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FROTH HEIGHT LEVEL SENSOR

BY

Joseph W. Glaser (USA)
2586 Windsor Court
Union City, CA 94587

Leroy Holmes (USA)
11336 Roeding Road
Denair, CA 95316

Ravindra S. Upadhye (USA)
916 Sherman Way
Pleasanton, CA 94566

John G. Wilder (USA)
2211 Bueno Vista Ave
Livermore, CA 94550

FROTH HEIGHT LEVEL SENSOR

The United States Government has rights in this invention pursuant to Contract No. W-7405-ENG-48 between the United States Department of Energy and the University of California for the operation of Lawrence Livermore National Laboratory.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to froth producing processes and more specifically, to measurement of froth height.

Description of Related Art

Locating and determining the physical parameters of froth is of vital importance in many different areas including paper manufacture, waste destruction and metals purification. Unfortunately, currently available techniques cannot survive the harsh environments found in these applications. These environmental conditions include high temperatures, abrasive, erosive, or corrosive fluids, as well as chemically reactive elements in the system to be probed.

The Molten Salt Destruction (MSD) process is one example of a process where it would be desirable to know if frothing occurs and if so, its height within the process chamber. Oxidation of mixed waste can be accomplished in an enclosed environment such as that found in the MSD process. The destruction of potentially toxic organic compounds is completely contained within the process chamber leaving the radioactive residue contained within the molten salt. As the fuel and oxidant are brought together within the molten salt, the liquid tends to bubble as the gases float upwards. The resultant froth and the height it attains must be known. Should the level of the froth rise too high within the process chamber, the froth would clog the hardware located at the top of the chamber thereby degrading process performance and throughput.

Classical foam height measuring techniques employing contact sensors, such as conductivity probes, have a tendency to clog as a result of deposit formation. In these environments, the diagnostic would require some mechanism to allow periodic flushing to clean the probe. When used in such areas as the pulp and paper industry, this cleaning mechanism is helpful but not always completely successful.

Resistance tape sensors, which are activated by the hydrostatic pressure near the surface of the liquid in which the gauge is submerged, has also been used to measure the level of the froth interface on top of ore enrichment columns. The froth level is a critical parameter in the enrichment process and must be monitored to ensure proper process operation. The froth, however is both hot and corrosive, necessitating the probe be placed in a protective envelope which isolates the probe from the direct environment being measured.

Ultrasonic and radar based sensors have sensor temperature operating limits. Since froth bubbles are not planar surfaces, beams scatter unpredictably off bubble surfaces. This introduces unacceptably large errors when trying to use these techniques to determine froth location.

U.S. Patent No. 2,511,649 is directed to a liquid level gauge to determine the approximate level of a liquid in a pressurized tank. Tubes of various known depths are inserted into the tank. In use, the valves in the head are successively opened until adjoining valves are discovered, one of which allows gas to escape, and the other of which allows liquid to escape.

U.S. Patent No. 4,393,705 is directed to a specific gravity level gauge. U.S. Patent No. 3,250,122 is directed to a method for determining the interface level in tankage of materials. U.S. Patent No. 3,664,365 is directed to a method and apparatus for the automatic supervision of liquid limits in closed tanks. U.S. Patent No. 4,567,761 is directed to a device for detecting variations in the height of the free level of a liquid by use of a differential pressure gauge.

U.S. Patent No. 4,669,309 is directed to a tank contents gauge having two pressure sensors to sense the liquid pressure at two tank positions at a known vertical separation. U.S. Patent No. 5,005,408 is directed to a gas weights compensation method for liquid depth gauging. U.S. Patent No. 5,073,253 is directed to a froth level measurement which includes a float, a nozzle, and an ultrasonic level detector.

Consequently, a need exists for a technique to more easily monitor the location and/or presence of froth under certain problematic environmental conditions.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method and apparatus for measurement of froth height, especially under adverse environmental conditions.

The present invention utilizes the pressure differential existing between process chamber ambient pressure and the froth pressure to determine the existence of a froth and its location. A single sensor, comprised of a tube located near the foaming liquid, another tube well away from the first, and a differential pressure gauge between the two tubes, can be used to determine the existence of the foam in the vicinity of the probe. In order to ensure stable operation, the tube located near the foaming liquid has gas flowing through it. This gas flow keeps the tube clear of foam and prevents clogging. Two sensors a known distance apart can be used to locate the froth assuming a uniform froth density. Where froth density is not constant, multiple sensors at differing heights with respect to each other, or a single movable sensor, are used. Information derived using the multiple or movable sensor yields unambiguous froth density and height data.

Thus, the present invention is inexpensive to operate, does not require a large amount of operator training and can be used in a variety of fashions under extreme conditions. As a single sensor, it can be used to determine the presence of foam as a go/no-go diagnostic. Where the froth location varies over a limited range, the dual sensor configuration will yield location and density information. Multiple or movable sensors are used to determine both froth density and height.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the basic design of the froth height level sensor.

Figure 2 shows the "dual probe" froth height level sensor.

Figure 3 shows an embodiment of the multiple sensor probe.

Figure 4 shows a moveable probe.

DETAILED DESCRIPTION OF THE INVENTION

One embodiment of the froth height measuring system is shown in Figure 1. The arrangement shown in figure 1 is used to determine the presence of foam, but not its actual location (go/no-go sensor). It consists of a gas injection tube and a differential pressure monitor between the injection tube and the reactor vessel. By initially positioning the injection tube 10 slightly above the quiescent fluid surface 12 and slowly flowing gas from gas source 14 through flow control orifice 16 and valve 18 through tube 10 to keep it free of froth once processing begins, the foam height may be determined by comparing the pressure difference between injection tube 10 and the vessel 22 at the static tube 24. The injection gas flow rate must be high enough to keep the tube free of foam but low enough so that the system dynamic pressure drop is low. Differential pressure gauge 26 is connected between tube 10 and tube 24.

Using point B (Fig. 1) as a vessel reference pressure, the pressure in the injection tube at point A (in the absence of froth in the tube, and neglecting the static gas head) is

$$P_A = P_B + h_L \qquad (1)$$

where

P_A is the pressure at point A;

P_B is the pressure at point B; and

h_L is the friction flow loss from A to B,

For low gas flow rates, h_L may be neglected.

The pressure at point D in the vessel (fig 1), may be written as:

$$P_D = P_B - \int_B^C \rho_{foam}\, g\, dh \tag{2}$$

where

C is the level of the foam surface;

P_D is the pressure at point D;

P_B is the pressure at point B;

ρ_{foam} is the density of the foam;

g is the acceleration due to gravity; and

dh is the incremental height.

The pressure difference between the reactor vessel and the injection tube (pressure at point D minus pressure at point A) may be written as (pressure at point A minus pressure at point D) may be written as

$$\Delta P = \int_B^C \rho_{foam}\, g\, dh \tag{3}$$

Or, in the case of a constant density foam (ρ_{foam} = constant)

$$\Delta P = \rho_{foam}\, g \Delta H_{foam} \tag{4}$$

As may be seen, these assumptions result in a relationship where the foam height ΔH_{foam} is proportional to the pressure difference measured between the injection tube and the reactor vessel. This relationship between foam height and pressure differential forms the basis for this invention. In the presence of a froth ($\Delta H > 0$), the sensor shown in figure 1 will respond, indicating the presence of froth.

However, even though the pressure differential and the froth height are related, it is not possible to determine the actual height without knowing froth density since there are two unknowns in equation 4: froth density and froth height. This problem is circumvented, for ρ_{foam} = constant, by measuring the froth pressure at two different known elevations (figure 2). If $\Delta P = \rho_{foam} g \Delta H$, h is the height of the foam and $\Delta H = X$, where X is the known elevation difference between the two tubes; P_{1d} and P_{2d} (Figure 2).

$$\Delta P = P_1 - P_2; \text{ and}$$

$$P_1 = \rho_{foam} g\, h; \text{ then}$$

$$\Delta P = \rho_{foam} g\, X;$$

$$P_1 - P_2 = \rho_{foam} g\, X; \text{ and}$$

$$P_1 - P_2 = \frac{P_1}{C} X \text{, therefore}$$

$$h = \frac{P_1 X}{P_1 - P_2} \quad . \qquad (5)$$

The two probe configuration shown in figure 2 can therefore be used to determine actual froth height (h), given the differential pressure obtained from sensor P_1, the difference in differential pressures obtained from both sensors ($P_1 - P_2$) and the height difference between sensors P_1 and P_2, assuming a constant froth density.

Figure 2 shows an embodiment of the invention. During validation tests sensor tubes were fabricated from four stainless steel tubes, 0.1" in diameter. The material used for the sensor tubes should be selected to match the environment within which the tubes will be placed. Tube diameter needs to be chosen such that assumptions associated with equation (2), i.e. $h_L \ll P_A - P_B$ in figure 1, remain valid. Increasing the tube diameter or decreasing the length of tube P_d (figure 2), can be used to maintain this requirement.

The tube labeled P_{1d} (figure 2)monitors the ambient pressure just above the static liquid level. P_{2d} is located a known distance above P_{1d} and monitors ambient pressure in that location. Since both P_{1d} and P_{2d} are located near the froth, a non-reactive gas at sufficient flow rate to keep the tubes clear is introduced through them (figure 2). Were this not done, the foam would clog the tube openings causing them to become unresponsive to the froth pressure, thereby causing the sensor to stop working or not yield reliable information. The tubes monitoring the chamber ambient pressure, labeled P_{1s} and P_{2s}, are located at the roof of the chamber, well away from pressure influences of the froth. A shield around them to prevent tube clogging is also recommended. Note that since the chamber ambient pressure is constant, i.e. $P_{1s}=P_{2s}$, only one port measuring ambient pressure is necessary.

As shown in figure 2, P_{1s} and P_{1d} are connected via flexible tubing to a differential pressure gauge 28. P_{2s} and P_{2d} are connected via flexible tubing to another differential pressure gauge 30. The gauge type and range should be selected based on the environmental conditions that will be encountered by the probe and gage. These include, anticipated froth pressure, chamber and liquid operating temperature, as well as foam and fluid chemical and mechanical composition. For purposes of the tests used to validate the operation of this sensor, a solid state piezo-resistive differential pressure gage with a range of ±5 inches water was used. Output from this transducer can be read directly from a meter or input into a computer or other device for process control. Similarly, P_{2s} and P_{2d} are connected to another transducer and readout/controller.

For the case where the froth density varies, multiple or moveable probes at differing locations are used to determine the density distribution. This invention comprises both techniques.

For the case of multiple probes (Figure 3), each tube location P_{nd} (where n=1,2,3...), is known. Then from equation 2, the froth density can be determined. An alternative explanation of why multiple probes work is that over incremental heights, the froth density can be assumed to be constant. Thus, two sensors a small distance apart approximate the condition shown in equation 5. Using this relation for all probes in the multiple probe set allows one to find the point where the froth density is zero and therefore the actual height of the froth. Each tube has a differential pressure gauge, as shown at 32.

Alternatively, any or all tubes P_{nd} can be connected to a motor/encoder combination and/or a telescope 34, as shown in Figure 4. The motor would be used to move the tube(s) and the encoder used to keep track of the position of the tube(s). The tube(s) would move to some position, that position would be noted, and the differential pressure data would be taken. The tube(s) would then move to the next position, with the process repeated for all positions. The cycle would then begin again for all positions. Height placement of the tube(s) could also be done manually. In any case, the tube position must be noted. Note also, that moveable probe(s) yield the same information as multiple static probes and are governed by the same principles.

Changes and modifications in the specifically described embodiments can be carried out without departing from the scope of the invention, which is intended to be limited by the scope of the appended claims.

FROTH HEIGHT LEVEL SENSOR

ABSTRACT OF THE DISCLOSURE

A single sensor, comprised of a tube located near the foaming liquid, and another well away from the first, are used to determine the existence of foam in the vicinity of the probe. Two sensors a known distance apart can be used to locate the froth assuming a uniform froth density. The present invention utilizes the pressure differential existing between process chamber ambient pressure and the froth pressure to determine the existence of a froth and its location. Where froth density is not constant, multiple sensors at differing heights with respect to each other, or a single movable sensor, are used. Information derived using the multiple or movable sensor yields unambiguous froth density and height data.

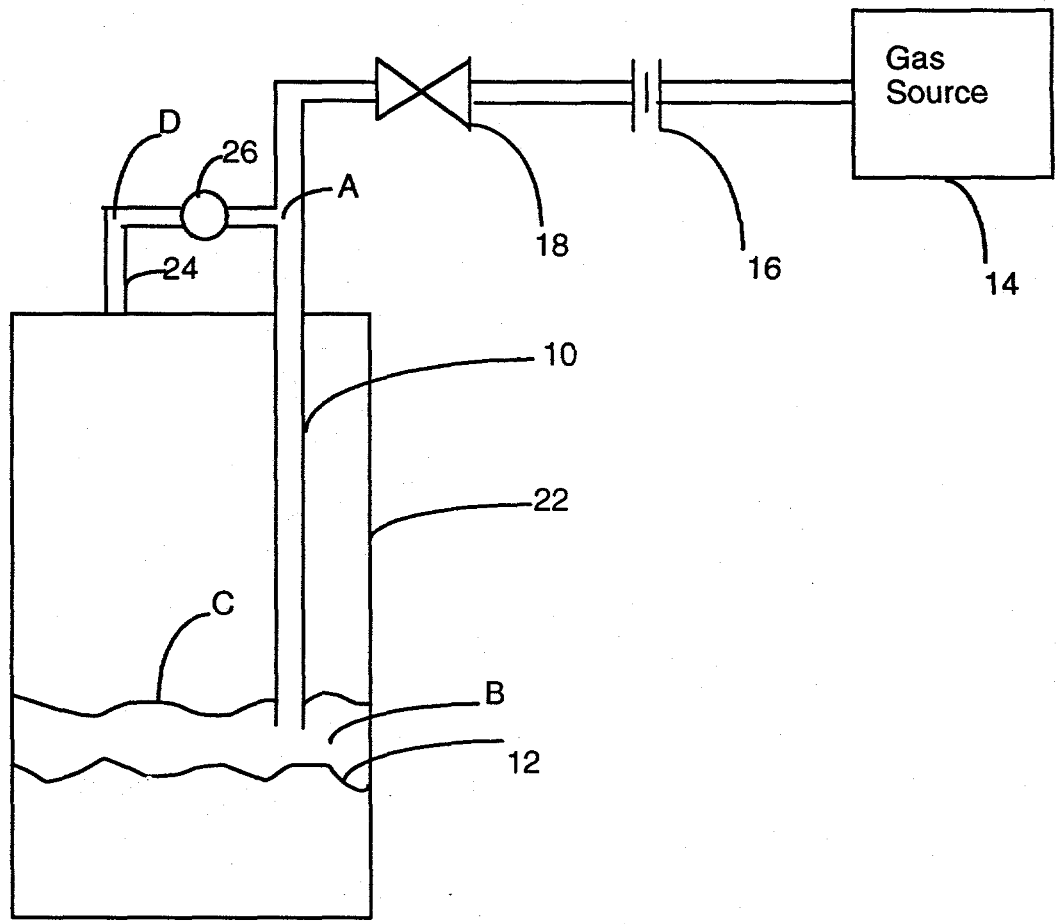

Figure 1

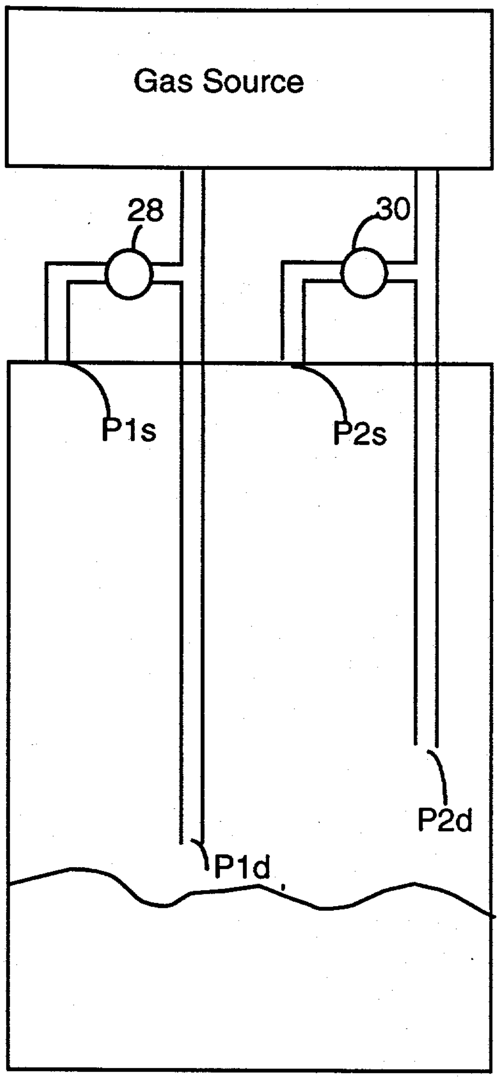

Figure 2

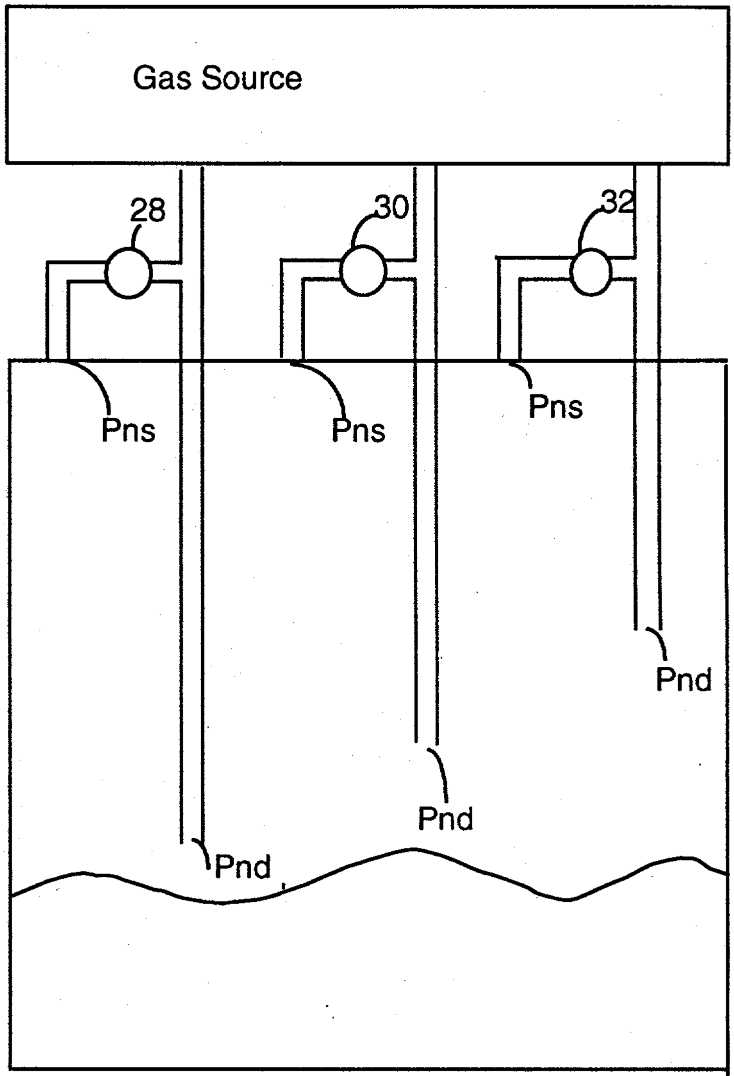

Figure 3

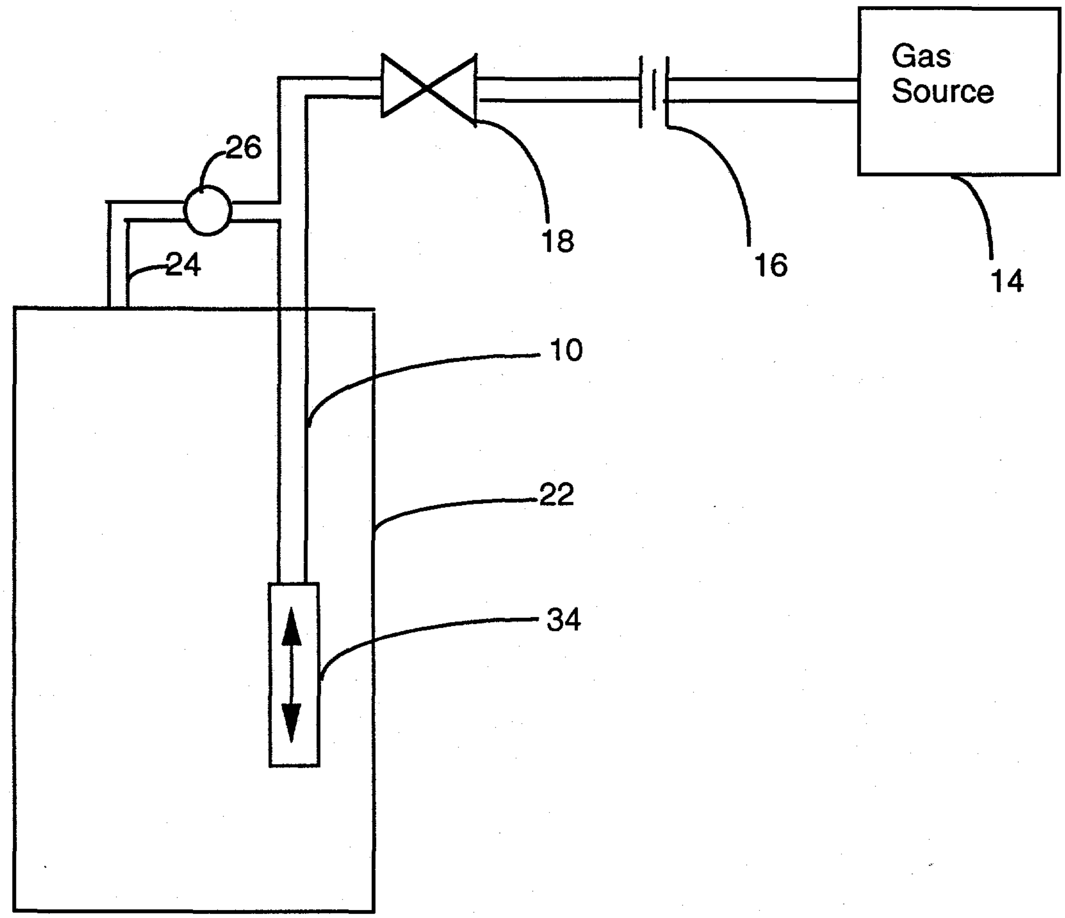

Figure 4