0. EXECUTIVE SUMMARY

0.1 INTRODUCTION

Electrolytic capacitors are passive electronic components whose basic function is to store energy. Fundamentally, it is a charge storage device which consists of two conducting plates separated by an insulator called dielectric. A variety of capacitors are in use in electronic and electrical circuits. A Capacitor is identified by the type of dielectric or plate material used on it. Some of the most common capacitors which find widespread application in electronics as well as electrical industries are paper, plastic film (such as Polystyrene, Polypropylene, Polycarbonate, etc.), Ceramic, Mica, Aluminium Electrolytic, Tantalum, and others.

A capacitor is expressed in terms of its capacitance, in MF (micro-farads) and its working voltage in Volts (V). Other parameters which specify its quality are Leakage Current, Dissipation Factor (also referred to as Loss Factor or Tan d).

0.2 ALUMINIUM ELECTROLYTIC CAPACITORS

Aluminium Electrolytic Capacitors are being used extensively for consumer electronic goods all over the world. Like any other type of capacitor the Aluminium Electrolytic Capacitors (AECs) too have two plates separated with a dielectric. While most other types of capacitors are bi-polar in nature (any polarity voltage can be connected to either of the plates) a good majority of AECs are polar. The outstanding advantage of electrolytic capacitors is the large capacitance/volume ratio. The large capacitance in ECs arises from very thin film of dielectric used of the order of 10^{-6} cm. The method of making film is by making anodic oxidation. Metals like Aluminium, Tantalum, Vanadium, Magnesium, Bismuth and Antimony are readily coated with a film of dielectric by electrolytic "forming process".

The forming process consists of the deposition of a thin film of Aluminium Oxide on the surface of the plate. Aluminium foil enters in the tank of electrolyte with a constant voltage applied and passes through the tank until the required thickness of film is produced.

The essential part of electrolytic capacitors and their functions are:-

Parts	Function
- Aluminium foil	- Positive or anode
- The oxide film	- Dielectric
- The Electrolyte (Usually a paste of glycol and ammonium tetraborate)	- Negative or true cathode
- Spacers	- Necessary to separate the cathode and anode film from direct contact
- A second Aluminium foil	- Contact electrode to the electrolyte: the cathode

General conditions which should be satisfied whenever electrolytic capacitor is used :-

- The peak voltage applied should be less than rated voltage.
- The applied voltage should never be reversed.
- The ripple current should not produce overheating.

The etched foil type is similar in construction to the plain foil type but the anode foil is mildly acid etched before forming with a consequent increase in the anode surface area. As the electrolyte is a paste it is able to make contact with the whole of the thin oxide film that is formed on this undulating surface. It is essential to control the etching process closely so that 'thin' spots are not left on the foil and also to ensure that no acid is left which might contaminate the foil. The increase in surface area results in a considerable increase in the capacitance obtainable. The polarisation capacitance of a plain aluminium plate is about 16 uF/in^2, whilst a foil etched to its maximum ratio and in glycol/boric acid electrolyte gives $125uF/in^2$.

0.3 TANTALUM ELECTROLYTIC CAPACITORS

Tantalum capacitor is finely powdered tantalum having a purity of the order of 99.7%. The capacitance is a function of surface area of the tantalum and its oxide film, it is desirable to use as a fine powder as is

practicable. Sintering takes place in vacuum at the temperature of 2,040°C. The vacuum is necessary because of the extreme reactivity of tantalum with all common gases at elevated temperature. Sintering performs the functions of welding the tantalum powder into a structurally strong porous mass and removing most of the small quantities of impurities, such as carbon, silicon and gases and all of the electrolysis salts normally present in the powder. After sintering the compacts are electrolytically oxidized to form the dielectric surface films.

0.4 USES

Electrolytic capacitors are mainly used in radio receiver, tape-recorders, TV (Black & White, Colour), PA equipment, Hi-fi system, defence computer, communication equipments and industrial applications.

0.5 RAW MATERIALS

The main raw materials used for manufacturing AECs are:

- Etched aluminium foils 30 to 60 microns thick.
- Formed aluminium foils (anodised etched aluminium foils) 50 to 90 microns thick.
- Condenser paper, craft and Manila Hemp and Duplex.
- Aluminium cans.
- Lead tabs.
- Electrolytes.
- Rubber bungs, EPDM, EPT rubber.
- Disc covers.
- Glue.
- Adhesive tape, high purity and high temperature.
- PVC heat shrinkable sleeve.
- Aluminium wire
- CP Wire (Copper plated).
- Plain aluminium foil.

0.6 STRUCTURE OF INDUSTRY

The total capacity issued by the Government of India for Electrolytic Capacitors and Tantalum Capacitors is as under :

(in Million Nos.)

	Electrolytic Capacitors	Tantalum Capacitors
- Industrial Licence	473.65	15.75
- Letters of Intent	53.00	
- Registration	968.00	40.00
TOTAL	1494.65	55.75

In addition to the above there are quite a few units manufacturing Electrolytic Capacitors in small scale. The average capacity of each manufacturers in small scale is between 0.5 to 3 million numbers of Electrolytic Capacitors per annum.

At present the total installed capacity in the organised sectors is approximately 375 million numbers for Electrolytic Capacitors and 7.75 million numbers for Tantalum Capacitors. However, most of the major manufacturers such as Punsumi, Webel Sen, Keltron have already planned to increase the installed capacity. Production of ECs during 1988 and 1989 was 359.35 and 426.48 Million numbers respectively. During the study, it was found that some of the existing ECs manufacturers are utilising more than 80% of their installed capacity. The increase in production is mainly due to the demand of ECs and the quality of ECs, which are being manufacture by the indigenous manufacturers.

0.7 EXPORT OF ELECTROLYTE CAPACITORS

Year	Quantity (M. Nos.)	Value (Rs. in Million)
1986	8.36	1.86
1987	5.79	2.21
1988	3.09	1.30
1989	36.75	22.67

0.8 MAJOR UNITS

At present there are 16 units manufacturing ECs in the organised sector. In addition to these, several units are manufacturing ECs in small scale sector. The following 8 units are manufacturing with foreign collaboration:

- Kerala State Electronics Devp. Corpn. Ltd. (Keltron), Cannanore.	- Aluminium Electrolytic Capacitors
- Meghalaya Industrial Development Corpn. Ltd., Shillong.	- Tantalum Capacitors
- Nav Bharat Enterprises, Hyderabad.	- Tantalum Capacitors
- Peico Electronics & Electricals Ltd., Bombay	- Aluminium Electrolytic Capacitors
- Rescon Manufacturing Pvt. Ltd., Pune.	- Aluminium Electrolytic Capacitors
- Sab Electronic Devices Sahibabad.	- Aluminium Electrolytic Capacitors
- Webel Sen Capacitors Ltd., Calcutta.	- Aluminium Electrolytic Capacitors
- Xenia Electronics Pvt. Ltd., Ranchi.	- Aluminium Electrolytic Capacitors

Other manufacturers who are manufacturing ECs, have adopted the technology either of the following manner or combination of the same.

- Purchase some technology through purchase of plant equipment and machinery.
- Diffusion of personnel from the existing unit.
- Training of personnel at manufacturing units overseas.
- Adopt standard technology from the published sources and develop the technology in-house by 'trial and error' method.

The ECs units are located all over the country except the central part of India.

The performance of ECs industry in the organised sector during last few

years is fairly steady. As per the information collected and available, except Xenia Electronics Pvt. Ltd., Ranchi, other units have done well. In fact some of the major units have taken effective steps for expansion of their existing unit. The small scale units are however, facing some problem. The major problem they are facing is the non-availability of indigenous good quality raw materials. The organised sector units are using 90 to 98% imported raw materials.

0.9 DEMAND

The demand of ECs is growing rapidly and it is estimated that by 1992 the annual demand of ECs will be close to 830 Million Nos. Import of ECs is not freely allowed. Some special types like very low ESR and very high voltage miniaturised ECs are being imported. The quality of ECs manufactured by some of the indigenous manufacturers is close to international standard. In fact some of Indian manufacturers are exporting their products to Italy, France, Spain and other countries.

0.10 TECHNOLOGY STATUS OF INDIAN INDUSTRY

At present most of the Indian EC manufacturers are manufacturing low voltage Aluminium Electrolytic Capacitors and some of them like Punsumi, Uptron, Webel Sen, are also manufacturing low voltage and high voltage Aluminium Electrolytic Capacitors. Some of the indigenous manufacturers are also exporting their products and due to the increased demand in domestic and export market, some of them have planned for expansion.

0.11 THE INTERNATIONAL SCENE

The total international market for ECs in 1988 was about US Dollars 2.3 Billion. Of this the share of Japan was US Dollars 869 Million accounting for about 38% of total market share. USA constituted 30% (US Dollars 697 Million) of the market, while Europe accounted for 20% (US Dollars 465 Million). In terms of production, however, out of the monthly production of 3300 Million Nos. of Aluminium Electrolytic Capacitors, in 1988, Japan, South Korea and Taiwan account for 2700 Million Nos. of which Japan itself contributes to 2000 Million. (Table 4.3)

The leading Asian producers of Aluminium Electrolytic Capacitors are as follows:

Japan

- Nippon Chemicon
- Nichicon
- Elna
- Shin EL Tsushin Kogyo
- Hitachi Condenser
- Toshin Kogyo
- Shoei Co.

South Korea

- Samhwa Elec/Nichicon Korea
- Daewoo
- Korea Elna
- Samsung
- Dongsung

Taiwan

- Kaimei Electronic
- Yeong Long
- Matsushita Taiwan
- Teapo
- Anodia

The basic technology for the manufacture of Aluminium Electrolytic Capacitors has changed a little since the first high performance AECs using formed and Etched Aluminium Foil was developed in late 1930's. However, over the years, specially with the advent of modern equipment utilising integrated circuit and with the demand imposed by improved and consistent performance over extended period of time, substantial adaption and process improvement have been made. Maximum attention is being paid by the leading overseas manufacturers to the following developments:

- Improved materials and their performance.
- Automation.
- Reliability and quality assurance.
- Higher tolerance to inverse voltage.
- Low ESR.
- Higher temperature capability.
- Miniaturisation.

0.12 TECHNOLOGY ABSORPTION AND GAPS

The standard process and technology for the manufacture of ECs is fairly well known at the industrial level in India even in the small scale. The 'real technology' lies in:

- Improved and indigenised raw material.
- Automation of manufacturing process for better yields.
- Improved quality and better manufacturing and material management techniques.

The only notable R&D effort at the National Laboratory has been attempted by the Central Electro-chemical Research Institute (CECRI), Karaikudi, to develop the technology for Etched Aluminium Foil. It has been observed during survey that the product using CECRI technology has not been found suitable by Indian ECs manufacturers. The process drawback appears to be the following:

- The CECRI process leads to improper etching uniformity arising out of the process deficiency.

- The etched foils have such extremely low gain that the gain factor is around 20 whereas the Foil available from leading overseas suppliers have gain factors in excess of 40 and in some cases exceed 70.

- The CECRI process is unable to compensate for the lower purity of Aluminium (99.5%) available indigenously as against the high purity (99.7%) conventionally required as basic material for use in the etched foil. Consequently, the high Chloride content in the Indian aluminium gets into the etched foil, and reacts with the Electrolyte in the EC thereby decreasing the capacitance and causing long term quality problem.

Whilst no other R&D efforts appeared to be currently in the pipeline in National Laboratories either for materials, parts or for equipment, out of the several of the leading Indian manufacturers of ECs, two indeed have in-house programmes for indigenisation or for process improvement, specifically in the areas of Electrolyte, some production equipment, jigs and fixures.

The most significant indigenous exercise in terms of technology development appears to be the in-house activities of leading manufacturers in modifying and expanding their product ranges to come out with product specifications to suit some peculiar requirements of the Indian market. Hence, the leading manufacturers such as Punsumi, are offering product ranges more diverse than even many of the leading International manufacturers and in fact, in several cases, product types which are unique only to India.

0.13 PROFITABILITY OF INDIAN INDUSTRY AND ITS RELATIONSHIP WITH TECHNOLOGY AND ABSORPTION

For the Indian ECs industry to improve its profitability of the companies, the following is required :

- Increased capacities with the capacity in excess of indigenous demand slated for exports.

- Substantially increased automation resulting in high International standard yields.

- Availability at competitive cost of International standard raw material, preferably from indigenous sources.

All these three factors are closely inter-related.

During study it was observed that trained manpower is not a constraint, also on a national basis shortage of resources does not appear to be a constraint. The principal constraint is, therefore, by international standard, smaller market size compounded by fragmented capacities resulting in insufficient level of automation as well as non-availability of quality materials. Some of the larger units who have been more successful and profitable during the past few years are actually beginning to automate to

increase capacities. The plant equipment used by the leading ECs manufacturers are identical and mostly sourced from Japan or elsewhere such as Taiwan.

Modernisation of ECs industry in India will require substantial importation of capital goods. Typically, to set up an additional capacity of 100 Million ECs/annum will require approximately Rs. 10 crores for plant equipment most of which would be in foreign exchange.

The basic technology to manufacture ECs of a very extensive range and variety is already available in India. However, in terms of actual gaps in the product range, the notable ones are regarding miniaturisation and high voltage/high temperature type ECs. These are already developed in advanced countries and the market in India for such ECs is just beginning to develop.

0.14 CONCLUSIONS

(i) Basic technology to manufacture ECs of standard types and range already exists in the country. The level of this technology is of a fairly high order.

(ii) The manufacture of ECs in the country is being more or less led by the three or four larger units which also serve as the repository of basic technology, some acquired through foreign collaborations some by other means such as through drawing/designs and diffusion of skilled personnel.

(iii) Inevitably, the smaller size units are getting squeezed out of the market.

(iv) The real heart of EC technology lies in the following, several of which are inter-linked :

- Miniaturisation.
- Optimised automation leading to improved production/productivity/quality.
- Improved materials leading to better specifications and miniaturisation.

- Latest quality and reliability testing techniques leading to better yields and reliability.

(v) Whilst there is a technology gap in all the above listed areas, the leading Indian ECs manufacturing units seem to be fully aware of this and are setting in motion steps to deal with the problem.

(vi) The Indian market demand for ECs is small by International standards and the supply is fragmented over five bigger units and several smaller units. This has resulted in individual plant capacities being lower than International levels.

0.15 RECOMMENDATIONS

(i) To be able to techno-economically justify the acquisition of newer technology, Indian ECs manufacturers may be required to substantially increase their production.

(ii) Since the Indian market offtake is limited, inevitably a big push has to be made into exports. The current World situation is favourable for export in the light of increased operating costs in the traditional sources of supply in the Far East as well as the rapid strengthening of their currencies. However, to be able to become a major force in the International ECs market, Indian units will need to bridge the technology gap regarding quality control, quality assurance and reliability.

(iii) The ultimate point of technology control will remain material technology. This presents a "Chicken and Egg" problem. It is economically unwise to invest in a materials unit until the volumes are large enough to justify. The volumes are restricted by limited demand of Capacitors in India and also by the non-availability of good and cheap material.

(iv) It makes little sense for a national R&D effort to develop such material technology from the basics. This may not be advisable in terms of cost and time involved, particularly when such technologies are available from abroad with reasonable ease. It may also be noted that technology in this field is advancing very rapidly.

(v) There are certain areas, as indicated above, where import of technology may be inevitable atleast for sometime to come. There is likely to be shortage of skilled manpower in this industry, particularly in the field of mass production techniques. This is to be viewed in the context of rapid growth of electronic industry as a whole and ECs industry in particular. Training could be imparted in the growing manufacturing base itself rather than in the educational and R&D institutions.

(vi) Major thrust is required in the field of exports by various manufacturing units. This would involve both direct export of these products as also indirect export through the product in which the item is used. It is likely that India would become a major exporter of consumer electronics such as TV sets and in that case the manufacturers of these items would provide a major market to the ECs manufacturers.

(vii) With the international thrust towards the use of leadless chip type components, it would be desirable that a study may be undertaken, in association with ELCINA, to analyse the types of components required on long term basis. The study should also analyse whether it would be worthwhile to go directly to chip type aluminium and tantalum electrolytic capacitor rather than going through the intermediate stage of miniaturisation of leaded type components.