Executive Summary

0.1. ESR or electro slag remelting (also referred to as electro flux remelting) is a process used for remelting and refining of steels and special alloys which are used for critical applications in aircraft, thermal and nuclear power plants, defence hardware, etc. The prime attribute of the process which differentiates it from other hosts of secondary refining processes is its capability to control both solidification structure and chemical homogeneity simultaneously. In most of the secondary refining processes except vacuum arc remelting, only chemical homogeneity can be achieved. There is no control over solidification structure.

The process was developed in USA during the years of the Second World War, but it was not employed for manufacture of critical aircraft alloys. The process was so-to-say rediscovered in early 60's mainly due to extensive work on the process done in USSR. Between 1965 to 1980, the tonnage of steels produced by ESR increased rapidly. For example, production of ESR Steels in the western world increased from about 10,000 tonnes in 1965 to more than 200,000 tonnes in 1980 - an increase of 20 folds in 15 years. The present installed capacity of ESR in the western world has been estimated at about 400,000 tonnes. The socialist countries such as USSR, China, Yugoslavia, etc. have made spectacular progress in the field. On a conservative basis, we can consider ESR installed capacity in the world to be about one million tonnes per year. The Indian production of ESR is about 2000 tonnes.

0.2. OBJECTIVES

The objective of the present Study was to assess the status of ESR technology in the country. A back-drop of the international scene would be essential to obtain a correct perspective. To prepare a comprehensive study, information was collected from various sources. These included questionnaires to Indian ESR units; survey of equipment and application literature from foreign equipment manufacturers; personal interviews with Indian ESR companies and other experts in the field; views of selected Experts in the field; and library work. All this information was collected over a period of five months, from April to September 1988. The final study has been compiled on the basis of this information.

0.3. THE PROCESS

To describe the process briefly, the material to be refined by ESR is first obtained in the form of an electrode which is essentially an ingot with nil or minimum taper. The electrode is suspended from a mast assembly which can vertically move at a controlled rate. A reactive slag bath is contained in a water cooled copper crucible. The tip of the electrode is kept dipped in the slag pool which is heated and kept molten by passing a high ampere, low voltage current through the same. The temperature of the slag bath is about 200°C higher than the melting point of the electrode material. As a result a thin film on the tip of the electrode melts. The liquid metal drops are formed which pass through the slag and deposit on the other side in the liquid metal pool which solidifies progressively. The liquid metal in the film and in the droplets is in contact with reactive slag and thus gets refined. The solidification rate of the liquid metal is controlled by the melting rate and water cooling.

The above is a general description of the basic process. A number of new developments have taken place. A short collar mould is most commonly employed now-a-days in place of a full length copper crucible. The power supply could be AC or DC. The inductance of power circuit is reduced by using bifilar electrode arrangement or by coaxial leads or by using low frequency power supply. Charged solid or premelted slags can be used.

During the ESR process, due to presence of an active slag which is essentially a mixture of CaF_2, CaO and Al_2O_3, sulphur removal from the liquid metal takes place rapidly. There is usually no change in chemical composition of the alloying elements but minor composition adjustments can be done during ESR melting. However, removal of hydrogen is difficult during ESR melting. Hydrogen has to be controlled by restricting, hydrogen content of the starting electrode. This has been one of the important limitations of the ESR process.

ESR process is used for remelting of :

- Special Steels
- Superalloys and
- Low Alloy Steels.

In addition the process has been used to some extent for recovery of titanium scrap. The current usage of ESR in western countries is estimated as follows :

TABLE - 0.1

USAGE OF ESR IN WESTERN COUNTRIES.

S.NO.	GRADES MELTED	% USAGE
1.	TOOL & DIE STEELS	37.5
2.	STAINLESS & NICKEL BASE ALLOYS	25.0
3.	HIGH STRENGTH CONsTRUCTIONAL	25.0
4.	SUPER ALLOYS	12.5
		100.0

0.4. APPLICATIONS

USSR makes substantial use of the process for manufacture of low alloy steels.

A number of new innovations of ESR have been developed. The important amongst these are listed below:

a) Slab Ingots.

b) Heavy Forging Ingots - Ingot Weights upto 300T have been reported.

c) Manufacture of Rolling Mill Rolls.

d) Electro Slag Hot Topping - particularly for large ingots.

e) Electro Slag Heating & Continuous Casting.

f) Electro Slag Melting under Pressure - particularly used for making nitrogen bearing steels.

g) Hollow Ingots.

h) Electro Slag Casting : A variety of castings can be produced using the process.

At present there are about 175 ESR installations in the western countries. An equal number of installations are probably located in the socialist countries. In the western world, USA has maximum ESR units. In Socialist countries, USSR has the maximum number. China has made significant progress in the field. They have indigenously designed and installed the largest ESR furnace in the world capable of making ingots of more than 200T weight.

0.5. INDIAN INDUSTRY.

The Indian ESR industry can be conveniently divided into three categories:

- **Commercial Large ESR Units.**
- **Commercial Units of Less than 200mm dia.**
- **Units operating at R&D Establishments.**

Presently there are 3 commercial units of category A above. These include MIDHANI, Firth India and TISCO. The TISCO unit has been closed for the last 2 years. MIDHANI is using the ESR to make stainless steels, superalloys and low alloy steels. Firth India melts mainly Tool Steels, Stainless Steels and Low Alloy Steels. MIDHANI's production is about 1200T/year whereas Firth India's production is about 500T/year.

A new 770mm INTECO ESR unit is being installed by M/s. Kalyani Steel Ltd, Pune. M/s. Speciality Alloys & Steels, Hyderabad have purchased a preowned Swedish ESR furnace but it has not been installed yet. MIDHANI is planning to instal another large diameter ESR unit. M/s. Heavy Engineering Corporation, Ranchi is considering installation of a 20T ESR unit to meet their in-house requirements of the forging ingots.

There are seven units of category B. Out of these, four are presently operating. Three of them produce mainly tool steel. One produces mainly stainless steel. The fifth unit at ITML, Nasik which was the first small scale unit in the country was closed down due to lockout at the factory. Two units are still in the project stage.

0.6. R & D

The principal R & D centres with strong interest in ESR are IIT Bombay, DMRL Hyderabad, IISC Bangalore and NML Jamshedpur. IIT Bombay has the distinction of providing design and know-how for almost half a dozen small commercial ESR units set up in the country.

It is gratifying to note that lot of indigenous know-how and equipment design capability has been developed in the country. All the small ESR unit operators are confident that they can scale up their manufacturing units to 600mm dia furnace. A computer controlled ESR is being designed and installed at IIT, Bombay. Thus in future the industry will need to import only very specialized know-how from abroad. The country could now infact export know-how for conventional ESR melting.

According to experts in the field; ESR is now an established secondary refining process. It has probably passed its peak and attained a plateau in the industrialized countries. The future developments in ESR will be towards specialized application such as electro slag casting, large forging ingots, pressure ESR, etc. The Indian alloy steel manufacturers feel that the ESR is not cost-effective vis-a-vis other secondary refining processes. Hence, they do not use ESR process in the manufacture of low alloy steels.

0.7. **GROWTH OF ESR IN INDIA.**

The large commercial units at MIDHANI and Firth India had benefit of foreign collaboration with M/s. Creusot-Loire of France and M/s. Firth Brown of UK respectively. Both the collaboration agreements were comprehensive including know-how document, foreign training and deputation of experts. Both the companies feel that they were able to effectively achieve transfer of technology. Bohler of Austria have limited collaboration agreement with M/s. Wootz Special Alloys, Delhi to provide designs of a small ESR furnace. Paton Institute, USSR has collaboration agreement with DMRL to provide drawings and other assistance to set up ESC facility. Paton Institute has also an arrangement with IISC Bangalore. M/s. Kalyani Steels Ltd. are finalizing comprehensive agreement including supply of equipment and know-how with M/s. INTECO of Austria. M/s. Speciality Alloys and Steels Ltd are planning know-how collaborations with a Swedish company.

0.8. The growth of ESR industry in India has been slow. When the first three commercial ESR units were set up in the country towards the end of the last decade, the technology was still contemporary. However, in subsequent years while many developments took place abroad in the field, the Indian industry remained static. Thereafter around 1985-86, there was renewed activity in the field, when a number of small ESR units were set up.

At present there are three large commercial ESR projects in pipeline. These include Kalyani Steels which is likely to be commissioned in 1989; Speciality Alloys and Steels, Hyderabad who have already imported a preowned ESR and are finalizing project configuration; and, MIDHANI who are actively contemplating setting up of a new large diameter ESR furnace. In addition, M/s. heavy Engineering Corporation, Ranchi is considering setting up of 20T ESR furnace to meet in-house requirements of large forging ingots. When these projects are commissioned, the ESR industry in the country will be one of the largest in the developing countries and even comparable to many European countries.

0.8. SUGGESTIONS

The following suggestions are made for further growth of this vital industry in the country.

i) In foreign countries, a substantial part of the ESR capacity-more than 25% is used for refining low alloy and constructional steels. In India this is at present negligible. Hence, the alloy steel producers should be made aware of the same. A necessary platform and publicity organ should be created for the same.

ii) Use of specialized ESR techniques such as ESC, hollow ingots, slabs and continuous casting should be thoroughly explored particularly at the R & D centres of SAIL, DRDO and other major private steel companies.

iii) The small ESR units in the country are faced with the problems of limited availability of tool steel/high alloy steel scrap and shortage of working capital. Since this is an important high-tech segment of the small scale industry in the country, their problems need to be studied and resolved.

iv) Future imports of ESR technology should preferably be confined to only specialized technologies such as ESC, pressure ESR, etc. Adequate technology for making ingots of steels is well established in the country.

v) Efforts should be made through NRDC/Indian Investment Centre or any other suitable agency to explore possibilities of exporting ESR technology to other developing countries such as Malaysia, Middle East, African countries, etc. A consultancy Firm could be engaged to prepare a suitable proposal for the same after examining all aspects.

vi) R & D programmes on slag chemistry, instrumentation and computer control should be encouraged because there are perceptible gaps in these fields in the Indian ESR Industry.

vii) A National Large Ingot ESR Facility should be created by harvesting indigenous talents. The small scale ESR entrepreneurs who have acquired a wealth of design experience could be associated with this effort. The facility will have to be set up where there is reasonable assurance of uninterrupted power supply for a few days at a stretch atleast. Such a facility could produce ingots for forging of large components required by thermal power plants, nuclear power plants, defence, ship building, etc. It will be a hightech project with lot of fall-out in related technologies. A committee of Experts be constituted to work out the various modalities. Alternatively, the job could be entrusted to a private consultancy Firm to examine all the aspects and formulate a proposal on the same in the form of a techno-economic feasibility report.

viii) A number of large size consultancy companies exist in the country which can provide technical consultancy for integrated/mini steel plants. But there is a lack of consultancy companies which can provide consultancy services in the fields of special steels and advanced technologies such as ESR, VAR, plasma melting, etc. A new consultancy organisation should be developed for the purpose. Some of existing consultancy organisations with initial base in the relevant hightech field could be encouraged to set up such an organisation in collaboration with Consultancy Development Centre of the Govt. of India or foreign consultancy firms.