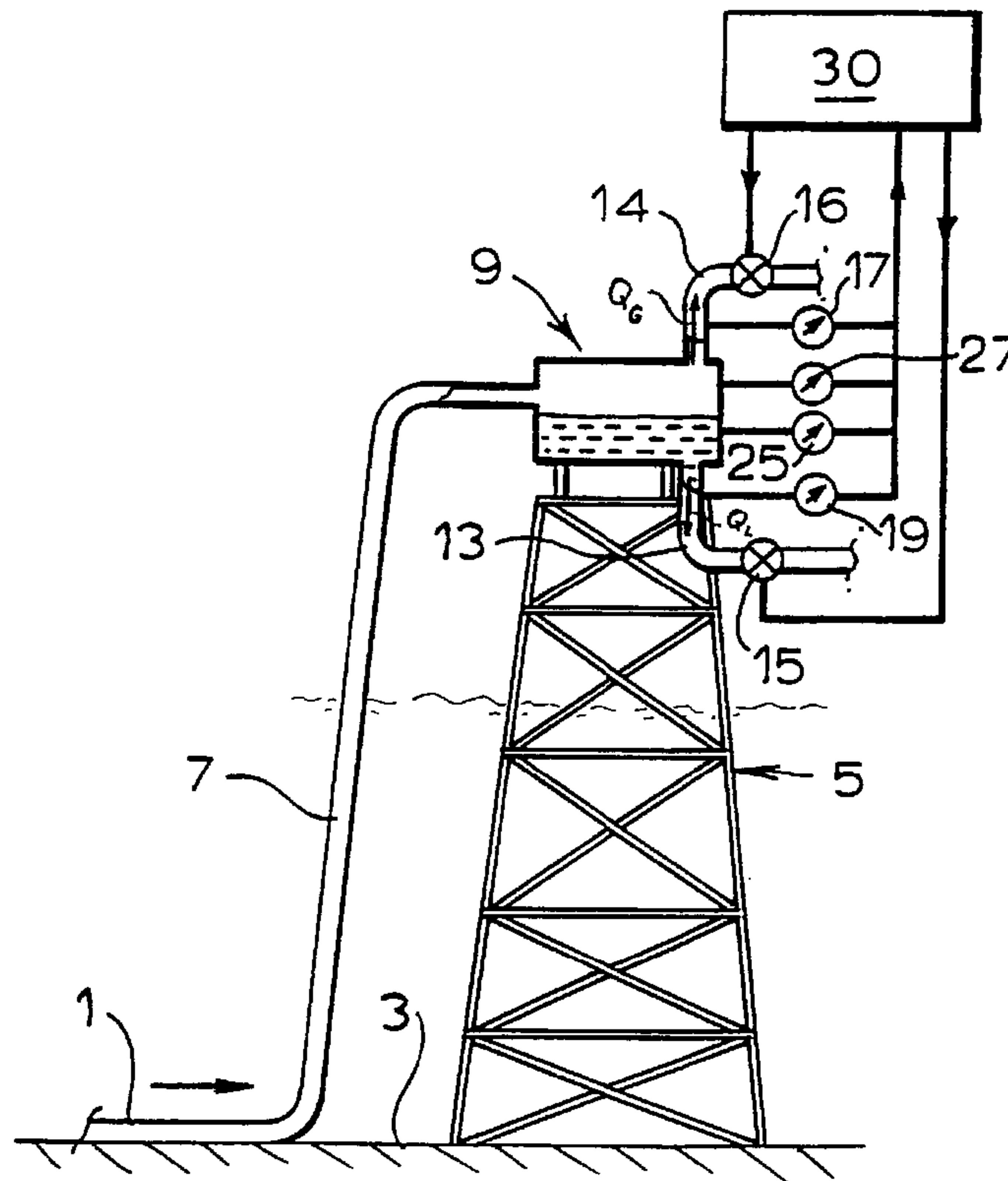




(86) Date de dépôt PCT/PCT Filing Date: 2000/11/07
 (87) Date publication PCT/PCT Publication Date: 2001/05/17
 (45) Date de délivrance/Issue Date: 2009/05/05
 (85) Entrée phase nationale/National Entry: 2002/04/24
 (86) N° demande PCT/PCT Application No.: EP 2000/011034
 (87) N° publication PCT/PCT Publication No.: 2001/034940
 (30) Priorité/Priority: 1999/11/08 (EP99203727.5)

(51) Cl.Int./Int.Cl. *E21B 43/12* (2006.01),
B01D 19/00 (2006.01), *E21B 43/36* (2006.01),
F17D 1/20 (2006.01), *E21B 43/01* (2006.01)
 (72) Inventeurs/Inventors:
 HAANDRIKMAN, GRITIENUS, NL;
 HENKES, RUDOLPHUS ALOYSIUS WIJNANDUS
 MARIA, NL;
 SEELEN, MARINUS GERARDUS WILHELMUS MARIA,
 NL;
 VREENEGOOR, ALOYSIUS JOHANNES NICOLAAS,
 NL
 (73) Propriétaire/Owner:
 SHELL CANADA LIMITED, CA
 (74) Agent: SMART & BIGGAR

(54) Titre : PROCÉDE ET SYSTÈME DE SUPPRESSION ET DE REGULATION D'UN ÉCOULEMENT A BOUCHONS
 DANS UN ÉCOULEMENT DE FLUIDE MULTIPHASE
 (54) Title: METHOD AND SYSTEM FOR SUPPRESSING AND CONTROLLING SLUG FLOW IN A MULTI-PHASE FLUID
 STREAM



(57) Abrégé/Abstract:

A method and system for suppressing and controlling liquid slugs and gas surges in a multiphase fluid flow line make use of a gas liquid separator (9) and a gas valve (16) in the gas outlet (14) and a liquid valve (15) in the liquid outlet (13) of said separators,

(57) **Abrégé(suite)/Abstract(continued):**

which valves (15, 16) are adjusted automatically in response to variations of one of more selected control variables, such as Q_{GAS} , Q_{Liquid} , $Q_{Liquid} + Q_{gas}$, L_{liquid} , P , and the control variable is changed automatically from time to time if one or more selected control variables reaches a pre-set threshold value.

WO 01/34940 A3

(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

(88) Date of publication of the international search report:
10 January 2002

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Published:

— *with international search report*

METHOD AND SYSTEM FOR SUPPRESSING AND CONTROLLING SLUG
FLOW IN A MULTI-PHASE FLUID STREAM

Background of the Invention

The invention relates to suppression and the control
of slug flow in a multi-phase fluid stream. More
particularly, the invention relates to a method and
5 system for suppressing and controlling liquid slugs and
gas surges in a stream of multi-phase fluid flowing
through a pipeline or a flowline system, which may
include a riser section, and a gas/liquid separator or
slugcatcher located downstream of the pipeline outlet or
10 the riser section.

In the oil and gas industry it is common practice to
transport a multiphase fluid containing crude oil or
condensate, water and gas from a well through a single
pipeline system to a process facility. For example, in
15 case of offshore oil production crude oil, production
water and associated gas are generally simultaneously
transported through a single subsea pipeline to
gas/liquid separating equipment located onshore or on an
offshore platform. Several flow regimes are known to
20 occur in such a stream of multiphase fluid, including
stratified flow, core flow, mist flow and slug flow. Of
these flow regimes slug flow is generally to be avoided
as it consists of alternating batches of liquid (termed
slugs) and gas surges. Under certain flow conditions
25 growth of liquid slugs may easily occur, which leads to
severe slugging whereby a flow pattern of alternating
production starvation (no flow), large liquid slugs and
strong gas surges at the exit of the flowline system
occur. Large liquid slugs can also be generated by
30 operational changes, e.g. the increase of the fluid

production during the start-up of a pipeline. Supplying such an alternating pattern of liquid slugs and gas surges to a gas/liquid separator strongly reduces the efficiency of the separator, as the gas/liquid separator must be operated with acceptable pressure fluctuations and should deliver an acceptably low liquid content in the gas outlet conduit and an acceptably low gas content in the liquid outlet conduit.

A method for preventing slug growth in a pipeline system during simultaneous transportation of a gas and a liquid through the pipeline system is disclosed in Oil & Gas journal, Nov. 12, 1979. In this known method a valve is arranged at the top of a riser, which valve is manually or automatically regulated so as to minimise the pipeline pressure upstream of the riser and to minimise the differential pressure fluctuations in the riser. Transmitters are used to transmit pressure signals for regulating the valve, which transmitters are installed at a subsea part of the pipeline system. This known method is based on the assumptions that severe slugging only occurs in pipelines having a section of downward inclination when seen in the direction of flow and that slug growth can be prevented by regulating the volumetric fluid flux as a function of fluid pressure variations.

JP-A-63-274408 discloses a separator control apparatus which adjusts a valve in a gas outlet of a gas liquid separator by adding the outputs of a supersonic multiphase flowmeter in the inlet of the separator and of a manometer within the separator to exert a constant pressure in the separator.

EP-B-410522 discloses a method of preventing slug growth in a stream of multiphase fluid flowing from a flowline into a gas/liquid separator, whereby fluid rate control means are provided to manipulate the fluid flow rate.

63293-3872

- 3 -

This known method comprises measuring the liquid flow rate in the liquid outlet of the separator and the gas flow rate in the gas outlet thereof, determining the fluid flux defined as the sum of the liquid flow rate and the gas flow rate, and operating the fluid flow rate control means so as to reduce a variation of the fluid flux. A drawback of this known method and of the method disclosed in JP-A-63-274408 is that measurement of the sum of the liquid and gas flow rates in a multiphase fluid stream is difficult and requires complex measuring equipment.

US patent Nos. 5,256,171; 5,377,714; 5,494,067; 5,544,672 and 5,711,338 disclose slug suppression methods in which the liquid level in a gas-liquid separation vessel is held as constant as possible. A disadvantage of these methods is that said liquid level is not always the best control parameter and that occasionally, e.g. during start-up still manual control or intervention is required.

An existing method known from EP-B-767699.

This known method comprises the steps of:

- measuring at least one control variable selected from the group of the liquid level in the separator, the liquid flow rate in the liquid outlet of the separator, the gas flow rate in the gas outlet of the separator, the sum of the liquid flow rate in the liquid outlet and the gas flow rate in the gas outlet, and the fluid pressure at or near the separator; and
- dynamically adjusting liquid and gas flow control valves in the liquid and gas outlets so as to reduce a difference between one or more selected control variables and a selected reference value of the selected control variable(s).

63293-3872

- 4 -

Field experience with the method according to EP-B-767699 has learned that this known method significantly suppresses slug flow in a multi-phase fluid stream but that, due to the origin of the liquid slugs, some slugs were
5 suppressed to a more limited extent than other slugs.

The method and system according to the present invention aims to provide a slug suppression and control method which even further controls slug flow than the known method and that can be operated automatically without
10 requiring human intervention.

Summary of the Invention

According to one aspect of the present invention, there is provided a method for suppressing and controlling liquid slugs and gas surges in a stream of multiphase fluid
15 flowing from a flowline into a gas/liquid separator which has a liquid outlet provided with a liquid flow control valve and a gas outlet provided with a gas flow control valve, the method comprising measuring at least one control variable selected from the group of a liquid level (L_{LIQ}) in
20 the separator, a liquid flow rate (Q_L) in the liquid outlet, a gas flow rate (Q_G) in the gas outlet, a sum (Q_L+Q_G) of the liquid flow rate in the liquid outlet and the gas flow rate in the gas outlet, and a fluid pressure (P) at or near the separator; adjusting said liquid and gas flow control valves
25 so as to reduce a difference between a selected control variable (Q_L+Q_G , Q_L , Q_G , P , L_{LIQ}) and a pre-set reference value of the selected control variable, characterized in that the method further comprises changing the selected control variable (Q_L+Q_G , Q_L , Q_G , P , L_{LIQ}) from time to time
30 automatically if one or more control variables reaches a pre-set value, wherein during normal operation the selected

63293-3872

- 5 -

control variable is the sum (Q_L+Q_G) of the liquid flow rate in the liquid outlet and the gas flow rate in the gas outlet, and wherein the selected control variable is changed into the liquid flow rate (Q_L) in the liquid outlet if the liquid level (L_{LIQ}) in the separator or the liquid flow rate (Q_L) in the liquid outlet reaches a pre-set value and wherein the control variable is changed back again into the sum (Q_L+Q_G) of the liquid flow rate in the liquid outlet and the gas flow rate in the gas outlet when said liquid level (L_{LIQ}) in the separator or liquid flow rate (Q_L) in the liquid outlet is below said pre-set value.

According to another aspect of the present invention, there is provided a system for suppressing and controlling liquid slugs in a stream of multi-phase fluid flowing from a flowline into a gas/liquid separator or slug catcher having a liquid outlet provided with a liquid flow control valve and a gas outlet provided with a gas flow control valve, the system comprising a control system for dynamically adjusting the position of said gas and liquid control valves in response to measurement of at least one control variable selected from the group of the liquid level (L_{LIQ}) in the separator, the liquid flow rate of (Q_L) in the liquid outlet, the gas flow rate (Q_G) in the gas outlet and a sum of the liquid and gas flow rates (Q_L+Q_G) in said outlets, characterized in that the control system is adapted to change from time to time the control variable (L_{LIQ} , Q_L , Q_G , Q_L+Q_G) in response to which said gas and liquid control valves are adjusted if a selected control variable has reached a pre-set value, wherein during normal operation the control variable is the sum (Q_L+Q_G) of the liquid flow rate in the liquid outlet and the gas flow rate in the gas outlet, and wherein the control variable is changed into the liquid flow rate (Q_L) in the liquid outlet if the liquid

63293-3872

- 5a -

level (L_{LIQ}) in the separator at least one of the liquid flow rate Q_L in the liquid outlet reaches the pre-set value and wherein the control variable is changed back again into the sum (Q_L+Q_G) of the liquid flow rate in the liquid outlet and the gas flow rate in the gas outlet when said liquid level (L_{LIQ}) in the separator or liquid flow rate (Q_L) in the liquid outlet is below said pre-set value.

As soon as the liquid level in the separator and/or liquid flow rate in the liquid outlet is again below said pre-set threshold value the system is automatically switched back into the default hybrid constant liquid level/constant mixture flow rate control mode.

The gas/liquid separator described hereinbefore can have sufficient capacity for processing the fluid stream, in which case said separator can be the only separator in the system. Alternatively, the separator can form a mini-separator which is located upstream a slug catching separator. The mini-separator then forms a primary separator of which the gas outlet and the liquid outlet debouch into the slug catching separator which forms a secondary separator.

Description of a preferred embodiment

The invention will now be described in more detail and by way of example with reference to the accompanying drawings in which:

Fig. 1 shows schematically a flowline system for carrying out the method according to the invention;

Fig. 2 shows schematically how the system operates in its default mode; and

5 Fig. 3 shows schematically how the system occasionally operates in its constant liquid flow and no gas flow mode.

The flowline system of Fig. 1 comprises an oil and/or gas production pipeline 1 extending on the seafloor 3
10 from a wellhead (not shown) of an oil and/or gas production well to an offshore platform 5, an upwardly inclined pipeline section in the form of a riser 7 connected to the platform 5 and a gas/liquid separator 9 having a liquid outlet conduit 13 and a gas outlet
15 conduit 14. The liquid outlet conduit 13 is provided with a liquid flow control valve 15, and the gas outlet conduit is provided with a gas flow control valve 16. The valves 15, 16 can be of any suitable type such as vortex amplifier disclosed in the Oil man, August 1987,
20 pp. 82-85. A gas flow meter 17 is provided in the gas outlet conduit 14 and a liquid flow meter 19 is provided in the liquid outlet conduit 13. The separator 9 is further provided with a liquid level gauge 25 and a pressure gauge 27. A control system 30 is provided which
25 receives signals from the gas flow meter 17, the liquid flow meter 19, the liquid level gauges 25, and the pressure gauge 27, which control system 30 controls the valves of 15,16 in a manner depending on the signals received by the control system 30. The liquid outlet
30 conduit 13 and the gas outlet conduit are in fluid communication with the interior of a slug-catching separator (not shown) located downstream the separator 9. The slug-catching separator is of a size considerably larger than the separator 9.

- 7 -

During start up of the system the liquid valve 15 is closed until the liquid level L_{LIQ} in the separator 9 reaches a selected level, whereas the gas valve (16) is adjusted dynamically such that the pressure measured by the pressure gauge 27 is maintained at a selected level.

As soon as the liquid level L_{LIQ} in the separator 9 has reached a selected level the system is automatically switched into the default total volumetric flow control mode shown in Fig. 2.

In the total volumetric flow control mode shown in Fig. 2 the liquid valve 15 is controlled to maintain a liquid level L_{LIQ} set point. In addition, the gas valve 16 is controlled to maintain a total volumetric flow $Q_L + Q_G$ set-point. The actual flow rate Q_L and Q_G are measured by the gas and liquid flow meters 17, 19 in the liquid and gas outlets 14 and 13. The sum of the output of the flow meters 17 and 19, is the variable to be controlled. The set-point of the total volumetric flow controller 30B is given by a pressure controller 30A in combination with algorithms which depend on the pipeline system 1,7.

For slugs, the total volumetric flow control scheme shown in Fig. 1 will not work optimally due to the fact that the level controller 30C is not bounded by the total volumetric flow. It will open the liquid valve 15 completely to keep the liquid level on its set-point. Therefore, the liquid flow control mode of operation shown in Fig. 3 is switched on when: (i) the liquid level L_{LIQ} in the separator 9 reaches a threshold value or (ii) the liquid flow rate Q_L in the liquid outlet 13 reaches a threshold value. The threshold value of the liquid flow rate Q_L may depend on external factors such as the liquid level or liquid drainage capacity of the first stage separator. This threshold value can also be used as the

set-point of the liquid flow controller 30C. The set-point of the total volumetric flow remains constant during liquid flow control.

5 Liquid flow control prevents acceleration of the slug. When the liquid level in the mini-separator 9 is decreased and the liquid flow rate is below the threshold value, the total volumetric control mode shown in Fig. 2 is switched on again. In the total volumetric control mode, the compressed gas phase (behind the slug) can be
10 produced without any gas surge.

63293-3872

- 9 -

CLAIMS:

1. A method for suppressing and controlling liquid slugs and gas surges in a stream of multiphase fluid flowing from a flowline into a gas/liquid separator which has a liquid outlet provided with a liquid flow control valve and a gas outlet provided with a gas flow control valve, the method comprising
- 5
- 10
- 15
- 20
- 25
- 30
- measuring at least one control variable selected from the group of a liquid level (L_{LIQ}) in the separator, a liquid flow rate (Q_L) in the liquid outlet, a gas flow rate (Q_G) in the gas outlet, a sum (Q_L+Q_G) of the liquid flow rate in the liquid outlet and the gas flow rate in the gas outlet, and a fluid pressure (P) at or near the separator;
 - adjusting said liquid and gas flow control valves so as to reduce a difference between a selected control variable (Q_L+Q_G , Q_L , Q_G , P , L_{LIQ}) and a pre-set reference value of the selected control variable, characterized in that the method further comprises
 - changing the selected control variable (Q_L+Q_G , Q_L , Q_G , P , L_{LIQ}) from time to time automatically if one or more control variables reaches a pre-set value, wherein during normal operation the selected control variable is the sum (Q_L+Q_G) of the liquid flow rate in the liquid outlet and the gas flow rate in the gas outlet, and wherein the selected control variable is changed into the liquid flow rate (Q_L) in the liquid outlet if the liquid level (L_{LIQ}) in the separator or the liquid flow rate (Q_L) in the liquid outlet reaches a pre-set value and wherein the control variable is changed back again into the sum (Q_L+Q_G) of the liquid flow rate in the liquid outlet and the gas flow rate in the gas outlet when said liquid level (L_{LIQ}) in the

63293-3872

- 10 -

separator or liquid flow rate (Q_L) in the liquid outlet is below said pre-set value.

2. The method of claim 1, wherein during normal operation the liquid flow control valve is adjusted such that variations of the liquid level (L_{LIQ}) in the separator are minimized, and the gas flow control valve is adjusted such that variations in the sum of the liquid and gas flow rates (Q_L+Q_G) in said outlets are minimized.

3. The method of claim 1, wherein during normal operation the sum (Q_L+Q_G) of the liquid flow rate in the liquid outlet and the gas flow rate in the gas outlet is controlled by dynamically adjusting the position of the gas flow rate control valve by means of a mixture flow controller which is set to maintain a total volumetric flow set-point and by dynamically adjusting the position of the liquid flow rate control valve by means of a liquid level controller.

4. The method of claim 3, wherein, if the liquid flow rate (Q_L) is selected as the control variable, the gas flow control valve is substantially closed and the liquid flow control valve is dynamically adjusted by a liquid flow controller which is set to maintain a liquid flow set-point.

5. The method of claim 4, wherein, if the liquid flow rate (Q_L) is selected as the control variable, a gas flow control valve is substantially closed by closing off or choking the gas flow control valve until the gas pressure reaches an unsafe level at which the gas flow control valve is operated as a pressure relief valve.

6. The method of any one of claims 1 to 5, wherein during a start-up period the liquid valve is closed until

63293-3872

- 11 -

the liquid level in the separator reaches a selected level, whereas the gas-valve is adjusted dynamically such that a pressure measured by a pressure gauge of the separator is maintained at a selected level.

5 7. A system for suppressing and controlling liquid slugs in a stream of multi-phase fluid flowing from a flowline into a gas/liquid separator or slug catcher having a liquid outlet provided with a liquid flow control valve and a gas outlet provided with a gas flow control valve, the
10 system comprising a control system for dynamically adjusting the position of said gas and liquid control valves in response to measurement of at least one control variable selected from the group of the liquid level (L_{LIQ}) in the separator, the liquid flow rate of (Q_L) in the liquid outlet,
15 the gas flow rate (Q_G) in the gas outlet and a sum of the liquid and gas flow rates (Q_L+Q_G) in said outlets,

characterized in that the control system is adapted to change from time to time the control variable (L_{LIQ} , Q_L , Q_G , Q_L+Q_G) in response to which said gas and liquid
20 control valves are adjusted if a selected control variable has reached a pre-set value,

wherein during normal operation the control variable is the sum (Q_L+Q_G) of the liquid flow rate in the liquid outlet and the gas flow rate in the gas outlet, and
25 wherein the control variable is changed into the liquid flow rate (Q_L) in the liquid outlet if the liquid level (L_{LIQ}) in the separator at least one of the liquid flow rate Q_L in the liquid outlet reaches the pre-set value and wherein the control variable is changed back again into the sum (Q_L+Q_G)
30 of the liquid flow rate in the liquid outlet and the gas flow rate in the gas outlet when said liquid level (L_{LIQ}) in

63293-3872

- 12 -

the separator or liquid flow rate (Q_L) in the liquid outlet is below said pre-set value.

8. The system of claim 7, wherein the control system is set such that during normal operation the liquid flow control valve is adjusted such that variations of the liquid level (L_{LIQ}) in the separator are minimized and the gas flow control valve is adjusted that variations in the sum of the liquid and gas flow rates (Q_L+Q_G) in said outlets are minimized, and wherein the control system substantially closes the gas flow control valve and the liquid flow control valve is adjusted such that variations in the liquid flow rate (Q_L) in the liquid outlet are minimized if either the liquid level (L_{LIQ}) in the separator reaches a threshold level or if the liquid flow rate (Q_L) in the liquid outlet reaches a threshold value.

9. The system of claim 7 wherein the flowline forms part of a hydrocarbon fluid production system through which a mixture of crude oil, condensate, water at least one of natural gas is produced from one or more hydrocarbon fluid production wells.

10. The system of claim 9 wherein the separator is a primary separator and wherein the liquid and gas outlets are fluid inlet conduits for a secondary separator or slug catcher which has a larger volume than the primary separator.

11. The system of claim 10 wherein primary and secondary separators are mounted on an offshore platform, on the seabed onshore, or downhole in an oil at least one of gas production well.

