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(54) Titre : PROCEDE ET APPAREIL POUR LA COMMANDE D'UN PROCEDE DE SEPARATION PAR FLOTTATION, COMPRENANT DES PARAMETRES DU PROCEDE DE FLOTTATION ET L'AJOUT D'UN REACTIF AFIN D'OPTIMISER LA RECUPERATION MINERALE

(54) Title: METHOD AND APPARATUS FOR THE CONTROL OF A FLOTATION SEPARATION PROCESS, INCLUDING PARAMETERS OF THE FLOTATION PROCESS AND REAGENT ADDITION TO OPTIMIZE MINERAL RECOVERY

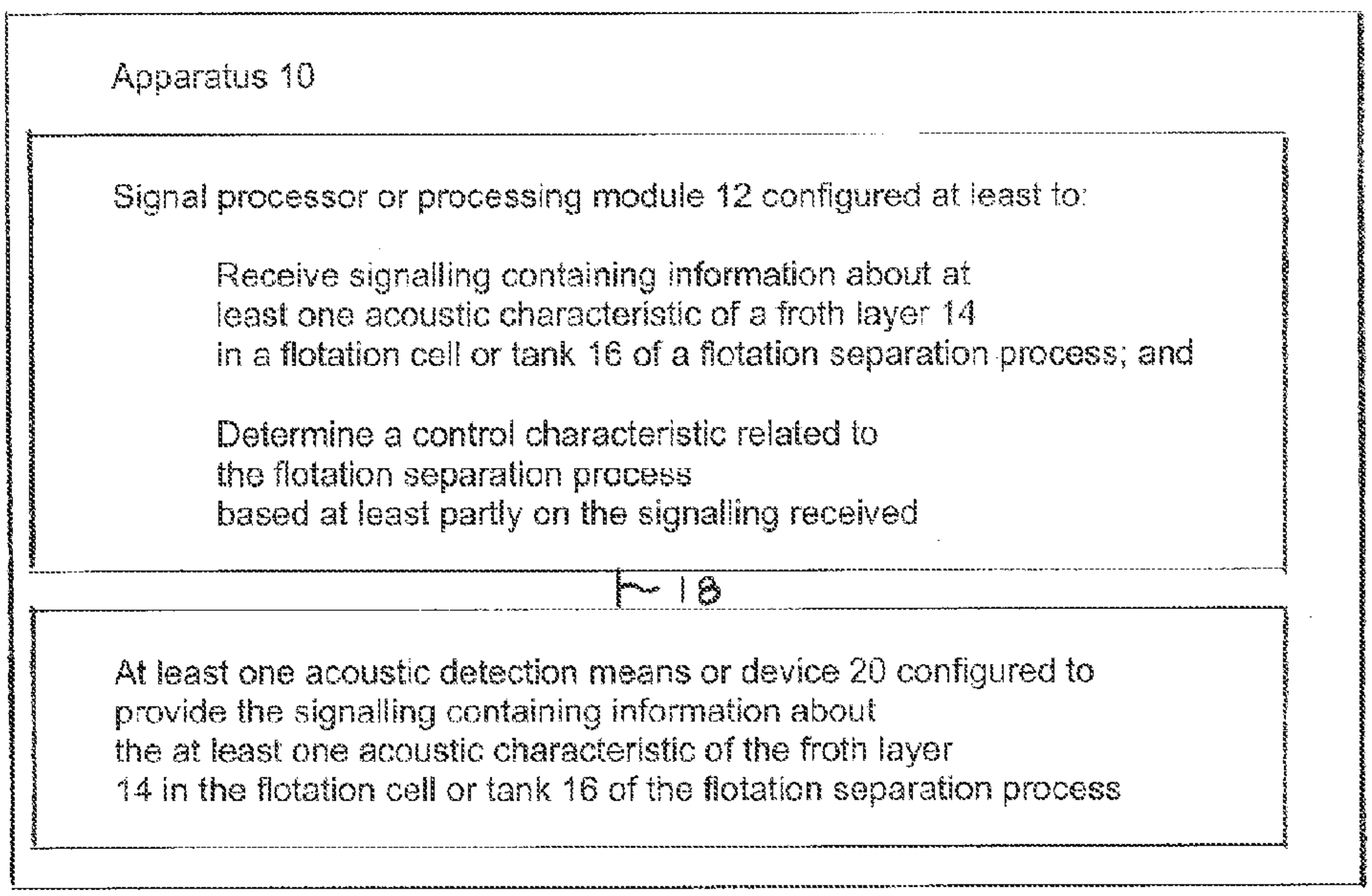


Figure 2

(57) Abrégé/Abstract:
A method and apparatus are provided to control of a flotation separation process, including parameters of the flotation process and reagent addition to optimize mineral recovery. The apparatus includes a signal processor or processing module configured at least to receive signalling containing information about at least one acoustic characteristic of a froth layer in a flotation cell or tank of a flotation separation process; and determine a control characteristic related to the flotation separation process based at least partly on the signalling received. The signal processor or processing module may also be configured at least to: provide corresponding signalling containing information to control the flotation separation process based at least partly on the control characteristic determined.

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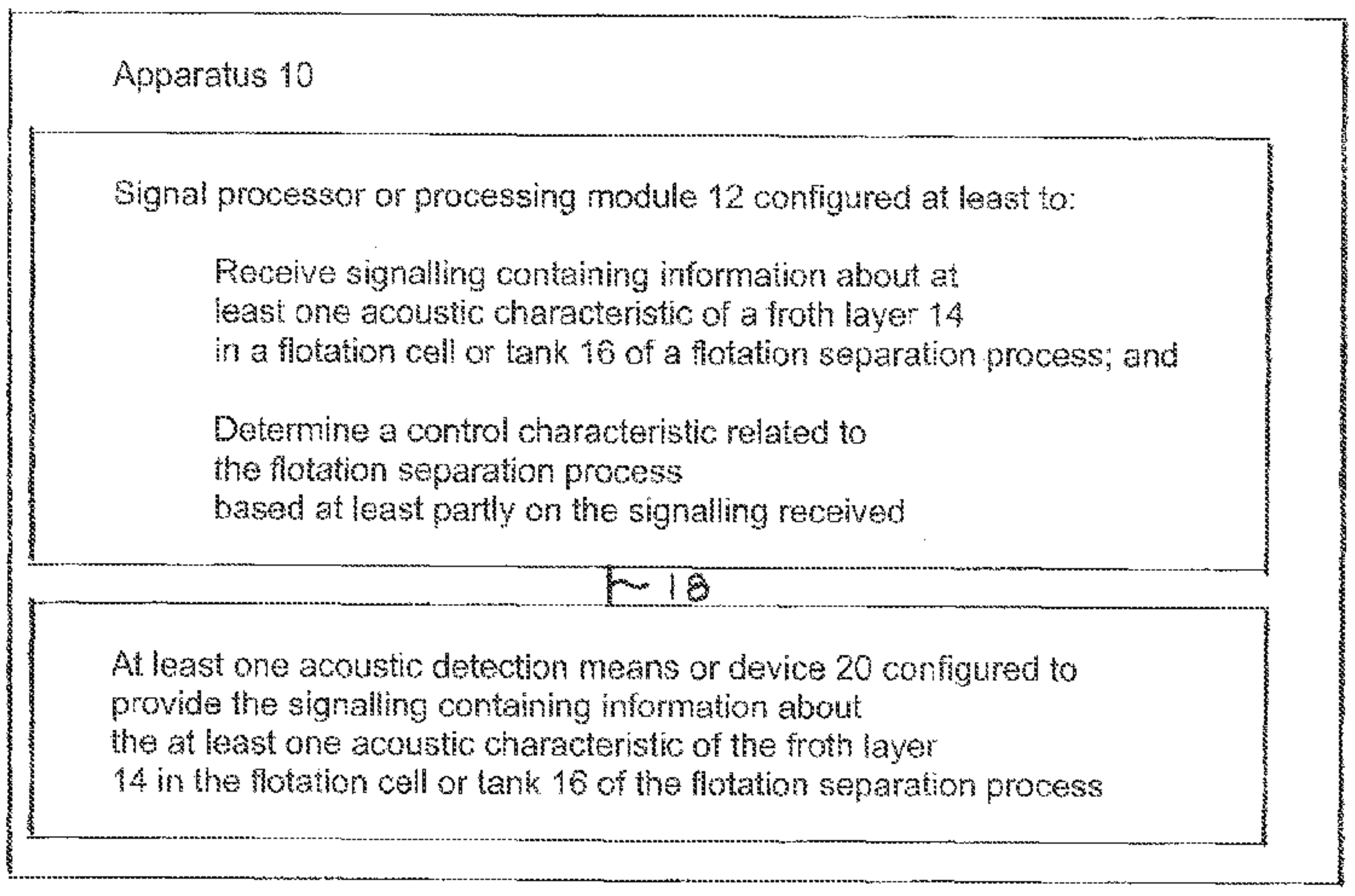


Figure 2

(57) Abstract: A method and apparatus are provided to control of a flotation separation process, including parameters of the flotation process and reagent addition to optimize mineral recovery. The apparatus includes a signal processor or processing module configured at least to receive signalling containing information about at least one acoustic characteristic of a froth layer in a flotation cell or tank of a flotation separation process; and determine a control characteristic related to the flotation separation process based at least partly on the signalling received. The signal processor or processing module may also be configured at least to: provide corresponding signalling containing information to control the flotation separation process based at least partly on the control characteristic determined.

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# METHOD AND APPARATUS FOR THE CONTROL OF A FLOTATION SEPARATION PROCESS, INCLUDING PARAMETERS OF THE FLOTATION PROCESS AND REAGENT ADDITION TO OPTIMIZE MINERAL RECOVERY

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims benefit to provisional patent application serial no. 61/379,899 (CCS-0006), filed 3 September 2010, which are all incorporated by reference in their entirety.

## BACKGROUND OF THE INVENTION

### 1. Field of Invention

This invention relates to a flotation process, e.g., such as a flotation separation process used in a mineral extraction processing system; and more particularly to a technique for controlling such a flotation separation process.

### 2. Description of Related Art

In many industrial processes, a flotation separation process is used to concentrate and clean the final product. A minerals processing plant, or beneficiation plant, is no exception. In the case of a copper concentrator as shown in Figure 1a, the input to the plant is water and ore (of a particular type and size distribution) and the outputs are copper concentrate and tailings. The processes consist of grinding, classification, flotation and thickening stages, as shown in Figure 1b. The grinding and classification stages produce a fine slurry of water, ore and chemicals which is then sent to the flotation stage. Once in the flotation stage, air and chemical reagents are used to float the copper minerals, while gange (tailings) is depressed. The recovered copper is cleaned and dried. The tailings are thickened and sent to a tailings pond.

In the flotation stage, the bubbles are introduced to the slurry to carry (float) the desired ore content to the top of the flotation cell, while the tailings are depressed and flow to the bottom of the cell. The performance of the flotation stage is dependent on many parameters. One of those is the floatability of the ore. The floatability is highly dependent on the type and doses of chemical reagents that are used to make the desired particles of ore hydrophobic. The chemical dosing rate is typically defined in units of grams of chemical per ton or ore processed. In some cases, more chemical is added than is necessary in order to make sure that enough is being used. These chemicals are very expensive and make up a sizable portion of a mineral processing plant's operational expenses.

Another factor in the performance of the flotation stage is the size of the bubbles, the overall amount of bubbles, and the rate or speed that the bubbles move / rise through the flotation cell. These bubbles create a layer of froth at the top of the flotation cell. The characteristics of the froth, such as the depth of the froth layer, its composition and its stability, also impact the performance of the flotation stage.

In a typical plant, operators will determine the ore tonnage rate by using a weight scale on the input ore feed to the first stage of grind. Then the reagent is added according to the prescribed dosing rate. It would be possible to optimize the addition of reagent and other control parameter, such as the addition of air and feed rate and density of the ore, to optimize the recovery of ore in the flotation stage.

SUMMARY OF THE INVENTION

In its broadest sense, the present invention provides a new and unique method and apparatus to control of a flotation separation process, including parameters of the flotation process and reagent addition to optimize mineral recovery.

According to some embodiments of the present invention, the apparatus may comprise a signal processor or processing module configured at least to:

receive signalling containing information about at least one acoustic characteristic of a froth layer in a flotation cell or tank of a flotation separation process; and

determine a control characteristic related to the flotation separation process based at least partly on the signalling received.

According to some embodiments of the present invention, the signal processor or processing module may also be configured at least to: provide corresponding signalling containing information to control the flotation separation process based at least partly on the control characteristic determined.

According to some embodiments of the present invention, acoustic sensing may be used to monitor the characteristics of the froth layer in the flotation cell or tank, e.g., to thereby maximize the recovery of ore. By way of example, the acoustic characteristics of the froth layer may then be used to control, e.g., reagent dosing, ore feed rate, ore feed density, froth depth, superficial gas velocity or other aspects of the flotation cell to maximize ore recovery.

According to some embodiments of the present invention, the acoustic characteristics of the ore may be monitored by using at least one acoustic detection means or device, such as for example a microphone. The acoustic detection means or device may be placed above the froth layer, directly in or near the froth layer, or below the froth layer.

According to some embodiments of the present invention, the at least one acoustic detection means or device may be placed below the froth layer, and the acoustic detection means may monitor the acoustics of the froth cell reflected at the interface between the froth layer and the layer below, known as the pulp zone, due to the difference in acoustic impedance between the froth layer and the pulp zone.

According to some embodiments of the present invention, two or more acoustic detection means or devices may be placed above and below the froth layer, in and below the froth layer, or entirely within the froth layer, and the acoustic detection means or devices may monitor the attenuation through the froth layer, between the froth layer and the pulp zone, between the froth layer and the air above the froth layer, or any combination.

According to some embodiments of the present invention, acoustic detection sensors may be mounted external to the flotation cell. In this embodiment, an acoustic guide may be placed within the tank to optimize the acquisition of the acoustic signal. For example, an acoustic waveguide may be placed within the flotation cell or tank such that the waveguide interacts with the tank solution and gas bubbles, and separate acoustic detection means are mounted on the exterior of the tank to acquire the acoustic signal from the waveguide.

According to some embodiments of the present invention, the acoustic detection means or devices may be positioned at a number of locations, such as above, within, and/or below the froth layer to monitor the acoustic characteristics of the froth layer.

According to some embodiments of the present invention, the at least one acoustic detection means or device may also be used to monitor the acoustic characteristics of the bubbles in the pulp zone to control the flotation cell, e.g., to optimize ore recovery.

According to some embodiments of the present invention, the acoustic detection methods disclosed herein may be augmented with acoustic sources place in, under, next to or above the froth layer.

By way of example, the signal processor or processor module may take the form of a processor and at least one memory including a computer program code, where the processor and at least one memory are configured to cause the apparatus to implement the functionality of the present invention, e.g., receive the signalling containing information about at least one acoustic characteristic of the froth layer in the flotation cell or tank of the flotation separation process; and determine the control characteristic related to the flotation separation process based at least partly on the signalling received. The processor and the at least one memory including the computer program code may also include one or more of the various features set forth above.

According to some embodiments, the present invention may take the form of a method that may comprise steps of receiving the signalling containing information about at least one acoustic characteristic of the froth layer in the flotation cell or tank of the flotation separation process; and determining the control characteristic related to the flotation separation process based at least partly on the signalling received. The method may also include one or more steps for implementing one or more of the various features set forth herein.

According to some embodiments of the present invention, the apparatus may also take the form of a computer-readable storage medium having computer-executable components for performing the steps of the aforementioned method. The computer-readable storage medium may also include, or be configured to perform, steps for implementing one or more of the various features set forth above.

According to some embodiments of the present invention, the apparatus may take the form of means for receiving signalling containing information about at least one acoustic characteristic of a froth layer in a flotation cell or tank of a flotation separation process; and means for determining a control characteristic related to the flotation separation process based at least partly on the signalling received, consistent with that shown and described herein. The apparatus may also include one or more other means for implementing the functionality associated with the various features set forth herein.

## BRIEF DESCRIPTION OF THE DRAWING

The drawing includes Figures 1 - 4, which may not be drawn to scale, as follows:

Figure 1a is a block diagram of a mineral extraction processing system in the form of a copper concentrator that is known in the art.

Figure 1b is a block diagram showing typical processing stages of a mineral extraction processing system that is known in the art.

Figure 2 is a block diagram of apparatus according to some embodiments of the present invention.

Figure 3 is a diagram of the apparatus shown in Figure 2 arranged in relation to a flotation cell or tank according to some embodiments of the present invention.

Figure 4 is a block diagram of a method having steps for implementing a flotation separation process according to some embodiments of the present invention.

DETAILED DESCRIPTION OF BEST MODE OF THE INVENTION

Figure 2 shows the present invention in the form of apparatus 10 configured to control of a flotation separation process, including parameters of the flotation process and reagent addition to optimize mineral recovery. By way of example, Figure 3 shows at least part of the flotation separation process, which, e.g., may be configured to form part of the mineral extraction processing system shown in Figure 1a, according to some embodiments of the present invention.

In Figure 2, the apparatus 10 may include a signal processor or processing module 12 configured to receive signalling containing information about at least one acoustic characteristic of a froth layer 14 in a flotation cell or tank 16 of the flotation separation process shown in Figure 3 and determine a control characteristic related to the flotation separation process based at least partly on the signalling received. The signal processor or processing module 12 may also be configured to provide corresponding signalling, e.g., along signal path 18, containing information to control the flotation separation process based at least partly on the control characteristic determined.

The apparatus 10 may also include at least one acoustic detection means or device generally indicated as 20 shown in Figure 3 configured to sense the at least one acoustic characteristic of the froth layer 14 in the flotation cell 16 and provide the signalling $S_1$, $S_2$, $S_3$, $S_4$, $S_5$, $S_6$, e.g., along the signal path 18 (Figure 2), containing information about the at least one acoustic characteristic of the froth layer 14 in the flotation cell or tank 16 of the flotation separation process. In Figure 3, the at least one acoustic detection means or device 20 may include one or more of acoustic detection means or device labeled $AD20_1$, $AD20_2$, $AD20_3$, $AD20_4$, $AD20_5$, $AD20_6$. By way of example, and consistent with that shown in Figure 3, the flotation separation process may also include a reagent dosing device 30 configured to provide a reagent dosing to the flotation cell or tank, e.g., in response to a reagent dosing signal $S_7$, as well as an ore feed device 32 configured to provide or feed ore to the flotation cell or tank, e.g., in response to an ore feed signal $S_8$. Reagent dosing device like element 30 and ore feed device like element 32 are known in the art, and the scope of the invention is not intended to be limited to any particular type or kind thereof either now known or later developed in the future.

According to some embodiments of the present invention, acoustic sensing may be used to monitor the characteristics of the froth layer 14 in the flotation cell 16 to thereby maximize the recovery of ore. The acoustic characteristics of the froth layer 14 may then be used to control, e.g., the reagent dosing, ore feed rate, ore feed density, froth depth, superficial gas velocity or other aspects of the flotation cell, e.g., to maximize ore recovery.

According to some embodiments of the present invention, the acoustic characteristics of the ore may be monitored by using the acoustic detection means 20, such as by using one or more microphones. The acoustic detection means 20 may be placed above the froth layer 14 like elements $AD20_1$, $AD20_4$, directly in or near the froth layer 14 like elements $AD20_2$, $AD20_5$, or below the froth layer 14 like elements $AD20_3$, $AD20_6$, consistent with that shown in Figure 3. Acoustic detection means 20, such as elements $AD20_1$, $AD20_2$, $AD20_3$, $AD20_4$, $AD20_5$, $AD20_6$, including microphones, for placing, arranging, or configuring above, below or in the froth layer 14 are known in the art, and the scope of the invention is not intended to be limited to any particular type or kind thereof either now known or later developed in the future.

According to some embodiments of the present invention, where the acoustic detection means 20 is placed below the froth layer 14, such as elements $AD20_3$, $AD20_6$, the acoustic detection means may be configured to monitor the acoustics of the froth cell or tank 16 reflected at the interface between the froth layer 14 and the layer below, known as the pulp zone and generally indicated by reference label 15, due to the difference in acoustic impedance between the froth layer 14 and the pulp zone 15.

According to some embodiments of the present invention, the acoustic detection means 20 may be positioned at a number of locations, such as above, within, and/or below the froth layer to monitor the acoustic characteristics of the froth layer. In Figure 3, the two or more acoustic detection means 20 are placed above and below the froth layer 14, such as elements $AD20_1$, $AD20_4$ and $AD20_3$, $AD20_6$, in, near and below the froth layer 14, such as elements $AD20_2$, $AD20_5$ and $AD20_3$, $AD20_6$, or entirely within the froth layer 14, such as element $AD20_2$, so the acoustic detection means 20 may be configured to monitor the attenuation through the froth layer 14, between the froth layer 14 and the pulp zone 15, between the froth layer 14 and the air above the froth layer 14, or any combination.

According to some embodiments of the present invention, acoustic detection sensors, such as $AD20_2$, $AD20_4$ and $AD20_6$, may be mounted external to the flotation cell 16, e.g., including on an outside wall 17. In such embodiments, an acoustic guide or waveguide 18 may be placed within the flotation cell or tank 16 to optimize the acquisition of the acoustic signal. For example, the acoustic waveguide 20 may be placed within the flotation cell or tank 16 such that the acoustic waveguide 18 interacts with the solution in the flotation cell or tank 16 and gas bubbles, and the separate acoustic detection means $AD20_2$, $AD20_4$ and $AD20_6$ are mounted on the exterior, e.g., on the outside wall 17, of the flotation cell or tank 16 to acquire the acoustic signal from the acoustic waveguide 18.

According to some embodiments of the present invention, the acoustic detection means 20 may also be used to monitor the acoustic characteristics of bubbles in the pulp zone 15 to control the flotation cell or tank 16 to optimize ore recovery.

According to some embodiments of the present invention, the acoustic detection techniques described herein may also be augmented with acoustic sources $AS_1$, $AS_2$, $AS_3$, $AS_4$, $AS_5$ placed in the froth layer 14 like elements $AS_4$, under the froth layer 14 like elements $AS_1$, $AS_2$, next to the froth layer 14 like elements $AS_3$ or above the froth layer 14 like element $AS_5$. Acoustic sources are known in the art, and the scope of the invention is not intended to be limited to any particular type or kind thereof either now known or later developed in the future. Moreover, a person skilled in the art would be able to place, implement, arrange or configure the acoustic source in, under, next to or above the froth layer 14 consistent with that shown in Figure 3 and described herein without undue experimentation, and the scope of the invention of the invention is not intended to be limited to any particular type or kind of placement, implementation, arrangement or configuration of the acoustic source in, under, next to or above the froth layer 14 in order to implement the present invention consistent with that disclosed herein.

## The Flotation Process

The present invention is described in relation to a flotation separation process, e.g., which may be configured to form part of the flotation process shown in Figure 1b, which itself may be configured to form part of the mineral extraction processing system shown in Figure 1a. However, the scope of the invention is not intended to include, or form part of, any particular type or kind of flotation process, or any particular type or kind of mineral extraction process system. For example, embodiments are envisioned in which the present invention may be implemented in other types or kinds of processes either now known or later developed in the future, including other types or kinds of flotation processes either now known or later developed in the future, as well as other types or kinds of mineral extraction process systems either now known or later developed in the future.

## Figure 4: The Method

According to some embodiments, the present invention may take the form of a method to control of a flotation separation process, including parameters of the flotation process and reagent addition to optimize mineral recovery. By way of example, Figure 4 shows a flowchart generally indicated as 48 having steps 50, 52 and 54 for implementing the flotation separation process, including a step 50 for receiving signalling containing information about at least one acoustic characteristic of such a froth layer 14 in such a flotation cell or tank 16 of such a flotation separation process as shown in Figure 3, and a step 52 for determining a control characteristic related to the flotation separation process based at least partly on the signalling received, e.g., using such an apparatus 10, including such a signal processor or processing module 12. The method may also include a step 54 for providing corresponding signalling containing information to control the flotation separation process based at least partly on the control characteristic determined, and as well as one or more other steps for implementing the other functionality set forth herein according to some embodiments of the present invention.

## The Signal Processor or Processing Module 12

According to some embodiments of the present invention, the functionality of the signal processor or processing module 12 may be implemented using hardware, software, firmware, or a combination thereof.

By way of example, and consistent with that shown and described herein, the signal processor or signal processing module 12 may be configured with at least one processor and at least one memory including computer program code, where the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to receive the signalling and determine the control characteristic in order to implement the present invention consistent with that disclosed herein.

In a typical software implementation, the signal processor or signal processing module 12 may include one or more microprocessor-based architectures having a microprocessor, a random access memory (RAM), a read only memory (ROM), input/output devices and control, data and address buses connecting the same. A person skilled in the art would be able to program such a microprocessor-based implementation to perform the functionality described herein without undue experimentation. The scope of the invention is not intended to be limited to any particular type or kind of signal processing implementation using technology either now known or later developed in the future.

## Applications Re Other Industrial Processes

By way of example, the present invention is described in relation to, and part of, a mineral extraction processing system for extracting minerals from ore. However, the scope of the invention is intended to include other types or kinds of industrial processes either now known or later developed in the future, including any mineral process, such as those related to processing substances or compounds that result from inorganic processes of nature and/or that are mined from the ground, as well as including either other extraction processing systems or other industrial processes, where the sorting, or classification, of product by size is critical to overall industrial process performance.

## The Scope of the Invention

While the invention has been described with reference to an exemplary embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, may modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed herein as the best mode contemplated for carrying out this invention.

WHAT IS CLAIMED IS:

1. An apparatus comprising:

a signal processor or processing module configured at least to:

receive signalling containing information about at least one acoustic characteristic of a froth layer in a flotation cell or tank of a flotation separation process; and

determine a control characteristic related to the flotation separation process based at least partly on the signalling received.

2. Apparatus according to claim 1, wherein the signal processor or processing module is configured to provide corresponding signalling containing information to control the flotation separation process based at least partly on the control characteristic determined.

3. Apparatus according to claim 1, wherein the control characteristic relates to parameters of the flotation separation process and reagent addition to optimize minerals recovery.

4. Apparatus according to claim 1, wherein the signal processor or processing module is configured to use the at least one acoustic characteristic to control reagent dosing, ore feed rate, ore feed density, froth depth, superficial gas velocity or other aspects of the flotation cell to maximize ore recovery.

5. Apparatus according to claim 1, wherein the signal processor or processing module is configured to receive the signalling from an acoustic detection device, including a microphone.

6. Apparatus according to claim 5, wherein the signal processor or processing module is configured to monitor the at least one acoustic characteristic of ore based at least partly on the signalling received from the acoustic detection device.

7. Apparatus according to claim 5, wherein the acoustic detection device is placed either above the froth layer, or directly in the froth layer, or below the froth layer.

8. Apparatus according to claim 1, wherein the signal processor or processing module is configured to receive the signalling from an acoustic detection device, including a microphone, placed below the froth layer and monitor acoustics of a froth cell reflected at an interface between the froth layer and a layer below the froth layer, including or also known as a pulp zone, based at least partly on a difference in an acoustic impedance between the froth layer and the pulp zone.

9. Apparatus according to claim 1, wherein the signal processor or processing module is configured to receive signals from two or more acoustic detection devices placed above and below the froth layer, in and below the froth layer, or entirely within the froth layer, and monitor the attenuation through the froth layer, between the froth layer and the pulp zone, between the froth layer and the air above the froth layer, or any combination, based at least partly on the signals received.

10. Apparatus according to claim 1, wherein the signal processor or processing module is configured to receive signals from acoustic detection sensors mounted external to the flotation cell or tank.

11. Apparatus according to claim 10, wherein the signals are received from an acoustic guide placed within the flotation cell or tank to optimize the acquisition of an acoustic signal.

12. Apparatus according to claim 11, wherein the signalling is received from an acoustic waveguide placed within the flotation cell or tank such that the acoustic waveguide interacts with the tank solution and gas bubbles, and from a separate acoustic detection device mounted on the exterior of the flotation cell or tank to acquire the acoustic signal from the acoustic waveguide.

13. Apparatus according to claim 1, wherein the signal processor or processing module is configured to receive the signalling from acoustic detection devices positioned at a number of locations, including above, within, and/or below the froth layer and monitor the acoustic characteristics of the froth layer.

14. Apparatus according to claim 1, wherein the signal processor or processing module is configured to receive the signalling from an acoustic detection device and monitor the acoustic characteristics of bubbles in a pulp zone to control the flotation cell to optimize ore recovery.

15. Apparatus according to claim 1, wherein the signal processor or signal processing module is configured to receive the signalling from an acoustic detection device augmented with acoustic sources configured, arranged or placed in, under, next to or above the froth layer.

16. Apparatus according to claim 1, wherein the apparatus further comprises an acoustic detection device, including a microphone, configured to provide the signalling.

17. Apparatus according to claim 16, wherein the acoustic detection device is configured, arranged or placed either above the froth layer, or directly in the froth layer, or below the froth layer.

18. Apparatus according to claim 1, wherein the apparatus further comprises two or more acoustic detection devices configured, arranged or placed above and below the froth layer, in and below the froth layer, or entirely within the froth layer, and configured to provide signals containing information about acoustic characteristics of the froth layer.

19. Apparatus according to claim 1, wherein the apparatus further comprises acoustic detection sensors mounted external to the flotation cell or tank and configured to provide signals containing information about acoustic characteristics of the froth layer.

20. Apparatus according to claim 19, wherein the apparatus further comprises an acoustic guide placed within the flotation cell or tank to optimize the acquisition of an acoustic signal and configured to provide the signals containing information about the acoustic characteristics of the froth layer.

21. Apparatus according to claim 20, wherein the apparatus further comprises an acoustic waveguide placed within the flotation cell or tank such that the acoustic waveguide interacts with the tank solution and gas bubbles, and comprises a separate acoustic detection device mounted on the exterior of the flotation cell or tank to acquire the acoustic signal from the acoustic waveguide, the acoustic waveguide and separate acoustic detection device being configured to provide the signals containing information about the acoustic characteristics of the froth layer.

22. Apparatus according to claim 1, wherein the apparatus further comprises acoustic detection devices positioned at a number of locations, including above, within, and/or below the froth layer and monitor the acoustic characteristics of the froth layer, configured to provide signals containing information about the acoustic characteristics of the froth layer.

23. Apparatus according to claim 1, wherein the apparatus further comprises an acoustic detection device augmented with acoustic sources configured, arranged or placed in, under, next to or above the froth layer.

24. Apparatus according to claim 1, wherein the signal processor or signal processing module comprises

at least one processor and at least one memory including computer program code, where the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to receive the signalling and determine the control characteristic.

25. A method comprising:

receiving signalling containing information about at least one acoustic characteristic of a froth layer in a flotation cell or tank of a flotation separation process; and

determining a control characteristic related to the flotation separation process based at least partly on the signalling received and using apparatus, including a signal processor or processing module.

26. A method according to claim 25, wherein the method further comprises providing corresponding signalling containing information to control the flotation separation process based at least partly on the control characteristic determined.

27. A method according to claim 25, wherein the control characteristic relates to parameters of the flotation separation process and reagent addition to optimize minerals recovery.

28. A method according to claim 25, wherein the method comprises using the at least one acoustic characteristic to control reagent dosing, ore feed rate, ore feed density, froth depth, superficial gas velocity or other aspects of the flotation cell to maximize ore recovery.

29. A method according to claim 25, wherein the method comprises receiving the signal from an acoustic detection device, including a microphone.

30. A method according to claim 29, wherein the method comprises monitoring the at least one acoustic characteristic of ore based at least partly on the signalling received from the acoustic detection device.

31. A method according to claim 29, wherein the acoustic detection device is placed either above the froth layer, or directly in the froth layer, or below the froth layer.

32. A method according to claim 25, wherein the method comprises receiving the signalling from an acoustic detection device, including a microphone, placed below the froth layer and monitor acoustics of a froth cell reflected at an interface between the froth layer and a layer below the froth layer, including or also known as a pulp zone, based at least partly on a difference in an acoustic impedance between the froth layer and the pulp zone.

33. A method according to claim 25, wherein the method comprises receiving signals from two or more acoustic detection devices placed above and below the froth layer, in and below the froth layer, or entirely within the froth layer, and monitor the attenuation through the froth layer, between the froth layer and the pulp zone, between the froth layer and the air above the froth layer, or any combination, based at least partly on the signals received.

34. A method according to claim 25, wherein the method comprises receiving signals from acoustic detection sensors mounted external to the flotation cell or tank.

35. A method according to claim 34, wherein the method comprises receiving the signals from an acoustic guide placed within the flotation cell or tank to optimize the acquisition of an acoustic signal.

36. A method according to claim 35, wherein the method comprises receiving the signals from an acoustic waveguide placed within the flotation cell or tank such that the acoustic waveguide interacts with the tank solution and gas bubbles, and from a separate acoustic detection device mounted on the exterior of the flotation cell or tank to acquire the acoustic signal from the acoustic waveguide.

37. A method according to claim 25, wherein the method comprises receiving signals from acoustic detection devices positioned at a number of locations, including above, within, and/or below the froth layer and monitor the acoustic characteristics of the froth layer.

38. A method according to claim 25, wherein the method comprises receiving the signalling from an acoustic detection device and monitoring the acoustic characteristics of bubbles in a pulp zone to control the flotation cell to optimize ore recovery.

39. A method according to claim 25, wherein the method comprises receiving the signalling from an acoustic detection device augmented with acoustic sources configured, arranged or placed in, under, next to or above the froth layer.

40. A method according to claim 25, wherein the method comprises configuring the signal processor or processing module with at least one processor and at least one memory including computer program code, where the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to receive the signalling and determine the control characteristic.

41. An apparatus comprising:

means for receiving signalling containing information about at least one acoustic characteristic of a froth layer in a flotation cell or tank of a flotation separation process; and

means for determining a control characteristic related to the flotation separation process based at least partly on the signalling received.

42. Apparatus according to claim 41, wherein the apparatus further comprises means for controlling the flotation separation process based at least partly on the control characteristic determined.

43. Apparatus according to claim 41, wherein the control characteristic relates to parameters of the flotation separation process and reagent addition to optimize minerals recovery.

44. Apparatus according to claim 41, wherein the apparatus further comprises means for using the at least one acoustic characteristic to control reagent dosing, ore feed rate, ore feed density, froth depth, superficial gas velocity or other aspects of the flotation cell to maximize ore recovery.

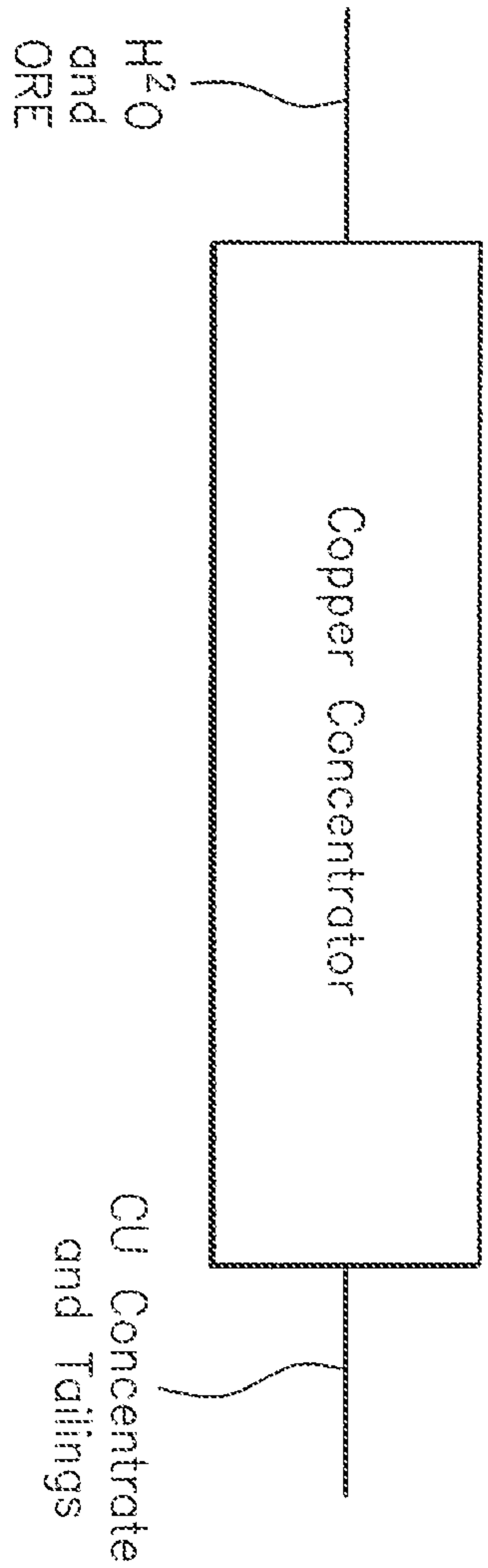



FIG. 1a : Mineral Extraction Processing System (PRIOR ART)

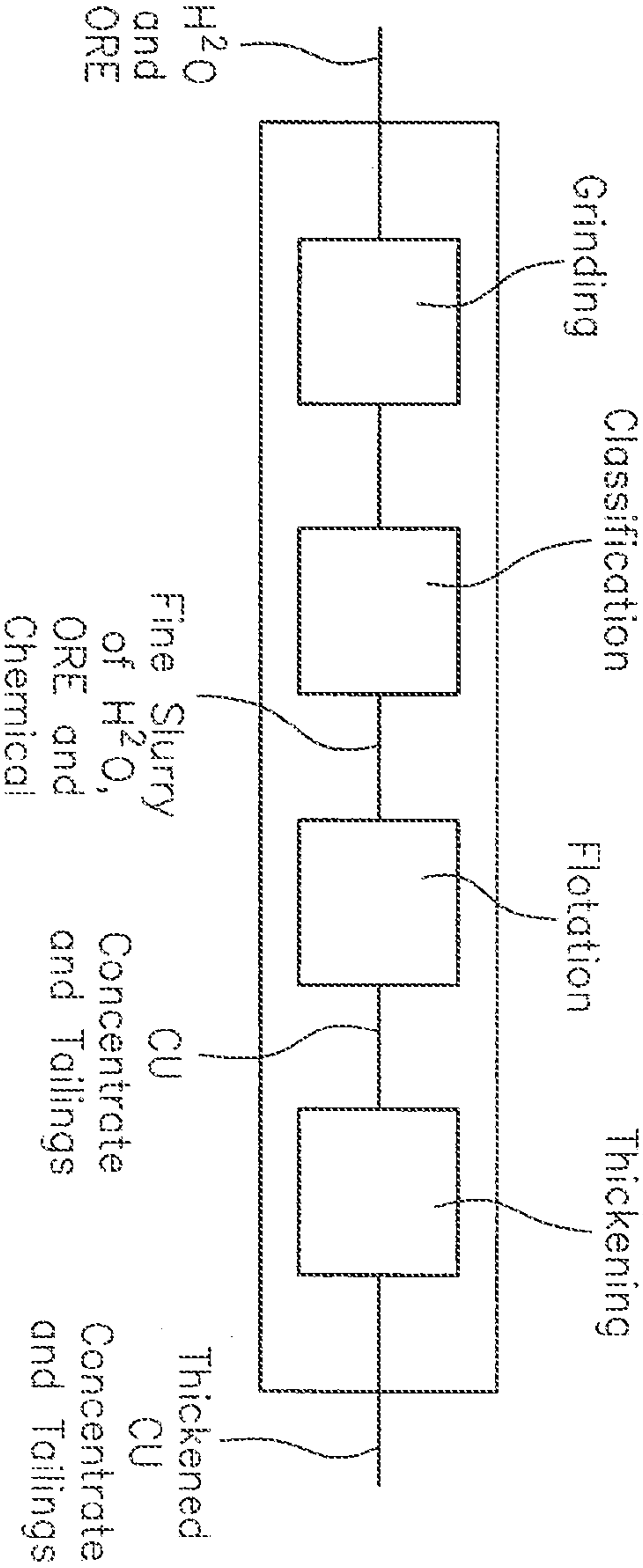



FIG. 1b (PRIOR ART)

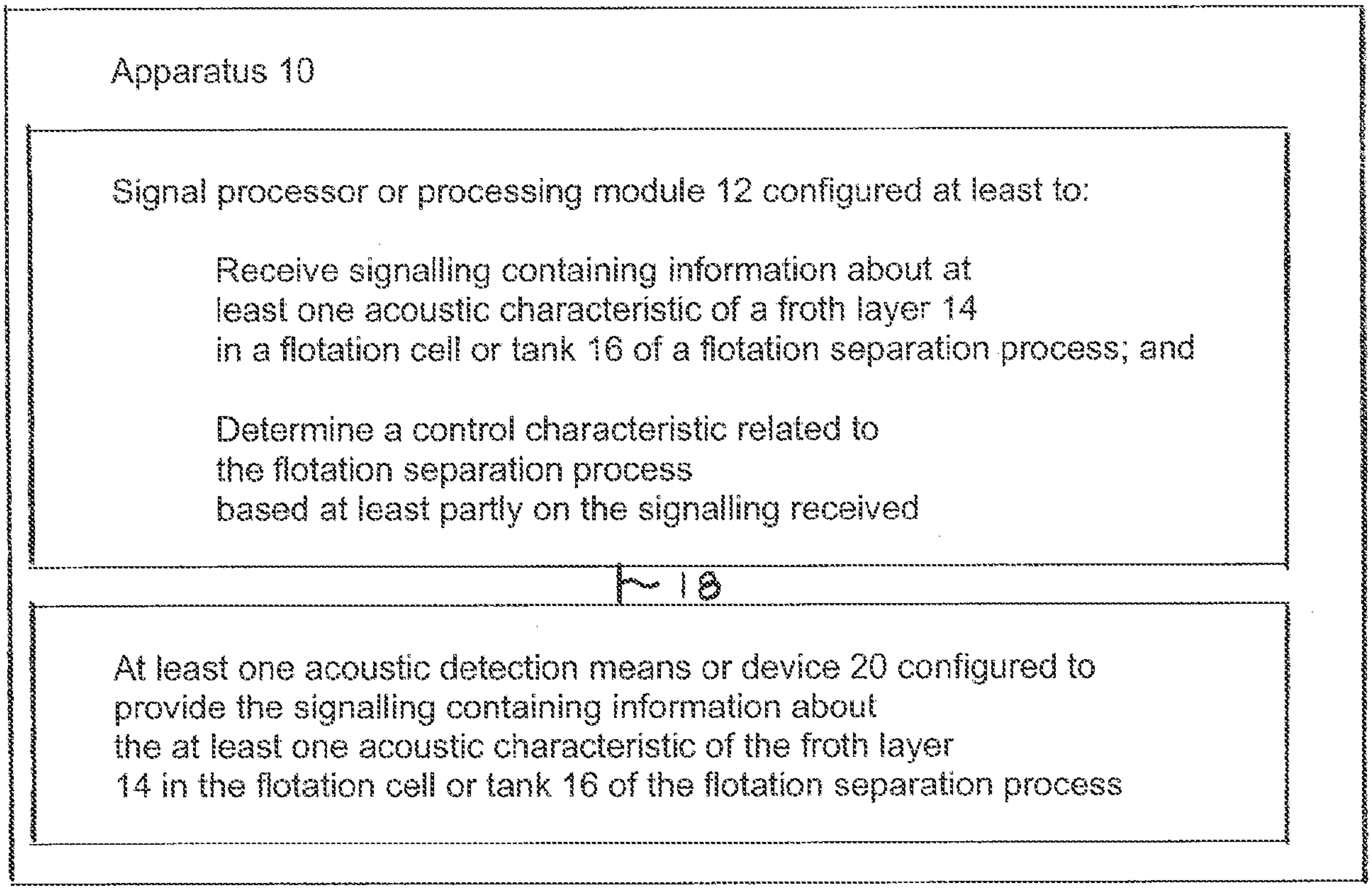



Figure 2

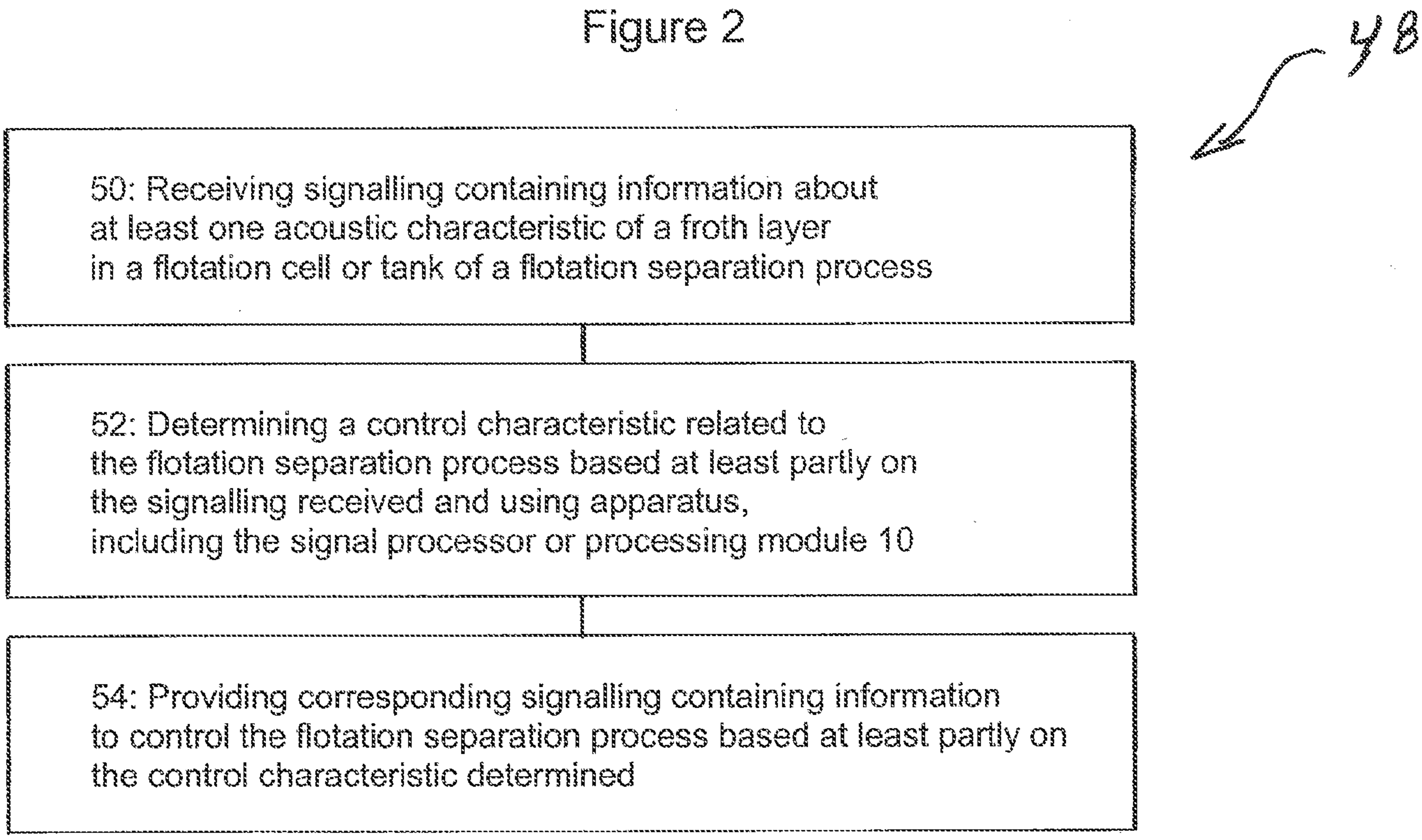
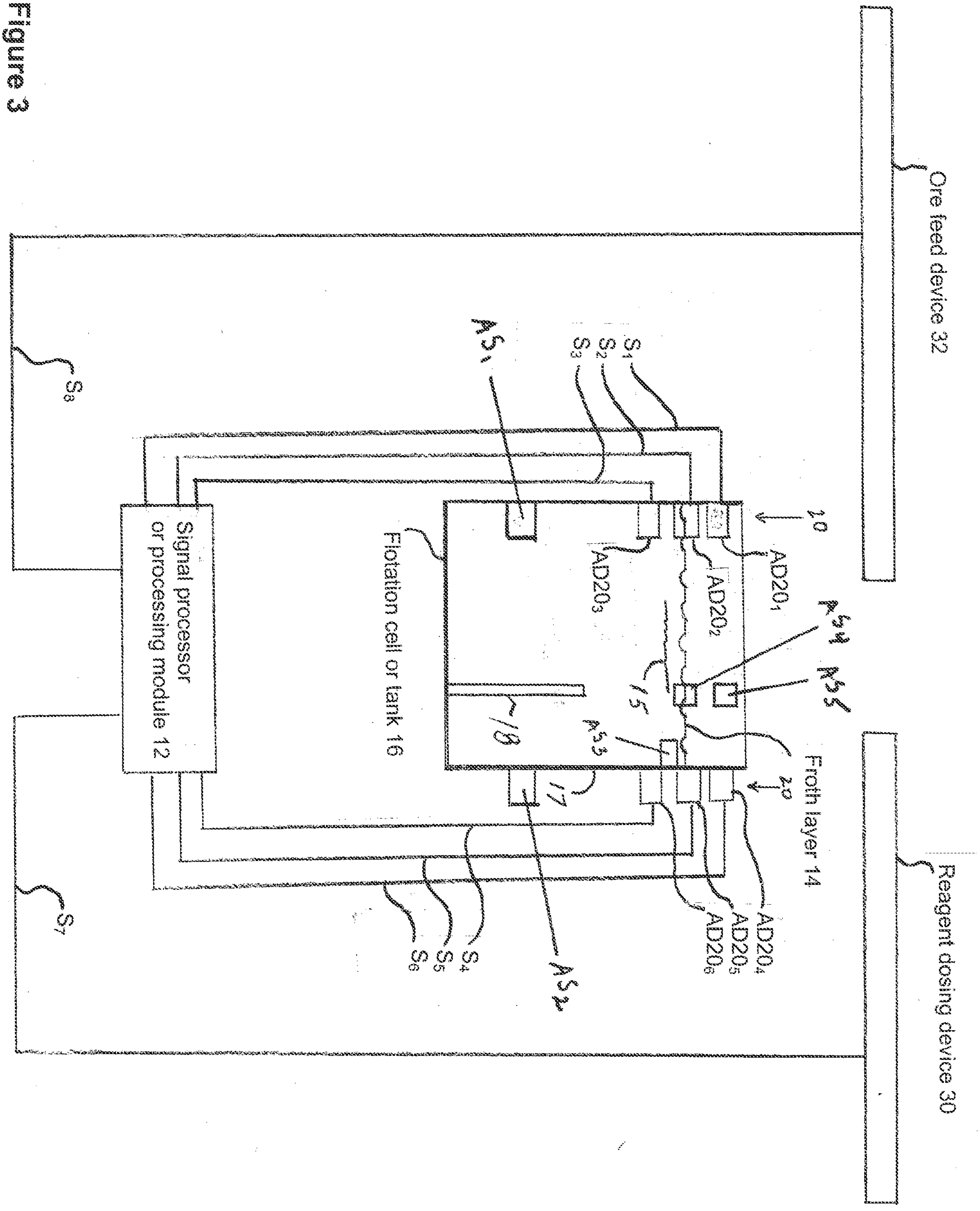



**Figure 4**

Figure 3


Ore feed device 32
Reagent dosing device 30
Signal processor or processing module 12
Flotation cell or tank 16
Froth layer 14
$AD20_1$
$AD20_2$
$AD20_3$
$AD20_4$
$AD20_5$
$AD20_6$
$S_1$
$S_2$
$S_3$
$S_4$
$S_5$
$S_6$
$S_7$
$S_8$
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$AS_5$
10
15
17
18
20

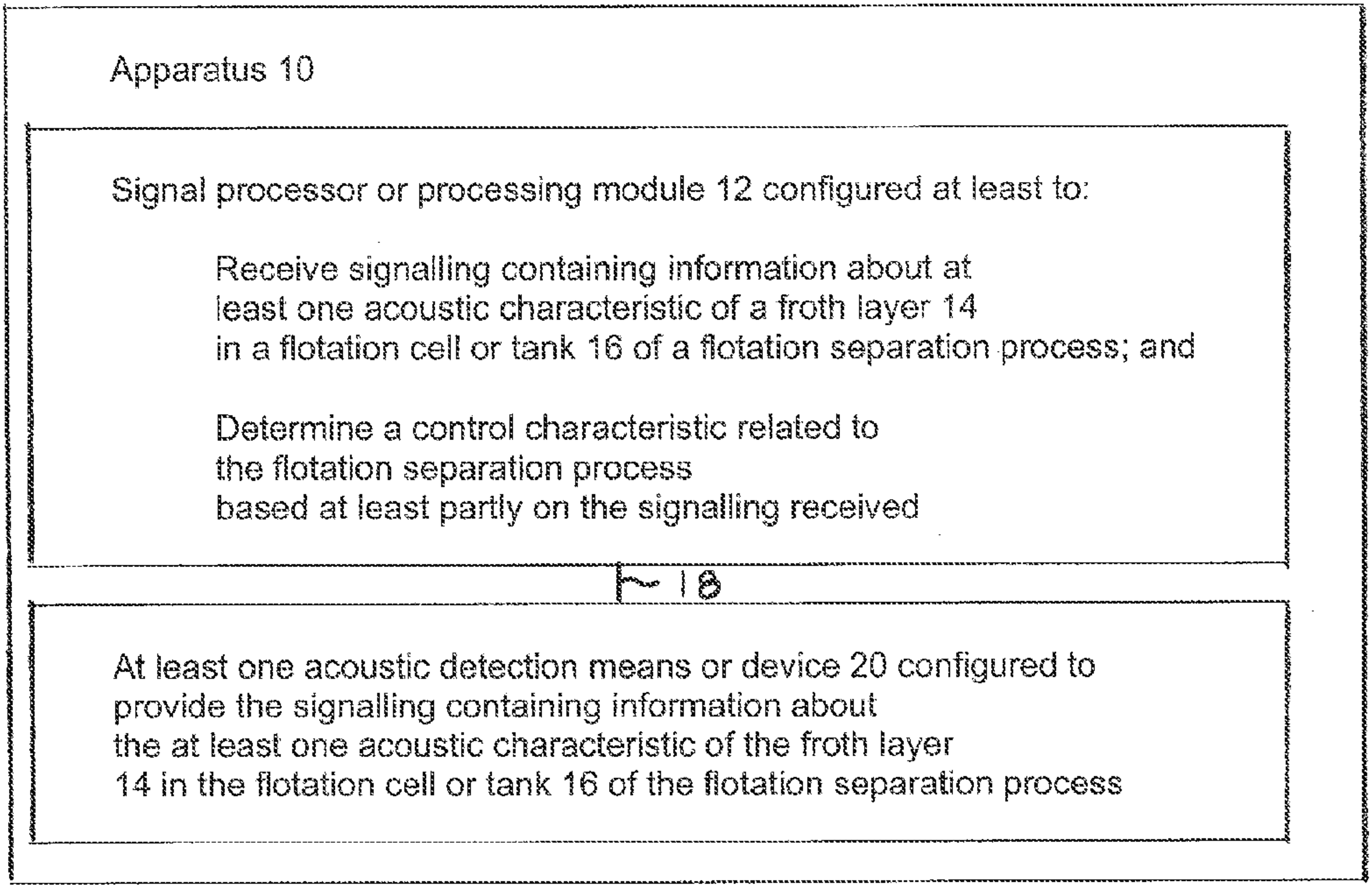
Apparatus 10
Signal processor or processing module 12 configured at least to:
Receive signalling containing information about at least one acoustic characteristic of a froth layer 14 in a flotation cell or tank 16 of a flotation separation process; and
Determine a control characteristic related to the flotation separation process based at least partly on the signalling received
18
At least one acoustic detection means or device 20 configured to provide the signalling containing information about the at least one acoustic characteristic of the froth layer 14 in the flotation cell or tank 16 of the flotation separation process

Figure 2