Knudsen Compressor I

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A model pumping system without a moving part, which makes use of thermal transpiration and is operated with its ends at an equal temperature, is constructed. The performance of the system is measured.

We have studied one-way flows through a pipe without average temperature and pressure gradients (or with two equal end conditions) and its pumping effect theoretically and experimentally.1-3) A one-way flow is found to be induced in a pipe consisting of two parts with different structure or thickness and heated in the middle part along it. In the present work, we prepare a cascade system consisting of ten revised units of the above experiment and carry out an experiment to obtain the data of the pumping effect of the system (the maximum pressure difference kept and the mass flux versus the pressure ratio between the two reservoirs). A half part of the unit (N part, say) is a pipe of inner diameter 15 mm and length 15 mm, and the other part (S part, say) is a bundle of 18 pipes of inner diameter 1.6 mm and length 15 mm (Figs. 1 and 2). The unit makes use of two effects: the effects of variation of the cross section and division of the passage. The system is joined with two reservoirs, one is a vacuum chamber of the bell jar, where the pipe system is put, and is kept at a constant pressure and the other is a steel tank of $8 \times 10^6$ mm$^3$ (Fig. 3). First the external rotary vacuum pump is operated to keep the pressure in the bell jar at a constant value. Keeping the bell jar at this pressure, we put on the heater and observe the pressure variation in the tank. During the initial state before heating, the pressure of the tank is higher than that of the bell jar by 0 ~ 0.3 Pa. The results are shown in Figs. 4 and 5. With the bell jar at 20 Pa, the pressure of the tank is reduced from 20 Pa to 11 Pa in 200 sec and to 8 Pa in 500 sec after the heater is put on. The latter is the minimum pressure attained in the tank. The flow speed is visualized by a windmill at the bell-jar-side end of the pipe system (Figs. 6 and 7). The performance (e.g., the minimum pressure) is reduced in the presence of the windmill. The results in Figs. 4 and 5 are for the experiments without the windmill.

References

Fig. 1: A unit of a pipe (S part + N part). (a) Overall view and (b) closer view.
Fig. 2: Cascade system consisting of ten units.

Fig. 3: Experimental apparatus.

Fig. 4: Time variation of the pressures $p$ in the bell jar and the tank. The $t$ is the time (sec) after the heater is put on and $p_0$ is the pressure in the bell jar at time $t = 0$. $p_0 = 10\, \text{Pa}$, $20\, \text{Pa}$, $40\, \text{Pa}$, and $80\, \text{Pa}$.

Fig. 5: Time variation of the temperatures $T$ (K) at the heater, an end of the pipe, and the tank. (See the caption of Fig. 4.) The temperature difference of the two ends of the pipe system is less than 1 K.

Fig. 6: Windmill to detect a flow.

Fig. 7: Time variation of the speed of rotation (rpm) of the windmill at $p_0 = 40\, \text{Pa}$. (See the caption of Fig. 4.) Slow rotation at the final stage (around 600 sec) may be attributed to evaporation of gases from solid surfaces, especially from heated ones in the system.