WIRE DRAWING.

R.A. CROSSLAND

Wire Drawing

(With particular reference to the Thurgoland district of South Yorkshire)

by R. A. Crossland

An individual study undertaken at Loughborough Training College for the Supplementary Certificate of Nottingham University

1958

Contents

		Page
Introduction		1
Chapter I	The History of Wire	5
" II	Early Wire Drawing in England	8
" III	The part played by South Yorkshire in the development of the Wire Industry	11
" IV	The introduction of mechanical mills for Wire Manufacture in England	12
" V	Techniques in the early days	15
" VI	Techniques at the Old Wire Mill in the 19th century	21
" VII	Wire Manufacture in the Thurgoland District in the early 20th century	28
" VIII	The wiredrawers of the early 20th century	31
" IX	Modern Wire Manufacture	34
Conclusion		40
Bibliography		41

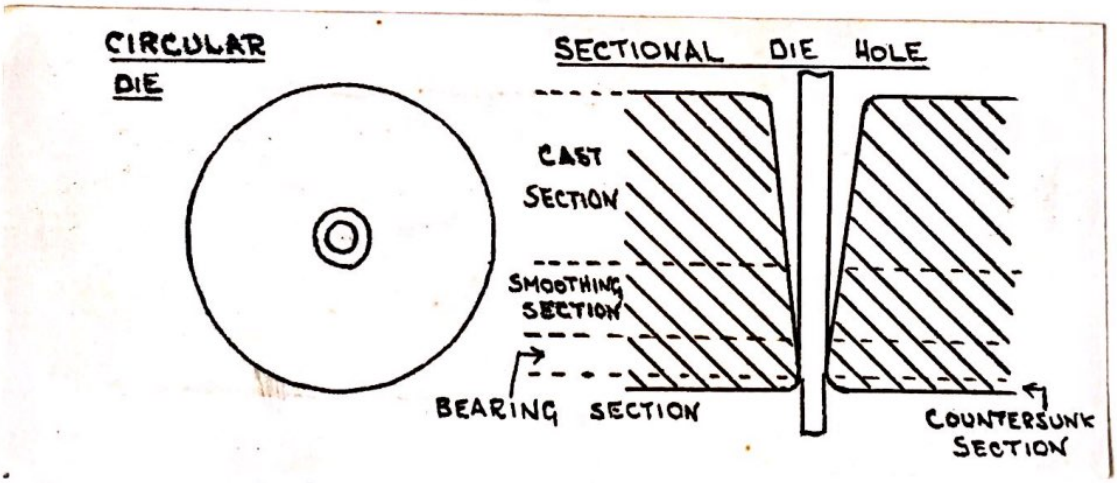
Wire Drawing, with particular reference to the Thurgoland district of South Yorkshire

---

Introduction

The adaptability of wire to the making of articles of use in man's service has expanded until it is now recognised as the product of some 150,000 uses. The growth and development of the industry may perhaps be more readily understood if an outline of present day wire manufacture is given briefly.

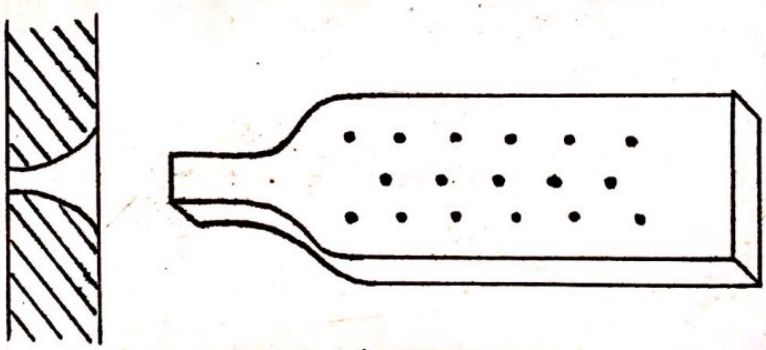
The smallest diameter of steel rod which can be economically produced by hot rolling is about 7/32". Below this size, friction between the rolls and the steel rod increases due to the rapid formation of scale, and the rod cools so rapidly that further reduction by this method becomes impracticable. The processing of rod into wire is one of drawing or pulling it, first through a lubricant to assist the reducing action and then through a series of dies suitably shaped and each smaller than the previous one. These dies (illustrated here)



are circular in shape and for the purpose of drawing wire which is round in section, have a circular hole through the centre. The hole is cone-shaped, tapering towards the exit where its diameter is less than that of the rod to be drawn through it. Each pass or draft through successive dies results in a reduction in diameter and lenghtening of the rod. The process is one of cold reduction with no consequent formation of scale and can therefore

be used to advantage for drawing rod of up to 5/8" in diameter, the finished surface of which must be smooth and bright, as for example in the production of ball steel for bearing manufacture. Uniformity of size to narrow tolerances and an increase in strength properties resulting from the drawing process are particular advantages and greatly increase the range of uses which wire will serve.

Wire drawing dies are made of an extremely hard material, tungsten carbide, or for very fine wire, from diamonds. The tungsten carbide dies have a very long life, but are expensive to produce when required to draw wire of any section other than circular. If shaped wire is required in small quantities it is drawn in the smaller mills by an age-old process, through a steel draw plate or wortle.



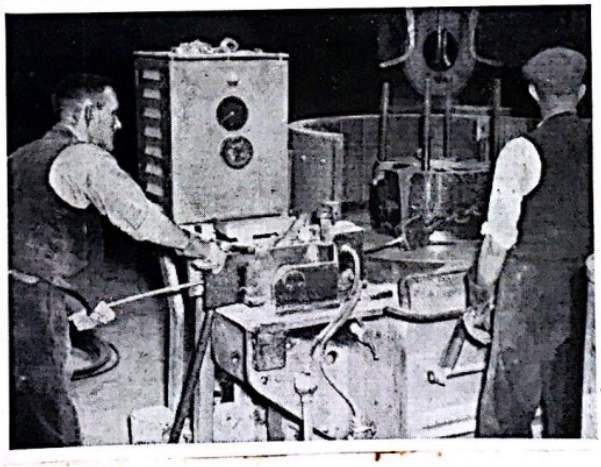
WORTLE PLATE

Tapered holes are made in the plate by means of high carbon steel punches and wire drawing by this method is a highly skilled craft.

Rod is supplied in coil form and before drawing begins must be annealed or softened by heating in a furnace to make it ductile and malleable. During the heating process, a scale forms on the surface of the material; this is removed by passing the rod, zig-zag fashion through a series of pulleys, as a

result of which the scale is broken off. The remainder is removed by pickling, that is, dipping the coils in an acid solution. Thorough washing removes most acid but dipping the coils in lime neutralises remaining traces. The lime coating used in conjunction with a lubricant assists the drawing action by reducing gliding friction in the die. The last operation before actual drawing is the drying of the wire. Formerly done by resting the coils near the annealing furnaces or in the sunshine during summer, special drying ovens now deal with the process in from two to three hours.

The actual drawing is done by a motorized block rather like a ship's capstan. The coil is placed on a feeding swift and the leading end of the rod is pointed on a swaging or reducing machine and in some works by heating to redness and stretching until it breaks into a conical point. This end is passed through the lubricant and the die, gripped by tongs attached to a pulling-in machine, and drawn slowly through the die as in the illustration.



When a length of two feet or so is drawn the end is released, the wire gauged for size with a micrometer and then securely fixed to the block which is then set in motion. The wire is wound round the block and on completion is passed on to the next process. When the required size is reached, for which several annealings and cleanings may have been necessary,

the wire may be polished by passing it through emery cloth, or it may proceed in an unpolished state to the next stage of manufacture.

Chapter I.

The History of Wire

In order to trace the development of the art or mystery, to use the terms of old apprentice indentures, of wire making, mention must be made of the first wire known to us through archeological research. Dr. Flinders Petrie in an article he contributed to "Ancient Egypt" in 1915 states that copper is the earliest metal of which we know anything in Egypt. It was discovered in the form of pins in prehistoric burial grounds along with the remains of bodies wrapped in goat skins. Dr. Petrie goes on to say that about 6,000 years ago, copper wire was made by cutting strips of thin sheet copper and hammering them to shape. Such wire was used to tie boxes together, to make bracelets and even to fix wall tiles. Similar methods of metal working were used by goldsmiths to make the bracelets found by Dr. Petrie in 1901 on the arm of a mummy in the Royal Tombs at Abydos in Egypt, which he estimated to be about 6,500 years old. I have purposely spoken of this as wire-making differing as it does from wire-drawing as previously described. The origin of wire drawing is not known but it is possible that the earliest die was a hard stone such as was used by primitive man as hammer or axe. This seems reasonable in view of the discovery, in ancient lake dwellings, of stones with one or more holes through them, and which antiquaries have labelled as "objects of unknown use". Bronze wire found on the site of a lake village near Maybole in Scotland round about the year 1879 is mentioned by Munro in the "Lake Dwellings of Europe" as dating to 1,000 B.C. and it is said to bear strong evidence of having been drawn through a stone wortle. Corroded iron, some of which had been wire chain work, was found by Thomas Bateman in a mound known as Hurdlow, near Buxton, in 1849 and is said to be of the Anglo-Saxon period say 440 - 1066 A.D. John Wilson, the Antiquary of Broomhead Hall, Bolsterstone recorded how William Earl of Strafford when making the south front of his house at Stainborough, near Barnsley, discovered during the foundation excavations in 1762-63, a square place walled round like a grave in which lay a man in armour. The earl sent some of the armour to the Royal Society and it was then judged to belong to the time of the Norman Conquest.

Made of wire, parts of the armour were studded with silver. The most confident estimate of the first wire drawing to be practised in Europe is given by O.H. Dohner in his book "The History of the Iron Wire Industry". In it he speaks of the origin of the invention of drawing as dating to a time between the 1st and 4th centuries A.D. when large quantities of wire were needed for the manufacture of shirts of mail. He imagines the wire to have been first forged out of pure iron which, after scouring to remove scale, was drawn by means of a plate stuck by its pointed end into a tree stump. Annealing as required could have been carried out in an open charcoal fire. The drawer would sit in a rocker, a similar arrangement to a child's swing, and, by bracing himself with his feet against the tree stump, could exert enough pull on his tongs to draw the wire through the hole in the plate. Marks made by the tongs would remain on the wire after each pull and yet it is understood that this method was continued in Sweden and Russia until early in the 18th century.

An old Latin manuscript by Theophilus a

Chapter II.

Early Wire Drawing in England

It has been discovered that draw plates or wortles were in use in York and in Barnsley in the 14th century. In the Register of the Freemen of York it is recorded that one Rad of Nottingham, a "wire-dragher" was admitted in 1300 A.D. to the privileges of a free-man of the City of York and the names of eleven card makers of the 14th century are also preserved. The "Gild Regulations" which are said to date from the 12th century forbad any York man to buy card leaves from Coventry for sale in York under a penalty of forty shillings. Rivalry evidently existed between York and Coventry where hand drawing was carried on to an extent of affording sufficient work to employ three men making wortles. The Coventry Leet Book names them:

A.D.1432. Joh. Smith - Writel-maker
A.D.1434. Tho. Smith - Writel-maker
A.D.1434. Will Smith - Writel-maker

The same book throws more light on the history of the wire trade, the following showing that the craft claimed an important position in the city. In A.D.1430 the Wardens of the "Wiredrawers of the City of Coventry with other worthy men of the same craft" sought permission of the chief magistrate to meet the whole of the expenses involved in the upkeep of the new canopy over the altar in the Church of St.Michael. The desire of the wiredrawers for equal recognition with other trades shows that they were proud to belong to the craft. Proof of the latter is demonstrated by a request made by the Guild to the Mayor in which "the worthy men of the craft" ask the Council to exercise vigilance over certain unworthy members. It is in the form of a bill delivered to John Euerdon, Mayor of Coventry in 1435 in which they ask the City Council to preserve the good name of Coventry by prohibiting certain abuses which were arising. These abuses are so naively described that the Council must have seen how grave they were in the eyes of the Guild members; the Council rose to the occasion and made the necessary ordinance. I think a part of

the bill is well worth recording here:

"September 14, 1435. To the Reverend Mayor of the City of Coventry, and to all worthy men of the same; for alsomuch as it is necessary and needful to every Governor of City and of Town to see such rule and governance may be had by the which the King's people may be truly ruled and demeaned; be it known to you that if certain ordinances of Crafts within this City, and in Special the Craft of wiredrawers, betaken good heed of, it is like much of the King's people and in special poor chapmen and clothmakers in time coming shall be greatly hindered; and as it may be supposed the principal cause is likely to be amongst them that have all the Craft in their own hands, that is to say, smythiers, brakemen, gurdelmen, and cardwire drawers, for he that hath all these crafts, may, offending his conscience, do much harm. First in the smithying, if he be negligent and misrule his iron that he worketh, by unkind heats or else in other manner the which when it is so spoilt is not to make no manner of chapman's ware of. Nevertheless for his own ease he will come to his brakeman and say to him; "Here is a stone of rough iron, the which must be tenderly cherished" and then the brakeman must needs do his Master's commandment and doth all that is in him that the master supposeth will not in no wise be holpen at the girdle. Then it shall be sold for hook wire. And when it is made in hooks and should serve the fisher to take fish when it cometh to distress. Then for feebleness it also breaketh, and thus is the fisher foully deceived to his great harm. And then the wire which the master supposeth will be cherished at the girdle, he shall come to his girdleman and say to him as he said to the brakeman; "Lo here is a string or two, that hath been misgoverned at the hearth my brakeman hath done his duty, I pray thee do now thine" and so he doth as his master biddeth him. And then he goeth to his cardwiredrawer, and saith the same to him and he doth as his master biddeth him. And then when the cardmaker hath bought this wire thus deceivably wrought he may not know it till it come to the crooking. Then it cratcheth and fareth foul; so the cardmaker is right heavy thereof, but nevertheless he seeth because it is cut, he must needs help himself in eschewing his

loss, he maketh cards thereof as well as he may. And when the cards have been sold to the Clothmaker and should be occupied, the teeth break and fall out anon, so the clothmaker is foully deceived. Wherefore sirs, at the reverence of God in furthering of the King's true liege people, and in eschewing of all deceits, weigheth this matter wisely and there as you see deceit is like to be, thereto setteth remedy by your wise discretions. For you may right well know by experience that and the smythier and the brakeman work together and no more, and the cardwiredrawers and the middlemen together and no more. Then it were to suppose that there should not so much deceivable wire be wrought and sold as there is; for and the Craft were severed in the manner as it is said above, then the cardwiredrawers and the middlemen must needs buy the wire that they shall work of the smythiers, and if the cardwiredrawer were once or twice deceived with untrue wire he would beware and then he would say unto the smythier that he bought the wire of: "Sir, I had of you late bad wire. Sir, amend your hand, or, in faith, I will no more buy of you." And then the smythier, lest he lost his customers would make true goods, and then, with the grace of God, the Craft should amend, and the King's people be not deceived with untrue goods."

Members of the "Wiredrawers Gild" totalled over 100, each man doing his own particular work. The smith forged down the iron bars into convenient sizes for the brakeman. The brakeman drew the bars through a coarse wortle by means of a hand lever or brake. I have heard the term "breaking down" applied to the first drawing of thick wire, in my own district - and the girdler annealed the wire. The middleman was the cleaner who removed the scale after annealing and he passed on the wire to the cardwiredrawer who drew the wire down to finished size before it was sent to the crooker whose task was to cut the wire into short lengths and bend them ready to make into cards or fish hooks. The cardmaker finally made the hand cards used in preparing wool for clothmaking. This might seem to be worked on a factory system, but in fact, all but the smith and the brakeman worked in their own homes.

Chapter III.

The part played by South Yorkshire in the development of the Wire Industry.

No wiresmiths or wiredrawers are mentioned as living in my own district of Thurgoland in the Poll Tax Returns of early 14th century but in those for 1379 a man named "Platesmyth" is mentioned as living in the village of Barnsley. It can be assumed that he made drawplates or wortles but the next evidence of Barnsley as a wire drawing area does not occur until about 1598. At the Barnsley Sessions of the Assizes, Francis Ellis, a juror stated that "there were from 500 - 600 tradesmen in the town such as wiredrawers, colliers and labourers, the greater part miserably poor." Richard Blome, in a "Description of the British Isles" published in 1669 writes that "Barnsley is situate on a hillside and near a brook. It is a reasonable well-built town with stone houses and hath a good market on a Wednesday, provisions, mault, all sorts of grain and wyre are here made, which is the only manufacture of this place."

The "Universal British Directory" published in 1798 in describing Barnsley says - "The town though it is well built of stone is called "Black Barnsley", but whether from its forges, which are continually smoking, or from the neighbouring moors, which have a sooty aspect like Blackheath, is not certain. It drives a considerable trade in wire and hardwares made of iron and steel. The wire manufacture is of considerable antiquity here and supposed to be the best in the kingdom from the goodness of the materials and the ingenuity of its artists. They manufacture two sorts, hard and soft wire; the hard is used for cotton and wool cards teeth, and the soft is used for stocking frame needles. There are eight wire makers. Hunter in his work "South Yorkshire" states that the manufacture of wire existed in Barnsley in the reign of James I 1603 - 1625, that Barnsley produced the best wire in the kingdom and that the industry declined in the end of the 18th century when linen making began.

Chapter IV.

The introduction of mechanical mills for Wire manufacture in England.

I have mentioned in a previous chapter that water power was used by Germans for wire drawing in the 14th century. It seems almost incredible that the idea of adapting the water wheel for use in wiredrawing was not thought of in England until much later; this is even more puzzling when the history books tell us of the existence, in almost every village, of the manorial corn mill, driven by water power.

In an article contributed by Mr. J. Phillips Bedson to the "Journal of the Iron and Steel Institute" for 1893 the author says he believes that the Tintern Abbey Wire Works in Monmouthshire were originally started in 1575 by four families who came from Germany. He describes their method as follows:

"They first hammered (called tilting) the charcoal rods into 1/4" square rods which afterwards they drew through drawing plates but not onto blocks. This was effected by means of a long pole which had a reciprocating motion, actuated by a water wheel and in this way worked backwards and forwards. In the forward stroke it drew the rod and wire through the plate, and on its return stroke, both of which were very slow, the workman sat and coiled up the length drawn by hand into a ring, and thus continued until the whole piece was drawn. The annealing was done in a kiln or brick oven where the wire was heated to redness and allowed to cool naturally. This formed a lot of scale which had to be removed by hammering and then scoured in a barrel filled with wire and gravel and caused to rotate by water power, half immersed in water for about twelve hours, when the wire was taken out, coated with flour-lees and ready for drawing on.

J. Bucknall Smith in his book entitled "Wire, its Manufacture and Uses" says that the first fully mechanical wire mill was erected in Surrey in 1663 but tradition asserts that the Old Wire Mill at Thurgoland may have been built in 1624. Originally a one-storey building, the mill was

taken down and rebuilt as shown in this photograph

on the old foundations sometime during the first half of the 19th century. The original date stone was marked 1624 and was included in the mill but has since disappeared with the closure of the mill in the early 1920's, since when it has been converted by the local Council into a water pump house. I have been unable to discover the name of the first owner but it may have been a William Wood whose son of the same name had a slitting mill bequeathed to him at Colne-bridge near Huddersfield. In "The Journal of Mr. John Hobson" included in "Yorkshire Diaries" published by the Surtees Society in 1871 the following is of interest in this connection.

1228-9. January 1st. Wednesday. This day, as Mr. Jonathan Swinden of Wortley Wier Miln was going along to Penistone with Mr. Fenton about 9 a clock in the morning, he was seized with an appoplectic fit and dropt of from his horse into

a little running water, nigh Shepperd Castle whither he was carried and died there about 7 of the clock at night. His unkle Mr. John Wood of Wier Miln who left him the estate died in such a fit." Referred to as the "Wortley Wire Mill" this is the one referred to by the writer of "The Tour of the Don" published in 1837 which is described as follows: "This is the old wire mill, so called to distinguish it from two or three other similar establishments a little lower down." Weight to the conjecture that the Woods owned the mill is lent by the fact that men of that name worked for more than a century at the trade. The industry must have been a flourishing one for in 1630 Charles I issued a proclamation forbidding the imports of wire from Europe because the home produced supply was sufficient both in quantity and quality. In this area the charcoal iron bars were forged at the Wortley Forges and the nearby Tilt Mills and the best were selected for processing into wire.

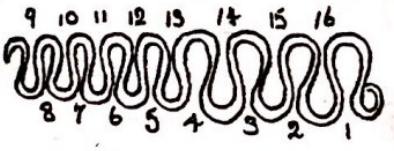
Chapter V.

Techniques in the Early Days.

Slitting of forged iron into strips for the smith to forge again into roughly circular section, all hand work, was superseded by the water power driven slitting mill and tilt hammer. The latter is said to have originated in England in the Forest of Dean early in the 16th century and the Tilt Mill of Thurgoland was working in the 17th century. Forged sheets from it were sent to the Old Wire Mill close to which stood a slitting mill, the machinery of which may have been brought by William Wood from the mill at Colne Bridge which was bequeathed to him. In this mill the sheets were slit into strips as wide as the sheet thickness. The edges of these strips were forged to give them a roughly octagonal section; in the smithy attached to the wire mill, after which they were pointed and passed on to the breaker-down or rumpling machine in the wire mill to be dealt with by the brakeman or first drawer. The early wire drawing block was made of wood both for hand and water power and for the finishing sizes hand drawing round such a block was still in use until late in the 19th century as shown in this photograph.

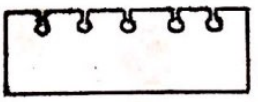
The gearing of the first mills such as bevel and other toothed wheels was almost entirely of wood and the water wheel shafts were of heavy oak beams as was the framework and shafts of the tilt hammers at the forges. The date when a wooden block was made sufficiently strong to bear by wooden gearing the strain of drawing wire as a continuous process through the full coil length is not known but the Tintern Abbey Works did not begin in 1575 with such a block. Provision was always made for drawing to continue by hand when, in summer, the water supply was insufficient to turn the wheel. The block was put out of gear and a bar placed across the block so that it could be turned by two men. J.Phillips Bedson records that the method in use to enter the wire was to pull it in by means of a cam and lever attached to the pulling in tongs at short ratches, and after each ratch, to grip the wire with the tongs and repeat the process. This caused marking of the wire each time it was gripped and meant that with small weights of wire wastage was considerable.

First attempts to measure the size of the drawn wire appear to have been made by using a piece of stiff iron wire bent to form a SHAPE as shown



FRENCH BENT WIRE GAUGE

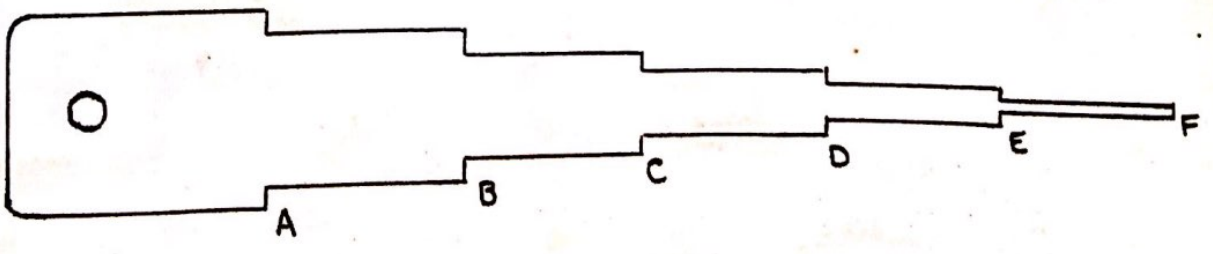
A slot gauge came next



FRENCH SLOT GAUGE

and these, both of European origin were followed in England by a step gauge in the 18th century.

STEP GAUGE FOR THE DRAFT OF WIRE (18th)

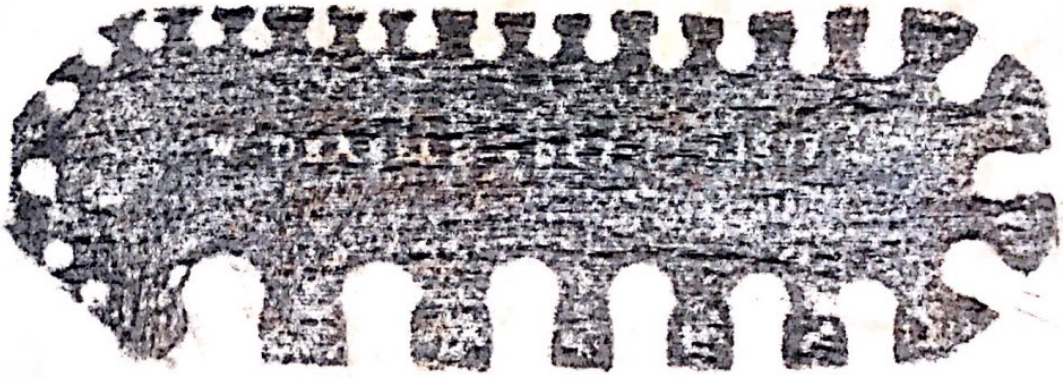


The skill of the wiredrawer in those days would lie in punching the hole in the wortle to such a size that the wire would be reduced sufficiently in diameter but would not break in the process. The step gauge which was simply a brass plate had steps cut at one end and was called a "size". The steps measured the increase which a certain length of wire should gain when passing through a certain hole. Referring to the sketch, AB was the original length of wire and AC, AD, AE and AF would be the lengths it would assume when drawn through successive holes. If the wire was found to stretch too little or too much with resultant breaking, the hole would be widened by driving in the punch, or contracted by hammering round, but never on, the exit side of the hole in the wortle whilst it was cold and re-punching. When all the holes had been used so many times that they could no longer be re-made, the wortle would be heated and hammered or "battered" to use the wiredrawer's term in order to close up the holes for re-opening as required.

As the drawer became able to guarantee wire size, customers began to order their requirements by gauge number and attempts were made to evolve a standard gauge.

Certain manufacturers in Warrington approached a man named Stubs asking him to make gauges to their standards. These were later subdivided into various other sizes and numbered to suit one of the largest manufacturers. This gauge was later adopted by other manufacturers of wire and became known as the Stubs Standard Wire Gauge. One, used in the Old Wire Mill at Thurgoland, has been carefully preserved and is in the possession of Mr. Fred Beet whose ancestor William Beet is mentioned in White's "History and General Directory of the Borough of Sheffield for 1837" as being "wiredrawer and coal owner of Wortley".

He has kindly given me permission to take a rubbing as shown OVERLEAF.



the date is 1829.

The Associated Chamber of Commerce appointed a Wire Gauge Committee in 1881 and in 1882 a new gauge was submitted. It was declared in 1883 under the Weights and Measures Act and made legal as the Imperial Standard Wire Gauge in 1884.

In mills erected where water was not available as a source of power, and there is no record of Barnsley having a water driven mill, horse power was used. Even as late as 1840 the Barnsley smith was reducing iron bars to a convenient size for the brakeman to draw into wire through a coarse draw plate on a horse driven block but without either water or steam power. I have mentioned previously that the trade declined in the late 18th century and in 1821 only two makers of wire remained in business in Barnsley. At one of these mills, that belonging to William Horsfall and Co., the late Mr. George Winterbottom learned the trade. He founded the firm of G. Winterbottom and Co., Needle and Fish Hook Wire Manufacturers of Oxspring Wire Works and in a paper which he read to the Stainboro' Literary Society in 1899 he describes fully the methods used during his lifetime. Before the installation of the steam engine for drawing wire in 1840 or 41, he relates that wire was first dealt with by a hand process called "planking" from the bench constructed of very strong planks. At one end of this bench was the standard or upright bar of iron against which the draw plate was fixed. The drawplate, a piece of flat steel about 9" long x 5" or 6" wide x $1\frac{1}{2}$" thick had three rows of conical holes

punched through it for drawing the wire. At the opposite end of the bench was the gearing, wheels worked in a rack to which was attached a strong pair of tongs which laid hold of the wire and pulled it through the drawplate a few feet at a time, until the whole of the rod was drawn through the plate. After drawing, the wire was coiled up and annealed in a large brick oven. After annealing it was scoured in order to remove the scale. It went through the "plankers" and annealer's hands four times, the process of planking being very laborious so that in summer time only boots, trousers and aprons were worn. After planking the wire was taken to the horse blocks which were worked by bevel gear fixed under the bench and driven by horse power in similar fashion to the old threshing machines on farms. When the wire left the horse blocks it was small enough to be drawn by hand by the "finishers". This was done on a wooden block about 7" in diameter and 9"deep with a lever through the top for hand turning. In all the drawing the wire had to be annealed and cleaned as was done with the larger sizes and before the introduction of sulphuric acid the wire had to undergo a pickling in swill "a most disagreeable mess to work in." The story of how this method first began is interesting in showing the part played by chance in so many new inventions, stainless steel being a particularly good example. In the case of wire pickling, however, it is said that Johann Gerdes of Altena in 1675 attempted to draw steel wire for the first time. He tried to draw it in the same way as the tough but soft Osemund iron was drawn and was so unsuccessful that he threw the steel wire onto a "certain place where everybody went to excrete his water." Some time later he attempted to draw the wire again and was astonished at his success. The water had worked as a lubricant in a similar way to the more modern wet drawing process of using copper sulphate, sulphuric acid and brewer's yeast. Mr.Winterbottom shows that it was still in use in England in the 19th century. He goes on to say that with the coming of steam and water power the trade became a much more pleasurable one and Yorkshire wire maintained its character as the only wire fit to use for making the best quality needles. The

steel came in straight rods of about one pound each in weight as rolling mills could not roll lengths of more than 10 or 12 lbs. each. From this history of the trade we see that the occupation of "brakeman" mentioned in the Coventry Leet Book in 1435 survived in Barnsley until the 19th century under the name of "planker".

Chapter VI.

Techniques at the Old Wire Mill in the 19th century.

Details from a paper written by the late J. Kenworthy and P. Longmuir for "Engineering" in 1913 enable a very clear picture to be built up of methods in use up to the beginning of and even into the present century.

The wortles examined by the authors were of puddled steel bars and an analysis of two of them showed a carbon content of 1.38% and 1.75%. They confirm Mr. Winterbottom's statement that rods were rolled in small weights and also state that they were tested by nicking, breaking and examination for soundness - probably "piping".

Annealing of the rods in an open oven was the first stage. Cooling in air followed and the scale, formed during annealing, was removed in a scouring barrel such as is shown in this photograph

Between 5 and 10 cwts. of wire were loaded into the barrel (shown with its end removed) and a barrowful of blast furnace slag was packed in with it. The end was bolted on to the barrel which was then connected to the water wheel. The barrel stood in a trough about 1' deep, more water was piped on from the mill stream and then it was put into gear. After a period ranging from 12 to 24 hours the wire was removed in a wet but clean condition and allowed to stand until a coat had formed on the surface of the wire by the action of the water. This coat was preserved by dipping the wire in starch. Drying the wire followed, this taking place either in the sun in summer as in this photograph

or on a carrying bar supported on stone pillars in front of the annealing ovens as in the next photograph.

At Thurgoland each drawer carried out all these operations himself as well as the actual drawing. The first two drawing holes in the wortle drew wire scoured in the barrel but in the later stages in drawing the wire was cleaned in swill for which a house-to-house collection was made.

Scale, caused by annealing, on the small sizes of wire was removed by "kinking" on a large clog of wood. This "kinking" every inch or so, and knocking on the clog was similar to the later method of banging but was done before cleaning. Cleaning came next and the wire was dried as previously mentioned. After drying the

wire was scoured by hand on a set of wooden pegs as shown in the photograph.

The box shown in the photograph held the scouring sand (although when boys did this work and had to provide their own sand they often kept it in the safest place - a trouser pocket) and the method was this. The coil of wire was put on the swift (shown in the foreground on the photograph) and the leading end of wire fastened to one of the pegs. Slack wire coming off the swift was held taut in a cloth by the left hand of the scourer. In his right hand he held thicknesses of oily flannel and sand and he rubbed this up and down the taut wire which he then looped over

the next peg and took another length for scouring. After the full length had been so dealt with the wire was replaced on the swift and the process repeated. It would then be drawn through two or three holes according to the diameter required. This was called jigging or common drawing and would be followed by annealing, kinking and cleaning, special care being taken to get a good surface finish on the wire. This would be followed by hand scouring either in the mill as already described or by women working in their own homes. As a boy I well remember my father showing me the cottage in which lived a very old lady known in her younger days as an excellent scourer of fine wire.

The reduction in finishing was about one gauge per hole and most of the needle wire was finished by hand drawing on a wooden block. Such a block is shown in the photograph

together with the essential tools. The wortle is at the bottom of the upright standard and in order to get even winding of wire onto the block, the wortle would be moved up and down the standard. A gauge similar to that shown in the previous rubbing, hand pulling-up tongs, a file for pointing the wire and a battering hammer and punches are also shown. Careful inspection of the hammer shaft shows the wear caused by the drawer's thumb.

This next photograph

shows an old swift used for pulling the wire

through scale-breaking pegs. This would be fixed on a bench and the wire threaded in and out of pegs fixed in a straight line. The principle is mechanically applied today for scale breaking in a modern mill.

Chapter VII.

Wire Manufacture in the Thurgoland District in the early 20th century.

The story of wire-drawing is continued by Mr. E.W. Winterbottom, a director of Oxspring Wire Works who began work in the mill in 1897 and who, together with his two brothers, has seen 60 years of progress. He says that he began work in the mill started by his grandfather, of whom I wrote earlier in the essay, at a time of change. Scouring by hand however he well remembers both by women outworkers and also by boys in the mill. In Mr. Winterbottom's own words "There was a beautiful rhythmic motion in which the lad moved backward and forwards, arms moving up and down, heel and toe action in the leg movements, almost like a graceful dancer." This method was replaced however by the simple one of running the wire through emery cloth, held in close contact with the wire by means of flat pieces of wood clamped together. This was repeated until the wire was brightly polished and enabled output to be increased. At that time seven mills were running, each using the water from the Don for their power. Two remain, the Oxspring Wire Works and the New Mill at Thurgoland. All of them worked for the Redditch needle trade, using steel produced by the crucible method. Sulphuric acid for cleaning was in general use and lime was replacing starch for coating the wire. Acid brittleness, (called "sperrity" by the wire drawer) made its appearance due to the partial absorption of hydrogen by the wire and was often cured by leaving the coils in the mill stream for a few weeks. The taper broach was introduced and enabled the drawer to make or "set" a hole in his wortle which gave a far truer diameter to the wire. Prior to this all holes were "set" by means of punches; the wiredrawer bought his punch steel from B. Huntsman's of Sheffield, the local smith drew each piece down to a round taper point and the drawer hardened, tempered and ground the punches to the size he required. This he did at home, most men, having in their gardens a wet grindstone of something like

1 foot in diameter. Payment was by piece-work rates and so punch making was done out of working hours. Wortles could not be bought with holes less than .064" and years of working with the battering hammer was required in order to reduce them sufficiently to draw the smaller sizes of needlewire such as .006" in diameter. Again in Mr. Winterbottom's own words, "One man named G. Green drew this small wire and a very delicate touch was required to tap a punch and turn a broach in a hole of .006" in diameter. On a cold morning these tools soon snapped and I can see G. Green now, waving his arms above his head as he broke his last taper broach" As the men provided their own tools it meant that he would have to go to Sheffield at his own expense and because he was on piecework he would also lose a day's wages. Stubs of Warrington supplied the large broaches (called rimers by the wiredrawers) and a watchmaker in Sheffield stocked the small ones. The confident drawer would hit his punch so hard that it bounced in the wortle hole. A straight hole was essential together with careful setting of the wortle so that the pull from the block was at right angles to it; only in this way was it possible to draw straight wire with less risk of "crooks" in the finished needles. Lighting, in addition to tools was supplied by each man, and candles were bought for winter working. A glimpse of the life of an essential helper to the trade comes to light when coal is mentioned. Annealing coal cost 6/9d per ton at the pit, with boiler coal at 4/6d per ton. Again quoting "What it cost to cart is hard to estimate. The carter H. Mitchell (Tubby) fetched two loads each day from the pit two miles away. He also looked after two horses and a pony, 6 cows, milking three of them, fed 3 to 40 pigs depending on the state of the litters, kept the place very tidy and with 24/-d per week was the best paid carter in the district and I should think the happiest."

The micrometer was in general use and wortles were improved upon. They were made of harder steel and the bearing of the hole was pricked and drilled to any required size.

Such plates needed far less working with hammer and punch before use and, being harder gave a better surface finish to the wire.

Chapter VIII.

The Wiredrawers of the early 20th century.

Mr. Winterbottom recalls that the men of that time were good servants and good wire-drawers whom he likes to remember. Generally they were of heavier build than the men of today, heavy boned and slow moving with large noses. He speaks of one whom I also remember, Joe Beet, a big strong man remarkable for his method of banging wire to remove the scale. When turning the coil to change his grip so that he could bang the opposite side he maintained the rhythm of his movement by swinging the coil above his head. As a young man Joe worked at the Tilt Wire Mill, the third of the mills in the Don valley at Thurgoland, and during one of the periods when few orders were being received Joe decided to try his luck as a policeman and approached the mill-owner Mr. J. Dyson, asking for a "character" by which he meant a testimonial. The reply was "Certainly Joe, but can tha' keep it?" Joe, with his strong sense of humour and fondness for practical joking decided that it would probably be too much for him and so he stayed on at his trade.

Much rivalry existed between the Tilt Mill where Joe worked and the New Mill situated some short distance higher in the valley, particularly concerning the size of the bonfire on November 5th. On one occasion Joe was known to float the New Mill bonfire logs down the mill stream to the Tilt Mill during the night and was discovered next morning drying them in front of the annealing furnaces.

This photograph

is of a small-size wiredrawer at the Tilt Mill but I cannot discover who he was. The wire is travelling from the leading off swift (which is slatted) through his left hand and then his right hand which gives the wire a half turn occasionally, known as "worming" the wire and done so as to disturb the lubricant at the entrance to the wortle plate.

Two of the wiredrawers at Oxspring were twins, George and Joe Peace; they were very much alike, well built with good features, hard

skin like leather with pale expressionless blue eyes. Both were good cricket players, Joe a good batsman but George not so good. Joe would bat first and when out George would go down and then the opposing side would complain to the umpire that it was the same man who had batted previously. The captain of the opposition and the umpire would closely examine both men but it often happened that Joe, the better batsman, had two innings much to the delight of his supporters.

George insisted on coming to work at 4.30 a.m. and when told that he would have to change to 6.30 in line with the others, he tried it for a time and then said "Mester, if I can't come at 4.30 a.m. I'm leaving. I just get up at 3.30 and wait till six." The working day began at 6.30 a.m. and when darkness came was continued by candlelight, there was no guaranteed week, little division of labour each man relying on his own personal skill at all stages of the processing. Although he worked long hours the wiredrawer worked a garden and often fed a pig. Many, along with quarrymen and forge workers of Wortley, were musical and as I have already described, possessed individuality and native wit sufficient to enliven the routine of the mill.

Chapter IX.

Modern Wire Manufacture

By the beginning of the First World War, Germany had made commercially usable dies of tungsten carbide alloys and during the ten years which followed, its use had largely replaced the wortle for the manufacture of round wire. In addition to crucible steel many new qualities were being drawn produced by the Siemens-Martin process and today the electric furnace is melting stainless and other alloy steels which the wire drawer is dealing with. Research departments, by their investigations into the fundamentals of the process are largely responsible for the way in which the industry has been able to keep pace with the demands made upon it.

Economical wire drawing insists that the required finished size is reached in as few stages as possible and in the shortest time. It is sensible, and research has proved, that the greatest reduction in cross sectional area can be made before any hardening through drawing has taken place. In fact the first pass can deform the wire so that 45-50% of the area is drawn down and this without any ill-effects to the wire. The shape of the drawing cone in the die is no longer made by the wiredrawer with hammer and punch to the contour which he thinks is right. This is now specified according to the quality of wire so that the product is kept as free from stress as possible and in order that the life of the die may be long.

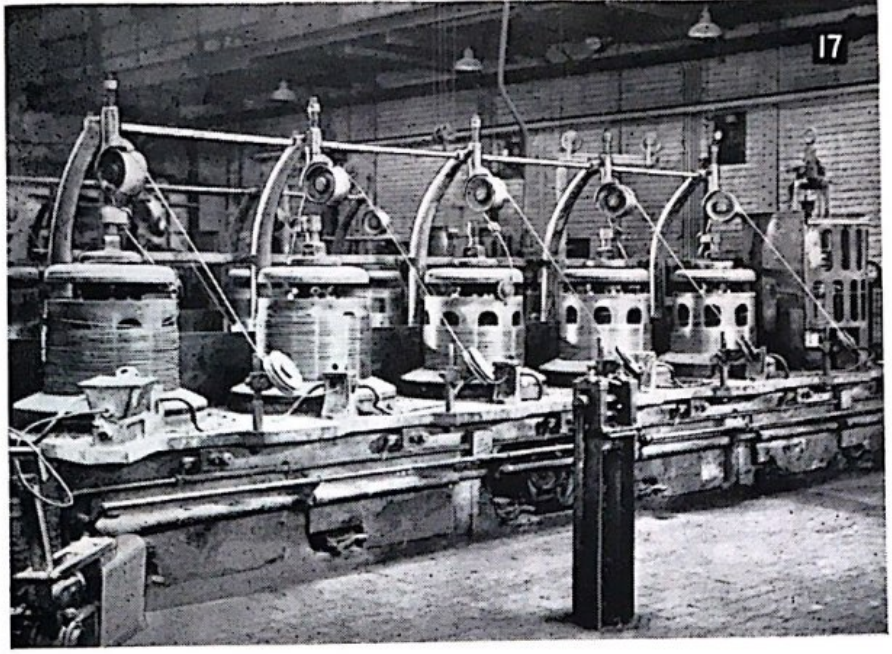
Preparation of the material for drawing has been studied and in this connection pernaps the greatest contribution of research has been with regard to handling. Mechanical means have replaced the arduous lifting and banging. The use of organic additives in the pickling vats now prevents acid brittleness due to hydrogen absorption and gives additional benefits in preventing uneven acid attack, fewer pickling blisters and less trouble from acid fumes.

Lubrication has been thoroughly studied. In the old days tallow was the universally recognised substance in use for coating the wire

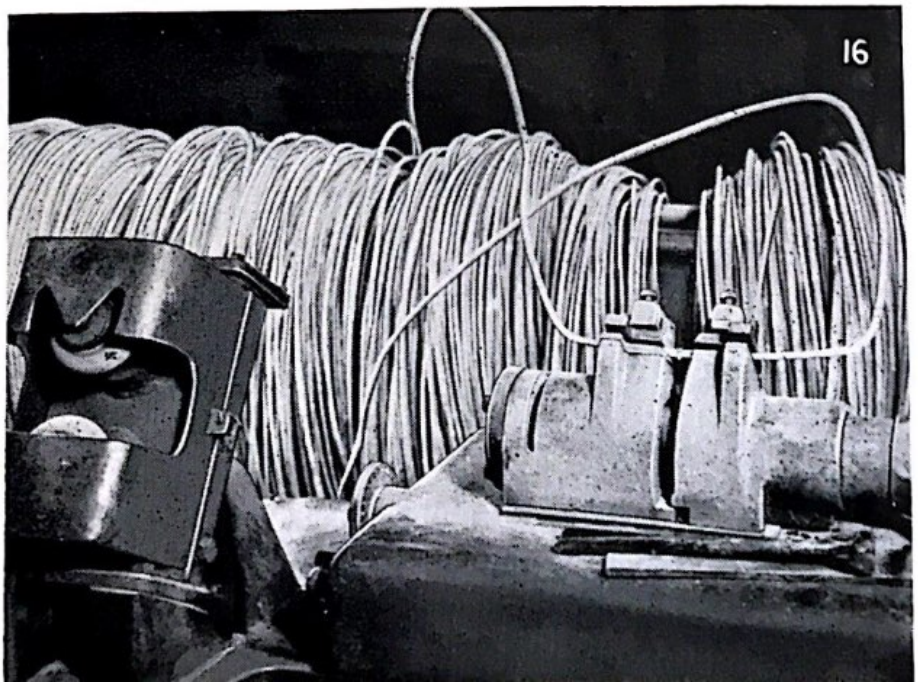
just before it entered the drawing hole in either wortle or die but many different oils and greases have since been tried as well as mixtures of them. Pulverized dry soap has been found most effective for reducing the power needed for drawing but it leaves the wire a dull grey whereas rape oil will give a bright finish to it.

Material of which the die is made has been found to influence the power needed for drawing. The diamond die gives a brighter polish to the wire and friction is correspondingly reduced. Elastic properties of hard metal dies and of the wire being drawn result in a difference in size (due to expansion) between the finished wire and the diameter of the hole through which it is drawn. When narrow tolerances are specified on the order it is necessary to know this difference in diameter and to allow for it when selecting the die. In this connection it is interesting to learn that it is possible to work with the tungsten carbide die to a tolerance of .00025".

Concerning the drawing equipment, the independent electric motor has proved useful in giving a range of two or three speeds to the heavy single block together with smoother starting of the drawing operation so reducing risk of breakage of the wire and damage to the die. This single block takes care of the larger sizes of wire but for material of .08" in diameter or less, lighter machines are in use with as many as 42 blocks in series, one man operating up to 12 of them. Multiple machines give an increased output compared with any others. In these the wire runs through a series of drawing dies and is only coiled at the end of the complete operation. This dispenses with the need to lift the coil off the block after each pass and transfer it to another feeding swift. Since the wire becomes elongated after the first pass, it must be drawn through the next die at an increased rate and so on from die to die.



In order to save time threading up the wire, several coils are joined by electric welding on an automatic machine. Annealing after welding can be done on the same machine and the flash at the weld junction smoothed off with a file.



Continuous machines drawing fine wire are usually fitted with diamond dies. These consist of a raw diamond with a small hole in the centre encased in a piece of brass. The hole in this very hard stone does not wear readily and large quantities of wire can be drawn through without any change in diameter. South West African diamonds are said to be the best for this purpose and they must be flawless with no cracks or pores. The drawing cone in a finished diamond die must be quite smooth with no trace of grooves and the true working cone or "bearing" to the wiredrawer, that is the part which actually comes into contact with the wire during drawing, must be very highly polished. The process of drilling the diamond was formerly worked on a special machine which used a needle coated with oil and fine diamond powder and took up to a fortnight with the hardest stones. Grinding and polishing on other machines brought the processing time up to a total of 100 working hours for dies to draw wires less than .0012" in diameter. The process has been improved upon by burning electrically to make the first hole and the manufacturing time reduced to some five hours. These dies are still so expensive that they are only used for wire of .020" in diameter or less. The tungsten carbide die is used for the larger wire and is said to allow a throughput of up to 200 times as much as that of the old wortle plate. Wear in the die is influenced by many factors - the initial shape of the cone or bearing, the quality of the die material, the surface finish on the die bearing, the cooling of the die, the preparation of the wire and the lubricant used. One of these, the cleaning and polishing of the die bearing has particular value in prolonging die life and in the small mill this is still done by the wire-drawer himself. A small electric motor is fitted with a self-centring chuck which grips the die and causes it to revolve at high speed. The drawer polishes the bearing surface of the cone by holding his punch against it coated with a mixture of oil and boron carbide powder. He finishes off the hole by means of a wooden stick covered with diamond dust at the tip; it is in effect a lapping process. Lapping machines are

an essential in the tool room of the large mill and the management are so aware of the importance of correct cone shape that they now install machines to measure the profile. These work by means of an internal feeler fitted with optical registering mechanism and other machines mirror the reflection of a drawing die showing both shape and surface finish. Investigations have shown that many drawing difficulties can be overcome by working with these machines to ensure pre-determined and most effective cone shape; reliance on individual hand skill of the drawer is largely eliminated. Through drawing and its resultant cold hardening, the tensile strength of wire is increased but at the same time, resistance to drawing increases. If more passes are made, a point is reached when the wire becomes overdrawn, that is, cracks form inside it and finally on the outside. Annealing or softening by heat treatment restores the malleability or flexibility but at the same time the strength gained through drawing is lost. A welcome development has been the new methods of bright annealing which protect the wire from scaling during the heating and cooling. It is refreshing to read that one branch of heat treatment of particular value was invented by an Englishman. In contrast to so many innovations brought about by Germans, that of wire patenting was a monopoly of this country for some years. It enables wire to be drawn to a much higher tensile strength than is possible with normal annealing and is thus especially valuable for such products as piano wire, spring steel wire and wire for rope making. Hardening and tempering by the continuous method is standard practice in many large mills and machines are being used which will combine many operations where each process was formerly the work of one machine. Drawing, cutting, straightening or reeling and polishing are all combined in one machine and enable very economic use to be made of available floor space and labour.

It is the aim of modern industry to expand standardised and controlled methods to the extent where individual skill is superfluous. The amount of finished wire dependant on the skill of the drawer rather than on that of the toolroom

engineer, for its accuracy and finish is decreasing rapidly. In this particular industry as in so many others the improvement in tools is obviating the need for personal skill. I was interested to hear the remarks of one wiredrawer when asked to compare his lot today with the period round about the first World War. He was satisfied with the piece work rates and spoke in praiseworthy fashion of improved conditions of work but yet seemed to regret the passing of those early days when he had to work his wortle into condition, harden and temper and grind his punches to drive a straight hole, before his wire could be drawn. That he felt this hard training to have been well worth while was shown by his attitude to the young men around him who had never used the wortle. He was sorry for them for they had no notion of "what was really happening" by which he meant that the drawing process was taken for granted and when the work did not proceed according to plan, they were bewildered, not knowing the reasons for the change. He alone, it seemed, was able to feel a sense of satisfaction which sprang from mastery of material acquired in the days when his livelihood depended entirely upon his personal skill.

Conclusion

The trade is being gradually taken over by the steel producing companies possessing as they do the raw materials, financial resources to purchase new machinery and development and design engineers to evolve other equipment. The future of the small mill is uncertain, for even if the owners are able to install new machines their small size prohibits successful competition against their large neighbours who offer facilities for further education, sports and social activities. Perhaps as jobbing mills they will continue to thrive, processing the smaller orders of special size, shape and quality, which the large works cannot plan to include economically. I hope they will survive because they hold a tradition of skill, energy and resource which is so essential a part of our national character.

Bibliography

(Additional to specific references mentioned in the study)

1. Various volumes of the Transactions of the Newcomen Society.

2. Steel Wire. Pomp.

3. Wire Drawing and the Cold Working of Steel. Adam.

4. Sheffield; its Story and its achievements. Walton.

5. An Encyclopaedia of the Iron and Steel Industry. Osborne.

6. Outline of Iron and Steel. Allison.

7. History of the West Riding of Yorkshire. White.

8. A History of Technology. Singer Holmyard and Hall.

9. The Smith. Robins.

10. The Story of Wortley Ironworks. Andrews.

11. The Manufacture of Iron and Steel. Brandt.

12. South Yorkshire. Hunter.