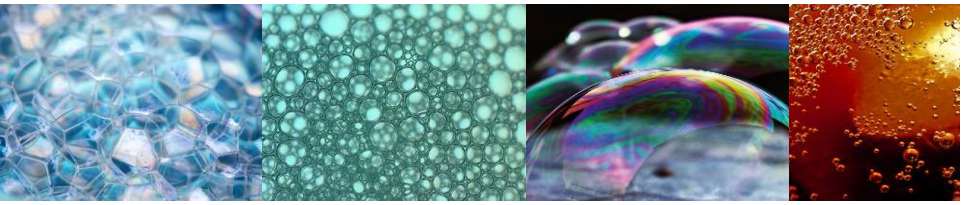


FOAMSCAN™
Foam Analyzer & Defoamer Tester

Teclis Scientific

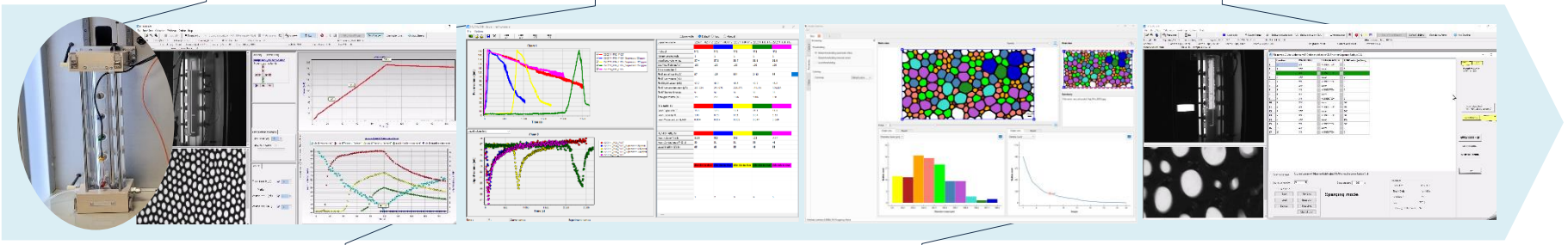
FOAMSCAN™ Key features and benefits

Cylindrical glass measuring tube equipped with electrodes and prisms to measure:
- Liquid volume by conductance
- Foam volume by image analysis
- Foam structure by image analysis

Sample Temperature **up to 90°C**

Versatile design
combination of 3 foaming modes in one measurement Unit
- by gas sparging
- By mechanical stirring
- Foam made by an external device

Automatic cleaning:
- avoid to remove the tube and clean it manually.
- 3 solvents inlets
- cleaning program can be fine-tuned depending on the surfactant



100% software-controlled measurement
Largest analysis area for foam detection (60 x 740 px) with sensitivity adjustment
Real-time calculation and display
Easy Comparison of the results
One click Images and data export to Excel

Foam structure analysis with Bubble Statistics Software:
- Automatic images features download
- Automatic thresholding
- Bubbles statistics calculated over time
- Liquid fraction calculated by image analysis
- One click Images and data export to Excel

FOAMSCAN™ The Solution for scientific foam analysis

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 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.

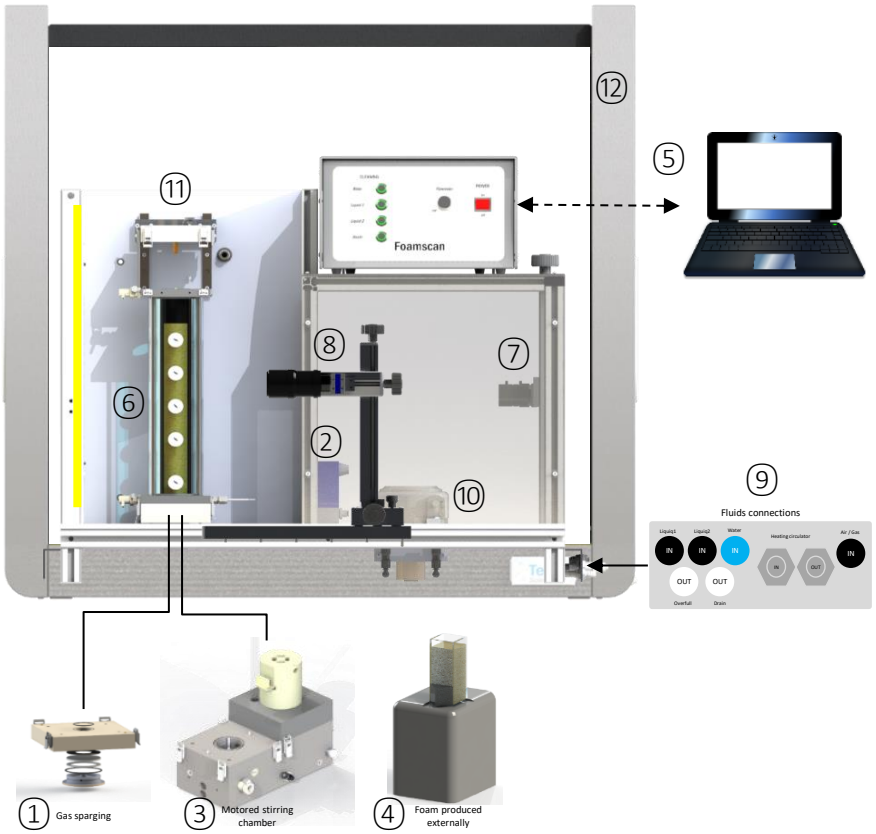
A lot of time is saved thanks to the **Automatic cleaning system**. A cleaning sequence can be programmed before or after the measurements avoiding to remove the tube to clean it.

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™ One tool, three foaming options

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.

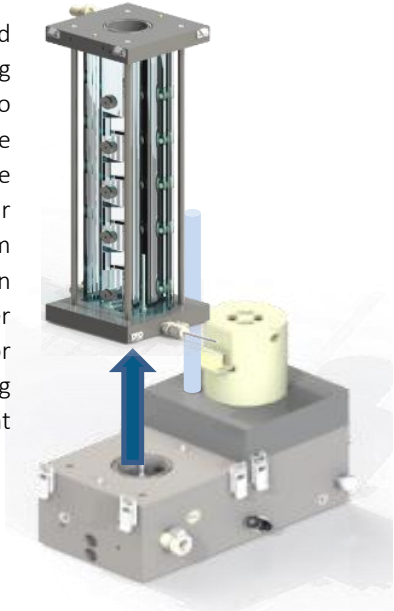
FOAMSCAN™ requires dry, filtered, compressed gas to operate. The Input pressure is 1-2 bar (15-30 PSI) to ensure proper operation of the mass flow controller.

Foam generated 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.



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™ One measuring tube combining image analysis and conductivity measurement

The 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 measured by image analysis from the main video camera. The 4 prisms ❸ are located over the entire length of the tube. They allow the 2nd 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.

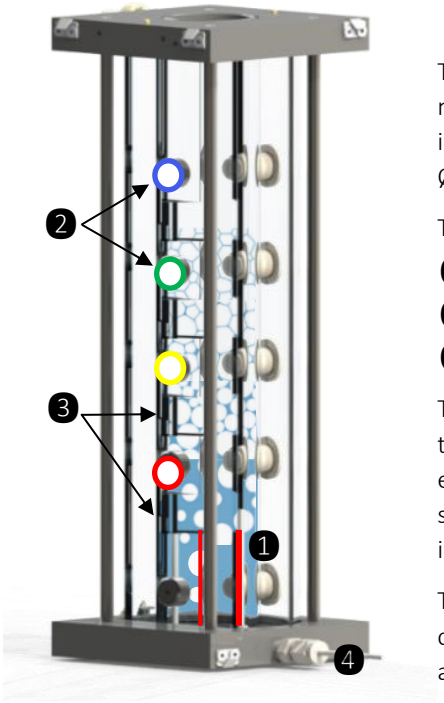
The light source ensures a very good contrast even with non-transparent solutions or with nanomaterials. Foam volume is calculated in real time and considers the liquid volume adjustments measured by conductance.

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 ❷ 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.



The standard glass measuring tube is made of borosilicate glass. The internal Volume is 285mL (H300mm x Ø35mm).

The standard tube is equipped with:

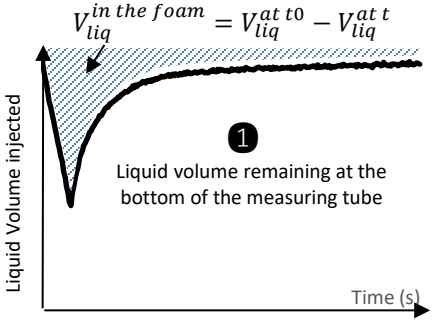
❶ A pair of straight electrodes

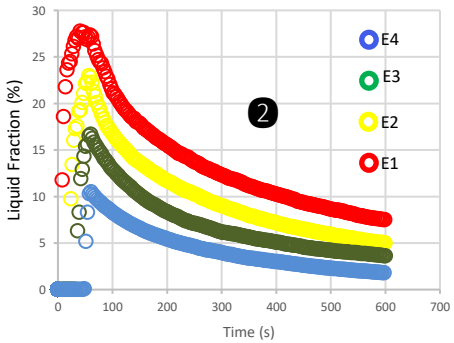
❷ 5 Pairs of round electrodes

❸ 4 borosilicate glass prisms

The double-walled allows to control the temperature up to 90°C from an external heating circulator. The Pt100 sensor ❹ measures the temperature inside the liquid sample.

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

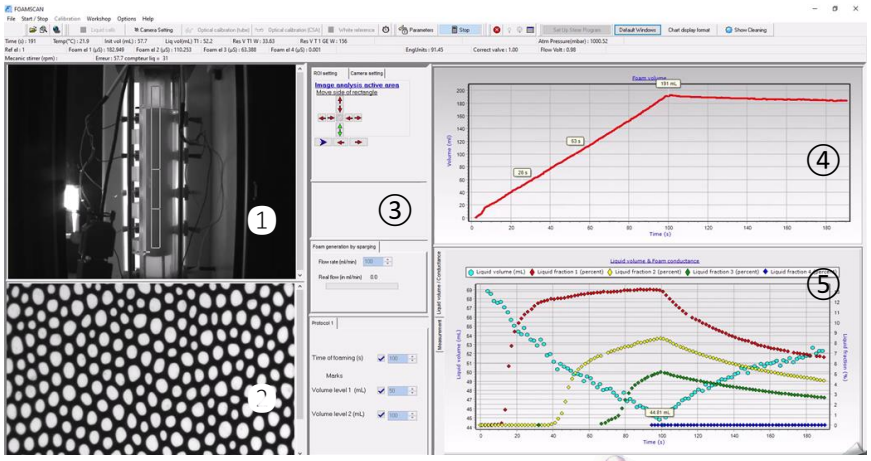
Measurement parameters: foaming protocol, time, gas flow rate or stirring speed, are fully Software-controlled.

Two 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 reached. This protocol is particularly suitable for low-foaming foams and obviously to measure antifoams effectiveness.

During measurement, the 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 calculation of the liquid volume and liquid 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 (sec)				●				●
Number of bubbles (nb)			●	●		●	●	
Size of bubbles (mm)			●			●		
Polydispersity			●			●	●	

The foam detection is calculated inside a large area of analysis (60 x 740 Px), and detection sensitivity can be increased from 75% to 98% to improve Foam detection accuracy. The live-video of the foam is displayed in real time allowing to see the real behavior of the foam .

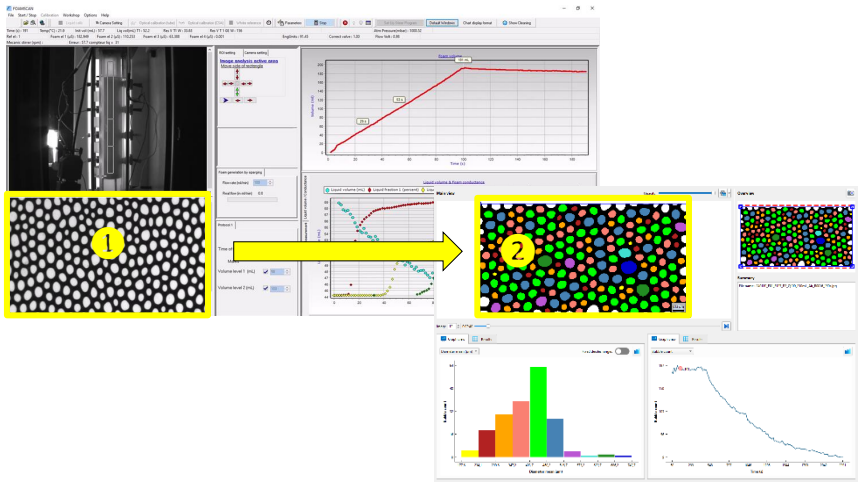
FOAMSCAN™ software offers a comparison function to open and easily compare experiments results without needing to export and analyze the data. Saving parameters including measurement configuration, images and results can be adjusted. All results can be exported to Excel files.

FOAMSCAN™ Foam structure analysis with BubbleStatistics™ software

FOAMSCAN™ module for Foam structure analysis is composed of:

- A 2nd video camera added to capture the images of the foam structure.
- BubbleStatistics™ software to analyze the images of the foam structure.

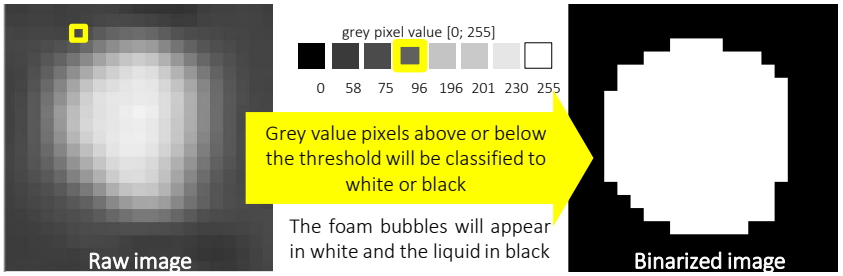
During the measurement, the images of the foam are captured ❶ by the 2d video camera focused on one of the 4 prisms located at 4 different heights of the foam column. The field of view can be adjusted to study wet foams with small bubbles (from 35µm) as well as dry foams with large bubbles.



The foam structure is analyzed post-measurement using the BubbleStatistics™ software ❷.

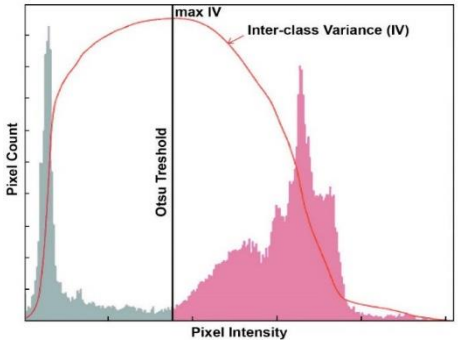
1. CAPTURE → browse and download the images of the Foam structure captured by the FOAMSCAN™
2. BINARIZE → Automatic image processing effectively binarizes the images
3. ANALYZE → Statistics on bubble size and distribution are automatically calculated and displayed in graph view or table.

Thresholding is the simplest method of segmenting images from a grayscale image to a binary image (Black and white), using a grey pixel value as a threshold. Binarization is critical in the accuracy and effectiveness of image analysis.



Global Thresholding applies a single threshold value to an entire image. **Local thresholding** considers small regions within the image to better adapt varying lighting conditions and complex intensity distributions.

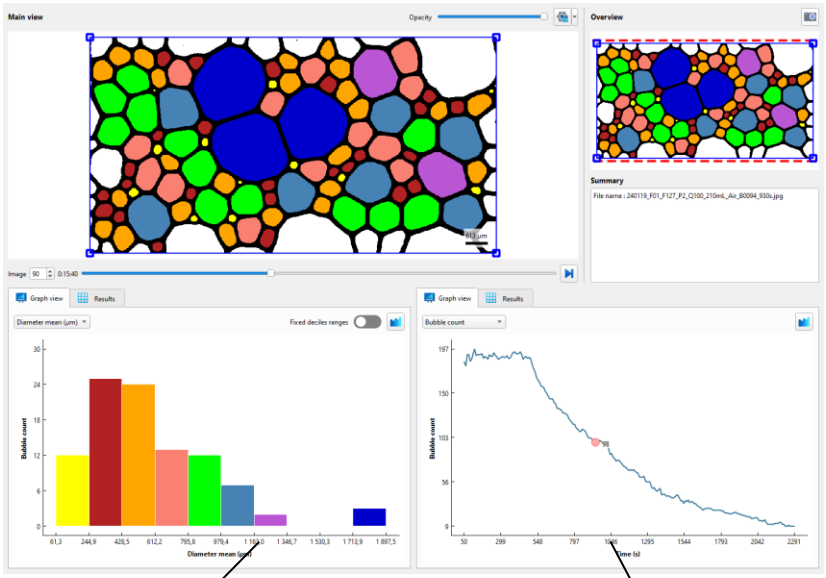
BubbleStatistics™ software applies automatically a **global thresholding based on Otsu method** which is effective to binarize almost all foam structure images captured with FOAMSCAN™. However, local thresholding can be used for complex foam images.



Otsu method:
The algorithm returns a single intensity threshold determined by minimizing intra-class intensity variance.

FOAMSCAN™ Foam structure analysis with BubbleStatistics™ software

As soon as images are downloaded, BubbleStatistics™ software calculates automatically and displays the data in graph view or table.

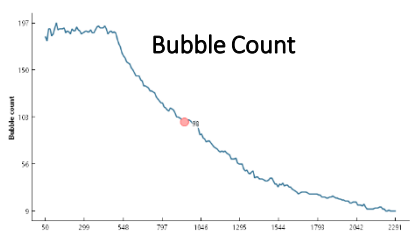


Statistics calculated for each bubble: diameter (min, max, mean), mean Radius, Perimeter, Area, Elliptical ratio, Eccentricity, Circularity

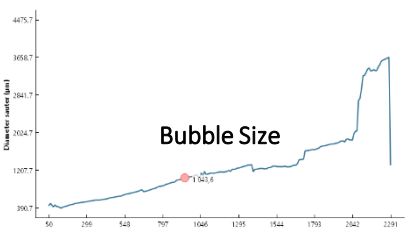
Statistics calculated over time: Bubble count, Density, Sauter Diameter, Bubble area, liquid area, Polydispersity index, Liquid fraction

Analysis can be fine-tuned applying classification and analysis filters. Local foam liquid fraction is calculated by image analysis which is helpful for solutions with low or no conductance.

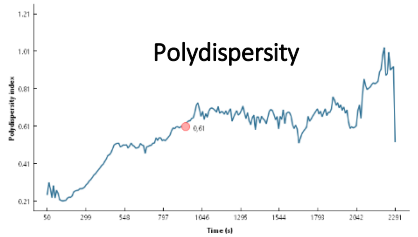
Stability properties can be analyzed over time:



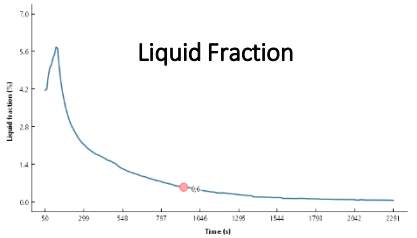
A significant increase or decrease in the **number of bubbles** indicates instability, while a stable number of bubbles suggests a more stable foam.



Regular decrease in bubble size indicates good foam stability, whereas **increase in bubble size indicates coalescence**. Constant bubble size suggests long-term stable foam.



An **increase in PDI indicates coalescence**, whereas a **low and stable PDI over time suggests coarsening** which helps to stability.



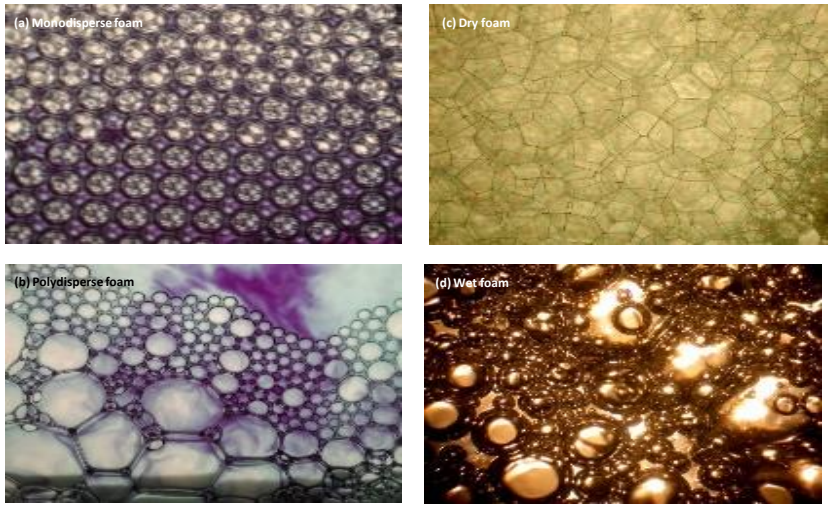
The evolution of the liquid fraction over time indicates the **drainage rate**

All Images and data can be exported in One click.

ABOUT LIQUID FOAMS

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)

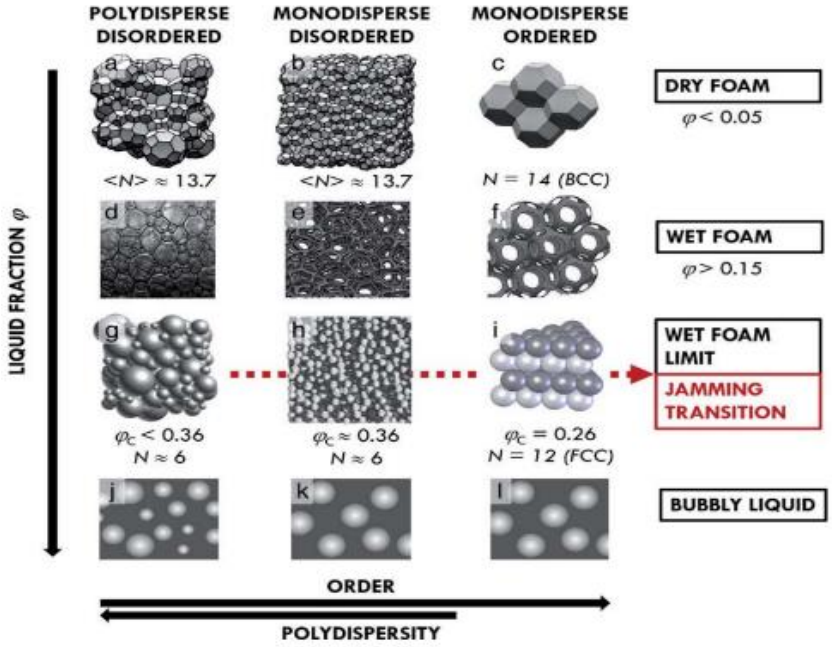
A liquid foam can be:

- 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]

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).

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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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6. Boos, J. et al., On how surfactant depletion during foam generation influences foam properties, Langmuir, 2012, 28, 9303
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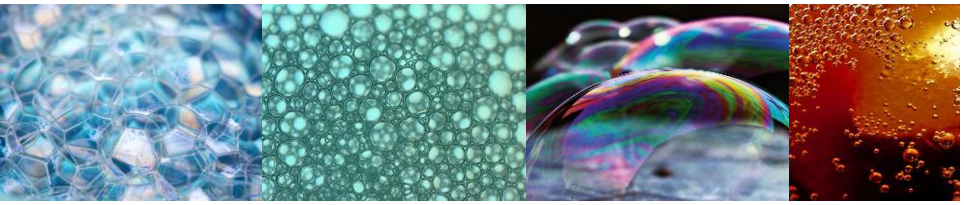


FOAMSCAN™
Foam Analyzer & Defoamer Tester

Teclis Scientific

FOAMSCAN™ specifications

Technical specifications

Foaming system by gas sparging		
Gas flow rate	20-500 mL/min (other flow-rate range from 100 to 5000 mL/min on demand)	
Approved gases	Air, Nitrogen, Oxygen, CO_2, Argon, Butane, Freon, Helium, Methane, Propane	
Max Pressure in	1-2 bar from central compressed gas supply or gas cylinders	
Sparging Base material	Peek	
Atmospheric pressure sensor	800 mbar to 1100 mbar	
O-rings	NBR	
Foaming system by stirring		
Stirring system	3-blade stainless steel motorized turbine	
Stirring speed	500 rpm to 6000 rpm	
Stirring Base material	anodised aluminium	
O-rings	NBR	
Optical system	**FOAMSCAN**	**FSA Module**
Camera	DMK 37AUX273	DMK 37AUX273
Interface	USB3 type C	USB3 type C
Resolution	1440x1080 px	1440x1080 px
Frame rate at full resolution	238 fps	238 fps
Lens	2.9/8.2 mm focal length	Partially Telecentric 55 mm focal length
Focus	Manual	Manual
Light source	LED 135 lm to 180 lm	LED 135 lm to 180 lm
Size of detectable bubble		35 µm to 2000 µm
Foam detection ROI	740x60 Px	25 mm² to 91 mm² (Px size: 7.6 to 14.5 µm)
Temperature		
Material	PT100	
Range	4 to 90 °C	
Accuracy	± 0.1 °C	
Location	Inside liquid sample	
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*	Up to 90°C using Double walled glass tube	
Chemical compatibility	Do not use organic solvents such as methanol, hexane, heptane, toluene, benzene, xylene, acetone, methyl ethyl ketone (MEK), ethyl/butyl acetate, chloroform, trichloroethylene, tetrahydrofuran (THF)	
Electrodes		
Material	Stainless steel 316L	
Conductance Range	0,1µs 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 (equivalent height or volume)	P1 = 55 mm or mL, P2 = 105 , P3 = 155 , P4 = 205	
Automatic cleaning		
pumps	Flow rate 1.6 to 2 L/mn	
cleaning liquid	3 liquid inlets	
Computer		
OS Compatibility	Windows 10-11 PRO	
Specifications required	Intel Core i5 or AMD Ryzen 5 / RAM 8-16 Go / Hard Drive SSD 1T	
USB port	5 at least	
Monitor	24' recommended	
Export Format	.xls / .txt/ .bmp / .jpg	

General specification

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	10 °C to 40 °C
Operating Pressure	Atmospheric

Measurement specifications

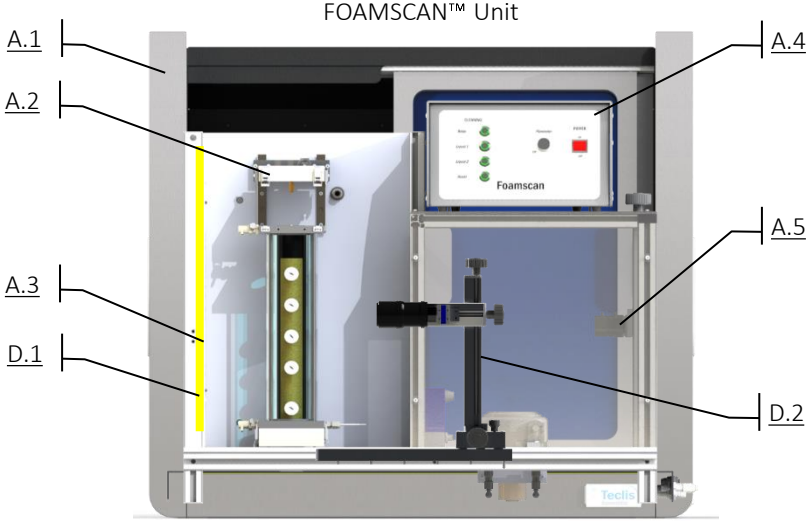
Sample	**by gas sparging**	**by stirring**	**External Foam**
Liquid sample	Aqueous	Aqueous	Aqueous
Maximum Viscosity	1000 mPa.s	1000 mPa.s	
pH range	2 to 11	2 to 11	
Optimum initial volume	30 mL to 60 mL	120 mL to 150 mL	25 mL to 500 mL
Data measured			
Foam height by image analysis	✓	✓	✓
Liquid volume by conductance	✓	✓	×
Liquid fraction by conductance	✓	✓	×
Temperature	✓	✓	×
Gas Flow rate	✓	×	×
Stirring speed	×	✓	×
Data calculated			
Foam volume (mL)	✓	✓	✓
Liquid Volume (mL)	✓	✓	×
Liquid Fraction (%)	✓	✓	×
Foam density	✓	✓	×
Foam capacity	✓	✓	×
Volume of gas injected	✓	✓	×
Bikerman Index (sec.)	✓	✓	×
Foam expansion	✓	✓	×
Foam volume half-life time (sec)	✓	✓	×
Liquid volume half-life time (sec)	✓	✓	×
Bubbles count	✓	✓	✓
Sauter Mean radius (mm)	✓	✓	✓
Bubble Mean area (mm2)	✓	✓	✓
Standard deviation	✓	✓	✓
Bubble size distribution	✓	✓	✓
Liquid Fraction (%)	✓	✓	✓
Glass Frits			
Size	Ø40mm - Thickness 3.5mm		
Porosity	P0- Pore size 180-250µm		
	P1 - Pore size 100-		
	P2 - Pore size 40-100µm		
	P3 - Pore size 16-40µm		
	P4 - Pore size 10-16µm		

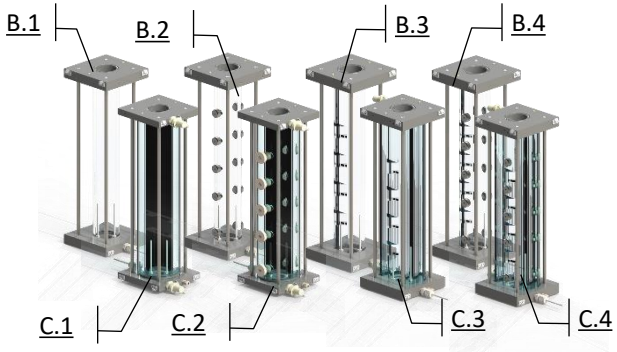
** Heating circulator not supplied and sold in option*

FOAMSCAN™ specifications

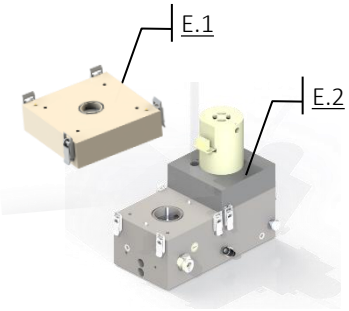
Part	N°	Technical description
FOAMSCAN™ Unit	A.1	Protective Cover with 2 removable doors
	A.2	Automatic cleaning system with 2 integrated peristaltic pumps
	A.3	Light source LED 180 lm / 19x50 cm
	A.4	Electronic Manual Command
	A.5	CCD video camera (USB2, 744x480, 76fps) and 2.9/8.2mm focal length
Measuring tube for Room Temperature only	B.1	Single walled glass tube
	B.2	Single walled glass tube equipped with electrodes
	B.3	Single walled glass tube equipped with prisms*
	B.4	Single walled glass tube equipped with electrodes & prisms*
Measuring tube for temperature control	C.1	Double walled glass tube (to be connected to heating circulator)
	C.2	Double walled glass tube equipped with electrodes
	C.3	Double walled glass tube equipped with prisms*
	C.4	Double walled glass tube equipped with electrodes + prisms*
Foam structure analysis *requires tube equipped with prisms	D.1	FSA Ligt source LED
	D.2	CCD video camera (USB2, 744x480, 76fps) and Partially Telecentric Lens (55mm Focal Length)
Foam generation Equipment	E.1	Removable gas injection base fitted with a housing for the glass frit (Ø40mm - Thickness 3.5mm - porosity 0 to 4)
	E.2	Removable stirring chamber (90-180ml) and 3-blade motorized turbine, stirring rate 500-6000rpm

FOAMSCAN™ Unit





Cylindrical glass Measuring tube



Foam generation Equipment

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