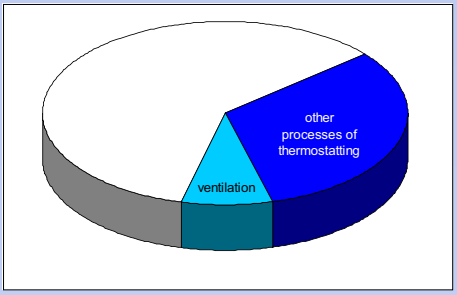
Russian Academy of Sciences
Program Systems Institute

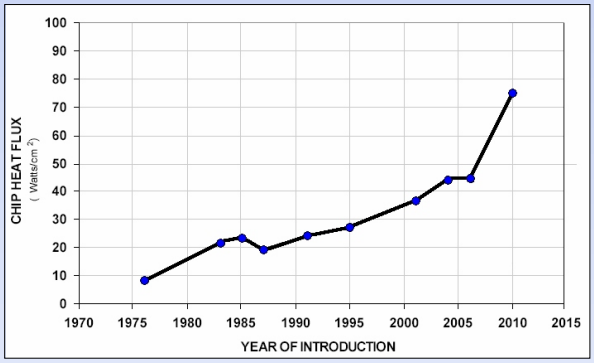
Optimal Control of Temperature Fields for Cooling of Supercomputer Facilities and Clusters and Energy Saving for Supercomputer Centers

Importance of the Investigation

More than 40% of overall energy produced is used to maintain temperature fields (e.g. heating, air conditioning, thermostatting of buildings, cryogenic systems, etc.) including 8% of energy expenses for ventilation.



There is a problem of thermostatting leading to maintain temperature fields of pregiven configuration using minimal energy input. A partial case of this problem is a problem on rational cooling of a supercomputer. An essential part of energy consumed by the supercomputer is spent for cooling.



Existing Cooling System: Shortcomings

The air for cooling is taken from the room where the supercomputer is located. This air is previously warmed up (especially in winter). Thus, we spend energy to warm the cooling air, and consequently to reduce the efficiency of cooling. The return of the warm air to the room requires an additional air-conditioning.

The installation of the supercomputer does not take into account hydrodynamic characteristics of air flows. Cables increment hydraulic resistance, which influences on the energy expenses.

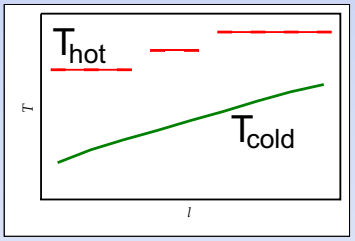
Coolers themselves produce heat while working; therefore the energy input increases.

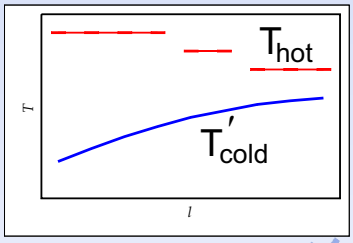
Reliability of the system is low because failure of a cooler implies failure of the correspondent computer unit.

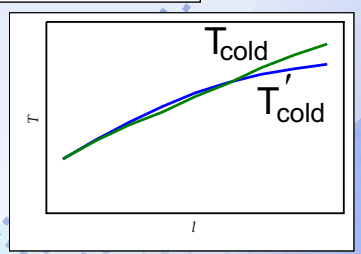
Heat exchange process is thermodynamically imperfect. To increase the efficiency of the process it is necessary to maintain ratio of temperatures of cold and hot agents to be constant.

Dependencies of temperature of cooling agent T_{cold} is represented in the diagrams with respect to length of a printed circuit board and temperatures of chips located on the board. Output temperature of the cooling agent is higher for the case when

$$\frac{T_{\text{cold}}}{T_{\text{hot}}} \approx \text{const}$$







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Enhanced Cooling System: Features

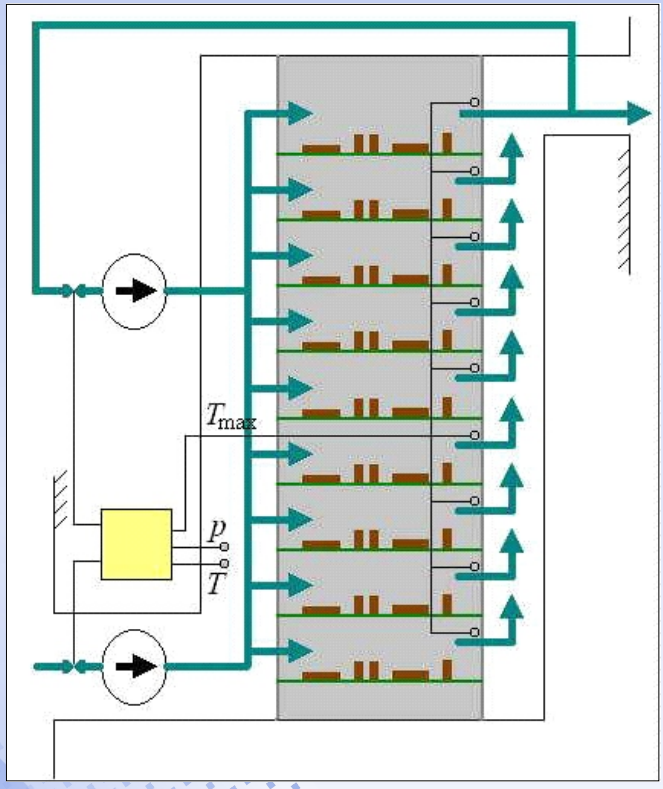
Optimal control of temperature and flow intensity of cooling air subject to temperature of outside air will allow minimization of the energy expenses.

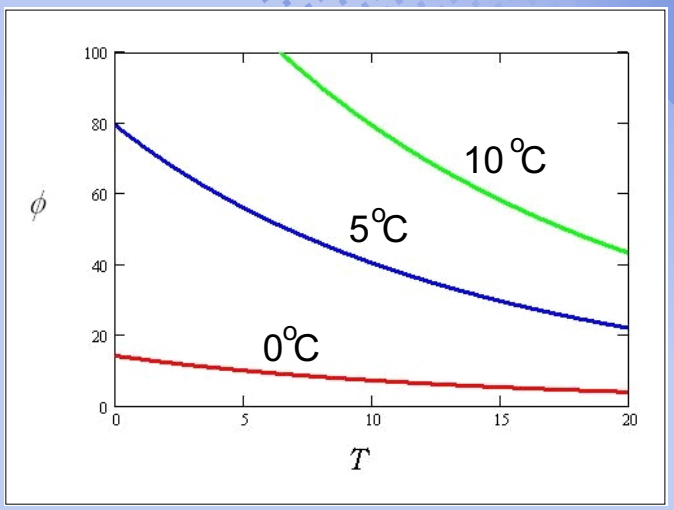
Excess pressure in the cluster box and removal of warmed air outwards.

Optimal allocation of chips on computer units and installation of cables will take into account hydrodynamic characteristics of air flows.

Central control unit for preparation and feeding of cold air can be doubled. That is why reliability of the system can be increased.

Unification of cooling systems will make possibile to use it with clusters of arbitrary configuration.





Dependency of the air humidity with respect to indoor temperature T is shown in the picture for three different values of outdoor temperature.

It is shown that water condensation on the computer units is impossible, even if humidity of the input air is very high.

Problems to be Solved

To determine configuration of temperature field of cooling fluids corresponding to minimal energy expenses. To develop a system of cooling maintaining this optimal field.

To determine an optimal intensity and temperature of air input flow with respect to outdoor temperature.

To develop rational outlines for installation of circuit boards and their allocation in the box.

To estimate the advisability of introducing an additional loop with natural circulation of cooling fluid.

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