Center of ultrasonic technologies

THEORETICAL FOUNDATIONS OF THE POSSIBILITY AND SENSITIVITY OF MEDIA CONTROL ACCORDING TO THE PARAMETERS OF PIEZOELECTRIC SYSTEMS

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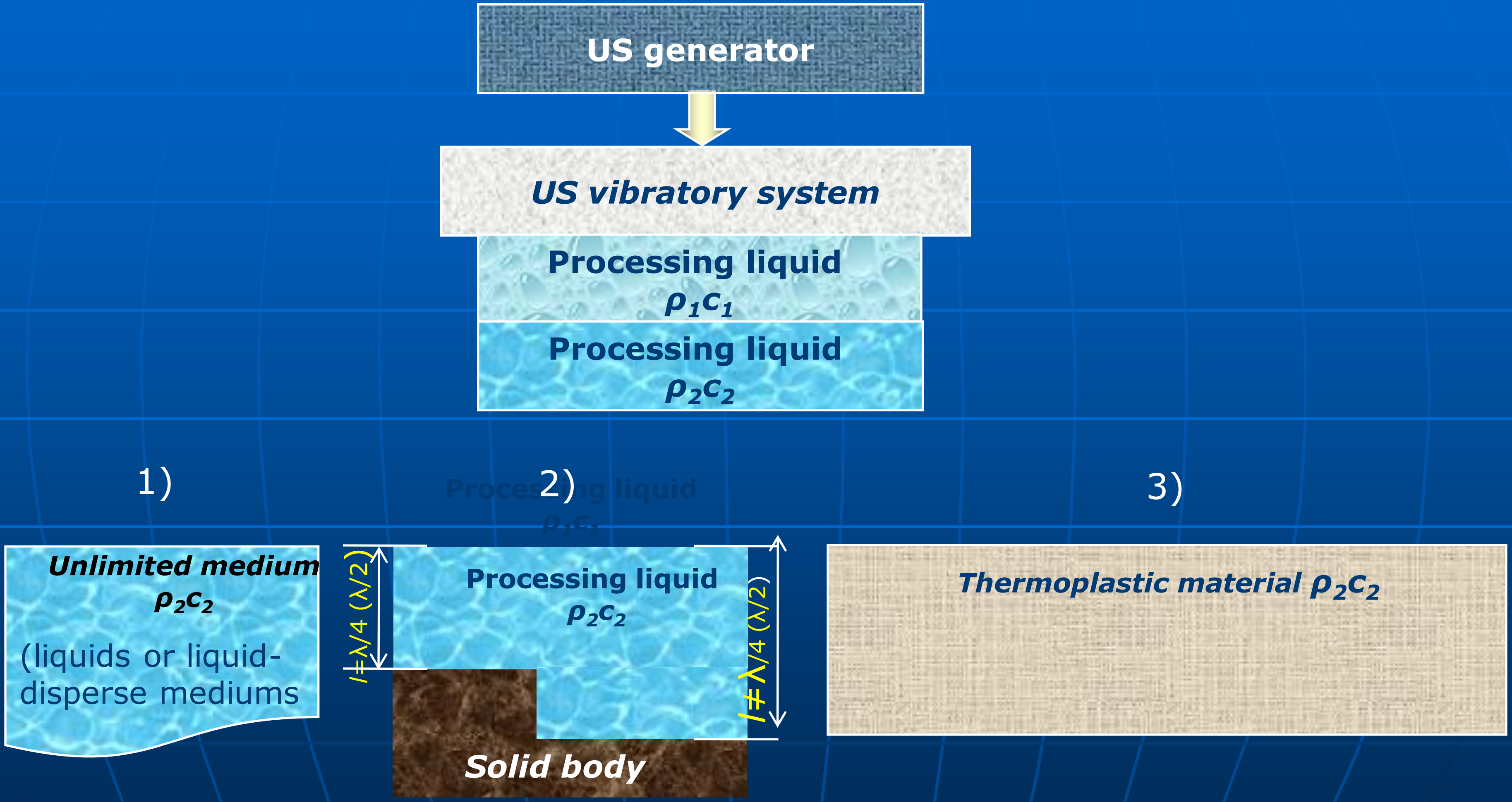
Features of ultrasonic exposure



US generator

US vibratory system

Processing liquid
$\rho_1 c_1$

Processing liquid
$\rho_2 c_2$

1)

Unlimited medium
$\rho_2 c_2$

(liquids or liquid-disperse mediums

2)

Processing liquid
$\rho_2 c_2$

$l \neq \lambda/4\ (\lambda/2)$

$l \neq \lambda/4\ (\lambda/2)$

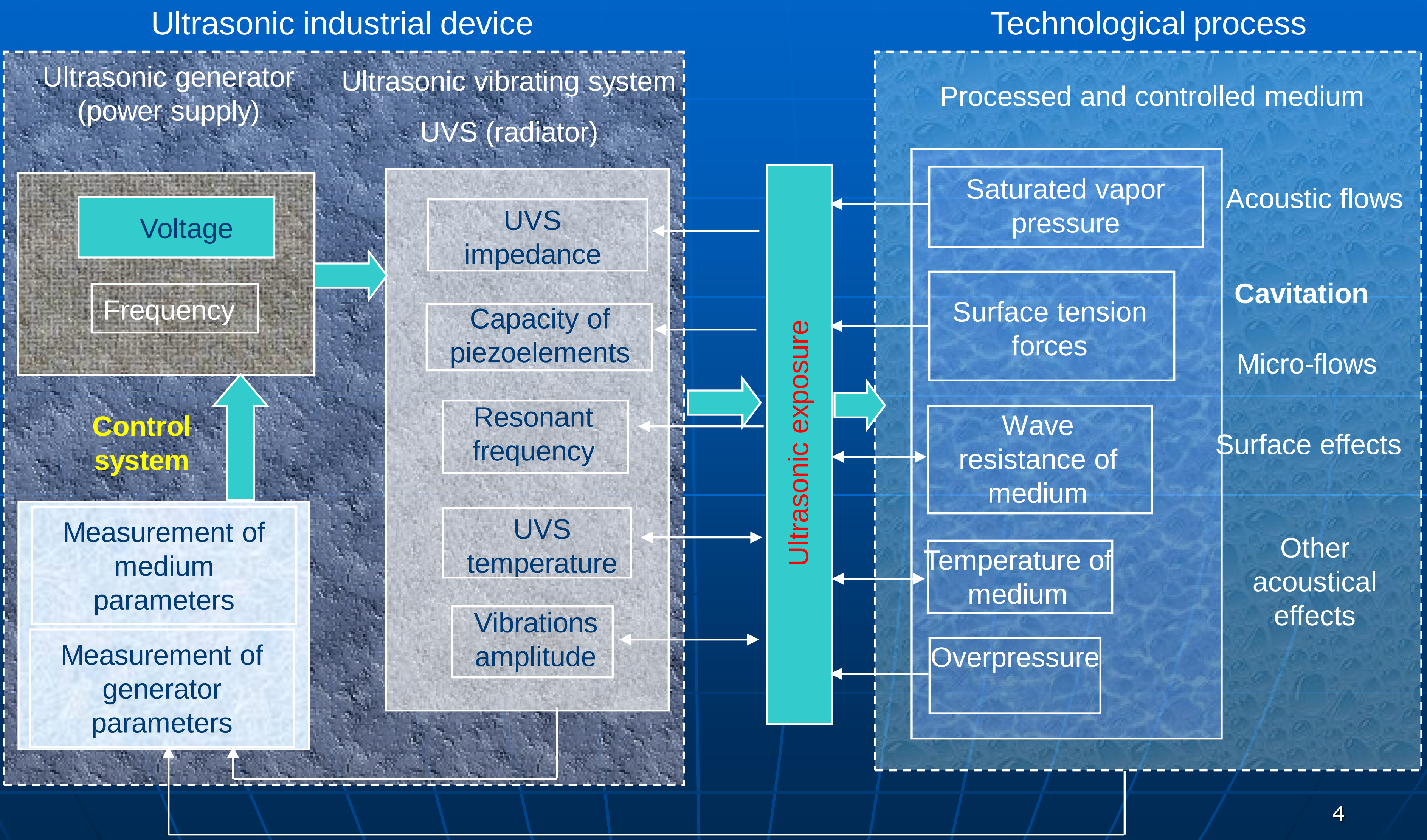
Solid body

3)

Thermoplastic material $\rho_2 c_2$

The absence of the criteria of continuous monitoring of the processing mediums parameters

Ultrasonic exposure



Ultrasonic industrial device

Ultrasonic generator (power supply)

Voltage

Frequency

Control system

Measurement of medium parameters

Measurement of generator parameters

Ultrasonic vibrating system

UVS (radiator)

UVS impedance

Capacity of piezoelements

Resonant frequency

UVS temperature

Vibrations amplitude

Ultrasonic exposure

Technological process

Processed and controlled medium

Saturated vapor pressure

Surface tension forces

Wave resistance of medium

Temperature of medium

Overpressure

Acoustic flows

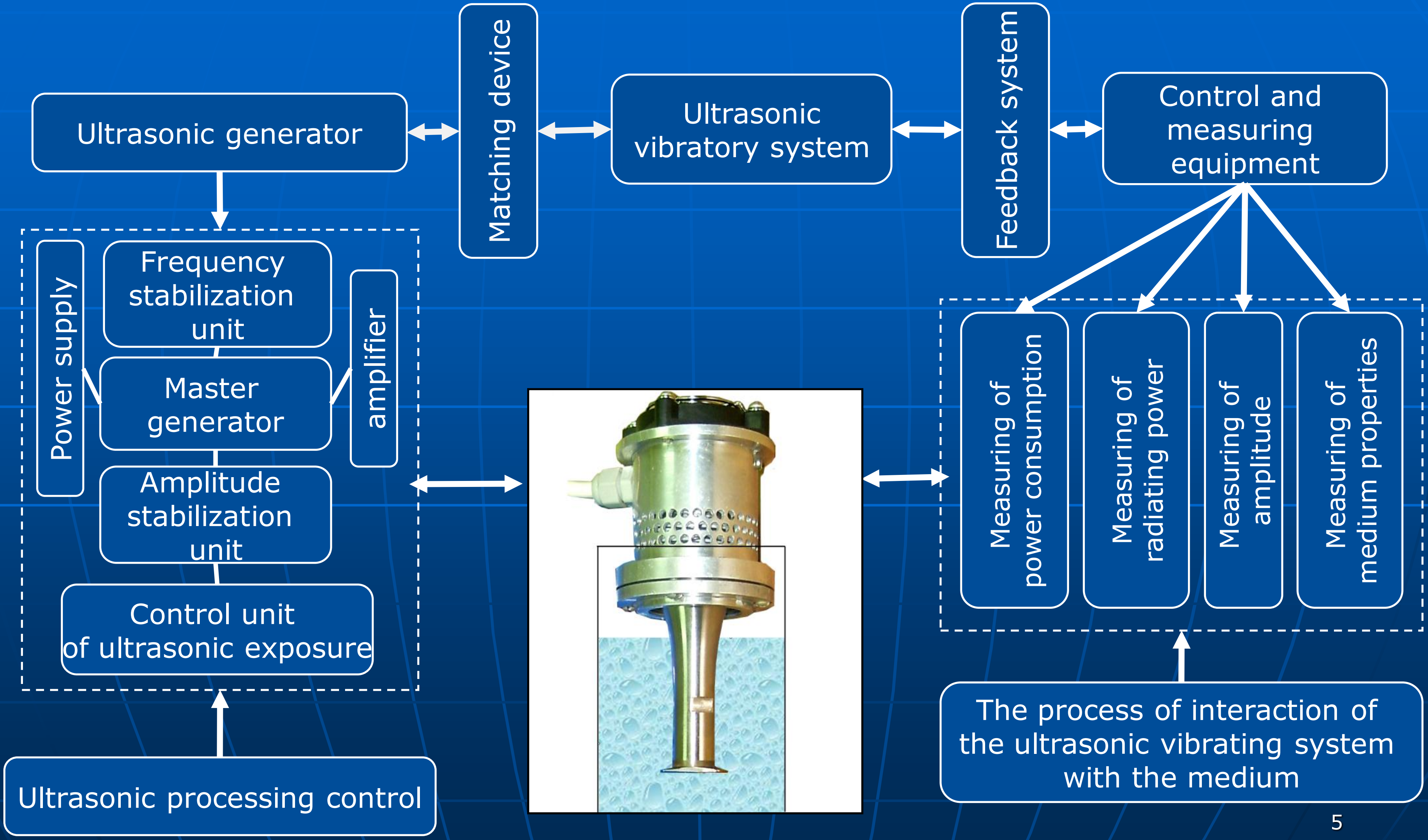
Cavitation

Micro-flows

Surface effects

Other acoustical effects

Ultrasonic industrial device



Ultrasonic generator

Matching device

Ultrasonic vibratory system

Feedback system

Control and measuring equipment

Power supply

Frequency stabilization unit

Master generator

amplifier

Amplitude stabilization unit

Control unit of ultrasonic exposure

Ultrasonic processing control

Measuring of power consumption

Measuring of radiating power

Measuring of amplitude

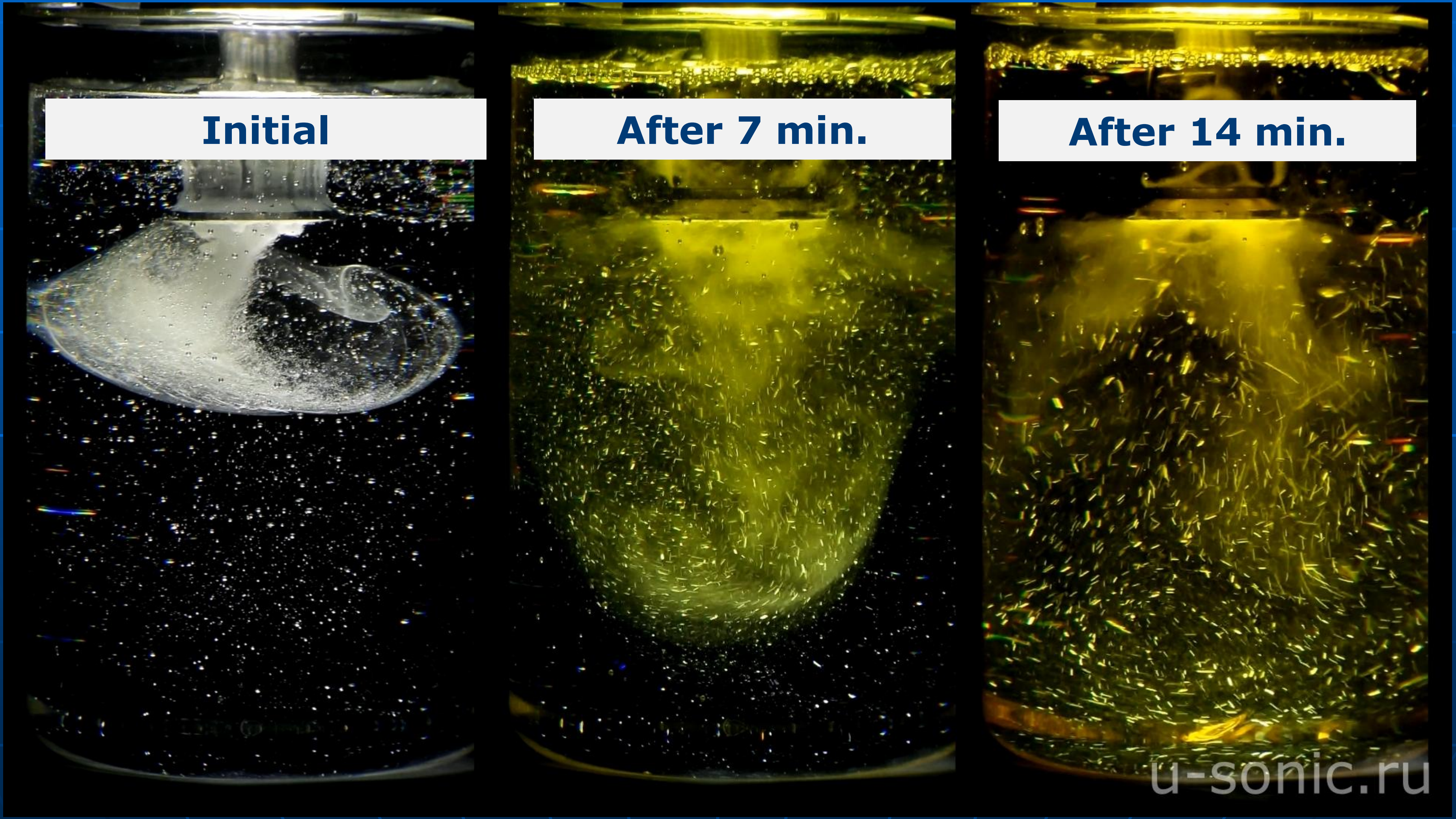
Measuring of medium properties

The process of interaction of the ultrasonic vibrating system with the medium

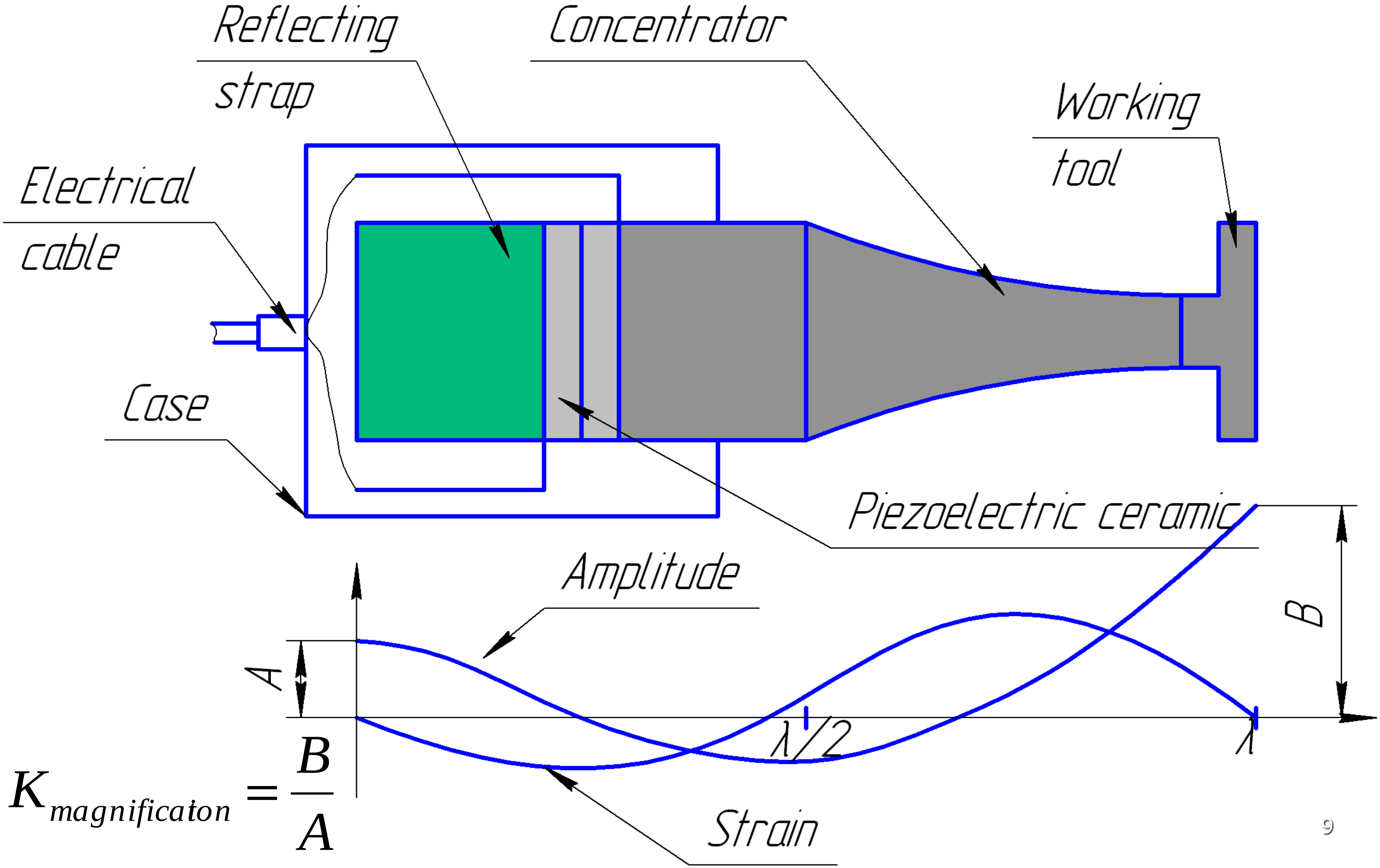
Drilling of frozen soil with temperature of liquid nitrogen

Ultrasonic exposure of melted metal (T more than 1000 C)

Influence of liquid medium temperature



Ultrasonic oscillation system



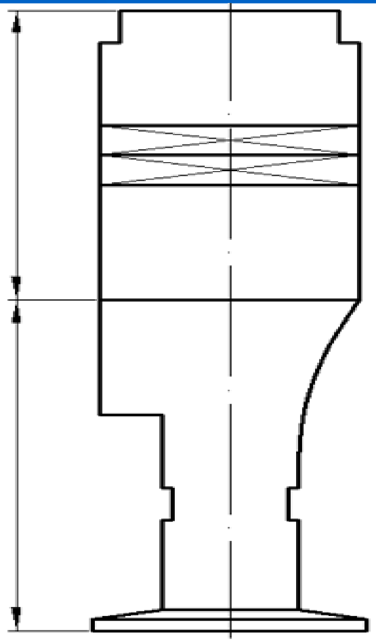
$$K_{magnificaton} = \frac{B}{A}$$

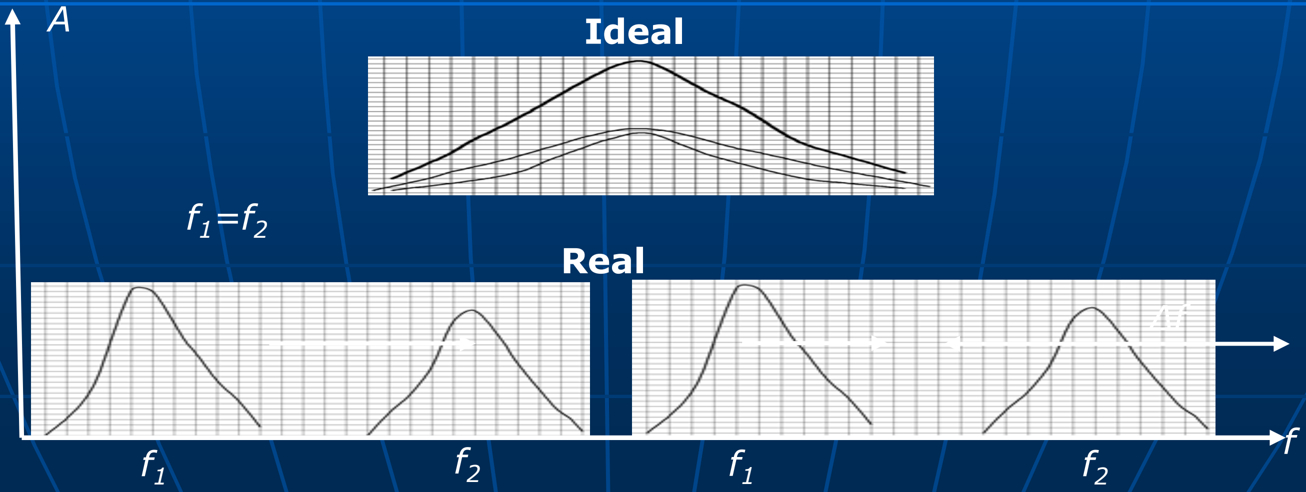
Main problem of vibratory system

1. Low efficiency (<50%)
2. High weight and length
3. Mismatch

$$f_1 = \frac{2c_1}{\lambda_1}$$

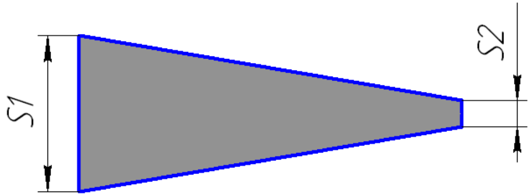
$$f_2 = \frac{2c_2}{\lambda_2}$$





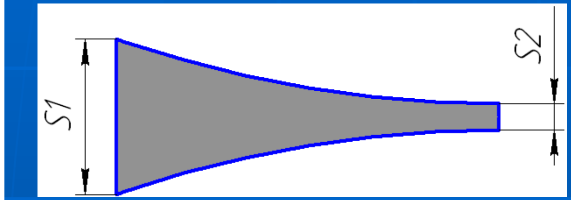
Magnifiers of ultrasonic oscillations

Conical



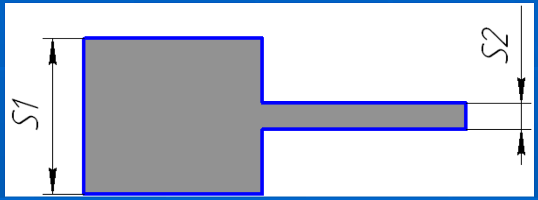
$$K = 0.8\sqrt{\frac{S_1}{S_2}} \quad Q=40$$

Exponential



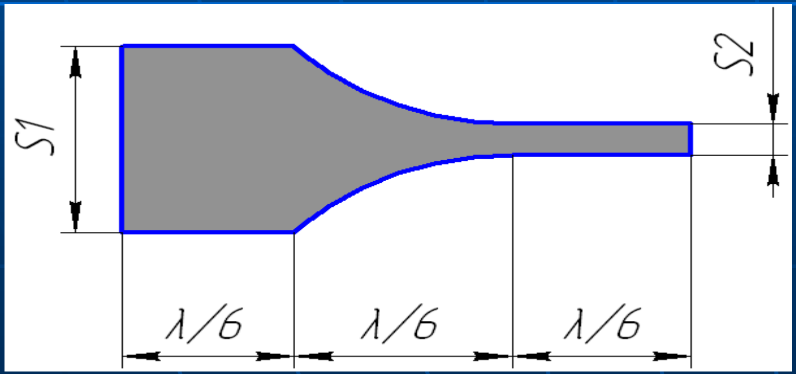
$$K = 1{,}1\sqrt{\frac{S_1}{S_2}} \quad Q=20$$

Stepping



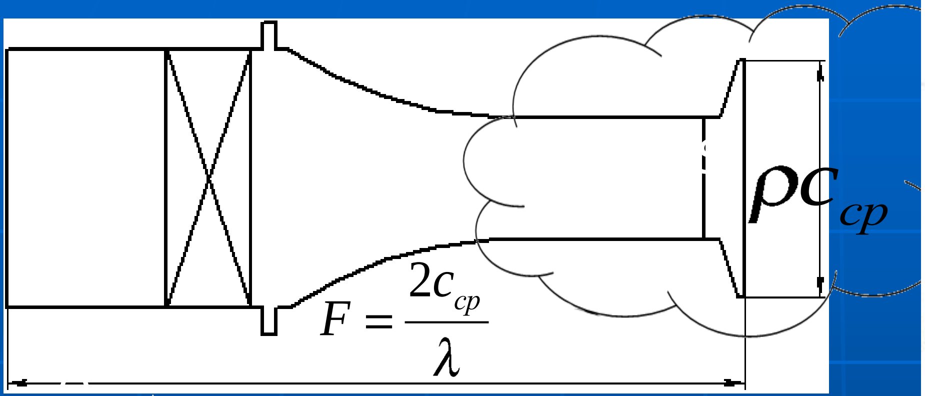
$$K = \frac{S_1}{S_2} \quad Q=150$$

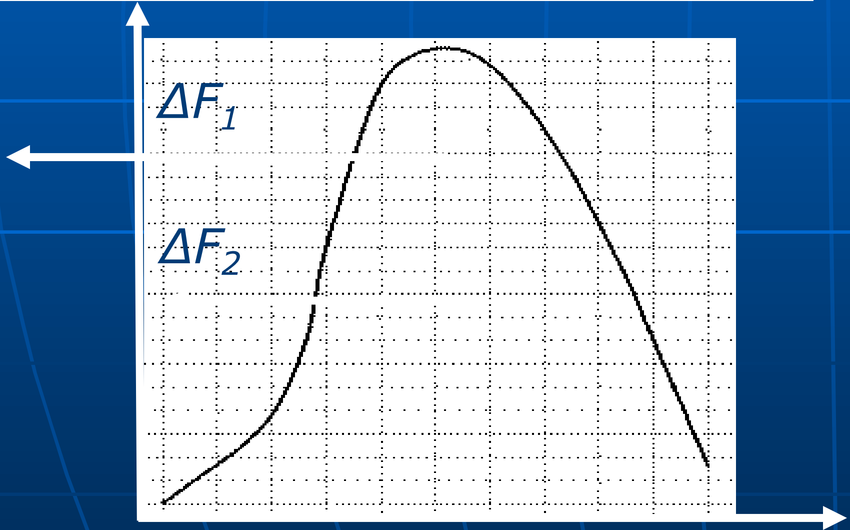
Stepping-exponential concentrator



$$K = (0.8-0.9)\frac{S_1}{S_2}$$

Half-wave vibratory system





Efficiency ≤ 80%

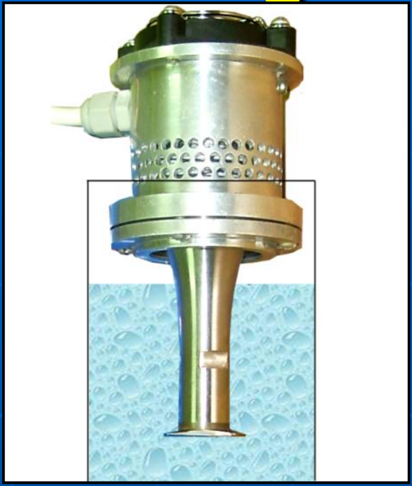
Vibration amplitude ≤100 um

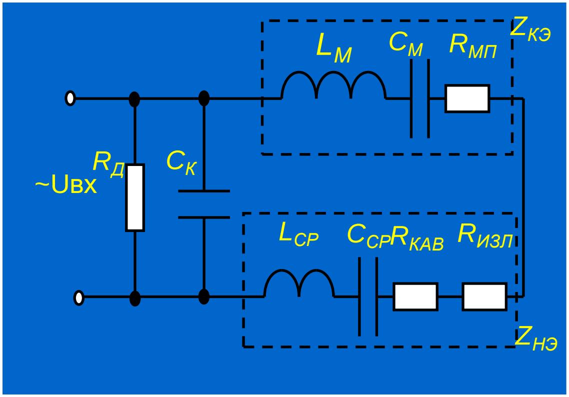
Gain factor ≥20

$\Delta F_1 = f\ (S, \rho c_{medium})$

$\Delta F_2 = f\ (T, U)$

Vibratory system as sensor of technological medium parameters





$R_д$ – resistance of dielectric losses;

$C_к$- capacity of piezoelements;

$R_{мп}$ – mechanical loss resistance;

$C_м$ – equivalent to the flexibility of the vibratory system material;

$L_м$ –equivalent to the mass of the material of the vibratory system;

$C_{ср}$, $L_{ср}$ – -elements that characterize the reactive properties of the processing medium;

$R_{изл}$ – element that characterizes the wave resistance of the medium;

$R_{кав}$ – an element that characterizes the energy costs for the creation and maintenance of cavitation;

$Z_{кэ}$ –impedance of the vibratory system;

$Z_{нэ}$ – impedance of the acoustic load.

$z=(z_{кэ}+z_{нэ})$;

$z_{нэ}=f(R_{кав}; R_{изл}; L_{ср})$;

$R_{изл}=f(\rho_{ср}c_{ср})$-output energy;

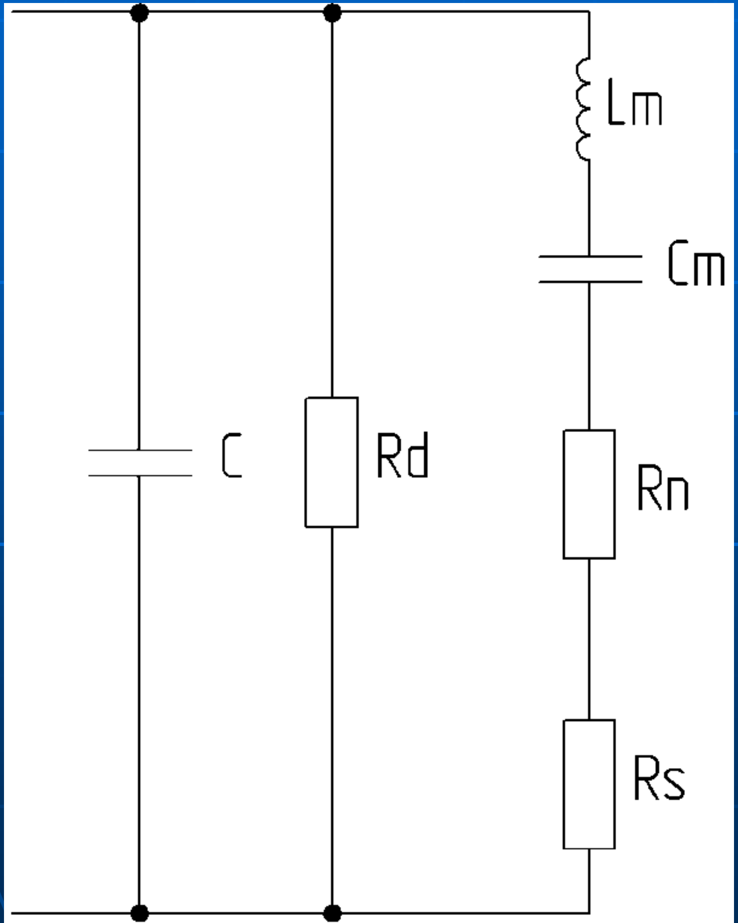
$L_{ср}=f(m_{присоед.})=f(\rho_{ср})$

Resonance properties;

$f_{рез}=f(\rho_{ср})$.

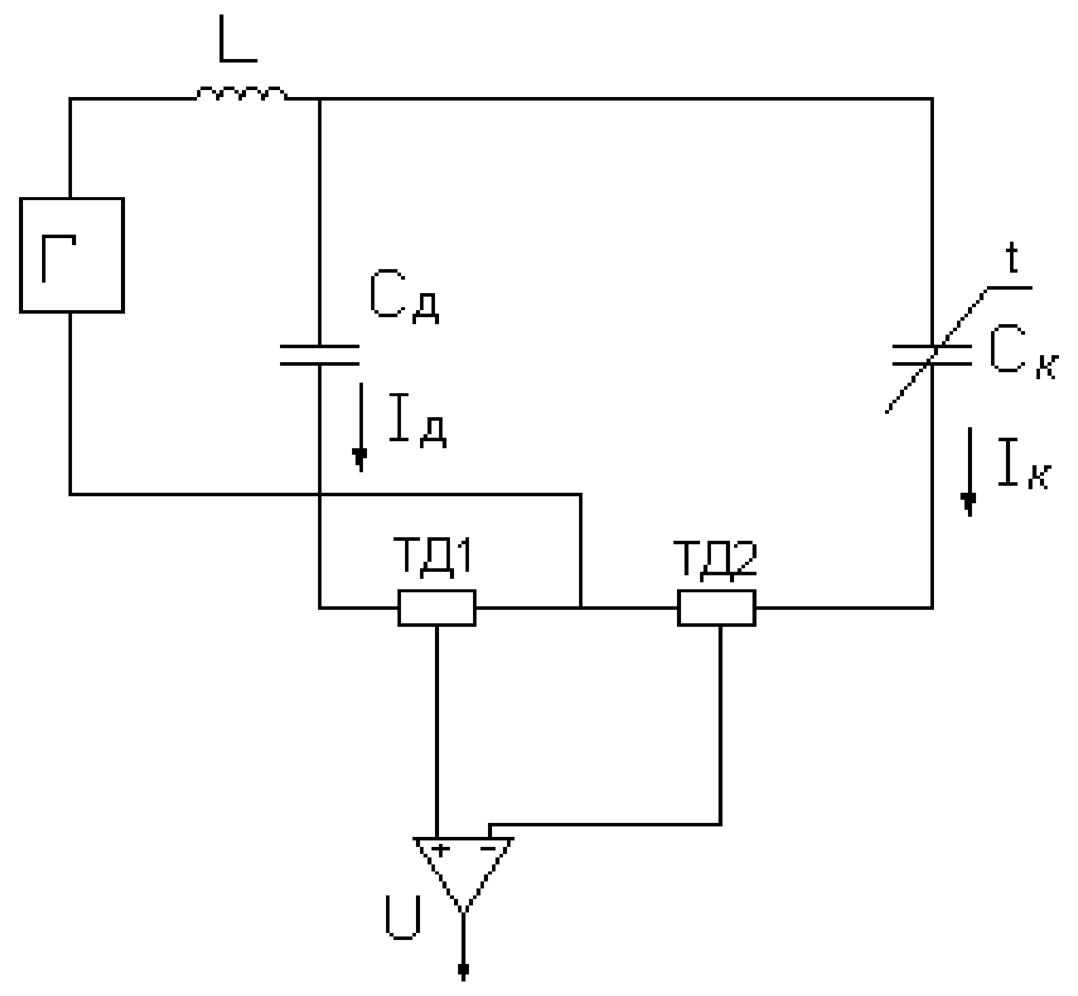
On the basis of the electrical equivalent circuit of the vibratory system, the dependences of its electrical parameters on the characteristics of the acoustic load and its own properties are obtained. This is makes it possible to measure the acoustic characteristics of medium.

A model of the vibratory system as a physical equivalent circuit

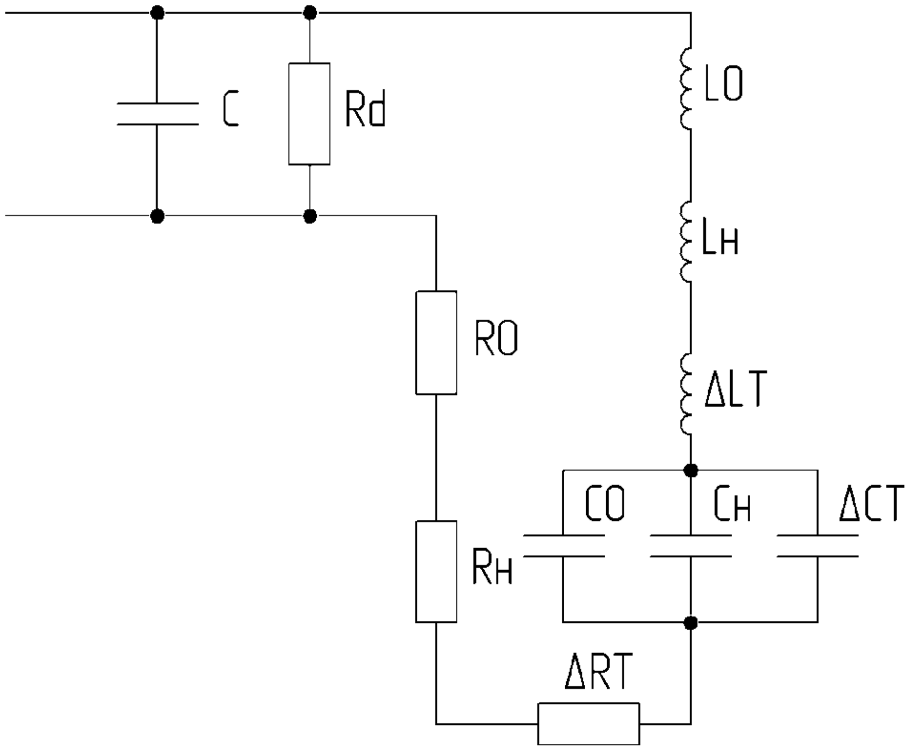


C – static capacity of piezoelements;
Rd – dielectric loss resistance;
Lm – mechanical branch inductance (equivalent to the vibrating mass of the transducer);
Cm – mechanical branch capacity (equivalent to flexibility);
Rn – mechanical loss resistance;
Rs – radiation resistance.

Control system



A vibratory system model that takes into account the medium parameters



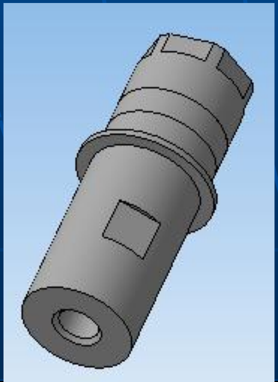
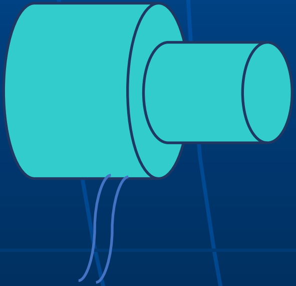
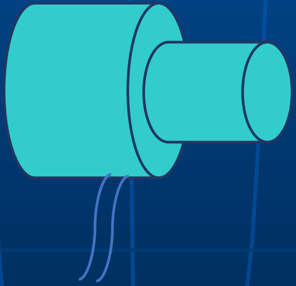
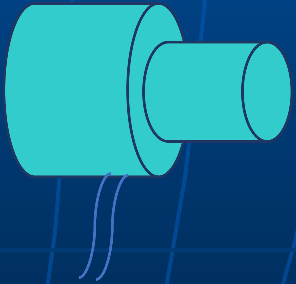
C – static capacity of piezoelements;
Rd – dielectric loss resistance of piezoelements;
$L0$ – inductance of the ultrasonic vibratory system;
$C0$ – capacitance of the ultrasonic vibratory system;
$R0$ – active resistance of the ultrasonic vibratory system;
$L\text{н}$ – acoustic load inductance;
$C\text{н}$ – acoustic load capacity;
$R\text{н}$ – active resistance of the acoustic load;
ΔLT – additional inductance caused by a change in propagation conditions;
ΔCT – additional capacitance caused by a change in propagation conditions;
ΔRT – additional capacitance caused by a change in propagation conditions.

Change in propagation conditions is changing the properties and structure of medium.

THE AIM OF THE RESEARCH IS IDENTIFICATION OF DEPENDENCIES

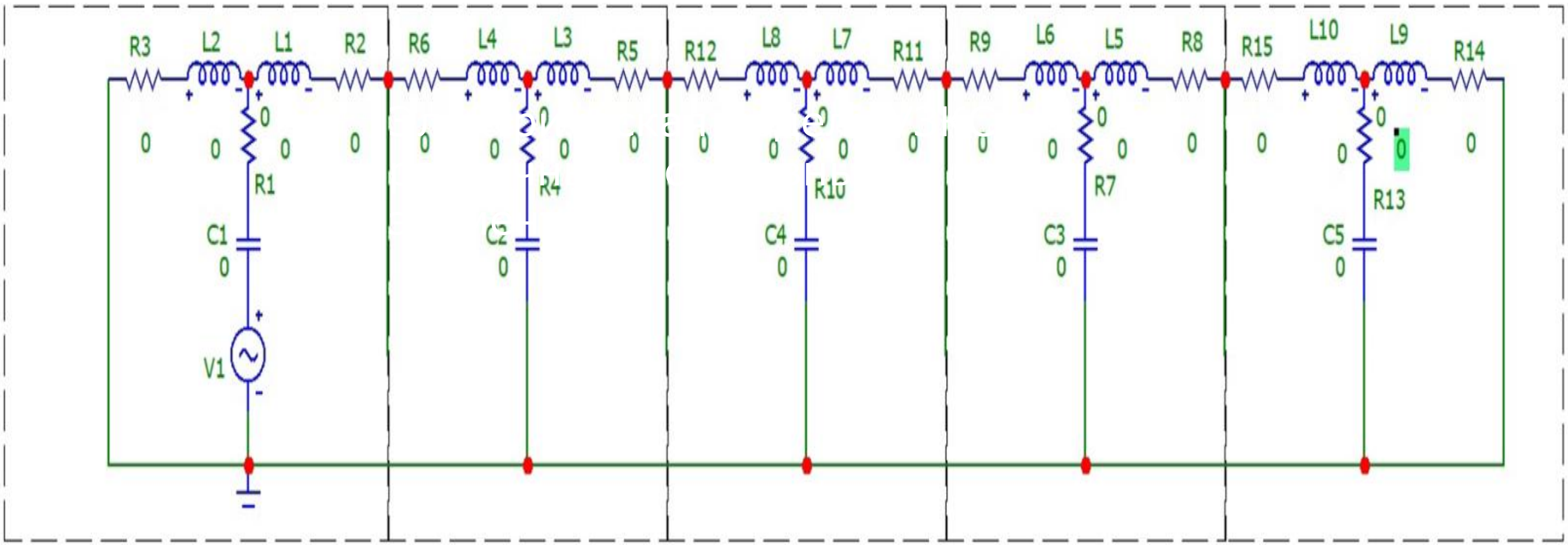
- Influence of changes in the working tool (destruction) on the electrical parameters of the piezoelectric vibratory system.
- Influence of the destruction of the reflecting surface (of the object being destroyed) on the electrical parameters of the piezoelectric vibratory system.
- Influence of changes in the conditions of ultrasonic exposure (increase in distances, change in the properties of materials, deviation from resonant conditions) on the electrical parameters of a piezoelectric vibratory system

THE SCHEME OF REALIZATION OF PROCESSING BY A PIEZOELECTRIC VIBRATORY SYSTEM (CLASSICAL)

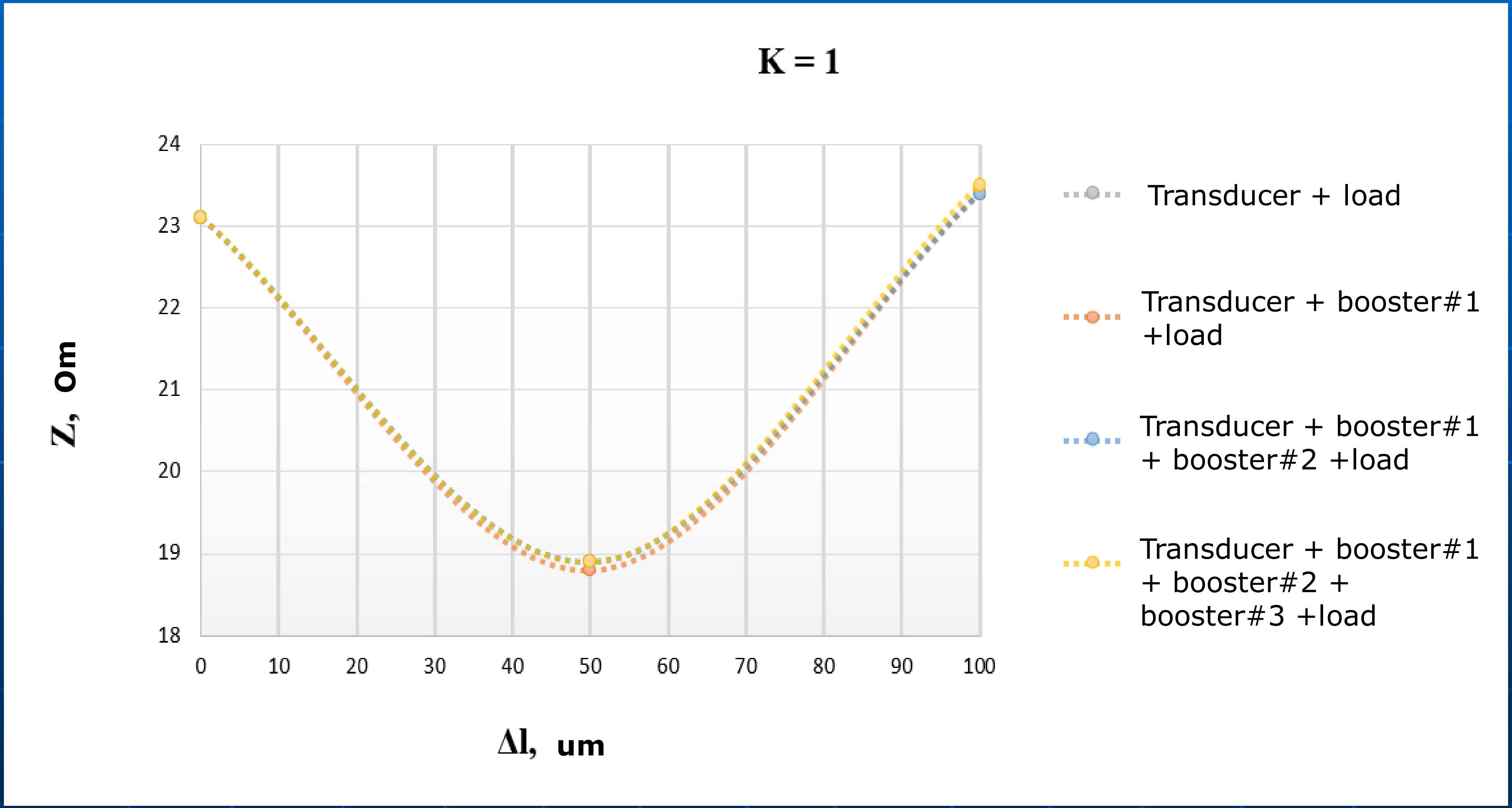
Langevin transducer (half-wave, gain factor 1, 1.5, 2) 	Booster #1 (half-wave, gain factor 1, 1.5, 2) 	Booster #2 (half-wave, gain factor 1, 1.5, 2) 	Booster #3 (half-wave, gain factor 1, 1.5, 2) 	Half-wave cylindrical working tool (load) 

EQUIVALENT ELECTRICAL MODEL OF ULTRASONIC VIBRATORY SYSTEM

Transducer Booster 1 Booster 2 Booster3 Load



The dependence of the impedance on working tool abrasion for various construction of vibratory system



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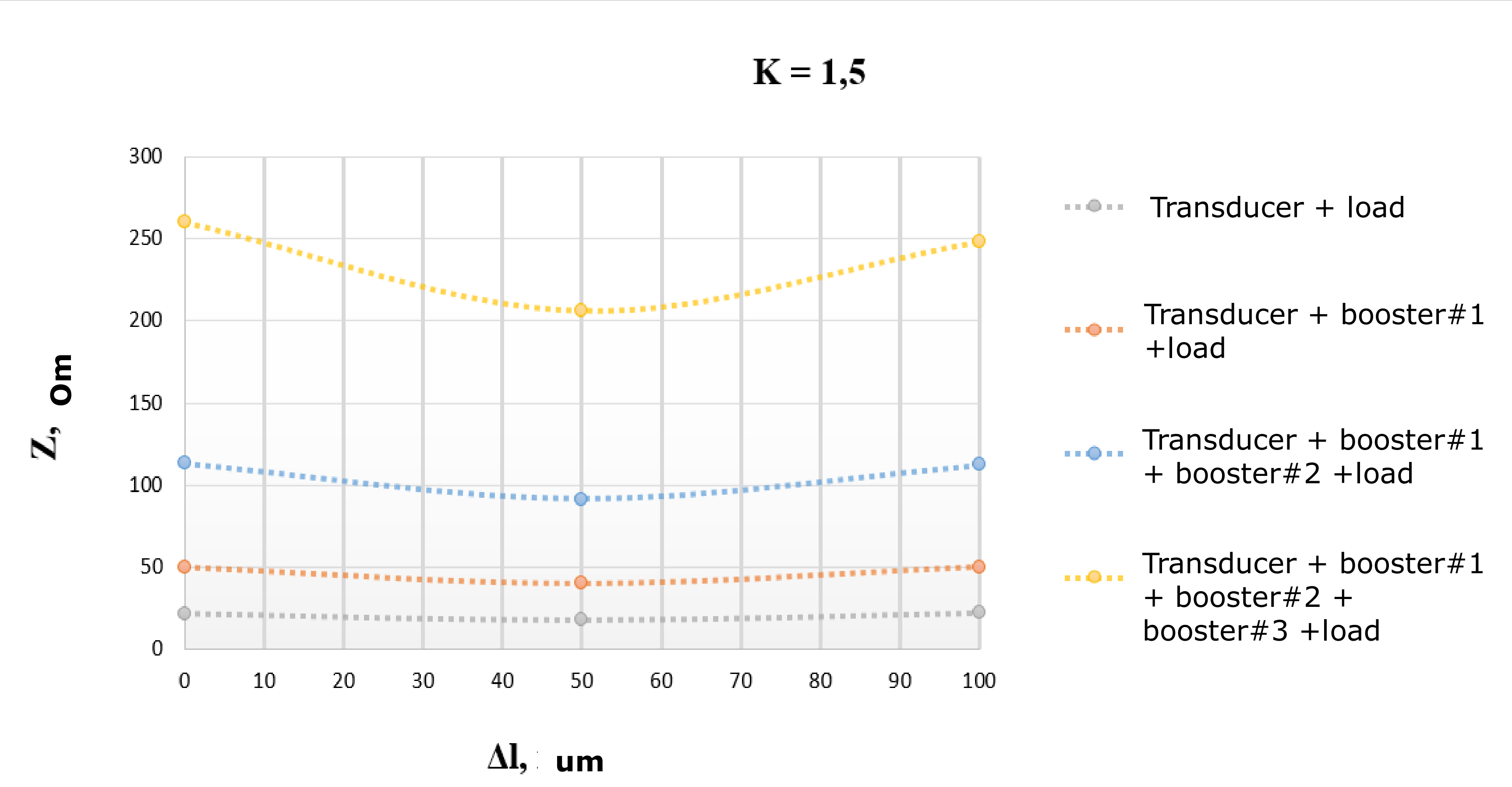

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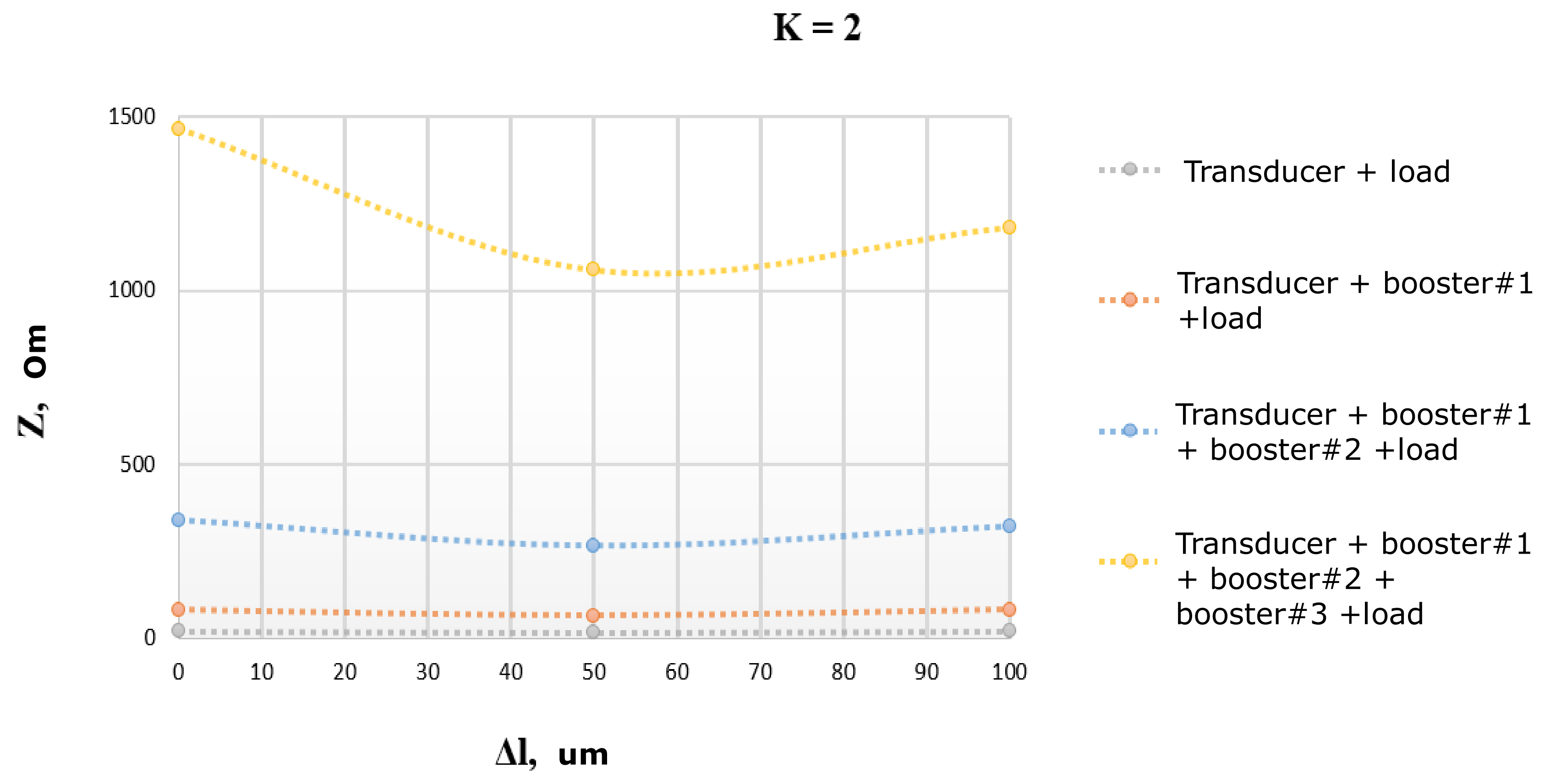
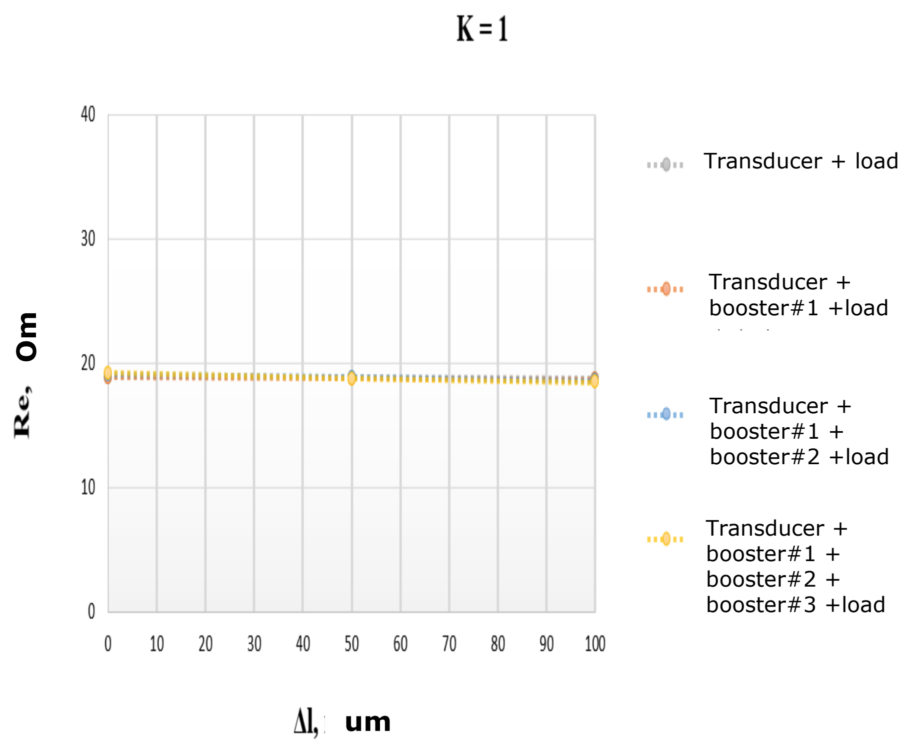
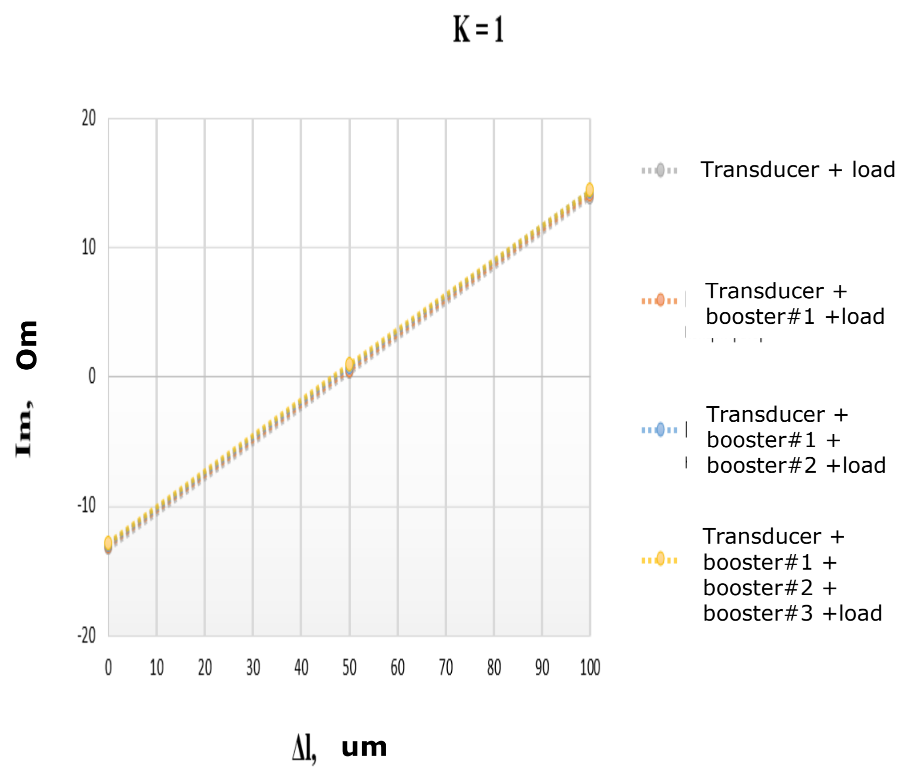


The dependence of the active and reactive resistance on working tool abrasion for various construction of vibratory system

Active resistance

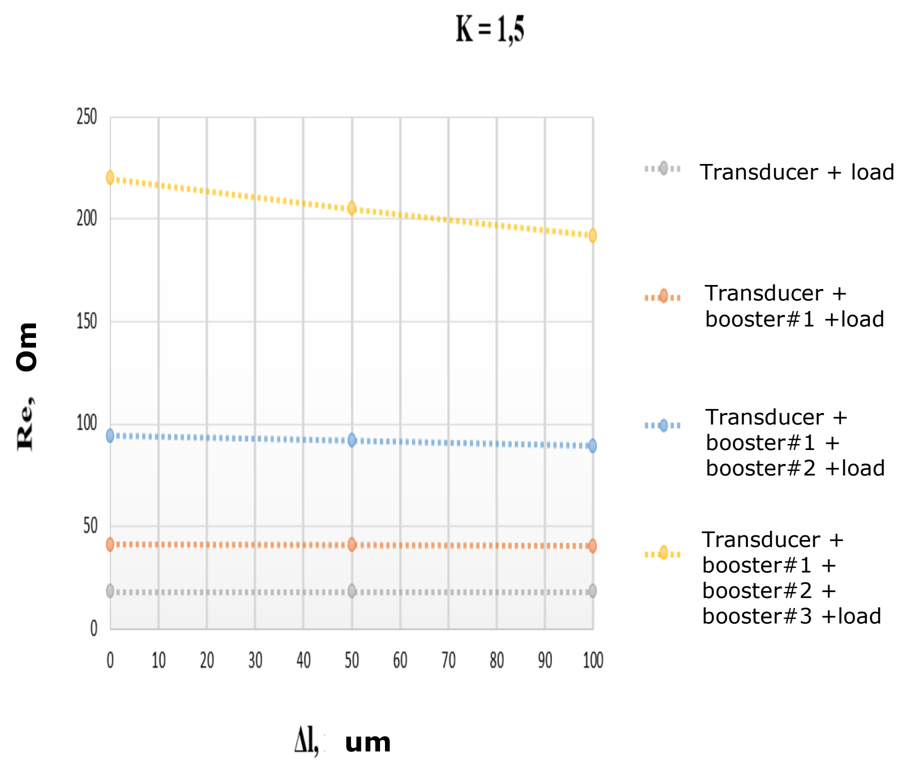


Reactive resistance

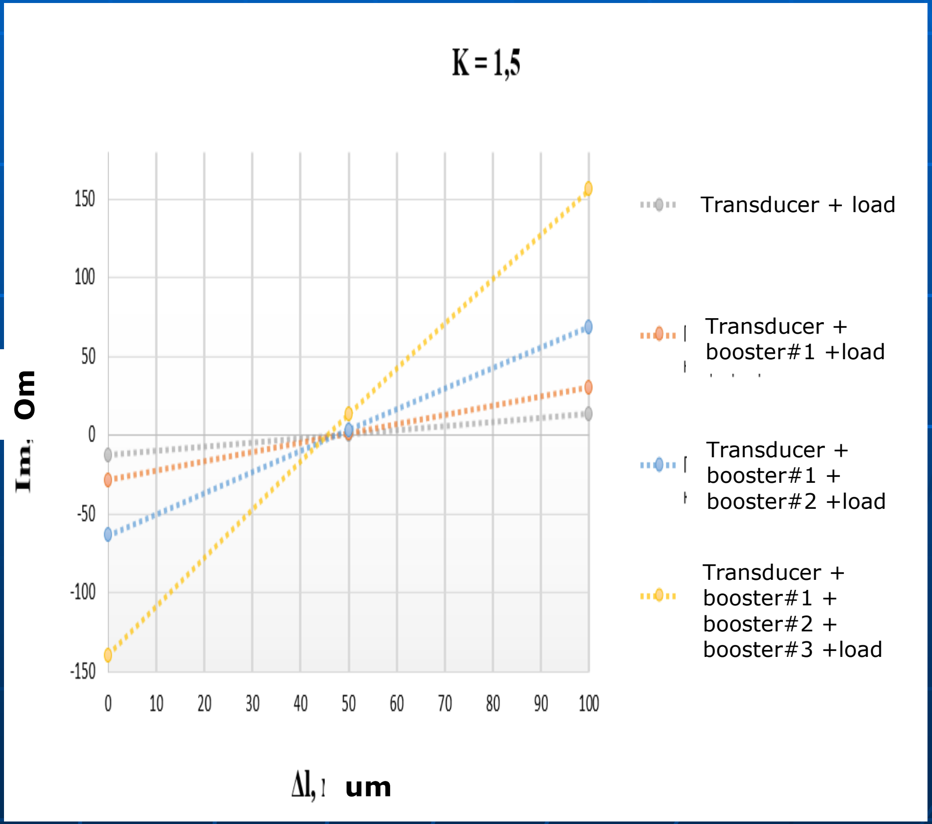


The dependence of the active and reactive resistance on working tool abrasion for various construction of vibratory system

Active resistance

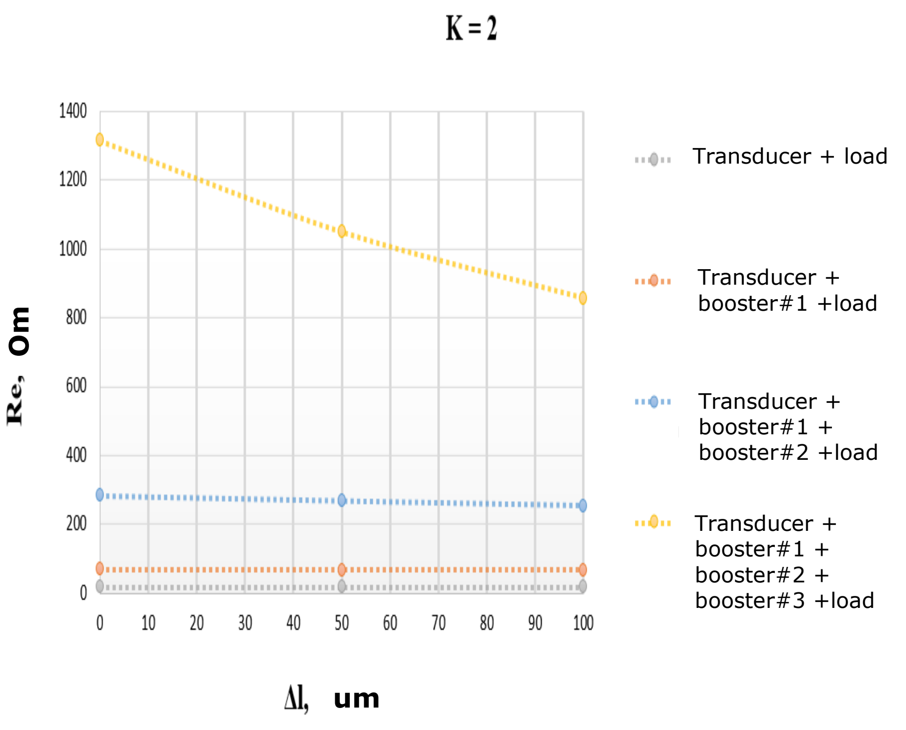


Reactive resistance

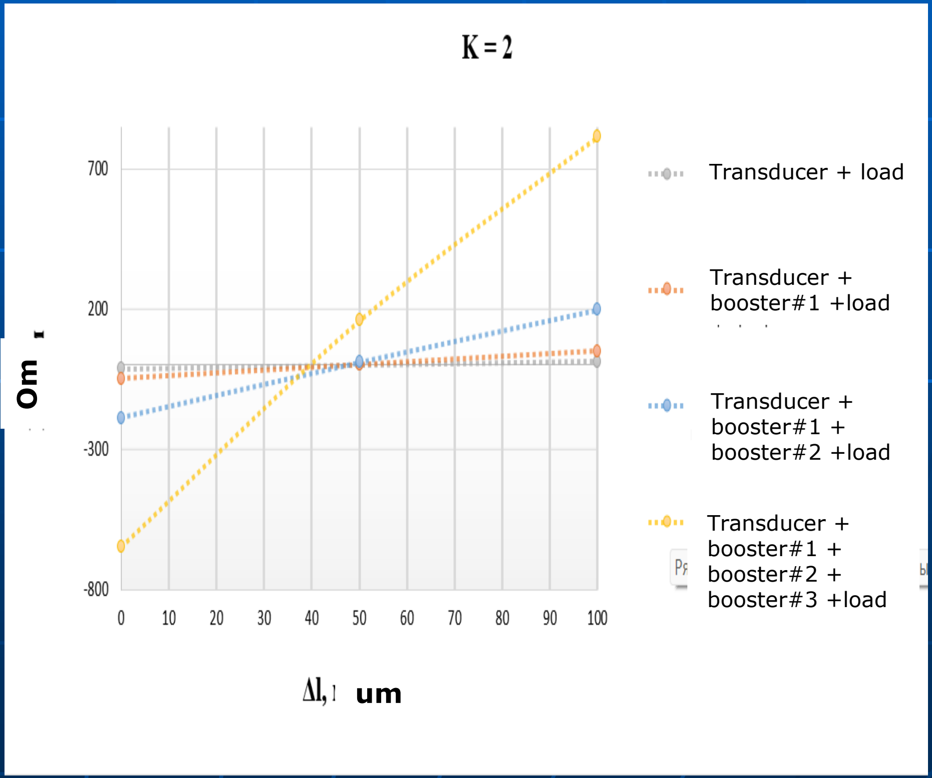


The dependence of the active and reactive resistance on working tool abrasion for various construction of vibratory system

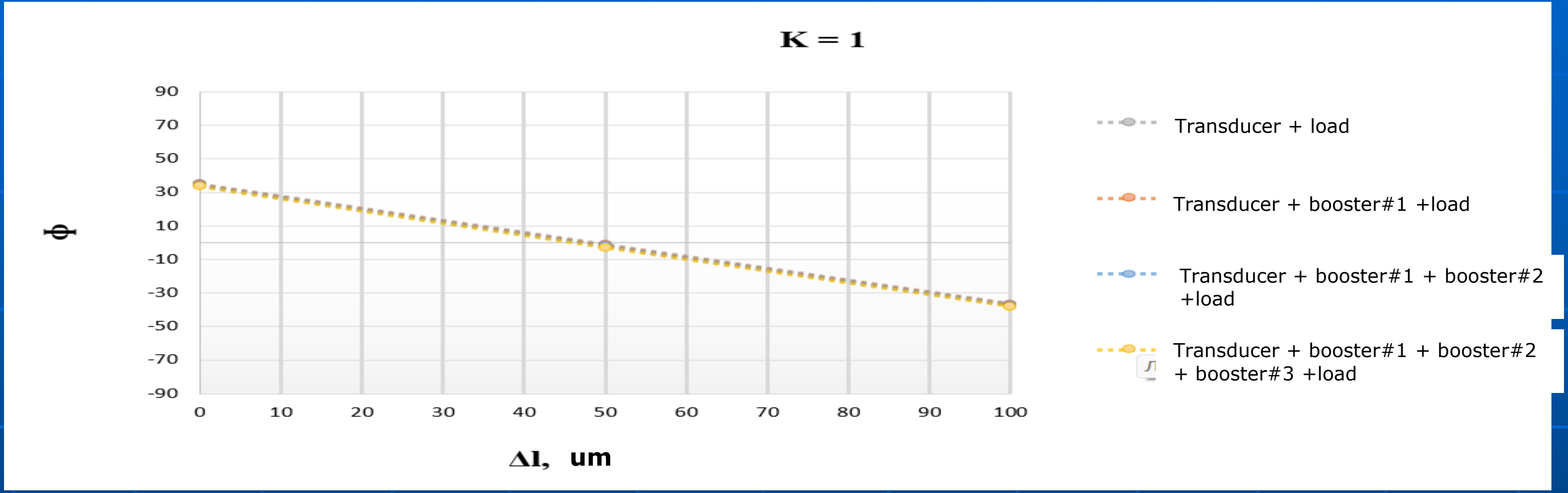
Active resistance

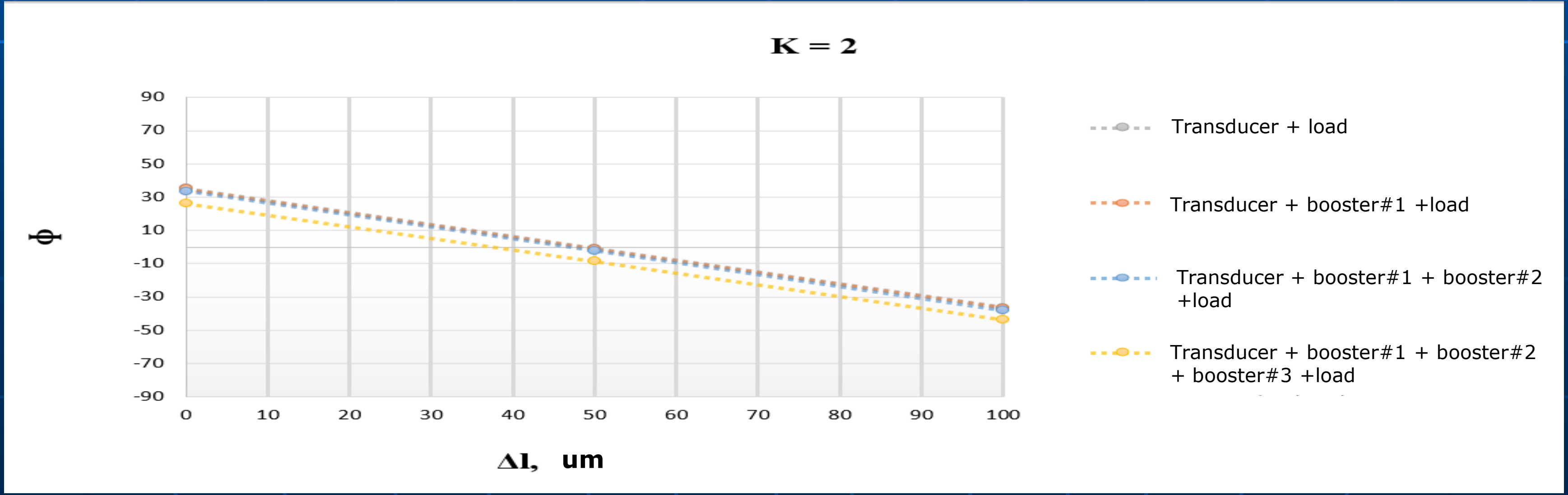


Reactive resistance



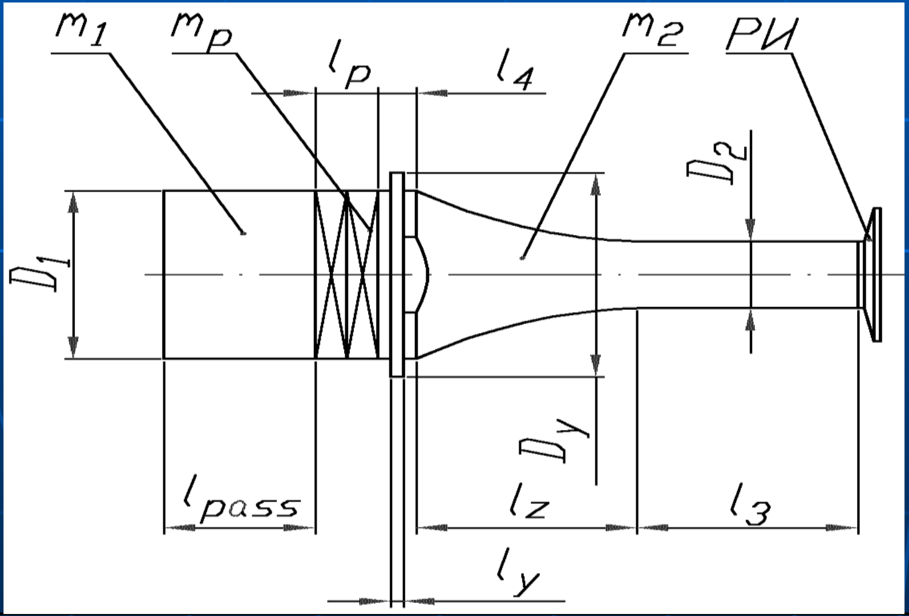
The dependence of the phase on vibratory system on working tool abrasion for various construction of vibratory system





THE SCHEME OF REALIZATION OF PROCESSING BY HALF-WAVE PIEZOELECTRIC VIBRATORY SYSTEM

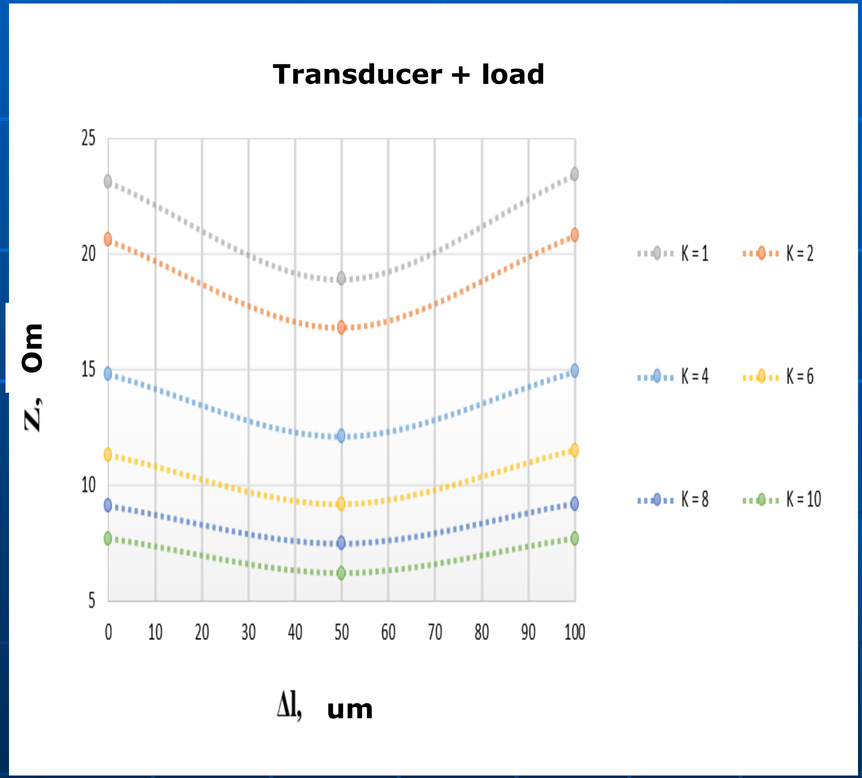
Transducer (half-wave, gain factor 1, 2, 4, 6, 8, 10)



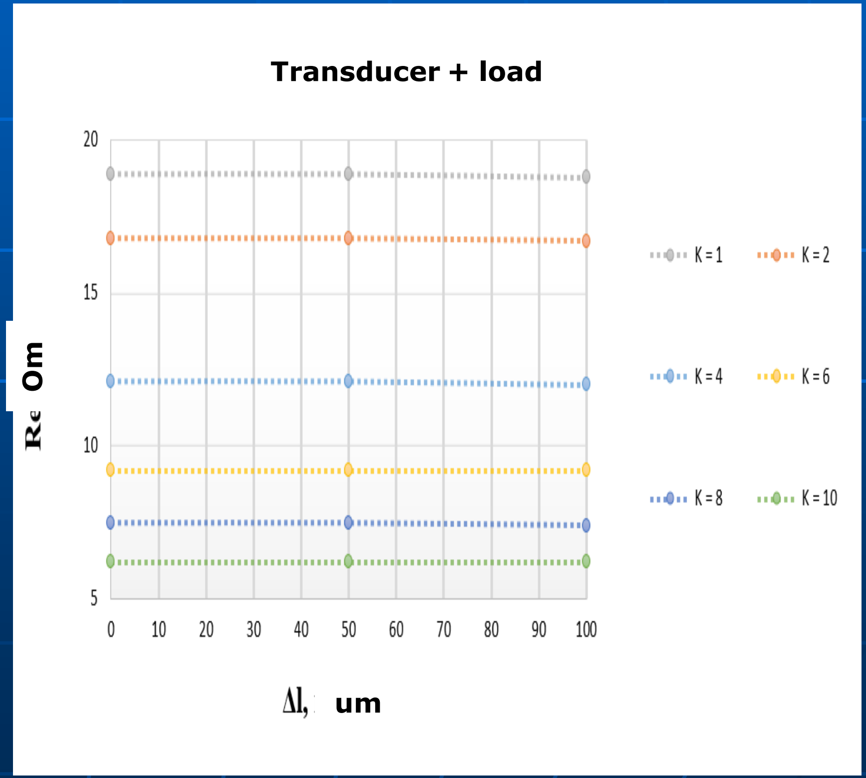
Half-wave cylindrical test working tool (load)

The dependence of resistance on working tool abrasion for various construction of vibratory system

Full wave resistance

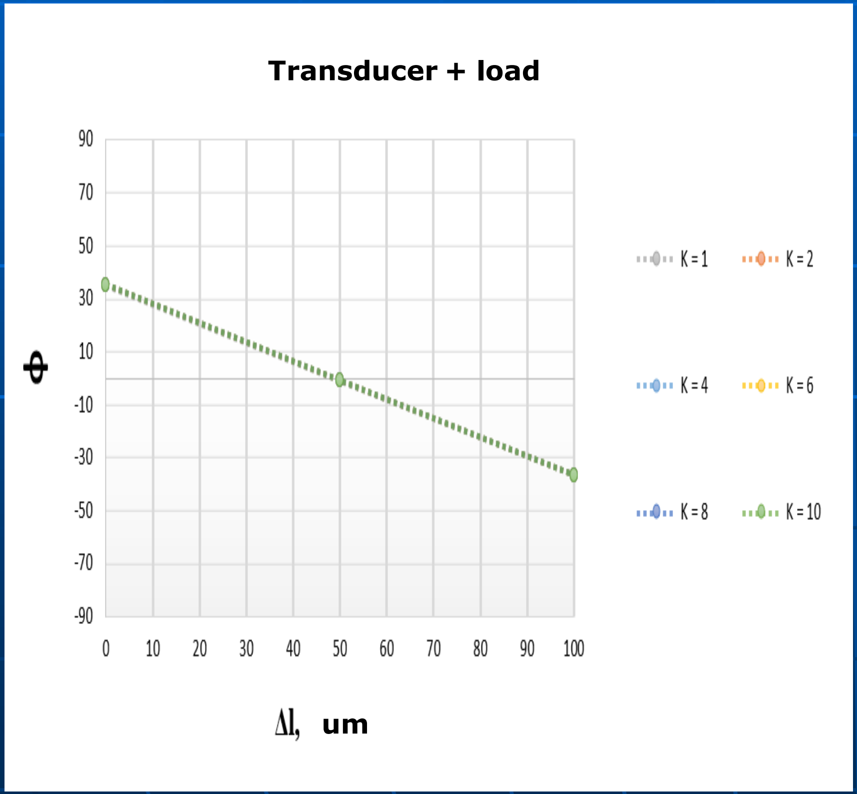


Active resistance

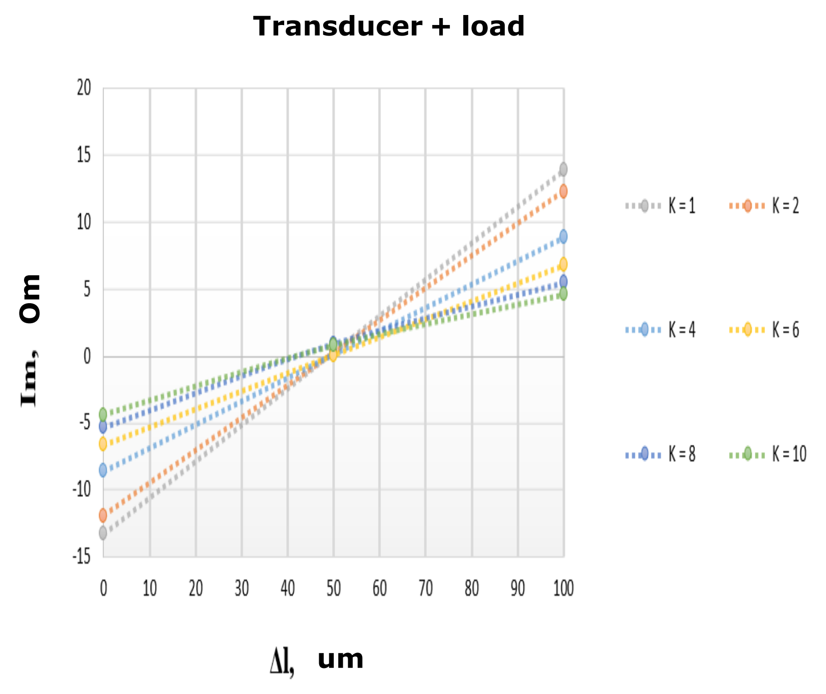


The dependence of phase and reactive resistance on working tool abrasion for various construction of vibratory system

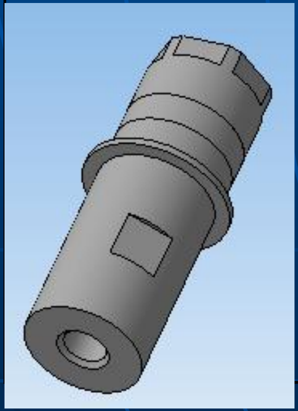
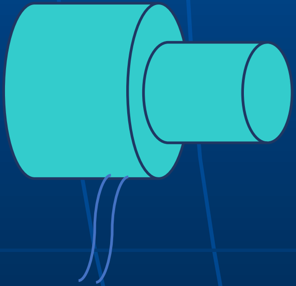
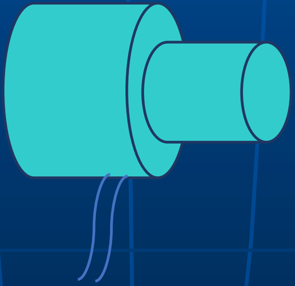
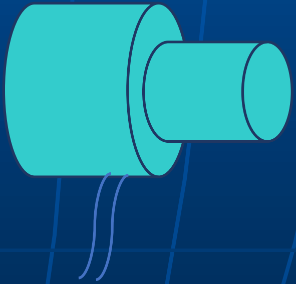
Phase



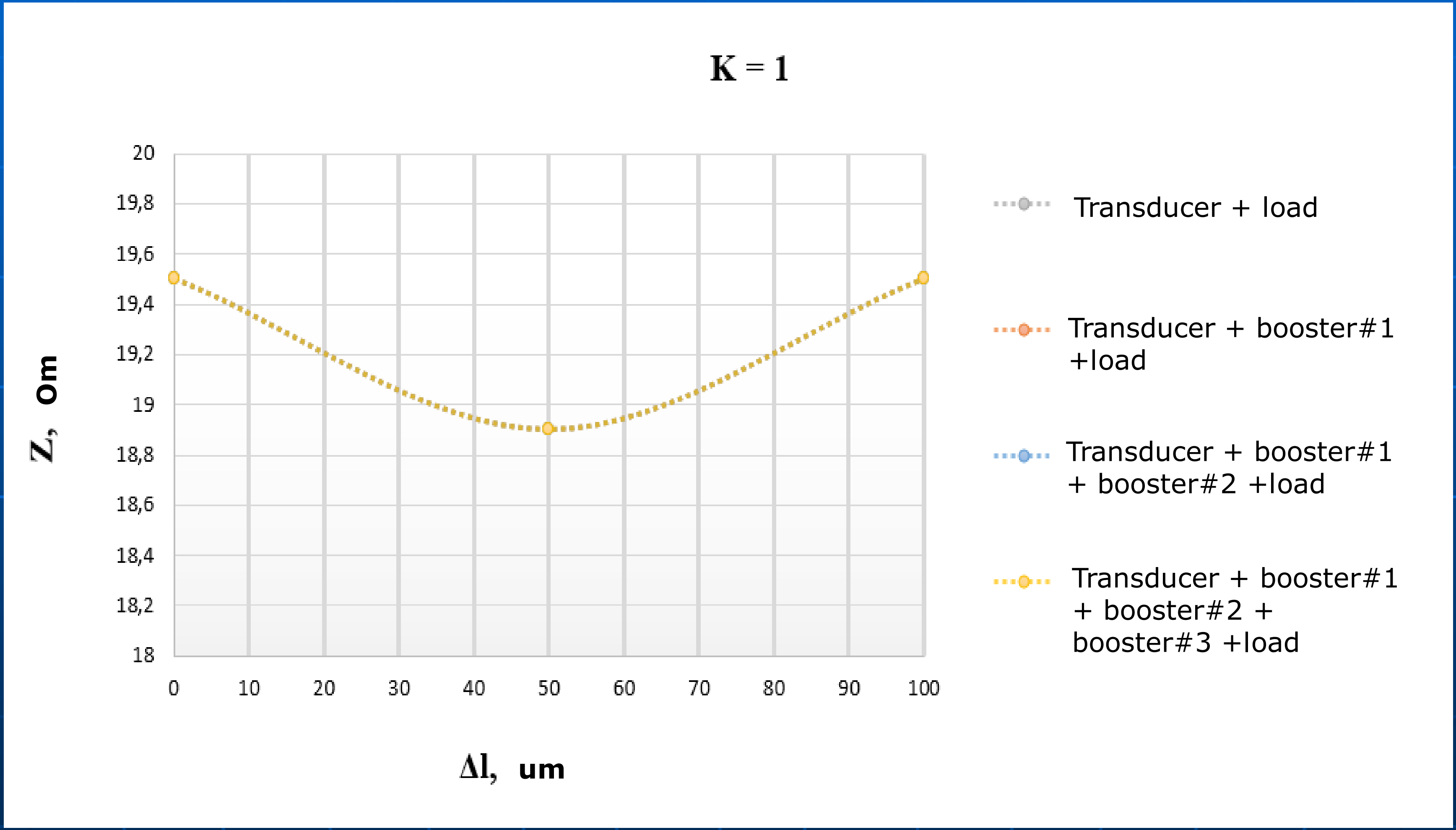
Reactive resistance



THE SCHEME OF ULTRASONIC EXPOSURE PROCESS

Langevin transducer (half-wave, gain factor 1, 1.5, 2)	Booster #1 (half-wave, gain factor 1, 1.5, 2)	Booster #2 (half-wave, gain factor 1, 1.5, 2)	Booster #3 (half-wave, gain factor 1, 1.5, 2)	Resonant gap (liquid or liquid-dispersed load)
				

The dependence of impedance on working tool abrasion for various construction of vibratory system



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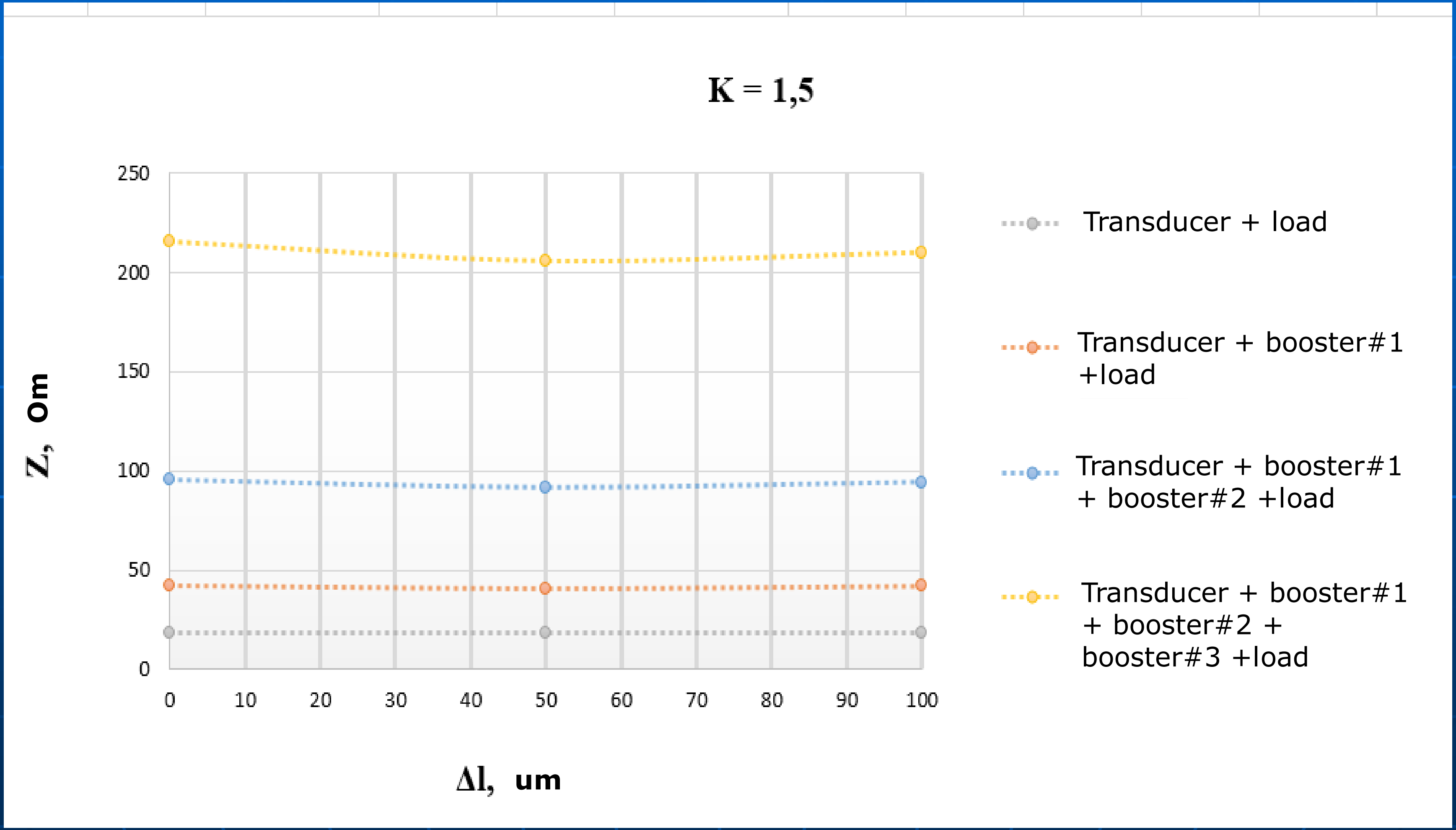

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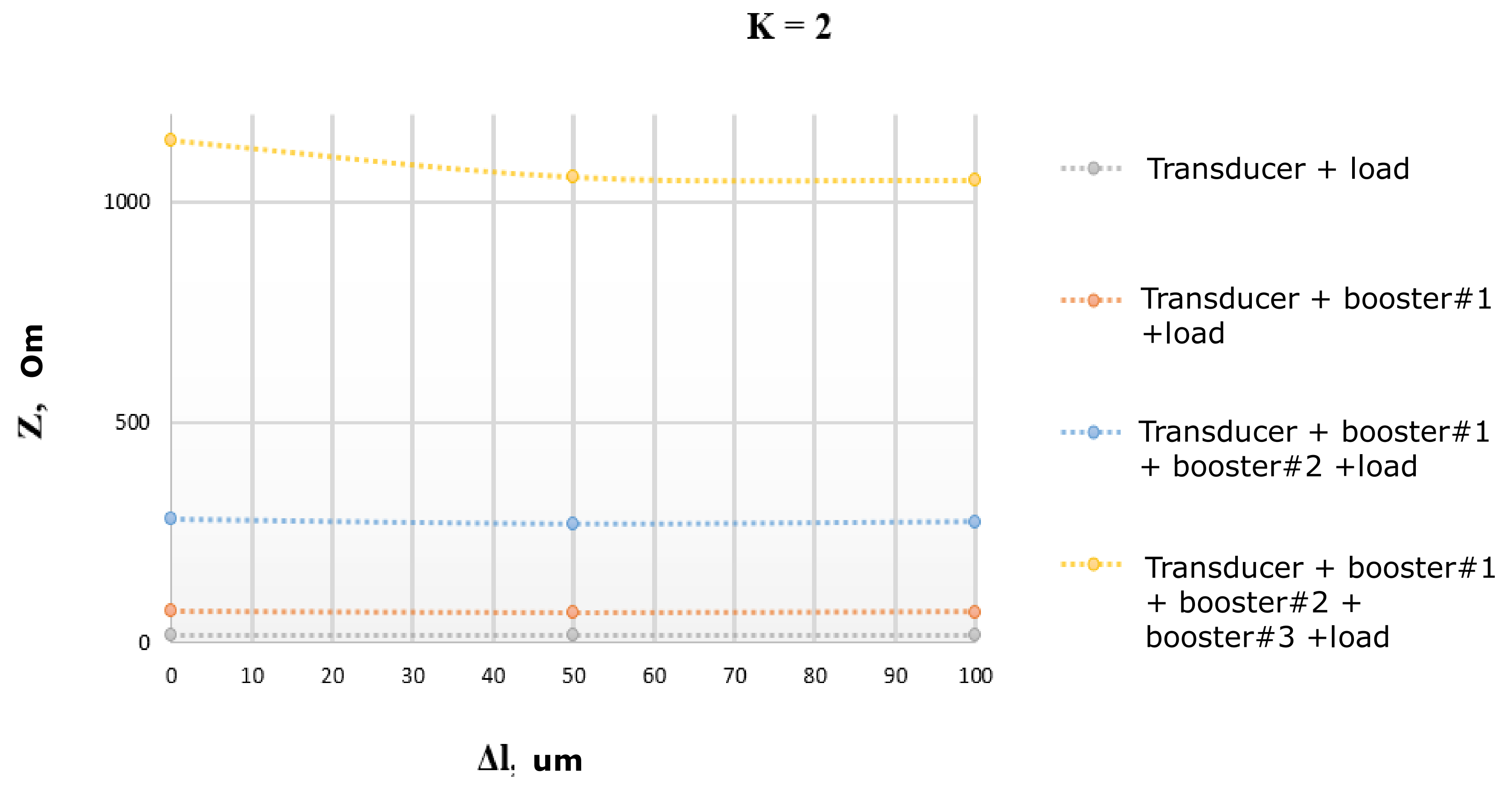
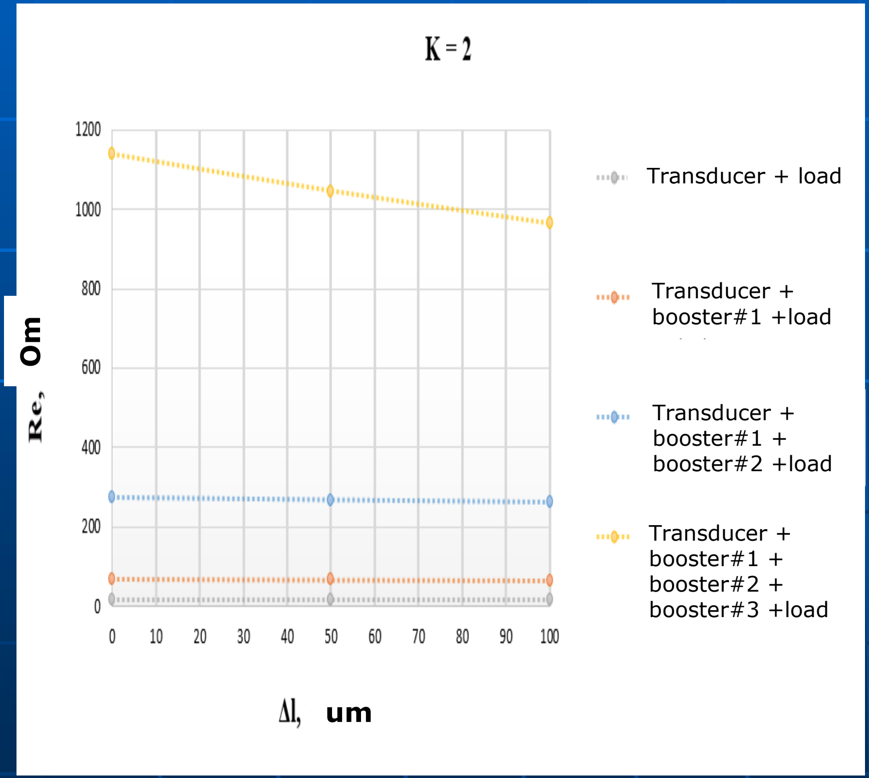
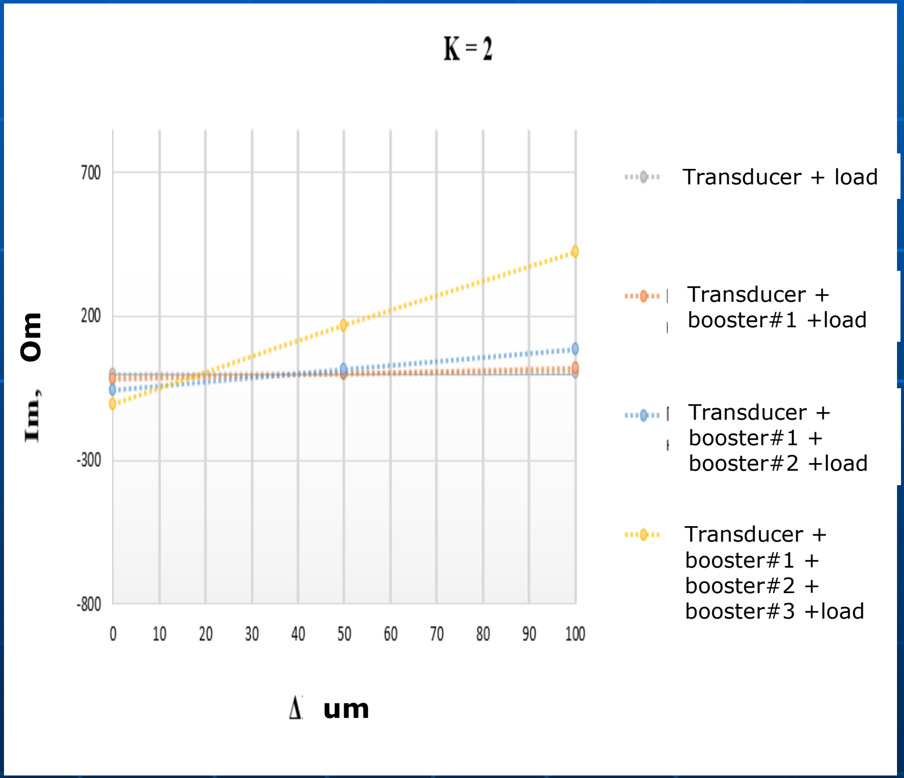


The dependence of the active and reactive resistance on change in propagation conditions for various construction of vibratory system

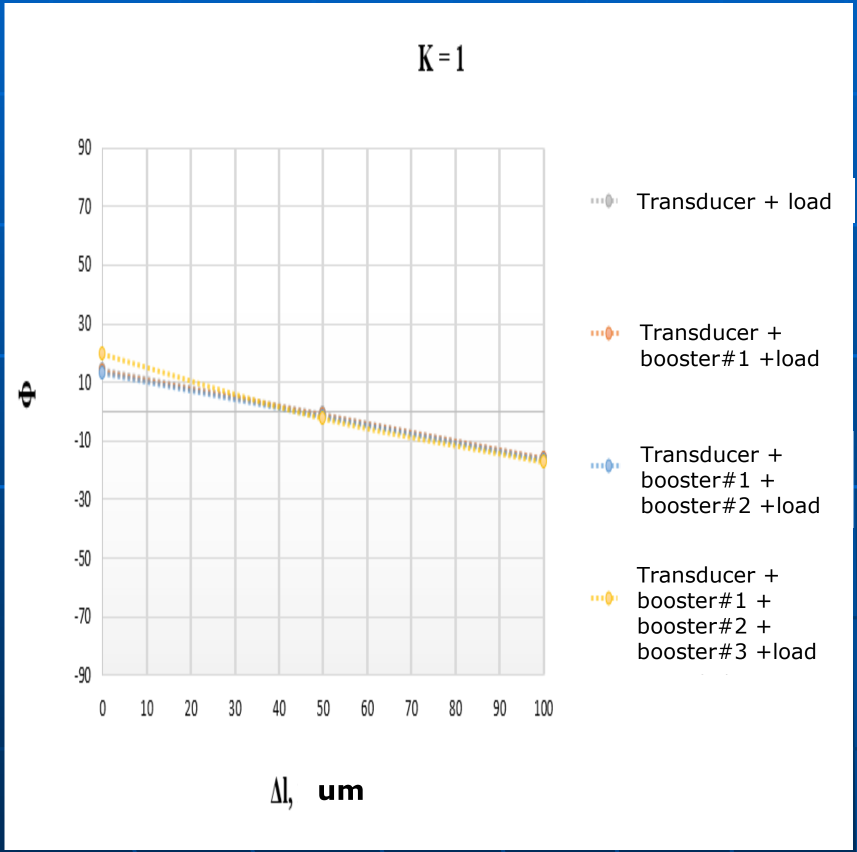
Active resistance

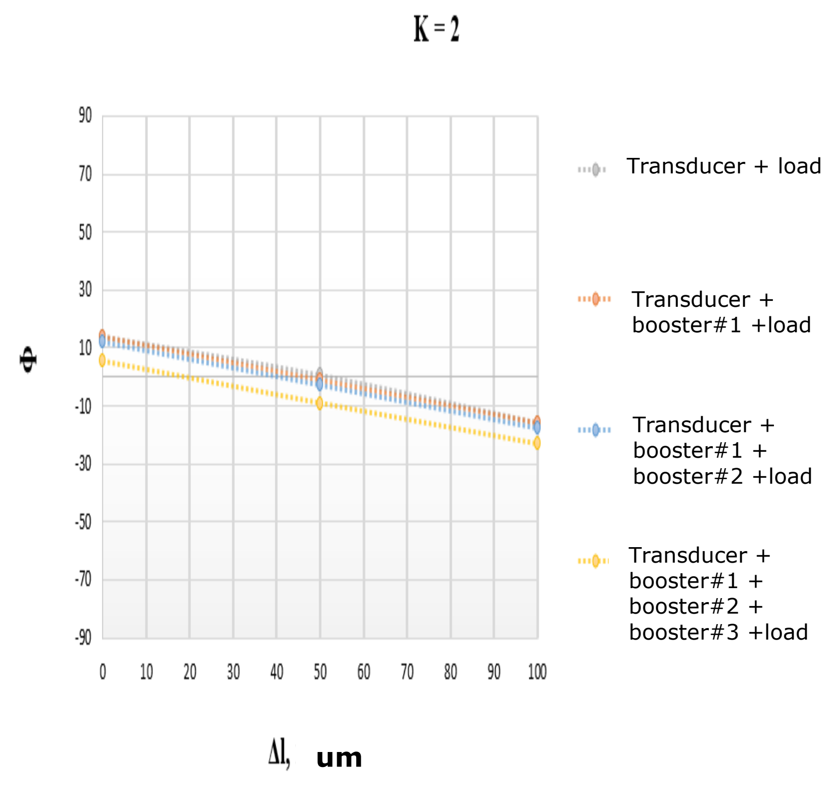


Reactive resistance

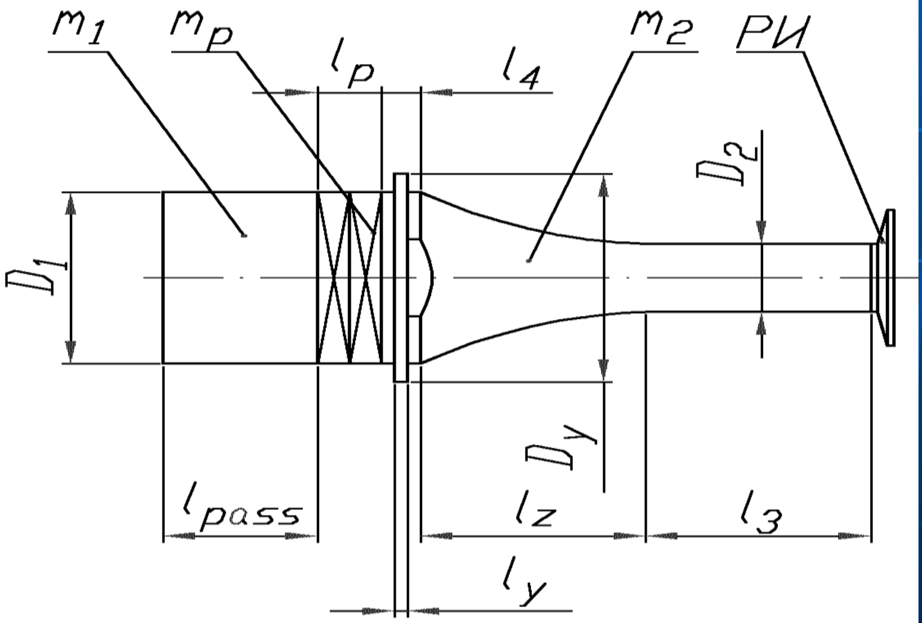
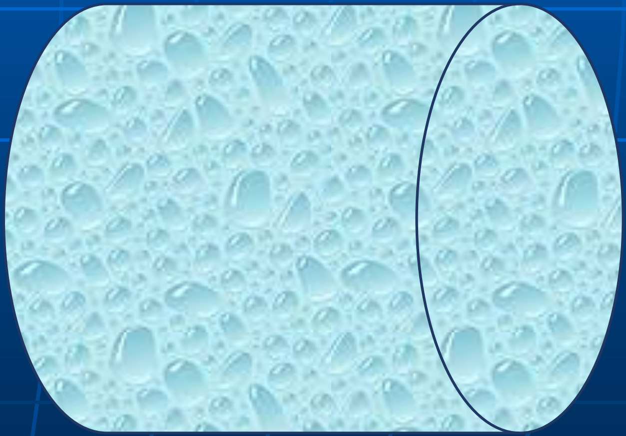


The dependence of the phase on change in propagation conditions for various construction of vibratory system



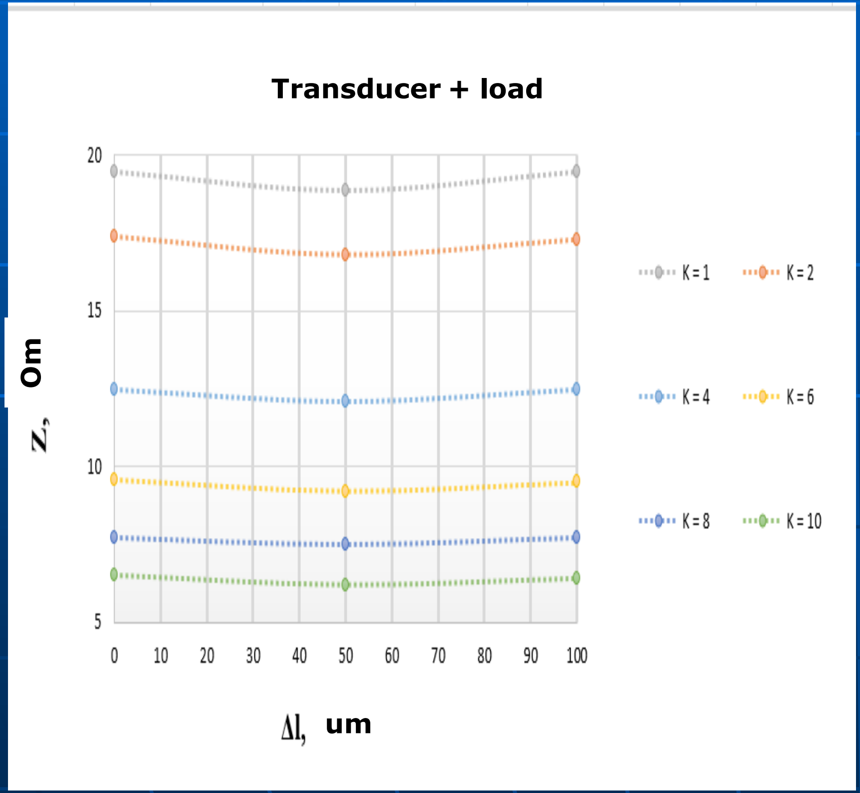


THE SCHEME OF REALIZATION OF PROCESSING BY A HALF-WAVE PIEZOELECTRIC SYSTEM

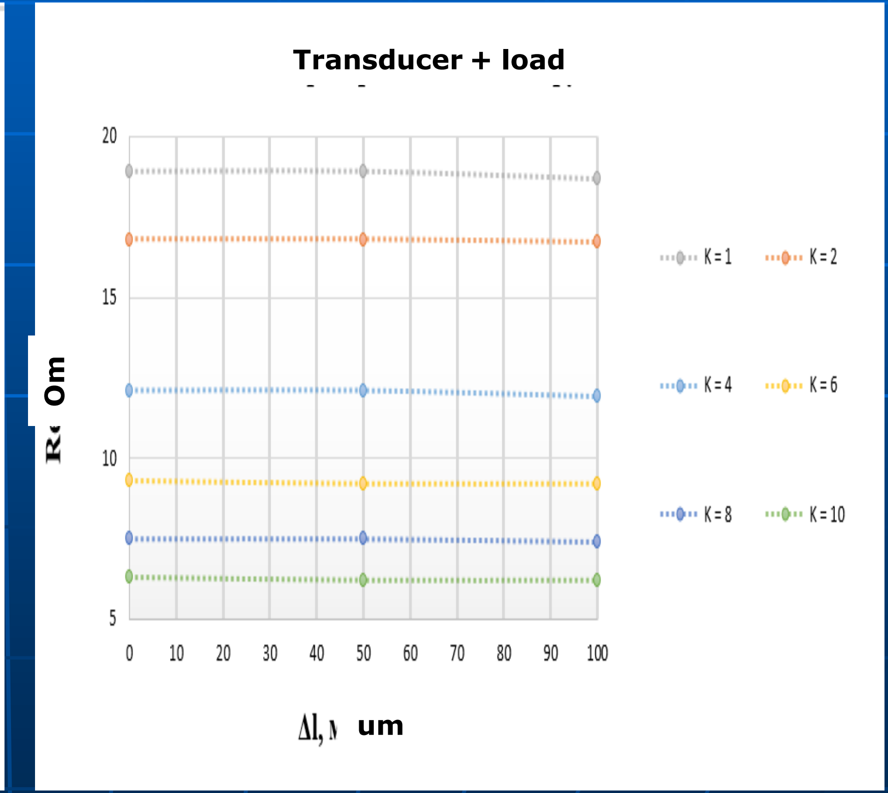
Transducer (half-wave, gain factor 1, 2, 4, 6, 8, 10)	Resonant gap (liquid or liquid-dispersed load)
	

The dependence of resistance on change in propagation conditions for various construction of vibratory system

Full wave resistance

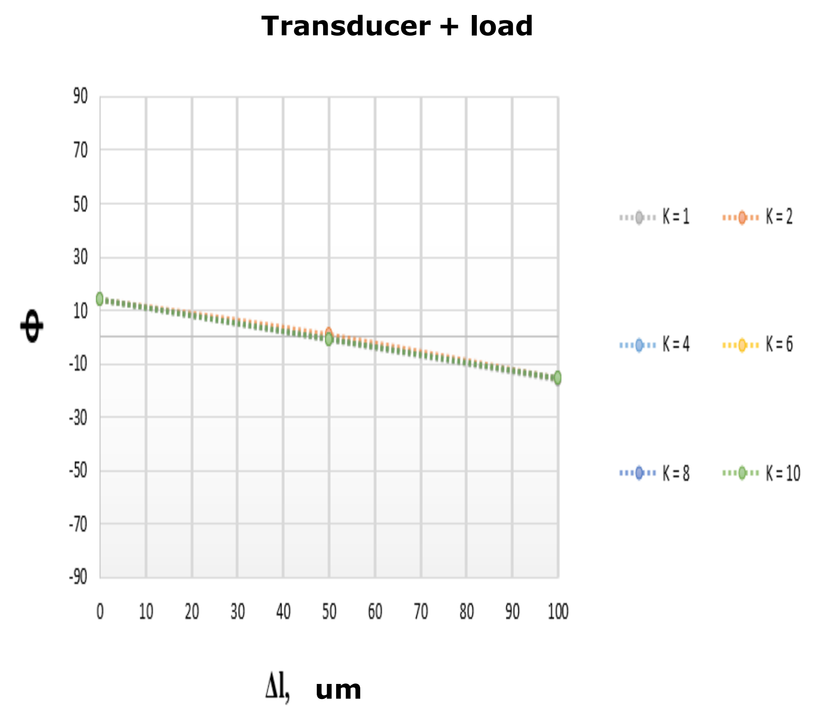


Active resistance

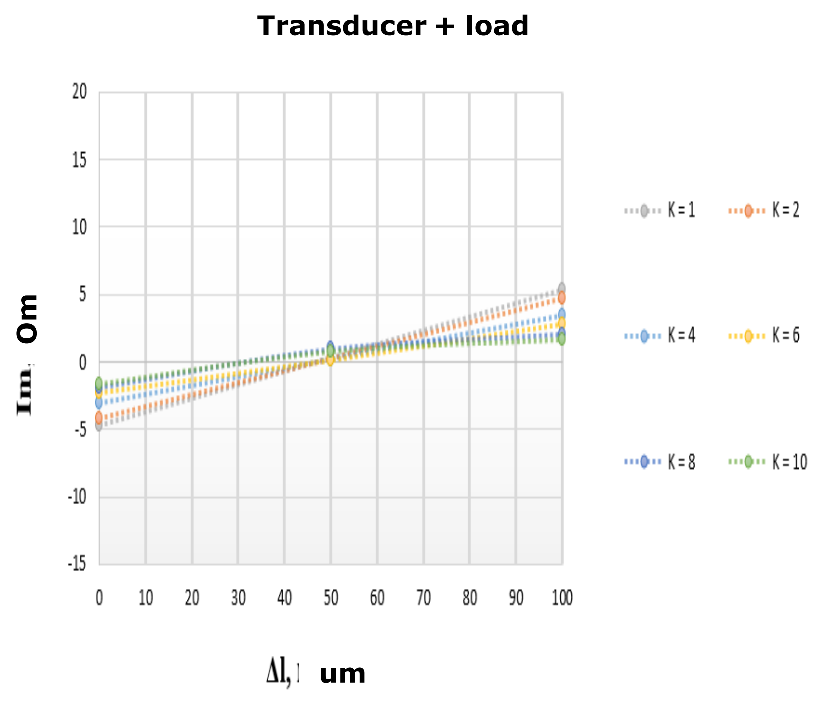


The dependence of phase and reactive resistance on change in propagation conditions for various construction of vibratory system

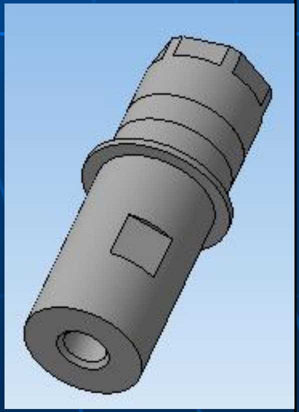
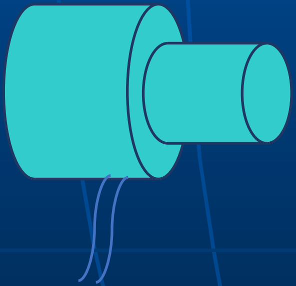
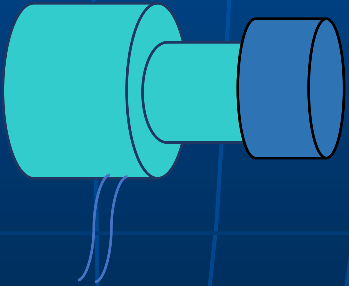
Phase



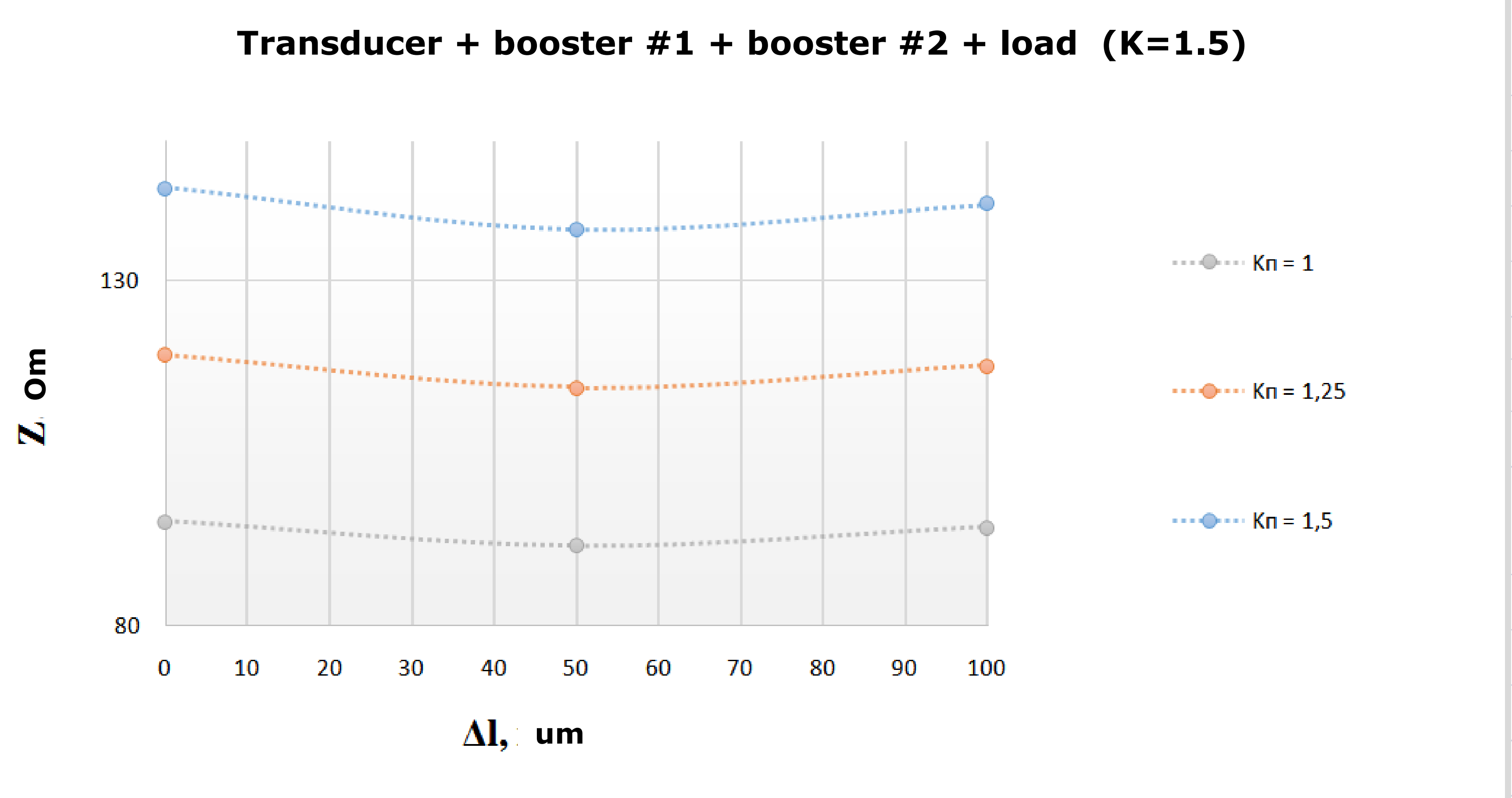
Reactive resistance



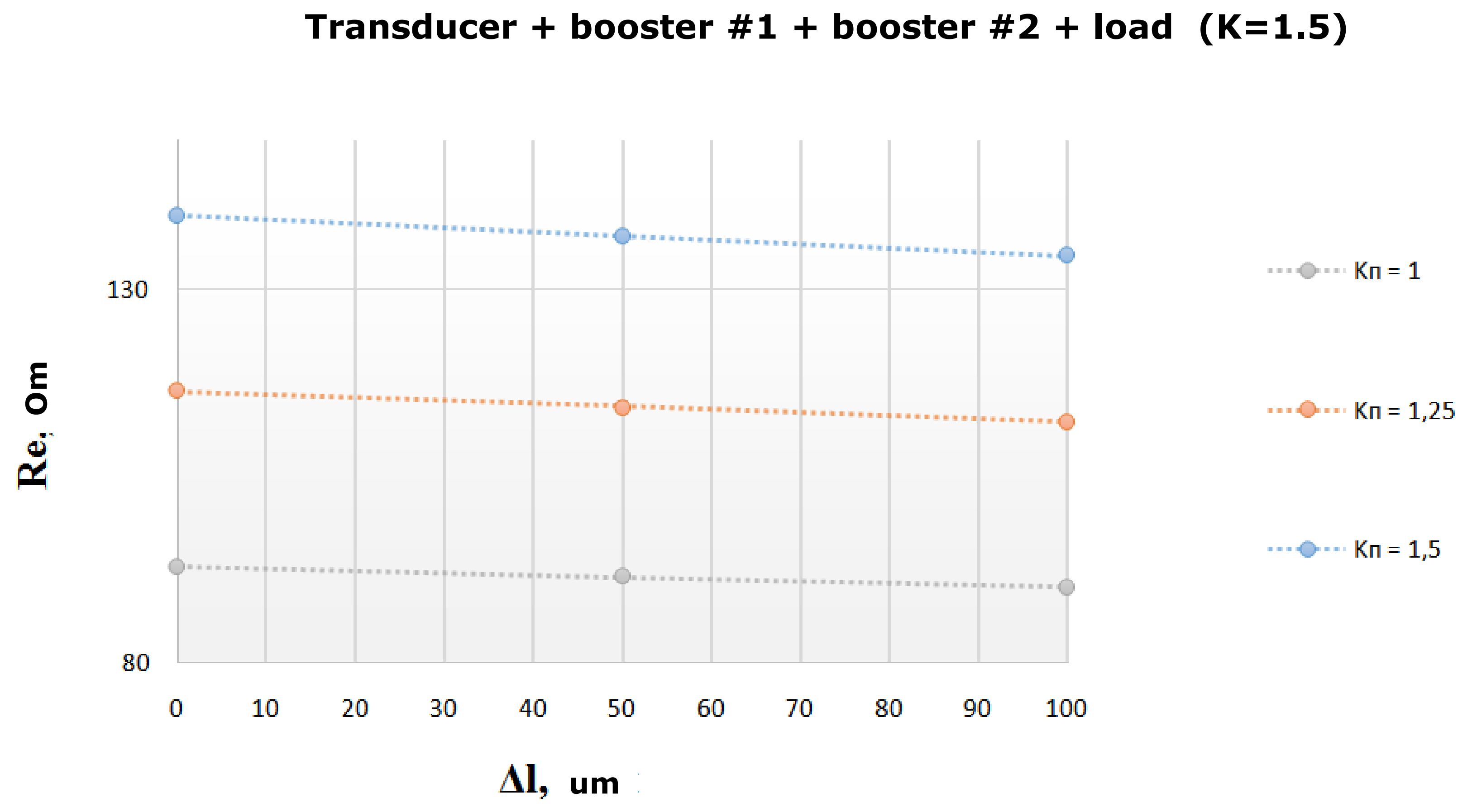
THE SCHEME OF REALIZATION OF PROCESSING BY VIBRATORY SYSTEM WITH A SPECIAL TOOL

Langevin transducer (half-wave, gain factor 1.5)	Booster #1 (half-wave, gain factor 1.5)	Booster #2 with a mushroom-shaped radiating element (half-wave, gain factor 1.5)	Resonant gap (liquid or liquid-dispersed load)
			

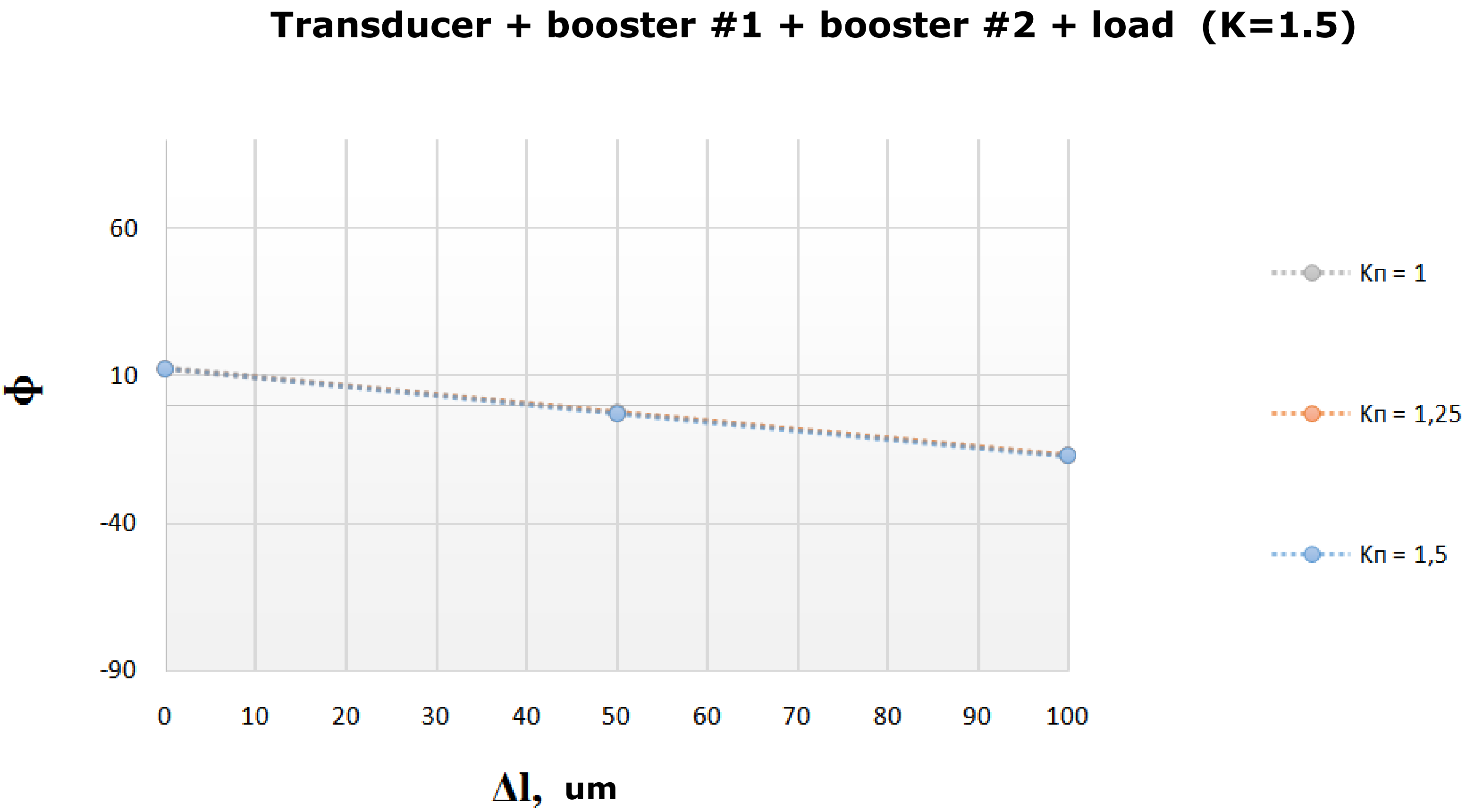
Dependence of the impedance of the ultrasonic radiator for different areas of contact with the medium



Dependence of the active resistance of the ultrasonic radiator for different areas of contact with the medium



Dependence of the reactive resistance of the ultrasonic radiator for different areas of contact with the medium



Dependence of the phase of the ultrasonic radiator current for different areas of contact of the radiating surface with the medium