BAKER BESSEMER'S HISTORIC AXLE-FORGING PLANT

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Baker Bessemer's Historic Axle-Forging Plant

BY
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(Read at the Science Museum, London, 2 March 1966)

The recent closing of the works of Baker Bessemer & Co. at Kilnhurst, near Rotherham, makes it imperative to collect information about the history of the firm before it is lost in the mists of the past. This has happened to too many items of historical engineering interest in the last 30 to 40 years.

The essential part of the plant described in this Paper is the forging manipulator installed 40 years ago. It represented what would be called in the horrible jargon of today a "major technological breakthrough." It was certainly not the first forging manipulator; that distinction probably belongs to the steam driven machine made at Vickers in 1897, and there were manipulators in the U.S.A. early in the present century; but it was the first successful forging manipulator in this country, and in fact there would be little to alter, except perhaps in the provision of automatic controls, if one were designing the machine today. The plant described in this paper is referred to as that of Baker Bessemer because that was the name of the firm when it closed down. The name however was only adopted after the Bessemer firm had been taken over in 1929 so that it wouldperhaps have beenmore correct to describe the plant as Baker's without any reference to Bessemer. The name of the firm when the plant was made was John Baker & Co.

The firm of Baker & Burnett, which was founded in 1874, advertised axles made of "best double fagotted scrap"; that is to say, wrought iron reworked and welded together by the forging operation. They did not forge axles themselves until 1906, and these were steel axles; they had put in their own steel making plant in 1905, and they continued to buy-in wrought iron forgings for those railways which had an old-fashioned preference for wrought iron axles. Some wrought iron axles were actually bought in from Wortley (where they had presumably been forged under a water hammer) as late as 1920. The steel axles were forged at Kilnhurst from 1906 to 1925, under a 3-ton steam hammer -the method was the traditional one at that time-five or six men and boys working hard to turn out between 20 and 30 axles a shift (depending on the type).

The interesting figure of Mr. George Baker now comes on the scene.In 1904, at the age of 26, he had taken over the engineering direction of the works when his father, John Baker (the founder of the firm), died from pneumonia contracted whilst clearing the site for the new works at Kilnhurst. George Baker was a man of boundless energy, together with an original and inventive mind. He was also fortunate enough to come into a family concern where he had a free hand to exercise these gifts. George Baker followed his own ideas without much reference to current designs. The axle manipulator shows little resemblance to the manipulators in use at that time in the U.S.A. It had the advantage of fresh thought, unhampered by previous traditions, which produced novel and successful features.He believed that any patent could be evaded and preferred a policy of secrecy. No general arrangement drawings were made; he made models of proposed machines in his own workshop at home; the particulars of the parts were scaled from the model. Pencil sketches of parts were handed to the foreman, who did not see a drawing of the complete machine. This method resembles that of Henry Bessemer, many years before, to protect his invention of a method of making substitute gold paint; drawings of individual parts were sent to various makers-the machine was assembled and operated behind closed doors by Bessemer's three brothers-in-law. Even today at Kilnhurst, there is a notice on the door of the axle shop which reads "Any workman using this shop as a thoroughfare will be liable to instant dismissal."

After the 1914-18 war, George Baker first turned his attention to modernising the tyre mill at Kilnhurst. A scheme of complete mechanisation halved the number of men needed, and in 1923 he was ready to do the same thing for the axle plant. The scheme included a continuous furnace for heating, an improved type of hammer and flow production through heat treatment, but the essence of the whole thing was the forging manipulator.

The machine was built in the works and set to work in 1925. Mr. Henry Baker (Member of the Society) who was managing director when the works dosed in 1964, had just started under his uncle George in 1925, and one of his first jobs was to put the new axle plant into commission and overcome its teething troubles.The fame of the machine spread through the Rotherham and Sheffield districts, but it only did so by the usual "grape vine," that is, from one man to another over pints of beer in "pubs." It is astonishing how little could be carried away in this way-the writer, at that time working in a forge in Sheffield, heard all these rumours but had no dear picture of what the machine was like.

Only one drawing, dated 1923, has survived.This is that for the long travel and cross travel carriages, and these were the only parts made outside, by Joseph Booth and Bros. of Rodley. No drawings of the trunk and gripping arrangements can be found today.

The machine was designed and built for a special purpose: to forge railway axles using a 5 ton steam hammer. It succeeded in something previously regarded as impossible, namely in withstanding the shock of the hammer blow transmitted through the forging. It was designed to handle 30 cwt., which made almost excessively ample provision for the heaviest axle. In accordance with the policy of secrecy, no photographs were taken of this machine when it was working. It is difficult to convey a mental image without some illustration, and the writer has therefore made sketches of the plant in operation as seen from the right and left side respectively.

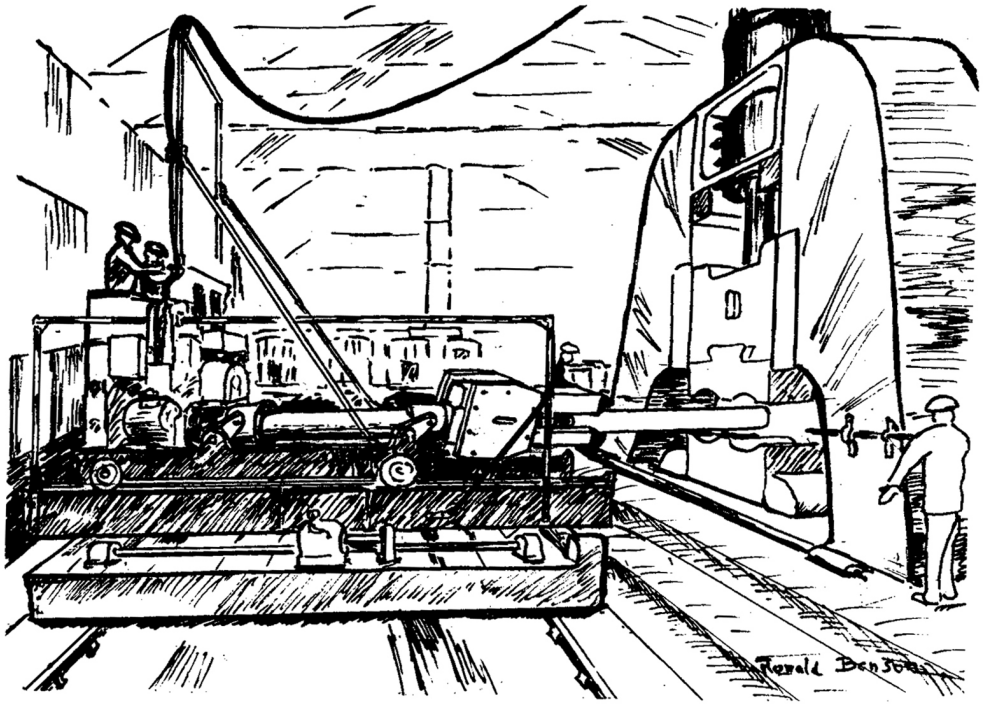


Figure 1: General side view of George Baker's Forging Manipulator

The main carriage ran on rails at about 20 ft. centres. These can be seen in the foreground in Fig. 1. On this carriage was mounted the cross travel carriage, about 16 ft. long and travelling on rails at 6 ft. 8 in. centres. This carriage had bearings on each side beam at the front end, nearest to the hammer, and about 5 ft. from the back end. These bearings formed pivots for pairs of bell-crank levers. The levers had two arms forward and downward respectively. The forward ends carried trunnions on the main trunk (or peel bar as it is termed nowadays) of the manipulator; when the lower arms were moved forward and backwards horizontally by a pneumatically operated piston, the trunk was raised or lowered with a true parallel motion, so that its centre line remained always horizontal; many manipulators have a peel, as the trunk is called nowadays, which is pivoted at the back and raised or lowered at the front, giving a radial instead of parallel movement to the work piece. The gripping mechanism also was unusual in design, in that the gripping jaws had a truly parallel motion and not the radial motion, often used, which makes it necessary to have pivoted gripping pieces. This is convenient enough for general work, but not satisfactory for axle making. The arrangement can be seen in Fig. 2.

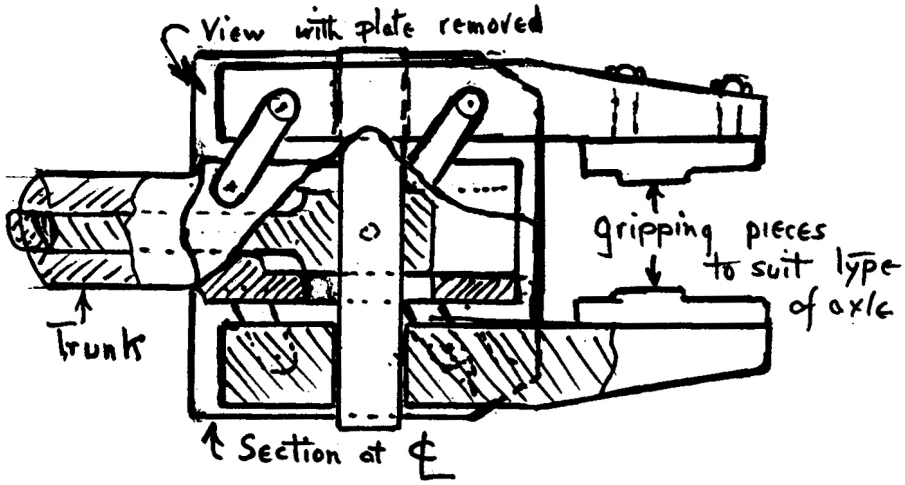


Figure 2: Sketch of Gripping Jaws with parallel motion

The front of the trunk carried two plates about 2 ft. long. Between these were the gripping jaws, projecting a further 2 ft. or so. These can be seen gripping the axle in Fig. 1. The front end of the trunk was square in section and carried, inside the plates mentioned, two pivot pins at each side, for pairs of links. These links, at their outer ends, were pivoted in the jaws. The square end of the trunk acted as a guide for a crosshead inside it. This crosshead was pushed forward by a rod through the hollow trunk operated by a pneumatic cylinder bolted to the back of the trunk. Through the crosshead passed a transverse key, secured to the crosshead and a sliding fit in a slot in each gripping jaw. Forward motion brought the jaws inwards under the action of the links, so gripping the axle. The piston was single acting, the jaws being released by spinning the trunk-centrifugal force opened the jaws and returned the ram. Detachable inserts were bolted to the front of the jaws with internal projections to suit the type of axle being forged. These projections were needed for the special measuring system which will be described in detail.

Rotation of the trunk was through gearing from an electric motor mounted above the trunk. The motor and the guard over the gearing can be seen just in front of the operator's platform in Fig. 4. In its use of power, however, the machine was particularly interesting (from a historical point of view) in that essentially it was pneumatically operated. The two important functions of gripping the work piece and maintaining the height were both powered in this way whereas present day practice is to do this by hydraulic power. The only hydraulic operation was that of the vertical ram used for turning the axle end for end. To perform this operation the forgeman ran the cross travel right back from the hammer. The hammer driver then raised a

fork on the end of a hydraulic ram rising from the floor of the cross carriage and independent of the machine. The forgeman opened the jaws between the rails and his helper then turned the axle with tongs, the ram of the hydraulic cylinder acting as a bearing for this rotation. The forgeman then closed the jaws to grip the first (or finished) end of the axle.

The air compressor was on the ground and fed a large air pressure storage vessel. From this vessel a pipe led to the roof and thence by a flexible rubber pipe to the moving carriage of the machine. This pipe can be seen clearly in Fig. 1. There was also a smaller air bottle in the air circuit carried on the carriage to obviate pipe friction and give quicker operation. This again is historically interesting and quite against present day practice which is to carry the whole pressure installation including often air hydraulic recuperator on the machine itself.

At this stage of the description a most important point should be made; it is that the machine itself was made to measure all the lengths required during forging. Inside the gripping jaws were projecting lugs just wide enough to fill the journal part of the axle when forged, but projecting sufficiently for the front edge to act as a locating stop for the first forging, as shown in Fig. 3.

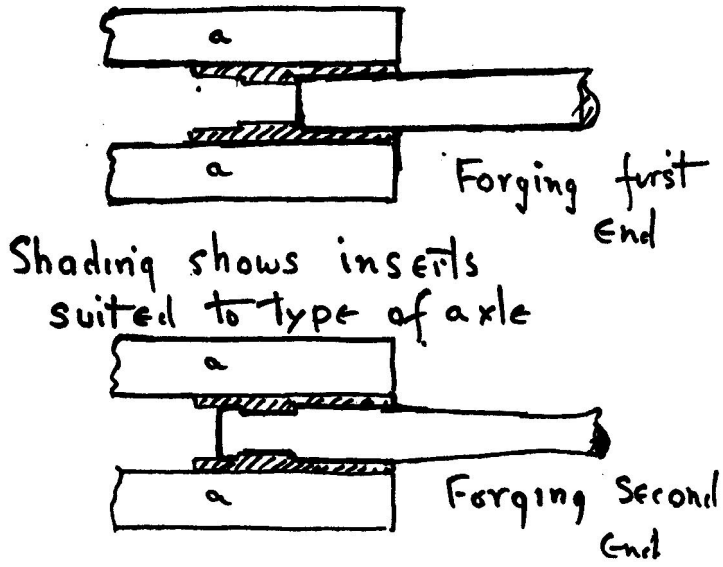


Figure 3: Location of axle in gripping jaws (a,a)

The relative positions of the hammer and the long travel carriage remained unchanged-all that was needed, therefore, was a measurement of the movement of the cross travel carriage; this was provided by a rail raised on supports from the long travel carriage. It can be seen in Fig. 1, looking like a hand rail. Lengths were read on this by a pointer fastened to the cross travel carriage just under the forgeman's right hand.

Two operators can be seen on the control platform. The forgeman or axle maker was able to work from the control platform because he did not have to go between the hammer legs to get his measurements of length. He operated the cross travel control himself, in accordance with his observations on the length measuring scale. On his left side was a youth who acted as assistant manipulator driver. The only other operator was the hammer driver-on the left of the hammer in Fig. 1. On the right can be seen the water boy; he sprayed the axle during forging to remove scale. The water pipe was fixed to the hammer leg; all the boy had to do was to open and close a valve. There seems little doubt that he could have been dispensed with and was, in fact, really a messenger and spare youth under training, but the extra hand was useful for such duties as changing tools, involving tupping key at the hammer.

The control of height during forging was a most interesting feature. The axle was lifted clear of the bottom tool during rotation between hammer blows. This was controlled by the forgeman; he synchronised the operation of the pneumatic lifting cylinder with the lifting of the hammer, lowering as the hammer descended. This did not need exact control, because the bottom position to which the trunk returned was controlled by a stop.

It is difficult to give a clear picture of this adjustable height control by a verbal description, and in Fig. 4. a cut-away view has been attempted. The stop operated on the lower arm of the left-hand rear bell-crank lever. It can be seen in Fig. 4. just in front of the wheel which is drawn cut away so as to show it. The stop was adjusted from blow to blow to correspond with the lowered centre line called for by the penetration of the hammer. The stop was moved by the assistant youth, through screw gear and chain from a hand-wheel with projecting spokes, shown in Fig. 4 on the left of the control platform.

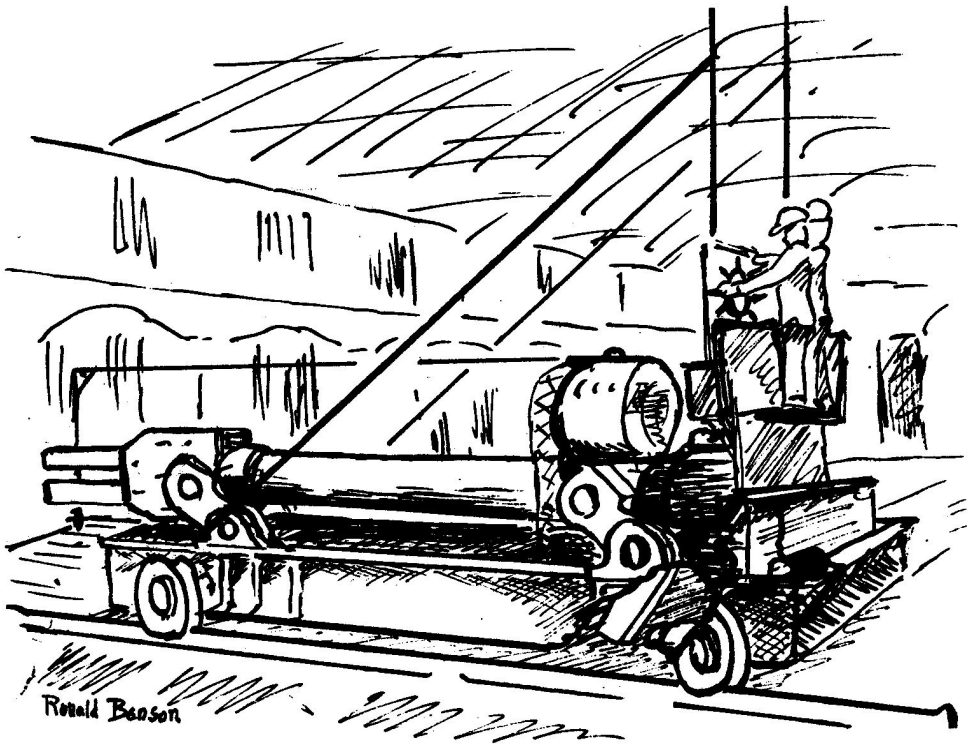


Figure 4: Height control mechanism

The spokes enabled him to get a very accurate estimate of the amount of screw-down applied. Thus there were two height controls: firstly a lifting movement controlled by the forgeman, between each hammer blow, the actual height of lift not being of critical importance; secondly a rigid control, by the assistant, of the height to which the trunk (and of course the axle with it) dropped, when allowed to drop by the forgeman. It should be noted that if the forgeman was a little late in releasing the lifting pressure, the hammer blow would force the peel down to the stop against the elastic pneumatic lifting pressure without damage, and also that during all these operations the centre line remained truly horizontal.

The assistant controlled the long travel, that is the movement of the main carriage to place the machine opposite either of the two grooves or passes in the forging tools. A pointer on the carriage, registering against two marks on the side of the pit, made this operation easy and exact; further movement of the main carriage was needed to fetch the heated blooms from the furnace and to take away and lay down the finished axles. Peel rotation was controlled by the forgeman's assistant, but required little attention from him, as a slipping clutch allowed momentary stoppage during contact of the hammer so that the motor drive could be left running continuously.

To sum up, the assistant operated the long travel, gripping, peel rotation and the height stop-the last being the duty which required continuous attention. He also turned the axle "end for end." The forgeman drove the cross travel and the lifting between blows. The latter must have become automatic, whilst the former engaged his full attention.

The complete change from older methods took some time to show its full value. Axle making was a traditional craft and a new skill had to be learnt; it was not, in fact, until 1927 that the possibilities were fully exploited.

When giving figures of output, it is important to say that most wagon axles are not machined for the whole length between the wheel seats, and that this black forged middle consists of two long tapers whose smaller ends meet at the middle of the axle. These black middles must be smoothly finished and free from marks, so that a considerable time must be spent, during forging, in planishing by numerous light blows of the hammer, whilst all scale is removed by spraying with water. If the middles of axles are to be machined, a much rougher finish is acceptable. Thus, whilst the normal output of black middled axles from the Baker plant was 12 axles an hour, much higher outputs (up to 18 an hour) were possible with some simple types and a rougher finish.

It is of interest to compare this machine and the system for making the axles which it made possible when it was introduced, 40 years ago, with the existing practice at that time. The conventional method of forging railway axles had not changed basically since the first axles were forged for the first railway in 1825 and even for the tramways before that. The material used was wrought iron and the hammers which forged it into axles were first water hammers, later steam-driven beam hammers, and finally the Nasmyth type of hammer. The change from wrought iron to steel was gradual, a preference by some users for the older material persisting certainly as late as 1920.

Axles have been forged in grooved tools (known to the trade as swage tools) for many years-the exact date of their introduction does not seem to be known, but it is interesting to note that the old water hammer at Wortley (now scheduled by the Ministry of Works for preservation as an Ancient Monument) has a pair of such tools, with two grooves or passes. Tools with three passes, known as "three-hole tools" have been used, but today the use of "two-hole" tools has become general practice again. The old axle hammers had tool faces as narrow as 15 in. or even less. The narrow face required less power and a 3-ton hammer was heavy enough. If the middle of the axle was of the same diameter throughout its length, these tools couldbe made to meet atthe required sizeand the axle passed backwards and forwards through the tools; when tapered middles were required, the tools could be made to meet at the smaller end of the taper and had to be "pegged up"; that is to say, separated by a peg or plate when forging the larger end of the taper; control of the longitudinal position in conjunction with the use of the peg required considerable skill.

Wider tools were introduced later, in some cases without alterations in handling methods. These wider tools needed more powerful hammers and also better guided tups in the hammers, because the wider tools led to off centre blows during forging. It should be stressed that the Baker manipulator, with its built-in scale for measuring lengths, did not call for the forgeman, or anyone else, to go "inside the leg" and enabled a hammer with extended guides and arches less than 5 ft. high to be used. The hammer was in fact more like a stamping hammer than a normal forging hammer.

The traditional method of handling axles during forging differs little from the method used for making general forgings under power hammers, which is still used today where manipulators have not been provided. It is well known, and is only re-examined here to show how the development of mechanised handling grew from it and replaced it. The axle maker has from a quite distant past supported his work-piece in the loop of an endless chain hanging from a pulley wheel suspended from a crane-usually a hand-operated crane with a pivoted jib. The forgeman (i.e. the axle maker) rotates the

axle between blows by means of some form of cross bar or turning stick attached to a staff or tongs, clipped or bolted on one end of the job. The supporting chain is placed a little behind the centre of the forging, that is, nearer to the forgeman so that the first half of the axle can reach the hammer tools. When the first half is forged, the tackle (as the tongs or staff are termed) must be taken off the unforged end and the axle turned "end for end," and tackle fastened to the finished end so that the second end can be forged. As the supporting chain is behind the middle point of the material, the axle is "heavy on" and tends to lie in the bottom tool between blows of the hammer. It is lifted during rotation either by a chain-suspended lever or by the forgeman "weighing on"; that is to say pressing down the tongs as he turns; the heavier the tongs the more they act as a counter balance, and the less effort needed for this latter method, but the greater the labour of handling the tongs themselves.

The hammer lever man and his skill is too wide a field for discussion here-in the old days lever men grew up on the job from being lads, and the lever was almost a part of the man. This was essential; if the point of the lever were ever in contact with the forging, when the hammer hit it, the handle would shoot the lever man high in the air with serious, possibly fatal results. In these days of mechanised handling, skilled lever men are becoming hard to find. The forgeman also controls the longitudinal position of his axle, in the forging tools, by pushing in or holding back on the cross bar during rotation. This is particularly needed to "clean out" the journals. The journal is a portion of rather smaller diameter at each end of the axle, with a collar on the outer side and the wheel seat on the inner side. This journal is formed by projecting portions inside one hole in the hammer tools. The other hole in the hammer tools is usually tapered to form the tapered middle part of the axlehere again longitudinal position has to be carefully controlled.

Measurements of the longitudinal position are needed to forge the journal and middle in their correct positions. The hammer is raised whilst one man holds a measuring rod on the axle.This is a steel strip, often about 1 in. x 1/4 in. section, on which the required lenghts are chalked. Another man observes the position relative to the side of the tools and signals for the axle to be moved in or out as required; as each part of the axle is finished its correct position has to be maintained, and repeated observations are required. The diameter of the various parts of the axle is controlled by the grooved tools, which meet face to face when producing the size required if the tools are wide enough; a width of 28 in. to 30 in. is needed; with narrower tools, pegging up is needed.

The correct height of the crane has to be controlled carefully, to avoid shock to the crane and bending of the axle during forging. Ability to withstand shock is usually provided by a coiled spring suspension between the crane and the top chain wheel.

To sum up, therefore, the six basic requirements are listed below. It will be seen that the plant, designed by Mr. George Baker 40 years ago, made provision for all of them.

(1) Gripping firmly and releasing easily.
(2) Rotating during forging.
(3) Lifting between blows during rotation.
(4) Maintaining correct height of centre line during forging, allowing it to descend as the diameter decreases.
(5) Measurement of length during forging.
(6) Ability to withstand shock.

Since that time quite a number of firms have used manipulators for forging axles, but it cannot honestly be said that any of them show any improvement on this comparatively old design.

The writer has put forward the view that, if a new machine were required for axle making today, a radically different approach would be the answer; quite possibly it would take the form of a selfcontained machine with the axle vertical, built-in

manipulators at top and bottom and a horizontally opposed press to do the actual forging-the whole under the control of one man. It seems unlikely, however, that present-day requirements will justify the building of such a machine in this country.

DISCUSSION

Mr. W. K. V. GALE (Past President), congratulated the speaker, and said that all too little had been written about the history of iron and steel forging. Consequently the Americans and Germans had gained most of the credit for development-as usual.

John Baker & Co. contributed much to the art but if little has been known hitherto of what the firm did, the blame rests squarely on its own shoulders. If ever a firm believed in closed doors and "Keep out" notices, John Baker did! Kilnhurst Steelworks was one of the very few steelworks which existed in my time which I never visited, but Mr. Benson, who would no doubt have been even less welcome than I was, since he was in the same line of business, evidently persevered more, and he found out much that is worth recording. I am very glad that he has put it down in writing, and look forward to hearing from him again, for I happen to be aware of the fact that he knows a great deal more than time has allowed him to tell tonight.

It might be worth while, to round off the story, to say that the old firm of Baker, which absorbed the business founded by Henry Bessemer and changed its name to John Baker & Bessemer Ltd. in 1929, is no more. The firm closed down in 1963 after having been taken over by a consortium of companies engaged in the same business. The main details of the history of the firm have been well recorded in a little book entitled The `Steel' Bakers of Rotherham written by Mr. Henry Baker (Member) and published privately in 1960. There is a copy in the Society's library.

Mr. BENSON, in reply to a query on the comparative reliability of axles of steel and of wrought iron, said that as steel had a higher elastic limit than wrought iron, the risk of fatigue failure arose at a higher stress in steel. On the other hand, the longitudinal structure of wrought iron made it less likely that with that material the cracking of one fibre would spread to the next and so propagate a fatigue crack.

Apropos the operation of steam hammers, Mr. BENSON said that in the Baker Bessemer works there still stood the last of the big hammers: a 15-ton steam hammer which was bought in Darlington in 1893, sold to Baker Bessemer in about 1904, and was still working when they closed down. There had been a great deal of interest in the hammer in Darlington, and the curator of the Bowes museum was anxious to get it and would like it put up as the entrance arch to the projected Folk Museum.

The present owners (English and United Steel jointly), he thought, would give it away; but the cost of transporting and re-erecting it would not be light. This hammer was known by the nick-name of "Tiny Tim."

A member stated that, as late as 1963, a Nasmyth steam hammer dated 1914 was still being worked at Ruston's by a family team-father, two sons and mother. Mr. BENSON knew that this system of "Littlemasters" working steam hammers had been general in Sheffield at the turn of the century. He had not heard of it in operation since the first world war.

CORRESPONDENCE

Mr. C. R. Blick wrote:
The steam hammer now exhibited at the Open Air Museum, Beamish, County Durham, is a 25 ton Nasmyth which was salvaged from the site of the Kilnhurst Steelworks of John Baker & Bessemer Ltd when that works closed down in 1963. Known as Tiny Tim, it had been at Darlington Forge until it became surplus to requirements as long ago as 1910 when it was sold for further use by (the then) Baker Bros Ltd who removed it to Kilnhurst Steelworks. Initially it was used at Kilnhurst for roughing out disc wheel centres, but was later used only for forging turbine rotor discs. When the Kilnhurst Works was demolished in 1963, it eventually stood alone and forlorn on a cleared site. It very nearly succumbed to the scrapman's torch but the very tender idea `conservation' was just stirring in those days and Tiny Tim was salvaged and sent back to Darlington Forge for storage until space could be found for it in a museum. It was acquired by Beamish Open Air Museum when that was established in the 1970s.

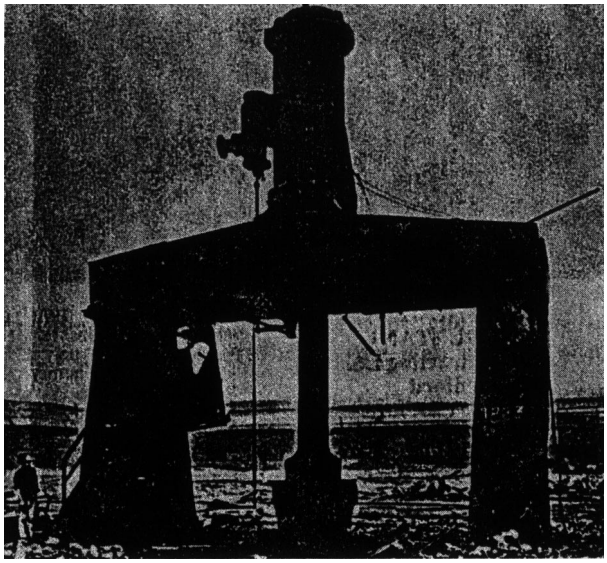


Figure 5: Nasmyth hammer Tiny Tim at the former Baker & Bessemer site during site clearance

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