Thermoelectric Cooling System
For Laboratory Centrifuge

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Abstract

The paper concerns the concept of a small laboratory centrifuge with a thermoelectric cooling system.
The thermoelectric system allows achieving the thermodynamic equilibrium inside the centrifuged material being tested in less than 20 minutes at the temperature level of $+4^0$C. For proper heat transfer between the cooled air inside the centrifuge and the ambient the highly efficient heat exchangers specially designed for that purpose have been applied.
Moreover the paper presents the results of experimental tests of the centrifuge model particularly in the aspect of heat transfer dynamics.

Introduction

It is obvious and commonly known that conditions of centrifuged materials to achieve their required properties and quality are highly important. The temperature for a given element should be precisely kept at desired level irrespectively of outside conditions otherwise the value of such material is questionable.
The laboratory centrifuge is a general-purpose centrifuge destined for applications where temperature control with high accuracy as well as reproducibility of any process time after time plays an essential role. Especially it is suitable for preparation biological, biochemical, food and other materials as an important element in a reliable preparation chain in medical, scientific and industrial laboratories. To give only a few examples: preparation of vaccines, medicines, reagents, blood and blood preserves and specimens.
The most common way of cooling applied in majority of centrifuges is the use of classical refrigerating units.
The paper presents an alternative to the classical compressor-based units solution of the problem of delivering reliable “cooling source” for the environment inside the laboratory centrifuge. This is thermoelectric cooling system. The idea of it was to build a small benchtop device that has some benefits over traditional compressor-based cooling systems. These benefits are:

- no CFCs or HCFCs – means environment protection,
- more compact design – saves valuable space,
- lower maintenance – cooling and heating achieved by solid-state Peltier effect,
- more precise temperature control – up to tens parts of a degree,
- wider temperature range – one unit can be applied for a number of applications with no need to use several units,
- quieter operation – fans are the only elements with moving parts.

Because of special value of the centrifuged materials special requirements stand before the equipment intended for the considered purpose. First of all it should be very reliable. Moreover, ease of use, cleaning and handling are important features.
According to the prescriptions for biological and biochemical materials preparation the main assumptions at the stage of designing of the thermoelectric cooling system have been taken as follows:

- reliable source of cooling running from 230VAC,
- minimum interior temperature $+4^0$C at the ambient of $+25^0$C achieved in less than 20 minutes,
- easy maintenance.

Thermoelectric cooling system construction

Before construction of the thermoelectric cooling system the indispensable calculations have been carried out for determining the heat losses and required cooling capacity. First has showed that heat flux of 120Watts through the walls to a 25^0C ambient maintains constant temperature of 4^0C inside. The use of four CP1.4-127-06L Melcor modules should be enough to balance that heat losses. But taking into consideration intensive air outflow during opening the lid of the centrifuge during loading and unloading and that the cooling system should have ability not only to keep the temperature of the load but to cool down the load in time below 20 minutes so six CP1.4-127-06L have been assumed as a cooling source.
Fig.1 presents the main elements of the laboratory centrifuge. The outer casing and the lid are made of sturdy PVC. The inner box consists of the stainless steel 1.0 mm thick. Inside the box there is placed an exchangeable rotor made of aluminum with holes for 18 tubes 2.2 or 1.5ml. The rotor is attached to the axle of electric motor equipped with a microprocessor-based electronic unit controlling time and speed of rotation, acceleration and deceleration. Special attention should be drawn to the solution of forced airflow cooling the material inside the tubes in the rotor. Under the rotor on the same axle there has been situated a metal propeller that during rotation causes pressure difference

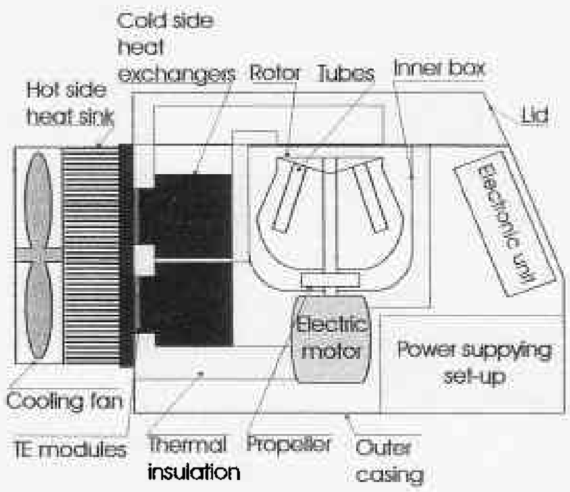

Fig.1 Schematic view of the laboratory centrifuge

in the inner chamber and the same the direction of cooling airflow is directed.

The thermoelectric cooling system is placed at the rear wall of the centrifuge. It comprises:

- thermoelectric modules as the "cooling source",
- one aluminum heat sink at the hot side of the modules,
- aluminum heat exchangers at the cold side,
- two cooling fans.

The hot side of the modules is placed on the heat sink plate. From that plate the heat is conducted along the fins and blew out to the surrounding air on the way of intensive forced convection. Two fans type 120x120x38mm with airflow of $180m^3$ per hour have been used for removing the access of heat to the ambient. To obtain very effective heat transfer through the heat sink its construction has been optimized. The footprint of the sink plate is 235 x 160 mm and 10mm in thickness. The aluminum fins long for 50mm and 0.5mm thick have been applied. The heat exchangers at the cold side have the footprint 60x60mm and 10mm thick and fins 50mm long and 0.5mm thick. Neverless to say that all surfaces being in contact between themselves are covered by a thin layer of silicone grease to minimize thermal resistances. All spaces where possible between outer casing, inner box and between cold and hot heat exchangers around thermoelectric modules and inside the lid have been filled with insulation of polyurethane foam to minimize heat losses.

The cold side of the thermoelectric system has been connected with the inner chamber of the centrifuge. The circulating cooling air flows through the fins of cold side heat exchangers, next goes to the specially formed channels in the lid and is directed on the rotor in the inner chamber. Than the air is conducted again to the cold side of the thermoelectric system though the holes made in the bottom of the inner box.

The same microprocessor-based controller watching for the correct temperature in the centrifuge automatically selects heating and cooling rates. In addition this electronic unit provides alarm signals in case of any power or temperature probe failure, temperature deviation over declared range as well as disconnecting the supplying power when an overheating of the hot side of the modules occurs.

On the basis of above consideration a model of the centrifuge with thermoelectric cooling system has been constructed.

Fig.2 shows the photographed centrifuge with the lid and the thermoelectric cooling system visible at the rear wall.

Some technical data:

Exterior dimensions: (w x d x h)	250x470x230mm
Electric supply	230V/50Hz
Max. capacity:	18x2.2ml
Max speed:	13000 rpm.

Experimental results

The measurements have been conducted for the described thermoelectric cooling system.

Scheme of a measurement system is shown in fig.3. The system has been based on a remote data acquisition. Temperature probes have been placed in chosen points as indicated in fig.3. Acquisition data modules have read signals from those probes. The host computer controls all the elements of the system by dedicated software. The measuring of temperature inside the material in rotating tubes has been carried out after stopping the rotor and then the acceleration process has been started again. The measurements have been repeated many times and the average values have been considered. The experimental tests have had the goal to verify the time of achieving the steady state as well as a temperature variation. First measurements have considered six CP1.4-127-06L modules (fig.4) and next (fig.5) with the use of only four such modules for comparison. In both cases the measured velocity of the air blowing between fins has lied in the range from 3.2 to 4.1 m/s. There have been measured: the ambient temperature (during tests 25^0C) and Tl-temperature of the load, Th-temperature of the hot side heat sink, Tw-temperature of the inner box, Tp-temperature of the cooling air inside the inner chamber, Tc-temperature of the cold side heat exchanger.

First measurements have the goal to answer the question which rotating speed is the most suitable for achieving the most effective and fastest way of cooling the load. They have shown that the optimum speed is about 5000rpm. Therefore at the pre-cooling stage that speed has been chosen until the temperature of the load has reached the required value of +4C. Then the

Fig.2 A model of the laboratory centrifuge

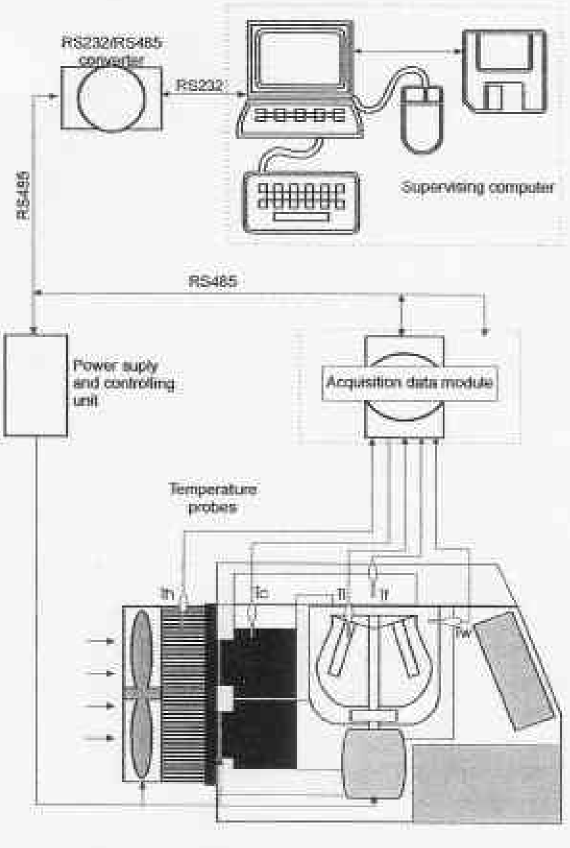

Fig.3 Scheme of measurement system and position of temperature probes

maximum allowable rotations of 13000rpm have been established.

Fig. 4 and 5 show temperatures in measuring points as a time function. In both cases the temperature level of $+4^0C$ has been achieved in less than 20 minutes. The electrical conditions have been established at the level of 14.2A for 24V for six modules and 9.2A for 24.5 for the case of four modules. But after switching the maximum rotations only the first case fulfills the condition of maintaining the steady state. In the second case the temperature increases consequently with time. It indicates that the cooling capacity is not enough for keeping the temperature inside the load at required level during the test.

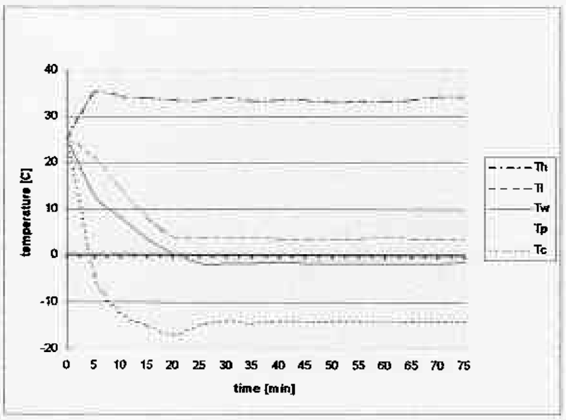

Fig.4. Measured temperatures vs. time for six modules

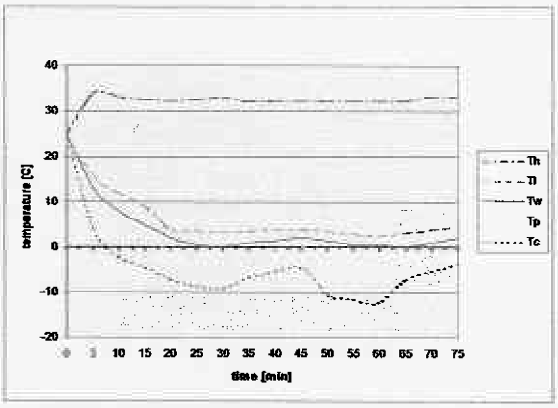

Fig.5. Measured temperatures vs. time for four modules

Conclusions

In general the presented thermoelectric cooling system for laboratory centrifuge fulfills the imposed thermal and constructional conditions.

- The applied thermoelectric cooling system with six modules type CP1.4-127-06L delivers enough cooling power to achieve and maintain temperature in the assumed range inside the internal centrifuge capacity.
- The electronic control unit allows keeping an accurate and safe internal environment.
- The forced air convection inside the centrifuge by use of a propeller integrated with the rotor is satisfactory.