Determination of gas temperature in the flow

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Abstract. The paper presents the results of thermal experimental studies, the purpose of which is to obtain the values of the gas flow temperature by the method gradient of the volume (mass) consumption. Explored the pipeline that is heated for on the short middle section. An equation was derived to determine the temperature of the gas in the heating zone by the measured static pressure before heating and after it and the gas consumption before and after heating. The practical significance lies in determining the thermodynamic parameters of the gas in the in the tract of the electrothermal Microdrive of a small spacecraft, when the experimental conditions and design features of the engine do not allow other methods to be used.

1. Introduction
Measurement of gas temperature in heat exchangers of resistive jet corrective engines of small thrusters spacecraft (SSC) is an urgent task, which inevitably arises in the design of new micro-engine samples. The relevance is due primarily to the miniaturization of the micro thrust SSC engines, that reduces, and in some cases, excludes the use of traditional means of measuring temperature, in the second place, high gas temperatures at the outlet of the engine chamber and inside it, as well as high temperatures of the housing elements (we are talking about electric arc engines of low thrust). The second circumstance leads to damage and melting of elements of measuring devices.

In experimental practice, thermal receivers using thermoelectric converters (thermocouples) are widely used. In stationary conditions the thermosensitive element of the thermocouple (junction) measures the equilibrium temperature, which is the balance between the heat supplied to junction and the heat withdrawn in the form of radiation and thermal conductivity of the thermocouple structure [1]. In the field of micro thrust a engines, the situation is complicated by the fact that the costs of heat carriers (mass flow of working gases) do not exceed 5 mg/s, and the pressure in the heating chamber is not higher than 0.5 ATM (for electric arc engine (EAE)) and 1000 Pa (for engine with dilatometric valve-evaporator (DMM) [2]). The electrical power supplied to the resistive elements of the EAE is not more than 70 W, for DMM this figure does not exceed 8 W, therefore, losses on radiation and thermal conductivity become significant.

Currently, the temperature measurement methods can be divided into contact and non-contact. In contact methods the primary transducer is in direct contact with the controlled a medium or surface. The primary converters are thermometers, expansion, resistance, thermoelectric converters, quartz temperature sensors in the frequency [3].

Contactless methods allow you to measure temperature at a distance from a controlled object or medium. This method is implemented in pyrometers [3].

As noted above, contact methods with thermoelectric transducers are widely used in the measurement of gas flow temperature. An indirect estimate of the gas temperature can be obtained by determining the heat loss of the pipeline through which the flow moves. This method is cumbersome with its mathematical apparatus, based on the Newton-Richman equation, which includes the heat transfer...
The search for this coefficient is a complex task, in which it is necessary to know the modes of gas flow in the pipeline, the coefficient of thermal conductivity of the gas, specific heat, the effective diameter of the molecules, etc.

Currently, the material-technical basis of scientific research laboratory Omsk state technical University "The propulsion system of micro-thrust small spacecraft" ("PSMT SSC") under investigation micromotors SSC of two types: electric arc with low power consumption and dilatometric. Difficulties in measuring the temperature of the gas inside the engine chambers are the high temperature of the body parts of the electric arc engine (900 °C and above) and the capillary flow elements of DMM. In both cases, the use of thermocouples is not possible.

2. Formulation of the problem
The task is to develop a method for determining the temperature of the gas flow in the working chamber of the low-thrust engine. The mathematical basis of the method should have a minimum number of physical parameters involved, because each new member of the mathematical model introduces an error in the results of calculations. For the practical implementation of the methodology should be sufficient material and technical base of the "PSMT SSC" without additional resources.

Problems solved in the course of the study and reflected in this work:
1. To develop a method for determining the temperature of the gas in the working chambers of an electrothermal Microdrive;
2. To conduct experimental studies at the stand and the subsequent theoretical processing of the experimental results in order to verify the technique.

3. Theory
It is known that with increasing gas temperature its viscosity increases. In laboratory tests, this is manifested in a drop in gas flow in the supply line. In the heating area there is a "thermal resistance", which leads to a drop in the mass flow of gas [4].

For low gas flow velocities, when the absolute value of the pressure changes slightly, the formula is valid [4]:

$$\frac{G_{\text{cold}}}{G_{\text{hot}}} = \sqrt{\frac{T_{\text{hot}}}{T_{\text{cold}}}} - 1,$$

(1)

where $G_{\text{cold}}$, $G_{\text{hot}}$ -respectively, the mass flow of gas before and after heating; $T_{\text{cold}}$, $T_{\text{hot}}$ -respectively, the temperature of the gas before and after heating. Formula (1) does not take into account the heat exchange between the walls of the pipeline and the gas.

In case the expiration of a heated gas into the vacuum, when changes in static pressure become visible, the formula (1) gives an inflated gas temperature (10-12 times).

To derive an equation that takes into account the change in gas pressure in the heated flow, consider the pipeline (figure 1) with thermodynamic parameters of the gas before heating (view A) and after heating the pipeline (view B).

In case of gas movement in the pipeline (position 1, figure 1) without heating, gas with parameters $f_0 = (T_0, P_0, \rho_0)$ it is entered through a device for determining the volume flow of gas (float rotameter, position 3 in figure 1) into pipeline 1. Passing the rotameter, the gas parameters vary slightly and become $f_1 = (T_1, P_1, \rho_1)$. The rotameter shows the value of the volumetric flow $Q_1$, the pressure gauge (position 4, figure 1) shows the static gas pressure at the outlet of the rotameter at the inlet of the pipeline. With a sleek pipeline of constant cross-section, pressure losses can be neglected and the gas parameters at the output $f_2 = f_1 = (T_0, P_1, \rho_1)$. The static pressure of the gas at the outlet is recorded by the pressure gauge 2.
Figure 1. Gas parameters in the pipeline before heating (A) and after heating (B)

In the case of heating the pipeline to $T_{el}$ temperature by an external source of heat, the gas parameters before and after the heating phase take the corresponding values

$$f_1 = (T_0, P_2, \rho_2) \quad \text{and} \quad f_4 = (T_1, P_3, \rho_3).$$

Due to the appearance of "thermal resistance", the pressure $P_2$, recorded by the pressure gauge 4 increases relative to $P_1$, and the pressure $P_3$, recorded by the pressure gauge 2, becomes lower $P_1 \leq P_3 \leq P_2$. The volume flow rate is determined by the rotameter and is $Q_2$. When gas is heated $Q_1 \geq Q_2$. Due to the drop in static pressure at the outlet of the pipeline, the gas velocity increases and the volume flow rate increases $Q_3 \geq Q_2$.

The basic equations put in the method are the continuity equations and equations of molecular kinetic theory of gases.

Continuity equations for cases A and B (figure 1) take the form:

$$Q_1 \cdot \rho_1 = Q_2 \cdot \rho_2 \quad \text{and} \quad Q_2 \cdot \rho_2 = Q_3 \cdot \rho_3.$$  \hspace{1cm} (2)

Since, the volume flow rates at the inlet to the pipeline before and after heating are recorded by the rotameter, it is possible to obtain a ratio with the known value of the left side:

$$Q_1 \cdot \rho_1 Q_2 \cdot \rho_2 \quad = \quad Q_3 \cdot \rho_3.$$  \hspace{1cm} (3)

The density of the gas can be expressed in terms of the free path of the molecules $\lambda$, the viscosity $\eta$ and the average speed of the molecules $\nu$ [5]:

$$\rho = \frac{3 \cdot \eta}{\nu \cdot \lambda}. \hspace{1cm} (4)$$

The average speed of molecules can be expressed in terms of thermodynamic parameters of the gas [5]:

$$\nu = \sqrt{\frac{8 \cdot R \cdot T}{\pi \cdot M}}, \hspace{1cm} (5)$$

where $R$ – universal gas constant; $M$ – molecular weight of gas; $T$ – gas temperature.

The average free path of the molecule is inversely proportional to the pressure [5]. According to molecular kinetic theory you can write:

$$\lambda = \frac{k \cdot T}{\sqrt{2 \cdot P \cdot \pi \cdot \sigma^2}}, \hspace{1cm} (6)$$

where $k$ – Boltzmann constant; $T$ – gas temperature; $P$ – gas pressure; $\sigma$ – the effective diameter of the molecules.

The dynamic viscosity of the gas, as a function of temperature, can be described by the Sutherland formula [6]:

$$\eta = \eta_0 \cdot \frac{C + T_0}{C + T} \cdot \left(\frac{T}{273}\right)^{\frac{3}{2}}, \hspace{1cm} (7)$$
where \( \eta_0 \) – dynamic viscosity at control temperature \( T_0 \); \( T \) – absolute temperature of the gas; \( C \) – Sutherland constant, which depends on the nature of the gas.

Thus, the equation (4) can be written as:

\[
\rho = \frac{3 \cdot \eta_0}{2 \cdot k} \left( \frac{C + T_0}{T + C} \right) \sqrt{\frac{\pi^3 \cdot M \cdot P \cdot \sigma^2}{T_0^3 \cdot \sqrt{R}}}.
\]

Equation (8)

Then, expressions for densities in cases A and B (figure 1) take the form:

\[
\begin{align*}
\rho_1 &= \frac{3 \cdot \eta_0}{2 \cdot k} \sqrt{\frac{\pi^3 \cdot M \cdot P_1 \cdot \sigma^2}{T_0^3 \cdot \sqrt{R}}} \\
\rho_2 &= \frac{3 \cdot \eta_0}{2 \cdot k} \sqrt{\frac{\pi^3 \cdot M \cdot P_2 \cdot \sigma^2}{T_0^3 \cdot \sqrt{R}}} \\
\rho_3 &= \frac{3 \cdot \eta_0}{2 \cdot k} \sqrt{\frac{\pi^3 \cdot M \cdot P_3 \cdot \sigma^2}{T_0^3 \cdot \sqrt{R}}} \\
\end{align*}
\]

Equation (9)

In case of equality of the areas of flow sections of the pipeline right side of equation (3) can be recorded through the speed cold \( v_1 \) and hot \( v_3 \) gas streams:

\[
\frac{Q_1 \cdot \rho_1}{Q_3 \cdot \rho_3} = \frac{v_1 \cdot \rho_1}{v_3 \cdot \rho_3}.
\]

Equation (10)

The rate of gas flow at a known pressure drop can be determined by the formula of Saint Venant [7]:

\[
v = \frac{2 \cdot \gamma \cdot R \cdot T}{\gamma - 1} \left[ 1 - \left( \frac{P}{P^*} \right)^{\gamma-1} \right],
\]

Equation (11)

where \( \gamma \) – adiabatic index of gas; \( P^* \) - gas source pressure; \( P \) – the pressure of the gas receiver.

According to the formula (11), we obtain the values of gas velocities at the outlet of the pipeline to the region with pressure \( P_{vak} \):

\[
\begin{align*}
v_1 &= \frac{2 \cdot \gamma \cdot R \cdot T_0}{\gamma - 1} \left[ 1 - \left( \frac{P_{vak}}{P_1} \right)^{\gamma-1} \right] \\
v_3 &= \frac{2 \cdot \gamma \cdot R \cdot T_3}{\gamma - 1} \left[ 1 - \left( \frac{P_{vak}}{P_3} \right)^{\gamma-1} \right]
\end{align*}
\]

Equation (12)

Substituting the formula (4) – (12) in the formula (3), after the transformation, you can obtain an equation to determine the temperature of the gas after the heating area, without taking into account heat exchange with the walls of the pipeline:

\[
\frac{Q_1}{Q_2} = \sqrt{\frac{T_0}{T_3}} \cdot \frac{P_2}{P_3} \cdot \left( \frac{T_1 + C}{T_0 + C} \right) \cdot \left[ 1 - \frac{\beta_{cold}}{\beta_{hot}} \right]^{\gamma-1},
\]

Equation (13)

where \( \beta_{cold} = \frac{P_{vak}}{P_1} \) u \( \beta_{hot} = \frac{P_{vak}}{P_3} \) – accordingly, the differentials pressure in the pipeline before and after heating.

In practice, the pressures \( P_1 \) and \( P_2 \) are easily determined by the pressure gauge installed at the inlet of the pipeline (the working chamber of the engine), while the instrument pressure \( P_3 \) is difficult to determine, especially for an electric arc micro engine. At the measuring point \( P_3 \) in the electric arc engine, the temperature of the housing elements rises above 900 °C.

The static pressure drop during heating can be determined from the equation of conservation of pulses [4]:

4
In equation (14), the gas density before the "thermal resistance" can be expressed in terms of the Mendeleev-Clapeyron equation:

\[ \rho_2 = \frac{P_2 \cdot M}{R \cdot T_0}. \]  

(15)

The speed of gas at the outlet of the pipeline can be determined by the equation (12), the speed of gas in the cold section of the pipeline can be determined by knowing \( Q_2 \) according to the rotameter and the area of the flow section of the pipeline \( F \):

\[ \nu_2 = \frac{Q_2}{F}. \]  

(16)

Substitute in the expression (14) formulas (12), (15) and (16) and we get:

\[ P_2 - P_3 = \nu_2 \cdot \rho_2 \cdot (\nu_3 - \nu_2). \]  

(17)

The joint solution of equations (13) and (16) allows to determine the gas flow temperature by the difference of volume flow rates. In equations (13) and (16), the recorded values are: the volume flow of gas before heating \( Q_1 \) and after heating \( Q_2 \) (by rotameter); the pressure at the inlet to the pipeline before heating \( P_1 \) and after heating \( P_2 \) (by manometer).

4. Research Results

To verify the theoretical calculations, the technique was applied in the analysis of the results of the experimental study of the heating of the working gas in an electric arc engine at the expiration of into vacuum and heating the gas in a pipeline of a constant cross section of the experimental stand at the expiration in atmosphere. The article presents the second case.

The experimental stand was manufactured in "PSMT SSC" and presented in figure 2.

![Image of experimental stand](image)

**Figure 2.** Experimental stand to determine the value of gas heating by the differential flow rates method

Working gas (air) is supplied from the compressor in the supply line experimental stand (position 6, figure 2). A mechanical pneumatic shut-off valve 1 is installed on the supply line. The line pressure is registered by the pressure gauge MP3A-UF (position 2). After the valve gas enters the rotameter RMA-0.1 GUZ (position 3), and after him in the heat block (the area with position 5 in figure 2), consisting of a pipeline with an internal diameter of 5 mm (position 8), electric heater of the pipeline 10 and thermocouple 9 located along the axis of the pipeline at the outlet of it. In the pipeline 10 at three points, conditionally in the area before the "thermal resistance", in the "thermal resistance" and after it, Prandtl tubes are installed. Further, numbering of these tubes is carried out "on a stream" (from left to right in figure 2): № 1 –in the field of cold gas; № 2 –in the heating zone; № 3 –in the field of hot gas. The pipeline is made of AISI 321 material and painted with black matte enamel to ensure accuracy of thermogram the thermographic camera (model Testo 875-lii). Prandtl tubes are connected.
to three blocks of piezometers 7 by means of flexible pipes. To observe the change in the volume flow of heated gas at the outlet of the heat block, a rotameter RMA-0.16 GUZ (position 4).

At the first stage of the experiment gas was supplied to the pipe without heating. The adjusting screw of the rotameter built the value of the flow rate on the model RMA-0.1 GUZ equal to 20 divisions. Static pressure was measured in the sections of the pipeline (dotted line in figure 3). Overpressure in the line -0.58 bar. Then the mechanical valve cut off the air flow and the heater was supplied with a voltage of 4 V (electric current 0.629 A). The pipeline was heated to equilibrium temperature (see the first column in the table 1): the maximum value of 83.3 °C; average – 33.2 °C. The heating area of the pipeline is limited by the dimensions of the heater. Relatively low thermal conductivity of steel AISI 321 does not allow the pipeline to warm up – the heating area does not go beyond the boundaries of Prandtl tubes. Then air was supplied, with the help of a thermal imager, the temperature of the pipeline was recorded minute by minute, the readings of the manometer, piezometers, thermocouple and rotameters were taken. The results of measurements are given in table 1 and 2.

![Figure 3. Static overpressure in the pipeline without heating and with heating](image_url)

The images are combined in scale. The red arrows show the static pressure measurement points, the white arrows show the temperature at the pressure measurement points and illustrate the thermal field displacement along the flow. From table 1 and 2 it is seen that there is an active heat exchange between the gas and the material of the pipeline: air, passing the heating zone, takes the thermal power and gives its part to the pipeline downstream, a thermocouple installed at the outlet of the pipeline coaxially with the flow, registers the residual heat content of the gas.

It is also seen that the flow rate of the heated gas is conditionally constant: when installing the flow rate in the "cold" pipe, the float of the rotameter was stationary at the level of 20 divisions, with the flow in the "hot" pipe, the float smoothly changed its position from 19 to 20 divisions. Despite the flow rate differences, the growth of the residual air temperature did not stop. In the seventh minute, the temperature of the gas on the thermocouple was 29.6 °C (± 2 °C – the measurement error of the thermocouples of the type TXA).

From table 1 and 2 it can be seen that the excess pressure in the supply line of the device MP3A-UF is 0.58 bar for the first four minutes of gas flow, then the pressure rises to 0.6-0.62 bar. This phenomenon has been observed in several measurements. This pressure jump can not be associated with heating the gas and the appearance of "thermal resistance" in the pipeline, and is a consequence of the air compressor pneumatic systems. The volume of the receiver is 6 l, when the gas ends, the pressure in the receiver decreases, the gas reducer is unloaded, the output pressure increases. In such cases, 1-2 division increases the volume flow rate in the rotameter. Static pressure in the "cold" pipeline and flow rate setting on the rotameter were made at an overpressure in the supply line of 0.58 bar. Therefore, to test the formula (13), experimental data on the pressures and consumption of the first four minutes of heating will be taken.

The results of the calculation of the air temperature in the heating zone are shown in table 3 and figure 4.
Table 1. The results of measurements in the area from 0 to 3 min.

| Parameter | Description |
|-----------|-------------|
| Equilibrium temperature of the pipeline without gas | The motion of the gas t=1 min; testimony MP3A-UF -0.58 bar; rotameter RMA-0.1 GUZ -19 (19.5) divisions; rotameter RMA -0.16 GUZ -23 divisions. |
| Thermocouple measurements during the whole time of motion of the gas | The motion of the gas t=2 min; testimony MP3A-UF -0.58 bar; rotameter RMA -0.1 GUZ -19 (19.5) divisions; rotameter RMA -0.16 GUZ -24 divisions. |
| The motion of the gas t=3 min; testimony MP3A-UF -0.58 bar; rotameter RMA -0.1 GUZ -20 (19.5) divisions; rotameter RMA -0.16 GUZ -26 divisions. |
Table 2. The results of measurements in the area from 4 to 7 min.

| Time (min) | Overpressure, Pa | Length of the pipeline, mm |
|-----------|------------------|---------------------------|
| 4         | -0.58 bar; RMA 0.1 GUZ -20 (19.5) divisions; | 200                      |
| 5         | -0.6 bar; RMA 0.1 GUZ -20 (19.5) divisions; | 250                      |
| 6         | -0.62 bar; RMA 0.1 GUZ -19 (19.5) divisions; | 200                      |
| 7         | -0.62 bar; RMA 0.1 GUZ -19 (19.5) divisions; | 250                      |
Figure 4. The estimated value of air temperature in the pipe and the temperature of the heater

In Table 3 and Figure 4 shows two curves of the change of the gas temperature with time. This is due to the swing of the float at the first two minutes of heating the air flow, as well as the inaccuracy of the float position registration at such small flow rate differences. Thus, the lines indicate the limits of possible temperatures. For Figure 4 in addition, the cooling lines of the heating element are given, which indicates the intake of thermal energy in the gas flow from the heating surfaces.

| Time, minutes | Rotameter reading RMA -0.1 GUZ -19 divisions | Rotameter reading RMA -0.1 GUZ -19.5 divisions | Thermocouple |
|---------------|----------------------------------------------|-----------------------------------------------|---------------|
| 1             | 79.37475727                                  | 59.47518093                                   | 27.06±2       |
| 2             | 79.23811786                                  | 59.34012191                                   | 28.17±2       |
| 3             | 44.48898432                                  | 44.48898432                                   | 28.79±2       |
| 4             | 44.22072765                                  | 44.22072765                                   | 29.07±2       |

As noted above, the gas in the pipeline moves with the heat exchange. The mechanism is as follows: at the initial moment of movement, the gas enters the heating area, takes part of the thermal energy from the wall, cooling it, with further movement downstream, gives part of the heat to the pipeline and reaches the thermocouple colder.

Consider the state of the system in the first four minutes of gas supply to the pipeline heated to the equilibrium temperature. Denote heat power gas received from the heater $P_{heater}$, thermal power given to the gas pipeline further downstream $P_{pipeline}$. Then, the residual thermal power of the gas recorded by the thermocouple is equal to:

$$P_{gas} = P_{heater} - P_{pipeline}$$  \hspace{1cm} (18) 

For Figure 5 the temperature fields of the pipeline before the gas start and a minute after the gas supply are presented.

Visible as the central area of the pipeline, where the heating element is located, is cooled, and the pipeline is heated downstream.

Figure 5. The temperature fields of the pipeline before the air supply and a minute after the supply
To search for thermal power, thermograms are represented as a field of points from which the temperature points of the pipeline are allocated. Knowing the length of the pipeline (300 mm) and the number of temperature points placed on this length, it is possible to present the pipeline as the number of n segments with a constant temperature. In this case, the thermal power received or given away by gas, can be expressed by the formula:

\[
P = \frac{c_p \cdot m}{n \cdot t} \left( \sum T_i - \sum T_j \right),
\]

(19)

where \(c_p\) – specific heat of the material (steel AISI 321 or heat-resistant sealant, in this case); \(m\) – mass of material; \(t\) – the time during which the temperature of the segment has changed from a value \(T_j\) to the value \(T_i\).

From the thermograms of the first four minutes of the gas motion the graphs of the thermal field displacement are obtained (figure 6).

Consider the line at \(t=0\) min and at \(t=1\) min (figure 6). The heating line of the pipeline before the heating zone is shifted to the left, which indicates an increase in the temperature of the gas (respectively, cooling the pipeline), then the pipeline heats up beyond the intersection point of the curves (the gas loses energy –cools). The same processes occur in the next three minutes, until the thermal system will not come to a stationary mode. Thus, the power set mode to the value \(P_{\text{heater}}\) is replaced by the power loss mode by the value \(P_{\text{pipeline}}\).

Using thermograms, formulas (18) and (19), knowing the mass flow of air, its specific heat and initial temperature, it is possible to determine the temperature of the air in the heating zone and at the outlet of the pipeline.

In table 4 and figure 7 the gas temperature values obtained from the power balance equation are given.
5. Discussion of results

Determination of the gas flow temperature is an important task of gas dynamic calculations. In this paper we propose a simple way to determine this important thermodynamic parameter through the static gas pressure and its volume (mass) flow rate. A formula was derived to determine the maximum temperature of the gas and an experimental stand was made.

As a result of experimental studies and theoretical processing, in addition to the method of volume flow rate difference, a method for determining the temperature of the gas based on the balance of thermal power was presented. This method was chosen as a verification method. The differential method and the power balance method give a qualitative picture of the gas temperature change in the non-stationary mode, when the gas is supplied to the heated surface. The method of determining of the gas the temperature thermocouples is accurate only in stationary mode, when the thermal balance on the thermocouple housing has already been established. Hence the disadvantage of the thermocouple method.

Determination of temperature by the formula (13) was intended for the solution of the specific tasks arising in the course of work of "PSMT SSC", proceeding from technical capabilities. The main advantage of the method of the differential is the applicability in a vacuum chamber at a large gas sparsity in the tract of the investigated samples of micro-motors, simplicity, based on the testimony of only two devices. The disadvantage of the method is the increasing error at small changes in gas temperature. First of all this is caused by small deviations of the rotameter float and measurement errors of the rotameter. To a lesser extent, this applies to the readings of the pressure gauge. This disadvantage can be compensated by the choice of measuring instruments of greater accuracy.

The method of thermal balance has high accuracy provided that the entire temperature field of the object under study is fixed, the knowledge of the masses and specific heat of all materials involved in the heat exchange. Therefore, good convergence with experimental data is possible for simple homogeneous structures under the condition of thermal imaging. In testing in vacuum conditions the last condition is impossible. Also, often the test objects are not homogeneous in materials.

Thus, the formula (13) reflects the method with the smallest number of values requiring measurement.
6. Summary and conclusions
The article presents the results of the authors' work in the field of measuring the thermodynamic parameters of gas. This work has a specific practical application: determining the temperature of the working medium in path of an electrothermal of the micro thrust SSC engines. The justification for the need for work is the technical impossibility of using other methods: area of the passing section of the micro thrust engines are commensurate with the dimensions of the thermocouple (for example, in DMM); fixation of the actual gas temperature by the thermocouple only in stationary mode; errors in the operation of the multi-channel temperature meter in case electromagnetic disturbances (in relation to the electric arc engine); technical impossibility of thermal imaging in a vacuum chamber.
The paper presents a method for determining the temperature of the gas, based on the method of falling its flow rate when heat supply. An experimental stand was made, thermal tests were carried out, which confirmed the theoretical calculations.

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References
[1] Repik E U, Sosedko Y P 2008 Methods and means of measuring the temperature of braking of the gas flow in challenging conditions for the flow Uchenye Zapiski TSAGI 4 pp 60-71
[2] Vavilov I S, Lukyanchuk A I, Yachmenev P S [and others] 2018 Smallsat dilatometric micromotor: estimation of characteristics IOP Conf. Series: Journal of Physics: Conference Series 1050 012096
[3] Ivanova G M, Kuznetsov N D, Chistyakov S V 2005 Heat engineering measurements and devices: textbook for universities (Moscow: Publishing MAI) 460
[4] Abramovich G N Applied gas dynamics 1991 (Moscow: Science) 600
[5] Kikoin A K, Kikoin I K Molecular physics 1976 (Moscow: Science) 480
[6] Adelson S V Processes and apparatus of oil refining and petrochemistry 1963 (Moscow: State scientific-technical publishing house of oil and mountain-fuel literature) 311
[7] Sivukhin D V General course of physics 2005 (Moscow: FIZMATLIT/MIPT) 551