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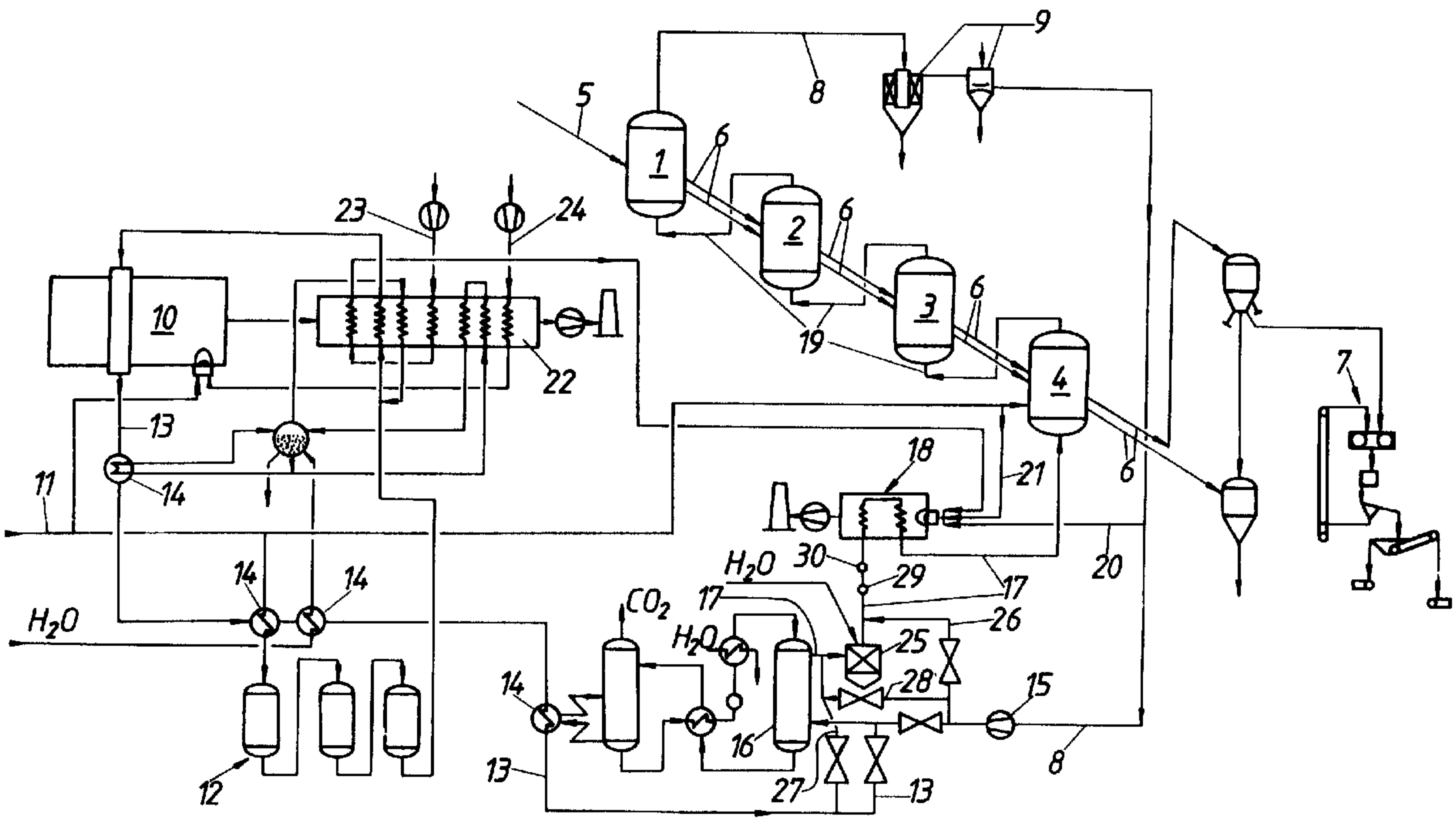
(54) **Titre** : PROCEDE DE REDUCTION DIRECTE DE MATERIAUX CONTENANT DE L'OXYDE DE FER
(54) **Title**: DIRECT REDUCTION PROCESS FOR IRON OXIDE-CONTAINING MATERIALS



(57) **Abrégé/Abstract**:
A direct reduction process for iron oxide-containing materials is disclosed. Synthesis gas is mixed with top gas produced during direct reduction of iron-oxide-containing materials and is used as reduction gas for direct reduction. In order to avoid or reduce metal dusting caused by an increased CO content of the reduction gas by a simple and economical technique and with a simple and economical equipment, while reducing energy consumption, the H_2O content of the reduction gas is set between 1 and 2 %, preferably at approximately 1.5 % by washing away the CO_2 contained in a partial volume of top gas before the top gas is used as reduction gas, the washed top gas is mixed with synthesis gas, is directly brought to a predetermined temperature by irrigation and at the same time saturated with H_2O, after direct irrigation it is heated up to a temperature above saturation temperature by admixture of non-washed top gas, and is then used as reduction gas.

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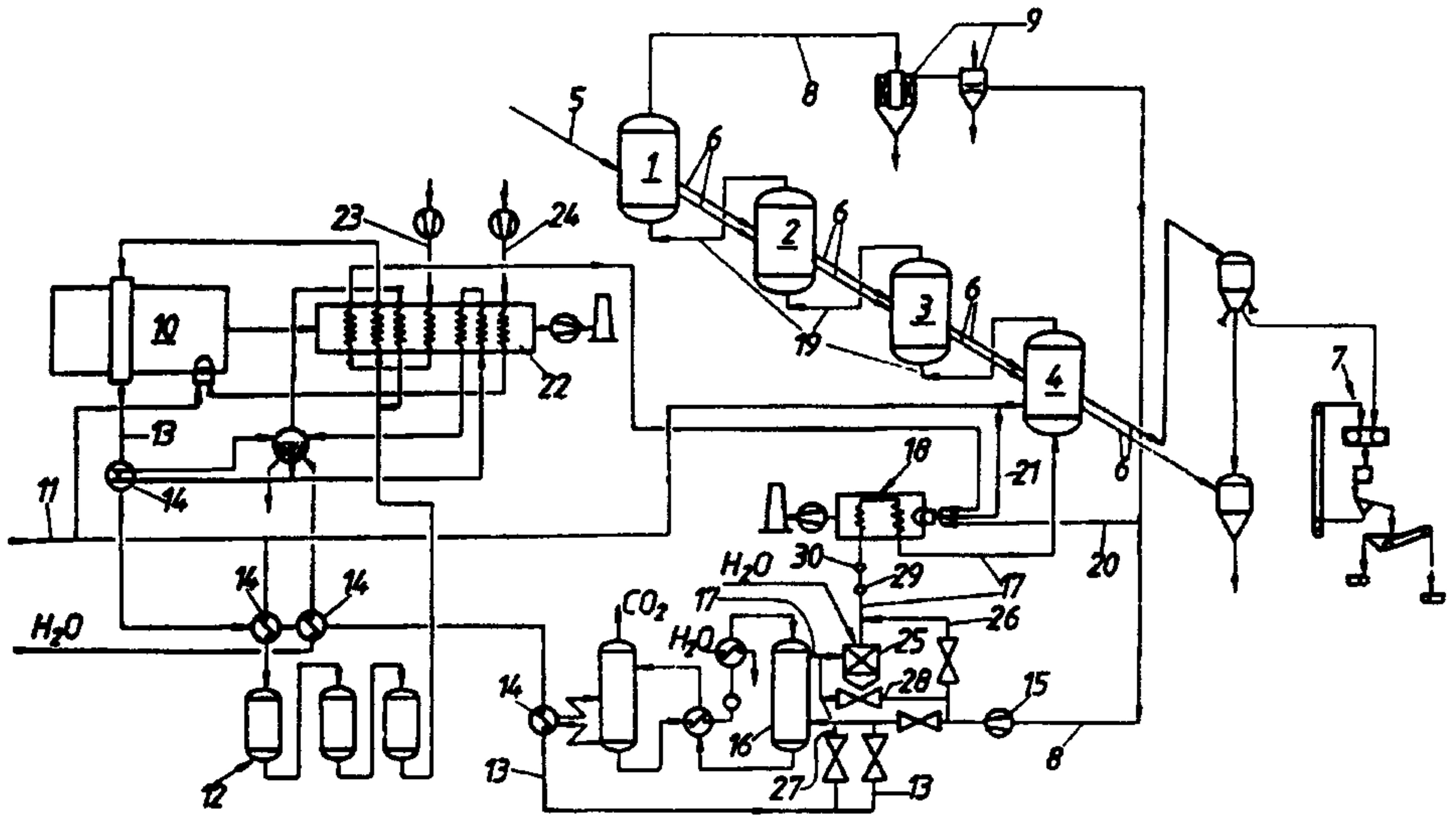
(54) Title: DIRECT REDUCTION PROCESS FOR IRON OXIDE-CONTAINING MATERIALS

(54) Bezeichnung: VERFAHREN ZUR DIREKTREDUKTION VON EISENOXIDHÄLTIGEM MATERIAL

(57) Abstract



A direct reduction process for iron oxide-containing materials is disclosed. Synthesis gas is mixed with top gas produced during direct reduction of iron-oxide-containing materials and is used as reduction gas for direct reduction. In order to avoid or reduce metal dusting caused by an increased CO content of the reduction gas by a simple and economical technique and with a simple and economical equipment, while reducing energy consumption, the H_2O content of the reduction gas is set between 1 and 2 %, preferably at approximately 1.5 % by washing away the CO_2 contained in a partial volume of top gas before the top gas is used as reduction gas, the washed top gas is mixed with synthesis gas, is directly brought to a predetermined temperature by irrigation and at the same time saturated with H_2O, after direct irrigation it is heated up to a temperature above saturation temperature by admixture of non-washed top gas, and is then used as reduction gas.

Direct Reduction Process for Iron-Oxide-Containing Materials

The invention relates to a process for the direct reduction of iron-containing material, wherein synthesis gas, preferably reformed natural gas, is mixed with top gas forming in the direct reduction of the iron-containing material and is used for direct reduction as a reducing gas which does not crack at reduction temperature, as well as a plant for carrying out the process.

A process of this type is known, for instance, from US-A - 2,752,234, US-A - 5,082,251 and EP-A - 0 571 358.

From EP-A - 0 571 358 it is known to carry out the reduction of fine ore not exclusively via the strongly endothermic reaction with H_2 according to

$$Fe_2O_3 + 3H_2 = 2\,Fe + 3H_2O - \Delta H,$$

but additionally via the reaction with CO according to

$$Fe_2O_3 + 3CO = 2\,Fe + 3CO_2 + \Delta H,$$

which is an exothermic reaction. Thereby, it is feasible to considerably lower the operational costs, in particular the energy costs, involved.

However, in metallic plant parts that get into contact with CO-containing reducing gas are subject to a high stress due to corrosion: The result, i.a., is metal decomposition, which is denoted as "metal dusting" in the technical literature. Metal dusting occurs to an increased extent at elevated temperatures, plant parts that get into contact with hot CO-containing reducing gas, thus, being particularly jeopardized. With a plant for carrying out the initially mentioned process, these are primarily the reactors employed for direct reduction and the gas heater heating the reducing gas to reduction temperature.

With a process according to the prior art, difficulties may occur in case the reducing gas has a water content that is either too high or too low. If the water content is too high, the reduction potential of the reducing gas decreases. As a result, a higher amount of reducing gas is required for direct reduction than would actually be necessary in accordance with the chemical potential of the reducing gas. A further difficulty arises if the water content of the reducing gas is too low, because too dry a reducing gas causes metal dusting to an increased extent. In order to minimize both of these drawbacks, it is necessary to adjust the optimum water content with great accuracy.

The invention aims at avoiding these disadvantages and difficulties and has as its object to provide a process of the initially defined kind, and a plant for carrying out the process, by which the occurrence of metal dusting is minimized or prevented in a simple manner despite an elevated CO content of the reducing gas, in particular, in a procedurally and structurally simple and cost-saving manner, so that the service life of metallic plant parts will be considerably increased, wherein it is, however, feasible to utilize the chemical reduction potential of the reducing gas to the optimum degree. Thereby, the energy demand, in particular, the demand of reducing gas, is to be minimized.

In accordance with the invention, this object is achieved in that an H_2O content of between 1 and 2 Vol. %, preferably amounting to about 1.5 Vol. %, is adjusted in the reducing gas by subjecting a partial volume of the top gas to CO_2 scrubbing prior to being used as a reducing gas, wherein the top gas subjected to CO_2 scrubbing is mixed with the synthesis gas, is brought to a predetermined temperature by direct irrigation while being saturated with H_2O, after direct irrigation is heated to a temperature above the saturation temperature by admixing CO_2-unscrubbed top gas, and subsequently is used as a reducing gas.

By directly cooling or directly heating by means of irrigation the top gas subjected to CO_2 scrubbing and the admixed synthesis gas to a predetermined temperature, it is feasible to saturate this gas mixture with water, the temperature being chosen as a function of the desired water content. By adjusting a given temperature of the reducing gas - which is very simple to realize in terms of controlling and at a high accuracy without great expenditure -, it is feasible to adjust the water content in the reducing gas at a very high accuracy, i.e., at a substantially higher accuracy than, for instance, by blowing in vapor through tuyeres or by taking other measures.

In order to avoid condensate formation by the reducing gas leaving the direct cooler in the saturated state - such condensate formation would induce the formation of sulfurous acid in gas-conducting tubes, which would result in pitting -, the temperature of the reducing gas is increased to a temperature above the saturation temperature, i.e., closely thereabove.

To be true, it is known from the prior art cited in the introductory part that reducing gases have an H_2O content of about 1.5 Vol. %. Yet, none of the prior art documents dealt with hereinabove has ever considered the adjustment of an H_2O content to a predetermined value with high accuracy or the way in which a predetermined H_2O content may be obtained in the reducing gas.

From FR-A - 975 404 it is known to treat iron oxide in a reduction zone at a temperature of between 750°C and 900°C, namely by a reducing gas consisting predominantly of hydrogen and a carbon-containing gas and which in the presence of the iron oxide can be cracked at the foregoing temperatures, so that carbon deposits on the iron oxide. Herein, the amount of carbon deposited on the iron oxide is regulated by effecting the deoxidation ofthe iron oxide in the presence of an amount of roughly 32 to 160 g water vapor per m^3 gas.

Preferably, reformed natural gas is employed as the synthesis gas and the reformed natural gas is subjected to CO_2 scrubbing prior to being used as a reducing gas, wherein a partial volume of the reformed natural gas under avoidance of CO_2 scrubbing, together with the top gas subjected to CO_2 scrubbing, is subjected to direct irrigation.

Suitably, a partial volume of the top gas under avoidance of CO_2 scrubbing, together with the top gas subjected to CO_2 scrubbing, is subjected to direct irrigation.

By the two last described measures, it is feasible to guarantee a predetermined CO_2 content in the reducing gas or a predetermined CO/CO_2 ratio in the reducing gas, respectively, thus further minimizing the risk of metal dusting.

A preferred embodiment for the direct reduction of iron-containing material, wherein synthesis gas, preferably reformed natural gas, is mixed with top gas forming in the direct reduction of the iron-containing material and is used for direct reduction as a reducing gas which does not crack at reduction temperature, is characterized in that an H_2O content of between 1 and 2 Vol. %, preferably amounting to about 1.5 Vol. %, is adjusted in the reducing gas by mixing the top gas subjected to CO_2 scrubbing with the synthesis gas, directly bringing the same to a predetermined temperature while enriching it with H_2O, subsequently subjecting it to mist collection and finally using it as a reducing gas.

In doing so, mist collection is provided after irrigation in order to avoid the formation of sulfurous acid such that any condensate forming will be eliminated from the reducing gas.

Another preferred embodiment for the direct reduction of iron-containing material, wherein synthesis gas, preferably reformed natural gas, is mixed with top gas forming in the direct reduction of the iron-containing material and is used for direct reduction as a reducing gas which does not crack at reduction temperature, is characterized in that an H_2O content of between 1 and 2 Vol. %, preferably amounting to about 1.5 Vol. %, is adjusted in the reducing gas by subjecting the top gas to CO_2 scrubbing prior to being used as a reducing gas, the desired H_2O content of the reducing gas being adjusted by temperature control of the CO_2 scrubber. In doing so, advantage is taken from the dependence of the H_2O content of the gas leaving the CO_2 scrubber on the operation temperature of the CO_2 scrubber.

Instead of reformed natural gas, one or several of the following gases may be used as synthesis gas(es):

- LD offgas
- EAF offgas
- blast furnace gas from blast furnace plants
- blast furnace gas from Corex plants
- coal gas
- Corex gas from Corex gasifier
- chemical gases.

A plant for carrying out the process, comprising at least one direct reduction reactor for receiving the iron-oxide-containing material and reducing the same, a reducing-gas supply duct leading to said direct reduction reactor and a top-gas discharge duct carrying off the direct reduction reactor the top gas forming in direct reduction, the top-gas discharge duct running into a CO_2 scrubber and the reducing gas formed of synthesis gas and of top gas getting into the direct reduction reactor through the reducing-gas supply duct and the reducing-gas supply duct leading from the CO_2 scrubber to the direct reduction reactor via a gas heater, is characterized in that the reducing-gas supply duct runs into a direct cooler and from there is further directed to the gas heater, and that the top-gas discharge duct, by means of a bypass duct avoiding the CO_2 scrubber, is flow-connected with the reducing-gas supply duct before entry of the latter into the gas heater.

Advantageously, a reformer for reforming natural gas and a reformed-gas duct departing from the reformer and joining the top-gas discharge duct are provided for the production of synthesis gas, both the reformed-gas duct and the top-gas discharge duct running into the CO_2 scrubber.

To adjust a preferred CO_2 content or a predetermined CO/CO_2 ratio in the reducing gas, the reformed-gas duct, by means of a bypass duct avoiding the CO_2 scrubber, advantageously is flow-connected with the reducing-gas supply duct before entry of the latter into the direct cooler.

To adjust a preferred CO_2 content in the reducing gas, it is, furthermore, advantageous if the top-gas discharge duct, by means of a bypass duct avoiding the CO_2 scrubber, is flow-connected with the reducing-gas supply duct before entry of the latter into the direct cooler.

Another preferred embodiment of the plant intended for carrying out the process, comprising at least one direct reduction reactor for receiving the iron-oxide-containing material and reducing the same, a reducing-gas supply duct leading to said direct reduction reactor and a top-gas discharge duct carrying off the direct reduction reactor the top gas forming in direct reduction, the top-gas discharge duct running into a CO_2 scrubber and the reducing gas formed of synthesis gas and of top gas getting into the direct reduction reactor through the reducing-gas supply duct and the reducing-gas supply duct leading from the CO_2 scrubber to the direct reduction reactor via a gas heater, is characterized in that the reducing-gas supply duct runs into a direct cooler and from there is conducted through a mist collector before entering the gas heater.

In the following, the invention will be explained in more detail by way of Figures 1 and 2 of the drawing, each illustrating a process diagram according to a preferred embodiment.

The plant according to the invention, in accordance with Fig. 1, comprises four whirl layer reactors 1 to 4 consecutively connected in series, wherein iron-oxide-containing material, such as fine ore, through an ore supply duct 5 is supplied to the first whirl layer reactor 1, in which heating to reduction temperature (or prereduction) takes place, and subsequently is conducted from one whirl layer reactor to another whirl layer reactor via conveying ducts 6. The completely reduced material (sponge iron) is hot-briquetted in a briquetting arrangement 7. If required, the reduced iron is protected from reoxidation during briquetting by an inert gas system not illustrated.

Prior to introducing the fine ore into the first whirl layer reactor 1, it is subjected to ore preparation, such as drying and sieving, not illustrated in detail.

Reducing gas is conducted in counterflow to the ore flow from one whirl layer reactor 4 to another whirl layer reactor 3 to 1 and is carried off the last whirl layer reactor 1, viewed in the gas flow direction, as a top gas through a top-gas discharge duct 8 and is cooled and scrubbed in a wet scrubber 9.

The production of reducing gas is effected by reforming in a reformer 10 natural gas fed through a duct 11 and desulfurized in a desulfurization plant 12. The gas leaving the reformer 10 and formed of natural gas and vapor essentially consists of H_2, CO, CH_4, H_2O and CO_2. This reformed natural gas is supplied through a reformed-gas duct 13 to several heat exchangers 14, in which it is cooled to 80 to 150°C, water thus being condensed out of the gas.

The reformed-gas duct 13 runs into the top-gas discharge duct 8 after the top gas has been compressed by means of a compressor 15. The mixed gas thus forming is passed through a CO_2 scrubber 16 and is freed from CO_2 and also from H_2S. It is then available as a reducing gas. This reducing gas, via a reducing-gas feed duct 17, is heated to a reducing-gas temperature of about 800°C in a gas heater 18 arranged to follow the CO_2 scrubber 16 and is fed to the first whirl layer reactor 4, viewed in the gas flow direction, where it reacts with the fine ores to produce directly reduced iron. The whirl layer reactors 4 to 1 are arranged in series; the reducing gas gets from one whirl layer reactor to another whirl layer reactor through connection ducts 19.

A portion of the top gas is sluiced out of the gas circulatory system 8, 17, 19 in order to avoid enrichment of inert gases, such as N_2. The sluiced-out top gas is fed through a branch duct 20 to the gas heater 18 for heating the reducing gas and is burnt there. Possible shortages of energy are supplemented by natural gas supplied through a feed duct 21.

The sensible heat of the reformed natural gas emerging from the reformer 10 as well as of the reformer smoke gases is utilized in a recuperator 22 to preheat the natural gas after passage through the desulfurization plant 12, to produce the vapor required for reformation and to preheat the combustion air supplied to the gas heater 18 through duct 23 as well as, if desired, also the reducing gas. The combustion air supplied to the reformer 10 through duct 24 is preheated as well.

To adjust a predetermined H_2O content in the reducing gas, the reducing gas is subjected to direct cooling or direct heating in a direct cooler 25, i.e., to cooling or heating by irrigation, thus getting into direct contact with water that is cooler or hotter than the reducing gas. In doing so, the H_2O content in the reducing gas decreases or increases to the point of saturation. In order to prevent condensation from taking place as the H_2O-saturated reducing gas is further conducted to the gas heater 18, hotter and unscrubbed top gas is fed to the reducing gas through a bypass duct 26 departing from the top-gas discharge duct 8 and running into the reducing-gas supply duct 17 before its entry into the gas heater 18. Thereby, the temperature of the reducing gas, which, for instance, has been adjusted to 70°C in the direct cooler 25, is increased to, for instance, 75°C. The reducing gas emerging from the gas heater 18 will then have the water content that corresponds to the saturation temperature (i.e., to the temperature of the reducing gas attained in the direct cooler 25) and according to which the reduction potential of the reducing gas still can be utilized to the optimum degree, the danger of the occurrence of metal dusting being minimized nevertheless.

To further minimize metal dusting, the CO/CO_2 ratio of the reducing gas advantageously is adjustable to a predetermined value, which suitably is effected by feeding, for instance, reformed gas directly into the reducing-gas supply duct 17 before its entry into the direct cooler 25, through a bypass duct avoiding the CO_2 scrubber. In doing so, it may still be suitable to inject a partial volume of the top gas directly into the reducing gas leaving the CO_2 scrubber 16 likewise by means of a bypass duct 28 (illustrated in broken lines), i.e., also in the unscrubbed state.

All of the bypass ducts 26, 27, 28 are equipped with adjustment or control valves to be adjusted or controlled on grounds of a measurement of the CO/CO_2 ratio of the reducing gas taken by means of a measuring station 29.

The desired CO/CO_2 ratio in the reducing gas also may be adjusted by passing all of the top gas and all of the reformed gas through the CO_2 scrubber 16, yet adjusting the latter to a wash-out level at which a portion of the CO_2 (and hence also a portion of the H_2S absorbed by the top gas from the ore during heating of the same) will remain in the gas emerging from the CO_2 scrubber 16. This has the advantage that no auxiliary means, such as bypass ducts including valves, need be provided, yet requires the total gas amount, i.e., all of the top gas and all of the reformed gas, to be passed through the CO_2 scrubber 16, the latter, thus, having to be dimensioned for such an amount.

The top gas leaving the whirl layer reactor 1 has an H_2S content ranging between 40 and 140 ppmV - depending on the sulfur content of the ore. As pointed out above, the H_2S gas forms during heating of the fine ore to reduction temperature or during the prereduction of the fine ore, respectively.

Since an elevated H_2S content in the reducing gas also reduces the development of metal dusting, it is particularly advantageous if H_2S no longer is completely washed out of the top gas by means of the CO_2 scrubber, but if it is taken care that the percentage of H_2S desired for the reducing gas be fed to the reducing gas from the top gas. In the instant case, this can be realized by means of bypass ducts 26, 28 bypassing the CO_2 scrubber 16, which bypass ducts depart from the top-gas discharge duct 8 and run into the reducing-gas supply duct 17. The control valves provided in the bypass ducts 26 and 28 are adjustable in a manner that an H_2S content ranging from 20 to 40 ppmV, preferably amounting to about 25 ppmV, is present in the reducing gas. In that case, the control valves preferably are activated via an H_2S measuring means 30.

According to the embodiment illustrated in Fig. 2 of a direct reduction plant, the formation of sulfurous acid by condensation of the reducing gas emerging from the direct cooler 25 in the saturated state is prevented by passing the reducing gas through a mist eliminator 31 prior to introduction into the gas heater 18.

The measures described above for adjusting the desired H_2O content, CO/CO_2 ratio and H_2S content in the reducing gas may be taken individually or also several of them or all in common in a manner that the most favorable process variant will be available for the respective operation conditions and as a function of the composition of the ore, etc.

The adjustment of a content of H_2O of 1.5% in the reducing gas is going to be explained by way of the following example:

100 t/h of dried fine ore are charged into a plant for the direct reduction of fine ore configured in accordance with Fig. 1 and designed for a production of 70 t/h of sponge iron. The fine ore has the following analysis:

Hematite	94.2	% by weight
Gangue	2.2	% by weight
Sulfur	0.02	% by weight

From the top gas forming in the direct reduction, 78,000 Nm^3/h are mixed with 48,000 Nm^3/h of reformed cold natural gas and passed through the CO_2 scrubber 16, in which the mixed gas is freed from CO_2 and the major portion of sulfur.

The reformed natural gas and the top gas have the chemical compositions indicated in the Table below in percent by volume.

	Reformed Natural Gas	Top Gas
CH_4	2.80	30.60
CO	4.80	5.80
CO_2	14.50	5.30
H_2	64.40	53.00
H_2O	13.50	0.70
N_2	0.0	4.60
H_2S	0.0	60.0 ppmV

The temperature of the reformed natural gas is 120°C, that of the top gas 100°C. The gas mixture emerging from the CO_2 scrubber 16 is supplied to the direct cooler 25 and cooled to a temperature of 68°C. The cooled gas mixture has the following composition in percent by volume:

CH_4	20.70
CO	6.10
CO_2	2.50
H_2	65.90
H_2O	1.90
N_2	2.90
H2S	2 ppmV

This gas mixture is mixed with 78,000 Nm^3/h of top gas that has not been passed through the CO_2 scrubber 16, but has been injected into the reducing-gas supply duct 17 through bypass duct 26. Such mixing produces the reducing gas fed to the gas heater 18 and subsequently to the whirl layer reactors 1 to 4, which reducing gas has a temperature of 75°C and the following chemical composition in percent by volume:

Reducing Gas	
CH_4	24.50
CO	6.0
CO_2	3.6
H_2	60.90
H_2O	1.5
N_2	3.5
H_2S	25 ppmV

The degree of metallization (Fe_{met}/Fe_{tot}) of the sponge iron is 92 %.

The invention is not limited to the above-described example, but is applicable also to other direct reduction processes, for instance, such in which the whirl layer reactors 1 to 4 are replaced with shaft furnaces for lumpy ore. The reformed natural gas also may be replaced with other reducing gases primarily containing CO and H_2, such as

- LD offgas
- EAF offgas
- blast furnace gas from blast furnace plants
- blast furnace gas from Corex plants
- coal gas
- Corex gas from Corex gasifier
- chemical gases.

CLAIMS:

1. A process for the production of a reducing gas to be used in the direct reduction of iron-oxide-containing material, wherein the reducing gas is comprised of a mixture of a synthesis gas with a top gas formed in the direct reduction process and does not crack at reduction temperature, said process comprising the steps of:

subjecting a partial volume of the top gas to CO_2 scrubbing, wherein the partial volume of top gas is mixed with the synthesis gas to form the reducing gas;

adjusting an H_2O content in the reducing gas to a range of between about 1 and 2 Vol. % by bringing the reducing gas to a predetermined temperature by direct irrigation with H_2O to saturate the reducing gas;

subsequently heating the reducing gas to a temperature above the saturation temperature of the reducing gas by admixing same with the remainder volume of the top gas which is not subjected to CO_2 scrubbing and which is at a temperature higher than the temperature of the reducing gas in the direct irrigation step; and

using the reducing gas in the direct reduction process of the iron-oxide-containing material which results in the production of the top gas.

2. A process for the production of a reducing gas to be used in the direct reduction of iron-oxide-containing material, wherein the reducing gas is comprised of a mixture of a synthesis gas with a top gas formed in the direct reduction process and does not crack at reduction temperature, said process comprising the steps of:

subjecting a partial volume of the top gas to CO_2 scrubbing, wherein the partial volume of top gas is mixed with the synthesis gas to form the reducing gas;

adjusting an H_2O content in the reducing gas to a range of between about 1 and 2 Vol. % by bringing the reducing gas to a predetermined temperature by direct irrigation with H_2O to enrich the reducing gas;

subsequently collecting any condensate which forms in the reducing gas; and

using the reducing gas in the direct reduction process of the iron-oxide-containing material which results in the production of the top gas.

3. A process for the production of a reducing gas to be used in the direct reduction of iron-oxide-containing material, wherein the reducing gas is comprised of a mixture of a synthesis gas with a top gas formed in the direct reduction process and does not crack at reduction temperature, said process comprising the steps of:

subjecting at least a partial volume of the top gas to CO_2 scrubbing in a CO_2 scrubber, wherein the top gas is mixed with the synthesis gas to form the reducing gas; and

adjusting an H_2O content in the reducing gas to a range of between about 1 and 2 Vol. % by controlling the temperature of the CO_2 scrubber.

4. A process according to claim 1, 2 or 3, wherein the H_2O content in the reducing gas is adjusted to about 1.5 Vol %.

5. A process according to claim 1, 2 or 3, wherein the synthesis gas is a reformed natural gas, and the process further comprises the steps of:

subjecting a partial volume of the reformed natural gas to CO_2 scrubbing; and

bypassing the remainder volume of the reformed natural gas around the CO_2 scrubbing process and subsequently joining the remainder volume of reformed natural gas with the reducing gas.

6. A process according to claim 1, 2 or 3, further comprising the step of bypassing a remainder volume of the top gas around the CO_2 scrubbing process and subsequently joining the remainder volume of top gas with the reducing gas.

7. A process according to claim 1, 2 or 3, wherein the synthesis gas is selected from an LD offgas, an EAF offgas, a blast furnace gas, a coal gas, a gas from a gasifier, chemical gases, and combinations thereof.

8. A process according to claim 1, wherein the process is carried out in a plant comprising:

at least one direct reduction reactor for receiving the iron-oxide-containing material and reducing the same;

a CO_2 scrubber;

a top-gas discharge duct connecting the at least one direct reduction reactor to the CO_2 scrubber;

a direct cooler;

a gas heater; and

a reducing-gas supply duct connecting the CO_2 scrubber through the direct cooler and the gas heater to the at least one direct reduction reactor;

wherein the top-gas discharge duct includes a bypass duct which bypasses the CO_2 scrubber and is flow-connected with the reducing-gas supply duct at a location between the CO_2 scrubber and the gas heater.

9. A process according to claim 8, wherein the plant further comprises:

a reformer for reforming natural gas; and

a reformed-gas duct connected to the reformer and joining the top-gas discharge duct at a location such that both the reformed-gas duct and the top-gas discharge duct feed into the CO_2 scrubber.

10. A process according to claim 9, wherein the reformed-gas duct includes a bypass duct which bypasses the CO_2 scrubber and is flow-connected with the reducing-gas supply duct at a location between the CO_2 scrubber and the direct cooler.

11. A process according to claim 8, 9 or 10, wherein the top-gas discharge duct further includes a second bypass duct which bypasses the CO_2 scrubber and is flow-connected with the reducing-gas supply duct at a location between the CO_2 scrubber and the direct cooler.

12. A process according to claim 2, wherein the process is carried out in a plant comprising:

at least one direct reduction reactor for receiving the iron-oxide-containing material and reducing the same;

a CO_2 scrubber;

a top-gas discharge duct connecting the at least one direct reduction reactor to the CO_2 scrubber;

a direct cooler;

a gas heater;

a mist collector; and

a reducing-gas supply duct connecting the CO_2 scrubber through the direct cooler, the mist collector, and the gas heater to the at least one direct reduction reactor.

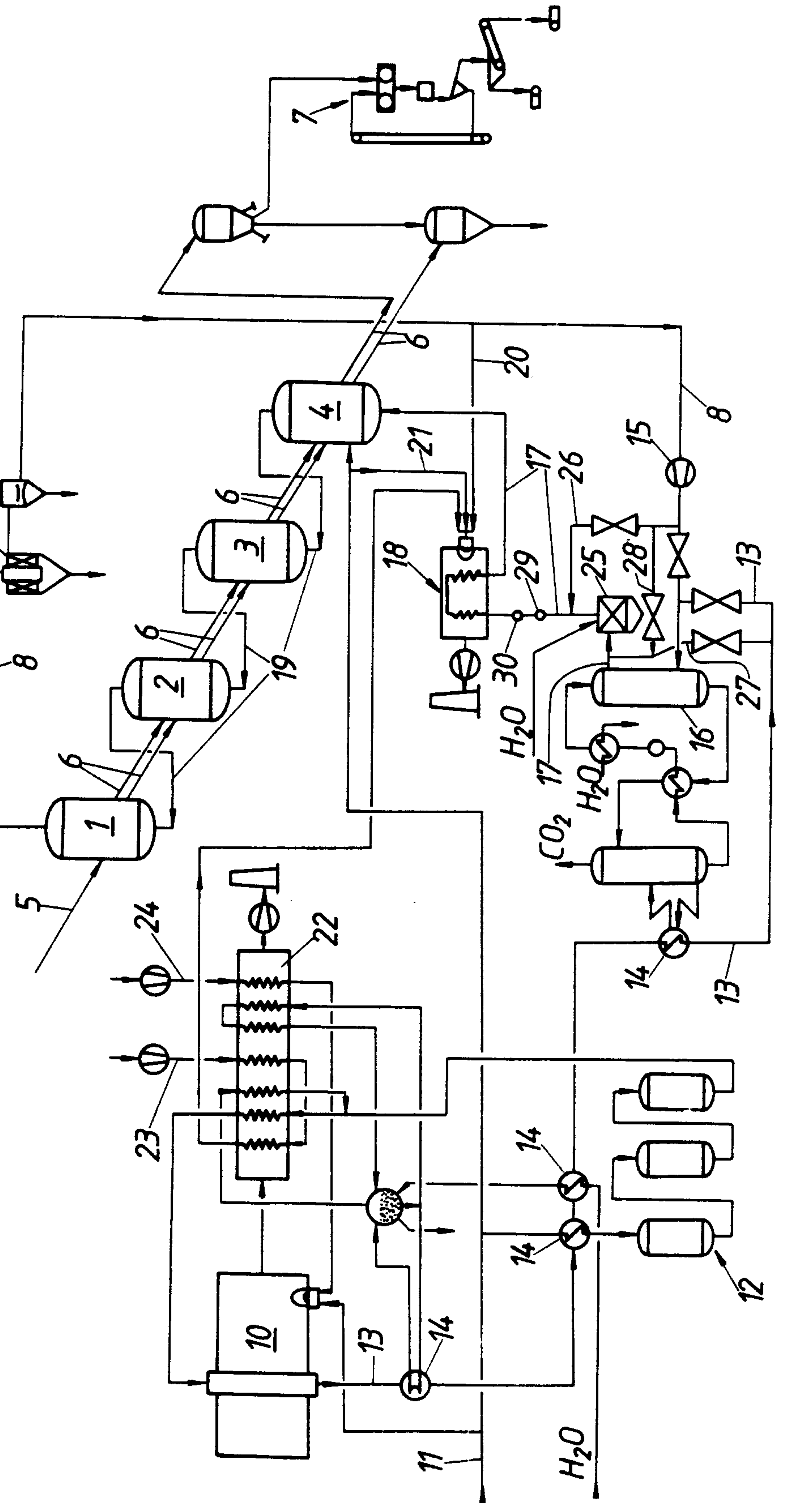
13. A process according to claim 12, wherein the plant further comprises:

a reformer for reforming natural gas; and

a reformed-gas duct connected to the reformer and joining the top-gas discharge duct at a location such that both the reformed-gas duct and the top-gas discharge duct feed into the CO_2 scrubber.

14. A process according to claim 12, wherein the reformed-gas duct includes a bypass duct which bypasses the CO_2 scrubber and is flow-connected with the reducing-gas supply duct at a location between the CO_2 scrubber and the direct cooler.

15. A process according to claim 12, wherein the top-gas discharge duct includes a bypass duct which bypasses the CO_2 scrubber and is flow-connected with the reducing-gas supply duct at a location between the CO_2 scrubber and the direct cooler.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H_2O
CO_2

FIG. 1

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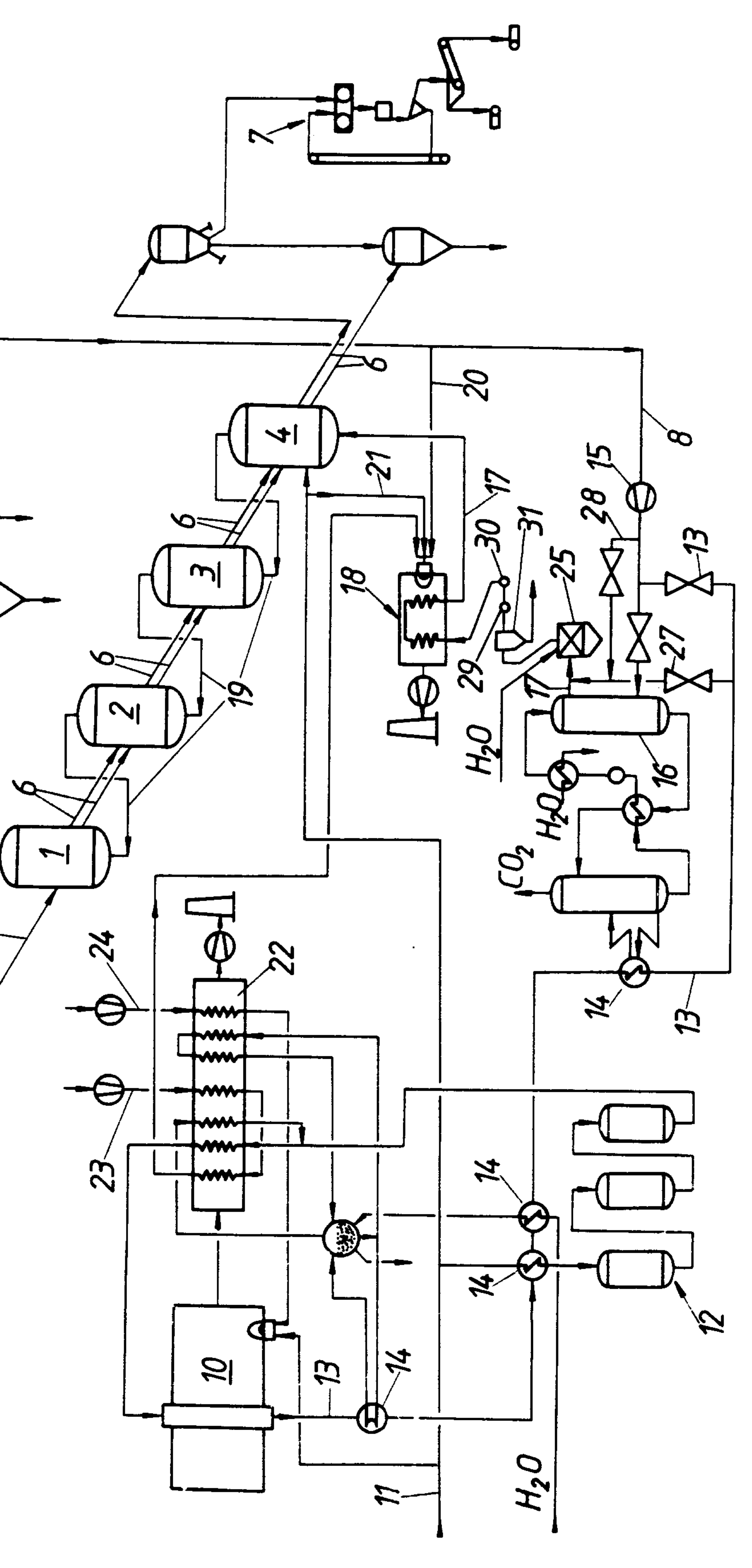
FIG. 2



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H_2O
CO_2