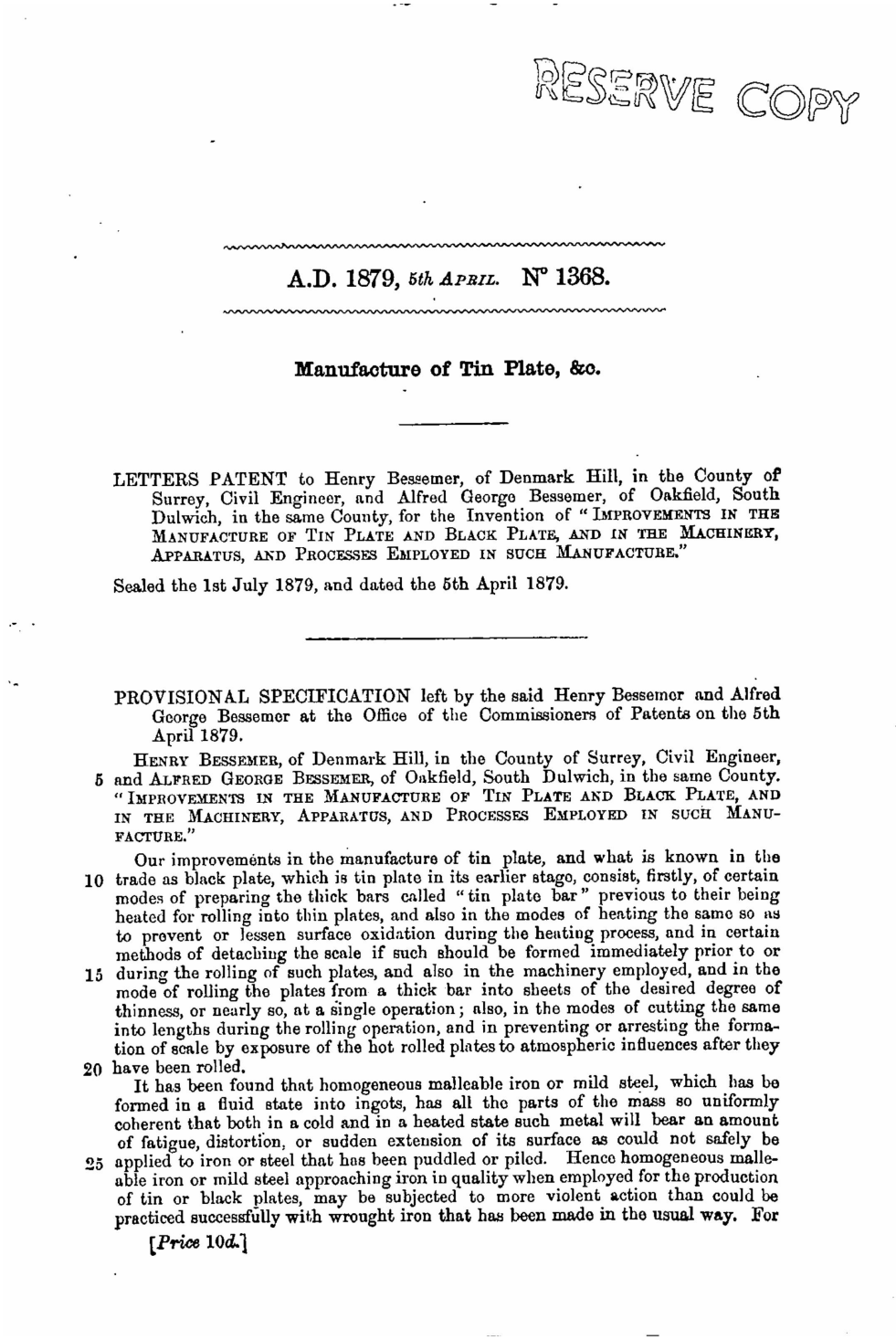
Online Appendix, 300 Years of British Patents

A Data Appendix

Figure A1: Example patent specification, GB187901368A



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A.D. 1879, *5th April.* N° 1368.

Manufacture of Tin Plate, &c.

LETTERS PATENT to Henry Bessemer, of Denmark Hill, in the County of Surrey, Civil Engineer, and Alfred George Bessemer, of Oakfield, South Dulwich, in the same County, for the Invention of "IMPROVEMENTS IN THE MANUFACTURE OF TIN PLATE AND BLACK PLATE, AND IN THE MACHINERY, APPARATUS, AND PROCESSES EMPLOYED IN SUCH MANUFACTURE."

Sealed the 1st July 1879, and dated the 5th April 1879.

PROVISIONAL SPECIFICATION left by the said Henry Bessemer and Alfred George Bessemer at the Office of the Commissioners of Patents on the 5th April 1879.

HENRY BESSEMER, of Denmark Hill, in the County of Surrey, Civil Engineer, and ALFRED GEORGE BESSEMER, of Oakfield, South Dulwich, in the same County. "IMPROVEMENTS IN THE MANUFACTURE OF TIN PLATE AND BLACK PLATE, AND IN THE MACHINERY, APPARATUS, AND PROCESSES EMPLOYED IN SUCH MANUFACTURE."

Our improvements in the manufacture of tin plate, and what is known in the trade as black plate, which is tin plate in its earlier stage, consist, firstly, of certain modes of preparing the thick bars called "tin plate bar" previous to their being heated for rolling into thin plates, and also in the modes of heating the same so as to prevent or lessen surface oxidation during the heating process, and in certain methods of detaching the scale if such should be formed immediately prior to or during the rolling of such plates, and also in the machinery employed, and in the mode of rolling the plates from a thick bar into sheets of the desired degree of thinness, or nearly so, at a single operation; also, in the modes of cutting the same into lengths during the rolling operation, and in preventing or arresting the formation of scale by exposure of the hot rolled plates to atmospheric influences after they have been rolled.

It has been found that homogeneous malleable iron or mild steel, which has be formed in a fluid state into ingots, has all the parts of the mass so uniformly coherent that both in a cold and in a heated state such metal will bear an amount of fatigue, distortion, or sudden extension of its surface as could not safely be applied to iron or steel that has been puddled or piled. Hence homogeneous malleable iron or mild steel approaching iron in quality when employed for the production of tin or black plates, may be subjected to more violent action than could be practiced successfully with wrought iron that has been made in the usual way. For

[*Price* 10*d.*]

Figure A1: Example patent specification, GB187901368A

the purposes of our Invention, we therefore prefer to employ homogeneous malleable iron or mild steel made by the Bessemer process of conversion, or by other means capable of producing metal of a similar character, and which metal, for the purposes of our Invention, may be rolled into long slabs or bars in the ordinary way or by any improved means, and we prefer to make such bars of the breadth, or nearly of the breadth, of the tin plates to be made therefrom, and of a thickness by preference varying from $^3/_8$ of an inch to $^3/_4$ of an inch; such long rolled bars may be cut into lengths varying from 3 to 6 feet, more or less. For this purpose we employ a hydraulic shearing machine, consisting of a fixed upper jaw, and a moveable lower jaw firmly attached to a rising and falling ram fitted into a water cylinder and properly guided in its frame; both the upper and under jaws are so formed with inclined or curved surfaces as not only to cut the bar in pieces of the desired length, but at the same time to squeeze and thin out or taper the end of the bar so cut, for the purpose of facilitating its entrance between the rolls; the bar, while being cut, is retained in a guide, so as to present its axis at right angles to the cutter of the shearing machine.

The tin plate bar having been cut into the desired lengths (preferably while hot) may be cleansed by pickling in dilute sulphuric or hydrocloric acid; the bar, having been thus freed from adhering scale, may then be passed cold through a pair of smooth plain rolls one or more times, in order to render its surface very smooth and even prior to reheating the same; or in lieu of this cold rolling the surface of the bars may have a very smooth or bright surface given to them by grinding their surfaces and edges by means of grindstones or emery wheels, whereby the surface of the thin plates produced therefrom are much improved. The tin plate bar is then ready for the heating and rolling processes, and in order to preserve the smooth and even surface of the bars, and prevent scaling during the heating process, we employ furnaces in which retorts are set in a manner similar to that employed in setting the retorts employed in the manufacture of coal gas, and which retorts may be formed of fire-clay or of metal, but as metal retorts conduct heat much more rapidly than clay, and as a very high temperature is required, we prefer in lieu of using cast iron for this purpose to make them of homogeneous malleable iron or steel, by casting or founding such metal into the desired form, and with or without shelves, partitions, grooves, or projections in the interior thereof, for the separation of the plates as may be desired. When plates are piled upon each other flat wise in such retorts, we prefer to protect the contiguous surfaces with a little lime or other matter in a state of fine powder, for the purpose of preventing adhesion at very high temperatures; and we also put into such retorts small lumps of coal or other substance capable of producing an artificial atmosphere in such retorts less capable of oxidizing the plates than pure atmospheric air. The ends of the retorts are moveable for the purpose of inserting the pieces of bar, and for the removal thereof, and in some cases where the retort furnaces cannot be placed near the rolling mill, we use moveable metal retorts or boxes for heating the tin plate bar, and which moveable retorts or boxes may be removed from the heating furnace and brought with the bars in them to the rolls. For the cheaper or inferior qualities the bars may be heated in a reverberatory or other suitable open furnace, in which case as little free oxygen as possible should be allowed to enter the furnace, but in any case bars so heated will have a scale of oxide formed upon them. We therefore pass the bars between several small rolls arranged after the manner of "plate bending rolls," whereby the bars passed through them will be bent once or more in opposite directions, for the purpose of detaching the scale from their surfaces, the detached portion of scale being blown away by jets of air or steam. Such rolls may be fitted in a separate frame, but we prefer to fix them in immediate connection with the main rolls, so that the operation of scaling the bar and rolling down to thin plate may go on simultaneously.

The rolling mill which we employ for the production of thin plates from the bars so heated consists of two main frames or housings, between which the main rolls revolve, and which frames may be united by bolts and flanges at the top and

Figure A1: Example patent specification, GB187901368A

bottom thereof, or in such way as to prevent the great force employed from causing any deviation in the true parallelism of the rolls. For the purposes of our Invention it is necessary that the rolls should be much larger in diameter than is required when rolling tin plates by passing them several times through the rolls, at each of which passes the plate or packet of plates is slightly reduced in thickness by altering the relative distance apart of the rolls. It is also desirable that the rolls should be driven at a much greater surface speed than is necessary when rolling tin plates in the ordinary way in order to allow the necessary heat to be maintained until the long piece of tin plate bar is formed into a sheet of great length, or into a greater number of shorter lengths of black plate. The main rolls run in brasses capable of accurate adjustment crosswise, so as to secure their true parallelism; the top roll is pressed upwards against its brasses by a lever, or preferably by a pair of hydraulic cylinders, so as always to run free of the lower roll; screws are employed to regulate the thickness of the metal passing between them, and divided discs are mounted on these screws to show how much they are moved, when an adjustment of them is necessary. The great speed that it is desirable to drive the rolls and the friction of their axes under heavy pressure renders it necessary that special precautions should be taken to prevent the overheating of the roll journals; for this purpose we carry water from an elevated reservoir in a pipe to the rolling mill; the main pipe is provided with a cock, by means of which the water may be turned on or off when required; small branch pipes proceed from this main to each of the journals of the main rolls, and are connected with the brasses in which they revolve, so that a film of walter may escape under pressure between the brasses and the journal as the latter revolves, and thus cool these surfaces effectually. In some cases jets of water from this main pipe may be projected in the form of spray upon the bar while being rolled to assist in detaching scale, or upon the thin sheet as it emerges from the rolls for the purpose of cooling it and preventing the formation of scale. Brackets are formed on the housings, to which a ribbed guide plate is attached, this guide plate has raised sides, between which the length of tin plate bar is guided during its passage through the rolls. Above and below this guide plate is a small roll driven by wheels on the main rolls or on the shafts by which they are driven, the space between the smaller rolls is such that the tin plate bar can be freely pushed along the guides in between them, its taper end going forward as far as the large rolls will permit. The lower small roll is then suddenly forced upward, so as to bite the bar between it and the upper small roll; by this means the tin plate bar will be carried forward with considerable force, presenting its tapered end into the small taper space left between the main rolls, which will so press upon it as to draw it between them. The space between the main rolls is so small that the sheet emerging therefrom will be thin enough or nearly thin enough to constitute the black plate required at a single rolling operation; the small rolls employed to force the taper end of the bar into the narrow wedged shape space between the main rolls may be driven by a carrier or ratchet wheel, so that when the main rolls seize the bar the small rolls may not unduly force it forward or offer any obstruction to the passage of the bar through the main rolls; the moment the workmen observes that the bar is being taken forward by the main rolls he will release the grip of the small rolls upon it. The small rolls or feeding rolls, as they may be called, we prefer to grip the bar by hydraulic pressure derived from an accumulator in a manner well understood, there being a small hydraulic ram and cylinder under each brass of the lower roll, so that the workman by means of a lever acting on a suitable valve may rapidly put on or take off the grip of the feeding rolls. It will be thus understood that if the main rolls are adjusted to a distance of one fiftieth of an inch apart, and further, that the tin plate bar is half an inch in thickness, that the issuing thin plate will be nearly twenty five times as long as the bar, and will produce about one hundred and fifty feet of black plate from a six foot length of bar at a single operation; and further, if the main rolls slightly exceed thirty inches in diameter, or are equal to eight feed in circumference, that about twenty revolutions only of the main rolls

Figure A1: Example patent specification, GB187901368A

will be required to pass a bar six feet long through them, and by giving a speed of say forty revolutions per minute to such rolls the time occupied in passing the bar through the rolls will be about half a minute, a speed which will cause such a developement of heat in the parts under pressure as greatly to facilitate the rolling operation. We however desire it to be understood that the size of the rolls, their speed of rotation, and the thickness of the bar employed, are only given approximately for the purpose of rendering the rolling process better understood, and may be modified as may be found desirable in practice. The thin sheet of metal as it rapidly emerges from between the rolls in a heated state may in some cases be made to pass between another pair of rolls, preferably of much less diameter than the main rolls, and may here undergo a further reduction in thickness, care being taken to speed those rolls so as to work properly in conjunction with the main rolls; or in lieu of this mode of operating we prefer to allow the thin sheet as it emerges from the main rolls to pass between guide plates which will conduct it into the jaws of a pair of vertically acting shears operated on by a cam, so as to make a very rapid movement through a very small distance, and thus cut off the issuing sheet into such lengths as may be desired, and which will be regulated by the relative velocity of the cam shaft and the main rolls; or in lieu of the reciprocating shears a revolving bar or cutter shod at each end with an adjustable cutter may be made to shear the metal into the lengths desired; in either case we place below the shearing apparatus a tank partly filled with water, oil, or other fluid, into which the plates as sheared off may fall, and thus prevent that oxidation of the surface which slowly cooling in the air would produce; if water acidulated with sulphuric or hydrochloric acid be employed the plate will be effectually cleaned of any external film of oxide.

In some cases it may be preferred to retain the long sheet of thin metal in a continuous piece, in which case we provide a revolving drum having a notch or opening on one side, the drum having its axes parallel to the axes of the main rolls, and so placed near the end of the guide plates that the sheet of thin metal may be directed into the notch before named, where, pushing against a catch, it will be locked fast to the drum, and at the same time throw the axis of the drum into gear with a revolving shaft, so that the thin sheet of metal may be wound up on the drum as fast as it is produced, the drum being replaced by an empty one for the next rolling operation.

If it be desired to make the edges of the thin plates more perfect than they are produced by the rolling operation we use a pair of revolving shears between the main rolls and that part of the apparatus where the thin sheet is cut into lengths, or wound on a drum, or is otherwise disposed of; these shearing rolls consist of a plain roll of an exact length corresponding with the intended breadth of the plate, and a second roll of the same length on which two circular discs are mounted, forming a sort of raised flange at each end with sharp chisel like cutting angles, which will cut off the uneven edges and render the sheet of metal even and parallel throughout its length, by which arrangements or some of them the length of tin plate bar when put into the rolling machine will be converted without labor or reheating in the furnace into a great number of thin plates sheared to the desired length and breadth and delivered into the pickling tank almost free from external scale, and in a very short period of time. The plates when cooled down in the tank, either with or without being annealed, may be wiped dry and be flattened and smoothed only, or they may be further extended if desired by cold rolling between polished cast steel rolls or highly polished chilled rolls set to a definite distance apart by screws, or as we prefer when used only for improving the surface of the plate, forced together by hydraulic cylinders actuated by an accumulator of small size under spring pressure, the cold rolling apparatus having a table at each side, the surface of which is at a tangent with the upper surface of the bottom roll, and will admit of the rapid passage of plates between them.

Figure A1: Example patent specification, GB187901368A

SPECIFICATION in pursuance of the conditions of the Letters Patent filed by the said Henry Bessemer and Alfred George Bessemer in the Great Seal Patent Office on the 4th October 1879.

HENRY BESSEMER, of Denmark Hill, in the County of Surrey, Civil Engineer, and ALFRED GEORGE BESSEMER, of Oakfield, South Dulwich, in the same County. "IMPROVEMENTS IN THE MANUFACTURE OF TIN PLATE AND BLACK PLATE, AND IN THE MACHINERY, APPARATUS, AND PROCESSES EMPLOYED IN SUCH MANUFACTURE."

Our improvements in the manufacture of tin plate and what is known in the trade as black plate, which is tin plate in its earlier stage, consist firstly of certain modes of preparing the thick bars called "tin plate bar" previous to their being heated for rolling into thin plates, and also in the modes of heating the same, so as to prevent or lessen surface oxidation during the heating process, and in certain methods of detaching the scale if such should be formed immediately prior to or during the rolling of such plates, and also in the machinery employed, and in the mode of rolling the plates from a thick bar into sheets of the desired degree of thinness or nearly so at a single operation; also in the modes of cutting the same into lengths during the rolling operation, and in preventing or arresting the formation of scale by exposure of the hot rolled plates to atmospheric influences after they have been rolled.

It has been found that homogeneous malleable iron or mild steel which has been formed in a fluid state into ingots has all the parts of the mass so uniformly coherent that both in a cold and in a heated state such metal will bear an amount of fatigue, distortion, or sudden extension of its surface as could not safely be applied to iron or steel that has been puddled or piled.

Hence homogeneous malleable iron or mild steel approaching iron in quality when employed for the production of tin or black plates may be subjected to more violent action than could be practiced successfully with wrought iron that has been made in the usual way. For the purposes of our Invention we therefore prefer to employ homogeneous malleable iron or mild steel made by the Bessemer process of conversion, or by other means capable of producing metal of a similar character, and which metal, for the purposes of our Invention, may be rolled into long slabs or bars in the ordinary way or by any improved means; and we prefer to make such bars of the breadth or nearly of the breadth of the tin plates to be made therefrom, and of a thickness by preference varying from $^3/_8$ of an inch to $^3/_4$ of an inch. Such long rolled bars should have clean and neatly formed edges, and a good clear or smooth surface, such as is obtained by the employment of grooved rolls as practised in the manufacture of ordinary merchant bars. While still hot from the rolling process such bars may be cut into lengths varying from 3 to 6 feet, more or less; for this purpose we employ a hydraulic shearing machine consisting of a fixed upper jaw and a moveable lower jaw firmly attached to a rising and falling ram fitted into a water cylinder and properly guided in its frame; both the upper and under jaws are so formed with inclined or curved surfaces as not only to cut the bar in pieces of the desired length, but at the same time to squeeze and thin out or taper the end of the bar so cut for the purpose of facilitating its entrance between the rolls. The bar while being cut is retained in a guide so as to present its axis at right angles to the cutter of the shearing machine.

And in order that the mode of constructing and operating such shearing apparatus may be fully understood we have represented the same on Sheet A of the annexed Drawings, where Figure 1 is a front elevation; Figure 2, a vertical section on the line A, B, of Figure 1; and Figure 3, a sectional plan on the line C, D, of Figure 1, where the ram *c* and the sliding plate *i* are omitted. In these Figures *a* represents a massive bed plate in which the hydraulic cylinder *b* is supported by its upper flange b^1; this cylinder we prefer to cast in mild steel and to bore out truly,

Figure A1: Example patent specification, GB187901368A

so as to accurately fit the ram *c*; a flanged collar *d* serves to confine the hydraulic leather in place, and at the same time to prevent the scales falling from the sheared metal entering the space between the ram and its cylinder. An inverted flanged ring *e* fitted on to the ram overhanges the vertical part of the ring *d* and thus effectually prevent the falling scale from entering between the ram and its cylinder.

Two massive castings *f*, *f*, are bolted by their lower flanges to the bed plate *a*, each having a pair of large steel bolts *g* passing up through them for the purpose of securing the cross head *h* of the apparatus firmly in place. The lower ends of the bolts *g* passing through the bed plate *a* and the crosshead *h* thus uniting the upper and lower parts of the framing firmly together. The inner faces of the castings *f*, *f*, are truly planed, and a recess or groove is formed in which a massive plate *i* may slide up and down; this groove is best seen at *y* in Figure 3. In order to insure the precision of this motion the grooves before referred to are made sufficiently wide to allow a bar of steel *k* to be fitted within the groove, and there held by bolts k^1 having slotted holes. There are also screws *m* passing through the casting *f* and pressing the bar *k* against the sliding plate *i*, and thus tighten it up as it wears and keep it steadily in place. The lower end of the slide *i* rests on the ram *c* and rises and falls with it, and the upper part of it has a shoulder on which rest two hardened and tempered pieces of steel *n* and *p*; the piece *n* forms the shearing part or lower jaw of the shears, and the piece *p* the pressing part used for tapering the end of the sheared bar; these pieces of steel are secured to the slide *i* by bolts, as shewn.

The crosshead *h* has a groove formed on its underside from end to end, and into this groove the upper end of the castings *f*, *f*, are fitted; the groove also serves to retain in place a piece of steel *q*, on the lower side of which is fitted the shearing and pressing blade *r*, secured thereto by bolts as shewn. The position of the cutting edge of the blade *r* may be adjusted by the removal or addition of thin packing pieces in the dovetailed side at q^x, against which it is forced by the screws *s*. To prevent too great a movement of the slide *i* in an upward direction, steel pieces *t*, *t*, are fitted to the crosshead *h*, which come in contact with the slide *i*, whenever the desired amount of tapering is given to the end of the bar, the position of the lower and upper jaw of the shearing apparatus at the time when the operation is completed, is shewn on a larger scale at Figure 4, where *u* shews a portion of the bar with its tapered end still held between the pressing pieces *p* and *r*, while in Figure 2, the bar *u* is shewn in the position it would occupy at the moment when the upper and lower cutting edges first come in contact with it. The guides for conducting the bar with its axis at right angles to the face of the cutters is omitted in the Drawings to allow other parts to be more clearly seen, it consists simply of a plate or frame with raised sides, forming a sort of trough in which the end of the plate lies when being fed into the apparatus. In some cases it may be found desirable to place the shearing apparatus in a pit or sunk space, so that the jaws of the shears shall be level with the floor of the rolling mill, thus allowing the bar to be pushed into or between the jaws without lifting it from the floor.

In working this apparatus, we prefer to employ an accumulator and force pumps, such as are in common use for working the hydraulic apparatus connected with the Bessemer process of making steel, but we prefer to use a higher pressure than is generally employed for that purpose; various arrangements of equilibrium valves or piston valves may be employed for the purpose of admitting water under pressure from the accumulator to the hydraulic cylinder *b* of this shearing apparatus. Such a valve should be employed for this purpose as will allow the operator without exerting much force to open a passage for the ingress and egress of water sufficiently large to produce a quick motion of the ram in either direction, and thus limit the time during which the cutting and pressing surfaces are in contact with the heated bar.

The tin plate bar having been cut into the desired lengths (preferably while hot), may be cleansed by pickling in dilute sulphuric or hydrochloric acid; the bar

Figure A1: Example patent specification, GB187901368A

having been thus freed from adhering scale may then be passed cold through a pair of smooth plain rolls one or more times, in order to render its surface very smooth and even prior to reheating the same; or in lieu of this cold rolling, or after such cold rolling process has been performed, the surface of the bars may have a very smooth or bright surface given to them by grinding their surfaces and edges by means of grindstones or emery wheels, whereby the surface of the thin plates produced therefrom are much improved. The tin plate bar is then ready for the heating and rolling processes; and in order to preserve the smooth and even surface of the bars, and prevent scaling during the heating process, we employ furnaces in which retorts are set in a manner similar to that employed in setting the retorts employed in the manufacture of coal gas, and which retorts may be formed of fire clay or of metal, but as metal retorts conduct heat much more rapidly than clay, and as a very high temperature is required, we prefer in lieu of using cast iron for this purpose to make them of homogeneous malleable iron or steel, by casting or founding such metal into the desired form, and with or without shelves, partitions, grooves, or projections in the interior thereof, for the separation of the plates as may be desired. When plates are piled upon each other flat wise in such retorts, we prefer to protect the contiguous surfaces with a little lime or other matter in a state of fine powder, for the purpose of preventing adhesion at very high temperatures, and we also put into such retorts small lumps of coal or other substance capable of producing an artificial atmosphere in such retorts, less capable of oxidizing the plates than pure atmospheric air; the ends of the retorts are moveable for the purpose of inserting the pieces of bar and for the removal thereof, and in some cases where the retort furnaces cannot be placed near the rolling mill, we use moveable metal retorts or boxes for heating the tin plate bar, and which moveable retorts or boxes may be removed from the heating furnace, and brought with the bars in them to the rolls.

The form and arrangements of the retort furnaces employed for heating the tin plate bars may be considerably varied, depending partly on the available space in the works and on the kind of fuel to be employed, but we prefer to place the retorts in a line all on the same level in preference to placing them one above the other, the height above the floor being such that the workman can most conveniently withdraw the bars from them by means of a pair of tongs suspended by a light rod or chain from an overhead slide or rail; we also prefer to place the rolling mill at such a height that the space between the rolls shall be about the same distance from the floor as the centre of the retorts.

The form of retort or heating chamber which we prefer is shewn in cross section at Figure 5, Sheet A, and in longitudinal vertical section at Figure 6. If the interior dimensions of such a retort are 13 inches in height by 18 inches in width and about 7 feet in length, it will allow 30 bars to be placed within it in an inclined position, as shown in Figure 5, provided these bars do not exceed 12 inches wide by ½ an inch in thickness and 6 feet in length, in which case each bar would weigh fully 1 cwt. Now the workman can roll off one of these bars on an average every 2 minutes, thus each retort will supply the mill for 1 hour, and during that time it will produce 30 cwt. of thin plates, hence as the bars require from 6 to 7 hours to heat them up to the proper pitch for rolling, a furnace with 8 retorts of the size indicated will keep up a continuous supply of heated bars for such a mill. We desire it to be understood that the times and weights herein mentioned may be subject to considerable variations from various causes, and are only given in order to indicate more clearly the general results of working on the principle embraced in our Invention. At Figure 6 we have shewn one end of the retorts A resting on a brick corbel at the back of the furnace; the opposite end of the retort enters the front wall, but does not pass through it, as much heat would in that case be conducted away, and we prefer to form this end of the retort with an inclined surface, so that a fire tile or plate B may rest and be luted close up against it, and thus confine the heat as much as possible during the time the bars are being heated; we also fix an iron frame C against the furnace wall, having a horizontal sliding plate

Figure A1: Example patent specification, GB187901368A

D closely fitted to it, and which can be easily pulled aside and closed again as the bars are withdrawn. It will be understood that the tile or plate D is only used prior to the withdrawal of the bars.

Small lumps of coal or other substance capable of producing a non-oxidizing atmosphere are put into the retort, as shewn at E. If desired, the bars may be placed upon each other, as shewn at Figure 7, which is a cross section of another form of retort suitable for that purpose. The importance of preventing any scaling of the bar will be apparent when it is considered how such scales would become embedded into and injure the surface of a thin plate when such plate is produced by a single passage through the rolls.

For the cheaper or inferior qualities the bars may be heated in a reverberatory or other suitable open furnace, in which case as little free oxygen as possible should be allowed to enter the furnace, but in any case bars so heated will have a scale of oxide formed upon them; we therefore pass the bars between several small rolls arranged after the manner of "plate bending rolls," whereby the bars passed through them will be bent once or more in opposite directions for the purpose of detaching the scale from their surfaces, the detached portion of scale being blown away by jets of air or steam; such rolls may be fitted in a separate frame, but we prefer to fix them in immediate connection with the main rolls, so that the operation of scaling the bar and rolling down to thin plate may go on simultaneously.

For this purpose we prefer to place three rolls in the same horizontal plane and parallel with each other, and only an inch or two apart, and above these rolls we place two other rolls, also parallel to each other and to the rolls beneath them; one of these upper rolls occupying a position vertically over one of the lower ones, while the other upper roll is placed vertically over the space left between the other two lower ones. The upper rolls are made to approach the lower ones so nearly that a bar cannot be passed between the series of rolls without being bent first in one direction and then in an opposite one, which will have the effect of throwing off any scale formed on their surfaces in the heating furnace.

The mode of mounting and driving bending rolls for bending iron plates is well understood, and admits of considerable variation in the details without affecting the general principle on which its efficiency depends. We therefore do not confine ourselves to any precise details of construction in such bending apparatus.

The rolling mill which we employ for the production of thin plates consists of two main frames or housings between which the main rolls revolve, and which frames may be united by bolts and flanges at the top and bottom thereof, or in such way as to prevent the great force employed from causing any deviation in the true parallelism of the rolls. For the purposes of our Invention it is necessary or desirable that the rolls should be much larger in diameter than is required when rolling tin plates by passing them several times through the rolls, at each of which passes the plate or packet of plates is slightly reduced in thickness by altering the relative distance apart of the rolls. It is also desirable that the rolls should be driven at a much greater surface speed than is necessary when rolling tin plates in the ordinary way, in order to allow the necessary heat to be maintained until the long piece of tin plate bar is formed into a sheet of great length or into a great number of shorter lengths of black plate. The main rolls run in brasses capable of accurate adjustment crosswise so as to secure their true parallelism, the top roll is pressed upwards against its brasses by a lever, or preferably by a pair of hydraulic cylinders, so as always to run free of the lower roll; screws are employed to regulate the thickness of the metal passing between them, and divided discs are mounted on these screws to show how much they are moved when an adjustment of them is necessary. The great speed that it is desirable to drive the rolls and the friction of their axes under heavy pressure renders it necessary that special precautions should be taken to prevent the over heating of the roll journals; for this purpose we carry water from an elevated reservoir in a pipe to the rolling mill, the main pipe is provided with a cock by means of which the water may be turned on or off when required; small branch pipes proceed from this main to each of the

Figure A1: Example patent specification, GB187901368A

journals of the main rolls, and are connected with the brasses in which they revolve, so that a film of water may escape under pressure between the brasses and the journal as the latter revolves and thus cool these surfaces effectually; in some cases jets of water from this main pipe may be projected in the form of spray upon the bar while being rolled to assist in detaching scale, or upon the thin sheet as it emerges from the rolls, for the purpose of cooling it and preventing the formation of scale. Brackets are formed on the housings to which a ribbed guide plate is attached; this guide plate has raised sides between which the length of tin plate bar is guided during its passage through the rolls. Above and below this guide plate is a small roll driven by wheels on the main rolls or on the shafts by which they are driven, the space between the smaller rolls is such that the tin plate bar can be freely pushed along the guides in between them, its taper end going forward as far as the large rolls will permit. The lower small roll is then suddenly forced upward so as to bite the bar between it and the upper small roll; by this means the tin plate bar will be carried forward with considerable force, presenting its tapered end into the small taper space left between the main rolls, which will so press upon it as to draw it in between them.

The space between the main rolls is so small that the sheet emerging therefrom will be thin enough or nearly thin enough to constitute the black plate required at a single rolling operation. The small rolls employed to force the taper end of the bar into the narrow wedged shape space between the main rolls may be driven by a carrier or ratchet wheel, so that when the main rolls seize the bar the small rolls may not unduly force it forward or offer any obstruction to the passage of the bar through the main rolls; the moment the workman observes that the bar is being taken forward by the main rolls he will release the grip of the small rolls upon it; we prefer that the small rolls (or feeding rolls as they may be called) should grip the bar by means of hydraulic pressure derived from an accumulator in a manner well understood, there being a small hydraulic ram and cylinder under each brass of the lower feeding roll, so that the workman by means of a lever acting on a suitable valve may rapidly put on or take off the grip of the feeding rolls. It will be thus understood that if the main rolls are adjusted to a distance of one fiftieth of an inch apart, and, further, that the tin plate bar is half an inch in thickness, that the issuing thin plate will be nearly twenty five times as long as the bar, and will produce about one hundred and fifty feet of black plate from a six foot length of bar at a single operation; and, further, if the main rolls slightly exceed thirty inches in diameter, or are equal to eight feet in circumference, that about twenty revolutions of the main rolls will be required to pass a bar six feet long through them, and by giving a speed of, say, forty revolutions per minute to such rolls the time occupied in passing the bar through the rolls will be about half a minute, a speed which will cause such a developement of heat in the parts under pressure as greatly to facilitate the rolling operation; we however desire it to be understood that the size of the rolls, their speed of rotation, and the thickness of the bar employed, are only given approximately for the purpose of rendering the rolling process better understood, and may be modified as may be found desirable in practice, but we nevertheless desire it to be understood that the amount of heat developed by the rapid application of great mechanical force plays an important part in our new system of rolling tin and black plates, for it is well known that the facility with which the flow or extension of iron under a given pressure takes place depends greatly on its temperature, hence we see in the rolling of tin plate, as heretofore generally practiced, by repeatedly passing the metal between the rolls, that the loss of heat both by radiation and by conduction into the rolls is in proportion to the gradually increasing surfaces and the time which those surfaces are exposed to radiation, hence gradual and progressive rolling becomes a cooling operation, greatly increasing the amount of mechanical force necessary to extend the plate, the rolling operation taking place under conditions most unfavorable to the extension of the plate, while the amount of mechanical force absorbed by the friction of the roll journals by these repeated operations is in proportion to the spaces passed through by their

Figure A1: Example patent specification, GB187901368A

surfaces, and the amount of pressure required to compress and extend the comparatively hard and cool surfaces of the metal passed through them, at the same time this cooling of the metal during the rolling process renders it necessary to heat the metal in the furnace again and again before the tin plate bar is reduced to plates of the desired degree of thickness.

Now in our new process of rolling tin and black plate we avoid much loss of heat by radiation by retaining every portion of the heated bar in its original massive form until the instant when each portion of it is required to undergo a sudden transformation from a thick bar to a very thin plate, the extreme rapidity of this change of form, and the force expended in thus suddenly altering the relative position which the molecules of the mass occupy with reference to each other developes a great amount of heat at the part where this change of form is effected; thus our system of rolling is a heating and not a cooling process, and the softening of the metal by this conversion of force into heat greatly facilitates the flow of the metal, and lessens the amount of strain on the rolls, which would otherwise be very great, at the same time the amount of mechanical power absorbed by the friction of the roll axles is reduced in proportion to the spaces passed through by their surfaces in producing a given quantity of plate, and the temperature and relative softness of the metal where the flow takes place.

It will be obvious that a mill so operating will produce a much greater quantity of plate in a given time, and with much less manual labour, and with a less number of heating furnaces than would be required in the present system of alternate rolling and reheating, while the loss of metal in shearing the uneven ends of the plates (as generally made) will be avoided. We would further remark that the thin sheet of metal as it rapidly emerges from between the rolls in a heated state may in some cases be made to pass between another pair of rolls, preferably of much less diameter than the main rolls, and may here undergo a further reduction in thickness, care being taken to speed these rolls so as to work properly in conjunction with the main rolls; or in lieu of this mode of operating we prefer to allow the thin sheet as it emerges from the main rolls to pass between guide plates, which will conduct it into the jaws of a pair of vertically acting shears operated on by a cam so as to make a very rapid movement through a very small distance, and thus cut off the issuing sheet into such lengths as may be desired, and which will be regulated by the relative velocity of the cam shaft and the main rolls; or in lieu of the reciprocating shears a revolving bar or cutter, shod at one or both ends with an adjustable cutter, may be made to shear the metal into the lengths desired. In either case we place below the shearing apparatus a tank partly filled with water, oil, or other fluid, into which the plates as sheared off may fall, and thus prevent that oxidation of the surface which slowly cooling in the air would produce. If water acidulated with sulphuric or hydrochloric acid be employed the plates will be effectually cleaned of any external film of oxide. In some cases it may be preferred to retain the long sheet of thin metal in a continuous piece, in which case we provide a revolving drum having a notch or opening on one side, the drum having its axes parallel to the axes of the main rolls, and so placed near the end of the guide plates that the sheet of thin metal may be directed into the notch before named, where pushing against a catch it will be locked fast to the drum, and at the same time throw the axis of the drum into gear with a revolving shaft, so that the thin sheet of metal may be wound up on the drum as fast as it is produced, the drum being replaced by an empty one for the next rolling operation; and in order that this mode of winding up the long sheet of thin metal on a drum as it emerges from the rolls may be fully understood, we have shewn so much of the apparatus as is necessary for this purpose at Figure 1 on Sheet C of the annexed Drawings, where *a* represents the shaft on which the winding drum *b* is mounted. The shaft *a* may be supported on brackets projecting from the housings of the rolling mill, or in a separate frame, and be driven by an ordinary driving drum and strap. The driving drum should be provided with a friction clutch, which will enable the driving drum to revolve without carrying the axle *a* with it whenever the winding

Figure A1: Example patent specification, GB187901368A

drum is held fast, but which will nevertheless cause the axle *a* and the winding drum *b* to revolve the moment the winding drum is allowed to do so. The sheet of thin metal C passes between horizontal guide plates *d*, and entering the notch or opening of the winding drum comes in contact with a small catch *e*, which it pushes forward into the cavity *f* formed behind the thickened edge of the opening into the drum. A lever *g*, mounted on a pin or centre *h*, has a very stout spring *i* pressing on one end of it; the opposite end is corrugated, and when released from the position shewn in the Drawing by the movement of the catch *e* the corrugated part suddenly moves upward, gripping the end of the plate *c* firmly between it and a similarly corrugated part formed on the inside of the drum at b^1. This movement of the lever *g* causes the pin or stop *n* attached to the lever *g* to be withdrawn from contact with a fixed stop *m*, which up to that time had prevented the winding drum from revolving, but which will by its removal allow the winding drum to revolve in the direction indicated by arrows, and wind up the thin plate of metal as fast as it emerges from the rolls. A portion of the drum b^2 is hinged at b^3 to the other part of the drum, and its upper end is held in position by jointed levers *p*, *p*, which hold it in the position shewn during the winding up of the thin plate, but as soon as this is done the levers *p*, *p*, are forced upward into the position shewn by dots, which will move inward or collapse one side of the winding drum, and allow the coil of thin plate to be readily removed, the winding drum being mounted outside its bearings for the purpose of facilitating the removal of the coil of plate.

If it be desired to make the edges of the thin plates more perfect than they are produced by the rolling operation we use a pair of revolving shears between the main rolls and that part of the apparatus where the thin sheet is cut into lengths or wound on a drum, or is otherwise disposed of; these shearing rolls consist of a plain roll of an exact length corresponding with the intended breadth of the plate, and a second roll of the same length on which two circular discs are mounted, forming a sort of raised flange at each end with sharp chisel-like cutting angles which will cut off the uneven edges and render the sheet of metal even and parallel throughout its length, by which arrangements or some of them the length of tin plate bar when put into the rolling machine will be converted without labour or reheating in the furnace into a great number of thin plates sheared to the desired length and breadth, and delivered into the pickling tank almost free from external scale, and in a very short period of time.

These shearing rolls detached from the rolling mill are shewn in elevation at Fig. 2 on Sheet C of the annexed Drawings, where 1 represents the body of the upper roll, having at each end a steel collar 2, the thickness of which regulates the distance between the tempered steel shearing discs 3, 3, which are held in place by the nuts 4, 4; a similar roll 5 has at each end a tempered steel collar or cutting disc 6, 6, the outer angle of which, in conjunction with the bevilled edges of the discs 3, 3, form the shearing part of the rolls, so that a sheet of metal whose width exceeds the distance apart of the cutters 3, 3, will have such superfluous metal sheared off, and be reduced to a parallel plate of the width between the cutters 3, 3. When such rolls are to be employed in connection with the rolling apparatus shewn at Figures 1, 2, and 3, on Sheet B, we prefer to place them in such a position that the thin sheet of metal issuing from the rolls may be received by them, so that the shearing of the plate may be effected prior to the sheet of metal reaching the revolving cutter, by which it is cut into separate plates, the cutting apparatus used for this latter purpose being in that case placed a little further from the main rolls in order to make room for these shearing rolls between it and the main rolls; these rolls may be driven by tooth gearing on the main driving shaft, the speed being such as to shear the edges as fast as the sheet emerges from the main rolls.

The plates when cooled down in the tank, either with or without being annealed, may be wiped dry and be flattened and smoothed only, or they may be further extended if desired by cold rolling between polished cast steel rolls or highly polished chilled rolls set to a definite distance apart by screws, or, as we prefer when used only for improving the surface of the plate, forced together by hydraulic

Figure A1: Example patent specification, GB187901368A

cylinders actuated by an accumulator of small size under spring pressure, the cold rolling apparatus having a table at each side, the surface of which is at a tangent with the upper surface of the bottom roll, and will admit of the rapid passage of plates between them.

A pair of rolls suitable for cold rolling the thin plates is shewn in cross section at Figure 3, Sheet C; these rolls may be mounted in frames such as are generally employed for rolling plate iron, and be driven in the ordinary way. We prefer that hard steel rolls should be used for this purpose, or chilled iron ones having smooth and well polished surfaces. We fix an iron table B, B, on each side of the lower roll. The top of the table should be planed flat, and its surface fixed at a tangent to the upper surface of the lower roll, so that a pile of plates placed on one table may be rapidly passed singly or otherwise between the rolls, and be received and piled upon each other at the other side, or be returned once or more times between them, as found desirable, so as to flatten, extend, and improve the surface of the tin or black plate so operated upon.

We desire further to observe that although we have hereinbefore shewn and described a method by which tin plates or black plates may be produced by a single pass of the tin plate bar through the rolls, and how the surface of thin plates so produced may be further extended or improved by a subsequent process of cold rolling, we nevertheless desire it to be understood that when thin plates are made from tin plate bar by a single pass through the rolls that such thin plate may be still further reduced in thickness when found desirable or necessary by hot rolling the same either in single thicknesses or when the same has been doubled once or more times, and that in all such cases we prefer to heat the plates for the rolling operation in retorts or chambers from which the products of combustion are excluded.

And in order that the general arrangement and mode of constructing a rolling apparatus suitable for the purposes of our Invention may be fully understood we have shewn the same on Sheet B of the Drawings annexed, where Figure 1 is a vertical cross section on the line A, B, of Figures 2 and 3 on the same Sheet; Figure 2 being a front elevation, and Figure 3 a plan of the same. In these Figures A, A, represent the two main frames or housings of the rolling mill secured by bolts and wedges to the foundation plate B. The upper part of these frames have projecting flanged pieces A^1 cast upon them for the purpose of holding them firmly together; they are further secured in position by keys passing vertically and horizontally in grooves between them as shewn. On the front side of the frames A protecting pieces A^2 are cast, into which the brasses C of the feeding rolls D, D, are fitted. The main rolls E, E, work in brasses shewn by dots at F in the main frames A, the screws G serving to regulate the thickness of the plate; any alteration of this thickness by turning the screws G is shewn by the divided discs mounted on the screws G; against the edges of these discs a pointer is fixed. The top main roll is held in place firmly upward against its bearings by means of the ram H carrying the brass I. This ram works in a cylindrical recess formed in the main frames as shewn by dots, one such ram and cylinder being employed beneath each of the journals of the top roll. The brasses of the lower main roll have wedged shaped recesses formed at their lower angles, into which steel wedges J, J, are accurately fitted, and by means of which these lower brasses may be adjusted so as to insure the true parallelism of the upper and lower rolls.

The feeding rolls D, D, may be adjusted by the screws K, but we prefer to support the brasses of the upper roll so that it is suspended at a short distance above the tin plate bar, while the lower roll sinks down sufficiently low to admit the introduction of the tin plate bar, freely between them, the bar being supported on the cross ribs L^1 of the guide frame L. When the bar is thus introduced between the rolls D and is pushed forward nearly in contact with the main rolls, the workman will by means of a suitable handle open a communication between the accumulator before referred to and the small rams M. The pipe of communication is shewn broken off at N; by this means the lower feeding roll will be lifted up, carrying

Figure A1: Example patent specification, GB187901368A

the tin plate bar with it and forcing it in contact with the upper feeding roll. The powerful grip of these rolls will carry the tin plate bar forward and force its tapered end into the narrow space left between the main rolls. It will be understood that both the feeding and main rolls are kept revolving by a powerful engine, and are coupled and geared together after the manner usually employed in rolling mills, and which gearing is therefore omitted in these Drawings. As the metal emerges in a thin sheet from between the rolls E it passes over the guide plate O, passing also over the lower portion P of the shears which is bolted to the main framing of the rolls. A frame Q is bolted securely to the bed plate B, and is further secured in place by stretcher bars R to the frames A, A, of the rolls. A shaft S is fitted into sliding brasses T which move in horizontal slots formed in the upper parts of the frame Q. This shaft has keyed upon it a revolving frame U to which a steel cutting bar V is bolted. The opposite end of the revolving frame has projecting pieces U^1 which serve to balance the weight equally on each side of the spindle S. A bar W is bolted to the main frames A having two curved projections W^1 formed upon it; these curves are slightly eccentric to the circular path of the cutting blade V; the distance apart of this revolving cutting blade V and the fixed cutter P is regulated by the screw X. At the opposite end of the slot is also a screw Y which acts in a strong spiral spring Z and forces the sliding brasses and axle S in the direction of the cutter P. It will be seen that the frame U has projecting parts U^1, seen best in Figure 4, which is a plan of the revolving cutter and its frame. These projections slide over the curved surfaces W^1 and prevent the two cutting edges from coming in forcible contact with each other, the piece of thin plate thus sheared off falls into the tank *a*, *a*, beneath the cutting apparatus. It will be understood that the axis S may be driven by a drum and strap or by change wheels so as to alter at pleasure its rate of rotation relatively to the speed at which the main rolls are driven, and thus the length of the plates sheared off may be made to vary as may be found desirable. We have also mentioned that the cooling of the brasses and journals of the rolls may be found necessary when such rolls are driven at high speeds under heavy pressure, for which purpose water under pressure is conveyed by branch pipes as hereinbefore referred to, and we prefer when so cooling the brasses and journals to form passages for its distribution over their surfaces, as shewn in Figures 5 and 6 on Sheet B, where *b* shews the junction of the pipe conveying the water; and *c*, *c*, the passages for its distribution for the purpose of effectually cooling the brasses and journals of the rolls.

Having described our Invention, and the manner in which the same may be carried into practical operation, we desire it to be understood that we do not confine ourselves to the precise details herein described so long as the peculiar principles of our Invention are retained, but what we do claim and desire to secure by these Letters Patent is as follows:—

First. The method of reducing heated tin plate bar to plate at one passage between the rolls, the bar being thus extended to many times its original length, and requiring no further hot rolling.

Second. The preparation of the tin plate bar, ensuring true and clear surfaces, free from scale, being presented to the rolls by which the bar is at one operation reduced to plate.

Third. The combination with the rolls by which the tin plate bar is at once extended to many times its original length and reduced to plate of nipping and propelling instruments by which the bar is forced to enter the nip of the reducing rolls.

Fourth. The combination of reducing rolls and nipping and propelling instruments forcing the tin plate bar to be taken by the reducing rolls, and of cutting apparatus automatically dividing the plate into suitable lengths as it issues from the rolls.

Fifth. The combination with reducing rolls, by which tin plate bar is at one operation extended to many times its original length and reduced to plate, of winding apparatus automatically coiling up the plate as it issues from the reducing rolls.

Figure A1: Example patent specification, GB187901368A

H. & A. G. Bessemer's Improvements in the Manufacture of Tin Plate, &c.

Sixth. The production of "black plate," or plate from which tin or plate is made from ingot metal by presenting a suitably prepared bar of such metal to rolls by which at one passage between the rolls the bar is reduced to plate, being extended to many times its original length.

Seventh. The general arrangement and construction of the hydraulic shearing apparatus for preparing the tin plate bar for the reducing rolls.

Eighth. The process of simultaneously shearing off and tapering by pressure by which the ends of the tin plate bars are adapted to enter between the reducing rolls.

Ninth. The process of passing heated tin plate bars between bending rolls to remove oxide or scale, and then immediately between reducing rolls, by which at one operation they are extended to many times their original length and reduced to plate.

Tenth. The process in the manufacture of black plate or plate from which tin plate is made of simultaneously rolling and automatically shearing the plate issuing continuously from the rolls into suitable lengths.

Eleventh. The process of heating tin plate bars in retorts or closed chambers and then rolling the same at one operation, and by a single passage between the reducing rolls into plates many times the length of the bar.

Twelfth. The process in the production of "black plate," or plate from which the tin plate is made, of simultaneously rolling, cutting, and receiving the cut off plates into a tank containing a suitable liquid.

Thirteenth. The process of grinding tin plate bars, and of heating the said bars in retorts or closed chambers to improve and preserve the surfaces presented to the rolls.

Fourteenth. The means for preserving from injury the surfaces of the reducing rolls by which tin plate bar is at one operation reduced to plate by the application of hydraulic cylinders to sustain the upper roll and effectually prevent it from falling into contact with the lower roll when the thin plate passes from between them.

Fifteenth. The means for preventing the heating of the bearings of the reducing rolls by which tin plate bar is at once reduced to plate, by causing water at high pressure to enter passages formed in the brass and to issue between the neck of the roll and the brass.

Sixteenth. The production of "black plate," or plate from which tin plate is made, by means and apparatus substantially as described and represented in the Drawings annexed.

In witness whereof, we, the said Henry Bessemer and Alfred George Bessemer, have hereunto set our hands and seals, this Fourth day of October, in the year of our Lord One thousand eight hundred and seventy nine.

HENRY BESSEMER. (L.S.)
ALFRED GEORGE BESSEMER. (L.S.)

LONDON: Printed by George Edward Eyre and William Spottiswoode,
Printers to the Queen's most Excellent Majesty.
For Her Majesty's Stationery Office.

1879.

Figure A1: Example patent specification, GB187901368A

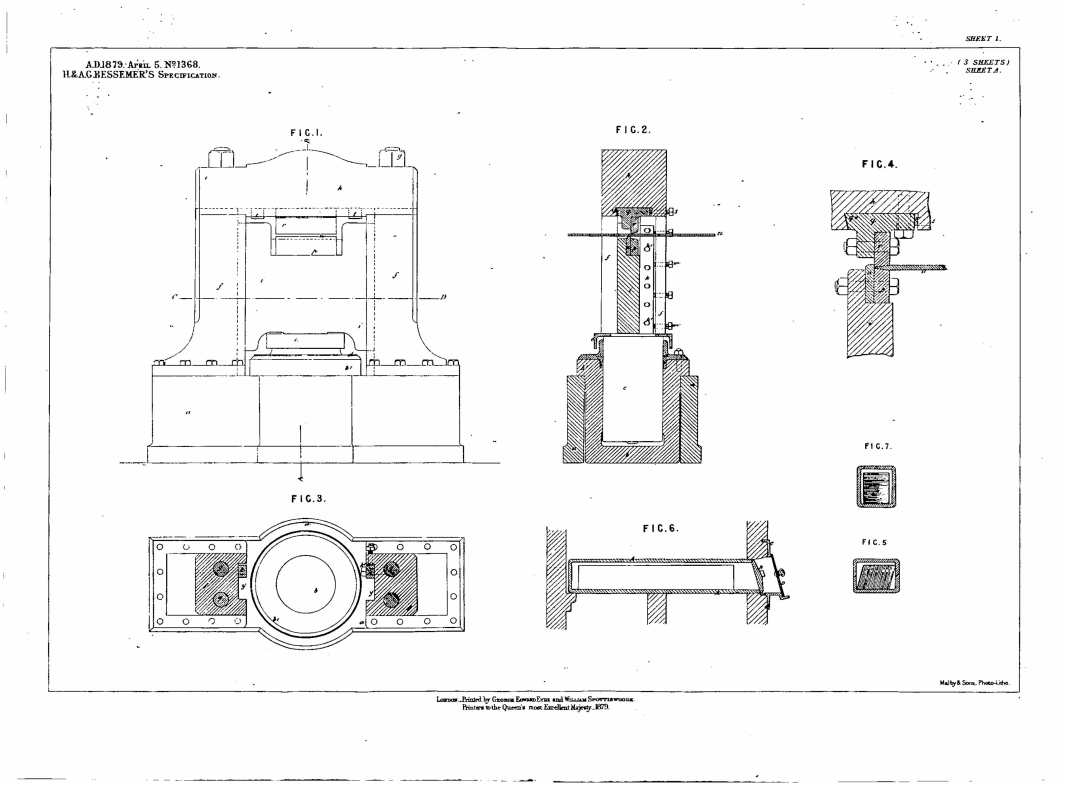


Figure A1: Example patent specification, GB187901368A

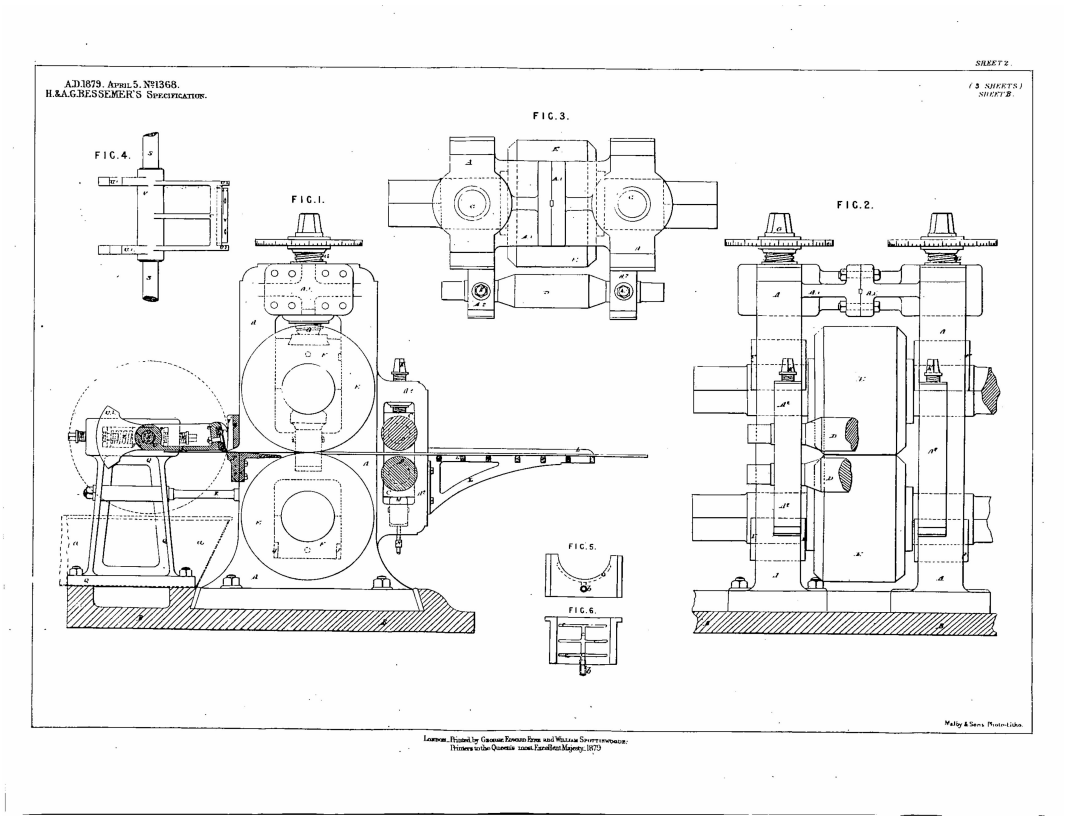
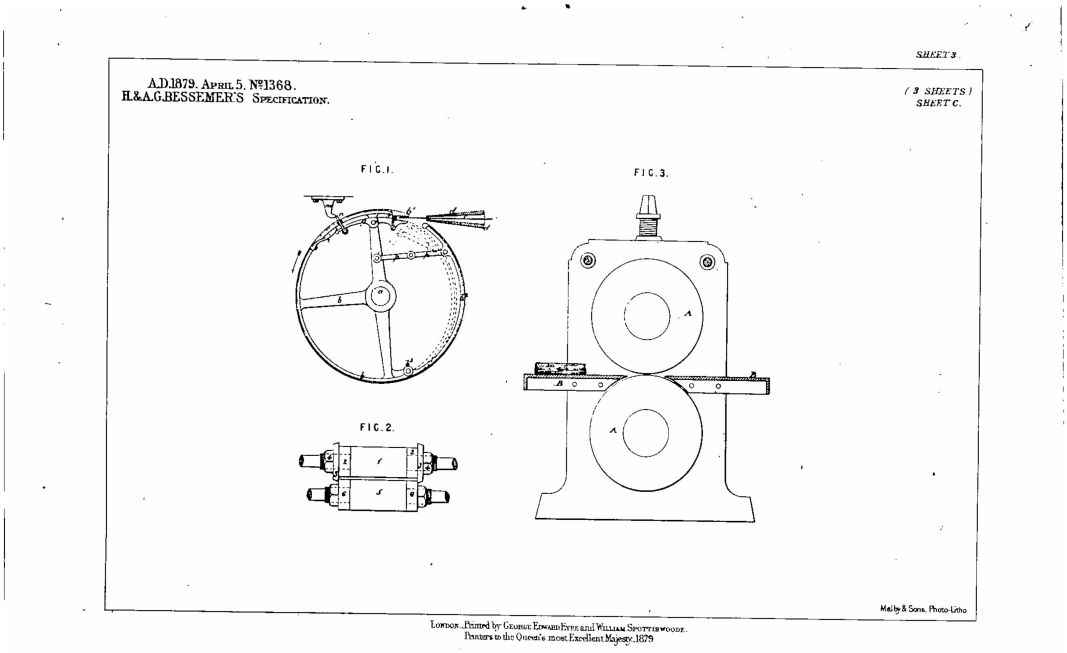


Figure A1: Example patent specification, GB187901368A



A.1 Data Processing Pipeline

Text Region Detection. We start with the original scans of patent specifications. Before using an optical character recognition (OCR) software to extract the text, we fine-tune a `YOLOv8` model—a state-of-the-art object detection model—on a custom dataset of patent scans to detect rectangular text regions. This helps minimize noise from non-text elements that could compromise OCR quality. To build our custom labelled dataset, one of the coauthors labeled these 420 scans. We then randomly split the labelled images 80-10-10 into train-validation-test sets. We train the model using default `YOLOv8` hyperparameters, except from a batch size of 128 and the maximum number of training epochs set to 300. We used the Roboflow UI to add standard data augmentations, increasing the training set to 1,008 images. Our model achieves 98.7% Mean Average Precision at 50% intersection-over-union (mAP50) on the test set, and 89.2% when averaged across stricter thresholds (mAP50-95). We then apply the trained model to our scans using the Ultralytics YOLO inference API with a confidence threshold of 0.5.

Optical Character Recognition (OCR). After detecting text regions, we use Google Cloud Vision as our OCR engine to extract text, which substantially outperforms alternatives like Tesseract and ABBYY FineReader in our manual quality assessments. Text regions are concatenated based on their y-coordinates—since the text is organized in a single column—to preserve the natural reading order of each page.

Word Tokenization. In addition to releasing the full specification texts, we build a list of tokenized words for each patent specification. This will help facilitate searching and textual analyses of the data that focus on keywords and n-grams. To do this, we first pre-process the extracted text by removing HTML tags and non-ASCII patterns, replacing hyphens with spaces, and then use a `spaCy` model (`en_core_web_lg`) to tokenize the full texts from all pages into individual words. Numbers and punctuation are dropped during tokenization.

Entity Extraction. We extract inventor information using a fine-tuned `XLM-RoBERTa-large` model. Our custom training dataset comprises 401 manually labeled patent front pages, with detailed annotations of spans of text containing full inventor names, occupational titles, permanent addresses, patent sealing, application or grant dates, firm affiliations of inventors, and foreign communicant information.[1][2] The annotation process entailed manual labelling jointly between one of the coauthors on this paper and a trained undergraduate research assistant who was provided with a detailed schema of instructions. The two labellers tagged spans of text within each of the front pages that contained each of the above categories of information. The labellers then cross-checked entities with one another to ensure that Type I and II errors occurred with minimal frequency in the labelled data. We then randomly create 60-20-20 train-validation-test splits of the dataset. The model is fine-tuned using a learning rate of 5e-5 and batch size of 42 for 29 epochs, with the learning

[1] Our custom dataset consists of 401 front page texts in total, 200 of which are randomly chosen from our data and 201 which were oversampled from those containing either firm or communicant information to ensure sufficient representation of these classes in the training data. Typically, it is best practice to build a custom training dataset by random sampling. In our case, the presence of severely underrepresented entities would lead to severe performance issues for these classes.

[2] Since `XLM-RoBERTA-large`, like most models in the `BERT` and `RoBERTa` families, has an upper limit of 512 input tokens, we truncate the front pages if they exceed 512 tokens.

rate optimized through grid search on the validation set and the number of epochs chosen by validation set performance within 50.[3] We evaluate using full-entity F1 scores, requiring exact matches of the full entity instead of the token.[4] Our test set performance is strong on common entities (names: 94.9%, occupations: 93.8%, addresses: 89.9%) with lower but acceptable accuracy on rarer entities like firm affiliations (76.2%) and foreign communications (81.8%). Using the same dataset and model architecture, we also extract patent titles, achieving a test set F1 score of 95.7% with hyperparameters (learning rate: 6e-05, 15 epochs) tuned in the same way.[5]

Relation Extraction and Refinement. Having extracted entities and patent titles, we then turn to standardizing historical addresses. This presents unique challenges due to the presence of errors arising from OCR and automated entity extraction, as well as historical addresses often differing from their modern counterparts. We employ OpenAI's `gpt-4o` for geocoding, achieving 94% accuracy in matching historical addresses to modern coordinates in our hand-coded validation sample of 200 manually verified cases. In constructing this validation set, we manually identify the nearest city, town, or village associated with the address by searching in Google Maps or corroborating from historical sources if an office or foundry is mentioned. We then check the coordinates returned to ensure they are within the administrative boundary of the city, town, or village, or alternatively that both longitude and latitude are within 0.1 degrees of the ground truth location. If multiple distinct locations are mentioned in the address string, we check the returned longitude and latitude coordinates against the first location only. Our prompt is in Figure A2. Out of 200 address strings, `gpt-4o` returned coherent coordinates in 187 cases.[6] We feed, as a batch, all the addresses for a given patent to `gpt-4o` since addresses that use context from others in the same specification are quite common e.g. "Birmingham, in the County of Warwick" and "Royal Leamington Spa, in the same County". We then turn to assigning address, occupation, and firm entities to inventors. For this, we employ a hybrid approach combining rule-based methods and `gpt-4o`. We first filter implausibly short entities (length no more than 2 characters) and de-duplicate these using Jaro-Winkler distance implemented using the `textdistance` package with a 0.9 similarity threshold. Then, for patents with a single identified inventor, all relevant entities are automatically assigned. For patents with multiple inventors, we use `gpt-4o` to perform relation extraction, feeding it the extracted entities, inventor names, and front page text and asking it to make assignment decisions.[7] Our manual checks suggest that providing `gpt-4o` with the extracted entities, as opposed to asking it to identify them, minimizes the risk that entities are hallucinated. We manually inspected a sample of cases, and found that this approach showed agreement with human judgment in every case.

[3] The batch size is set to utilize the maximal memory capacity of 2 NVIDIA RTX A6000 GPUs.

[4] Standard token-level F1 is too lenient for our task given that entities which are only partially extracted are effectively unusable for downstream research.

[5] Using the same custom dataset of 401 front pages, one of the co-authors on this paper manually labelled the data from each front page. This results in a dataset of named entities with only a single class, the title.

[6] Our manual checks using Google Maps are at `https://github.com/matthewleechen/UKHistoricalPatents/blob/main/replication/manual_validation_set_addresses.csv`.

[7] Our prompt that we use is in Figure A3.

Figure A2: GPT4o Prompt for Relation Extraction with Multiple Inventors

```
You are a helpful assistant that provides precise geographic coordinates for historical addresses
from patent records.  Consider international locations while defaulting to UK only for ambiguous
cases with no clear context.
These addresses are from British historical patent records, but the locations mentioned could be
anywhere in the world, not just the UK. Please provide latitude and longitude coordinates for each
address.
Important guidelines:
    1. The addresses could be from any country, not just the UK.
    2. For ambiguous place names (e.g., "Rochester" which exists in UK and US), use the UK
       location only if there's no clear indication of another country.
    3. If there are multiple distinct locations mentioned, georeference the first.
    4. Return null for both latitude and longitude if:
        • The location is too vague.
        • There are multiple candidate locations and no clear context.
        • The historical location cannot be accurately mapped to modern coordinates.
Return results as a JSON array with 'text', 'latitude', 'longitude'.  Addresses to process:
```

Figure A3: GPT4o Prompt for Relation Extraction with Multiple Inventors

```
You are an expert in inferring relations between named entities in historical patent text.
You are to output only the updated list of dictionaries in JSON format, without any additional text
or explanations.
Here is a list of people and entities extracted from a patent document.  Based on the context of
the document, assign a new dictionary key 'person_id' to every 'OCC', 'ADD', and 'FIRM' entity.
For 'OCC', 'ADD', and 'FIRM' entities, if they apply to only one person, assign a single integer
(e.g., "person_id":  2).
If they apply to multiple people, assign a list of person_ids (e.g., "person_id":  [1, 2]).
Do not include any explanations, comments, or extra text.  Return only the updated list of
dictionaries in valid JSON format.
People:  {[p['entity_text'] for p in persons]}
Entities:  {entities_str}
Context:  {page_text}
```

Linking Inventors across Patents. Our final task is linking inventors across patents. This is a challenging task, and our goal is to automatically scale up the careful manual approach taken by Hanlon (2025). This approach seeks to link based on the (1) name of the inventor, (2) patent year, (3) occupation of the inventor, (3) their address, (4) firm affiliation, and (5) the associated patent title. We frame this as an embedding clustering problem, where similar inventor records should have nearby vector representations. Our approach is to fine-tune an embedding model on a custom dataset of human-generated ground truth matches. To train our linking model, we construct a custom dataset of 3,000 inventor-patent pairs following Hanlon (2025)'s protocol, with oversampling of same-name pairs. One coauthor manually created conservative linkages, requiring unambiguous evidence from multiple fields to establish matches. This means that wherever multiple pieces of linking information were not present, individuals were not linked. Using this as ground truth, we fine-tune `all-mpnet-base-v2`, a `SentenceTransformers` model, using the `LinkTransformer` framework (Arora and Dell, 2024). The model is trained with supervised contrastive loss for 100 epochs, and all other standard `LinkTransformer` hyperparameters. We evaluate using standard information retrieval metrics. Focusing on accuracy, for 98.7% of patent-inventor pairs, the model correctly identifies a matching inventor with the same assigned label as its closest result. We apply this model to our full dataset, using single-linkage (SLINK) clustering with cosine similarity on the resulting embeddings to identify unique inventors. The clustering uses all default `LinkTransformer` single-linkage clustering parameters: a minimum cluster size of 1 and a cluster threshold of 0.1. Finally, where multiple name entities from the same patent's front page were identified as belonging to the same inventor cluster (i.e. instances where the same inventor's name is mentioned multiple times on the front page), we retain only the first mention of the name and discard subsequent mentions. Visual inspection confirms high-quality inventor linkages across the dataset. However, since our linking procedure relies on occupational, geographic, and firm characteristics, the algorithm may underperform when matching inventors who change jobs, locations, or employers between patents. This creates potential bias towards identifying stable inventors.

B Additional Figures & Tables

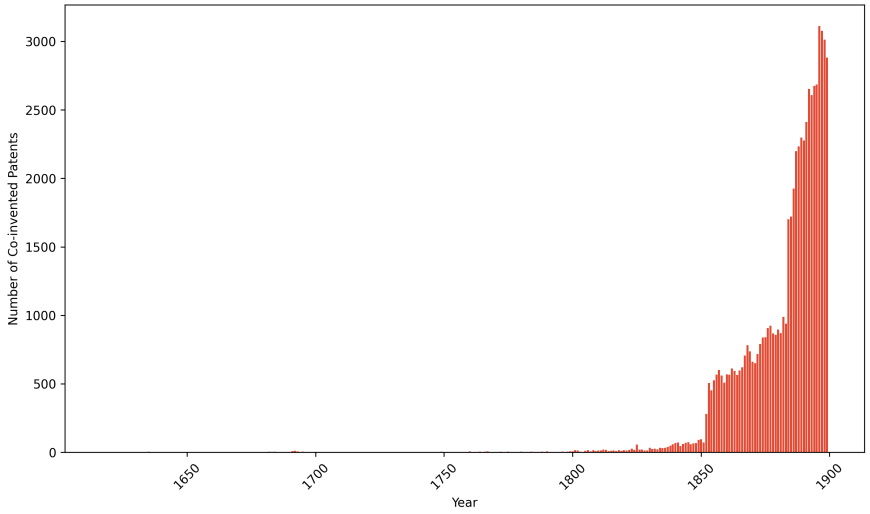
Table B1: Distribution of Patents per Inventor

Number of Patents	Number of Inventors
1	157,858
2	23,667
3	8,744
4	4,391
≥ 5	10,422
Total	205,082

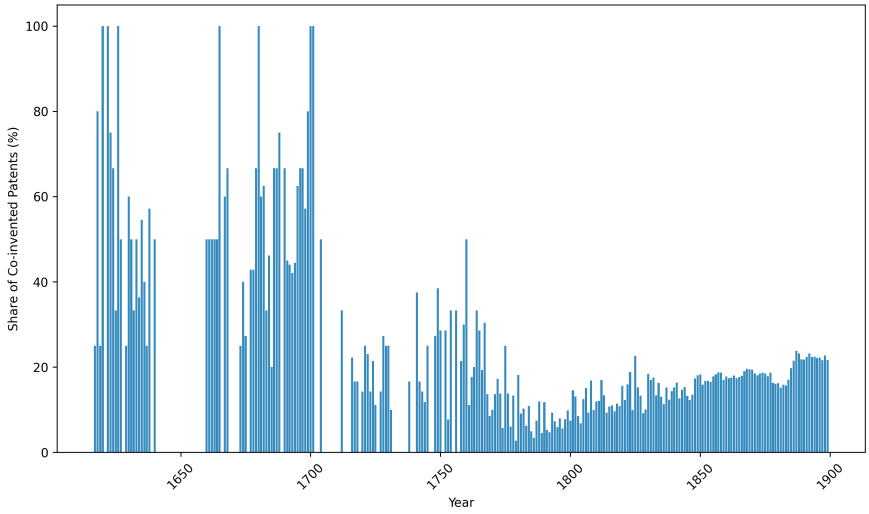
Note: Table displays the number of inventors from our full coverage period that patented 1, 2, 3, 4, and at least 5, inventions.

Figure B1: Patents with Multiple Inventors

(a) Number of Coinvented Inventions



(b) Share of Coinvented Inventions



Note: Plot displays the count (a) and percentage (b) of inventors with more than one inventor name entity detected in a given year, over the course of our full period (1617-1899).

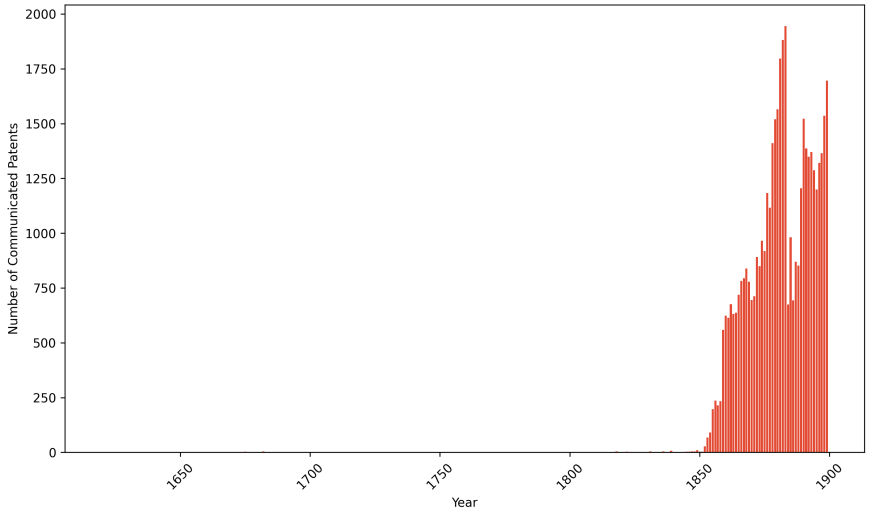
Table B2: Most Distinctive Words by Occupation

Occupation	**Distinctive Terms**
engineer	valve, steam, water, cylinder, air, shaft, wheel, apparatus, lever, piston
manufacturer	manufacturer, upon, plate, two, part, spring, frame, side, material, tube
gentleman	gentleman, water, upon, air, apparatus, two, wheel, john, plate, patent
patent agent	patent, lake, water, upon, shaft, apparatus, abroad, two, acid, plate
civil engineer	water, air, apparatus, steam, valve, two, cylinder, engineer, william, shaft
merchant	water, apparatus, air, two, material, upon, plate, part, suitable, wheel
mechanical engineer	valve, shaft, wheel, mechanical, lever, steam, cylinder, water, upon, plate
machinist	shaft, lever, wheel, machine, upon, roller, rollers, plate, bar, motion
electrical engineer	electrical, circuit, electric, current, armature, switch, contact, lamp, magnet, wire
chemist	acid, solution, water, process, soda, gas, mixture, lime, manufacture, liquid
manager	shaft, lever, wheel, upon, machine, roller, rollers, plate, apparatus, part
machine maker	machine, lever, shaft, rollers, roller, wheel, motion, upon, yarn, spindle
chartered patent agent	acid, water, solution, shaft, provided, air, lever, two, wheel, agent
mechanic	lever, shaft, wheel, bar, upon, machine, spring, frame, roller, plate
electrician	circuit, current, electric, armature, battery, contact, wire, magnet, carbon, electro
consulting engineer	robert, water, lake, steam, valve, air, william, upon, cylinder, shaft
manufacturing chemist	acid, solution, soda, water, lime, manufacture, gas, process, mixture, iron
esquire	letters, patent, water, john, year, shall, time, great, seal, majesty
inventor	provided, shaft, frame, wheel, shown, spring, side, upon, adapted, plate
architect	water, air, frame, side, two, pipe, material, form, made, suitable

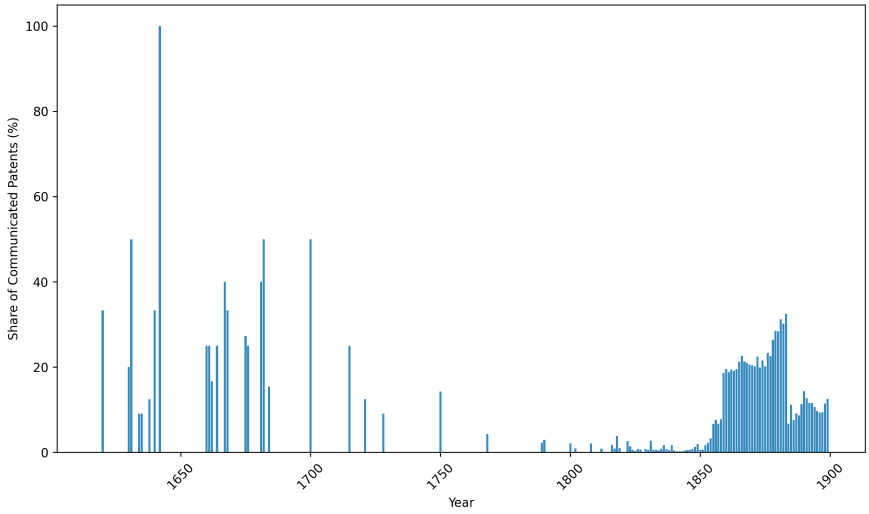
Note: Table displays the most distinctive words by TF-IDF score in the full texts of patents associated with a given occupation. Occupations are standardized using a series of rules: we drop plural mentions of occupations, and group together common abbreviations for 'gentleman' and 'esquire'. We then take the modal occupation of inventors (or if there does not exist a mode for a particular inventor, we assign a random occupation). TF-IDF scores are calculated using the `scikit-learn` TfidfVectorizer with the maximum number of features limited to 1,000. We restrict to words that are at least 3 letters in length, appear in at least 5 patents, and appear in at most 70% of patents.

Figure B2: Patents Communicated from Abroad

(a) Number of Communicated Inventions



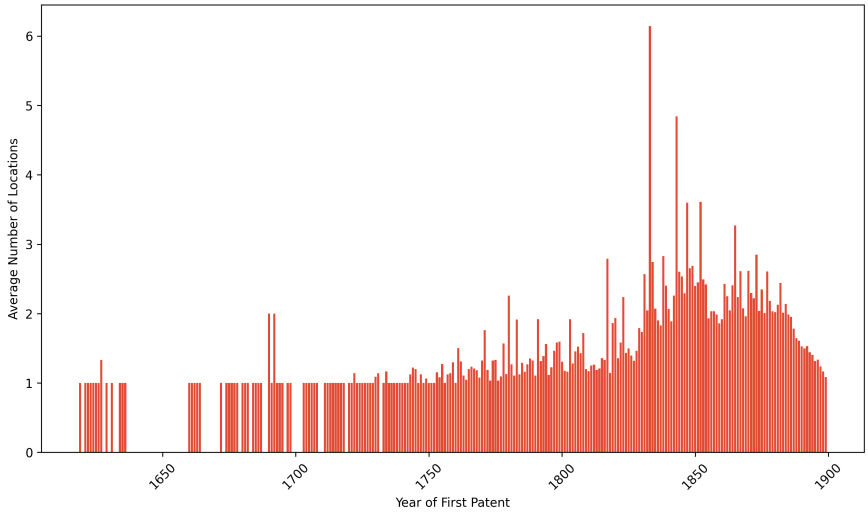
(b) Share of Communicated Inventions



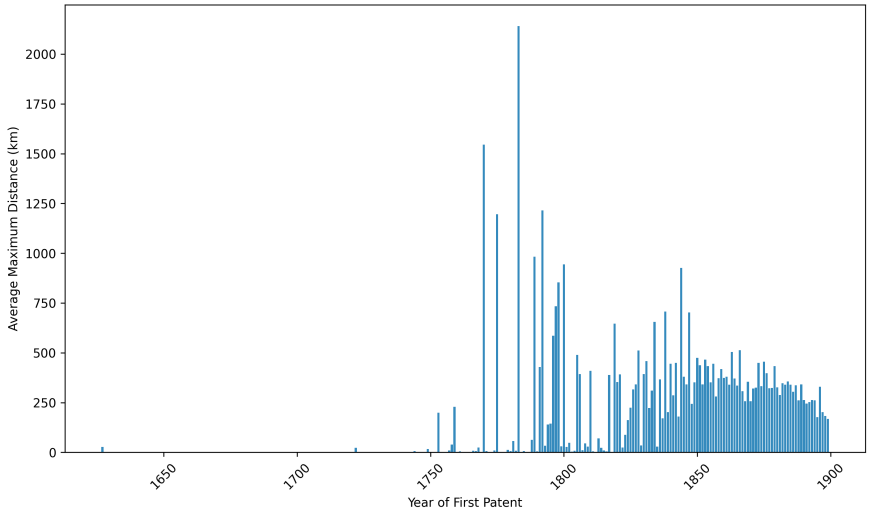
Note: Plot displays the number (a) and percentage (b) of patents with any identified foreign communicant information extracted over the course of our full period (1617-1899).

Figure B3: Mobility by Inventor Cohort

(a) Average Number of Locations



(b) Maximum Distance between Locations



Note: The denominator in both plots is the count of inventors who first patented in a given year that have at least one associated location (longitude-latitude coordinate). In (a), the numerator is the number of unique locations for a given inventor averaged over all inventors. In (b), the numerator is the maximum distance between unique locations for a given inventor averaged over all inventors.

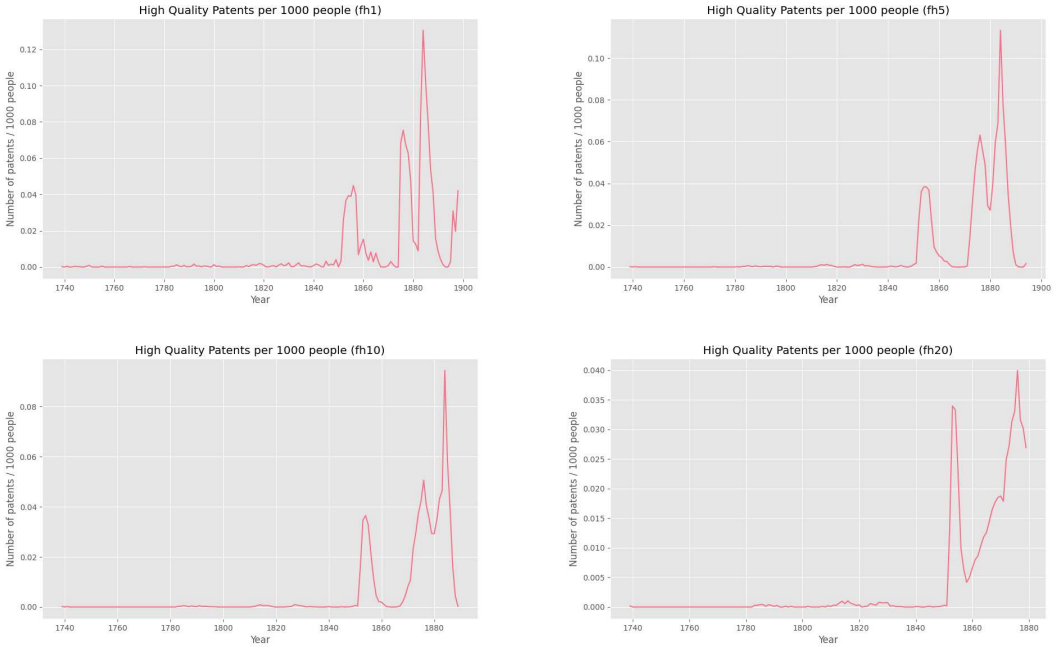
Table B3: Breakthrough Scores and Patent Quality Measures

	Patent Eminence		BCI	
	(1)	(2)	(3)	(4)
FH1				
Breakthrough Score	-0.127	0.195	-0.030	0.183
	(0.188)	(0.253)	(0.106)	(0.147)
Mean Dep. Var.	0.070	0.070	0.003	0.003
Year FE	No	Yes	No	Yes
Industry FE	No	Yes	No	Yes
Observations	12071	12071	12071	12071
FH5				
Breakthrough Score	0.348***	0.383	-0.001	0.332**
	(0.050)	(0.253)	(0.030)	(0.147)
Mean Dep. Var.	0.070	0.070	0.003	0.003
Year FE	No	Yes	No	Yes
Industry FE	No	Yes	No	Yes
Observations	12071	12071	12071	12071
FH10				
Breakthrough Score	0.356***	0.375*	0.024	0.357***
	(0.039)	(0.203)	(0.023)	(0.118)
Mean Dep. Var.	0.070	0.070	0.003	0.003
Year FE	No	Yes	No	Yes
Industry FE	No	Yes	No	Yes
Observations	12071	12071	12071	12071
FH20				
Breakthrough Score	0.392***	0.494***	0.032	0.416***
	(0.040)	(0.166)	(0.023)	(0.097)
Mean Dep. Var.	0.070	0.070	0.003	0.003
Year FE	No	Yes	No	Yes
Industry FE	No	Yes	No	Yes
Observations	12071	12071	12071	12071

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust SEs in parentheses.

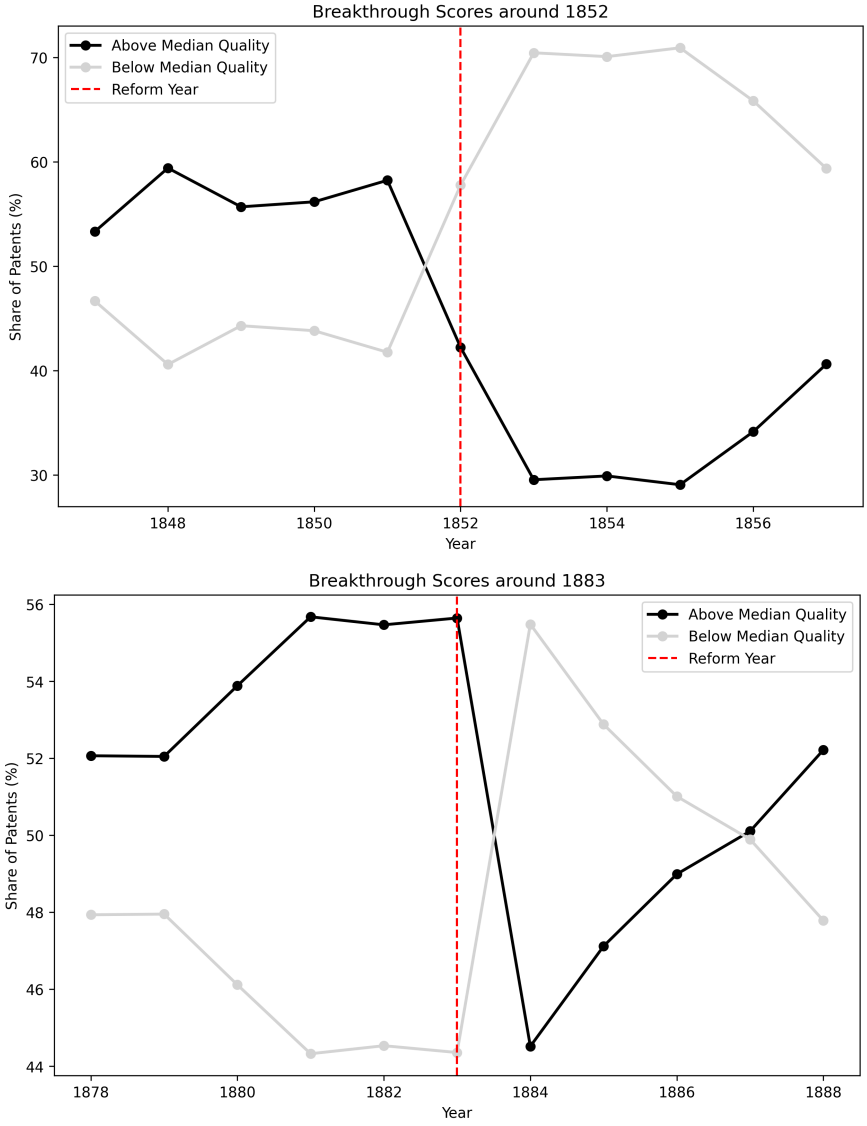
Note: Table displays results from OLS regressions of the outcome measures from Nuvolari et al. (2021) on the breakthrough score. Columns (1) and (2) use the patent eminence indicator as outcome variable. Columns (3) and (4) use the continuous Bibliographic Composite Index (BCI) as the outcome variable. Columns (2) and (4) control for year and industry fixed effects. All regressions use a fixed 5 year backward horizon and results are shown for variable 1, 5, 10, and 20 year forward horizons.

Figure B4: Kelly et al. (2021) Breakthrough Patents Over Time



Note: Plots show the number of breakthrough patents, defined as those falling in the top 10% of the unconditional distribution of breakthrough scores, net of year fixed effects. We normalize by the population of England. Population data is from: `https://ourworldindata.org/grapher/population-of-england-millennium?time=1700..latest`

Figure B5: Breakthrough Patenting around Reform Years



Note: Plots display the share of patents above and below unconditional median breakthrough scores, net of year fixed effects using a forward horizon of 10.

Table B4: Top 20 Occupations overrepresented in Breakthrough Patents

Occupation	**Full Sample Count**	**Top Decile Count**	**Ratio**
Doctor Of Law	147	53	1.97
Engineers And Patent Agent	319	71	1.21
Knight	128	26	1.11
Telegraph Engineer	188	34	0.99
Boot And Shoe Manufacturer	172	30	0.95
Gunmaker	127	22	0.95
Patent Agent And Consulting Engineer	199	33	0.90
Brassfounder	419	68	0.89
Agent	540	83	0.84
Tailor	167	25	0.82
Baronet	208	31	0.81
Spinster	115	17	0.81
Architect	696	102	0.80
Physician	174	25	0.78
Commission Agent	301	43	0.78
Engraver	157	22	0.76
Designer	143	20	0.76
Card Manufacturer	105	14	0.73
Lamp Manufacturer	301	40	0.73
Steel Manufacturer	215	28	0.71

Note: This table shows occupations that are disproportionately represented in the top decile of breakthrough scores (residualized by year fixed effects). Only occupations with at least 100 appearances in the full sample are included.

Figure B6: Highest Breakthrough Score Patents by Year

Year	Patent ID	Title	Inventors
1739	GB173900569A	A NEW INVENTION FOR MAKING TOUGH AND BRITTLE ME...	Unknown
1740	GB174000573A	An EveINE NEWLY INVENTED BY HIM, THE SAID JOHN ...	JOHN EUGENE
1741	GB174100575A	AN ENGINE FOR THE MAKING OF ALL SORTS OF BRICKS...	WILLIAM BAILEY
1742	GB174200586A	THE ART OF PRINTING SEVERAL SORTS OR SPECIES OF...	DANTELL CHAPPELL
1743	GB174300592A	MEDICINE PREPARED IN PART CHYMI- CALLY AND COMP...	JOHN HOOPER
1744	GB174400611A	A NEW METHOD OF MAKING GOODS OF THE SAME NATURE...	GEORGE GARRETT
1745	GB174500615A	A SELF-REGULATING WIND MACHINE	EDMUND LEB
1746	GB174600616A		DIEDERICK WESSELL LINDEN
1747	GB174700627A	A TINCTURE OR MEDICINE	THOMAS JACKSON
1748	GB174800635A	THE ART OB MISTERY OF DYING GREEN AND BLUE SAXO...	GEORGE SPENCE, CHARLES DOLBY, JOHN CHRISTOPHER WEGUELIN
1749	GB174900648A	DRAWING COALES, STONES, WATER, OR OTHER HEAVY B...	THOMAS STOKOE, WILLIAM NEWTON
1750	GB175000657A	A NEW & CURIOUS MACHINE OR ENGINE FOR PRICKING ...	WILLIAM PENNINGTON
1751	GB175100659A	A PARTICULAR ART AND METHOD OF PRINTING, PAINTI...	JOHN ELLIOTT
1752	GB175200673A	A CERTAIN MEDICINE CALLED OLEUM ANODINUM, OR BR...	JAMES JACKSON, Joseph Collett
1753	GB175300678A	A PAIR OF PUMPS, THE BARRELS WHEREOF ARE MADE O...	THOMAS CRAVEN
1754	GB175400693A	AN ENGINE TO BE WORKED EITHER BY MEN, HORSES, W...	JAMES TAYLOR
1755	GB175500700A	NEW INVENTED POWDERS, CALLED ANTI-EPILEPTIC POW...	WILLIAM LOWTHER
1756	GB175600710A	PECULIAR NEW INVENTED METHOD OF MANUFACTURING S...	CHARLES ARD
1757	GB175700711A	NEW INVENTED METHOD OP FASHIONING AND COLOURING...	ROBERT MORRIS
1758	GB175800731A	NEW-INVENTED MARINE OBSERVATORY, AND NEW- ADAPT...	CHRISTOPHER IRWIN
1759	GB175900735A	TAKING OFF WOOL FROM SHEEP SKINS, PREFERABLE TO...	CHRISTOPHER LEBRECHT CHRYSEL
1760	GB176000756A	A MACHINE UPON NEW PRINCIPLES FOR EXERTING THE ...	XAVIER D'ARLES DE LINIERE, Francis Xavier d'Arles de Liniere
1761	GB176100762A	NEW METHOD OF WORKING MINES OF COALS AND METALS...	Michael Meinzies,
1762	GB176200771A	A NEW CONSTRUCTION OR METHOD FOR THE MAKING OF ...	DAVID MARIE
1763	GB176300791A	A NEW MEDICINAL COMPOSITION, CALLED THE STOMACH...	WILLIAM FORDYCE
1764	GB176400819A	A NEW METHOD OF MAKING WATCHES	FRIEDERIECK KEHLHOFF
1765	GB176500834A	A COMPOSITION OR STONE PASTE, MADE WITH OILS AN...	DAVID WARK
1766	GB176600856A	A MACHINE FOR MAKING WOMEN'S MITTS AND GLOVES	DANIEL AUGUSTIN MARCNARD
1767	GB176700878A	A METHOD OF PREPARING AND MAKING SAGO, VERMICEL...	SAMUEL BOWEN
1768	GB176800896A	A MACHINE OF AN ENTIRELY NEW CONSTRUCTION, FOR ...	ROBERT MACKELL, Andrew Meikle
1769	GB176900926A	A MOST CERTAIN AND INFALLIBLE METHOD TO PREVENT...	ANNE STELL
1770	GB177000949A	INVENTION OF A NEW METHOD OF CONSTRUCTING AND. ...	DUGALD CLARK
1771	GB177100996A	A NEW INSTRUMENT OR MACHINE, WHICH I CALL A TRA...	ROBERT BRAND
1772	GB177201025A	A MACHINE FOR RAISING METALS, MINERALS, OR OTHE...	JOHN BUDGE
1773	GB177301044A	AN HYDRAULIC ENGINE, TO BE WORKED BY WATER ONLY...	CHRIS- TOPHER GULLETT
1774	GB177401068A	MAKING, CHASING, OR IMBOSSING IN LEAD ALL SORTS...	WILLIAM STORER
1775	GB177501102A	NEW METHOD OF CASTING ALL SORTS OF HINGES READY...	JOHN IZON, THOMAS WHITEHURST
1776	GB177601135A	A MILL FOR SQUEESING OR GRINDING OF SUGAR CANES...	THOMAS WRIGHT
1777	GB177701153A	A CERTAIN ENGINE OR MACHINE, CONSISTING OF DIVE...	THOMAS CROWLEY
1778	GB177801194A	NEW-INVENTED MACHINE OR	JOHN TALBOT, Smith
1779	GB177901237A	A NEW METHOD OP WEAVING DIAPER AND DAMASK LINEN...	WILLIAM CHEAPE
1780	GB178001249A	MAKING WATCHES UPON A NEW CONSTRUCTION, SO AS T...	LOUIS RECORDON, Lewis Recordon
1781	GB178101306A	CERTAIN NEW METHODS OF APPLYING THE VIBRATING O...	James Watt
1782	GB178201321A	CERTAIN NEW IMPROVE- MENTS UPON STEAM OR FIRE E...	JANES Warr, James Watt
1783	GB178301364A	AN INSTRU- MENT OR MACHINE TO TAKE AND CONVEY P...	EDWARD WHATMORE
1784	GB178401447A	CERTAIN NEW IMPROVEMENTS ON THE STEAM ENGINE, A...	SUTTON THOMAS WOOD
1785	GB178501498A	A MACHINE WHICH MAY BE USED SEPARATELY, OR AB A...	JOHN HORN
1786	GB178601564A	NEW INVENTED ENGINES OR MACHINES FOR THE PURPOS...	JOHN ROYDS
1787	GB178701628A	A REGULATOR ON A NEW PRINCIPLE FOR WIND AND OTH...	THOMAS MEAD

Figure B6: Highest Breakthrough Score Patents by Year

1788	GB178801673A	CERTAIN NEW METHODS OF CONSTRUCTING BOILERS FOR...	JAMES RUMSEY
1789	GB178901688A	A DRILL AND HOE PLOUGH ON A NEW CONSTRUCTION	SAMUEL RIDGE
1790	GB179001738A	NEW & IMPROVED CERTAIN METHODS OF APPLYING THE ...	JAMES RUMSEY
1791	GB179101825A	NEW AND IMPROVED CERTAIN METHODS OF APPLYING TH...	JAMES RUMSEY
1792	GB179201879A	CERTAIN NEW-CON- STRUCTED MACHINERY, TO BE APPL...	WILLIAM KELLY
1793	GB179301951A	VARIOUS NEW AND IMPROVED METHODS AND MEANS OF W...	SAMUEL BENTHAM
1794	GB179401994A	AN APPARATUS BY WHICH SHIPS VESSELS MAY BE DISC...	WILLIAM FITZGERALD
1795	GB179502077A	AN APPA- BATUS OR MACHINERY FOR MEASURING OF DI...	EDWARD HEWLINGS
1796	GB179602127A	NEW-DISCOVERED INVENTION AND IMPROVEMENTS IN TH...	VALENTINE CLOSE, JAMES KEELING
1797	GB179702157A	NEW INVENTED METHOD OF CURING ALL THE DEFORMITI...	TIMOTHY SHELDRAKE
1798	GB179802257A	NEW INVENTED APPARATUS FOR RAISING BEER, ALE, W...	THOMAS STATON
1799	GB179902294A	Ax ADDITION AND IMPROVEMENT APPLICABLE TO THE B...	HUMPHREY JEFFREYS
1800	GB180002406A	A LAMP OR LIGHT	JOSEPH GASTON JOHN BAPTISTE DE THIVILLE
1801	GB180102478A	A NEW AND USEFUL MACHINE FOR CUTTING ONE OR MOR...	MARC ISAMBARD BRUNEL
1802	GB180202571A	A MACHINE FOR THE PURPOSE OF MANUFACTURING, BY ...	ROBERT BROWN
1803	GB180302702A	AN ARTIFICIAL METHOD OF SWEEPING CHINNIES, AND ...	ELIZABETH BELL
1804	GB180402758A	A METHOD OF MAKING WHITE LEAD DIFFERENT FROM TH...	JOHN, SWIFT SAXELBYE
1805	GB180502889A	A ROTATORY ENGINE FOR APPLYING THE POWERS OF FL...	JOHN TROTTER
1806	GB180602990A	VARIOUS IMPROVEMENTS IN THE APPLICATION OF STEA...	WILLIAM NICHOLSON
1807	GB180703027A	NEW AND IMPROVED MACHINES AND MACHINERY FOR PRE...	SAMUEL WILLIAMS
1808	GB180803151A	A MACHINE FOR THE MAKING OB MANUFACTURING OF BO...	JOHN HEATHCOAT
1809	GB180903201A	A MODE OF CONSTRUCTION OR ARRANGEMENT FOR ANY B...	WILLIAM CONGREVE
1810	GB181003309A	CERTAIN METHODS OF MANUFACTURING MACHINES FOR P...	MAJOR PRATT
1811	GB181103434A	A MACHINE OR MACHINES POR THE MANUFACTURE OF BO...	JOHN BROWN
1812	GB181203524A	AN ENGINE OR MACHINE TO BE WROUGHT BY STEAM OR ...	WILLIAM ONIONS
1813	GB181303662A	SEVERAL IMPROVEMENTS IN DIFFERENT STAGES OF ROP...	GEORGE DUNCAN
1814	GB181403804A	SUNDRY IMPROVEMENTS IN CARRIAGES (AND SUBSTITUT...	LEWIS GOMPERTZ
1815	GB181503945A	AN IMPROVED SHEARING MACHINE	JOHN LEWIS
1816	GB181604027A	A LOCK FOR FASTENING DOORS, GATES, DRAWERS, DES...	THOMAS RUXTON
1817	GB181704129A	CERTAIN COMBINATIONS OF AND IMPROVEMENTS IN MAC...	SETH HUNT
1818	GB181804272A	IMPROVEMENTS IN CERTAIN PARTS OF THE MACHINERY ...	WILLIAM EATON
1819	GB181904400A	CERTAIN MACHINERY AND IMPLEMENTS APPLICABLE TO ...	JACOB PERKINS
1820	GB182004464A	A MACHINE OR PRESS, CHIEFLY APPLI- CABLE TO PRI...	ROBERT WINCH
1821	GB182104543A	CERTAIN IMPROVE- MENTS IN MACHINERY FOR WEAVING...	STEPHEN WILSON
1822	GB182204726A	CERTAIN MACHINERY OR IMPLEMENTS APPLICABLE TO T...	RICHARD' ROBERTS
1823	GB182304753A	NEW AND IMPROVED METHOD OR PRINCIPLE OF A PORTA...	WILLIAM GoSSAGE
1824	GB182405001A	AN IMPROVED METHOD OF METHODS OF ABSTRACTING OR...	JOHN VALLANCE
1825	GB182505294A	IMPROVE- MENTS IN MACHINERY FOR PREPARING, DRAW...	ALEXANDER LAMB, WILLIAM SUTTILL
1826	GB182605423A	A NEW APPARATUS ON WHICH TO SUSPEND CARRIAGE BO...	HENRY CHARLES LACY
1827	GB182705557A	AN IMPROVE- MENT OR IMPROVEMENTS UPON LAMPS	JAMES SMETHURST
1828	GB182805628A	AN IMPROVED METHOD OF PROPELLING CARRIAGES OR V...	NATHAN GOUGH
1829	GB182905792A		Thomas Arnold
1830	GB183006001A	IMPROVEMENTS FOR SPINNING AND TWISTING SILK AND...	FRANCIS MOLYNEUX, WILLIAM BUNDY
1831	GB183106065A	AN IMPROVED APPARATUS FOR IMPRESSING, STAMPING,...	CHARLES MEPHAM HANNINGTON
1832	GB183206232A	CERTAIN IMPROVEMENTS IN MACHINERY FOR MAKING NAILS	WILLIAM CHURCH
1833	GB183306492A	IMPROVEMENTS IN MANUFACTURING THE PRUSSIATE OF ...	HERMAN HENDRIKS
1834	GB183406640A	CERTAIN IMPROVEMENTS IN CUTTING, GRINDING, SHOO...	JOHN GOLD
1835	GB183506875A	CERTAIN IMPROVEMENTS IN VENTILATING SUB- TERANE...	JOHN COOPER DOUGLAS
1836	GB183607135A	IMPROVEMENTS IN PROPELLING VESSELS; ALSO IMPROV...	SAMUEL HALL
1837	GB183707337A	CERTAIN APPARATUS FOR THE RELIEF OR CORRECTION ...	JOSEPIT AMESBURY

Figure B6: Highest Breakthrough Score Patents by Year

1838	GB183807851A	IMPROVEMENTS IN APPLYING HEAT FOR GENERATING ST…	CHARLES FLUDE
1839	GB183908216A	IMPROVEMENTS IN BEER, CYDEE, AND SPIRIT ENGINES	SAMUEL STOCKER
1840	GB184008716A		Junius Smith
1841	GB184109022A	IMPROVEMENTS IN PRODUCING REGU- AND APPLYING EL…	CHARLES WHEATSTONE
1842	GB184209357A	IMPROVE- MENTS IN MACHINERY OR APPARATUS FOR MA…	WILLIAM TUDOR MABLEY
1843	GB184309944A	IMPROVEMENTS IN THE MANUFACTURE OF CANDLES, AND…	GEORGE GWYNNE, GEORGE FERGUSSON WILSON
1844	GB184410141A	IMPROVEMENTS IN WATER MACHINES OR ENGINES ON ST…	JOHN AITKEN
1845	GB184500814A	IMPROVEMENTS IN THE MANUFACTURE OF RAILWAY AND …	Robert Hadfield
1846	GB184611512A		GEORGE DAVID MYERS, WILLIAM COOPER, JAMES WANSBROUGH
1847	GB184711713A	IMPROVEMENTS IN STEAM ENGINES, ATMOSPHERIC ENGI…	JOHN AITKEN
1848	GB184812276A	CERTAIN IMPROVEMENTS IN APPARATUS FOR THE PRODU…	FENNELL ALLMAN
1849	GB184912534A	IMPROVEMENTS IN THE DEPOSITION AND MANUFACTURE …	ALEXANDER PARKES
1850	GB185013364A	IMPROVEMENTS IN THE MANUFACTURE OF WOOLLEN AND …	CHRIS- TOPHER NICKELS, Chris-, topher Nickels
1851	GB185113877A	CERTAIN ALLOYS AND COMBINATIONS OF METALS	Jois DAVIE MORRIES STIRLING
1852	GB185200312A	Bird at the Office of the Commissioners of Pate…	James Bird
1853	GB185302298A	IMPROVE- MENTS IN OBTAINING POWER BY MECHANICAL…	William James Matthias, Thomas Bailey
1854	GB185401799A	AN IMPROVEMENT IN THE MANUFACTURE OF BRUSHES	Robert Griffiths
1855	GB185501411A	THE EMPLOYMENT OF A NEW MATERIAL IN THE MANUFAC…	Giovanni Martenoli de Martinoi, Juan Francisco O De Lara
1856	GB185602998A	IMPROVEMENTS IN APPARATUS FOR GRATING AND CRUSH…	John Draper
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