



(22) **Date de dépôt/Filing Date:** 2017/04/28

(41) **Mise à la disp. pub./Open to Public Insp.:** 2017/07/05

(45) **Date de délivrance/Issue Date:** 2018/07/24

(51) **Cl.Int./Int.Cl.** **B03B 9/02** (2006.01),
B03D 1/02 (2006.01)

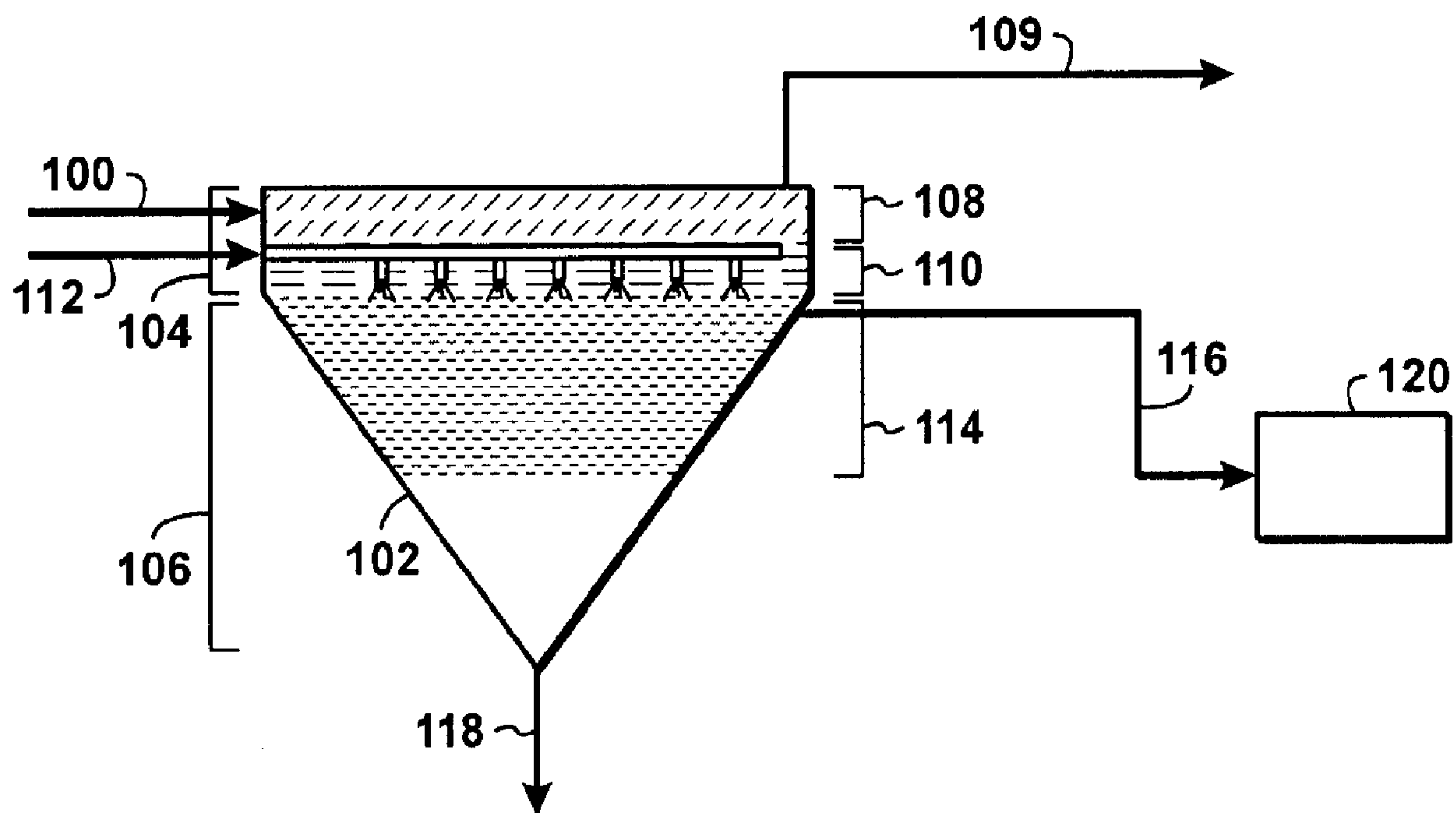
(72) **Inventeurs/Inventors:**
SAKUHUNI, GIVEMORE, CA;
CASTELLANOS DUARTE, DIANA Y., US;
CULLINANE, JOHN T., US

(73) **Propriétaires/Owners:**
EXXONMOBIL UPSTREAM RESEARCH COMPANY,
US;
IMPERIAL OIL RESOURCES LIMITED, CA

(74) **Agent:** BORDEN LADNER GERVAIS LLP

(54) **Titre :** EXTRACTION DE SABLES BITUMINEUX A BASE D'EAU UTILISANT L'ENNOIEMENT

(54) **Title:** WATER-BASED OIL SAND EXTRACTION USING OVERWASH



(57) **Abrégé/Abstract:**

Disclosed is a water-based oil sand extraction method including introducing a feed stream comprising bitumen, solids, and water into an extraction vessel; and introducing a froth overwash into the extraction vessel above a froth layer in the extraction vessel for facilitating solids removal from the froth layer.

ABSTRACT

Disclosed is a water-based oil sand extraction method including introducing a feed stream comprising bitumen, solids, and water into an extraction vessel; and introducing a froth overwash into the extraction vessel above a froth layer in the extraction vessel for facilitating solids removal from the froth layer.

WATER-BASED OIL SAND EXTRACTION USING OVERWASH

BACKGROUND

Field of Disclosure

[0001] The disclosure relates generally to the field of oil sand processing, and more particularly to water-based extraction.

Description of Related Art

[0002] This section is intended to introduce various aspects of the art, which may be associated with the present disclosure. This discussion is believed to assist in providing a framework to facilitate a better understanding of particular aspects of the present disclosure. Accordingly, it should be understood that this section should be read in this light, and not necessarily as admissions of prior art.

[0003] Modern society is greatly dependent on the use of hydrocarbon resources for fuels and chemical feedstocks. Hydrocarbons are generally found in subsurface formations that can be termed “reservoirs”. Removing hydrocarbons from the reservoirs depends on numerous physical properties of the subsurface formations, such as the permeability of the rock containing the hydrocarbons, the ability of the hydrocarbons to flow through the subsurface formations, and the proportion of hydrocarbons present, among other things. Easily harvested sources of hydrocarbons are dwindling, leaving less accessible sources to satisfy future energy needs. As the costs of hydrocarbons increase, the less accessible sources become more economically attractive.

[0004] Recently, the harvesting of oil sand to remove heavy oil has become more economical. Hydrocarbon removal from oil sand may be performed by several techniques. For example, a well can be drilled to an oil sand reservoir and steam, hot air, solvents, or a combination thereof, can be injected to release the hydrocarbons. The released hydrocarbons may be collected by wells and brought to the surface. In another technique, strip or surface

mining may be performed to access the oil sand, which can be treated with water, steam or solvents to extract the heavy oil.

[0005] Oil sand extraction processes are used to liberate and separate bitumen from oil sand so that the bitumen can be further processed to produce synthetic crude oil or mixed with diluent to form “dilbit” and be transported to a refinery plant. Numerous oil sand extraction processes have been developed and commercialized, many of which involve the use of water as a processing medium. Where the oil sand is treated with water, the technique may be referred to as water-based extraction (WBE) or as a water-based oil sand extraction process. WBE is a commonly used process to extract bitumen from mined oil sand.

[0006] One WBE process is the Clark hot water extraction process (the “Clark Process”). This process typically requires that mined oil sand be conditioned for extraction by being crushed to a desired lump size and then combined with hot water and perhaps other agents to form a conditioned slurry of water and crushed oil sand. In the Clark Process, an amount of sodium hydroxide (caustic) may be added to the slurry to increase the slurry pH, which enhances the liberation and separation of bitumen from the oil sand. Other WBE processes may use other temperatures and may include other conditioning agents, which are added to the oil sand slurry, or may operate without conditioning agents. This slurry is first processed in a Primary Separation Cell (PSC), also known as a Primary Separation Vessel (PSV), to extract the bitumen from the slurry.

[0007] In one WBE process, a water and oil sand slurry is separated into three major streams in the PSC: bitumen froth, middlings, and a PSC underflow (also referred to as coarse sand tailings (CST)).

[0008] Regardless of the type of WBE process employed, the process will typically result in the production of a bitumen froth that requires treatment with a solvent. For example, in the Clark Process, a bitumen froth stream comprises bitumen, solids, and water. Certain processes use naphtha to dilute bitumen froth before separating the product bitumen by centrifugation. These processes are called naphtha froth treatment (NFT) processes. Other

processes use a paraffinic solvent, and are called paraffinic froth treatment (PFT) processes, to produce pipelineable bitumen with low levels of solids and water. In the PFT process, a paraffinic solvent (for example, a mixture of iso-pentane and n-pentane) is used to dilute the froth before separating the product, diluted bitumen, by gravity. A portion of the asphaltenes in the bitumen is also rejected by design in the PFT process and this rejection is used to achieve reduced solids and water levels. In both the NFT and the PFT processes, the diluted tailings (comprising water, solids and some hydrocarbon) are separated from the diluted product bitumen.

[0009] Solvent is typically recovered from the diluted product bitumen component before the bitumen is delivered to a refining facility for further processing.

[0010] The PFT process may comprise at least three units: Froth Separation Unit (FSU), Solvent Recovery Unit (SRU) and Tailings Solvent Recovery Unit (TSRU). Mixing of the solvent with the feed bitumen froth may be carried out counter-currently in two stages in separate froth separation units. The bitumen froth comprises bitumen, water, and solids. A typical composition of bitumen froth is about 60 wt. % bitumen, 30 wt. % water, and 10 wt. % solids. The paraffinic solvent is used to dilute the froth before separating the product bitumen by gravity. The foregoing is only an example of a PFT process and the values are provided by way of example only. An example of a PFT process is described in Canadian Patent No. 2,587,166 to Sury.

[0011] From the PSC, the middlings, which may comprise bitumen as well as about 10-30 wt. % or about 20-25 wt.% solids based on the total wt. % of the middlings, is withdrawn and sent to the flotation cells to further recover bitumen. The middlings are processed by bubbling air through the slurry and creating a bitumen froth, which is recycled back to the PSC. Fine tailings (FT) from the flotation cells, comprising mostly solids and water, are sent for further treatment or disposed in an external tailings area (ETA).

[0012] It would be desirable to have an alternative or improved method of water-based oil sand extraction for facilitating solids removal from the froth layer.

SUMMARY

[0013] It is an object of the present disclosure to provide a method of water-based oil sand extraction for facilitating solids removal from the froth layer.

[0014] Disclosed is a water-based oil sand extraction method including introducing a feed stream comprising bitumen, solids, and water into an extraction vessel; and introducing a froth overwash into the extraction vessel above a froth layer in the extraction vessel for facilitating solids removal from the froth layer.

[0015] The foregoing has broadly outlined the features of the present disclosure so that the detailed description that follows may be better understood. Additional features will also be described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] These and other features, aspects and advantages of the disclosure will become apparent from the following description, appending claims and the accompanying drawings, which are briefly described below.

[0017] Fig. 1 is a schematic of a froth underwash in a PSC.

[0018] Fig. 2 is a schematic of a froth overwash in a PSC.

[0019] Fig. 3 is a schematic of a froth overwash and underwash in a PSC.

[0020] Fig. 4 is a schematic of froth overwash in flotation cells.

[0021] Fig. 5 is a graph of froth solids versus caustic addition (weight fraction of solids in the froth).

[0022] Fig. 6 is a graph of graph of froth quality: bitumen/solids ratio versus caustic addition.

[0023] Fig. 7 is a graph of froth SFR (sands to fines ratio) versus caustic addition.

[0024] Fig. 8 is graph of fraction of solids in the bitumen froth having a size $< 45 \text{ um}$ (measured in wt. % fraction in froth) versus caustic addition.

[0025] Fig. 9 is a graph of fraction of solids in the bitumen froth having a size $> 45 \text{um}$ (measured in wt. % fraction in froth) versus caustic addition.

[0026] Fig. 10 is a graph of primary bitumen recovery (%) versus caustic addition.

[0027] It should be noted that the figures are merely examples and no limitations on the scope of the present disclosure are intended thereby. Further, the figures are generally not drawn to scale, but are drafted for purposes of convenience and clarity in illustrating various aspects of the disclosure.

DETAILED DESCRIPTION

[0028] For the purpose of promoting an understanding of the principles of the disclosure, reference will now be made to the features illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the disclosure is thereby intended. Any alterations and further modifications, and any further applications of the principles of the disclosure as described herein are contemplated as would normally occur to one skilled in the art to which the disclosure relates. It will be apparent to those skilled in the relevant art that some features that are not relevant to the present disclosure may not be shown in the drawings for the sake of clarity.

[0029] At the outset, for ease of reference, certain terms used in this application and their meaning as used in this context are set forth below. To the extent a term used herein is not defined below, it should be given the broadest definition persons in the pertinent art have given that term as reflected in at least one printed publication or issued patent. Further, the present processes are not limited by the usage of the terms shown below, as all equivalents, synonyms, new developments and terms or processes that serve the same or a similar purpose are considered to be within the scope of the present disclosure.

[0030] Throughout this disclosure, where a range is used, any number between or inclusive of the range is implied.

[0031] A “hydrocarbon” is an organic compound that primarily includes the elements of hydrogen and carbon, although nitrogen, sulfur, oxygen, metals, or any number of other elements may be present in small amounts. Hydrocarbons generally refer to components found in heavy oil or in oil sand. However, the techniques described are not limited to heavy oils but may also be used with any number of other reservoirs to improve gravity drainage of liquids. Hydrocarbon compounds may be aliphatic or aromatic, and may be straight chained, branched, or partially or fully cyclic.

[0032] “Bitumen” is a naturally occurring heavy oil material. Generally, it is the hydrocarbon component found in oil sand. Bitumen can vary in composition depending upon the degree of loss of more volatile components. It can vary from a very viscous, tar-like, semi-solid material to solid forms. The hydrocarbon types found in bitumen can include aliphatics, aromatics, resins, and asphaltenes. A typical bitumen might be composed of:

19 weight (wt.) % aliphatics (which can range from 5 wt. % - 30 wt. %, or higher);
 19 wt. % asphaltenes (which can range from 5 wt. % - 30 wt. %, or higher);
 30 wt. % aromatics (which can range from 15 wt. % - 50 wt. %, or higher);
 32 wt. % resins (which can range from 15 wt. % - 50 wt. %, or higher); and
 some amount of sulfur (which can range in excess of 7 wt. %), the weight % based upon total weight of the bitumen.

In addition, bitumen can contain some water and nitrogen compounds ranging from less than 0.4 wt. % to in excess of 0.7 wt. %. The percentage of the hydrocarbon found in bitumen can vary. The term “heavy oil” includes bitumen as well as lighter materials that may be found in a sand or carbonate reservoir.

[0033] “Heavy oil” includes oils which are classified by the American Petroleum Institute (“API”), as heavy oils, extra heavy oils, or bitumens. The term “heavy oil” includes bitumen. Heavy oil may have a viscosity of about 1,000 centipoise (cP) or more, 10,000 cP or more, 100,000 cP or more, or 1,000,000 cP or more. In general, a heavy oil has an API gravity

between 22.3° API (density of 920 kilograms per meter cubed (kg/m^3) or 0.920 grams per centimeter cubed (g/cm^3)) and 10.0° API (density of 1,000 kg/m^3 or 1 g/cm^3). An extra heavy oil, in general, has an API gravity of less than 10.0° API (density greater than 1,000 kg/m^3 or 1 g/cm^3). For example, a source of heavy oil includes oil sand or bituminous sand, which is a combination of clay, sand, water and bitumen.

[0034] “Fine particles” or “fines” are generally defined as those solids having a size of less than 44 microns (μm), as determined by laser diffraction particle size measurement.

[0035] “Coarse particles” are generally defined as those solids having a size of greater than 44 microns (μm).

[0036] The term “solvent” as used in the present disclosure should be understood to mean either a single solvent, or a combination of solvents.

[0037] The terms “approximately,” “about,” “substantially,” and similar terms are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. It should be understood by those of skill in the art who review this disclosure that these terms are intended to allow a description of certain features described and claimed without restricting the scope of these features to the precise numeral ranges provided. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and are considered to be within the scope of the disclosure.

[0038] The articles “the”, “a” and “an” are not necessarily limited to mean only one, but rather are inclusive and open ended so as to include, optionally, multiple such elements.

[0039] The term “paraffinic solvent” (also known as aliphatic) as used herein means solvents comprising normal paraffins, isoparaffins or blends thereof in amounts greater than 50 wt. %. Presence of other components such as olefins, aromatics or naphthenes may counteract the function of the paraffinic solvent and hence may be present in an amount of only 1 to 20 wt. % combined, for instance no more than 3 wt. %. The paraffinic solvent may be a C_4 to C_{20}

or C₄ to C₆ paraffinic hydrocarbon solvent or a combination of iso and normal components thereof. The paraffinic solvent may comprise pentane, iso-pentane, or a combination thereof. The paraffinic solvent may comprise about 60 wt. % pentane and about 40 wt. % iso-pentane, with none or less than 20 wt. % of the counteracting components referred above.

[0040] Certain extraction vessels carry more solids to the overflow or bitumen froth than desired. One of the mechanisms by which solids can report to the froth is by physical entrainment or entrapment of hydrophilic solids. Many primary separation cells (PSCs) use an underwash system, which introduces fresh hot water below the froth layer in order to reduce solids carry over and hence froth solids by providing a cleaner water phase through which bitumen loaded air bubbles rise prior to collecting in the froth layer. In addition, the underwash layer helps to increase the froth temperature, lowering the viscosity and improving handling. The underwash also serves as a buffer to separate the high solids middlings and a bitumen laden froth layer and may be especially helpful for high fines low bitumen ores to mitigate sludging. Despite a stable underwash layer of considerable depth, the underwash may be insufficient to adequately reduce froth solids.

[0041] The present inventors have discovered that aerated bitumen froth has good drainage and is capable of draining water introduced from the top of the froth layer, and in the process, draining solids either entrained or entrapped in the water phase or on the water/oil interface. Proposed herein is a method of reducing froth solids by introducing an overwash on top of the froth layer. Proof of concept test results are described below with reference to Figure 3 and show that solids in the bitumen froth can be reduced by up to 50% by a water spray without significantly impacting bitumen recovery.

[0042] A water-based oil sand extraction method may comprise: a) introducing a feed stream comprising bitumen, solids, and water into an extraction vessel; and b) introducing a froth overwash into the extraction vessel above a froth layer in the extraction vessel for facilitating solids removal from the froth layer.

[0043] The feed stream may be any suitable feed stream comprising bitumen, solids, and water. For instance, the feed stream may be a feed stream to a PSC or middlings from a PSC for feeding to a mechanical or column flotation cell. The extraction vessel may be any suitable extraction vessel. For instance, the extraction vessel may be a PSC or a mechanical or column flotation cell.

[0044] Step b) may be effected prior to de-aerating the froth layer. De-aerating is a known practice in WBE.

[0045] The overwash may be any suitable overwash and may comprise water. The overwash may be of any suitable temperature and may have a temperature of 25 to 100 degrees Celsius. The overwash may further comprise at least one process aid. The process aid may be any suitable process aid for assisting the process and may comprise caustic, frothers, viscosity modifiers, or a combination thereof.

[0046] The method may further comprise introducing a froth underwash into the extraction vessel beneath the froth layer in the extraction vessel for reducing solids entrainment in the froth layer. The froth overwash and the froth underwash may be supplied by a common wash stream or distinct wash streams, for instance at different temperatures or different compositions. The different compositions may include different chemical compositions of, and/or different concentrations of, process aids.

[0047] The underwash is used for reducing solids entrainment in the froth layer, that is, reducing solids carry-over, or preventing an amount of solids entrained in the froth. The overwash is used for facilitating solids removal from the froth layer, that is, mitigating an amount of entrained solids.

[0048] The froth overwash flowrate and a froth underwash flowrate may be controlled by adjusting a split of the common wash stream into the froth overwash and the froth underwash. The common wash stream may have a constant flowrate. A minimum overwash flow rate may be required to penetrate through the froth later to ensure or increase the effectiveness of the overwash.

[0049] The froth overwash flowrate may be fixed and a froth underwash flowrate may be varied based on dilution wash requirements, density in the extraction vessel, a bitumen-water interface level, underwash layer stability, or a combination thereof. Underwash layer stability may be increased by raising the underwash flow rate to provide a thicker and/or denser underwash layer.

[0050] The froth underwash flowrate may be fixed and the froth overwash flowrate may be varied based on froth quality. That is, a lower froth quality (i.e. higher solids content in the froth), the higher the flowrate of the underwash that may be desired.

[0051] The methods herein may further comprise withdrawing a bitumen froth from the PSC; withdrawing a middlings from the PSC; and withdrawing a coarse sand tailings (CST) from the PSC. The methods herein may further comprise introducing the middlings stream into a mechanical or column flotation cell; and introducing a second froth overwash into the mechanical or column flotation cell above a second froth layer in the mechanical or column flotation cell for facilitating solids removal from the second froth layer.

[0052] The froth overwash may be provided in the form of a spray to maximize water contact with froth. The method may be for improving bitumen froth quality. For instance, the bitumen froth may have a solids content of less than 15 wt. %. The method may also be for reducing a sand to fines ratio of solids in the bitumen froth.

[0053] Consistent with the above described methods, a system for water-based oil sand extraction may comprise a primary separation cell (PSC) for receiving a feed stream comprising bitumen, solids, and water; and a froth overwash system for introducing a froth overwash into the PSC above a froth layer in the PSC for facilitating solids removal from the froth layer.

[0054] Consistent with the above described methods, a system for water-based oil sand extraction may comprise a mechanical or column flotation cell for receiving a middlings stream from a primary separation cell (PSC); and a second froth overwash system for introducing a second froth overwash into the mechanical or column flotation cell above a second froth layer

in the mechanical or column flotation cell for facilitating solids removal from the second froth layer.

[0055] Figures 1 to 4 illustrate four configurations. Figure 1 shows a conventional underwash in a PSC. The PSC is an important part of WBE as bitumen froth is separated from the majority of water and solids. Figure 1 depicts an example of a PSC and its operation. With reference to Figure 1, the feed to the PSC (102) is a feed stream (100) comprising bitumen, solids, and water, which may be an aerated oil sand slurry from a hydrotransport line stemming from mined oil sand ore. The illustrated PSC (102) comprises a cylindrical section (104) at the top where aerated bitumen froth with some solids and water rises upwards and flows to the next process equipment for cleanup in froth treatment, and a conical section (106) below, which creates a densification zone (comprising the majority of solids and water) establishing a vertical density gradient in the PSC, which enables separation of bitumen froth. The cylindrical section (104) may comprise a froth layer (108), an underwash layer (110) into which an underwash (112) is added, and a middlings layer (114). Three streams typically leave the PSC (102), namely, a bitumen froth (109) comprising the majority of the bitumen from the oil sand which is withdrawn near the top of the PSC, middlings (116) comprising some bitumen which is withdrawn near the bottom of the cylindrical section of the PSC and which are sent to flotation cells (120) for secondary recovery of bitumen, and a coarse sands tailings (CST) (118) which are withdrawn at the bottom of the PSC. The CST (118) may comprise water and the majority of solids from the oil sand slurry. The CST (118) typically contains some bitumen which is one of the primary locations for losses of bitumen in the WBE process. A small amount of bitumen is also lost to the flotation tailings (not shown, also called fine tailings), the stream leaving the flotation cells (120) from the secondary recovery process. The flotation cells (not shown) also produce a recovered bitumen stream (not shown) which may be passed back into the PSC (102).

[0056] Figure 2 shows an overwash system in a PSC according to an embodiment of the processes and systems disclosed herein. With reference to Figure 2, the feed to the PSC (202) is a feed stream (200) comprising bitumen, solids, and water, which may be an aerated oil sand slurry from a hydrotransport line stemming from mined oil sand ore. The froth layer (208) sits above the middlings layer (214). Three streams typically leave the PSC (202),

namely, a bitumen froth (209) comprising the majority of the bitumen from the oil sand which is withdrawn near the top of the PSC, middlings (216) comprising some bitumen which is withdrawn near the bottom of the cylindrical section of the PSC and which are sent to flotation cells (220) for secondary recovery of bitumen, and a coarse sands tailings (CST) (218) which are withdrawn at the bottom of the PSC. The CST (218) may comprise water and the majority of solids from the oil sand slurry. The CST (218) typically contains some bitumen which is one of the primary locations for losses of bitumen in the WBE process. A small amount of bitumen is also lost to the flotation tailings (222, also called fine tailings), the stream leaving the flotation cells (220) from the secondary recovery process. The flotation cells (220) also produce a recovered bitumen stream which may be passed back into the PSC (202) as a recycle stream (226). A froth overwash (224) is introduced into the PSC above the froth layer (208) in the PSC (202) for facilitating solids removal from the froth layer (208).

[0057] Figure 3 shows an overwash system and an underwash system in a PSC according to an embodiment of the processes and systems disclosed herein. As in Figure 2, the feed to the PSC (302) is a feed stream (300). The froth layer (308) sits above the middlings layer (314). The streams leaving the PSC (302) are the bitumen froth (309), middlings (316) which are sent to flotation cells (320) and coarse sands tailings (CST) (318). The flotation tailings (322, also called fine tailings) leave the flotation cells (320). The flotation cells (320) also produce a recovered bitumen stream (326) which may be passed back into the PSC (302). A froth overwash (324) is introduced into the PSC above the froth layer (308) in the PSC (302) for facilitating solids removal from the froth layer (308). A froth underwash (328) is introduced into the PSC below the froth layer (308) in the PSC (302) for reducing solids entrainment in the froth layer (308).

[0058] Figure 4 shows an application of an underwash system in flotation cells according to an embodiment of the processes and systems disclosed herein. As in Figures 2 and 3, the feed to the PSC (402) is a feed stream (400). The streams leaving the PSC (402) are the bitumen froth (not shown), middlings (416) which are sent to flotation cells (420) and coarse sands tailings (CST) (418). The flotation tailings (422) leave the flotation cells (420). The flotation cells (420) also produce a recovered bitumen stream (426) which may be passed back

into the PSC (402). The middlings (416) are processed by bubbling air through the middlings (416) and creating a bitumen froth (not shown), which may be recycled back to the PSC (402). Fine tailings (FT) (422) from the flotation cells (420), comprising mostly solids and water, may be sent for further treatment or disposed in an external tailings area (ETA). A froth overwash (430) is introduced into the flotation cells (420) above a froth layer (432) for facilitating solids removal from the froth layer (432).

[0059] Experimental

[0060] Experimental Procedure:

[0061] Table 1. Ore characteristics

Bitumen wt. %	Water wt. %	Solids wt. %	Fines wt. % (Solids basis)
12	4	84	13-15

Base case:

1. **Conditioning:** Water was mixed with ore to create a dense slurry (water to ore ratio of about 0.43), using an impeller speed of 600 rpm (revolutions per minute) for 10 minutes, and air injection greater than 150 sccm (standard cubic centimeters per minute).
2. **Flotation:** 725 ml of dilution water was added mixing was continued for 10 minutes (with no air injection).
3. **Collect primary froth:** Primary froth was scraped for subsequent characterization

Froth washing:

1. **Conditioning:** Water was mixed with ore to create a dense slurry (water to ore ratio of about 0.43), using an impeller speed of 600 rpm for 10 minutes, and air injection above 150 sccm.
2. **Flotation:** 575 ml of dilution water was added and mixing was continued for 10min (with no air injection).

3. **Froth washing:** 150 ml of water was added on top of the nascent froth layer (flow rate of about 20ml/min)
4. **Collect primary froth:** Primary froth was scraped for subsequent characterization

[0062] Experimental Results:

[0063] Figs. 5-10 illustrate the experimental results difference between the base case (without froth washing) and case with froth washing.

[0064] Fig. 5 is a graph of froth solids versus caustic addition (weight fraction of solids in the froth). As illustrated, the froth washing improved (decreased) the froth solids wt. %.

[0065] Fig. 6 is a graph of graph of froth quality: Bitumen/Solids ratio versus caustic addition. As illustrated, the froth washing improved (increased) froth quality.

[0066] Fig. 7 is a graph of froth SFR (sands to fines ratio) versus caustic addition. As illustrated, the froth washing improved (decreased) froth SFR.

[0067] Fig. 8 is graph of fraction of solids in the bitumen froth having a size less 45 μm (wt% fraction in froth) versus caustic addition. As illustrated, the froth washing improved (decreased) the wt. fraction of solids less than 45 μm .

[0068] Fig. 9 is a graph of fraction of solids in the bitumen froth having a size > 45um (wt% fraction in froth) versus caustic addition. As illustrated, the froth washing improved (decreased) the wt. fraction of solids greater than 45 μm .

[0069] Fig. 10 is a graph of primary bitumen recovery (%) versus caustic addition. As illustrated, when caustic was 0 and 150 ppm, the froth washing improved (increased) the primary recovery.

[0070] The scope of the claims should not be limited by particular embodiments set forth herein, but should be construed in a manner consistent with the specification as a whole.

CLAIMS:

1. A water-based oil sand extraction method comprising:
 - a) introducing a feed stream comprising bitumen, solids, and water into an extraction vessel; and
 - b) introducing a froth overwash into the extraction vessel above a froth layer in the extraction vessel for facilitating solids removal from the froth layer.
2. The method of claim 1, wherein step b) is effected prior to de-aerating the froth layer.
3. The method of claim 1 or 2, wherein the overwash comprises water.
4. The method of any one of claims 1 to 3, wherein the overwash has a temperature of 25 to 100 degrees Celsius.
5. The method of claim 3 or 4, wherein the overwash further comprises at least one process aid.
6. The method of claim 5, wherein the process aid is comprised of caustic, frothers, viscosity modifiers, or a combination thereof.
7. The method of any one of claims 1 to 6, further comprising introducing a froth underwash into the extraction vessel beneath the froth layer in the extraction vessel for reducing solids entrainment in the froth layer.
8. The method of claim 7, wherein the froth overwash and the froth underwash are supplied by a common wash stream.

9. The method of claim 8, wherein a froth overwash flowrate and a froth underwash flowrate are controlled by adjusting a split of the common wash stream into the froth overwash and the froth underwash.
10. The method of claim 8 or 9, wherein the common wash stream has a constant flowrate.
11. The method of claim 7, wherein a froth overwash flowrate is fixed and a froth underwash flowrate is varied based on dilution wash requirements, density in the extraction vessel, a bitumen-water interface level, underwash layer stability, or a combination thereof.
12. The method of claim 7, wherein the froth overwash and the froth underwash are supplied by distinct wash streams.
13. The method of claim 7, wherein the froth underwash flowrate is fixed and the froth overwash flowrate is varied based on froth quality.
14. The method of any one of claims 1 to 8, wherein a froth overwash flowrate is high enough to penetrate through the froth layer.
15. The method of any one of claims 1 to 14, wherein the extraction vessel is a primary separation cell (PSC).
16. The method of claim 15, further comprising:
 - c) withdrawing a bitumen froth from the PSC;
 - d) withdrawing a middlings stream from the PSC; and
 - e) withdrawing a coarse sand tailings (CST) from the PSC.
17. The method of any one of claims 1 to 14, wherein the extraction vessel is a mechanical or column flotation cell.

18. The method of claim 17, wherein the feed stream into the mechanical or column flotation cell is a middlings stream from a primary separation cell (PSC).
19. The method of any one of claims 1 to 18, wherein the froth overwash is provided in the form of a spray.
20. The method of any one of claims 1 to 19, for improving bitumen froth quality to a solids content of less than 15 wt. %.
21. The method of any one of claims 1 to 20, for reducing a sand to fines ratio of solids in the bitumen froth.
22. The method of claim 16, further comprising:
- a) introducing the middlings stream into a mechanical or column flotation cell; and
 - b) introducing a second froth overwash into the mechanical or column flotation cell above a second froth layer in the mechanical or column flotation cell for facilitating solids removal from the second froth layer.
23. A system for water-based oil sand extraction, the system comprising:
- a) a primary separation cell (PSC) for receiving a feed stream comprising bitumen, solids, and water; and
 - b) a froth overwash system for introducing a froth overwash into the PSC above a froth layer in the PSC for facilitating solids removal from the froth layer.
24. A system for water-based oil sand extraction, the system comprising:
- a) a mechanical or column flotation cell for receiving a middlings stream from a primary separation cell (PSC); and
 - b) a froth overwash system for introducing a froth overwash into the mechanical or column flotation cell above a froth layer in the mechanical or column flotation cell for facilitating solids removal from the froth layer.

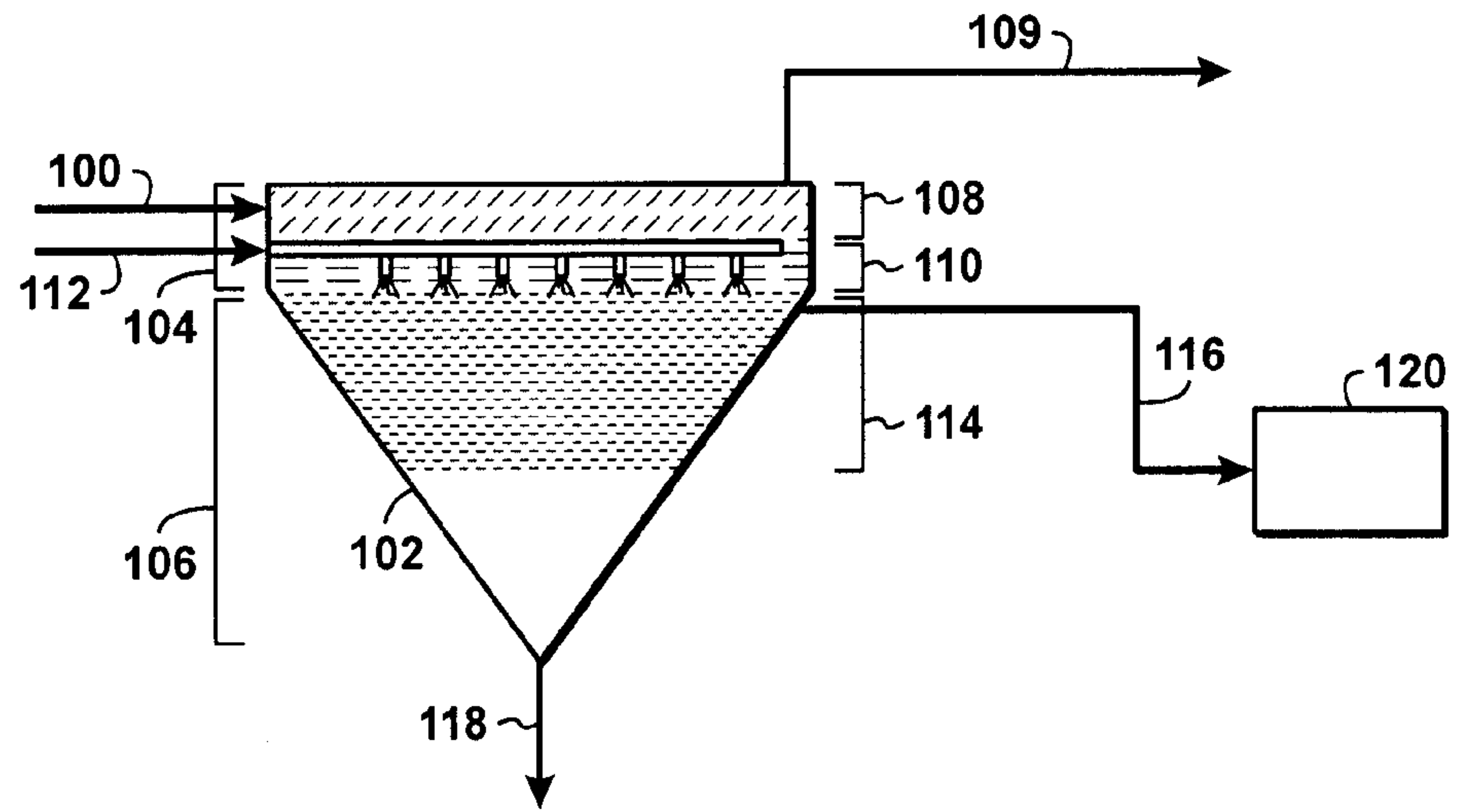


FIG. 1

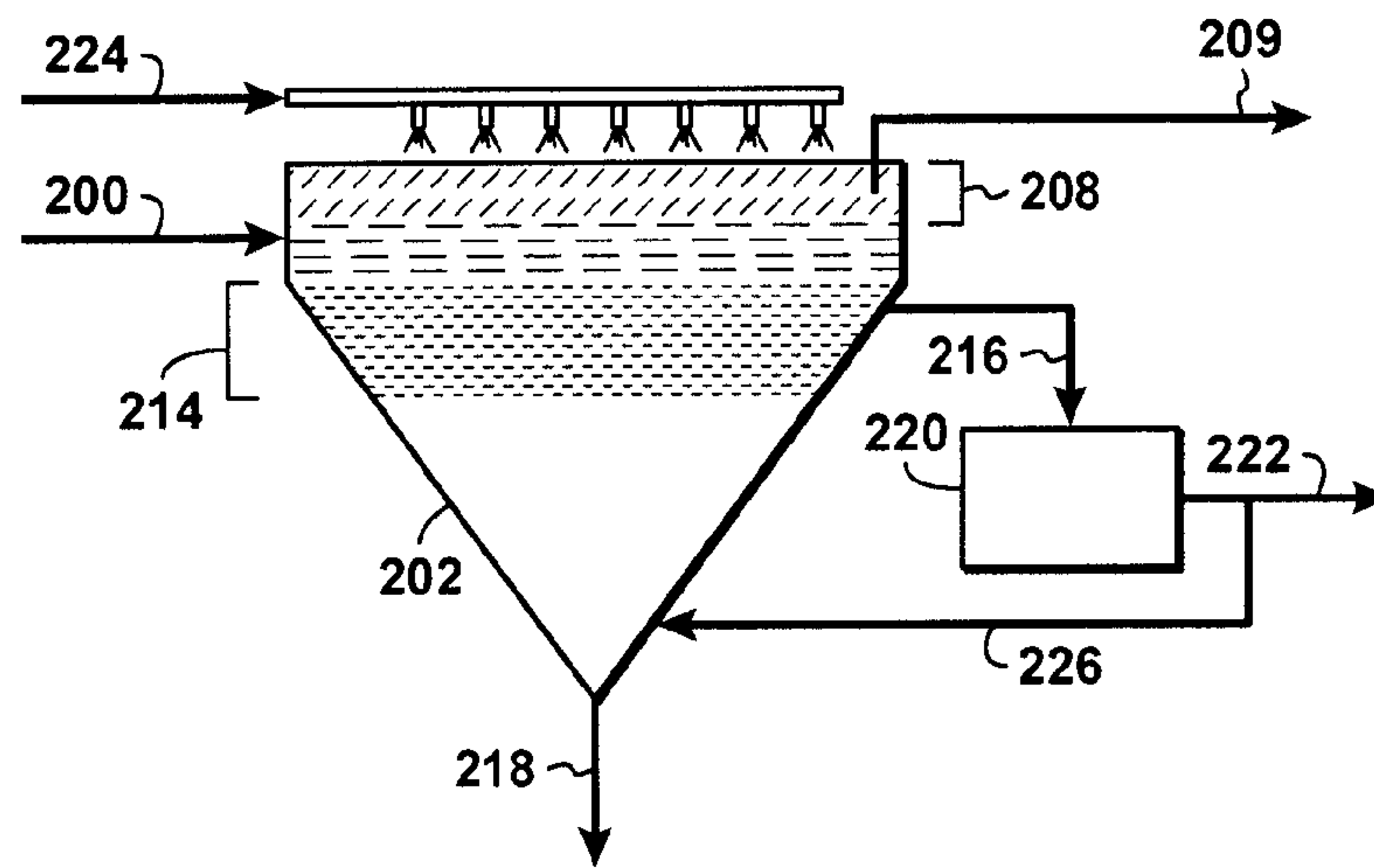


FIG. 2

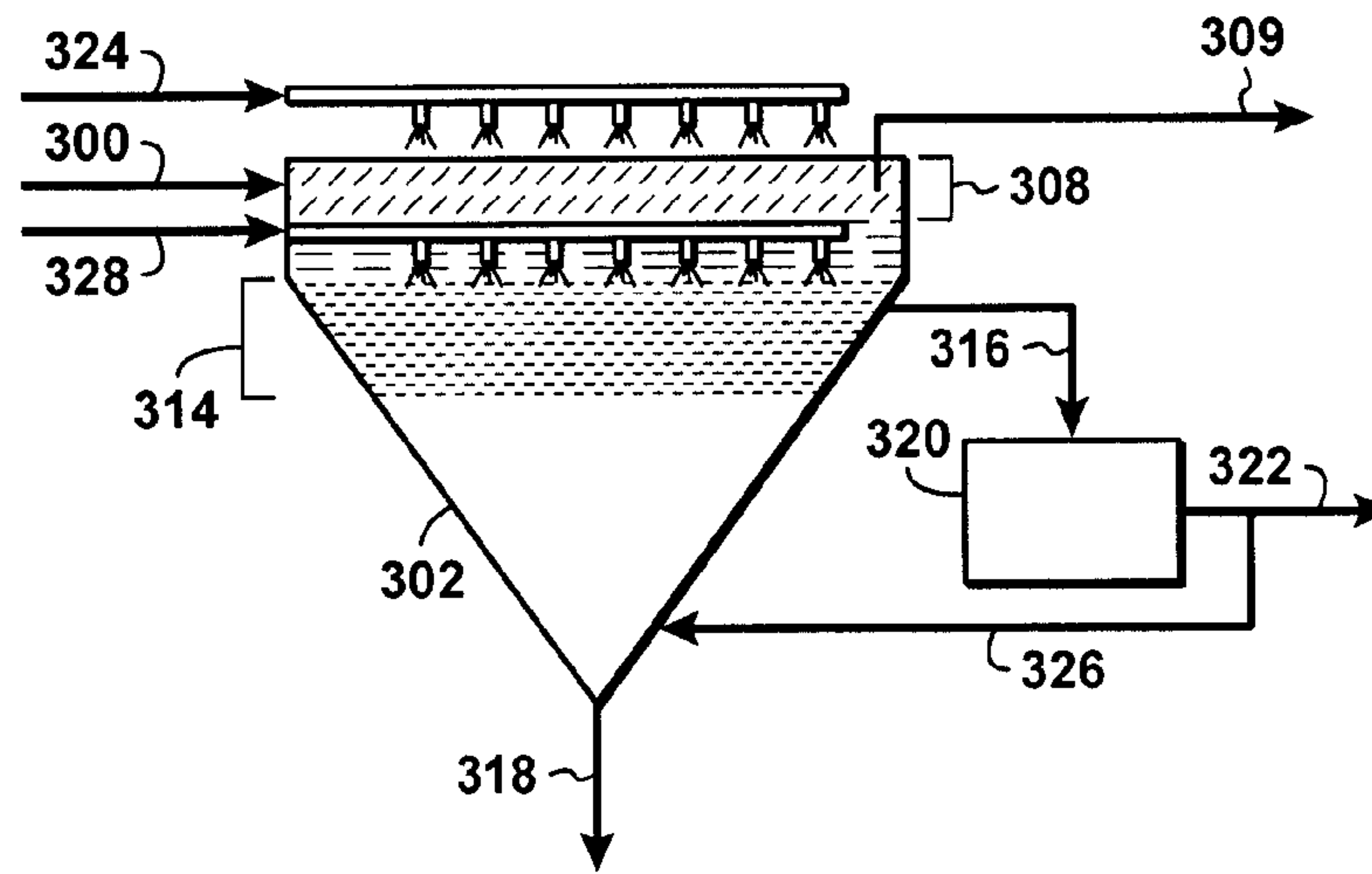


FIG. 3

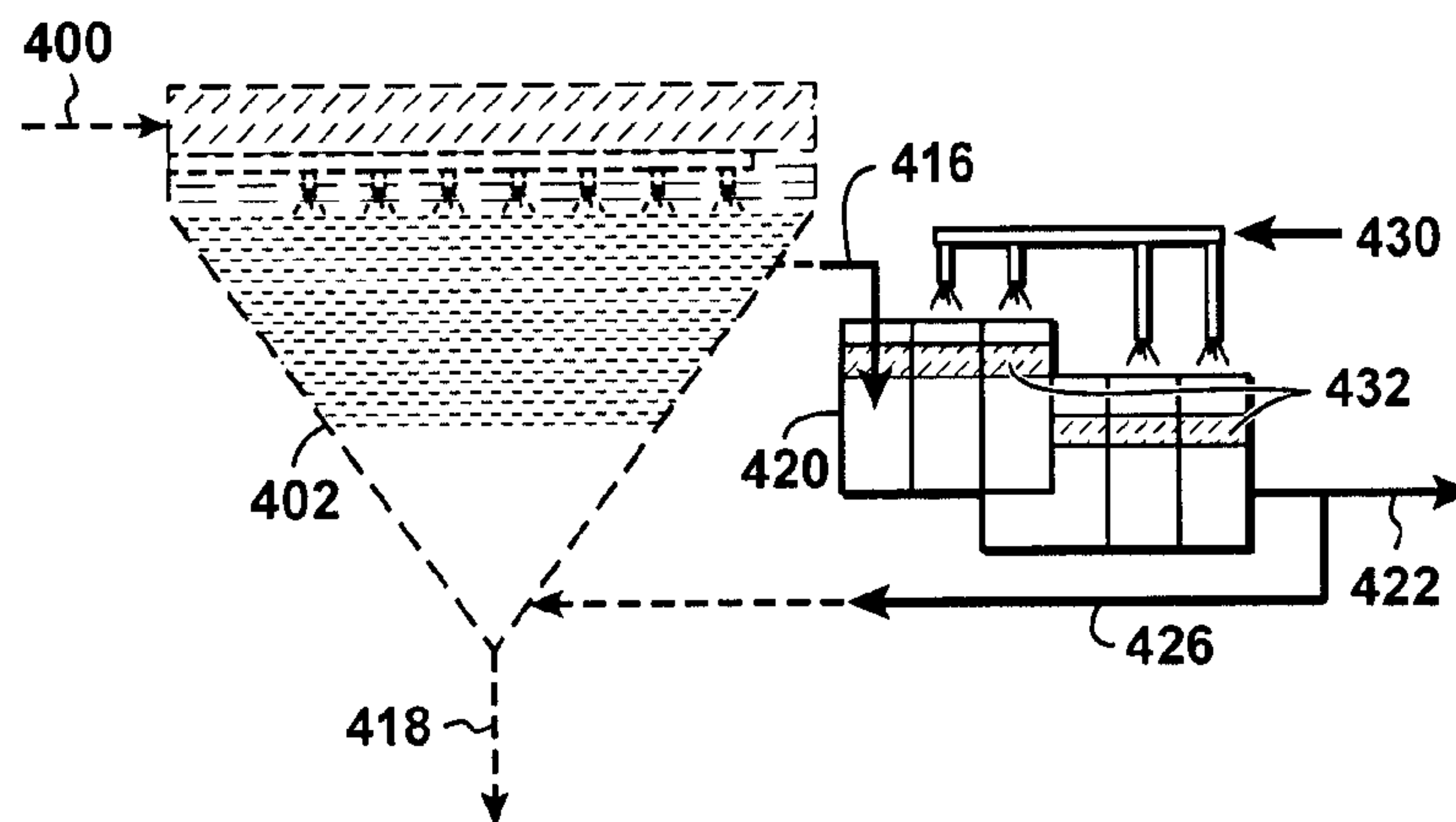


FIG. 4

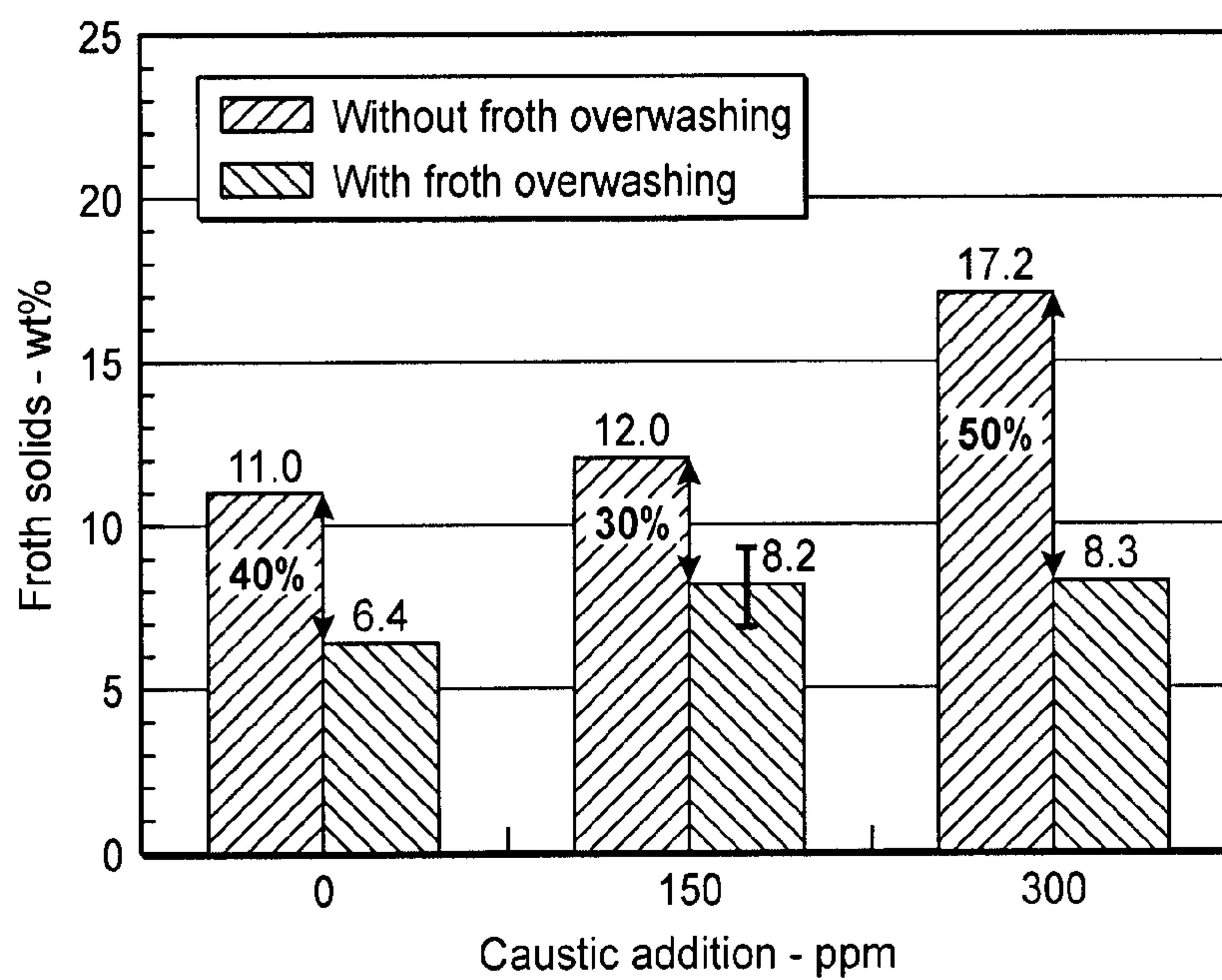


FIG. 5

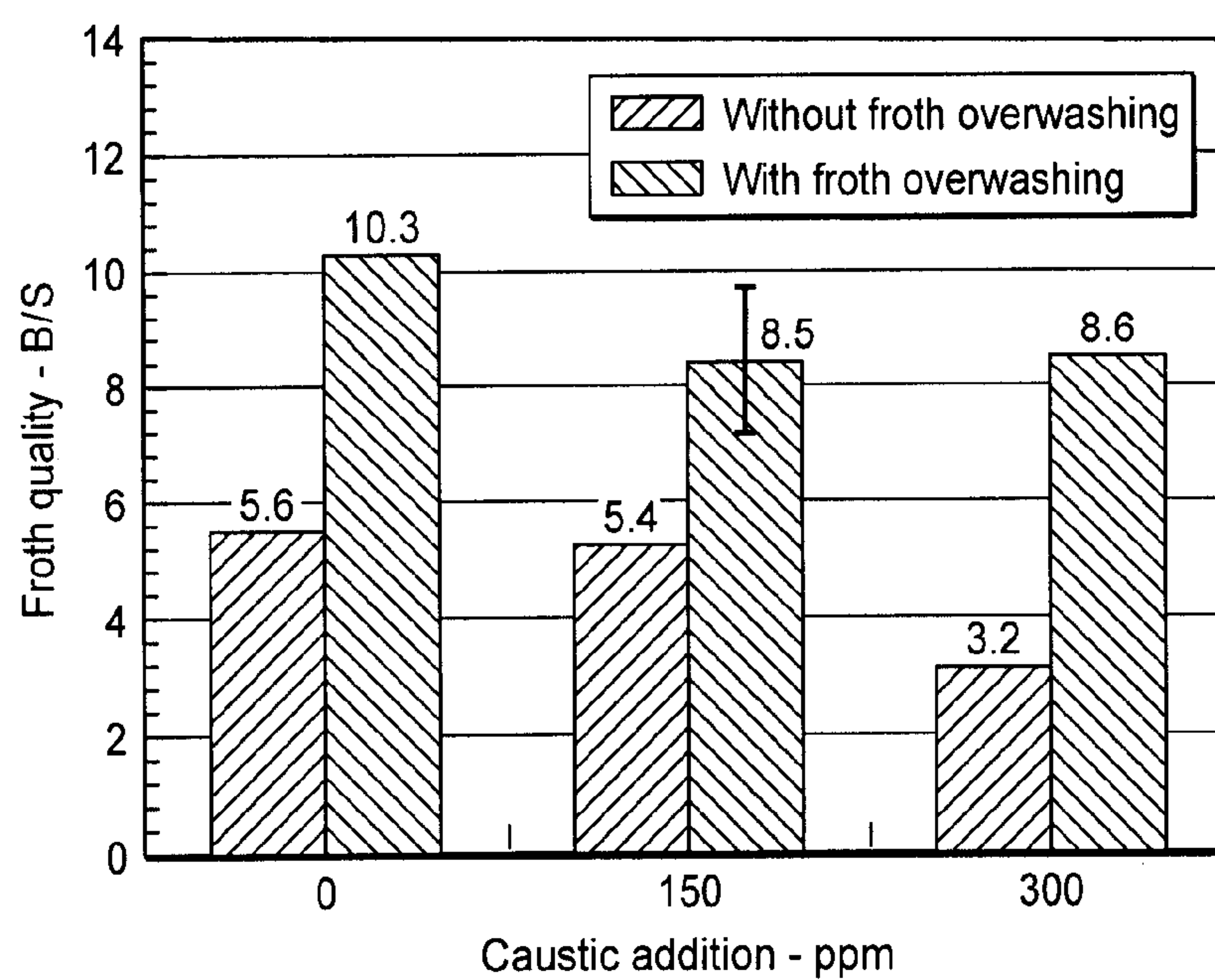


FIG. 6

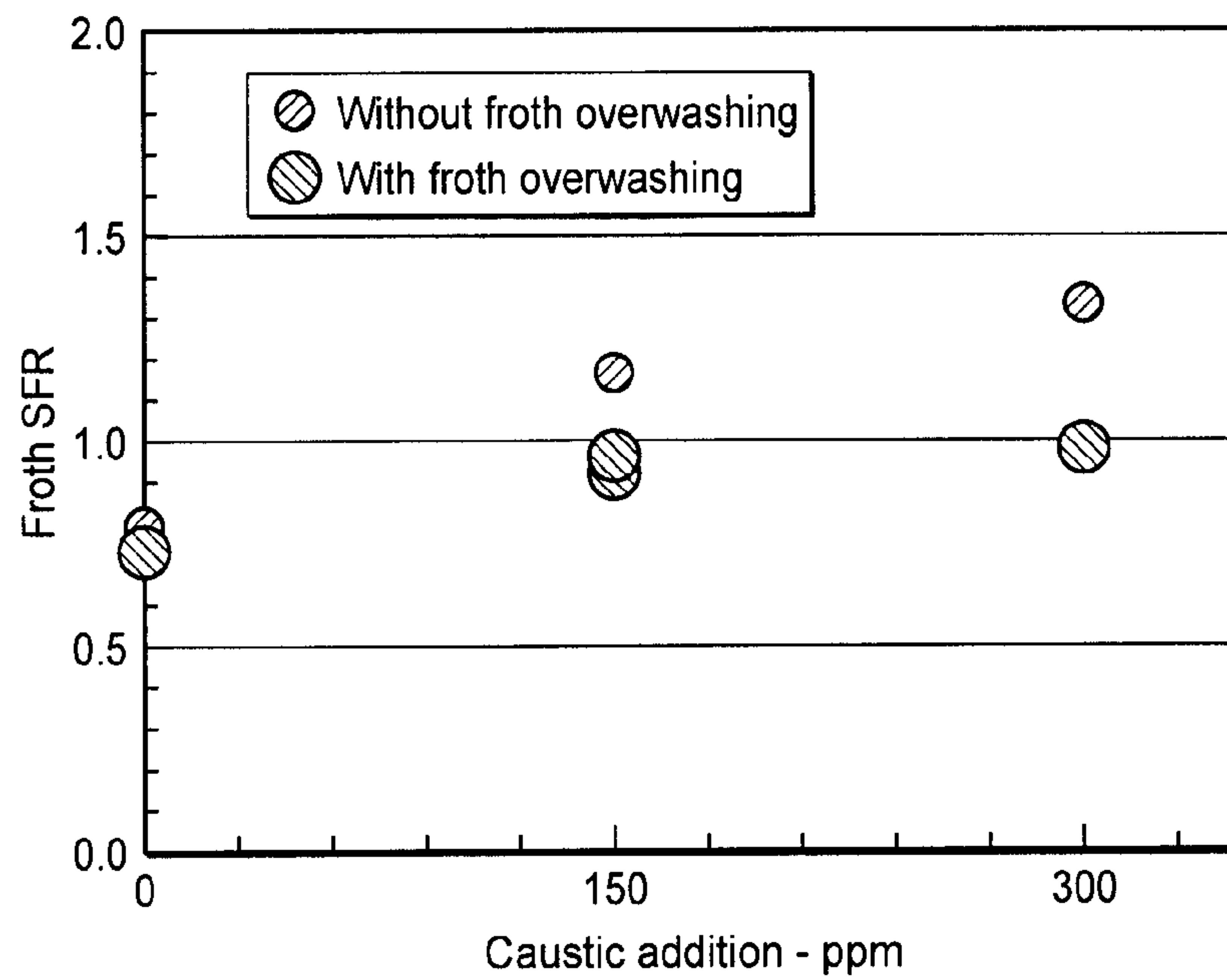


FIG. 7

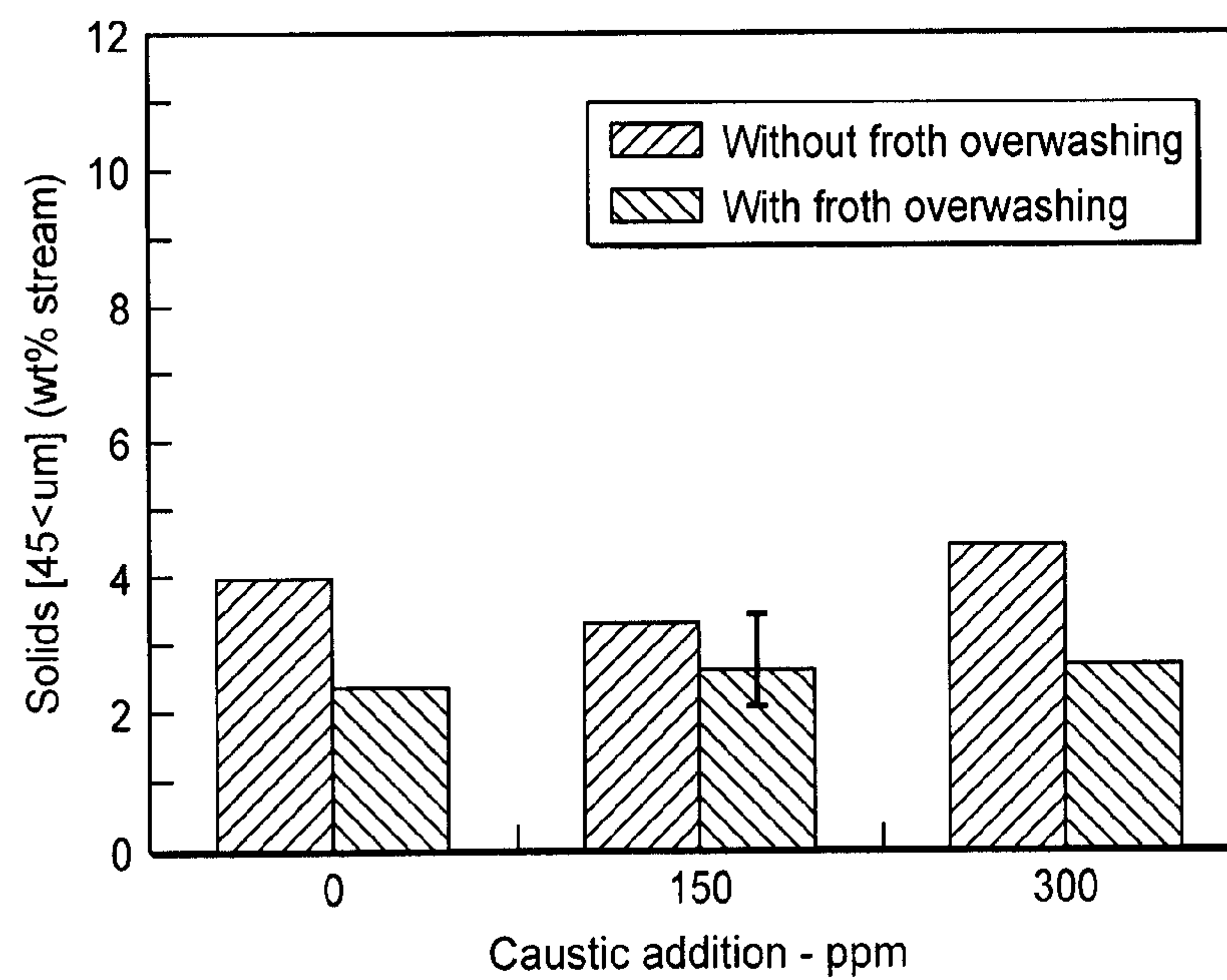


FIG. 8

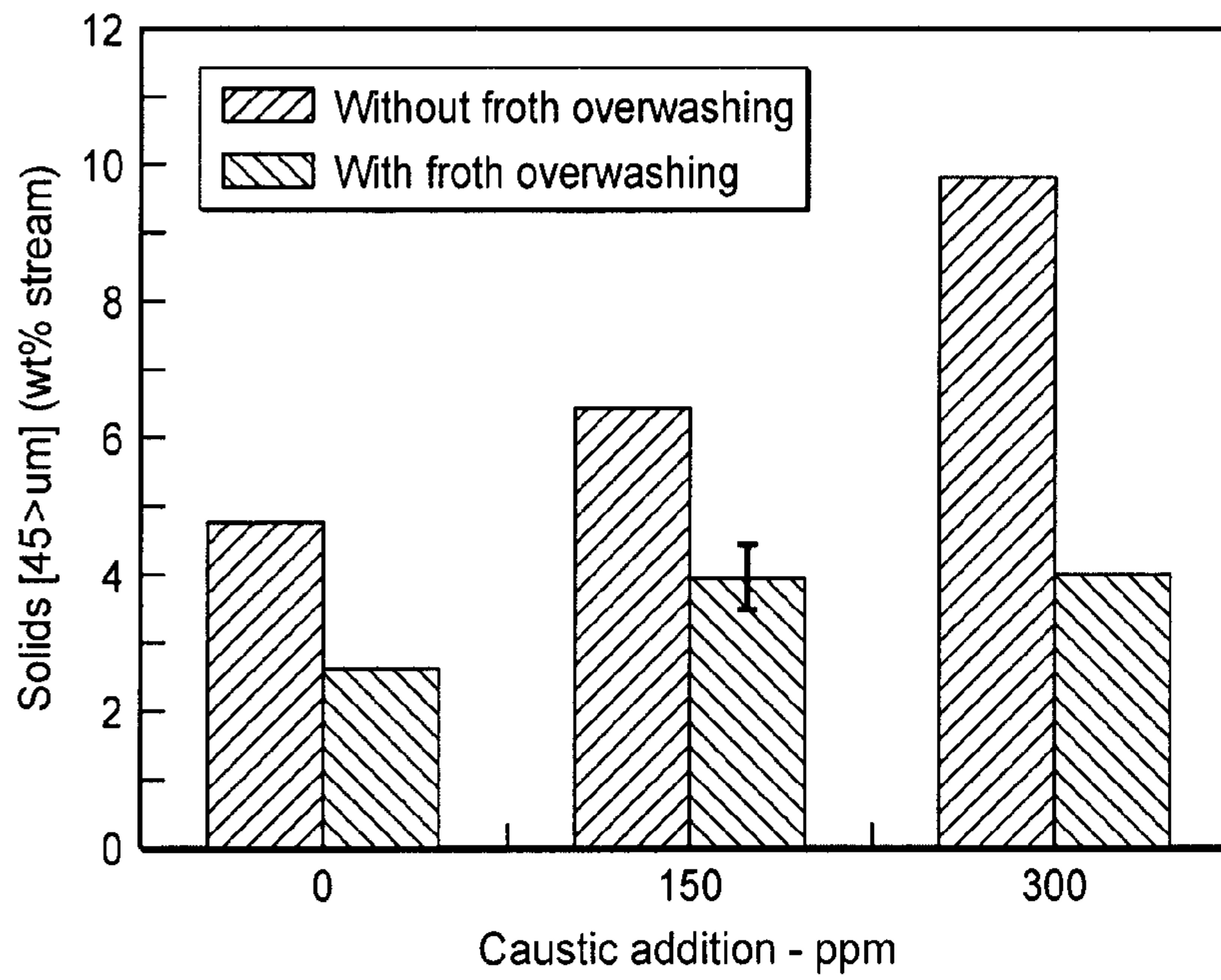


FIG. 9

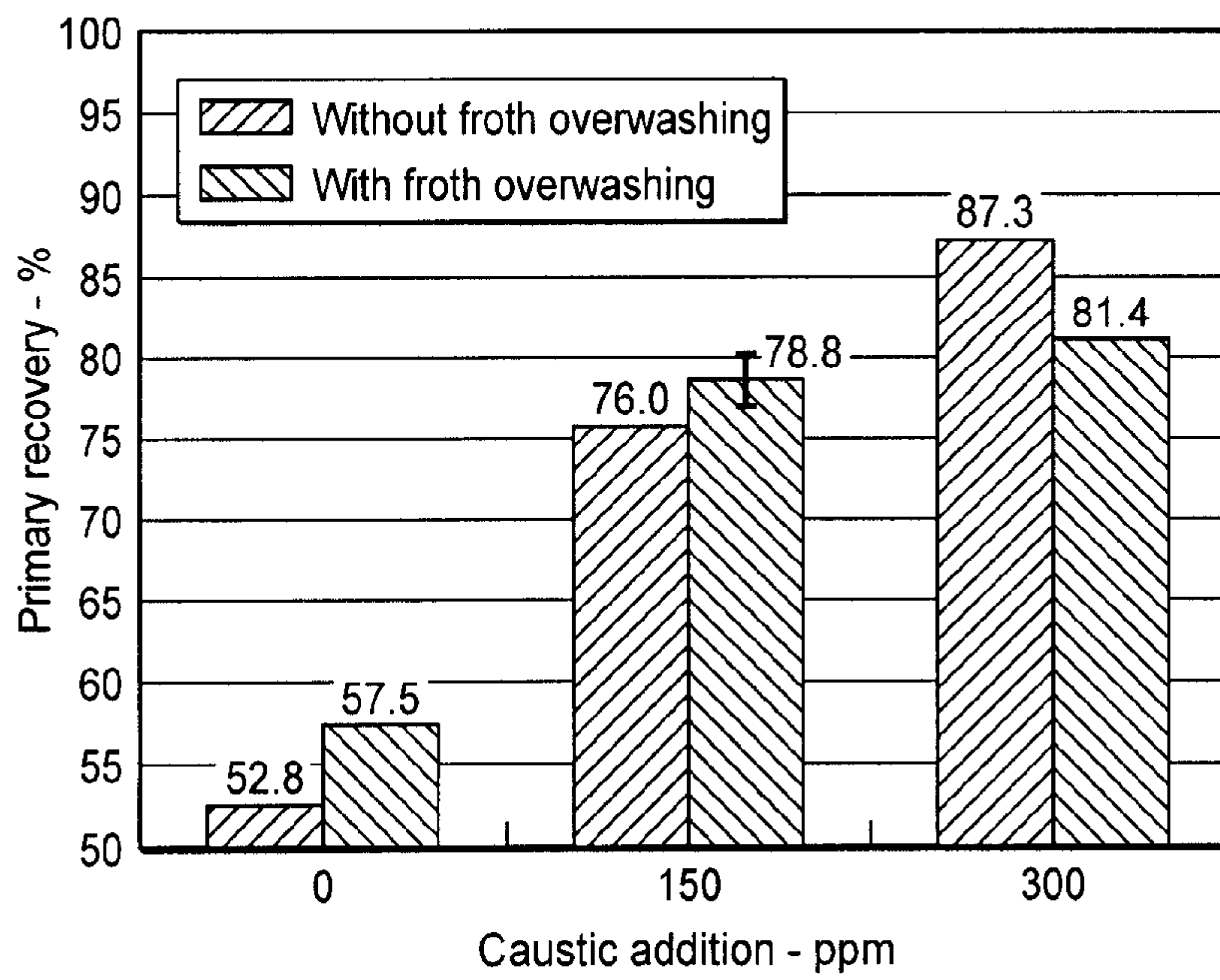


FIG. 10

