STRATEGIES IN THE DEVELOPMENT OF INNOVATIVE VIRGIN OLIVE OIL EXTRACTION PLANTS

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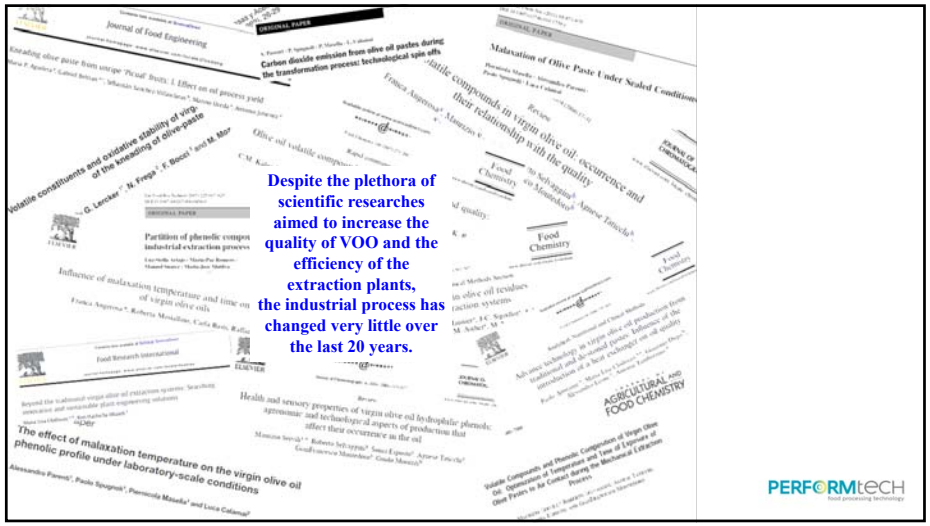
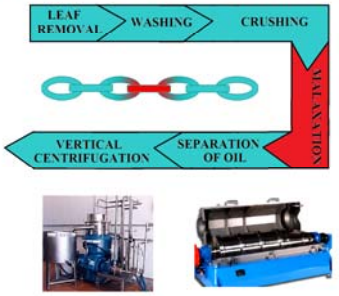


Despite the plethora of scientific researches aimed to increase the quality of VOO and the efficiency of the extraction plants, the industrial process has changed very little over the last 20 years.

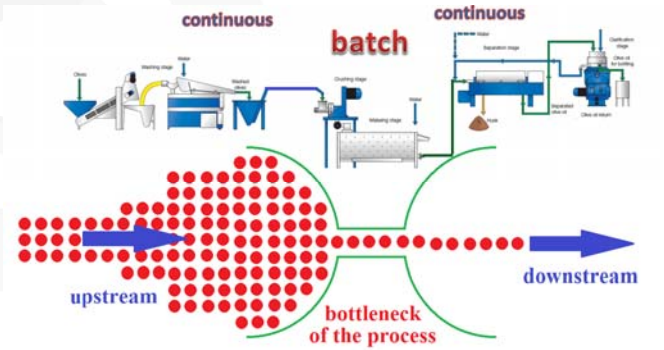
The last big revolution in the VOO extraction plants has been the introduction of the horizontal centrifuge (decanter), coupled with the malaxation machine



If we look at the continuous extraction system we can see that it is composed by a series of devices able to work in a continuous mode.

The weakest link of the chain in the VOO extraction process is the malaxation.

The malaxation phase actually represents the "bottleneck" of the continuous extraction process.



A bottleneck is a stage in a process that causes the entire process to slow down.

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Currently the system used to guarantee continuity to the process, without interrupting the activity of the machines upstream and downstream of the malaxer, consists in placing several malaxing machines in parallel, with an heavy economic investment.

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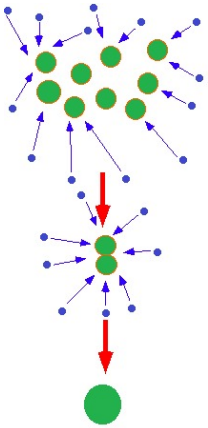
Traditionally, the malaxing step consists of a low and continuous kneading of olive paste at a carefully monitored temperature. This phase is especially useful for achieving high and satisfactory yields of extraction. In fact, this essential technological operation helps the small droplets of the oil formed during the milling to merge into large drops that can be easily separated through a centrifugal system.



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In addition, this operation disrupts a proportion of the oily cells remained unbroken during the crushing, allowing the recovery of another oil fraction.

However, malaxation of olive paste must be considered much more than a simple physical separation, because a complex bioprocess takes place that is very relevant to the quality and composition of the final product.

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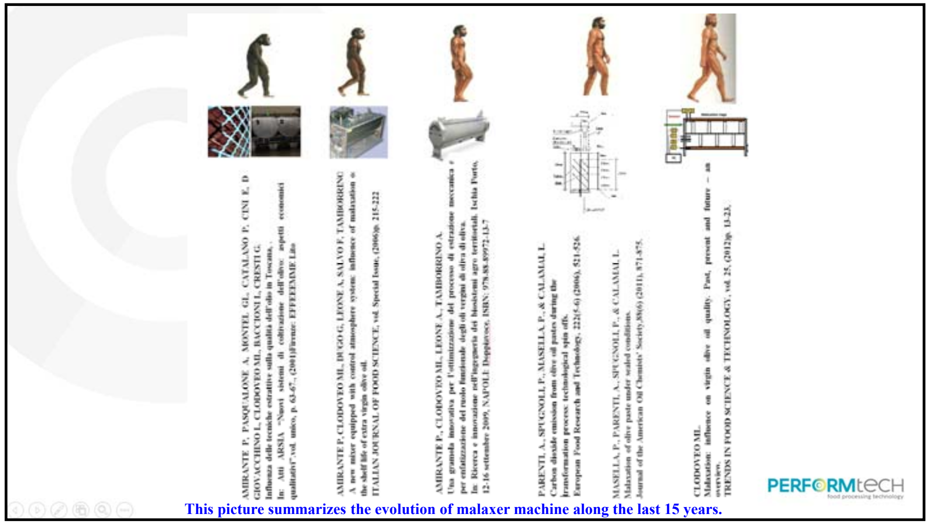
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This picture summarizes the evolution of malaxer machine along the last 15 years.


WHAT'S THE NEXT
CHALLENGE
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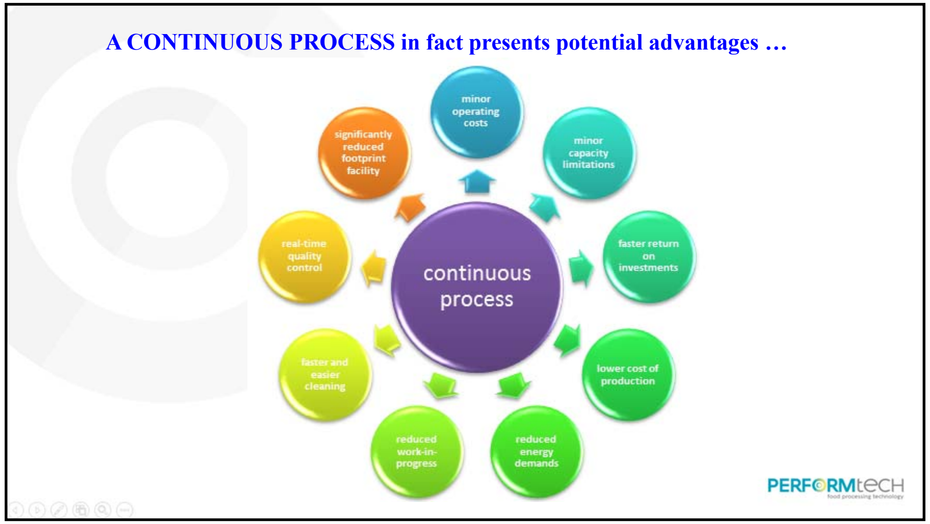
A CONTINUOUS PROCESS in fact presents potential advantages …
continuous process
minor operating costs
minor capacity limitations
faster return on investments
lower cost of production
reduced energy demands
reduced work-in-progress
faster and easier cleaning
real-time quality control
significantly reduced footprint facility
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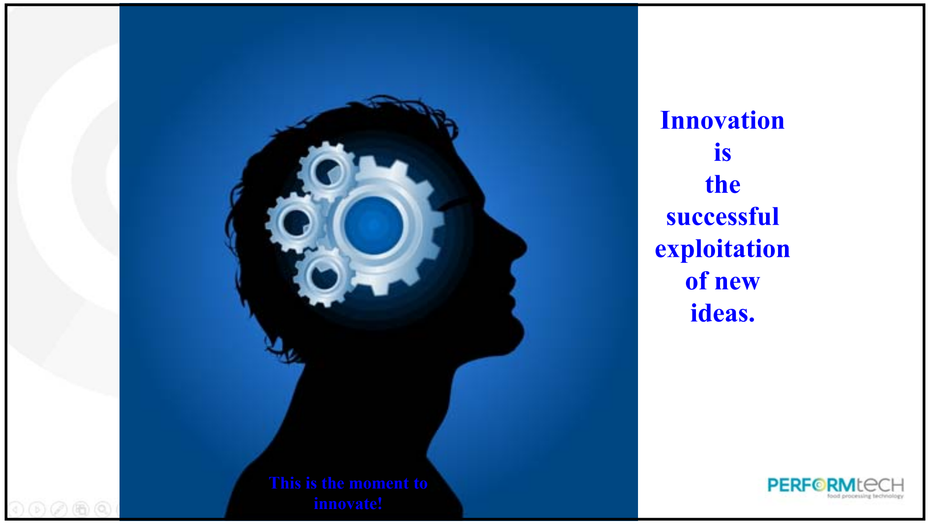
Innovation is the successful exploitation of new ideas.
This is the moment to innovate!
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Starting from these observations I explored the possibility to include in the VOO extraction process an emerging food technology such as ULTRASOUNDS and MICROWAVES

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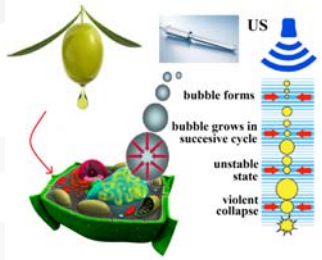

Ultrasounds are sound waves with frequencies higher than the upper audible limit of human hearing.

Ultrasound devices operate with frequencies from 20 kHz up to several gigahertz.

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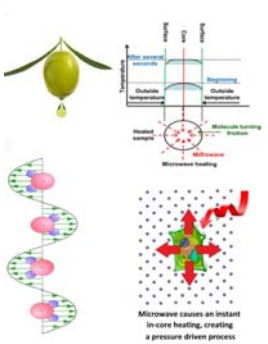
Microwaves are a form of electromagnetic radiation with wavelengths ranging from one meter to one millimeter; with frequencies between 300 MHz (100 cm) and 300 GHz (0.1 cm).

Microwave radiation at a frequency near 2.45 GHz (12 cm) can cause dielectric heating primarily by absorption of the energy in water present in many foods.



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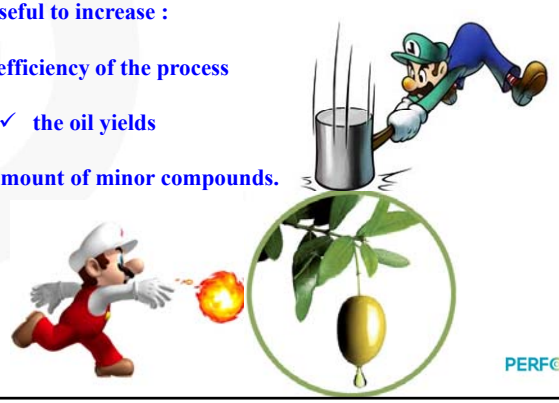
Both ULTRASOUNDS and MICROWAVES have THERMAL AND MECHANICAL EFFECTS useful to increase :

- ✓ the efficiency of the process
- ✓ the oil yields
- ✓ and the amount of minor compounds.



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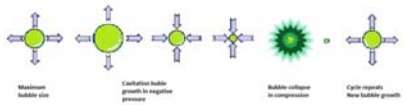
Ultrasounds

The mechanical effect of ultrasounds is mainly due to cavitation phenomena.
Cavitation is the formation, growth and implosion of gas bubbles at high negative pressure, which promotes the release of minor compounds from the plant tissue by disrupting the cells.



The thermal effect of ultrasound occurs as kinetic energy from the ultrasound waves is absorbed by a medium. Absorption is a mechanism that represents that portion of ultrasonic wave that is converted into heat.

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Microwaves

Microwave heating is a process in which the materials couple with microwaves, absorb the electromagnetic energy volumetrically, and transform it into heat .

Microwave technology presents also a mechanical effects due to the heating which determines an increasing of the vegetal tissue volume and, in this way, cells explode releasing their content into the liquid phase.

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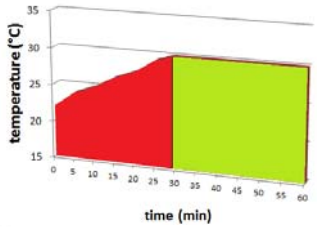
Changing a process needs to start from an accurate observation of the weaknesses of the current technology



Monitoring the olive paste temperature trend during the malaxation
we can distinguish two different periods:
- the pre-heating
- The real malaxation phase

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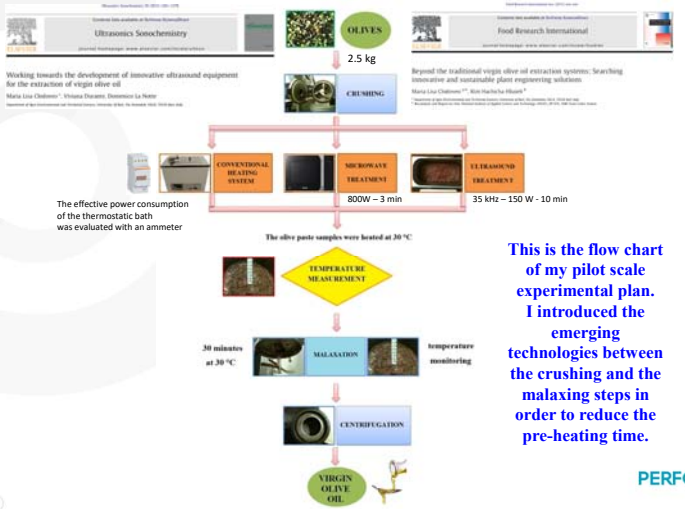

This is the flow chart of my pilot scale experimental plan. I introduced the emerging technologies between the crushing and the malaxing steps in order to reduce the pre-heating time.

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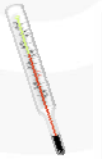
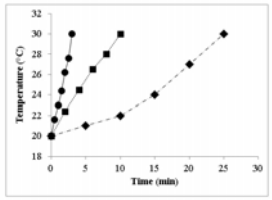
Thermal effect of US and MW on olive paste and its influence on the length of malaxation

US and MW processes reduced significantly the pre-heating stage of the malaxation: the industrial application of these technologies could represent the first step toward a continuous malaxing phase.





Influence of the olive paste heating system on the duration of the pre-heating stage: conventional heating method (♦), US treatment(■) MW treatment(●).

This picture summarizes the obtained results.

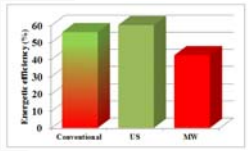
As you can see, the main parameters legally established (acidity, peroxide value, and specific extinction coefficients (K_{232} and K_{270})) to evaluate VOO quality were not affected by the US and MW treatments.

	Free acidity (%)				Peroxide Value (meq O_2/kg)				K_{232}				K_{270}			
	I		II		I		II		I		II		I		II	
	mv	SD	mv	SD	mv	SD	mv	SD	mv	SD	mv	SD	mv	SD	mv	SD
Conventional heating	0.30±0.02		0.35±0.03		6.19±0.39		6.65±0.41		1.48±0.01		1.49±0.01		0.10±0.01		0.11±0.01	
US heating	0.31±0.04		0.36±0.04		5.77±0.42		6.45±0.38		1.48±0.00		1.49±0.01		0.11±0.01		0.12±0.01	
MW heating	0.29±0.02		0.34±0.03		6.31±0.35		7.1±0.49		1.49±0.01		1.49±0.00		0.10±0.01		0.11±0.01	

Average values of some qualitative parameters of extracted VOOs employing three different methods: conventional heating, US and MW in a pilot scale plant. Olive oil extraction experiments were performed in triplicate in two different weeks (I, II), and chemical analysis of the oil obtained were conducted in duplicate. The results were expressed as mean value (mv) ± Standard Deviation (SD).

Beyond the traditional virgin olive oil extraction systems: Searching innovative and sustainable plant engineering solutions

Maria Lisa Clodoveo [a,*], Rim Hachicha Hbaieb [b]



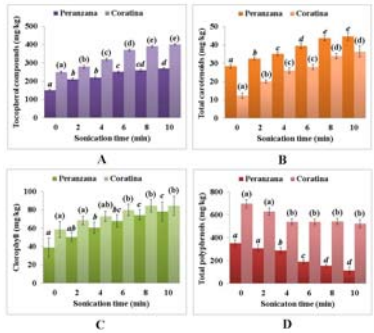
The energetic efficiency of the three different heating systems (conventional, US and MW).

$$\eta = \frac{transferred\ heating\ power\,(\mathrm{W})}{input\ electric power\,(\mathrm{W})} \cdot 100.$$

The evaluation of the energetic efficiency shows that ultrasound treatment was the most sustainable system to warm up the olive paste until the process temperature.

As previously mentioned, cavitation phenomena are responsible for the disruption of cell tissues releasing minor compounds.

The increasing of sonication time determined the increment of tocopherols, carotenoids and chlorophylls. The decrement in polyphenol content could be due to the exposition to the oxygen in this experimental conditions.



Changes in concentrations of tocopherols (mg/kg) (A), total carotenoids (mg/kg) (B), chlorophylls (mg/kg) (C) and total phenols (mg/kg) (D) of VOOs extracted employing the traditional method and after sonication treatment of olive paste for 2, 4, 6, 8 and 10 minutes.

Ultrasounds

The mechanical effect of olive paste is clear also observing the oil yields.

At pilot scale the average increase of extracted VOO after 8 minutes of sonication was about 8 g per kilogram of olives.

Treatment	Yield (%)		
	mv	SD	
Untreated	16.2	±0.3	a
Ultrasound treatment on olive paste (4 min)	16.8	±0.5	ab
Ultrasound treatment on olive paste (8 min)	17.2	±0.3	b

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In an industrial full scale plant with a working capacity of 2000 kg of olives/h, if the plant works 8 h/day, with an average extraction yield of 16%, it produces about 2500 kg of VOO per day.

Employing the ultrasound technology, assuming at least an increase of about 5 g of extracted VOO per kilogram of olives, the quantity of extracted VOO per day could increase of about of 80 kg with an increment of 3% of the total VOO production.

Treatment	Yield (%)		
	mv	SD	
Untreated	16.2	±0.3	a
Ultrasound treatment on olive paste (4 min)	16.8	±0.5	ab
Ultrasound treatment on olive paste (8 min)	17.2	±0.3	b

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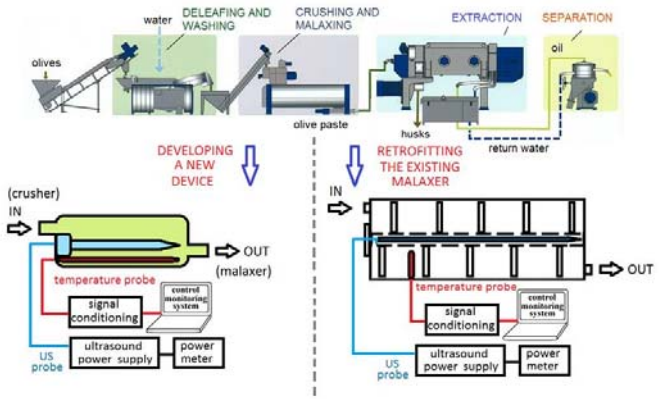
Is it easy to scale-up this technology?

The scaling up of this technology can be realized following two hypothesis:



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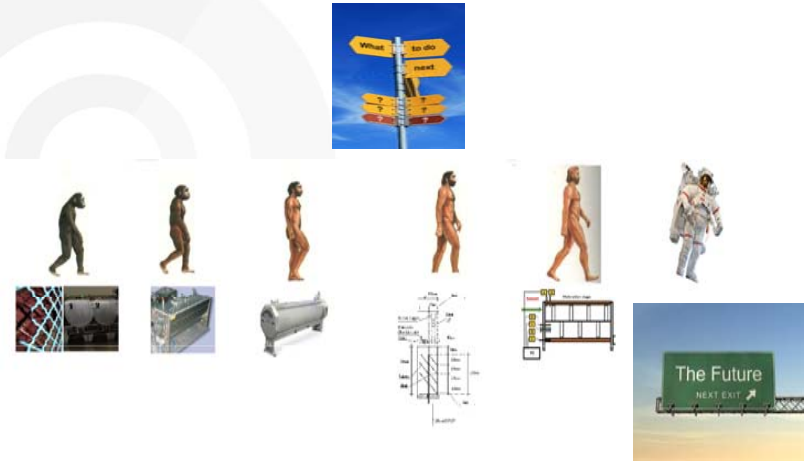

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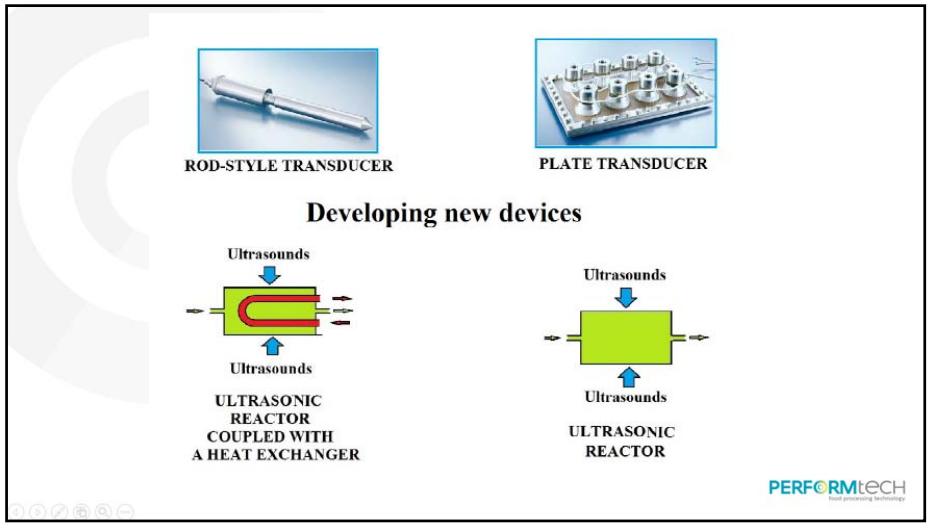
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PLATE TRANSDUCER
Developing new devices
Ultrasounds
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