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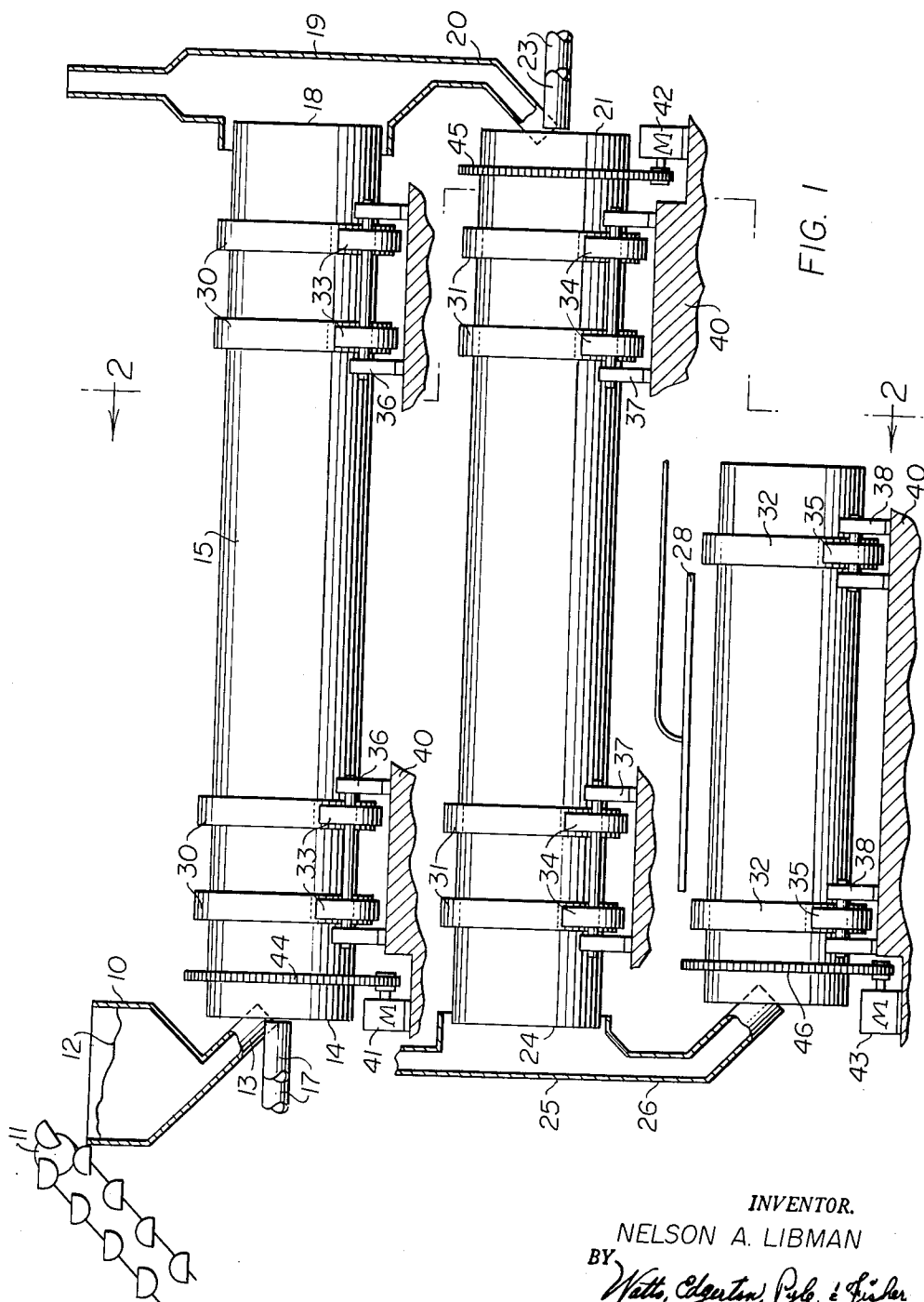
N. A. LIBMAN

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ABRASIVE MATERIAL AND METHOD OF MAKING SAME

Original Filed Sept. 1, 1960

3 Sheets-Sheet 1



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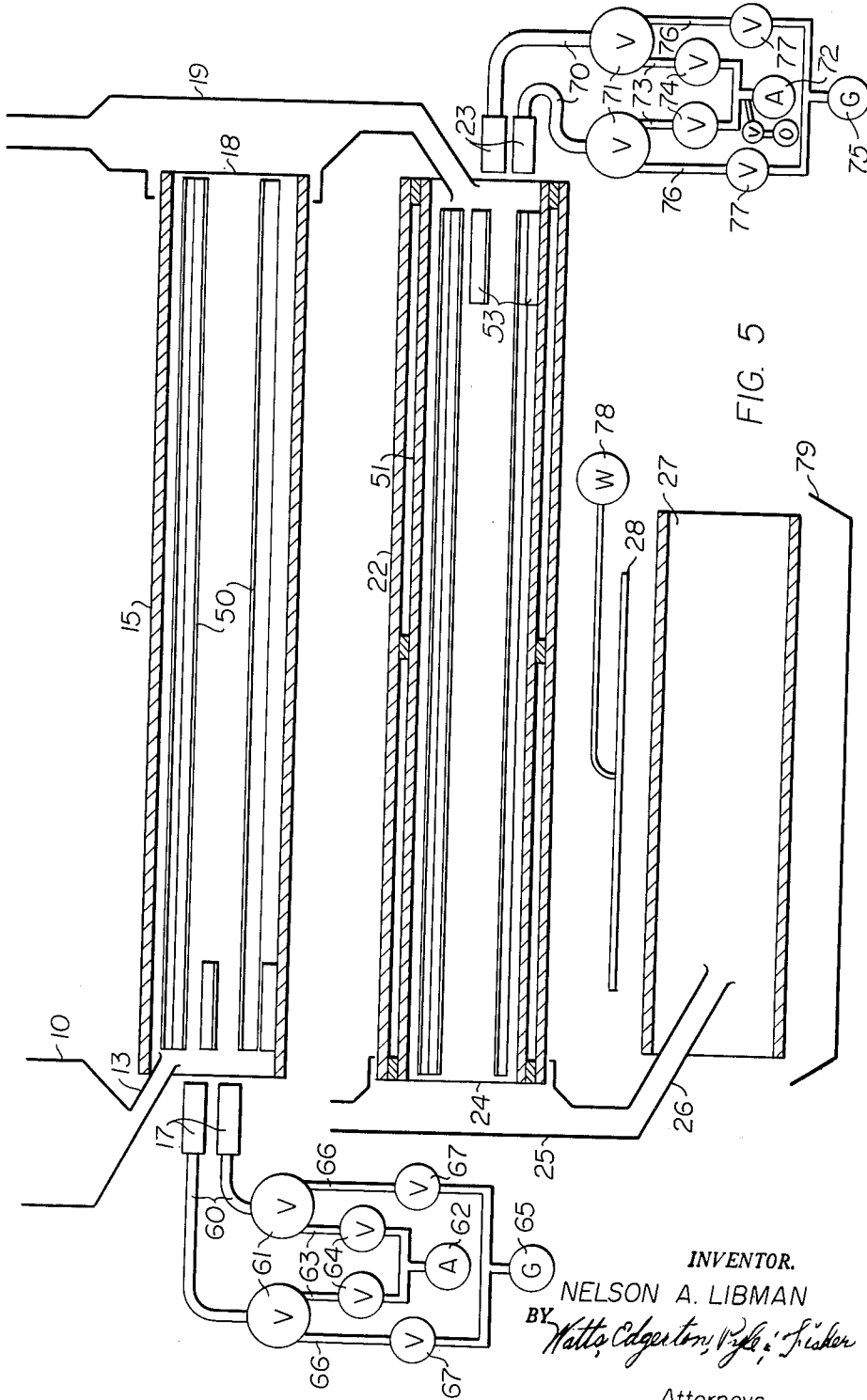
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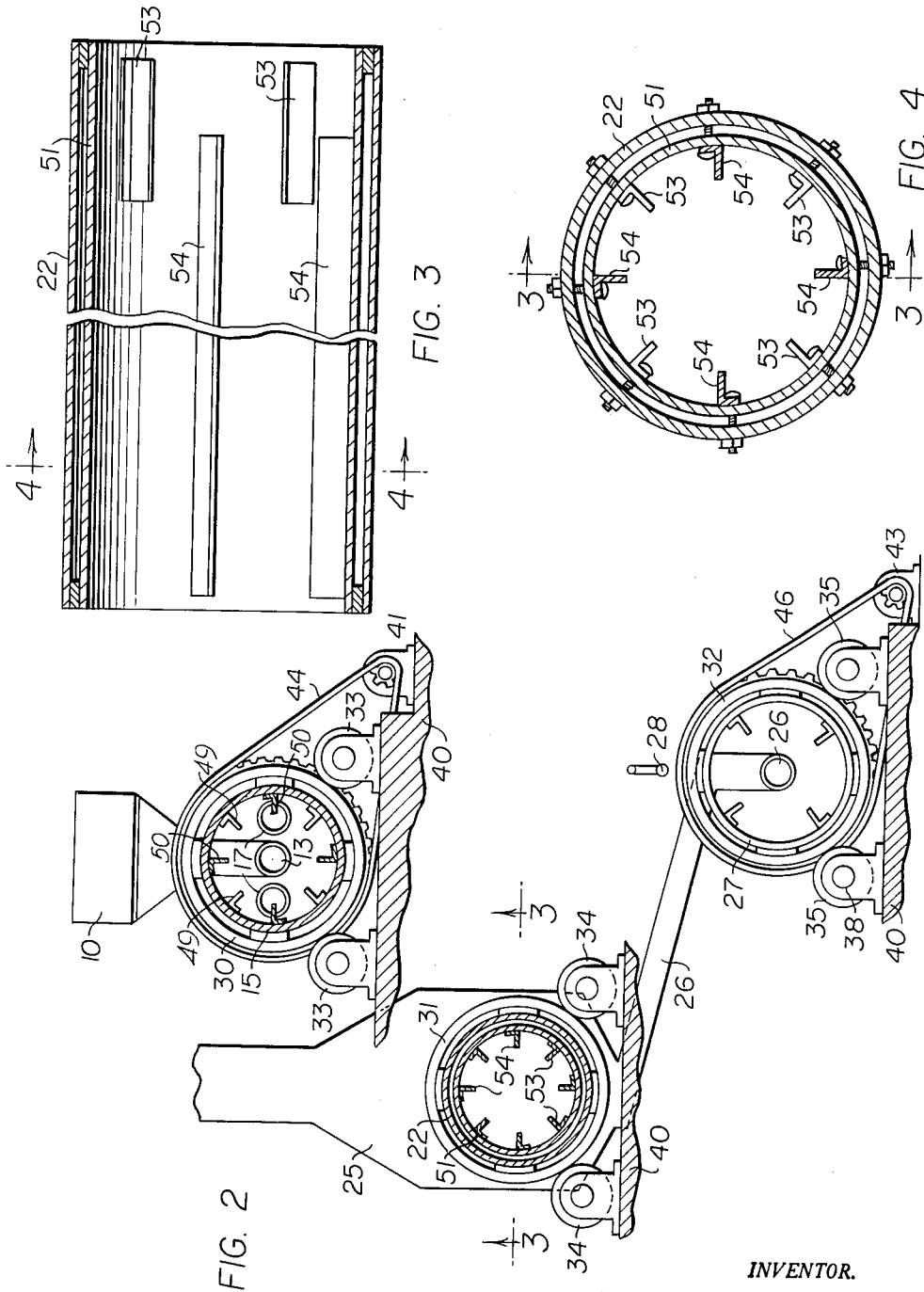
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3,245,840

ABRASIVE MATERIAL AND METHOD OF MAKING SAME

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Division of application Ser. No. 53,426, Sept. 1, 1960, now Patent No. 3,150,224, dated Sept. 22, 1964. Continuation of application Ser. No. 80,505, Jan. 3, 1961. This application Nov. 15, 1963, Ser. No. 334,683
10 Claims. (Cl. 148—3)

The subject matter of this application relating to methods of making shot constitutes a division of application Serial No. 53,426 for Method and Apparatus for Making Steel Shot, filed September 1, 1960, now Patent No. 3,150,224. The subject matter of this application relating to steel shot constitutes a continuation of application Serial No. 80,505 for Abrasive Material and Method of Making Same, filed January 3, 1961, now abandoned. Applications Serial Nos. 53,426 and 80,505 are continuation-in-part applications of application Serial No. 37,885 for Abrasive Material and Method of Making Same, filed June 22, 1960 and now abandoned.

This invention pertains to steel shot of the type used in blast cleaning castings and the like, and to novel and improved methods for making such shot.

In many manufacturing processes metal bodies, such as steel castings, are treated by impinging metal shot against surfaces of the body. In blast cleaning, the body being treated is placed in a suitable container and metal pellets known as shot are impinged against the surfaces of the body. The impingement is usually obtained either by entraining the shot in a blast of air to project the shot, or by mechanical means projecting the shot, against the body. This art is known generally as metal blasting, or shot blasting, and will be referred to here by these terms.

The types of shot used in metal blasting usually are classified as iron, malleable or steel. The malleable shot is superior to chilled iron in terms of life characteristics and steel is, of course, superior to malleable. At the same time, the cost of chilled iron shot is quite low, the malleable more expensive than the chilled iron, and the steel, heretofore, has been quite expensive.

Generally speaking, most manufacturing techniques can be satisfactorily performed with any one of the three classes of shot. Accordingly, the shot is usually selected for a given job on a basis of cost of sufficient shot of the selected type to do the job.

The present invention provides a simplified method of producing steel shot of a very high and uniform quantity at a cost comparable to the cost of producing malleable. The method provides improved control so that the standards of quality can be maintained over both large and small production runs and a resultant steel shot of superior characteristics is produced.

With the present invention, iron shot, which is usually formed by a quenching process, is heated to a temperature which is high enough to cause the carbon in the shot to migrate. The temperature at the same time is, of course, maintained below the fusing temperature of the shot. A flow of oxygen is passed over the shot while it is simultaneously tumbled and maintained at the described temperature. This oxygen flow is continued until enough of the migrating carbon has been oxidized to reduce the carbon content in the shot to less than 1.7% and preferably well below 1.0%.

The resultant shot is characterized by a long life, abrasive resistance, and a relatively high sulphur content.

With this invention gray iron is first melted in a cupola. The gray iron is then formed into a stream which is dispersed as by a blast of air to separate the stream

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into a plurality of drops. The drops are then caught in a quenching tank to produce, as a result, chilled iron pellets. These chilled iron pellets are then sorted or graded into groups, each of which includes pellets of substantially uniform size.

The pellets of one group are then placed in a feed bin. They are continuously gravity fed from the feed bin into a first tube. The tube is an elongated cylindrical tube which is open at its ends. The shot pellets are annealed in the tube as they are passing through the tube. The pellets then pass from the first tube outlet through a gravity conveyor to an inlet of a second tube. The second tube is formed of a material which has less affinity for oxygen at the temperatures under consideration than does the carbon in the pellets. As the pellets are passed through the second tube, they are heated to a temperature of 1650° F. and less than the fusing point of the pellets. They are maintained in the second tube until the carbon content is less than 1.7%. Thereafter, they are gravity fed to a water-cooled tube for air cooling or water quenching depending on the hardness desired.

Accordingly, an object of this invention is to provide a novel and improved continuous process of converting pellets of iron shot into high quality steel abrasive shot.

Another object of this invention is to provide novel and improved steel shot.

A related principal object is to provide simplified, easy to control methods of producing shot.

A more specific object of the invention is to provide a novel and improved method of producing steel shot which includes causing the carbon in iron shot to migrate by heating the shot and passing oxygen over the hot shot to burn the carbon.

Another more specific object of the invention is to provide novel and improved steel shot characterized by relatively high sulphur and phosphorous contents.

Other objects and a fuller understanding of the invention may be had by referring to the following description and claims taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a side elevational view, the parts broken away and removed for clarity of detail, of an apparatus for manufacturing steel shot in accordance with this invention;

FIGURE 2 is a sectional view of the apparatus as seen from the plane indicated by the line 2—2 of FIG. 1;

FIGURE 3 is an enlarged, fragmentary view as seen from the plane indicated by the line 3—3 of FIG. 2;

FIGURE 4 is a sectional view as seen from the plane indicated by the line 4—4 of FIG. 3;

FIGURE 5 is a diagrammatic view of the apparatus and the controls;

FIGURE 6 is a photomicrographic illustration of a central portion of a shot pellet made in accordance with this invention; and,

FIGURE 7 is a photomicrographic illustration of a portion near the surface of one of the shot pellets made in accordance with this invention.

Since this invention includes both an article and method for making it, the specification will be divided into two parts. The first part will describe the process of making shot, and the second part will describe the product.

PROCESS

In making steel shot by the new and novel process of this invention, a plurality of chilled iron pellets are first formed. The preferred method for forming the chilled iron pellets is to melt a quantity of gray iron in a cupola. The melted iron is then poured from the cupola into a stream. The stream is separated and broken into drops of appropriate size by any of several known and accepted

techniques. This may be accomplished by a blast of air, water, or other fluid, or by mechanical means. The drops are caught in a quenching tank where the chilling action of the water solidifies the drops into chilled iron pellets or shot. The resultant chilled iron pellets are brittle and short lived if used as shot. They have a carbon content which is usually in excess of 3%.

As the next preferred step, the shot is graded into size to sort out those of suitable size for use as metal blasting shot. Any shot which is too large to pass through the screen with 0.078" openings is comminuted to break it into particles of suitable size. The comminuted particles are also sorted into shot of appropriate sizes.

A group of shot pellets of a selected size are next heated to a temperature which is below the fusion point of the pellets but sufficiently high to cause the carbon in the shot pellets to migrate. This temperature usually is in excess of about 1650° F. with the fusing temperature being about 2060° F. to 2200° F., depending on the shot size. The heating is preferably accomplished in a continuous manner by passing a quantity of burned natural gas laden with hot air over the shot. Simultaneously, the shot is tumbled to expose the entire surface of each pellet to the passing, hot-air-laden gas. The tumbling and the passage of gas is continued for a period of from about 18 minutes to 45 minutes, depending upon the selected temperature, the shot size, and the amount of oxygen available in the gas passed over the shot. This step of the process is continued until the carbon has been lowered to less than 1.7% by weight in each of the pellets. Preferably, the carbon is lowered below 1%.

Reference is now made to FIGS. 1-5 of the drawings which illustrate suitable apparatus for continuously heating the chilled iron pellets and converting the pellets into steel shot. As shown most clearly in FIG. 1, a feed bin 10 is provided. The chilled iron pellets are continuously fed to the bin by a conveyor 11. A supply of pellets, indicated generally by reference numeral 12, are continuously gravity fed from the bin 10 through a pellet nozzle 12. The pellet nozzle 13 continuously delivers a supply of the chilled iron pellets to the inlet end 14 of an annealing tube 15.

A pair of burner nozzles 17 are positioned adjacent the inlet end 14 of the annealing tube 15. A suitable fuel, such as natural gas mixed with an appropriate quantity of air is directed from each of the nozzles 17 to provide a continuous flow of hot gas through the tube 15. The flow of hot gas both heats the pellets and propels them through the tube 15.

As the pellets are propelled from the tube through its outlet end 18, they are trapped by a combination deflection baffle and hood 19. A hood outlet 20 is provided to conduct the gravity fed flow of pellets through an inlet end 21 of a second and lower tube 22. The lower tube 22 is a carbon removal tube.

The carbon removal tube 22 has another pair of nozzles 23 positioned adjacent its inlet end 21. These nozzles 23 provide a continuous blast of air and fuel which is burned in a manner similar to fuel projected by the annealing tube nozzle 17. The pellets are projected through the carbon removal tube 22 until they come out the outlet end 24. From the outlet end 24 of the tube 22, the pellets enter another combination hood and deflection baffle 25.

The pellets coming out of the outlet end 24 of the carbon removal tube 22 are steel pellets. These steel pellets or shot are gravity fed through a conduit 26 into a cooling tube 27. The steel pellets are air-cooled within the cooling tube 27 which, in turn, is continuously cooled by a water bath provided by an elongated spray nozzle 28. The pellets also may be quenched in a tank 79 (FIG. 5) or subjected to a water spray for quick cooling.

Each of the tubes through which the pellets pass are shown to have a plurality of annular support collars. These annular support collars are designated by reference numerals 30, 31, 32 on the tubes 15, 22, 27, respectively.

A plurality of support wheels 33, 34, 35 are provided for the tubes 15, 22, 27, respectively. The support wheels 33, 34, 35 are respectively journaled at 36, 37, 38 on a frame 40. As is best shown in FIG. 2, the support wheels 33, 34, 35 are provided in pairs such that each one of the collars 30, 31, 32 rides on an associated horizontally spaced pair of support wheels 33, 34, 35, respectively. In this manner, the tubes 15, 22, 27 are rotatably supported on the frame 40.

Motors 41, 42, 43 are mounted on the frame 40 and suitably connected to the tubes 15, 22, 27 to cause relative rotation of the frame and tubes. In the embodiment shown, all of the motors drive the tubes with chains and sprockets shown at 44, 45, 46, respectively.

In the case of the annealing tube 15, a very satisfactory member can be made with a single, one-piece, cast steel, tubular cylinder. The plurality of inlet guide baffles 49 are provided in the interior of the tube adjacent the inlet 14 to assist in directing the pellets into the interior of the annealing tube 15. A series of elongated agitation baffles 50 are in the tube and they extend from near the inlet end 14 to the outlet end 18 to agitate the pellets in the tubes as the device is used.

One of the outstanding advantages of the invention is attained by the construction of the carbon removal tube 22 which differs in construction from the annealing tube 15. As shown, the carbon removal tube 22 includes an inner sleeve liner 51. This sleeve liner is formed of a material having a carbon-free work surface. The term "carbon-free" is intended to mean a material having a work surface that is carbon-free relative to the minimum carbon content desired in the steel shot produced. That is to say, the work surface of the liner 51 has a carbon content which is at least equal to and preferably less than the minimum carbon content desired in the steel shot.

The preferred material for the sleeve liner 51 is a carbon-free stainless steel. The liner 51 may be formed of a stainless steel material which initially has a work surface with an excess of carbon above the desired minimum carbon content of the steel shot, and the mechanism operated for a time, with or without pellets passing through it in the manner described to decarburize the liner 51.

The material of the liner 51 must, as indicated above, have a work surface which is carbon-free relative to the steel shot produced. It must also be capable of withstanding up to the fusing temperature of the pellets. This fusing temperature will be in the neighborhood of 2250° F., depending upon the size and chemical content of the particular pellets. It is also essential that the sleeve liner 51 be formed of a material which has less affinity for oxygen than does carbon in the temperature ranges to which the liner will be subjected, namely, from about 1650° F. to the fusing point of the pellets. The work surface of the liner 51 must also have good abrasion resistance to withstand the eroding action of the pellets passing therethrough. Obviously, other materials which have these described characteristics may be substituted for the preferred carbon-free stainless steel.

The carbon removal tube 22 is also shown as being provided with a plurality of inlet baffles 53 adjacent the inlet end 21. The inlet baffles 53 correspond and function to the inlet baffles 49 of the annealing tube 15. Agitation baffles 54 which correspond in function and general construction to the agitation baffles 50 are also provided in the carbon removal tube 22. The baffles 53, 54 of the carbon removal tube are formed of a carbon-free material capable of withstanding the temperatures found in the tube and having less affinity for oxygen at those temperatures than does carbon in the shot. These baffles, like the work surface of the sleeve liner 51, need not be completely carbon-free at the time of installation, but will be made so when the apparatus is operated according to the described process.

The burners 17 are supplied by suitable conduits 60. The conduits 60 may be supplied by suitable mixing valves

61, or, in the alternative, connected directly to suitable fuel and air supplies. In the arrangement shown, a supply of air under pressure 62 is connected to the mixing valve 61 by a conduit 63. Valves 64 are provided to control the pressure and volume of air supplied to the mixing valves 61. Fuel under pressure, preferably natural gas, is supplied by a source 65. The gas and fuel is conducted by conduits 66 to the mixing valves 61. The pressure and volume control valves 67 are in the conduit 66 and control the quantity and pressure of the gas supplied to the mixing valves.

To control the temperature in the carbon removal tube 22 and the rate of flow of shot through the tube, controls for the nozzles 23 are provided which are similar to the controls for the nozzle 17. Thus, conduits 40 conduct mixed gas and air from mixing valves 71. Mixing valves 71 are supplied air under pressure from a suitable source 72 by conduits 73. Volume and pressure control valves 74 control the air supplied to the mixing valves 71. Fuel under pressure is supplied by a source 75 to the mixing valves by conduit 76. Volume and pressure control valves 77 are provided to control the quantity of pressure of the fuel.

Improved carbon removal characteristics are obtained if the air is enriched with extra oxygen. Oxygen is supplied from a source 85 which is controlled by a valve 86 and connected to the air supply conduit 73.

The operation of the described apparatus will be best understood by reference to FIG. 5. As generally described above, chilled iron shot pellets are continuously fed from the bin 10 through the pellet nozzle 13 into the annealing tube 15. The pellets are blown through the annealing tube by the blast of burned natural gas or other fuel emitted by the nozzles 17. As the pellets pass through the tube 15 they are agitated by the baffles 50 as the tube 15 continuously rotates. The agitation exposes all of the pellets to the hot gases emitted by the nozzles 17 and thus assures uniform heat treatment of each of the pellets.

It should be noted that while the tube 15 is identified as an annealing tube and while the process which occurs in that tube is an annealing action, one of its principal purposes in the process is to pre-heat the pellets prior to their conduction into the carbon-removal tube 22. The pellets, as they are emitted from the annealing tube 15, will be chilled iron pellets that are partially, if not completely, transformed into malleable iron shot.

The valves 64, 67 are adjusted so that the gases emitted by the nozzle 17 maintain the temperature of the pellets in the annealing tube 50 in a range of from about 900° F. to about 1200° F. The pellets are conveyed through the tube 15 by this flowing consumed fuel and air mixture in a time range of from about 9 to about 22 minutes.

The pellets are conveyed from the outlet end 18 of the annealing tube 15 and immediately and while still hot are fed into the inlet 21 of the carbon-removal tube 22. The pellets are conveyed through the carbon-removal tube 22 in a time range of from about 9 to 22 minutes and at a temperature of from about 1650° F. to the fusing point of the pellets which, as previously noted, will be about 2250° F.

As will be apparent from the foregoing description, the carbon-removal tube 22, and more particularly the carbon-free work surface of the liner 51, has less affinity for hot oxygen than does the carbon in the shot entering the carbon-removal tube from the annealing tube 15. Thus, when the pellets are conveyed through the carbon-removal tube 22 at the speed and temperature described, the carbon in the pellets tends to migrate to their surfaces. As the hot oxygen-laden air passes over the surfaces of the pellets, the carbon is oxidized or burned off, thus converting the annealed shot to steel shot. With the pellets maintained in the tube for the indicated period of time and under the described conditions, the carbon is lowered

to less than 1.7% by weight in each of the pellets and preferably is lowered to less than 1%. Adjustment of the valves 74, 77 and therefore the volume of the air and fuel supply is used to control the temperature and rate of flow of the pellets and thus to obtain this desired end.

According to the preferred process, the pellets are air cooled in the tube 27 after the migrating carbon in the pellets has been burned off to reduce the carbon content to less than 1.7%. If desired, the pellets can also be quenched and/or water cooled in the tank 79 to increase the hardness of the steel shot produced.

Since the process comprising this invention is continuous, periodic samplings of the finished product may be made to provide an excellent, practical application of statistical quality control. Samples periodically taken can be immediately subjected to suitable testing, such as a centrifugal impact test, to determine the physical properties of the product. If the product in any given sample is slightly varied from the desired product, adjustment may be made in the air and fuel supplies to improve the characteristics.

EXAMPLE OF THE PROCESS

As a specific example, the shot used will be capable of passing through a screen with an 0.078 inch opening. With shot, for example, of approximately 0.033 inch size, the shot will be passed through an annealing tube or 2 feet in diameter and 18 feet in length at about 2 tons to about 3 tons per hour and preferably at about 3 tons per hour. To propel shot through the annealing tube at this rate, air at from about 150 to about 300 cubic feet per minute and preferably about 300 will be fed to the burners 17. Natural gas is mixed with the air to provide an adequate supply of consumed gases at the temperatures described. There are from about 8 to 11 parts of air to one of gas and preferably about 11. The pressure of the natural gas will be from about 6 ounces to about 8 ounces and preferably about 8 ounces, while the pressure of the air will be from 15 ounces to 20 ounces and preferably about 20 ounces.

After the shot has passed through the annealing tube of this example, it will be conveyed to a carbon removal tube of about 2 feet in diameter and about 18 feet in length at about 2 tons to about 3 tons per hour and preferably at about 3. To propel shot through the carbon removal tube at this rate, air at from about 150 to about 300 cubic feet per minute and preferably about 300 cubic feet per minute is fed to the burners 23. This air is mixed with natural gas in the same ratios as in the burners 17 to provide an adequate supply of oxygen-laden, consumed gases at the temperatures described. The pressure of the natural gas will be from about 6 ounces to about 8 ounces and preferably about 8 ounces, while the pressure of the air will be from 15 ounces to 20 ounces and preferably about 20 ounces.

Oxygen is added, if desired, at up to 80 cubic feet a minute, preferably about 10 parts of oxygen are added to one of air. Thus, under the described preferred conditions 30 cubic feet per minute of oxygen are added to the mixture. This is especially important with larger size shot where relatively large amounts of oxygen are needed.

THE PRODUCT

The product produced has some unusual and outstanding characteristics. As can be seen in the photomicrographs, there is a substantial gradient of carbon increasing from the outer surface of the pellet to the core. Preferably the surface of the pellet is hypoeutectoid and the core hypereutectoid. Thus, a soft, ductile, tough outer surface and a relatively hard core are formed.

The product produced by the previously described process is extremely tough and durable, has exceptional wear characteristics, and a very long abrasion life. The shot so produced is readily discernible from prior known metal shot because it has a different chemical analysis.

Schedule A sets out broadly and Schedule B in more detail suitable quantities of ingredients in metal shot made in accordance with the teachings of this invention:

Schedule A.—Material:	Percentage by weight
Carbon -----	Less than 1.7.
Phosphorous -----	From about .02 to 0.90.
Sulphur -----	From about 0.10 to about 0.25.
Iron, alloying materials and impurities -----	Remainder.

Schedule B.—Material:	Percentage by weight
Carbon -----	Less than 1.7.
Manganese -----	From about 0.25 to about 0.75.
Phosphorous -----	From about 0.02 to about 0.90.
Sulphur -----	From about 0.10 to about 0.25.
Silicon -----	From about 0.20 to about 2.0.
The balance -----	Substantially all steel alloy.

The steel alloy making up the balance will, of course, be predominantly iron. Other alloying material such as copper, chrome and impurities may be present. A typical formulation of a shot pellet made in accordance with this teaching is as follows.

Example I

Material:	Percentage by weight
Carbon -----	0.48
Manganese -----	0.32
Phosphorous -----	0.209
Sulphur -----	0.163
Silicon -----	1.04
Iron and steel alloying materials and impurities -----	Balance

Example II

Material:	Percentage by weight
Carbon -----	.31
Manganese -----	.89
Phosphorous -----	.038
Sulphur -----	.135
Silicon -----	1.30
Magnesium -----	.015

For economic reasons, it is impractical to employ a highly-alloyed iron and hence the process has been limited to low-alloy irons, i.e. iron having less than 10% by weight alloying elements. Further, it is not practical to employ this method with impurities other than phosphorus or sulphur being greater than 3½%. With a greater amount of impurities, the iron does not become satisfactory shot.

While this invention has been described with a great deal of detail, it is believed that it essentially comprises a novel and improved steel shot characterized by a carbon content of less than 1.7%, a phosphorus content of from .02 to 0.90%, and a sulphur content of from 0.10 to 0.25%. The invention also comprises a novel and improved steel shot characterized by a ductile hypoeutectoid surface and a relatively harder hypereutectoid core. The invention also comprises an improved method of making shot, including the steps of heating the shot to a temperature sufficiently high to cause the carbon to migrate, exposing the heated shot to a flow of oxygen while maintaining the shot in such temperature range to reduce the carbon to less than 1.7%.

Many modifications and variations of the invention will be apparent to those skilled in the art in view of the foregoing detailed disclosure. Therefore, it is to be understood that, within the scope of the appended claims, the invention can be practiced otherwise than as specifically shown and described.

What is claimed is:

1. A process of making steel shot from chilled iron pellets comprising the steps of introducing a quantity of chilled iron pellets into a tube having an inner work surface, said work surface being characterized by having less affinity for oxygen than the carbon in the chilled iron

pellets at temperatures of at least 1650° F., rotating the tube to agitate the pellets, heating and maintaining said pellets to a temperature which is at least about 1650° F. and less than the fusing point of the pellets, said pellets being heated by directing a flow of decarburizing gas over the pellets while in the tube, and constantly moving the pellets through the tube until the average carbon content thereof is less than 1.7% by weight.

2. A process of making steel shot from iron pellets comprising the steps of introducing a quantity of pellets into a tube, said tube having a work surface characterized by a lower affinity for oxygen at temperatures of at least 1650° F. than the carbon in the pellets, and decarburizing the pellets until the carbon content thereof is less than about 1.7% by weight, said pellets being decarburized by continuously moving them in the tube in a flow of decarburizing gas.

3. A process of making steel shot from chilled white iron pellets comprising the steps of introducing a quantity of the chilled white iron pellets into a tube having a plurality of agitating baffles therein, the inner work surface of said tube being characterized by a lower affinity for oxygen at temperatures of at least 1650° F. than the carbon in the chilled white iron pellets, elevating and maintaining the temperature of the pellets to at least 1650° F. but less than the fusing point of the pellets by directing a flow of hot decarburizing gas over the pellets while in the tube, constantly moving the shot through the tube while maintaining the shot in the tube until the carbon content thereof is less than 1.7% by weight, and thereafter cooling the pellets.

4. A process of making steel shot from iron pellets comprising continuously introducing a flow of iron pellets into a first tube, said first tube having an inlet end and an outlet end and a plurality of agitating baffles therein, heating the iron pellets while in said first tube to a temperature in the range of from about 900° F. to about 1200° F., simultaneously moving the pellets through said first tube by directing a flow of hot gas axially therethrough from said inlet to said outlet ends, conveying the pellets from the outlet end of said first tube to a second tube having an inlet end and an outlet end, said second tube having an inner work surface which is heat resistant and characterized by a lower affinity for oxygen at temperatures at least 1650° F. than the carbon in the pellets, heating the pellets while in said second tube to at least 1650° F. but less than the fusing point of the pellets while simultaneously continuously moving the pellets through said second tube by directing a flow of hot decarburizing gas axially therethrough from its inlet end to its outlet end, and maintaining the pellets in said second tube until the carbon content thereof is less than 1.7% by weight.

5. A process of making steel shot comprising melting a quantity of grey iron in a cupola, forming the melted iron in a pouring stream, dispersing the stream to separate it into pellets, catching the pellets in a quenching tank, sorting the pellets by size into groups, placing the pellets of one group into a bin having a tubular feed spout connecting the bin to the inlet end of a first tube, continuously introducing pellets into the inlet end of said first tube, annealing the pellets by heating them while in said first tube to a temperature of from about 900° F. to about 1200° F., simultaneously continuously moving the pellets through said first tube by directing a flow of hot gas axially therethrough from the inlet to the outlet ends, gravity conveying the pellets from the outlet end of said first tube to the inlet end of a second tube formed of heat resistant, carbon-free material, heating the pellets while in said second tube to at least 1650° F. and less than 2200° F. while simultaneously continuously moving the pellets through said second tube by a flow of hot oxygen-laden gas, maintaining the pellets in said second tube until the carbon content thereof is less than about 1.7% by weight, and rotating both the first

and second tubes constantly to agitate the pellets therein.

6. The process as claimed in claim 5 including the step of conveying the pellets from the outlet end of said second tube to a cooling station, and simultaneously and continuously cooling the cooling station with water.

7. The process as claimed in claim 2 wherein the pellets are moved through said tube in quantities and speeds of from about two to three tons per hour with air flowing through said tube at the rate of from about 150 to about 300 cubic feet per minute and one part natural gas for each 8 to 11 parts of air.

8. The process as claimed in claim 7 wherein the flow of gas includes up to about 80 cubic feet per minute of oxygen added to the air.

9. The process of forming steel abrasive shot comprising melting a quantity of grey iron in a cupola, forming the melted iron into a pouring stream, dispersing the stream to separate it into pellets having an average carbon content in excess of 1.7% by weight, catching the pellets in a quenching tank, sorting the pellets by size into groups having a maximum size of about .078", placing the pellets of one group into a vessel formed of a material capable of withstanding a fusing temperature of the pellets and having a lower affinity for oxygen than carbon in the pellets at temperatures of about 1650° F. to the fusing temperature, flowing a decarburizing atmosphere of burned gases having oxygen entrained therein over the pellets of one group to heat the pellets of said one group to at least 1650° F. and less than the fusing temperature, continuing the flow of burned gas and entrained oxygen until the pellets of said one group have a carbon content less than about 1.7% by weight and exhibit a substantial carbon gradient increasing from a tough, hypoeutectoid outer surface to a relatively hard,

hypereutectoid core, and agitating the pellets in said vessel while flowing said gas and oxygen.

10. A process of making steel shot comprising forming a plurality of chilled iron pellets containing carbon in excess of 3%, less than 10% alloying elements, less than 3½% combined phosphorous, sulphur and impurities, and the balance iron, heat treating said chilled iron pellets under conditions affecting a transformation into malleable iron shot, and thereafter transforming said malleable iron shot to steel shot by heating and decarburizing said malleable iron shot until the average total carbon content is less than 1.7% by weight, said steel shot being further characterized by a substantial carbon gradient increasing from a tough, hypoeutectoid surface to a relatively hard, hypereutectoid core.

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