TECH BRIEF

What Makes Foam Detection So Difficult

What is Foam?

Partly because we are all familiar with it, foam has the appearance of a simple material: bath foam, bubbles in a milkshake or the head on a glass of beer. However, foam is a very complex, dynamic material involving physical, chemical, and biological processes in its generation.

Most common foams are an unstable, two-phase medium of gas and liquid with a structure consisting of gas pockets trapped in a network of thin liquid films and plateau borders although some foams can be highly stable and persistent.

Introduction

Foam is created through the entrapment of gas within a liquid, resulting in the formation of a dispersion with a bubbly or frothy structure. There are several mechanisms through which foam can be generated:

- **Mechanical agitation:** Agitating a liquid vigorously can introduce air or gas into the liquid, forming bubbles. This agitation can be achieved through stirring, shaking, or other mechanical means.
- **Gas evolution:** In some processes, gas is produced as a byproduct of chemical reactions or biological activity within a liquid. The evolution of gas bubbles leads to the formation of foam.
- **Chemical reaction:** Certain chemical reactions produce gas as a reaction product. When these reactions occur within a liquid, the gas bubbles generated can become trapped, resulting in foam formation.
- **Surfactant action:** Surfactants are molecules that have both hydrophilic (water-attracting) and hydrophobic (water-repelling) regions. When surfactants are present in a liquid, they can stabilize gas bubbles by lowering the surface tension at the gas-liquid interface, allowing foam to persist.
- **Whipping or aeration:** Introducing air into a liquid through whipping or aeration can lead to the formation of foam. This process is commonly used in food preparation, such as whipping cream or egg whites.
- **Foaming agents:** Certain chemicals, known as foaming agents, are specifically designed to promote foam formation. These agents typically contain surfactants or other compounds that stabilize gas bubbles within a liquid.

Regardless of the mechanism involved, foam formation occurs when gas bubbles become dispersed within a liquid or solid phase and are stabilized to some degree, leading to the characteristic bubbly structure of foam. The stability and persistence of foam depend on various factors, including the properties of the liquid, the presence of surfactants or foaming agents, and the intensity of agitation or gas evolution.

The Problem of Foam in Process Applications

Within foam, there is a natural liquid flow along the delicate films encapsulating the bubbles. Draining from top to bottom, this flow creates a density gradient across the foam layer because bubble walls become thinner at the top. Eventually, bubbles at the top of the foam layer collapse due to this drainage, prompting a perpetual equilibrium between material collapse and replenishment from the liquid surface beneath, establishing a maximum height for the foam layer.

However, with the introduction of foam-stabilizing agents such as proteins, this natural drainage along the bubble walls is impeded, resulting in significantly enhanced foam stability. Consequently, the generation rate of foam can surpass its dispersal rate, leading to significant and often problematic foam accumulation. Proteins, being elongated molecules, adhere to the liquid films between bubbles, obstructing or even halting liquid drainage and enabling continuous growth of the foam layer.

While foam may seem an innocuous side effect in many industrial applications, in excess it can be damaging to equipment and costly to clean up, particularly when there is an environmental impact. For example, in anaerobic digestion, unchecked foam can obstruct pressure valves, causing over-pressurization, digester damage, and leakage. In fermentation vessels it can infiltrate overhead pipework and tubing, blinding gas exit filters that can result in reduced batch yield, even total loss.

Excess foam generation can be caused by external factors such as system design and pump leaks. In complex processes like digestion, additional variables such as temperature fluctuations, feedstock variations, and pH levels can further influence foam generation rates.

It is evident that uncontrolled foam poses significant challenges in many process systems. Addressing these challenges necessitates the prioritization of vigilant monitoring within industry and there is a trend to install foam level monitoring equipment wherever "foam out" events are likely to impact process operations or invite scrutiny from environmental stewards. However, for the successful implementation of automated foam detection and control systems, understanding the complexities of measuring foam and the limitations of current technologies is crucial.

One major obstacle lies in the composition of foam, which typically comprises only 1% liquid and 99% gas. Conventional liquid level detection instruments are designed for 100% liquid and therefore cannot accurately discern the ~1% liquid component within foam. Furthermore, process generated foam will often leave a [thick] coating on any surface it is in contact with. This coating can be the source of false positives for foam level with many liquid level instruments, triggering actions such as defoamer chemical addition when they are not needed – a wasteful and expensive activity. It is therefore vital to understand the limitations of the available level technologies before deployment in foam detection applications to ensure a successful outcome.

Foam Overflow
No one wants their day ruined by foam

Radar

How It works

RD Series Radar
Highly accurate for continuous liquid and solids level measurement

Radar is used for continuous level measurement. Modern devices use high-frequency microwave signals (24-26 or 80 GHz) that are unaffected by dust, pressure, temperature, viscosity, or vacuum. The measured level is proportional to the difference in frequency between the transmitted and received microwaves. This technology is suitable for measurement ranges up to 100 m and provides high levels of accuracy for certain applications. The effectiveness of radar technology is dependent on the dielectric constant of the material being monitored. Radar usually works better on products with a dielectric constant of greater than 2.0. In some applications it can measure down to 1.1, but this requires advanced software and very stable conditions.

Why it cannot reliably detect foam

Radar technology relies on having enough energy returned form the process surface to produce a measurement. The lower the dielectric, the less energy is returned. Because foam is 99% gas, its dielectric is far too low to produce a return “echo” that these devices will reliably detect – in fact a radar will usually ignore any foam layer and measure the liquid level beneath it. Radar can produce reasonable results on thicker, dirtier foams (typically ones with a “crusty” layer) as they have a higher dielectric, but this cannot always be relied upon.

Capacitance

ME10 Capacitance
Widely used, very low costtechnology for many level applications

How it works

Much like radar, capacitance is reliant on the dielectric of the product for its measurement. It is a versatile technology and provides simple, accurate and reliable level control for a wide range of applications. Capacitance is suitable for use with a great many liquids, pastes, and slurries – even solids, granules, powders, and pellets.

Why it cannot reliably detect foam

Sadly, capacitance also has the same problem as radar with low dielectric products and will need to be adjusted to use its highest sensitivity setting to have any chance to detect foam. Even adjusted for high sensitivity, it will still likely still miss light foam plus there will be a tendency for false positives caused by build-up on the probe, high humidity (in enclosed vessels), condensation, and proximity to the liquid level below. Capacitance probes are often specified for foam level detection because of their low cost but very often do not perform well. Where they are satisfactory, they often require a significant amount of maintenance in the form of cleaning

Ultrasonic

Microflex D Ultrasonic
Low cost, non-contact liquid level measurement

How It works

Ultrasonic technology provides a highly cost-effective, easy-to-install, non-contact solution for a wide range of level measurement applications. A transducer emits high frequency soundwaves (up to 50 kHz) and measures time-of-flight to and from the material surface to calculate distance, and therefore level, of liquids and solids. They are very popular in storage tanks and waste pits, and can also be found installed for open water applications such as river or reservoir level.

Why it cannot reliably detect foam

Ultrasonic devices struggle with foam as the emitted sound-waves are absorbed when they hit the foam. The signal is lost and nothing returned to the sensor.

Vibrating tuning fork

TF Series Vibrating Fork
An ideal point level solution for both solids and liquids.

How it works

Vibrating tuning fork sensors are used throughout industry as single point level detection devices. The characteristic forks are vibrated at their natural resonant frequency and work by sensing changes in that frequency when they come into contact with a liquid or solid. The liquid or solid must have sufficient mass and/or viscosity to affect the operating frequency of the tuning forks

Why it cannot reliably detect foam

Foam is usually light and has very low viscosity therefore a vibrating tuning fork sensor cannot reliably sense foam. Furthermore, because of the delicate nature of the liquid films in a foam layer, the vibrating probe can excavate a void within the foam by bursting the bubbles surrounding it, resulting in a false negative or failed indication. In dense foams, a vibrating tuning fork sensor can provide some detection of foam level but will often be quickly rendered ineffective due to coating and build up between the forks.

A Reliable Solution to Foam Measurement

SureSense Foam
SureSense is the only instrument designed specifically to detect foam level

Foam, despite its ubiquity in various industrial processes, presents a formidable challenge for reliable detection and measurement due to its composition and dynamic nature. Comprising a mere 1% liquid content with variable density and liquid distribution throughout its height, traditional liquid level measurement devices prove inadequate for assessing foam levels reliably. To overcome this challenge, a specialized solution tailored for foam detection is necessary.

Two primary obstacles impede the reliable detection of foam:

1. **Low dielectric nature:** With its composition predominantly consisting of 99% air or gas, foam exhibits an extremely low dielectric, complicating conventional measurement approaches.
2. **Sensor coating:** Foam tends to coat sensors and probes, impairing their functionality and rendering them ineffective for reliable measurement.

To address these challenges, Hycontrol developed their SureSense and SmartFoam products. Instead of repurposing sensors designed for liquid level detection, Hycontrol created a purpose-built probe equipped with a sensing electrode designed to pass a minimal electrical current through foam. This current travels back to an attached electronic unit through a ground connection to the liquid beneath the foam, facilitating precise foam detection in all scenarios.

Crucially, to mitigate the risk of sensor coating causing false readings, a second electrode, known as the guard electrode, was introduced. Positioned above the sensing electrode, the guard electrode creates an isolation layer between the two. This configuration ensures that the sensing electrode exclusively measures foam occurrences below it, while the guard electrode detects any fouling effects occurring above it. Through meticulous electronic balancing of the guard and sensing measurements, this highly sensitive probe can effectively withstand substantial fouling while remaining fully operational, enhancing its reliability and accuracy in foam detection applications.

In conclusion, the development of a purpose-built solution by Hycontrol offers a reliable method for foam level detection and measurement, overcoming the limitations of traditional liquid level detection devices. By addressing the unique challenges posed by foam, such a solution paves the way for improved process control and optimization across a myriad of industrial sectors.

Conclusion

Ultimately, the development of a purpose-built solution by Hycontrol offers a reliable method for foam level detection and measurement, overcoming the limitations of traditional liquid level detection devices. By addressing the unique challenges posed by foam, such a solution paves the way for improved process control and optimization across a myriad of industrial sectors.

Learn More

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