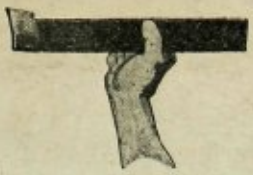

"CRUCIBLE TOOL STEEL"

A Paper Read by

MR. ROY C. McKENNA

President of

VANADIUM-ALLOYS STEEL COMPANY

at a dinner given to salesmen of this Company at Pittsburgh Athletic Association Club Rooms, Pittsburgh, Pa., January 3rd, 1917

MR. TOASTMASTER AND GENTLEMEN:

Being a firm believer in "Preparedness," and anticipating that I might be called upon by the Toastmaster this evening, I came prepared and will read my remarks, taking as my subject—

CRUCIBLE TOOL STEEL

The manufacture of Crucible Tool Steel is my life-work, and one would think that on this subject it would not be necessary to prepare. This would be true were it not for the fact that my audience's interest is also in Crucible Tool Steel.

I cannot hope to offer to the gentlemen present anything new or novel; I can only hope to refresh your memory on some points which you may have forgotten and summarize the conclusions reached from the experience of us all.

Unless it be the "Wines of the Rhine" or the "Champagnes of France," no article of commerce has imparted a fame to the district in which it is produced to a greater extent than Crucible Tool Steel to Sheffield. Men and boys select their razors and knives by trade-names. However unattractive the appearance of a knife, a known trade-mark of a Sheffield manufacturer is the passport to a boy's heart.

Behind this trade-name is the deserved reputation o an institution which has prized Quality in Crucible Tool Steel. The Art of making Crucible Tool Steel has been handed down from father to son for generations.

Some will say that on account of our increased knowledge of chemistry and metallurgy, that the making of Crucible Tool Steel has ceased to be an Art, but has become a Science. The making of Crucible Tool Steel is still an Art, aided by Science. If the making of Crucible Tool Steel was an exact Science, not an Art, there would be no difference in steels of the same grade and our competitors would make a tool steel equal to our own.

We justly pride ourselves upon the uniformity of our product, yet each bar of steel has an individuality. There is something more to Crucible Tool Steel than mere chemical content.

I take occasion now to call attention to the fallacy of purchasers of crucible steel buying to chemical analysis. Equally important to the composition of the steel is the Melting, Hammering or Forging, and Rolling. If a steel is melted too long it is spoiled, regardless of chemical content. It must be heated uniformly; neither too fast nor too slow. The head-melter of a crucible steel plant is an important personage, and his compensation is only exceeded by high officials of the Company.

The importance of Hammering crucible and High Speed Steel is admitted by all informed on the subject. The hammer-shop is so important that it is the general practice to allow the head-hammerman to employ his helpers, and his compensation is based on tonnage and the Quality of his work.

The Rolling of crucible or High Speed Steel is second in importance only to Hammering. Good ingots may be spoiled in Hammering or Rolling.

It is not necessary for me to speak of annealing and tempering of steel at this time, for every man here is thoroughly versed on these subjects and realizes their importance.

As President of this Company it is my duty to see that the policies of the Board of Directors are carried out. One policy of our Company is—"Quality First."

I can speak with pride of the management of the Company and without egotism, for the management is under the able jurisdiction of our General Manager, Mr. D. T. Sipe, with his brother, Mr. C. R. Sipe, as Superintendent.

Without disparaging the advantages of technical education, I am glad that Mr. D. T. Sipe is a practical man and has received his knowledge of the business from the School of Experience. Mr. Sipe's worth to the Company is due, not only to his knowledge of Crucible Tool Steel, but to his knowledge of men, which could only have been secured by working with them side by side.

The entire organization of our Company consists of young men. We are a young Company, with the future before us. We are progressive, but still wise enough to hold to those practices in the making of Tool Steel proven by ages to be the best; until practice, not theory, has proven the superiority of the new.

We were prepared, so that when the unprecedented demand for High Speed Steel (due to the European War) came, we were not only able to increase our production

without detriment to Quality, but have built an organization able to carry on with increased vigor the contest to come when the battlefields of Europe are again under the plow.

The contest will not be alone with manufacturers of Crucible Tool Steel in America, but against the competition of all Europe; unhandicapped by eight hours a day, unmolested by inane factory laws, and unmoved by appeals of their employes for better working conditions.

The military training and efficiency reached in Europe in the manufacture of munitions of war would make dangerous competition under any tariff, and America will be nearer free-trade than any large nation on earth when the European War is over.

The crucible process of making steel is the simplest method known, but it is also the most costly. Where Quality in steel is desired, steel made by crucible process is specified.

Good grade carbon and alloy steels can be made in an electric furnace. The melting of steel in an electric furnace is cheaper than in crucibles; also, in crucibles, only the purest base materials can be introduced in the Mix; whereas in an electric furnace, impure and cheaper materials can be introduced, and sulphur and phosphorus can be eliminated in the process of melting.

Another advantage of the electrical process over crucible practice is that the chemical contents of the steel can be kept within narrower limits.

Those of you who will visit the mill tomorrow will see in operation a Three-ton Heroult Electric Furnace of the latest improved type, melting an alloy steel.

It is not my intention to go into the respective merits of crucible and electric furnace practice, except that crucible steel practice has earned its right to exist from time immemorial (although the most costly), ON ACCOUNT OF THE IMPORTANCE OF MELTING A QUALITY STEEL SLOWLY AND AT A UNIFORM HEAT. I MUST LEAVE IT TO OTHERS TO PROVE WHETHER OR NOT A MASS OF THREE TO SIX TONS OF STEEL IN AN ELECTRIC FURNACE CAN BE MELTED AS EVENLY AND UNIFORMLY AS IN A CRUCIBLE CONTAINING NOT OVER 80 TO 90 POUNDS. IT IS MY PROPHECY THAT AS LONG AS TOOL STEEL OF QUALITY IS REQUIRED, THAT CRUCIBLE PRACTICE WILL BE CONTINUED. The electric furnace has its place, and there is no question of the superiority of electric-furnace steel over open-hearth.

The master-product of the crucible steel manufacturer is a Tungsten-Chrome-Vanadium-Alloy Steel, known to the trade as "High Speed Steel."

To the gentlemen here it is not necessary to go back to the discovery of Mushet, or self-hardening steel, and trace the development of High Speed Steel to present-day perfection, as in this attainment we have all had our part.

A salesman of High Speed Steel is not only a salesman but an expert in forging and tempering his product, and is also capable of advising the user as to speed and feed. On these points I will not touch, but will explain the process of manufacture of High Speed Steel until it reaches your hands, although I know that on this subject many of you are as familiar as I am.

The relative merits of crucible and electric steel in straight carbon and alloy steels we will leave to the trade to decide, but High Speed Steel, our master product, will be made by the old-fashioned crucible process. The theoretical advantages of the electric furnace may be admitted, but there is still a human element in High-Speed Steel. That good High Speed Steel can be made in an electric furnace has not been demonstrated: whether this is due to an inherent fault in the electric furnace or to the human desire to use cheaper base materials and thus take advantage of the capability of the electric furnace in the purification of the steel unattainable by any other process, is not of interest to us this evening.

In making steel by crucible practice, only the purest base materials can be used. This does not mean that with present-day prices for High Speed Steel, economy must not be practiced or that imported alloys must be used where American product is just as good or better.

Before commencing a description of the manufacture of High Speed Steel, I should probably tell you of our equipment, but as you will visit the plant tomorrow, this will be deferred until then.

Our steel is melted in two 30-pot crucible furnaces using graphite crucibles and natural gas. The "Mix" for High Speed Steel is made up of base materials such as low-phosphorus melting iron, charcoal, High Speed Steel which has been rejected in the course of manufacture on account of structure, not analysis, etc. All materials in the Mix are carefully weighed to the fraction of an ounce. The more expensive materials are carefully prepared in a room close to the furnance, known as the "Medicine

Room." Ferro-Vanadium, Ferro-Tungsten and Ferro-Chrome are three important elements in the Medicine. These alloys are weighed even more carefully than the material in the Mix, if that were possible.

A formula once adopted for the Mix and Medicine, is religiously adhered to. In adopting a formula for High-speed steel it is as important that provision be made to have a slag of correct thickness and density as it is to have the proper amounts of Tungsten, Vanadium and other ingredients. Great care is taken to preserve the uniformity of the Mix and Medicine—the hardening agents are placed at the bottom of the crucible and the iron carefully packed over them. The materials most easily melted are generally placed near the top of the crucibles, so that upon melting to the density of molasses, they cover these elements liable to gather carbon from the graphite crucibles.

I have spoken of the importance of melting High Speed Steel slowly and at a uniform heat. The time required to melt High Speed Steel is variable; the melter's experience is his chief guide in determining when the melt is ready. For the most part the melter depends upon his eye to determine the progress of the melt, and if he makes a mistake it may be a total loss.

High Speed Steel must not be poured until it has become quiescent, as in this condition the chances of the resulting ingot being sound, that is, free from blow-holes, are much better than if the steel is bubbling.

The technical term for pouring High Speed Steel is "Teeming," and Teeming is an important operation, performed by the melter himself. The slag is skimmed off and the teemer quickly empties the remaining contents of the crucible into the mold. Inasmuch as the moulds are so small in section, it requires a very high order of skill to teem properly, as the stream of melted steel must not at any time strike against the sides of the mold. In case of large ingots made for special purposes, ladle-heats are made. In a ladle-heat, the entire 30 pots may be poured into the ladle, and from the ladle into the large molds.

It is important that all ingots be cooled gradually, and in case of large ingots from ladle-heats, they are rushed, red-hot, before they can become set, to the hammer furnace. The rapid cooling of an ingot would develop serious defects or cracks. On account of the outside of the ingot cooling more rapidly than the inside, there is in every ingot a "Pipe." This pipe is filled by placing a hot-top brick on the top of the mold and pouring the melted steel into the pipe.

The ingots when cooled are "Cropped;" that is, the top knocked off to remove the "Pipe" or segregated portion. A sample is taken at this time from every ingot for carbon analysis, and one sample is taken from each heat for complete analysis.

The only element liable to vary in a heat of High Speed Steel is carbon. We can therefore tell the approximate analysis of any ingot number.

Although we may apparently be successful in filling the "Pipe" in an ingot, it is found upon hammering that the pipe end of the ingot will open, and to prevent this tendency of the pipe to extend further into the ingot, the hammer-man crops from four to six inches off the pipe end.

When the hammered billet is "Cogged" (second hammering), it is again necessary for the hammer-man to crop the billet.

The importance of hammering High Speed Steel at correct temperature is second in importance only to melting. The heat at which to hammer High Speed Steel is left to the judgment of the hammer-man. It is also upon the hammer-man's eye that we depend to detect any defects that may develop in the structure of the steel. These defects he removes by "Chipping." Any defect which may develop and which may not be discovered in the hammering, will develop in the rolling of the steel, and will cause the rejection of the bar.

I trust that you men will appreciate the amount of hammering or working High Speed Steel receives before it is sent to the rolling mill for finishing. That this hammering is sufficient is proven by our producing as hammer-scale, 12% of the ingot weight cast. The skill of the hammer-men is so great that they can finish steel to within $\frac{1}{64}''$ of size specified on a four-ton hammer; with even greater accuracy on the smaller and finishing hammers. The skill of our rollers is attested by the accuracy of our finished product, and is generally within .001" to size.

Fifteen percent of all the labor in our plant is consumed in inspection. Ingots are carefully inspected for physical defects, and if the defects are found to be serious the entire ingot is rejected and set aside to be re-melted. This is true only in case of physical defects, for any heat found not to be within the limits as to chemical analysis, is scrapped, and not re-melted. If only minor defects are found in the ingots, these are

ground out before hammering. The hammered billet is likewise inspected for physical defects, and minor defects developed in the hammering are ground out. The hammered billet may be rejected if the defect developed in the hammering is serious. The cogged billet is likewise inspected before being sent to the rolling mill.

After the finished bars are rolled, they are annealed and pickled, and sent to the warehouse, where they undergo the final and most rigid inspection, and any defect visible to the naked eye causes the rejection of the bar, or that portion of the bar in which the defect exists.

I have told you that ingots not within our limits as to chemical analysis are rejected—not re-melted, and have also described the inspection of ingots, billets, cogged billets and bar stock.

The percentage of High Speed Steel melted and cast into ingots that passes the ordeal of four rigid inspections for physical defects is small. The controlling factor in the cost of High Speed Steel is the percentage of finished steel to ingot weight. The success or failure of the manufacturer depends upon the ability to keep this percentage within reasonable limits with certainty that the portion of finished steel containing physical defects will be negligible.

To men so well informed I hesitate to speak of chemical analysis of High Speed Steel, as the importance of this has been over-emphasized to the trade. I will only relate the fundamental properties imparted to High Speed Steel by each element entering into its composition, and not discuss the intermingling relations of the elements to each other, as this subject is too complex for discussion here.

The selection of a standard analysis for High Speed Steel, together with allowable variations, is left to our metallurgist. The selection of a standard analysis is always a compromise between cutting edge and strength, hardness and toughness, with the single exception of Vanadium, every element improving the cutting quality of High Speed Steel causes brittleness, and every element giving strength and toughness is injurious to good cutting quality.

In selecting a standard analysis the combination of elements giving the best results as to cutting quality and strength at "Red-Hardness" is chosen. It is up to you to educate the trade to know that what they want is a High Speed Steel of good cutting quality, with

maximum strength at Red-Hardness—not at atmospheric temperature. OFTEN A TOOL IS CONDEMNED AS "TOO SOFT" UPON A SUPERFICIAL FILE TEST AT ATMOSPHERIC TEMPERATURE, THAT WOULD NOT ONLY RETAIN, BUT INCREASE ITS HARDNESS AT RED HEAT AND HIGHER.

The only test for High Speed Steel is actual work, and it is upon the thousands of tests our High Speed Steel undergoes that decides our standard analysis.

IRON—The base of High Speed Steel is iron, and the best grade of iron must be used. This is usually imported from Sweden, but a good grade of American iron can now be obtained.

CARBON—Carbon gives to the iron the property of hardening. Carbon control is one of the most difficult problems with which the manufacturer must contend.

TUNGSTEN—Tungsten is the most important element, and together with Chromium, gives to High Speed Steel that property known as "Red Hardness"—this renders it indispensable to the machine shop. About 22% Tungsten is introduced into the High Speed Steel Mix, and the finished product contains from 16% to 20%. Our average analysis of Tungsten for the month of November was 18.62%.

CHROMIUM—Chromium is equally as important as Tungsten in imparting to High Speed Steel that property of maintaining hardness at even white heat. Chromium also imparts to steel a hardening property similar to that given by carbon, although to a less degree. The hardness imparted to steel by Chromium is accompanied by brittleness, and any Chromium in excess of 5% would render High Speed Steel too brittle for any purpose with the probable exception of lathe tool bits. To secure the best results in High Speed Steel, Chromium should be a little under one-fourth of the tungsten content. Our average analysis for November was 4.14%.

VANADIUM—You all are familiar with the importance of Vanadium in High Speed Steel. Vanadium was first introduced in High Speed Steel as a scavenger; it, however, soon became evident that the addition of Vanadium, up to about 1% in High Speed Steel, greatly improved its cutting qualities. Our average Vanadium analysis for the month of November was 1.04%.

SULPHUR AND PHOSPHORUS—Sulphur and Phosphorus are two elements detrimental to all steel, but are probably slightly less harmful in High Speed Steel than in carbon steel: they should be kept as low as possible. Sulphur produces "Red-Shortness" and Phosphorus, "Cold-Shortness."

MANGANESE—Manganese is added as a fixing agent. It seems to hinder the formation of double-carbides of Tungsten. It is also an antidote for Sulphur. Much Manganese would make the steel "Cold-Short" and liable to fire-cracking. A small amount of Manganese in High Speed Steel tends toward strength and toughness in the body of the steel.

The percentage of Manganese in High Speed Steel should be small—not over .10 to .20.

SILICON—Silicon is a scavenger and has properties similar to Manganese. Excessive Silicon causes brittleness and also sensibly lowers the cutting speed. .10 to .15 is most satisfactory.

You will notice that I have told you what is done; not how to do it. Those of you who will visit the plant will see how it is done—experience alone can teach you how to do it. There is much in the manufacture of Crucible Steel that I know and have not told you—there is much that I do not know that is practiced in our own mill.

I trust I have convinced you that the manufacture of High Speed Steel is an Art.

Is the present price of High Speed Steel justified by the care used in the making?

Do you appreciate the increased cost of raw materials, crucibles, fuel, labor and supplies? That I mentioned crucibles second in justification of present prices for High Speed Steel is not because we are now paying three times their former price, but owing to American clay used, they are giving less than one-half the usual number of heats.

EVERY CRUCIBLE THAT BURNS OUT MEANS THE LOSS OF A POT OF HIGH-SPEED STEEL.

However proud we are of the men advanced from humbler positions to those of importance, we could not hope that younger men as melters, hammer-men and rollers could have the same efficiency as our older men.

Statistics show that each pound of High Speed Steel displaces seven pounds of carbon steel, viz: One pound of High Speed Steel removes as much material as seven pounds of straight carbon steel. No less an authority than Secretary Lane of the Department of the Interior in the December, 1915, issue of the National Geographic Magazine stated that one man and one machine, using High Speed Steel, did more work than five men and five machines using carbon steel.

The price of High Speed Steel is justified, not only by the value to the user, but by cost. Gentlemen, you should be proud of the product you sell.

Of several contributing factors to our success I will make mention:—

FIRST—The ownership of a tract of Tungsten property in Colorado which supplied us with a source of Ferberite Tungsten Ore—the purest in the world—helped us to maintain the quality of our High Speed Steel through a period of great difficulty. We hope to hear further of the Vasco Mining Company from Mr. W. H. McKenna, who has recently returned from Boulder.

SECOND. Of this I dare not speak, for my first knowledge of this infant industry some years ago was Bill McKenna's reference to it as "Dem Sipe's Hobby." As Mr. Sipe is with us this evening and we will hear from him later, I can only say from "Dem Sipe's Hobby" has developed an industry—the manufacturing of Ferro-Tungsten, and we are today not only supplying our American friends making High Speed Steel with the purest Ferro-Tungsten ever made on God's green earth, but are shipping our product to all parts of the world to which transportation is open.

THIRD. To the loyalty of our men—to our metallurgist, Mr. R. L. Sessions and his assistants—to our chemical laboratory—to our continuance of research work, and to co-operation between our mill and salesmen.

Of co-operation between mill and salesmen, no one is more responsible than our Toastmaster of the evening, Mr. H. N. Surrey, and I hope that he will speak on this subject.

At the conclusion of Mr. McKenna's address—Mr. Surrey, our General Sales Manager, acting as Toastmaster, addressed the meeting as follows:

GENTLEMEN:

In the course of our President's remarks you will recall he made mention of the difference between High Speed Steel made by the Electric furnace method and the Crucible method. I must place particular emphasis on this, and direct your attention to the extreme unfairness on the part of some of the trade comparing our RED CUT SUPERIOR with other brands of High Speed Steel as manufactured by newly organized steel companies, and also other concerns who have recently taken up its manufacture due to the lure presented by the great demand.

The last six months of 1915 and the year 1916 constitute a remarkable era in the manufacture of High Speed Steel.

The demand for this product became so great that the usual preference of the trade for reputable and well-known makes was not quite as evident as formerly, and the prestige of a trade name lost some of its value. The trade has to a certain extent assumed that High Speed Steels of different manufacture are nearer equal in quality and value than ever before. This is untrue, as some steels now being marketed as High Speed Steel are a disgrace to the makers.

High Speed Steel being sold at a lower price than that asked at present for all reputable and standard brands is in almost every instance made by a company not manufacturing High Speed Steel two years ago, and is usually not Crucible but Electric Furnace Steel.

As conditions in the High Speed Steel trade become more settled, the preference of the trade for established and reputable brands will be greater than ever. There may be an inclination on the part of some users to believe that the present price for High Speed Steel is not justified by the increased cost. Brother Salesmen, you know and we know that the price asked for a Nationally Known Quality Steel cannot be and never will be in excess of its value.

The trade should be given to understand that the controlling factor in the cost of High Speed Steel is not the percentage of Tungsten, Vanadium, etc., that it contains, but our strict, self-imposed requirements as to structure, analysis and inspection placed upon our product to defend and insure its quality.

It is not our ambition to be known as the largest producers, but rather as makers of the best product. We are now making only one grade of High Speed Steel, and that grade is made the best we know how.

We, too, could cheapen production methods—slice a little here from our rigid inspection, pare a little there from many other important items of manufacture, and perhaps resort to the Electric Furnace to greatly increase capacity, and then go out and shout to the American user that we could beat the present legitimate price of High Speed Steel. But—you can rest assured we won't sell our heritage for temporary gain. We have given our pledge to the trade—to our customers whose faith we respect and honor—and as long as we remain in the manufacture of First Quality Tool Steels our friends and customers will be supplied with a product of Highest Quality.