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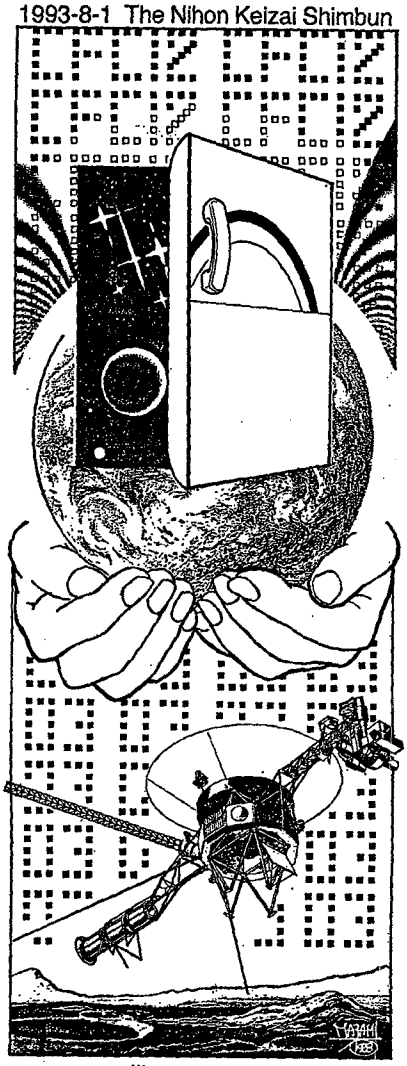

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LECTURE N° 8 -2

INDUSTRIAL APPLICATIONS

John G. Stockholm

1. INTRODUCTION

We review pastt industrial applications and will examine the future. Color slides of applications will be shown.
The references given in paragraphe 2 are in Reference List 1 and those of paragraphe 3 are in List 2

2. TE MODULE TECHNOLOGY

2.1 PAST APPLICATIONS

2.1.1. R.C.A.

This company was one of the first companies to invest heavily in thermoelectrics. They manufactured many small consumer type products. In particular they made a 30kW air conditioning unit for the US Navy,[4] that uses thermoelectric modules.

2.1.2. Carrier Corporation.

This company worked on Naval applications. Hudelson.[5,6] A 3.5 kW air conditioning unit with heat rejection to water. The unit consists of 6 subunits each one containing 4 TE modules. Each TE module is 13.7*17.8 cm, has 130 TE elements with an individual area of 1.13 cm^2 and a TE element height of 2.54 mm. This is much bigger than present day commercial TE modules
Carrier built in the mid 1960's a thermoelectric air conditioning and heating system for the headquarters of Johnson S C in Racine, Wisconsin. Unfortunately nothing was ever published on the installation. The system consisted of about 30 decentralized air conditioning units with heat rejection to a water circuit. During a visit to the installation in 1973, the system was operating, the only problem was the non availability of spares, especially concerning the power supplies and controls, so several of the units were not in operation. A photograph of a unit, taken down for repair, laid out on the floor shows the unit . The cooling power of each unit is of 1.5 kW and the heating power of 1.8 kW.
The TE modules were made by Carrier, they are 12*12 cm with 64 elements, the thickness is of 2.5 mm but the exact TE element area is not know it has been estimated to be around 60 mm2. The maximum electrical current was 80 A in the cooling mode.
After finishing this installation Carrier stopped all activity in thermoelectrics.

2.1.3. Borg-Warner Corporation:

This company was very active, but published practically nothing,[7] so it is very hard to know all that they did. Their main activity was in small compact systems that used ceramic thermoelectric modules.

2.1.4. US Navy

The US Navy was a major driving force in developing thermoelectrics in the early sixties. A very interesting paper on a frozen stores box and chilled stores box.[8] The units produce cold air and reject the heat into a water circuit at 7 °C. The cooling power is of 0.7 kW, for the chilled stores at - 1 °C and of 2.5 kW for the frozen store at - 18 °C. The systems consists of subunits each one containing 36 modules. The TE modules are 8.4*8.4 cm and 15 mm high. Each module contains 48 TE elements of diameter 7.1 mm (area = 40 mm^2), with height of 9.9 mm.

2.2. PRESENT APPLICATIONS

2.2.1. TECA.

TECA of Chicago are today the only company commercializing cooling systems that contain many modules. A typical product is the C4000 air conditioner, the heat is rejected to air, it has a cooling power of 400 W when the inlet temperatures on the cooled side and on the heated side are equal to 60 °C. It consists of 4 subunits joined together. All the air circuits are in parallel. A subunit is approximately 15*30*24 cm, the cooling is obtained with commercially available TE modules, the number of modules and their characteristics are proprietary. A photograph of one subunit is given in Figure 9 and the performances for model Americool 4000 series are given in Figure 10.

2.2.2. Midwest Research Institute

Midwest Research Institute of Kansas City Mo. USA, has developed a micro climate thermoelectric air conditioning unit for the pilots of helicopters.[9] The unit has a cooling power of 1000 W. It contains 96 ceramic commercial modules, each one contains 254 TE elements, the size of the elements are proprietary. The TE modules are assembled 6 at a time between two continuous plates with folded lanced fins. They have also developed a unit for ground vehicles.[10]

2.3. FUTURE APPLICATIONS

The equipments developed by Midwest Research Institute will become commercial in the near future.

Development work is on going on thermoelectric cooling systems with TE modules. There are essentially two domains: Space cooling for electronics and air conditioning. The applications are numerous, the limitation today is the high cost. Prototypes have been built for the air conditioning of telephone booths

Feasibility studies have been done for:

- air conditioning of train driver's cabs.
- cool rooms and deep freeze rooms for the Navy, history is repeating itself.[8]

The specifications change but the basic difficulties remain the same. Fortunately technology has progressed and systems of today can meet specifications which were unreachable 30 years ago.

3. INTEGRATED TE ELEMENT TECHNOLOGY

3.1 Past designs

Many companies were involved in Thermoelectrics in the early sixties an excellent review by Lynch[6] covers this period. There were many designs but not many large scale application have been built over the years, the best way to present the designs is through the patents that were filed and that are relative to large systems. Many designs did not mature into equipments for lack of development work, nevertheless some of them are very valid and deserve attention.

3.1.1. INVENTORS

The most prolific of inventors in Thermoelectrics was Elfving who filed over 15 different patents, his most frequent air technology used tubes with fins, but none of his ideas were ever used in large systems.
There are many people who filed just a few patents, but of some of them are of great importance because they influenced the trend of integrating the thermoelectric material to the heat exchangers. They are Lindenblad of RCA, A. B. Newton of Borg-Warner Corp., C. J. Mole and H. D. Coe of Westinghouse Corp and J Buffet of Air Industrie.

Patents were filed in 1964 on the structure in columns for air-air by C. J. Mole[7] of Westinghouse and by A. B. Newton[8] of York and. The Mole patent was published in 1965 while the Newton patent was only published in 1970, which indicates that there was opposition to the publishing of the Newton patent, the reasons are not publicly known. A major concept was from Coe[9] of Westinghouse, it is a column assembly of alternating hot and cold heat exchangers that are compressed together by wires to form a cubic type structure.
The Newton, Mole and Coe patents constitute the base of air-air subunits for large systems where pieces of thermoelectric material are used and the electrical current goes through the air heat exchangers.

There were many patents on linear structures[10,11,12,13] but none lead to any known prototypes.
For water-air units Mole[14] patented the concept of not electrically insulating the water heat exchangers and having bellows between each heat exchanger in a planar structure.
For water-water systems Benicourt[15] patented a column structure, that uses capped TE material with a flat surface on one side and either a spherical or cylindrical surface on the other.

3.1.2. BORG-WARNER

The York Division of Borg-Warner was only interested in air-air systems. The approach taken by Newton was to solder the entire "cubic" structure simultaneously in an oven. Borg-Warner had a policy of not publishing, so very little is known outside of what is in the patents. It seems that they encountered major difficulties when soldering all the junctions simultaneously.

3.1.3. WESTINGHOUSE

For air-air they took the same approach[16]. The columns are tightened with a central tie rod. They manufactured small units with cooling powers of several hundred watts for some military prototypes, but were never commercialized.

For water-water they published in 1972 two highly documented papers[16,17], that covered the design of a 7 kW unit model 20GS.
Westinghouse was very active in water-air systems for naval applications.[16,18]
The basic design was on the Mole patent[14]. The US Navy had a thermoelectric unit made by Westinghouse for the air conditioning on the US Dolphin It is a water-air unit, the structure is planar and the water is in direct contact with the electrical circuit. The operating voltage is in the range of 5 V so as to avoid electro-corrosion. It was in operation for over 10 years.

3.1.4. ASEA

A prototype unit to air condition and to heat a passenger railway coach was built by ASEA for the Swedish railways. Two articles published in Swedish have been found: one by Ridal[19] of the Swedish railways and one by Lundqvist[20] of ASEA
It was based on 2 patents by Widakowich.[21,22] The first is a planar structure that uses thermoelectric material, the second is on capping the TE material with copper and having a pressure contact.
The units were operated for several years and then were dismantled.

3.1.5. AIR INDUSTRIE - RAILWAY APPLICATION

Air Industrie was a manufacturer of compression cycle air conditioning for passenger railway coaches. In 1973 they initiated a development program for thermoelectric air conditioning passenger of railway coaches for the French railways.

The design was the column structure. It was based on a patent by Gaudel[23] This type of structure was retained after studying the planar and the linear structures. It was considered to be the most sturdy of the three structures. The thermoelectric material also used caps, because soldering a complete unit was found to be unreliable. The program lead to a coach being equipped in late 1977 with a 20 kW air-conditioning unit.[24] The coach was operated for over 10 years without a single thermoelectric failure.

3.1.6. AIR INDUSTRIE - NAVAL APPLICATION

In 1980 the French Navy started with Air Industrie a R and D program to develop a water-water unit for producing cold water for air conditioning. The structure chosen was the column structure[15] with the water tubing electrically insulated from the heat exchangers that are in the electrical circuit. The tubing is connected to the mass. The patent indicates capped TE material with on one side a flat surface and on the other, either a spherical, or a cylindrical interface. This interface is to allow during the tightening process a movement of the cylinder or sphere to compensate for non parallelism of consecutive layers of water heat exchangers.

A patent[25] covers the mechanical linking of the hot and cold tubes so as to reduce differential thermal expansion. Because of the differential thermal expansion of the hot and cold tubes, they used capped TE material with one flat surface so as to absorb the mechanical shear stresses transmitted by the tubes.

The Units have been described[26,27] and have undergone extensive endurance testing for more than 5 years.

4. CONCLUSIONS

The TE module technology is extensively used while the integrated technology has not been developed for lack of sufficient production requirements.

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