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(54) Title: PROCESSES AND SYSTEMS FOR DRYING LIQUID BROMINE

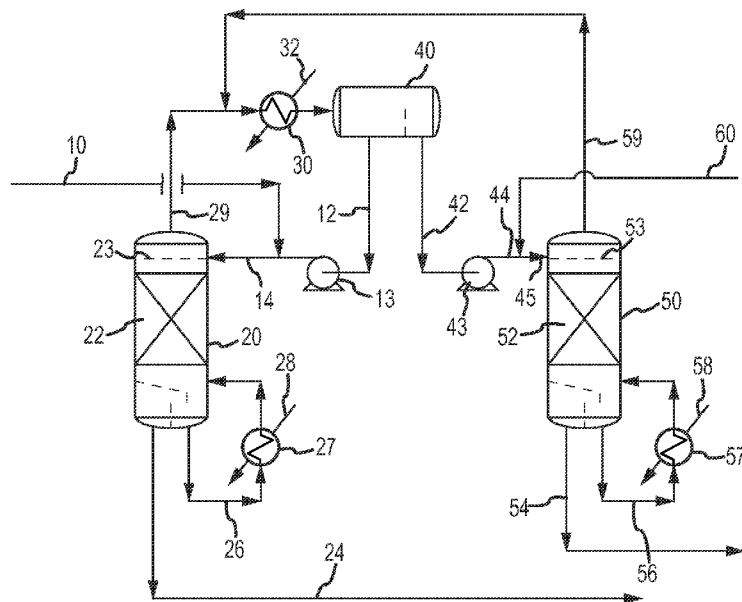


FIG. 1A

(57) Abstract: Processes and systems for drying liquid bromine utilizing two fractionators to produce a substantially dry liquid bromine stream and a substantially bromine-free water stream. Wet bromine liquid may be conveyed to a first fractionator wherein a substantially dry bromine liquid is produced, while a vapor stream from the first fractionator may be condensed into a first liquid phase comprising bromine saturated with water and a second liquid phase comprising water saturated with bromine. The water saturated with bromine may be conveyed to a second fractionator to produce at least substantially bromine-free water.

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PROCESSES AND SYSTEMS FOR DRYING LIQUID BROMINE

BACKGROUND OF THE INVENTION

5 The present invention relates to processes and systems for drying wet bromine liquid, and more particularly, in one or more embodiments, to processes and systems for drying wet bromine liquid in a system having two fractionators, one for separating substantially dry bromine from wet bromine liquid and another for separating substantially pure water from water having
10 bromine dissolved therein.

 Bromine has a wide variety of industrial uses, including in the preparation of disinfectants, chemical flame retardants, and photographic materials, in water purification processes, and as an intermediate in the manufacture of dyestuffs, drugs, resins and refrigerants. Bromine may also
15 be used in the bromination of alkanes to produce alkyl bromides that in turn have uses in processes, such as the production of higher molecular weight hydrocarbons useful as chemical intermediates and as blending stock or fuels. Many of the uses prefer dry bromine containing less than 5 wppm water.

20 Wet bromine is highly corrosive and requires that components used to handle wet bromine be constructed of corrosion-resistant materials or coatings, such as tantalum, which are extremely expensive. As dry bromine is much less corrosive than wet bromine, it usually is advantageous to use dry bromine in most industrial processes employing bromine.

25 Some processes that have been proposed for drying bromine utilize a drying agent for the adsorption of water therefrom. However, the use of a drying agent is accompanied by many drawbacks. If the drying agent is a solid, for example an inorganic salt, solid incrustations form on the surface of the drying agent rendering the surface impermeable and therefore decreasing
30 the efficiency of the drying agent. When liquid drying agents are used, for instance sulfuric acid, bromine may become contaminated with components of the drying agents. Another drawback in using drying agents is that the drying agent must be regenerated or additional fresh drying agent must be added or used at varying intervals.

In accordance with another process, liquid bromine having a water and chlorine content is kept at about its boiling point, gradually loses water and chlorine and over a period of time to drop the water and chlorine content to lower levels. While this process produces bromine with reduced water and chlorine content, it is not deemed commercially practical as keeping the bromine liquid at the boiling point causes significant loss of bromine with the evaporated water and chlorine. In addition, for large flow rates of bromine, the long residence time needed for this process requires large bromine storages which present tremendous hazard risk. Furthermore, this process does not achieve requisite low levels of water and chlorine.

Liquid crude bromine containing impurities, such as water and chlorine, is vaporized and heated to greater than 700° F in accordance with another process, added to steam and condensed to form water and liquid bromine. The liquid bromine is separated from water and dried over concentrated sulfuric acid. The dried bromine is then distilled to remove its heavy end contaminants. The purified bromine produced having an overall purity of 99.98 percent or better, i.e. less than 200 wppm of overall impurities. Chlorine < 30 wppm; organic material < 30 wppm; water < 30 wppm; and HCl < 2wppm; nonvolatile residue < 60 wppm. Bromine dried by this process still contains a moisture level not low enough to prevent corrosion at elevated temperatures. Also, the process generates a dilute sulfuric acid solution which is a waste stream requiring disposal.

Thus, a need exists for processes and systems for drying liquid bromine without the use of drying agents and their attendant problems which is economical, results in two streams of high purity, dry bromine and substantially bromine-free water, and does not require additional environmental treatment of by-products.

SUMMARY OF THE INVENTION

To achieve the foregoing and other objects, and in accordance with the purposes of the present invention, as embodied and broadly described herein, one characterization of the present invention is a process comprising fractionating a wet bromine liquid in a first fractionator at conditions to produce at least a substantially dry bromine liquid and water saturated with bromine. The water saturated with bromine is fractionated in a second fractionator at conditions to produce at least substantially bromine-free water.

In another characterization of the present invention, a process is provided which comprises contacting wet bromine liquid with substantially dry bromine vapor so as to volatilize substantially all water dissolved in the wet bromine liquid and produce a substantially dry bromine liquid and a first bromine and water vapor. The first bromine and water vapor are condensed to form at least a first liquid phase comprising bromine saturated with water and a second liquid phase comprising water saturated with bromine. The first liquid phase and the second liquid phase are separated and the second liquid phase is contacted with substantially pure water vapor so as to volatilize substantially all bromine dissolved in the water and produce substantially bromine-free liquid water and a second bromine and water vapor.

In still another characterization of the present invention, a system is provided for drying wet bromine liquid which comprises a first fractionator, a heat exchanger, a separator and a second fractionator. The first fractionator has an inlet in the upper end thereof for wet bromine liquid, an outlet in the lower end thereof for substantially dry bromine liquid and an outlet in the upper end thereof for a first bromine and water vapor. The first fractionator is configured to countercurrently contact wet bromine liquid with substantially dry bromine vapor so as to volatilize substantially all water dissolved in the wet bromine liquid and produce a substantially dry bromine liquid. The heat exchanger is in fluid communication with the upper outlet of the first fractionator for condensing the first bromine and water vapor to form at least a first liquid phase comprising bromine saturated with water and a second liquid phase comprising water saturated with bromine. The separator is in fluid

communication with the heat exchanger for separating the first liquid phase and the second liquid phase. The second fractionator is in fluid communication with the separator and has an inlet in the upper end thereof for the second liquid phase, an outlet in the lower end thereof for substantially
5 bromine-free water and an outlet in the upper end thereof for a second water and bromine vapor. The second fractionator is configured to countercurrently contact the second liquid phase with substantially pure water vapor so as to volatilize substantially all bromine dissolved in the water and produce substantially bromine-free water

10

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate the embodiments of the present invention and,
15 together with the description, serve to explain the principles of the invention.

In the drawings:

FIG. 1 is a schematic of one embodiment of the processes of the present invention;

20 FIG. 1A is a schematic of another embodiment of the processes of the present invention;

FIG. 2 is a graph illustrating the solubility of water in bromine;

FIG. 3 is a graph illustrating the solubility of bromine in water; and

25 FIG. 4 is a block flow diagram of a still further embodiment of the processes of the present invention as incorporated into processes for the production of higher hydrocarbons from alkyl bromides.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The term "wet bromine liquid" as used herein refers to bromine liquid
30 having water dissolved therein and may also include free water, especially where liquid bromine is separated by gravity from water. As illustrated in FIG. 2, water has limited solubility in liquid bromine which increases with temperature and at 50° C is 700 wppm water in liquid bromine.

Suitable sources that may generate wet bromine liquid in various embodiments of the present invention include, but are not limited to, elemental bromine, bromine salts, aqueous hydrobromic acid, metal bromide salts, and the like. The bromine dried using the present invention may be a product stream for external sale in some embodiments or a recycle stream for internal reuse in other instances or a feed stream for downstream process in other examples. Certain embodiments of the methods of the invention are described below. Although figures are provided that schematically show certain aspects of the processes of the present invention, these figures should not be viewed as limiting on any particular process of the invention.

A schematic generally depicting the processes and systems of the present invention is illustrated in FIG. 1 and depicts some aspects of certain embodiments of the processes of the present invention. In accordance with the schematic as illustrated in FIG. 1, a stream 10 of wet bromine liquid may be combined with a pumped recycle stream 12 of wet bromine liquid and introduced at a temperature of from about 40° C to about 150° C and a pressure of about 1.50 barg to about 10 barg into a bromine fractionator 20. Fractionator 20 may contain a number of trays or equivalent packing material, both identified as 22 in FIG. 1, as will be evident to a skilled artisan. The wet bromine liquid may be introduced into bromine fractionator 20 above the top tray or the top of the packing material 22. Fractionator 20 may include a liquid distributor or manifold 23 to more uniformly distribute the wet bromine liquid throughout the internal, cross sectional area of bromine fractionator 20. A product stream 24 of substantially dry bromine liquid, for example containing less than about 5.0 wppm water, more preferably less about 1.0 wppm water, and most preferably less than about 0.5 wppm water, may be withdrawn at the bottom of fractionator 20 for further use, sale, or both. Another stream 26 of dry bromine liquid may be withdrawn from the bottom of the bromine fractionator 20 and vaporized in reboiler 27 by means of low pressure steam 28 in a manner as will be evident to a skilled artisan before being introduced back into fractionator 20 at or near the bottom thereof. In this manner, substantially dry bromine vapor may flow upwardly through fractionator 20 contacting the wet bromine liquid flowing downwardly through the fractionator.

Given that water dissolved in the wet bromine liquid is the more volatile component, substantially all of the water dissolved in the wet bromine liquid may be volatilized and carried upwardly by bromine vapor which may be withdrawn from the top of bromine fractionator 20 via stream 29. The number
5 of trays or volume of equivalent packing utilized in bromine fractionator 20 may be readily determined using an appropriate McCabe Thiele diagram as will be evident to a skilled artisan.

The overhead vapor stream 29 may be condensed in a heat exchanger 30 against cooling water 32 and conveyed to a reflux separator drum 40
10 wherein the bromine and water may condense and separate into two liquid phases: bromine saturated with water and water saturated with bromine. Preferably, the reflux separator drum 40 is operated with a sufficiently long residence time to produce saturated liquid phases, i.e. bromine saturated with water and water saturated with bromine. The bromine saturated with water,
15 i.e. wet bromine liquid, in stream 12 may be pumped, combined with stream 10 of wet bromine liquid feed to form stream 14, and introduced at or near the top of bromine fractionator 20 as previously described by any suitable means, such as pump 13. The water saturated with bromine in stream 42 may be pumped as stream 44 and introduced at or near the top of a water fractionator
20 50 by any suitable means, such as pump 43. Fractionator 50 may contain a number of trays or equivalent packing material, both identified as 52 in FIG. 1, as will be evident to a skilled artisan. The water saturated with bromine may be introduced into water fractionator 50 above the top tray or the top of the packing material 52. Fractionator 50 may include a liquid distributor or
25 manifold 53 to more uniformly distribute the water saturated with bromine throughout the internal, cross sectional area of water 50. A product stream 54 of substantially bromine-free water, for example containing less than about 5.0 wppm bromine, more preferably less than about 1.0 wppm bromine, and most preferably less than about 0.5 wppm bromine, may be withdrawn at or
30 near the bottom of fractionator 50 for further use, sale, or both. Another stream 56 of relatively pure water may be withdrawn from the bottom of the water fractionator 50 and vaporized in reboiler 57 by means of low pressure low pressure steam 58 in a manner as will be evident to a skilled artisan

before being introduced back into fractionator 50 at or near the bottom thereof. In this manner, substantially pure water vapor may flow upwardly through fractionator 50 contacting the water saturated with bromine flowing downwardly through the fractionator. Given that bromine dissolved in the water saturated with bromine is the more volatile component, substantially all of the bromine dissolved in the water saturated with bromine may be volatilized and carried upwardly by water vapor which may be withdrawn from the top of water fractionator 50 via stream 59. Stream 59 may be combined with overhead vapor stream 29 from bromine fractionator 20 prior to conveyance to heat exchanger 30 and reflux separator drum 40 to separate water and bromine into two phases as previously described. The number of trays or volume of equivalent packing utilized in bromine fractionator 50 may be readily determined using an appropriate McCabe Thiele diagram as will be evident to a skilled artisan. It is preferred that the process described above with respect to FIG. 1 be operated continuously.

In accordance with another embodiment of the processes and systems of the present invention schematically illustrated in FIG. 1A, a stream 60 of water containing bromine may be combined with the water saturated with bromine in stream 44 and introduced at or near the top of a water fractionator 50 by any suitable means, such as pump 43. Stream 60 may be from any suitable source and, where the process depicted in FIG. 1A is incorporated into another process, for example as depicted in and described below with respect to FIG. 4, stream 60 may be from the same process into which the process of the present invention is incorporated, a different process or source or a combination thereof.

A block flow diagram generally depicting an embodiment of the processes of the present invention as incorporated into a process for producing high molecular weight hydrocarbons is illustrated in FIG. 4. As utilized in this context, the term "high molecular weight hydrocarbons" as used herein refers to hydrocarbons comprising C₃ chains and longer hydrocarbon chains. In some embodiments, the higher molecular weight hydrocarbons may be used directly as a product (e.g., LPG, motor fuel, etc.). In other instances, the higher molecular weight hydrocarbon stream may be used as

an intermediate product or as a feedstock for further processing. In other instances, the higher molecular weight hydrocarbons may be further processed, for example, to produce gasoline grade fuels, diesel grade fuels, and fuel additives. In some embodiments, the higher molecular weight hydrocarbons obtained by the processes of the present invention can be used directly as a motor gasoline fuel having a substantial aromatic content, as a fuel blending stock, or as feedstock for further processing, such as an aromatic feed to a process producing aromatic polymers, such as polystyrene or related polymers, or as an olefin feed to a process for producing polyolefins. The term "olefins" as used herein refers to hydrocarbons that contain two to six carbon atoms and at least one carbon-carbon double bond. The olefins may be further processed if desired. For instance, in some instances, the olefins produced by the processes of the present invention may be further reacted in a polymerization reaction (for example, a reaction using a metallocene catalyst) to produce poly(olefins), which may be useful in many end products such as plastics or synthetic lubricants.

The end use of the high molecular weight hydrocarbons, the olefins or mixtures thereof may depend on the particular catalyst employed in the oligomerization portion of the methods discussed below, as well as the operating parameters employed in the process. Other uses will be evident to those skilled in the art with the benefit of this disclosure.

In some embodiments, the present invention as depicted in FIG. 4 comprises reacting a feed gas stream with bromine from a suitable bromine source as previously discussed to produce alkyl bromides. As used herein, the term "alkyl bromides" refers to mono, di, and tri-brominated alkanes, and combinations of these. These alkyl bromides may then be reacted over suitable catalysts so as to form olefins, higher molecular weight hydrocarbons or mixtures thereof.

Lower molecular weight alkanes may be used as a feed stock for the methods described herein. A suitable source of lower molecular weight alkanes may be natural gas. As utilized throughout this description, the term "lower molecular weight alkanes" refers to methane, ethane, propane, butane, pentane or mixtures of two or more of these individual alkanes. The lower

molecular weight alkanes may be from any suitable source, for example, any source of gas that provides lower molecular weight alkanes, whether naturally occurring or synthetically produced. Examples of sources of lower molecular weight alkanes for use in the processes of the present invention include, but
5 are not limited to, natural gas, coal-bed methane, regasified liquefied natural gas, gas derived from gas hydrates and/or clathrates, gas derived from anaerobic decomposition of organic matter or biomass, gas derived in the processing of tar sands, and synthetically produced natural gas or alkanes. Combinations of these may be suitable as well in some embodiments. In
10 some embodiments, it may be desirable to treat the feed gas to remove undesirable compounds, such as sulfur compounds and carbon dioxide. In any event, it is important to note that small amounts of carbon dioxide, e.g., less than about 2 mol %, can be tolerated in the feed gas to the processes of the present invention.

15 Although major aspects of what is believed to be the primary chemical reactions involved in the methods are discussed as it is believed that they occur, it should be understood that side reactions may take place. One should not assume that the failure to discuss any particular side reaction herein means that that reaction does not occur. Conversely, those that are
20 discussed should not be considered exhaustive or limiting. Additionally, although figures are provided that schematically show certain aspects of the methods of the present invention, these figures should not be viewed as limiting on any particular method of the invention.

In accordance with the general depiction of the processes of the
25 present invention as illustrated in FIG. 4, a gas stream containing lower molecular weight alkanes, comprised of a mixture of a feed gas plus a recycled gas stream, and a substantially dry bromine vapor are reacted in an alkyl bromination stage to produce alkyl bromides and hydrobromic acid. The resultant alkyl bromides are reacted over a suitable catalyst in the presence of
30 hydrobromic acid in an alkyl bromide conversion stage to form olefins, higher molecular weight hydrocarbons or mixtures thereof. The particular olefins and higher molecular weight hydrocarbons produced will be dependent upon the catalyst employed in the alkyl bromide conversion stage, the composition of

the alkyl bromides introduced into this stage and the exact operating parameters employed in this stage. The mixture of hydrobromic acid and olefins, higher molecular weight hydrocarbons or mixtures thereof are contacted with an aqueous solution in a hydrobromic acid (HBr) removal stage to remove hydrobromic acid from the olefins and higher molecular weight hydrocarbons. The resultant aqueous solution having hydrobromic acid dissolved therein may also be contacted with a feed gas in this HBr removal stage to remove any residual hydrocarbons from the aqueous solution.

10 The feed gas, residual hydrocarbons and olefins, higher molecular weight hydrocarbons or mixtures thereof are conveyed to a dehydration and product recovery unit wherein water may be removed from the remaining constituents. The feed gas and primarily methane and ethane hydrocarbons are then separated from the olefins, higher molecular weight hydrocarbons or mixtures thereof and conveyed to the alkane bromination stage of the present invention. The remaining olefins, higher molecular weight hydrocarbons or mixtures thereof are removed from the dehydration and product recovery stage for use as a fuel, a fuel blend or for further petrochemical or fuel processing.

20 As further generally illustrated in FIG. 4, the aqueous solution containing hydrobromic acid may be conveyed to a bromide oxidation stage. The aqueous solution that is used to contact the olefins, higher molecular weight hydrocarbons or mixtures thereof may contain a partially oxidized metal bromide salt or the aqueous solution may be passed through a bed of a partially oxidized metal bromide salt in the bromide oxidation stage of the process. Hydrobromic acid that is dissolved in the aqueous solution may be neutralized by the partially oxidized metal bromide salt to yield a metal bromide salt and water. The resultant metal bromide salt may be oxidized with air in the bromide oxidation stage of the present invention to yield bromine vapor entrained with spent air and moisture which are subsequently cooled, via suitable means such as against cooling water in heat exchangers, to condense out bromine and water from spent air into two immiscible liquid streams: wet liquid bromine and water saturated with bromine. The same

stage also yields a partially oxidized metal bromide salt which may be reused to neutralize and remove hydrobromic acid from the aqueous solution used to contact the olefins, higher molecular weight hydrocarbons or mixtures thereof produced by the process.

5 The wet liquid bromine stream and the water saturated with bromine stream may be conveyed to the bromine dehydration stage of the present invention which comprises two stage fractionation system as previously described in detail above with respect to FIG. 1A to generate a substantially dry bromine liquid, for example containing less than 1.0 wppm water, which
10 may be pumped, vaporized and recycled to the alkane bromination stage. Elimination of substantially all water vapor from the bromination step by using substantially dry bromine eliminates the formation of unwanted carbon dioxide thereby increasing the selectivity of alkane bromination to alkyl bromides and eliminating the large amount of waste heat generated in the formation of
15 carbon dioxide from alkanes. A substantially pure water phase, for example containing less than about 1.0 wppm bromine, may also be removed from the stage for further use, sale or both.

To facilitate a better understanding of the present invention, the following examples of certain aspects of some embodiments are given. The
20 following examples should not be read or construed in any manner to limit, or define, the entire scope of the invention.

EXAMPLE 1

A stream of wet bromine liquid at 105° C and 10 barg and containing
25 1,500 wppm water is fed at a rate of 1,000 kg/h into the top of a bromine fractionator, having a packed bed with total packing height of 14 meter. A thermosyphon reboiler operates with a boilup ratio of 0.11, a return stream vapor fraction of 0.25 and a duty of 5.55 kW. A water bromine vapor mixture flows upwardly through the fractionator contacting wet bromine liquid flowing
30 downwardly through the fractionator over the packed bed. Vapor leaving the top of the bromine fractionator is condensed in a suitable heat exchanger, and the water bromine phases are separated in reflux separator drum into two liquid phases: water rich phase and bromine rich phase. The bromine rich

phase (153 kg/h, at 59° C and 1,693 wppm water) is returned to the bromine fractionator as reflux by mixing with the feed stream. The bottoms bromine product (998 kg/h) contains < 1.0 wppm water.

The water rich phase from the reflux separator drum (1.6 kg/h and 3.7
5 wt % Br₂) is routed to the top of the water fractionator, where the bromine is stripped off to yield a bottoms water product with < 1.0 wppm bromine (1.5 kg/h). The water fractionator consists of a 4 meter high packed bed. The thermosyphon reboiler in this fractionator operates with a boilup ratio of 0.125, return stream vapor fraction of 0.2, and a duty of 0.12kW. The water bromine
10 vapor mixture leaving the top of the water fractionator is combined with the vapor leaving the top of the bromine fractionator prior to being condensed in a suitable heat exchanger and conveyed to the reflux separator drum for separation of the water and bromine liquid phases. The condenser duty is 9.2 kW. Operation data are summarized in the following Table 1.

15

TABLE 1

	Bromine Fractionator	Water Fractionator
Feed Stage	Top of tower	Top of tower
Feed Rate, kg/h [Note1]	1,153	1.6
Feed Composition [Note2]		
Bromine, wt %	99.85	3.71
Water, wt %	0.15	96.29
Packing Height (m)	14	4
Reboiler Duty, kW	5.55	0.12
Reboiler Temperature, °C	81	120
Reboiler Pressure, barg	1.0	1.0
Shared Condenser Duty, kW	9.2	
Shared Condenser Temperature, °C	53	
Shared Condenser Pressure, barg	0.7	

Note 1: Feed rate herein refers to the flow rate of the liquid stream entering the top of tower.

Note 2: Feed composition herein refers to the composition of the liquid stream entering the top of tower.

5

EXAMPLE 2

A stream of wet bromine liquid at 50° C and 1.2 barg and having 1,000 wppm water is fed at a rate of 1,000 kg/h into the top of a bromine fractionator, having a packed bed with total packing height of 14 meter. A thermosyphon reboiler operates a duty of 7.07 kW. A water bromine vapor

10

mixture flows upwardly through the fractionator contacting wet bromine liquid flowing downwardly through the fractionator over the packed bed. Vapor leaving the top of the bromine fractionator is condensed in a suitable heat exchanger, and the water bromine phases are separated in reflux separator drum into two liquid phases: water rich phase and bromine rich phase. The bromine rich phase (51 kg/h, at 59° C) is returned to the bromine fractionator as reflux by mixing with the feed stream. The bottoms bromine product contains < 1.0 wppm water.

A stream of water containing 4 wt% bromine (117 kg/h, at 50° C 1.2 barg) combines the water rich phase from the reflux separator drum (1.7 kg/h and 3.7 wt % Br₂) and the mixture is routed to the top of the water fractionator, where the bromine is stripped off to yield a bottoms water product with < 1.0 wppm bromine (113 kg/h). The water fractionator consists of a 4 meter high packed bed. The thermosyphon reboiler in this fractionator operates with a duty of 9.88 kW. The water bromine vapor mixture leaving the top of the water fractionator is combined with the vapor leaving the top of the bromine fractionator prior to being condensed in a suitable heat exchanger and conveyed to the reflux separator drum for separation of the water and bromine liquid phases. The condenser duty is 3.8 kW. Operation data are summarized in the following Table 2.

TABLE 2

	Bromine Fractionator	Water Fractionator
Feed Stage	Top of tower	Top of tower
Feed Rate, kg/h [Note1]	1,051	116
Feed Composition [Note2]		
Bromine, wt %	99.90	96.0
Water, wt %	0.10	0.04
Packing Height (m)	14	4
Reboiler Duty, kW	7.07	9.88
Reboiler Temperature, °C	81	120
Reboiler Pressure, barg	1.0	1.0
Shared Condenser Duty, kW	3.8	
Shared Condenser Temperature, °C	53	
Shared Condenser Pressure, barg	0.7	

Note 1: Feed rate herein refers to the flow rate of the liquid stream entering the top of tower.

Note 2: Feed composition herein refers to the composition of the liquid stream entering the top of tower.

The processes and systems of the present invention are less expensive than conventional processes since the substantially dry bromine vapor that may be produced by the process of the present invention permits the use of less expensive alloys, for example Hastelloy or Inconel for reboiler 27 and carbon

steel for reboiler 57 than those that have been previously used, for example tantalum for reboiler 27 and titanium for reboiler 57, to counteract the highly corrosive natures of wet bromine liquid and bromine-containing water. Further, since the processes and systems of the present invention operate at
5 low pressures in the range of about 1.5 barg to about 10 barg and at relatively low temperatures in the range of about 40° C to about 150° C, such operating conditions permit the use of less expensive equipment of relatively simple design that are constructed from readily available metal alloys or polymer-lined or glass-lined vessels, piping and pumps.

10 While the processes and systems of the present invention have been described above with respect to drying bromine, i.e. removing water from bromine, it will be understood by a skilled artisan that the processes and systems of the present invention may also remove other impurities, such as chlorine and dissolved light gas components such as nitrogen and methane,
15 which may require certain alterations to the operating parameters of the processes and systems.

While the foregoing preferred embodiments of the invention have been described and shown, it is understood that the alternatives and modifications, such as those suggested and others, may be made thereto
20 and fall within the scope of the invention.

CLAIMS

We claim:

1. A process comprising:
fractionating a wet bromine liquid in a first fractionator at conditions to
5 produce at least a substantially dry bromine liquid and water saturated with
bromine; and
fractionating said water saturated with bromine in a second fractionator
at conditions to produce at least substantially bromine-free water.
2. The process of claim 1 wherein said substantially dry bromine liquid
10 contains less than about 5.0 wppm water.
3. The process of claim 2 wherein said substantially dry bromine liquid
contains less than about 1.0 wppm water.
4. The process of claim 3 wherein said substantially dry bromine liquid
contains less than about 0.5 wppm water.
- 15 5. The process of claim 1 wherein the temperature at which such first
fractionator operates is from about 40° C to about 150° C.
6. The process of claim 1 wherein the pressure at which such first
fractionator operates is from about 1.50 barg to about 10 barg.
7. The process of claim 1 wherein said substantially bromine-free water
20 contains less than about 5.0 wppm bromine.
8. The process of claim 7 wherein said substantially bromine-free water
contains less than about 1.0 wppm bromine.
9. The process of claim 8 wherein said substantially bromine-free water
contains less than about 0.5 wppm bromine.
- 25 10. The process of claim 1 wherein the temperature at which such second
fractionator operates is from about 100° C to about 120° C.
11. The process of claim 1 wherein the pressure at which such second
fractionator operates is from about 0.7 barg to about 1.0 barg.
12. A process comprising:
30 (a) contacting wet bromine liquid with substantially dry bromine
vapor so as to volatilize substantially all water dissolved in the wet bromine
liquid and produce a substantially dry bromine liquid and a first bromine and
water vapor;

(b) condensing the first bromine and water vapor to form at least a first liquid phase comprising bromine saturated with water and a second liquid phase comprising water saturated with bromine;

(c) separating the first liquid phase and the second liquid phase;
5 and

(d) contacting the second liquid phase with substantially pure water vapor so as to volatilize substantially all bromine dissolved in the water and produce substantially bromine-free liquid water and a second bromine and water vapor.

10 13. The process of claim 12 further comprising:

combining the first bromine and water vapor generated in step (a) and the second bromine and water vapor generated in step (d) prior to the step of condensing.

14. The process of claim 12 further comprising:

15 heating a portion of the substantially dry bromine liquid to form at least a portion of the substantially dry bromine vapor used to contact wet bromine liquid.

15. The process of claim 12 further comprising:

20 heating a portion of the substantially pure water to form at least a portion of the substantially bromine-free water vapor used to contact the said second liquid phase in step (c) comprising water saturated with bromine.

16. The process of claim 12 wherein said substantially dry bromine liquid contains less than about 5.0 wppm water.

17. The process of claim 16 wherein said substantially dry bromine liquid
25 contains less than about 1.0 wppm water.

18. The process of claim 17 wherein said substantially dry bromine liquid contains less than about 0.5 wppm water.

19. The process of claim 12 wherein the temperature at which such step of contacting wet bromine liquid with substantially dry bromine vapor occurs is
30 from about 40° C to about 150° C.

20. The process of claim 12 wherein the pressure at which such step of contacting wet bromine liquid with substantially dry bromine vapor occurs is from about 1.50 barg to about 10 barg.

21. The process of claim 12 wherein said substantially bromine-free liquid water contains less than about 5.0 wppm bromine.
22. The process of claim 21 wherein said substantially bromine-free liquid water contains less than about 1.0 wppm bromine.
- 5 23. The process of claim 22 wherein said substantially bromine-free liquid water contains less than about 0.5 wppm bromine.
24. The process of claim 12 wherein the temperature at which the step of contacting the second liquid phase with substantially pure water vapor occurs is from about 72° C to about 81° C.
- 10 25. The process of claim 12 wherein the pressure at which the step of contacting the second liquid phase with substantially pure water vapor occurs is from about 1.5 barg to about 10 barg.
26. The process of claim 12 further comprising:
combining the second liquid phase with the wet bromine liquid prior to
15 said step of contacting the wet bromine liquid with the substantially dry bromine vapor.
27. The process of claim 12 wherein said steps are continuously performed.
28. The process of claim 12 wherein both of said steps of contacting are
20 performed countercurrently.
29. The process of claim 12 further comprising:
heating the substantially dry bromine liquid to form a substantially dry
bromine vapor; and
reacting a gaseous feed having lower molecular weight alkanes with
25 the substantially dry bromine vapor to form alkyl bromides and hydrobromic acid.
30. The process of claim 29 further comprising:
reacting said alkyl bromides in the presence of said hydrobromic acid
and a synthetic crystalline alumino-silicate catalyst and at a temperature
30 sufficient to form higher molecular weight hydrocarbons and additional hydrobromic acid.

31. The process of claim 30 further comprising:

converting said hydrobromic acid and said additional hydrobromic acid to wet bromine liquid.

32. A system for drying wet bromine liquid comprising:

5 a first fractionator having an inlet in the upper end thereof for wet bromine liquid, an outlet in the lower end thereof for substantially dry bromine liquid and an outlet in the upper end thereof for a first bromine and water vapor, said first fractionator being configured to countercurrently contact wet bromine liquid with substantially dry bromine vapor so as to volatilize
10 substantially all water dissolved in the wet bromine liquid and produce a substantially dry bromine liquid;

a heat exchanger in fluid communication with the upper outlet of the first fractionator for condensing the first bromine and water vapor to form at least a first liquid phase comprising bromine saturated with water and a
15 second liquid phase comprising water saturated with bromine;

a separator in fluid communication with the heat exchanger for separating the first liquid phase and the second liquid phase; and

a second fractionator in fluid communication with the separator and having an inlet in the upper end thereof for the second liquid phase, an outlet
20 in the lower end thereof for substantially bromine-free water and an outlet in the upper end thereof for a second bromine and water vapor, said second fractionator being configured to countercurrently contact the second liquid phase with substantially pure water vapor so as to volatilize substantially all bromine dissolved in the water and produce substantially bromine-free water.

25 33. The system of claim 32 further comprising:

a reboiler in fluid communication with the first fractionator and configured to heat the substantially dry bromine liquid and form the substantially dry bromine vapor.

34. The system of claim 32 further comprising:

30 a reboiler in fluid communication with the second fractionator and configured to heat the substantially bromine-free water and form the substantially bromine-free water vapor.

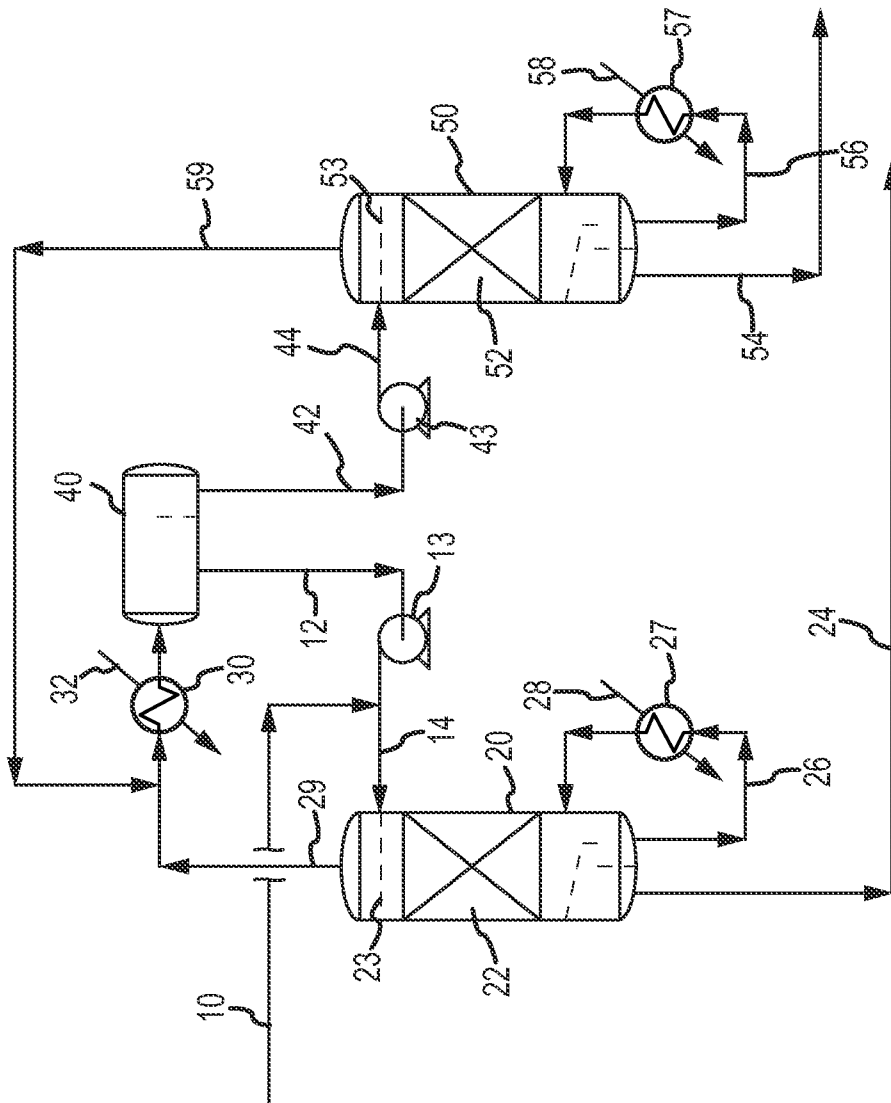


FIG.1

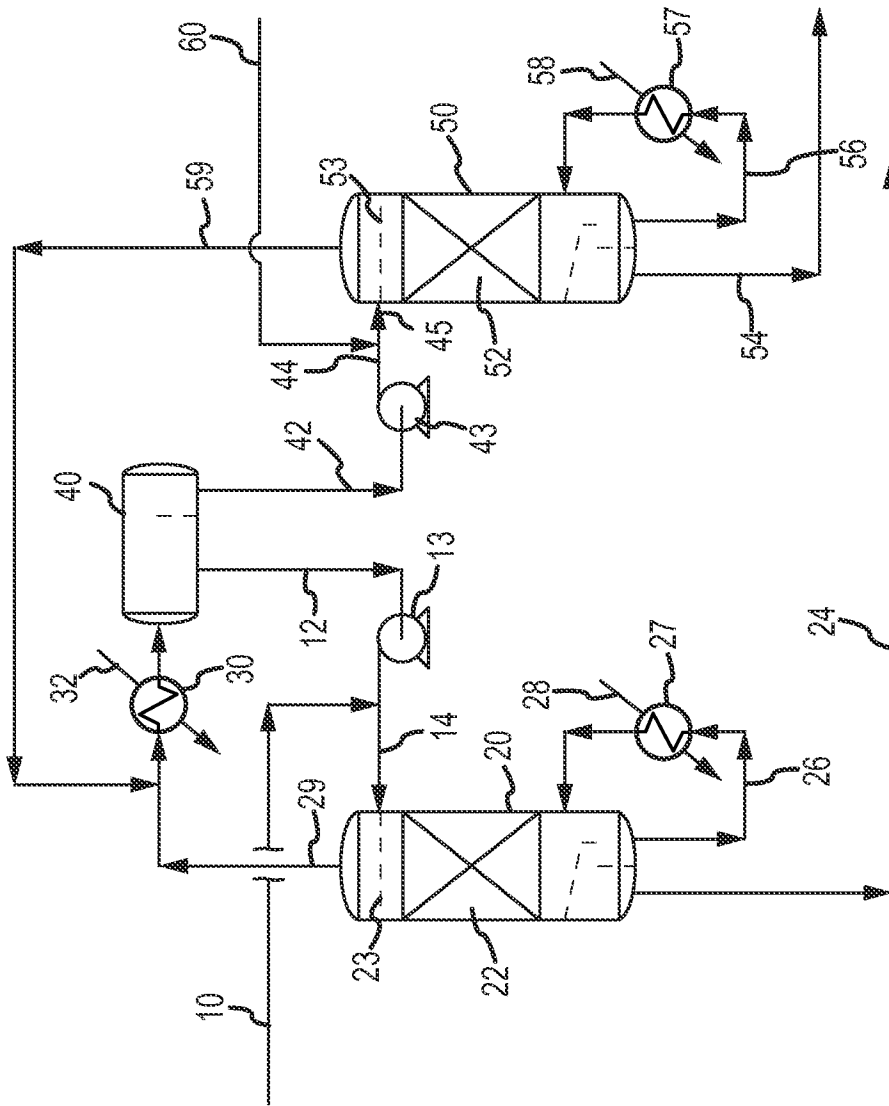


FIG.1A

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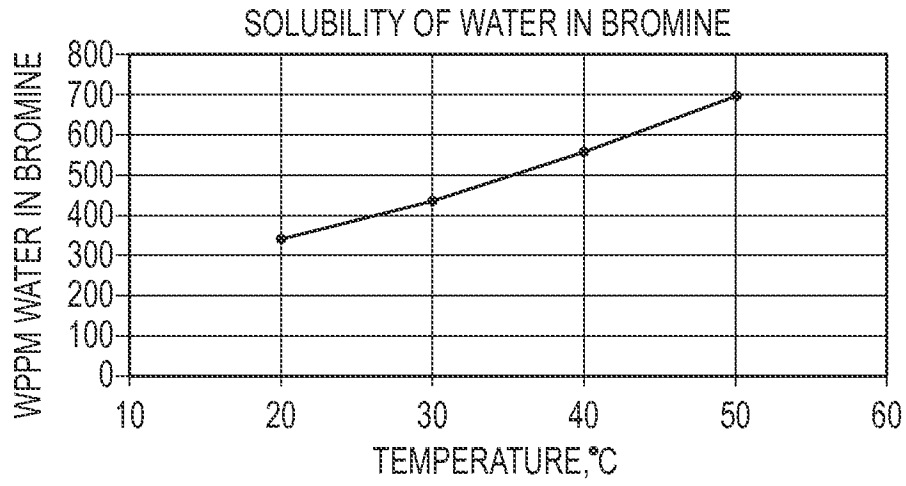


FIG.2

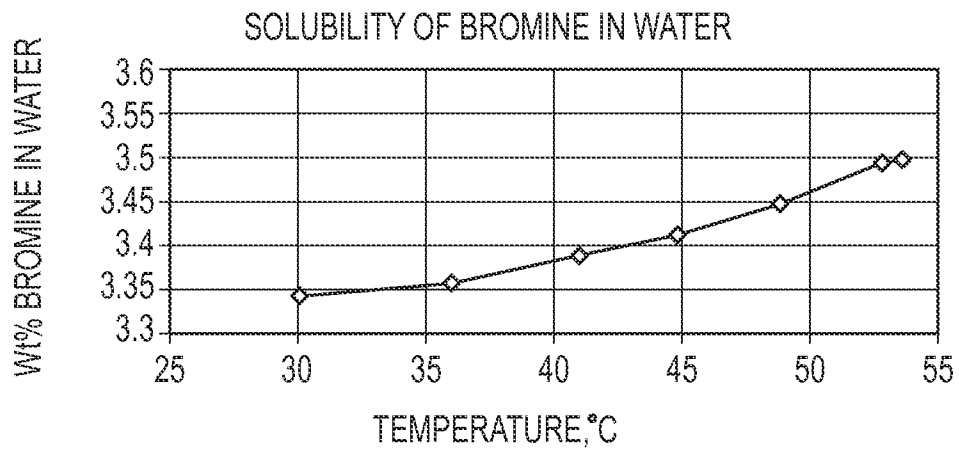


FIG.3

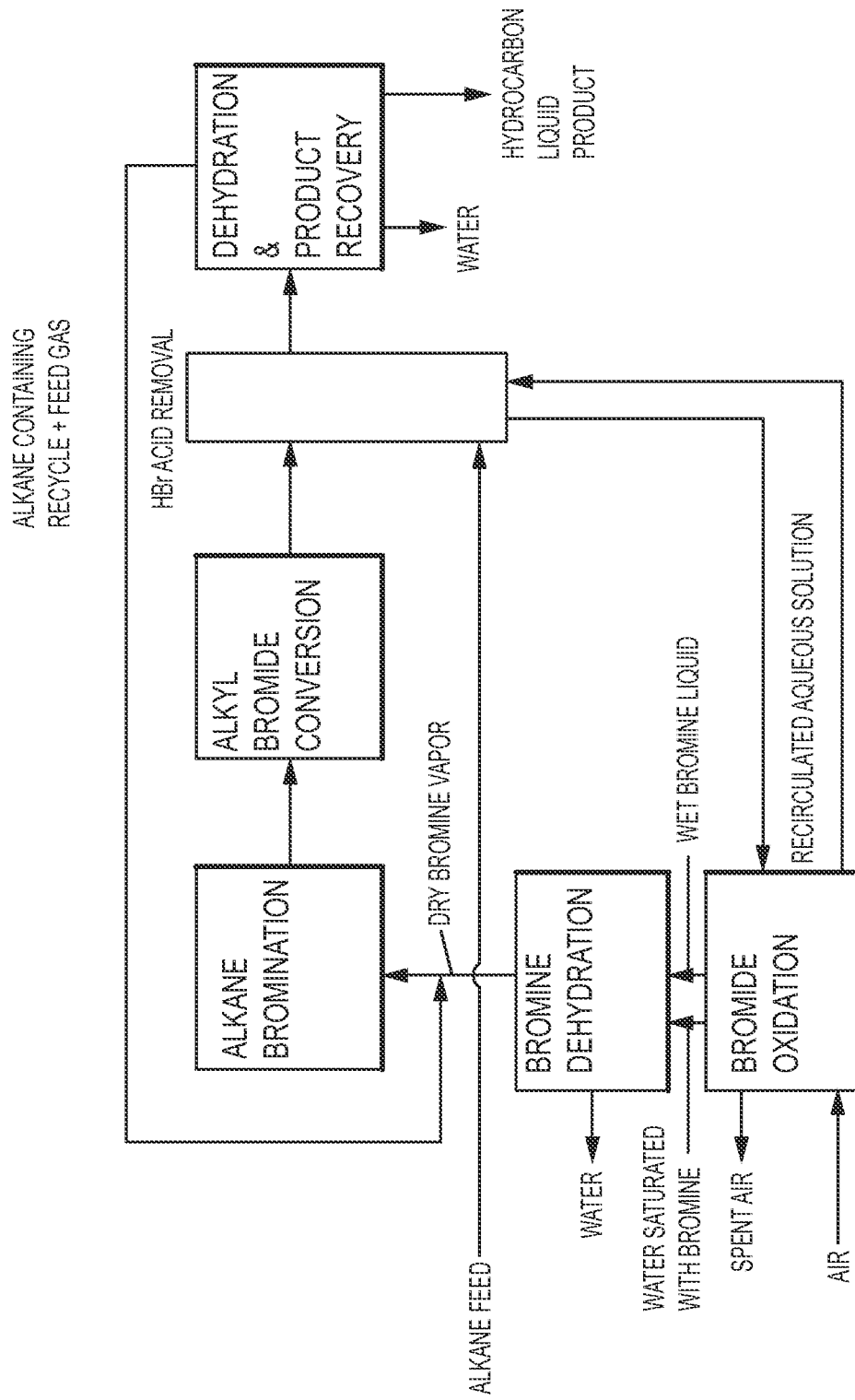


FIG.4

INTERNATIONAL SEARCH REPORT

2012/027716 15 06 2012

International application No.

PCT/US 12/27716

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - C01B 7/09 (2012.01)

USPC - 423/500

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - C01B 7/09 (2012.01)

USPC - 423/500

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

IPC(8) - C01B 7/09; C01B (2012.01)

USPC - 423/500

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

PubWest (PGPB,USPT,USOC,EPAB,JPAB); DialogWeb (File 348 European Patents Fulltext; File 349 WIPO/PCT Patents Fulltext); USPTO; Espacenet; Google Patents; Google Scholar. Search terms: bromine, chlorine, countercurrent\$, dried, drying, gas, gaseous, halogen, heated, heating, iodine, liquid, moisture, reboil\$, reflux\$, vapor, vaporiz\$, water, wet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3,615,265 A (Gartner) 26 October 1971 (26.10.1971) Fig 1; Table; col 1, ln 30-33; col 1, ln 62-64; col 2, ln 10-21; col 2, ln 37-38; col 2, ln 41-46	1-34
Y	US 2011/0015458 A1 (Waycuilis et al.) 20 January 2011 (20.01.2011) Fig 2; Fig 7; Fig 8; para [0114]; [0118]; [0119]; [0121]; [0157] to [0160]; [0162]; [0195]; [0168]; [0175]	1-34
A	US 2,320,257 A (Beekhuis) 25 May 1943 (25.05.1943) col 1, ln 19-25	1-34
A	US 3,314,762 A (Hahn) 18 April 1967 (18.04.1967) Fig 1	1-34

 Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

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Date of mailing of the international search report

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