Designing and experimental validation of prototypes of liquid lithium plasma facing components for steady-state tokamak

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ABSTRACT

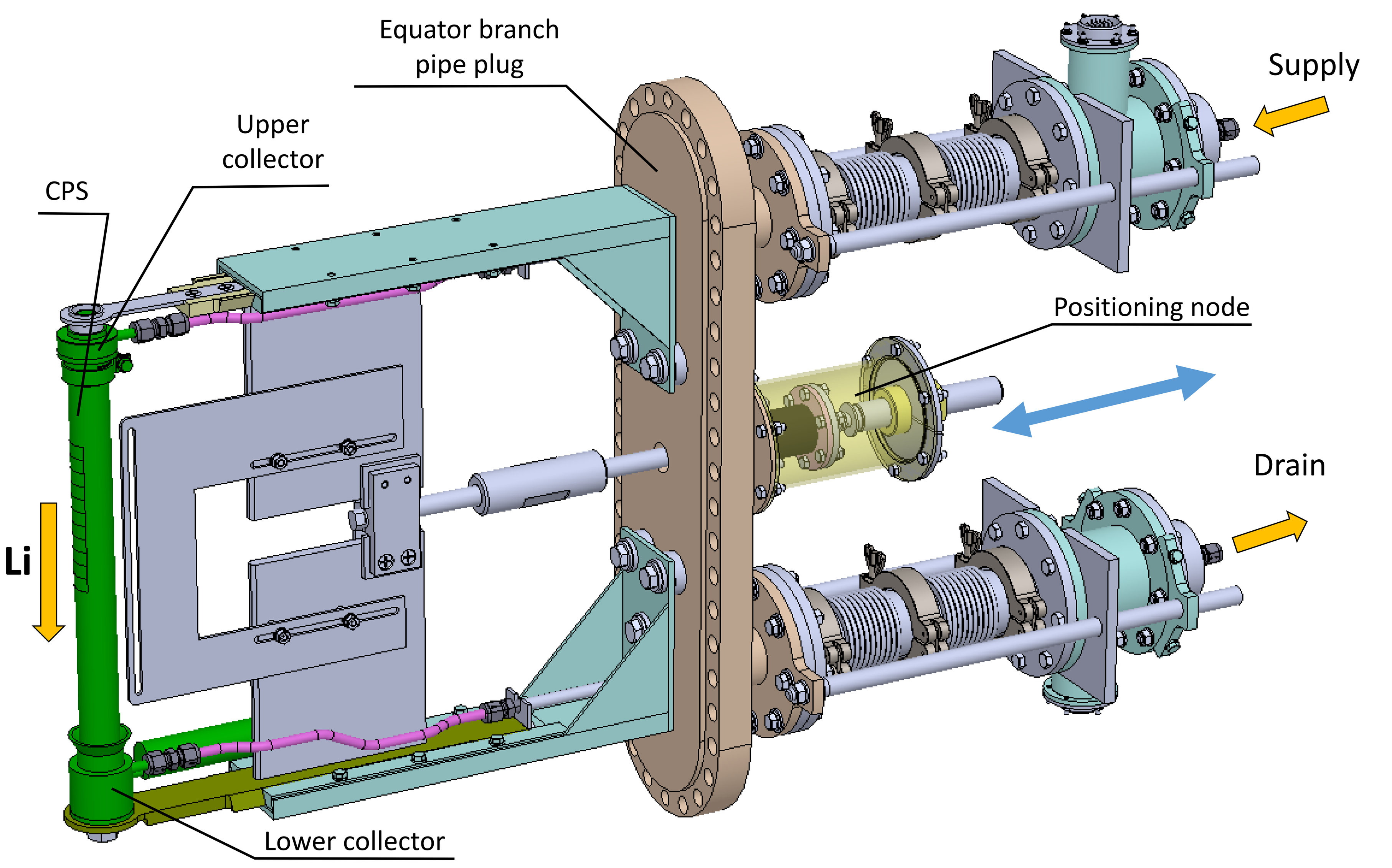
The Russian concept of steady-state operating plasma-facing components (PFC) based on the use of a stagnant or slowly flowing liquid metal (LM) as a plasma-facing material enclosed in a capillary-porous system (CPS) integrates all the advantages of LM with the possibility of uniform distribution of its layer on the surface, regardless of its orientation in space, with high resistance to splashing under electromagnetic force. Heat removal is provided by thermal conductivity through the PFC structure to the flowing coolant.

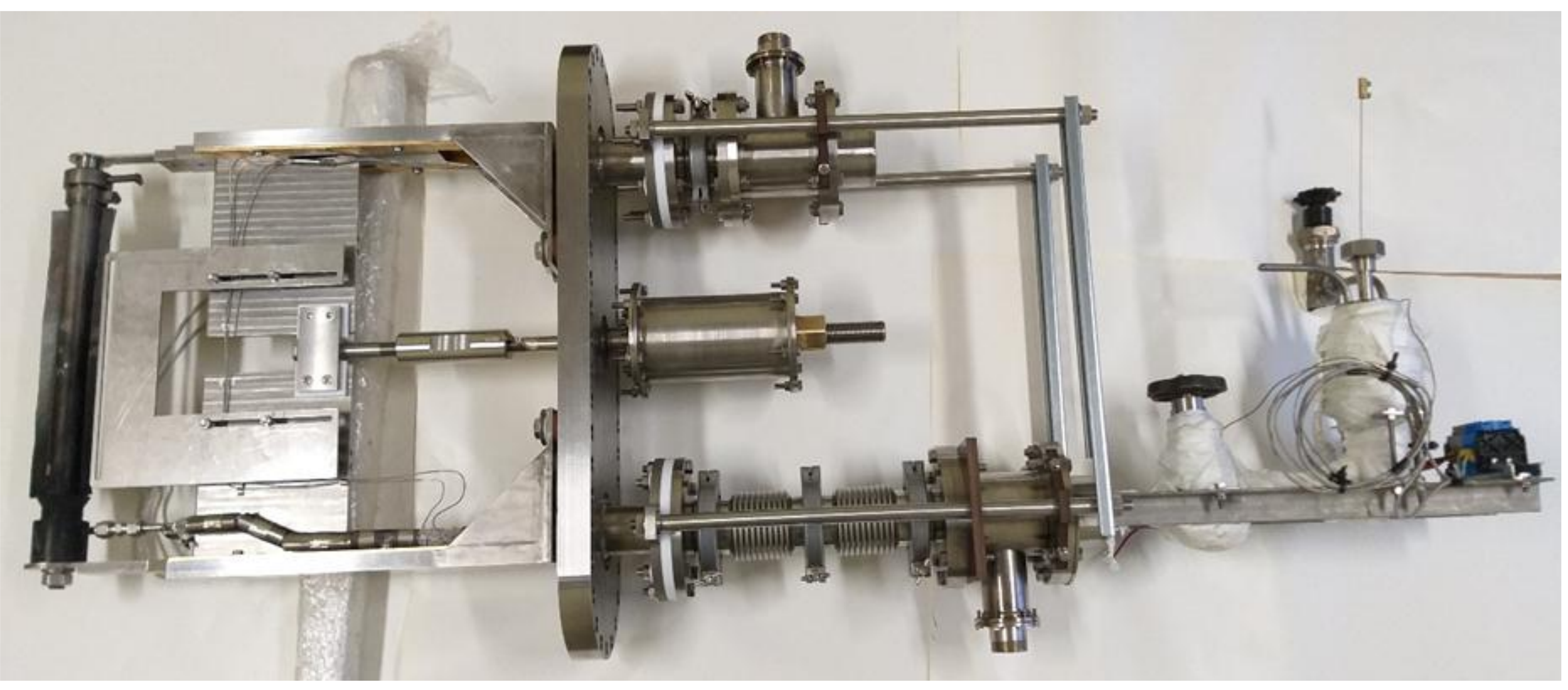
The development program for liquid metal PFCs, including the creation and model testing of prototypes, is aimed at solving the following key tasks:

1. providing continuous refilling and even distribution of LM on the CPS surface;
2. achieve periodical replacement of liquid metal (in particular, lithium) in the CPS structure with the aim to decrease of the concentration of dissolved tritium and interstitials;
3. study the ability of LM surface cleaning from the deposited films and products of interaction of LM with the residual gases through a providing of LM flow on the surface and in the structure of CPS;
4. development of design and operation parameters definition for the LM supply systems;
5. study of the process of removal of energy flux of high density from the PFC surface;
6. development of design and operation parameters definition for the systems of effective heat exhaust. Solving these problems will allow creating reliable and capable PFC for a stationary tokamak reactor.

PROTOTYPE OF THE LITHIUM LIMITER OF T-11M

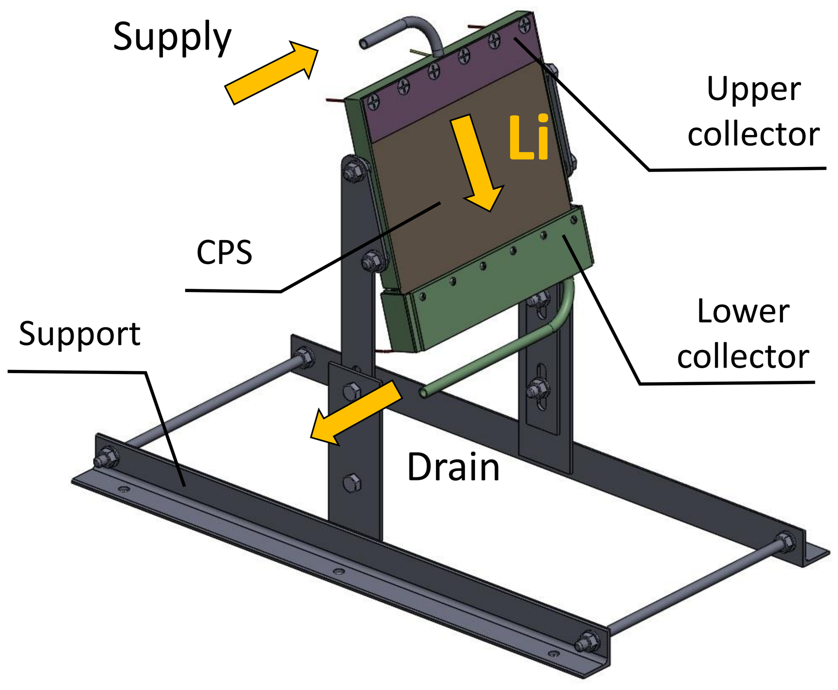
(The solution of the problems according to program points 1-4)



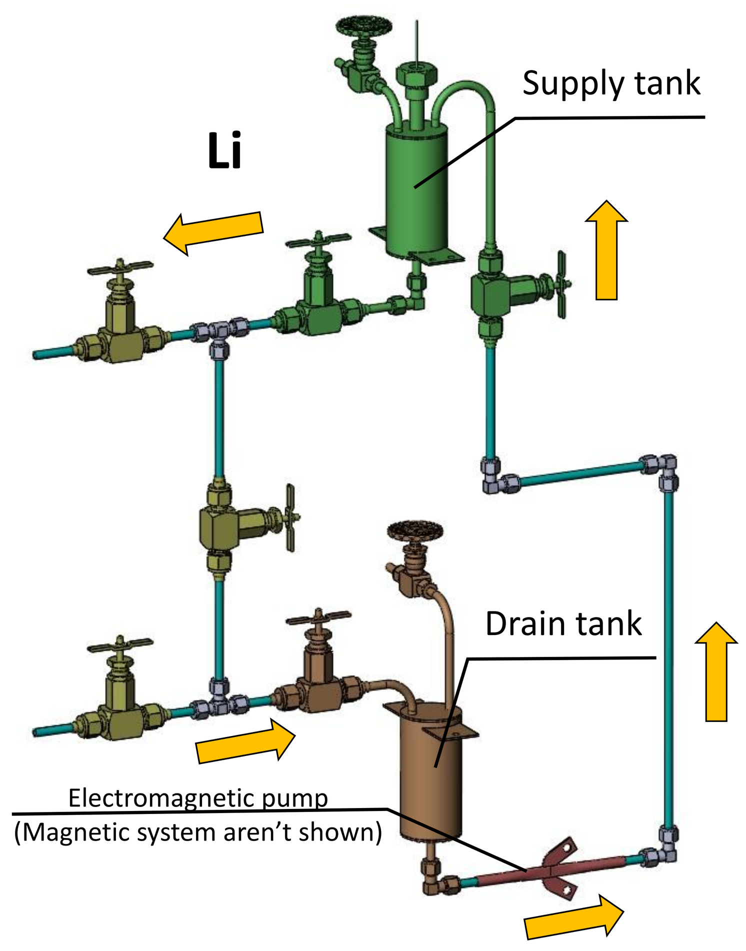


MOCKUP OF THE LITHIUM DIVERTOR TARGET OF T-15MD

(The solution of the problems according to program points 1-4)



EXTERNAL LITHIUM SUPPLY / REPLACEMENT SYSTEM OF LIMITER AND MOCKUP



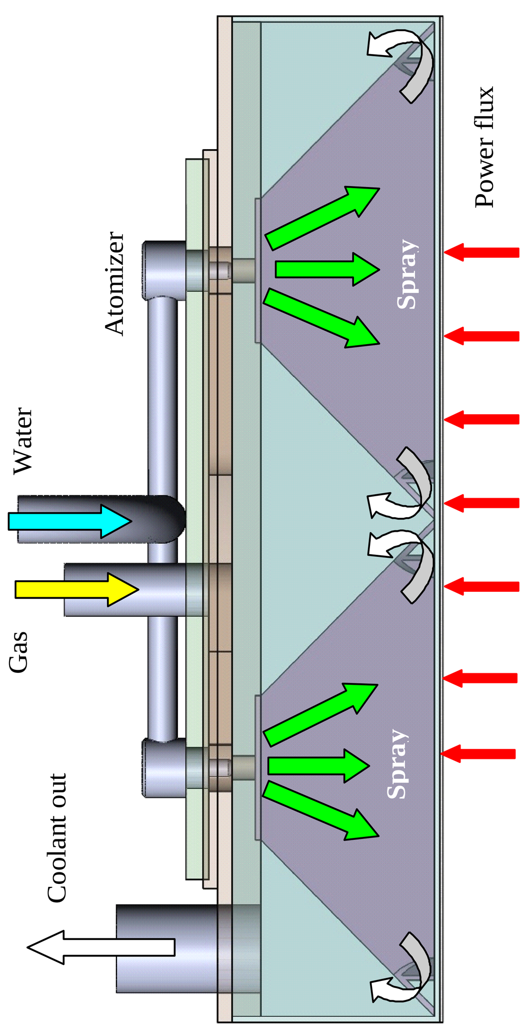
MAIN PARAMETERS OF THE LITHIUM IN-VESSEL ELEMENTS

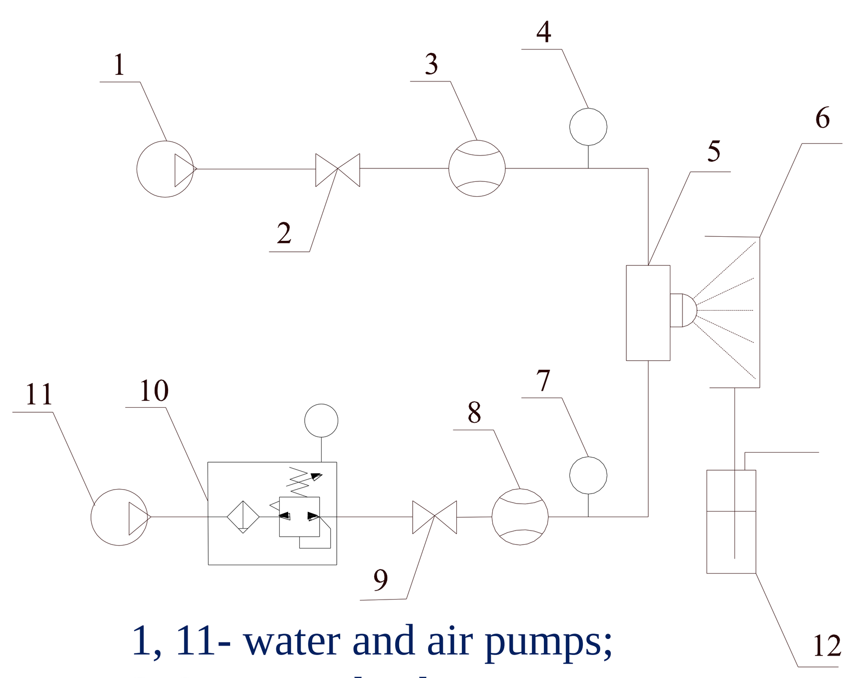
Parameter	Value	
	Lithium limiter of T-11M	Mockup of lithium divertor target of T-15MD
Dimensions, mm	height - 300, diameter - 32	height – 190, width – 120
Lithium surface area, cm^2	300	228
Lithium volume, cm^3	254	400
Operating temperature, °C	200-600	200-600

The first experiments in pilot facility demonstrated the possibility of creating a uniformly distributed flow of lithium both in the structure and on the surface of the CPS. The rate of Li exchange in the CPS was ~**0.4 cm^3/s** and the surface flow rate was ~**1 cm/s**.

IN-VESSEL ELEMENT MOCKUP BASED ON COOLING BY TWO-PHASE COOLANT AND COOLING SYSTEM SCHEMES

(The solution of the problems according to program points 5-6)





1, 11- water and air pumps;
2, 9 – control valve;
3,7- flowmeter;
4, 7- pressure meter;
5- atomizer;
6- plasma facing surface;
12- calorimeter

The evaluation of the heat exhaust efficiency is controlled by the value of the receiving surface temperature and using a calorimeter. To date, it has been found that at power flux up to 12 MW/m^2 the effective heat removal is provided at a coolant pressure not higher than **0.2 MPa** with a heat transfer coefficient of **70-100 kW/m^2K**. About this studies see more in poster with ID 765