

ON MECHANICAL PUDDLING.

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During the last few years various attempts have been made to apply machinery to the purpose of Puddling Iron, by adapting it to the ordinary puddling furnaces, where it is made to do the heaviest portion of the work, but leaving the workman to exercise his skill in guiding the tools, and in working and finishing the heat much as in the old way. Special machinery for this purpose was invented and first used, the writer believes, in France; and a great deal of ingenuity has been expended upon the subject, both in France and England. In England, although the machines were somewhat simplified, and rendered as perfect as machinery of the kind can well be made, they have not met with much favour, and very few are now at work; but these machines have not received the attention and encouragement which in the writer's opinion they deserve.

Other attempts have been made to dispense with manual labour altogether in puddling, by giving motion to the furnace itself, in order to produce the necessary agitation in the metal, and so render the use of tools nearly or altogether unnecessary. One plan is to impart a rocking motion to the furnace; and in another the bed of the furnace is made to revolve on a vertical axis, or an axis slightly inclined from the vertical. Another plan was that of Messrs. Walker and Warren, for making the furnace in the form of a cylinder, which was to be lined to the proper shape, and made to revolve on friction wheels with the axis horizontal or nearly so. No experiments on a practical scale however were made in connection with the origination of this idea, as far as the writer is aware; but it was subsequently taken up by Mr. Tooth, who made a long series of experiments on puddling in cylindrical vessels, and appears to have

been the first to succeed in producing puddled balls without the intervention of manual labour. For more than twenty years the writer's attention has been directed to the question of mechanical puddling; and he has watched carefully every attempt which has been made to improve the system of puddling, either by lessening the labour of the workman or by endeavouring to dispense with manual labour altogether.

Some years since the writer commenced a series of experiments on mechanical puddling, taking the above idea of the horizontal cylindrical vessel as the one most likely to fulfil all the conditions which he held to be essential; and the purpose of the present paper is to detail the amount of success achieved, and more particularly the many grave difficulties that have been met with, some of which have not yet been overcome.

Having arrived at the conclusion that the horizontal vessel was the best, the next step was to ascertain the best form. In designing the experimental vessel, the writer took as a guide the internal area of a common puddling furnace at the bridge and flue; and made a vessel which when lined should have openings at the ends about equal in area to those of the common puddling furnaces. The middle diameter and length of the vessel were such that a heat of 5 or 6 cwts. could be worked without boiling over. The form of vessel was thus arrived at that is shown in Fig. 6, Plate 35, where the shape of the experimental vessel is indicated by the dotted lines.

The notion of bringing out the heat in several balls was discarded, because with the form of vessel adopted it would have been next to impossible to do this; and for rail-making, which is the principal trade at Dowlais, a large ball, say of 6 cwts., is a positive advantage. The size of the bridge end of the vessel is just sufficient to allow a ball of 6 cwts. to pass through, and the vessel is adapted to work a sufficient quantity of iron for producing a ball of about this weight, as shown dotted at A in Fig. 6; a specimen of the ball is exhibited to the meeting. Each end of the experimental vessel was made symmetrical in shape, as shown by the dotted lines.

The vessel is made of 3-8ths inch boiler plates, with covering strips over the joints, as shown in Figs. 6 and 7, Plates 35 and 36. Its entire length is 8 ft. 2 ins., and the greatest diameter is 5 ft. 9 ins.; the diameter of the shell at the flue end is 2 ft. 4 ins., and at the bridge end 2 ft. 10 ins. The vessel is divided vertically into two halves, which are joined by strong angle-irons. On the bridge end of the vessel is shrunk a strong wrought-iron hoop B, 6 ins. wide by 2 ins. thick; and upon the flue end another wrought-iron hoop C is fixed, of the section shown in Fig. 6; to this hoop is bolted the spur wheel D whereby the vessel is driven, which is put on in two pieces and fastened by bolts, as shown in the drawing. The hoops B and C at the ends, and the edges of the middle angle-irons, are turned up true in the lathe. The vessels are all made to a gauge, so that any vessel will work in any set of bearings. Two trunnions EE are fixed to each vessel for the purpose, of lifting it out of its bearings, and also for tipping it; these trunnions are firmly bolted to the middle angle-irons, and are fixed as nearly as possible in the centre of gravity of the vessel when lined.

After completing a series of experiments with a single vessel, a Forge for containing eight working vessels of slightly modified form was designed, as shown in Figs. 1, 2, and 3, Plate 33, one half of which was erected, with the charging and tipping arrangements, a steam hammer for working the balls, and a steam crane for lifting the vessels. With these four vessels a large quantity of iron has been made and a great number of experiments tried.

Figs. 9 and 10, Plate 37, show a side and end view of the vessel in position for receiving its charge. Although cold iron may be charged into the vessel and melted in it in the ordinary way, arrangements were made for running it in hot from a blast furnace, to save time in melting. A strong wrought-iron loop F suspended from the steam crane is hitched to the trunnions E of the vessel; the ends of this loop drop into sockets in the strong cast-iron frame G which supports the vessel while it is being charged. After the charge is run in by the spout at H, the vessel is lifted by the crane and placed in its proper bearings, where it is immediately thrown into gear, and the operation of puddling commences.

Figs. 11 and 12, Plate 38, show the vessel in the position for tipping. When the heat is finished the vessel is lifted by the crane from its bearings, and placed in a cast-iron frame, the ends of the loop F passing through holes in the side brackets JJ to keep the vessel in position. A clutch I is then thrown into gear with the trunnion E by the lever K, and by turning the spindle L with a common winch handle, the vessel may be tipped with ease in either direction. The cinder is first discharged from the small end; and then for discharging the ball, the bridge end of the vessel is turned down, as shown by the dotted lines in Fig. 11; and the ball drops out upon a carriage, ready to be taken to the hammer. The vessel is then brought back to a horizontal position and lifted by the crane into the charging frame previously described, whence it is again taken when filled to the driving gear for puddling.

Figs. 4 and 5, Plate 34, show an end elevation and plan of the driving machinery, and the position of the vessels when at work. The vessels are arranged in pairs, each pair being worked by a small 8-inch cylinder engine M. The vessel A is shown on its bearings, while its fellow is removed so as to show more clearly the framework and the friction wheels NN upon which it rests when at work. The firegrate P, Figs. 5 and 6, is of the same dimensions as the grate of an ordinary puddling furnace; and the flue Q communicates by an underground culvert with a chimney common to four puddling vessels, as shown in Figs. 1 and 2. The fluebox is fitted with a door R, like a common puddling furnace door, and a damper S, as shown in Fig. 6. Rings of angle-iron are bolted to the throats of the firebox and fluebox, as shown in Fig. 6; these rings are concentric with the hoops B and C on the ends of the vessel, and a space of 2 or 3 inches is left at each end between the hoops and the angle-iron rings. These spaces are closed by a telescope joint by means of thin bands TT sliding upon the angle-iron rings; and these bands may either be made to close the joints entirely, or may be left partially open for the admission of air at the firebox end, as much as the workman considers necessary during the process of puddling. When the vessel is being lifted out of its bearings these bands are slid back, so as to allow a few inches of clearance between the vessel and the fixed firebox and fluebox.

The vessels are driven by spur gearing, as indicated in Fig. 4; and either vessel of the pair may be disengaged independently of the other, by sliding its driving pinion out of gear. When at work each vessel rests upon the friction wheels NN of large diameter, as shown in Figs. 6 and 7. At the flue end these wheels fit into a groove in the end bearing C of the vessel, Fig. 6, so as to prevent end motion.

Figs. 1, 2, and 3 show the general arrangement of the forge as designed, one half of which was erected at the Dowlais Works. The puddling vessels A A are arranged in pairs round the steam crane U, Fig. 2; V is the position of the vessels when being filled with their charge from the blast furnace W, and X is the position when they are being emptied. The steam hammer for reducing the balls to square blooms is situated at Y; and Z Z are small cranes for lifting the vessels when they are being lined. The circular arrangement of the puddling vessels round a central crane has been chosen by the writer as the one best suited to the situation; but they may be arranged in lines, or in any other manner which may be deemed most convenient for working and handling them.

The chief difficulty in puddling in revolving vessels is to get a lining which will withstand the chemical action of the melted metal and cinder, and the mechanical action of the iron from the time it comes to nature until it is balled up. The successful use of "ganister" for lining the Bessemer converting vessels led the writer to try this substance, and the vessels were in the first place lined with ganister rammed in in the same way as in the Bessemer converters. The linings of ganister stood on the whole very fairly, but the iron produced was cold-short; and although various devices were used to get over this grave defect, they have not been entirely successful. Various linings have been tried, indeed almost every likely substance, and some of them in various forms. One of the most successful was what is known as "titanic ore" from Egersund in Norway, introduced to the writer's notice by Mr. Riley. This substance was used in solid blocks in its natural condition, and also finely ground, tempered, and rammed in the same way as the ganister linings; it stood very fairly, particularly in solid blocks, and the iron produced was of a

better quality than with the ganister lining, being less cold-short, and also free from red-shortness when properly treated in the furnaces. The titanite ore and the ganister were found on the whole the best of the materials used for lining the puddling vessels, and they may be taken as types of the various substances tried.

The linings were put in in various ways. Sometimes the material was used in its natural condition, as in the case of the titanite ore; and sometimes it was reduced to powder, tempered, and rammed round a core, and then carefully dried *in situ*. In other cases the ground material was made into bricks of the proper size and form to fit the vessels, and these were burnt in the usual way, and set carefully in the vessel with cement, generally of the same material.

Some of the substances tried for lining, from which better results might have been expected, failed signally: in this class were "bulldog" and "puddling ore." As soon as it was known that experiments were being made at Dowlais on a large scale, suggestions were sent to the writer from all quarters, mostly from England, but many from the continent of Europe, and some even from America. The writer may fairly say that he gave every feasible suggestion a fair trial, when it was practicable to do so. A lining of iron in imitation of the common puddling furnace was a favourite plan with many, and to test it the writer had a vessel lined with iron bars, placed on edge in the longitudinal direction and firmly secured to the vessel; the spaces between the bars were filled and rammed hard with one of the best lining materials. The bars were for the purpose of preventing the lining from being abraded by the action of the granular iron in the course of puddling; and it was hoped that the lining in its turn might prevent the iron from adhering to the edges of the bars. As was feared however, the iron stuck fast to the bars wherever their edges were exposed, to such an extent that in one instance the whole heat adhered to the sides of the vessel. As far as the writer's experience goes, it is next to impossible to prevent the puddled iron from adhering to the *clean* surface of an iron lining, heated to the temperature necessary for puddling.

It was observed that with the natural draught through the vessels the action produced on the charge by the oxygen of the air was not

so marked and effective as in ordinary puddling furnaces ; which was easily accounted for by the form of the vessels, the iron not being so directly exposed to the action of the air passing through the furnaces. To remedy this defect, blast was introduced at the firebox end, and made to impinge upon the surface of the charge. This had a marked effect in improving the quality of the iron ; it removed a great portion of the impurities, and as a consequence produced a cinder richer in iron and more closely approximating to that of the ordinary puddling furnaces.

Although the quality of iron produced was not altogether satisfactory—and this is the great difficulty still to be solved—the quality was wonderfully uniform : there was no bad puddling in the ordinary sense, the iron being all perfectly and uniformly worked.

The results here briefly stated were arrived at by a long series of experiments on mechanical puddling, made with great care, and on a scale sufficiently large and practical to render them thoroughly reliable ; and the writer's aim in the present paper has been to give a complete account of all that has been done at Dowlais in trying to cheapen and improve what is perhaps the most important process in the iron manufacture—a process that appears likely to hold its ground in some form or other for very many years, inasmuch as it is the only method at present known by which on a large scale the great bulk of the pig iron made can be converted into malleable iron or steel. Although by the Bessemer process certain qualities of pig iron can be converted into a material which for nearly every purpose is greatly superior to the malleable iron produced by puddling, this method unfortunately admits only of dealing with iron practically free from certain impurities that are common to the great bulk of the pig iron produced in almost every country ; and thus the application of this highly ingenious and beautiful process is limited. It seems not improbable indeed that the Bessemer process, even yet in its infancy, may owe its full development to puddling ; for it has already been practically demonstrated that steel of excellent quality can be made from common pig iron purified by the puddling process, and therefore the expense of puddling seems to be the only obstacle

in the way of its application for preparing common pig iron for the Bessemer converters.

Looking at the subject of iron manufacture as a whole, there appears to be no commercial question at the present time of so much importance to the world at large as that of cheapening the mode of purifying crude iron. At present this is effected by such a combination of high skill and severe manual labour as can only be purchased at great cost; and this cost will doubtless go on increasing, unless something is done to lighten materially the labour of the puddler and so render his occupation more endurable. In England it may be said that the extension of the iron manufacture is limited by the supply of labour in this particular branch; and there are serious doubts whether under any circumstances the supply will keep pace with the demand.

Mr. MENELAUS showed one of the puddled balls that had been produced in one of the puddling vessels at Dowlais, the weight of the ball being about 6 cwts.

The PRESIDENT enquired whether there was a greater liability of the cinder becoming wrapped up in the ball in that mode of puddling, on account of the ball being formed by rolling over and over in the revolving puddling vessel.

Mr. MENELAUS replied that the risk of wrapping up cinder in the ball was not found to be greater than in ordinary puddling; and although the actual quantity of cinder contained in the ball was greater, that was only in proportion to the increased size of the ball itself produced from the puddling vessel.

Mr. C. W. SIEMENS remarked that the subject of puddling iron was one that he had been engaged upon for some years, with the object of improving and economising the process, and he was satisfied that any improvement such as the one now described, which could

dispense with the toilsome manual operation at present prevailing, would be of very great value. In reference to the plan tried at Dowlais, the one difficulty which had principally struck him was, how to make a lining for the puddling vessel which should stand for a sufficient length of time to be practically successful; and it appeared from the paper just read that this had been found the chief practical difficulty in the experiments, and that it had not yet been successfully overcome. In his own trials of puddling furnaces he had found that the particular part where the lining failed was all along the line of the surface of the melted iron, and in the revolving puddling vessel now described that line was continually changing.

In the new mode of puddling now described, one point upon which he would be glad of further information was, whether there was sufficient means of watching the operation during its successive stages, so as to regulate the nature of the heat given. In the ordinary puddling furnaces a melting heat was first required, for reducing the metal to a fluid state as rapidly as possible; but in the present instance the melting was not done in the puddling vessel, the melted iron being run in direct from the cupola or blast furnace. Then came the period of stirring, an operation which required great attention, because if the iron was deprived of its carbon or "came to nature" too soon, it would not mix properly with the cinder, and therefore a great deal of the foreign matter originally contained in the iron would remain in it, instead of being removed by the cinder. During this operation the condition of the metal could be completely watched in the ordinary puddling furnaces, through the door at which the puddler's tool or "rabble" was inserted. A smoky or reducing flame was necessary until the metal had become sufficiently freed from impurities; after which a keen oxidising flame was employed, to cause the crystals of iron to be formed, and finally prepare the metal for balling up. In the revolving puddling vessel described in the paper he did not see that there could be the same means of watching the progress of the process.

In regard to the mode of introducing the flame from the firebox into the revolving puddling vessel, it struck him as objectionable

that the axis of the flame coincided so nearly with the axis of the vessel ; and it appeared to him that what was wanted was to get the direction of the flame more inclined to the axis of the vessel, as the flame was required to strike downwards upon the metal, instead of simply passing over it parallel to its surface. This was not so easy to manage with the revolving vessel as in an ordinary puddling furnace, unless it were done by the aid of a blast applied in an inclined direction ; but then the employment of blast would be attended with an extra loss of the metal itself by oxidation. He thought however that a regenerative gas furnace would remove this difficulty, by allowing of the flame being introduced in an inclined direction without requiring the use of blast.

He enquired also whether the actual loss of metal in puddling by the revolving vessel was found to be greater than in the ordinary puddling furnace. The question of commercial economy was perhaps of secondary importance, in comparison with the primary consideration of the practical success of the process for the manufacture of iron ; and the mechanical arrangements for performing the operation of puddling appeared certainly to be well carried out.

Mr. F. J. BRAMWELL enquired what was the rate of revolution of the puddling vessel, and whether it was uniform during the whole time of the operation ; and also what was the length of time ordinarily occupied, from the time of running the melted iron into the puddling vessel until the finished ball was ready for turning out. He asked also whether any red ore or other material containing iron was employed for lining the puddling vessel, as was done sometimes in ordinary puddling furnaces, and if so in what quantity it was used and how it was applied ; because in some instances of an apparently high yield obtained from puddling furnaces in which a large proportion of red ore was used for the lining, he believed that part of the yield was really due to the reduction of the lining itself during the process of puddling.

Mr. MENELAUS said that the first object which he had aimed at in the endeavour to accomplish mechanical puddling had been to obtain a good result in regard to the quality of material produced, before attending to the question of commercial economy ; but he must

frankly admit that all the attempts which had been made at the Dowlais Iron Works during several years past had not yet resulted in success; and so far indeed was the process described in the paper from proving yet a practical success, that at the present time the puddling machines were all standing idle. The importance of lightening the puddler's labour was very seriously felt at Dowlais, where there were as many as 150 puddling furnaces to be kept constantly at work; and great difficulty had been experienced in finding regularly a sufficient number of men to work so large a number of furnaces. If the laborious part of the process could be lightened, men could more easily be got to perform the rest of the work; but there were so many conditions essential to successful puddling, that it was extremely difficult to substitute mechanical agency for the present manual labour.

The means of watching the process of puddling in the revolving vessel was through the end door (B, Fig. 6) in the fluebox, and the damper in the fluebox allowed of regulating the heat in the vessel; and in both these respects the facilities afforded in the new plan were as great as in the ordinary puddling furnaces. The direction of the flame entering the puddling vessel from the firebox was originally parallel to the axis of the vessel, the mouth of the firebox having been built cylindrical in the first instance, the same as the mouth of the fluebox at the opposite end of the puddling vessel; but afterwards the brickwork was altered, by making the top of the firebox mouth to slope downwards (as shown at M, Figs. 6 and 8), so as to deflect the flame down upon the metal in the puddling vessel as much as possible. It was not easy however, on account of the shape of the puddling vessel, to deflect the flame to the full extent that was desirable, though this was readily managed in the ordinary puddling furnaces.

The rate of revolution of the puddling vessels in working was about six revolutions per minute during the time that the iron remained liquid; but the speed could be varied at will, and during the balling up it was reduced to two or three revolutions per minute. One man attended to a pair of vessels, and each vessel turned out six heats per day. Although the melted metal was run direct into

the puddling vessel, to save the time and expense of melting it down in the vessel, the slight saving of time thus effected was not sufficient to admit of increasing the number of heats worked in the day, because by far the greatest portion of the time was occupied in the operation of puddling. In regard to the use of red ore in the puddling vessel, it was necessary in all puddling furnaces to introduce oxide of iron in some form; this was used in the revolving vessels in the same way as in ordinary puddling furnaces, and among other substances he had used the red ore for the purpose. The loss of iron in puddling was very nearly the same as in the ordinary furnaces, being about 2 or 3 cwts. per ton of pig metal charged into the furnace.

The PRESIDENT enquired about the durability of the lining of the puddling vessel, what had been the greatest number of heats that had been worked in one vessel before it required to be relined; he supposed it was the question of lining which would principally determine the ultimate success or failure of the plan of mechanical puddling now described.

Mr. MENELAUS replied that he attributed the present failure of the attempt solely to the failure of the lining in the puddling vessel; the chemical action of the melted metal and cinder, together with the mechanical action of the iron in its granular state, soon wore the lining away, and it got mixed with the iron, which was consequently rendered inferior in quality; little or no injury was done to the lining by the rolling of the iron when balled up. One of the best lining materials was ganister, which had been found to stand about one hundred heats. Another lining had been made of hard cinder and red ore, liquefied in the vessel, and allowed to cool gradually while the vessel slowly revolved, so as to line the interior with a uniform coating; but this lining, like the others, had failed.

Mr. E. WILLIAMS said he had seen the puddling machines at work at Dowlais, and he was at a loss to understand why there should be any more difficulty in watching the process and regulating the heat during the whole of the operation than there was in the ordinary puddling furnaces. There appeared to him to be quite sufficient facility for seeing the metal through the door in the fluebox;

and for regulating the heat the puddler could have recourse either to the damper or to the fire itself. While witnessing the experiments at Dowlais he had been much struck by the very efficient stirring produced by the revolving puddling vessel, which was better than any stirring by the ordinary mode with a rabble. As the iron began to come to nature it adhered to the side of the revolving vessel, and was carried up until it fell over again to the bottom in a sort of spray; and in this way it was exposed most completely to the action of the flame.

With regard to the sand lining of the revolving puddling vessel, it produced exactly the same evil that existed during the earliest years of puddling, when the furnace bottom was sand, and the quality of the iron worked in the furnace was thereby greatly injured. Some thirty years ago the cast-iron furnace-bottom was introduced, from which the greatest advantage resulted; in fact this was the chief improvement that had been made since the original invention of puddling. In the revolving puddling vessel the essential difference from an ordinary puddling furnace was that the part which was at one moment the bottom of the furnace formed at the next moment the roof; and the lining would not stand the heat. He thought however that a wrought-iron vessel might be lined with strong cinder, and suggested that a plentiful stream of cold water should be applied outside in order to set the lining. There would probably be some need of experiment to determine the thickness at which this lining would stand; but he felt sure such a lining could be made to stand, and if so it would be better than any other. He did not think that any one who had seen what had been done at Dowlais would regard the attempt as having failed; the lining of the puddling vessel was at present the only failure; and all the mechanical arrangements appeared very good.

Mr. E. W. RICHARDS said that he had also seen the experiments on mechanical puddling while in progress at Dowlais, and thought the process was remarkably simple as there carried out; and he fully concurred in considering the results thus far arrived at as most satisfactory, the only serious difficulty that yet remained being the lining of the puddling vessel.

Mr. E. RILEY said he had seen the puddling vessel at work at Dowlais, and had witnessed many of the experiments with different sorts of lining; and he thought the best course to pursue would be to endeavour to apply the same material that was found to stand best as the lining of ordinary puddling furnaces. The material found most durable for this purpose he believed was what was known as "best tap cinder" from the balling or reheating furnaces with cast-iron bottoms, which was delivered to the puddlers for fettling their furnaces; it was found so satisfactory that it would no doubt be used more extensively if it could be obtained in sufficient quantity. The best chance of success he thought, in lining the revolving puddling vessel, would be to run this material into moulds like bricks, of suitable shape to fit the vessel, and then thoroughly anneal it by cooling it very slowly. The casting of the material in moulds could be very readily done, and although the lining would no doubt wear away very rapidly at first, he concurred in thinking that the wear would only continue to a certain extent, and that the thickness of the lining would thus regulate itself. He had little doubt that the titanite ore, referred to in the paper, if it could have been cast into bricks in the same way, would have answered for the lining of the puddling vessel; but the only experiments tried with it were made by grinding it up and pressing it into moulds by hydraulic pressure, and when used in this way it did not answer. He suggested also that a trial might advantageously be made with the "best tap cinder" mixed with some of the titanite ore, or with hæmatite or magnetic oxide of iron now obtained from Sweden; for having had some experience in the use of a material of that composition for fettling, he had found its property of resisting fire to be very great.

With regard to regulating the heat and watching the process of puddling, he thought these points were as successfully attained in the revolving puddling vessel as in an ordinary furnace. The real difficulty at present was the lining; and when that had been successfully overcome, any further points could then be considered that might require attention.

Mr. E. WILLIAMS observed, with regard to the cinder fettling which had been referred to, that he used a large quantity of that material for the puddling furnaces at Middlesbrough; and one of the best ways of making it was found to be by mixing with the cinder a quantity of the scale from the shingling hammers and roughing-down rolls, and even a few scraps of bar iron. The whole was then melted down in a very hot furnace, and run into blocks, which were built against the sides of the puddling furnaces as needed. He had also himself constructed an experimental puddling vessel similar to those at Dowlais, but of smaller size, 6 feet long and 3 feet diameter, which he had succeeded in lining with this "iron fettling" by letting the material run in very slowly, keeping the vessel revolving gently. By this means he had succeeded in getting a lining 2 inches thick all over the inside of the vessel, the outside being kept as cold as possible during the time by a stream of cold water; and he hoped to continue the experiments with this lining. One point of importance he considered was that the vessel should only puddle a single heat, and should then be allowed to cool down while the next heat was worked in another vessel; and he thought this mode of working would materially increase the durability of the lining. It was decidedly preferable he believed to run the melted iron into the puddling vessel, as had been done at Dowlais, instead of melting down the charge in the vessel; the cost of melting the iron in a separate furnace was less than in the puddling vessel.

The PRESIDENT enquired how far the destruction of the lining had been found practically to affect the quality of the iron produced from the revolving puddling vessel, as compared with that worked in ordinary puddling furnaces.

Mr. MENELAUS replied that the iron was so much impaired in quality as to be not marketable, when this destruction of the lining took place to the greatest extent.

Mr. I. L. BELL remarked that the very candid admission respecting the quality of the iron produced by the mechanical puddling led him to infer that there were other conditions to be considered, besides those of a mechanical nature; and the character of those other conditions might be illustrated by a reference to another manufacturing process.

In the manufacture of soda, where the object was by application of heat to convert the sulphate of soda into carbonate of soda, the main difficulty was to ensure the perfect decomposition of all the material ; but if this were not completely effected, the result was only a loss to the manufacturer, by interfering with the available produce of soda, whilst the quality of the soda actually produced was not deteriorated by the presence of small quantities of the original raw material remaining undecomposed. In the manufacture of iron, on the other hand, a different class of difficulties had to be encountered, because the presence of even a small proportion of sulphur or phosphorus was a contamination fatal to the quality of the metal, and the greatest amount of skill was required to get rid of these ingredients. The puddler judged from the appearance of the metal in the furnace what variations were required to be made in the flame by regulating the supply of air ; but so much was this still a mere matter of guesswork, that even in working the same materials nothing was more difficult than to secure the same uniform quality of iron throughout ; and he had found that on no two days was the quality precisely the same, notwithstanding the greatest care to ensure uniformity in the materials. One very encouraging feature therefore of the trials at Dowlais was the remarkable uniformity which was stated to have been experienced in the quality of the iron produced ; and although the iron produced was not satisfactory at present, yet the uniformity in the quality must be looked upon as a point of much importance, because it might fairly be expected that, when the difficulties which now beset the process were ultimately overcome, means would thereby be arrived at of producing a good quality of iron with more complete uniformity than was possible in the present condition of the iron manufacture. Hitherto attention had necessarily been directed mainly to difficulties of a purely mechanical nature ; but he thought the investigation of the chemical conditions attending the process might with advantage be considered simultaneously. With regard to the construction and working of the revolving puddling vessel, he did not see any reason why the control of the operation should not be quite as easy in this case as in an ordinary puddling furnace, as soon as means were devised of maintaining the vessel in working order.

Mr. W. E. NEWTON remarked that, although the history of invention was for the most part a history of failures, it was by no means the case that the failures were so generally recorded as was desirable: and therefore they were the more indebted for the complete account now given of an attempt which had not yet issued in complete success; and if other efforts which had not at present proved successful were recorded in an equally candid spirit, with the particulars of the difficulties that had been encountered, less time would be lost in blundering a second time over ground previously tried. He agreed with the remarks which had been made as to the importance of not losing sight of the chemical questions affecting the process of puddling, and thought it would be a mistake to attend exclusively to the mechanical features of the subject and to endeavour to perform the whole process by mechanical means alone: and he mentioned that an attempt to supersede the present manual operation of puddling was now being made at Stalybridge, by means of both chemical and mechanical agencies in combination, and the experiments had been attended with partial though not complete success. As the object of the puddler's labour in stirring the metal in the furnace was to expose all portions of it to the action of the air, in order to effect the oxidation or decarbonisation of the original pig metal for converting it into wrought iron, there seemed no reason why this might not be accomplished by adopting Mr. Bessemer's system of forcing air from below through a mass of melted metal: and Mr. Siemens having devised the means of generating a supply of gas to be used in place of raw fuel, he suggested that a reducing gas might be introduced below the surface of the melted iron, while an oxidising flame was made to play upon the surface. By this means the process would be brought under complete control, and the puddler's labour would be greatly abridged.

Mr. MENELAUS observed that, although mechanical puddling was the subject of the paper, and the mechanical part of the question had alone been dwelt upon, the chemistry of the subject had not been neglected, and this had been under the able supervision of Mr. Child, the chemist of the Dowlais Iron Works. The practical difficulty however which at present interfered with the success of the

experiments was in his opinion almost entirely of a mechanical nature, namely the lining of the puddling vessel; and it was this point which had specially occupied his own attention. It was right to state that he had had the valuable aid for a time of Mr. E. Williams, and also the help of the best practical puddlers at the Dowlais Works during the experiments. The remarkable uniformity obtained in the quality of the iron puddled in the revolving vessel he considered was to be attributed to the fact that a machine was neither lazy nor dishonest; and therefore the same amount of work was always put into the metal, and the result was perfectly uniform. In hand puddling on the contrary it was often found that portions of badly puddled iron had been wrapped up in the ball by the puddler; and there were great variations in the quality of the iron produced.

Mr. W. CLAY mentioned that graphite, which was nearly pure carbon, would stand a remarkable degree of heat and resist a great amount of wear and tear, and he had found it last for the sides of puddling furnaces much longer than either red ore or the best tap cinder. Another material that he had used with success, which had not the objection of re-dosing the iron with carbon, was a mixture of the graphite with iron ore. In France he believed a mixture of ground coke and tar was sometimes used for making the bottoms of puddling furnaces; he had himself tried it in one of Mr. Siemens' regenerative puddling furnaces working *spiegel-eisen*, and the furnace was worked continuously for nearly a month under a great heat, without the bottom requiring renewal. He enquired whether any of these materials had been tried for lining the puddling vessel in the experiments at Dowlais.

Mr. MENELAUS replied that he had not tried graphite for lining the puddling vessel; he had tried ground coke and tar, but with only very partial success, and had therefore abandoned the idea of looking any further in that direction. The experiments he feared had exhausted almost every material that appeared likely to succeed; but now that general attention was directed to the subject he hoped something might ultimately be devised which would answer the required purpose.

Mr. C. COCHRANE enquired whether any objection was found in practice from the heat that would issue at the open mouth of the firebox, when the puddling vessel was removed from the driving machinery on the completion of working a charge.

Mr. MENELAUS explained that no difficulty was experienced in that respect, because the only draught upon the fire was that produced through the puddling vessel and the fluebox by the chimney which created the draught ; and as there was no longer any draught upon the fire when the puddling vessel was removed, no emission of flame took place at that time from the open mouth of the firebox ; and no inconvenience was experienced from the heat in standing within two or three feet of the open firebox mouth.

The PRESIDENT enquired whether the balls produced from the puddling vessel were hammered or squeezed ; and he asked what was the object of the unsymmetrical form given to the two ends of the vessel, as shown in the drawing.

Mr. MENELAUS said that the balls produced from the puddling vessel were all hammered under the steam hammer in the forge. In the original experimental puddling vessel the two ends were made symmetrical (as shown by the dotted lines in Fig. 6) ; but the subsequent vessels had been made with unsymmetrical ends, having a bulge at each end, for the purpose of giving the fluid iron an end motion during the rotation of the vessel, with the idea of ensuring a more thorough working of the iron. Experience had shown however that this was not necessary in practice, and that the original shape with symmetrical ends was preferable ; and it had the advantage of being simpler for construction and lining, as the transverse section was then a true circle in all parts.

Mr. W. E. NEWTON mentioned that a plan of horizontal puddling furnace had been proposed, having a revolving bottom carried upon an axis slightly inclined to the vertical, so as to convert the rotary movement into something like a rocking motion of the furnace bottom, in order to make the ball roll about during the puddling. He enquired whether any attempts had been made at Dowlais to employ a rocking motion, instead of the rotary motion of the revolving puddling vessel.

Mr. MENELAUS replied that he had not tried a rocking motion, except so far as that sort of movement was produced by the unsymmetrical ends of the revolving puddling vessel ; but he found the simple rotary motion produced quite sufficient effect in working the iron in the vessel, and he considered this plan was most likely to prove ultimately successful. In the first experiments he had also tried reversing the motion of the puddling vessel about every two minutes, making a dozen revolutions in one direction, and then a dozen back again ; but this was not found to be any improvement over the simpler plan of driving the vessel continuously in the same direction.

The PRESIDENT enquired what had been the practical success up to the present time in the working of the other methods which had been tried for effecting mechanical puddling, without having recourse to a rotary motion.

Mr. MENELAUS replied that the machine invented in France some years ago for working the ordinary puddling tool or rabble in the ordinary furnaces had been introduced into England, and applied by Mr. Bennett to the puddling furnaces at the Wombbridge Iron Works, Shropshire, as described by him at a former meeting of the Institution (see Proceedings Inst. M. E. 1864, page 298) ; and great credit was due to Mr. Bennett for the ingenuity he had displayed in simplifying and improving the machinery. The plan however had not been taken up extensively elsewhere. The object in that case was to do away with the severe labour of puddling, by performing the rabbling action by mechanical means, leaving the puddler to exercise only his skill in controlling the operation ; and he believed the plan was a great success as far as it went, but he thought it did not go far enough, as it did not ball up the iron at the completion of the puddling. His own object was to do away with the puddler's labour altogether, so as to enable one skilled workman to manage three or four furnaces simultaneously. Where great skill and great bodily labour were required in combination, high wages were inevitable ; and unless some scheme could be devised for doing away with the hard work in puddling, he did not know where men enough would be got to perform the work, or how the manufacture of iron would ultimately be carried on.

Mr. E. RILEY mentioned that there was also another machine by Mr. Griffiths of Derby, for working the ordinary puddler's rabble, which had been employed at the Milton and Elsecar Iron Works near Barnsley; but at these works he understood the machines had not found favour with the men, and when it was at length left to the option of the men whether the machines should be used or not, they had preferred not to use them, except for working grey iron, which involved the severest labour in puddling. At the Tow Law Iron Works near Darlington another description of puddling machine for the same object had been tried, and the men had the option of using it, but seldom did so.

Mr. E. WILLIAMS remarked that even if only the rabbling of the metal in the ordinary puddling furnace were done by machinery, that would be an important advantage; for the greatest skill and labour of the puddler were required when the balling up commenced, at which time in the ordinary process his strength was nearly exhausted by the previous puddling.

Mr. F. W. WEBB mentioned that he was working at Bolton one of Mr. Siemens' regenerative puddling furnaces; and although the puddling was still done by manual power, there was a considerable saving of labour to the men, as shown by the fact that three shifts of 8 hours each were made every 24 hours, each shift consisting of six heats, and each heat taking on an average 70 minutes; whereas in the old furnaces two shifts of 12 hours each per 24 hours were about the average, each shift consisting of six heats. The great advantage of the regenerative furnace for puddling was that it gave the means of obtaining any temperature or flame that was wanted, and was most perfectly under control; and it effected a considerable saving in fuel.

Mr. W. M. NEILSON observed that the plan of mechanical puddling described in the paper was evidently not the result merely of a lucky idea, but had been carefully worked out by Mr. Menelaus under the pressure of necessity, in the long series of experiments of which he had now given them the particulars; and although he had not yet completely succeeded in the object aimed at, they were equally indebted to him for his labours, and could well understand how great his

exertions had been. At the present time it was indeed discreditable to so splendid a manufacture as that of iron, that it was dependent upon the class of labour which was required in puddling; but now that so much attention was being directed to this subject, he trusted this particular department of the iron manufacture would not long continue in its present state; and he was sure the further efforts of Mr. Menelaus in the direction of mechanical puddling would be watched with the liveliest interest.

The PRESIDENT considered they were greatly indebted to Mr. Menelaus for the perseverance and talent he had displayed in striving to carry out the system of mechanical puddling now described; and hoped he would not relax his efforts in endeavouring to attain the important object in view. There was no heavier kind of work than that of the puddler, for which consequently it was necessary to pay very dearly; and it was therefore highly desirable to lessen the amount of that labour, and leave the puddler to look on and exercise his skill only in the control of the process.

He moved a vote of thanks to Mr. Menelaus for his paper, which was passed.

The Meeting was then adjourned to the following day.

The Adjourned Meeting of the Members was held in the Lecture Theatre of the Conservatoire Impérial des Arts et Métiers, Paris, on Thursday, 6th June, 1867; JOHN PENN, Esq., President, in the Chair.

The following paper was read :—

Forge for Puddling Machinery at Dowlais Iron Works.

Fig. 1. *Longitudinal Section.*

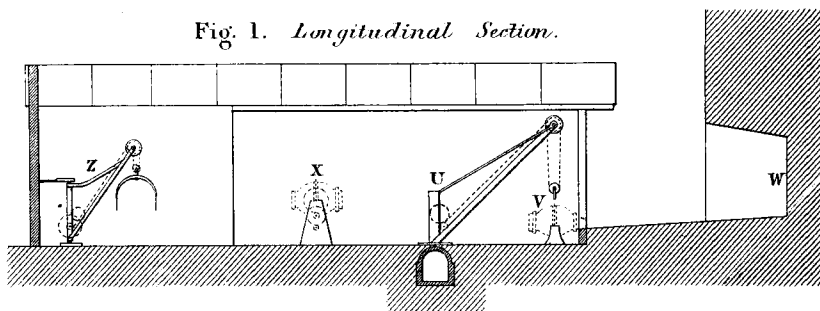


Fig. 2. *Plan.*

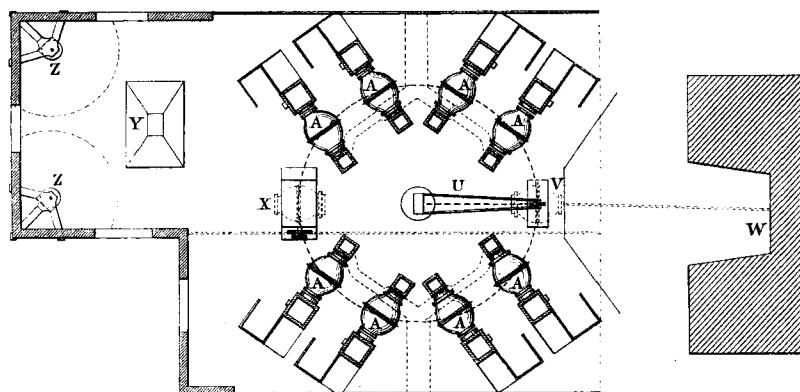
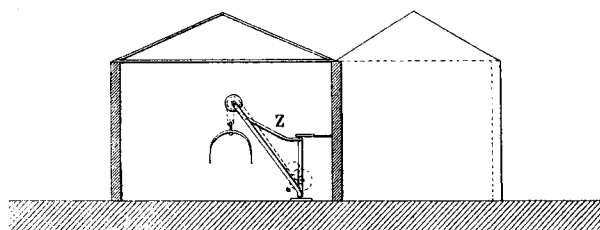


Fig. 3. *Transverse Section.*



(*Proceedings Inst. M.E. 1867. Page 151.*)

Scale $\frac{1}{400}^{\text{th}}$

0 10 20 30 40 50 60 70 80 90 100 Feet.

Fig. 4. *End Elevation of Driving Machinery driving a pair of Puddling Vessels.*

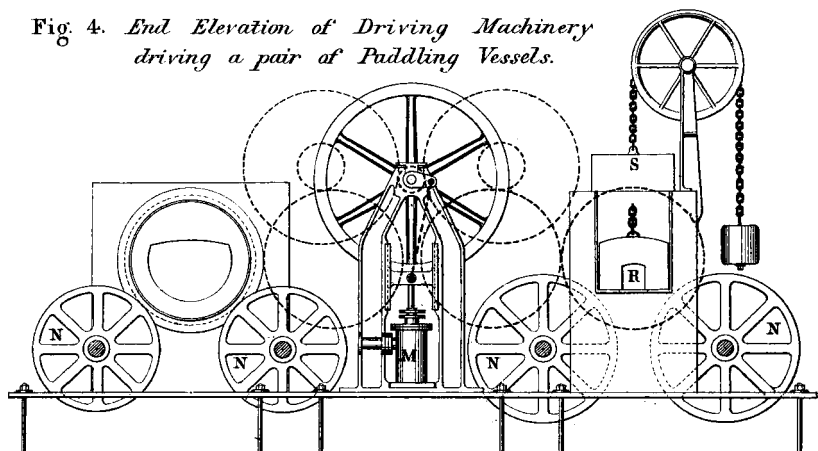
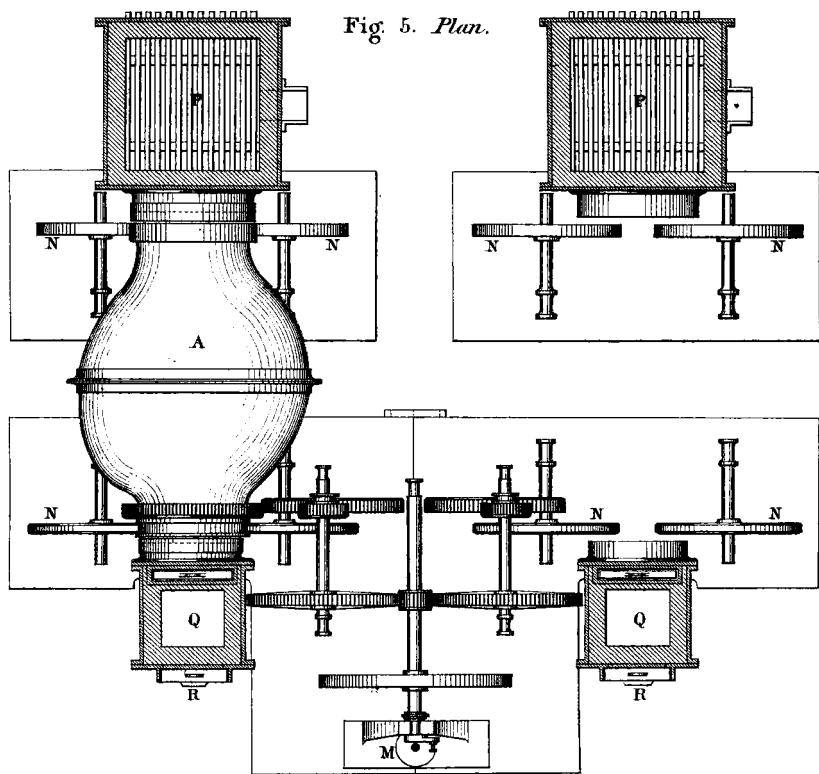


Fig. 5. *Plan.*



(Proceedings Inst. M.E. 1867. Page 151.)

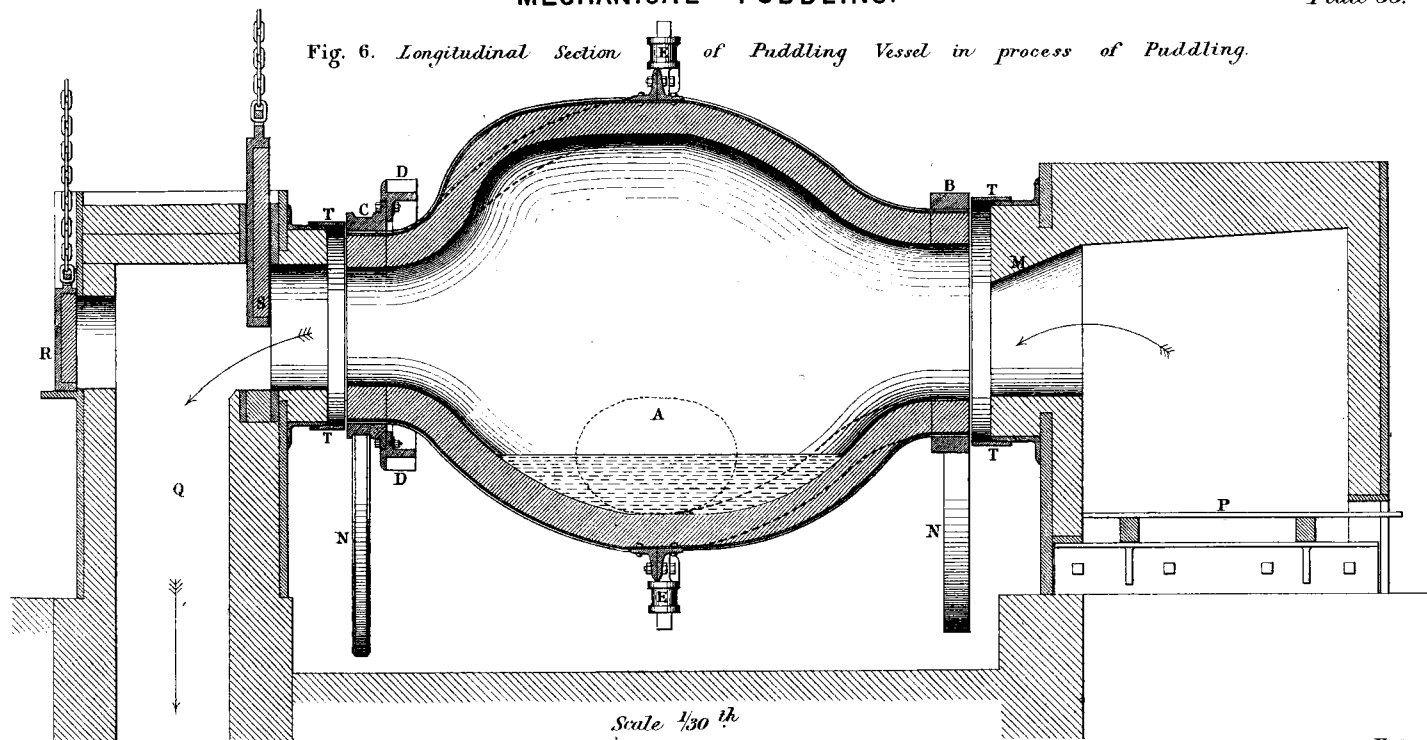
Scale $\frac{1}{60}$ in

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Feet.

MECHANICAL PUDDLING.

Plate 35.

Fig. 6. Longitudinal Section of Puddling Vessel in process of Puddling.



(Proceedings Inst. M.E. 1867. Page 151.)

Scale $\frac{1}{30}$ th
0 1 2 3 4 5 6 7 8 9 10 Feet.

MECHANICAL PUDDLING.

Plate 36.

Fig. 7. *End Elevation of Puddling Vessel in working position.*

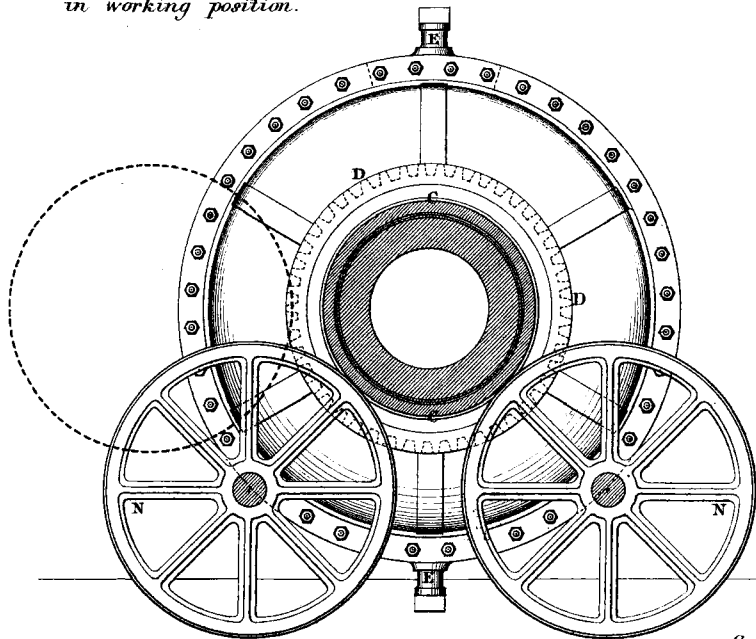
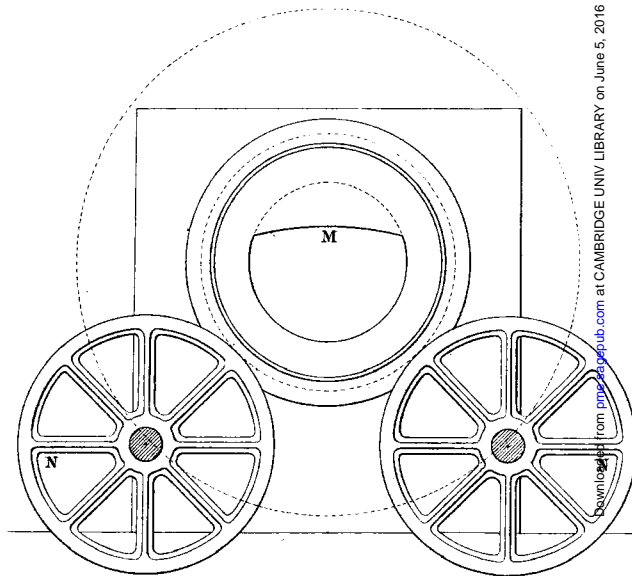


Fig. 8. *Elevation of Mouth of Firebox, with Puddling Vessel removed.*



Scale $\frac{1}{30}$ th



(Proceedings Inst. M.E. 1867. Page 151.)

MECHANICAL PUDDLING.

Plate 37.

*Puddling Vessel in position
for receiving the charge.*

Fig. 9. Side Elevation.

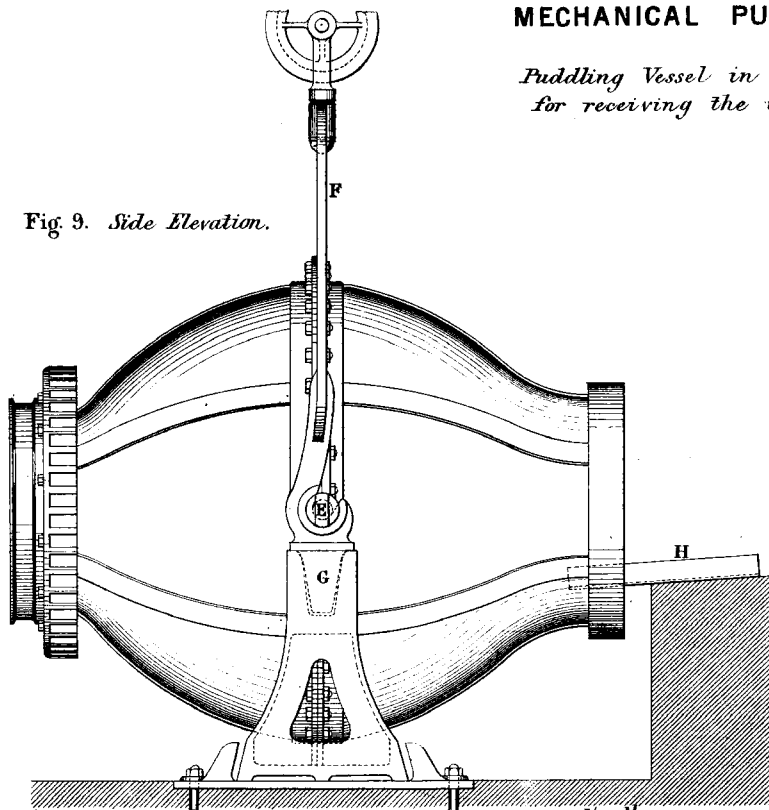
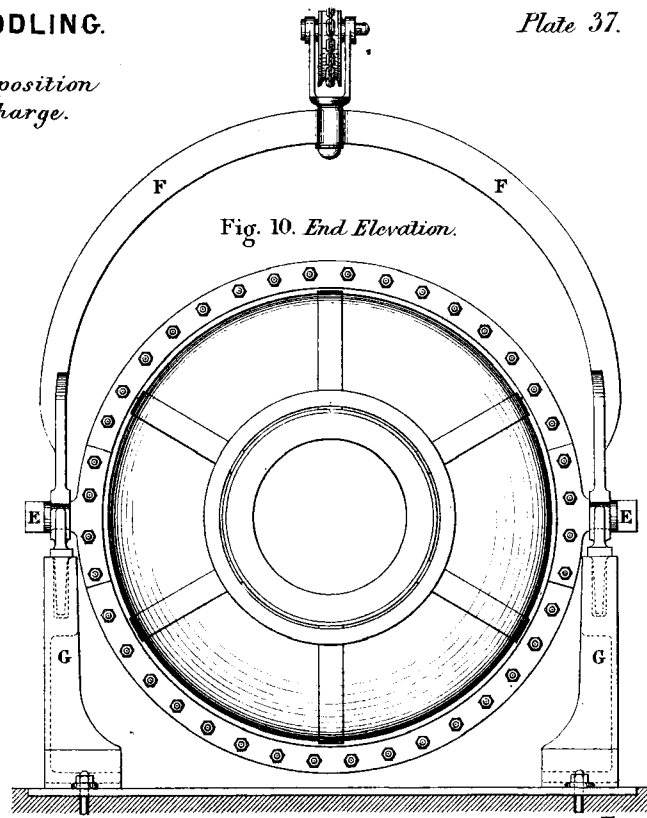


Fig. 10. End Elevation.



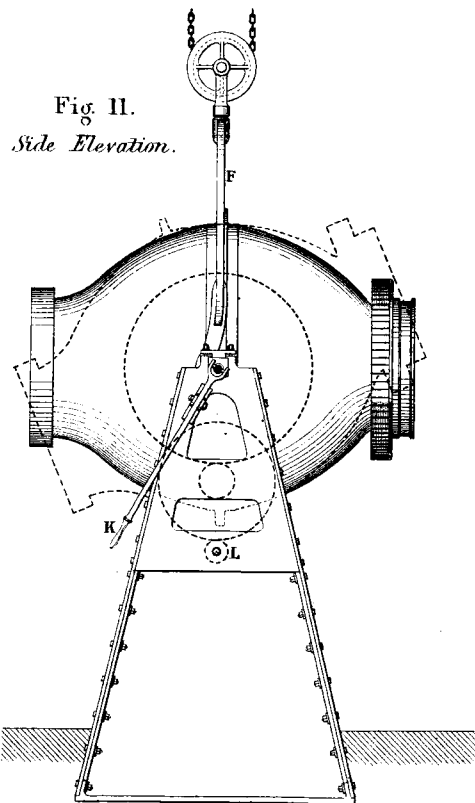
(Proceedings Inst. M.E. 1867. Page 151.)

Scale $\frac{1}{30}^{th}$

0 1 2 3 4 5 6 7 8 Feet.

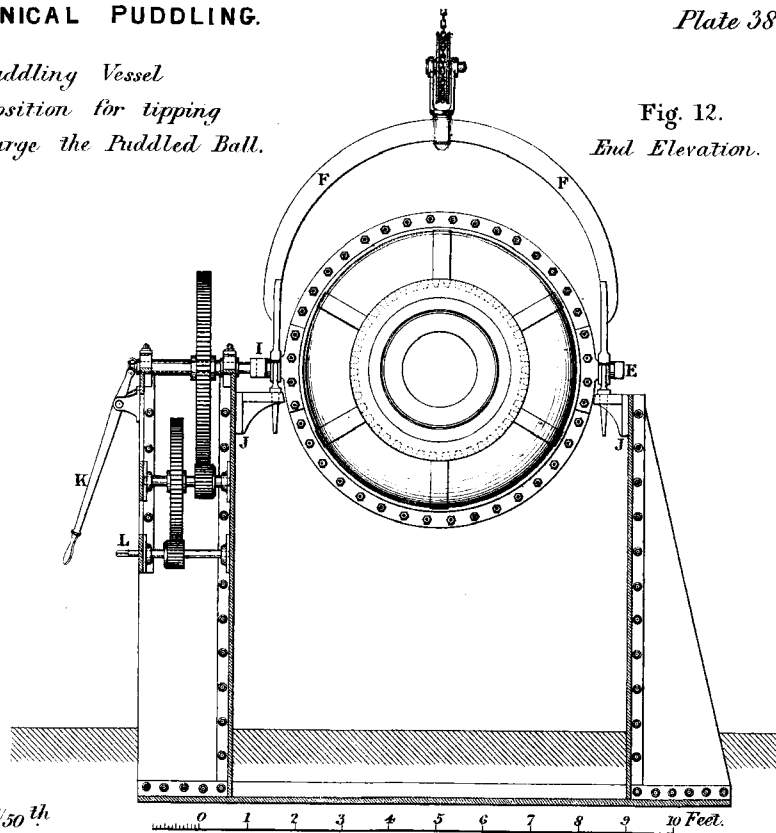
MECHANICAL PUDDLING.

Plate 38.



(Proceedings Inst. M.E. 1867. Page 151.)

*Puddling Vessel
in position for tipping
to discharge the Puddled Ball.*



Scale $\frac{1}{50}^{th}$

Fig. 12.
End Elevation.