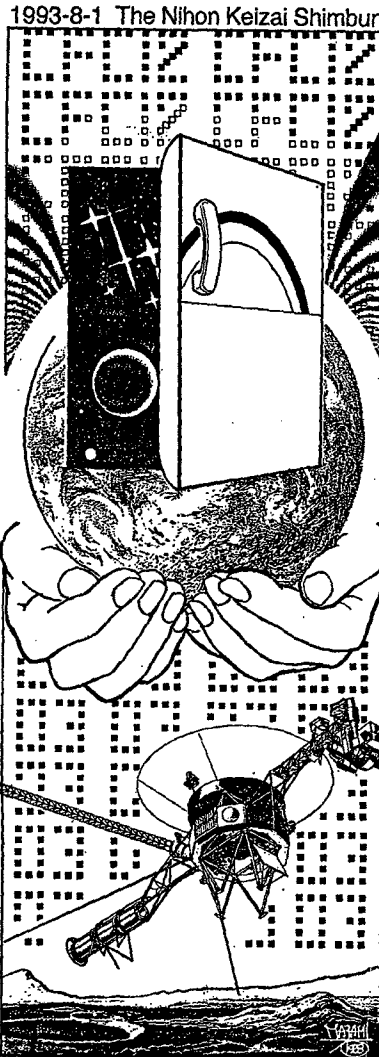


The International Thermoelectric Society

SCT- 93

SHORT COURSE ON THERMOELECTRICS



Illustrate by Masami Ishii

*FOR THE GREEN
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Short Course on Thermoelectrics - 1993 (SCT-93)

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CONSUMER APPLICATIONS FOR THERMOELECTRIC COOLING

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TE TECHNOLOGY, INC.

1. INTRODUCTION

Commercialization of thermoelectric (TE) cooling applications started only a little over three decades ago. The technology of thermoelectrics offered numerous advantages over "conventional" cooling technologies, but widespread market penetration was stymied by high cost and low efficiency.

The efficiency issue diminishes in importance as the overall capacity of the system decreases. Thus, for cooling systems with heat loads less than a few hundred watts, the advantages of TE cooling begin to overtake the concerns over higher operating power. Input power concerns start to become secondary concerns for applications in the 10's of watts. Ultimately, for "spot" cooling applications, TE reigns supreme.

Recently, the concern over ozone depletion and the accompanying ban on CFC's, has added new vigor to the TE cooling industry and has fostered more awareness of the TE industry as a whole.

Consumer applications were slower to materialize because this market segment is much more sensitive to price than markets such as industrial, medical, space and military. Essentially, TE has always been a good deal for those who can afford it, but the average consumer has essentially deemed that the price was too high. This has been unfortunate for the growth of the TE cooling industry since the consumer market is probably larger than any of the other market segments.

However, the consumer price "threshold" is rapidly being approached by thermoelectrics. This is a result of two phenomena. One is that the Consumer Price Index (in the USA) has risen to 5 times that of 3 decades ago. The other is that TE prices have steadily declined (or, at least held constant) over that same period. The relative price of TE today is approximately 1/40th of the price in 1960 and the trend is still downward. Eventually, the consumer "threshold" will be sufficiently penetrated creating a new age for thermoelectric cooling.

2. ADVANTAGES OF TE COOLING

Probably, the most important advantage of thermoelectrics is its flexibility and logistics. The slogan of a leading TE manufacturer

reads: "Uses for thermoelectrics are as limitless as the human imagination". Anyone who has served the role of a TE applications engineer will echo that concept. In fact, pursuit of use for TE has seem to go beyond imagination sometimes. A responsible TE engineer will spend a fairly significant portion of his time talking potential customers out of using TE. The industry has suffered enough from "black eyes" due to over-zealous claims for TE and most of us work very hard to maintain credibility for ourselves, our companies and the industry at large.

Thermoelectric cooling units have many unique advantages over other types of coolers in their application area:

2.1 Size

They can be tailored to fit the application by easy addition or subtraction of modules to fill the need accurately and avoid waste.

2.2 Power Input

Due to tailored nodular construction, power requirements can be reduced to a minimum. Power is provided through a single pair of leads.

2.3 Reliability

There are no parts that wear or clog, and no delicate moving parts. Gases, corrosive liquids or chemicals that will leak or dissipate with age are also eliminated. These features result in greatly reduced maintenance requirements.

2.4 Ruggedness

Thermoelectric coolers have a very high resistance to shock and vibration. Potted TE modules have survived shock levels as high as 20,000 G's in all 3 axes.

2.5 Logistics

There are no requirements at the load for pumping refrigerant or for a source of coolant such as liquid nitrogen to be added during operation of the system. They can also operate in any orientation and make no acoustical noise.

2.6 Remote Control

The unit and heat sink are required in the cooling area. The power supply and most other control equipment can be mounted and operated remotely.

2.7 Cooling Range

Thermoelectric coolers are capable of operating from any heat-sink temperature from +100°C to - 100°C.

2.8 Temperature Control

Simple electronic schemes allow control within a fraction of a degree of desired load temperatures above or below ambient.

3. CONSUMER APPLICATIONS

Thermoelectric modules are extremely versatile and have been used in countless applications from picnic boxes to fingernail polish cool-dry units. Some TE consumer products have matured and consume more than half of all TE modules produced in the world. Others have fallen out of favor, but primarily due to marketing problems rather than technical shortcomings.

If one were interested in creating a new TE consumer product, he may not necessarily need to invent one. In fact, many "would-be" inventors have discovered that their "new" TE invention had already been patented. During the 1960's and into the 1970's, many creative TE material research scientists were struggling to maintain their TE project in the face of management's disenchantment with failed "break-throughs". To revive interest, he resorted to inventiveness for numerous, "sure-thing", clever TE product ideas - something management could comprehend and, hopefully, rejuvenate corporate support. Unfortunately, most of these product ideas did not survive the "market test". However, many of those failed acceptance only because of the high cost of TE modules at that time. This cost issue will be addressed in more detail below. Suffice to say, one could easily uncover a potential wealth of new product ideas by simply exploring the patents issued during this period. No need to worry about patent violation and licensing, they are now all in the public domain.

The following is a partial list of consumer applications currently being marketed:

Wine Cabinet Coolers	Picnic Baskets
Microscope Slide Coolers	Fish Keepers for Boats
Canned Beverage Quick-Coolers	Aquarium Cooler/Heaters
Silent-Cool Hotel Refrigerators	Pillow Coolers
Home and Office Water Coolers	Fuel Vapor Distillers
De-humidifiers	CCD Telescope Coolers
Recreation Vehicle Refrigerators	Aircraft Water Coolers
Cream Dispensers	Display Cabinets
Photo Developing Solution Coolers	Ice Cube Makers
Restaurant Service-Stand Coolers	

Today, the portable refrigerator/cool-box accounts for most of the TE modules used in consumer products. Tomorrow, it could easily be overtaken by other consumer products such as some new designs now on the drawing board for chilling bottled drinking water.

4. PRICE ANALYSIS

It has been said that the three most important factors needed for a successful consumer product are price, **Price** and **Price**. As mentioned above, many a consumer product has succumbed to infanticide - especially in the 1960's - 1970's. These product ideas deserve another look.

First, examine the impact of inflation. Figure 1 is a plot of the consumer price index for all products in the USA over the life of commercial thermoelectrics. These data were extracted from reports published by the USA Department of Commerce. This graph indicates a factor of 5 increase since 1960.

What has happened to TE module prices? To answer this question, data was extracted from price lists published by Melcor (Materials Electronic Products Corporation), the undisputed world leader in production of consumer-used TE modules. All of their modules were evaluated on the basis of price per watt of cooling capacity and the lowest price-per-watt TE module was determined for three operating module voltages: 3 volts, 7 volts and 12 volts. These prices were adjusted to account for the rise in the consumer price index by "normalizing" to the 1993 consumer price index.

In 1960, the largest voltage TE module offered was a 3 volt module. It had a price tag of \$43.09 per watt (1993 dollars) for 1 unit and \$9.79 per watt for units in the 1000 piece quantity.

By 1969, the 7-volt TE module was introduced at a price per watt of \$5.46 for 1 and \$1.39 for 1000 in 1993 dollars. This module better-served the consumer market because two modules could be driven by a standard 12 VDC power source at a reasonably low current. Figure 2 illustrates the remarkable drop in price from then until now.

During the 1970's, Melcor announced to the industry that they were going to produce and market a small TE picnic-box cooler. They also announced that they were doing this only to prove to the world that it could be done and that they would back out and let the entrepreneurs take over once their point was proven. This single event represents the birth of TE consumer products. This "infant" was nourished by the introduction of a single, 12 volt TE module in 1981. By this point in time, the prices for this module rapidly converged to the lowest price per watt of any TE module. This combination of events did more to foster the growth of the TE cooling industry than all the TE scientists and engineers of the world who were stepping over each other to lay claim to a few tenths of a Z unit improvement.

The trend for TE module prices is more clearly evident in Figure 3 (long term) and Figure 4 (recent trend). The Y-axis is a dimensionless ratio of the price per watt in 1993 dollars to today's best price per watt. As observed from this graph, the 1993 price of

the first 7-volt TE module in 1969 was nearly six times the price of today's 12-volt module. In fact, the price of a 12-volt module is less than half that of just 10 years ago.

Certainly, the trend for the cost of thermoelectrics relative to costs for everything else is for lower prices yet in the future. It would be a challenge to find any other commodity which has a steadily and significantly reduced price as TE modules over a period of 3 decades.

There is one final price factor for consideration as illustrated in Figure 5. The Y-axis is the dimensionless ratio of price for 1 unit to the price for 1000 units. Prior to 1980, it was much more expensive to purchase a single TE module compared to the production price. This high ratio could have been quite discouraging for a "budding" entrepreneur to get underway. However, since the 1980's he could obtain experimental modules at a price of only about 1.5 times that of a production module.

5. CONCLUSIONS

The conclusions are that we are slowly but surely approaching the "critical mass" for TE consumer products. Never has there been a better time for the entrepreneur to examine the market potential for a TE consumer product. The price of TE modules for all of those wonderful product patents of the 1960's is now 1/40th what it was in 1960. Current prototype prices are 1/177th what they were in 1960. Certainly, these dramatic changes warrant a new look at some old ideas.

Have we bottomed out? Don't count on it! The trend is for continued lower prices. The technology is there for another dramatic price reduction. Already, TE cooling is breaking through the "consumer resistance threshold" with the advent of 36 quart TE refrigerator for less than \$93 retail and a TE "mini-cooler" for less than \$40 retail.

TE materials scientists and engineers, it is your turn now. Yes, there seems to be some encouraging "super insulation" possibilities that can reduce the impact of the less efficient TE cooler. Now, if that can be accompanied by corresponding improvements in Z (forecasted by some current TE material researchers), the TE cooling industry may yet yield the rewards consistent with the intensity and dedication of the TE pioneers who brought us to this point in history.

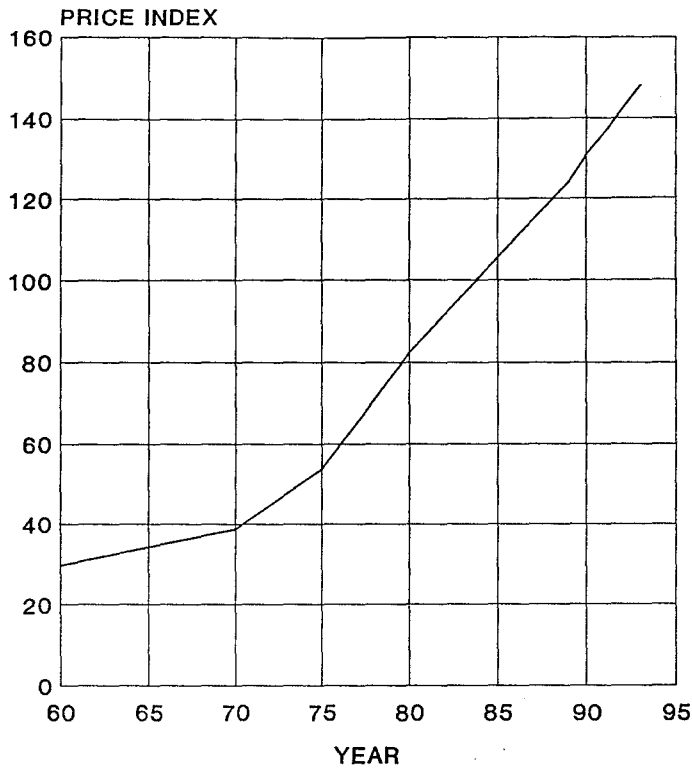


Figure 1. Consumer Price Index for all goods, published by the USA Department of commerce.

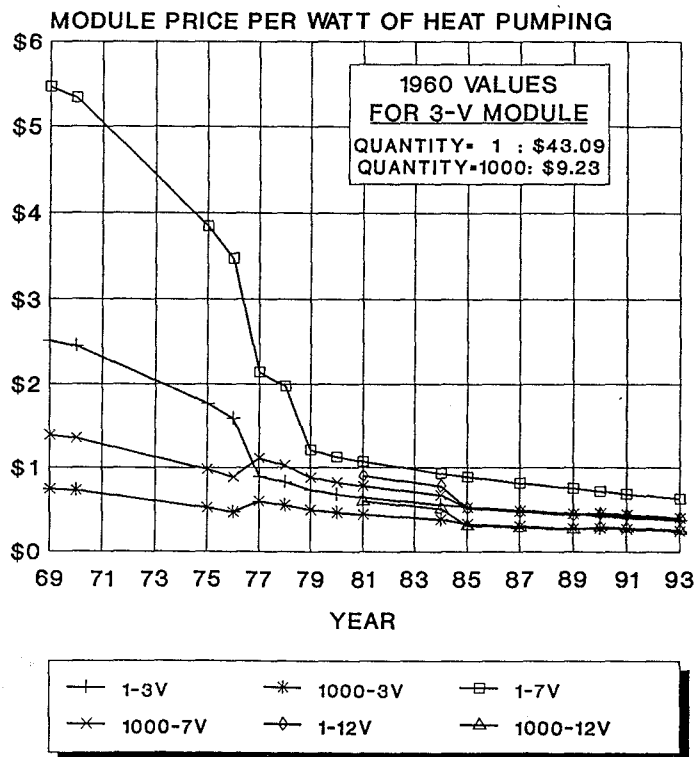


Figure 2. Price per watt of cooling power for Melcor TE modules adjusted to 1993 US dollars.

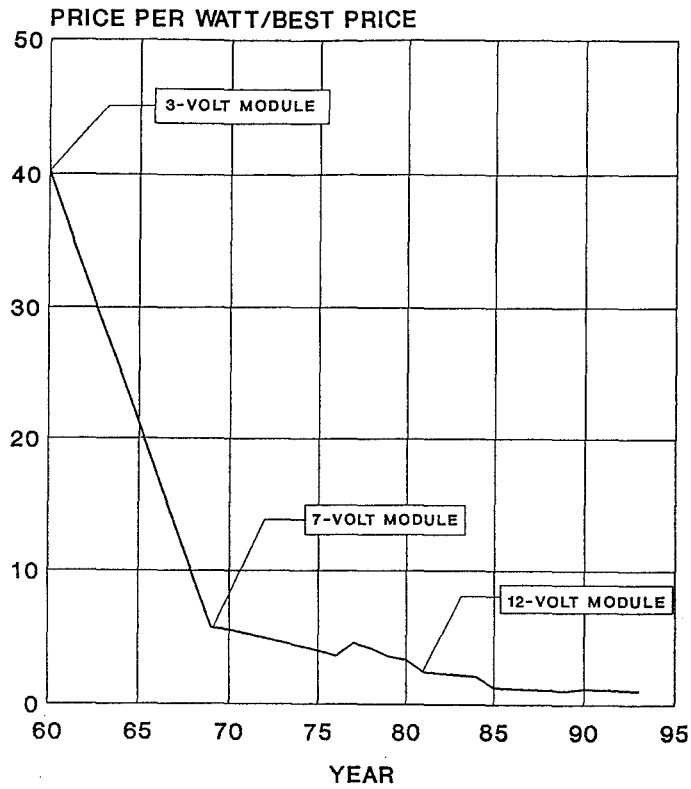


Figure 3. Ratio of Melcor's historical price per cooling watt adjusted to 1993 prices to today's best price per cooling watt.

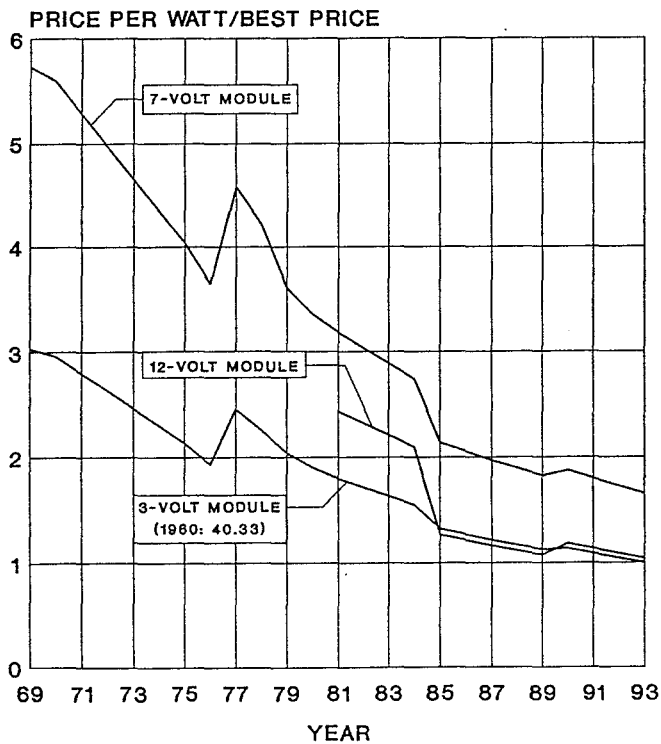


Figure 4. Recent trends by TE module type for price ratios as defined for Figure 3.

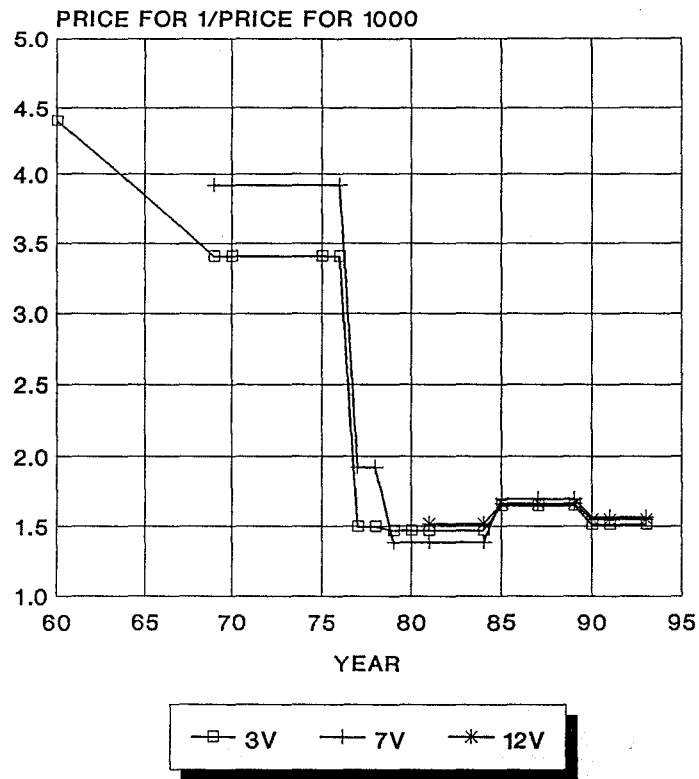


Figure 5. Historical ratio of prototype price (1 Unit) to production price (1000 units) for each TE module type.