

STEELINESS

**Evidence by William Hardy of Thames Iron Works to the
Special Committee on Iron**

January 1861

**David Bournell
May 2019**

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, weight, 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 William Hardy.

Mr William Hardy

William Hardy was the ironmaster at Thames Iron Works and had previously worked for CJ Mare.

The Transcript

Date: 30 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 - The firm to which you belong have been largely concerned, have they not, in the building iron ships?

A - Yes.

Q - What is the greatest thickness of iron that you have used in plates?

A - Four inches and a-half thick.

Q - To what purpose have they been applied?

A - For plating the outside.

Q - For war purposes?

A - Yes; I speak of the "Warrior."

Q - That is, of course attached to a wooden backing?

A - Yes.

Q - Have you ever considered the subject of building ships for war purposes, and attaching the iron plates to an iron frame work, without any wooden backing?

A - No; I have never considered that subject.

Q - Neither theoretically no practically?

A - I have not.

Q - Have you any data from which you can give the Committee information on that subject?

A - None.

Q - I will put this to you as a question: let it be assumed that experiment may decide, that, in building ships for war purposes, it would be desirable to do away entirely with the wooden element in there construction, what would appear to you to be the thickest iron plate that could be used in covering a ship's side, the ships are considered could be of 2,000, 3,000, 4,000, 5,000, 6,000, and 7,000 tons burden, respectively, to carry one tier of heavy ordinance, with the lower port sale still at 8'6" from the water at load draft, covered over by a plated deck, and with engines, stores, and fuel for prolonged propulsion at a high velocity, the plating below the waterline to be of a thickness suitable for safe navigation, and the plating, the letter cause of the question being that to which the Committee wish your attention especially to be directed?

A - You are speaking more in reference to the construction and strength of ships, to carry these things, and I know very little about it. My business has been making of iron. I know little about the requisite scantling for ships of different sizes.

Q - If the committee were to submit this question to the company with which you are connected, they would, probably, be able to give us some information?

A - It would be a question more for Mr. Ash, our naval architect, to answer.

Mr. Fairbairn - You manufacture iron and at the Thames Iron Works?

A - Yes.

Q - In your manufacture of those large thick plates, at the Thames Iron Works, do you manufacture them from scrap?

A - Yes.

Q - Entirely from scrap?

A - We have not been manufacturing the whole of the plates from scrap, as we were ordered to put a certain portion of puddled iron. We do not puddle; we bought it from Milton, in Yorkshire.

Q - Do you combine the puddled iron that you purchase from Milton, in Yorkshire, with your scrap iron?

A - Yes; and roll in the scrap into the bars before making it into a slab; we put layers of paddled iron amongst it.

Q - Is it, therefore, a combination of puddled iron and scrap?

A - Yes.

Q - In what proportions?

A - A third of puddled iron with two-thirds of the best rolled scrap.

Q - Will you be so good as to inform the Committee where you collect the scrap from; do you collect it from all quarters?

A - The scrap is generally bought from gatherers in London, and we can always get enough to carry on the works. We use 10,000 tons a year of it; but I should think that there are four times that quantity to be found

Q - Do you clean the scrap before you use it?

A - Yes; if it requires cleaning.

Q - You consider it essential, in order to obtain sound plates that you should have it clean?

A - In all cases to have the ironing clean, or we should get blisters, and unsound places.

Q - Do you use any particular process as to cleaning, such as cutting up, or shaking it about?

A - We carefully look over all our scrap iron, and, if we find any paint upon it, we burn it in the furnace till it all comes off. We do not think that the scoria has any serious effect upon it ourselves.

Q - Do you receive the iron from Yorkshire in the shape of a puddled bar?

A - Yes.

Q - Ready for piling

A - Yes.

Q - Will you be so good as to inform the Committee how you make up your bars, with reference to the puddled bars, and also with reference to the scrap bars?

A - These (*describing the same*), would represent a bar five inches broad, and we should cut them and put them down, three of them like that for the bottom of the pile, and should then cross that, edged in that way (*describing the same*), with scrap iron, and then cross it again with puddled bars.

Q - How many layers would there be?

A - That depends on the size of the pile. We charge this about 4 cwt. into our ball furnace, taking care in all cases, to keep the scrap iron outside the pile

Q - What is the object of that?

A - The puddled iron will never stand so much the action of the fire as the scrap iron will.

Q - Is the scrap iron and more soft?

A - It is softer than the other, and of a better quality.

Q - And tougher?

A - Decidedly so.

Q - Of what size have you made your plates?

A - We have made our plates of about 4 tons weight.

Q - What would be the size of a plate of that weight?

A - Sixteen feet long, three feet wide, and four and a-half inches thick. We work in this way - we begin, and lay two slabs at the end of our porter-bar, we mould them out till we get the width of the plate to begin with, and we then lay three slabs on, in that form (*describing the same*), taking care, in all cases, to break the joint.

Q - Do you roll them?

A - No.

Q - Do you put them all under the hammer?

A - Yes.

Q - You then bring them to a flat plate?

A - Yes; four inches and a-half thick.

Q - Then you weld the sides, I suppose, on that principle?

A - Yes.

Q - Then you take three slabs?

A - Yes; we start with one, and then put on the second and third, taking care to have sufficient material to keep well at work, under the hammer, in order to turn the pieces out sound.

Q - Are those slabs heated in separate furnaces?

A - No; They are laid on the top of the pile each time and are brought to a welding heat in the large furnace.

Q - Having got your pile, and got it up to the temperature when it is at a welding heat, you draw it out by a machine, and get it under the hammer at once?

A - Yes; and begin hammering with Nasmyth's steam-hammer; four tons is weight of the hammer we use.

Q - Do you give it heavy blows at first?

A - That would all depend upon circumstances.

Q - With regard to the formation of these plates, have you paid particular attention to the direction of the fibre in plates, or do you cross it

A - In the first place, the fibre is invariably, as the length of the bar, longitudinal with the bars, then we cross it, and have the fibre both ways; but I never consider that there is much fibre in a hammered piece of iron; it always appears to me that the fibre is, in some measure, broken, and, that granulation takes place from hammering; you can produce plenty of fibre from rolled iron

Q - Is that the case with a soft iron?

A - Yes.

Q - It gives every indication of elongation when under the action of the hammer, it draws out?

A - Yes; we are tonging and grooving the plates for the batteries; these specimens (*handing in the same*) are our planings; this came off at the tongue of a battery plate, and that came out of a plate sixteen feet long, and has never broken; there is puddled bar in that.

Q - In the course of your experience have you paid any attention at all to puddled steel?

A - We do nothing in that; we had some steel that came up from Liverpool some time ago for the purpose of endeavouring to make a better plate, but we could do nothing with it.

Q - Suppose, for instance, that you could get some of that pedal steel, could you weld it into your scrap iron, and into your puddled bars?

A - No; I think not.

Q - Suppose that instead of pursuing the system that you now do, in piling the slabs, and welding of them together under the hammer, that you first had a layer scrap iron, then a thin layer of steel, and upon that again your scrap iron, or puddled bars, and perhaps another layer of puddled bars, and afterwards scrap; what should you think of that?

A - We have never tried, but I should be fearful, from what we have seen, that we could do nothing with puddled steel.

Q - Do you think that you could not unite to them together?

A - I think not.

Q - That there would be no amalgamation?

A - I think not. I think that it is of a very indifferent character indeed, and of there appears to be a rawness about it; at least we can do nothing with it.

Q - What do you think of the homogenous iron?

A - we have never used that.

Q - I mean Bessemer's process

A - Anything that creates a brittle article is not fit for the purpose of plating ships sides. I should go for scrap, and scrap iron alone, because I have had more experience in making it.

For all our heavy forgings that we make for James Watt and Company, John Penn and Sons, and Maudesley, Sons and Field, we use nothing but scrap iron.

Q - I suppose it is chiefly for axles and cranks?

A - Yes; for marine purposes.

Q - Have you made any experiments at all upon the plates with regard to their resisting power?

A - No, we have not done so ourselves; we have sent some to the Government, and I have heard that sometimes they have stood pretty well, and sometimes indifferently; but I know scarcely anything upon that subject.

Q - You have kept no register of what the results have been?

A - No; but I may here mention that when these plates are worked under the hammer and cleansed with water, the plate becomes hammer-hardened, and rather brittle; to remedy which we put it into a furnace, sixteen feet long, heat it to a tolerable heat, bring it out, lay it along and let it cool gradually, Ross and kneeling it.

Q - Do you anneal all the hard plates?

A - Every one.

Q - Are they all softened?

A - Yes; in fact they go under two processes of that sort. In the first place, with a large plates, we put them into the furnace to straighten them, so as to enable us to tongue and groove, and before bending them down by wedges to the curve of the ship's side, we are obliged to anneal them over again.

Q - The iron cuts well?

A - Yes.

Q - Will you inform the committee in what way, after you get the plates formed, and welded, and annealed, you cut them to sizes; is that done by a planing machine?

A - Yes, we playing them down to the weight required, cut out the groove on one side, and leave the tongue on the other.

Q - Do you do the ends in the same way?

A - Yes.

Q - With regard to the softness or hardness of the iron, you consider that the plates are better for cutting after you have had them annealed, but the question is whether they are better to resist shot or not?

A - I think there is no question about it, that if a plate going upon a ship's side be hammer-hardened, if severely punished it will fracture; but if softened and there is sufficient strength in it, I think you will merely indent the plate without breaking it.

Q - You have seen the "Warrior," and the way in which the plates are being put on?

A - Yes; we are now putting them on; the first *strake* is on; we have forged all the plates for the "Warrior" at the Thames Iron Works.

Q - What is your opinion as to the backing that they should have? Should the backing, in your opinion, be of wood, or could iron be used, dispensing with wood altogether?

A - I think it is a very good backing, and of the sort of backing that I think, to look at it, is necessary; and I think that, in some measure, it would prevent that severe shock that would take place on the rivets if it were made all of iron, for, if you lose the rivet heads, the ship be at liberty.

Q - have you any suggestion to make with regard to how these plates should be fastened on the side of a ship in order to best to resist the impact of shot?

A - I think that it is almost impossible to devise a better plan than we have, to drill a hole through them. I would say sixteen holes through one of those plates 15 feet long, and inch and a half in diameter, we have countersunk the head so as to make it smooth on the surface, and there are two nuts on the inside, a double nut, and I cannot conceive a better plan and that for fastening those plates.

Q - What is the distance between the bolts?

A - I should think about from fifteen to eighteen inches.

Q - And that you consider is the best mode of fastening?

A - I think so; I cannot conceive a better mode of fastening than that, myself.

Q - Are the bolts made of the same quality of iron?

A - Yes; of scrap-iron.

Q - Also annealed?

A - No; that is rolled iron, which is fibrous, therefore does not require annealing.

Q - Do you make the bolt-iron yourself?

A - Yes; that is also from the best scrap.

Colonel Henderson - do you conceive that hammered iron, or rolled iron is the best to resist shot?

A - I think there is no difference between them, if the iron which is to be made into rolled plate be first welded under the hammer into one compact slab.

Q - You think they would be equally good?

A - Yes.

Q - Do you know anything of the process called Stirling's process?

A - That is a peculiar iron, a portion of wrought-iron put in with the cast-iron, for toughening the cast iron; but I think it is very little used now; it was brought out some time ago, and it is melted with cast iron.

Q - Do you consider that the grooving which is resorted to in the construction of the "Warrior" will improve the plating?

A - I think that may be the means of supporting the plate if fractured, and of holding the piece on that is fractured. Suppose, for example, that this piece of paper was the plate hit, and that the head of this piece (*describing the same*) were broken off, I think that in consequence of having a groove on the bottom of the side might keep that that piece (*explaining the same*) in its place.

Q - Supposing it to be a very small hole?

A - Yes; that is my idea of tonguing and grooving; that, if the plate should break, the iron should still keep to its work; the groove is half-an-inch deep and three-quarters of an inch broad.

Q - Do you think that it is sufficient to hold it together?

A - If we understand it right, it is meant to prevent the pieces falling away which might be fractured by the shot.

Q - Do you think it would have that effect?

A - Yes; I think it would, partially so.

Chairman. - In drilling the holes in the plate, are they in lines?

A - They are a little zigzag.

Q - How many holes are there in a square foot?

A - I think that we have only about sixteen holes in a plate sixteen feet long by three feet wide; it would not be desirable to have too many large holes.

Q - Are these holes all at the edges of the plates?

A - No.

Q - Of what the description of iron all the bolts made?

A - They are made of the best scrap iron.

Q - Of the same description as the iron which composes the plates?

A - Yes; but rolled instead of being hammered.

Q - Are the nuts cast?

A - No; they are wrought-iron nuts

Dr. Percy. - In getting scrap iron you are not, from what you say, likely to suffer any inconvenience from the presence of other metals in it, such as tin?

A - We have it, but that never goes into our hammered iron, we keep it out.

Q - What would be the effect of a little brass in it?

A - The work would be unsound.

Q - You could not puddle at all then, could you?

A - We could not work it; these things are generally indicated under the hammer by all sorts of blue and red fires.

Q - Do you say that a puddled bar will not stand the action of heat so well as a scrap-iron

A - Yes; the scrap-iron has gone through several processes more than the puddled iron.

Q - With regard to the use of Nasmyth's hammer you said that you varied the strength of the blow according to circumstances; what are the circumstances that require a heavy blow, and what are the circumstances that require a light blow?

A - These. Supposing we are bringing a large heat out of the fire, and we see that it has had too much fire, and that it is a little tender, we should not let the Nasmyth's hammer fall down on this with all its weight, for it would smash it.

Q - It requires a slight blow for tender iron?

A - Yes; it does.

Q - If the iron be thoroughly good at the commencement you may apply any blow, may you not?

A - In welding a scarf we should not do it.

Q - But still good I will receive a heavy blow with impunity?

A - Yes.

Mr. Pole. - I did not quite understand your description of how you made the plates; that is to say, what is the last process is?

A - This we will suppose is our porter bar (*describing at the same*), that goes into the furnace, and we begin by laying on slabs in this manner (*describing the same*). We put them into the furnace, taking welding heats upon them till we have sufficient to spread them out to three feet wide, then we finish at the plates to three feet wide, and four and a-half inches thick.

Q - You make first a short piece of plate of the full thickness, and then weld another piece on to it, until you get the necessary length?

A - Yes.

Q - How do you make these welds; are they scarfed?

A - Yes.

Q - An inclined scarf?

A - Yes; and then we weld another piece on to that.

Q - About what width do you make it?

A - Eighteen inched by one foot, as near as possible.

Q - And that is very unlikely to make a good sound weld, is it?

A - Yes; we have both the end and the middle in the fire at the same time, which enables us to make very good welds; the end and the middle are in the fire at the same time, and all our large forgings for marine purposes are made by that process now.

Q - But they are faggoted each in pieces of the full length?

A - No; that plan is abandoned.

Q - Do not you try get them all in long pieces?

A - Never.

Q - You prefer making them in short lengths scarf welded together?

A - Yes.

Q - Then you do not heat the same part of a plate many times over?

A - No.

Q - Not so many times as to do it damage by too frequent heating?

A - no; but just as much as will make a perfect and sound job

Q - It is a fact, is it not, that the heating of iron many times over, beyond a certain number of times, deteriorates its quality?

A - I do not think it does any good.

Q - I wish to ascertain whether you make a plate in such a way as to avoid heating the same part too frequently?

A - We avoided that, in all cases as much as we can.

Q - Can you state generally, whether a hard or a soft plate is best calculated to resist the impact of shot?

A - A soft and tough plate it is certainly the best.

Q - Can you obtain the requisite degree of softness by annealing after hammering?

A - Yes; I think so.

Q - Generally speaking, will not a rolled plate be softer than a hammered one?

A - Not upon the plan that we adopt. Or are hammered plates, after being finished, are thoroughly annealed and softened.

Q - Your firm, I believe, succeeded Mare and Company?

A - Yes; I was with Messrs. Mare.

Q - And you have not only taken to the iron making business, but also to the boat-building business?

A - Yes.

Q - With regard to tongues and grooves, do you not think, that independently of the advantage that you state there is in keeping a broken piece in, your plan makes the plates mutually self supporting, and relieves the bolts?

A - Yes; but the bolts are sufficient to carry anything of that sort, there are 16 bolts in a plate, all an inch and a-half in diameter.

Q - have you witnessed any firing at the plates?

A - No.

Q - You do not know what the effect would be on the bolts?

A - No.

Q - Did you state that the groove in the plates was only three quarters of an inch wide, by half an inch deep, in a four and a quarter inch plate?

A - Yes.

Q - With reference to the value of plates prepared as yours are, per ton, does that depend upon the weight of the plates?

A - Yes; but we would as soon make plates of five tons as of three tons.

Q - At the same price?

A - We should charge more per ton.

Q - About what would the charge should be in the two cases?

A - For plates of three tons, I dare say we should ask £26 per ton and £30a ton for the others; that would be from the hammer, not planed or tongued, or grooved.

Q - Would you approve of making a plate of different qualities, harder in front, or with a harder layer in the middle, or with any variation of the quality and the thickness of the plate?

A - I cannot recommend anything of that sort. I should think that one of uniform quality would be found to answer the best, made from the strongest iron.

Q - And being uniformly tough and soft throughout?

A - Particularly soft and tough.

Q - But uniform throughout?

A - Yes.

Q - Do you in trimming up the edges of the plates plane them or slot them?

A - We plane them; we plane the long side, and slot the ends off; that is that for the convenience of our machines.

Q - Which is the best process of those two, and the cheapest?

A - It is a mere matter of convenience, as to the machinery we do it with.

Chairman. - Could any inference, as to the resisting the power of an iron plate, be drawn from a violent punching blow given by fixing a punch, for instance, on a steam hammer?

A - Yes; but I do not think there is sufficient strength in the gear of a steam-hammer to do anything of that sort safely.

Q - Not on a thin plate?

A - Yes; I have no doubt that we could punch a hole right through a thin plate, under our steam-hammer

Q - So that you could ascertain the different weight and the velocity which were necessary to produce a given indentation?

A - Yes.

Q - Have you have the means to show us such an experiment as that?

A - Yes, at the risk of damaging the hammer.

Q - Would it be, in your opinion, of any value has a comparative analysis of the toughness and resisting power of different iron plates?

A - Yes; I think that important information might be obtained from experiments of that sort

Q - And with considerable more economy as to time and labour, than by fixing targets, and firing at them with artillery?

A - Yes.

Q - Would there be any difficulty in attaching a punch to a hammer?

A - No; we could make a hammer and put a punch into it.

Q - Would the Committee have any difficulty, collectively or singly, or their Secretary, in obtaining access to the "Warrior" at any time?

A - None whatever.

Mr. Fairbairn. - I think you say that your plates are grooved and tongued?

A - Yes.

Q - Suppose a plate to be knocked out by a shot, what means would you have of putting a new one in its place?

A - To replace it by a plate, tongued and grooved as before, you would have to take all the plates out above it.

Q - Are the plates put on longitudinally?

A - Yes.

Q - How many plates have you in depth?

A - Seven.

Q - Suppose the one in the middle was damaged, what would you do?

A - In that case, the best way would be to cut off the projecting tongues and put in a plate, relying simply upon the bolts for support.

Chairman. - A plain one?

A - Yes. There is one observation that I wish to make; there has been a great deal of talk respecting rolled plates, and I believe, gentlemen, you all know that rolled plates are usually rolled from piles, and I never could conceive that the welds in plates rolled from piles, five feet long and three feet wide, could be equal to those in hammered plates, or in plates rolled from hammered slabs.

Q - I think you first pile and make three slabs and then you put those together as you described to us one on each side leaving a space between, you pile them together?

A - Yes.

Q - The question then just arises whether, if you had long bars and a good reverberatory furnace, equal to the length of the plate, or nearly equal to it, you could lay them on transversely, and then put them through the rolls, giving a sufficient pressure equal to your hammering, and whether one would not be as good as the other?

A - I think not; I think you must forge the slab first absolutely sound before you begin.

Dr. Percy. - How can you tell when it is absolutely sound?

A - only by drilling through it.

Q - Do you think that by using any other qualities of iron than those which you employ for the "Warrior" plates, you could produce plates possessing greater softness and greater toughness?

A - I am not aware of any mixture that would be better than from scrap iron.

Q - Do you think that those are made from scrap iron are the softest and toughest that can be made?

A - Yes I think so.

Mr. Fairbairn. - The way in which you octane this softness and toughness, is that by kneeling them after you have hammered them, allowing them to cool slowly?

A - Yes.

Q - Have you ever heard of Arrowsmith's plan; building up a plate in bars, and then welding them together?

A - Yes; in that case he rolls them; that is the plan for all land batteries.

Q - What do you think of that mode?

A - I think it is quite practicable to be done for jobs of that sort, and that it would answer the purpose.

Q - Is it possible to get the welds sound by rolling?

A - Yes; because you are dealing there with a piece of iron that he's not very large in section.

End of interview.