Oct. 17, 1950 C. SUNDSTROM ET AL 2,525,973

APPARATUS FOR FEEDING SOLID MATERIAL

Filed Nov. 19, 1946 4 Sheets-Sheet 1

FIG.1.

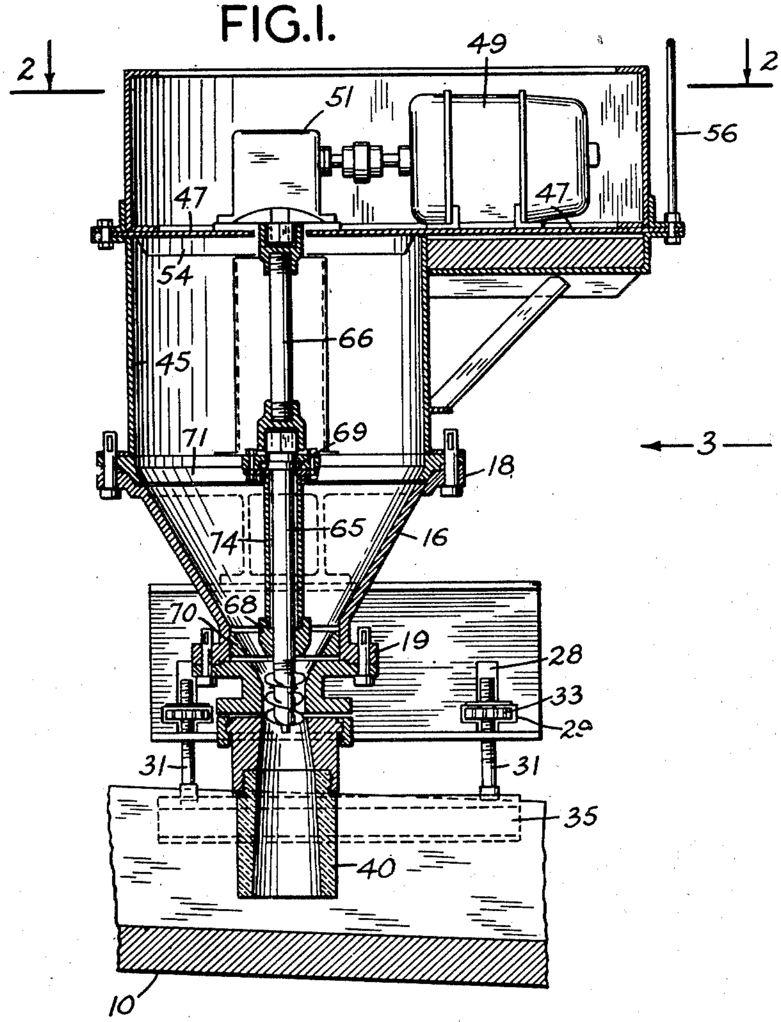

FIG.2.

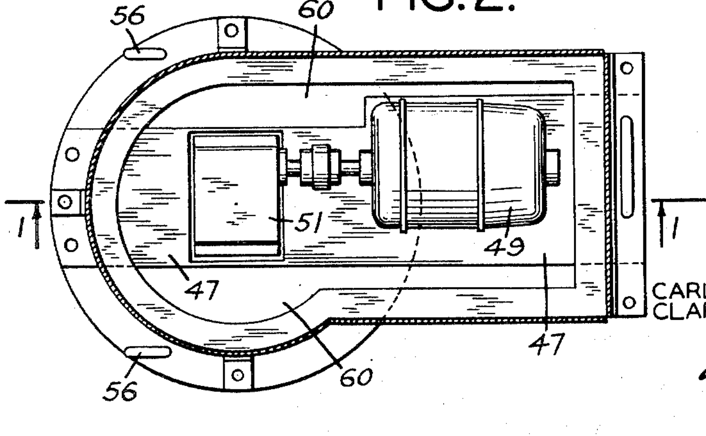

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FIG. 3.

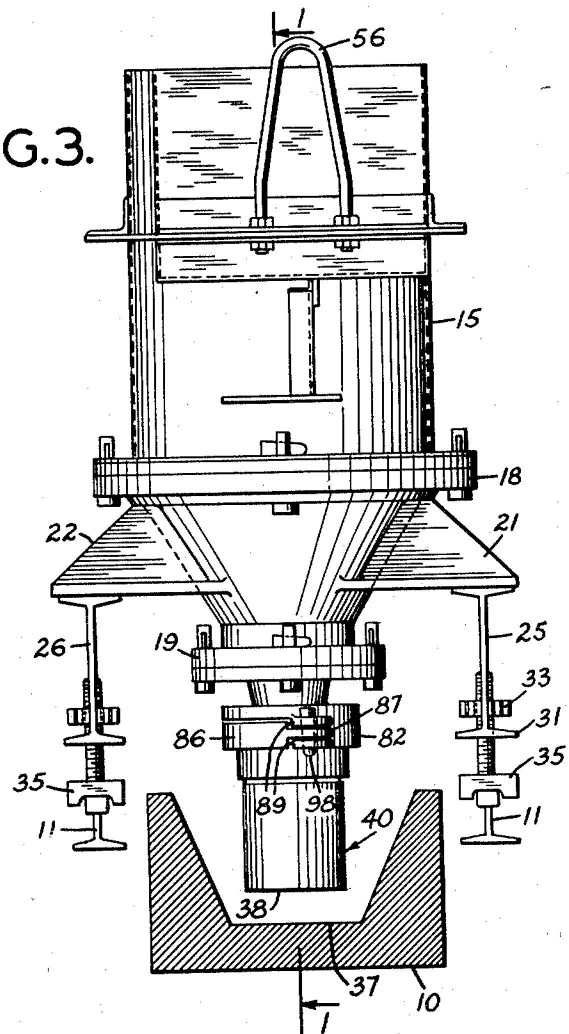

FIG. 5.

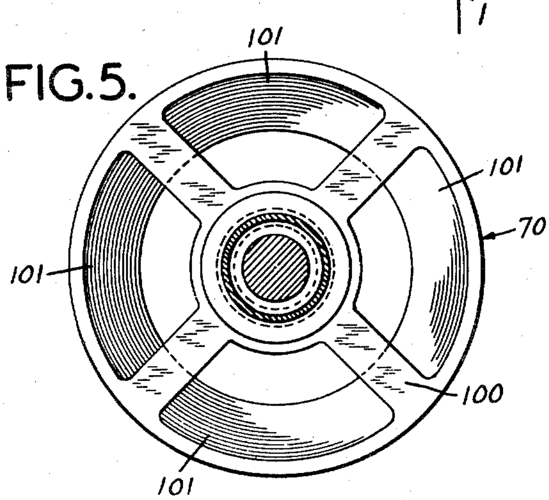

FIG. 12.

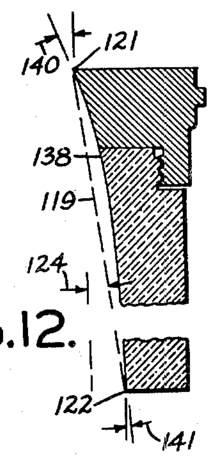

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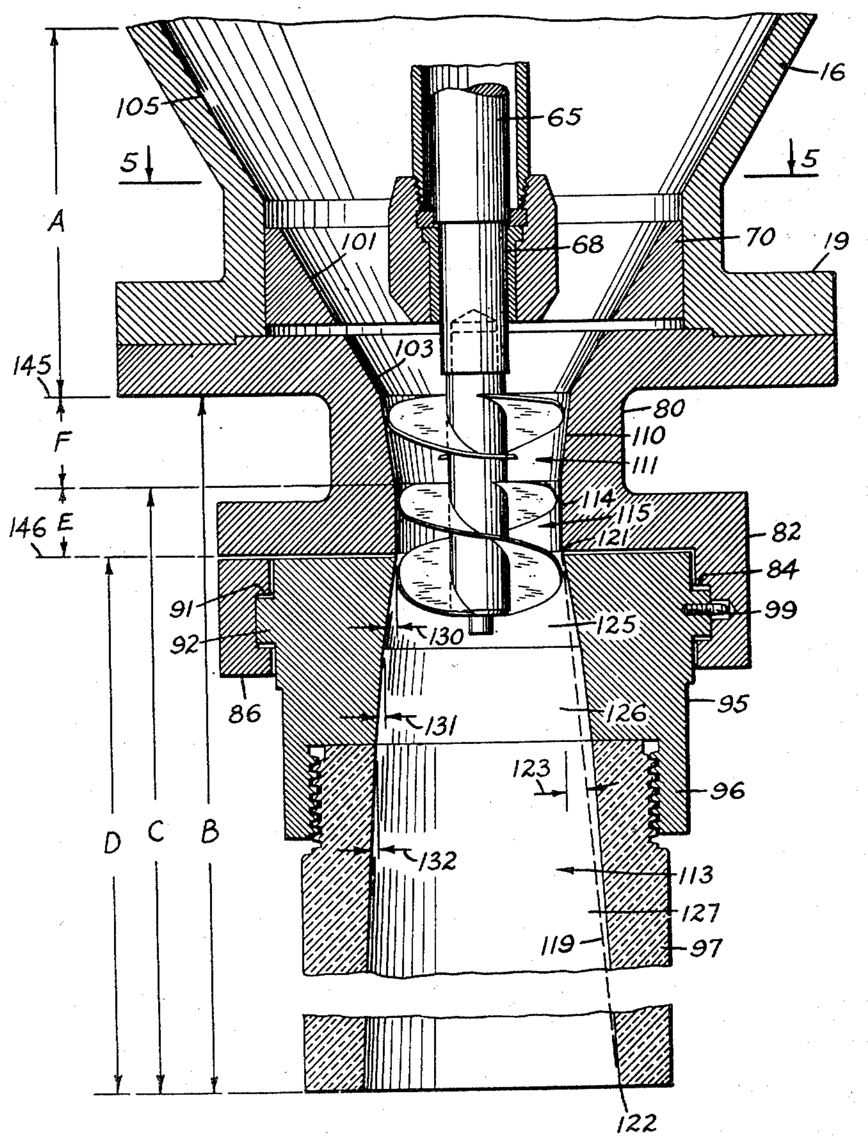
FIG. 4.



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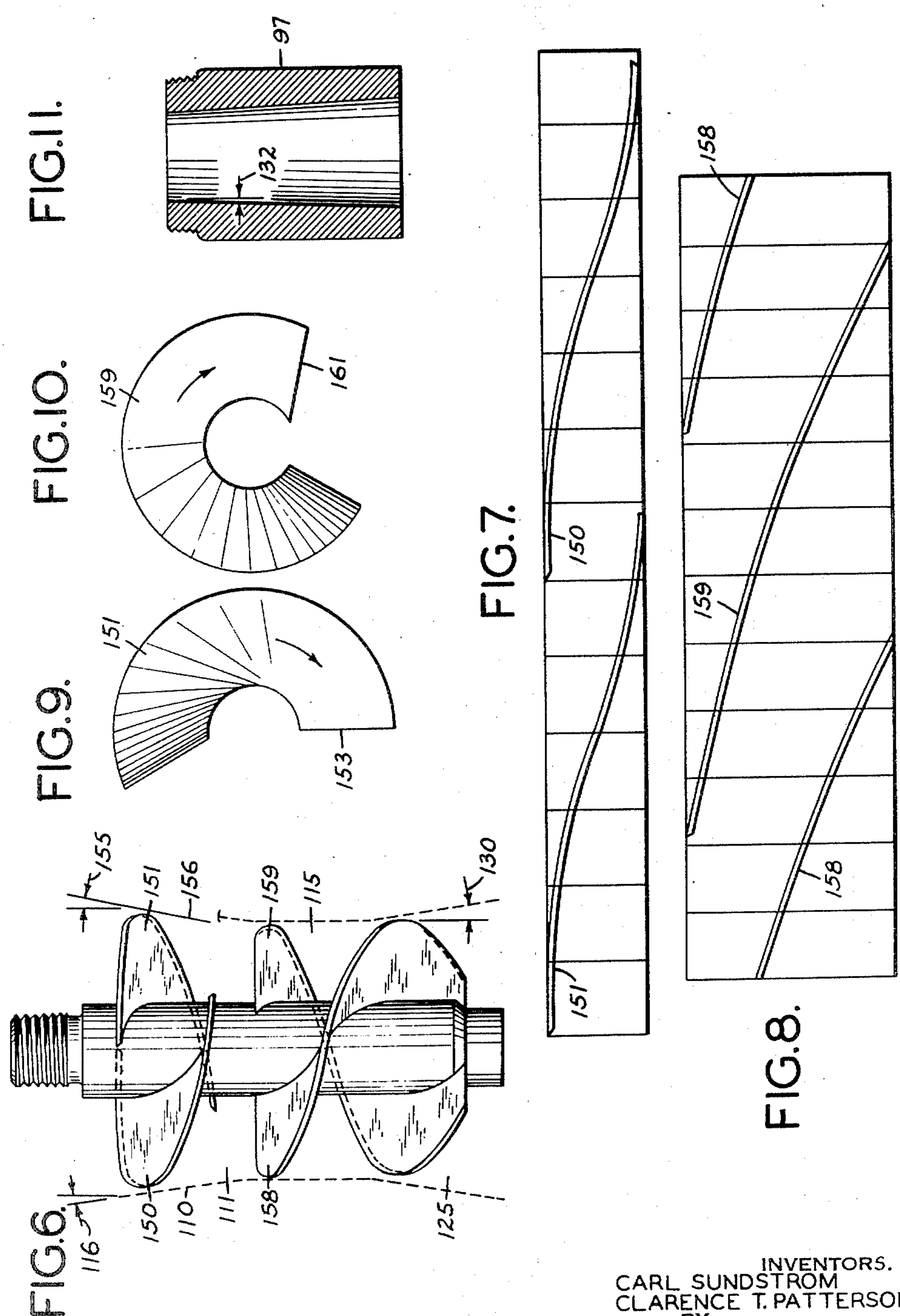

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Patented Oct. 17, 1950

2,525,973

UNITED STATES PATENT OFFICE

2,525,973

APPARATUS FOR FEEDING SOLID MATERIAL

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Application November 19, 1946, Serial No. 710,732

6 Claims. (Cl. 214—17)

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This invention relates to apparatus the preferred embodiments of which are particularly suited for use in metallurgical operations, for example for feeding a treating agent such as solid comminuted anhydrous soda ash (Na_2CO_3) into and beneath the surface of molten iron to effect desulfurization thereof.

The invention, its objects and advantages will appear from the following description taken in connection with the accompanying drawings showing a preferred form of apparatus by which the preferred process aspects of the invention may be carried out. In the drawings—Fig. 1 is a vertical section taken on line 1—1 of Fig. 2; Fig. 2 is a plan view taken on line 2—2 of Fig. 1; Fig. 3 is an end elevation looking in the direction of the arrow 3 of Fig. 1; Fig. 4 is an enlarged vertical sectional detail of portions of Fig. 1; Fig. 5 is a plan view of a detail taken on the line 5—5 of Fig. 4; Fig. 6 is an enlarged elevation of a feed screw; Figs. 7 and 8 are developments of the outer peripheries of the screw flights of Fig. 6; Fig. 9 is a plan of one of the upper screw flights of Fig. 6; Fig. 10 is a plan of one of the lower screw flights of Fig. 6; Fig. 11 is a vertical section of a lower portion of a preferred terminal delivery tube, and Fig. 12 is a fragmental vertical section of a modified form of a terminal delivery tube.

Figs. 1 and 3 show in vertical longitudinal and transverse cross-sections a sloping runner or trough 10 thru which molten pig iron may be flowed, for example from the spout of a blast furnace to one or more of the mixing ladles customarily used in the art. On either side of the runner and arranged parallel thereto are horizontal rails 11, positioned with respect to the runner in the relation of Fig. 3, suitable supports for the runner and rails not being shown.

A preferred embodiment of the feeding apparatus of this invention comprises an inverted cone-shaped casting 16 having upper and lower outwardly projecting circumferential flanges 18 and 19. Projecting outwardly on the opposite sides of casing 16 are supporting brackets 21 and 22 which may be integral with casting 16. The upper surfaces of I-beams 25 and 26 are welded to the under faces of brackets 21 and 22. The lower faces and parts of the webs of I-beams 25 and 26 are cut out as at 28 and 29 (Fig. 1) to accommodate the heavy upwardly projecting, threaded studs 31 and their corresponding adjusting nuts 33. The pairs of studs 31 located on either side of the runner are fixedly attached at their lower ends to elongated shoes 35 the under faces of which are channeled to seat the adjacent upper

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surfaces of rails 11. Thus, feed apparatus 15 is supported thru brackets 21 and 22 by rails 11 in such a way that, by suitable manipulation of nuts 33, the apparatus may be levelled and the vertical distance between the bottom 37 of runner 10 and the lower extremity 38 of terminal delivery tube or conduit designated as a whole by 40 may be adjusted, i. e. the extent of submergence of terminal conduit in the molten iron in runner 10 may be regulated as required. Studs 31, shoes 35 and nuts 33 may be replaced by any mechanical devices by which the feed apparatus 15 may be supported rigidly above the runner in such a way that the tube 40 extends into the molten iron at any desired angle, either on or off the vertical.

Projecting upwardly from the upper flange 18 of casting 16 is a circular casing 45 carrying on its upper end an elongated rectangular platform 47 which supports at its outer end a variable high-speed motor 49. The shaft of the latter is connected to a speed reducer 51 supported by platform 47 and bars 54 and positioned on the vertical axis of casing 45. The framework is provided at suitable points with eyes 56 by means of which the whole apparatus including the I-beams 25 and 26 and the supporting shoes 35 may be conveniently moved from place to place by a crane. It will be seen from Fig. 2, that the configuration of platform 47 is such as to provide openings 60 of substantial size and thru which treating agent may be fed into cylindrical section 45 and casting 16 which together form a bin adapted to accommodate several hundred pounds of treating material.

A feed screw shaft (Fig. 1) comprises a lower section 65 and an upper section 66. Lower section 65 is rotatably but rigidly mounted in bearings 68 and 69 carried by spiders 70 and 71, and is surrounded by a protective tubular casing 74 to which lubricant may be supplied by suitable means. Section 66 of the shaft, above spider 71, is in the form of a spindle connected to the upper end of shaft section 65 and to the low speed side of reducer 51, connection between the spindle and speed reducer and between the spindle and the shaft section 65 being somewhat flexible.

Fig. 4 shows in vertical cross-section an enlarged detail of apparatus which, in accordance with the present invention, may be successfully employed to feed a solid relatively finely divided treating material such as substantially anhydrous soda ash into and beneath the surface of the liquid material to be treated such as molten pig iron against the back pressure exerted by the liquid into which the material is being introduced. In order to feed a treating agent into the body of a material being treated some kind of a feed conduit and propulsion means for forcing the treating agent thru the conduit are necessary. Piston-like propulsion devices are cumbersome in any case and at best furnish only an intermittent supply of treating agent. Hence, the screw type of mechanism is the practical form of propulsion device. However, in the metallurgical art, the treating agent employed frequently has a specific gravity substantially less than that of the material being treated. This characteristic alone contributes substantially to the difficulty encountered in forcing the lighter treating agent into the body of material being treated. Further, the treating agent is usually relatively finely divided and, in general, packs easily even under moderate pressure. Moreover, in connection with the introduction of treating agent into a hot material such as molten iron, high temperatures prevailing are likely to create a condition of incipient or semi-fusion of the treating material in the feed conduit. In our early attempts to feed soda ash into and beneath the surface of molten iron by means of commonly known forms of conduits and associated feed screws, it was found that, largely because of the foregoing factors, the treating material even when using only moderate pressure either packed into stone like lumps so hard that it was impossible to rotate the screw, or packed between the screw flights with the result that the treating material turned with the screw and was not forwarded.

After considerable experimentation and investigation, we have discovered modes of handling treating agent and apparatus elements which make it possible to supply a stream of treating materials of the types described to a point of use at a constant or variable rate without the aforementioned difficulties. The invention includes a conduit thru which the treating material is fed together with propelling means in the conduit which forward the material thru the conduit into the material to be treated. The invention comprises the discovery of methods for forwarding the treating agent thru such conduit and the finding of certain characteristics of the structural configuration of the confining walls of the feed conduit, a particular type of propulsion means, and the relationship between such propulsion means and the configuration of the confining walls of the feed conduit.

Referring particularly to Fig. 4, a casting **80**, bolted to lower flange **19** of casting **16**, is provided thru 180° of its lower outer circumference with a depending flange **82** channeled in its inner face as at **84**. Hinged to one vertical end of flange **82** is a horizontally swingable clamp **86** having on its free end a hasp **87** adapted to slip in between eyes **89** cast onto flange **82**. The inner vertical face of clamp **86** is channeled at **91** similarly to channel **84** of flange **82**. Coextensive channels **84** and **91** receive the outwardly projecting rib **92** of an annular metal casting **95** constituting the upper section of the terminal delivery conduit **40**. The inner vertical face of a depending flange **96** is threaded to facilitate a rigid connection to the upper threaded end of the lower section **97** of the terminal delivery tube **40**. When pin **98** is in place as in Fig. 3 and swinging clamp **86** is in position shown in Figs. 3 and 4, the terminal tube **40** as a whole is locked securely to casting **80**. On the other hand, by simply removing pin **98** of Fig. 3 and swinging the clamp **86** outwardly, casting **95** may be readily removed to permit replacement of a deteriorated lower section **97**. Casting **95** may be provided with a stud **99** to facilitate return of casting **95** to the same position relative to casting **80**.

As illustrated in Figs. 4 and 5, the spider **70** is formed with two or more arms **100** affording support for shaft bearing **68**, and also with inner frusto-conical faces **101**. The upper portion of casting **80** has an axial cut-out which forms an inwardly and downwardly sloping face **103**. When the main casting **16**, casting **80** and spider **70** are assembled as in Fig. 4, faces **101** of spider **70** and face **103** of casting **80** are coextensive with the inner face **105** of casting **16**. Faces **103**, **101** and **105**, or any such similar arrangement, indicated within the vertical distance A of Fig. 4 may be considered as a means for supplying treating material to the subsequently described feed conduit.

Referring to Fig. 4, the feed conduit of this invention comprises (*a*) a compressing conduit **110** forming a treating agent gathering and compressing zone **111**; (*b*) the terminal delivery conduit **40** comprising casting **95** and lower section **97** and forming terminal delivery zone **113**; and (*c*) preferably an intermediate conduit **114** forming an intermediate delivery zone **115**; in the preferred form, the intermediate delivery conduit **114** and terminal delivery conduit **40** constituting what may be designated as the delivery conduit as a whole. The feed conduit may be represented by distance B; the delivery conduit in its entirety, by distance C; the terminal delivery conduit, by distance D; the preferred intermediate delivery conduit, by distance E; and the gathering and compressing zone, by distance F.

In accordance with the invention, the casting **80** is cut out axially to provide inwardly tapering confining walls forming compressing zone **111** having a radius or diameter which decreases, preferably at a constant rate, in the direction of flow of material, i. e. having a decreasing cross-sectional area throughout vertical distance F. To facilitate gathering of particles of treating material and at least some compression thereof, we find that the confining walls forming the compression zone should converge at least to some extent, preferably at a relatively low angle within the range of 2° to 5° with respect to the vertical. The dotted lines of Fig. 6 represent the walls of a part of the feed conduit. Unless otherwise indicated, it will be understood that specific mathematical values given herein are mentioned for purposes of illustration and not limitation. In the specific embodiment described, the angle between the confining wall of compressing zone **111** and the vertical, i. e. the angle of decreasing radius, may be about 4° 20′, as indicated at **116**, Fig. 6.

In the preferred form of the invention, the delivery conduit as a whole includes a preliminary or intermediate delivery zone of appreciable lineal length and having a constant cross-sectional area, such zone being formed by cylindrical confining walls **114** of casting **80**. In the preferred modification, the horizontal cross-sectional area of the intermediate delivery zone corresponds with the minimum horizontal cross-sectional area of the gathering and compressing zone.

In operation, at least a substantial portion of the lower section **97** of the terminal delivery conduit **40** is immersed in the liquid being treated, e. g. molten iron. Thus, temperatures are high throughout practically the entire length of the terminal delivery conduit. We have found that, because of high temperatures and the above described characteristics of treating materials in general and soda ash in particular, successful ultimate introduction of the treating agent beneath the surface of the material being treated depends to a major extent on the configuration of the confining walls of the terminal delivery conduit. It has been found that these walls should diverge in the direction of flow of treating material, that is, such walls should "flare" outwardly with respect to the most constricted cross-sectional area of the entire feed conduit. This "flaring" affords a terminal delivery zone of lineally increasing horizontal cross-sectional area. Forward movement of treating agent thru the terminal conduit 40 appears to depend largely upon two factors: first, the indication that the treating material is in a condition most resistant to flow at a point in the feed conduit just subsequent to the plane of discharge of treating agent from the most restricted horizontal cross-sectional area of the feed conduit; and second, the back pressure built up within the terminal delivery tube by the molten iron in which the terminal tube is immersed, it appearing that fluid back pressure substantially more than proportionally increases the non-flowable characteristics of the treating agent at the plane named.

In this specification, the angle between the vertical and a line, dotted line 119 Fig. 4, connecting points 121 and 122 is considered as the "average angle of flare." Hence, in Figs. 4 and 12, the arrows at 123 and 124 designate the average angles of flare of the modifications shown.

Because of the conditions described above, in order to cut down the high inherent resistance to flow of treating agent at the plane of introduction into the terminal delivery conduit, and to minimize the adverse effects of fluid back pressure in the terminal delivery zone, according to the preferred embodiment of the invention we have found that the best results with respect to provision of readily controllable feed of treating agent into the material being treated may be had by providing terminal delivery zone confining walls which have (*a*) at the treating agent inlet end of the terminal delivery tube, a total angle of flare which is substantially greater than the average angle of flare, and (*b*) at the bottom of the terminal delivery conduit, a relatively small and minimum angle of flare which is less than the average angle of flare. With this type of confining wall, the horizontal cross-sectional area of the bore of the terminal delivery zone is always increasing, and the diameter of the bore is always increasing but the rate of increase of diameter throughout the length of the terminal delivery zone is not constant. The purpose of this arrangement is to provide: first, a terminal delivery zone having a continually increasing horizontal cross-sectional area; second, at the inlet end of the terminal delivery conduit, a zone of maximum angle of flare which permits maximum feasible expansion of the compressed treating agent particles immediately on their introduction into the terminal delivery zone; and third, at the bottom of the terminal delivery zone, a minimum horizontal cross-sectional area which reduces fluid back pressure as much as possible, and which cooperates with other features of design to maintain the treating material in the lower portions of the terminal delivery conduit in the form of a compact core which, though readily movable, seals off backflow of gases and

to some extent insulates upper portions of the feed conduit from high temperatures.

The foregoing objectives are well accomplished by the preferred structure of terminal delivery conduit 40 of Fig. 4 which is designed to afford three sections 125, 126 and 127. In the particular specific embodiment being described, the "average angle of flare," the angle at 123, is about 3° 50′; the total angle of flare of the confining wall of section 125 as indicated at 130 is about 9° 30′; the angle of flare of the wall of section 126 indicated at 131 is about 4° 45′; and the angle of flare of the wall of lowermost section 127 as at 132 is about 2° 45′. This arrangement affords a section 125 in which the treating agent, immediately on discharge from the feed conduit zone of greatest restriction, is allowed to expand at a maximum rate at a time when the treating agent is in a condition most likely to set up into a solid lump and/or become semi-fused to the adjacent walls of tube 40. Subsequently, treating agent passes down thru section 126 having a horizontal cross-sectional area which continually increases, and a diameter which continually increases but at a rate less than that of section 125. Thereafter the treating agent, while now in a condition apparently less susceptible to caking and plugging notwithstanding increasing temperatures, is forced down thru section 127 which has a continually increasing horizontal cross-sectional area, and a diameter which continually increases but at a rate less than that of section 126. Whatever may be an exact explanation or the reasons involved, commercial scale operation shows that plugging of treating agent in the feed conduit is avoided, and the horizontal cross-sectional area of the extreme bottom end of terminal delivery zone 113 is minimized.

In the construction above described, the average angle of flare at 123 (Fig. 4) may lie in the range of 2° to 5°, preferably in the range of 3° to 4°; total angle of flare at 130 may vary from 8° to 12°; the angle of flare at 131 is less than the total angle of flare at 130 and may be greater than, equal to or less than the average angle of flare; and the angle of flare at 132 may be above zero to anything less than the average angle of flare.

The above described 3-step configuration of the confining wall of the terminal delivery zone 113 may be modified as indicated in Fig. 12, that is, a solid line connecting points 121 and 122 (Fig. 4) may be in the form of a smooth curve 138 as in Fig. 12. The maximum angle of flare 140 (Fig. 12) may correspond with or be greater than the total angle of flare at 130 (Fig. 4), and in Fig. 12 the angle of flare at 141 may be reduced to practically zero. With this wall conformation it will be seen that the cross-sectional area of zone 113 is always increasing, and that while the diameter of the terminal delivery zone bore is continually increasing, the rate of such increase drops off progressively.

The bore of the terminal delivery tube 40, distance D of Fig. 4, may be described further in terms of the relative areas of the treating material inlet and outlet ends. In the specific embodiment described, the horizontal cross-sectional area of the inlet end bears the same relation to the horizontal cross-sectional area of the outlet end as does one to about 2.6. While this area ratio may vary from one to not less than 1.75 to not more than 3.5, in the preferred and most satisfactory embodiment, this area ratio varies from one to not less than 2 to not more than 3. Taking into account these area ratios and the above described average angles of flare, it will be seen that the lengths of terminal delivery tube 40 automatically take care of themselves.

Although any horizontal cross-section of the bore of the above described terminal delivery tube 40 is circular, this form need not be adhered to rigidly. Thus, horizontal cross-sectional form may be polygonal (a plane figure bounded by three or more sides) e. g. octagonal or hexagonal. Whatever this particular form may be, it will be seen that—in the direction of treating material flow—horizontal cross-sectional area continually increases; and any diametric measurement, when taken at a right angle to the axis of the bore and in a given vertical plane which includes the axis of the bore, continually increases but the rate of increase need not be necessarily constant throughout the terminal delivery zone. In the case of bores having horizontal cross-sections of polygonal form, the above described average and other angles of flare may be utilized with reference to the upwardly and downwardly extending median of a conduit side.

In addition to the construction and design of terminal tube 40 as above detailed, diametrical and vertical (or lineal) relations of sections of the feed conduit lying within guide lines 145 and 146 of Fig. 4 are of importance. Considering the diameter of the most restricted area of the feed conduit (the diameter of intermediate delivery zone 115) as a basis of reference denoted by an arbitrary value 5, distance E may vary in the range about 0.5 to 2.5; and distance F, in the range of about 3.0 to 5.0.

The lower section 97 of the terminal delivery tube 40 may be of any suitable material which will withstand the chemical and physical conditions prevailing during use of the apparatus. When employing the feeder for introduction of treating agent such as soda ash into molten metal, section 97 should be made of refractory material which does not readily react with soda ash at the temperature of molten iron, and we have found that graphite or carbon are markedly satisfactory materials. Such substances have good workability, are resistant to thermal shock when suddenly struck by a flow of hot metal, are inert to the chemical action of hot sodium carbonate and molten iron, and have a low coefficient of expansion. Additionally, it has been found that hot metals do not wet these materials which is of particular advantage in that the flow of treating agent can be completely suspended while the tube is submerged in the metal without obstructing the exit of the tube, and thus allowing feeding to be intermittent if desirable throughout any treatment period.

Upper section 95 of the terminal delivery tube 40 should be made of material which is more resistant to abrasion than is the preferred graphite or carbon of lower section 97. We find that the abrasive action of soda ash in the areas just beneath the most constricted portion of the delivery conduit is high, and accordingly it is preferred to make upper section 95 of cast steel suitably machined. It will be noted that in the embodiment of Fig. 4, section 95 accommodates zones 125 and 126, while lower section 97 forms zone 127. Such specific demarkation is a structural convenience, although generally about a fifth or more of the total length of conduit 40 should be made of material highly resistant to abrasion.

In accordance with the invention, propulsion of treating material thru the feed conduit is effected by a rotating screw characterized by hav-

ing at least one upper flight lying within the compressing zone, and at least one lower flight, disconnected from and non-contiguous to the upper flight, at least a portion of which lower flight lies within the terminal delivery zone, i. e. the zone immediately subsequent to the most restricted cross-sectional area of the feed conduit. This feed screw is further characterized in that preferably at least the terminal portion of the upper flight has a decreasing pitch, and in that the lower flight has an increasing pitch.

A preferred form of feed screw is illustrated in front elevation in Fig. 6, in the developments of Figs. 7 and 8, and the details of Figs. 9 and 10. Referring to Fig. 6, the gathering and compressing zone 111 is provided with two flights 150 and 151 the latter being shown in plan in Fig. 9. The leading edges 153 of the upper flights are radially disposed, positioned with respect to each other at 180°, and preferably lie in the uppermost horizontal plane of compressing zone 111. These flights have a circumferential length preferably more than 180° and less than 360°, some appreciable overlapping being provided. The vertical length of the flights is preferably appreciably less than the vertical length of compressing zone 111, thus affording a construction in which approximately the lower third of the total vertical length of compressing zone 111 is flightless.

The outer peripheries of the flights are conical. Preferably, the angle of decreasing radius of the upper flights is greater than the angle of decreasing radius of the adjacent conical surface of conduit 110. In the specific embodiment shown, the angle of decreasing radius of the upper flights, i. e. the angle at 155 between solid line 156 and the vertical is about 6° 30′. Such angle may vary preferably in the range of 5° to 8°, but may be as wide as 5° to 10°. Relation of flights 150 and 151 to each other is shown in the development of Fig. 7 in which each vertical subdivision represents 30 degrees of circumference on the outer peripheries. Approximately, the first half of each flight has an increasing pitch, and approximately the second half of each flight has a decreasing pitch. In the embodiments shown, the pitch increases at a relatively constant rate from about a little more than zero to a value of about 5 and then decreases at a relatively constant rate to a value of about 3. These values are based on the above mentioned arbitrary value of 5 for the most restricted area of the feed conduit, i. e. the diameter of intermediate delivery zone 115. If desired, each upper flight may have throughout its total length a decreasing pitch, preferably constantly decreasing, in which instance the pitch may decrease from an initial value of about 5 to a final value of about 3. Ordinarily, the upper flights should not have an increasing pitch throughout their length. The diameter of the top of the upper flights is preferably appreciably less, e. g. ⅛ inch than the corresponding diameter of compressing zone 111. This feature in conjunction with the preferred decreasing pitch of at least the terminal portions of the upper flights and the smaller angle of decreasing radius of compressing zone conduit 110, contribute to effecting the needed moderate compression of the treating agent without overloading of the screw or causing the treating agent to rotate with the screw without forwarding. In the preferred embodiment disclosed the upper flights, functioning in a non-close fitting conduit 110 and having initial increasing pitch, quickly gather the treating agent, briefly compress it by an approximate equal length of decreasing pitch, and then push this partly compacted material thru a length of contracting but flightless conduit to be picked up by the leading edges of the lower flights.

The lower end of the feed screw is provided with two flights 158 and 159, a portion of each flight lying preferably within the zone of most restricted cross-sectional area and also within the immediately subsequent zone, i. e. the initial section 125 of the terminal delivery zone 113. Flight 159 is shown in plan in Fig. 10. The leading edges 161 of the lower flights lie preferably in the horizontal plane constituting the bottom of the compressing zone 111. The lower flights have a circumferential length preferably more than 180° and less than 360°, this length being such as to afford a substantial overlap which is preferably of an angular value greater than the overlap of upper flights 150 and 151. In the preferred form, the vertical length of flights 158 and 159 is such that each flight extends thru the total length of the intermediate delivery zone 115, and into and thru an appreciable length of the initial section 125 of terminal delivery zone 113. In zone 115, the lower flights loosen and start to forward the treating agent which has been moderately compressed in zone 111. The outer peripheries of flights 158 and 159 are preferably cylindrical throughout their entire length. The relation of flights 158 and 159 to each other is shown in development of Fig. 8 in which each vertical subdivision likewise represents 30° of circumference on the outer peripheries. The pitch of each flight preferably increases at a relatively constant rate from e. g. an initial value of about 3 to a final value of about 8, these values also being based on the above mentioned arbitrary value of 5 for the most restricted area of the feed conduit, i. e. the diameter of intermediate delivery zone 115. The increasing pitch of flights 158 and 159 effects forwarding of treating agent into the inlet end of zone 113 at a rate in excess of the rate of forwarding of material thru compression zone 111. The feed screw is driven thru the shaft and reducer 51, by motor 49 which may be so designed and arranged as to make it possible to readily vary the rate of rotation of the screw to thereby control the rate of feed of treating agent to the point of use.

The process and apparatus of the invention may be used as follows to feed soda ash to hot blast furnace metal. Before the furnace is tapped, the assembly is set over the iron runner in the cast house at any suitable location, provisions having been made in the runner to afford a suitable pool of metal so that the end of the terminal delivery tube 40 will be submerged at a depth beneath the surface of the metal when the furnace is tapped. The delivery tube can be set in a vertical position, and under certain conditions it may be of advantage to arrange the assembly so that tube 40 enters the metal at some angle other than the vertical. When the tube, or tubes in case of a feeder with more than one tube, is in place and before the furnace is tapped, the feed screw mechanism is started and run until the delivery tube is filled with soda ash and held in place by the bottom of the runner. The screw is then stopped and the furnace tapped. When the molten metal starts to run, the screw is again started and soda ash is fed into the metal beneath its surface at a rate depending upon the judged rate of flow of the metal and the amount of sulfur judged to be in the iron. For practical purposes of quality control, it has been found that the amount of sulfur in the iron as it comes from the furnace can be estimated sufficiently close by visual methods and the rate of flow of the iron also can be estimated sufficiently close in the same manner.

During its travel through the delivery tube into the iron the soda ash becomes heated inside the tube so that when it reaches the end of the tube and enters the iron it has become fused and molten, and thus in effect there is an introduction of molten soda ash into the molten iron; the soda ash being fused by the sensible heat of the iron. The soda ash may be introduced at various depths beneath the surface of the iron; for example say 4 inches to 8 inches but other depths may be used. On entering the iron the fused soda ash dissociates under prevailing conditions of temperature and in the presence of carbon in the iron to form sodium oxide and sodium vapor which have strong affinity for the sulfur present in the iron. This dissociation is accompanied by an evolution of gas which causes some turbulence of the metal with a resultant good dispersion of the desulfurizing medium thru the metal giving aid to efficient sulfur reduction. The products of the desulfurizing reaction and any unconsumed sodium or sodium compounds present in the metal rise to the surface of the metal within a few feet of the point of their introduction, and may be removed in any suitable way. The foregoing feed of soda ash may be applied equally well to a specially designed and constructed runner at some point external to the cast house such as at a mixer where the iron can be transferred thru the desulfurizing system either into a transfer ladle or other receiver.

While particularly adapted for use as described, the feeder assembly is adapted for introduction of other treating agents such as oxides and flue dust wherein such application is beneficial to quality and for the introduction of alloys and other materials commonly introduced prior to the primary reduction or refining equipment. Treating materials may be fed into not only hot blast furnace metal but also to molten steel, hot cupola metal or any other metal in the molten state. The apparatus affords particular advantage in the treatment of hot metal with materials which have a specific gravity considerably less than that of the metal to be treated in that the treating agent is introduced under the surface of the molten metal thus facilitating desirable intimate contact between the two, and in the case of material such as soda ash it effectually introduces the treating agent in the fused and molten condition beneath the surface of the molten metal. In commercial scale operations, the apparatus of the invention has made it possible to feed soda ash beneath the surface of molten pig iron in quantities varying from 10 to 60 pounds per minute.

We claim:

1. Apparatus adaptable for feeding solid comminuted material to a point of use against a back pressure comprising a feed conduit, means for supplying material to said conduit, the confining wall of said conduit forming (*a*) adjacent said supply means a compressing zone including a lineal section of decreasing cross-sectional area and (*b*) a delivery zone including a lineal section of increasing cross-sectional area, means for propelling material thru said conduit, said propelling means including in said compressing zone a

screw flight having an at least terminally decreasing pitch, and in said delivery zone a screw flight having an increasing pitch, adjacent ends of said flights being non-contiguous and substantially spaced apart.

2. Apparatus adaptable for feeding solid comminuted material to a point of use against a back pressure comprising a feed conduit, means for supplying material to said conduit, the confining wall of said conduit forming (*a*) adjacent said supply means a compressing zone of lineally decreasing cross-sectional area, (*b*) an intermediate delivery zone of lineally constant cross-sectional area, and (*c*) a terminal delivery zone of lineally increasing cross-sectional area, means for propelling material thru said conduit, said propelling means including in said compressing zone a screw flight having an at least terminally decreasing pitch, and in said intermediate and terminal delivery zones a screw flight having an increasing pitch, adjacent ends of said flights being non-contiguous and substantially spaced apart.

3. Apparatus adaptable for feeding solid comminuted material to a point of use against a back pressure comprising a feed conduit, means for supplying material to said conduit, the confining wall of said conduit forming (*a*) adjacent said supply means a compressing zone of lineally decreasing cross-sectional area, (*b*) an intermediate delivery zone of lineally constant cross-sectional area, and (*c*) a terminal delivery zone of lineally increasing cross-sectional area, means for propelling material thru said conduit, said propelling means including (1) in said compressing zone a double flight screw each flight having a circumferential length of more than 180° and less than 360° and having an at least teminally decreasing pitch, and (2) in said intermediate zone and in at least a portion of said terminal delivery zone a double flight screw each flight having a circumferential length of more than 180° and less than 360° and having an increasing pitch, adjacent ends of said screws being non-contiguous and substantially spaced apart.

4. Apparatus adaptable for feeding solid comminuted material to a point of use against a back pressure comprising a feed conduit, means for supplying material to said conduit, said conduit comprising (*a*) adjacent said supply means a compressing zone of lineally decreasing cross-sectional area, and (*b*) a terminal delivery zone having a lineal section of increasing cross-sectional area formed by a flaring wall, the area ratio of the inlet end of said section to the outlet end thereof being one to not less than 2 and not more than 3, the average angle of flare of said wall being in the range of 3°–4°, and the total angle of flare of said wall at the inlet end of said section being substantially in excess of the average angle of flare; means for propelling material thru said conduit, said propelling means comprising (1) in said compressing zone a double flight screw each flight having a circumferential length of more than 180° and less than 360° and having an at least terminally decreasing pitch, and (2) in at least a portion of said terminal delivery zone a double flight screw each flight having a circumferential length of more than 180° and less than 360° and having an increasing pitch, adjacent ends of said screw being non-contiguous and substantially spaced apart.

5. Apparatus adaptable for feeding solid comminuted material to a point of use against a back pressure comprising a feed conduit, means for supplying material to said conduit, said conduit comprising (*a*) adjacent said supply means a compressing zone of lineally decreasing cross-sectional area, and (*b*) a delivery zone including a lineal section of non-uniformly increasing cross-sectional area formed by a flaring wall having an average angle of flare, the total angle of flare of said wall at the inlet end of said section being greater than the average angle of flare, the total angle of flare of said wall at the outlet end of said section being less than said average angle of flare; means for propelling material thru said conduit, said propelling means including in said compressing zone a screw flight having an at least terminally decreasing pitch, and in said delivery zone a screw flight having an increasing pitch, adjacent ends of said screw being non-contiguous and substantially spaced apart.

6. Apparatus adaptable for feeding solid comminuted material to a point of use against a back pressure comprising a feed conduit, means for supplying material to said conduit, the confining wall of said conduit forming (*a*) adjacent said supply means a compressing zone of lineally decreasing cross-sectional area, (*b*) an intermediate delivery zone of lineally constant cross-sectional area, and (*c*) a terminal delivery zone of lineally increasing cross-sectional area, means for propelling material thru said conduit, said propelling means including in said compressing zone a screw flight having an at least terminally decreasing pitch, and in said terminal delivery zone a screw flight having an increasing pitch, adjacent ends of said flights being non-contiguous and substantially spaced apart.

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