carbon, the chromium and tungsten they usually contain has the function of holding the carbon in such a state that the sparks characteristic of ordinary tool steel are entirely absent.

The sparks follow a straight line similar to wrought iron sparks, but give very much less light and end abruptly in a chrome yellow, pear-shaped mass.

Fig. 6 shows the sparks produced by a certain kind of manganese steel which contains very much less manganese than is present in the common manganese steel used in railroad frogs and switches. A characteristic of sparks from manganese steel is their intense brilliancy and white color.

Fig. 7 shows the kind of sparks from the earlier

grade of Mushett air hardening steel. These sparks are hardly luminous, being dark red in color, and although this steel contains about 2 per cent of carbon, it shows none of the characteristic sparks obtained from a straight carbon steel containing the same amount of carbon.

Fig. 8 represents sparks from a special brand of steel known as magnet steel. The color of these sparks is orange, the characteristics differing in the manner shown by the diagram.

These are not all the varieties of sparks capable of being produced from iron and steels, but should give the reader an idea of the most common varieties. The soft metals like brass, bronze and aluminium do not

give sparks, while cast iron gives a very short, dark red spark which ends in the production of a spurt in all directions.

Practical use can be made of the spark test in a good many instances, notably by the tool maker who has to handle different kinds of steel. Should a carbon steel be given the heat treatment required by a high speed steel, it would be ruined; or should a high speed steel be given the heat treatment proper for an ordinary carbon steel, it would not work at the highest efficiency. By using as standards steels of known properties, one about which there is the slightest degree of doubt can be readily correlated by means of a spark test.

The Reconstruction of the Quebec Bridge*

A Design Proposed by a Russian Engineer

By Prof. G. Kriwoschein, Colonel in the Imperial Russian Engineer Corps, St. Petersburg

It will be remembered that the Quebec bridge over the St. Lawrence River in Canada collapsed, while in process of construction, on the 29th of August, 1907. The commission appointed by the government ascertained that the immediate cause of the collapse was

dian government; this body worked out a new project for the bridge, which showed the same fundamental errors. This commission was occupied for three years with the preparation of the design, which involved the expenditure of \$150,000. The result was a project

this body did not think fit to submit the project to a closer inspection, in spite of the correctness of the technical proposal, in complete indifference to the fine appearance of the structure and to the resultant saving of expense, and contented itself with the statement that the difficulty of constructing the movable supports stood in the way of the system proposed.

Without permitting myself to enter into a critical

Fig. 1.—The Design Proposed for the Quebec Bridge by Prof. Kriwoschein.

to be found in a faultily constructed member of the lower chord; from a careful consideration of the description of the bridge as well as of the collapse itself, however, it is clear that the real reason lay in faulty design, in particular:

(1) The extreme narrowness of the bridge, which was only 1/27 of the mean or average span, and 1/4.7 of the height of the principal truss.

(2) The great length of the cantilever arm, in comparison with the span of the side opening (1/1.12) and, as a necessary consequence of the physical proportions just named, the deficient lateral rigidity when subjected to wind, as well as the extremely small resistance of the bridge to torsional stresses (in consequence of the excessive loading of one truss).

After the collapse of the bridge, a commission known as the Board of Engineers was appointed by the Canadian government.

* Translated from *Der Eisenbau*.

which was in every sense inadequate.¹

Then a new competition was advertised by the commission on January 3rd, 1910, for the submission of designs and methods of carrying out the construction, in which one of the conditions was that the projects should be submitted absolutely free of charge. In the endeavor to apprise the commission of one of the possible solutions of the extremely difficult problem, the author worked out a sketch design of the Quebec bridge (Fig. 1) and submitted it to the commission for its opinion. In the case of the system proposed by the author, there was a saving in cable alone of \$1,365,000, and a still greater saving in the bridge arch.

This circumstance should have induced the commission to examine and work out in detail the solution thus submitted. Instead of this, however, on account of the fact that the project had originated abroad,

¹ SCIENTIFIC AMERICAN, No. 7, 1910, pages 148 and 154.

Fig. 2.—The Quebec Bridge as Approved by the Canadian Commission.

Fig. 3.—Design for Quebec Bridge by Prof. Kriwoschein.

Fig. 4.—Details of Prof. Kriwoschein's Design.

Fig. 5.—Cross-section at the End Abutment.

Fig. 6.—Cross-section at the Center.

Fig. 7.—Cross-section at the Main Abutment.

consideration of the answer of the commission, I can only observe with satisfaction that the commission has now decided upon a considerably greater breadth of bridge, which seems to indicate that recognition is now gained for the fact that the extremely small breadth was one of the principal causes of the collapse.

Figs. 2 and 3 represent comparative drawings of the Quebec bridge of which:

Fig. 2 is after the design of the commission.

Fig. 3 is after the design of the author.

In Fig. 4 the elevation and the dimensions of the arch bridge design may be seen, in which horizontal measurements, the heights in the clear, the spans, etc., as well as the super-elevation of the railway were adopted in accordance with the specifications of the commission. The dimensions are as follows:

The side-spans 5,210 feet; the middle-span $L=1,758$ feet; the height of the catenary $f_1=1/10 L$; the height of the arch $f_2=1/9 L$; the breadth of the bridge $b=1/3.3 h_0=1/18.5 L$, in which h_0 is the height of the truss above the abutment. From these measurements it is clear that the stability of the bridge is thoroughly satisfactory.

The system of the principal truss of the bridge consists in the middle span of a combination of the suspension cable with the arch, in which the cable is hung from the side girders. The ends of the side girders are anchored to the shore.

Of the four supports, one must be fixed, or immovable; while the others are movable. The arch may be a three hinged arch, in which case the system is statically

Fig. 12.—Side Girders

Fig. 13.—Middle Arch.

determinate; or it may be a two hinged arch, in which case the system is statically indeterminate. The stresses resulting from variations in temperature in the latter system are insignificant (not over 9 per cent).

Figs. 5 to 7 represent cross-sections of the bridge. In Figs. 8 to 11 the method of erecting the bridge is clearly seen. First of all the side girders are set up. Then the cable is drawn across from one girder to the other, while the shore ends of the side girders are anchored by means of temporary anchor chains. Now the roadway and the bridge arch may be attached to the cables, during which process it is to be noted that the ends of the arch must not be fastened to the girders. After the entire middle arch is assembled, the union of the arch with the girders may be effected. In this way the entire weight of the bridge itself may be transmitted to the cables, without producing any stress in the arch, so that the latter is strained only by the live loads.

The conditions of equilibrium for the side girders, neglecting the cables and the arch, are represented by the following expressions (Fig. 12):

- (1) $H_1 = H_2 = 0$.
- (2) $A = B = 0$.
- (3) $H_1 h_0 = B L_1 = 0$.

The results of the calculation are as follows:

(1) The horizontal shear $H_1 = H_2$ is equal to the tension in the catenary.

(2) In the girders we have only vertical compression.

$$A = B = \frac{H h_0}{L_1}$$

Let us now consider the middle arch (Fig. 13). The following forces will be acting on the arch: The load P , the tension in the suspension rods q , the horizontal shear H and the vertical resistances of the girders A and B .

From the moment equation with respect to the right joint

$$A L + \frac{q L^2}{2} - P (L - a) = 0,$$

we obtain

$$A = \frac{P(L - a)}{L} - H \frac{4f_1}{L},$$

in which has been substituted²

$$q = H \frac{8f_1}{L^2}$$

If we substitute in the moment equation for the middle joint for the forces situated to the left of this joint

$$A \frac{L}{2} + \frac{q L}{2} \cdot \frac{L}{4} - P \left(\frac{L}{2} - a \right) - H f_2 = 0$$

the value for A which has been determined as above, we find that the horizontal stress in the chain and the horizontal thrust of the arch are equal:

² For a parabolic cable $H = \frac{q L^2}{8f_1}$

$$H = \frac{P a}{2(f_1 + f_2)}$$

For the case of uniform loading of the central arch we obtain:

$$H = 2 \int_0^{L/2} \frac{p a d a}{2(f_1 + f_2)} \quad \text{or} \quad H = \frac{p L^2}{8(f_1 + f_2)}$$

This formula is significant in that the horizontal stress of the cable and the horizontal thrust of the arch are not inversely proportional to the height of the catenary f_1 , but rather to the sum of the heights of

$$= \frac{(27,500 + 16,000) \times 1758^2}{8 \times 175 \times 0.929} = 103,367,000 \text{ pounds.}$$

The necessary cross-section of the cable, in case the permissible stress is 60,000 pounds per square inch (material—crucible steel), is given by

$$F_1 = \frac{103,367,000}{60,000} = 1,723 \text{ square inches.}$$

For one cable

$$F = \frac{1,723}{2} = 861.5 \text{ square inches.}$$

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

Figs. 8, 9, 10, 11.—Procedure in Assembling the Bridge.

the catenary f_1 and of the arch f_2 . Thus, for example, if $f_1 = f_2$, we have

$$H = \frac{p L^2}{16f_1},$$

that is to say, half as much as for the catenary with a stiffening girder.

Saving in Material.—The saving attained by the application of the system proposed by me, consisting of a cable with an arch in place of a cable with a girder, may be proved in the following way:

Since the weight of the Quebec bridge is not known, let us take the length of the Manhattan bridge (from *Engineering News*, 1909, No. 16. Manhattan bridge, Ralph Modjeski's Report); this is entirely permissible since the arches of both bridges are almost equal in size.

The live load $p = 16,000$ pounds per foot.

The permanent load $g_0 = 18,000$ pounds per foot without the cable.

The permanent load $g = 22,900$ pounds per foot with cable.

The central arch of the Manhattan bridge $L_1 = 1,470$ feet.

The central arch of the Quebec bridge $L_2 = 1,758$ feet.

If we assume that the weight increases in proportion to the span of the arch, in which case the coefficient of proportionality is

$$\alpha = \frac{1,758}{1,470} = 1.20,$$

we obtain for the Quebec bridge

$$g = 22,900 \times 1.20 = 27,500 \text{ pounds per foot.}$$

I. Cables with Girder.

The greatest bending moment of the girder is given by $M = 0.019 p L^2 = 0.019 \times 16,000 \times 1,758^2 = 939,531,000$ pounds $\times$ feet = 939,531,000 $\times$ 12 pounds $\times$ inches.

In case the permissible stress in the girder is $K = 40,000$ pounds per square inch (material—nickelsteel.) the necessary moment of resistance is

$$W = \frac{M}{K} = \frac{939,531,000 \times 12}{40,000} = 281,856 \text{ inches}^3.$$

The necessary cross-section of chord metal

$$F = \frac{W}{K} = \frac{281,856}{50 \times 12} = 470 \text{ square inches}$$

if the height of the girder in feet is 50.

The height of the catenary $f_1 = 175$ feet.

The tangent of the angle of slope of the outermost member of the catenary is:

$$\tan \alpha = \frac{350}{879} = 0.398$$

$$\cos \alpha = 0.929.$$

The greatest tension in the cable (for both girders)

$$S_{max} = \frac{(g+p)L^2}{8f_1} \cdot \frac{1}{\cos \alpha}$$

The diameter of the cable, assuming solid cross-section, $d = 33$ inches.

II. Cables With Arch.

The greatest stress in the catenary is given by

$$S_{max} = \frac{(g_0 + g_c + p)L^2}{8(f_1 + f_2)} \cdot \frac{1}{\cos \alpha},$$

in which

$g_0 = 21,600$ pounds per foot, the weight without the cable,

$g_c =$ the unknown weight of the cable,

$p = 16,000$ pounds per foot, the live load,

$f_1 = 175$ feet, the height of the catenary,

$f_2 = 200$ feet, the height of the arch.

The weight of the cable may be expressed by the following formula:³

$$g_c = \left(\frac{F \text{ sq. in.}}{12 \times 12} \times 1 \text{ ft.} \right) \times 490 \text{ lbs.} = \frac{S \times 490}{60,000 \times 12 \times 12}$$

where for F the value $F = \frac{S}{K} = \frac{S}{60,000}$ has been inserted.

If we insert the value for g_c thus found in the previous formula, we obtain:

$$S = \frac{(g_0 + p)L^2}{8(f_1 + f_2) \cos \alpha - \frac{490L^2}{60,000 \times 12 \times 12}}$$

$$= \frac{(21,600 + 16,000) \times 1758^2}{8(175 + 200) \times 0.929 - \frac{490 \times 1758^2}{60,000 \times 12 \times 12}}$$

= 44,489,000 pounds.

The necessary cross-section of two cables is

$$T = \frac{44,489,000}{60,000} = 741 \text{ square inches.}$$

For one cable

$$F = \frac{741}{2} = 370.5 \text{ square inches.}$$

which gives as the diameter of the cable

$$d = 21.8 \text{ inches.}$$

The length of the cable in the central span

$$2s = 2y \left[1 + \frac{2}{3} \left(\frac{x}{y} \right)^2 \right] = 2 \times 879 \left[1 + \frac{2}{3} \left(\frac{175}{879} \right)^2 \right]$$

$$= 1,758 \times 1.026 = 1,803 \text{ feet.}$$

In addition, in the side spans 533 feet each, and in the anchor cables 200 feet each; in all

$$Z = 1,803 + 533 \times 2 + 200 \times 2 = 3,269 \text{ feet.}$$

The saving in weight of the cable is

$$3,269 \times \frac{(1,723 - 741)}{12 \times 12} \times 490 = 10,923,000 \text{ pounds}$$

$$(= 4,950 \text{ metric tons}).$$

³ 1 cubic foot = 0.0283 c. b. m.

1 cubic foot of cast steel weighs 490 pounds.

If we assume that the price of the cable, including transportation charges, amounts to \$125 for 1,000 pounds, we have for the saving $10,923 \times \$125 = \$1,365,000$.

In this manner it is possible to attain by the application of the proposed system a saving in cable alone of \$1,365,000.

CONCLUSION.

From the preceding description and calculation it is apparent, that through the application of the system

proposed by the author, consisting of a catenary with an arch, it would have been possible not only to have attained an enormous saving but also to have gained a number of additional advantages, as follows:

1. The advantage of a greater strength of the bridge in a sidewise direction.
2. The possibility of employing semi-diagonals, in which the stress is half as great as in the case of diagonals.
3. The possibility of employing such a system of cross diagonals, which without rendering the girder

statically indeterminate, would cause the diagonals to be subjected to half the usual tension.

4. The application of auxiliary diagonals in the side spans and the horizontal ties, by means of which the sum of the compression members would be reduced by one half.

Unfortunately the commission overlooked all this, and without having arrived at a comprehension of the project, gave its uncalled for opinion respecting the difficulty of designing movable supports upon rollers.

Metal Fakes

How the Unwary Buyer is Deceived

THERE are, of course, in the scrap metal trade (as in every other trade) a number of unscrupulous men, and it behoves the honest ones to be continually on their guard against being taken in. The following, according to *The Brass World*, are some of the methods employed to deceive the unwary buyer:

SENDING YELLOW BRASS CHIPS.

A dodge that seems to be frequently worked consists in mixing a certain amount (as much as the chips will stand) with yellow sand. In this way the scrap metal man obtains brass prices for sand.

As sand, if mixed with the chips direct, would be noticeable the following method is carried out to overcome it: Scrap bronze powder is easily obtained in the scrap metal market, and is the sweepings, etc., produced in the manufacture of bronze powder. It is very fine and slightly greasy. It readily adheres to anything, except wet material. The sand is dried and then mixed with a small quantity of the bronze powder. This coats them over. The bronze powder is practically the same color as the brass. In reality it is made from yellow brass, and is not bronze at all, although so called. It is also cheaper than the brass chips.

The sand, when covered with the bronze powder, is mixed with the chips and is then entirely concealed. The usual amount of sand to mix with the chips is about 10 per cent, and when added to them it is very difficult to see it. Those who purchase the chips, therefore, obtain the sand at the price of the chips. To look at a pile of chips of this kind, one would say that they were of good quality.

The method of ascertaining this deception is to take some of the chips and examine them. As yellow brass chips are usually fine, the sand is not readily seen, although the particles may be detected if they are spread out on a paper. The usual method, however, and one that is absolutely certain, is to take a small quantity of the chips, soak out the oil and grease in benzine or gasoline so that acid will act upon them, and then dissolve (in a porcelain dish) in dilute nitric acid. One part of the strong acid and one part of water are used. The chips will dissolve and leave the sand.

MIXING RED GRINDINGS WITH COMPOSITION CHIPS.

Composition chips command a comparatively high price as compared with red grindings. The latter, of course, result from the grinding of composition castings on an emery wheel, and contain a considerable amount of emery and molding sand from the foundry.

If composition chips and red grindings are mixed in the ordinary manner, the two will separate when shipped on account of the difference in size. In order to prevent this some American dealers of the lower class have been known to coat the chips over with molasses and then mix them with the grindings. In this manner the two will adhere and will not separate in shipping.

In using the molasses in this manner it is possible to mix from 5 to 10 per cent (or even more) of red grindings with the chips without being conspicuous, and unless the purchaser is forewarned he will not usually detect it. As there is a considerable difference in value between the chips and the red grindings this is a deception to be guarded against.

SPURIOUS CASTINGS.

Buyers are usually willing to believe the best of castings. In the case of composition castings they assume that if the metal was once cast, is red, and has been in use, it must be good. Hence they do not hesitate to purchase any form of composition casting.

Unscrupulous people have taken advantage of this fact to carry out a very careful deception.

Washings, railroad chips mixed with babbitt metal, or other form of scrap, that is, of such a character that a brass founder would never think of using it for making castings, are melted and cast into various common shapes found in the trade. As it would hardly pay to make valves or other complicated castings (although there are instances in which it might be done), simple castings only are made. One of the favorite shapes is large rings of the shape of a bearing. When cast, these are broken up and then are ready for sale.

The buyer, having such broken castings offered to him, at once believes that they were originally in use, wore out, and were discarded. He files them, and

they show red metal. Consequently he believes that the castings are of good metal. The more ingenuity has been displayed in making the castings in forms that will serve to indicate that good metal had been used in them, the more the buyer will be deceived. The discovery of this method of making "scrap composition castings" leads one to believe that "all is not gold that glitters."

PICKLING WASHINGS.

The term "washings" is used to designate the metal left in washing out the coal and slag from brass foundry ashes. Washings of this kind, when they come from brass foundries making red metal castings alone (such as, for example, steam metal valves), are always a desirable material, and can be used in the making of composition castings.

As such washings have usually been sold by the appearance, it is customary to wash them quite clean, and then, if they are entirely uniform in color and red, they command a good price. If, however, they are mixed with yellow brass washings, even in a small amount, the yellow color is so conspicuous that the whole material cannot be sold for red washings, but comes under the head of "mixed washings," and the price which they will bring is much lower.

In order to change the color of these metal washings before they are mixed with the red ones, they are sometimes "pickled." By doing this the surface of the yellow metal is changed to red. The method followed is simply to pickle the yellow washings in weak sulphuric acid (oil of vitriol). About nine parts of water and one part of sulphuric acid are used. The washings are immersed in it until the zinc in the brass is dissolved out, leaving the copper on the surface. This, of course, takes place only superficially, but still it is sufficient to color the washings. The pickling operation may take several hours if the pickle is cold, but if hot it acts very rapidly and the red color is obtained in a few minutes. The washings are then rinsed in water, and they will have a red color.

The yellow brass washings thus colored red on the surface are mixed with the red washings so that the whole lot has a uniform red color. The practice is, according to our contemporary, legitimate in one way, but is dangerous in another. Yellow washings are now rarely good on account of the extensive use of aluminium in making yellow brass castings. Aluminium is never used in the red metals. By thus mixing the yellow washings with the red, aluminium may be introduced. Were it not for the aluminium the red washings might melt to a red ingot, even though containing a small amount of yellow metal, but the presence of aluminium ruins the whole lot for any purpose that can be found for red brass except the cheapest class of railroad work, and even in this it cannot always be used.

Measuring the Height of an Aeroplane

THE following method is applicable to the measurement of the altitude of any object and does not involve trigonometrical computations.

Cut from a sheet of heavy bristol board two square pieces, each exactly ten inches along the side. Tie the end of a four-foot length of heavy thread around a pin and drive the pin into the corner of one of the board squares. Start the pin in the edge of the bristol board at the extreme corner and drive it toward the center of the square so that only the head of the pin shows when driven in. Attach a pin and thread to the other square in exactly the same manner. Tie to the free end of each thread a heavy nail.

Thrust two sticks into the ground just one hundred feet apart as measured with a tape and tying the end of a cord around one stick carry the cord to and around the other stick, then back to and around the first, and so continue until five complete circuits have been made, and one thousand feet of cord measured off. Cut and wind the piece upon a bobbin for future use.

Preparations are now completed for measuring the altitude of an aeroplane, or of a cloud or mountain peak, for that matter. Assume that a large level field is available for operations and that measurements are to be made of the height of an aeroplane above the level of this field. Two observers establish themselves one thousand feet apart as measured by the prepared piece of cord. Observations are to be taken only when

an imagined line drawn from observer number one to the aeroplane passes directly over the head of observer number two; in other words, when observer number one would see the aeroplane strike the ground *beyond* and in line with observer number two, if it were at the moment of observation to make a vertical descent. When the plane swings into this alignment each observer raises his square and holds it with its faces vertical, the weighted thread hanging from the highest corner. Then with the right eye each sights at the plane along the upper edge of his square as if he were aiming at the plane with a rifle, the upper edge of the square representing the rifle barrel (Fig. 1). At the same time the thread must hang freely, yet at rest, along the left face of the square. Still holding a perfect sight on the

plane, press the hanging thread with the thumb of the left hand carefully and firmly against the face of the square. With a sharp pencil, mark on the board the position of the thread by the intersection of the arms of a cross as at P (Figs. 1 and 2). It is evident that the more distant observer sees the plane at an angle of elevation measured by the angle A (Fig. 1), while the nearer observer notes a larger angle B (Fig. 2).

Next, bring the card board squares together and place them upon a large table, or a floor, edge to edge, with the corner C at the corner d (Figs. 1, 2, and 3). Stretch each thread into its former position across its marked point P. The threads will cross at some point m (Fig. 3). The points b, d, and m form a reduced size picture of the positions of the two observers and the

plane, respectively, where the length of the line m n corresponds to the height of the plane. Point n is the foot of the perpendicular dropped from m upon the line b d produced. If the length of line m n be twenty inches, or twice the length of b d (which is ten inches) then the height of the plane is twice the distance between the two observers, or twice a thousand feet. In short, the height of the plane is as many hundreds of feet as is the length of m n in inches. If m n be twenty-six and one half inches, the plane is twenty-six hundred and fifty feet high.

To measure the height of most clouds the observers would do well to place themselves one mile apart on a straight and level road and take observations when the cloud comes into line above the road. In this case, one tenth of the number of inches contained in the line m n is the height of the cloud in miles. If m n be forty-five inches, the cloud is four and a half miles high. Further, if the distance d n (Fig. 3) be, say, thirty-five inches, the nearer observer would have to walk forward three and one half miles before finding the cloud directly above him.