

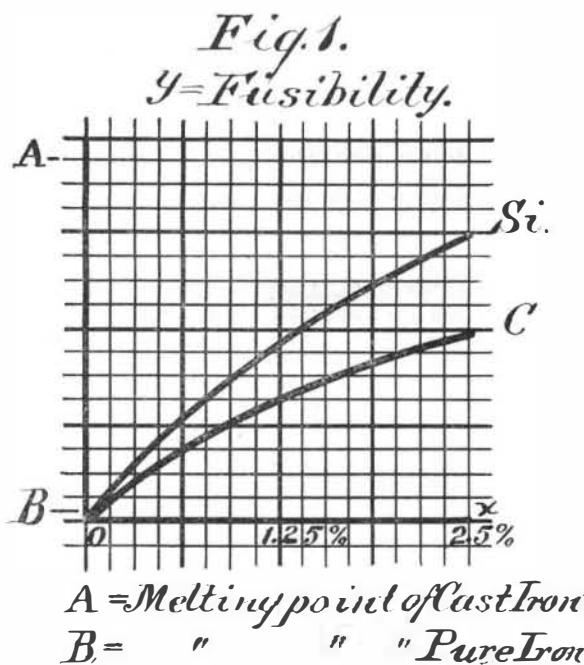
## SIBLEY COLLEGE LECTURES.—1892-93.

BY THE CORNELL UNIVERSITY NON-RESIDENT LECTURERS IN MECHANICAL ENGINEERING.

ON SOME OF THE MECHANICAL PROPERTIES OF HIGH STEEL AS RELATED TO ITS COMPOSITION AND STRUCTURE.\*

By JOHN W. LANGLEY, Ph.D.

THE subject of steel is so large a one it will be necessary in the outset to lay down the limits of the present lecture, because even when restricted to the scope of



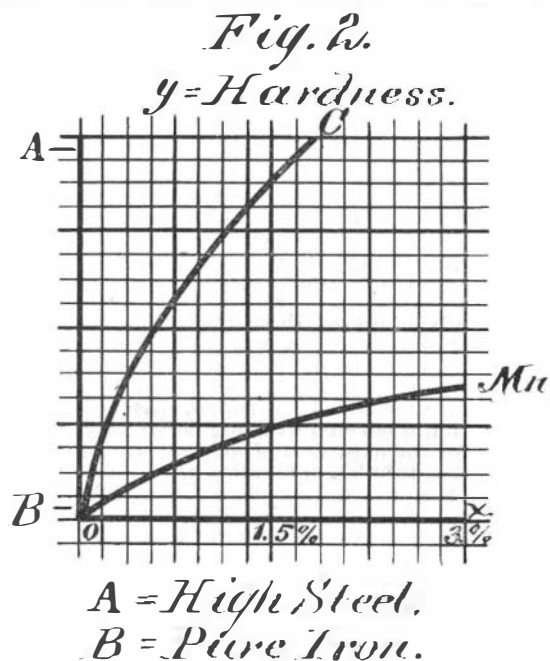
its title many hundred pages would fail to exhaust the topic. Let me then say we will consider here only high carbon steel of the grade known as tool steel, and we will leave wholly on one side alloy steels, such as those containing chromium, tungsten, nickel, or large quantities of manganese.

Furthermore, only steel whose composition is within the ordinary limits of commercial manufacture and whose general or all-around properties have been long fairly well known need occupy our attention to-day. We will also consider only the influence of composition on its properties in their general or average action rather than in any special case.

First, then, I will offer you a definition of steel which may serve for the purpose of this lecture, premising, however, that I do not offer it as a universal formula, or one which is not open to adverse criticism. Steel may be defined as "iron holding in solution (or combination) carbon principally, and also small quantities of silicon, phosphorus, sulphur, and manganese."

The word solution in the above definition dominates the whole expression; let me explain the sense in which it is used. When a student begins the study of chemistry he soon learns that chemical combinations occur in definite and fixed proportions based on atomic weights. Sodium chloride, for example, is a perfectly definite atomic combination, unchangeable, we believe, in its percentage composition without complete loss of its identity. It may stand as the type of all this class of substances. But also we know of a different kind of union between bodies, called solution, as when sugar or salt dissolves in water; here both the solids and the water undergo a progressive modification of properties with change of the relative proportions of the two in the mixture.

This is a type of indefinite composition. But many phenomena known to-day point to a gradual merging of these two classes into each other. Some chemists



consider all solutions as forms of atomic combination. Experiment and theory unite to show that the mere act of dissolving a body, as sodium chloride, in water tends to dissociate it into its elements, and if a sufficient volume of water is taken, an actual liberation of chlorine seems to occur. I consider that the kind of union between carbon and iron exhibited by steel is on the border line between a typical chemical compound and a simple aqueous solution, but nearer to the latter than to the former.

\* A lecture delivered before Sibley College, Cornell University, December 9, 1892.

All tool steel contains in addition to iron and carbon four other elements—silicon, sulphur, phosphorus, and manganese. The first three are unavoidably present, and the manufacturer tries to have their proportions as small as possible; the last one is intentionally added because of its beneficial effect on steel during hot working. It is doubtful if manganese exerts any good influence on cold steel, and it is certain that if its amount is not very small its action is pernicious.

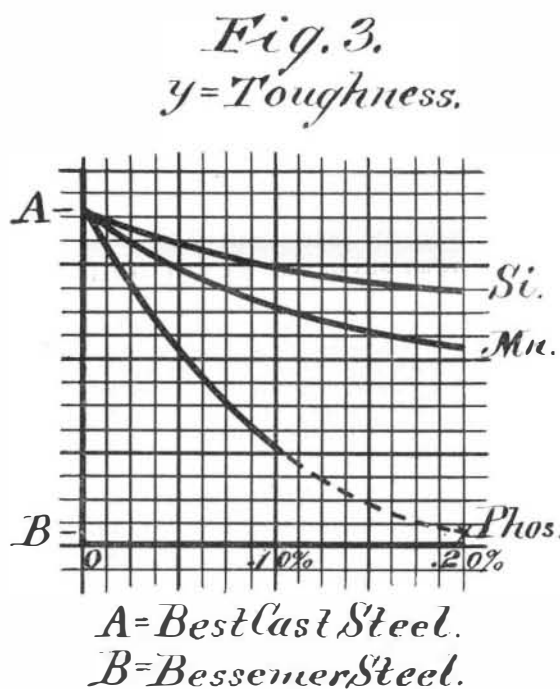
The ranges of composition of tool steel are as follows:

| Ranges.         | Average High Grade. |
|-----------------|---------------------|
| C. 0.5 — 1.50   | 1.20                |
| Si. 0.05 — 0.30 | 0.20                |
| P. 0.01 — 0.05  | 0.02                |
| S. 0.003 — 0.04 | 0.008               |
| Mn. 0.08 — 0.50 | 0.20                |

The action of foreign matter on iron when melted with it is governed by the following general law: "Each addition of small quantities of any of the above elements to iron reduces the melting point, the ductility, and the electric conductivity of the iron, while at the same time it increases the hardness and the magnetic retentivity."

But the individual effect of each of the five elements, carbon, silicon, phosphorus, sulphur and manganese, differs greatly on the general mechanical properties. If we plot this graphically, we find that none of them can be expressed as a linear function of the equation of a curve. By this I mean, letting  $y$  equal any property of steel which can be expressed on a numerical scale, and  $x$  the corresponding quantities of the element, then in a diagram constructed on rectangular axes we shall not get a straight line, but instead, curves having a general resemblance to the parabola,  $y^2 = px$ , but not accurately so. We may write them approximately  $y^2 = fx$ , where  $f$  itself may become variable. They all tend, with possibly the exception of the manganese hardness curve, to become asymptotes to the axis of  $x$ .

Taking up for consideration the specific action of certain elements, we notice that the one which has the most notable influence on the melting point is silicon, and next carbon. In Fig. 1 the vertical axis is drawn with reference to A and B, while the horizontal axis represents per cents. of silicon and carbon, both of these being in the so-called combined state, i. e., held perfectly in solution.



The lowered melting point of steel is the principal reason why it is practically impossible to weld it. The metal passes through a granular stage before complete plasticity is reached, and then almost at once melting begins. The plastic state, which extends over a considerable temperature range in iron and very mild steel, is so brief in high steel that only rods of very small section can be heated with sufficient uniformity to permit of welding during the brief period while the metal is cooling through this plastic state. Very small tool steel rods of less than one-quarter inch cross section can be welded fairly well, but not large ones from this cause. Silicon is especially prejudicial in this respect.

The element which confers hardness on steel is chiefly carbon. It is pre-eminent in this respect, but manganese can nearly rival it, provided it is introduced in very considerable quantities of from seven to twenty per cent. This is shown in Fig. 2. Here small quantities of manganese are inferior to carbon in hardening power, but when manganese reaches fifteen per cent. it rivals carbon at one per cent.

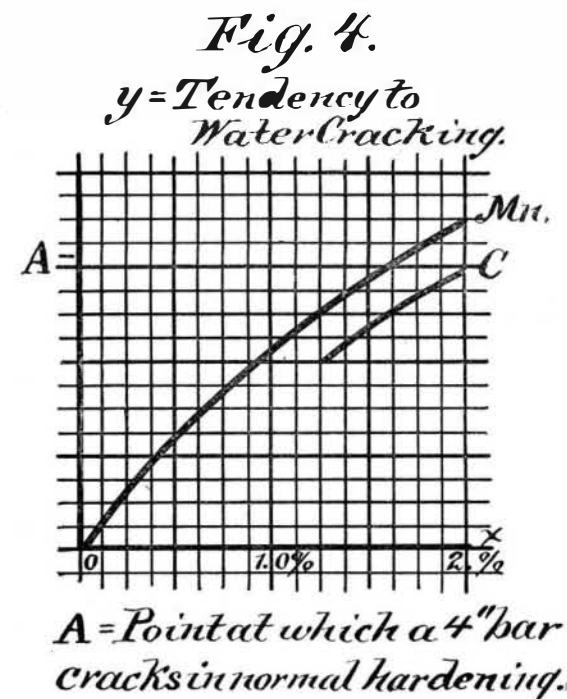
The most useful tool steel is that which combines toughness with hardness. Mere hardness can be readily attained, as for instance in chilled cast iron, or in steel holding a large quantity of both carbon and manganese; but in these cases the material will be very brittle. A tool which will hold an edge when working on fairly hard material or when cutting at high linear velocity must possess enough elasticity and ductility to enable it to yield slightly under the fluctuating stresses brought to bear on it by the work. The best steel after hardening and tempering will do this. Therefore, the best steel for a cutting tool for working either wood or iron is the one which combines toughness with hardness. If we bring various samples of steel as nearly as possible to the same degree of hardness, then they will be found to differ greatly in their toughness, i. e., to forces tending to crumble away the cutting edge.

In Fig. 3, uniform hardness is assumed.  $y$  is the axis of toughness. The point, A, represents the best grade of steel made from Swedish iron. B, a cheap grade of Bessemer steel.

A and B have the following composition:

|                 | A     | B    |
|-----------------|-------|------|
| Silicon.....    | 0.12  | 0.10 |
| Manganese.....  | 0.15  | 0.30 |
| Sulphur.....    | 0.004 | 0.04 |
| Phosphorus..... | 0.01  | 0.11 |
| Carbon.....     | 1.25  | 1.25 |

The curves in this figure are concave upward because they indicate decreasing values of  $y$ . Also they cut the axis of  $y$  at a point above A to indicate that the ideal steel would consist only of iron and carbon;



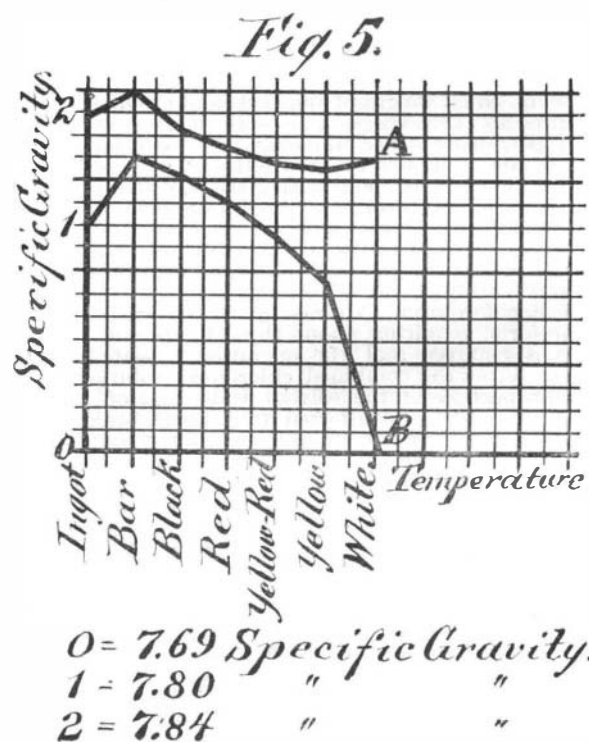
probably, however, some manganese would have to be present, on account of its specific beneficial effect on hot working.

The phosphorus curve is partly dotted, because steel is rarely permitted to contain more than 0.11 of this element. Its extremely deleterious action is sufficiently shown in the figure.

Another very important quality of steel is its ability to go through the operation of hardening by being plunged into water. Some steels show an almost invincible tendency to crack in the process. Probably the tool maker has more trouble from this cause than from any other defect. If we take a bar, say four inches in diameter, and harden it, using all normal precautions, then it will be found that some steels will inevitably crack. Let this state, where the four inch bar will crack even in the hands of an expert, be called A in the annexed diagram, Fig. 4, then if we start with carbon at 1.25 as a minimum, we shall find manganese to be the agent which chiefly causes water cracking, and it is this evil tendency which compels the manufacturer to keep this element low in amount, much less in fact than he would like to use to make the metal go readily through the rolls without breaking.

The cause of water cracking is partly chemical, partly mechanical. Chemical, because of the changed condition of the carbon brought about by sudden cooling; mechanical, because this results in a violent expansion of the metal; hardened steel being of an increased volume and a lessened specific gravity compared to the same piece before hardening.

Some years ago the writer made a study of a large



number of samples, a portion of the results of which are given in Diagram 5.

By means of a crown drill samples were bored out from a set of ingots containing different percentages of carbon, but which were alike in other respects. These are marked "ingot" in the figure. The ingots were drawn down into  $\frac{3}{8}$  inch round bars, which were then heated to a dazzling white heat at one end, while they were left cold at the other. In this state they were plunged into water, and when cold broken off into short pieces which represented the temperatures noted in the figure. This method of studying the

effect of heat on fractures was devised by Mr. William Metcalf. On taking the specific gravities of these samples it was at once apparent that the rods in the original state were all denser than the ingots, but from this point on the pieces decrease in density in proportion to the temperature to which they had been subjected, showing a permanent expansion by the operation of hardening. Also, the higher the carbon the greater was the disposition to crack in the overheated samples.

In Fig. 5 only two sets are shown.

A had carbon, 0.526  
B " " 1.080

The actual figures from which the curves were plotted are:

|                 | A          | B          |
|-----------------|------------|------------|
| Carbon.....     | 0.529      | 1.080      |
|                 | Densities. | Densities. |
| Ingot.....      | 7.841      | 7.805      |
| Bar.....        | 7.844      | 7.825      |
| Black.....      | 7.831      | 7.811      |
| Red.....        | 7.826      | 7.798      |
| Red-yellow..... | 7.823      | 7.769      |
| Yellow.....     | 7.814      | 7.741      |
| White.....      | 7.818      | 7.690      |

Sample B was cracked in the pieces heated to a white and to a yellow heat. Sample A was not cracked in any of the pieces. As a red-yellow heat is the best temperature for hardening, it is at once apparent from the above figures why high carbon makes this operation so critical a one. Also, why steel should never be heated above the minimum temperature necessary to thoroughly harden it.

A few words may be added here on shop precautions in the hardening of steel which do not depend on its chemical composition.

It takes much longer to heat a piece of metal uniformly than is generally supposed. I found that on placing a piece of steel  $\frac{3}{8}$  of an inch in diameter by 3 inches long in the interior of a red hot iron tube, it took about 20 minutes for it to attain sensibly the temperature of the surrounding walls.

All pieces showing sharp projecting angles, such as milling cutters and large twist drills, are especially liable to crack, because of uneven heating, since the tendency is for the outside to be much hotter than the interior. Such pieces should be very gradually heated in a moderate fire burning without flame; they should be frequently removed for short intervals and finally heated a little above the best temperature for dipping. Then they should be suffered to cool very gradually to the critical temperature and be plunged into water.

The reason of this is because during the heating the outside tends to be the hottest, while during cooling the reverse is the case; hence by slightly overheating and then catching the right temperature during the cooling stage a more uniform distribution of heat between the outside and interior will result.

#### CONFETTI AND SERPENTINES.

Who is there in Paris that is not acquainted with "confetti" (those of paper, of course), on account of having received them square in the face, or of having thrown them at the merry promenaders who, on public holidays, give the streets a picturesque and sometimes so animated an aspect. This year they have had a particular success during the days of Mid-Lent and Shrove Tuesday.

At Nice, Barcelona, and Venice, in the warm and charming countries in which King Carnival sees the return of these customary splendors every winter, the confetti, as well known, are bonbons of plaster, of which the weight is sufficient to permit the promenaders to answer the flower bedecked and garlanded balconies. The

So the confetti of paper, the only kind possible at Paris, has acquired the freedom of the city among us, and the street vendors, who on certain days of merry making go about hawking this article at always lower prices, can still hope for nice little profits.

These confetti, in fact, the net cost of which is insignificant, are especially profitable to the middlemen. And, in reflecting upon it, it seems very just that the money that the Parisian thus throws into the street, voluntarily and for his pleasure, should go to give a little comfort and gayety, moreover, to those who, far from knowing the superfluous, have not always the necessary.

The manufacture of paper confetti is exceedingly simple. The crude material is the colored paper used for show bills, and certain manufacturers employ as

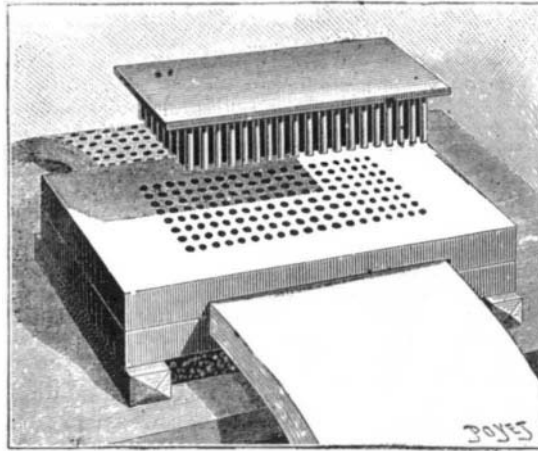


FIG. 3.—APPARATUS FOR THE MANUFACTURE OF CONFETTI.

many as fifteen different colors. The sheets are superposed to a thickness of 3 or 4 inches, and the package thus formed is slid between two steel tables provided with numerous apertures from 2 to 3 inches in diameter. These apertures are opposite each other in the two tables.

Steel punches, formed of an equal number of solid cylinders suspended from one plate in common enter, by friction, the corresponding apertures of the double table, Fig. 3. These punches come into contact with the material to be perforated, and, ever pushed forward by the great pressure exerted upon them, remove throughout the whole thickness of the paper a series of disks that fall into a basket placed beneath. The punches are withdrawn mechanically, the paper is shifted in the same manner, and the operation, which has lasted a second, begins anew. As may be seen, these confetti are not cut out, but stamped out; and in this there is an advantage, for were the punches formed of hollow tubes with cutting edges, not only would the latter very quickly wear away, but the confetti would become packed in the tube and the operation would be necessarily slower. So it is preferred to stamp them. This, it is true, requires a stronger pressure, but that is easily obtained either with an hydraulic motor or a steam engine. At Paris some of the large manufacturers employ a 25 horse power engine.

The waste material varies from 25 to 30 per cent. It is far from being lost, for it is sent to the paper mill, where it is put into the paper stamp, which, under the dissolving action of water, triturates the pulp in draw-

able if a number of the combatants, in the streets at least, stopped picking up their ammunition from the dust.

It would be interesting to know the output of confetti at Paris on a public holiday. Being given that there now exist several manufacturers of this article, their sales would have to be added together, and this is a statistic that one will not fail to make ere long. But we can at present furnish an approximate figure. On Shrove Tuesday, Ferret & Co., on Etienne-Marcel Street, sold 66,000 pounds, say 600,000, of the smallest sized bags. Let us carry the calculation still further: the small cornet is very aristocratic and good for the redoubts of the Casino or the masked balls of the Opera House. The street vender sells it on the boulevards, carrying his stock in a basket (Fig. 1), but he also delivers the confetti by the "bushel," which is a modest glass. Now the small cornets hold about  $3\frac{1}{2}$  glasses, and it was therefore two million glasses of confetti that the Parisians threw into each other's faces last Shrove Tuesday, and, at the current price of two cents per glass, the merry fray cost about \$40,000, 20 per cent. of which, at the most, went to the manufacturers, while the rest was divided among the middlemen.

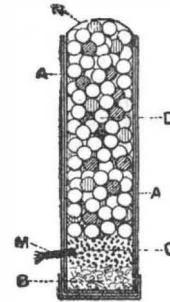


FIG. 4.—CONFETTI BOMB.

And yet, the confetti did not have all the honors of the day, favor having gone to the "serpentes." These are formed of a roll of paper which is thrown in the street or from balconies, and which winds around carriages and pedestrians in falling. At fancy dress balls they are thrown also at the dancers (Fig. 2).

The manufacture of these serpentes, which are exactly like the rolls of paper employed in telegraphy, is very simple. Let us suppose all the operations finished that are necessary to obtain colored paper sufficiently strong and adapted to the use that is to be made of it. This paper in most cases is wound in measure as it is manufactured. It suffices then to have upon the revolving wooden axis upon which the paper is superposed in rolls, circular disks forming knives and so spaced that, by the very fact of its winding, the sheet of paper is separated into a certain number of bands of the desired width ( $\frac{1}{8}$  inch). After a certain length has been obtained, the paper is cut parallel with the axis, the latter is removed, and we then have as many serpentes as there were disks, less one. It afterward suffices to glue the outer extremity of the paper (the unwinding having to begin from the center), and the serpentine is ready to deliver to the trade.

Up to the present, the mean length of these serpentes is 200 yards, and this explains why they can easily undulate from one side of a street to the other. Were they longer, they would not be practical, the resistance of the paper being inadequate; and such resistance alone limits their length, for paper mills manufacture rolls four feet in width by 30,000 feet in length for newspapers, and there would be nothing to prevent the manufacture of serpentes of as great a length were it possible to utilize them.

And now what new invention will be introduced to-morrow to entertain and amuse the great city? Manufacturers are about to bring out confetti rockets and confetti bombs, thus grouping in a single object the noise of the fire-cracker and the volley of paper missiles. Fig. 4 shows a bomb. It consists essentially of a strong cylinder formed of cardboard rolled three or four times upon itself. At B there is some asbestos, at C a small quantity of explosive material, and at D a mass of confetti. The whole is capped by paper, N, of little strength. The powder is ignited through the slow match, M, and it detonates expels the confetti, which ascend to a height of ten feet and fall in a true rain. The asbestos serves to prevent the transmission of fire to the cardboard.—*La Nature*.

#### THE POSITION OF PATHOLOGY AMONG THE BIOLOGICAL SCIENCES.\*

By Professor RUDOLF VIRCHOW, Foreign Member of the Royal Society.

GENTLEMEN: It is now nearly ten years since this illustrious society conferred on me the unexpected honor of electing me one of its foreign members. Not alone this, but last autumn it deemed me worthy of a further honor, in awarding me the Copley medal—token of the highest recognition of my work, the significance of which far exceeds the distinctions which the changing favor of political powers is accustomed to bestow. Nevertheless, deeply as I appreciated this mark of its constant and increasing esteem, still I was not in a position to offer my thanks personally to the society. Numerous duties, official and private, the weight of which has increased with each year, compelled me to work continuously at home, and the extension of international relations, becoming more intimate, has for a long time restricted the freedom of my movements even during the vacations. With great indulgence, which I fully know how to appreciate, the council has allowed me to postpone the date of my appearance in its midst. Hence you see me only to-day among you, and I may tell you in person how very grateful I am to this society, and how great an incentive to new efforts your recognition has become to me.

Who of us is not in need of friendly encouragement in the changing events of life? True, happiness is not based on the appreciation of others, but on the con-

\* Delivered before the Royal Society on Thursday, March 16, 1893.



FIG. 1.—A VENDER OF CONFETTI.



FIG. 2.—SERPENTINES AT A MASKED BALL.

merry combatants protect their faces with netting or metallic masks, and, although the plaster breaks and spots the parti-colored costumes with white, the incoherence is only the greater for it, and the gayety increases so much the more.

At Paris the mask is impossible for the promenader who strolls along the boulevards as a simple onlooker. His tranquil humor will doubtless easily put up with a handful of small pieces of paper that lash his face, but it may be presumed that he would not, without protest, accept a hail of small pieces of plaster from which his clothes would have much to suffer.

ing it out without altering the fibers, which are preserved more or less intact. This pulp will yield a paper of a little lower quality that may be easily utilized.

The confetti obtained as above described are first beaten and worked in order to well scatter the small piles, and then mixed and stirred in order to confound the different colors. Finally, they are put up in bags or cornets, large or small, weighing  $1\frac{1}{2}$  ounce, 3 ounces or 2 pounds.

Thus packed, the confetti are ready for the battle, which, although innocent, would become more agree-