EFFECT OF PARTITIONS ON FLOW STRUCTURE WITH NATURAL CONVECTION IN A CLOSED VOLUME.
II. TWO VERTICAL PARTITIONS

K. P. Morgunov and T. Yu. Morgunova

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The authors consider natural-convective flow of gas under the action of a heat source in a two-dimensional closed rectangular cavity with two vertical partitions. The effect of the relative position and dimensions of the partitions on the flow pattern is investigated.

Introduction. A growing interest of researchers has been noted in recent years concerning the natural-convective flow of gases and liquids in closed volumes. This interest is caused by the importance of the process in different technical applications, and this one has to do with fields of rather complex geometry.

In the first part of the present investigation [1] we have described the method and results of the numerical solution to the problem on natural convection of gas under the heat source action in a two-dimensional closed rectangular cavity with one vertical partition located on the upper or lower side. In the case of two partitions in the cavity, especially for those with the considerable relative height, the flow structure is essentially complicated, and the velocity and temperature gradients become substantial; this fact leads to development of unstable numerical methods during calculations. In order to overcome this difficulty, the authors of [2] suggested the use of cubic splines, with which they considered the problem on two-dimensional convection in square cavities with partitions of a relative height of 0.75 nonsymmetrically located on the upper and lower horizontal walls. The flow pattern of gas in a square cavity with two isothermal vertical walls at different temperature and two partitions, one of which is placed on the floor and the other – on the cavity ceiling is numerically investigated in [3]. The height of the partitions is taken to be equal to one third of the side L/3. Three positions of the partitions are considered: one above the other at the center; the partition on the ceiling is placed at a distance of L/3 from the hot wall, the partition on the floor – at a distance of L/3 from the cold wall; and, the opposite, the partition on the ceiling is located at a distance of L/3 from the cold wall, whereas on the floor – at a distance of L/3 from the hot wall. The partitions have a finite thermal conductivity coefficient; two values of the relation between the thermal conductivity coefficients for the partition and gas filling the cavity, i.e., $\lambda_{part}/\lambda_{gas} = 2$ (P = partition = part; G = gas) and $\lambda_{part}/\lambda_{gas} = 500$, are considered. The relative position of the partitions as well as their heat conduction are noted to exert the considerable effect on the flow structure.

Mathematical Model and the Solution Results. We consider the gas-filled two-dimensional closed rectangular cavity with two vertical partitions. An isothermal band located directly near the heat-insulated vertical wall is a source of heat liberation. The opposite vertical wall is isothermal with low temperature. The horizontal walls and the surface of the partitions are heat-insulated.

The mathematical formulation of the problem and boundary conditions are analogous to those presented in [1]. We emphasize that from computational considerations [1] the thickness of projections was taken to be equal to L/(k – 2). The cavity was assumed to be filled by air with Prandtl number Pr = 0.72.

As the first variant of the geometric structure, we examine the closed rectangular cavity with two projections of the same length placed on the upper horizontal wall symmetrically with respect to the central vertical cavity axis (x/H = 0.5L/H). Figure 1 exhibits the calculation results of the temperature distribution for $Gr = 1.4 \cdot 10^5$ and $1.4 \cdot 10^6$, relative cavity elongation L/H = 10 and of the heat source with length l/H = 1.5. From the analysis of the calculation results it is seen that (as in the case

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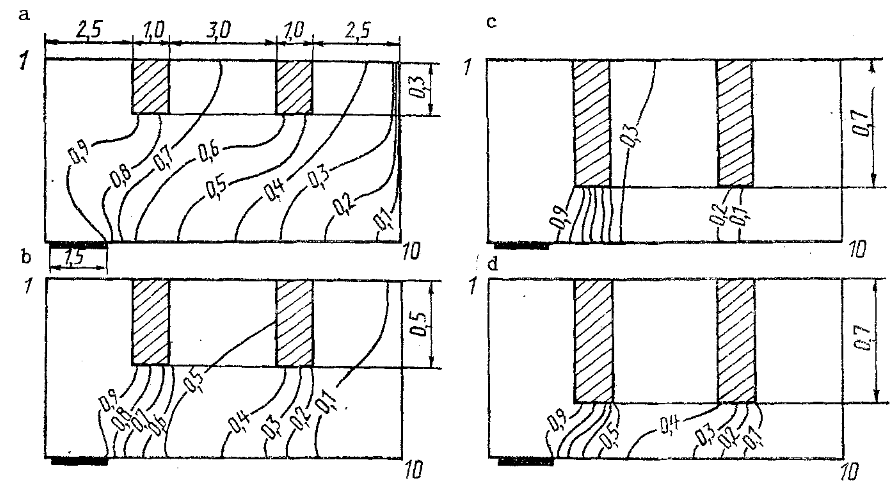

Fig. 1. Temperature distribution in a cavity for the case of two symmetrical partitions: a, b, c) Gr = $1.4 \cdot 10^5$; d) Gr = $1.4 \cdot 10^6$.

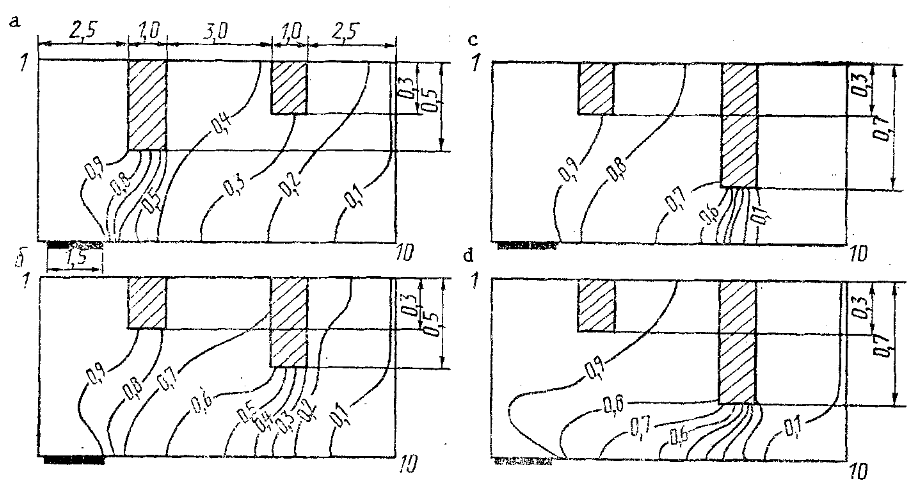

Fig. 2. Temperature distribution in a cavity for the case of partitions with different relative heights: a, b, c) Gr = $1.4 \cdot 10^5$; d) Gr = $1.4 \cdot 10^6$.

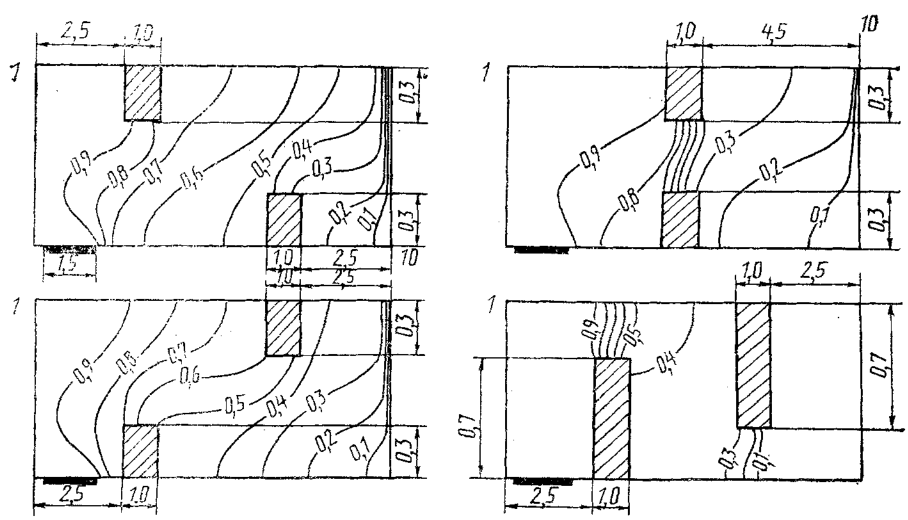

Fig. 3. Temperature distribution in a cavity for the case of location of partitions on the upper and lower walls; Gr = $1.4 \cdot 10^5$.

of the presence of one projection [1]) if the relative height of the projections becomes greater than 0.5, then the heat source effect on the flow behind the projections essentially decreases. In this situation both projections exert the influence on the process. For example, at $h/H = 0.7$ penetration of the flow behind the first projection is small, and behind the second one it practically does not penetrate. The temperature over the whole region behind the second projection is close to that of the cold wall ($T < 0.1$). Even the increase in the intensity of the heat liberation source ($Gr = 1.4 \cdot 10^6$) at the projection height of 0.7H and more has only the insignificant effect on the temperature distribution behind the projections.

Figure 2 illustrates the temperature distributions in the cavities with the partitions of dissimilar relative height at various relative positions on the upper horizontal wall. The partitions are located symmetrically about the central vertical cavity axis; the relative cavity length $L/H = 10$; the calculation results for two values of Grashof number $Gr = 1.4 \cdot 10^5$ and $1.4 \cdot 10^6$ are given. General regularities of the flow, observed in the cases of one partition in the cavity or the two partitions with the same relative height, are also manifested here, and in this situation the greater of two partitions exerts the main influence on the flow structure. If the more extended partition lies near to the heat source, so it restricts the heat penetration into the remaining part of the cavity. The smaller partition placed behind the cavity affects weakly the flow structure. In the case when the more extended partition is spaced close to the isothermal wall, it has a determining effect on the flow structure. If we remove the smaller partition, the flow pattern varies only slightly (the comparison with the results of work [1] confirms this fact). At a relative height of the greater partition more than 0.5 the flow penetration into the region behind the projection is also restricted as in the case of one partition.

There are also some interesting cases when the projections are placed on the upper and lower horizontal cavity walls (Fig. 3). And here, too, the laws typical for the cavities with one projection are manifested. The projection from above which is near the heat liberation source confines the propagation of the heated flow along the upper cavity wall, while the projection from the bottom near the isothermal wall restricts the propagation of the cold flow along the floor. If the projections are located one above the other, then the dimensions and the position of the aperture have a determining effect on the flow pattern. With the aperture, equal to 0.3H and less the gas heat flux penetration into the region of the cavity, adjoining the cold wall, is essentially impeded, and the lower the aperture is placed, the less this region is affected by the heat source.

Conclusion. In this work we present the results of the numerical calculation of the natural-convective gas flow in the closed volume under the action of a heat source. The gas flow in the two-dimensional rectangular cavities with heat-insulated partitions located on the upper and lower horizontal walls is investigated.

The calculation results for a wide range of changes in the geometrical characteristics of the cavities testify to the fact that the relative height of the partitions, their relative dimensions and the position exert the main effect on the flow structure. In the presence of two partitions in the cavity the qualitative specific features of the flow characteristic for natural convection in the cavities with one partition remain valid. If both partitions are placed on one of the horizontal walls (the upper and the lower), then the partition with the greater relative height has the determining effect on the flow.

The suggested calculation method and the obtained results may be useful when investigating problems of the building mechanics, atomic power energetics, and solar power engineering.

NOTATION

Gr, Grashof number; H, cavity height; h, partition height; L, cavity length in the horizontal direction; l, heat source extension; p, hydrodynamic component of gas; Pr, Prandtl number; λ_{gas}, thermal conductivity coefficient of gas; λ_{part}, thermal conductivity coefficient of the partition material; k, number of nodes in the difference grid along the horizontal.

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