small amount of magnanese that is added for this purpose is oxidized out in a few meltings so that not the slightest trace can be found in the bronze.

INTERNAL STRAINS IN IRON AND STEEL.*

By HENRY D. HIBBARD.

A NOTED ordnance engineer once said to a friend, in speaking of the production of great steel guns, "How is it? We design our guns with a factor of safety of eight, and the guns burst." The vague way in which internal stresses and strains in iron and steel are often considered and spoken of makes it worth while to examine their causes and results, how they may be advantageously dealt with, and how when detrimental they may be reduced or kept within harmless proportions. Rankine defines "strain" as a change of form or dimensions of a solid or liquid mass produced by a stress. This definition seems not intended to cover strains due to internal stresses, and it will help us in the present inquiry to consider strain as a tendency to change as well as an actual change of form.

Internal strains in iron and steel are the result of stresses within the mass of the piece, some parts being in tension and some in compression, each part striving to relieve itself from strain and make the piece assume a form in which all parts are at rest. The internal strains we are now to consider are not those due to the stresses of the service which the piece is rendering, but those which originate or at least are contained in the piece itself.

Internal strains reduce the specific gravity of a piece of iron or steel. Consequently, the metal is heaviest when it is in the annealed state. It is common to assume that a piece of steel which has been cold hammered or cold rolled or wire drawn is "more dense" after these operations than it was before, when it is actually lighter. Internal strains accompany if they do not indeed cause inferior resistance of the metal to chemical action. A file broken off, and the broken end immersed in dilute hydrochloric acid, has been found to have lost a greater thickness of metal from the hardest part, at and near the outside, in which the strains are greatest, than from the less hard central portion. The quick corrosion of wire nails and wire fence may possibly be ascribed to the cold-worked condition, and directly or indirectly to the internal strains. The corroding agent more readily enters the mass of the metal, it may be, because of larger intermolecular spaces.

TWO GENERAL CLASSES OF STRAINS.

For the purpose of this paper, internal strains in iron and steel may be divided into two classes, according to the causes which produce them: 1. Those caused by an irregular rate of change in temperature—that is, of heating or cooling. 2. Those caused by cold working or permanent change of shape of the piece under consideration by mechanical means at atmospheric temperatures, or at least at temperatures below that at which the metal is softened.

Internal strains due to irregular heating or cooling are by far the more important of the two classes. Because iron expands when heated and contracts when cooled, and indirectly for other reasons, internal strains, varying in all degrees from harmless to fatal, exist in all pieces of iron and steel. This arises from the fact that all commercial iron and steel is the product of processes involving heat, the strains in most cases being those set up by the more or less irregular rate of cooling. The amount of change in temperature does not affect the strains produced. The rate determines all.

The strains due to irregular cooling, unless chemical changes are involved, are apparently between part and part. Those due to cold working may be considered as between molecule and molecule because of the disarrangement of the molecular formation. The latter results usually in strains between the parts as well. Strains which come under this division of the subject should be considered under two aspects: 1. Those which arise during the continuance of the causes which produce them—that is, temporary strains. 2. Those which remain after their causes have ceased to act—that is, permanent strains. Temporary strains in many cases become permanent, especially when set up during cooling at an irregular rate. The phenomena of permanent strains are, during their formation, the same as of temporary strains.

The following cases will illustrate the two ways in which each kind of strain may result in rupture of the piece. When an ingot of hard steel is placed in a red-hot furnace, and is so ruptured internally by the faster expansion of the exterior, due to the rapid heating it undergoes, that it separates into pieces when forced or rolled, its ruin was caused by strains occurring while the cause, namely, the quick heating, was in operation. This is a typical example of temporary strains in steel. When a boiler plate of soft steel, lying cold on the floor of the shop, cracks suddenly, it is because of strains existing after their cause had ceased its action. This is the usual kind of internal strains occurring in iron and steel, and is the kind chiefly meant in what follows in this part; it is an example of permanent strain. These two instances cited are, it will be understood, extreme cases, in which the piece is ruptured by the intensity of the strains. Strictly speaking, permanent strains are but relatively permanent, since they decrease when the piece is again heated, or through the seasoning or annealing action of time. When strains result in rupture of the piece of metal they are thereby much reduced in amount and otherwise modified.

While strains are unavoidable, they are—except in special cases—undesirable in proportion as they are great. The exceptions arise when the strains increase desirable properties, as, for instance, hardness in hardened steel.

Expansion and contraction of iron and steel by change of temperature, where the new temperature has become uniform throughout the piece or structure, does not set up new permanent strains or materially change those existing between the different parts of the piece or structure, provided the different parts are all of the same kind of metal, or at least of metals having the same coefficients of expansion. In a structure made of metals having different coefficients of expansion rigidly fastened together, a change of temperature is sure to increase or decrease the strains.

The intensity of the strains considered in this part depends on the following determining factors: (1) The rate of change of temperature; (2) the shape of the piece; (3) the bulk or volume of the piece; (4) the elastic limit of the metal; (5) the ductility of the metal; (6) the coefficient of expansion of the metal.

THE RATE OF CHANGE IN TEMPERATURE.

1. The rate of change of temperature is the great governing condition producing or reducing internal strains, both temporary and permanent. The faster the rate, the greater the strains. The amount of change, however great, is unimportant in this connection if the rate be sufficiently slow. The rate depends on the difference between the temperature of the piece of metal and that of its environment, and on the heat conductivity of the metal. The greater the difference in the temperatures mentioned, the greater the strains resulting, and the greater the heat conductivity the less the strains. A poor heat conductor like manganese steel must, if massive, be heated very slowly if dangerous strains are to be avoided.

Extreme cases, in which the rates of change of temperature are the greatest met with in the practical manipulation of iron and steel, are: for rising temperature, when the article is placed cold within the hot heating chamber of a furnace; and for lowering temperature, when it is taken heated from a furnace and plunged into a cooling bath. During a change of temperature strains are set up within the piece, through the differences in expansion and contraction, due to differences of temperature of the parts. These differences are the greater for a given iron or steel article the more rapid the rate of change.

To avoid danger to the piece from this cause, which is the one to which may be directly laid nearly all the actual damage done by strains in iron and steel, one must maintain less difference between the temperature of the article and that of its environment. If the dangerous strains arise in heating the article it must be heated more slowly. The heating chamber or receptacle must not be too much hotter than the article placed therein. In extreme cases, the chamber and the article must be slowly heated together, this procedure being called for, however, only in the heating of bulky articles of very hard iron or steel.

WHERE SLOW COOLING IS ESSENTIAL.

When dangerous strains are liable to arise from too rapid cooling, they may sometimes, as in the case of a cast-iron car wheel, be relieved or reduced in intensity by a slower rate of cooling, the red-hot wheels being piled up in tight soaking pits built in the ground, and allowed to cool very slowly. The lowering of the temperature of both the thick and thin parts is maintained at a rate sufficiently uniform to insure their reaching ordinary atmospheric temperatures at about the same time; the thicker parts do not then continue their contraction after the thinner have ceased theirs, which action, if it took place, would result in strains that might easily be dangerous to the integrity of the wheel, in view of the almost total lack of ductility in the cast iron of which it is made.

Many steel castings may not be allowed to cool in the open, or even in the sand, without danger of spontaneous rupture from internal strains, but must be placed while still hot in a heated receptacle, usually a furnace, and allowed to cool with the furnace at a much slower rate than if in the open air. Steel wheels, as well as the iron car wheels mentioned above, usually require such treatment, though the ductility of the softer grades may admit of its omission. On the other hand, the greater coefficient of expansion of steel tends to set up greater strains than those of the iron wheels.

In special cases, for example, in cutting tools of steel where only the cutting edges demand the rapid change of temperature, some relief, often adequate, is to be afforded by heating only the cutting edges themselves to the hardening heat. Then the remainder of the article will not have to undergo such a rapid change of temperature as if made as hot as the hottest part, and the resulting strains in the tool will be much lessened and perhaps made harmless.

If a piece of cold iron or steel of uniform temperature, in which the strains are the result of cooling, be cooled further, uniformly as to the exterior surface, the strains will be temporarily reduced and may be wholly eliminated during the cooling operation, only to be restored much as before when the temperature of the pieces has again become uniform. Such a piece of steel presents during the further cooling the only exception to the statement that all pieces of cold iron and steel have internal strains. A further practical exception is found in the case of a piece of cold iron or steel which has been cooled from a red heat, at which it is too soft to have strains, at an exceedingly slow rate, as in the case of the car wheel mentioned.

When the slow rate of cooling is actually continued to atmospheric temperature the article is practically free from strain.

Spontaneous cracks in cold soft steel are still not wholly explained. When such cracks occur in hard and hardened steels or in cast irons which have practically no ductility they are easier to understand, though even in such cases just what was the "last straw" which caused the rupture is not usually apparent. This is on the assumption that the composition of the steel is suitable, particularly as regards phosphorus and oxygen, which must not be present in too great proportions, and further that the steel was well cast and rolled or forged.

Whether or not in the case of the soft steel boiler plate it was an additional strain due to a slight change in temperature, or vibration from some outside cause, or that the fatigue of the metal under strain progressed more rapidly than the relief of strain due to time, and the operation of what might be called annealing by natural causes, is not clear. It is probably directly due to the last of these possible causes following a lessening of the ductility of the metal through working of the piece at the well-known critical temperature termed the "blue heat." Spontaneous rupture never occurs in an old article of iron or steel, provided, of course, that no new strains have been set up within it.

THE SHAPE OF THE PIECE.

2. The shape of the piece of metal affects strains very greatly when it is heated or cooled. If it be made up of relatively thick and thin parts continuously connected to each other, such as the thin web and thick hub and rim of a car wheel, on changing its temperature strains will be set up within it, not only between the interior and surface portions, but between the thick and thin parts as a whole. In the case of a cast car wheel these latter strains are those which are dangerous, causing the breakage and consequent destruction of the usefulness of the wheel if they be allowed to develop to their fullest extent by allowing the wheel to follow its own rate of cooling in the open.

Large plane surfaces tend to intensify strains due to change of temperature of a piece of iron or steel either from heating, cooling from a high or casting temperature, or quenching. The plane surface, cooling or heating more quickly at its edges than elsewhere, cannot yield to internal tension or compression stresses by change of shape, as such stresses act in straight lines within the piece. Relief may sometimes be afforded by curving or corrugating the surface, as in a casting. But a flat sheet like a saw blade may not admit of this, and then means must be employed to conduct the operation of hardening the teeth, when the strains are set up, so that they will not crack the saw. In the case of a large circular saw blade, partial heating is used, and is effected by protecting the central portion of the sheet with thicker iron plates during the heating and cooling operations. The protected portion is not hardened, and has therefore a lower elastic limit and a higher ductility than the hardened rim, and will thus yield a little without breaking.

THE BULK OR VOLUME OF THE PIECE.

3. The bulk of the piece of metal has great influence on its strains when its temperature is changed because of the distance which heat must be conducted between the surface and interior parts. When the bulk and therefore this distance is relatively great the strains are great in proportion, and when the bulk is small they are less. High conductivity of heat tends to offset great bulk in the strains resulting from a change in temperature.

With a piece of metal of a given contour the strains from either cause may be much reduced by reducing the bulk by means of recesses or slots or other holes properly made in the piece. The quenching operation in particular then causes much less strain. In the case of a large tap this principle is applied by drilling a hole along its axis, which has a double effect. First, it allows the cooling fluid to cool the interior nearly as quickly as the exterior as a whole, and secondly, it reduces the actual thickness of the metal to a fraction, perhaps a third, of what it would be otherwise, and in that way reduces the strains due to bulk.

Solid steel armor plates are sometimes cracked internally by the cooling strains arising from the quenching operation, though the steel is rather soft, with carbon from 0.20 to 0.25 per cent, except the hard face. This may be due to either or both of two causes: 1. When the mass of the armor plate or other piece of iron or steel is so great that the final contraction of the interior portion when cooled may not be compensated for by a reduction of cross-section of the metal (such as occurs when a test piece of ductile metal is pulled apart in the testing machine), then internal cracks may occur from the metal being overstrained, regardless of the ductility of the metal. 2. The ductility of the soft steel of the body of the plate is impaired by the long-continued heating without work during the carbonization by the cementation process of the face, which is to be hard, and for that reason will not endure internal strains as well as its composition would indicate. Holes or recesses not being admissible, though they have been recommended by some, re-organizing or annealing to break up the coarse crystalline structure existing in the plate is resorted to, after cementation, in an effort to avoid this defect. Nevertheless, the results are not always as desired.

LAYERS OF SOFT AND HIGH-CARBON STEEL.

It does seem, however, that careful experiment should develop a method for making a large soft steel ingot, with a high-carbon steel layer on one side, which

* From a paper read before American Institute of Mining Engineers.

could be forged into an armor plate, thus avoiding the expensive and harmful cementation process. When an article of iron or steel is liable to crack in service from strains, the danger is sometimes best avoided by making it in two or more pieces. This practically amounts to putting cracks in the thing, but often they may be located so as to cause no trouble. The following example will illustrate: A cast-iron bottom plate, on the center of which was cast a large ingot of steel, was broken the first time used, by the expansion of the central part heated by the molten steel. On making a plate for the purpose of four pieces bolted together no further trouble from this cause resulted.

4. The elastic limit of the metal affects the intensity of the strains, because when it is low it may allow the metal to yield under the stresses which cause strains so as to relieve them in part.

5. Ductility of iron or steel sometimes allows it to yield without fracture under stresses of sufficient magnitude, so that the strains are in some degree lessened. A highly ductile metal rarely or never breaks from internal strains unless extremely massive. A metal supposed to have great ductility may actually have very little, due, perhaps, to ill treatment. The boiler plate mentioned had probably been damaged by working at the black or blue heat, so that its ductility was impaired, and the strains arising from irregular heating and cooling were more than the remaining ductility could allow for, and rupture ensued. The armor plates cited also had their ductility much reduced by the long heating during cementation. When, as in cast iron and hardened high-carbon steel, there is no ductility, and the elastic limit coincides with the ultimate strength, the strains set up in cooling cannot be relieved, and may easily reach an intensity which will cause the piece to crack or break.

HEATING TO RELIEVE STRAIN MUST BE SLOW.

6. The coefficient of expansion, strictly speaking, wholly determines the intensity of the strains arising from irregular rates of change of temperature in metals, for if it became zero such strains would not occur. The greater the rate of expansion the more intense become the strains arising from a given rate of change in temperature.

Heating a piece of iron or steel to any degree below the temperature at which it softens will increase the strains within it in proportion to the rate of heating. Therefore, heating to relieve dangerous strain, which is often resorted to, must be very slowly done, so that the interior is heated nearly as fast as the exterior, or the extra strain due to the more rapid expansion of the exterior parts may cause the rupture it is the purpose of the heating to avoid. By such slow heating something like the seasoning effect of time and slightly higher than atmospheric temperature is given to the piece. This effect may be used on large massive heat-treated articles of high-carbon steel, such as heavy cutters and projectiles, and heavy articles of toughened manganese steel, all of which are in a high state of strain, due to immersion at high temperature in a cooling bath.

The increase of strain due to even slow and moderate heating, as, for instance, to the temperature of boiling water, may be used for testing hard heat-treated objects, such as armor-piercing projectiles, to determine whether or not they are in a dangerous condition, or rather to separate those in danger of spontaneous rupture from those which are not. Without some means for discriminating between them, some of them may lose their points by spontaneous rupture months after they are made and have traveled far.

When a cold massive piece of steel, as an ingot, is to be heated in a furnace, it is a matter of importance to know whether its previous cooling was rapid or slow. If rapid, it may contain so much strain as to be ruptured internally by the heating operation, while if it has been slowly cooled it may, because of smaller internal strains, endure that operation safely. To reduce strains in ingots which are to be cooled to the atmospheric temperature, the rate of cooling should be retarded.

INTERNAL STRAINS CAUSED BY COLD WORKING.

The strains due to cold working iron or steel are the result of molecular displacement and very likely of mere changes in the intermolecular spaces, but the theory of the matter we may for the present leave out of consideration. The phenomena occurring with these strains include higher tensile strength, higher elastic limit, greater hardness, less ductility, and lower specific gravity. Strains are an unavoidable accompaniment of cold working iron and steel. Those due to cold rolling or wire drawing purposely applied have often useful effects when properly taken advantage of, while harmful or undesirable effects may be avoided by reducing them by annealing or other proper heat treatment. When the pieces of metal so cold worked are not large and the ductility considerable, there is no danger of spontaneous rupture. The cold working may, indeed, be continued so as to cause dangerous strains if they be not relieved by heating. The service of larger pieces may be such that they are subjected to cold working, as in the case of a die ring for a centrifugal ore-grinding machine, which will cause flow of the metal with resulting strains, and may distort the piece or even tear it apart or break it.

Something like spontaneous rupture is met with in cold rolled or cold drawn shafting when the cold working of the surface portions has so extended them that the interior is strained beyond its strength and thereby ruptured at intervals across the shaft. In that case, when the outer portions are turned off, the bar may drop apart.

USEFUL COLD WORKING STRAINS.

The beneficial effects of strains due to cold working come from the higher tensile strength and elastic limit of the metal. Drawn or cold rolled shafting is much stronger per unit of cross-section than before the cold working, and wire may be made whose ultimate strength is increased several times by the strains set up in the drawing operation. Wire drawing strains give to some varieties of spring wire the greater part of their springiness.

The increased strength of iron and steel wire due to the strains of cold working is made useful in many ways. In the wire cables of suspension bridges it is relied upon and figured in as part of the tensile strength of the wire. In wire for piano strings and for deep-sea sounding, tensile strengths of over 400,000 pounds per square inch have been attained, the greater part of which is due to the internal strains set up in the wire-drawing process.

The effect of seasoning or annealing by time on cold-worked iron or steel, such as wire, is probably not known, but is very likely an appreciable amount, which, as in bridge wire, may reach important proportions with the lapse of decades.

Strains in cold-worked iron or steel may be detrimental in a way. A piece of straight cold-drawn shafting, if machined, as, for instance, in key-seating or in turning, is very liable to be not straight after the machining, as cutting away a part of the strained metal removes part of the stresses, and those remaining cause the resultant effect to be different from what it was, and the new adjustment necessary is found in a new shape of the piece.

The modifications and removal of strains due to cold working by heating for long or short periods of time, one or more times, to temperatures below redness requires investigation. By these temperatures is meant those all the way down to atmospheric, and especially those from 212 to 408 degrees F., the latter being the temperature at which a faint straw color is given to steel of a certain composition. Removal of dangerous strains by subjection to heat not great enough to discolor the surface of the metal would be a good thing in many ways, if feasible. A cold-worked piece of shafting, which will break off in the lathe when the outer skin is removed, might perhaps be practically cured by such heating between the rolling or drawing operations.

In the specifications for wire for a great suspension bridge, the wire as drawn must have a tensile strength of 215,000 pounds per square inch, and after galvanizing must have a tensile strength of 200,000 pounds per square inch. This decrease of 15,000 pounds per square inch is the loss of strength due to removal of strains by heating the wire for a brief period to the galvanizing temperature, or, say, to 800 deg. F. If the heating even at that temperature were long continued, a much larger loss of tensile strength would no doubt result.

THE SEASONING EFFECT OF TIME.

Many believe that there is a reduction of strain in iron and steel by the seasoning effect of time. Old cast-iron cannon, which had given the normal amount of service, were said to have had their strength restored by years of rest. The strains in such cannon were, it is true, the result of service stresses, but such strains in this case are analogous to those produced by cold working, and especially as far as they are affected by annealing by time. In the case of an article of hardened steel, seasoning or annealing by time is held to relieve strains, with the result that the piece is freed from danger of spontaneous fracture or change of shape after being finished, while if unhardened, its strength and ductility are increased by such seasoning. In cold-worked steel the strength will probably decrease in time, as will the elastic limit, while the ductility will increase.

It is probable that such effect as is produced by time upon a piece of iron or steel is chiefly the result of alternate heating and cooling within the limits of the daily range of temperature, but there is evidence indicating at least that seasoning is effected by time alone, whether or not the temperature of the piece is subject to change.

Consideration of the question of seasoning by time brings up the very interesting one previously alluded to, concerning which we are as much or more in the dark, which is that of annealing iron and steel at low temperatures; that is, in the first phase, at not higher than 212 deg. F.; in the second phase, between 212 deg. and the lowest temperature at which steel will be given the faintest straw color, about 408 deg.; and in the third, at temperatures between this and red heat. The temperatures giving steel the tempering colors, straw, yellow, blue, etc., vary for different grades of steel, and therefore cannot be stated exactly for steels as a whole. There is much to be learned in these fields, and the second of the three mentioned seems especially to hold out hope of practical benefit to mankind from applications of its laws. We need to know the effect on each kind of steel object in every condition of size, shape, composition and treatment, of time, temperature, and fluctuations of temperature within the limits named.

CHEMICAL CHANGES AND STRAINS.

Annealing by time may be expected to act in a different way on cold-worked steel in which the strains may be the result of disturbed molecular arrangements, from that on hardened steel, in which the strains result in great part if indirectly from the chemical constitution of the steel. Perhaps it can be determined just how much of the hardness of hardened

steel is due to chemical change and how much to strain. If there is no chemical change in heating hardened high-carbon steel to temperatures not higher than the blue color, or even higher, say, to 800 deg. F., then it would appear that any hardening or increase of tensile strength or decrease of ductility which is removed by heating, short or continued, to temperatures not above the blue or the higher degree mentioned, is due to the strains in the piece. The properties due to chemical constitution will then be permanent in the absence of high heat, while those due to strain may fade in time. Internal strains, when in moderate degrees, may either increase or decrease the tensile strength of steel, as shown by many tests of steel in which annealed bars sometimes show higher, but usually lower, tensile strength than the unannealed.

That strains in hardened steel are of a quite different nature from those in cold-worked steel may be shown by the attraction of a magnet. A piece of hardened steel with and without intense strains acts very differently from a piece of wire-drawn steel with and without strains when its attraction for or by a magnet is measured. A file in a hardened condition, which gave a pull of 12 ounces with a common horseshoe magnet, gave, after being heated to the blue heat, a pull of 27 ounces, and after being heated red hot and slowly cooled, 31 ounces. The magnet gave, on its keeper, a net pull of 43 ounces. Tenpenny wire nails have, with the same magnet, an average pull of 27 ounces, while similar nails, heated to redness and slowly cooled, an average pull of 24 ounces. In the nails the strains seemed to have no effect in reducing the amount of the pull, but, if anything, to increase it. Still, the determination was made by crude means, and cannot be accepted as doing more than indicate the effect of the cold working on this property. The apparatus consisted of a small spring balance, the magnet, and pieces under examination.

In the case of the file, the question is more complex. If the carbon is not changed in chemical condition by heating to the blue heat, as has been maintained, then the great increase in the susceptibility to attraction by a magnet must apparently be laid to the elimination of strains. If not, then to an allotropic modification of the iron itself.

THE USE OF FULMINATE OF GOLD IN ELECTROPLATING.

The use of fulminate of gold in making up a gold-plating solution seems to have originated with Roseleur, to whom we owe so much in laying the cornerstone of the art of electroplating. While the fulminate is extensively used in certain sections, it is unknown in others and many platers have never heard of it. Those who use the fulminate, however, turn out excellent work and are believers in it. Those who use the chloride of gold for directly making the bath have usually never tried the fulminate.

Fulminate of gold is made by precipitating a weak solution of chloride of gold by ammonia. The precipitation is carried out with the hot solution. The fulminate of gold separates out and settles down to the bottom of the vessel. The clear solution is poured off and hot water added and the whole stirred. After settling, the clear liquid is again poured off and this is repeated until all impurities are washed out. *The fulminate of gold must not be allowed to dry or it will explode.* While wet, however, it is harmless. After thoroughly washing, it is dissolved in cyanide in the regular manner. The bath is then used in the same manner as the chloride of gold bath.

The advantage of the fulminate of gold lies in the brightness and luster of the deposit. It is for this reason that it is used. The fact that commercial gold is not pure is, perhaps, not widely known. It rarely runs over 997 parts per 1,000 in fineness. The other three parts are silver, copper, zinc, and other metals. Silver and copper, however, are the principal impurities.

When such commercial gold is dissolved in aqua-regia, all of the copper goes into solution and a little of the silver (chloride of silver is not entirely insoluble in muriatic acid) and instead of pure chloride of gold, one containing a little silver and copper is produced. It is the presence of silver and copper that injures a gold bath and prevents it from producing a bright deposit of a rich color. It is this slight amount of impurity that determines the character of a gold deposit. If a gold bath is made from chloride of gold the chances of doing satisfactory gilding are not as good as they are when the fulminate of gold is used.

The advantage of the fulminate of gold lies in the fact that both the chloride of copper and chloride of silver are soluble in ammonia. When, therefore, the chloride of gold is precipitated with ammonia, the silver and copper go into solution and are easily washed out, and only the pure fulminate of gold is left. It is this fact alone that renders the use of fulminate of gold so satisfactory.—Brass World.

It appears probable that one gramme of radium diminishes in weight by about half a milligramme per annum; hence, if the funds of some society admitted of the imprisonment of some definite mass of radium, our successors a hundred years hence would, even if they possessed only the apparatus now at our disposal, be able to determine its loss with sufficient accuracy to enable them to verify the truth of the conclusions arrived at by the physicist of to-day, while the investigation of the radio-activity of the residue would possibly throw light on problems now awaiting solution.