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STUDY OF THE DEPENDENCE OF THE DISTRIBUTION OF THE PLASMA PARAMETERS ALONG THE HOLLOW CATHODE FROM THE BASIC PARAMETERS OF THE NON-SELF-SUSTAINED GLOW DISCHARGE

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The relevance of the work

Surface modification by ion-plasma methods has been actively developed and studied recently in science and technology, and, as a result, the range of products processed by such methods is expanding. However, until the last moment, ion-plasma treatment of the internal surfaces of the cavities remains technologically most difficult to implement.

The work is devoted to expanding the possibility of ion-plasma methods for treating the inner surface of extended metal cavities of complex shape, by identifying the main factors affecting the ignition, maintenance and uniform spatial distribution of a non-self-contained glow discharge with a hollow cathode for chemical-thermal treatment of the inner surfaces of cavities of complex shape.

- **Fields of application:** oil and gas and chemical industry, mechanical engineering, nuclear industry, automotive industry, defense industry.

- **Products to be processed:** pipelines, manifolds, dies with internal surfaces, gas turbine engine parts, oil and gas industry parts, firearms barrels.

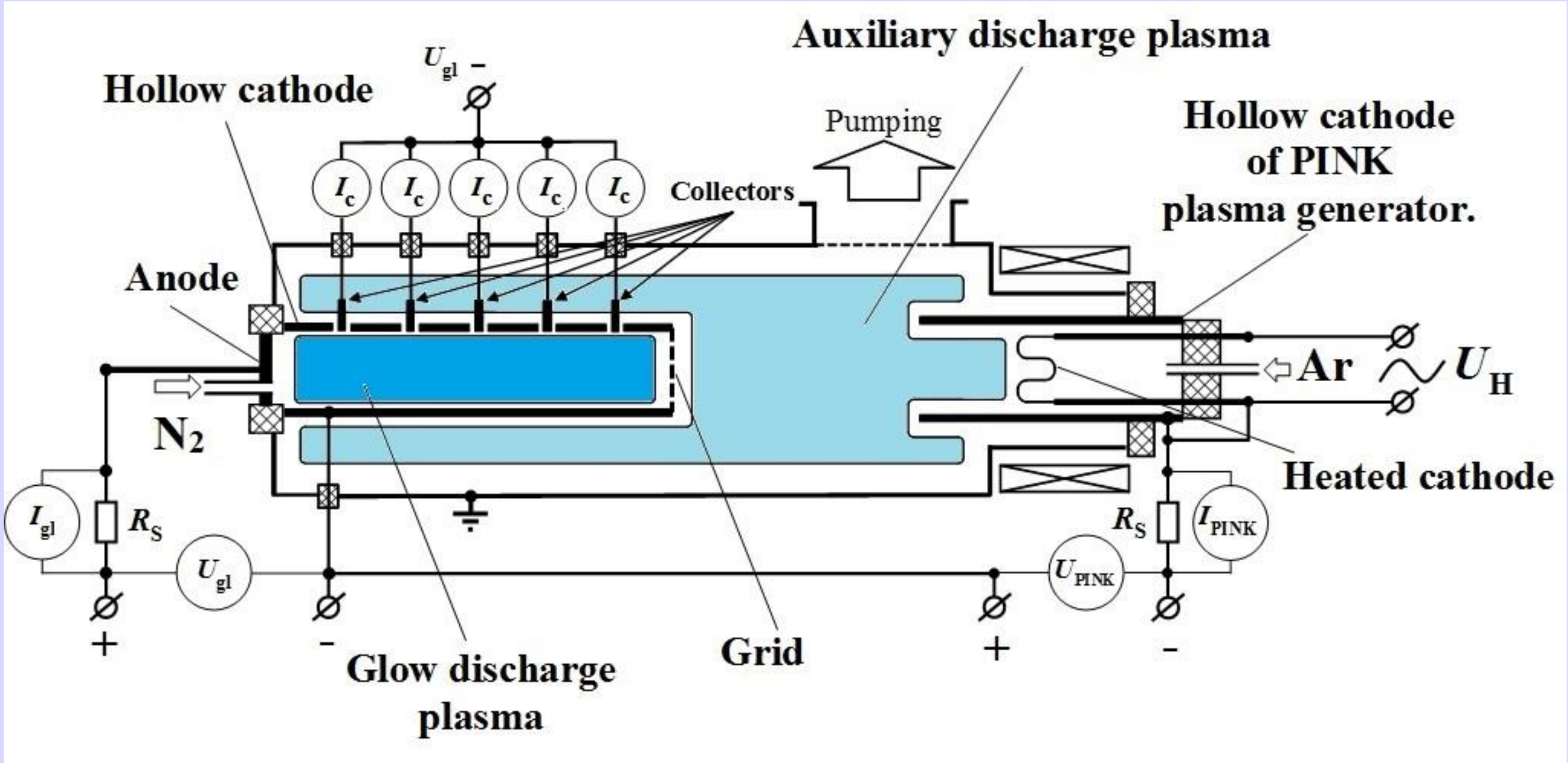
Objectives:

- **achieve uniform generation of glow discharge plasma along the entire length in the long curvilinear cavity of the pipeline.**

Tasks:

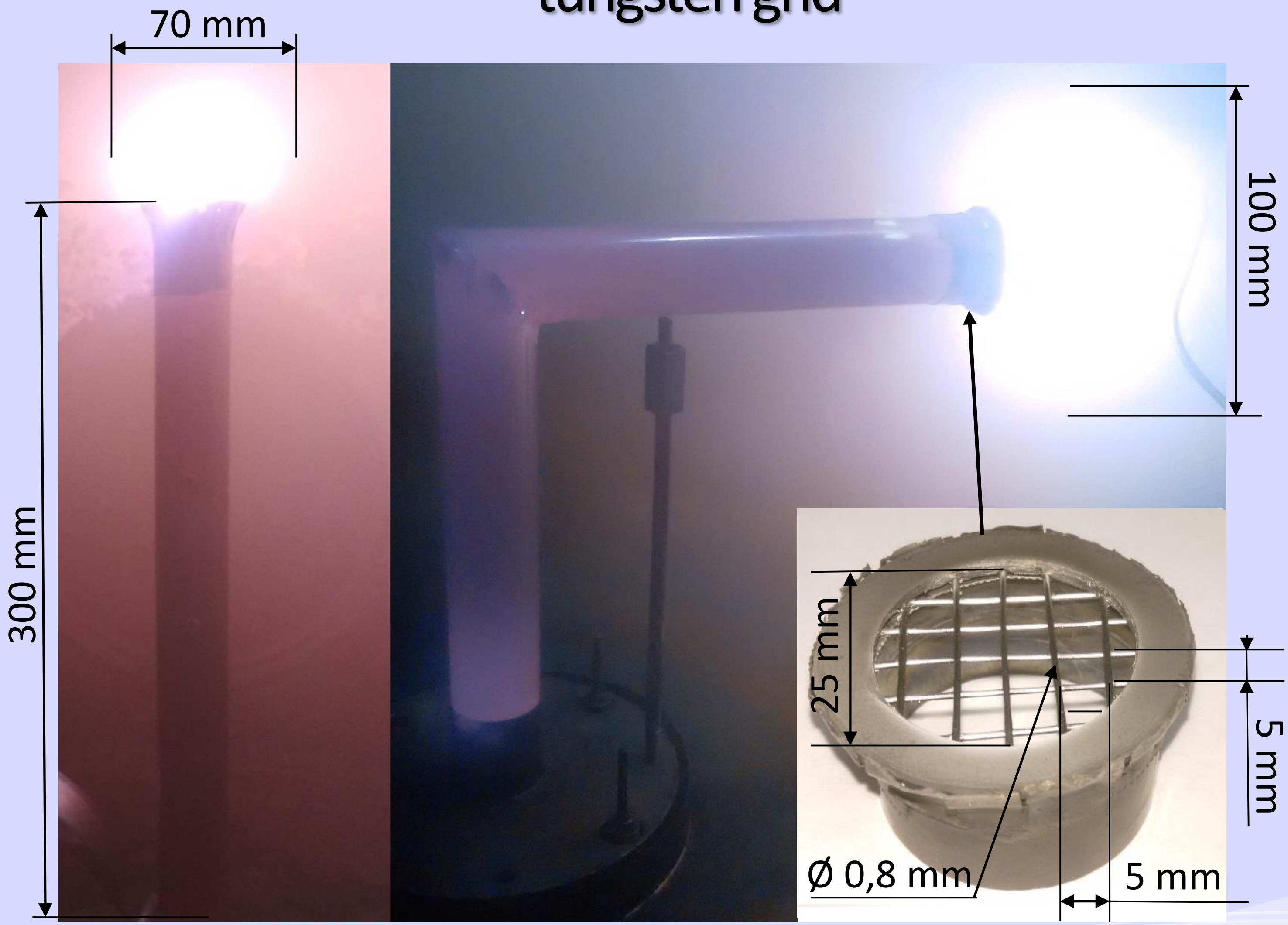
- **Study of the influence of the main parameters of a non-self-sustaining glow discharge on the change in the distribution of ion current density along the hollow cathode.**

The system of plasma generation by means of a non-self-sustaining glow discharge with a hollow cathode



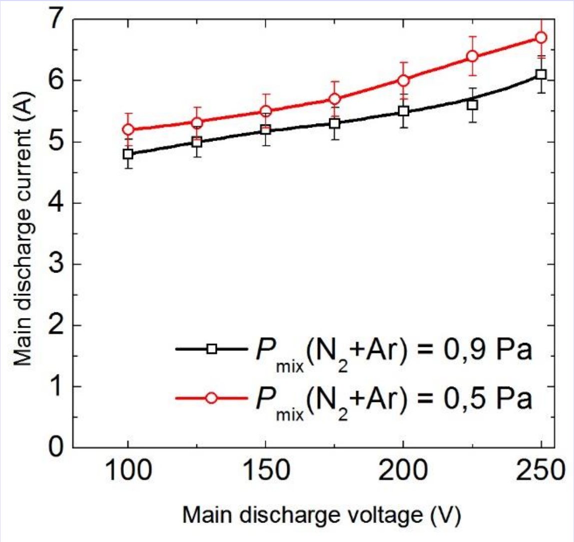
Plasma generation inside a long cavity was carried out using a two-discharge system. In this system, the cathode was a tube, inside which a non-self-sustaining glow discharge was ignited, and the anode was a flat water-cooled electrode located near the end of the tube. The opposite end of the pipeline is covered with a grid, which together with the outer surface of the workpiece is an anode for an auxiliary arc discharge with a combined hot and hollow cathode (PINK). Electrons are injected from the auxiliary discharge plasma through a grid located at the end of the cavity to be treated. The electrons passing through the grid ionize the plasma-forming gas. The grid is also necessary to stabilize the boundary of the auxiliary plasma at the moment of discharge ignition. Since the walls of the pipeline are the cathode and form an electrostatic trap, the accelerated electrons begin to oscillate in the cavity to be treated until they lose their energy due to inelastic collisions with gas molecules or escape to the anode.

Photographs of hollow cathodes of a rectilinear, curved shape and a tungsten grid

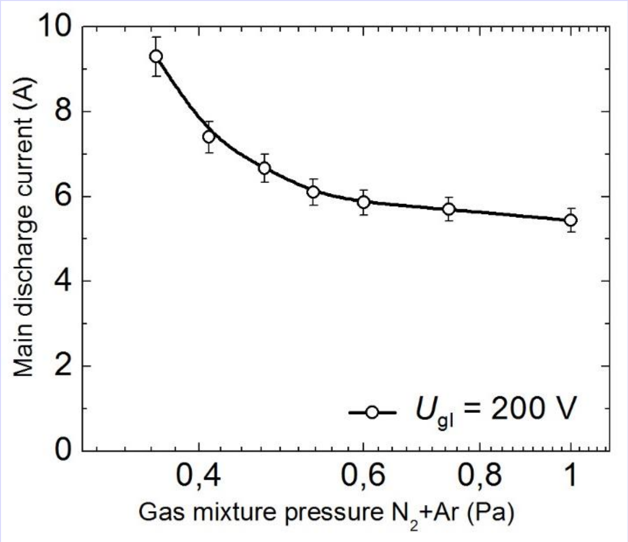


During the generation of the main discharge plasma, the grid is not the interface between the main discharge plasma and the auxiliary discharge plasma due to the mesh size exceeding 2 widths of the cathode layer of the main discharge. As a result, the glow discharge plasma extends beyond the grid to form a bright spherical plasma formation bounded by a double layer at the plasma interface of the main and auxiliary discharges.

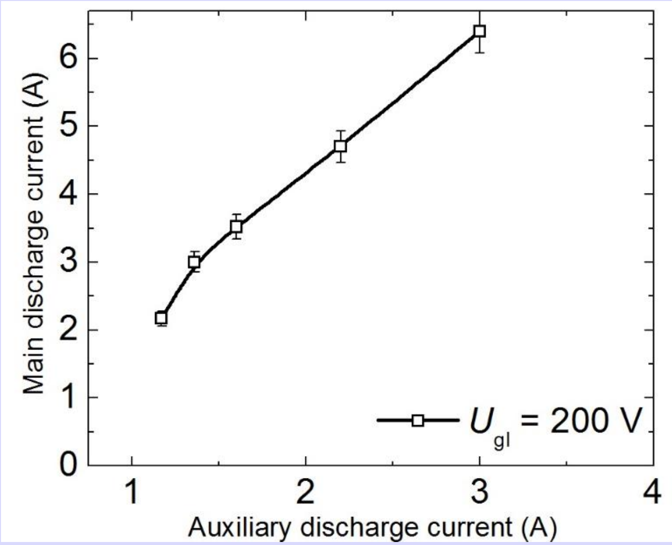
Results of investigation of parameters of a non-self-sustaining glow discharge



Volt-ampere characteristic of non-self-sustaining glow discharge at $\boldsymbol{I_{PINK}}$ **= 3 A** and $\boldsymbol{U_{PINK}}$ **= 130 V.**

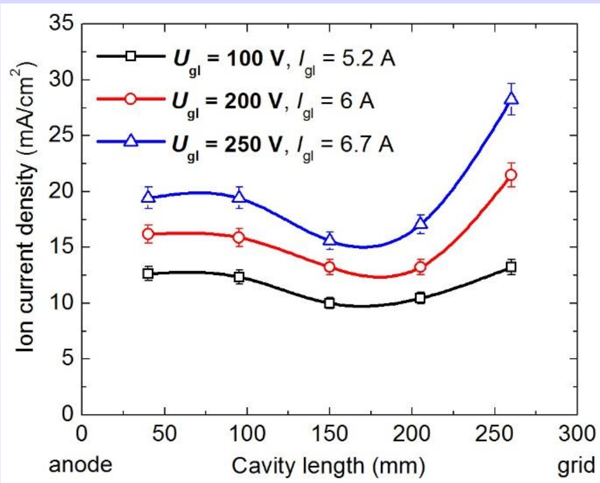


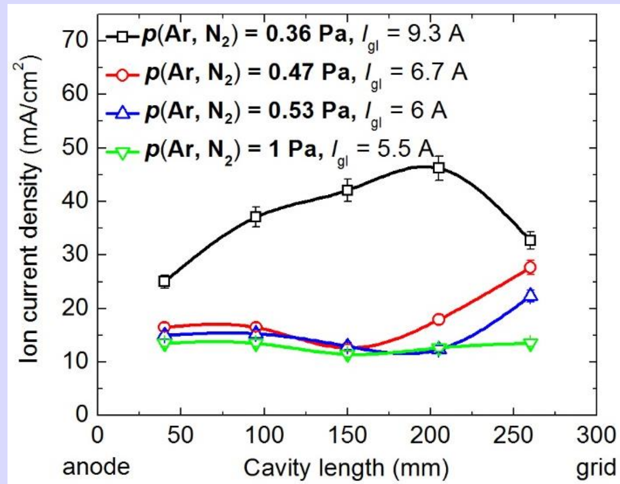
Dependence of the current of a non-self-sustaining glow discharge on the gas pressure at $\boldsymbol{I_{PINK}}$ **= 3 A** and $\boldsymbol{U_{PINK}}$ **= 130 V.**

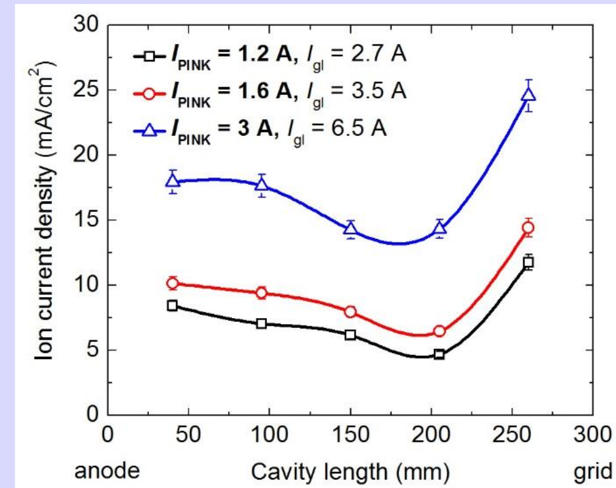


The dependence of the main discharge current on the auxiliary discharge current (PINK) at $\boldsymbol{p_{(N_2+Ar)}}$ **= 0,5 Pa.**

Dependence of the distribution of ion current density along the internal cavity of rectilinear hollow cathode







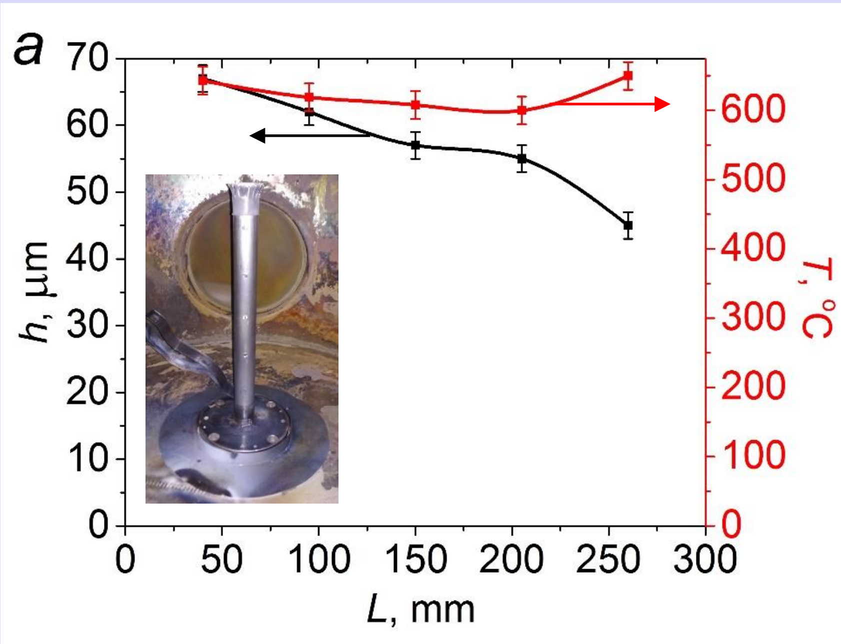
The dependence on the voltage of the main glow discharge at $\boldsymbol{I_{пинк}}$ **= 3 A,** $\boldsymbol{U_{pink}}$ **= 130 V** and $\boldsymbol{p_{(Ar,\, N_2)}}$ **= 0,53 Pa.**

Dependence on gas pressure at $\boldsymbol{I_{pink}}$ **= 3 A,** $\boldsymbol{U_{pink}}$ **= 130 V** and $\boldsymbol{U_{gl}}$ **= 200 V.**

Dependence on auxiliary discharge current (PINK) at $\boldsymbol{p_{(Ar,\, N_2)}}$ **= 0,53 Pa** and $\boldsymbol{U_{gl}}$ **= 200 V.**

Results of experiments of nitriding of internal cavity of pipelines of straight and curved shape

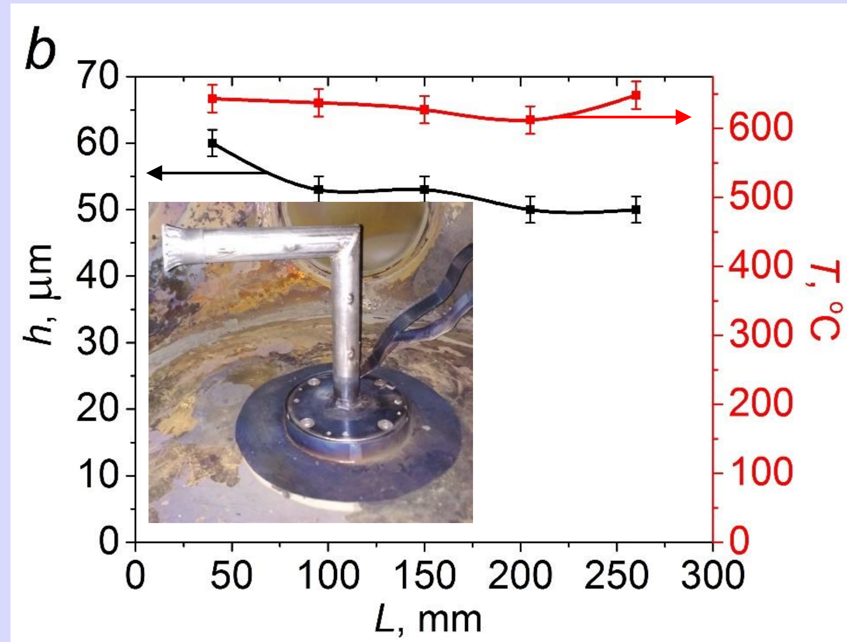
Straight tube.



Experiment Parameters:
U_{gl} = 200 V, **I_{gl} = 6 A**, I_{pink} = 3,2 A,
P_{mix} = 1 Pa, **T = (595-650) °C**.
The duration of the process is **1 hour**.

Nitrided layer thickness:
(45 – 67) µm.

Curved tube.



Experiment Parameters:
$U_{тл}$ = 200 V, **I_{gl} = 4 A**, I_{pink} = 2 A,
P_{mix} = 1 Pa, **T = (612-648) °C**.
The duration of the process is **1 hour**.

Nitrided layer thickness:
(50 – 60) µm.

Conclusion

The work shows that a **non-self-sustained glow discharge with external electron injection** from the auxiliary discharge plasma "PINK" allows you to create a plasma inside an elongated metal cavity, which is a hollow cathode, with a length of **300 mm** and an internal diameter of **25 mm** at glow discharge voltages from **100 V to 250 V** and at a gas mixture pressure from **0.36 Pa to 1 Pa**. Inside this extended cavity, the degree of inhomogeneity of the generated plasma can be achieved up to **±11.5%** of the average ionic current density due to multiple oscillations in the hollow cathode, mainly due to electrons injected from the auxiliary discharge plasma.

This plasma can be used in the processes of ion-plasma treatment of the inner surface of elongated articles not only straight, but also curved due to the use of discharge with a hollow cathode of low pressure.

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Thanks for your attention!

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