The research of the modified SPT-70 thruster parameters and characteristics

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Abstract: The article presents results of the work carried out at EDB Fakel to modify the SPT-70 thruster. The modification intends to increase thrust, specific, lifetime and strength characteristics operating on xenon. Parameters and characteristics of the SPT-70M laboratory model were investigated in a wide range of discharge currents and discharge voltages. The discharge power range during this test was from 150 to 1200 W operating on Xenon. Parameters were verified at various configurations of the discharge chamber channel output part simulating a different accumulated lifetime. Parameters and characteristics of the SPT-70M laboratory model have been researched operating on krypton. The article presents the test results in the discharge power range from 250 W to 1000 W at the discharge voltage from 200 V to 400 V. Based on the lab model investigation results, an engineering model of the SPT-70M was developed and manufactured with a higher lifetime and thrust characteristics, with a smaller number of parts used and lower labor intensity (lower price).

Nomenclature

\[\begin{align*}
Id & = \text{Discharge current} \\
Ud & = \text{Discharge voltage} \\
Nd & = \text{Discharge power} \\
F & = \text{Thrust} \\
Psp & = \text{Specific impulse} \\
Xe & = \text{Xenon} \\
Kr & = \text{Krypton}
\end{align*}\]

I. Introduction

A n analysis of current trends in the use of electric propulsion systems (EP) for satellite shows¹ that the need for low and medium discharge power thruster is getting relevant nowadays. It is related to the development of commercial space programs, which include the production of large satellite constellation, for example such programs as OneWeb, StarLink. In these missions, the satellite usually weighs more than 100 kg and are placed at Low Earth Orbit (LEO) (altitude 1000 - 1300 km). Setting up this type of programs can expand the number of maneuvers performed by EP. For example, these systems can be used to make such maneuvers as transferring the satellite to the operating orbit, altitude and attitude control, and withdrawing the satellite from the operating orbit. One of the types of EP that is able to carry out a set of these maneuvers is state plasma thruster (SPT).

To achieve these goals, SPT has to satisfy the requirements:

- the operating range of the thruster discharge power should be from 500 W to 1200 W;
- the thruster has to provide at least 1 MN-s of total impulse

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During the development of satellite constellations, which include a large number of spacecraft, economical requirements such as cost of thruster production and its operation are also important, in addition to the abovementioned requirements to thruster parameters.

An acceptable cost of manufacture of thruster might be reached by optimizing the thruster construction and simplifying its producing.

One of the ways to achieve a reduction of the cost of thruster operation is replacement of the high-priced Xenon propellant to a cheaper alternative propellant, for example Krypton.

The SPT-70 series are the most suitable thruster for operation in the required range of discharge power among the list of SPTs which have been developed at EDB Fakel.

The first version of SPT-70 (M-70) was developed and tested in the 80s. The thruster was widely used as part of the module TM-70 on such spacecraft as Cosmos and Plasma-A.

SPT-70BR is the latest version of the SPT-70 series, which was used as a part of the traction module on Yamal-100. Nowadays it is operating on such spacecraft as KazSat-1, KazSat-2, Express-MD1, Express-MD2, Yamal-2007.

A design of the M-70 and the SPT-70BR has been optimized for operating at the range of discharge power from 600 W to 700 W. The design of thruster’s magnetic system and thruster’s thermal scheme is limited to operation at higher discharge power (no more than 900 W). Lifetime of these thrusters is 3100 hours and has been proven by a firing test. This lifetime is approximately equivalent to 450 kNs of total impulse.

A comparison of modern requirements for the thruster’s parameters and characteristics of LEO satellite constellations with the parameters and characteristics of existing version of the M-70 and SPT-70BR shows their incomplete compliance.

The goals of this work were to modernize the existing type of the SPT-70 and to bring it into line with modern requirements as well as to investigate its parameters and characteristics.

This article presents the results of work that has been done to achieve these goals.

II. Experimental Apparatus and Techniques

A. The prototypes of the modified thrusters

During the modification of the thruster, the following problems are to be solved:

- expanding operating range of thruster’s discharge power;
- increasing thrust, specific and lifetime characteristics;
- improving operational characteristics and manufacturability of a modernized engine.

Two prototypes, the lab model SPT-70M (LM) and the engineering model SPT-70M (EM) were manufactured to test the design of the modernized SPT-70:

LM was designed to determine the main parameters of the magnetic system and to conduct a preliminary thrust check and specific parameters check of the thruster in a wide range of discharge currents and voltages as well as the lifetime characteristics of the modernized thruster by modeling the configurations of the output part of the discharge chamber channel conforming to various lifetime of the thruster. The test results of the lab model were used to develop the EM.

The thrust and specific parameters of the thruster were checked in the various range of discharge power on the engineering model. The stability of parameters during the long-term operation was also checked. The resource characteristics of the thruster’s design have been defined. A preliminary examination of structure mechanical strength was made, and the temperature fields of the thruster’s components were determined. Based on test results of the engineering model, the strength and thermal models of the thruster were adjusted.

Based on the design of the EM, a primarily estimated strength and thermal models have been developed.

The erosion reserve of the discharge chamber insulator was increased to improve the lifetime characteristics. The material of the discharge chamber insulator has been replaced to a more erosion-resistant material based on pure boron nitride. The erosion resistance of this material is approximately 1.6 - 1.7 times greater than the BGP-10 ceramic which the discharge chambers of the M-70 and SPT-70BR was made of.

The main option of the electric power supply circuit of the magnetic system coils is the option when they are included in the discharge circuit. Additional supply of magnetic coils from a separate source has to be provided to ensure optimal parameters of the magnetic field in various discharge modes. An option when the magnetic coils are not in the discharge circuit and are energized from a separate power supply source can also be considered. In this case, the power source of the magnetic coils should switch on after appearance of discharge current.

In order to increase the parameters and lifetime characteristics, a similar concept of modernization to the concept of the SPT-100 modernization previously held at the EDB Fakel was used to modify the magnetic system of
SPT-70M. The main idea of this concept is to form a special so-called focusing field configuration with a large positive magnetic field gradient and take out the position of the maximum magnetic induction beyond the edge of the accelerator channel to improve the resource characteristics.

Providing a wide operating range of discharge power was achieved by creating a margin for magnetic saturation in the elements of the magnetic system.

Drafting the configuration of the magnetic lens to increase the lifetime characteristics of the thruster, results of lifetime tests of thrusters of other sizes were also taken into account.

The results of the computation of the magnetic system were used to develop and manufacture the LM’s magnetic system of SPT-70M. The design of the EM1’s magnetic system of SPT-100M\(^3\) was used as the basic design of the LM’s magnetic system.

The design of the SPT-70M’s EM was developed in order to qualify as the closest resemblance to the design of QM stage. The LM parametric test’s data was used during developing the EM magnetic system as well.

The EM has been designed emphasizing the improving manufacturability and simplifying details and assemblies. In particular, it relates to the configuration of the magnetic system. This configuration of the magnetic system reduces the number of details and assemblies. In addition, manufacturing and control technologies have been changed for most parts of the thruster. All this set reduces the complexity of manufacturing the thruster and consequently decreases the cost of the thruster.

SPT-70M was developed with the possibility of being delivered as autonomous thruster and as a part of the propulsion system. This is the first thruster of the SPT-70 family which is able to be autonomously delivered.

The engine includes ~ 50% of units previously checked and qualified as part of other products. The cathode KE-1R, which was performed as part of the SPT-50M engine\(^5\), is used as a cathode in SPT-70M.

The appearance of the model with thermocouples installed on it before the beginning fire tests is shown at Figure 1.

B. Experimental Apparatus

The tests were carried out at the EDB Fakel’s stands, which are equipped with a cryogenic pumping system.

A volume of the stand's vacuum chamber is 20 m\(^3\). The diameter of the fire compartment is 1900 mm. The distance from the exit plate of the thruster’s discharge chamber to the opposite wall of the vacuum chamber is 4200 mm.

The capacity of the pumping system allowed for a maximum pressure in the vacuum chamber of \(6.5 \times 10^{-5}\) mm hg (by air) at during the tests with a total flow to the thruster of 4.5 mg/s.

In order to measure the thrust, the stand is equipped with a thrust measurement system with a torsion pendulum type of thrust meter. The main measurement error of the system is 2.5%. To increase the accuracy of the thrust measurements, the entire system was calibrated before the start of the tests, as well as during the tests and at the end of each of series of tests. The results of the measurements obtained during the tests were also corrected for the thermal drift of the thrust meter.

The stand is equipped with a system for supplying, regulating and measuring the flow rate of the propellant, which allows for the operation of the thruster on both xenon and krypton. The substitution of the propellant was conducted without opening the vacuum chamber. The system provides the supply and flow measurement to the anode up to 6 mg / s and to the cathode - up to 0.6 mg / s. The main error of measuring the flow rate in the anode path is 2.5% and in the cathode path is 3.0 %. The flow measurement system was additionally calibrated before the start of testing and after each replacement of the propellant to reduce the error of measurement.

The electric power of both thruster samples was supplied from stand’s electric power systems.

Temperature sensors, thermocouples, were mounted into the outer and inner walls of the lab model’s discharge chamber to determine its temperatures. In order to increase the measurement accuracy, thermocouples were glued into
the body of the insulator of the discharge chamber. An example of mounting a thermocouple on the outer wall of the discharge chamber is shown at Figure 2.

The error of temperature measurement during the tests did not exceed ± 7 °C.

Thermocouples were also installed on the EM for a preliminary assessment of its thermal state and a preliminary verification of its thermal model (see Figure 1).

III. Results

A. Results of lab model’s tests

Parametric tests of the laboratory model of the SPT-70M were carried out in a wide range of discharge currents and voltages at a discharge power of 200 to 1200 W.

The magnetic coils were energized from separate sources of electrical power during these tests. Currents in the magnetic coils were being optimized at each of the modes. The main criterion, but not the only, of optimizing the magnetic field was the minimum discharge current. The specific impulse values, fluctuations of the discharge current, and the temperature of the discharge chamber walls were also taken into account during these optimizations.

Figure 3 shows the dependence of thrust and specific impulse on discharge power at three fixed values of the discharge current.

The specific impulse for all modes has been calculated under the condition that the cathode flowrate is 0.2 mg / s. The same condition was also adopted when calculating the specific impulse according to the results of tests with krypton.

Figure 4 shows the dependency thrust and specific impulse on discharge power at discharge voltage 300 V.

The obtained data shows that the thruster is able to operate at a discharge power from 200 to 1200 W. The optimal operating range of discharge power is range more than 600 W. However, the thruster has acceptable parameters in the low discharge power area. Its efficiency in this range might be increased by reducing the cathode flowrate. It should be noted that a maintaining discharge (keeper) is required to keep the cathode operating mode at a discharge power of less than 300 W.

Figure 3. The dependency of a) thrust and b) specific impulse of SPT-70M in the discharge current range from 1.5 A to 3.0 A operating on Xe.

Figure 4. The dependency of a) thrust and b) specific impulse of SPT-70M on discharge power at discharge voltage 300 V during its operating on Xe

Initially, the SPT-70M had been designed as an Xe-powered thruster, but taking into account the growing interest in the use of propellants alternative to xenon, its parameters on Kr were tested.
The thrust and specific parameters of the SPT-70M’s laboratory model when its operating on Kr were determined in the same range of discharge powers as it had operated on xenon. The parametric test was carried out in the range of discharge voltages from 200 V to 400 V. Its results are presented at Figure 5. The results, which were obtained during LM’s operating on Xe at discharge voltage 300 V, are shown at the same figure for comparison.

![Graphs showing thrust and specific impulse vs. discharge power for Xe and Kr](image1)

**Figure 5. The dependency of a) thrust and b) specific impulse of SPT-70M on discharge power during its operating on Kr.**

An analysis of the obtained results shows that the thrust for Kr is ~ 25 ... 30% lower than that of Xe at comparable discharge power modes. Due to a lower value of the propellant utilization factor (utilization coefficient), a greater divergence of the flow and a longer acceleration zone than that of Xe, the decrease of thrust for krypton is observed. Losses to the walls in the acceleration zone are increasing when divergence of the flow is great. This case can be proved by the results of temperature measurements of the discharge chamber’s walls. The temperatures of the outer and inner walls were 400 °C and 418 °C, respectively, at discharge power 660 W during thruster operation on xenon. When it was working on krypton at the same discharge power and with the same currents in magnetic coils, the temperatures increased to 420 °C and 460 °C, respectively.

Specific impulse for Kr is lower than that of Xe when thruster operates at discharge power less than 900 W. Specific impulses for Kr at discharge power more than 1000 W with discharge voltages 350 V and 400 V become equal and higher than specific impulse with Xe.

The optimal operating range of the discharge parameters for the SPT-70M on krypton might be a discharge power range from 900 to 1200 W with discharge voltage from 300 to 350 V.

Comparison of the parameters of the modernized thruster with the parameters of its analogue, SPT-70BR, are given in Table 1.

**Table 1. Parameters of STP-70BR and STP-70M.**

<table>
<thead>
<tr>
<th>Mode P, W</th>
<th>Ud, V</th>
<th>Thruster</th>
<th>Parameters F, mN</th>
<th>Isp, sec</th>
<th>Eff, %</th>
<th>Propellant</th>
</tr>
</thead>
<tbody>
<tr>
<td>660</td>
<td>300</td>
<td>STP-70BR</td>
<td>39</td>
<td>1470</td>
<td>43</td>
<td>Xe</td>
</tr>
<tr>
<td>660</td>
<td>300</td>
<td>STP-70M</td>
<td>41,3</td>
<td>1580</td>
<td>49</td>
<td>Kr</td>
</tr>
<tr>
<td>660</td>
<td>300</td>
<td></td>
<td>31,3</td>
<td>1460</td>
<td>35</td>
<td></td>
</tr>
</tbody>
</table>

A comparative analysis of the parameters SPT-70BR and SPT-70M obtained after its operating on xenon shows their growth by about 5 - 7% after the modernization done of SPT-70M.

One of the main requirements to the thruster is to produce required total impulse. This requirement usually defines the requirements to the thruster lifetime. The engine lifetime is mostly determined by the wear (erosion) of the insulator of the discharge chamber and the erosion margin of the insulator.

In addition, requirements to stability of thrust and specific impulse and to minimum values of these parameters during long-term operation are also set.

As it was previously written, the SPT-70 direct operating time on xenon is 3100 hours. The facts that the erosion reserve of the SPT-70M’s discharge chamber has been increased and the insulator material has been replaced by a more erosion-resistant material allow to predict that the thruster is able to produce a total impulse of at least 1 MN s.
As it has been shown that the thrust for Kr is \( \sim 25 \ldots 30\% \) lower than that of Xe at the same discharge power for each propellant. This means that to generate a total impulse thruster has to operate on krypton longer by that percent of time than it would be operating on xenon. Therefore, problems with the thruster lifetime\(^6\) working on krypton may be faced.

The studies of the ceramic samples’ erosion rate when thruster is working on krypton showed that it is \( 30 \ldots 50\% \) less than the rate of erosion on xenon\(^9\) in terms of everything else being equal. But tests of discharge chambers in the thrusters do not give a clear answer about its lifetime characteristic operating on krypton\(^10\). Therefore, in order to clarify the forecast of the lifetime characteristics of the STP-70M discharge chamber’s working on krypton, a comparative erosion tests were carried out.

The tests were carried out on a lab model SPT-70M. Before the test, a discharge chamber made of the same ceramic, BGP-10 (the main components of BN and SiO2), as the ceramic of the M-70’s discharge chamber was installed in the thruster. The configuration of output part of the discharge chamber is comparative to \( \sim 80 \) hours’ lifetime. The tests were being conducted at a similar operating mode to that of the M-70 (discharge current 2.2 A, discharge voltage 300 V). In the beginning of the test, the currents in the magnetic coils had been optimized to minimize the discharge current. The test duration was \( \sim 100 \) hours.

After the tests were completed, the erosion rates of the M-70 discharge chamber’s erosion profile during its operation on xenon were compared with the erosion rates of the lab model SPT-70M during its operation on krypton. The comparison results showed that the erosion rate when thruster operates on krypton is \( 30 \ldots 35\% \) higher than on xenon at identical operating modes and with the same channel configuration and the same material of the discharge chamber.

Another one thruster’s characteristics is the stability of its parameters during long-term operation or lifetime. A preliminary forecast of the stability of parameters during its lifetime can be made according to the results of tests of thruster with the configurations of the discharge chamber’s output parts, which simulate the erosion profile of various operating times\(^11\). Such kind of tests can also be used to predict erosion processes\(^12\).

Parametric tests the thruster with the different profile’s configurations of output part of the discharge chamber insulator’s which imitate different operating times were conducted on LM to assess the stability of the SPT-70M’s parameters during its lifetime.

The first configuration simulated the so-called steady-state\(^11\) profile outline that is comparative to the forecast profile of \( \sim 1200 \ldots 1300 \) hours operating time. The profile was forecasted for the condition that the material of the discharge chamber insulator is BGP-10, the propellant is xenon and the discharge power is 660 W (discharge voltage 300 V, discharge current 2.2 A).

The second profile simulated so-called ultimate lifetime (configuration simulating the ultimate erosion of the insulator). In both cases, the thruster was tested on Xe. Erosion of the output part is minimal or completely ends with this configuration of the discharge chamber.

Figure 6 shows the appearance of this profile before and after the test. After the test, no signs of erosion on the insulator profile were observed. This view is similar to the profile view of the SPT-100D in the ultimate state when there is no erosion\(^13\).

The tests were carried out at the range of discharge powers from 200 W to 1200 W with discharge voltages of 300 V and 450 V in the ultimate profile configuration. The test results for these two discharge voltage modes are presented at Figure 7.

![Figure 6. The ultimate lifetime configuration of discharge chamber insulator before(a) and after (b) the tests.](image-url)
The summary test results of the laboratory model at the discharge power mode 660 W and different erosion profiles are presented in Table 2.

### Table 2. The results of tests of thruster with different output part of the discharge chamber

<table>
<thead>
<tr>
<th>Outline of the profile</th>
<th>Thrust, mN</th>
<th>Specific Impulse, s</th>
</tr>
</thead>
<tbody>
<tr>
<td>At the beginning</td>
<td>41.1</td>
<td>1520</td>
</tr>
<tr>
<td>1200…1300 h operating time</td>
<td>40.5</td>
<td>1490</td>
</tr>
<tr>
<td>&quot;Ultimate lifetime&quot;</td>
<td>40.8</td>
<td>1450</td>
</tr>
</tbody>
</table>

The test results show good stability of the parameters when the geometry of the output part of the discharge chamber’s channel has been changed. The lower thrust value for the profile simulating the 1200...1300 hours lifetime is associated with the process of running-in of the simulated profile surface after its machining. These results were obtained during parametric tests, whose duration was significantly less than the running-in time that takes several dozens of hours.

The results of the tests allow us to make a preliminary conclusion about the stability of thrust and specific parameters in the process of direct lifetime tests. This conclusion will be verified by direct lifetime tests.

### B. Results of engineering model’s tests.

After manufacturing, the EM of SPT-70M has passed parametric tests on xenon and krypton. The method of conducting these tests was similar to the method of parametric tests of the laboratory model.

The range of tested modes was narrowed in these tests. We paid main attention to checking the thrust and specific parameters for perspective operating points and clarifying the parameters of the magnetic system during its operation at these points.

General views of the engine during its operation on xenon and krypton are presented at Figure 8.

![SPT-70M during the operating on xenon and krypton](image)

**Figure 8. SPT-70M during the operating on a) Xenon and b) Krypton**

The dependencies of thrust and specific impulse of SPT-70M on discharge power during its operating on Xe with discharge voltage 300 V are shown at Figure 9.
Figure 9. The dependency of a) thrust and b) specific impulse of SPT-70M from discharge power during its operating on Xe

The thrust is 41.4 mN with a specific impulse of 1645 s at the checkpoint at a discharge power 660 W ($U_d = 300$ V).

The dependencies of thrust and specific impulse of SPT-70M on discharge power during its operating on Kr with discharge voltage 300 V are shown at Figure 10.

Figure 10. The dependency of a) thrust and b) specific impulse of SPT-70M on discharge power during its operating on Kr.

The thrust is 32.4 mN with a specific impulse of 1665 s at the checkpoint at a discharge power 660 W ($U_d = 300$ V). In the 900 W discharge power mode ($U_d = 300$ V), the thrust is 44.3 mN with specific impulse 1585 s, which is comparable with the parameters and characteristics of the thruster operating on Xe at the 660 W discharge power mode.

The 100-hour fire test, the erosion test, was performed to clarify the forecast of EM’s lifetime operating on krypton. The tests were performed at the discharge power 900 W (the discharge current 3.0 A, the discharge voltage 300 V). The geometric characteristics of the erosion zone were measured before and after the test. These results were used to estimate the erosion rate of the discharge chamber’s insulator during the thruster operation on krypton. The obtained values of the erosion rate of the insulator are close to the erosion rate of the insulator of the SPT-70BR’s discharge chamber (material of the insulator is BGP-10) during its operation on xenon at the discharge power 670 W.

The appearance of the EM after the fire test is shown at Figure 11.

The obtained result confirms the earlier conclusion that the erosion rate of the discharge chamber’s insulator during the thruster operation on krypton is ~ 30% higher than the erosion rate during the thruster operation on xenon.

The accurateness of the earlier made assessment of the erosion rates ratio after the erosion tests of LM is justified as it will be described below.

The erosion test was performed at the discharge power of 900 W when the discharge power was ~ 1.35 times greater than the discharge power during the life tests of SPT-70BR. To estimate the value of the erosion rate, a clause
can be accepted that the erosion rate is proportional to the discharge power. As it was written above, the EM’s discharge chamber was made of the material which erosion resistance is 1.6...1.7 times greater than that erosion resistance of BGP-10. And how it pointed out previously that the erosion rates during operating thruster on different xenon and krypton gases are close. As a result, it turns out that the erosion rate during the thruster operation on krypton is about 1.30 ... 1.35 times the erosion rate during the thruster operation on xenon in the case of the same operation condition.

The greater value of the erosion rate during EM’s operation on krypton can be explained, in particular, by the following. As study shows\textsuperscript{14}, the erosion process is significantly dependent on the magnetic field configuration in the discharge chamber’s channel. The erosion rate is minimal if the magnetic field configuration is optimal. In our case, the configuration of EM’s magnetic lens has been optimized for the thruster operation on xenon. It is also known that the optimal configurations of the magnetic field in the discharge chamber’s channel throughout the thruster operation on xenon and krypton are different\textsuperscript{7}. Perhaps, it might be the reason of the increasing of the erosion rate when EM operates on krypton.

EDB Fakel are conducting a lifetime test of SPT-70M EM on krypton to clarify the dynamics of the thruster’s parameters and its rate of erosion during its long-term operation on krypton. The test are being carried out at the discharge power of 900 W (discharge current 3.0 A, discharge voltage 300 V). The average thrust during this time of operation was 42 mN at a specific impulse of 1520 s.

C. Preliminary verification of strength and thermal models

The strength finite element model of EM is developed in the NISA / Display application package and to verify it a finite element model was created in the LMS system (see Figure 12) which is used during mechanical tests. The figure also shows the directions of the axes of mechanical loads’ impact.

In order to obtain data for preliminary verification of the EM’s strength model, the thruster was tested for mechanical stresses.

The test was done in the following sequence: resonance test – random vibration test – resonance test.

The thruster has undergone a sinusoidal vibration in the frequency range 5 - 2000 Hz with an amplitude value of vibration acceleration equal to 0.5 g during resonance tests. The tests were carried out by the method of smooth frequency sweep. A frequency scanning speed was 2.0 octaves per minute.

When test for the effects of random vibrations was in process, the following loads were exposed to the thruster: along the plane of the thruster mount (X and Z axes) - 6.3 g, perpendicular to the mount plane - 12.2 g. The exposure duration along each axis was 60 s.

After the test was over, no visible mechanical damage has been detected and the EM has remained in technically sound condition.

The analysis of the resonance test’s results shows that the obtained changes of the resonant frequencies are within the acceptable values after testing for the effects of random vibrations. The lowest resonant frequency of the thruster is 211 Hz.

The results of the preliminary mechanical test will be used to clarify the strength model of the SPT-70M. The results of temperature measurements of EM’s units that have been obtained after the firing tests were used to preliminarily define the temperature distribution over the thruster design. The calculation was performed in a simplified version of the thermal model with a simulation of the maximum possible effect of direct and reflected flows of thermal radiation of the Sun and the Earth on the thruster in two boundary conditions:

- the temperature of the mounting place + 55 °C;
- in case of the absence of external heat fluxes and seat temperature - 25 °C

The temperature distribution over the thruster is calculated for the thruster operation on krypton at the discharge power of 600 W, 800 W and 1000 W.

The temperature values do not reach critical values at any points and the total value of the lost thermal flux lies in the range of 1.2 W to 4.1 W. At the specified thermal boundary conditions of conductive thermal flux on each foot from 0.05 W/K to 0.5 W/K the temperature values lie in the allowable range. The final value of this conductive thermal coupling will be determined based on the results of the “cold” thermal balance test.

The results of the preliminary mechanical test will be used to clarify the strength model of the SPT-70M.
IV. Conclusion

A prototype of new modernized SPT-70M has been designed and manufactured at EDB “Fakel” that satisfies modern requirements. According to the results of the magnetic system modernization, the thruster’s parameters have been increased by 5 - 7% at 660 W discharge power mode with discharge voltage 300 V operating on Xe. In this mode, thrust is 41.4 mN with a specific impulse of 1645 s. The new thruster prototype is also capable of working on Kr. Operating on it, the thrust is 32.4 mN with a specific impulse of 1665 s at discharge power 660 W with discharge voltage 300 V and the thrust is 44.4 mN with a specific impulse 1585 s at the 900 W discharge mode (Ud = 300 V).

The EM of SPT-70M is passing the lifetime test. The SPT-70M’s EM2 is planned to be manufactured taking into account the obtained results described above. A vast set of tests of the EM2 including parametric tests on both propellant, Xe and Kr, and tests of environment’s influence (mechanical and thermal-vacuum tests) is to be conducted.

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