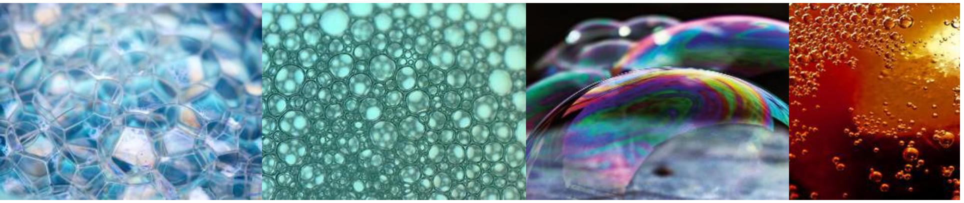

FOAMSCAN™
Foam & Bubbles Analyzer

Teclis Scientific

RIFERIMENTO PER L'ITALIA

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In many industries, using liquid foams provide advantages: foams are lightweight and easy to handle; foams allow to use less raw material for a fixed volume of the final product; foams have interesting expansion properties...

For many researchers, measuring and analyzing foam is a challenge. Handmade custom solutions are commonly used in many labs.

Being able to generate a controlled liquid foam (geometrical structure, liquid fraction) and understanding the phenomena responsible of its destabilization is hence crucial to optimize products formulation and industrial processes.

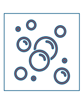
FOAMSCAN™ is the solution to get science-based foam analysis and scientifically optimize foam-forming or foam-prevention products and process.

FOAMSCAN™ Foam Analyzer

By sparging a gas through a Porous glass filter

By Mechanical stirring

Externally produced foam



FOAMSCAN™ has a smart modular and evolutive design that allows to study foam properties. By providing accurately controlled foaming whether by means of gas sparging or by stirring, FOAMSCAN™ enables reproducible, precise and process-related measurements, as well as foams produced externally study.

Measuring Foam volume is a must but certainly not sufficient to get a full understanding of a foam properties. As a matter of fact, scientists demonstrated that foam liquid fraction and bubbles size and distribution are two key parameters to understand life and death of liquid foams.

FOAMSCAN™ offers a smart combination of image analysis and conductivity measurements to provide with a set of results. Only one experiment delivers reliable data about Foaming capacity, Foamability, Foam density, Foam stability, Drainage or effectiveness of anti-foams.

Liquid foams encompass multiple functions that are expected in various applications.

	Reducing the use of raw materials	Expansion properties	Insulation properties	Trapping substances of interest	Absorbing or applying pressures	Proving elasticity to a fluid	Providing a foam structure to a solid
Cleaning	•					•	
Surface treatment	•		•			•	
Construction materials							•
Fight against pollution	•	•	•	•		•	
Firefighting		•	•				
Natural resource extraction				•	•	•	
Cosmetics	•					•	
Food	•					•	•

Therefore, Liquid Foams are common in:

- Food: beers, chocolate mousse, ice cream, meringue…
- Cosmetics and detergency: soap, shaving foam, toothpaste…
- Civil engineering to enhance the insulation properties (thermal and acoustic) of construction materials, cement…
- Industry: froth flotation
- Anti-foam and defoamer effectiveness [1]
- Oil & Gas: foam flooding [2]

FOAMSCAN™ A smart modular and evolutive design

FOAMSCAN™ has **a smart modular design** and can characterize in real time:

- foam generated by injecting a gas into a liquid through a porous glass frit ①. The mass-flow meter ② controls precisely the gas flow-rate.
- foam generated by stirring a liquid ③ with a controlled speed rate,
- foam produced externally ④.

Measurement parameters are **100 % Software-controlled** ⑤ ensuring experiment reproducibility.

Once the measurement starts, the foam rises inside the cylindrical glass measuring tube ⑥. The foam volume is calculated in real time by image analysis ⑦. The liquid volume and Foam Liquid fraction are calculated in real time by conductance. Foam structure images are captured by the 2nd video camera ⑧ to analyze bubbles size and distribution.

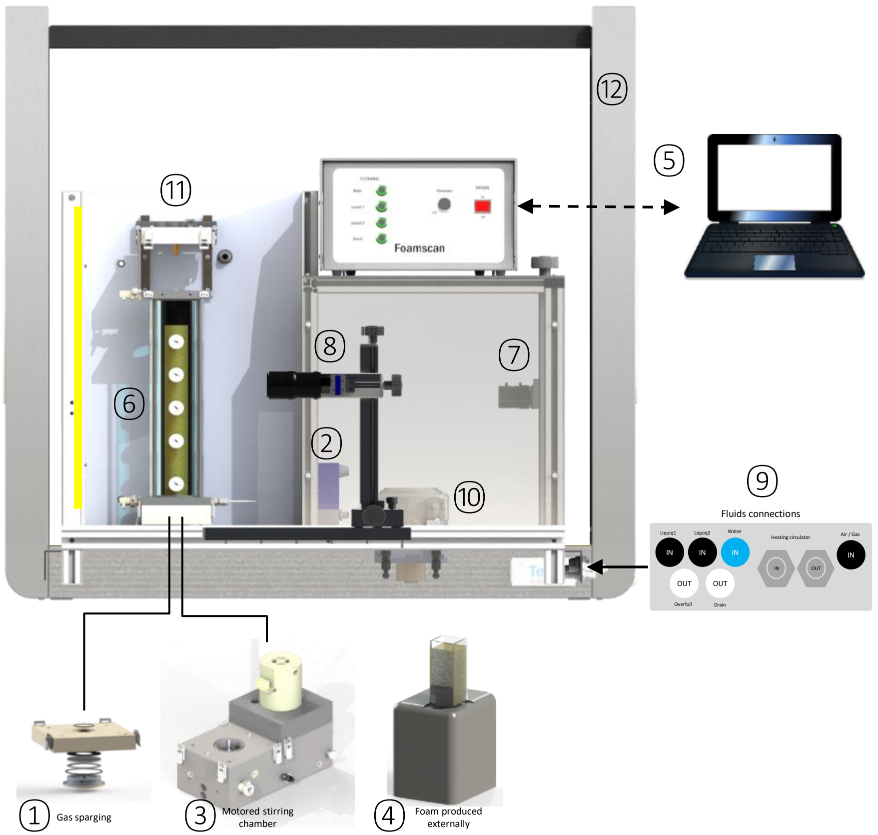
A lot of time is saved thanks to the **Automatic cleaning system**. A cleaning sequence can be programmed before or after the measurements avoiding to remove the tube to clean it.

The automatic cleaning system has connections ⑨ for two liquids other than water. A built-in waste pump ⑩ drains sample from the foam column after completion of a measurement. A second pump is used to provide water and/or cleaning liquids at the top of the foam column ⑪ to clean it between measurements.

Pt100 sensor measures the temperature inside the liquid sample. If a thermostatic bath is connected to FOAMSCAN™ , it should be fitted with the quick disconnect couplings supplied with FOAMSCAN™ accessories and connected to the side of the instrument.

FOAMSCAN™ is provided in a protective box ⑫ that protects from light disturbance and dust.

FOAMSCAN™ Foam Analyzer



1. Foaming by gas sparging	7. Main CCD video camera
2. Mass Flow Controller	8. 2nd CCD Video camera
3. Foaming by mechanical stirring	9. Fluids connections
4. Externally produced foam	10. Pumps
5. Electronic command & software	11. Automatic cleaning system
6. Cylindrical Glass measuring tube	12. Cover

FOAMSCAN™ Foam generated by gas sparging

The foam is generated by injecting a gas such as Air, Nitrogen, CO_2 … into the liquid through a Porous glass filter with a controlled flow rate.

FOAMSCAN™ is supplied standard with a Mass Flow Controller delivering 20 to 500 mL/min. However, other flow rate mass flow controllers can be provided on demand. An Atmospheric pressure sensor is integrated to precisely adjust the flow rate depending on real atmospheric pressure.

The mass flow meter is calibrated on air. When another gas is selected in the FOAMSCAN™ software, it is automatically set in control parameters of the mass flow controller, to provide the accurate flow rate.

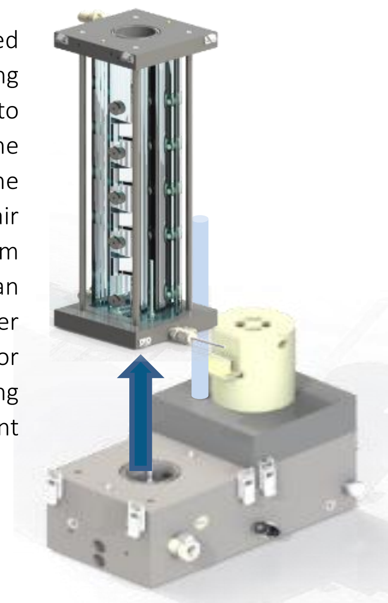
FOAMSCAN™ requires dry, filtered, compressed gas to operate. The Input pressure is 1-2 bar (15-30 PSI) to ensure proper operation of the mass flow controller.

FOAMSCAN™ Foam by mechanical stirring

The foam is generated by stirring the liquid mechanically in a stirring chamber with a controlled speed rate.

When the motor starts, the liquid is stirred by a 3-blade motorized turbine generating the foam. As the foam grows, it is expelled from the foaming chamber and pass through 3 channels towards the glass measuring tube. The stirring speed is 500-6000 rpm, fully software-controlled, maximum speed depends on the viscosity of the liquid.

A pipe is connected to the stirring chamber. Thanks to an electro-valve the pipe fills the chamber with air during foam formation and can switch to water supply for automatic cleaning after measurement is complete.



FOAMSCAN™ Foam produced externally

The Equipment to study foam generated by an external device is provided with a Quartz Cuvette 25 mL or a Borosilicate Glass tube 500mL equipped with a right-angle Prism and holding base to be fixed on the FOAMSCAN™ unit for an easy fitting and perfect alignment with the video camera.

Measurements can be made at room temperature only. Other tubes sizes on demand.

FOAMSCAN™ standard double-walled Cylindrical glass measuring tube equipped with electrodes and prisms is the must to measure foaming properties.

Image analysis

The foam height is measures by image analysis from the main video camera. The 4 prisms ❸ allow the 2^{nd} video camera to capture bubbles images for **foam structure statistical analysis**.

The foam height detection is based on full image analysis. The region of interest that is considered for the calculation can be adjusted. This two features allow to make an average on grey-level pixels for the height detection, leading to a more accurate measurement.

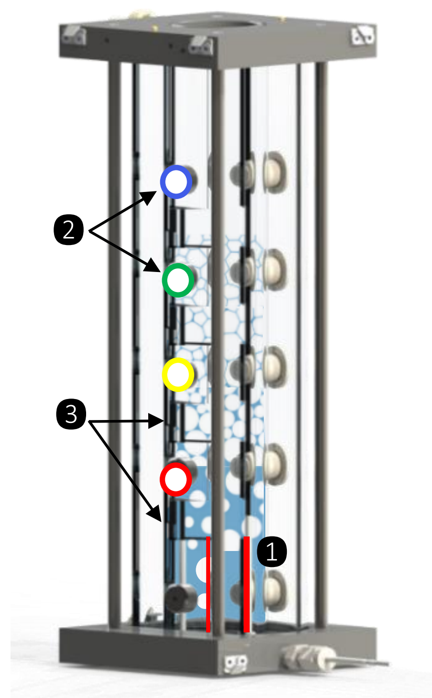
The light source ensures a very good contrast even with non-transparent solutions or with nanomaterials. Foam volume is calculated in real time and considers the liquid volume adjustments measured by conductance.

Conductance measurements

The pair of **straight electrodes** ❶ **measures the volume of liquid** and the liquid trapped in the foam by AC conductivity (µs).

For foams generated by gas sparging the straight electrodes are located at the bottom of the measuring tube. For foams by stirring the two vertical electrodes are in the stirring chamber.

The 5 pairs of round electrodes ❸ are located over the entire length of the tube. They measure the Foam conductance by AC conductivity (µs). The lowest electrode is covered by the liquid and is the reference to calculate the **Foam Liquid fraction** (%) at 4 different heights of the column.



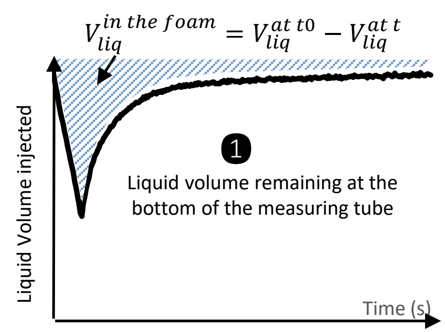
Made of borosilicate glass, the internal Volume is 285mL (H300mm x Ø35mm).

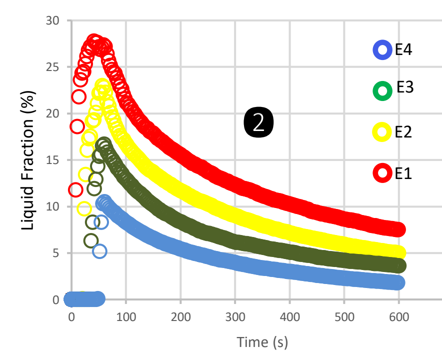
The standard tube is equipped with:

- ❶ straight electrodes
- ❷ 5 Pairs of round electrodes
- ❸ 4 prisms

The double-walled allows to control the temperature up to 90°C from an external circulating bath during measurement.

The Cylindrical glass measuring tubes can be chosen in other configurations and be made of Quartz on demand.





FOAMSCAN™ Fully Software-controlled parameters and measurements

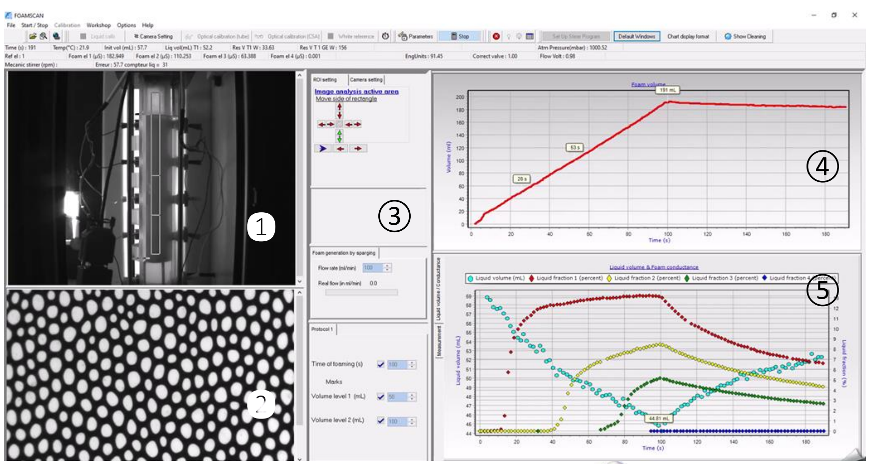
Measurement parameters: foaming protocol, time, gas flow rate or stirring speed, are fully Software-controlled.

Two different foaming protocol can be selected:

1. Foam is generated for a chosen time. This protocol is suitable for studying stable foaming solutions with high gas capture rates. This protocol is the best for comparing foams that have similar lifetimes
2. Foam is generated until a targeted volume of foam is achieved. This protocol is particularly suitable for low-foaming foams and obviously to measure antifoams effectiveness.

During measurement, FOAMSCAN™ software displays:

- Live images of the foam column ① from the main video camera and Live images of the foam structure ② from the 2nd video camera,
- Summary of the protocol settings ③,
- Real time calculation of the foam volume ④ and real time liquid volume/fraction ⑤.



FOAMSCAN™ software offers a **smart combination of image analysis and conductivity measurements to provide with an accurate set of results** to characterize foaming properties and effectiveness of antifoams.

Properties / Measurement results	Foaming			Stability and aging				
	Foamability	Foam wetness	Foam texture	Foam Decay	Drainage	Ostwald ripening	Coalescence	Antifoam effectiveness
Foam volume (mL)	•			•				•
Liquid Volume (mL)	•	•		•	•			•
Liquid Fraction (%)		•		•	•			
Foam capacity	•							
Volume of gas injected	•							
Foam expansion	•							
Foam density	•	•		•	•			
Bikerman Index (sec.)	•							
Foam volume half-life time (mL)				•				•
Number of bubbles (nb)			•	•		•	•	
Size of bubbles (mm)			•			•		
Polydispersity			•			•	•	

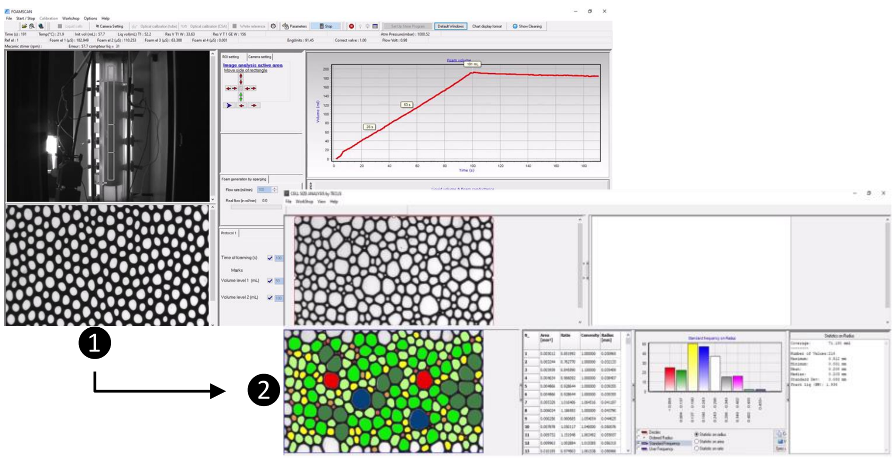
The live-video of the foam is displayed in real time allowing to see the real behavior of the foam .

FOAMSCAN™ software offers a comparison function to open and easily compare experiments results without needing to export and analyze the data. Saving parameters including measurement configuration, images and results can be adjusted. All results can be exported to Excel files.

Foam structure analysis module is composed of:

- A second video camera to capture the images of the foam structure
- A CSA software to calculate the bubbles statistical analysis.

The video camera can be focused on one of the 4 prisms located at 4 different heights of the foam column. During the measurement, the images of the foam are captured ❶. Bubbles size and distribution are analyzed in a 2nd step using the CSA software ❷.



CSA software is a powerful image processing tool tailored to identify distribution of object size. CSA software performs image segmentation, detects the bubbles automatically and calculates the statistics. It covers most state-of-the-art techniques in digital image processing, from classical algorithms to advanced solutions ready-made for specific tasks.

After image processing, one image per second is analyzed by the CSA software. Data are calculated and displayed:

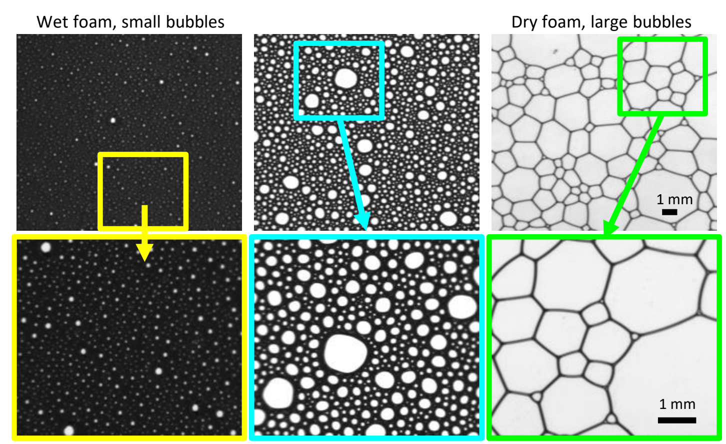
- statistical data (No, area, radius…) for each bubble
- distribution histogram
- statistical summary is displayed for each image calculated

The liquid fraction can also be calculated by CSA software [3]. This functionality allows to calculate foam liquid fraction even for solutions with low or no conductivity.

The field of view can be adjusted to study wet foams with small bubbles as well as dry foams with large bubbles

- Zoom out to increase the statistical number of bubbles.
- Zoom in to observe details such as plateau borders or small bubbles from 50 µm.

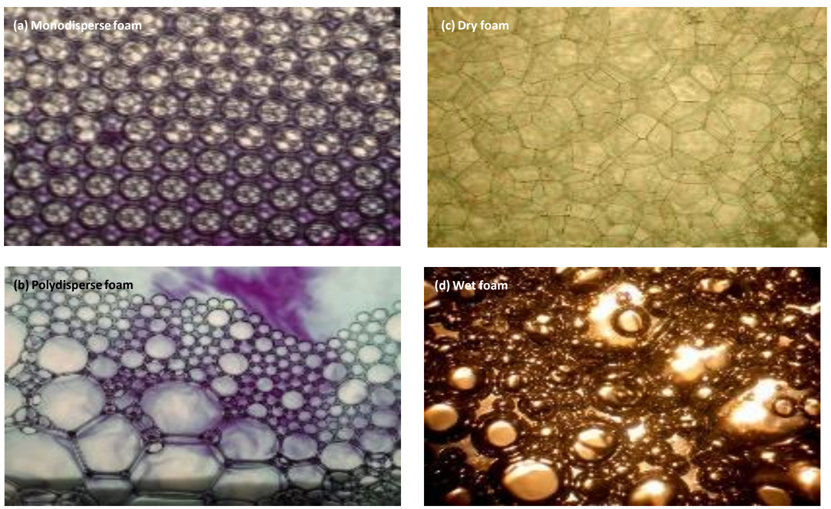
All results can be exported to Excel files.



Pictures at high magnification are recorded a few second after recorded the picture at low magnification

The issue of foamability and foam stability are crucial for many industrial applications, from beer industry to health care products such as shampoos and foam flotation processes for mineral separation. Number of foam tests are used in the industry to characterize foam properties. However, accurate measurement of foam properties represents a challenge.

A liquid foam consists in a suspension of gas bubbles in a liquid continuous phase. Its appearance can vary considerably from one system to another.



Foams with different structures (pictures taken by A. van der Net)

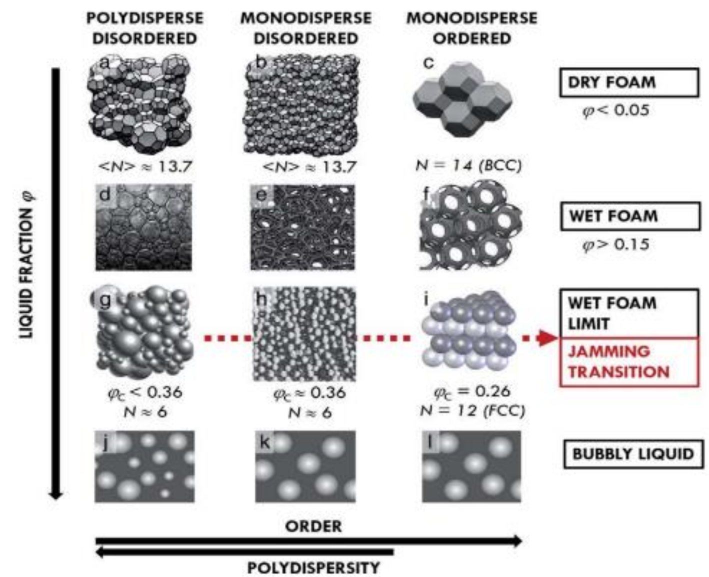
A liquid foam can be:

- Monodisperse: composed of bubbles of the same size
- Polydisperse: Composed of bubbles of different sizes
- Dry: containing a small amount of liquid (angular aspect)
- Wet: with rounded bubbles

It has been demonstrated that the structure of a liquid foam [4] is governed by the following parameters:

- **liquid fraction,**
- **Polydispersity,**
- and **order/disorder.**

If these parameters are known, the structure of a liquid foam and the number of neighbors per bubble can be predicted.



Representation of different foam structures as a function of the following key parameters: liquid fraction ϕ, polydispersity and order/disorder [1]

ABOUT LIQUID FOAMS

Liquid foams are transient systems. After the generation step, their geometrical structure and liquid volume fraction evolve with time. Moreover, different aging mechanisms lead to the destabilization of the foam and ultimately to its destruction.

Different methods can be used to generate a liquid foam [5]

- Gas injection in a liquid through a porous media
- Mechanical stirring
- Liquid recirculation
- Chemical and biological reactions (Polyurethane, yeasts)
- Depressurization (fizzy drinks)

In all these processes, an energy input is required but not sufficient to generate foams. **Surfactants play a key role on the foamability of a solution.**

Life and death of liquid foams

Different aging mechanisms lead to foam destabilization [6]:

- Drainage: After the generation of a liquid foam, the macroscopic motion of bubbles stops, and the liquid starts draining due to gravity which induces variations in the liquid volume fraction [7]
- Ostwald ripening :Since Laplace pressure is proportional to ${}^{1}/_{R}$ with R being the radius of the bubble, the gas contained in the smaller bubbles will migrate to the larger ones where the pressure is smaller, which induces variations in the number and size of bubbles
- Coalescence: The coalescence corresponds to the rupture of a liquid film separating two bubbles. Coalescence can be due to local rearrangements of bubbles, which induces variations in the number of bubbles

Anti-foaming agents and defoamers

A liquid foam can be an industrial byproduct or have a temporary utility which requires to get rid of it at the end of the process. In this context, a few methods have been developed to avoid the generation of a foam (anti-foaming agent) or to destruct an already existing foam (defoamer).

References

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2. Janssen, M. et al., Foam-Assisted Chemical Flooding for Enhanced Oil Recovery: Effects of Slug Salinity and Drive Foam Strength, Energy Fuels, **2019**, 33, 4951
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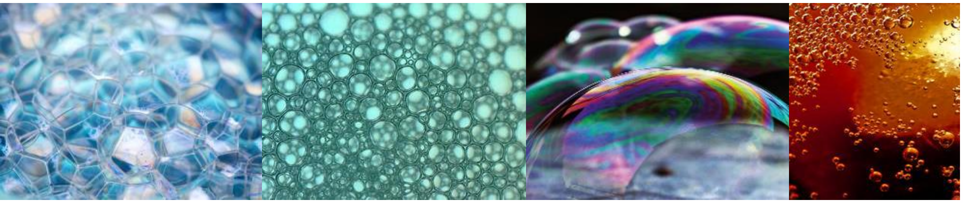

FOAMSCAN™
Specifications

Teclis Scientific

FOAMSCAN™ specifications

Technical specifications

Operating system		
Gas flow rate	20-500 mL/min (other flow-rate range from 100 to 5000 mL/min on demand)	
Approved gases	Air, Nitrogen, Oxygen, Carbon dioxide, Argon, Butane, Freon, Helium, Methane, Propane	
Max Pressure in	1-2 bar	
Stirring speed	500 rpm to 6000 rpm	
Atmospheric pressure sensor	800 mbar to 1100 mbar	
Optical system	**Main**	**CSA**
CCD camera	CCD video camera	CCD video camera
Connection	USB2	USB2
Performance	76 fps at 744x480 px	76 fps at 744x480 px
Lens	2.9/8.2 mm focal length	Partially Telecentric 55 mm focal length
Field of View		Min = 91 mm² / Px size = 14.5 µm Max = 25 mm² / Px size = 7.6 µm
Size of detectable bubble	35 µm to 2000 µm	
Focus	Manual	
Light source	LED 135 lm to 180 lm	
Temperature measurement		
Material	PT100	
Range	4 to 90 °C	
Accuracy	0.1 °C	
Location	Inside liquid sample	
Pressure measurement	Atmospheric	
Measuring tube		
Material	Optical borosilicate glass BK7 , peek, Inox, anodized aluminium	
Size	H 300 mm x Ø 35 mm	
Intrenal Volume	285 mL	
Temperature control	Double walled glass tube	
range	10 to 90 °C , +/-	
Chemical compatibility	Use of organic solvents such as acetone, MEK, THF, or xylene may damage the tube	
Electrodes		
Material	Stainless steel 316	
Measurement	Conductance in µs	
Range	1µs to 100 000µs	
Position (on tube height)	E0=15mm, E1=80mm, E2=130mm, E3=180mm, E4=230mm	
Right Angle Prisms		
Material	Uncoated, N-BK7 Right Angle Prism	
Size	20 x 20 mm, Length of Hypotenuse 28.3 mm	
Position (on tube height)	P1 = 55 mm, P2 = 105 mm, P3 = 155 mm, P4 = 205 mm	
Automatic cleaning		
peristaltic pumps	Flow rate 1.6 to 2 L/mn	
solvents	3 cleaning solution inlets	
Hardware	Window 10 pro / Processor Intel I5 / RAM 8 Giga / Hard Drive 1 T SSD	

Measurement specifications

Sample Volume			
Foam by gas sparging	30 mL to 60 mL		
Foam by stirring	120 mL to 150 mL		
External Foam	25 mL to 500 mL		
FOAMSCAN Software			
Data measured	Foam height by image analysis		
	Liquid volume by conductance		
	Liquid fraction by conductance		
	Temperature		
	Gas Flow rate		
	Stirring speed		
Results calculated	**Foamability**	**Stability and aging**	
	Foam volume (mL)	Foam volume (mL)	
	Liquid Volume (mL)	Liquid Volume (mL)	
	Liquid Fraction (%)	Liquid Fraction (%)	
	Foam density	Foam density	
	Foam capacity	Foam volume half-life time (mL)	
	Volume of gas injected	Liquid volume half-life time (mL)	
	Foam expansion		
	Bikerman Index (sec.)		
CSA software results		Bubbles count	
		Bubble Mean radius (mm)	
		Bubble area (mm2)	
		Bubble size distribution	
		Liquid Fraction (%)	
Glass Frits			
Size	Ø40mm - Thickness 3.5mm		
Porosity	porosity0- Pore size 180-250µm	porosity 2 - Pore size 40-100µm	porosity 4 - Pore size 10-16µm
	porosity1 - Pore size 100-160µm	porosity 3 - Pore size 16-40µm	
O-rings	**NBR**	**FKM**	**FFKM**
Temperature max	80 °C	220 °C	250 °C
Supercritical conditions	Yes	No	Yes
Chemical compatibility	No organic solvents. Good compatibility with acid and base		Full

General specifications

Instrument dimensions	
Size (L/W/H) with cover	85/57/78 cm
Weight	40 kg
Power supply	
Voltage	95 V to 240 V
Frequency	50 Hz to 60 Hz
Intensity	5 A
Environnement	
Operating temperature	15 °C to 30 °C