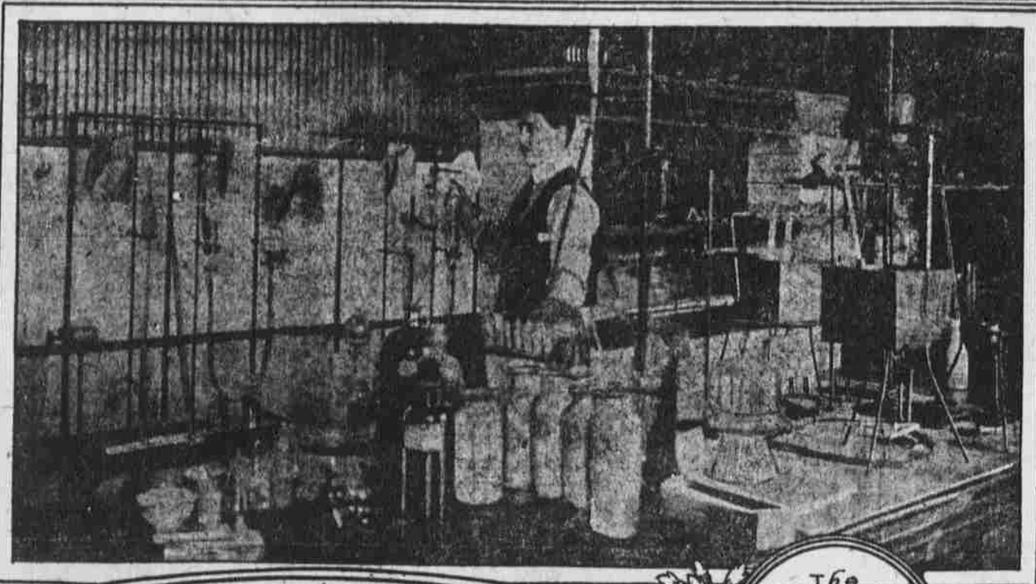
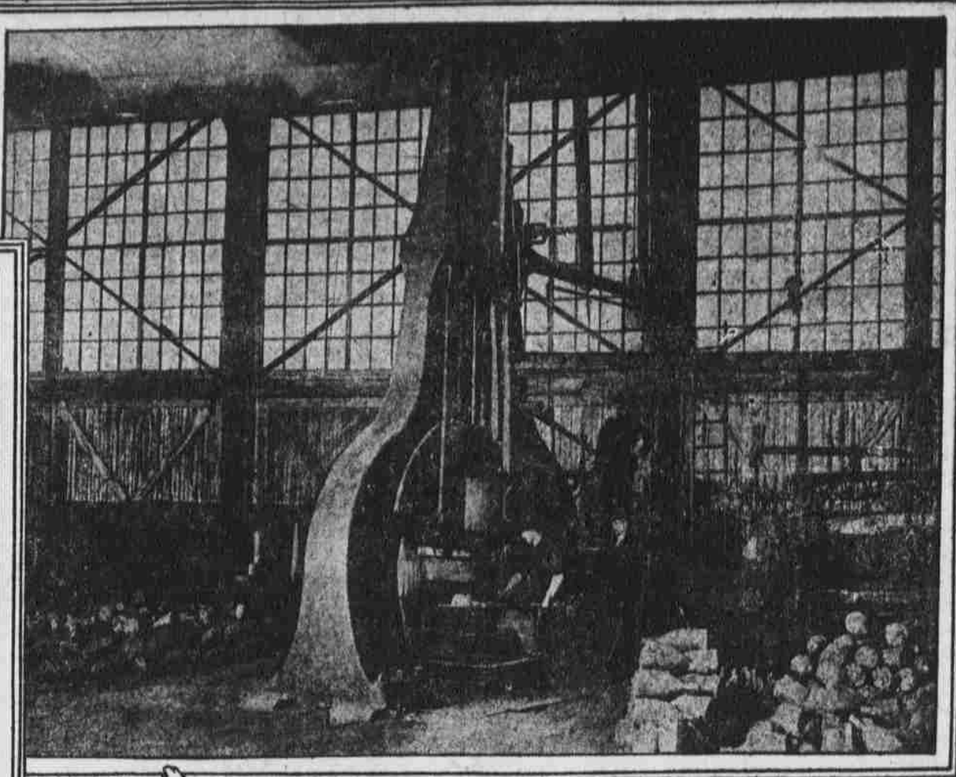
Arnold's Invention Marks Another Step Toward the Development of Supersteel

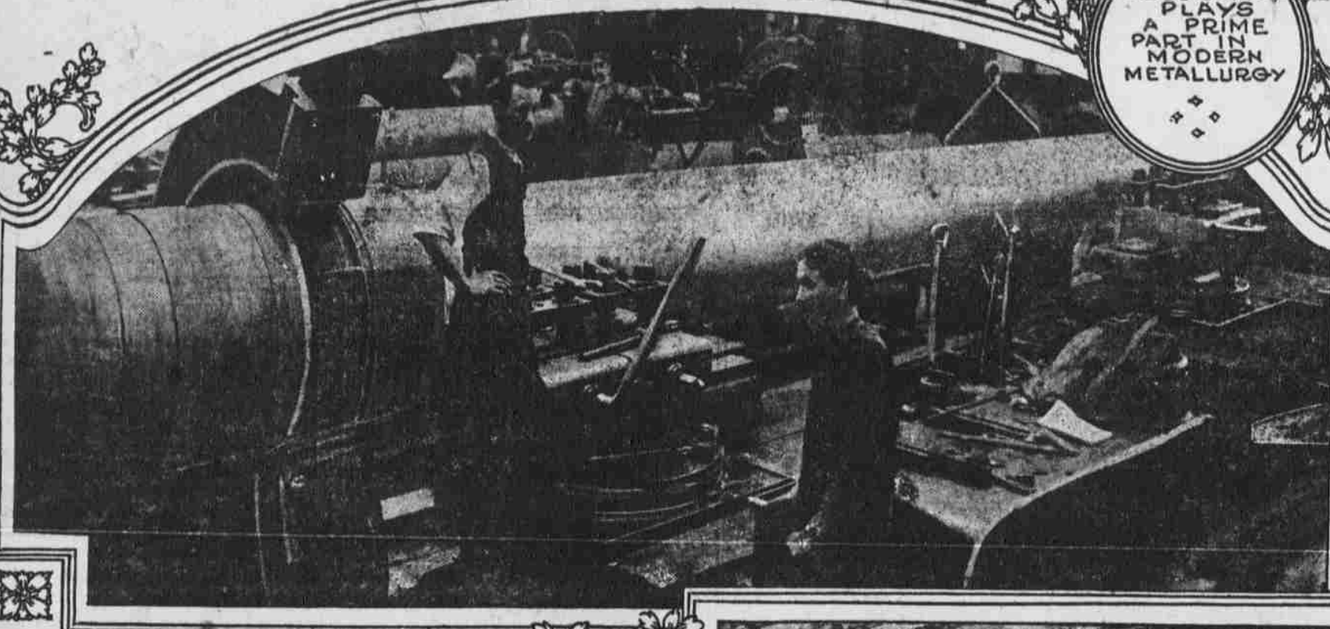
Use of Molybdenum, Key Metal in English Scientist's Formula, However, Already Was Known in This Country—Full Importance of His Discovery Yet to Be Determined

By ROBERT G. SKERRETT.

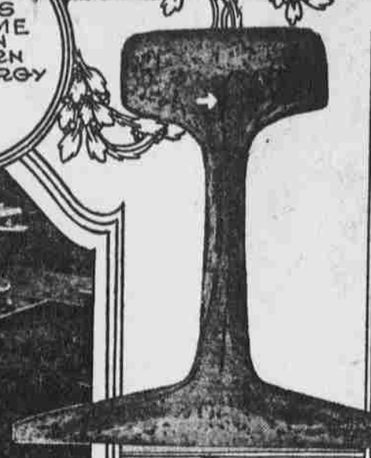




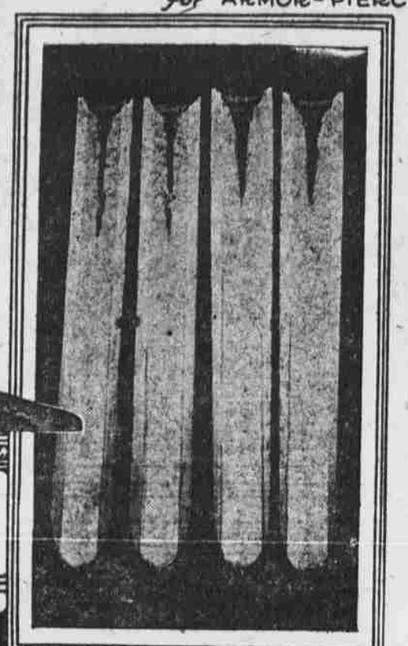
FORGING ROUGH BLANKS of SPECIAL STEEL for ARMOR-PIERCING PROJECTILES



THE LABORATORY PLAYS A PRIME PART IN MODERN METALLURGY



WHITE ARROW MARKS FATAL FLAW IN A STEEL RAIL



INGOTS OF HIGH-SPEED TOOL STEEL SHOWING DEFECTIVE CAVITY OR "PIPE"

HIGH-SPEED TOOL STEEL HAS REVOLUTIONIZED MACHINE SHOP PRACTICE

STRENGTHENING GUYS of The FLYING MACHINE MUST BE of AN ESPECIALLY HIGH GRADE of STEEL

SUPERSTEEL! What is it; and why is it what it is? Has Prof. John Oliver Arnold of Sheffield University, England, really given the world something radically new in the realm of metallurgy, or has he merely given professional indorsement to a mill practice that is by no means novel on this side of the Atlantic?

It was not more than a few decades back when the broad term steel differentiated that metal from iron by reason of the former containing just sufficient carbon to make it capable of hardening greatly when suddenly subjected to a cooling bath. Text books on the subject revealed how varying percentages of carbon would affect the degree of hardness, and they further devoted space to the relative values of water, oil, &c., as mediums by which the refrigeration could be best achieved.

To put it mildly, the practice of steel making, so far as it concerned the physical niceties of the metal, became in practice pretty much of a rule of thumb procedure, and the ultimate product was the consequence of a hit and miss performance on the part of the furnaceman. In short, the personal equation cut a conspicuous figure in the character of each melt.

The Bessemer Process.

Along about 1856 Henry Bessemer invented his converter, by which he showed it to be possible to produce within an astonishingly short period a superior sort of soft steel. The Bessemer process revolutionized the industry and opened the way for the general substitution of steel for iron in many kinds of structural work. But in the course of years, particularly here in America, the Bessemer process lost its preeminence because it depended fundamentally upon fairly pure iron ores, i. e., those low in phosphorus. These we could not get from native deposits. The outlook for the steel mills in America was not a hopeful one, but once more resourcefulness came to the rescue. Sir William Siemens's open hearth furnace, conceived in 1861, and subsequently and successively improved, saved the day.

The open hearth furnace permitted the utilization of so-called low grade ores; and because of its more leisurely operation enabled the attendant to control the melt and to effect a measure of purification not feasible where the Bessemer converter was depended upon. Prof. Bradley Stoughton of Columbia University tells us: "During the year 1906 the Bessemer process in the United States yielded very much to the basic open hearth, and it would seem as if there was no chance of its ever taking up so important a position again unless new iron ores low in phosphorus are discovered."

Phosporus makes steel brittle, and this is especially noticeable in cold weather when the metal is subjected to shock. An alarming number of rail breakages upon our steam roads about twelve years ago gave the Bessemer process a pretty black eye.

So much for the general background in the realm of steel where the vast tonnage was devoted to rails and structural purposes. The majority of these producers made no claims to niceties of composition, and the purchasers were content if the metal upon analysis came within liberal approximations of broadly stated specifications.

Even so, there were technicists, metallurgists who had blazed the way for steels of superior qualities—they were the laboratory workers who were laying a firm foundation for a day of amazing revelations and the manufacture of steels capable of doing things undreamed of by the great army of steel makers. These changes were wrought gradually—beginning about fifty years ago—by adding to the carbon and iron of steel varying percentages of alloying elements. These facts must be borne in mind if we are to appreciate just what Prof. Arnold, with his associate, Prof. Fred Ibbotson, has done recently.

Henry D. Hibbard of the United States Bureau of Mines has dealt in an interesting way with the manufacture and the uses of alloy steels—employing the latter term to set these products apart from the bulk of the output of the steel furnaces. As he tells us: "Probably the first useful alloy steel was Robert Mushet's self-hardening tungsten tool steel, patented in 1868. Fifteen years later chromium steel was struggling for recognition for some purposes, the chief of which was for the manufacture of solid shot for piercing armor.

"In both of these steels the effect of the alloying element as used was in a way proportional to the amount contained. In 1882 Hadfield made his epoch making discovery of manganese steel and demonstrated that in iron metallurgy it is not safe to take for granted anything as to the properties of an alloy of iron with other elements, basing one's opinion on past experience and knowledge, and that the effect of an alloying element may not be proportional to its content. The development of useful nickel steels followed in a few years, and the field thus opened has since been worked by many zealous and able men, with results of great importance and value."

Perseverance Won.

Prof. Stoughton has gone somewhat more into detail than Mr. Hibbard in explaining the true inwardness of Robert A. Hadfield's untiring ingenuity, which resulted in a material whose properties were not only the opposite of what might have been reasonably expected but whose combination of great hardness and great ductility was unknown previously and might rationally have been believed to be impossible of realization.

"Constant study and perseverance," he says, "must have been the qualities that led to this revolutionary invention, and it has establish beyond question the principle that because a given amount of any element produces a given effect upon steels, it does not follow that a different amount will give the same effect in a different degree. Indeed a different amount may give an entirely different and perhaps an exactly contrary, effect as is the case of the effect of manganese upon steel."

Continuing, this eminent authority explains: "When the manganese in steel is over 1 per cent. the metal becomes hard and somewhat brittle, and these qualities increase in intensity with every increase of manganese until when we have 4 to 5.5 per cent. the steel can be powdered under the hammer. But as the manganese is increased from this point these properties do not increase, and when we reach 7 per cent. an entirely new set of properties begin to appear. These are well marked at 10 per cent. of manganese, and reach a maximum at 12 to 15 per cent."

In latter years, thanks to the steadily widening activities of the chemist and the resources of the laboratory, steel making has become a science in a large measure where before it was, in its highest expression, nothing more than an art. Because of these investigations steels are bringing about profound changes in various industrial fields; and the metallurgist is patiently trying out a wide variety of elements in his search for special steels.

Some of these products have had an ephemeral career of service, while others have obtained a seemingly permanent commercial hold. Even so, the man in the laboratory is not content, for he is bent upon improving these and possibly calling still others into being. He is doing this because science, largely aided by the microscope and the deep etching of certain corrosive chemicals, has disclosed the intimate get up of steel and established the fact that the physical arrangement of the metal's constituents varies accordingly as the steel is subjected to different heat treatments.

To make alloy steels, such elements as manganese, silicon, tungsten, nickel, chromium, vanadium, cobalt, zirconium, uranium, &c., are resorted to, and a well nigh bewildering employment of one or more of these in divers percentages will produce physical alterations, distinctive characteristics of a more or less marked dissimilarity. What is particularly significant is the fact that an unsatisfactory alloying element of to-day may be the promoting cause of a momentous development to-morrow, and all on account of a difference in the quantity used or the manner in which the alloy controls the readjustment of the body substance of the steel while the metal is undergoing one or two heat treatments.

Alloys are added to steel for two purposes: first, as a curative agent during the casting of the molten metal into ingots—i. e., to prevent the formation of blowholes and to control the vertical extent of the "pipe" or central cavity, both of which constitute defects; and, next, to impart to the steel certain lasting properties that can perhaps be enhanced by carefully regulated heat treatments.

Tungsten a Key Metal.

Tungsten is valuable because of its effect on the finished and treated steel, and simple tungsten steel has figured for thirty or forty years in the manufacture of permanent magnets, dynamos, &c. However, it has been found useful in the manufacture of tool steel, and despite some conclusions to the contrary it has served to render the bores of cannon less subject to the attack of the erosive superheated gases of the burning powder.

Tungsten has been called one of our vitally necessary "key" metals, and one authority has said: "To deprive a nation of tungsten is to cripple its military power in time of war, and its industrial power in time of peace." Further, from the same source, we are informed: "Without high speed steels, machine tools could not be produced nor operated in sufficient quantity to make the 'seventy-five' and its thousands of shells, the rifle and the machine gun and its millions of cartridges, nor could automobiles, farm machinery, ships or engines be replenished after the sword has been happily sheathed."

The Germans realized this prior to the war, and with characteristic foresight they set about acquiring a substantial monopoly of the world's tungsten production. But the blockade of the Central Powers during the course of the recent titanic struggle shut the Teutons out from further supplies, and they accordingly cast about them for native or nearby resources of an alloying element which would serve the same purpose.

This they found in uranium, and proof of its potential value was established prior to the conflict by a German firm engaged in marketing ferro-uranium for use in the manufacture of steel. Here in the United States uranium steel has won recognition since 1914, and it seems that a small percentage of uranium will answer for a very much larger percentage of tungsten. High speed steel alloyed with uranium has shown excellent cutting qualities.

Chromium in steel increases the hardness of the metal and, for that reason, it answers admirably for stamp shoes and dies in the machinery required for pulverizing certain gold and silver ores preparatory to their refining. Again, this alloy enters into the steel plates used for the walls and doors of our large burglar-proof safes or vaults. Further, chromium steels are worked into balls and rollers for bearings, which, because of their hardness, are able to support very heavy loads and to endure without serious wear for a long time. It was chrome which the famous Krupp Works introduced some years back into the best of German armor plate, and similarly this alloy gave projectiles a greater power to attack and to penetrate defensive walls of steel.

Simple nickel steel possesses additional strength and ductility by reason of that alloy, and owing to this fact is adaptable to structural purposes, such as bridges, gun forgings, machine parts, automobiles and many other uses too severe for ordinary steels. Nickel steel saves some weight, a matter of importance in bridges, for instance, having great spans. Accordingly, this metal was worked into the Queensboro and Manhattan bridges and in other large viaducts. Simple nickel steels contain from 2 to 4 per cent. of that metal.

Prof. J. O. Arnold, who now claims to have evolved a supersteel with A. A. Read, discovered about five years ago that a 13 per cent. nickel-iron alloy and 0.55 per cent. carbon possessed the highest strength of any of the nickel steels. Before Arnold and Read hit upon that exact percentage of nickel it was commonly believed that 15 per cent. of nickel would give the greatest strength for such an alloy. This is merely illustrative of how knowledge widens in the course of time. It is also suggestive that the 13 per cent. nickel-iron alloy was so hard as to be unmachinable.

However, 22 per cent. nickel steel is desirable when resistance to rusting or corrosion is the aim. Accordingly, the valve stems of the salt water fire protection service of New York city are made of this latter composition; and this same alloy is employed for the spark plug poles of internal combustion engines and automobiles.

Nickel Chromium Important.

Nickel steel containing 30 per cent. of nickel does admirably well when used in boiler tubes for seagoing ships. By increasing the nickel to 36 per cent. a metal called invar is produced which, because of its slight expansion and contraction under atmospheric changes, is especially suited for clock pendulums, the springs of chronometer balances and rods for measuring instruments. Further, by running up the nickel content to 46 per cent., with a suitable measure of carbon, there results a composition known as platinite, which, owing to its low coefficient of expansion, has been substituted for platinum in leading wires in the glass bases of electric incandescent lamp bulbs.

Nickel chromium steels, commonly spoken of as chrome nickel steels, are said to be among the most important structural alloy steels and their field of usefulness is continually widening. This metal can be made somewhat more cheaply than simple nickel steel of the same strength and ductility containing a smaller total of the alloying elements, and chromium is less costly than nickel.

The physical properties of nickel chromium steel can be radically altered for the better by suitable heat treatments. This bears upon a point which the expert of the Bureau of Mines, Mr. Hibbard, has emphasized in this manner: "The effects of heat treatment are so great that a certain steel may be given a very wide range of properties, depending on the treatment, and any desired set of properties within that range may be obtained solely by varying the heat treatment. The principal variant is the degree of the second heating. The lower this is, the stronger and stiffer the steel; and the higher, the weaker and more ductile it is.

The nickel chromium steels find many fields of service open to them. They figure extensively in the getup of automobiles, in the making of armor plate, in the production of armor piercing projectiles and in the manufacture of rails. As Mr. Hibbard remarks—and his point brings out how steels can be made to meet special requirements: "It is curious that nickel is considered to improve the quality of shot, although generally held to injure the quality of high speed tool steels.

"In use there seems to be a parallel between the requirements of the two, except for the important and vital difference as to the required speed at which they respectively meet the metal to be penetrated. The speed of impact of the shot enables it to enter when no amount of pressure will effect the same result." It is pressure upon which the tool counts to cut the opposing metal.

Broke Before Red Hot.

As might be imagined readily, pressure on a tool produces heat, and in the run of tool steels twenty years ago the cutting edge broke after the temperature rose high enough to make that part of the tool brittle. This failure occurred long before the metal reached a state of red hotness. And then F. W. Taylor and Maunsel White, at the works of the Bethlehem Steel Company, in 1899, developed a high speed tool steel which, at a red heat, would go on cutting at an astonishingly rapid rate.

They used for their steel alloying chromium and tungsten, and subjected the products to a unique heat treatment of their devising. The Taylor-White tools could cut so fast and deep that they delivered chips at a blue heat and in amazing quantities; and at the Bethlehem shop, to the confusion of the sceptical, a young man lighted a cigarette with one of these chips.

Since then further progress has been made in the evolution of high speed tool steels, and these are capable of cutting continuously at speeds from three to five times as great as that practicable with other tools. It is said that the tendency of the makers is toward somewhat uniform composition as regards the contents of the alloying elements whose benefits have become fairly well known, and whose use as a consequence may be considered established. Specifically, these alloying elements are tungsten and chromium, with the addition of vanadium and cobalt—according to the views of the various producers. Vanadium, like chromium, is said to increase red hardness of the cutting edge.

Under date of 1913 Frank L. Hess, in a pamphlet issued by the United States Geological Survey, makes this statement: "Cobalt has been tried many times as a steel alloy without making a notable improvement in the resulting steel." And then he quotes a French experimenter who says: "Cobalt steels show no properties that are of industrial interest." Even so, two years later, owing to the laboratory work of the metallurgist, the United States Bureau of Mines informs the world that "cobalt now threatens to change tool steel manufacture because of the properties it imparts.

"This result was hardly to have been expected in view of the experience with nickel, which cobalt much resembles, as nickel has been condemned by nearly every manufacturer as not being a desirable ingredient of high speed tool steels because of the effect it has of making the edge soft or 'leady.'"

And now we come to Prof. Arnold's supersteel, which, so cable dispatches tell

(Continued on Tenth Page.)