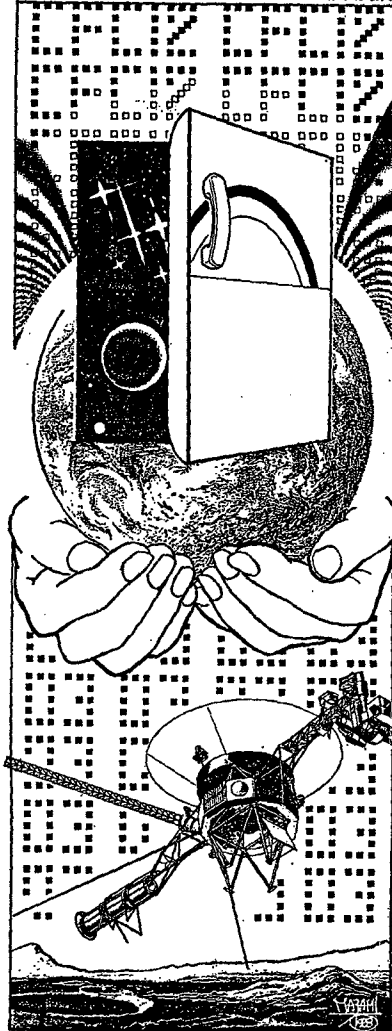


The International Thermoelectric Society

SCT- 93

SHORT COURSE ON THERMOELECTRICS

1993-8-1 The Nihon Keizai Shimbun



Illustrate by Masami Ishii

*FOR THE GREEN
21st CENTURY*

**Pacific Convention Plaza Yokohama
Japan**

8th November 1993

Sponsored by the International Thermoelectric Society

Organized by ITS Japan Branch

Edited by: The International Thermoelectric Society

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Short Course on Thermoelectrics - 1993 (SCT-93)

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LECTURE 8

**LABORATORY, INDUSTRIAL
AND
CONSUMER APPLICATIONS**

I LABORATORY APPLICATIONS

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LECTURE 8

LABORATORY, INDUSTRIAL AND CONSUMER APPLICATIONS

I LABORATORY APPLICATIONS

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1 INTRODUCTION

Since a fully comprehensive account of all available laboratory applications using thermoelectrics (abbreviated TE) is beyond the scope of this text. The analysis is limited to the examples given below. The areas of practical usage which are listed below, indicate the versatility and broad range of laboratory application of thermoelectrics. The examples of practical application will be shown by the transparencies or slides in this cause.

1. 1. Laboratory Equipment using TE Cooling

The equipment consists of three components; (i) TE cooling unit, (ii) DC power source/controller system and (iii) an accessory system which is highly specific to satisfy the desired purpose.

In this course equipment of relatively low cooling capacity, i.e. less than hundreds of watts, is classified under the following categories; 1. Measurement, 2. Biotechnology, 3. Medical, 4. Electronics, 5. General Purpose.

2. BASIC CONSTRUCTION OF A COOLING UNIT

The TE cooling unit in the equipment consists of three components; (i) the TE module, (ii) the heat dissipator at the hot side of the TE module which is indispensable to the TE cooling unit and (iii) the cooling component at the cold side of the TE module.

The solid body to be cooled can be cooled in direct contact with the cold ceramic plate of the module, but in most cases the body is cooled through (i) the heat conductive plate, the block and the bath, (ii) the cooling heat exchanger, for example the forced air convection fin, or (iii) the liquid jacket. Each type functions specifically.

applications. The standardized TE cooling units are economical and suitable for general purpose applications.

The examples of the specifications of each TE cooling equipment are indicated in Table 1; (i) the name of equipment, (ii) the number of stages, (iii) configuration of the cooling and heat dissipating system, (iv) obtainable minimum temperature on the cool mode; T_{\min} ($^{\circ}\text{C}$) of the cooled body, (v) maximum temperature on the heat mode; T_{\max} ($^{\circ}\text{C}$) of the heated body, (vi) magnitude of the cooling power Q_c (W) at T_{\min} , (vii) the TE cooling unit or the total system power consumption.

3. LABORATORY EQUIPMENT CLASSIFIED BY USAGE

3. 1. Measurement

3. 1. 1. Micro Photo Calorie Meter

The Cu cave which is a TE controlled black body (NiP-plating) can be used to measure the power of light, its wavelength range; 0.4 to 1.8 μm , power range; 100 μW to 200mW within $\pm 1\%$ accuracy by isothermal control of a TE Module.

3. 1. 2. Dew Point Sensor

The mirror is mounted from a single-stage to a five-stage Peltier module which can cool the mirror below the ambient temperature. LED illuminates the mirror and a photodetector monitors light reflected from the mirror. Another LED/photodetector provides a reference measurement. When sample gas is passed over the cooled mirror, dew begins to form and the dew droplets scatter the light. The detector on which the light is reflected from the mirror senses a drop in light intensity compared to the reference photodetector. The two photodetector pairs are arranged in an electrical bridge circuit. The mirror surface temperature is automatically and continuously controlled at the dew point temperature of the sample gas.

3. 1. 3. Freezing Point Apparatus 1

This apparatus is used for detecting the freezing and melting points of hydrocarbon mixtures such as aviation fuels. The test sample needs to be cooled to about -60°C to determine the freezing point and to be heated back to room temperature to determine the melting point. Cooling and heating are provided by two three-stage TE modules in the apparatus, top-stage; 71 couples (element length: 3 mm), middle-stage; 71 couples (element length: 6 mm), bottom-stage; 127 couples (element length: 6 mm). To keep the hot side of the Peltier modules below 20°C or so, a mixture of ice and water was chosen as a suitable medium.

3. 1. 4. Blackbody Radiation Standard

The blackbody plate, 50 x 50 mm, emissivity >0.98 , is controlled at a temperatures of -20°C to 70°C , temperature uniformity $\pm 0.1^{\circ}\text{C}$ by the TE module. The plate provides the blackbody radiation standard at the desired temperature.

3. 1. 5. Photomultiplier Housing

The TE cooled housing for photomultiplier provides low noise, low dark current operation, gain stability and signal-to-noise ratio improvement for the photomultiplier measurement.

3. 1. 6. Gas Sampling Dehumidifier Unit

Pollution gas such as engine exhaust fumes, chimney smoke etc. contains water

vapor. When the gas being sampled is induced in the infrared analyzer, water vapor can give a false reading of the sample and or the corrosive aqueous solution formed from the condensed water in the analyzer may damage the analyzer detector. The anticorrosive gas flow jacket is cooled by TE modules at a temperature of $1.5\sim 3.0^{\circ}\text{C}\pm 0.1^{\circ}\text{C}$. Water vapor contained in the gas being sampled is condensed before passing through the gas jacket and removed as drain water.

3. 1. 7. Ice Point Reference Chamber

The chamber consists of a copper cylinder closed at one end and fitted with a flexible metal bellows at the other. The chamber is completely filled with pure water for ice point reference or with pure water and air for triple point reference which is cooled by Peltier modules. A sealed water/ice or water/air/ice mixture automatically controlled gives the ice point, $0\pm 0.01^{\circ}\text{C}$ or the triple point of water.

3. 1. 8. Water Bath for sampling SO_2 Bubbler

Wet-chemical SO_2 sampling procedures is adversely affected by high ambient temperatures, up to 75% of SO_2 in a collected or stored sample can be lost over a 24-hour period at 50°C due to thermal instability, and the loss continues to increase as the ambient temperature increases. The SO_2 bubbler and reagent are maintained between 7 and 17°C in an ambient temperature range from -25 to 50°C by TE modules.

3. 1. 9. Oil Clouding Point Apparatus

The oil sample being tested is cooled to -34°C to determine the clouding point. Cooling is provided by two two-stage TE modules with forced air heat dissipators.

3. 1. 10. Refractometer

A pump circulating water externally controls the environmental temperatures for refractometer using TE modules. (see 3. 5. 4. Liquid Circulating Apparatus)

3. 2. Biotechnology

3. 2. 1. Bio Activity Monitor-Calorie Meter

The direct and continuous monitoring of the very small heat effect associated with biological events in living organisms up to $250\sim 300\mu\text{W}/\text{ml}$ can be achieved by isothermal control of TE modules. The limit of detectability is $0.15\mu\text{W}$ to $1.0\mu\text{W}$ at $25^{\circ}\text{C}\pm 0.01^{\circ}\text{C}$ in a controlled environment with a pump circulating water externally using TE modules. (see 3. 5. 4. Liquid Circulating Apparatus)

3. 2. 2. DNA Sequence Reactor

The DNA sequence reactor is maintained at the constant temperature of 37°C by a pump circulating water externally using TE modules. (see 3. 5. 4. Liquid Circulating Apparatus)

3. 2. 3. Spectrophotometer Cell Thermoprogrammer

The temperature of the spectrophotometer cell holder is controlled with a TE cooling unit for DNA thermal denaturation - renaturation applications in nucleic acid and protein studies. It provides programmed heating and cooling of samples in the Spectrophotometer cell in the temperature range of $0\sim 99.9^{\circ}\text{C}\pm 0.1^{\circ}\text{C}$. Temperature agreement between Cells better than $\pm 0.2^{\circ}\text{C}$ at 40°C , better than $\pm 0.5^{\circ}\text{C}$ at 99°C , cooling rate 10°C per minute max.

3. 2. 4. Programmable Thermal Controller

The TE cooling unit provides rapid heat transfer to and from the test tube holder block with cooling rates up to 1°C per second from 0°C to 100°C , accuracy $\pm 0.5^{\circ}\text{C}$ with no overshoot. It is a precise and convenient programmable thermal controller for DNA, RNA and other samples. The accessory temperature control system has 2K

bytes of non-volatile memory available to store up to 100 user-defined programs.

3. 2. 5 Mini Fridge for Blood

The bench top TE cooler provides controlled, pre-test conditions for specimens and reagents, eliminating the need for containers of ice or repeated trips to the refrigerator. For blood banking, for coagulation - store heat sensitive specimens and reagents at 4~8°C. Ideal for blood banking, RIA, coagulation and enzyme studies.

3. 2. 6. Photosynthesis Analyzer

The photosynthesis analyzer environment is temperature controlled with a small sized TE air conditioner. (see 3. 5. 5 Air Conditioner)

3. 2. 7. Osmometer

The freezing point of a solution is determined precisely. The Osmotic pressure of the solution can be indicated by milli-osmol with the freezing point method. A small amount of solution in the sample tube (0.3~2ml) is frozen by dipping it in a low temperature ethylene glycol (90%, 100ml) bath cooled to the temperature of -11°C by a two-stage TE module (top-stage; 32 couples, bottom-stage; 128 couples, element size; 2.8 x 2.8 x 2mm).

3. 2. 8. Chromatography Column Holders

The liquid chromatography column is temperature controlled with a TE cooling unit. (see 3. 5. 3 Cold Plate)

3. 2. 9. Thermoprogrammer for Bio Active Analyzer

The bio active analyzer-calorie meter environment is temperature controlled at 25°C±0.01°C with a pump circulating water externally using TE modules. (see 3. 5. 4 Liquid Circulating Apparatus)

3. 2. 10. Centrifuge

The temperature of the centrifuge environment is controlled by a TE cooling unit. (see 3. 5. 3. Cold Plate)

3. 3. Medical

3. 3. 1. Hot/Cold Stimulator

The TE cooling/heating unit at the end of the pencil-type probe, supplies heat or coldness in a determined cycle, sometimes alternating between hot and cold, sometimes maintaining either hot or cold for given periods of time. Consequently, it multiplies the function of treatment known as Acupuncture or Moxa in the Orient. It can also be used to check the human-body temperature sense organ.

3. 3. 2. Cryosurgical Destroyer 2

The cryosurgical thermoelectric destroyer is a kind of Cryotherapy based upon freezing of pathological tissue which is then rejected from an organism. The equipment consists of a control set-up and an operating cryoprobe. The nominal temperature of the cryoprobe is -50°C using a two-stage TE module with water coolant for hot side heat dissipation.

3. 3. 3. Microscope Stage Cooler

The TE cooled microscope stage provides temperature control from -20°C to 60°C±0.1°C for specimens to be mounted on a microscope stage.

3. 3. 4. Microtome Stage Cooler

A TE cooling stage is used as a microtome attachment. The temperature of the specimen for the microscope is lowered or raised when desired, by regulating the current flow to the TE module. A current reversing switch is provided for rapid warming of the freezing plate, thus allowing the specimen to be removed quickly.

3. 3. 5. Portable Mini (Insulin) Cool Box

Insulin is maintained at the temperatures of 5°C to 15°C by the portable TE cooling box at the ambient temperature of 45°C. The box has a self-contained power supply, inner capacity; 30 cm².

3. 3. 6. Cold Plate for Dental Cement

The temperature of dental cement is controlled on the TE cooled plate. The plate delays the solidifying time for dental cement. (see 3. 5. 3. Cold Plate)

3. 3. 7. Cold/Hot Therapy Blanket

Water is pumped from the water jacket of the TE cooling unit and circulated through the blanket. The equipment is a closed loop blanket system for hot or cold therapy.

3. 3. 8. Mist Tent

The environment in a tent is cooled by the TE air conditioner providing an ideal environment for the use of inhalers.

3. 4. Electronics

3. 4. 1. Photo Detector (InAs)

3. 4. 2. CCD Video camera Heads

3. 4. 3. Photo Detector (HgCdTe)

3. 4. 4. Photo detector (InAs, HgCdTe, Ge, PbS, PbSe)

3. 4. 5. X-Ray Spectrometer ³

3. 4. 6. Optical Communication Laser Diode

3. 4. 7. Interferometer Laser Diode

3. 4. 8. Low Noise Amplifier for Satellite Earth Station

3. 4. 9. Microprocessor-IC Environmental Controller

3. 5. General Purpose

3. 5.1. Vacuum Pump Baffle

The TE cooled baffle is incorporated for use on diffusion pumped high vacuum systems and eliminates the need for compressors and cooling coils required by other baffle techniques. Temperature of chevron fins achieve as low as -35°C.

3. 5. 2. Immersion Cooler

The TE modules are enclosed in a heat exchanging metal case. With this type of immersion heat pump, the case facilitates the lowering of temperatures of small insulated laboratory baths.

3. 5. 3. Cold Plate

The cold plates are the most basic type of TE cooling unit. Standardized TE cold plates for general purpose with a proper heat dissipator and water-proof sealing, are available in a wide variety of sizes. The larger size the greater the cooling capacity and the higher the energy demand. They can be used in various types of liquid circulating apparatus, air conditioning systems custom built for a specific purpose.

3. 5. 4. Liquid Circulating Apparatus

The TE cooling system is easily operated for cooling/heating or automatically controlling the temperature of the circulating liquid. The liquid is pumped through the liquid jacket in contact with the TE module which has an appropriate heat dissipator. This is a universal liquid temperature controlled system.

3. 5. 5. Air Conditioner

The air convection heat exchanger fin is in contact with the TE module with an appropriate heat dissipator. The air passing through the fin is circulated by the blower. Where in general use this type of air conditioner maintains a clean air-conditioned

environment.

4. Other Applications

The Seebeck coefficient of TE materials is greater than that of metals. TE couple or modules can be used for temperature sensors, pyrometers, IR detectors and for other applications. They can be small, light and have a small heat capacity. High signal response and figure of merit are essential. Thin film TE couple or modules are good for such applications. L. I. Anatyshuk has been promoting R & D in this field ^{4, 5, 6, 7}

4. 1. TE Radiation Receivers ⁴

- 4. 1. 1. Multi-channel IR Fire Informers
- 4. 1. 2. IR-Radiation and Microwave Sensors
- 4. 1. 3. Ultrasonic Sensors
- 4. 1. 4. Distant Fire Alarm Systems
- 4. 1. 5. Pyrometry
- 4. 1. 6. IR Spectrophotometers and Radiometers
- 4. 1. 7. Optical Gas Analyzers
- 4. 1. 8. Coordinate-sensitive Long-wave IR-Radiation Receivers
- 4. 1. 9. Fast Laser Receivers
- 4. 1.10. Gas and Liquid Expenditure Sensors

4. 2. High-precision thermal converter ^{5, 6, 7}

- 4. 2. 1. Special National Standard
- 4. 2. 2. Transported Standards for International Comparison
- 4. 2. 3. Operation Standards and Standard Means
- 4. 2. 4. Test Sets
- 4. 2. 5. Digital Voltmeters and Amperemeters
- 4. 2. 6. 1 and 2 Category Standard Means
- 4. 2. 7. Converter Standard Sets
- 4. 2. 8. Standard Meters for Wire Communication
- 4. 2. 9. Standard Measures
- 4. 2.10. Calibrators
- 4. 2.11. Comparators

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TABLE 1. LABORATORY EQUIPMENT (i)

NAME OF EQUIPMENT	NUMBER OF STAGES	COLD/HOT-SIDE CONFIGURATION FA: Forced Air, NA: Natural Air LB: Liquid Bath, AB: Air Box LJ: Liquid Jacket, GJ: Gas Jacket	COOL-MODE MINIMUM TEMP. T _{min}	HEAT-MODE MAXIMUM TEMP. T _{max}	COOLING POWER Q _c at T _{min}	HEAT DISSIPATING MEDIUM	TE UNIT POWER CONSUMPTION	TOTAL SYSTEM POWER CONSUMPTION
			°C	°C	W	°C		
Measurement								
1 Micro Photo Calorie Meter	1	Cu-Cave(NiP-plating, L:5 mm)/NA	20		0.2	Air (20)		90W
2 Dew Point Sensor 2-stage	2	Mirror/NA or LJ	-35	85	0.5	Air (25)		
2 Dew Point Sensor 5-stage	5	Mirror/LJ	-80	35	0.5	Water (15)		
2 Dew Point Sensor 1-stage	1	Mirror/NA or LJ	-15	80	1	Air (25)		
2 Dew Point Sensor 4-stage	4	Mirror/NA or LJ	-75	35	1	Water (15)		
3 Freezing Point Apparatus	3	Sample Holder(28x28x4mm)/Ice+ Water	-60	0	2	Water (20)	50W	
4 Black Body Radiation Standard	1	Black Body Plate (50x50mm)/FA	0	70	3	Air (20)	100W	250W
5 Photomultiplier Housing	1	Photo-Tube Block/FA or LJ	-20		5	Air (20)		
6 Gas Sampling Dehumidifier Unit	1	AJ/FA	1	3	5	Air (40)	6Vx4A	100Vx1.4A
7 Ice Point Reference Chamber	1	Gas-tight Casing(Water)/FA	0		5	Air (35)	6Vx4A	50W
7 Triple Point of Water	1	Gas-tight Casing(Water+Air)/FA	0		10	Air (35)		144W
8 Water Bath for sampling SO2 Bubbler	1	WB(100ml)/FA	7	17	10	Air (50)		
9 Oil Clouding Point	2	Test Tube Holder/FA	-25	25	15	Air (30)		
10 Refractometer	1	Liquid Bath(1.8lit) LJ/FA	10	60	60	Air (30)		100Vx7.5A
2. Biotechnology								
2.1 Bio Activity Monitor-Calorie Meter	1	Detector Tube(L.D. 14mm)/LB	20	80	0.0003	Water (20)		300W
2.2 DNA Sequence Reactor	1	WJ/FA	37	37	1.5	Air (20)	3Vx0.8A	
2.3 Spectrophotometer Cell Thermoprogrammer	1	Cuvette(1 cm)x4/FA	0	99.9	2	Air (25)	48W	
2.4 Programmable Thermal Controller	1	Test Tube(600.5ml)x60 Holder/FA	0	100	10	Air (25)		
2.5 Mini Fridge for Blood	1	Test Tube Block/FA	4		10	Air (25)		
2.6 Photosynthesis Analyzer	1	Box(12 lit) FA/LJ	5	45	15	Water (20)		100Vx5A
2.7 Osmometer	2	Bath(90% Ethylene Glycol 100ml)/FA	-11		25	Air (35)		240W
2.8 Chromatography Column Holders	1	Column Holder Al-Block/FA	30	70	30	Air (30)	3Vx16A	

TABLE 1. LABORATORY EQUIPMENT (ii)

	1	LJ/FA	-10	80	70	Air (2.5)	
2.9	Thermoprogrammer for Bio Active Analyzer						
2.10	Centrifuge	Case/FA	20		600	Air (2.5)	
3. Medical							
3.1	Hot/Cold Stimulator	Probe/NA	0	50	0.1	Air (2.5)	
3.2	Cryosurgical Destroyer	Cryoprobe/LJ	-50		2	Water (20)	100W
3.1	Temperature Sense Organ Tester	Probe/FA	10	40	0.3	Air (2.5)	0.5W
3.1	Hot/Cold Moxa	Probe/NA	15	57	2	Air (2.5)	8W
3.3	Microscope Stage Cooler	Stage (30x37mm) with Hole/LJ	-20	60	3	Water (20)	100W
3.4	Microtome Stage Cooler	Stage/LJ	-35		4	Water (20)	3.7Vx20A
3.5	Portable Mini(Insulin) Cool Box	AB(30 ml)/FA	5	15	5	Air (4.5)	50W
3.6	Cold Plate for Dental Cement	Al-Plate(90x160mm)/FA	18	20	10	Air (2.5)	200W
3.7	Cold/Hot Therapy Blanket	LJ/LJ	4	40	30	Air (20)	120Vx2A
3.8	Mist Tent	FA/FA	15	25	150	Air (20)	130Vx1.5A 345W
4. Electronics							
4.1	Photo Detector (InAs)	Detector(InAs)/NA	-73		0.05	Air (2.5)	5Vx0.8A
4.2	CCD Video Camera Heads	CCD(384x576 sci-grade)/FA	-45		0.05	Air (2.5)	
4.3	Photo Detector (HgCdTe)	Detector(HgCdTe)/NA	-50		0.1	Air (2.5)	3Vx1A
4.4	Photo Detector (InAs, HgCdTe, Ge, PbS, PbSe)	Detector/NA	-30		0.2	Air (2.5)	0.4Vx1A
4.5	X-Ray Spectrometer	Detector(Si-Li)/FA	-100		0.164	Air (20)	12Vx5A
4.6	Optical Communication Laser Diode	LD/NA	25		0.5	Air (50)	1.4Vx1A
4.7	Interferometer Laser Diode	LD/NA	25		0.5	Air (50)	1.5Vx1A
4.8	Low Noise Amplifier for Satellite Earth Station	FET/FA	-45		1.5	Air (60)	600W
4.9	Microprocessor-IC Environmental Controller	Al-plate(66x66mm)/FA	0	4	8	Air (3.5)	12Vx3.5A
General Purpose							
1	Vacuum Pump Baffle	Chevron Fin/FA	-30		3	Air (20)	
2	Immersion Cooler	Ni-Plate Case/LJ	-25	60	17	Water (20)	4.8Vx4.8A
3	Cold Plate	Plate/WJ or FA	0	70	70	Air (2.5)	240W
4	Liquid Circulating Apparatus	Wj/WJ or FA	-10	70	70	Air (2.5)	
5	Air Conditioner	FA/FA	-5	70	50	Air (2.5)	115Vx6.0A