THIRD INTERNATIONAL CONFERENCE ON HEAT PIPES

L. L. Vasil'ev

The Third International Conference on Heat Pipes was held at Palo Alto (U.S.A.) on May 22-24, 1978. The conference was organized by NASA, the European Center for Cosmic Research, and a number of firms and universities.

The conference committee consisted of G. M. Grover (U.S.A.), President, A. Aktsensi (Holland), S. A. Busse (Italy), R. D. Dann (Great Britain), M. Groll (West Germany), S. Ollendorf (U.S.A.), F. Polyashek (Czechoslovakia), F. Reale (Italy), V. I. Subbotin (USSR), and L. L. Vasil'ev (USSR).

Seventy-seven papers were read at the conference, which was divided into 13 sections. The first and second sections considered into the limiting modes of operation of heat pipes (14 papers). These sections considered pipes with longitudinal grooves with different profiles, and also pipes with circular grooves (screw threads) with arteries of grids or a baked powder and grids. The modes of operation of pipes with refueling or incomplete fueling with liquid, nonstationary modes of operation (the start up of a heat pipe, and its transition to a new mode of operation) were considered. Particular attention was devoted to the interaction between flows of vapor and liquid, and the flow dynamics of vapors and liquids in pipes of different geometrical shape. Interest was expressed in heat pipes in a gravitational field. It was shown that heat pipes with circular grooves have considerable advantages over smooth-walled thermosyphons. For example, in copper pipes charged with water, heat-transfer coefficients were obtained in the evaporation and condensation zones of 4500 and 11,900 $W/m^2 \cdot deg$ C.

The theme of the papers read in sections three and four was the use of heat pipes in a gravitational field.

The main trends in the use of heat pipes in the utilization of secondary energy resources in industry, in the cooling and thermostating of electronic equipment, quantum electronic components, and temperature control of cosmic apparatus were discussed. Considerable attention was given to problems of the utilization of solar energy, as well as the use of heat pipes for freezing the ground, for cooling molds and presses, and for preserving meat and other products.

A number of papers mentioned the possibility of producing laser mirrors and gas-discharge lasers using the heat-pipe principle.

Section five was devoted to papers describing research on fundamental transfer processes with evaporation, boiling and condensation in wick structures of heat pipes. The structure of the flow of a film of liquids close to the surface of separation of the pipe wall – liquid film – vapor was considered. An estimate was given of the value of the capillary pressure for different heat flows taking into account the London – Van der Waal forces. It was shown that the capillary pressure decreases when the heat flow along a line of separation increases.

In a number of papers an analysis was given of the heat-exchange process during evaporation and boiling of liquids in grooves. It was shown that the heat transfer depends mainly on the thickness of the film and the thermal conductivity of the liquid, the maximum heat flows in film evaporation and boiling of a liquid are comparable, and in a number of cases exceed the heat flow when a liquid boils in a large volume. It has been established by experimental investigations of heat exchange when water and other low boiling point liquids evaporate in wicks, having good thermal contact with the wall, that even with $q = 1.5 \cdot 10^6$ W/m^2 the boiling of water is not observed. Heat exchange occurs by evaporation of the liquid in pores on the surface of separation of the liquid and vapor.

Film condensation of water vapor on the copper walls of a centrifugal heat pipe with a velocity of rotation of 700, 1400, and 2800 rpm occurs more intensively (by 100%) if the heat-exchange surface is covered with a network of grooves. The results of an investigation of drop condensation on the side surface

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of a rotating truncated cone covered with a film of n-octadecyl mercaptan were also presented. Drop condensation considerably improves the heat exchange (by more than 100%) particularly at low speeds of revolution.

Section six considered gas-controlled heat pipes. New methods for the numerical analysis of a model of the Edwards and Marcus diffusion front with different heat fluxes and quantities of uncondensed gas have been developed. As a result, it now appears possible to predict accurately the temperature of the evaporator of the heat pipe. A theoretical and experimental description of the energy transfer process and and of the material in gas-controlled thermostats was given.

Thermostats have been designed for use in a gravitational field. Water, ethyl alcohol, etc. are used as the liquid in the temperature range from 0 to 100°C. The temperature can be kept constant to an accuracy of ±0.001 deg C/day.

Flexible gas-controlled heat pipes of stainless steel with arteries having the shape of a figure eight in the transverse cross section enable one, using ammonia, to transfer 90 W without gas bubbles appearing in the arteries. The theory of the condensation process in the presence of uncondensed gas in a centrifugal heat tube was developed.

The theory took into account the effect of the thermal properties of the material of the walls of the working and cooling liquids, and the concentration of uncondensed gas on the profile of the temperature field of the walls of the condenser and the heat-flux density.

Papers on cryogenic heat pipes, diodes, and switching devices were presented in section seven. Investigations have been carried out in the temperature range 70-200°K of heat pipes using CH_4, CH_6, N_2 and CF_4 liquids and of capillary structures (four forms of open grooves, grooves covered with a grid, several layers of grid, axial grooves, etc.).

Considerable attention was given at the conference to work on the use of heat pipes in space (sections eight, nine, and ten).

Radiators on heat tubes having variable and constant thermal resistance with a large ratio of the thermal resistance in the attached and unattached states (6000/1) are widely used at the present time. A prototype of such radiators was fitted on the American Apollo spacecraft. The majority of the radiators consist of a set of gas-controlled heat pipes.

Radiation panels on heat pipes have considerable advantages over other forms of temperature control in space. Their effectiveness naturally depends to some extent on the trajectory of the flight of the spacecraft. At the present time, using radiation panels consisting of cryogenic heat pipes filled with hydrogen or neon, one can obtain a temperature of 20-40°K due to the discharge of radiation energy into open space.

An analysis was given of the operation of the radiation panel of the Explorer spacecraft consisting of gas-controlled heat pipes and the usual radial heat pipes rotating at a speed of 10 rpm. It was shown that this system of heat control is better than a jalousie. Similar investigations were made for the Marot Type Communications Spacecraft. The heat control system consisted of three heat pipes and thermostats, two vertical heat pipes and eight gas-controlled heat pipes. All the pipes are filled with ammonia and have axial grooves. The radiation panels that cool the electronic equipment in the Arcomset spacecraft have an overall weight of 4.3 kg, a radiation area of 1.7 m^2, and consist of a system of rectangular heat pipes assembled in a honeycomb system occupying a small volume.

High-power gas-controlled heat pipes for the Shuttle spacecraft have a flat shape and are intended for the cooling and temperature control of the electronic apparatus for a period of 6-9 months.

Work has also been carried out to investigate the parameters of liquid metal heat pipes using mercury, potassium, sodium, and lithium.

In a paper presented at the ERDA Atomic Center, heat pipes that transfer energy of more than 10 kW/cm^2 of the transverse cross section of the tube for a heat flux density in the evaporator of 100 W/cm^2 were described. The wick of the heat pipe is made of finely dispersed metal powder.

A paper describing the American program for the use of heat pipes in space was presented at the Goddard Space Flight Center, NASA.

In section 11 papers were presented devoted to new methods of using heat pipes and new constructions. An osmotic heat pipe was described and a heat pipe for the Shuttle spacecraft usinga liquid pump of a new type was proposed.

In section 12 the possibility of using heat pipes to cool electrical machinery, electric motors, and high-voltage transformers, the cooling of nickel–cadmium batteries and electronic modules were considered.

Section 13 was also devoted to the use of heat pipes in space. An analysis of the parameters of heat pipes with axial grooves was given, and their use in atomic reactors employing fast neutrons for spacecraft with a heat power of 0.1-5 mW and a life of 10 years was described. The heat pipes were made of molybdenum, and enriched 90IS-10 ZrC or UO_2 was used as the energy source. A method of making grooves in heat pipes by electroerosion was described.

Hence, on the basis of the papers presented at the conference, we can conclude that the importance of heat pipes and heat exchangers based on them in different areas of industry is continually growing. This is an area which can save hundreds of millions of rubles in the national economy.