PUSONICS

Advanced Power Ultrasonic Technologies

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OUTLINE

- The Company
- High power ultrasound
- A novel family of power ultrasonic devices
- Applications of the new technology

THE COMPANY

- PUSONICS SL is a “spin-off” of the Spanish Research Council (CSIC)
- Objective: *Development, manufacturing and commercialization of high power ultrasonic systems for industrial processes*.
- Is licensed by CSIC with relevant patents
- Is supported by:
  - CSIC highly specialized staff
  - 3BYMESA

THE FOUNDERS 1/2

CSIC:

- Is the largest multidisciplinary body for Scientific Research of Spain with a total staff of 10,000 people.
- The Power Ultrasonics Group within the CSIC:
  - Has 30 years of experience in the field of power
  - Is a world leader in this field
  - Holds more than 30 patents in high power ultrasonics.
  - Licensed to PUSONICS with relevant patents.
  - The Power Ultrasonics Group collaborates with PUSONICS and own shares of the company.

THE FOUNDERS 2/2

3BYMESA:

- Is a Spanish Industrial Electronics Manufacturer
- Has an ISO9001:2000 Quality Certification
- Main fields of activity:
  - Design and fabrication of magnetic components, coils and transformers.
  - Design of hardware, software and firmware for electronics equipment. development of prototypes.
  - Manufacturing of electronic systems.

PUSONICS STAFF: WHO WE ARE

- **Prof. Gallego-Juárez** is the Principal Scientific Adviser and Promoter of PUSONICS. He has lead the Power Ultrasonics Group (PUG) at the CSIC for over 30 years. He holds over 30 patents in power ultrasound and he is author of over 200 publications related to this field.
- **Dr. Andrea Cardoni** is the R&D and Technical Director of PUSONICS since 2010**.** He was formerly a Lecturer in Mechanical Engineering at the University of Glasgow (UK). His research has been concentrated in the field of power ultrasonics for the past 13 years. His main expertise focuses in the design of ultrasonic devices for industrial and medical applications. He is author of more than 60 publications and a Book Chapter.
- **Mrs Florence Buisson** is PUSONICS General Manager. She received formal education on management of start-up technological companies from the IE Business School and EOI Business School, both at Madrid. She worked at the CSIC for over twenty years administrating research projects.
- The other PUSONICS **technical staff** has been working in the CSIC at the development of a number of novel ultrasonic devices for various years.

OUR EXPERIENCE

At PUSONICS we collaborate with a wide range of companies, both domestically and internationally.

ULTRASOUND

Ultrasound (US) is a branch of acoustics which deals with the generation and use of inaudible acoustic waves.

There are two broad areas of use of US known as low- and high-intensity applications.

In **low-intensity applications** (low power ultrasound), the aim is to convey information about or through a system (high frequency, low power). Example: NDT, medical Imaging.

In **high-intensity applications** (high power ultrasound), the intent is to permanently alter a system. (low frequency, high power). PUSONICS is concerned with the development of high power applications.

HIGH POWER ULTRASONICS (HPU) AND ITS APPLICATIONS

Applications of HPU

Food Industry
- Defoaming
- Drying
- Extraction
- Cutting
- Degassing
- Mixing

Medicine (Surgery)
- Bone cutting
- Soft tissue cutting
- Tumor treatments
- Dentistry

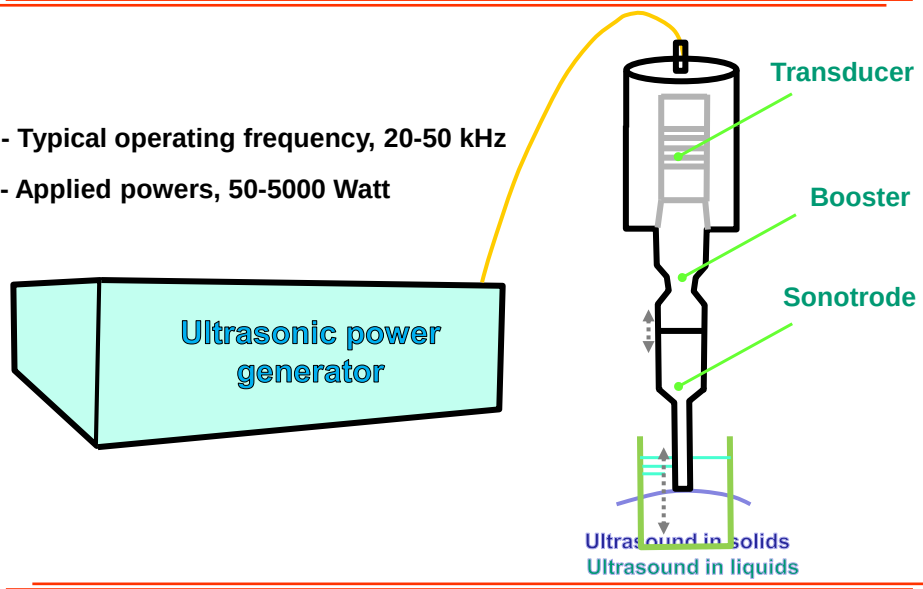
Manufacturing
- Cleaning
- Welding of plastics
- Sealing of packages
- Debubbling of coatings
- Dispertion/size reduction of solids

Environment/ Sonochemistry
- Air-cleaning
- Liquid-solid separation
- Cell distruction
- Biotechnology
- Crystallization

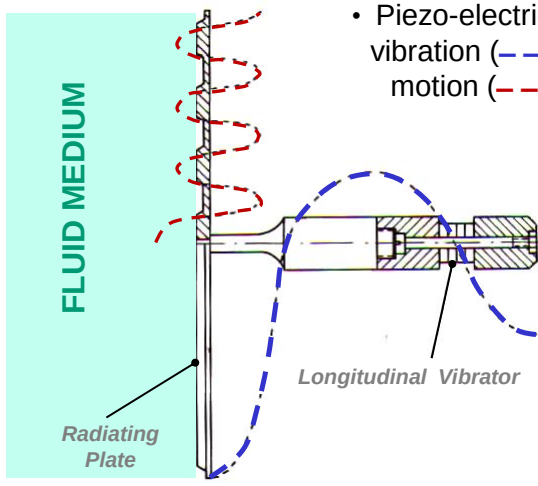
CONVENTIONAL POWER ULTRASONIC SYSTEM

- Typical operating frequency, 20-50 kHz

- Applied powers, 50-5000 Watt



NOVEL ULTRASONIC SYSTEM: THE PLATE-TRANSDUCER



- Piezo-electrically generated longitudinal vibration (– – –) is converted in a flexural motion (– – –) of the radiating plate.

Flexural mode: Nodal circles

A FAMILY OF POWER ULTRASONIC PLATE TRANSDUCERS

Plate-transducers developed to operate in gas, liquid, and multi-phase media

http://www.youtube.com/watch?v=-g-xtdU5E_k

ULTRASONIC DEFOAMING

THE PROBLEM OF FOAM IN INDUSTRY

- Foam is generally an unwanted by-product of many manufacturing processes because it causes difficulties in process control, equipment operation, and production rate.
- There are several conventional methods to control foams, the most efficient is the use of chemical anti-foaming agents but they contaminate the product.
- Other methods involving mechanical, thermal or electrical devices are not as effective.
- **High-intensity ultrasonic waves represent a clean and efficient methodology to break foam bubbles**

ULTRASONIC DEFOAMING SYSTEM (UDS): A PATENTED GREEN SOLUTION

Plate-transducer

Tuned frequency= 25 kHz
Electro-Acoustic efficiency = 75 %

Driving electronics

Electric power applied to the transducer up 1kW

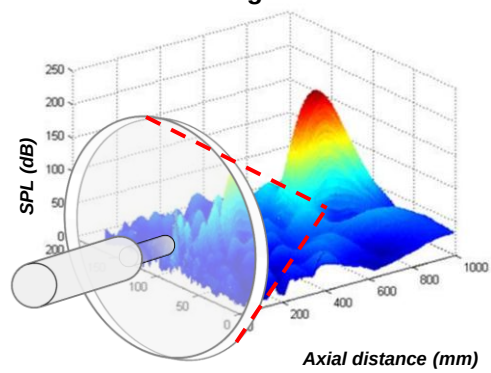
FOCUSED ACOUSTIC FIELD: 3D REPRESENTATION

Plate profiles are designed to achieve various acoustic field configurations.

Ultrasonic energy focusing may be achieved via a plate grooved profile.

The acoustic pressure is used to efficiently break foam.

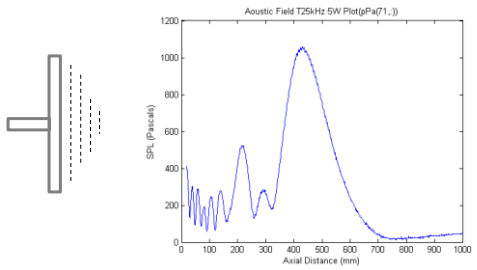
Acoustic field generated in air



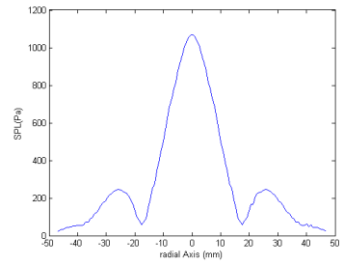
Focus area = 4.5 cm²
Acoustic Intensity = 10 W/cm²

FOCUSED ACOUSTIC FIELD: 1D & 2D REPRESENTATIONS

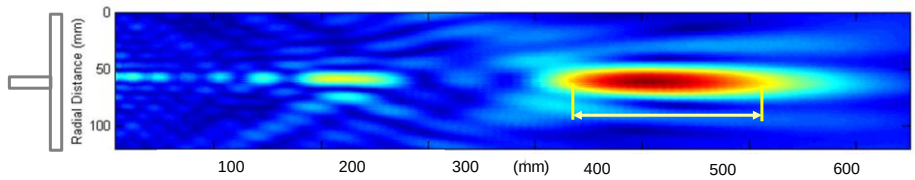
Measured Axial Sound Pressure



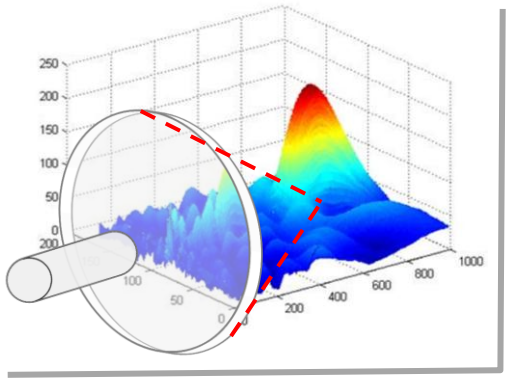
Measured Radial Sound Pressure

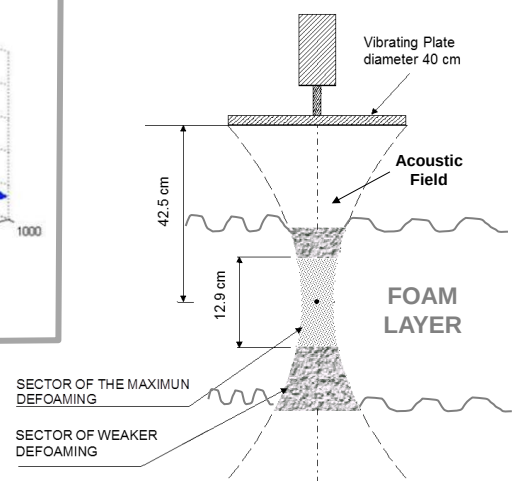


Measured Axial and Radial Sound Pressure



FOCUSED ACOUSTIC FIELD AND ITS DEFOAMING ABILITY

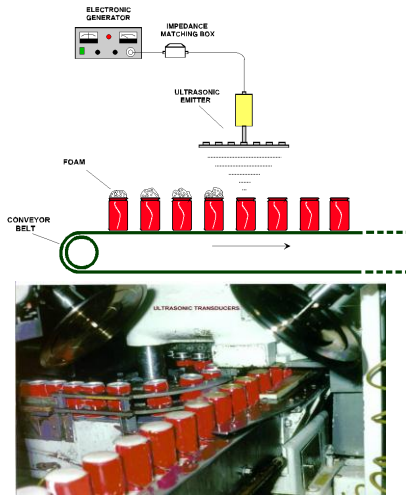




Various effects are responsible for foam collapse: acoustic pressure, bubbles resonance, atomization, etc.

ULTRASONIC DEFOAMING IN INDUSTRIAL APPLICATIONS

Filling operation



Reactors

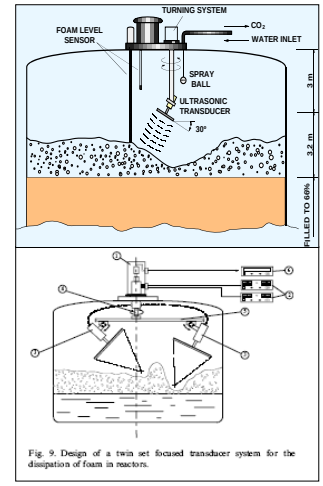


Fig. 9. Design of a twin set focused transducer system for the dissipation of foam in reactors.

UDS APPLIED TO A FOOD REACTOR

http://www.youtube.com/watch?v=ArQ5X-9tXGk

UDS IN TANK APPLICATIONS 1/2

UDS IN A BEER TANK 2/2

UDS APPLIED TO BOTTLING LINES

http://www.youtube.com/watch?v=jM5x8Qd8Ilk

PUSONICS RESEARCH

ULTRASONIC DRYING OF FOOD

FOOD DRYING METHODS

- Conventional procedures
  - Hot air drying
  - Freeze-drying
- Non-thermal procedures
  - Mechanical (centrifugal)

High intensity ultrasonic waves can be used for the dehydration of food materials

ULTRASOUND ASSISTED HOT-AIR DRYING

- Pressure variations ⟹ increase evaporation rate
- Oscillating velocity effect ⟹ increase drying rate of air at constant velocity
- Microstreamings at interfaces ⟹ reduction of diffusion boundary layer ⟹ increases mass transfer and accelerates diffusion

27

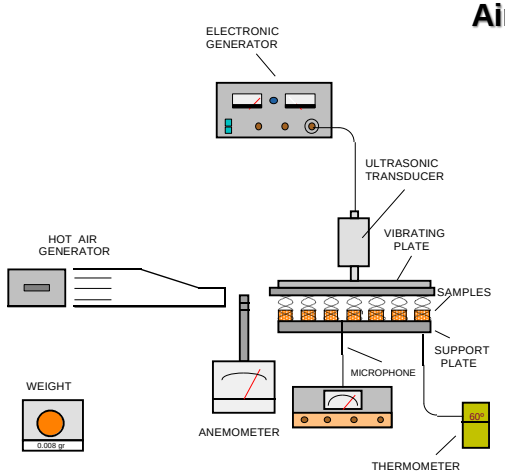
ALTERNATIVE ULTRASONIC DRYING TECHNIQUES

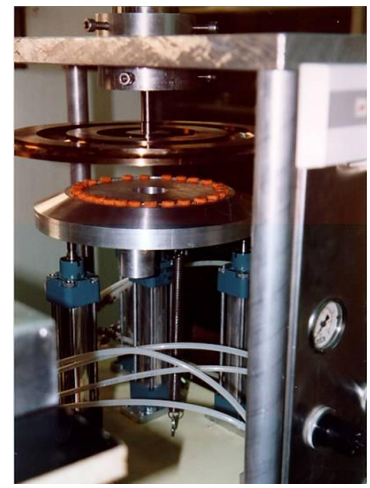
- New ultrasonic technology for food drying:
  - Forced-air drying assisted by air-borne ultrasound
  - Ultrasonic drying by applying ultrasound in direct contact with the material.

28

ULTRASONIC DRYING OF VEGETABLES

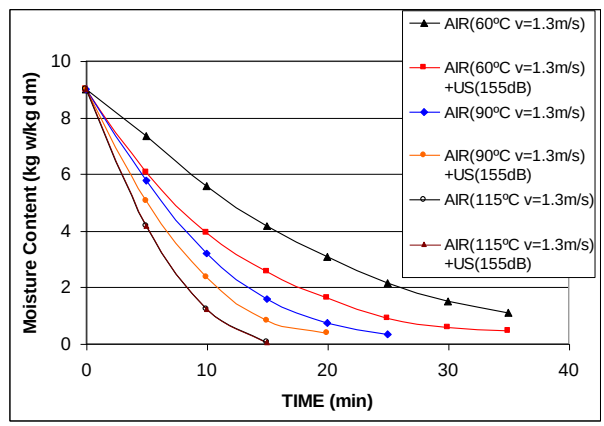
Air-borne ultrasound dryer





ULTRASONIC DRYING

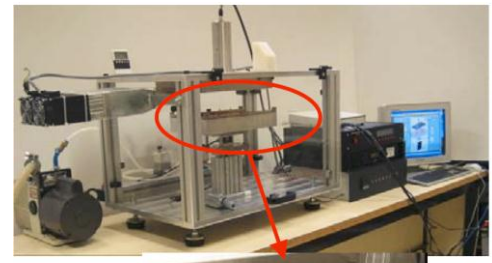
Kinetics of air-borne ultrasound drying (carrot slices)



ULTRASONIC DRYING

Ultrasonic drying via direct contact

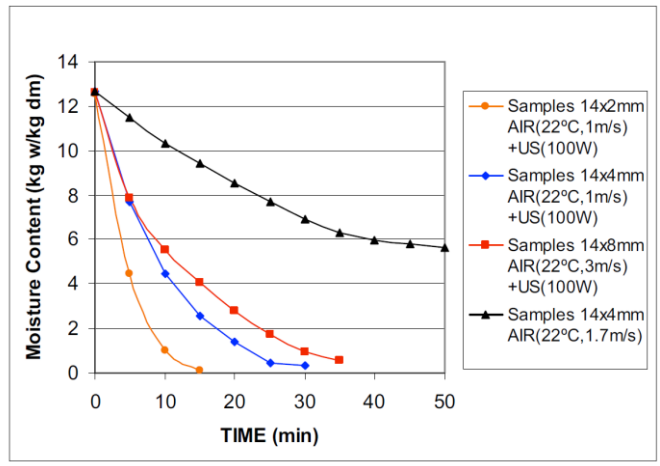
Contact between transducer plate and food material favours deep penetration of acoustic energy.



Food is subjected to a rapid series of contractions and expansions producing a kind of "sponge effect" and the quick migration of moisture.

ULTRASONIC DRYING

Kinetics of ultrasonic drying through direct contact

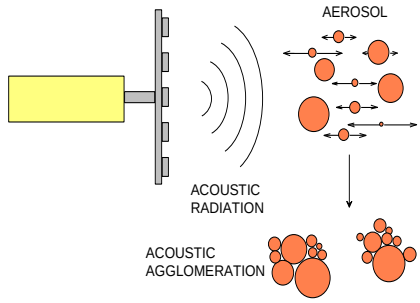


ENVIRONMENTAL PROCESSES: AIR CLEANING

AIRBORNE SUSPENDED FINE PARTICLES IN THE ENVIRONMENT

- Chemically active particles from industrial emissions (coal and fuel-oil burning, steel-melting industry, cement industry, etc.)
- Radioactive and toxic particles from major accidents (nuclear or chemical plants)
- Particles from natural disasters (volcanic eruptions, fires,…)

ACOUSTIC AGGLOMERATION AND PRECIPITATION OF MICRONIC AND SUBMICRON AEROSOL PARTICLES



Orthokinetic effect

– Relative motion between particles of different sizes

Hydrodynamic effects

Acoustic wake effect

– Viscous asymmetries in the flow field around the particles

Mutual radiation pressure effect

– Nonlinear interactions between particle scattering waves and incident field.

35

ACOUSTIC AGGLOMERATION REQUIREMENTS

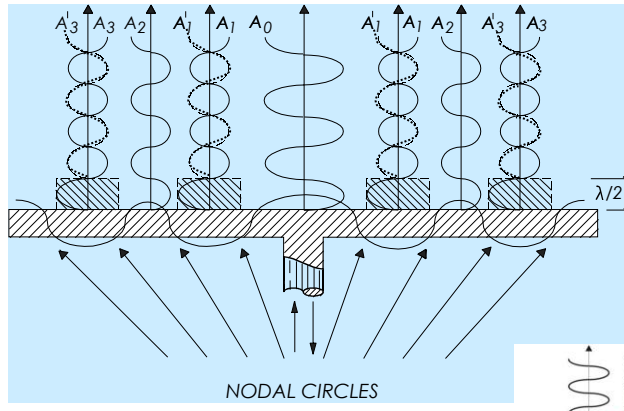
- Strong acoustic fields (140-165 dB)
  ⇒ Powerful sound sources

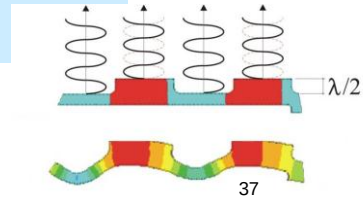
- Field homogeneity within the agglomeration system
  ⇒ Adequate geometry and dimensions

- Acoustic frequency adjusted to the particle size range
  ⇒ Changes in the frequency during the agglomeration process

36

PHASE MATCHING BY DIRECTIONAL STEPPED-PLATE RADIATOR

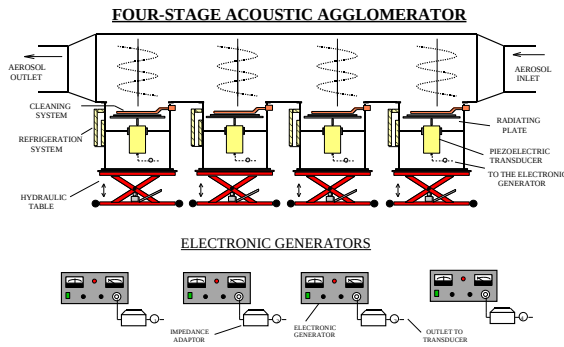




37

MULTI-FREQUENCY ACOUSTIC AGGLOMERATOR

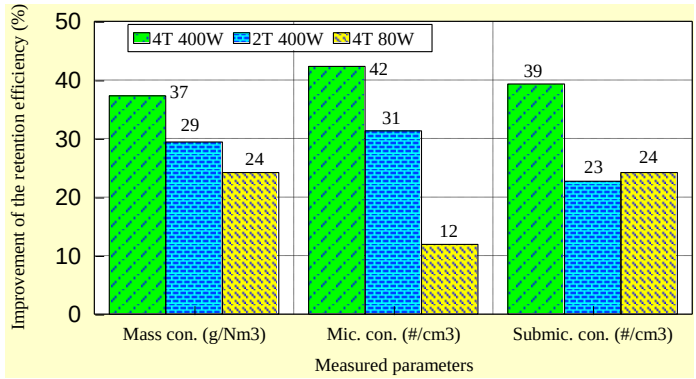
Diesel Power Plant (Mahon, Spain)



38

RESULTS

REDUCTION OF PARTICLE EMISSIONS, MICRON AND SUBMICRON RANGES

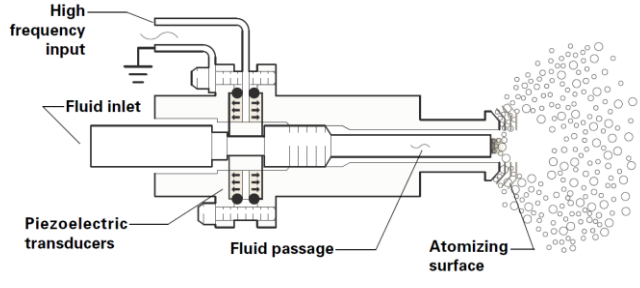


39

ACOUSTIC AGGLOMERATION VIDEOS

ULTRASONIC ATOMIZATION OF LIQUIDS

ULTRASONIC ATOMIZATION 1/3



Limitation:

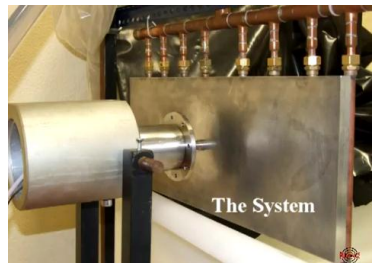
Max flow rate: 20 L/h

$D = (\frac{\pi\sigma}{\rho f^2})^{1/3} = \lambda_C/2$; *D = drop diameter;*

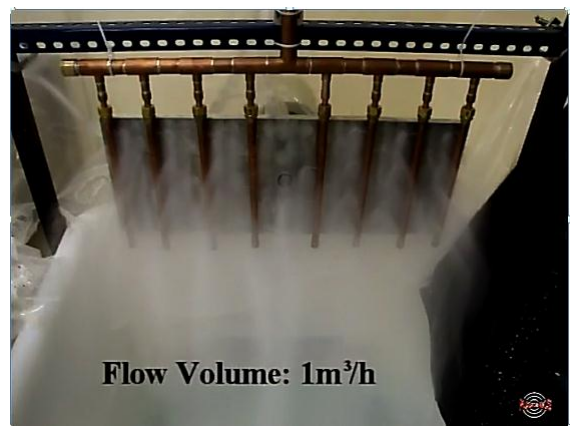
σ = Surface tension; *f= operating frequency*

Example (water): σ =72.8 dinas/cm, ρ= 1gr/cm^3, con f = 21kHz, gives D=80 microns

ULTRASONIC ATOMIZATION 2/3



ULTRASONIC ATOMIZATION 3/3



http://www.youtube.com/watch?v=TQ1L0588zy8

SUMMARY

- This presentation has highlighted the industrial potential of a novel family of Power Ultrasonic Systems. A few examples of the implementability of this new technology have been given.

- Other industrial applications may benefit from power ultrasound. A list of processes/operations wherein PUSONICS technology may be already introduced has been provided.