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DESING AND REALIZATION OF AN IMPROVED PATALOGY EQUIPMENT BY GIVING A FROZEN ABILITY

ABSTRACT

Cryostat is a device used in the preparation of fractions to be gained in order to be researched in emergency surgical biopsy as microscopic. It is structured as a kind of rotary microtome replaced in the cool area. That the device enables to research cooled fractions without taking tissue tracking in light microscope by painting immediately is one of the most significant advantage of the device. As to disadvantages of the device are their costliness and hard mobilization comparing with rotary microtome. Besides it takes long time to reach operating temperature value. In this study, cryostat feature has been gained to rotary microtome by means of thermoelectric system. Performed system has the feature of freezing and cutting tissues in a very short time. Besides it can be moved easily owing to being very light. By this way, disadvantages of the cryostat device have been annihilated. Performance analysis of performed system has been made in Selcuk University Meram Medical Faculty, Department of Pathology

Keywords: Rotary microtome, Cryostat, Thermoelectric module, Thermoelectric device, Cryotome

SOĞUTUCU ÖZELLİĞİ KAZANDIRILMIŞ DOKU DONDURMA AMAÇLI BİR PATOLOJİ CİHAZI TASARIMI VE GERÇEKLEŞTİRİLMESİ

ÖZET

Kriyostat, acil cerrahi biyopsilerin mikroskobik olarak incelenebilmesi için elde edilecek kesitlerin hazırlanmasında kullanılan bir cihazdır. Soğuk alan içerisine yerleştirilmiş bir çeşit rotary mikrotom yapısındadır. Dondurularak alınan kesitlerin ototeknikon takibi gerektirmeksizin hemen boyanarak ışık mikroskobunda incelenebilmesi olanağı vermesi cihazın en büyük avantajlarıdır. Dezavantajları ise rotary mikrotoma göre pahalı ve taşınmalarının zor olmasıdır. Ayrıca kullanılabilecek çalışma sıcaklık değerine ulaşması uzun zaman almaktadır. Bu çalışmada rotary microtoma termoelektrik sistem yardımıyla, kriyostat özelliği kazandırılmıştır. Gerçekleştirilen sistem dokuyu çok kısa zamanda dondurma ve kesme özelliğine sahiptir. Ayrıca hafif olduğundan kolayca taşınabilmektedir. Bu sayede Kriyostat cihazının dezavantajları ortadan kaldırılmıştır. Gerçekleştirilen sistemin performans analizi Selçuk Üniversitesi Meram Tıp Fakültesi Patoloji A.D'da yapılmıştır.

Anahtar Kelimeler: Döner Mikrotom, Cryostat, Termoelektrik Modül, Termoelektrik Cihaz, Isı Kontrol

1. INTRODUCTION (GİRİŞ)

Microtome is irrevocable device of pathology labs. It is used for taking tissues on lame by cutting them in micron diameter (4-5µ). Later these tissues taken on lame are painted and diagnosed by being analyzed with light microscope and putting cover slip on it. Tissues taken autotecnicon follow-up in routine practice are embed in paraffin and taken over lame with the help of microtome. For this operation, rotary and sliding microtome devices are used. Because of time constraint, autotecnicon follow up of tissues and embedding in paraffin processes are not performed in the situations to be diagnosed during operation. In such cases, it is required to freeze and harden tissues immediately and start to paint the tissues by taking thin sections from them. And for that operation, another type of microtome cryostat device (frozen device) is used [1].

Cryostat is used for painting tissues immediately taken over lame in surgical biopsies in which emergence diagnosis have to be given. It enables to give a diagnosis in 15 minutes owing to having not autotecnicon follow up and embedding in paraffin processes. It is structured as a kind of rotary microtome replaced in cool area. Being able to take fast and thin section close to the quality of embed in paraffin and autotecnicon follow up and therefore enabling to the research of light microscope in a short time after painting are advantages of the device. As to disadvantages of the device are their costliness and hard mobilization [2 and 3].

In the study T. Rutherford et. al. performed; they made a microtome running with thermoelectric module instead of running with CO2. And that microtome consists of assemblies of series-connected thermo elements. Cooling control is made via direct current supply to the units. They cooled microtome and knife separately by means of thermo elements [4].

In the study W. S. HARDY et. al. performed; they placed semi-conductor materials to microtome and succeeded to have sections from tissues. They observed that cooling microtome knife would result in a better way comparing with cooling with CO_2 [5].

In the study David H. Barry et. al. performed; they placed a brass cylindrical container 11.5 cm high and 7.5 cm in diameter in insulated wooden box. A 2.2 cm diameter hole was drilled in the centre of the removable brass lid on the underside of which a holder was attached for a cryostat tissue carrier. By the help of these materials and container, tissues froze immediately and became ready to be taken sections [6].

William J. Waddel et. al. designed a hydraulic system enabling low humid and preventing icing aimed to have sections being smooth taken from microtome [7].

Işık H. et al. designed thermoelectric system controlled by a microcontroller is developed to induce renal hypothermia [8].

Table 1. Nomenclature
(Tablo 1. Adlandırma)

Nomenclature	
COP	$=QL\ /\ P$
$COPopt$	Optimum COP
I	Current through the thermoelectric module (amp)
$I\ opt$	Current at the condition of optimum COP (amp)
$K\ t$	total thermal conductivity of thermoelectric module,(WC^{-1})
$Q\ L$	cooling capacity (W)
$Q\ opt$	Cooling capacity at the condition of optimum $COP(W)$
P	Electric power supplied to the thermoelectric module(W)
R	total electrical resistance of thermo-electric module(ohm)
$R\ F$	thermal resistance of heat sink $(^{\circ}CW^{-1})$
$R\ Fopt$	thermal resistance of heat sink at the condition of optimum COP $(^{\circ}CW^{-1})$
$T\ a$	ambient temperature $(^{\circ}C$)
T_H	hot-end temperature of the thermo-electric module
$T\ L$	cold-end temperature of the thermo-electric module
V	voltage to the thermoelectric module (volt)
$V\ opt$	voltage to the thermoelectric module at the condition of optimum COP (volt)
Z	figure of merit of thermoelectric module (K^{-1})
α	Seebeck coefficient of thermoelectric module $(V^{\circ}\ C^{-1}$)
ΔT	$=\ T_H - T_L$

2. RESEARCH SIGNIFICANCE (ÇALIŞMANIN ÖNEMİ)

Microtomes that work with paraffin method used in pathology laboratories are not convenient for the situations requiring immediate result since paraffin work process takes long time. As to cryotomes designed for the situations requiring immediate results are both more expensive and have movement limitations owing to their largeness comparing with microtomes. This designed system eliminates all these negativities. Namely this system can be used both in situations requiring immediate results and can be moved much more easier than cryotomes to desired place thanks to its ease of movement.

Many microtomes present in pathology laboratories at the present time and run with paraffin method can be used more productively thanks to the method mentioned in this study and can be gained cryotom specifications with little cost. Thus, many microtomes that are old model and inactive in pathology laboratories can be gained cryotom specification.

3. THE PRINCIPLE AND CHARACTERISTICS OF THERMOELECTRIC DEVICE (TERMOELEKTRİK CİHAZIN KARAKTERİSTLİKLERİ VE PRENSİBİ)

Thermoelectric cooler has been widely used in military, aerospace, instrument, and industrial or commercial products, as a cooling device for specific purposes [9 and 10]. This technology has existed for about 40 years. Many researchers are concerned about the physical properties of the thermoelectric material and the manufacturing technique of thermoelectric modules. In addition to the improvement of the thermoelectric material and module, the system analysis of a thermoelectric cooler is equally important in designing a high-performance thermoelectric cooler. This is however sometimes ignored by many researchers.

The design procedure of a thermoelectric cooler usually follows the performance curves of the thermo- electric module which is provided by the manufacturer. Usually, the design of a thermoelectric

cooler starts from a given temperature difference across the hot and cold sides of the module $\Delta T = (T_H - T_L)$ and the required cooling capacity QL[11]. The current I for the thermoelectric module is determined from a measured $\Delta T - I$ curve at a fixed QL. The V- I curves at zero cooling capacity ($QL = 0$) and at zero temperature difference ($\Delta T = 0$) are then used to determine the voltages V as the upper and the lower bonds, respectively. The required thermal resistance of the heat sink is finally evaluated. An iteration procedure is necessary since the heat sink design may not be feasible and the assumed ΔT may not be practical. In addition, the above design method only determines the range of the applied voltage. The actual value of V needs to be determined experimentally.

The theoretical equations for the thermoelectric module performance include the voltage equation [12 and 13].

$$\mathrm{V} = \alpha(T_H - T_L) + IR, \tag{1}$$

The input power equation:

$$\mathrm{P} = \alpha I(T_H - T_L) + I^2 R \tag{2}$$

the cooling capacity equation:

$$Q_L = \alpha I T_L - \frac{1}{2} I^2 R - K_t (T_h - T_L) \tag{3}$$

The total heat rejection equation:

$$Q_H = P + Q_L = \alpha I T_H - \frac{1}{2} I^2 R - K_t (T_H - T_L), \tag{4}$$

and COP is defines as

$$COP = \frac{Q_L}{P} \tag{5}$$

where α is the seebeck coefficient of the module, $V^0 C^{-1}$; R is the total electrical resistance, ohm; K^t is the total thermal conductivity, $W^0 C^{-1}$. An important physical property for the thermoelectric module is the configure of merit Z which is defined as

$$Z = \frac{\alpha^2}{K_t R} \tag{6}$$

The measurement of the physical properties of a thermoelectric module (α, R and K_t) are quite simple. By using the present test facility, the seebeck coefficient α can be measured from a pure conduction test, i.e. letting $I = 0$. Measuring the hot-end and the cold-end temperatures, T_H and T_L, and the induced thermoelectric voltage V, we can determine α from Eq. (1) with $I = 0$.

Measuring Q_L, at $I = 0$, we can determine the thermal conductivity K_t from the heat conduction equation, i.e. Eq. (3) with $I = 0$. Using the testing data of V at various I, T_L, T_H, and the measured α, we can determine the total resistance R from Eq. (1). For easy implementation, a computer program was written to automatically read the test data and analyze the physical properties [14].

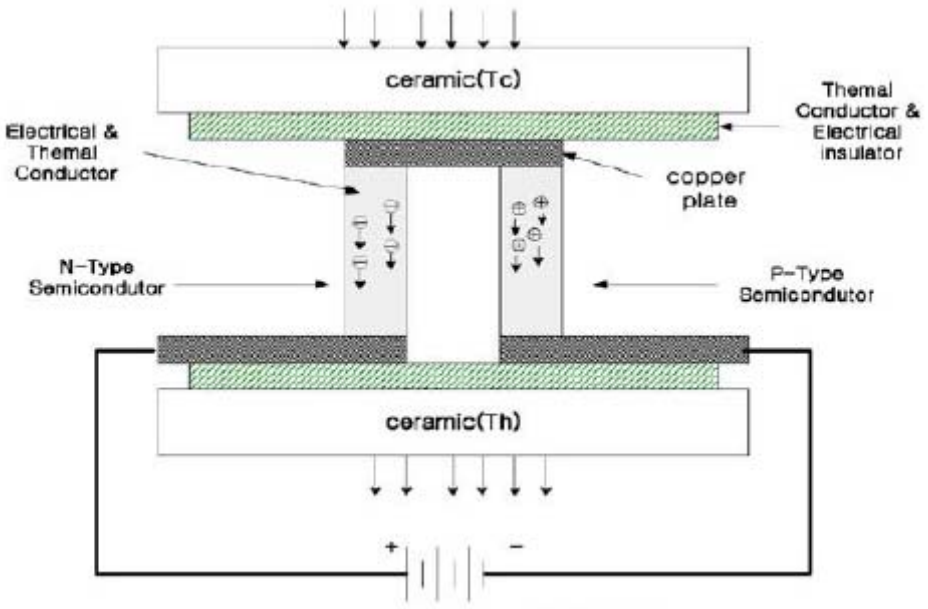

Figure 1. Principle of thermoelectric device
(Şekil 1. Termoelektrik cihazın prensibi)

4. TEMPERATURE CONTROL WITH PID CONTROL UNITS (PID KONTROL UNİTELERİYLE SICAKLIK KONTROLÜ)

The use of digital controllers is increasing gradually in the last decades. Developments in the electronics and microprocessor technology bring out the need for discrete approximation to PID controllers. Block diagram of a closed loop digital controller is shown below [15].

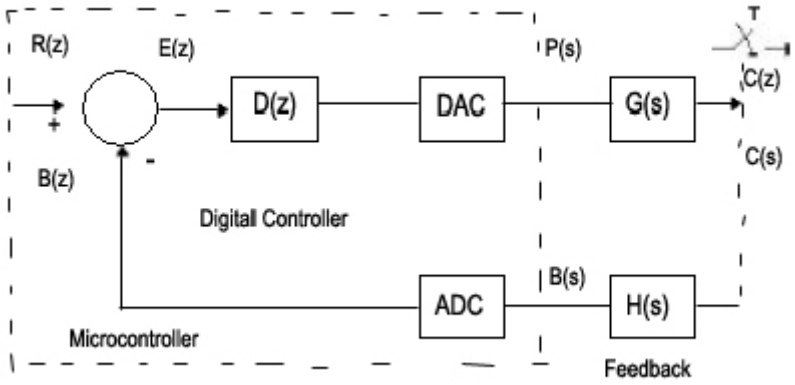

Figure 2. Block diagram of a closed loop digital controller
(Şekil 2. Bir kapalı devre dijital denetleyicinin control şeması)

Control signal of the PID controller for each sampling interval (T) is determined as;

$$P_1 = P_0 + (e_1 - e_2)K_p + (e_1 - 2e_2 + e_3).\frac{K_d}{T} + (e_1 + e_2).\frac{K_i T}{2} \quad (7)$$

where;
K_p, K_d and K_i are coefficients of proportional, integral and derivative elements, respectively. P_0 is the control signal of the previous sampling, e_1 is the current error, e_2 is error of previous sampling and

e_3 is the error of the sampling before previous sampling. And the PID algorithm which is used in the microcontroller is obtained by using approximate trapezoidal iteration and derivative, as shown in Figure 3 [16].

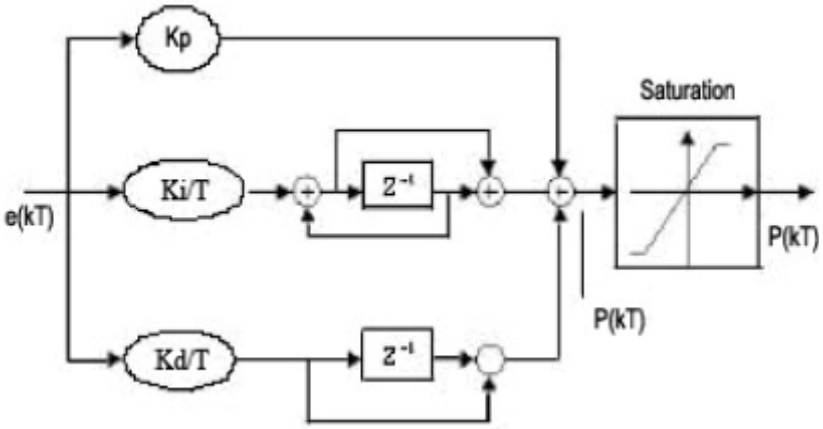

Figure 3. Structure of the realized PID controller
(Şekil 3. Farklı PID denetleyicisinin yapısı)

5. DESIGNED SYSTEM (SİSTEM TASARIMI)

In this study, a frozen ability pathology equipment system is designed and manufactured. The block diagram of developed system is shown in Figure 4.

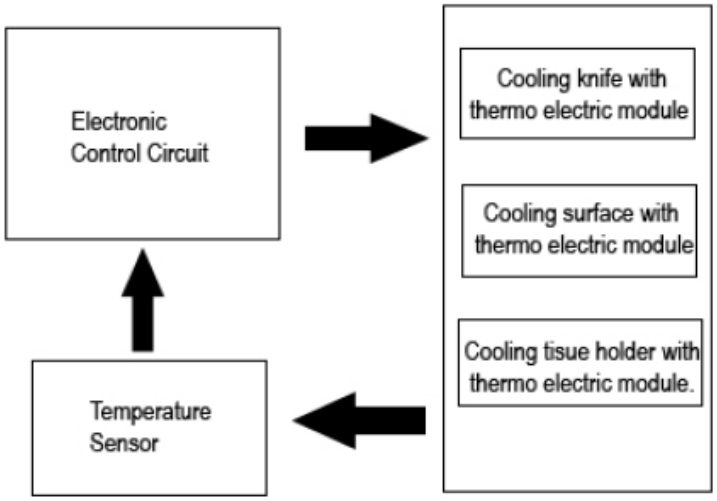

Figure 4. Block diagram of the developed system
(Şekil 4. Geliştirilen sistemin blok şeması)

In this study, a new frozen ability pathology equipment system was designed by having some changes on rotary microtome branded as leica. This system has both tissue cutting and tissue freezing features. The system consists of blocks as in Figure 4.

System runs as follows; firstly tissue sample is frozen on freezing surface (Figure 6). The tissue frozen on the freezing surface is placed in tissue holder (Figure 6). Sections are taken by the help of cooled knife (Figure 6) from placed tissue sample.

Cutting knife and tissue holder of microtome were cooled by adding thermoelectric modules. A tissue freezing surface was also added to microtome. Temperature value in the system is controlled

using electronic control circuits. The Temperature value obtained from output of knife sensors, tissue holder sensors, freezing tissue surface sensors. The temperature value on microtome knife, tissue freezing surface and tissue holder are determined by means of K type thermocouple sensors and transferred to electronic control circuit. Owing to this circuit, the surface of microtome to be cooled can be adjusted to the desired temperature value proportionally.

Chosen peltier module feature is; 40x40x2 mm size and is a thermoelectric module being 100 watt at $\Delta T = 70^{\circ}C$. One of these modules is for tissue freezing, two of them are for holder cooling and two are for cooling the knife.

Water circulation was used in all cooled parts with pump and condenser aiming to keep the temperature at the desired level and helping to cooling system used in the designed system (Figure 5). Owing to this water circulation, it was enabled to keep the temperature at the desired level.

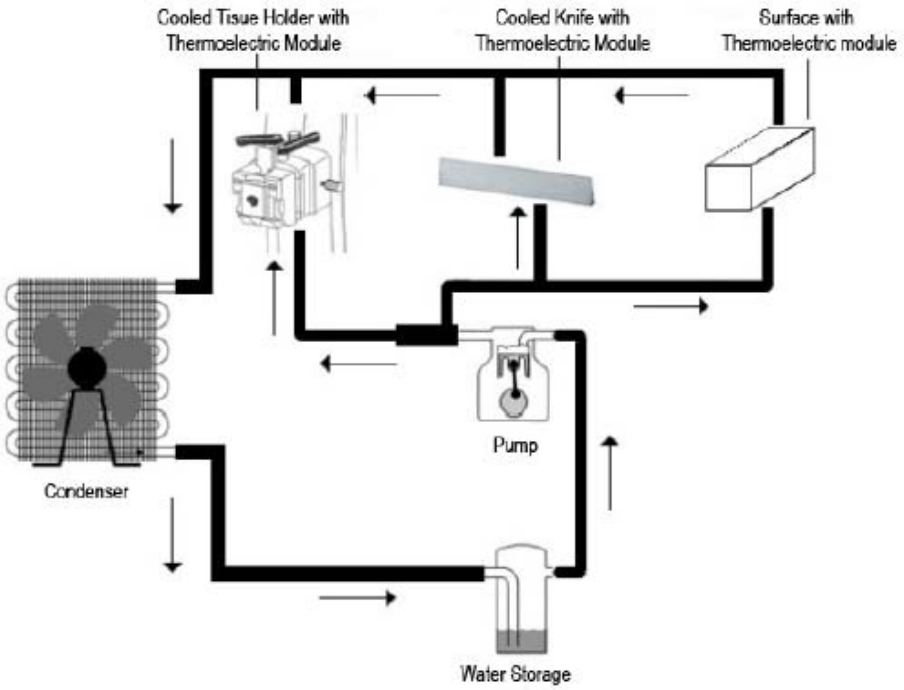

Figure 5. Diagram of water circulation system
(Şekil 5. Su dolaşım sisteminin diyagramı)

Designed system gets high current (50 ampere). To support the system, SMPS (switch mode power supply) was used.

6. RESULT AND DISCUSSION (SONUÇ VE TARTIŞMA)

Microtome is a device taking sections from organ for the aim of performing histopathological research. Microtome that is used for cutting tissues embed in paraffin and used in pathology labs, is not convenient for emergence situations due to the fact that paraffin process takes long time. As to cryostats designed for emergence situations have the disadvantages of costliness and hard mobilization because of their sizes comparing with microtome. This system that is designed and performed, gained rotary microtome cryostat feature by means of thermoelectric system. Performed system has the feature of freezing and cutting tissues in a short time. Being besides it can be

moved easily owing to being very light. By this way, disadvantages of the cryostat device have been annihilated. Performance analysis of performed system has been made in Selcuk University Meram Medical Faculty, Department of Pathology

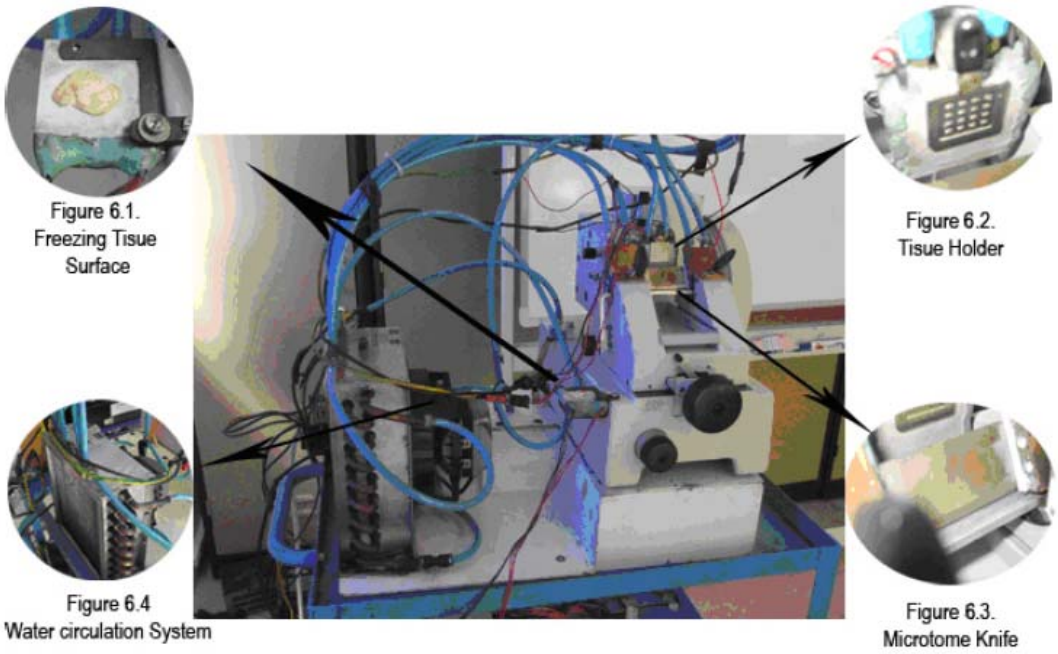

Figure 6. External view of the developed device
(Şekil 6. Geliştirilen cihazın dış görünümü)

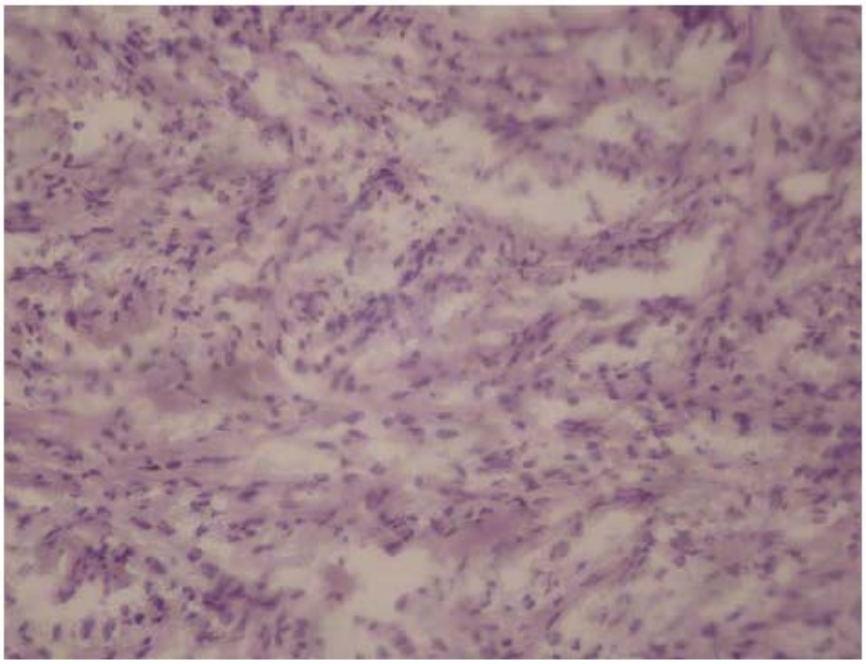

Figure 7. Microscopic image of the tissue taken from the developed device
(Şekil 7. Geliştirilen cihazdan alınan dokunun mikroskopik görüntüsü)

Gained result is given in Table 1, Table 2, Table 3 and graphed in Figure 8, Figure 9 and Figure 10.

Table 1. Cooling test results of freezing tissue surface
(Tablo 1. Dondurulan doku yüzeyinin soğutma test sonuçları)

Time (Min.)	0	5	10	15	20	25	30
Temperature (°C)	14,8	-7,1	-20,6	-20,7	-20,3	-20,3	-20,3

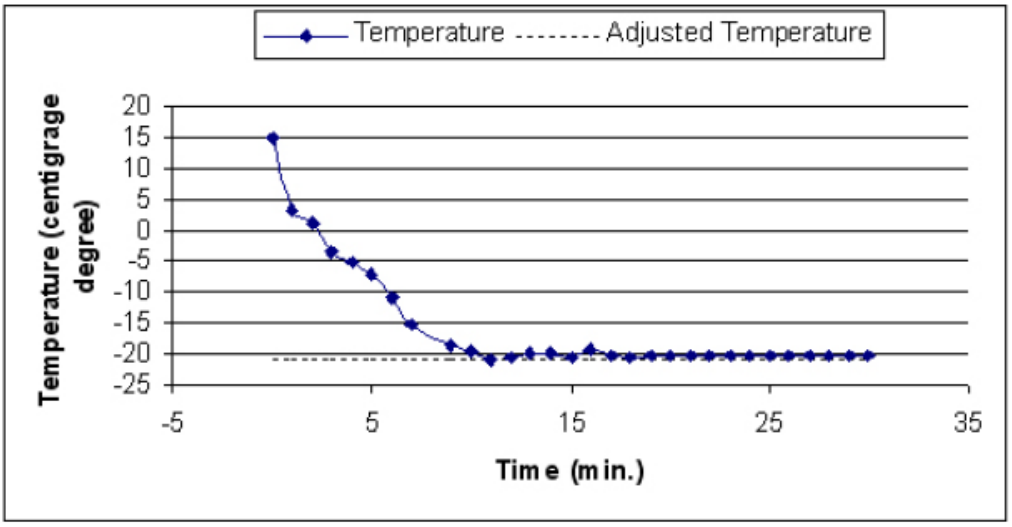

Figure 8. Freezing tissue surface temperature variation graph
(Şekil 8. Dondurulan dokunun yüsey sıcaklık değişim grafiği)

Table 2. Cooling test results of tissue holder
(Tablo 2. Dokunun soğutma test sonuçları)

Time (Min.)	0	5	10	15	20	25	30
Temperature (°C)	14,2	-6,9	-18,7	-18,7	-19,3	-19,6	-19,3

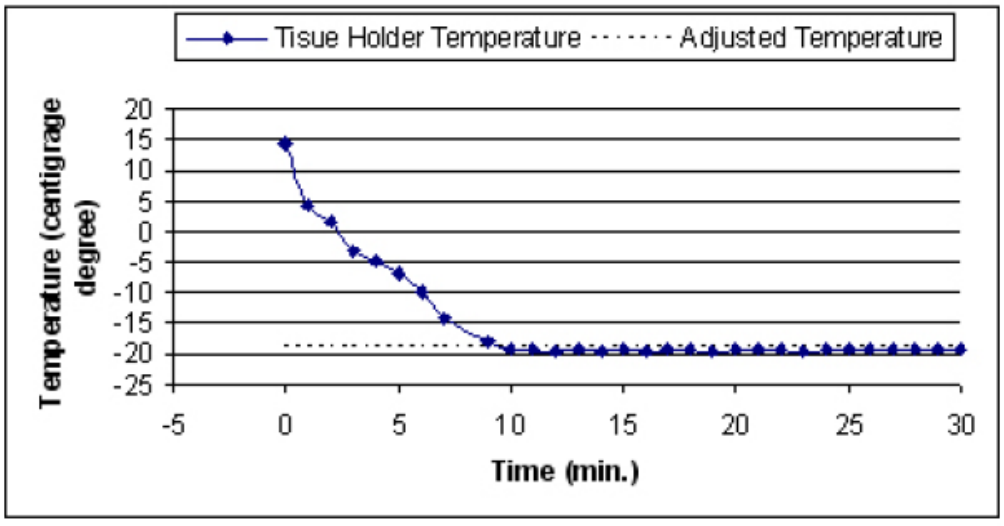

Figure 9. Tissue holder temperature variation graph
(Şekil 9. Doku tutucu sıcaklık değişim grafiği)

Table 3. Cooling test results of microtome knife
(Tablo 3. Mikroatomun soğutma test sonuçları)

Time (Min.)	0	5	10	15	20	25	30
Temperature (°C)	15,3	-7,5	-18,6	-18,5	-18,2	-18,2	-18,2

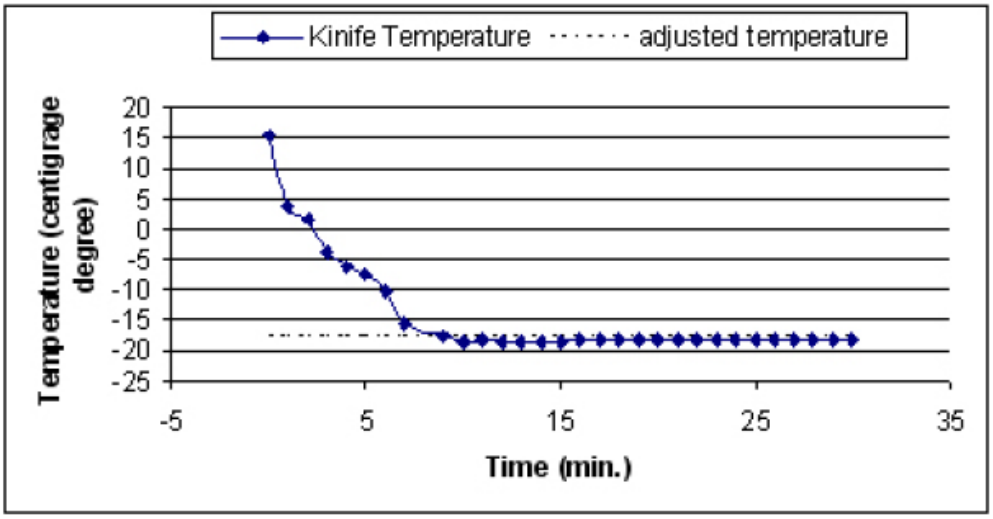

Figure 10. Microtome knife temperature variation graph
(Şekil 10. Mikroatom bıçak sıcaklık değişim grafiği)

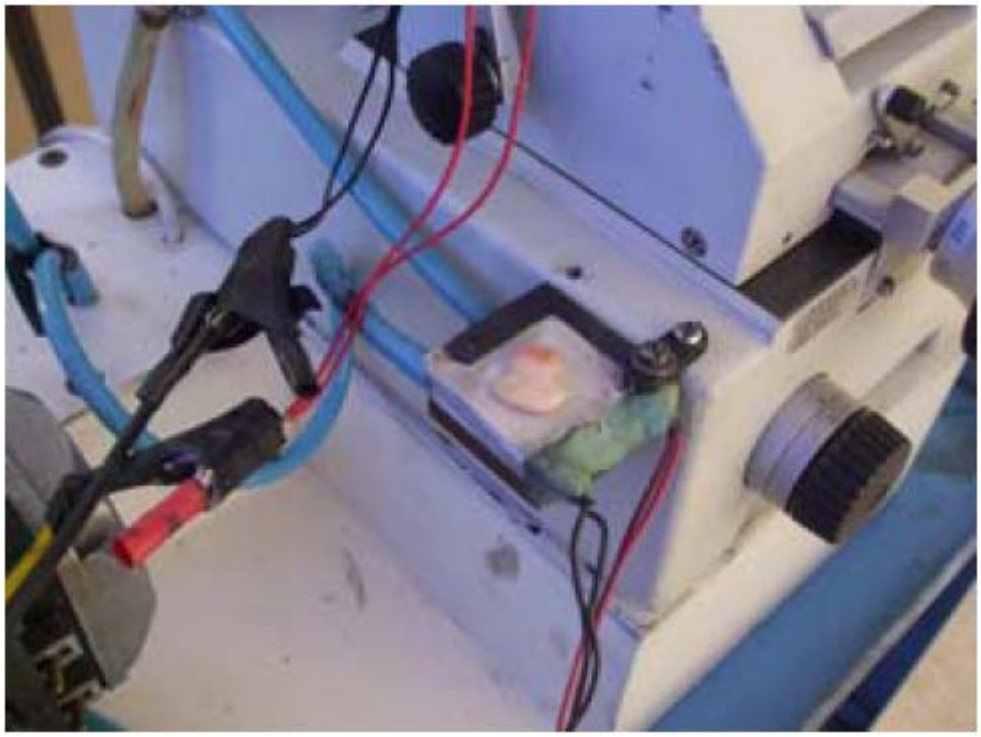

Figure 11. Freezing tissue surface and freezing tissue
(Şekil 11. Doku dondurma ve donan doku yüzeyi)

The tissue sample in Figure 7 was frozen and cut by pathology device for freezing tissue designed and performed and microscopic image of the tissue was shown in Figure 7. Microscopic image of the tissue in Figure 7 was analyzed by laboratory crew in Selcuk University Meram Medical Faculty Department of Pathology and being

practicable of the pathology device was taken as feedback. Prof. Dr. Mustafa Cihat AVUNDUK is an academic member in Selcuk University Meram Medical Faculty Department of Pathology and is one of the laboratory crew who made the research.

This performed study was carried out on a modified rotary microtome. In future studies, it is seen that a new microtome having cryostat feature can be designed and produced by developing this study. Hereof required patent application was made by project group.

This study has been conducted as the Graduate Thesis of Yavuz ÜNAL from S.Ü. Institute of Science. We would like to give our special thanks to Selçuk University for their material support and contributions towards scientific research projects.

REFERENCES (KAYNAKLAR)

1. Carson, F.L., (1997). Histotechnology-A self-Instructional text. 2nd ed. ASCP Chicago
2. Bancroft, J.D., (1990). Theory and practice of histological techniques. 3rd ed. London:Churchill Livingstone.
3. Woods, EA, Ellis. (1996) Laboratory Histopathology. A Complete Reference. 3rd ed. Churchill Livingstone.
4. Rutherford, T.., Hardy, W.S., and Isherwood P.A., (1964). A Thermoelectrically Cooled Microtome Table and Knife. Biotechnic and Histochemistry. Volume 39, Issue, pages 185 –190.
5. Hardy, W.S. and Rutherford, T., (1962). Thermo-electric apparatus for the preparation of fresh-frozen tissue sections. Nature, 196, 785786.
6. David, H.B., Spring, B.J., (1967) An Apparatus for Rapid Attachment of Frozen Tissue to Cryostat Tissue Carriers., Biotechnic and Histochemistry., Volume 42, Issue., pages 147–149.
7. William, J.W., (1969) C.Marlowe., A Hydraulic Powered Microtome in a Commercial Freezer; An Improved Cryostat for Large Sections., Biotechnic and Histochemistry, Volume 44, Issue , pages **81–85**.
8. Işik, H., (2005). A New Microcontroller Supervised Thermoelectric Renal Hypothermia System., Journal of Medical Systems, Volume 29, Issue 5 Pages: 441–447.
9. Andersen, J.R., (1962) Thermoelectric air conditioner for sub-marines. Adv Energy Conv;2:241-8.
10. Mei, V.C., Chen, F.C., Mathiprakasam, and B., (1989). Comparison of thermoelectric and vapor cycle technologies for ground- water heat pump application. ASME J Solar Energy Eng;111:353-7.
11. Anon. (1990). Thermoelectric cooler selection guide. Marlow Industries, Inc.,
12. Soo, S.L., (1968). Direct energy conversion. Englewood Cliffs (NJ): Prentice Hall, Inc, (chapter 5)
13. Goldsmid, H.J., (1986) Electronic Refrigeration. Englewood Cliffs(NJ): Prentice-Hall, Inc.,
14. Huang, B.J., Chin C.J., and Duang C.L.. (1999). A design method of thermoelectric cooler., International Journal of Refrigeration.
15. Sarıoğlu, M.K., (1991). Otomatik Kontrol (I) ITU,
16. Kuo, N. and Benjamin, C. (1992). Digital Control Systems, Saunders College Publishing.