Hydrodynamic Cavitation Technology for Process Intensification

The tale of the journey from the research laboratory to the market place

By E-Pic S.r.l. and CaviMax Ltd

26th PIN Meeting, The Beehive, Newcastle University,

Wednesday 16th May 2018

Presented by

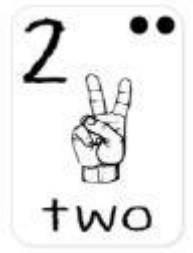
CaviMax Hydrodynamic Cavitation

- The leading UK supplier and knowledge bank for Hydrodynamic Cavitation Process Intensification

- World wide distributor and engineering systems integration of the patented E-Pic S.r.l. Rotocav cavitation reactor

Hydrodynamic Cavitation Technology for Process Intensification – A tale in 3 halves

The tale of E-Pic process intensification technologies and hydrodynamic cavitation – The Beginning



The tale of CaviMax – Innovative technology to improve the biogas sector – The Middle

The tale of next steps - wider implications of using hydrodynamic cavitation across multiple industries for decarbonisation/ energy reduction/ carbon & monetary savings – The End

The tale of E-Pic process intensification technologies and hydrodynamic cavitation

E-PIC Srl

www.epic-srl.com

E-PIC main focus are: Process Intensification & Process Development

- Optimization
- Process development
- Innovation
- Phenomena interpretation

Aim: design a process which has chemical kinetics as its only limitation. This means that all other processing limitations such as mass transfer, heat transfer and hydrodynamics are eliminated.

..Smaller…

Safer…

…Cleaner…

…Cheaper!

(Stankiewicz's approach)

E-PIC Srl

E-PIC EXPERTISE

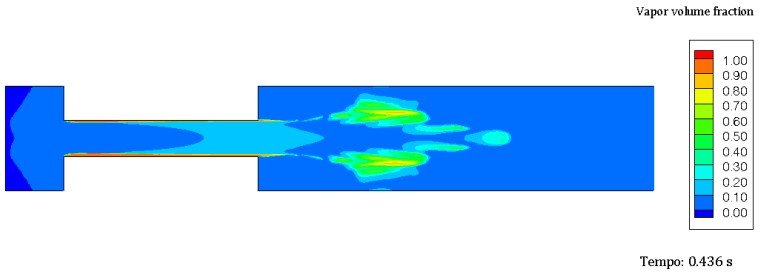
- INNOVATION AND PROCESS DEVELOPMENT
- OPTIMIZATION OF PROCESSES, PROCESS INTENSIFICATION, ASSISTANCE AND CONSULTING SERVICES
- TECHNICAL SUPPORT IN DESIGN AND DEVELOPMENT OF NEW EQUIPMENT

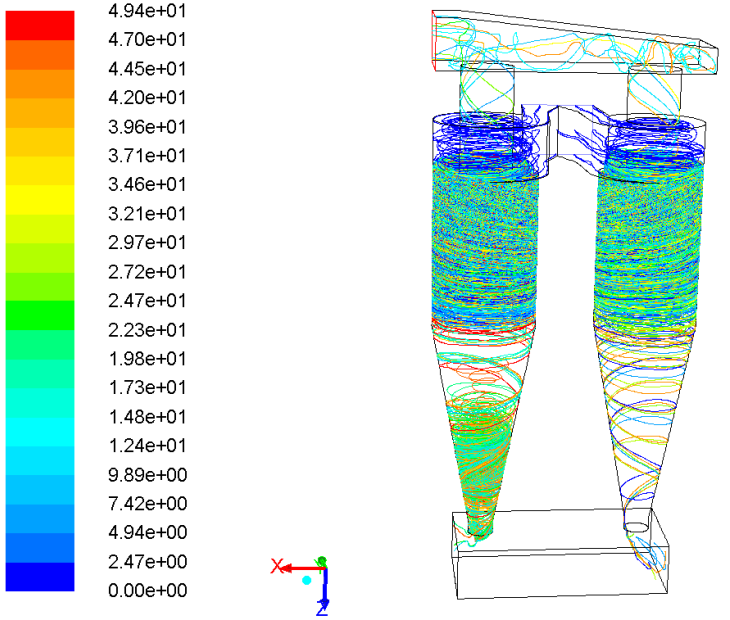
E-PIC Srl

PROCESS DEVELOPMENT

E-PIC S.r.l. can offer scientific and technological support in the optimization of existing processes as well as in the frame of technology development projects, in all phases of the development path, till industrialization

PROCESS CALCULATION MODELLING





E-PIC Srl

E-PIC NETWORKS

E-PIC S.r.l. has established and continues to improve relationships and cooperation with:

WORLDSCALE ACADEMIC EXCELLENCE CENTERS

To enhance the effects of **University-industry technology transfer**, with the aim of improving the dissemination of scientific knowledge, facilitating the **development of innovative** techniques and the implementation of **new solutions**

PROCESS ENGINEERS

BBC Ricerche

(Process Engineers Association)

E-PIC Srl

CAVITATION IS A PHYSICAL PHENOMENON DUE TO THE LIQUID – VAPOR TRANSITION

At constant temperature

The high velocity produces a local pressure reduction, when it falls below the vapor pressure, in the liquid media a number of micro-cavities are generated and subsequently (when the pressure is recovered)collapse

At constant pressure

The temperature of the liquid increases till the boiling point, corresponding to its vapor pressure

…But CAVITATION can be controlled…
And used as a tool OF PROCESS INTENSIFICATION

TYPES OF CAVITATION

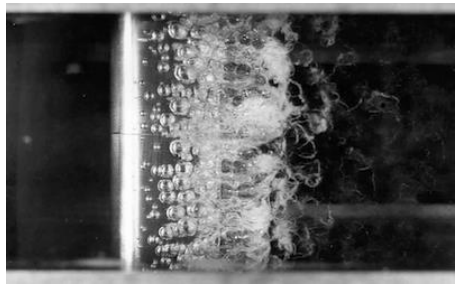
Controlled cavitation in industrial processes

Acoustic cavitation

The liquid is subjected to a pressure acoustic wave generated by an ultrasonic transducer

Hydrodynamic cavitation

The liquid is forced to passed throught a series of elements to generate cavitation



E-PIC Srl

EXPERTISE

Electric cavitation

Optic cavitation

TECHNOLOGICAL DEVELOPMENT OF THE E-PIC'S SONOCHEMICAL REACTOR

The development of a NEW TECHNOLOGY requires several steps: design, simulations, optimization, construction, experimental proof, validation

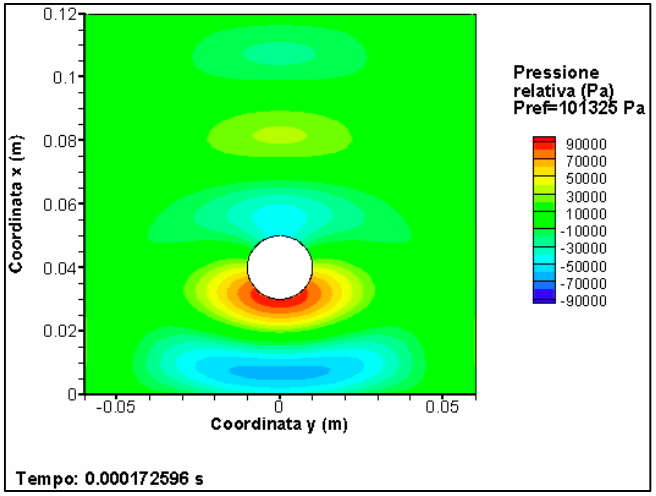
Industrial scale

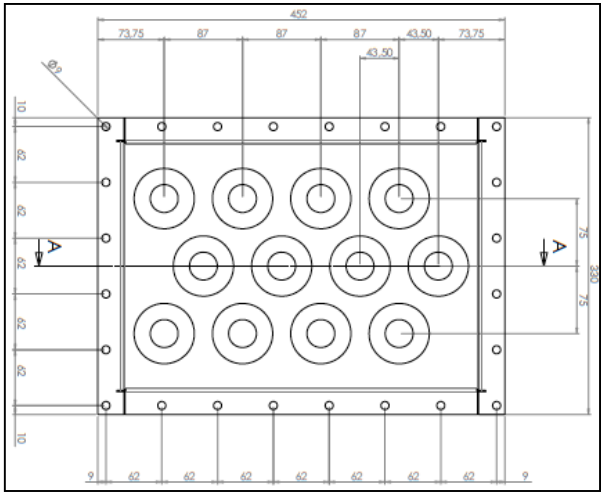
Pilot scale

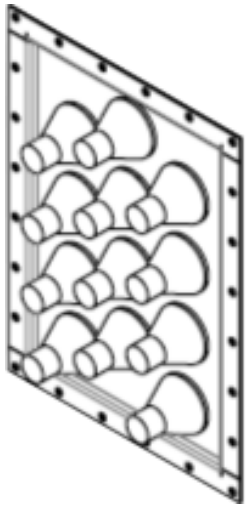
Laboratory scale

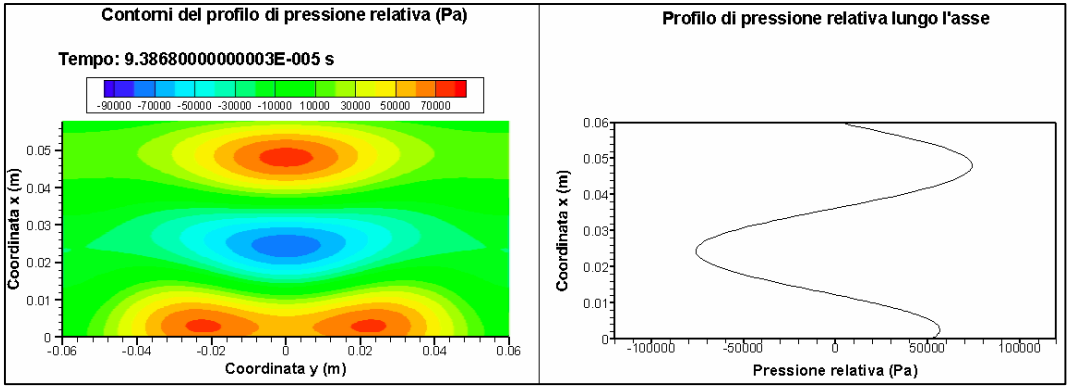
E-PIC Srl

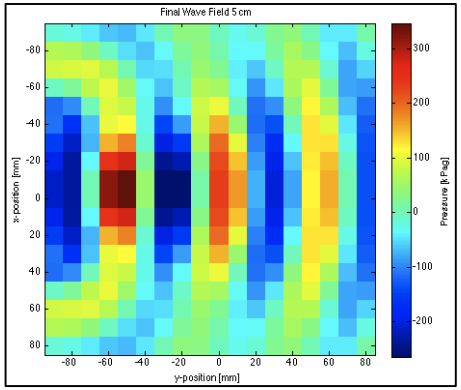
Design and simulation of the pilot unit





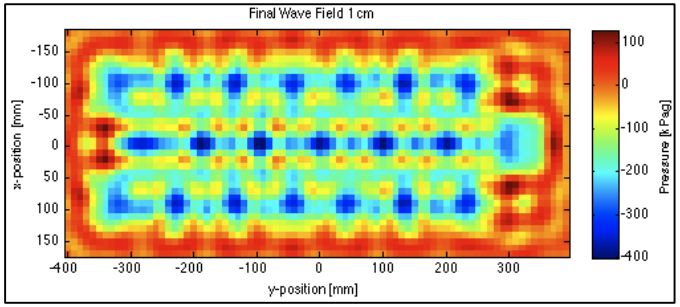


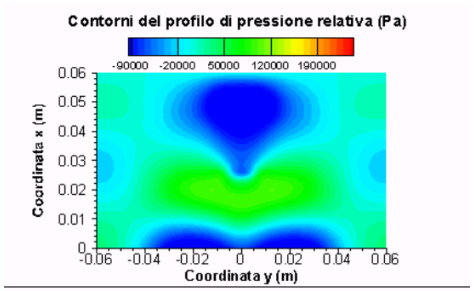


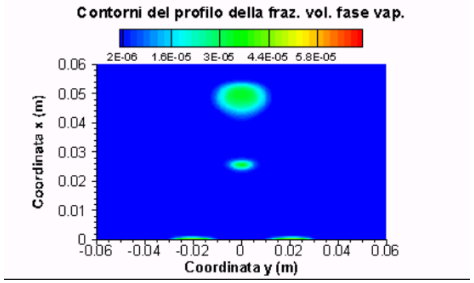


DEVELOPMENT PATH

Construction and optimization of the pilot unit







E-PIC Srl

DEVELOPMENT PATH

Experimental tests & Identification of drawbacks of

SONOCHEMICAL REACTOR:

- Limited depth of wave penetration: not all treated liquid is subjected to cavitation
- Difficulties in the choice of the best operative parameters: the transducers work better when the treated liquid moves in laminar flow, but turbulence promotes many other important aspects for the treatment
- Lower efficiency at industrial scale compared to laboratory scale. It is too expensive to generate the same high energy density tested at the laboratory scale
- Presence of a lot of electronic components: high maintenance costs

E-PIC Srl

TECHNOLOGICAL DEVELOPMENT OF THE E-PIC'S HYDRONYNAMIC CAVITATION SYSTEMS

IN DEPTH STUDY OF THE BEST CONFIGURATION

STATIC ELEMENTS

PERFORATES PLATES

VENTURI TUBES

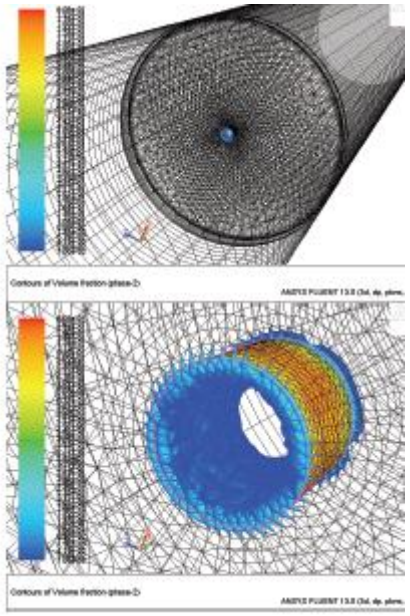
DYNAMIC SYSTEMS

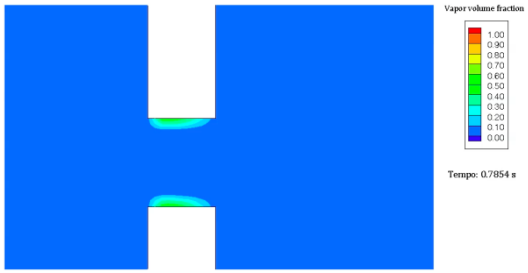
ROTOR – STATOR DEVICES

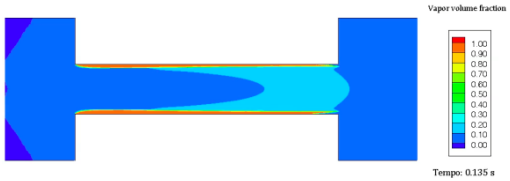
E-PIC Srl

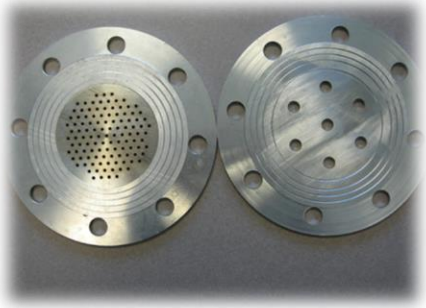
E-PIC'S STATIC ELEMENTS

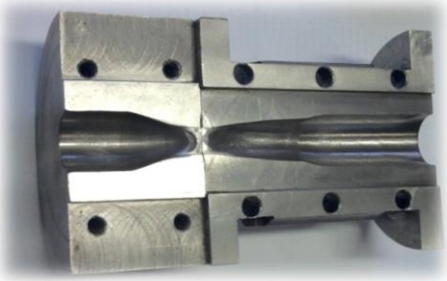
PERFORATED PLATES & VENTURI TUBES

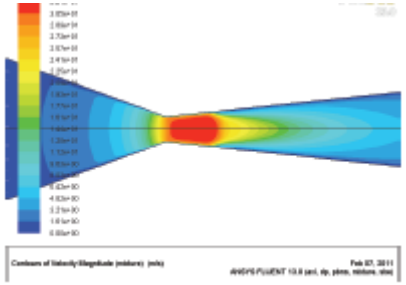












E-PIC Srl

ANALYSIS OF CAVITATIONAL STATIC ELEMENTS

- ✓ Capital cost saving
- ✓ Easy & compact
- ✓ Safe technology
- ✓ Easy scale-up, installation, replacement and maintenance

- All the liquid should be pumped at high pressure
- There are too many energy conversions: *Electric energy (pump) – Pressure energy – Kinetic energy – Pressure energy*
- Clogging problems
- Low efficiency

HOW TO IMPROVE THESE SYSTEMS & CAVITATIONAL EFFECT?

BY ARRANGING ELEMENTS IN A NEW AND MORE EFFICIENT DYNAMIC SYSTEM : THE ROTOCAV

E-PIC Srl

TECHNOLOGICAL DEVELOPMENT OF THE E-PIC'S HYDRODYNAMIC REACTOR: ROTOCAV

Industrial scale

75kW & 40,000 l/h

Pilot scale

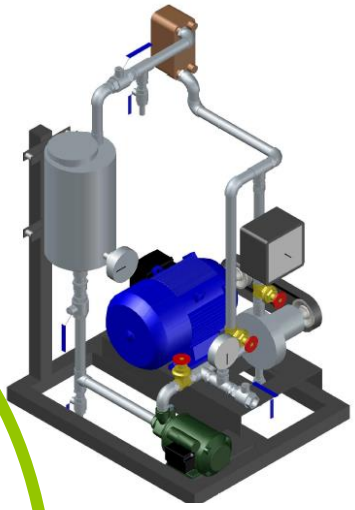
Laboratory scale

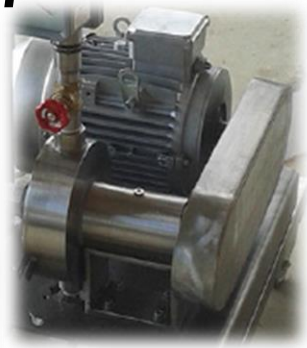
4kW & 500 l/h

E-PIC Srl

SCALE UP OF ROTOCAV

E-PIC DEVELOPED DIFFERENT PROTOTYPES OF PILOT UNIT



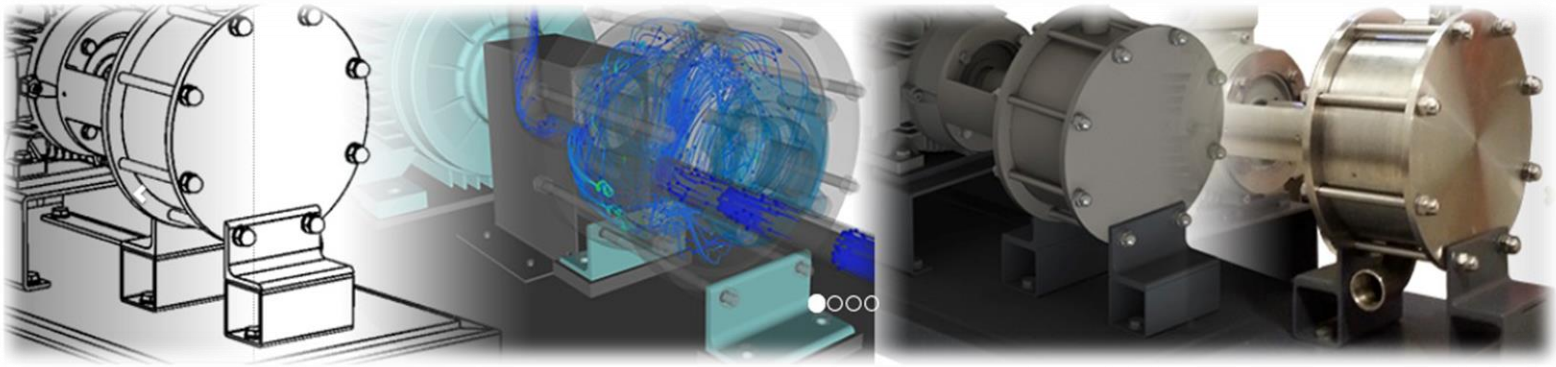


THE LAST ONE IS THE BEST:
It overcomes all the SCALE UP problems

Operative parameters and design criteria of the lab machine are preserved for all the available industrial sizes

E-PIC Srl

...FROM THE IDEA....
TO THE BEST CONFIGURATION



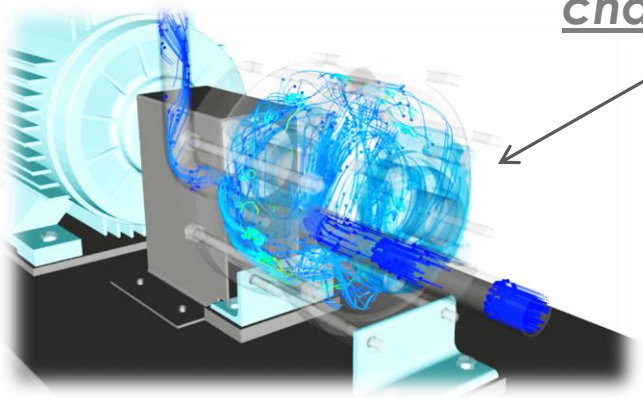
ROTOCAV is designed to **MAXIMIZE THE AREA TO GENERATE CAVITATION**: *compared to the other dynamic hydrodynamic cavitators of the same size on the market,* ***volume of cavitation can be 3-4 times more***

E-PIC Srl

ROTOCAV: HOW DOES IT WORK

ROTOCAV is an E-PIC S.r.l. proprietary technology that achieves controlled hydrodynamic cavitation by forcing fluids, which has to be treated, through its rotor-stator apparatus.

During high speed rotation, rotor channels are periodically aligned with stator channels. The processed liquid is accelerated in the radial direction in the cavitation chamber and, flowing through the free channels, is subjected to a pressure wave resulting in cavitation.



The heart of the system: the cavitation chamber

The ROTOCAV is defined according to *process intensification* approach, which improves the development of **faster, cleaner smaller** and **cheaper** devices. ROTOCAV enchances existing processes and product functionality and it is really appealing if compared to conventional systems.

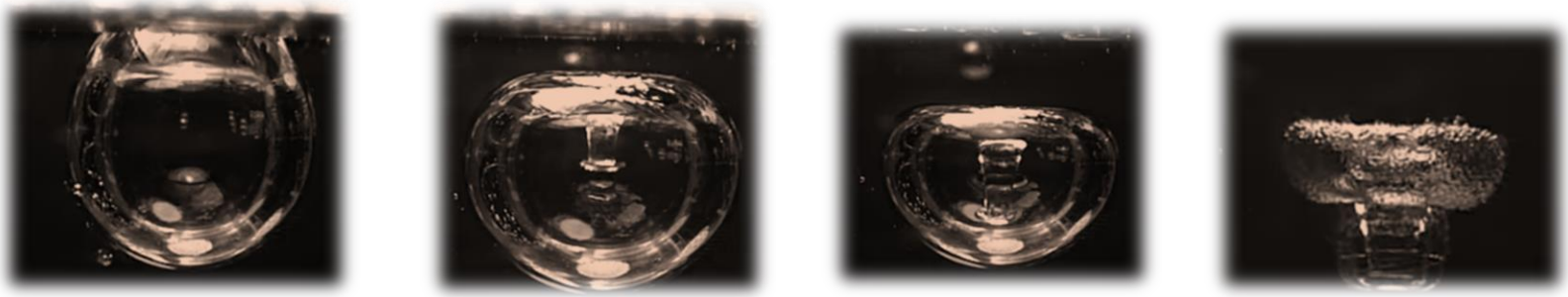
E-PIC Srl

ROTOCAV AND CAVITATION

Cavitation induced by ROTOCAV is a **controlled CAVITATION**

When a liquid passes through the cavitation chamber, it undergoes a sudden increase in its velocity at the expense of local pressure. When local pressure falls below the vapor pressure, micro-cavities are generated in the liquid media and subsequently collapse, while pressure is recovered downstream the constrictions.

DYNAMIC EVOLUTION OF THE BUBBLES



Generation ***Growth*** ***Collapse***

When the micro-bubbles collapse, high local pressure and temperature created by thee microsecond cyclical micro-jets, millions of cavitation events with a localized pressure of >1000 atmospheres per bubble collapse.

E-PIC Srl

ROTOCAV EXPERIMENTAL TESTS

The use of ROTOCAV as a PI technique in the extraction of bioactive compounds from natural matrices

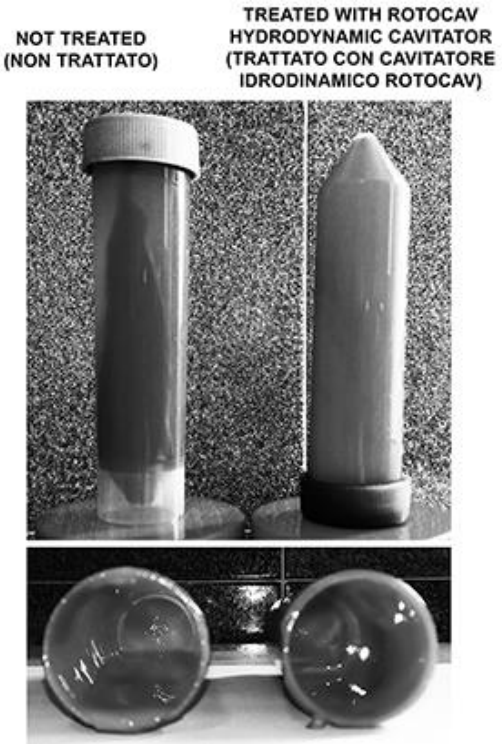
E-PIC Srl

ROTOCAV EXPERIMENTAL TESTS

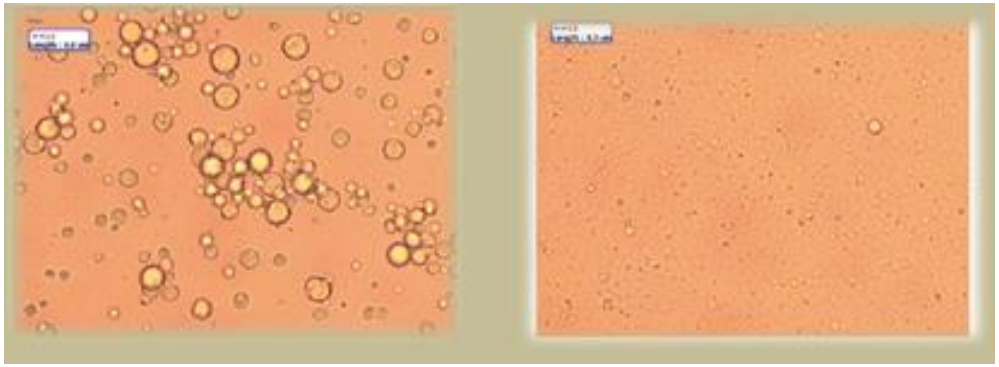
E-PIC Srl

The use of ROTOCAV as a PI technique in the production of BIODIESEL

ROTOCAV EXPERIMENTAL TESTS



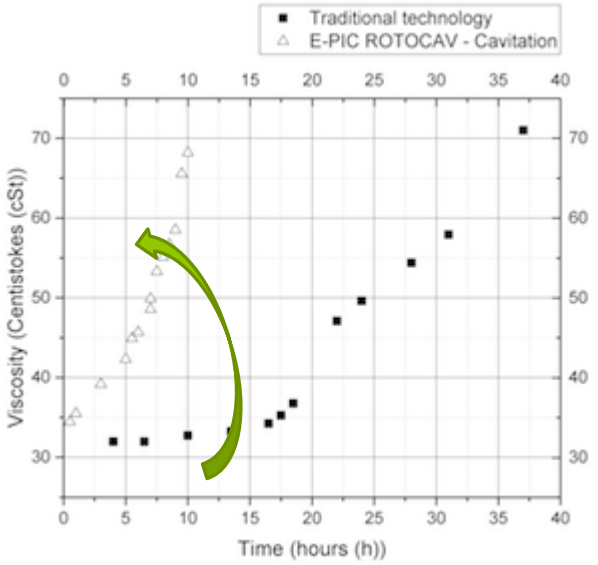
The use of ROTOCAV as a PI technique in the HOMOGENIZATION & DISAGGREGATION



E-PIC Srl

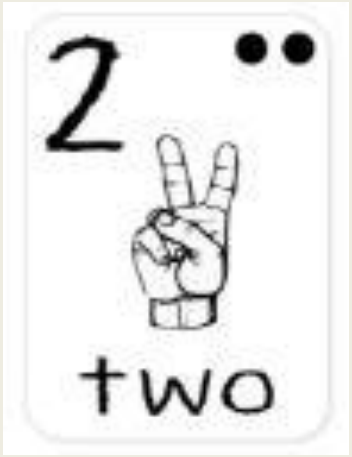
ROTOCAV EXPERIMENTAL TESTS

The use of ROTOCAV as a PI technique in the GAS –LIQUID MIXING IN THE CHEMICAL REACTIONS



The reaction time decreases by about 1/3 in respect to the traditional process

E-PIC Srl



The tale of CaviMax – Innovative technology to improve the biogas sector

Enter the innovator, the early adopter & the entrepreneur – Mr Owen Yeatman of Farmergy Ltd

- Multi Industry knowledge and a wide network of anaerobic digestion and water treatment professionals and peers around the world
- We don't just sell biogas plants we own and run them, we understand the needs of the AD bacteria and the plant operators alike
- Lots of experience of all aspects of the biogas industry since the beginning
- We've seen the good, the bad and the ugly biogas plant and know what is required in correct design in the beginning stages and how to bring a poorly performing plant back to balance and profitability
- Experience of building biogas plants based upon the innovative wiefferink Combibag/ Flex fermenter concept

ACTIVELY ON THE HUNT FOR NEW TECH TO IMPROVE THE PERFORMANCE OF BIOGAS PLANTS, HEARD ABOUT CAVITATION AT A TRADE SHOW

www.farmergy.co.uk

Cavitation technology for efficient biogas production

How we are harnessing the power of cavitation for our industry, what problems needed overcoming?

Hydrodynamic cavitation for disintegration of high lignin feedstocks and recalcitrant substrates

CaviMax – The Biomass Disintegrator

Benefits of cavitation for anaerobic digestion and renewable gas sector

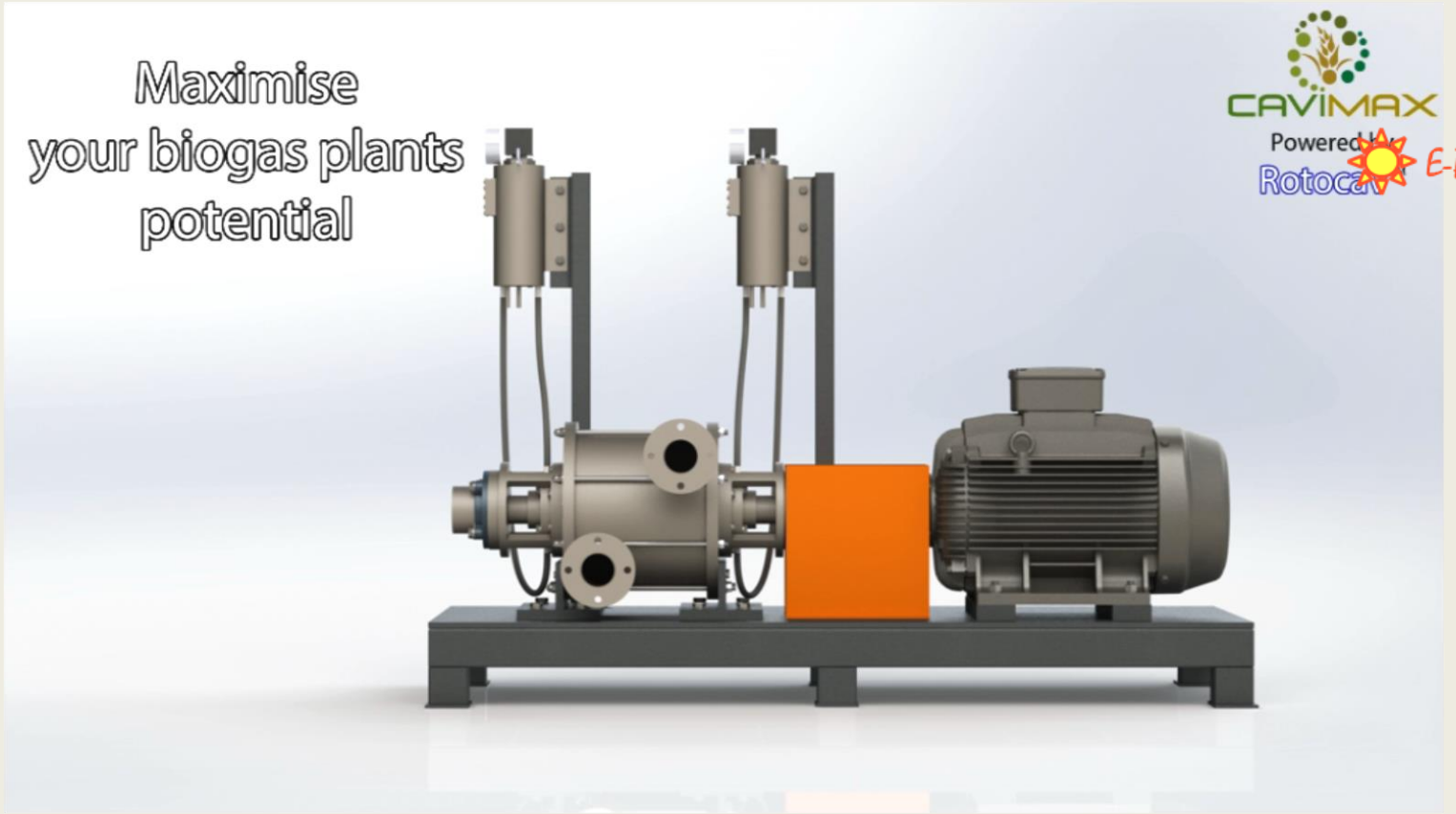
How is CaviMax harnessing the power of cavitation for the biogas industry? What problems needed overcoming?

Many anaerobic digestion plants undersized to increase sales quotas
Many evolutions of design, some of them dead ends
Many plants built to the ‘spreadsheet’ with little link to real time operating parameters
Many plants now not achieving the returns promised
Many plants are now limping along, not providing enough income to engineer out problems
Changes in feedstocks allowed per tariff, reduction of energy crops, waste component now a factor
Lignocellulosic and recalcitrant organic materials are problems for the AD industry
Floating layers cause major headaches
Lack of space to increase digestion capacity and retention time
Reduction of subsidies means that only 2 new biomethane plants were built last year in the UK

All of the above can be overcome by installing a CaviMax, plus a whole list of intangibles that get poor / average plants to the top of the performance spectrum, which in this industry is BIG MONEY

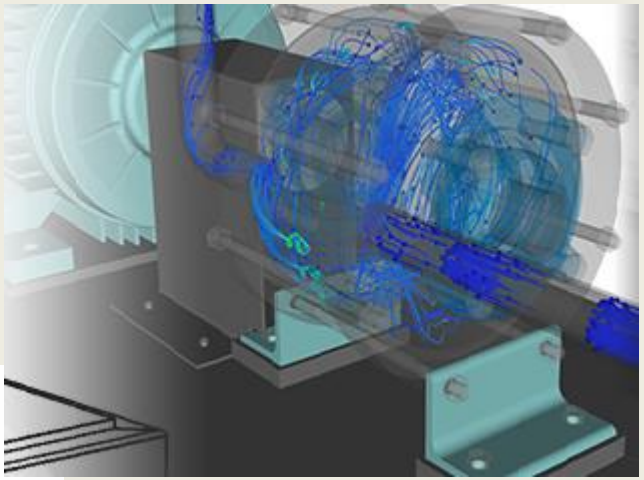
The E-Pic ROTOCAV hydrodynamic cavitation reactor at the heart of every CaviMax

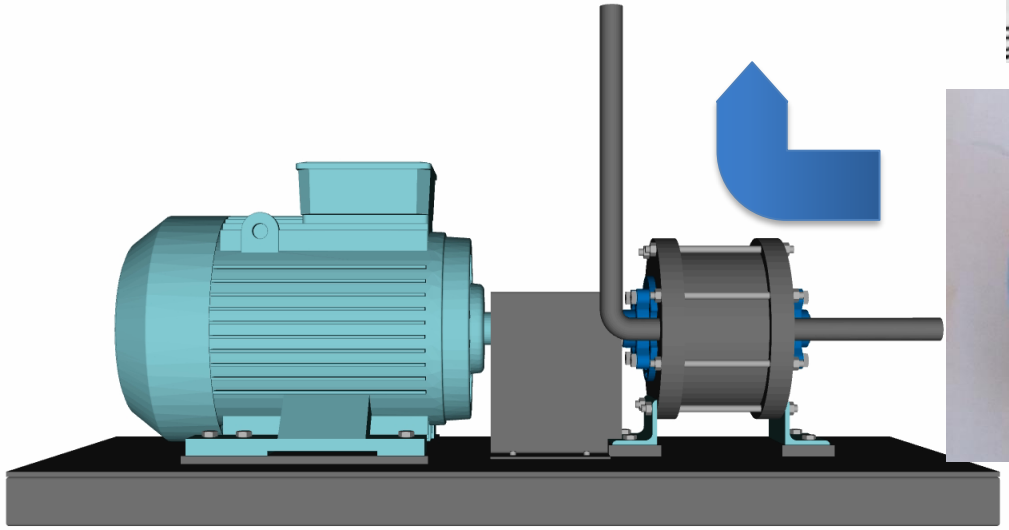
Meet the star of the show…

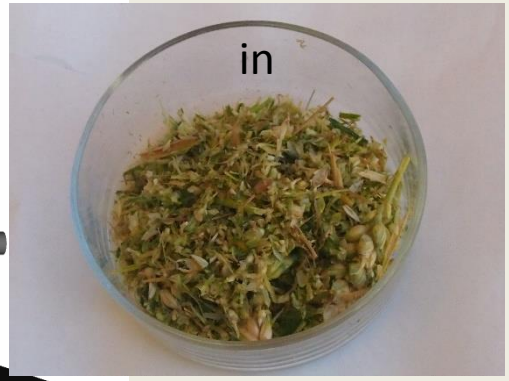


CaviMax – The Biomass Disintegrator

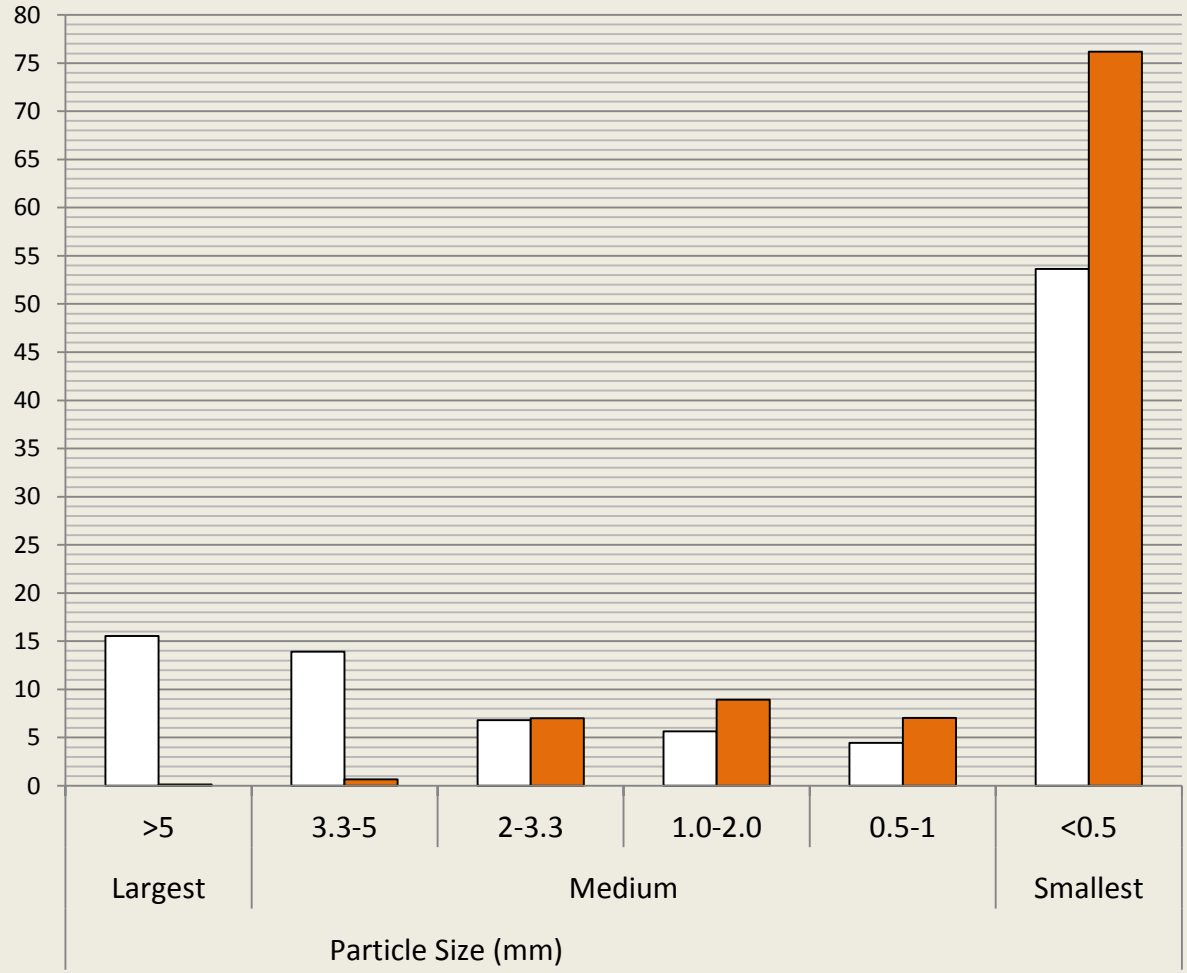
Inside the cavitation chamber – liquids pumped at speed through a spinning rotor-stator, forcing liquids through channels creates pressure differentials in the liquid







Effects of cavitation – reduction in particle sizes



Same dry matter content, however particle sizes are redistributed

□ Untreated Substrate

■ Cavitated Substrate

CAVIMAX

cavitation induced biomass disintegration is powerful enough to breakdown lignocellulose to access cellular juices for biogas production

= ability to use high lignin feedstocks & recalcitrant waste materials as feedstocks

Features of controlled hydrodynamic cavitation

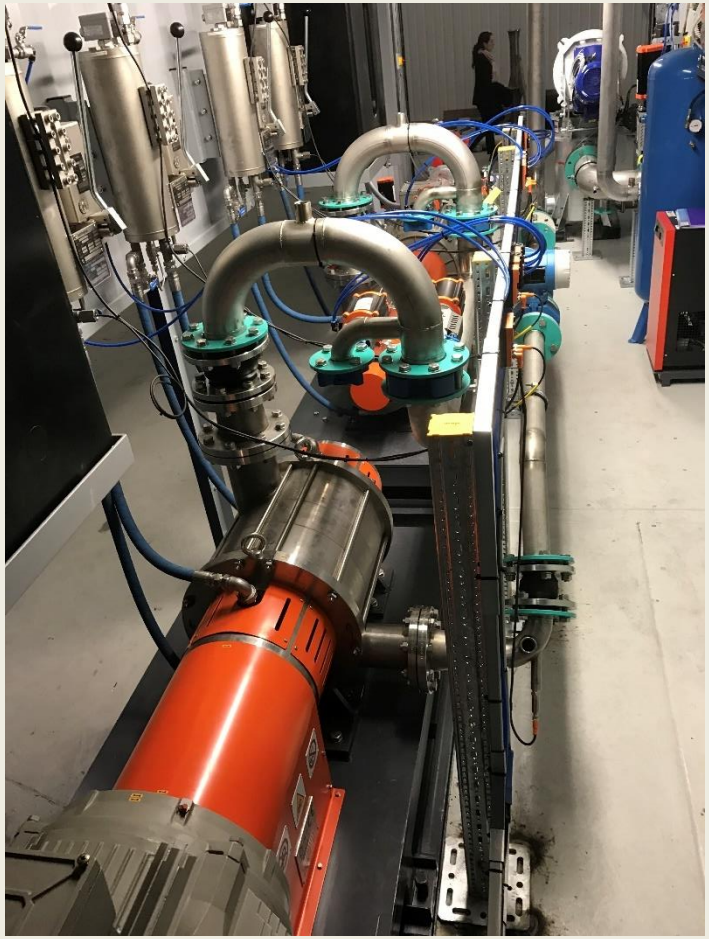
Process intensification technology
Breaks down lignocellulose
Deals with recalcitrant materials
Drastically reduces particle size of treated substance
Multiple treatment positioning, feedstock pre-treatment or mid process
Low maintenance simple design
Multiple machines can be used to reduce feedstock and manufacturing costs and treat effluent waste waters leaving the site – DOUBLE WIN
Can also be utilised for bio-diesel production and oil refining
A range of sizes available to suit your plant and requirements
Environmentally friendly, efficient and economical in its application

Benefits of cavitation for biogas plant operation

- Reduce feedstock costs or increase biogas production
- Ability to digest high lignin feed stocks – utilise straw
- Add value to secondary sludges and biosolids
- Decrease problematic floating layer – important when dealing with grass and straw (crust reduction in digester)
- Increased availability of cellular juices
- Acceleration of hydrolysis & the anaerobic digestion process
- Reduce retention time in digester
- Increased pumpability of substrate
- Reduced plant downtime due to blockages
- Reduction in H_2S levels when using grass as feedstock

CaviMax containerised unit fitted out in factory

CaviMax factory fitout photos



CaviMax onsite photos

A CaviMax C150 Biomass Disintegrator treating a floating layer in a primary digester of a biogas plant with CHP and biomethane gas to grid plant in Scotland, current data is up to 56% increase in biogas and reduced viscosity, possibly averaging 30% there is visual improvement of the digestate

E-PIC Srl Consultants, theorists, researchers & inventors

Rotocav Epic's patented product of 8 years in the making

farmergy From feasibility to installation, carbon footprint lowering products that increase your profits. Projects - waste from energy, renewable transport fuels, renewable gases and bioeconomy consultants

AD•vantage Biogas Anaerobic Digestion plant operation, maintenance, design, engineering & microbiological - managing large portfolios of AD plants for themselves and other independent operators

CAVIMAX CaviMax started as a joint venture between the heads of Farmergy and ADvantage biogas. CaviMax now provides product and engineering integration for multiple applications and markets. Distribution, sales & marketing agents of Rotocav

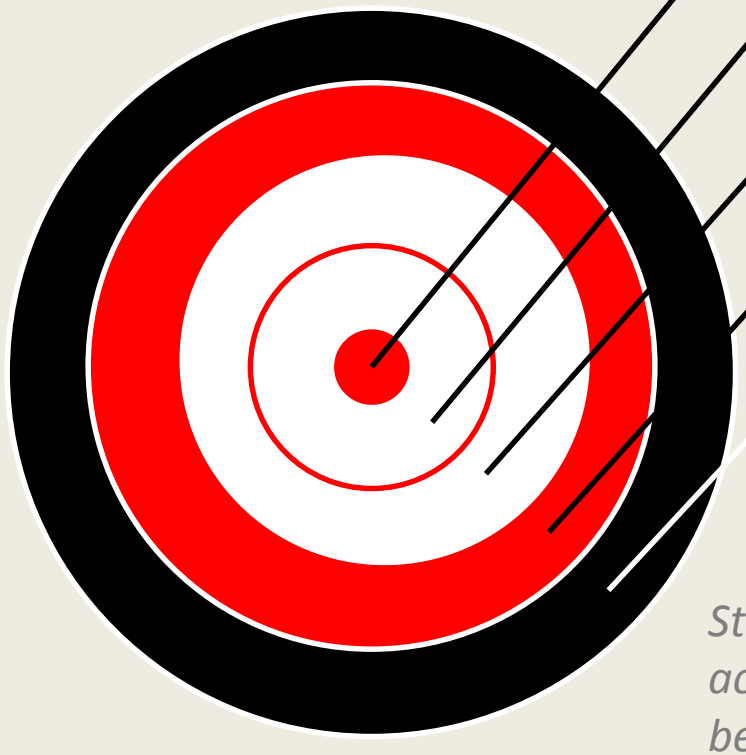
A synergistic collaboration, working to each of our strengths and passions

The tale of next steps –

The wider potential of using hydrodynamic cavitation across multiple industries for decarbonisation/ energy reduction/ carbon & monetary savings

- UK engineering / sustainable chemistry sector
- A tool for the circular bioeconomy & biorefining

Hydrodynamic Cavitation Technology – Versatile, adaptable & non niche



Suitable for multiple industrial sectors

Variety of sized machines available to suit your requirements

Fully integrated containerised systems available – plug and play

Bespoke engineering service – CaviMax integrates the Rotocav cavitator into your current system

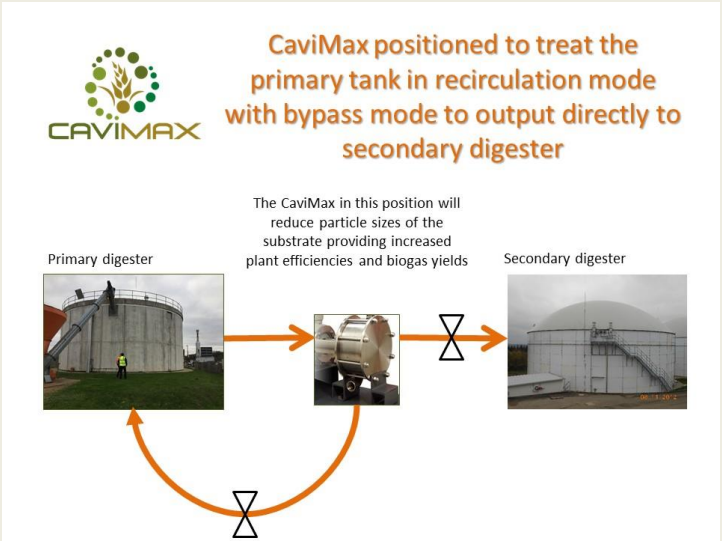
No need to redesign an entire factory or process line – integrate to upscale current practices, a disruptive upgrade

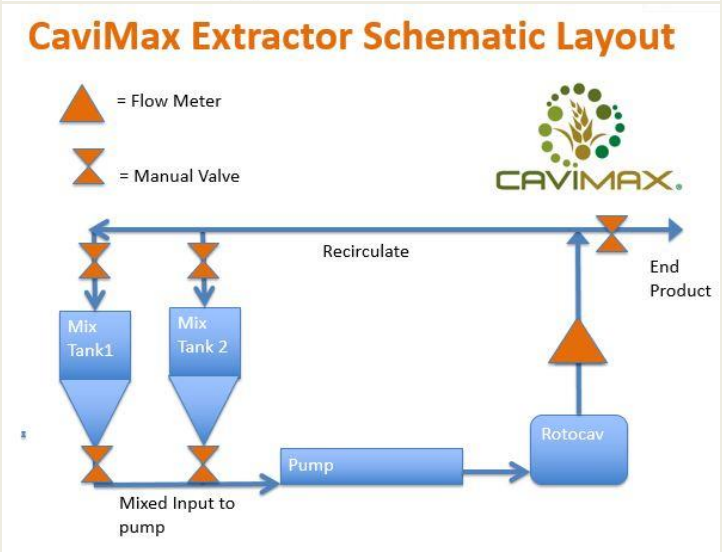
Start and end particle size in the process flow liquid are accommodated by changing the size of the gap between the rotor and the stator, other than that it's the same machine across the industrial sectors

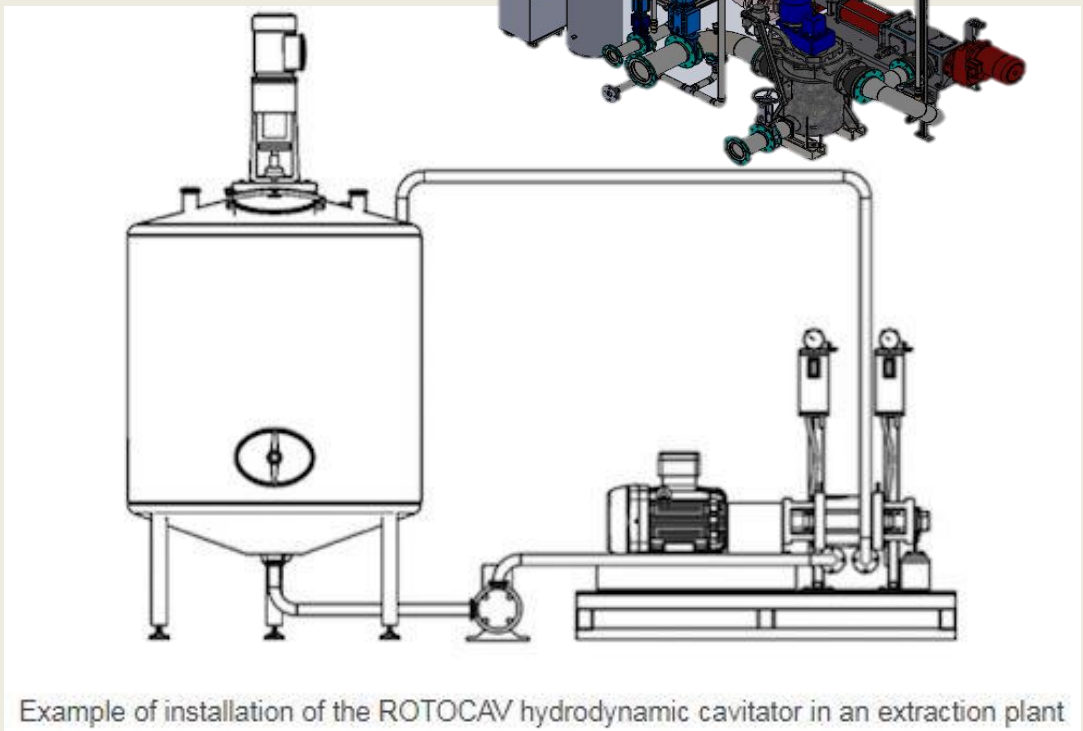
Full range of industrial sized Rotocav's to suit process needs

Model	Power (kW)	RPM	Tank Capacity (litres) Batch mode	Volume Flow (litres/hour) Continuous mode
CaviLab Pilot Plant	4	3000	100	800
C11	11	3000	250-500	4000
C22	22	3000	500 - 1000	8000
C37	37	1500	1000 - 2000	16000
C55	55	1500	2000 - 3500	25000
C75	75	1500	3500 - 5000	40000
C150	150	1500	7000 - 10000	80,000

Work with our engineering team to retrofit the cavitation reactor into a current process line to upscale current practices or design from new







CaviMax sectors and vectors

CaviMax turns the Rotocav reactor into a viable finished end product engineered specifically for any given task dependent on the end result required by the client

Initial vertical marketing vector is **biogas**, start with what you know, as we have researched the subject we have found out about the joys of PI, and the many and varied weird and wonderful applications for hydrodynamic cavitation processing…

Current applications

- RENEWABLE ENERGY –THE BIOMASS DISINTEGRATOR FOR BIOGAS PLANTS
- PIGFEED **EAT** - **E**NHANCED **A**NIMALFEED **T**ECHNOLOGY
- CRUDE OIL UPGRADING
- DEAGGLOMERATION OF NANO MATERIALS
- BIODIESEL PRODUCTION
- SUSTAINABLE CHEMICAL REACTIONS
- EXTRACTIONS FROM ORGANIC BIOMATRICIES
- COSTMETICS INDUSTRY

and where next ……..algae processing, biorefining?

Results of our CaviLab trials

- We cavitate material and send to a lab for independent analysis – BMP (Biochemical Methane Potential)
- We've achieved biomethane uplifts of between **10% and 56%** depending on the positioning of the machine and the substrates and feedstocks
- If we were to work on a conservative 20% process uplift across multiple industries then we have a de-escalation of energy and feedstock use (if used to do more with less, rather than just do more)

Hydrodynamic cavitation CleanTech for the UK

There is finally a hydrodynamic cavitation team now based in the UK

We have a full engineering and service team 40+ biogas plant engineers and environmental scientists

Full co-operation and knowledge transfer between E-Pic and CaviMax, continuous product development based on feedback from each application

There is an industry waiting in the wings, based on years of research
The more people and teams take ownership of this CleanTech the better

Multiple industry decarbonisation, a new sector the UK can excel in, hydrodynamic cavitation can be taught in the following departments and more…in fact the same machine can be used interdepartmentally as it has it's own set of wheels…

- **Chemical engineering**
- **Mechanical engineering**
- **Food and drink production**
- **Environmental sciences**

Hydrodynamic cavitation CleanTech for the UK and beyond

A technology to serve the aims of the:-

UK Clean Growth Strategy

UN Sustainable Development Goals

Circular Economy

LEAN manufacturing

Bioeconomy

Hydrodynamic cavitation at the Labscale
De-risk R&D by taking small steps

Laboratory scale test rig to calculate what process uplift cavitation can provide:-

1. Send us samples to cavitate and return to you for investigation
2. Hire CaviLab for longer trials
3. Buy a CaviLab for your laboratory and/or pilot plant, buy back and upscale options

- 200l/h, 400l/h, 800l/h flow rates
- >3.6 kW/h depending on rotor speed required and materials processed
- Power output shown to calculate energy usage in operation for OPEX calculations

Once you have proved your hypothesis….it's time to scale up

CaviMax for industry – Full service & callout team

Time is money, our ethos is to minimise downtime, so we provide the following for our industrial units:-

- Full UK coverage service and maintenance division
- CaviMax service & maintenance plan
- Remote dial in problem identification worldwide
- Controls and sensors readily available in most countries worldwide, easily replaceable and automatically programmed once integrated into the CaviMax system
- Critical spares onsite with CaviMax
- Training provided for onsite maintenance team
- Camera and audio steam from CaviMax container to UK team to help guide the overseas onsite maintenance team if required

We have expertise in the following areas

Biogas and electric energy from agro-food/farming waste
Biomethane from biogas for transport – avoid fluctuations in diesel
Utilisation of biowaste as energy – increase your profits
Circular economy – turn waste into feedstock
Water treatment – reduce pollution, use less water
Upscale bioresources – extractions/ break down algae/lignocellulose
Biofuels and oils – extracted from biomass waste
Oils – upscaling of crude oils

What is your area of expertise?

Take part in the bioeconomy and decarbonisation of business to future-proof your company, be smart, resilient and profitable

Current research work by

E-PIC Srl

Rotocav

To give you an idea…we have investigated following cavitation industrial applications:

- Milk sterilization (hydrodynamic cavitation - lab scale and demonstration scale)
- Milk homogenization (hydrodynamic cavitation - lab scale and demonstration scale)
- COD reduction on pharma/fine chemical waste-water with COD > 100.000 (hydrodynamic cavitation + Ozone - lab scale and demonstration scale)
- Salt precipitation (hydrodynamic cavitation - lab scale and demonstration; precipitation of carbonates, bicarbonates and sulphates)
- Cooling tower water treatment (hydrodynamic cavitation - lab scale and demonstration scale; by treating cooling water hold up with hydrodynamic cavitation, one can competitively prevent algae formation, scale precipitation, and can increase the water recycling coefficient)
- Postconsumer plastic flakes washing (ultrasound cavitation in a proprietary spouted bed washer/extractor - lab scale and pilot scale)
- Transesterification of fatty acid for biodiesel production both from virgin oil as well as from exhausted cooking oil (hydrodynamic cavitation - lab scale and demonstration scale)
- Oxydesulphurization of diesel oil (ultrasound cavitation - lab scale and pilot scale)
- Oxidation of oil for preparation of leather treatment chemicals (hydrodynamic cavitation - lab scale and demonstration scale)
- Biomass pretreatment (hydrodynamic cavitation - lab scale and demonstration scale)
- Reduction particle size and homogenization of cosmetic products (hydrodynamic cavitation - lab scale and demonstration scale)
- chemical reactions (hydrodynamic cavitation - lab scale and demonstration scale)
- Extraction of active compound from herbs and fruit: extraction of oleuropeine from olive leaves, extraction of lycopene from tomato peel, extraction of carotenoids from tomato pulp in powder, extraction of phospholipids from krill , extraction of pectin, terpenoids and flavonoids from orange seeds and peels, polyphenols extraction from cocoa waste and hazelnuts, stevioside and rebaudioside extraction from stevia leaves and others…extraction of aroma from vanilla, wormwood, passion flower, black tea, chamomile, cranberry, maté, guarana, pepper, garlic, ginseng…(hydrodynamic cavitation - lab scale and demonstration scale) If you have read this far well done, you are keen & interested now over to you for some bright ideas...

What is your area of expertise?
What has this talk made you think about?
How would you apply this tech?

Thanks for listening

CaviMax Cavitation Engineering & Systems Integration

Include Hydrodynamic Cavitation in your innovative / disruptive / PI technology evaluations

- ✓ Laboratory scale reactors for R&D
- ✓ Full range of industrial sized reactors to suit flow and processes
- ✓ Full service back up and SLAs to suit
- ✓ All reactors available as ATEX & Non ATEX rated
- ✓ Finance option packages available

www.cavimax.co.uk

CIRCULAR ECONOMY CLUB

CaviMax are members of ADBA - Anaerobic Digestion and Bioresources Association and the Circular Economy Club

ADBA MEMBER

Emma Greenwood BSc(Hons) PgDip M.W.M.Soc
Business Development Manager

greenwood@cavimax.co.uk
(07912) 210369
www.cavimax.co.uk

CAVIMAX LTD, Lowbrook Farm, Belchalwell,
Blandford Forum, Dorset, DT11 0EQ, United Kingdom

Hydrodynamic Cavitation Technology
www.cavimax.co.uk

CAVIMAX.

biogas / bioresources / biomass disintegration / extractions
oils & biofuels / food & drink / water treatment

Process Intensification
Sustainable Chemistry
Upscaling Bioresources
Circular Economies
Disruptive Technology

CaviMax Cavitation @CAVIMAXltd