

# STEELINESS

## EVIDENCE BY GEORGE GRANT SANDERSON TO THE SPECIAL COMMITTEE ON IRON

### Introduction

The Special Committee on Iron was set up in January 1861 brief to 'ascertain the thickness, size, and weight of iron plates of a specified composition and manufacture but will resist shot of given shape, wait, and material, at a given velocities, striking both directly and at given angles'. Its membership was drawn from the Navy, the Royal Artillery (the two branches of the military most concerned with using iron for defensive purposes) and to support its more scientific brief a number of eminent scientist and engineers.

The printed reports of the Special Committee are held in the National Archive and give detailed records of their investigations. The 1861/2 Report the Committee provided records of the interviews they held with a large number of witnesses and can be found under reference - WO33/11

The Committee interviewed three iron-masters who had experience of actually making armour plates. These were:

- ★ George Grant Sanderson of Samuel Beale & Co, Rotherham
- ★ William Clay of the Mersey Iron Works, Liverpool
- ★ William Hardy of Thames Iron Works

This transcript is a record of the interview with George Sanderson.

### Mr George Sanderson

George Grant Sanderson was the Manager of Samuel Beale and Co, of the Park Gate Works in Rotherham. They were amongst the most experienced armour makers in the country and so Mr Sanderson's evidence is interesting. For this reason I have transcribed it in full partly because it provides the first detailed description of the process of rolling armour plates that Samuel Beale & Co pioneered, but also because it is an example of a discussion between a practical engineer and eminent scientists at a time when the scientific method of experimentation was still being developed.

### The transcript

Date: 29 January 1861

Present from the Special Committee: Captain JC Dalrymple Hay RN (Chairman), Colonel Henderson RA, Dr Percy FRS, Mr Fairbairn FRS, Mr Pole FRS, Captain Dyer RA (Secretary)

Chairman - This committee has been assembled for the purpose, among other subjects, of enquiring into the best quality of iron for resisting heavy blows from projectiles at high velocities, and the best mode of preparing the metal; and we are anxious to obtain your opinion on these subjects, and to hear any suggestions that you have to make, that may assist us in the investigation committed into our hands.

A - Then may I state that for Samuel Beale and Company, of the Park Gate Iron Works, I have made 1,000 tons of plates; it is more than four years since I made the first 300 tons for the "Terror", of the Tyne, which was built by Messrs. Palmer; since then I have made 700

tons, within the last five months, for the same purpose, only thicker, they were four and a-half inches thick; in the former case they were not so thick, only three and a-half and four inches. This is a specimen (*exhibiting the same*) of what we make, and they are now uniform throughout; four and a-half inches, of various lengths and widths.

Mr Fairbairn - Dis you make those plates for experiment?

A - Yes: I did.

Q - What were the dimensions?

A - Eleven feet by three feet, two inches and four and a-half inches thick; one was taken from Palmer, Brothers and Company's Works, after it had been sent from the Park Gate Works to Jarrow. And the other one was taken from the Works.

Chairman - Rolled plates, and the other plates supplied to Her Majesty's Authorities, under the name of "Palmer and Company's" rolled iron, came from your works?

A - Yes.

Q - Then Palmer and Company have no means of constructing that description of plate?

A - Not the slightest.

Q - Do you know of your own knowledge that all the plates which are supplied as "Palmer and Company's" plates are produced at the works of Beale and Company?

A - Yes.

Q - You are almost certain that any plates supplied by "Palmer and Company" have been produced at your Works?

A - Just so. I do not believe that any other house has yet made any.

Q - Not for Jarrow?

A - No; nor yet rolled plates. I believe that ours is the only house that has rolled any of these armour plates.

Q - And are they all of one consistency?

A - They are all of one character. My main object is to get them alike, and that they fracture soft.

Q - Will you state to the Committee the ore, and the nature of the fuel, and the process of manipulation which you adopt?

A - First of all, we puddle in the ordinary way under what is called a tilt hammer. We obtain the ore from near Kimberworth, which is about eight miles from Sheffield. We use Lord Fitzwilliam's coal, which is very excellent fuel. I believe there is no better in the country. For getting up a large class of work, we puddle from Derbyshire pig iron made from Clay band ironstone and refined iron mixed, and make it into twelve inch bars; we then cut those up again, and mix them with two thirds of our own scrap iron, for the piles: the scrap bars are made of the same width and thickness as the puddled bars. We put those together and roll them into what we call No. 1 sabs, which are composed of scores of layers; in consequence

of the two-thirds of scrap being originally piled, sometime before, they are all of our own make; we use no foreign scrap - no marine scrap. I do not put a bit of it in for this purpose. Then these No. 1's, according to the size of the plate required, are made of a certain length, and a certain width, an inch and a-quarter thick, and the thickness is uniform. All the raw iron is sheared and taken off the plate; there is always a certain amount of rough iron outside; that is taken off like a finished plate; four of those inch and a-quarter plates are then put together, and welded into another plate two and a quarter inches thick

Mr Fairburn - Do you mean that your bars are of the same length, or nearly the same length, as the plate: is it a large pile?

A - Yes; we pile it to make these inch and a-quarter plates; the pile is what we call doubled; it is made from then layers of puddled bars and scrap bars mixed together, and all made into these inch and a-quarter plates.

Q - Will you be good enough to state how those bars are mixed; the puddled bars and the scrap?

A - They are mixed in the piling.

Q - Alternately?

A - Yes.

Q - Do you put the scrap bars, or the puddled bars outside?

A - I generally prefer to have the puddled iron on the outer side, merely for the top and bottom to have a more uniform skin; the puddled iron will roll with a clearer skin than the scrap iron in many cases, and we keep the puddled iron outside; it is not the thickness of a sheet of writing paper sometimes.

Q - Have you any arrangements, with regard to making up these piles, as to the direction of the fibre, or do you cross it?

A - The scraps naturally will be crossed, but the puddled iron is rolled the cross way; there is only about one third of puddled iron to two of scrap; the puddled bar is cut two or three feet long probably, and it is rolled the cross way, but the fibres become crossed and, when broken, produce a fracture such as the Committee will see in this specimen. (*pointing to same*)

Q - In this process I think you stated that the puddled iron is on the outer part, and the scrap is the inner?

A - Yes.

Q - Which of those two irons, when in this state, do you consider the toughest?

A - They are all alike; whenever scrap bars are used for the outside there is the probability of shells being formed; but the puddled iron, being made of all one uniform mixture, is more likely to roll sound.

Mr Pole - Do you mean peeling off?

A - Yes; like little skelps, or thin leaves.

Mr Fairbairn - This sample appears to be very uniform in its character in the fracture?

A - Yes; I have proved the whole 1,000 tons that I have made; and I have machinery for drilling, &c., which enable me to do this. If I meet with a misfortune, and find I have a plate not perfect, I try it in this way. I put it under the drill, and there are three drills running the whole width, three feet three; and I run a course of hoes through it, leaving so much (*describing the same*) between. I find the greatest difficulty to teat it asunder afterwards.

Q - In puddling the pig iron, when you take out the balls, do you put them under the hammer?

A - Yes; we take them on a carriage to keep them as pure as possible, for if you draw them along the floor you may pick up a piece of brick, like a pea, and this would roll perhaps a foot or two into the bar, so that I convey them on a carriage to the hammer, and there is no possibility of dirt sticking to the puddled bar; and the scrap piles the same, they all go on a carriage from the furnace to the hammer.

Q - Does the scrap iron go under the same hammer?

A - Yes.

Q - Are your bars, forming the pile, all hammered previously to being rolled into the puddled bars?

A - Yes; I make a No. 1 slab, five feet by three, by an inch and a-quarter. Then the four of these are put together to be made into another slab, and rolled all the lengthway, we get the width in the first instance and roll to probably five or six feet, and to two and a-quarter thick. According to the length of the armour plate that is required, and afterwards four of these are put together, and are welded, at one heat, into a plate.

Q - By rolling?

A - Yes; it is done in half a minute. I have taken the largest armour-plate, out of the furnace, which is of a peculiar construction, and, in half a minute, welded it all, and there is no piece of iron so large can go under the hammer and be treated so, in so short a time, and that is the main point, with the superior coal that we have.

Q - How many heatings does the iron undergo by this process?

A - I should think about seven times form the pig?

Q - Do you find it improves or deteriorates by such frequent heatings?

A - I never find it so in these armour-plates. I never find the iron weak in so large a body as that.

Mr Fairbairn - Not in large masses?

A - No.

Mr Pole - How many times would it be heated from the puddled bar?

A - The puddling is one heat, the doubling the No. 1 slabs or plates making three heats; the four No. 1 slabs or plates to make the 2 $\frac{1}{4}$ -inch slabs or plates, four heats; and four 2 $\frac{1}{4}$ -inch slabs or plates (to make the armour-plate) making five heats from the puddling.

Q - Considering the puddled bar the first?

A - Yes; it is about five times. Then there is taking into account the scrap; that scrap is off the plate previously, but is still comes round again the same as a puddled bar.

Q - Do you think that in making bars and plates from scrap, you restore, or renew, the iron as if it was new iron, or that you deteriorate it, in taking them from scrap?

A - I would not put my faith in collected scrap, for example marine scrap, I would not use that; but my own scrap is from the iron that we start with ourselves, it is our own manufactured scrap.

Q - You do not collect it in the country?

A - No; it is our own scrap from the pig.

Chairman - It is scrap of your own manufacture?

A - Yes; it is from our own work, and it is pure, it has never left the premises; it originates from the rolling process and the clippings.

Dr Percy - The cross ends?

A - Yes; the cross ends and the shearings are included under the term scrap, but the difference between our scrap and marine scrap is very wide indeed. I have received many thousands of tons of scrap collected in London, but the great difficulty that we had to get anything that was sound was in consequence of the brass, lead and solder that was in it; and to get it clean was almost impossible; but our own scrap is thoroughly clean.

Mr Fairbairn - You have not stated what was the nature of the ore, or the chemical analysis that you have of your ore?

A - We get our own ore in the neighbourhood, and it contains about 33 per cent of iron, and is the Yorkshire clay band, it is in nodules or in balls; that is considered the best iron, but it is very expensive ironstone to get; we get it about sixty yards from the surface, like coal.

Q - Is there much sulphur or phosphorus in your coal?

A - No; comparatively little.

Q - It is not the same quality as they have at the Low Moor Works?

A - No; their coal is much shorter, and entirely free, I believe from sulphur. Our iron does not receive any injury from what little sulphur there is in our coal. We use a very hard coal for heating this heavy work, and it is so full of combustible matter and tar, that a flame from a rich coal like that upon that large mass of iron cannot possibly injure it.

Q - Is it highly bituminous?

A - Yes; so much so that in heating a piece of iron of five tons, for armour-plates, or other large work, you take it out and roll it, at one heat, and that is a branch of the iron business that is not carried on, that I am aware of, except at the Park Gate Works.

Q - With such a description of fuel you have no difficulty in raising your temperature?

A - No; from the construction of the furnace, together with the mode in which we heat it.

Q - What is the extent of your furnace?

A - About 10 feet long and six feet wide, and the bars go in in this way (*describing the same*); the grate is in this form, and the chimney is on this side (*describing the same*). We have had a great many points to arrive at to get at the best for heating such large lumps. I have sent some plates away last week 17 feet 3½ inches by 3 feet 3 wide, weighing 4 tons 8 cwt. When finishes. I have some larger than this to do.

Q - With regard to the rolls, I suppose they are of very large dimensions, and of great strength, in order to give the required pressure in welding these immense plates?

A - They are of about 20 inches in diameter, by 6 feet 6 inches long. My furnace is exactly in a line with the centre of these rolls, and a railway leads from the mouth of the furnace to the rolls. I could not get 200 men to pull one of these piles out for me at all in a string; but by practice every day in doing it, as a matter of course, we get into ready ways of getting them out. I work with a reverse gearing; I can reverse the rolls either way in an instant. I put a pair of tongs on the pile. And the top-roll pulls the pile out.

Q - How do you get such a large mass out of the furnace when it is in a welding state of heat?

A - This sheet of paper will represent the pile; four of these are from nine to ten inches high, and it takes about four and a half or five hours to heat a mass. When we charge the furnace we put one of these two-and-a-half-slabs on a sand bottom, and then place another one on this with rollers; we pull the rollers out, and bring the third one and treat it in the same way, and so on with the fourth; and we take care in rolling these slabs that we match them so that they are like four bricks made out of the same mould, not too much off, sideways, and not too much off endways: they will measure close on ten inches, when in the cold state in the furnace, and we then get a very powerful bar to raise up the front part of those four layers when we begin to fire; then we put two large bricks underneath and raise the pile up from the bottom of the furnace nine inches at least; we do not let it touch the bottom, and we put prepared firebricks, one on this corner (*describing the same*), and so on, so that the flames from the grate may go underneath and over; in about four and a half hours when this is ready we lower it down on to the bottom. We have a door at the back, and one at the front; and we know whether this end is hotter than the front one; for it would not do to bring out a large piece of iron with one end hot and the other cold; we should break down all the machinery, we can see every portion of it, and so soon as it is hot, and ready to come out we have a strong pair of tongs which we clip the four together; and we put a chain around the top roller with seven or eight men holding together, and when it bites the rolls and the chain, the mouth of the tongs closes and bites the iron; they are ragged at the face with rough teeth so as to go into the soft hot iron; there is a carriage which stands in front of the furnace less than the size of the pile, and the top is full of round bars from the side frames; we put two pieces of wood underneath the pile to make it slip easily, and the moment the bite comes on, from the roll, taking hold of the tongs, it slips over these pieces of wood, and drops onto the carriage; I have an arrangement made so that there is sufficient fall from the front of the furnace to give it momentum. There is a trigger which fastens the carriage to the front of the furnace, and a man pulls a bolt out, and liberates it; and they have small chains on the other side of the rolls; and the rolls are then reversed, and they give it all the speed they can; from the front of the furnace it is about sixteen to twenty feet down to the rolls, and I may say that out of all the plates that I have rolled I have had but two misfortunes.

Q - The whole of this is effected by the jaws of the large tongues?

A - There is the pulling out until it comes on to the carriage, and then the tongs are liberated; there is a certain amount of pull with a small chain, the main shoving behind.

Q - How long would it take from your first beginning to pull out from the furnace until you get it into the rolls?

A - Half a minute.

Q - Is none of the temperature lost?

A - No; the scoria runs out like water right and left and in all directions. The rolls are six feet six inches. In rolling a plate of three feet six, allowing so much in the rough, meaning to finish it to three feet three; I have the necessary width; the cinders will fly away six or seven feet as liquid as oil.

Q - I think you stated that in putting on your layers of two and a quarter inches thick you put them on so nicely formed before you put them into the furnace that they match each other?

A - Yes; I do not like to see one pile further out than the other, because the iron will waste if all the four layers are not of one length and width.

Q - When you get it out and get it into the rolls you roll it, as I understand you, backwards and forwards?

A - Yes, with a reverse motion.

Q - After you have got the rolling completed do you cut the sides of the plate into shape?

A - Yes; we cut then into shape when they are cold. I have finished a plate, so far as rolling, in three minutes, and had in on the floor undergoing the process of straightening.

Q - You put it on a perfectly plain surface, and straighten it?

A - Yes by a simple arrangement, which I hit upon four years ago; at that time the plates were very narrow, not more than two feet wide. I use a waster, and we batter it so, eight or ten men do it, and it has such an effect upon a large piece of iron like that, that it gives way before it like a piece of putty. I may mention that I have heard no complaints from the parties for whom I have made these plates - Westwood, Baillie, Campbell and Company<sup>1</sup>, Palmer Brothers and Company. They are so straight that the fact is I could not straighten them any better hot. We finish them on planing, drilling and slotting machines.

Q - Do you use sand for welding purposes?

A - Only when the pile comes out; we get out sand from the Trent. It is always essential in all iron to get a little dry sand sifted, and just as the pile is coming out to spread a little over it; that increases the scoria and makes it more fusible, and it runs out on the outer surface just like a wave; you can see the sand following the roll as it goes one way or the other.

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<sup>1</sup> Note - Westwood Baillie, Campbell and Co were a Thames shipbuilder. They build the Ironclads HMS *Resistance* launched in April 1861 and HMS *Valiant* launched in 14.10.1863

After the plates are rolled the outer side of the plate is generally coated in cinders nearly the eighth of an inch thick.

Q - Having got your plate rolled and straightened you allow it to cool?

A - Yes.

Q - Then you take it up and cut the edges?

A - Yes.

Q - By what means do you do that?

At first I drilled the ends until I got slotting machines. In drilling any plate, although I get my sides pretty fair for being square, yet there is always a round end like that (*describing the same*). In drilling any plate, if it was for a plate eleven feet, I would see that this end (*describing the same*) was quite sound, and drill across here (*pointing to the same*) or slot. This piece of iron has been drilled and broken, but before I had slotting machines I used to drill all; now having a quantity to make for both the house I have mentioned, and having been engaged during the last five months with them, I have got a couple of slotting machines in order to forward the work. I think it is a pity to put a plate on to a planing machine, and plane say nine inches that you need not plane at all, but first slot both ends off it to the length required, and you have nothing but the sides afterwards to contend with.

Q - I apprehend that slotting machines are the best way of doing it, as you can take a very narrow cut off?

A - Yes; and I have just latterly got a frame-plate slotting machine, it is now just getting into order, I put a rough plate on it, and the machine travels all round it, takes the ends off and slots the sides, but I think I get on as well with the planing machine.

Q - Of what width is the tool that you use?

A - We can take a three-eighth shaving off from end to end.

Q - Is that the width of the cut?

A - Yes.

Q - Does not the tool get fast in that case?

A - Not at all; we begin at the top side and take a three-eighth face from it, and the shaving will be a little feather-edged like that (*describing the same*), the square side and the narrow side, and it comes out to the full extent.

Q - In cutting your plate do you not think it would probably reduce the cost provided you had some instrument, such as a circular saw, so that the moment it came out the roll, if you could get it into the machine, you would only have to run your circular saw into water and cut it right off at once?

A - I have thought a good deal about that, and a gentleman was speaking to me about a machine that he was sure would answer the purpose. His idea was to make one saw to work two and a quarter, and the other to work two and a quarter.

Q - One below and one above?

A - yes; but I doubt very much whether the saws would stand the work. A machine would have to be made to prove this. When a piece of iron like that so hot comes out, I would venture to say that the inside of it is quite in a fluid state, and when laid down in a fluid state I do not know what sort of casting would stand so enormous a heat as that for any time. It is not exactly the length that I look to but it is the overplus. I have sometimes nine or ten inches more than I want; for instance a 17-8 plate would be nearly nineteen feet when rolled, and I should like to see how these machines are to do it; but I believe is my own mode of doing the work cold.

Q - I apprehend that the danger would be in the iron getting hot?

A - The difficulty would be to keep them cool no doubt. The saws and we use for other purposes run about 1,100 a minute; they are of cast steel and about four feet four in diameter, and they last a pretty long time, but they ultimately become cracked, and I do not know what would happen with such large pieces of iron as those contemplated.

Q - You would require some cooling process, and to draw it through very rapidly?

A - Yes; and it would require a strong machine to do such heavy work as these armour plates.

Q - To what extent do you think you could in point of size, other make those plates; suppose, for example, that you had an order for 1,000 tons, could you go up to xxxx?

A - No; it would be a monstrous affair that.

Q - you would want new machinery altogether?

A - Yes; quite so. I have made them up to four tons eight.

Q - the largest has been 17 feet, has it not?

A - Yes; seventeen feet eight by three feet three inches by four and a half thick; that is, close up on five tons when finished.

Chairman - Could you increase the thickness of the plates with facility?

A - Yes.

Q - to what extent?

A - I do not know how do you think you would want them; but I could make them a couple of inches thicker.

Q - Say 7 inches?

A - Yes.

Q - With your present machinery?

A - Yes; but that would be adding tremendously to the weight. I could not go to those sizes if I increased the thickness. But we have it all to learn, and we have been learning during the last four or five years.

Mr Fairburn - In the engineering world it is stated that the only criterion as to what you can do is the money that is paid?

A - As a matter of course.

Q - In your experience in the manufacturing very large plates, have you paid much attention to the position in which you placed the fibre, in order that its power of resistance to penetration may be as great as possible?

A - I have always endeavoured to place the fibres as much across as possible; the scraps are piled in such a bit peculiar way that they run both right and left, and all across.

Q - you are aware that in the manufacture of railway it is found necessary, to lay them longitudinally and transversely?

A - Yes.

Q - If the piling is arranged with the fibres standing up on the end, like a brush, the duration of the tire is very much increased?

A - Yes; they pile of this way for the wearing surface; but I have often seen them crush out after use.

Q - Then, from your experience, would you recommend any manufacture of that sort; in order to secure the greatest possible tenacity in a barplate, and the greatest power of resisting projectiles at high velocities?

A - I have not tried it.

Q - Do you think it would be worth while to make the experiment at your works, to see what the effect would be?

A - In the rolling of eight the No. 1 slabs an inch and a-quarter thick; that is very strong scrap iron. These scraps are not played all the flat way; many of them are edge ways, so that a great deal of the iron is actually both vertical and transverse.

Q - Have you given any attention to the homogeneous iron or steel?

A - I have done nothing at all with it, and I do not suppose that we shall. I am not aware of any inclination that exists in that way. I have seen many samples of it, both good and bad, and I call it a rather irregular.

Q - What is your opinion as to it? Suppose you could get some of this rolled steel, and that you put a layer of it in the middle, the question then would be whether that would increase the resisting power of the plate?

A - I think it would become too uncertain as to quality. Judging from the general reports that I have heard of the puddled steel, there is no dependence to be placed upon it. The homogeneous iron is scrap melted in a crucible, and the other is puddled, and I have heard reports which are unfavourable to both of them.

Dr. Percy - Do you use any mixture of ores, or is it one particular ore that you use?

A - We use haematite ore from Cumberland, Schneider and Company's haematite as a mixture, but only in small quantities.

Q - Are those ores the so called hard ores, or soft ones?

A - The haematite is a soft ore.

Q - Not a hard ore?

A - No; it is that ore that we get which invariably produces a soft iron; it contains about seventy per cent. of iron

Q - Is that the case with the hard ore?

A - No.

Q - the quality of iron which is produced from hard ore is manifestly different from that which is produced from soft ore?

A - yes.

Q - Do you use haematite alone?

A - No; we use it with the clayband.

Q - You produce grey iron?

A - Yes; No. 4 forge pig.

Q - Do you puddle with a mixture of refined iron and number four?

A - Yes; strong forge No. 4. Where these plates are made is a different department altogether from the other part of the works.

Q - As to the mode of carrying the balls on a carriage, there is nothing particularly special about that, is there?

A - It is merely to ensure freedom from dirt.

Q - In the Welsh works it is a common practice, is it not?

A - Yes. It is resorted to, to ensure the iron being clean. In larger masses of iron like that you cannot be too careful.

Q - In hammering the ball, is it Nasmyth's hammer that you use, or the old helve?

A - The old fashioned helve, six tons in weight.

Q - Do you think that is the best?

A - Yes; and it will always remain so, I think.

Q - You have mentioned the thickness of the pile from which one of these large plates is made?

A - Yes: and, at the last time of heating, it is rather over nine inches.

Q - Do you consider that the soundest plate will be produced by hammering, or rolling.

A - I think, judging from my experience, by rolling.

Q - Have you had any experience in the working of iron of different qualities?

A - No; it is a difficult matter to combine steel and iron together

Q - Will not that depend upon the degree in which the iron is steely? Suppose, for example, that you had something intermediate between wrought-iron and steel, would not there be less difficulty then, than in the case of what you call steel?

A - Yes; but you cannot always ensure with accuracy the steel and iron combining.

Q - have you made any experiments upon that subject?

A - I have made a great many experiments in making tires with CC N D blister steel, and with English iron, called Sanders's patents tires, about seventeen or eighteen years ago, and we always found great difficulty in combining the iron and steel together.

Q - Still you may have iron much less steely than that?

A - Yes, it was obliged to be very mild.

Q - Was it cemented in the usual way in the converting furnace?

A - Yes: and if you got it a little bit too highly carbonized it tumbled all down; it requires great care.

Q - But it becomes less difficult in proportion as the iron is less steely?

A - Just so.

Mr Pole - Have you ever seen experiments made on your own plates?

A - No. I have not.

Q - You have, I presume, a general notion of what the effect upon the plates of this quality would be?

A - Mr Beale has seen one or two experiments at Portsmouth, and, from what he told me, I understand that the shot indented them, the that plates being so soft.

Q - Then you would think that softness tend to prevent cracking or breaking?

A - Yes, certainly; I think so.

Q - Judging from the whole of your experience as two large plates, should you say that softness and toughness are the most desirable qualities to obtain?

A - Yes, and soundness

Q - You would set your face against hardness either in the general quality of the plate, or in any special parts of it?

A - Yes.

Q - Would you think well of a plate having a double quality, with a tough inside and a hard face?

A - I think the hard face would very soon destroy the tough part; it would hold it together, but I think it would all crack like my putting my fist through a pane of glass.

Q - You think such a plate might be made, but that it would not be desirable when done?

A - No; it would be more difficult to make, and still have a tendency to fracture when it received a blow.

Q - You think that plates should be soft and tough and homogenous throughout?

A - Yes, as tough as it was possible to make them.

Q - You would not approve of interlarding a plate with harder material in the centre like a sandwich?

A - No.

Q - Did you ever hear that the plates of the "Gloire" are so arranged?

A - No.

Q - You would strive after softness and toughness?

A - Yes.

Q - You are, I presume, acquainted with the Low Moor, or the best Yorkshire quality of iron?

A - Yes.

Q - Is that in your opinion too hard for plates?

A - I think it is. I think that I have seen a plate from the neighbouring works of the same quality, which, when a shot struck the plate, it starred and cracked, being so hard.

Q - That, although so very valuable for many engineering purposes, you think it would be not only more expensive, but at the same time less adapted for the purpose than the softer and cheaper quality?

A - I think so.

Q - Are you acquainted with the Staffordshire qualities of iron?

A - Yes.

Q - They are, I believe, generally of about the quality of your make, soft and tough?

A - Something of that class.

Q - You do not squeeze the puddled bars?

A - No; they are all hammered throughout.

Q - You stated that you have supplied plates for Palmer and Co.?

A - Yes.

Q - Then a certain kind of iron that we have heard spoken of as Palmer's rolled iron is in reality yours?

A - Yes.

Q - They have no means of making rolled iron?

A - No, neither hammered nor rolled.

Q - You have supplied then?

A - Yes. Nearly five hundred tons up to this time.

Q - Have they always been rolled the plates of this quality?

A - Yes, precisely.

Q - Have you also supplied Messrs. Campbell?

A - Yes; they are for the same class of ship—the "Defence" and the "Defiance<sup>2</sup>." Westwood's and Palmer's are both alike, as I understand.

Q - The ships are of what size, and for what purpose?

A - I think they are 100 feet less than the "Warrior" and "Black Prince" in length. I think the "Warrior" and the "Black Prince" have a course of plates more. In the "Defence" and the "Defiance" there are only six courses of armour-plates.

Q - What is the style of the plates?

A - They are from eight feet to seventeen feet eight, of the various widths, none under three feet, three feet one, - three feet two, and three feet three; but they have to be tongued; and if they have given us a little latitude – a little over the mark – to allow for their trimming up.

Q - What do you do to the edges?

A - We trim them square up.

Q - Then the plates are bent to the form of the ship by the shipbuilder?

A - Yes.

Q - And the grooves are planed by them?

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<sup>2</sup> Note - HMS *Defiance* was in fact the last wooden hulled battleship to be launched in Britain. Mr Sanderson may be referring here to the HMS *Resistance*, which was built by Westwood, Bailey, Campbell & Co and was launched in April 1861.

A - Yes.

Q - Are they generally square at the grooves and tongue?

A - Yes, about an inch and three-eighths.

Q - Not angular?

A - No; they are both tongue and groove a length way of the plate, and edgeways, as I understand all round

Q - What is the depth of grooves?

A - I think about three-fourths of an inch

Q - And the width?

A - An inch and three eights, or an inch and seven sixteenths.

Q - It is essential that be outside of the plate must be planed and groove?

A - Yes, to see what it is; then you can see what article you have; but to saw them I do not think you could see what it was.

Q - What is the object of your using scrap? Is it merely to use it up, or has it any influence on the quality of the plate?

A - I think it strengthens the iron generally – it being scrap of our own make – and I think it is desirable to put a certain portion in; we were requested to do so, and our scrap being of such a character we think that it strengthens the iron, and that we get more fibre.

Q - I think you have stated that you did not think hammering a plate would be a great advantage, as to giving a sounder weld?

A - No.

Q - Have you reason to think that the welds you have made are more liable to be unsound with all the care you have taken?

A - I think, as far as I have tested plates, that the mode in which we put them together, and that the heat we subject them to, that they must be thoroughly sound.

Q - You have not thought of any improvement that is required in that process?

A - From the means that we adopt, and superior from the particular construction of our furnace, and the coal that we work with, we place of the greatest reliance upon our work being done properly.

Q - How many times do you pass a plate through the rolls from the last heat

A - If it is nine inches it goes through probably six times.

Q - With the same heat?

A - Yes; and the cinder is invariably running the first three times it goes through.

Q - How much is it pinched each time?

A - The first time going through we take it down an inch and a-quarter; it comes down with such a force from the furnace, that there is no chance but what the roller will bite it; it is instantly through, and there is such a pressure upon it, that it frees it from all the scoria; and the second time of going through the cinders run equally as well – quite fluid each time it is pinched, sufficient to bring it to four and a-half inches when finished.

Q - Could you make hammered plates, if it was desirable?

A - Not with our present means.

Q - Your plates, I presume, are expensive, and the price increases per ton and varies with the weight of the plates?

A - Yes; those heavy plates; there is great risk in making with them, and also in the machinery, if we get a waster it is a serious matter.

Q - If you made them still thicker, would the price per ton increase still more?

A - The lengths would have to be shorter; I could not keep the same length, and put two inches on. I would go as far as I could in weight, but I should say that five tons would be the outside at present

Q - What is about the present value of the plates per ton?

A - £30 per ton, finished in the way I have told you.

Q - Do you mean for the largest?

A - No; the largest over fifteen feet would go up £32 a ton, or something like that. I do not know exactly, but for the general sizes under 15 feet they are £30 a ton; we put a great deal of work on them to ensure good work.

Q - You have made already a large weight of them?

A - Yes; for the two vessels that I have mentioned close up on 700 tons. I have made about 240 tons four years ago. I may say I have made 1,000 tons of rolled armour plates up to the present day. I have now 300 tons, to finish the last for both ships.

Q - If you had thicker plates to make, it would be purely increasing the number of the slabs and shortening them a little?

A - Just so.

Q - You would make the plates in the same way?

A - Yes; and put more layers on them. There are hundreds of layers, or what I call leaves (*pointing to a specimen*). I could not exactly say how many.

Q - With regard to the arrangement of the fibre; suppose were you to pile a piece, with the upper part in the form of a brush, would not the rolling after that be also a position to alter the position of the fibre, and make it longitudinal?

A - Yes, I am sure it would.

Q - Is not the fibre produced by rolling?

A - Yes.

Q - If you put in a piece in that way (describing the same) would not the operation it must be subjected to by rolling be liable to alter the position of the fibres and make it longitudinal?

A - Yes; you could not keep it in the same form.

Q - After that plate was rolled you could not preserve the vertical position of the fibres?

A - I think not; I have done it with tires.

Q - They are not rolled?

A - Tyres are sometimes rolled and sometimes hammered, according to the work they have to do; but that would be great to difficulty in getting them sound in such plates as those, if rolled edgeways.

Q - They are not so likely to weld?

A - You are not so unlikely to get the cinders out; that might be bound up in these upright squares.

Q - Some new processes for making iron have been lately introduced; have you had any experience with regard to puddled steel?

A - No.

Q - Do you think that a mild steel made in that way would be a good material, or would it be too hard?

A - I am afraid so, and that we should not put in the amount of work that we do, to insure fibre. It would not have at the same toughness, but it would become hard.

Q - Do you know whether, generally, the puddled steel process can be depended upon for uniformity in its make?

A - I have heard that it is very irregular indeed.

Q - There is another process for making homogenous iron do you know anything of that?

A - I have heard some reports about it, that is not that it is not generally uniform

Q - Have you seen any plates made in that way?

A - Yes I have, at Sheffield

Q - Are they made by hammering all by rolling?

A - A quantity of clipped scraps is put into a crucible in the same way as making cast-steel; manganese and other matters are put in with it, and that is all fused down to a liquid state

and Paul out and made into ingots, and they are either rolled all hammered; if it is for a plate roll it

Q - Is this process liable to irregularity in its action?

A - I have been told so.

Q - Then there is a third process, which is Bessemer's; do you know anything about that?

A - Yes, I have been through his works once.

Q - Have you ever tried of that process?

A - No.

Q - Do you think that it is liable to the same objection, namely, irregularity in its production?

A - I think Mr Bessemer told me that he had had a great deal to contend with in getting the results that he required for many purposes: it is very hard, it shows a very hard fracture indeed. I have a piece of rail that was sent to me the other day, the fracture is as hard as cast-steel.

Q - Yours is a manufacture not at all experimental, and it is now quite a commercial thing with you?

A - Yes; it is a regular part of our trade. I do not know that any other house is rolling armour plates.

Q - Do you think that the plates you send out now are the best adapted of any that you can suggest to resist the blows of hard shot?

A - As far as I have known, judging from the general reports of these sort of plates, the principal thing that is required is iron tough and sound, so that the shot will not break and fracture the plate in consequence of the amount of fibre in it.

Chairman - Are you satisfied that the result you have arrived at is perfect, all that it may be improved?

A - I do not know that I could improve it; my main object is to get iron of a character soft and tough and sound, and when it is done I think I cannot possibly do more. I believe that experiments have been made with our plates to satisfy the parties who are interested in the matter.

Mr. Pole - Have you formed any opinion as to the best mode of fastening plates in the construction of a ship to which they are to be attached as a face?

A - No, I have not.

Q - You have not entered into the use of them?

A - No; but I have heard parties say that's a thought instead of the tongue projecting over one plate, if a bar was introduced, and you made them with two grooves a single bar in between, it would be a great point in fastening these plates to the side of a ship of war. Then as to the bolts that I think is a very important point. An experiment took place, I think, at

Portsmouth, upon a plate, from Palmer Brothers, that I made two years ago, but unfortunately the bolts not being sufficiently tough gave way. Iron for bolts requires it to be made up on the same principle as I have described, and to be as full of fibre as possible.

Mr. Fairbairn - Did you make any of these bolts?

A - For the second experiment I did, but not for the first. When the shot struck the plates the bolts gave way, and away the plate went, in consequence of the quality of the bolts not being sufficiently good; but in the second experiment, I think, the plates stood.

Q - Did you use the same sort of iron in making the bolts?

A - Yes, precisely; and the object is to get it has full of fibre, and as strong as possible.

Q - Have you ascertained what is the tensile strength of that iron? Have you had it tested?

A - No, merely by breaking previously to making the bolts; I made, forged, turned, and screwed them.

Q - You have not torn the iron asunder longitudinally?

A - No; but I should say that the test I put it to, that of nicking it and breaking it to clean off, was a good test.

Mr. Pole - I suppose that the Low Moor iron would be better adapted for bolts run this iron (*pointing to a specimen*)?

A - Yes, it would; but some of the Low Moor iron if you nicked it would break short off.

Dr. Percy - If nicked on one or both sides?

A - On one side only; it would break off short; but you may nick a bar all round of that iron (*pointing to the same*), and it would not break because it is full of fibre.

Mr. Fairbairn - Have you ever tried, in hammering with a light hammer, to see whether the vibration had any effect in destroying the fibre?

A - It hardens it considerably.

Q - If it is hammered cold?

A - Yes, it crystallizes.

Q - Do you know whether, if a part of that iron were laid on the edge of an anvil after being hammered with a light hammer, it would not drop off at once?

A - It might, and it might not, I really cannot say; but I have nicked that iron all round and broken the skin of it all round, and then it has bent round, being tough.

Mr. Pole - Have you ever known and incidents positively authenticated in which a piece of thoroughly good iron was rendered bad by hammering cold?

A - Yes, I recollect making a shaft for James Watt; I was then at the French Walls Iron Works<sup>3</sup>; it was a marine shaft, very short, about twenty-five cwt., and made from a very good iron; but their forgerman had kibbled it under the hammer, or in other words, he had hammered it so cold that's the men could not get the tools to face it; it made it so hard, and there came a complaint to me about it.

Q - But it does not follow that it made it less tenuous?

A - The parings from it broke off very short.

Q - Would it, do you think, have been weaker for its purpose in that state than it was before?

A - I do not know whether they did or not and anneal it afterwards.

Dr. Percy - Would not that process remove the hardness?

A - Yises.

Col. Henderson - do you test your plates in any way before you deliver them?

A - Merely by generally finishing them, by planing and dressing them up.

Q - By the roll?

A - Yes, and by the general inspection at the machines while dressing them up to the sizes given.

Chairman - You do not subject them to any punching test?

A - No; but I did drill the plates that I made four years ago; we put holes through; an-inch-and-three-eighths holes were put in; but in this case we have not anything to do with the drilling, tonging, or the grooving

Mr Pole - What quantity of plates could you make with your present means in a month?

A - I am making eighteen a week just now.

Q - How many tons?

A - They vary.

Q - Thirty or forty tons a week?

A - I should say, about sixty or seventy tons a week with our present means. I could extend the finishing department.

Col. Henderson<sup>4</sup> - Would there be any difficulty in making bars of iron say ten inches square?

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<sup>3</sup> Note - The French Walls Works, in Smethwick, Birmingham, was operated by James Watt from the mid 1830's to 1842 and produced boiler plates and engine forgings and for his Soho Foundry.

<sup>4</sup> Note - Col. Henderson was probably exploring the use of iron bars for land fortifications, which was of interest to the Royal Artillery.

A - There is a difficulty in the collecting the quantity of iron to make them; they could be made sound, but they would require a great deal of care in getting the bulk up

Q - They would be about the same length as the plates, would they not?

A - Yes; but it would be still an expensive bar to make, such a size as that.

Q - But they would be sound if made?

A - Yes, and full of fibre to; no doubt of it.

Q - Do you make boiler-plates?

A - When I am not in such a trade as this, I make 150 tons a-week.

Q - Do you test them before you deliver them?

A - Yes; we break them, and then take a scrap of every plate, and break it round to see the fibre, and sometimes smith it; for a boiler-plate you require to cross pile the iron, and for a plate of fifteen feet long, three feet wide and a half an inch thick, the constant lengthening of the plate, I think, destroys the cross piling in a great measure.

Mr. Pole - And it distributes the fibre in the direction of the passage through the rolls?

A - Yes.

Col. Henderson - You cross pile it to make it tougher where there is a bend?

A - Yes; to make it stand either the one way or the other: it is a greater matter to get a boiler-plate to smith at a sharp angle; but it is done by working from scrap iron, I'm getting the iron free from being red short.

Q - But if you retain the fibre across in that way (*pointing to a specimen*) in one case, why not in the other?

A - In consequence of the lengthening of the plate in the way of rolling the cross piling is disturbed. This is what we call the lengthway; it will bend well enough that way (*explaining the same*), but the cross way it is so difficult to get its to bend in that way (*describing the same*).

Q - Do you think that you could arrive at any results as to the tenacity or toughness of thick four and a-half inches plates, by testing plates of an inch or an inch and a-half in thickness, made of a similar quality of iron?

A - Yes; I test the scrap from which I start in shearing the five feet by three feet three inches and a-quarter plates. I test the scrap, and then it is invariably as tough as the plate is.

Q - Suppose you took a plate of an inch thick, and fired at it with a rifle, do you think that you could arrive at any results as to the best quality of iron for making thicker plates?

A - If the plate was sound and fibrous in character, you would find that the musket ball would not injure it; but if you got one made of a hard class of iron the musket ball would very soon destroy it.

Q - Then do you think that that would afford a means of arriving at a result?

A - Yes. I was in Dublin two years ago, they were practising at the Pigeon House, and there they had a cast iron target, which they were smashing by firing at it; and I said to the person in charge, "why do not you get a wrought iron plate? you might fire at that for years with impunity;" and he said "these are just what we have from the Tower, and they are cast iron targets; and they were lying about in large quantities; that was a comparison between cast-iron wrought-iron. In our neighbourhood we have had a wrought iron target put up for the Volunteer Corps, and they have been firing at it for a considerable time and you can see no marks of fracture whatever.

Mr. Pole - Are you favourable to the idea of putting corrugations or bosses of any kind on the front of a plate or would you prefer a plain surface?

A - I do not see how it could roll.

Mr. Fairbairn - You could do that by shaping the rolls could you not?

A - Not without the slabs are being previously prepared; you could not bend them out of a flat pile, such as we make now; I mean the sheered iron for these armour plates; it would not do to form a very large angle, the iron would tear in rolling. We find great difficulty in getting an inch and a quarter rise, for it tears the fibres of the iron.

Mr. Pole - But suppose it could be done, would it in your opinion, be a good plan or not for resisting shot?

A - I cannot say.

Q - Do you know anything of the best means of preserving iron exposed to the water or to the air?

A - I do not know of any other means than to get the scale off the iron, and frequently painting it; if you paint on the scale it crumbles off.

Q - Have you any further suggestions to make to the Committee?

A - No.

Dr. Percy - Are you of opinion, that by using **any** other qualities of pig iron whatever, you could produce thick plates of a tougher and softer quality?

A - I do not think it is possible. They cannot be made any softer, I am sure, than that sample (*pointing to the same*).

End of interview.