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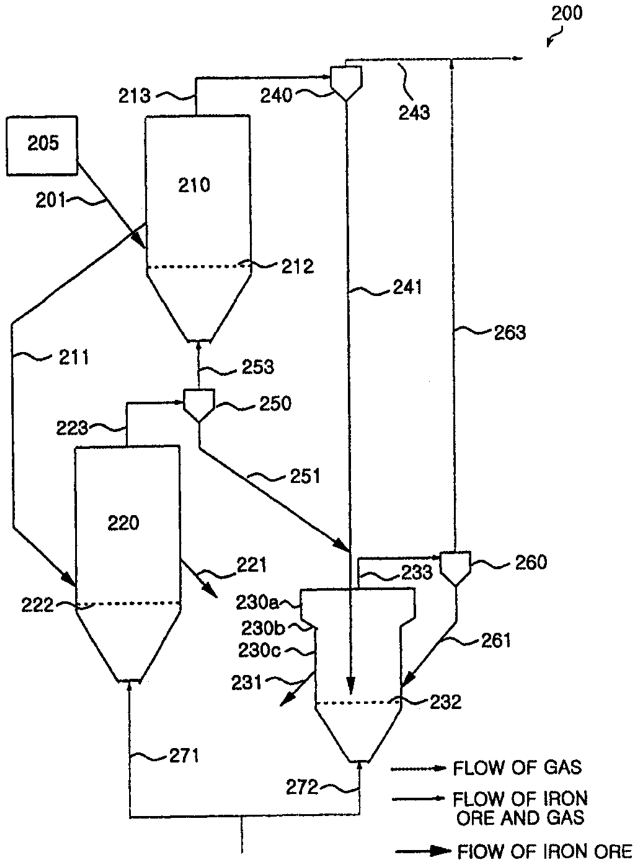
(54) Title: FLUIDIZED BED TYPE FINE IRON ORE REDUCING APPARATUS, AND METHOD THEREFOR

(57) Abstract

A fluidized bed type reducing apparatus for reducing a fine iron ore of a wide particle size distribution includes a first fluidized bed type furnace (210) for a first reduction of only coarse/intermediate iron ores and a second fluidized bed type furnace (220) for the reduction of the iron ores of the first fluidized bed type furnace (210). A first cyclone (240) captures fine iron ore particles from the discharge gas of the first fluidized bed type furnace (210) and a second cyclone (250) captures those from that of the second fluidized bed type furnace (220). In a third fluidized bed type furnace (230) the fine iron ore particles are reduced which have been captured by the first and second cyclones (240 and 250). A third cyclone (260) captures the extremely fine iron ore particles discharged from the third fluidized bed type furnace (230) to recycle them to the third fluidized bed type furnace (230).



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FLUIDIZED BED TYPE FINE IRON ORE REDUCING APPARATUS, AND METHOD THEREFOR

FIELD OF THE INVENTION

The present invention relates to a fluidized bed type reducing apparatus for reducing a fine iron ore of a wide particle size distribution in a fluidized state, and a method for reducing the fine iron ore by using the apparatus. More specifically, the present invention relates to a fluidized bed type fine iron ore reducing apparatus and a method therefor, in which the reduction is carried out by classifying the particle sizes of the fine iron ore, thereby minimizing the particle elutriation loss.

BACKGROUND OF THE INVENTION

In the current molten iron production lines, the blast furnace method forms the main stream. Recently, the shaft type smelting reduction process using the pellets and lump ore has been commercialized to produce the molten iron. However, the above two processes have the restriction that only agglomerated raw materials can be used.

In the blast furnace process, there is used a sintered ore which is made by mixing coke (made from coal as a fual), a fine iron ore and an auxiliary raw material, thereby producing a molten pig iron. In this method, the facility for the pre-treatment of the raw material is increased, and in this connection, the environmental pollution problem has become serious. Therefore, regarding this matter, the environmental regulation has been imposed. Meanwhile, in the shaft type smelting reduction iron producing process, there are used the iron ore pellets made from the fine ore as the raw material, or there are used the lump iron ore of limited sizes, to produce the molten pig iron.

Thus in the blast furnace process or in the shaft type smelting reduction process, the fine iron ore cannot be directly used, but a pre-treatment has to be carried out. Therefore, the fluidized bed type smelting reduction process is calling the attentions as a means to replace the existing blast furnace method, because the fluidized bed type smelting reduction process can directly use the fine iron ore which is cheap and profusely buried. Therefore, studies on the fluidized bed type furnace are being briskly carried out.

The smelting reduction process is divided into a pre-reducing stage and a final reducing stage. At the pre-reducing stage, the raw ore is pre-reduced into a solid state, while at the final reducing stage, the pre-reduced iron is put into a melter-gasifier to produce a finally reduced pig iron. Generally, the pre-reducing stage is classified into moving bed type and a fluidized bed type based on the particle sizes. It is known that the fluidized bed type is advantageous in the case of a fine iron ore of a wide particle size distribution, because the fluidized bed type furnace reduces the raw iron ore by means of the reducing gas within the reducing furnace. That is, the fluidized bed type furnace is efficient in the bed permeability and the gas utilization.

An example of this fluidized bed type molten pig iron manufacturing apparatus is disclosed in Korean Patent No. 117065 (1997), and this apparatus is illustrated in FIG. 1.

As shown in FIG. 1, the fluidized bed type molten pig iron manufacturing apparatus includes: a first fluidized bed type furnace 110 having a conical shape with a wide top and a narrow bottom so as to stably fluidize a fine iron ore of a wide particle size distribution, for drying/pre-heating the fine iron ore under a bubble fluidizing state to improve the reduction rate and the gas utilization rate; a first cyclone 140 for collecting fine iron ore particles contained in the discharge gas of the first fluidized bed type furnace; a second fluidized bed type furnace 120 for pre-reducing the fine iron ore after its drying/pre-heating by the first fluidized bed type furnace; a second cyclone 150 for collecting fine iron ore particles contained in the discharge gas of the second fluidized bed type furnace; a third fluidized bed type furnace 130 for finally reducing the fine iron ore after its pre-reduction by the second fluidized bed type furnace; a third cyclone 160 for collecting fine iron ore particles contained in the discharge gas of the third fluidized bed type furnace; and a melter-gasifier 180 for melting-reducing the finally reduced iron of the third fluidized bed type furnace 130.

Reference code 170 in the drawing indicates a iron ore hopper.

However, in the conventional fluidized bed type pre-reducing furnace of FIG.1, the fine iron ore which has not been captured by the first cyclone 140 is discharged through a gas discharge hole, with the result that the elutriation loss of the iron ore is very large. Particularly, during the pre-reduction of the iron ore, the degradation phenomenon occurs mostly at the early stage of the reduction. Therefore, a large amount of fine iron ore is elutriated after it is degraded during the first pre-reduction by the first fluidized bed type furnace 110 and during the mechanical degradation by the fluidizing. Thus the first cyclone is overloaded, and therefore, the separation of the iron ore from the discharge gas is inhibited, with the result that a large amount of fine iron ore is discharged together with the discharge gas, thereby increasing the loss.

Further, when the reduced iron of a wide particle distribution, which has been finally reduced by the third fluidized bed type furnace 130, is fed into the melter-gasifier 180, the fine reduced iron particles are dropped to below the melter-gasifier so as to be scattered away.

A fluidized bed type reducing apparatus was disclosed by the present inventors under Korean Patent Application No. 97-71432. In this apparatus also, there have been found the problems that the cyclones are overloaded by the fine particles coming from the final pre-reducing furnace, and that the efficiency is lowered.

SUMMARY OF THE INVENTION

The present invention is intended to overcome the above described disadvantages of the conventional techniques. In order to overcome the above described disadvantages of the conventional techniques, the present inventors have carried out studies and researches for a long time, and based on the studies and researches, the present inventors came to propose the apparatus of the present invention.

Therefore it is an object of the present invention to provide a fluidized bed type fine iron ore reducing apparatus, and a method therefor, in which the reduction is carried out by classifying the particle sizes so as to improve the reduction degree and the gas utilization rate, and so as to minimize the elutriation loss of the iron ore.

In achieving the above object, the fluidized bed type fine iron ore reducing apparatus for reducing a fine iron ore of a wide particle size distribution according to the present invention includes: a first fluidized bed type furnace for carrying out a first reduction on only coarse /intermediate iron ores among fine iron ores of a wide particle size distribution by forming a bubble fluidizing bed after their charge from a charging hopper, while making fine iron ore particles fly away; a second fluidized bed type furnace for carrying out a reduction for a second time on the coarse/intermediate iron ores discharged from the first fluidized bed type furnace; a first cyclone for capturing fine iron ore particles elutriated from the first fluidized bed type furnace; a second cyclone for capturing fine iron ore particles elutriated from the second fluidized bed type furnace; a third fine particle fluidized bed type furnace for carrying out a second reduction on the iron ores captured by the first and second cyclones, by forming a bubble fluidizing bed; a third cyclone for capturing extremely fine iron ore particles from a discharge gas of the third fluidized bed type furnace.

In another aspect of the present invention, the fluidized bed type fine iron ore reducing apparatus for reducing a fine iron ore of a wide particle size distribution according to the present invention includes: a first fluidized bed type furnace for carrying out a first reduction on only coarse/intermediate iron ores among fine iron ores of a wide particle size distribution by forming a bubble fluidizing bed after their charge from a charging hopper, while making fine iron ore particles fly away; a second fine particle fluidized bed type furnace for carrying out a first reduction on the fine iron ore particles discharged from the first fluidized bed type furnace; a first cyclone for capturing extremely fine iron ore particles elutriated from the second fluidized bed type furnace; a third fluidized bed type furnace for carrying out a second reduction on the iron ores first-reduced by the first and second fluidized bed type furnaces, by forming a bubble fluidizing bed; a second cyclone for capturing an extremely fine iron ore elutriated from the third fluidized bed type furnace.

The present invention also provides a method for manufacturing a reduced iron by using the above described apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

The above object and other advantages of the present invention will become more apparent by describing in detail the preferred embodiment of the present invention with reference to the attached drawings in which:

FIG. 1 illustrates the conventional fluidized bed type reducing apparatus for reducing a fine iron ore; and

FIG. 2 illustrates an example of the fluidized bed type reducing apparatus for reducing a fine iron ore according to the present invention;

FIG. 3 illustrates another example of the fluidized bed type reducing apparatus for reducing a fine iron ore according to the present invention; and

FIG. 4 illustrates still another example of the fluidized bed type reducing apparatus for reducing a fine iron ore according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 2 illustrates an example of the fluidized bed type reducing apparatus for reducing a fine iron ore according to the present invention.

As shown in FIG. 2, the fluidized bed type fine iron ore reducing apparatus 200 for reducing a fine iron ore of a wide particle size distribution according to the present invention includes: a first fluidized bed type furnace 210 for carrying out a first reduction on only coarse/ intermediate iron ores among fine iron ores of a wide particle size distribution by forming a bubble fluidizing bed after their charge from a charging hopper 205, while making fine iron ore particles fly away; a second fluidized bed type furnace 220 for carrying out a reduction for a second time on the coarse/intermediate iron ores discharged from the first fluidized bed type furnace 210; a first cyclone 240 for capturing fine iron ore particles elutriated from the first fluidized bed type furnace 210; a second cyclone 250 for capturing fine iron ore particles elutriated from the second fluidized bed type furnace 220; a third fine particle fluidized bed type furnace 230 for carrying out a second reduction on the iron ores captured by the first and second cyclones 240 and 250, by forming a bubble fluidizing bed; and a third cyclone 260 for capturing extremely fine iron ore particles from a discharge gas of the third fluidized bed type furnace 230.

The first fluidized bed type furnace 210 is cylindrical, and a first gas supplying pipe 253 is connected to the bottom of the furnace 210, for supplying the reducing gas into the reducing furnace, while a first gas distributor 212 is installed in the lower portion of it.

Further, a first charging pipe 201 is connected to a side wall of the first fluidized bed type furnace 210, for supplying a fine iron ore from the charging hopper 205. Further, a first discharge pipe 211 is connected to the side wall of the second fluidized bed type furnace 220, for discharging the pre-reduced intermediate/coarse iron ores.

The top of the first fluidized bed type furnace 210 is connected through a first discharge gas discharging pipe 213 to the first cyclone 240.

Further, a first circulation pipe 241 is connected to the bottom of the first cyclone 240, for circulating the fine iron ore particles (which are contained in the discharge gas of the first fluidized bed type furnace) to the third fluidized bed type furnace 230. A fourth discharge gas discharging pipe 243 is connected to the top of the first cyclone 240, for discharging the discharge gas after the separation of the fine iron ore particles.

The second fluidized bed type furnace 220 is cylindrical, and a second gas supplying pipe 271 is connected to the bottom of the furnace 220, while a second gas distributor 222 is installed in the lower portion of the furnace 220.

A first charging pipe 201 is connected to a side wall of said first fluidized bed type furnace, for supplying a fine iron ore from said hopper 205 to said first furnace 210. And a first discharge pipe 211 is connected to the side wall of the first fluidized bed type furnace 210, first fluidized bed type furnace 210, for discharging the first-reduced intermediate/coarse iron ore particles from the first fluidized bed type furnace 210 to the second fluidized bed type furnace 220.

The top of the second fluidized bed type furnace 220 is connected through a second discharge gas discharging pipe 223 to the second cyclone 250.

A second circulation pipe 251 is connected to the bottom of the second cyclone 250, for circulating a fine iron ore particles (which are contained in the discharge gas of the second fluidized bed type furnace 220) to the third fluidized bed type furnace 230. Further, a first gas supplying pipe 253 is connected to the top of the second cyclone 250, for supplying the discharge gas after its separation from the fine iron ore particles.

As shown in FIG. 2, the second circulating pipe 251 communicates to the first circulating pipe 241, and thus, the fine iron ore particles which are contained in the discharge gas of the second fluidized bed type furnace 220 are supplied through the second and first circulating pipes 251 and 241 to the third fluidized bed type furnace 230.

The present invention is not limited to the above described structure, but the second circulating pipe 251 may be directly connected to the third fluidized bed type furnace 230.

The third fine particle fluidized bed type furnace 230 includes an expanded portion 230a, a tapered portion 230b and a narrow portion 230c.

Within the lower portion of the narrow portion 230c, there is installed a third gas distributor 232. Further, a third reducing gas supplying pipe 272 is connected to the bottom of the third fluidized bed type furnace 230, for supplying a reducing gas.

A third discharging pipe 231 is connected to the side wall of the narrow portion 230c (above the third gas distributor 232), for discharging the reduced fine iron particles from the third fluidized bed type furnace 230.

The expanded portion 230a of the third fluidized bed type furnace 230 is connected through a third discharge gas discharging pipe 233 to the third cyclone 260.

A third circulating pipe 261 is connected to the bottom of the third cyclone 260, for circulating the fine iron ore particles (which are contained in the discharge gas of the third fluidized bed type furnace 230) back to the third fluidized bed type furnace 230.

A fifth discharge gas discharging pipe 263 is connected to the top of the third cyclone 260, for discharging the discharge gas after its separation from the fine iron ore particles. The fifth discharge gas discharging pipe 263 should be preferably connected to a fourth discharge gas discharging pipe 243.

Of course, the fifth discharge gas discharging pipe 263 may not be connected to a fourth discharge gas discharging pipe 243.

Further, the first circulating pipe 251 extends down to the lower interior of the third fluidized bed type furnace 230 after passing through the expanded portion 230a of the third fluidized bed type furnace 230.

The height of the first and second fluidized bed type furnaces 210 and 220 should be preferably 10 - 15 times as large as the inner diameter of them. The reason is as follows. That is, if the height is less than 10 times the inner diameter, the fluidizing of the iron ore particles is not efficient within the furnace, and therefore, even the intermediate/coarse iron ore particles may fly away. On the other hand, if the height is more than 15 times the inner diameter, then the fine iron ore particles cannot efficiently fly.

Meanwhile, the inner diameter of the narrow portion 230c of the third fluidized bed type furnace 230 is just as large as the inner diameter of the bottom of the tapered portion 230b. The inner diameter of the expanded portion 230a is just as large as the inner diameter of the top of the tapered portion 230b.

The inner diameter of the expanded portion 230a should be preferably 1.5 - 2.0 times as large as the inner diameter of the narrow portion, so that the gas flow velocity can be reduced within the furnace while inhibiting the elutriation of the fine iron ore particles.

The overall height of the third fluidized bed type furnace 230 should be preferably 10 - 20 times as large as the inner diameter of the narrow portion, so that a sufficient fluidizing space can be secured, and that the elutriation of the fine iron ore particles can be inhibited. The height of the narrow portion 230c should be preferably 1.0 - 1.5 times as large as the height of the expanded portion 230a.

Meanwhile, the inclination of the tapered portion 230b should be preferably 30 - 50° relative to the vertical line.

FIG. 3 illustrates another example of the fluidized bed type reducing apparatus for reducing a fine iron ore according to the present invention.

As shown in FIG. 3, the fluidized bed type fine iron ore reducing apparatus 300 for reducing a fine iron ore of a wide particle size distribution according to the present invention includes: a first fluidized bed type furnace 310 for carrying out a first reduction on only coarse /intermediate iron ores among fine iron ores of a wide particle size distribution by forming a bubble fluidizing bed after their charge from a charging hopper, while making fine iron ore particles fly away; a second fluidized bed type furnace 320 for carrying out a reduction for a second time on the coarse/intermediate iron ores discharged from the first fluidized bed type furnace; a first cyclone 340 for capturing fine iron ore particles elutriated from the first fluidized bed type furnace 310; a second cyclone 350 for capturing fine iron ore particles elutriated from the second fluidized bed type furnace 320; a third fine particle fluidized bed type furnace 330 for carrying out a second reduction on the iron ores captured by the first and second cyclones 340 and 350, by forming a bubble fluidizing bed; and a third cyclone 360 for capturing the extremely fine iron ore particles from the discharge gas of the third fluidized bed type furnace 330.

The first fluidized bed type furnace 310 is cylindrical, and a first gas distributor 312 is installed within the lower portion of it. A first gas supplying pipe 355 is connected to the bottom of the furnace 310, for supplying the discharge gases of the second and third fluidized bed type furnaces 320 and 330 as reducing gases into the first fluidized bed type furnace 310.

Further, a first charging pipe 301 is connected to a side wall of the first fluidized bed type furnace 310, for supplying a fine iron ore and a flux such as lime stone from the charging hopper. Further, a first discharge pipe 311 is connected to the side wall of the second fluidized bed type furnace 320, for discharging the pre-reduced intermediate/coarse iron ores.

The top of the first fluidized bed type furnace 310 is connected through a first discharge gas discharging pipe 313 to the first cyclone 340.

A first fine ore supplying pipe 343 is connected to the bottom of the first cyclone 340, for supplying the fine iron ore particles (which are contained in the discharge gas of the first fluidized bed type furnace 310) back to the first fluidized bed type furnace 310. Preferably, the first fine ore supplying pipe 343 should be extended into the lower portion of the first fluidized bed type furnace 310.

A sixth discharge gas discharging pipe 344 is connected to the first cyclone 340, for discharging the discharge gas of the first fluidized bed type furnace 310 after its separation from the fine iron ore particles.

A second fine particle supplying pipe 342 is connected to the first fine particle supplying pipe 343, for supplying the fine iron ore particles to the third fluidized bed type furnace 330. Between the first and second fine particle supplying pipes 343 and 342, there is disposed a first two-way valve 341.

The second fluidized bed type furnace 320 is cylindrical, and a second gas distributor 322 is installed within the lower portion of it. A second reducing gas supplying pipe 371 is connected to the bottom of the furnace 320. On the wall above the second gas distributor 322, there is connected a first discharge pipe 311 for discharging the first-reduced intermediate/coarse iron ore particles from the first fluidized bed type furnace 310, and there is also connected a second discharging pipe 321 for discharging the finally reduced intermediate/coarse iron ore particles.

The top of the second fluidized bed type furnace 320 is connected through a second discharge gas discharging pipe 323 to the second cyclone 350.

A third fine particle supplying pipe 353 is connected to the bottom of the second cyclone 350, for supplying the fine iron ore particles which are contained in the discharge gas of the second fluidized bed type furnace 320. Preferably, the third fine particle supplying pipe 353 should be extended down to the lower interior of the second fluidized bed type furnace 320.

A fourth fine particle supplying pipe 354 is connected to the third fine particle supplying pipe 353, for supplying the fine iron ore particles to the third fluidized bed type furnace 330. Preferably, the fourth fine particle supplying pipe 354 should be extended down to the lower interior of the third fluidized bed type furnace 330.

A second two-way valve 352 is installed at a connection portion between said third and fourth fine particle supplying pipes 353 and 354.

A first reducing gas supplying pipe 355 is connected to the second cyclone 350, for supplying the discharge gas as a reducing gas after its separation from the fine iron ore particles. The first reducing gas supplying pipe 355 is connected to the bottom of the first fluidized bed type furnace 310.

The third fine particle fluidized bed type furnace 330 is cylindrical, and a first gas dispersing plate 332 is installed in the lower portion of it. A third reducing gas supplying pipe 372 is connected to the bottom of the third fine particle fluidized bed type furnace 330, for supplying a reducing gas.

As shown in FIG. 3, in the case where the reducing apparatus of the present invention is connected to a melter-gasifier 380, the second and third reducing gas supplying pipes 371 and 372 should be preferably connected to the melter-gasifier 380 so as to use the discharge gas of the melter-gasifier 380 as a reducing gas.

A third discharging pipe 331 is connected to the side wall of the third fine particle fluidized bed type furnace 330, for discharging the reduced fine iron ore particles. Further, a second fine particle supplying pipe 342 is connected to the side wall of the third fine particle fluidized bed type furnace 330, for supplying the fine iron ore particles which have been captured by the first cyclone 340.

The top of the third fine particle fluidized bed type furnace 330 is connected through a third discharge gas discharging pipe 333 to the third cyclone 360.

A fifth fine particle supplying pipe 361 is connected to the lower portion of the third cyclone 360, for supplying the fine iron ore particles (which are contained in the discharge gas of the third fine particle fluidized bed type furnace 330) back to the third fine particle fluidized bed type furnace 330.

A fourth discharge gas discharging pipe 362 is connected to the top of the third cyclone 360, for discharging the discharge gas after its separation from the fine iron ore particles. The fourth discharge gas discharging pipe 362 is connected to the first reducing gas supplying pipe 355.

Meanwhile, the second and third reducing gas supplying pipes 371 and 372 should be preferably provided with first and second flow rate adjusting valves 375 and 377 respectively.

As shown in FIG. 3, in the case where the melter-gasifier 380 is installed, the second and third reducing gas supplying pipes 371 and 372 are connected to the top of the melter-gasifier 380, and are also connected to a fifth discharge gas discharging pipe 383 which discharges the discharge gas of the melter-gasifier 380. Further, a second discharging pipe 321 is connected to the melter-gasifier 380 for the circulation of the iron ore.

Further, a third discharging pipe 331 is connected to a melting furnace 335.

Oxygen (O_2) should be preferably supplied to the first, second and third reducing gas supplying pipes 355, 371 and 372.

In FIG. 3, reference code 381 indicates the molten iron, and 382 indicates the coal layer.

FIG. 4 illustrates still another example of the fluidized bed type reducing apparatus for reducing a fine iron ore according to the present invention.

As shown in FIG. 4, the fluidized bed type fine iron ore reducing apparatus 400 for reducing a fine iron ore of a wide particle size distribution according to the present invention includes: a first fluidized bed type furnace 410 for receiving a reducing gas through its bottom, and for receiving a fine iron ore through a charging hopper 405 and first charging pipe 401, to carry out a first reduction on only coarse/intermediate iron ores among fine iron ores of a wide particle size distribution by forming a bubble fluidizing bed, while making fine iron ore particles fly away; a second fine particle fluidized bed type furnace 420 with a wide top and a narrow bottom, for carrying out a first reduction on the fine iron ores discharged from the first fluidized bed type furnace, by forming a bubble fluidizing bed; a first cyclone 440 for capturing extremely fine iron ore particles elutriated from the second fluidized bed type furnace, and for discharging the final discharge gas after its separation from fine iron ore particles; a third fluidized bed type furnace 430 for carrying out a second reduction on the intermediate /coarse iron ore particles first-reduced by the first fluidized bed type furnace and on the fine iron ore particles first-reduced by the second fluidized bed type furnace, by forming a bubble fluidizing bed; and a second cyclone 450 for capturing an extremely fine iron ore contained in a discharge gas of the third fluidized bed type furnace 430, to supply a part of it back to the third fluidized bed type furnace 430, while discharging the discharge gas through the top after its separation from the fine iron ore particles.

A first gas supplying pipe 414 is connected to the bottom of the first fluidized bed type furnace 410, for supplying a reducing gas into the furnace 410, while a gas distributor 412 is installed in the lower portion of the furnace 410.

To the side wall of the first fluidized bed type furnace 410, there are connected: a first charging pipe 401 connected to a charging hopper for supplying a fine iron ore and a flux such as lime stone or the like into the fluidized bed; a first discharging pipe for discharging a first-reduced intermediate/coarse iron ores into the third fluidized bed type furnace 430; and a first circulating pipe 415 for supplying the elutriated fine iron ore particles to the second fluidized bed type furnace 420. The first circulating pipe 415 is disposed above the first discharging pipe 411.

The second fine particle fluidized bed type furnace 420 includes an expanded portion 420a, a tapered portion 420b and a narrow portion 420c, its top portion being wide and its bottom portion being narrow,

A second gas distributor 422 is installed within the narrow portion 420c, while a second reducing gas supplying pipe 427 is connected to the bottom of the second fluidized bed type furnace 420, for supplying the discharge gas of the third fluidized bed type furnace 430 as a reducing gas.

To the side wall of the narrow portion 420c above the second gas distributor 422, there is connected a second discharging pipe 421 for discharging the first-reduced fine iron ore particles. The second discharging pipe 421 extends into a narrow portion 430c of the third fluidized bed type furnace 430, and in this manner, the second and third fluidized bed type furnaces 420 and 430 communicate to each other for circulations of the iron ore.

To the side wall of the narrow portion 420c above the gas distributor 422, there is connected a first circulating pipe 415 for supplying into the second fine particle fluidized bed type furnace 420 the fine iron ore particles which have been elutriated from the first fluidized bed type furnace 410 and which have been captured by the first cyclone 440. The expanded portion 420a of the second fine particle fluidized bed type furnace 420 is connected through a first discharge gas discharging pipe 423 to the first cyclone 440.

Below the first cyclone 440, a second circulating pipe 441 communicates to the first circulating pipe 415. A second discharge gas discharging pipe 443 is connected to the top of the first cyclone 440, for discharging the discharge gas which has been separated from the fine iron ore particles.

The third fluidized bed type furnace 430 includes an expanded portion 430a, a tapered portion 430b and a narrow portion 430c, its top portion being wide and its bottom portion being narrow.

A gas distributor 432 is installed in the narrow portion 430c, while a third reducing gas supplying pipe 471 is connected to the bottom of the third fluidized bed type furnace 430, for supplying a reducing gas.

To the side wall of the narrow portion 430c above the gas distributor 432, there is connected a first discharging pipe 411, and thus, the first-reduced intermediate/coarse iron ores which are outputted from the first fluidized bed type furnace 410 are supplied to the third fluidized bed type furnace 430.

A fourth discharging pipe 431 is connected to the side wall of the third fluidized bed type furnace 430, so that the second-reduced iron of the third fluidized bed type furnace 430 can be discharged to the outside. Preferably, the fourth discharging pipe 431 should be connected through a screw conveyor 435 to the third fluidized bed type furnace 430, thereby discharging the reduced iron to the melter-gasifier 480.

The expanded portion 430a of the third fluidized bed type furnace 430 is connected through a third discharge gas discharging pipe 433 to the second cyclone 450.

A circulating pipe 451 is connected to the bottom of the second cyclone 450. This circulating pipe 451 is also connected to: a third circulating pipe 454 for circulating a part of the fine iron ore particles (contained in the discharge gas of the third fluidized bed type furnace 430) back to the third fluidized bed type furnace 430; and a third discharging pipe 455 for discharging the rest of the fine iron ore particles to the outside.

At the position where the circulating pipe 451, the third circulating pipe 454 and the third discharging pipe 455 are connected, there is installed a rotary gate 452 which feeds a part of the fine iron ore particles (captured by the second cyclone 450) into the third fluidized bed type furnace 430, and discharges the remaining part to the outside.

A fourth discharge gas discharging pipe 453 is connected to the top of the second cyclone 450, for discharging the discharge gas after its separation from the fine iron ore particles. The fourth discharge gas discharging pipe 453 communicates to a first reducing gas supplying pipe 414 of the first fluidized bed type furnace 410, and to a second reducing gas supplying pipe 427 of the second fine particle fluidized bed type furnace 420.

Meanwhile, it will be desirable to provide a gas reforming system 460, so that a part of the discharge gas of the first cyclone 440 can be reformed to circulate it to the first and second fluidized bed type furnaces 410 and 420.

In the case where the gas reforming system 460 is provided, it is made to communicate through a reformed gas supplying pipe 462 to the fourth discharge gas discharging pipe 453, and is also made to communicate through a discharge gas circulating pipe 461 to the second discharge gas discharging pipe 443.

Further, as shown in FIG. 4, the fluidized bed type reducing apparatus 400 according to the present invention should preferably include a melter-gasifier 480 which receives the second-reduced iron from the third fluidized bed type furnace 430 to melt-reduce it into a molten iron.

The melter-gasifier 480 is provided with a third cyclone 484, and this third cyclone 484 captures the fine iron ore particles from the discharge gas of the melter-gasifier 480 to circulate them back to the melter-gasifier 480. The discharge gas which has been separated from the fine iron ore particles is discharged through the top of the third cyclone 484.

The top of the melter-gasifier 480 is connected through a fifth discharge gas discharging pipe 481 to the third cyclone 484.

A fourth circulating pipe 482 is connected to the bottom of the third cyclone 484, so that the fine iron ore particles contained in the discharge gas of the melter-gasifier 480 can be circulated back to the melter-gasifier 480. A third reducing gas supplying pipe 436 is connected to the top of the third cyclone 484, for discharging the discharge gas. This third reducing gas supplying pipe 436 is connected to the bottom of the third fluidized bed type furnace 430, for supplying the discharge gas of the melter-gasifier 480 to the third furnace 430.

It is desirable to make the fourth circulating pipe 482 communicate to the third discharging pipe 455, so that a part of the fine iron ore particles of the second cyclone 450 can be charged into the lower portion of the melter-gasifier 480. The third fluidized bed type furnace 430 is connected through a fourth discharging pipe 431 to the melter-gasifier 480, for circulation of the iron ore.

Meanwhile, the height of the first fluidized bed type furnace 410 should be preferably 10-20 times as large as its own inner diameter. The reason is as follows. That is, if the height is less than 10 times, the fluidizing of the iron ore within the furnace cannot be efficient, and therefore, even the intermediate/coarse iron ore particles may fly into the second fluidized bed type furnace 420. On the other hand, if the height is more than 20 times, then the elutriation of the fine iron ore particles cannot be efficient.

Meanwhile, the inner diameters of the narrow portions 420c and 430c of the second and third fluidized bed type furnaces 420 and 430 are maintained at the inner diameters of the bottoms of the tapered portions 420b and 430b, while the inner diameters of the expanded portions 420a and 430a are maintained at the inner diameters of the tops of the tapered portions 420b and 430b.

The inner diameters of the expanded portions 420a and 430a should be preferably 1.5 - 2.0 times as large as the inner diameters of the narrow portions, so that the gas flow velocity within the furnaces can be decreased so as to inhibit the elutriation of the fine iron ore particles.

The overall heights of the second and third fluidized bed type furnaces 420 and 430 should be preferably 10 - 25 times as large as the inner diameters of the narrow portions, so that a sufficient fluidizing space can be secured, and that the elutriation of the fine iron ore particles can be inhibited. The heights of the narrow portions 420c and 430c should be preferably 1.0 - 1.5 times as large as the height of the expanded portions 420a and 430a.

Meanwhile, the inclination of the tapered portions 420b and 430b should be preferably 30 - 50° relative to the vertical line.

Now the method for manufacturing a reduced iron by using the fluidized bed type reducing apparatus according to the present invention will be described.

First the method will be described by referring to the fluidized bed type reducing apparatus of FIG. 2.

A fine iron ore is charged from the charging hopper 205 through the first charging pipe 201 into the first fluidized bed type furnace 210. Of this fine iron ore, the fine iron ore particles are flown away, while the intermediate/coarse iron ores are first-reduced by forming a bubble fluidizing bed within the first fluidized bed type furnace 210 by the action of the reducing gas which has been introduced through the first gas supplying pipe 253 and has passed through the first gas distributor 212.

The intermediate/coarse iron ores which have been first-reduced by the first fluidized bed type furnace 210 are supplied through the first discharging pipe 211 into the middle portion of the fluidized bed of the second fluidized bed type furnace 220 so as to be reduced for a second time by the reducing gas which has been supplied through the second gas supplying pipe 271.

In the second fluidized bed type furnace 220, the fine iron ore particles are flown loaded in the discharge gas like in the first fluidized bed type furnace 210.

Meanwhile, the fine iron ore particles which have been flown from the first and second fluidized bed type furnaces 210 and 220 are separated from the gas by the first and second cyclones 240 and 250. Then the fine iron ore particles are supplied through the first circulating pipe 241 and the second circulating pipe 251 into the third fine particle fluidized bed type furnace 230, and are reduced for a second time by the reducing gas which has been introduced through the third gas supplying pipe 272.

The extremely fine iron ore particles which have been flown loaded in the gas from the third fine particle fluidized bed type furnace 230 are separated from the gas by the third cyclone 260, and then, are circulated through the third circulating pipe 261 back to the third fine particle fluidized bed type furnace 230.

The reduced iron which has been reduced twice by the second and third fluidized bed type furnaces 220 and 230 is finally discharged through the second and third discharging pipes 221 and 231.

In the present invention as described above, the third fine particle fluidized bed type furnace 230 is provided as a fine iron ore reducing furnace for reducing the fine iron ore particles which have been discharged from the first and second cyclones 240 and 250. The cyclones have a sufficient fine particle capturing capability, and therefore, the dust content in the gas is greatly lowered, with the result that an effective treatment of the fine iron ore particles is rendered possible.

Meanwhile, the gas flow velocity within the first and second fluidized bed type furnaces 210 and 220 should be preferably 1.2 - 2.5 times as fast as the minimum fluidizing velocity of the iron ore particles which stay within the furnaces. In this manner, the separation of the fine iron ore particles from the intermediate/coarse particles can be efficiently carried out, as well as promoting their movements.

The gas flow velocity within the third fine particle fluidized bed type furnace 230 should be preferably 1.2 - 2.0 times as fast as the minimum fluidizing velocity of the iron ore particles which stay within the furnace.

Now the method for reducing a fine iron ore by using the apparatus according to the present invention will be described by referring to the fluidized bed type reducing apparatus 300 of FIG. 3.

The fine iron ore is charged into the first fluidized bed type furnace 310, and the reducing gas of the first furnace 310 is the discharge gases of the second and third fluidized bed type furnaces 320 and 330. Under this condition, if the target temperature of the first fluidized bed type furnace 310 cannot be attained by the discharge gases of the second and third fluidized bed type furnaces 320 and 330, then oxygen is injected to raise the temperature of the reducing gas, thereby adjusting the internal temperature of the first fluidized bed type furnace 310.

In the conical first fluidized bed type furnace 310, the coarse/intermediate iron ore particles are first-reduced by the reducing gas incoming through the first reducing gas supplying pipe 355, but also a degradation phenomenon occurs, thereby steeply increasing the content of the fine iron ore particles. Such large amounts of fine particles are captured by the first cyclone 340.

At the initial stage of the operation, the first two-way valve 341 is opened toward the first fluidized bed type furnace 310, so that the fine particles of the first cyclone 340 can be recycled. However, upon reaching the normal operation stage with a constant height of the fluidizing bed, the first two-way valve 341 is opened toward the third fine particle fluidized bed type furnace 330 to feed the fine particles into the third fluidized bed type furnace 330. In this manner, the fine iron ore particles are treated without recycling them when they are steadily outputted from the first fluidized bed type furnace 310. Thus the load of the first cyclone 340 is alleviated, so that it can show a good efficiency.

The discharge gas which has been separated from the fine iron ore particles by the first cyclone 340 is scrubbed to remove the dusts by the help of a wet type dust remover 390.

Meanwhile, the first-reduced intermediate/coarse iron ore ores which have not been flown away at the first fluidized bed type furnace 310 are supplied to the second fluidized bed type furnace 320 so as to be finally reduced. Under this condition, if the reducing gas does not attain to the target temperature at the second fluidized bed type furnace 320, then oxygen is injected to adjust the temperature of the second fluidized bed type furnace 320.

The fine iron ore particles which are contained in the discharge gas of the second fluidized bed type furnace 320 are captured by the second cyclone 350, and are circulated by opening a second two-way valve 352 toward the second fluidized bed type furnace 320 at the initial operation stage. However, at the normal operation stage at which the fluidizing bed maintains a constant height within the furnace, the second two-way valve 352 is opened toward the third fine particle fluidized bed type furnace 330, so that the pre-reduced fine iron ore particles can be supplied to the third fluidized bed type furnace 330. That is, the reduced fine iron ore particles are not circulated to the second fluidized bed type furnace 320, and thus, the fine iron ore particle capturing capability of the second cyclone 350 is improved, thereby making it possible to efficiently remove the fine particles from the discharge gas. Meanwhile, the intermediate/coarse iron ores which have not been flown away at the second fluidized bed type furnace 320 are finally reduced and outputted to the melter-gasifier 380 by which they are melt-reduced into a pig iron.

Meanwhile, the fine iron ore particles which have been captured by the first and second cyclones 340 and 350 and which have been supplied into the third fine particle fluidized bed type furnace 330 are finally reduced by the discharge gas of the melter-gasifier 380, which is supplied through the third reducing gas supplying pipe 372. If this reducing gas (discharge gas) does not attain to the target temperature, then oxygen is injected to raise the temperature, thereby adjusting the temperature of the third fluidized bed type furnace 330.

The fine particles which are contained in the discharge gas of the third fluidized bed type furnace 330 are captured by the third cyclone 360 to be circulated to the third fluidized bed type furnace 330. The reduced fine iron particles which are discharged from the third fine particle fluidized bed type furnace 330 are supplied into the melter-gasifier 380 together with oxygen by the help of the melting burner 335. Thus they are not flown away from the melter-gasifier 380, but are dropped to be manufactured into a molten pig iron.

The discharge gas (to be used as a reducing gas) of the melter-gasifier 380 is distributed to the second and third fluidized bed type furnaces 320 and 330, while the flow rates of this discharge gas are adjusted by the flow rate adjusting valves 375 and 377.

Meanwhile, the gas flow velocity within the first and second fluidized bed type furnaces 310 and 320 should be preferably 1.5 - 1.7 times as fast as the minimum fluidizing velocity of the iron ore particles which stay within the furnaces. In this manner, the reduction of the particles can be efficiently carried out, as well as promoting their movements.

The gas flow velocity within the third fluidized bed type furnace 330 should be preferably 1.3 - 1.5 times as fast as the minimum fluidizing velocity of the iron ore particles which stay within the furnace, this velocity range being the optimum velocity of the bubble fluidizing bed.

Further, the internal reducing gas temperature of the fluidized bed of the first fluidized bed type furnace 310 should be preferably 750 - 800°C for an efficient iron ore reduction. The reducing gas temperature of the fluidized bed of the second and third fluidized bed type furnace 320 and 330 should be preferably 840 - 860°C.

As described above, when the first and second fluidized bed type furnaces 310 and 320 enter into the normal operation stage with a constant height of the fine iron ore fluidized bed, the first and second two-way valves are opened toward the third fine particle fluidized bed type furnace 330. Accordingly, the fine particle capturing capabilities of the first and second cyclones 340 and 350 are maintained at superior level, and therefore, a low content of the fine particles within the discharge gas is realized, thereby making it possible to efficiently treat the fine iron ore.

Now the method for reducing a fine iron ore by using the apparatus of FIG. 4 according to the present invention will be described.

Of the iron ores which have been supplied from the charging hopper 405 through the first charging pipe 401 into the first fluidized bed type furnace 410, the fine iron ore particles are flown away, while the intermediate /coarse iron ore particles are reduced for a first time by a reducing gas (incoming through the bottom of the furnace) by forming a bubble fluidizing bed.

The fine iron ore particles which have been flown from the first fluidized bed type furnace 410 are supplied through the first circulating pipe 415 into the second fine particle fluidized bed type furnace 420. This fine particles form a bubble fluidizing bed together with the reducing gas incoming through the bottom of the furnace, so as to be reduced for a first time. Meanwhile, the extremely fine iron ore particles which have been flown contained in the discharge gas of the second fine particle fluidized bed type furnace 420 are separated from the discharge gas by the first cyclone 440, and are circulated through the second and first circulating pipes 441 and 415 to the second fine particle fluidized bed type furnace 420.

Meanwhile, a part of the discharge gas which has been separated from the iron ore particles by the first cyclone 440 is finally discharged through the second discharge gas discharging pipe 443 to the outside, while the rest is circulated through the discharge gas circulating pipe 461 to the gas reforming system 460 depending on needs. After being reformed, the gas is supplied through the reformed gas supplying pipe 462 to the first and second fluidized bed type furnaces 410 and 420.

The iron ores which have been reduced for a first time by the first and second fluidized bed type furnaces 410 and 420 are supplied through the first and second discharging pipes 411 and 421 to the third fluidized bed type furnace

430 so as to be reduced for a second time by a reducing gas by forming a bubble fluidizing bed.

The extremely fine iron ore particles which have been flown contained in the discharge gas of the third fluidized bed type furnace 430 are separated from the discharge gas by the second cyclone 450. A part of them is circulated through the circulating pipe 451, the rotary gate 452 and the third circulating pipe 454 to the third fluidized bed type furnace 430, while the rest of them are supplied through the circulating pipe 451, the rotary gate 452, the third discharging pipe 455 and the fourth circulating pipe 482 to the melter-gasifier 480 or the outside.

Meanwhile, the discharge gas which has been separated from the fine iron ore particles by the second cyclone 450 is supplied as a reducing gas through the fourth discharge gas discharging pipe 453 to the first and second fluidized bed type furnaces 410 and 420 to form a fluidizing bed there.

The iron ore which has been reduced for a second time by the third fluidized bed type furnace 430 is either discharged through the fourth discharging pipe 431 to the outside, or is supplied to the melter-gasifier 480 to be melted so as to be manufactured into a pig iron.

The extremely fine iron ore particles which have been flown contained in the discharge gas of the melter-gasifier 480 are separated from the discharge gas by the third cyclone 484 to be circulated through the fourth circulating pipe 482 back to the melter-gasifier 480. The discharge gas which has been separated from the fine iron ore particles is supplied through the third reducing gas supplying pipe 436 to the third fluidized bed type furnace 430 as a reducing and fluidizing gas.

Meanwhile, the gas flow velocity within the first fluidized bed type furnace 410 should be preferably 1.2 - 3.5 times as fast as the minimum fluidizing velocity of the iron ore particles which stay within the furnace. In this manner, the reduction of the intermediate/coarse particles can be efficiently carried out, as well as promoting their movements.

The gas flow velocity within the second and third fluidized bed type furnaces 420 and 430 should be preferably 1.2 - 2.5 times as fast as the minimum fluidizing velocity of the iron ore particles which stay within the furnaces.

In the case where the reduced iron is manufactured by using the apparatus of the present invention, the intermediate/coarse iron ore particles which have been first-reduced by the first fluidized bed type furnace 410 are supplied into the third fluidized bed type furnace 430 through the first discharging pipe 411 which extends to the middle level of the fluidizing bed of the third fluidized bed type furnace 430. The fine iron ore particles which have been first-reduced by the second fluidized bed type furnace 420 are supplied to the third fluidized bed type furnace 430 through the second discharging pipe 421 which extends to the bottom of the fluidizing bed of the third fluidized bed type furnace 430. That is, the supplying positions of the fine and intermediate/coarse iron ore particles are different. The reason for this is as follows. If the fine iron ore particles are supplied to a position same as that of the intermediate/coarse particles, then they cannot have a sufficient staying time within the third fluidized bed type furnace 430, but can be flown away. Therefore, the supplying position for the fine iron ore particles is made lower than that of the intermediate /coarse iron ore particles, so that the fine iron particles can have a sufficient staying time for a second reduction.

Further, in the apparatus of the present invention, the intermediate/coarse iron ore particles which have been second-reduced by the third fluidized bed type furnace 430 are transferred to the screw conveyor 435 which is disposed below the third fluidized bed type furnace 430, so as to be supplied through the fourth discharging pipe 431 to the melter-gasifier 480. Further, the fine iron ore particles which have been second-reduced by the third fluidized bed type furnace 430 and flown therefrom are separated from the discharge gas by the second cyclone 450. A part of them is circulated to the third fluidized bed type furnace 430, while the rest are supplied through the third discharging pipe 455 to the melter-gasifier 480. The third discharging pipe 455 is connected to the fourth circulating pipe 482 which circulates the fine iron ore particles (which have been flown from the melter-gasifier 480 and captured by the third cyclone 484) back to the melter-gasifier 480.

In the present invention as described above, the fine iron ore particles and the intermediate/coarse iron ore particles are separately reduced, and they are charged separately. Therefore, the fine particle capturing capabilities of the cyclones are improved, thereby minimizing the elutriation loss of the fine iron ore particles.

FIGs. 2, 3 and 4 illustrate two-stage fluidized bed type reducing apparatuses, but the present invention is not limited to the two-stage apparatus, but can cover a three-stage apparatus and multi-stage apparatuses.

Now the present invention will be described based on actual examples.

<Example 1>

The pre-reducing apparatus of FIG. 2 was used, and the sizes of the fluidized bed type furnaces were as shown in Table 1. The chemical composition and the particle size distribution were as shown in Tables 2 and 3, and the conditions of Tables 4 and 5 were adopted in carrying out the reducing experiments.

<Table 1> Inner diameters and heights of the fluidized bed type furnaces

Furnace	Size
First Furnace	Inner diameter: 0.5 m Height: 5.0 m (above the gas distributor)
Second furnace	Inner diameter: 0.5 m Height: 5.0 m (above the gas distributor)
Third furnace	ID of narrow portion: 0.3 m ID of expanded portion: 0.6 m Height of narrow portion: 3 m (above the distributor) Height of expanded portion: 3 m (from bottom of tapered portion)

<Table 2> Chemical composition of raw iron ore

Ingredient	T.Fe	FeO	SiO_2	Al_2O_3	Mn	S	P	Moisture
wt%	63.49	0.37	4.32	2.33	0.05	0.007	0.063	5.41

<Table 3> Particle size distribution of raw iron ore

P size (mm)	<0.125	0.25-0.125	0.5-0.25	1-0.5	3-1	5-3	5-8	8-10
wt%	14.5	10.0	9.1	9.2	22.2	17.5	10.4	7.1

<Table 4> Conditions of reducing gas

Gas composition	CO: 65%, CO_2: 5%, H_2: 25%, N_2: 5%
Temperature	750 - 850°C
Pressure	1.5 - 2.0 Kgf/cm^2

<Table 5> Gas flow within the fluidized bed type furnaces

Furnace	Magnitude
First furnace	Flow velocity: 2.5 m/s
Second furnace	Flow velocity: 2.5 m/s
Third furnace	Flow velocity in narrow portn: 0.4 m/s Flow velocity in expanded portn: 0.1 m/s

Reduction experiments were carried out at the conditions of the above tables. Then it was found that the reduced iron began to be discharged at 60 minutes after the charging of the iron ore from the hopper into the first fluidized bed type furnace. In the case of the intermediate /coarse iron ores at the second fluidized bed type furnace, the average reduction rate was 88 - 92%. At the third fine particle fluidized bed type furnace, the average reduction rate was 86 - 90%. The average gas utilization rate was 30 - 35%, and the gas consumption rate was 1350 - 1500 Nm^3/t-ore, while the elutriation rate was less than 5%. Thus a good result was obtained.

<Example 2>

A reduction experiment was carried out by using the reducing apparatus of FIG. 3 having dimensions as entered below. Then the elutriation rate and the dust content in the discharge gas were measured, and the results are shown in Table 6 below.

1) Dimensions and conditions of the reducing apparatus

A. Conical first and second fluidized bed type furnaces

- ID of narrow portion: 0.3 m
- ID of expanded portion: 0.7 m
- Conical angle: 4 degrees
- Height of tapered portion: 4.0 m
- Height of cylindrical portion: 2.5 m
- Flow velocity: 1.2 m/s
- Pressure: 1.8 Kgf/cm^2 (first furnace),
  2.0 Kgf/cm^2 (second furnace)

B. Third fine particle fluidized bed type furnace

- ID: 0.25 m
- Height (above gas distributor): 2 m
- Flow velocity: 0.2 m/s
- Pressure: 2.0 Kgf/cm^2

C. Raw materials

a. Fine iron ore (-8 mm)

- Chemical composition: 62.17% of T.Fe, 0.51% of

FeO, 5.5% of SiO_2, 0.11% of TiO_2, 0.05% of Mn, 0.012% of S, 0.65% of P, and 2.32% of crystalline water

- Particle size distribution: -0.05 mm: 4.6%, 0.05-0.15 mm: 5.4%, 0.15-0.5 mm: 16.8%, 0.5-4.75 mm: 59.4%, and 4.75-8 mm: 13.8%.

b. Gas

- Chemical composition: 65% of CO, 25% of H_2, 5% of CO_2, and 5% of N_2

- Gas temperature: second and third furnaces: 850°C, and first furnace: 780°C

<Table 6>

	Conditions	Dust content in gas (g/Nm^3)	elutriation rate (%)
Exp 1	Not via third furnace	2.5	0.41
Exp 2	Via third furnace	0.7	0.11

In the above experiments, it was found that the dust content was greatly decreased by passing through the third fine particle fluidized bed type furnace, thereby drastically reducing the elutriation loss of the iron ore particles. The gas utilization rate was 30 - 35%, and the gas consumption rate was 1300 - 1500 Nm^3/ton-ore. The iron ore particles which were supplied from the conical first fluidized bed type furnace to the conical second fluidized bed type furnace showed a reduction rate of 30 - 40%, while the reduced iron particles which were supplied from the second fluidized bed type furnace to the melter-gasifier showed a reduction rate of 80 - 85%. The fine iron particles which were discharged from the third fluidized bed type furnace showed a reduction rate as high as about 90%. Thus it was seen that the reduction rate was further improved by employing the third fluidized bed type furnace.

<Example 3>

In manufacturing a reduced iron, there was used the reducing apparatus of FIG. 4 with the sizes of Table 7. The chemical composition and the particle size distribution were as shown in Tables 8 and 9, while the reducing conditions were as shown in Tables 10 and 11.

<Table 7> Inner diameters and heights of the fluidized bed type furnaces

Furnace	Size
First Furnace	Inner diameter: 0.2 m Height: 4.0 m
Second furnace	ID of narrow portion: 0.4 m ID of expanded portion: 0.8 m Height of narrow portion: 3.5 m (above the gas distreibutor) Height of expanded portion: 3.5 m (from bottom of tapered portion)
Third furnace	ID of narrow portion: 0.3 m ID of expanded portion: 0.6 m Height of narrow portion: 3 m (above the dispersing plate) Height of expanded portion: 3 m (from bottom of tapered portion)

<Table 8> Chemical composition of raw iron ore

Ingredient	T.Fe	FeO	SiO_2	Al_2O_3	Mn	S	P	Moisture
wt%	63.49	0.37	4.32	2.33	0.05	0.007	0.063	5.41

<Table 9> Particle size distribution of raw iron ore

Pl size (mm)	<0.125	0.25-0.125	0.5-0.25	1-0.5	3-1	5-3	8-5
wt%	15.0	10.2	10.1	10.2	23.9	18.6	12.0

<Table 10> Conditions of reducing gas

Gas composition	CO: 65%, CO_2: 5%, H_2: 25%, N_2: 5%
Temperature	750 - 850°C
Pressure	1.5 - 2.0 Kgf/cm^2

<Table 11> Gas flow within fluidized bed type furnaces

Furnace	Magnitude
First furnace	Flow velocity: 4.0 m/s
Second furnace	Velocity in narrow portion: 0.4 m/s Velocity in expanded portion: 0.1 m/s
Third furnace	Velocity in narrow portion: 2.0 m/s Velocity in expanded portion: 0.5 m/s

Reduction experiments were carried out at the conditions of the above tables. Then it was found that the reduced iron began to be discharged at 60 minutes after the charging of the iron ore from the hopper into the first fluidized bed type furnace. The average reduction rate was 88 - 92% regardless of the particle sizes. The average gas utilization rate was 30 - 32%, and the gas consumption rate was 1300 - 1400 Nm^3/t-ore, while the flielutriation rate was less than 5%. Thus a good result was obtained.

According to the present invention as described above, the fine iron ore particles and the intermediate/coarse iron ore particles are separately reduced, and therefore, the fine particle treating loads of the cyclones are alleviated, thereby improving the fine particle removing capabilities. Therefore, a fine iron ore having a wide particle size distribution can be reduced more efficiently with a less elutriation loss.

WHAT IS CLAIMED IS:

1. A fluidized bed type reducing apparatus for pre-reducing a fine iron ore with a wide particle size distribution, comprising:

a first fluidized bed type furnace 210 for carrying out a first reduction on only coarse/intermediate iron ores among fine iron ores of a wide particle size distribution by forming a bubble fluidizing bed after their charge from a charging hopper 205, while making fine iron ore particles fly away;

a second fluidized bed type furnace 220 for carrying out a second reduction on the coarse/intermediate iron ores first-reduced by said first fluidized bed type furnace 210 by forming a bubble fluidizing bed;

a first cyclone 240 for capturing the fine iron ore particles from a discharge gas discharged from said first fluidized bed type furnace 210;

a second cyclone 250 for capturing the fine iron ore particles from a discharge gas discharged from said second fluidized bed type furnace 220;

a third fine particle fluidized bed type furnace 230 for carrying out a second reduction on the fine iron ore particles discharged from said first and second cyclones 240 and 250 by forming a bubble fluidizing bed;

a third cyclone 260 for capturing extremely fine iron ore particles from a discharge gas of said third fine particle fluidized bed type furnace 230 to circulate them back to said third fluidized bed type furnace 230;

said first fluidized bed type furnace 210 being cylindrical; a first gas distributor 212 being installed in a lower portion of it; a first reducing gas supplying pipe 253 being connected to a bottom of said first fluidized bed type furnace 210, for supplying the discharge gas of said second fluidized bed type furnace 220 to use the gas as a reducing gas; a first charging pipe 201 being connected to a side wall of said first fluidized bed type furnace 210, for supplying a fine iron ore from said charging hopper 205 to said first fluidized bed type furnace 210; and a first discharging pipe 211 being connected to a side wall of said first furnace 210, for discharging first-reduced intermediate/coarse iron ore particles;

said first cyclone 240 being connected through a first discharger gas discharging pipe 213 to a top of said first fluidized bed type furnace 210; a first circulating pipe 241 being connected to a bottom of said first cyclone 240, for circulating the fine iron ore particles of the discharge gas of said first fluidized bed type furnace 210 to said third fine particle fluidized bed type furnace 230; and a fourth discharge gas discharging pipe 243 being connected to a top of said first cyclone 240, for discharging a discharge gas after its separation from the fine iron ore particles;

said second fluidized bed type furnace 220 being cylindrical, with a second gas distributor 222 being installed within a lower portion of it; a second reducing gas supplying pipe 271 being connected to a bottom of said second fluidized bed type furnace 220, for supplying a reducing gas; a first discharging pipe 211 being connected to said first fluidized bed type furnace 210, for discharging a first-reduced intermediate/coarse iron ore particles to said second fluidized bed type furnace 220; and a second discharging pipe 221 being connected to said first fluidized bed type furnace 210, for discharging second-reduced intermediate/coarse iron ore particles;

said second cyclone 250 being connected through a second discharge gas discharging pipe 223 to a top of said second fluidized bed type furnace 220; a second circulating pipe 251 being connected to a bottom of said first cyclone 240, for circulating the fine iron ore particles of the discharge gas of said second fluidized bed type furnace 220 to said third fine particle fluidized bed type furnace 230; and a first gas supplying pipe 253 being connected to a top of said first cyclone 240, for supplying the discharge gas to said first fluidized bed type furnace 210 after its separation from the fine iron ore particles;

said third fine particle fluidized bed type furnace 230 comprising an expanded portion 230a, a tapered portion 230b and a narrow portion 230c; a third gas distributor 232 being installed within a lower portion of said narrow portion 230c; a third reducing gas supplying pipe 272 being connected to a bottom of said third fluidized bed type furnace 230, for supplying a reducing gas; and a third discharging pipe 231 being connected to a side wall of said narrow portion 230c above said third gas distributor 232, for discharging reduced fine iron ore particles from said third fluidized bed type furnace 230; and

said expanded portion 230a of said third fine particle fluidized bed type furnace 230 being connected through a third discharge gas discharging pipe 233 to said third cyclone 260; a third circulating pipe 261 being connected to a bottom of said third cyclone 260, for circulating the fine iron ore particles of the discharge gas of said third fine particle fluidized bed type furnace 230 back to said third fluidized bed type furnace 230; and a fifth discharge gas discharging pipe 263 being connected to a top of said third cyclone 260, for discharging the discharge gas after its separation from the fine iron ore particles.

2. The fluidized bed type reducing apparatus as claimed in claim 1, wherein said second circulating pipe 251 communicates to said first circulating pipe 241, and said fifth discharge gas discharging pipe 263 is connected to said fourth discharge gas discharging pipe 243.

3. The fluidized bed type reducing apparatus as claimed in any one of claims 1 and 2, wherein said first and second fluidized bed type furnaces 210 and 220 have heights 10 - 15 times as large as their inner diameters; said narrow portion 230c of said third fluidized bed type furnace 230 has an inner diameter same as that of a bottom of said tapered portion 230b; said expanded portion 230a has an inner diameter same as that of a top of said tapered portion 230b, and has an inner diameter 1.5 - 2.0 times as large as that of said narrow portion; said third fluidized bed type furnace 230 has an overall height 10 - 20 times as large as the inner diameter of said narrow portion; said narrow portion 230c has a height 1.0 - 1.5 times as large as that of said expanded portion 230a; and said tapered portion 230b has an inclination angle of 30 - 50° relative to a vertical line.

4. A method for reducing a fine iron ore having a wide particle size distribution by using a fluidized bed type reducing apparatus, comprising the steps of:

carrying out a first reduction by a first fluidized bed type furnace 210 on only coarse/intermediate iron ores among fine iron ores of a wide particle size distribution by forming a bubble fluidizing bed after their charge from a charging hopper 205, while making fine iron ore particles fly away;

carrying out a second reduction by a second fluidized bed type furnace 220 on the coarse/intermediate iron ores after first-reduced by said first fluidized bed type furnace 210, by forming a bubble fluidizing bed;

capturing by a first cyclone 240 and by a second cyclone 250 the fine iron ore particles from a discharge gas discharged from said first fluidized bed type furnace 220 and said second fluidized bed type furnace 230; and

carrying out by a third fine particle fluidized bed type furnace 230 a second reduction on the fine iron ore particles discharged from said first and second cyclones 240 and 250 by forming a bubble fluidizing bed, and for capturing by a third cyclone 260 extremely fine iron ore particles from a discharge gas of said third fluidized bed type furnace 230 to circulate them back to said third fluidized bed type furnace 230;

characterized in that:

a gas flow velocities within said first and second fluidized bed type furnaces 210 and 220 are 1.2 - 2.5 times as fast as a minimum fluidizing velocity of an iron ore staying within said furnace; and

gas flow velocities within said third fluidized bed type furnace 230 is 1.2 - 2.0 times as fast as a minimum fluidizing velocities of iron ores staying within said furnaces.

5. A fluidized bed type reducing apparatus for pre-reducing a fine iron ore with a wide particle size distribution, comprising:

a first fluidized bed type furnace 310 for carrying out a first reduction on only coarse/intermediate iron ores among fine iron ores of a wide particle size distribution by forming a bubble fluidizing bed after their charge from a charging hopper, while making fine iron ore particles fly away;

a second fluidized bed type furnace 320 for carrying out a second reduction on the coarse/intermediate iron ores after first-reduced by said first fluidized bed type furnace 310, by forming a bubble fluidizing bed;

a first cyclone 340 for capturing the fine iron ore particles from a discharge gas discharged from said first fluidized bed type furnace 310;

a second cyclone 350 for capturing the fine iron ore particles from a discharge gas discharged from said second fluidized bed type furnace 320;

a third fine particle fluidized bed type furnace 330 for carrying out a second reduction on the fine iron ore particles discharged from said first and second cyclones 340 and 350 by forming a bubble fluidizing bed;

a third cyclone 360 for capturing extremely fine iron ore particles from a discharge gas of said third fluidized bed type furnace 330 to circulate them back to said third fluidized bed type furnace 330;

said first fluidized bed type furnace 310 being cylindrical; a first gas distributor 312 being installed within a lower portion of it; a first reducing gas supplying pipe 355 being connected to a bottom of said first fluidized bed type furnace 310, for supplying the discharge gases of said second and third fluidized bed type furnace 320 and 330 to use the gases as reducing gases; a first charging pipe 301 being connected to a side wall of said first fluidized bed type furnace 310, for supplying a fine iron ore and a flux such as lime stone to said first fluidized bed type furnace 310; and a first discharging pipe 311 being connected to a side wall of said first furnace 310, for discharging the first-reduced intermediate/coarse iron ore particles to said second fluidized bed type furnace 320;

said first cyclone 340 being connected through a first discharge gas discharging pipe 313 to a top of said first fluidized bed type furnace 310;

a first fine iron ore particle supplying pipe 343 being connected to a bottom of said first cyclone 340, for circulating the fine iron ore particles of the discharge gas of said first fluidized bed type furnace 310 back to said first fluidized bed type furnace 310; a second fine iron ore particle supplying pipe 342 being connected to said first fine iron ore particle supplying pipe 343, for supplying the fine iron ore particles to said third fluidized bed type furnace 330; a first two-way valve 341 being to connected to a connecting portion between said first and second fine iron ore particle supplying pipes 343 and 342; a sixth discharge gas discharging pipe 344 being connected to a top of said first cyclone 340, for discharging a discharge gas after its separation from the fine iron ore particles; and said sixth discharge gas discharging pipe 344 communicating to a wet type dust remover 390;

said second fluidized bed type furnace 320 being cylindrical, with a second gas distributor 322 being installed within a lower portion of it; a second reducing gas supplying pipe 371 being connected to a bottom of said second fluidized bed type furnace 320, for supplying a reducing gas; a first discharging pipe 311 being connected to a side wall above said second gas distributor 322, for supplying the intermediate/coarse iron ore particles first-reduced by said first fluidized bed type furnace 310; and a second discharging pipe 321 being connected to a side wall above said second gas distributor 322, for discharging a second-reduced intermediate/coarse iron ore;

said second cyclone 350 being connected through a second discharge gas discharging pipe 323 to a top of said second fluidized bed type furnace 220;

a third fine particle supplying pipe 353 being connected to a bottom of said second cyclone 350, for supplying the fine iron ore particles of a discharge gas of said second fluidized bed type furnace 320 back to said second fluidized bed type furnace 320; a fourth fine particle supplying pipe 354 being connected to said third fine particle supplying pipe 353, for supplying the fine iron ore particles to said third fluidized bed type furnace 330; and a second two-way valve 352 being installed at a connection portion between said third and fourth fine particle supplying pipes 353 and 354;

said third fluidized bed type furnace 330 being cylindrical; a third gas distributor 332 being installed within a lower portion of said third furnace 330; a third reducing gas supplying pipe 372 being connected to a bottom of said third fluidized bed type furnace 330, for supplying a reducing gas; and a third discharging pipe 331 being connected to a side wall above said third gas distributor 332, for discharging reduced fine iron ore particles; and

a top of said third fine particle fluidized bed type furnace 330 being connected through a third discharge gas discharging pipe 333 to said third cyclone 360; a fifth fine particle supplying pipe 361 being connected to a bottom of said third cyclone 360, for supplying fine iron ore particles of a discharge gas of said third fluidized bed type furnace 330 back to said third fluidized bed type furnace 330; a fifth discharge gas discharging pipe 362 being connected to a top of said third cyclone 360, for discharging the discharge gas after its separation from the fine iron ore particles; and said fifth discharge gas discharging pipe 362 communicating to said first reducing gas supplying pipe 355.

6. The fluidized bed type reducing apparatus as claimed in claim 5, wherein said second and third reducing gas supplying pipes 371 and 372 are provided with first and second flow rate adjusting valves 375 and 377 respectively.

7. The fluidized bed type reducing apparatus as claimed in any one of claims 5 and 6, wherein said first and second fine iron ore particle supplying pipes 343 and 353 extend into lower portions of said first and second fluidized bed type furnace 310 and 320 respectively.

8. A method for reducing a fine iron ore by using a fluidized bed type reducing apparatus of claims 5 to 7, comprising the steps of:

carrying out a first reduction on coarse/intermediate iron ore particles among the fine iron ore charged into a first fluidized bed type furnace 310 by using discharge gases of second and third fluidized bed type furnaces 320 and 330; recirculating fine iron ore particles of a first cyclone 340 by opening a two-way valve 341 toward said first fluidized bed type furnace 310 at an initial stage; and opening said first two-way valve 341 toward said third fluidized bed type furnace 330 upon reaching a normal operation stage with a constant fluidizing height, so as to charge the fine iron ore particles into said third fluidized bed type furnace 330;

carrying out a final reduction on the coarse/intermediate iron ore particles by using a reducing gas incoming through a bottom of said furnace after the first reduction by said first fluidized bed type furnace 310; opening a second two-way valve 352 toward said second fluidized bed type furnace 320 to circulate fine iron ore particles after their capture by said second cyclone 350 back to the said second fluidized bed type furnace 320 at an initial stage; and opening said second two-way valve 352 toward said third fluidized bed type furnace 330 upon reaching a normal operation stage with a constant fluidizing height, so as to charge the reduced fine iron ore particles into said third fluidized bed type furnace 330; and

carrying out a final reduction on the pre-reduced fine iron ore particles of said third fluidized bed type furnace 330 after their charge into said furnace 330 after being captured by said first and second cyclones 340 and 350.

9. The method as claimed in claim 8, wherein said first and second two-way valves 341 and 352 are interlockedly opened/closed so as to charge the pre-reduced fine iron ore into said third fluidized bed type furnace 330.

10. The method as claimed in any one of claims 8 and 9, wherein reduced fine ore particles discharged from said third fluidized bed type furnace 330 are fed into said melter-gasifier 380 by said melting burner 335; and intermediate/coarse iron ore particles discharged from said second fluidized bed type furnace 320 are also charged int said melter-gasifier 380.

11. The method as claimed in any one of claims 8 and 9, wherein gas flow velocities within said first and second fluidized bed type furnaces 310 and 320 are 1.5 - 1.7 times as fast as a minimum fluidizing velocity of an iron ore staying within said furnaces; and

a gas flow velocity within said third fluidized bed type furnace 130 is 1.3 - 1.5 times as fast as a minimum fluidizing velocity of an iron ore staying within said furnace.

12. The method as claimed in claim 11, wherein a reducing gas temperature within the fluidizing layer of said first fluidized bed type furnace 310 is controlled to a range of 750 - 800°C, and reducing gas temperatures within the fluidizing layers of said second and third fluidized bed type furnaces 320 and 330 are controlled to a range of 840 - 860°C.

13. The method as claimed in claim 10, wherein gas flow velocities within said first and second fluidized bed type furnaces 310 and 320 are 1.5 - 1.7 times as fast as a minimum fluidizing velocity of an iron ore staying within said furnaces;

a gas flow velocity within said third fluidized bed type furnace 130 is 1.3 - 1.5 times as fast as a minimum fluidizing velocity of an iron ore staying within said furnace;

a reducing gas temperature within the fluidizing layer of said first fluidized bed type furnace 310 is controlled to a range of 750 - 800°C; and

reducing gas temperatures within the fluidizing layers of said second and third fluidized bed type furnaces 320 and 330 are controlled to a range of 840 - 860°C.

14. A fluidized bed type reducing apparatus for pre-reducing a fine iron ore with a wide particle size distribution, comprising:

a first fluidized bed type furnace 410 for receiving a reducing gas through its bottom, and for receiving a fine iron ore through a charging hopper 405 and a first charging pipe 401, to carry out a first reduction on only coarse/intermediate iron ores among fine iron ores by forming a bubble fluidizing bed, while making fine iron ore particles fly away;

a second fine particle fluidized bed type furnace 420 with a wide top and a narrow bottom, for carrying out a first reduction on the fine iron ore particles discharged from said first fluidized bed type furnace, by forming a bubble fluidizing bed;

a third fluidized bed type furnace 430 for carrying out a second reduction on the intermediate/coarse iron ore particles first-reduced by the first fluidized bed type furnace and on the fine iron ore particles first-reduced by the second fluidized bed type furnace, by forming a bubble fluidizing bed;

a first cyclone 440 for capturing the extremely fine iron ore particles contained in a discharge gas of the second fluidized bed type furnace 420, and for supplying them back to the second fluidized bed type furnace 420;

a second cyclone 450 for capturing an extremely fine iron ore contained in a discharge gas of said third fluidized bed type furnace 430, to supply a part of it back to said third fluidized bed type furnace 430, while discharging a remaining part, and discharging the discharge gas through its top after its separation from the fine iron ore particles;

said first fluidized bed type furnace 410 being cylindrical; a first gas distributor 412 being installed within a lower portion of said first fluidized bed type furnace 410; a first gas supplying pipe 414 being connected to a bottom of said first fluidized bed type furnace 410, for supplying a reducing gas into said furnace 410; a first charging pipe 401 being connected to a side wall of said first fluidized bed type furnace 410, for supplying a fine iron ore and a flux such as lime stone into said first fluidized bed type furnace 410; a first discharging pipe 411 being connected to the side wall of said first fluidized bed type furnace 410, for discharging first-reduced intermediate/coarse iron ore particles into said third fluidized bed type furnace 430; and a first circulating pipe 415 being connected to a side wall of said first fluidized bed type furnace 410 above said first discharging pipe 411, for supplying the elutriated iron ore particles to said second fluidized bed type furnace 420;

said second fine particle fluidized bed type furnace 420 having a wide top portion and a narrow bottom portion, and including an expanded portion 420a, a tapered portion 420b and a narrow portion 420c; a second gas distributor 422 being installed within the narrow portion 420c; and a second reducing gas supplying pipe 427 being connected to a bottom of said second fluidized bed type furnace 420, for supplying a discharge gas of said third fluidized bed type furnace 430 as a reducing gas;

a second discharging pipe 421 being connected to a side wall of said narrow portion 420c above said second gas distributor 422, for discharging the first-reduced fine iron ore particles; said second discharging pipe 421 extending into a narrow portion 430c of said third fluidized bed type furnace 430, and in this manner, said second and third fluidized bed type furnaces 420 and 430 communicating to each other for circulations of the iron ore; a first circulating pipe 415 being connected to a side wall of said narrow portion 420c above said second gas distributor 422, for supplying into said second fine particle fluidized bed type furnace 420 the fine iron ore particles (which have been elutriated from the first fluidized bed type furnace 410 and which have been captured by the first cyclone 440); and said expanded portion 420a of said second fine particle fluidized bed type furnace 420 being connected through a first discharge gas discharging pipe 423 to said first cyclone 440;

a second circulating pipe 441 below the first cyclone 440 communicates to the first circulating pipe 415; and a second discharge gas discharging pipe 443 being connected to the top of the first cyclone 440, for discharging the discharge gas which has been separated from the fine iron ore particles;

a gas reforming system 460 being provided to reform a part of the discharge gas of said first cyclone 440 so as to circulate it to said first and second fluidized bed type furnaces 410 and 420; and said gas reforming system 460 being made to communicate through a reformed gas supplying pipe 462 to said fourth discharge gas discharging pipe 453, and being made to communicate through a discharge gas circulating pipe 461 to said second discharge gas discharging pipe 443;

said third fluidized bed type furnace 430 comprising an expanded portion 430a, a tapered portion 430b and a narrow portion 430c, its top portion being wide and its bottom portion being narrow; a gas dispersing plate 432 being installed within said narrow portion 430c; a third reducing gas supplying pipe 436 being connected to a bottom of said third fluidized bed type furnace 430, for supplying a reducing gas; a fourth discharging pipe 431 being connected to a side wall of said third fluidized bed type furnace 430; and said expanded portion 430a of said third fluidized bed type furnace 430 being connected through a third discharge gas discharging pipe 433 to said second cyclone 450;

one end of a first discharging pipe 411 being connected to a side wall of said narrow portion 430c above said gas distributor 432; another end of said first discharging pipe 411 being connected to a side wall of said third fluidized bed type furnace 430; one end of a second discharging pipe 421 being connected to a side wall of said second fluidized bed type furnace 420; and another end of it extending into said narrow portion 430c of said third fluidized bed type furnace 430; and

a circulating pipe 451 being connected to a bottom of said second cyclone 450; said circulating pipe 451 being also connected to: a third circulating pipe 454 for circulating a part of the fine iron ore particles (contained in the discharge gas of said third fluidized bed type furnace 430) back to said third fluidized bed type furnace 430, and a third discharging pipe 455 for discharging the rest of the fine iron ore particles to an outside; and a rotary gate 452 being connected to a position where said circulating pipe 451, said third circulating pipe 454 and said third discharging pipe 455 are connected together.

15. The fluidized bed type reducing apparatus as claimed in claim 14, wherein said first fluidized bed type furnace 410 has a height 10 - 20 times as large as its inner diameter; said narrow portions 420c and 430c of said

second and third fluidized bed type furnaces 420 and 430 have inner diameters same as those of bottoms of said tapered portions 420b and 430b; said expanded portions 420a and 430a have inner diameters same as those of tops of said tapered portions 420b and 430b, and have inner diameters 1.5 - 2.0 times as large as those of said narrow portions; said second and third fluidized bed type furnaces 420 and 430 have overall heights 10 - 25 times as large as the inner diameters of said narrow portions; said narrow portions 420c and 430c have heights 1.0 - 1.5 times as large as those of said expanded portions 420a and 430a; and said tapered portions 420b and 430b have inclination angles of 30 - 50° relative to a vertical line.

16. The fluidized bed type reducing apparatus as claimed in any one of claims 14 and 15, wherein a melter-gasifier 480 receives a second-reduced iron from said third fluidized bed type furnace 430 to melt-reduce it so as to manufacture pig iron; and

a top of said melter-gasifier 480 being connected through a fifth discharge gas discharging pipe 481 to said third cyclone 484; a fourth circulating pipe 482 being connected to a bottom of said third cyclone 484, to make the fine iron ore particles (contained in the discharge gas of the melter-gasifier 480) circulated back to said melter-gasifier 480; a third reducing gas supplying pipe 436 being connected to a top of said third cyclone 484, for discharging the discharge gas; said third reducing gas supplying pipe 436 being connected to a bottom of said third fluidized bed type furnace 430, for supplying the discharge gas of said melter-gasifier 480 to said third furnace 430; and said fourth circulating pipe 482 communicating to said third discharging pipe 455.

17. The fluidized bed type reducing apparatus as claimed in claims 16, wherein a screw conveyor 435 is installed at a side of said third fluidized bed type furnace 430, for discharging a finally reduced iron to the outside; and

said fourth discharging pipe 431 is connected through said screw conveyor 435 to said third fluidized bed type furnace 430.

18. A method for pre-reducing a fine iron ore by using a fluidized bed type reducing apparatus, characterized in that:

a gas flow velocity within a first fluidized bed type furnace 410 is 1.2 - 3.5 times as fast as a minimum fluidizing velocity of iron ore particles staying within said furnace, to efficiently separate fine iron ore particles from intermediate/coarse iron ore particles, and to efficiently fluidize them; gas flow velocities within second and third fluidized bed type furnaces 420 and 430 are 1.2 - 2.5 times as fast as a minimum fluidizing velocity of iron ore particles staying within said furnaces, this being an optimum velocity of a bubble fluidizing bed.

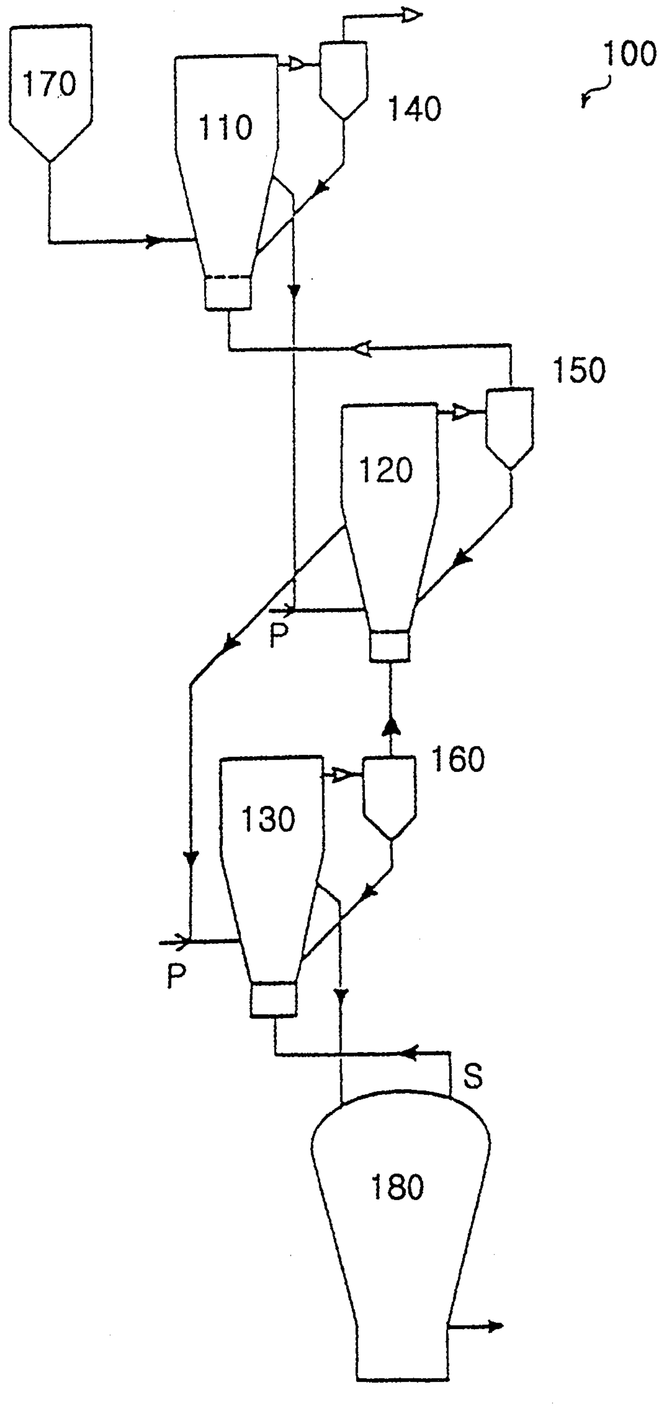


FIG. 1

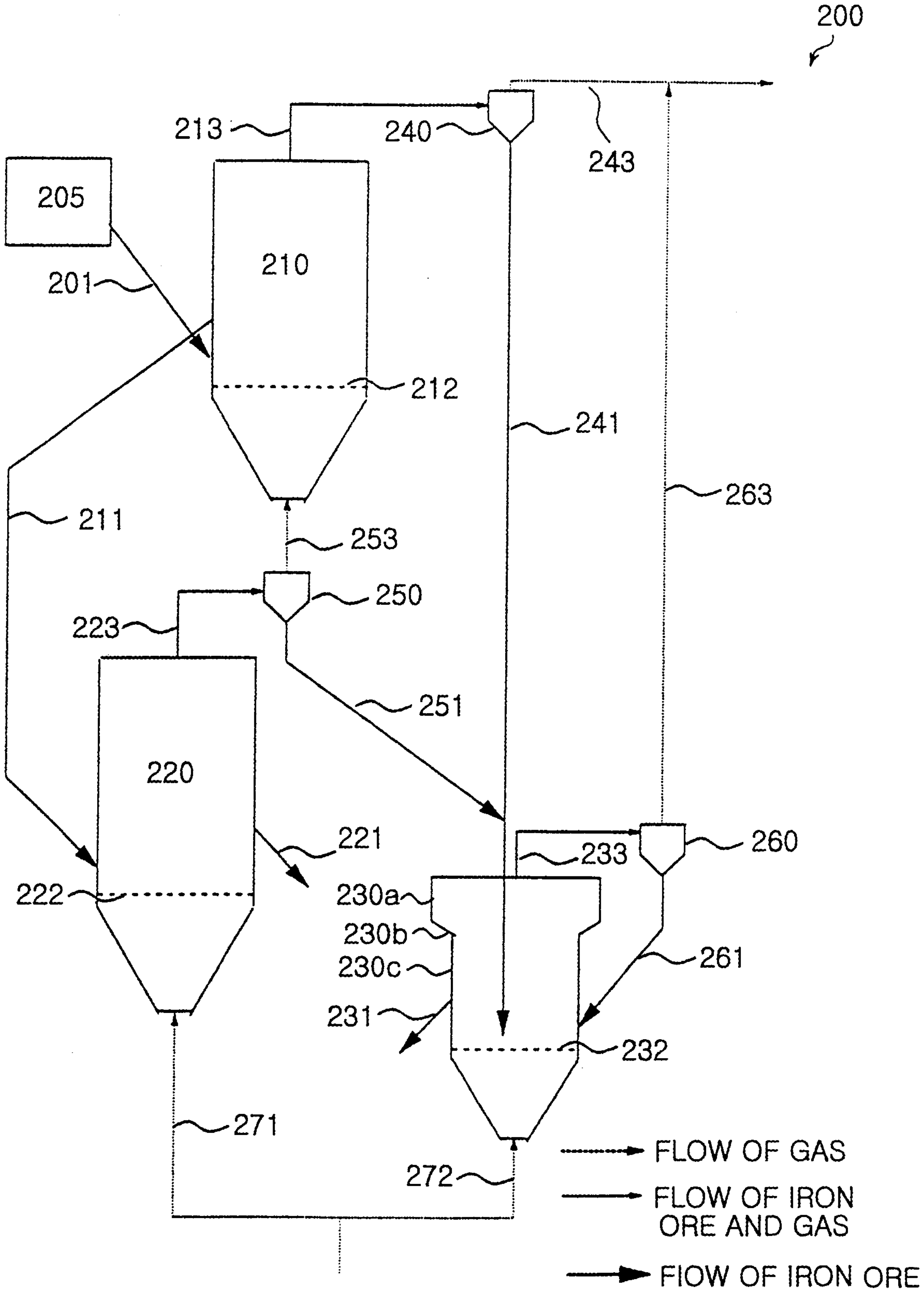

200
205
210
213
240
243
201
212
241
263
211
253
250
223
251
220
221
233
260
222
230a
230b
230c
231
261
232
271
272
FLOW OF GAS
FLOW OF IRON ORE AND GAS
FIOW OF IRON ORE

FIG. 2

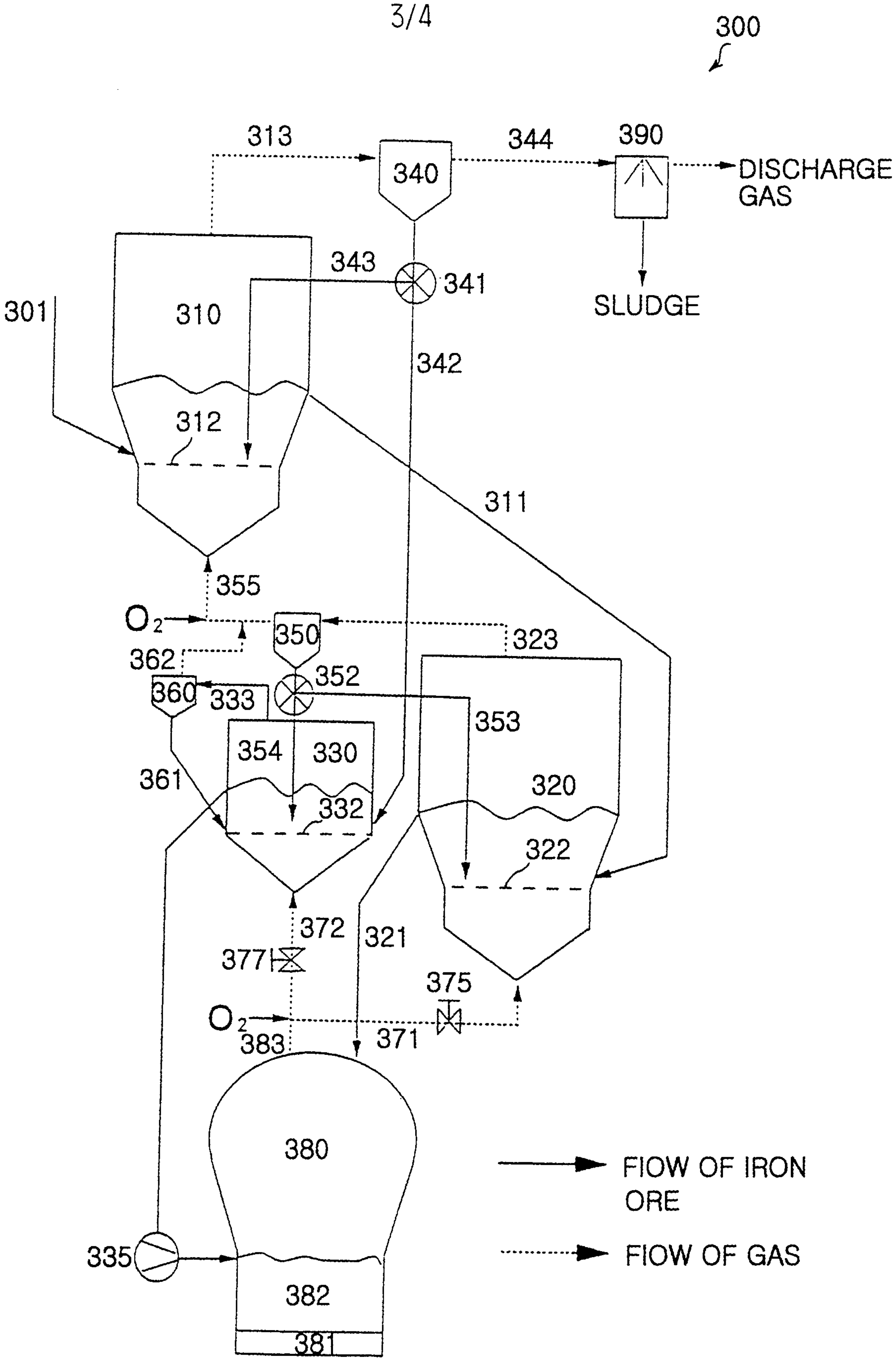
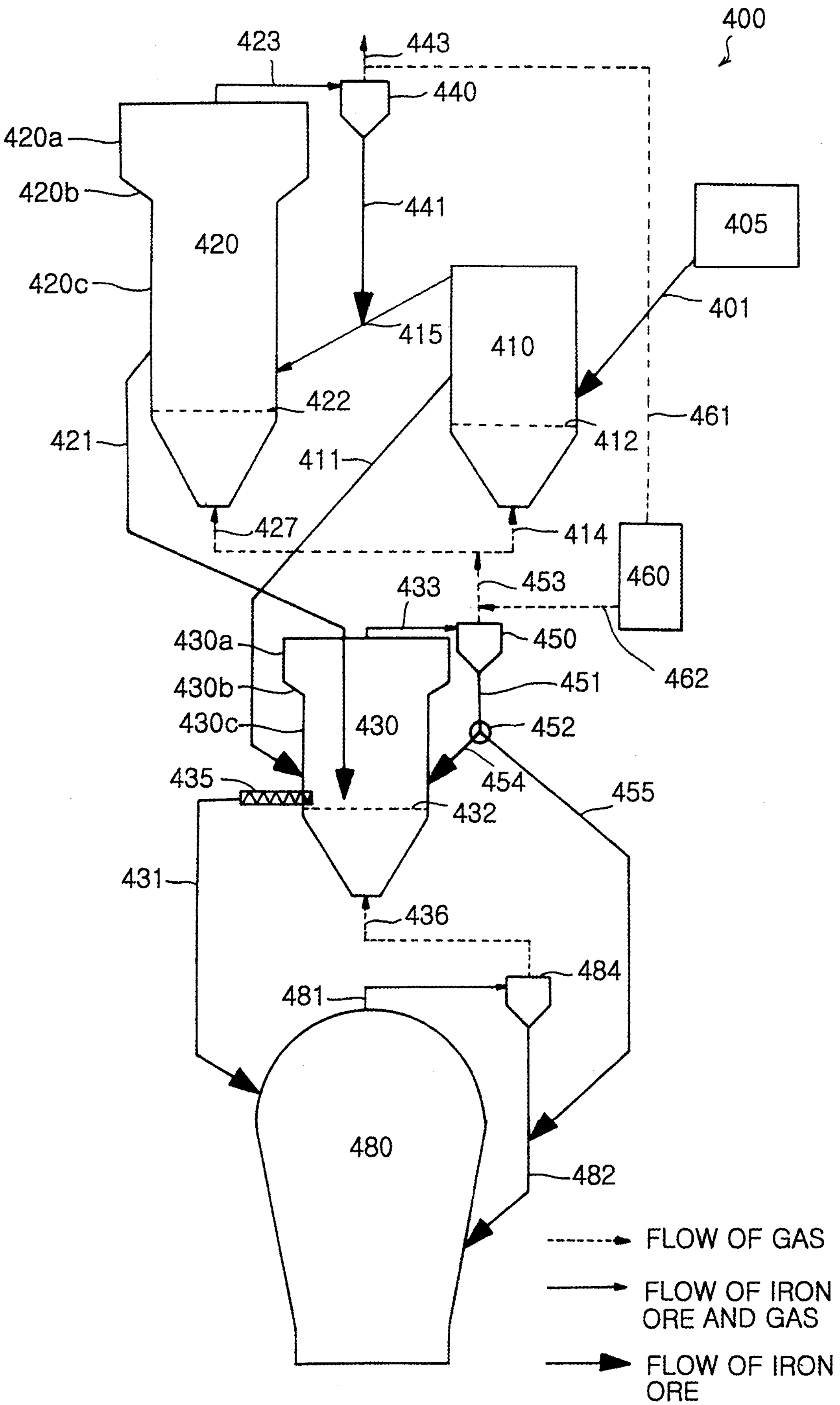

300
313
344
390
340
DISCHARGE GAS
343
341
301
310
SLUDGE
342
312
311
355
O2
350
323
362
352
360
333
353
354
330
361
320
332
322
372
321
377
375
O2
383
371
380
FIOW OF IRON ORE
FIOW OF GAS
335
382
381

FIG. 3



400
423
443
440
420a
420b
420
420c
441
405
401
415
410
422
461
412
421
411
427
414
460
433
453
430a
450
462
430b
451
430c
430
452
435
454
455
432
431
436
484
481
480
482
FLOW OF GAS
FLOW OF IRON ORE AND GAS
FLOW OF IRON ORE

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR 99/00729

A. CLASSIFICATION OF SUBJECT MATTER

IPC⁷: C 21 B 13/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC⁷: C 21 B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97/24463 A1 (POHANG IRON & STEEL) 10 July 1997 (10.07.97), claims, figures 2- 4.	1-18
A	WO 96/21045 A1 (POHANG IRON & STEEL) 11 July 1996 (11.07.96), totality.	1-18

☐ Further documents are listed in the continuation of Box C.　　☒ See patent family annex.

* Special categories of cited documents:
„A" document defining the general state of the art which is not considered to be of particular relevance
„E" earlier application or patent but published on or after the international filing date
„L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
„O" document referring to an oral disclosure, use, exhibition or other means
„P" document published prior to the international filing date but later than the priority date claimed
„T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
„X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
„Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
„&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
01 February 2000 (01.02.00)	31 March 2000 (31.03.00)

Name and mailing adress of the ISA/AT	Authorized officer
Austrian Patent Office Kohlmarkt 8-10; A-1014 Vienna Facsimile No. 1/53424/535	Koller Telephone No. 1/53424/458

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR 99/00729

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