NOTES ON MAKING STEEL FOR MUNITIONS

CONFERENCE BY

MAJOR R. R. NIX, ORDNANCE DEPARTMENT

BEFORE THE

ARMY INDUSTRIAL COLLEGE

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War making and steel making, historically at least, are inseparable. Strangely enough the scientific development of the one has depended upon the progressive strides of the other. The subject of making steel for munitions is treated historically by rapid glances into the past in order that the striking changes and developments in steel metallurgy may be illustrated by the improvements in the so-called destructive implements of war and in the constructive mechanisms of the steel industry as well. Metallurgy is defined as the science which treats of the preparation of metals from their ores and their adaptations to the purposes for which used. Munitions are all requirements of fighting forces - commercial and non-commercial.

These amateurish notes are prepared by way of making of record in the office of the Assistant Secretary of War a few of the significant contacts of the Army and the Navy with the steel industry and in order that the students of this college may be oriented before their visit to steel mills. The theme of this paper is too big to be attempted by anyone outside of the steel industry.

Here is a super-mission which awaits accomplishment, here a theme which presents a great opportunity to an executive of the greatest of great American industries. Particularly within the personal experience of many outstanding leaders in the steel world there is much to be recorded in the development of a theme which will serve to impart the breath of life into Industrial Preparedness, which will keep the spirit of Patriotism alive, and carry an enduring inspiration from generation unto generation of Americans.

Dates given in marginal headings serve to tie in certain developments of steel with critical periods of American History. These dates are given in better chronological sequence on Chart I herewith.

Up to Christian Era

Aristotle states that iron formed the first currency. Probably it was first reduced from its ores by the Hittites 3000 or 4000 years ago. The first iron was smelted by blowing a charcoal fire containing ore and shaping the metallic regulus principally impure wrought iron by hammering. Its first common use was likely among the primitive Nomadic Peoples around the Aegean and Black Seas in the form of more efficient implements of war than their bronze weapons. Primitive American civilizations developed the use of bronze and copper but not of iron.

More recently the Greeks and subsequently the Romans became somewhat proficient in its metallurgy. The success of the conquests of these peoples depended in large measure on their instruments of war which in turn gave a stimulus to the art of extracting and fashioning metals. Only small pieces of metal, however, could be wrought into shape.

Before 1492

The first real advance in this metallurgy, after thousands of years, came about 1340 when iron makers of Central Europe succeeded in casting iron. They accomplished this step by a new type of furnace built of masonry enclosing a vertical shaft in the form of two truncated cones placed end to end resembling the modern blast furnace. Ore, flux, and wood-charcoal were charged in the top and air blown in at the bottom. The largest castings during the sixteenth century were two or three tons, which permitted a great upward limit to the size of cannon.

Around 1775

The blast furnace developed with the use of coke in 1619, followed about 200 years later by the use of the hot blast. Rolled sheet iron came in the first part (1728) and rolled rounds and squares (1783) in the last part of the eighteenth century. Not until the development of the steam engine could sheet iron be produced commercially.

Just as the birth of iron is recorded thousands of years ago in the crude weapons of primitive peoples so also the ancient origin of steel is in evidence in the famous blades of Damascus, Syria. Iron was first hardened and strengthened by the crucible process or a combination of the cementation and crucible processes. These methods for making steel were lost during the middle ages, but around 1600 the cementation process was revived in Belgium and in 1742 the crucible process was rediscovered in England.

Events Associated with 1812

Prior to 1812 gun barrel tubes were made by hand from plates which were bent into cylinders with edges overlapped and welded over a mandrel. About 1815 a Scotch inventor, William Murdock, conceived the idea of screwing together old musket barrels in the form of continuous tubes for conducting coal gas for lighting purposes. The popularity of this lighting system stimulated inventors to produce tubes more rapidly and at lower cost. Whereas the tube industry was first advanced by the invention of the flint lock gun in 1640, the adaptation of these gun barrels to the use of conducting gas for lighting purposes likewise caused a revolution in the art of tube making.

About the Time of Civil War - 1860

A phenomenal stride in quantity production of steel occurred with the invention of the Bessemer Process. Sir Henry Bessemer's energies were directed to the problem of steel making in an attempt to improve the construction of guns. Believing that an advance in artillery design and construction depended upon the manufacture of better metal in larger quantity he experimented at his own iron works in St. Pancras. Later he erected a steel works at Sheffield which began to operate in 1860 Now-a-days a Bessemer Converter, with a capacity of 15 tons, may treat 600 tons of metal in 24 hours, whereas an open-hearth furnace, with a capacity of 75 tons, may treat 150. The largest electric furnace to date has a capacity of 50 tons. By comparison crucibles have a capacity of only 80 to 124 pounds. Steel ingots for cannon have increased in proportion to these rapid strides in tonnage a set of ingots for our major caliber guns weighing 180 tons.

We have shown by a very few of the many examples how the Armies and Navies of the world have influenced and been influenced by the development of the iron and steel industry. A few instances will illustrate the close cooperation which has always existed between our Army and Navy and the American Steel Industry.

In America the first iron works was installed on the James River in Virginia (1619) and one hundred years later the first furnace using hot blast was built. Up to 100 years ago the capacity of furnaces ranged from one to six tons a day. Today the capacity is 100 times as great.

Around 1898

The use of iron as a recognized unit of ship construction dates back to 1818. Steel came in use between 1870 and 1875. The American Navy has pioneered the seas with iron and steel ships. In fact the first turret ship was the "Monitor" of Civil War fame with a belt of 8" built-up armor protecting 11" turret guns. The turret design is significant from a metallurgical standpoint in that a race was started in Naval Ordnance between the supremacy of gun and armor which was reflected favorably in the improvements required in steel making.

A signal influence on the steel industry resulted from the building of four naval vessels, the Chicago, Atlanta, Boston and Dolphin, because of the high quality of steel demanded. Enormous difficulty was experienced in meeting the specifications, but in the end the manufacturers learned the art of making good steel. This was a typical example of what we call an "Educational Order". The Chester Rolling Mills, Chester, Pennsylvania, the Norway Iron and Steel Company, South Boston, Massachusetts, Park Brothers and Company and the Phoenix Iron Company of Philadelphia, Pennsylvania, supplied the steel and the contractor, John Roach of Chester, Pennsylvania, built a mill to handle certain of the material. The first ship built, the Dolphin, was completed in 1885, was placed out of commission in 1921, and sold by the Navy in 1922 - not a bad testimonial as to the quality of this steel.

The Midvale Steel Works received from the Army the first large order for steel gun tube forgings placed in the United States (1883). Here is another example of an "Educational Order" in that it did much to increase the knowledge and experience of the Midvale Company in the manufacture of good steel. In 1887 the Midvale Steel Works satisfatorily completed a stern frame steel casting for the Charleston weighing 6,720 pounds, the first large steel casting ever attempted. This pioneer work of the Navy in encouraging the steel-castings industry led to the use of large steel castings by the railroads for locomotive frames and other structural parts and consequently advanced by many years the large production of the steel casting industry.

While further tests of cast iron rifles were practically abandoned in the United States in 1871 the feasibility of making steel-cast guns up to 10" caliber, with weight of casting 60 tons, was conceded by 1887. In this year the Pittsburgh Steel Casting Company and the Standard Steel Casting Company started the manufacture of steel-cast 6 inch high powered rifles for the Navy. Both Army and Navy Ordnance, however, were at this time, within the limit of appropriations provided by Congress, encouraging the steel industry to still further progress in the manufacture of high grade steel. The Otis Iron and Steel Company of Cleveland, Ohio, Jones and Laughlin of Pittsburgh, and the Trenton Iron Company of Trenton, New Jersey, were engaged in fabricating parts of a 10" wire-wound steel gun. The Bethlehem Iron Company was engaged on a Naval Order for 1,225 tons of steel gun forgings for 6, 8, 10 and 12 inch calibers. Up to the end of 1887 the Midvale Steel Company had turned out 320 tons of gun forgings for the Navy and 168 for the Army and the Cambria Iron works 17 tons for the Army. Other commercial steel works engaged on fabricating parts of built up forged steel guns about this time were the West Point Foundry, the South Boston Iron works, the Nashua Steel Company and the Firth-Sterling Steel Company. Experience in the matter of fabricating built-up forged steel guns gained by all these establishments and applied to commercial lines of endeavor far outweighted the relatively small tonnages involved.

A good example of the immediate application of the technical experience of that time (1887) is given on page 104 "Gun Making in the United States" - Birnie. "The method of improving the quality of car axles by treating by the so-called water tempering process at the Cambria Iron Works is very largely due to the care and research made by the capable officers of that Company in studying the manufacture of Ordnance metal."

Knowledge of the making and heat treating high-grade steels and alloys and the development of heavy shaping machinery was confined to the establishments engaged on Ordnance work in spite of the fact that the great mechanical and industrial revolution was already well launched and its progress necessarily dependent upon the use of steel in steam engines, electric machines, gas engines and machine tools.

The first armor plant in this country resulted from the efforts of the Navy persuading the Bethlehem Iron Company (subsequently Bethlehem Steel Corporation) to undertake the project. "In order to satisfy ordnance requirements in the manufacture of enormous gun forgings, thick, heavy armor plate and large steel castings special machinery had to be designed. Naturally the cost of development was borne by the Bureau of Ordnance but in the end the Nation as a whole benefited * * *. With a view to producing metal-cutting tools which would economically machine heavy armor plate and gun forgings the Bethlehem Steel Company developed the well-known 'Taylor-White' process of treating high-speed steel. This steel is now used in metal-cutting tools that, by many, are considered as having revolutionized machine shop practice throughout the entire world * * *. The world was searched for methods of manufacture of suitable armor plate, and in the search and subsequent laboratory investigations of the effect of alloying steel with various other ingredients and of novel heat treatments of steel, there were discovered or evolved many of the special alloys of iron with nickel, chrome, vanadium and other metals which today are of the utmost importance to industry in general. The Bureau of Ordnance paid for many of these experiments, allowing great laboratories to be supported, thus permitting this most important work to be carried on to the highest degree of success. As a result of continued experiment in the production of high-grade steels suitable for Navy purposes an impetus was given to this industry which carried it along to the present day where it now stands at the head of the steel industry of the world" - " The U. S. Navy as an Industrial Asset." Office of Naval Intelligence revised to July 1, 1924. While the automobile industry fell heir to this wealth of experience its phenomenal growth created a wide and ever increasing demand for high grade alloy steels and thereby served to enrich this field of metallurgical research, particularly in the past 20 or 30 years.

Great economies and strides in mass production throughout the industry have been effected in recent years by the integration of mines, railroad and steamship lines, blast furnaces, steel mills and rolling mills.

Very Sketchy Outline Since 1917.

The very profitable influence of military research and studies on the great economic fabric of this country which depends upon steel may also be illustrated by brief reference to the work at the Watertown Arsenal, Boston, Massachusetts, and recent developments in the industrial mobilization plan for steel.

The testing machine at Watertown Arsenal is one of the largest and most efficient in this country. Under authority of an Act of Congress approved March 3, 1875, the testing machine was made available for the tests of metals and other materials for industrial purposes. A machine capable of exerting and measuring a strain of tension and compression of 800,000 pounds was unheard of up to that time. Commercial establishments all over the United States have availed themselves of these tests and reports of the tests for half a century. These invaluable records constitute a permanent contribution to steel metallurgy.

For the past four years extensive tests have been conducted at Watertown Arsenal on the cold working of tubes from the interior by hydraulic pressure. The primary purpose of these experiments is to develop rapid production of gun and shell forgings. There is promise even in the larger calibers that a single tube subjected to cold working may replace the forged steel built up gun since an ideal condition of stresses exists throughout the metal to resist interior powder pressure. The inner layers are in a state of compression decreasing gradually to zero at an ideal place in the wall of the tube. Outward from this neutral zone the metal is set in a state of tension increasing to a maximum at the outer surface. A factor of safety is gained beyond the elastic limit of the metal depending principally upon the gap between the elastic limit and the ultimate strength of the material. In this connection seamless tubes have given very satisfactory results for 75 m/m shell. In a general way the physical qualities of the metal are improved by stretching beyond the elastic limit in much the same way that wire is improved by drawing. This process has met with such success that the Ordnance Department has adopted it as the standard method of constructing guns not to exceed 6" bore. The Navy has also used this method satisfactorily for guns up to 6" caliber. Their machine is installed at the Washington Navy Yard. This process of cold working has already received commercial application for rims of large fly wheels and for cylinders of high pressure engines.

Defects in steel, such as slag inclusions, are readily developed by applying internal pressures much below the contemplated elastic limits. The machine which is used for this purpose may be readily perfected so that by a simple and rapid test defective guns and ammunition may be eliminated before issue to the service. X-ray work being developed at Watertown Arsenal serves a similar purpose to locate defects and weak spots in the material. In fact considerable X-ray work of this nature for industrial purposes is now being done at the Arsenal.

Among the variety of other problems in the metallurgy of steel, which will tend to improve the quality of metals for ordnance and commercial purposes the following are typical:

(1) Experimental work on centrifugal casting of steel ingots for guns so as to expedite production and improve the homogeneity of the metal. The rotation of the mold creates considerable pressure on the molten metal and drives non-metallic impurities to the center where they are removed by a boring operation. The tube is then treated by the cold working process referred to above. It should be especially noted that this process is still in the experimental stage. Another method under consideration is to build up the gun from concentric seamless tubes and expand them to a permanent set by the cold working process. The latter method was suggested by Mr. Ralph Dravo, an Ordnance District Chief. Both these methods will expedite production by the use of standard machine tools instead of special purpose machine tools for the principal machining operations.

(2) Determination of the effects of variations of sulphur and phosphorus in different compositions of steel. This investigation is being conducted under the auspices of the American Society for Testing Materials.

(3) Determination of effect of addition of molybdenum to steels on the physical properties and also on the Charpy test.

Results of these tests are particularly interesting in that they suggest that molybdenum may be satisfactorily substituted for nickel in an emergency for use in gun steels or as is now being done in automobile steels.

(4) Investigation of the Practicability of developing high speed tool steel, using molybdenum as the principal alloy. This work is being conducted in cooperation with the Climax Molybdenum Corporation of America and promises to result in a molybdenum high speed tool steel superior to the commercial compositions. Elimination of the necessity of using tungsten in high speed steels will solve one of our major problems in strategic materials.

(5) X-Ray of metals.

On account of the pioneer nature of this work the Watertown Arsenal first developed laboratory technique. Realizing the practical application of the work to the steel industry as a whole to develop internal defects (not otherwise discoverable in metal during manufacture) and thereby improve the quality of steel gererally, the Ordnance Department has endeavored to expedite the recognition and acceptance of the method by private industry. Consequently radiographic results obtained at the arsenal have been presented in lectures before technical societies and colleges and published in technical journals of wide circulation.

Three years' experience in the X-ray laboratory indicate that the radiographic method is a success and may be relied upon in commercial practice to detect sub-surface defects in gross structure. Moreover, X-ray metallography investigations permit of the measurements of actual distance between atoms with an accuracy of .1 of an atom diameter under ideal conditions. Such novel investigations are bound to result in greatly improved steels since a better understanding is now possible between elemental structures, chemical analysis and physical properties, and the effects of heat treatment, alloying constituents and other making, shaping or treating processes on these elemental structures. For example, investigations already disclose that cold working produces changes in the atomic spacing such as are also caused by heat treating steel.

While the Watertown Arsenal is contributing more than any other individual institution within the Army to the development of the quality of steel other agencies are also directly or indirectly active. The Engineering and Research Division of the Air Corps at Dayton, Ohio, is engaged on the perfection of airplane steel construction design and specifications. A fruitful effort is being made to have commercial aviation adopt Government specifications largely with a view to standardizing parts so as to secure interchangeability and profit by the sad experience in this respect of the early growth of the auto industry. The Medical Department at the New York Depot is investigating the subject of stainless steels for surgical instruments. Springfield Armory is testing the relative merits of carbon and alloy steels against erosion of rifle barrels. Rock Island Arsenal is procuring samples of steel from the Ludlum Steel Company and the Firth-Sterling Steel Company on an investigation to prevent corrosion of steel recoil mechanisms of artillery. Ordnance District Chiefs are cooperating with outstanding industrial establishments as the National Tube Company in the development of seamless tubes for guns and projectiles. The War Department Commodity Committee on Ferro-Alloys initiated the investigation with the Climax Molybdenum Corporation of America on the practicability of substituting molybdenum for tungsten in high speed steels, and has been instrumental in providing Ordnance funds to carry on investigations by the Bureau of Mines for the purpose of utilizing local sources of manganiferous ores in steel making instead of having the industry dependent upon foreign sources of supply (Bulletin 393, Bureau of Mines).

Before explaining the cooperation between the Office of the Assistant Secretary of War and the steel industry, the indirect contributions of the Army Engineer Corps to the development of the steel industry deserve special mention in this historical sketch. Lieut. George Washington Whistler, Corps of Engineers, introduced in the construction and design of the primitive American locomotive such superior style of workmanship that he may well be considered responsible for the real beginning of the American locomotive and engine industry. Incidentally he was the inventor of the whistle for locomotives. The first American built locomotive, Peter Cooper model of 1829, had boiler tubes improvised from gun barrels. This model was used on the Baltimore and Ohio Railroad upon which Whistler

was employed 1828-1829 as an associate engineer, having charge of the first mile of track laid on this road, this being first track for passenger cars put down by any company in this country. From this early start the railroads now require 28% of the enormous steel production of the United States.

In the first use of concrete in mass, Army Engineers laid the foundation in our fortifications for the subsequent development on a large scale of steel reinforced concrete throughout America. Army Engineers are responsible for the design and erection of that masterpiece of concrete and steel construction which will serve as an international model for years to come, the locks of the Panama Canal, the gigantic and wonderfully balanced gates of which demanded 60,000 tons of steel. Current steel problems being studied by the Engineer Corps in connection with industrial preparedness are illustrated by their planning for the procurement of high strength, light steel bridges.

For the past two years War Department Commodity Committee #45, Iron and Steel, has maintained close contact with the industry in developing an industrial mobilization plan for iron and steel. The first step consisted in adopting the same terminology for the Army and the Navy to designate different classes of steel as used by the industry - this in order that we might speak the same language. War requirements, including estimates for an "Emergency Fleet", are now shown by the fourteen War Department Procurement Districts in the nine commercial classes of steel, to wit.

1. Steel forging billets and forgings.
2. Steel rounds, squares and flats.
3. Structural shapes.
4. Sheared and U F Plates.
5. Sheets and Tin Plates.
6. Tubular Products.
7. Wire and Wire Products.
8. Steel Rails.
9. Steel and Iron Castings.

The next step was to show capacities of the steel mills likewise by War Department Procurement Districts under the nine classes of steel. The third and final step was to designate "allowances" in short tons on steel mills to cover these requirements in consideration of essential civilian needs. Essential civilian needs correspond to the requirements of the Railroad, Food and Fuel Administrations and the vital Domestic Non-Government requirements in the past war. It is proposed to submit this plan upon completion to the American Iron and Steel Institute in order that the full and united cooperation of the industry may be secured.

It is believed that this plan will prove of mutual benefit to the Government and to the steel industry in the event of an emergency, since requirements will be intelligible and the industry will know in advance what it is expected to accomplish in the nature of curtailments, priorities and stimulated production. Each steel mill will know its allotted mission in the general plan. Benefiting by current contact of the Office, Assistant Secretary of War with the steel industry and

by district surveys, it is expected that the plan may be gradually perfected so as to insure an equitable distribution of the war load with respect to capacities and field service of facilities with due regard to such factors as power, labor, transportation and commercial practice in the flow of raw materials and semi-finished products.

Mr. James B. Bonner is the official contact of our office with the steel industry. As Vice Chairman of the Committee on Steel Distribution during the past war he was charged with the allocation of 17,000,000 tons of Government requirements in iron and steel. Through his good offices Dr. John S. Unger, Manager Central Research Bureau, Carnegie Steel Company, appeared before the Iron and Steel Committee on May 29, 1926, and answered technical questions submitted by supply branches on the metallurgy of steel, such as Engineer Corps physical requirements for high strength steel for bridges and Ordnance Department physical and chemical requirements for gun and shell forgings. Moreover, Mr. Bonner has volunteered to furnish the steel committee with experts on any of the nine classes of steel as occasions demand.

The work of the steel committee thus far has resulted in considerable economy in obviating the necessity for many surveys on steel mills, particularly for strictly commercial items. With our knowledge of capacities and requirements being perfected from time to time the dislocation and confusion which occurred in the past war may be effectively averted. Among the numerous difficulties which resulted from lack of planning in the world war the case of the projectile is typical. Cross-hauls and delays in production necessitated a complete reallocation of all orders for projectile steel before the end of 1917. From Page 122 "American Industry in the war" - Baruch, the following extract is self-explanatory, "To illustrate A Buffalo steel manufacturer was making an enormous tonnage of projectile steel to be shipped in bar form to a Cincinnati forge plant to be forged into projectile forgings, which were in turn to be shipped back to Buffalo for machining into finished projectiles. A steel plant within 50 miles of Cincinnati was making projectile bars which were being sent to Buffalo for forging and machining.* * * Arrangements were made to have the steel bars rolled in Buffalo shipped to a near-by plant and machine shop for finishing, and in turn the Cincinnati forge man was supplied by the steel mills in his district. There were hundreds of changes of this character, which, while difficult of solution, were fully justified by the transportation situation, which had become a very important factor in our war program. Many millions of ton-miles and an enormous amount of money and time were saved by these transfers." While similar conditions do prevail among certain industries in time of peace, they should be eliminated in the event of a major war.

Exaggerated requirements and an unbalanced program should be effectively eliminated as the steel plan is progressively developed. Our Chiefs of Supply Branches and their district Chiefs are most strenuously attacking this problem. Taking the case of the projectile again as one of the many examples of the past war, 25,000,000 shell billets 75 m/m were available the first year whereas only 10,000,000 had been machined and less than 5,000,000 complete rounds manufactured.

Requirements in steel are now being coordinated with planned production of finished articles. 6,065,162 tons of projectile steel were recorded as our requirements on September, 1918. 4,199,099 tons were delivered in 1918. 2,000,000 tons or less could have been utilized by us in 1919. "Our program calls for more steel than is being used by the entire Allies put together and in figuring the number of guns which we will have at the front next May and the maximum rate of fire which we could hope to do, the program seems entirely out of proportion . * * * I would use a little more care before converting over too many mills for the rolling of projectile steel" - Letter from U. S. War Industries Board Mission dated Paris October 1, 1918.

Concluding this broad outline, charts are prepared which require little by way of explanation, giving the principal methods of making, shaping and treating steel, and depict the flow of raw materials.

Chart I	- Significant Periods for Steel Metallurgy
Chart II	- Making Pig Iron
Chart III	- Making Steel (Open Hearth)
Chart IV	- Making Steel (Bessemer)
Chart V	- Making Steel (General)
Chart VI	- Shaping Steel
Chart VII	- Treating Steel
Chart VIII	- Steel Distribution
Chart IX	- Strategic Raw Materials - Drawing 204.

Outstanding facts to military men in this historical survey are (1) The incentive of the steel industry is to attain large scale production most economically. (2) The incentive of Army and Navy Engineers is to produce the best quality of steel for battle efficiency. While this military incentive is not to be lost sight of in industrial planning, early mass production demands that we adapt our requirements as far as practicable to commercial standards. Moreover, industrial planning should not only assure the adequate mobilization of the steel industry but should render America self contained in the strategic materials which enter into the manufacture of steel and its alloys - principally ferro-manganese, tungsten and nickel. Fortunately, from the standpoint of national defense, the commercial demand for high quality steel is well established. With the gradual advance of the airplane to the status of a major industry in this country it is to be anticipated that marked improvements in metallurgy such as accompanied the growth of the automobile industry may evolve on a wide and sound economic basis.

The brief record revealed by this historical outline warrants full treatment by those in the steel industry who are best qualified by knowledge and experience to develop the subject adequately. Graduates of the Army Industrial College will have many opportunities to help perfect the steel plan during peace and will be among those best qualified to facilitate its execution in an emergency. Some of you may have the opportunity to encourage the placing of "Educational Orders" so that the art of manufacturing technical material may be kept alive in the steel industry. An "Educational Order" does not mean a profit-making

scheme for the manufacturer. It, therefore, does not mean the development of a civilian industry devoted principally to the manufacture of war material. It does mean, however, reimbursement by the Government for expenditures in running small orders through private shops so as to work out all "kinks" and "bugs" in factory plans prepared by the manufacturers to insure the earliest possible production of such technical items as Ordnance and airplanes. Some of you may have the opportunity of establishing war reserves in strategic ferro-alloys, which is the only safe policy until industrial planning is prepared to solve such problems by alternate and satisfactory methods.

SIGNIFICANT PERIODS
FOR
STEEL METALLURGY
(ASSOCIATED WITH CRITICAL DATES IN AMERICAN HISTORY)

TO CHRISTIAN ERA
WROUGHT IRON

Used for Weapons
[illegible] Hittites 2000 BC
[illegible] - Alexander 320 BC
[illegible] - Julius Caesar 50 BC
[illegible] at time of Caesar.

DISCOVERY OF AMERICA
1492
CAST IRON

First blast furnace developed by iron makers of Central Europe 1300.

REVOLUTIONARY WAR
1775
STEEL

Cementation process revived Benjamin 1600 and crucible in England 1742.
Coke in blast furnace 1619.
First iron works America 1619.
Flint lock gun stimulates tube industry 1640.
Hot blast American 1719.
Rolled sheet iron 1720.
Ferro alloys discovered
Nickel 1751, Manganese 1774,
Tungsten 1781, Molybdenum 1782.

WAR OF
1812
LIMITED CAPACITIES

Furnaces 1 to 6 tons a day.
Crucibles up to 124 lbs.
First American steam boat 1807.
Musket barrels used for gas line stimulated tube industry 1815.
Iron recognized standard for ships 1818.
Lt. Whistler and the American locomotive 1829
Ferro alloy discovered random 1830.
First steam hammer 1838.

CIVIL WAR
1860
LARGE CAPACITIES

Mechanical and industrial revolution launched.
Henry Bessemer to advance Artillery design began to operate works at Sheffield in 1860.
First American Bessemer Converter 1867 (and first dynamo)
Spiegeleisen - iron alloy of iron and manganese introduced in Bessemer process to handle other than Swedish ores to prevent hot shortness (low in Mn high in P.)
Siemens open hearth regenerative principle 1868.
Battle ship "Monitor" the first turret design of civil war time started race between armor and projectiles.
Cast iron guns abandoned 1871.
Blast furnace capacity 100 tons a day, converter 3-5 tons, original open hearth 5 tons.

SPANISH AMERICAN WAR
1898
METALLURGICAL IMPROVEMENTS

Basic Bessemer (used abroad)
Thomas Gilchrist used basic lining and added lime giving high C. low P. steel 1878.
Sir W. Siemens developed electric arc furnace 1879 - gradually substituted for crucible after 1900.
Testing machine Watertown Arsenal 1875.
First steel for ships 1870-1875.
Development automobiles since 1880.
Naval contracts for steel ships 1883 improved knowledge of art.
First America armor plant Midvale 1883.
Bethlehem and Midvale working on first large orders for steel gun forgings 1885.
First large steel casting for stern frame of "Chicago" gave impetus to use by railroads 1887.
High speed tool steels developed at Bethlehem for machining armor 1890.
Industrial and mechanical revolution well launched and automobile industry creates wide demand for alloy steels and stimulates improvements in metallurgy.

ENTRY IN WORLD WAR
1917
RECENT DEVELOPMENTS

At Watertown Arsenal, Boston Mass.
1. Cold working of tubes.
2. X-ray metallography
3. Centrifugal castings.
By Air Corps of Dayton, O.
Standardizing air craft design.
By Industrial Mobilization Plans
By integrating blast furnace steel and rolling mill.
Development of aircraft since first design of 1897 to the status of a major industry in U.S. creating large demand for highest quality of metals
Present Capacities
Blast furnaces up to 600 tons in a 24 hour day.
Open hearth 75-100 tons each averaging 15 heats a week except as duplexing units with 40 heats a week
Bessemer up to 600 tons a day, 15 tons a heat.
Crucible max heat 124 lbs.
Electric max heat 50 tons

TRACED BY [illegible]
EXAMINED BY [illegible] 1/2/62

CHART I