apparatus for the assay of silver ores by the wet way is in case No. 7, Gallery E.; the large blast furnace and blowing engine for South Wales is in the principal room, A; Messrs. Naylor, Vickers & Co.'s model of a Sheffield steel works faces the principal entrance of the small room, and the lead smoke condensor from Wanlock Head mines is placed opposite to it. The arrangement of the series in the wall cases in the gallery is not a systematic one, the individual models being placed according to the available space, without regard to strict arrangement. The following is an analysis of the chief contents.

CASE No. 1.

Furnaces used in the Saxon smelting works, blast furnaces, and reverberatory smelting calcining furnace, up to the production of argentiferous lead; Cornish tin furnace and Belgian zinc furnace.

CASE No. 2.

Furnaces and machinery used in the Saxon smelting works for the production of metallic silver, including cupelling and refining furnaces for silver lead, amalgamating machinery, and retort for distilling silver amalgam, and the apparatus for the extraction of silver by the wet way without mercury.

CASE No. 3.

Iron furnaces, cupolas and puddling furnaces, including such blast furnaces as are not on the table opposite to them.

CASE No. 4.

Miscellaneous objects, including the ore and slag hearths, and Siemen's gas furnaces and generator.

On the table are placed, commencing from the eastward,

Furnaces used by chemical manufacturers.

Pattinson's desilvering pots, opposite case.

Blast furnaces with and without apparatus for economizing the waste gases.

No. N. 1, 2.—BLAST FURNACES USED IN THE SAXON SILVER LEAD SMELTING WORKS.

No. N. 1. SINGLE FURNACES.

No. N. 2. DOUBLE FURNACES.

Scale, $\frac{1}{16}$. $\frac{3}{4}$ of an inch to 1 foot.

These are small blast furnaces with four-sided shafts, which are used in the production of argentiferous lead from the ores which have been previously calcined in the furnaces No. N. 3. The single furnace has only one charging place and one twyer or blast pipe, while the double one has two and a charging place in each of the side walls, the descent of the materials being regulated by a central dividing wall extending about half way down the shaft. The hearth of the furnace is formed of a mixture of coke dust and clay moulded into a pit or sump for collecting the reduced metal, which is tapped off at intervals of six hours. The upper edge of the dam bounding the sump in front, is continued into an inclined plane, over which the slag runs continuously. Cold blast air is used very slightly above the pressure of the atmosphere. The lead produced in these furnaces is treated in the cupellation hearth, No. N. 12.

No. N. 3.—Saxon Calciner with Flue Chambers.

Scale, $\frac{1}{16}$. $\frac{3}{4}$ of an inch to 1 foot.

This is the small roasting furnace known at Freiberg as the Hungarian furnace; it is used for roasting silver ores with salt in order to convert the sulphide of silver they contain into chloride, so as to render them fit for subsequent treatment in the amalgamating machines. It is also used to a certain extent in roasting lead ores to prepare them for fusion in the blast furnace. The smoke passes through two chambers placed above the bed of the furnace before entering the chimney, which intercepts a considerable portion of the finely divided metallic substances carried over by the draught.

No. N. 4.—Saxon Calciner for Lead Ores.

Scale, $\frac{1}{16}$. $\frac{3}{4}$ of an inch to 1 foot.

This is called the English roasting furnace, and has to a great extent replaced the small Hungarian furnace No. N. 3. It is capable of containing a charge of 25 cwt., and has four working apertures, two on each side, for receiving the tool used in stirring and turning the ore. Each of these apertures is covered by a hood and short chimney for carrying away the sulphurous acid vapours produced during the roasting. The fresh charges are introduced into the furnace from the cast-iron trough above the bed, through two holes cut through the roof; the finished product is discharged through four square shoots, cut through the bed and placed immediately within the working openings, into four low chambers in the masonry of the substructure. The cast-iron plate covering the roof corresponds in outline to the bed of the furnace.

No. N. 5.—Saxon Reverberatory Fusion Furnace.

Scale, $\frac{1}{16}$. $\frac{3}{4}$ of an inch to 1 foot.

This furnace, built after the pattern of the large furnaces used in the Swansea copper smelting works, is used in concentrating poor ores containing iron pyrites and a small quantity of silver into a regulus, which when calcined supplies the iron necessary for the reduction of the galena in the lead ores treated in the blast furnaces Nos. N. 1, 2. The bed of the furnace is made of fire clay and quartz, with a depression in the centre in which the regulus or metal separates from the slag. The charge, consisting of earthy and pyritic ores and lead slags, is discharged from the mixing floor above, into a large hopper running upon rails and closed below by a sliding door moved by a rack and pinion motion, and passes into the furnace through a square hole in the roof covering the bed. The slags are drawn through an opening in the wall opposite the fire-place, the regulus is tapped on the side opposite to the stack, and is received either in sand or cast-iron moulds.

No. N. 6.—Cornish Reverberatory Furnace for Tin Smelting. Presented by Messrs. R. Mitchell, & Co.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

The process of reducing tin from the ore is a comparatively simple one, owing to the high state of concentration in which the ore is delivered to the smelter; a very high temperature is, however, required. A reverbatory furnace with a tall stack is employed. The bed is made of fire-clay; the ore in the state of fine powder, with an addition of anthracite powder and a little fluor spar, is charged through two openings in the long side-wall on the inner side of the case. The slags are drawn through an aperture in the wall at the flue end, called the mouth of the furnace, having a cast-iron roller placed in front of it for supporting the working tool or the riffling bar. The reduced metal is tapped through a hole on the side opposite to the charging hole, and is allowed to run into the clay bed on the left. The refining process is conducted in a similar furnace; the metal having been melted at the lowest possible temperature is run out into the refining kettle, a large cast-iron pot with a fire underneath it, and subjected to the process of poling, by lowering a round billet of green wood into the molten metal whereby a current of reducing gases is generated, bringing the lighter impurities to the surface, which are then skimmed off, after which the refined metal is ladled out into iron ingot moulds. The green wood billet is mounted in an iron cage at the end of a vertical bar, suspended to a crane by a double purchase tackle, with a loaded box attached to it for keeping the wood below the surface of the melted metal.

No. N. 7.—Belgian Zinc Furnace.

Scale, $\frac{1}{15}$. $\frac{4}{5}$ of an inch to 1 foot.

This furnace is used for the production of zinc from both blende and calamine. The ore, having been previously roasted, is placed in a series of cylindrical fire-clay retorts arranged one above another in horizontal rows to the number of 40, in a large chamber with a semi-cylindrical roof, having a fire-place below. The metal is collected in conical clay receivers, fitting into the mouths of the tubes, and covered by wrought-iron caps, also conical. The flame after heating the retorts passes through a smaller chamber, in which the clay tubes are baked previously to their being used in the furnaces.

No. N. 8.—Sifting Machine used in the Saxon Amalgamation Works.

Scale, $\frac{1}{8}$. $1\frac{1}{2}$ inches to 1 foot.

The ores intended for amalgamation, after having been roasted with salt and iron pyrites in the reverberatory furnace No. N. 3, are sifted through an eight-sided drum sieve contained within the hutch, having a slight backward inclination; the upper bearing of the axle is cylindrical, the lower one has a cam wheel attached to it, which rests on a step-shaped bearing, giving a slight lateral jerking motion to the sieve as it revolves. The ore is fed through an inclined shoe or trough, which receives a jerking motion from a cam wheel and lever acting against a wooden spring beam. The gauze covering the upper part of the sieve is of a double thickness, and separates a sufficiently fine grained material for grinding; the bulk of the stuff passing through the single thickness is again sifted through a finer sieve; the coarser lumps are returned to the calciner to be roasted with a fresh addition of salt.

No. N. 9.—Mill and Bolting Machine used in the Saxon Amalgamation Works.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

The sifted ore from No. N. 8 is here ground between granite millstones, making 130 revolutions per minute; the flour is bolted through a fine sieve and discharged through a door in the hutch into the railway waggon alongside. The arrangements are similar to those of an ordinary flour mill driven by water power, the bolting machine being driven by a belt on the principal shaft.

No. N. 10.—Saxon Amalgamating Barrels and Washing Machine.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

The ore, after it has been ground in the mill No. N. 9, is treated in the amalgamating barrels with water, scrap iron, and mercury. The charge of finely pulverized ore contained in the square box at the top is introduced into the barrel through an upright pipe, terminated by a canvass hose with an iron nozzle. The barrels are made of oak staves strongly hooped with wrought iron, and provided with trunnions at the ends, which run on wooden bearings. One side of the barrel has a toothed ring of cast iron fixed to it, which gears into the large driving wheel. The barrel is put in or out of gear by a setting screw, which allows the bearing on the driving side to be moved sideways, so as to bring together or disengage the teeth of the gearing wheels. The process lasts twenty-four hours, during which time the barrels are turned continuously, and for the greater part of that time at about 22 revolutions per minute. The scrap iron acts upon the chloride of silver, reducing the latter to the metallic state, and the finely divided metal so produced dissolves in the mercury, forming a liquid amalgam. At the end of the process the bulk of the mercury is run off through a small hole in the bung; the remaining contents, with the exception of the pieces of iron which are kept back by a grating, are thrown into the washing machine below. This is an ordinary dolly tub with a rotating paddle, which stirs up the desilverized mud and allows any particles of mercury that may have become entangled with it to collect at the bottom. The amalgam so obtained is removed as soon as a sufficient quantity has accumulated, usually about once in three weeks, it is much more impure than that which is run off in the first instance with the bulk of the mercury, and is treated separately.

No. N. 11.—Retort for Distilling Silver Amalgam.

Scale, $\frac{1}{6}$. 2 inches to 1 foot.

The liquid amalgam from the barrels is filtered through canvas bags under the pressure of a column of mercury, the result being a pasty compound containing about 15 per cent. of silver, from which the mercury is driven off by heating it to redness in a closed vessel. The furnace contains a single horizontal retort of elliptical section, heated by a fire on a grate underneath. The amalgam is introduced through the front of the retort, which is closed by a flat plate secured by screw clamps. The mercury collects at the other end and passes by a funnel-shaped hood into an inclined cast-iron tube of smaller size, which terminates in front of the furnace near the level of the ground, and is discharged into iron basins placed in front for its reception. This system is found to be attended with less loss of mercury than the old plan of heating the amalgam under a bell and condensing the volatized metal in water.

No. N. 12.—German Cupelling Furnace, Treibeheerd.

Scale, $\frac{1}{16}$. $\frac{3}{4}$ of an inch to 1 foot.

This is a reverberatory furnace without a stack, in which pine wood, a fuel giving a large amount of flame, is used; the necessary current of air for maintaining an oxidizing atmosphere in the hearth being supplied by two twyers at the back. It is used for separating silver from argentiferous lead by exposing the latter in a melted condition on an impermeable surface to the action of an oxidizing blast, whereby the lead is converted into litharge, which melts and can be drawn off through a notch in the side of the bed opposite the twyers. As soon as the whole of the lead has been removed the silver remains on the hearth in the form of a thin circular cake, which, after it has been cooled by pouring water on it, is removed in a single mass. For this purpose it is necessary to remove the hood or vaulted cover of the furnace by the crane in front. The hood is made of sheet iron lined internally with a refractory coating of fire-clay and quartz. The lining is made to adhere to the surface of the iron hood by a large number of clips or studs made of short pieces of hoop iron stuck through perforations in the plates, and having their ends bent into double hooks on the inner side. The bed or hearth is made of a marly limestone containing a considerable quantity of silica, which is reduced to a fine state of division, stamped in moist, and brought to a very smooth surface by moulding while still in a damp state. The model represents the substructure of the furnace without the marl hearth, which requires to be renewed at each operation; the former one, being compacted by infiltrated litharge, is broken out and returned to the ore-smelting furnace in order to recover the lead and silver that it contains.

No. N. 13. Silver Refining Furnace.

Scale, $\frac{1}{16}$. $\frac{3}{4}$ of an inch to 1 foot.

This furnace is used for refining the silver obtained in the large cupelling hearth, and differs from it chiefly in the shape and size of the hearth; a marl bed is used capable of containing from 10 to 15 cwts. of silver, which is melted under an oxidizing blast until the last traces of foreign metals are removed. The cover of the hearth is made of wrought iron, and is moveable in a manner similar to that in the preceding example.

No. N. 14.—Apparatus for the Extraction of Silver from its Ores by the Wet Way.

Scale, $\frac{1}{24}$. $\frac{1}{2}$ an inch to 1 foot.

In addition to the process of barrel amalgamation, which has been latterly abandoned at Freiberg, two other principal processes are employed in the extraction of silver from its ore by the wet way. These are, Augustin's process, in which the silver is first converted into chloride by roasting the ore with salt, as in the first stage of the amalgamation process, and is afterwards dissolved out by a strong solution of salt at a boiling temperature; and Ziervogel's process, in which the sulphide of silver in the substance under treatment is converted by careful roasting into sulphate of silver, a salt that is soluble in boiling water. The silver in the solution is in either case separated by passing it over plates of metallic copper, or the finely divided metal obtained from the solution of a copper salt by cementation with scrap iron is employed for the same purpose. The apparatus employed is shown in the model, it consists of a series of wooden vats with perforated false bottoms, containing the substance to be desilverized, which are mounted on railway trucks for the convenience of moving them along the upper stage of the building. The exhausting liquor, whether brine or plain water, is supplied from the boiler fixed in a small furnace at the right hand of the building. The silver-bearing solution runs off through a small wooden launder, and drops through perforations into the precipitating vessels, a series of vats arranged in four steps, one above another, containing cement copper or copper plates, and provided with wooden cocks, through which the solution from the vats in the upper series is run off into those next below them, and so on to the bottom. The liquor from the lowest vats is discharged into a large wooden tank, containing fragments of old iron, which decompose the copper salt formed during the reduction of the silver, as finely divided as cement copper. A portion of the acid liquor is returned to be used in the exhaustion of a fresh quantity of material. The cement silver deposited in the precipitating tubs is collected at intervals, and after washing, which is dried, compacted by hydraulic pressure in moulds, and melted into bars, ready for delivery to the mint. The desilverized residues in the upper tubs are shot down the inclined plane on the left hand corner of the upper stage, and are subsequently smelted for copper.

Neither of the above processes appears to be well adapted for the treatment of ores direct, and they are chiefly employed for the desilverizing of argentiferous copper compounds, such as result from the fusion of the copper-slates of Mansfield and the richer qualities of metal or regulus produced in the later stages of the Swansea copper smelting process, when foreign argentiferous ores are treated.

NO. N. 15.—PATTINSON'S DESILVERIZING POTS AND CUPELLING FURNACE, USED AT THE WANLOCK HEAD MINES. PRESENTED BY THE ROYAL COMMISSIONERS OF THE EXHIBITION 1851.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

NO. N. 16.—PLAN AND SECTION OF A SERIES OF PATTINSON'S POTS, AND LADLE USED IN THE PROCESS. PRESENTED BY THE LATE H. L. PATTINSON, ESQ.

The system of enriching lead poor in silver by crystallization was introduced by the late Mr. H. L. Pattinson in the year 1833, and depends upon the fact, that when lead containing silver is melted and left to cool slowly, the lead solidifies first, and may be separated in the form of a crystalline powder from the fluid portion, which retains the bulk of the silver. The apparatus used consists of a row of cast-iron pots, of a hemispherical form, set in masonry, and having a fire-place underneath each. The original lead, containing from five to eight ounces of silver to the ton, is, if sufficiently pure, melted in the central pot and gradually cooled, the crystals as they separate being scooped out by a large perforated ladle, similar to that placed in the northern corner of the Model Room A., between the cases containing the mining tools. The crystals are passed continuously to the left, becoming poorer in each pot, while the enriched residues pass to the right, the ultimate results being that the pot on the extreme left contains merchantable lead with only half an ounce, and the corresponding one at the other end yields lead with from 75 to 80 ounces of silver, or upwards, which is ready for cupellation. The value of the metal in the intermediate pots is shown in the large diagram presented by Mr. Pattinson. The mode of conducting the process is subject to much variation.

The enriched lead is subjected to the process of cupellation in a small reverberatory furnace, with a moveable bed, called a test bottom, made of bone ash, stamped into an elliptical ring of iron bound by transverse bars at the bottom. The lead is first melted in the small pot on the left-hand side of the furnace, and is then ladled into the basin in the corner, from which it runs by a cast-iron gutter into the test. The long axis of the elliptical test is placed across the furnace, *i.e.*, at right angles to the direction of the flame, the blast being applied at one end, while the litharge overflows at the opposite end. Owing to the small size of the test, it is not possible to put the whole quantity of lead to be treated, into the furnace at one time; it is therefore concentrated in separate portions until a small quantity of rich lead remains, which by a final cupellation yields a cake of silver nearly as large as the test bottom. The black parts in this model represent those that are made of wrought iron in the actual furnace, and the bright ones such as are made of cast iron.

No. N. 17.—Lead Smoke Condenser at Wanlock Head Lead Works.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

This model is placed at the entrance of the Model Room A., from the principal floor of the Museum. According to the description published in the Catalogue of the Exhibition of 1851, it consists of a rectangular building in masonry, about 30 feet in height, divided into two chambers by a partition wall, one of which communicates with a tall chimney adjoining. The smoke from the eight furnaces in the works is carried by separate flues into a large chamber (not in the model), and thence by a larger flue into the bottom of the first chamber of the condenser, being made on its way to the top to pass, first, by means of zigzag walls, four times through a shower of water, which is constantly dropping from a perforated reservoir at the top of the tower, and afterwards through a coke filter about two feet square, also washed by a stream of water, after which it enters the second or vacuum chamber. This is a rectangular chamber, seven feet long by five feet broad, and about 30 feet high, having a cast-iron water trough on its summit, which is kept constantly filled to the depth of from 6 to 10 inches, the bottom of the trough having 12 rectangular apertures in it, each about an inch broad, and extending over its whole breadth. These holes are covered by a horizontal slide below the trough, having a similar series of apertures in it, which receives a reciprocating motion from a water wheel. When at the centre of the stroke, the holes in the slide coincide in position with those in the trough, and a heavy shower of water falls through the whole height of the chamber, removing all the fine particles held in suspension by the smoke, that have escaped the action of the water in the first chamber. As soon as the holes in the water trough are closed by the solid portion of slide, a vacuum is formed in the chamber, and the pressure of the external atmosphere at the mouths of the furnaces comes into play to overcome the resistance offered to the passage of the smoke through the various impediments in the first part of the condenser. The particles of solid matter separated by the water pass out with it at the bottom of the chambers, and are collected in dykes or slime pits similar to those used in dressing finely divided minerals, the deposit yielding 33 per cent. of lead, with about 4½ oz. of silver to the ton. The water for the top cistern is supplied by a force pump attached to the over-shot wheel that works the sliding plate.

No. N. 18.—Ore Hearth.

No. N. 19.—Slag Hearth.

No. N. 20.—Ore Hearth, with Hood.

All to scale of $\frac{1}{12}$. 1 inch to 1 foot.

These furnaces are used in the reduction of lead ores in the north of England, where the galena is comparatively pure, being mixed chiefly with calc spar and a small quantity of blende, containing from 70 to 80 per cent. of lead when delivered to the smelter. The ore hearth is a small square furnace having a low shaft built of rectangular blocks of cast iron set in masonry. The shaft is enclosed on the back and side walls, and has a narrow opening in the bottom of the front wall, before which is fixed a cast-iron plate with a gutter in it for conveying the reduced lead to the melting pot in front, whence it is ladled out into the ingot moulds. The ore, which is subjected to a preliminary roasting in a reverberatory calciner, is exposed to the action of a blast of air introduced through a nozzle in the back wall, at such a temperature as to allow the reduced lead to liquate out from the earthy matters and unreduced portions of ore into the hearth bottom, which is also made of cast iron, until it fills up to the level of the edge of the inclined plane or work stone in front, when it is received by the gutter and runs off into the melting pot in front. The vitrified portions, which are separated by picking over the unreduced pasty masses on the work stone, are known as grey slags, and are subsequently treated for the lead they contain, in the slag hearth.

The small models Nos. N. 19, 20 are made from the description of the process of ore hearth smelting in the second volume of the "Transactions of the Natural History "Society of Northumberland," by the late H. L. Pattinson, Esq. The large model with the hood over the furnace was exhibited at the Great Exhibition in 1851.

The slag hearth has a square shaft about three feet deep, with a twyer in the hinder wall about 14 inches below the top edge. All the parts above the twyer being subjected to great heat, are made of refractory brickwork; below that level, however, the heat is inconsiderable, and the worn-out bearers, and other old cast-iron work of the ore hearth, may be used. The shaft is entirely solid, with the exception of an opening in the lower part of the front wall; the bottom of the hearth is formed by an inclined cast-iron plate, whose lower end overlaps the edge of a cast-iron pan placed in front. This pan is heated by a fire placed below it, and is divided into two unequal portions by a partition reaching nearly to the bottom. A pit dug in the floor in front of the pan is filled with water by means of pipes, when the hearth is at work. The larger division of the iron pan, and the whole of the furnace below the twyer, are filled with hard cinders taken from the ash-pit of the reverberatory furnace; the working part of the shaft is charged alternately with coke and grey slags from the ore hearth. The lead as it reduces separates from the earthy matters, which melt to a liquid slag, and both sink down together through the column of cinders in the lower part of the shaft. The metal settles first, owing to its superior density, and filtering through the larger division of the pan collects in the middle one, whence it is scooped put into ingot moulds. The slag cooling as it falls becomes viscid, and is made to pass over the surface of the ashes in the larger pan into the water tank in front, where it is granulated, so that any lead that it may have entangled with it may be removed by washing.

BLAST FURNACES FOR IRON SMELTING.

No. N. 21.—SECTIONAL MODEL OF BLAST FURNACE.

No. N. 22.—GERMAN CHARCOAL BLAST FURNACE.

Scale, $\frac{1}{32}$. $\frac{3}{8}$ of an inch to 1 foot.

No. N. 23.—SOUTH WALES.—ANTHRACITE BLAST FURNACE.

Scale, $\frac{1}{48}$. $\frac{1}{4}$ of an inch to 1 foot.

No. N. 24.—BLAST FURNACE AND BLOWING ENGINE AT PENYDARREN IRON WORKS, SOUTH WALES.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

No. N. 25.—BLAST FURNACE AND HOT-AIR STOVES AT YSTALYFERA IRON WORKS. PRESENTED BY MR. J. P. BUDD.

Scale, $\frac{1}{12}$. 1 inch to 1 foot.

No. N. 26.—BLAST FURNACE AT BLAINA IRON WORKS.

Scale, $\frac{1}{24}$. $\frac{1}{2}$ inch to 1 foot.

No. N. 27.—BLAST FURNACE WITH APPLICATION OF WASTE GASES. BY MESSRS. THOMAS AND LAURENS.

Scale, $\frac{1}{20}$. $\frac{3}{5}$ of an inch to 1 foot.

The typical form of an old fashioned blast furnace for iron smelting is shown in the sectional model No. N. 21, and in the section attached to No. N. 23. It consists essentially of two truncated cones of unequal height, joined together by their bases; the longer one is the uppermost, and is placed upright, the smaller one being inverted, having the smallest end underneath. This part of the furnace is called the boshes, below which is the hearth, a short contracted shaft of rectangular section, perforated on three sides to allow of the insertion of the blast nozzle or twyers. The third side is closed by a dam, over which the slag flows continuously, whilst the iron is collected in the bottom of the hearth, and is tapped off into sand moulds at intervals of 12 hours. In newer furnaces the shape of the shaft departs considerably from the old conical form, the sharply contracted slopes at the junction of the two cones being effaced by the insertion of a cylindrical portion ; in some instances a barrel-shaped form is obtained by the use of a curved instead of a straight-sided section. The inner part of the furnace, called the ring wall, is made of fire-brick, surrounded by an external casing of common brickwork or stone masonry, with or without binding hoops of wrought iron. In all the furnaces now under consideration the casing is extremely massive, but in newer ones a simple jacket of wrought-iron plates is used, a construction resembling that usually employed for ironfounders' small blast furnaces called cupolas. In No. N. 24 a short chimney is placed above the furnace proper; this is called the tunnel head, and is perforated with four openings, through which the charges of ore, coke or coal, and limestone are introduced.

The method of supplying the blast is shown in No. N. 24. The blast engine has a large vertical cylinder, in which a tightly fitting piston is moved up and down by power communicated from a rotatory shaft by a crank and connecting rod acting at one end of a vibrating beam, the piston rod being attached by a parallel motion to the other end. Three boxes containing ten rectangular clack valves of leather are fixed to the top cylinder cover; these valves open, as the piston descends, giving a free passage for the external air to enter, and fill the cylinder; on the return stroke the valves are closed, and the air inside is compressed until it reaches the maximum pressure prevailing in the regulator, when it passes through a similar series of discharge valves over by the passage on the right-hand side into the hollow upright column parallel to the cylinder which communicates with the principal air-pipe or blast main. A corresponding series of valves is placed in the lower cylinder cover; their action is similar to and alternate with those of the top. The blast regulator is a large spherical vessel made of wrought iron placed outside the engine-house; it receives the air in an irregular stream from the engine, and delivers it under uniform pressure to the furnace. A loaded safety valve placed on the main immediately adjacent to the reservoir determines the extreme working pressure. The twyers or nozzles are connected with the blast main by tubes of smaller section, each having a sluice valve near the junction, for regulating the current. Two of the twyers in this model are adapted for cold air; they are made of copper, and are connected with the fixed end of the pipe by leather hose: the third is connected with a hot blast apparatus, consisting of nine semi-circular arched cast-iron pipes, placed vertically and parallel to each other in a small furnace, with a fire grate underneath them; their ends are fixed into two parallel horizontal tubes, through one of which the cold air enters, whilst the heated air passes out through the other. The hot blast nozzle can be adjusted in position, either as regards height or laterally, by a ball and socket motion. The temperature to which the air is heated varies from 250° to 400° Fahrenheit in charcoal furnaces, and from 600° to 800° in coke or coal furnaces. A water twyer, such as is used for hot blast furnaces, is placed on the floor below the model of the blast engine; this is a hollow conical cast-iron pipe, set in the wall of the furnace, and kept cool by a stream of water circulating through the hollow part to prevent the end of the blast pipe or twyer proper from being melted by the intense heat generated in the furnace by the contact of the heated air with the fuel. In cold blast furnaces, the first effect of the blast at its entrance is a cooling one, so that a short nozzle of half-melted matter is formed in front of the twyer, which protects it, and renders the use of water twyers unnecessary.

No. N. 25 is a model of an anthracite blast furnace at Ystalyfera, in South Wales, where the blast is heated by the waste gases which, under ordinary circumstances, are allowed to burn away at the top of the tunnel head. It is of considerable interest as representing the arrangements adopted in the first gas-saving furnace constructed in this country having been exhibited by Mr. J. P. Budd at the meeting of the British Association at Swansea, in 1848. A wrought-iron cylinder is inserted in the top of the shaft extending a short distance downwards, so as to enclose a certain space between its outer surface and the ring wall, in which the gas collects as it rises. The discharge takes place through four elliptical flues in brickwork, which lead the gas into the heating stoves on the right hand side of the furnace. These are two large chambers in which the blast pipes are arranged in a series of inverted U's, giving a large amount of heating surface, as it was originally intended to employ the sensible heat of the gases only, the draught through the chamber being regulated by a tall chimney with a damper at the top. A very much greater effect may, however, be obtained by burning the waste gases, which consist essentially of nitrogen and carbonic oxide, with air in the same manner as ordinary fuel, a plan that is now almost universally adopted in English gas saving furnaces.

The Ystalyfera furnace last noticed is an example of an open-topped gas-saving furnace. Nos. N. 26 and 27 illustrate two methods in which the top of the furnace is closed except at the moment of charging. The former, No. N. 26, has a pair of cast-iron bearers intersecting each other at right angles, built into the masonry of the shaft a short distance below the top, which carry an obtuse cast-iron cone for distributing the materials thrown in, uniformly in the space below. A cylinder similar to that used in the preceding example is fixed at the top of the shaft, it reaches nearly down to the top of the cone, the intermediate space forming the passage by which the charges enter the furnace. A second cylinder of larger diameter, moving on the outer side of the first one, suspended by a pair of flat-link chains to an arch-headed lever, forms a kind of slide valve for covering the passage; which when lowered rests with its bottom edge on the top of the cone and cuts off all communication between the atmosphere and the interior of the furnace. When the slide is drawn up by depressing the outer arm of the lever, the passage between the fixed tube and the cone is opened for the introduction of the charge. The gases are taken off by a rectangular tube on one side, having a throttle-valve attached to it for regulating the amount of aperture; when the valve is closed the gases are allowed to escape into the air by a chimney on the opposite side having a closely fitting damper at the top, which under ordinary circumstances is shut.

In Messrs. Laurent and Thomas' model, No. N. 27, the throat of the furnace is covered by a conical cap, sliding on three upright pillars, whose lower edge when shut rests in a ring-shaped trough filled with water. The gases are taken off by two circular pipes placed opposite to each other, a provision being made for clearing them of solid matters held in mechanical suspension before arriving at the points of combustion. This is effected by having a continuous slit in the under side of the conducting pipes, below which a water trough is suspended for the purpose of receiving all the soluble or mechanical intermixed substances which may be present in the gaseous current. The blast heating stoves in this model are of a peculiar construction; the gas is burnt in a chamber containing several upright tubes having internal cores covered with ridges or teeth, which are heated from the outside, the space between the inner sides of the tubes and the cores forming the air passages. The arrangement is such, that all the joints of the tubes are outside the furnace so as to prevent leakage by the unequal expansion consequent on the heating of dissimilar surfaces in contact. Another portion of the gas is applied for raising steam for the blast engines. The boilers employed are of the reversed flame class, that is, plain cylindrical high-pressure boilers with heating tubes of smaller diameter placed below them. The flame is made to impinge first on the main boiler and then passes round the heating tubes, the course of the feed water being in the reverse direction. This model was exhibited at the Paris Exhibition in 1855. The most approved principle for taking off the gases now in use is the so-called "cup and cone," in which the joint is made by a moveable cone, similar in shape to the fixed one in No. N. 26, suspended to a bell-crank lever which bears against the edge of a fixed conical cup, fixed in the position of top cylinder in the same model.

No. N. 23 is a furnace of small height and capacity, in which anthracite is used as fuel, it has seven twyers varying in diameter from 2¾ to 1½ inches; the largest is placed at the back, the six smaller ones are arranged in threes on the sides. The supply of air is 3,000 cubic feet per minute, at 2¼ lbs. above the atmospheric pressure, heated to 612° Fahrenheit.

No. N. 28.—German open Fire. (Frisch Feuer.)

Scale, $\frac{1}{20}$. $\frac{3}{5}$ of an inch to 1 foot.

This is a small blast hearth with a single twyer, such as still is used on the continent of Europe to a limited extent for the conversion of cast into wrought iron or steel. A similar class of furnace is used in the Pyrenees for producing wrought iron from the ore direct; in a few small forges they are also used for re-heating or melting purposes. No exact information has been furnished as to the locality or purposes of this model.

No. N. 29.—Cupola with Fan Blower.

Scale, $\frac{1}{16}$. ¾ of an inch to 1 foot.

The cupola is a small blast furnace with a cylindrical shaft, employed for re-melting pig-iron in the production of castings. The hearth is formed with a slope towards the tap hole.

The main blast pipe is provided with two twyers placed opposite to each other; it is made with a telescopic joint, and three different series of holes for the passage of the twyers are pierced through the wall of the furnace at different heights, in order to allow of the accumulation of larger or smaller quantities of melted metal, according to the requirements of the casting. Those holes that are not in use are stopped with fire-brick plugs.

The furnace is blown by a fan with straight arms, similar to that described at p. 126, which produces a considerable volume of blast, but at a pressure very slightly in excess of that of the atmosphere.

No. N. 30.—Model of Coke Ovens used in South Wales. Presented by Messrs. Vivian & Sons.

This represents a series of four coke ovens of the simplest form; they are low arched chambers nearly rectangular in plan, increasing slightly in width towards the front. Two ovens are placed back to back, so that their flues discharge into a common stack. A line of railway for the waggons bringing the coal runs across each series.

The coal is charged through a square aperture in the roof of the oven, sufficient being introduced to fill up the chamber to the springing of the arch. The mouth is then built up with brickwork, with the exception of a few small draught holes which are left above the level of the top of the charge, the heat remaining from the preceding operation being sufficient for igniting the fresh coal. When the coking is completed the charge is drawn by an iron rod called the needle, which slides in a gutter below the floor, and takes hold of an iron cross bar placed at the far end of the oven, the two together forming a tool resembling a large hoe, which can be worked by manual or other power, according to the requirements of the case, the removal of the charge being facilitated by the gradual increase in the width of the floor towards the front.

No. N. 31.—Puddling Furnace at the Bromford Iron Works, South Staffordshire.

Scale, about $\frac{1}{6}$ of full size.

This furnace is described at full length in the second part of Dr. Percy's Metallurgy, page 640. The parts made in dark wood are of cast iron in the original, the lighter portions represent fire-brick work. It is used for the conversion of cast iron into malleable iron by exposing the former in a melted state to the action of the air, whereby the carbon contained is oxidized, leaving a spongy partially agglutinated mass of malleable metal behind at a sufficiently high temperature to be capable of consolidation by hammering or rolling. The fire-place, the arch and sides above the bed, the flue, and the lining of the stack are formed of Stourbridge fire-bricks; the bed is made of a cast-iron frame supported on pillars of the same material, lined with a refractory coating of peroxide of iron, either in the form of calcined puddling furnace slag or "bull dog" hammer scale or hematite iron ore. The area of the fire-grate is nearly as large as that of the bed; the whole structure is cased by upright cast-iron plates bound together by wrought-iron cross ties. There are four apertures on the outer side of the furnace, that on the right hand is the fire-hole through which the coal is charged on to the fire-grate; the next is a small hole called the staff hole through which the staff, a wrought-iron rod used in removing the ball or spongy mass of iron from the furnace to the hammer, is brought up to a welding heat; the large door, suspended by a lever with a counterpoise on the left, is used for introducing and removing the charge; it is shut down when the furnace is working; the shaft of the rabble or tool by which the puddler draws the particles of metal together into a ball passes through the small notched opening on the lower edge. The small square hole underneath the door is called the tap hole; it forms the passage for the slag or tap cinder produced during the process, and during the puddling it is stopped up with sand.

No. N. 32.—SIEMENS' REGENERATIVE GAS FURNACE FOR PLATE GLASS MELTING. PRESENTED BY C. W. SIEMENS, ESQ., F.R.S.

Scale, about $\frac{1}{12}$ of full size.

This invention consists in the application of large vaulted chambers filled with loosely stacked firebricks for intercepting the excess of heat in the gaseous products of combustion passing away from furnaces above that necessary for carrying them out of the stack at a proper velocity. When the brickwork and sides of the chamber have been heated to the highest temperature attainable, the current is diverted to a similar adjacent chamber, and the fuel, consisting of combustible gases produced in a special generator, is introduced at a comparatively low temperature, and is allowed to pass through in a continuous current on its way to the place of combustion until the heat has been entirely absorbed. The process is then repeated with the other chambers, of which there are four in all; they are worked in pairs alternately, two being heated by the exhaust current at the same time that the others are giving up their heat to the fuel.

This gas generator is shown in section in the right-hand part of the model; the fuel is introduced into a large chamber through the round stoppered plates in the top; the front wall is of triangular section inclined, and has a small ladder or step-grate at its lower end with a water pipe below it. The chamber is filled full of coal or other similar fuel, which is very slowly consumed by reason of the small area for the admission of air presented by the grate; the carbonic acid produced by the combustion near the outside is converted into carbonic oxide as it rises through the thick column of dull red hot coal above it, and a further supply of gases, consisting principally of carbonic oxide and hydrogen, is produced by the steam which rises through the fuel from perforations in the water pipe below the grate. The gas is collected by an arched flue running along the back of the fire-places, whence it passes by the large cast-iron pipe joining the two parts of the model together into the regenerators placed below the chamber in which the melting pots are contained. The same principle is applied in the construction of puddling furnaces; a description of such a furnace is to be found in Dr. Percy's Metallurgy of Iron and Steel, at page 682.

No. N. 33.—Model of a Steel Converting, Refining, and Casting Works, &c. Presented by Messrs. Naylor, Vickers, & Co.

Scale, about $\frac{1}{12}$ of full size.

This model faces the entrance of the model room from the principal floor of the Museum. It comprises two portions, the converting and melting furnaces, which are placed on the left-hand side, and the rolling mill and forge with its reheating and annealing furnaces contained in a separate building. The different parts are as follows, commencing from the left:—

Converting furnaces. One is shown in section, having two large chests or pots made of fire-brick, which are filled with bars of wrought iron stacked in alternate layers with charcoal. They are heated by a fire placed underneath; the flame circulates about the outside of the chest by a series of rectangular flues communicating with three short chimnies on either side, the whole being covered by a tall conical hood. The process lasts about ten days; the bars are removed after the furnace has cooled, when they are found to be converted into the substance known as blister steel.

II. The melting furnaces. The blister steel taken from the converting or cementing furnace is broken up into small fragments, which are assorted according to quality, the most highly carbonized portions yielding the hardest product. The broken pieces are melted in clay crucibles, holding from 30 to 40 lbs. each, in air furnaces heated with coke; each furnace holds two crucibles, arranged in the manner shown in section in the model. The top of the furnace is placed nearly at the same level as the floor of the casting shop. It is covered by a square fire-brick slab or "quarry," set in a wrought-iron frame, having a projecting handle on one side. There are two square shallow cast-iron boxes filled with coke dust set in the centre line of the floor, called the teaming holes, which are used for supporting the pots after they are drawn from the furnace, previously to their contents being cast into ingot moulds. The coke lining prevents the pot from being cracked by coming in contact with the iron sides of the box. Three charges can be melted in the same pot before it becomes unserviceable. In the left hand corner of the shop, opposite to the range of furnaces, is placed the annealing grate, in which the pots are heated up to redness before they are put into the melting furnaces.

III. The rolling mill contains on the left-hand side a train of four pairs of rolls for bars arranged in the following order:—

No. 1. Round bars.
„ 2. Square bars.
„ 3. „
„ 4. Flat bars.

A shearing lever for cutting bars up in lengths suitable for piling is attached to this train. Adjacent to it are two reheating furnaces for two different lengths of bars. In the centre of the shop are the plate rolls; they have two large reheating furnaces attached to them. At the right hand end are placed three tilt hammers, which are used in drawing out blister into shear steel bars. They are of small size, having heads varying from 150 to 500 lbs. weight, mounted on wooden helves, strengthened with wrought-iron hoops, and are driven at great speed, from 150 to 350 blows per minute, with a small lift. The two furnaces on the right are used for heating the piles up to a welding heat, previously to their being tilted into bars.

No. N. 34. — Apparatus for the Manufacture of Stannate of Soda. Presented by James Young, Esq., F.R.S.

Scale, about $\frac{1}{12}$ of full size.

Stannate of soda is a compound of oxide of tin (stannic acid) with soda, used by dyers as a mordant or fixing medium for certain vegetable colours. It is obtained by heating a mixture of finely divided tin ore with a solution of caustic soda in a large hemispherical iron pan, heated by a fire-place below. The action is facilitated by a rotatory stirrer, driven by steam power, which continually agitates the mixture. The product of the first operation is transferred into a lixiviating tank adjacent, where it is dissolved in water heated by the waste steam from the engine. The liquor obtained by this operation is pumped up to a large clarifying tank, supported on pillars, whence it is run into iron evaporating pans. The finished salt is afterwards dried on a hot bench or drying stove, shown on the outer side of the model, and is then ready to be packed in casks for sale.

Nos. N. 35, 36.—Apparatus for the Manufacture of Soda Ash.

Scale, about $\frac{1}{12}$ of full size.

These are two out of the numerous appliances used in the manufacture of carbonate of soda from common salt. No. N. 35 is a lead condensing chamber in which the vapour of sulphurous acid arising from the combustion of sulphur or iron pyrites in the kiln adjoining is converted into weak sulphuric acid by the action of nitrate of soda. The weak liquor drawn from the chambers is afterwards concentrated by distillation in a platinum alembic. No. N. 36 is a reverberatory furnace with a double bed. The portion nearest to the fire grate, which is at a lower level than the other part, is used for the decomposition of salt by the action of the sulphuric acid obtained in the first part of the process. The resulting products are sulphate of soda, which is dried on the outer part of the furnace bed, and hydrochloric acid gas, which is carried with the products of combustion out of the furnace, but is not allowed to escape into the atmosphere, the smoke being first led through tall towers filled with broken stone or fragments of coke kept moist by a continual trickling current of water, which dissolves the gas and delivers it in the form of liquid hydrochloric acid at the bottom of the condensers.

The other parts of process which are not illustrated by models are, the fusion of the sulphate of soda with coal and lime into the so-called black ash, the decomposition of the black ash by carbonate of lime, and the subsequent crystallization of the carbonate of soda from solution.

No. N. 37.—Pyrometer for Determining the Temperature of the Interior of Furnaces. By Captain Bystrom, Royal Swedish Artillery.

This instrument involves the application of an indirect method of determining high temperatures by quenching a highly heated mass of metal of small size in a quantity of water also of a known but much larger weight. The temperature of the metal representing that of the interior of the furnace is calculated from the increase of temperature produced in the water by a simple table supplied with the instrument.

The metallic masses employed are small balls either of steel or platinum, the former weighing seven grammes and the latter eight grammes; the weight of water in the cistern is 300 grammes. The ball is supported at the end of a horizontal muffle or D-shaped tube by a wire passing through a hole in the centre. When heated the wire is withdrawn and the ball is detached by a projecting wedge-shaped mass at the mouth of a communicating inclined tube passing through the wall of the furnace and closed by a hinged valve at the lower end. The ball falls down this tube and is received in a wire cage at the end of a broad-mouthed funnel placed in the lid of the water vessel. The increase of temperature is observed by means of a thermometer divided on the centigrade scale to tenths of degrees.

With the steel ball an increase of -	1°	of temperature in the water indicates - -	345°	in the furnace above the final temperature of the water employed.
	2°		555°	
	3°		725°	
	4°		853°	
With the platinum an increase of -	1°		930°	
	2°		1455°	
	3°		1805°	

The tables are arranged in such a manner that in the higher degrees observed differences of 0·05°, ·06°, and ·07° correspond to 20° in the furnace.

No. N. 38.—Gay Lussac's Apparatus for Silver Assaying by the Wet Way.

This apparatus is used in the principal European mints for the determination of the amount of silver contained in bars presented for coinage. It depends upon the fact, that when chloride of silver is produced by the addition of common salt to a portion of the alloy dissolved in nitric acid, the silver is precipitated in the form of a chloride; the precipitate, although a bulky one, may be made to assume the form of a heavy coarse-grained powder by agitating the vessel in which the operation is performed, and the liquor becomes sufficiently clear to allow of the least cloudiness being seen, if any should be produced by a fresh addition of the re-agent. The strength of the ordinary or normal solution of salt employed, is such, that a given volume, usually 100 cubic centimetres, shall exactly precipitate one gramme of fine silver. The weight of the assay sample must be varied with the fineness of the metal, it being desirable to operate on a quantity containing one gramme of fine silver; it is therefore necessary to know approximately the composition of the alloy before proceeding to the exact assay. After using the normal solution, the amount of variation from the legal standard is determined by adding measures of a solution of salt one-tenth of the strength of the first, should the precipitation of the silver be incomplete. If, on the other hand, too much salt should have been added in the first instance, the excess is determined by the use of a solution of nitrate of silver, one measure of which corresponds to an equal volume of the decimal salt solution.

The normal solution of salt is contained in a cylindrical copper cistern tinned on the inside, which is placed on the upper shelf. It communicates with the pipette by a brass elbow tube, below which is a vertical glass tube containing a thermometer for determining the temperature of the solution, it being necessary to introduce a correction for alterations in the strength of the liquid, produced by changes in the density due to variation from the standard temperature of 15° centigrade. The pipette has a cylindrical body with a neck and tail of smaller bore, the latter being brought to a fine point; it is fixed in a vertical position by two horizontal wooden arms projecting from a bracket attached to the wall. The neck of the pipette is connected to the bottom of the tube containing the thermometer by a silver cap with two stop-cocks, one of which serves for the admission of the solution from the reservoir, whilst the other is intended to allow the air contained in the pipette to escape during the filling. The bottle containing the solution of the metal to be assayed is placed in one division of the sliding top of the table on the floor of the case, the other division is a hollow pillar containing a sponge adjusted at such a height that it just touches the point of the pipette when placed underneath it.

The method of using the apparatus is as follows:—The assayer having stopped the point of the pipette with his finger, opens the two stop-cocks, and allows the solution to flow in until it stands a little above the gauge point cut on the neck of the tube. The stop-cocks are then closed, and the stand with the sponge is placed below the point of the pipette. By opening the lower cock the solution is allowed to run to waste until it stands at the exact level of the gauge mark in the neck, the excess of the liquid being absorbed by the sponge. The bottle is then brought under the pipette and the measured volume of solution is allowed to flow into it.

As soon as ten bottles have each received a measure of the solution they are stoppered and placed in the shaking apparatus; this is a cage having ten divisions, each holding a bottle, with a hinged cover fitting over the stoppers, suspended by a leather strap to the end of a bar spring projecting from the wall, the lower end being fastened to a coiled wire spring fixed to the floor. As these springs act against each other the cage is kept in a state of oscillation by exerting an intermittent pressure with the hand upon the top part.

When the solution in the bottles has cleared by the subsidence of the chloride of silver they are removed, and are then examined by the addition of a measure of the decimal salt solution from a small pipette containing one centimetre; all those in which any precipitate is produced are returned to the cage to be shaken afresh, and the process is repeated as long as any cloudiness is produced by a fresh addition of solution. Those bottles on the contrary, in which no fresh precipitate is produced by the first measure of the decimal salt solution, are treated with the decimal silver solution, in order to determine how much the original volume of the normal solution employed, was in excess of the amount necessary for the precipitation of the silver present. Samples that are richer than the standard require fresh additions of the decimal salt solution, until no further precipitate ensues. It is then considered that probably one-half of the last cubic centimetre added was unnecessary, and an allowance of one half-thousandth is made in the fineness; thus, supposing originally, in addition to 100 cubic centimetres of normal solution, five centimetres of the decimal salt solution have produced a precipitate, and the sixth has not, the fineness is assumed to be $\frac{900\frac{1}{2}}{1000}$, or $\frac{896}{1000}$, corresponding to the normal solution; or $\frac{4\frac{1}{2}}{1000}$, corresponding to the effective part of the decimal solution, because $\frac{4}{1000}$ was not sufficient, and $\frac{5}{1000}$ was in excess.

In the Imperial mint in Paris bars for coinage must contain $\frac{900}{1000}$ of fine silver, but a variation of $\frac{3}{1000}$ above or below the legal standard is tolerated. The original quantities of the metal taken for assay are therefore adjusted in such a manner that 100 cubic centimetres of the normal solution correspond to a fineness $\frac{896}{1000}$, or one-thousandth below the minimum legal fineness.

All the samples therefore that do not give a fresh precipitate by the addition of one cubic centimetre of the decimal salt solution are at once rejected, and it is therefore not necessary to use the decimal silver solution unless the absolute fineness of the bar is required to be known. The assay samples are dissolved in nitric acid in the bottles in which the precipitation is performed; ten samples are treated at a time, the solution being facilitated by heating them in the copper water bath placed on the lower shelf. A pair of bellows with a bent glass nozzle is used for removing the nitrous fumes from the bottles before the stoppers are put into their places, it is suspended on the side wall of the case. In making the standard solution the salt is stirred through the water in the cistern by a whisk formed of a piece of macintosh cloth tied to the end of a split cane; this is placed in the back of the case.

Examples of the pipettes employed for the decimal solutions are suspended in the rack below the upper shelf.

Nos. N. 39, 40.—Models of Assayers' Furnaces. Presented by the Patent Plumbago Crucible Company.

These are small furnaces made of fine clay bound with hoop iron. No. 39 is a muffle furnace used for the assay of silver ores by cupellation; six different sizes are made of this pattern, ranging from 10 to 13 inches in internal diameter, and from 19 to 26 inches in height. Melting furnaces similar to No. N. 40 are made in nine sizes, increasing from 6¼ inches to 12¾ inches in diameter, and from 19 inches to 32 inches in height. In either case the models are about one-third of the dimensions of the smallest size.

No. L. 4*.—Blake's Stone Breaking Machine.

Scale, about ⅛ of real size.

This machine is used for breaking up masses of ore to the proper size for treatment by the wet stamping process. The stone is broken by the pressure of a vibrating jaw or lever studded with shallow V-grooves against a similarly grooved surface attached to the framing of the machine. The driving power is transmitted from a rotating shaft by an eccentric, having the lower end of its rod in connexion with two levers, one of which oscillates about a fixed centre, while the opposite one, which is linked to the back of the vibrating arm of the crusher, has no fixed point, but can be moved laterally. As the rod of the eccentric rises it tends to draw the levers from their inclined position into line with each other, but as one of them is fixed so as to be incapable of lateral motion, the whole of the horizontal elongation takes place on the opposite one, whereby the vibrating arm is thrust outwards against the stone to be broken. The arm is returned to its former position at the change of the stroke by a spring. The cross bar carrying the centre of the fixed lever is capable of a slight lateral movement by means of a setting screw, in order to regulate the minimum distance between the crushing surfaces, and consequently the size of the fragments produced.

The model represents the form of machine in use in the Saxon mines; it is somewhat simpler in construction than those employed in England. It makes about 250 revolutions per minute, and is capable of crushing 5 tons of hard pyritic and quartzose vein stuff per hour.

LONDON:
Printed by GEORGE E. EYRE and WILLIAM SPOTTISWOODE
Printers to the Queen's most Excellent Majesty.
For Her Majesty's Stationery Office.
[5510.—500.—3/65.]