ONE HUNDRED AND TWENTY-EIGHTH PAPER

(OF TRANSACTIONS).

# THE VALUE OF ANNEALING.

BY

THE HON. SECRETARY

READ AT

58 ROMFORD ROAD, STRATFORD,

ON

*MONDAY, JANUARY 8th, 1906.*

CHAIRMAN:

MR. FRANK COOPER (MEMBER OF COUNCIL).

THE subject I have chosen to bring before you is introduced with the object of inducing a discussion which it is hoped will obtain some conclusive evidence based upon experience to show the value of annealing, to what extent that value is of practical service, how far it can be relied on to restore the original strength to material treated by the process, and to what metals its application is of value. It is well known that by gently hammering in one place a rod of iron or the link of a chain such can be made so brittle that very much less than the breaking strain of the section of the iron applied to either the rod or the chain will cause fracture. It is conceivable that an expert may even break a rod so hardened over his arm which otherwise would simply bend, as in the experiment which doubtless many have tried in the workshop. The force which in the one case breaks the section may in the other only bend a rod of similar section—not due to any deterioration in the metal or inherent weakness in its composition, but simply to an alteration in the disposition of the minute particles which combined give the fibre and strength to the whole. This alteration is brought about under continued cold treatment and by hammering or vibratory action; the antidote is hot treatment with gradual cooling—the more gradual the better.

In the Statutory Rules and Orders, 1904, No. 1,617, issued by the Secretary of State the following paragraph occurs: "All machinery and chains and other gear used in hoisting or lowering in connection with goods handled at a wharf shall have been tested, and shall be periodically examined. All such chains shall be effectually softened by annealing or firing when necessary, and all half-inch or smaller chains in general use shall be so annealed or fired once in every six months. If the chains are part of the outfit carried by a sea-going ship, it shall be a sufficient compliance with the regulation as regards softening by annealing or firing of half-inch or smaller chains that no such chains shall be used unless they have been so annealed or fired within six months preceding. As regards chains, the safe load indicated by the test, the date of last annealing, and any other particulars prescribed by the Secretary of State, shall be entered in a register, which shall be kept on the premises, unless some other place has been approved in writing by the chief inspector." The fact that such regulations and recommendations have been issued by the Government goes to show that in the opinion of the expert advisers annealing is deemed to be of considerable value.

In the manufacture of glass the process of annealing is carried out in the final stage in order to reduce its brittleness. In toughened glass the process of annealing is more elaborate, and in some cases oil is used as a medium in order to obtain a degree of toughness not reached in the ordinary way. The effect of the annealing on glass is much the same as its effects on metal, and it may be said to render them all more able to undergo another spell of work with their initial strength, if the process is carried out after they have been fatigued by hammering, vibratory action, or by movements tending to harden the metal, thus rendering it less able to meet its requirements in resisting fracture.

It may be remarked by the way that an analogous process holds good in respect to its effect on over-worked humanity, where decay and disaster to the organism is prevented by change of occupation or of air and surroundings; or, again, when strained relations have resulted in chronic growling and general rustiness in carrying on the routine of duty, a good warm flare-up is usually followed by a happier condition of mind all round, to the advantage of all concerned. The truer the steel the more good will result from the heat generated, tending to cause the opposing elements to dovetail into one another.

The tempering of steel, the case-hardening of iron, and the making of malleable iron castings come under the category of the subject of annealing. By heating metals which have been subjected to fatigue and allowing them to cool again very gradually the molecules readily accommodate themselves to one another in the process, and are so knit together when the mass reaches a normal temperature that the whole piece becomes of its normal strength of fibre. On the other hand, when metals are worked and hammered, then suddenly cooled, they become more brittle and more liable to yield under stress or when strained. Many instances will doubtless occur to members where boiler plates have been so worked and left to cool in the open, with the result that they have been found split a few hours afterwards; or, again, where a boiler has been blown down and emptied too quickly, with the result that the furnace saddles or tube plates have been found cracked. These bad results have followed from neglect of the ordinary rules which we are all familiar with—that it is not good to allow a boiler to cool down quickly, nor is it good to raise steam quickly; and here we have in our ordinary practice the element of annealing, and we recognise its value. It has not been unknown to have a cylinder cracked, due to carrying out too literally the request to put steam on the engines immediately. Especially does this come into play with water-tube boilers giving steam quickly.

Steam pipes after years of work, especially when subjected by reason of their surroundings and bindings by straphangers or plates, to vibration, aggravated by the want of free play to adapt themselves to circumstances, are admittedly improved by annealing, when the hardening of the metal is reduced by heating once more to its original texture and toughness.

In frosty weather, when the temperature of the atmosphere runs down towards zero, we are more alive to the risks of heating up engines and boilers too quickly, and, on the other hand, of cooling them down; so, also, we are more on the look-out for flaws and defects, knowing that the risks are greater when the temperature is low, and the contraction of metals tends to harden them unduly by the alteration in the particles. The recommendations of the commission appointed to investigate the manufacture and conditions of use of cylinders or bottles for containing gases of high expansive force go to show that when the result of the inquiries was published in 1896 the consensus of opinion was in favour of annealing. The witnesses examined by the commission were chiefly drawn from the users of the cylinders in the filling process, the carriers, and the users of the gas. A well-known firm of brewers suggested that gas cylinders should be made in accordance with the Board of Trade regulations for marine boilers, in order to ensure a minimum of risk, and that they should be made as light as possible compatible with safety. This suggestion was also made by others in more or less modified form; and when we consider the large number of cylinders in daily use all over the country, on board ship for refrigeration, to the number of thirty to forty per steamer containing spare supplies, or shipped as cargo, we will doubtless endorse the opinion implied in the suggestions. The following is quoted from a circular issued by a firm of manufacturers: "We hereby certify that all cylinders containing carbonic acid gas supplied by us have been periodically annealed and tested by us to a pressure of $1\frac{1}{2}$ tons per sq. in., and are made in accordance with the recommendations of the British Government Committee of 1896. External diameter, $5\frac{1}{2}$ in.; thickness of metal, $\frac{1}{4}$ in."

The suggestions made by those who were favourable to annealing differed in respect to the periods which might be allowed to elapse between the dates of annealing, and one firm considered that cylinders should be reannealed, as the makers occasionally overlooked the final annealing before despatching from the works, and for another most important reason—it ensured all extraneous matter being burned out of the cylinder.

A very important and vital consideration in connection with the testing and annealing of gas cylinders arises when a cylinder has been tested and its water capacity increases under test without again returning to its original capacity, thus showing that the metal has been strained beyond its elastic limit, and consequently also decreasing to some extent the thickness of the cylinder shell.

The recommendations in the Blue-Book give a thickness of ·251 in. for $5\frac{1}{2}$-in. cylinders, and in practice the thickness varies from $\frac{1}{4}$ in. to $\frac{3}{8}$ in. It is evident the committee concluded the thickness should be rather over $\frac{1}{4}$ in.; but if this is considered to be the minimum, what assurance can be given that this will be maintained throughout in the manufacture unless a margin be allowed for irregularity? Those who adopt the $\frac{3}{8}$-in. thickness probably take the $\frac{1}{16}$ in. as the margin.

Suppose we take a cylinder which has been originally ·25 in. thick, and has been in use for three years. It is received by a firm, which has no knowledge of its history, to refill. It is tested, and as a result its water capacity is increased by 5 per cent. The question now arises whether that cylinder should be condemned or annealed and refilled. The arguments in favour of condemnation are:

1. The cylinder was possibly of irregular section to begin with, and under ·25 in. at a portion of the shell; hence the increase of water capacity would probably occur at the thinnest part, reducing it still further, and bringing the margin of strength down to a narrow limit.

2. The cylinder may have been previously tested, with a like result, and unrecorded, so that the 5 per cent. increase of water capacity might not in the second case be on the original but on a previous increase when tested.

3. There is no rigid rule as to refilling cylinders, and it is quite possible for a firm to refill those intended for sea stock and a tropical voyage to the same extent as those intended for home use only—that is to say, the 25 per cent. margin for expansion under higher temperature may be overlooked as an imperative condition. Thus the extra pressure coming upon a thinned cylinder might result in disaster.

4. In the event of a fatal result arising out of a burst cylinder the evidence would throw the blame upon the firm who last tested the cylinder; and if the evidence further revealed that the metal had been strained to a permanent set of 5 per cent. or more before refilling the conclusion might be bad for the firm concerned.

On the other hand, it might be argued that 5 per cent. increase of capacity is so small as to be a negligible quantity, and that to condemn a cylinder costing perhaps £4 10s. for such a reason would be throwing away money.

There are firms who, when they find a cylinder increases permanently its water capacity under test, at once condemn it, and no doubt this is the wisest and safest plan; but in the interests of the public safety it appears to me that some regulations should be made and enforced all round. There is possibly a tendency on the part of some firms to run risks in order to supply customers who desire to get the utmost value for their money and who may be unaware of the risks, and if their attention were called to these by a Government inspector or otherwise they might acquiesce in the regulations. The importation of cylinders would also come under the same regulations, and it would give confidence to the ever-enlarging circle of users, whether in this country for home use or especially at sea for use in the tropics.

Mr. E. W. Ross (Hon. Finance Secretary): As this subject has been introduced with a view to raising an instructive discussion, with exchange of thought and experience as to annealing—whether it is beneficial and necessary or otherwise—of the various materials which engineers have daily to deal with, I have pleasure in adding my quota.

Annealing might be said to be the loosening of any abnormal restraint on the particles or molecules and allowing them freedom of attraction to one another. In metals this may be attained by heating to a dark red heat, just sufficient to allow a flow of the particles back to their natural position in the mass. That annealing is necessary and beneficial after metals have been worked in various manufactures is abundantly evident. Copper and copper alloys, such as Muntz metal and similar alloys, when drawn out into tubes, rods, wire, or sheet, require to be passed through the annealing process before the further work of manufacture is put upon them, both for ease of working and on account of brittleness through compression of the molecules. Again, it has been found beneficial to anneal all copper steam pipes periodically, after having done work for which they were made, as there appears to be a hardening process going on by repeated heating and cooling, as is indicated by the Board of Trade in their procedure with regard to pipes. In copper pipes for conducting water this change in character does not appear to occur, and annealing is seldom necessary. Where material is used as sparingly as necessity permits, and where the tensile strain limit is very often closely approached, the metal is readily made crystalline, and thus more liable to fracture. In such cases especially, the material should be annealed. But where the material is abundant over any dream of tensile or torsional fracture, but necessary for the sake of rigidity, then the necessity for annealing is not so much apparent. The chain is a good example of the former, where lightness with the necessary strength should be combined. An Act of Parliament came into force in January, 1905, requiring all chains of certain thickness to be annealed and tested periodically, and it appears to me that it would be better and safer if they were tested first and annealed afterwards. Testing after annealing to a certain degree tends to put the material in the same condition as it would be after having done useful work equal to the testing fatigue. If a chain will not stand a recognised test strain before annealing, it seems to me the sooner it is condemned the better; for the risk of danger must be often present while at work, as it is not the steady strain of a lift, but the jerks and surges experienced, which brings the material near the test strain.

Steel requires the most careful manipulation in annealing—especially steels of the harder qualities; and this danger of imperfect annealing renders it a doubtful material where sudden shock is likely to occur. I think some of us have had experience of the broken steel junk ring bolt or stud, with its attendant consequences, possibly through imperfect annealing. Several parts of machinery are made of cast steel for strength and lightness, combined with less cost, where much machining would be necessary. These require annealing so as to regulate any inequality in the contraction when cooling, however carefully that may have been done. Those who have had the machine tool over such parts have often found a patchiness of hard and soft, which shows the necessity of the operation. In days past, time and expense were not so much thought of as to-day. Speed of turn-out with cheapness, yet with the highest degree of reliability, are the order of the day. What the tool turned out then at great expense of time and cost the hydraulic press and steam-hammer of to-day turn out infinitely cheaper. But here again those parts which are to enter as vital parts into the intricate machinery of to-day must be annealed for safety's sake. Economy in our coal consumption, with higher boiler pressures, has called for changes in our boilers. In place of the old plain iron or steel furnace we now have the corrugated mild steel furnace, with the varying sections of the different makers, which are wonders of manufacture, but yet simple to manufacture with the tools now at command. These have all to be carefully annealed before passing out of the forge for use in their respective boilers, so that there may be complete homogeneity of hardness throughout the whole furnace. That the various changes of temperature and conditions, with voyage after voyage of the boiler's life, does bring a change in the nature of steel furnaces is amply proved by practical experience. A boiler has come home after a long voyage absolutely tight and with all its furnaces in perfect condition; on being refilled a water leakage has been shown, and on examination a crack has shown itself. Even while repairs were being carried out on or near a furnace a report has been heard, and on inspection a crack discovered. How came the weaknesses? The cause is apparently due to a hardening of the particles at that particular place or in close proximity to it, causing an unequal strain; hence the fractures. I think this shows the necessity for annealing the furnace in the first place before use, and afterwards careful handling during service. The old way of blowing down boilers on arrival in port is now unheard of, as nowadays they are allowed to reasonably cool down, and are then pumped out. Contraction is thus more gentle, and this hardening or chilling action on the furnaces modified. Steel boiler stays are also subject to being hardened by use and liable to fracture, and as it is not practicable to anneal they are mostly renewed in iron a size larger.

We have another item on board ship of late years in the shape of the gas bottle for refrigerator purposes, which I am afraid sometimes undergoes rougher treatment than is intended for it, when we hear of cylinders being used as rollers and the rough transport treatment mentioned by Mr. Mackenzie in his recent paper. This, besides the unknown pressures to which sometimes the bottles have to submit, renders annealing absolutely necessary. Glass also comes under the engineer's notice—as, for instance, when we hear the "gentle whispers" sometimes used when gauge-glass after gauge-glass flies into pieces when the cocks have been opened, however carefully done. I heard the other day of one ship on a voyage to Australia and back using one and a half gross of gauge-glasses. How necessary is it, then, that the material should be properly annealed glass! In our home life we have the incandescent light glasses, made of annealed glass "made in Austria." Why should not these be "made in Britain"? But it is better, perhaps, not to enter on that question in this period of hot-headed political debate. Our crockery ware, also, is all properly annealed before it is sent on the public market; otherwise what is its fate?

There is another point which we might call "Nature's annealing," or natural annealing. We all know what we term "fatigue" in metal, which is reached sooner where the "area of material to work done" is close. This occurs when there is a molecular disturbance, weakness, or fatigue in a shaft or spindle, and if a period of rest is given—it may be for weeks or years—the shaft or spindle is understood to regain its strength. This can only occur by the particles not being subjected to work to flow back to their original position and natural affinity for one another. Very often, as in case of large brass-cased shafts which it is impossible to pass through the fire, this is resorted to. I am not prepared to give any tests or proofs that this is so, but I think it is accepted by many, and this I venture to call "Nature's annealing." I know of several shafts which have been replaced from spare, not due to any defect, but simply to give them a rest with the object of again being refitted. If practical and experienced men had not an idea that the material would regain its previous condition they would not put their employers to this expense. From these few remarks I have made it appears that annealing is an indispensable condition for the life and working of the various details I have mentioned. I have not gone into the numerous ways that end is accomplished, as they each have intricacies of their own which only the several trades to which they appertain can efficiently carry out. That annealing is necessary and beneficial is shown by everyday practical experience, and by theory also.

The CHAIRMAN : I do not think I have ever heard a better description of annealing than that given by Mr. Ross—also his remarks about testing of chains, which has never struck me before; and I think that chains should be tested first and annealed afterwards. With regard to Mr. Adamson's remarks about brittleness through hammering, I saw a case the other day of a new style of piston ring made of cast iron, which, after being hammered right opposite the opening, was opened at least 3 in., and did not break, the ring being 7 in. in diameter. That is an instance of hammering causing the opposite effect to brittleness. I have some other remarks to make on the subject, but will open the discussion with these.

Mr. TIMPSON (Member) stated that on one occasion at sea he had suffered largely through gauge glasses breaking, so he had them put into the cook's boiler and had them boiled before being used, and found that by this procedure the trouble was greatly reduced. He could not agree with Mr. Ross that the best glass came from Austria, as in his experience the best glass at present on the market was British.

The CHAIRMAN: I think this opens a very large subject. Annealing and hardening are very much akin. I think we are agreed that annealing is a good process. Perhaps someone can give us the best methods of annealing.

Mr. G. W. NEWALL (Member) : Is it known at all what takes place in metals when they are fatigued or require annealing. What is it that demands annealing? As regards the relation of the molecules to one another, have we any knowledge of what has taken place? Also it struck me whilst the paper was being read, what effect would magnetism have as an annealer? He thought that when a metal was fatigued the molecules had lost their fibre, as it were, and that heat and magnetism might be able to restore that fibre, and affinity which the molecules seem to have for each other. He did not know if it had ever been tested that magnetism would be of use, and should like to hear of any experiment in that direction.

Mr. TIMPSON said, in regard to Mr. Newall's remarks, he had experience of the binding wires of an armature breaking; the wire was very brittle, which would seem to show electricity had an opposite effect to annealing. He had also found in renewing portions of wiring aboard ship that the old wire was short, and broke on bending.

Mr. J. CLARK (Companion) said that, in connection with the new Government regulations in regard to chains, Mr. Ross considered the test should be carried out before annealing, but he thought that, seeing annealing was a recognised process to benefit the material, it was quite in order that chains should not be tested until afterwards.

He quoted the fact that Mr. Hiorns, the metallurgical authority, stated that a temperature of about 1,300° F. is a critical point in the heating of steel, and illustrated on the blackboard the recalescence points.

It was interesting to know that a point could be obtained in a practical manner without any special instrument.

If a poker be heated to white heat and allowed to cool in the dark it would be found that during the process of cooling there is a time when the metal seems to get hotter, as shown by a slight glow. This is the recalescence point.

To heat a metal to redness and let it cool is not necessarily annealing; it may be causing a worse condition. He thought that in laying down an Act of this description, when so many classes had to deal with chains, some guide should have been embodied in the regulations.

With regard to the effect of annealing, he had one or two results which might be interesting. It was a fact that metal as it came from the mills, such as steel bars, would give better tensile results than after it was machined.

The following results showed the value of annealing material which had an ultimate tensile strength of 28½ tons. A contraction of area at point of fracture before annealing of 14 per cent. was increased to 55 per cent. contraction of area, while the tensile strength was 26½ tons per square inch.

There was one point about the new Act he considered rather interesting to note—that it did not depend upon the work the chain had done, but the time. It may have been lying idle, but it had to be annealed.

He thought it was a huge subject, and that steel was only one material in connection with it, and, no doubt, as it was followed up more closely, some of the lost arts would be discovered, such as the tempering of copper, which he thought was one of the lost arts, as well as points in connection with the manufacture of glass.

Mr. G. W. NEWALL: Perhaps the ancients used magnetism in tempering copper.

Mr. W. E. FARENDEN (Associate) said he would like to ask Mr. Clark what difference he had found in the tensile strength of different materials before annealing and after.

Mr. J. CLARK: The first result was material not annealed, the second result was annealed material.

Mr. BRITTON (Member) said he was very much interested in the paper, and thoroughly agreed that all machinery, gear, etc., should be tested and annealed periodically. He mentioned a case of a chain tested to five tons breaking with a weight of thirty-five hundredweight, and causing a nasty accident, through not having been annealed for some time. He advocated annealing as frequently as possible.

He asked the writer's opinion of what he thought was a medium time for blowing down a boiler. He understood it was customary on many London ships to blow down immediately, but he personally thought it wiser to take time over it and let the boiler cool slowly.

Another case that came under his notice a few days ago was that of a cylinder of a steam pump. He had seen it tested to 450 lb., and it worked very satisfactorily for some weeks; when on one occasion it was started under the ordinary pressure of about 70 lb., and run for some time, when without any warning the cylinder cracked. There was no flaw in the metal, and it was examined afterwards, but none found. He supposed some hardening had taken place in the metal, which he could not account for.

He was not aware of the Act of Parliament referred to, but considered it a right and proper one, and agreed that testing should come before annealing.

Mr. R. MACKENZIE (Assoc. Member) said there was a question he would like to ask with regard to annealing; it was in reference to bolts for holding down a compressor. The pressure was sometimes up to 1,300 lb., and on three different occasions the bolts had broken.

There were four holding-down bolts of $1\frac{1}{8}$ in. in diameter, and they were advised to have them annealed. They had them annealed, and the bolts seemed to last about twelve or thirteen months and then they would break again. He would like to know why the annealed bolt did not act any better than the unannealed one.

Another thing that had struck him with regard to this question was that he believed with an axle of a railway carriage when the metal was fatigued the railway company took the axle out and put it on the scrap-heap. Now, if annealing was beneficial, and saved expense, would it not have been advisable to anneal those axles rather than scrap them?

In connection with $CO_2$ cylinders, after a cylinder had been pumped up to 5,000 lb. and had been permanently stretched, but after re-annealing still passed the stretch test, would that cylinder be safe to put into circulation again?

Mr. A. O. WALKER (Member) said he was sorry he was too late to hear the paper read, but he would mention that, with regard to their experience of dynamo magnets, it was most unlikely that magnetism would suit for annealing when it was considered that the softest iron was obtained in the first place for the construction of the magnets.

Referring to the annealing of chains before testing, he thought this was done as much for cleaning purposes as anything else, firing being the surest means of getting rid of the grease with which they were generally covered while at work.

A certain American firm had a belt fastener, which consisted of very tough bronze wire, with which the ends of the belt were sewn together, the ends being butted, and they claimed that the wire was so prepared that no amount of working would crystallise it.

Mr. D. S. LEE, R.N.R. (Member) said he would like to ask Mr. Clark where the critical point of heating steel came in. Referring to the diagram on the blackboard, he had raised the temperature to a certain degree for annealing, and then he had produced the curve to a still higher point, called the recalescent point, about 1,300° F. He would like to ask what was practically known as the burning temperature. About 2,500° F. was white heat, and the temperature of the electric arc was about 3,000° F., so that the burning temperature for iron and steel must be somewhere between 1,300° and 3,000° F.

With regard to chains he could not agree with Mr. Ross as to having them tested first and annealed afterwards. He thought that the theory of annealing was to restore the molecules back to their natural position, and then the test should come afterwards. With copper pipes there was a law compelling users to have them annealed periodically. If a pipe was put into the fire and heated to a temperature, which the coppersmith would have gained by experience only, that copper pipe was supposed to be as good as when it was originally made.

Mr. E. W. Ross (Hon. Finance Secretary) said that some years ago there was a great talk of magnetism in propeller shafts, and the question was raised, "How far magnetism did affect them." He had tried to ascertain the amount of magnetism between shafts, and had found considerable in some and not much in others. In several instances where shafts had suffered it had been put down to magnetism as being the cause of the hardening effect on the iron.

Mr. G. W. NEWALL said he supposed a ship containing such magnetism must have journeyed over the magnetic lines of the earth, and that her steel being affected by it.

Mr. D. S. LEE thought that the single-wire system using the ship for conveying the electricity back to the dynamo would have an effect on the numerous destructive actions that took place—such as the corrosion of bilge and ballast pipes—but where there was any difference in potential there was always bound to be an action going on.

Mr. NEWALL said that he did not think it was the electricity generated on the ship so much as the magnetic lines of the earth, which he thought disturbed us more than we knew of.

Mr. LEE: I would like to mention another case of annealing or softening, in connection with a Harveyised armour plate. The holes for fastening the plate to the ship's skin are all drilled in place, and to soften the steel sufficiently to get a drill through the electric arc is called into play. For a hole 4 in. in diameter the arc is made to spark across a gap nearly that size, and the metal is softened in between. The heating of the metal between the conductors does not seem to affect the plate for more than 2 in. from the side of the hole.

Now is it a chemical change that takes place in the metal or the restoration of the molecules to their original position that enables the drill to penetrate and get through the modern armour plate?

The CHAIRMAN: There are one or two remarks I would like to pass in connection with this subject. The word "annealing" is derived from the Anglo-Saxon "ancælan," to kindle; but there are really two processes in annealing—one heating, the other cooling—each of equal importance. It is necessary in annealing to heat to the right temperature and at a proper rate, as well as to cool gradually and slowly. In annealing cutters, for instance, which will have an irregular section when finished, it is not enough to anneal the cutter blank. A far more satisfactory job is the result if the blank is annealed after it has been roughed out in the lathe to its approximate form, and the hole drilled to near its finished size. Very often the smith or hardener is blamed for spoiling a tool, when the tool-maker was the cause of the trouble. Take a long reamer, for instance. By the time the tool-maker has finished turning and milling he finds on removing the reamer from the centres that it is crooked, and straightway he commences to hammer it. The result, of course, is the setting up of internal strains, which are removed when the hardener puts it in the fire, and by the time the hardening process is over, the reamer is like a dog's hind leg, and the smith is blamed. If the tool-maker had heated the reamer before straightening the trouble would have been avoided. Remember, it is just as bad to make the piece too hot for annealing as to cool it too quickly. The slower the cooling process the softer will the material be.

Attention to the following will save many a good tool, viz.:

1. Do not overheat steel either for hardening or annealing.

2. Do not subject it to heat for a longer period than is necessary after it is uniformly heated. This will injure the material even if it is not overheated.

3. Heat steel to the same temperature for annealing as hardening.

4. Uniform heating for annealing is as essential as uniform heating for hardening.

5. Be careful not to anneal tool steel with any substance, such as phosphorus (bone contains phosphorus), that will take away its hardening properties.

6. Heating is a softening process, cooling is a hardening

process. The slower the cooling process, the softer will the material be—other things being equal. It is therefore advisable never to place red-hot steel to be annealed in cold or damp lime or ashes.

Nobody is more deserving of our sympathy than the hardener, for I believe no man bears more of other people's burdens—faults—than the smith.

Referring to Mr. Ross's remarks *re* glass, I trust he does not attribute in any degree our lack of skill in making glass or the partial loss of our glass trade to any political or fiscal cause. If so, why is it that under the same political and fiscal systems our other trades, such as shipbuilding, have advanced by leaps and bounds?

Mr. E. W. Ross: I think there is not much to reply to on the few remarks I made, except the question raised on annealing and testing chains. Personally, I am still of opinion that annealing should come after testing, for the reasons I mentioned, wherever and whenever practicable.

Mr. McKenzie spoke of the repeated breaking of bolts in a particular machine he mentioned, and asked for a cause. Without getting fuller particulars as to conditions it is difficult to state one, but there may have been too few bolts, and of inadequate size. Or, again, how often may bolts be brought near their strength limit by being over-tightened by spanner and hammer and crystallised by this strain? Bolts are sometimes reduced in body size to the diameter of the bottom of the thread, as it is there they most often fracture. This gives them greater reliability. Many crosshead, crank-pin, and other similar bolts are thus dealt with.

Mr. James Adamson: Referring to Mr. Clark's remarks regarding the regulations anent loading and discharging gear, it is definitely stated that all chains of $\frac{1}{2}$-in. and under are to be tested and annealed every six months, but there is no recommendation as to how the annealing has to be carried out, nor is there any stipulation as to the temperature required for the process. It is thus left with those who are entrusted with the work, on the presumption that the process is in sufficiently general use to be so left. That such a presumption is probably not justified has been more than hinted at in the discussion to-night, and it appears to me that we have gained something by ventilating the question and eliciting the views of Mr. Clark and others on the subject. Concerning the hardening of iron and steel, it seems quite conceivable that a rod or chain might be made so brittle by gentle tapping for some time that it could be broken over the arm when struck sharply at the critical spot.

The regulations enforced by Government departments and others regarding gas cylinders are in some cases very strict, and are so in the interests of the public safety. Those of the Indian Government, for instance, include an impact test, the cylinders being thrown from a certain height on to a hard ground. The Blue Book containing the evidence given before the commission, the experimental data and the finding of the committee, is interesting reading to those concerned in the use and abuse of these cylinders, and will repay perusal. A copy will be left in the reading room for the service of members. The subject of our meeting to-night was suggested to me by the appeal in Mr. Mackenzie's paper on $CO_2$ cylinders, when also we had exhibited to us samples which had been burst under test pressures. It is evident that a common ground exists of sufficient importance to found some definite regulations upon, not only for the guidance and information of those whose duties call them to handle such cylinders, but for the public safety. Therefore I would urge that a few rules should be formulated and enforced all round. I have heard that cylinders have been sent to firms to refill for ships' use without any stipulations as to making provision for passing through the tropics. The amount of gas put into the cylinders might therefore be greater than it would otherwise be—that is, 25 per cent. less than the water capacity. I have also heard that cases have occurred where the firm supplying the gas has been expostulated with for not getting more into the cylinders—as if short measure of gas were given, like a milk supply—and threatened with the loss of the order unless the bottles were better—i.e., more fully—charged. Mr. Farenden referred to less gas being got out of cylinders than should be; but I apprehend this had reference to the actual weight put in. The difficulty of completely emptying a cylinder occurs in the last few pounds, when by heating it the expansive force is not made sufficient to bring the pressure above that which is in the machine being charged, and possibly moisture or water in the cylinders. Now that the $CO_2$ refrigerating machines are being so largely used for the carriage of frozen and chilled cargoes, it seems necessary that some definite rules and regulations should be enforced, which shall be binding on all. Probably the number of cylinders in circulation now in this country is many times what it was when the Blue Book with the recommendations of the Government committee was issued, and if the finding in 1896 took the shape of recommendations only, the time has come when some at least of these should become legal regulations. Each ship fitted with refrigerators of the $CO_2$ type for cargo work requires from thirty to forty cylinders, and as there have been instances of burst cylinders, due probably to overheating, with consequent high expansion and pressure, it appears quite time that some universal regulations should be followed, as, meantime, we are to some extent in the hands of the firms supplying the gas, who, with the best intentions, may not be altogether alive to the conditions ruling on shipboard, especially as it is not always specified in the orders that the cylinders are to be charged for a tropical voyage. In the evidence given to the commission of 1896 one firm gave the following opinion in referring to the manufacture of cylinders: "Steel to pass the Board of Trade bending, shutting, annealing, and elongation tests as set forth in instructions to their surveyors for marine boilers. This will ensure material of great ductility. Cylinders to be manufactured according to instructions determined by the Board of Trade." Another firm considered that "what is wanted is that all gas compressors should be bound under the same regulations, so that the element of competition can never clash with the question of judgment as to the safety of cylinders. All cylinders which have been strained should at once be destroyed. Gas compressors should accept each the other's annealing and test marks." Many other opinions could be quoted, both as expressed before the commission and in our present-day experience, all pointing to the desirability of having regulations; while many are also questioning the wisdom of allowing cylinders, either empty or charged, to be imported without some restriction in respect to strength and texture. They may be cheaper—that is not the question now being dealt with—but are they safe for general use? I have been informed of one firm which recently imported over 3,000. The conditions of the specification to which they were made I cannot say. We know of at least one instance where an engineer was killed owing to the bursting of a cylinder while he was heating it to get the gas out, and that instance alone shows the wisdom of giving a strong warning note on the subject of heating cylinders, especially in view of the fact that about 100 or more of these may be emptied during a voyage where forty cylinders represent one charge.

Mr. Britton asked how long a boiler should be left to cool down before emptying it. I am reminded by the question of the gentleman who wished to engage a careful coachman, and inquired of each candidate for the post how near he could drive to the edge of a precipice without going over. One stated in inches, another in feet. The man who was appointed replied that he would keep as far away from the edge as he could. So do we hear of those who proclaim in how short a time they can empty boilers and get up steam. On the other hand, it seems to me the condition and life of a boiler depends a good deal on the treatment it receives in the acts of raising steam and lowering it. Twenty-four hours is approximately a good average time to allow for either act—more or slightly less according to atmospheric conditions. It pays, in the long run, to take time. While serving my apprenticeship I was sent with a journeyman to erect an engine and boiler in the country for agricultural work during a very severe winter. After the job was completed arrangements were made for a steam test, and in the morning, with keen frost in the air and ice around us on the ponds, we found the cylinder split. This was attributed to contraction of the metal. No doubt we have had similar experiences in connection with boilers developing cracks when too hastily heated up or cooled down. Regarding the axles of railway carriages and waggons, my impression is that they are stocked after running so many miles, and ultimately used after being annealed or worked again in the fire.

I cannot say that in my experience of ships fitted with the single wire system of electric light the mortality in shafting has been greater than those with the double wire. I may, however, refer members who are interested in following out this suggestion to the discussion on Papers No. XC. and XCI., Vol. XII., on propeller shafts, by Messrs. E. Nicholl and G. F. Mason, where the view was expressed by a chief engineer running on the Australian coast that the single wire system was responsible for propeller shaft corrosion. Mr. Flood, in the discussion on Paper No. CXIII., Vol. XV., by Mr. Bales, referred to the Harveyised plates which Mr. Lee has commented upon.

Mr. Mackenzie's experience with holding down bolts is similar to that we sometimes have with junk ring-bolts and others subjected to similar strain. The texture of the material may not be suitable; they may be too small in diameter or not enough of them. In fact, they seem to be similar to the cylinders which Mr. Mackenzie referred to in his paper as passing the elastic limit, while being tightened up from time to time, so that annealing, although softening them, does not make up for what the bolts have lost in strength.

It is satisfactory that our discussion has been entered into with such spirit. The subject is by no means exhausted, and I hope that the ideas which have been expressed may be productive of good.

One of our members some years ago gave a good deal of attention to the possibility of electric or magnetic current being generated in the line of shafting, and tried experiments to prove this, and collect the current in the tunnel; he also experimented with a view to carry an electric or magnetic current into boilers, in order to prevent pitting and corrosion. The reference made by Mr. Ross bears out the idea that a current may be generated, and that, indeed, it has been demonstrated. In one of the first or second years' papers the subject was brought up in the course of discussion.

The meeting closed with the usual votes of thanks, and in seconding the vote to the Chairman Mr. FARENDEN urged that steps should be taken to place the regulations as to $CO_2$ cylinders on a proper basis.

---

Forwarded subsequent to the meeting:

DEAR MR. ADAMSON,—I am afraid I have not had time to carefully study your excellent paper on "The Value of Annealing," read at the Institute. I note, however, that you go carefully into the question of bottles or cylinders containing compressed liquified gases which come largely into use in connection with refrigeration, with which I am intimately associated.

There is another article which I think is not referred to in your paper which is also common to all refrigerating machines working on the ammonia compression system, which I think should be frequently annealed—I refer to the steel or wrought iron compressor valves. These are very likely to become brittle, due to the constant hammering on the seats, and I have known of cases of machines used solely for ice-making, which are run almost continuously night and day throughout the season, where through want of proper attention to the subject your paper deals with the heads of the valves have dropped off, got into the compressor, and resulted in serious accidents.

It is also well to remember that these valves are subjected to very considerable changes of temperature, and I can scarcely think of any piece of machinery where annealing is likely to be of more benefit than in the case of these particular valves.

I consider it is most desirable to have such valves annealed at least once every year.

I gathered from your remarks the other day when talking on the subject that there may be a further discussion on the points brought forward by your paper, and if my comments are in time you are of course at liberty to make what use of them you think proper.—Yours faithfully,

F. R. TATAM,
Member.

---

The following are regulations issued by the India Office in connection with the carriage of cyclinders:

REGULATIONS TO BE OBSERVED IN CONNECTION WITH THE SHIPMENT OF CYLINDERS CONTAINING LIQUID CARBONIC ACID GAS OR AMMONIA ON VESSELS CONVEYING STORES FOR THE GOVERNMENT OF INDIA.

The cylinder must be manufactured from mild steel or wrought iron, lap welded or seamless. A steel or iron cap must be provided which can be fastened securely over the valve fittings so as to prevent them from injury during transport. Each cylinder must have passed the prescribed proof shortly after it has been carefully annealed, and should bear the following marks or stamps:

(*a*) The name of the firm which charged it, and a mark or number by means of which it can be identified in their books.

(*b*) A stamp showing that it has passed the tests prescribed below, with date on which the last test was applied. The date of the last test should not be more than two years antecedent to the time of shipment.

(*c*) The weight of the empty cylinder without cap, and the water capacity of the cylinder in pounds.

*In case of Cylinders to hold Liquid Carbonic Acid.*

The cylinder must stand a test pressure of 224 atmospheres (or 3,360 lb. per square inch) without showing a permanent stretch (or enlargement of its cubic capacity) of more than 10 per cent. of the temporary stretch shown while under the test pressure. The amount of carbonic acid contained in the cylinder must not exceed two-thirds of a pound per pound of its water capacity.

*In case of Cylinders to hold Liquid Ammonia.*

The cylinder must stand a test pressure of 100 atmospheres (1,500 lb. to the square inch) without showing a permanent stretch of more than 10 per cent. of the temporary stretch. The valve fitting should be of iron.

The amount of ammonia contained in the cylinder must not exceed half a pound per pound of its water capacity.

All cylinders must be stowed on deck away from boilers, engines, or steam pipes. The place selected should be at some little distance from any sleeping quarters and not in close proximity to any artificial heat.

The cylinders must be protected against the direct rays of the sun by an awning, of a light colour, and stretched over them in such a manner as to allow the air to circulate freely beneath it. The cylinders should, of course, not be stowed in the neighbourhood of any vessels containing acids, or in such a position that acid could reach them in case of leakage from, or breakage of, the vessels in which they are contained.

E. GRANT BURLS,
Director-General of Stores.

India Office,
March, 1897.

It will be observed that the date of the above regulations is in the year subsequent to the date of the Royal Commission on the subject, when the necessity for enforcing rules as to the shipment of cylinders containing a highly expansive gas to a hot climate like that of India became manifest. As these regulations were referred to in the discussion on annealing, they are printed in full for the information of members. Any member desiring to pursue the subject further will find "The Handling of Dangerous Goods," by H. J. Phillips, of considerable interest on consulting the book in the library.

JAS. ADAMSON,
Hon. Secretary.