OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

19934

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
DEPARTMENT OF INDUSTRIAL OPERATIONS
INDUSTRIAL OPERATIONS TECHNOLOGY DIVISION
ENGINEERING INDUSTRIES BRANCH

TECHNICAL PAPER ON ENVIRONMENT PROTECTION IN ENGINEERING IN GENERAL AND IN THE ELECTRICAL AND ELECTRONICS INDUSTRY IN PARTICULAR

RB-J-13300-041-2

Mr. PREPARED BY:
GRUJA BLAGOJEVIC, B.Sc.&M.Sc — Consultant
in Electrical Engineering

Vienna, October 1992

Backstop Off: Mr Kaulfersch
IO/T/ENG

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
DEPARTMENT OF INDUSTRIAL OPERATIONS
INDUSTRIAL OPERATIONS TECHNOLOGY DIVISION
ENGINEERING INDUSTRIES BRANCH

TECHNICAL PAPER ON ENVIRONMENT PROTECTION IN ENGINEERING IN GENERAL AND IN THE ELECTRICAL AND ELECTRONICS INDUSTRY IN PARTICULAR

RB-J-13300-041-2

PREPARED BY:
GRUJA BLAGOJEVIC, B.Sc.&M.Sc
in Electrical Engineering

Vienna, October 1992

TABLE OF CONTENTS

I INTRODUCTION

I.1. PAPER'S BACKGROUND

I.2. SUBJECT OF THE PAPER

I INTRODUCTION

I 1. PAPER'S BACKGROUND

Engineering industry plays a very important role in the development of the developing countries. In addition to the chemical and metallurgical industries, this industry is the most basic one with plans for further expansion. But these industries are also the most pollutive. The air, water and soil, especially in developed, industrialized countries, have become so contamined, that further development of these industries is threatened without application of appropriate environmental protection measures. Developing countries have the opportunity to avoid most of the mistakes and environmental problems faced by developed countries in their industrialization by learning from their experience and applying the already proved methods and measures for abatement against dispersal of wastes into various environmental media, air, water and soil.

Many environmental problems have accumulated over the years of ignorance and neglect. But in the last decade serious global concern has concentrated on the protective measures and sustainable development. The goal of the sustainable development is to achieve and maintain economic growth without degrading environmental quality and depleting the natural resources. The development is sustainable if it meets the needs of the present without limiting the potential to meet the needs of future generations. The only true development is one which is based on the fact that man does not inherit nature from his father but is borrowing it from his children. By knowing this fact there is a consensus that industrial development needs to be environmentally sustainable. The industry itself needs to develop technological solutions which will make production less polluting by introducing clean processes, material recovery and reuse, recycling, and for that unavoidable wastes to apply waste treatment in an environmentally sound way.

This paper is concentrating on application of environmental protection measures in order to prevent or minimize air, water and soil pollution from the engineering industries in general and electrical and electronics industries in particular. The start for its preparation is based on the conclusions and recommendations of Joint UNIDO/APCTT Workshop on Environmental Considerations and Waste Recycling in the Chemical, Metallurgical and Engineering Industries for representatives of Member States of UNIDO, non-governmental organizations and industry in Asia and Pacific Region, held at Manila, the Philippines from 9 to 13 December 1991. Therefore, consequently the objectives, issues and recommendations of the above Workshop are reexamined and summarized as follows:

The objectives of the Workshop included promotion in the region of awareness of the status and potential for future growth of the chemical, metallurgical and engineering industries, with a goal of sustainable development; promotion of the utilization of and transfer of low and non-waste, energy efficient technologies; waste prevention and minimization, waste recycling, and promotion of institutional structures, policies, legislation and awareness building. These objectives were successfully transferred in recommendations which were prepared on the basis of keynote papers, specific keynote papers, country papers, presentations and discusssions.

In the plenary session of the Workshop and individual group meetings concerning the chemical, metallurgical and engineering industries, due attention was paid to the following issues and problems:

- The need to provide information to industry concerning immediate benefits to it through application of appropriate low waste technologies, materials recovery and waste recycling.

- The need to provide information to industry about benefits to it through enhanced managerial practices to reduce waste at source.

- The need, to promote raw material or product changes or process substitution with a process which applies cleaner technology in order to eliminate or minimize hazardous processes and/or products.

- The need for creation of waste treatment and/or safe disposal centers which operate on a national and regional basis.

- The need for waste exchange and monitoring waste exchange schemes on a national and regional basis for viable recycling or industrial reuse.

- The need for New Projects Environmental Impact Assessment (EIA)

- The need for better training of industry management, technical and operational staff to ensure effective application of appropriate low waste technologies, material recovery, waste recycling and good house-keeping practices.

- The need that governments promote waste recycling in general and encourage policies on selection of location of certain hazardous industries.

- The need to ensure that legislation in every country accurately reflects environmental requirements without adversely affecting the competitiveness of industry.

In relation to the above issues and problems which were raised in the workshop, **the recommendations for governments are:**

- Governments should continue to issue regionally coordinated legislation considering real environmental impacts of hazardous and polluting raw materials, processes and products. The incentives for waste recycling should be granted wherever practicable, providing that the national industries will not be in a disadvantageous market position. A national waste management policy which encourages waste recycling and exchange should be implemented and national waste treatment and recovery centers should be established.

- Governments should support financially Research and Development activities of industries, universities and institutes for waste minimization, materials recovery, waste recycling, introducing of clean technologies in processes and safe disposal of hazardous waste. Training of managers, maintenance (technical) and operational staff within industry in order to maximize application of waste minimization, recovery and recycling techniques, as well as clean processes and waste treatment and safe disposal of hazardous waste is necessary and support of governments is highly required. Environmental awareness of public and industries should be also raised through training / education and media.

- The governments should support and contribute to the preparation and implementation of a Code of Practice for industry on key issues covering hazardous chemicals from international trade, transfer and implementation of low waste technologies, location and relocation of hazardous operations in appropriate areas and sites, industrial safety and training programme, standards, implementation of control procedures, monitoring of emissions, etc. The support in preparation of this Code of Practice should be given also by United Nations Organizations and agencies.

In relation to United Nations Organizations and agencies the Workshop recommended that:

- Increased financial support is provided for establishment and development of user friendly information systems on water conservation, waste minimization, material recovery, new processes or processing methods, cost-effective end-of-pipe treatment facilities, waste exchange.

- Support is given to promote the exchange of experience and information through sector specific seminars, workshops, training courses as well as for training on the implementation of low waste technologies and operating procedures.

- Support is given to the preparation of an industry wide guideline document for implementation of waste minimization, waste recovery and recycling opportunities.

- Support is given to a detailed survey of hazardous industrial raw materials, chemical by-products and products including classification and potential effects on health, soil, water, air, etc., as well as their handling, treatments, recovery and disposal.

- Support is given to the establishment of a list of raw materials, processes and products which should be substituted.

- Technical assistance is provided in establishing pilot plant programme to assess potentially viable technologies for environmental compatibility, as well as assistance in assessment and selection of appropriate technologies.

- Support is given to governments in the design, formulation and harmonization of legislation, as well as in their implementation.

- Support is given to the preparation of studies and projects on environmental protection managements.

These recommendations need to be transferred through follow-up actions in practical UNIDO, governments and industrial companies activities. This paper is aimed to elaborate the activities of UNIDO in order to prevent environment pollution from the engineering industries in general and electrical and electronics industries in particular.

I 2. SUBJECT OF THE PAPER

Starting from the recommendations of joint UNIDO/APCTT Workshop on environmental considerations and waste recycling in the chemical, metallurgical and engineering industries, held in Manila, this paper is aimed to provide practical inputs in the fields of application of protection measures in order to prevent air, water and soil pollution from the engineering industries in general and electrical and electronics industries in particular. The topic of this paper is fulfilled in the introduction and in five further sections.

Section II elaborates the general consideration on environmental protection measures in Engineering Industries by giving a short description of operations in Engineering Industries, identifying main pollutants and shortly discussing protection measures. Special attention is given in this section to the fact that contamination and degradation of air, water and soil are such that resource base for future generations is endangered and human survival and future socio-economic development become limited. Equitable and sustainable development is not any more a future task, it is the criterion by which all existing and future projects include considerations of environmental issues. For achieving environmental sound operations, the appropriate protection measures have to be applied. These measures in the priority order are classified as follows: first waste source reduction, than on-site recycling and material recovery, off-site recycling and re-use, end-of-pipe treatment/incineration with energy recovery and at last safe waste disposal.

In Section III attention is paid to the elaboration of environment protection in electrical and electronics industries. A short description of these industries is given due to the necessity that for identification of environment protection measures a reasonably good technical background and a good understanding of manufacturing processes are required. It is also necessary to fully understand the nature of all waste streams, such as aqueous, gaseous and solid. The exact circumstances by which the streams are generated are important in order to eliminate or minimize pollution before it arises. Measures and equipment for environment pollution and energy management are elaborated with special attention paid to application of automation means in the control and supervision of the processes, and rehabilitation of equipment and plants is considered.

Energy saving and efficiency improvement in electrical and electronics industries are considered in **Section IV**. Opportunities in relation to these industries are also given.

Section V outlines the proposal of UNIDO actions in Engineering Industries in general and in the Electrical and Electronics Industries in particular in respect to follow-up the recommendations of the Joint UNIDO/APCTT Workshop on environmental considerations and waste recycling in the chemical, metallurgical and engineering industries, held in Manila, the Philippines, what could make this paper to be used as UNIDO brochure for presentation of UNIDO standpoint for solving environmental problems and issues in electrical and electronics industries.

References are given in Section VI

So, the principal issues covered by this paper include a short description of the production and processing operations, which require input of chemicals and which generate pollution of water, land and air. Principal chemical inputs and pollution outputs for some operations are briefly described. Based on this, the objective of the paper is firstly to identify a procedure by which effective environment protection in engineering in general and in electrical and electronics industries in particular can be achieved through application of effective pollution control. Afterwards some practical measures and methodologies in achieving this aim are described.

II GENERAL CONSIDERATIONS ON ENVIRONMENT PROTECTION IN ENGINEERING INDUSTRIES

II 1. ENGINEERING INDUSTRIES

II 2. MAIN ENVIRONMENTAL POLLUTANTS

II 3. PROTECTION MEASURES

II GENERAL CONSIDERATIONS ON ENVIRONMENT PROTECTION IN ENGINEERING INDUSTRIES

II 1. ENGINEERING INDUSTRIES

Engineering industries encompass a diversity of industries which are not included in the chemical and metallurgical industries, such as electrical and electronics industries, non-electrical machinery industries, agro and food processing machinery industries, packing machinery industries, transport equipment industries, etc. These industries and related manufacturing industries are shown in figure II.1-1. The manufacturing processes involve a large number of chemical and metallurgical operations which relate to metal preparation and finishing, casting forging, welding, etc. Therefore, some of these common operations, which have environmental impact, are described below, especially operations related to surface improvement.

II 1.1. General

Almost every Engineering industry involves some of processes applied in metal preparation and finiching industry, such as surface improvement operations

The surface improvement process involves the following operations:

- cleaning of surface
- hardening or softening
- surface coating with metal or organic materials
- rinsing

All the operations related to metal preparation and finishing can be divided into three different categories:

Mechanical operations which include:

- grinding

- grit or shot blasting
- buffing
- deburring
- polishing

Chemical processes which include:

- degreasing
- acid pickling
- alcaline and acid cleaning
- surface neutralising
- chromating
- phosphating
- dipping
- polishing
- passivation
- stripping
- electroless nickel and copper plating

Electro-chemical processes which include:

- anodic cleaning
- cathodic cleaning
- anodising
- electroplating

II.1.2. Preparation processes

Preparation processes include sequential operations for the surface treatment, including cleaning, rinsing and drying. Cleaning of surface is a surface preparation for the next operation in the technological chain. There are different cleaning methods, including acid or alkaline cleaning, solvent cleaning, emulsion cleaning, mechanical cleaning, ultrasonic cleaning, etc.

The cleaning operation consists of two or more steps required for removing grease, oil, soil and oxide films from the base metal. This operation is necessary to ensure good adhesion of coating materials to the surface of the work piece.

Cleaning is necessary in the engineering industries, of course because of other reasons too, such as:

- The materials are often degreased to remove protective oil film, etc. which could interfere with subsequent working processes.

- Removing of cutting oils, drawing or processing lubricants, and swarf after machining or metal forming to enable the subsequent heat treatment or finishing operations.

- Before inspection for crack detection in forgings, castings, etc. the parts need proper cleaning.

- Exceptionally thorough cleaning is essential before electroplating to ensure effective and uniform layer.

There are a great number of cleaning methods suitable for different materials, such as metals, plastics, glass ware, etc. which have to be cleaned, and for different types of dirt, swarf and other undesirable contamintants, including processing aids, protective coatings, etc., to be removed.

In addition to the coarse mechanical, thermal and electrothermal processes, major cleaning methods used in cleaning processes in engineering industries are:

- use of aqueous solutions of alkalis, emulsions and di-phase cleaners
- use of solvents

<u>Aqueous cleaning method</u>

Alkalis, such as strong or mild alkalis, silicates, phosphates, borates, are used in soak tanks, pressure sprays and electrolytic cleaning equipment. Agitation is an essential requisite for this kind of cleaning. Soil is removed from the workpiece by detergent action. After this displacement, the soil is distributed throughout the solution as an emulsion.

<u>Emulsion cleaners</u>

The emulsion cleaners bring the soil into contact with both organic solvent and an aqueous solution of detergent. Solvents and detergents function together. On the contaminated workpiece first the solvents containing surface-active agents are appliced by brushing, spraying or dipping, and later the solvent and soil are removed by brushing with water.

Di-phase cleaners

These cleaners, as the name implies, have two phases. They permit contact of contaminated workpiece with solvent and water. On the top of water the solvent floats as a separate layer. By raising and lowering of the workpiece through the two layers adequate contact of the soil and solvent or water is obtained. Use of spray equipment in which the two components are mixed is also a method of di-phase cleaning.

Solvent cleaning method

The solvent cleaning method is based on the solvents characteristics that they readily dissolve oils, fats and greases. In addition to these characteristics, they evaporate readily, leaving the workpiece in a dry neutral condition, suitable for any subsequent operation.

Simple methods of solvent cleaning include wiping with solvent-soaked rags, applying by brush, immersion in tanks, jetting or spraying.

Vapour cleaning process exploits the unique properties of halogenated solvents, such as high vapor density, effective non-flammability in use, and exceptional solvent power.. A simple vapour degreasing plant consists of a welding tank equipped with electrical heaters and water cooled condensing coil. The solvent is boiled in the sump, filling the tank with vapour to the level of condensing coil. The cool workpieces to be cleaned are suspended in the vapour zone. On their surface solvent is condensed and dissolves the oil and grease. Condensation is continued until the workpieces reach vapour temperature. When the workpieces are lifted out of the vapour, the solvent film rapidly evaporates, leaving them clean and dry.

Rinsing is an operation by which the rest of some chemical materials on the surface of work pieces are rinsed by using water. There are different methods of rinsing which a metal finisher uses for rinsing purposes, such as flow rinsing, static rinse baths, cascade rinsing, etc.

Sequential treatments in an alkaline solution and then in an acid solution with intermediate rinsing are typical pretreatment processes. Such a typical pretreatment process for electroplating is shown in figure II.1-2.

II 1.3. Finishing processes

Finishing processes include coating of metals with other metals or with organic materials (insulated materials) as well as coating of insulated board with metal layer.

Surface coating with metals or organic materials includes different techniques, such as metal deposition by electrolytic technique, conversion coating used for organic materials, electropainting through electro-coating of surface with organic materials. Some of these techniques will be described in more details in section III when the electronic technological processes will be elaborated. In this section only some general descriptions of finishing processes will be given.

Metal deposition can occur from acid or alkaline solution. Acid plating baths contain the metal salt in the form of sulphate or chloride or a mixture of two. Alkaline plating baths contain the metal salt in the form of cyanide. The solutions in the baths are usually replenished by dissolution of the metal from anodes in form of plates or in form of suspended metal baskets that contain small pieces.

Surface treatments include anodizing, chemical brightening, electroless plating and chromating or other conversion treatment. Conversion coatings of zinc and iron phosphates are carried out on steel for subsequent organic coatings and for lubricating in forming dyes.

Small parts are plated by using barrel plating. Larger parts are plated by using the rack plating method.

II 1.4. Other processes

Many other processes are applied in engineering industries, such as mechanical operations: bonding, sawing, bending, smoothing, roughening, etc.; heat treatment operations: hardening, annealing, etc. To give now a detailed description of all the other available operations would exceed the scope of this paper, but that is not necessary due to the fact that most of the problems in relation to environment pollution appear from the metal preparation and finishing processes applied in the technological line for manufacturing of engineering products. Therefore a short description of the operations carried out in metal preparation and finishing was given, although strictly the environmental problems in connection with these operations are of a metallurgical nature.

II 2. MAIN ENVIRONMENTAL POLLUTANTS

The main environmental pollutants from engineering industries are the wastes generated in the processes, including raw materials, materials used for cleaning purposes, waste waters, dust, airborne particles, acid fumes, organic fumes, alkaline and acid solutions, etc. Constituents of the input raw materials will appear in the waste discharge, such as

- oil and grease in insoluble and emulsified form
- base metal dissolved during pickling processes
- metals or elements stripped from the components
- chemicals used in effluent treatment processes

The majority of pollution in engineering industries comes from poor housekeeping, spills, etc. From all of these discharged wastes, the ones which contain heavy metals, acid, alkalies and solvents are considered to be potentially hazardous. The metals and solvents discharged to land can easily become a part of the leachate from disposal site for their drainage into surface waters and underground water supplies. The emission of volatile solvents, acid fumes, mists to air can cause considerable environmental problems and they are a serious threat to human health. Especially dangerous are the volatile organic compounds, which react with sunlight and other compounds present in the air and form a variety of secondary pollutants, including ozone. A result of photochemical pollution is smog, but low-level ozone pollution is an even more important problem. Its toxity endangers the plant life and human health.

Emission to Atmosphere

Potential emissions to the atmosphere include:

- all gas phase chemicals used in production
- volatile organic compounds from open metal cleaning and degreasing units and other solvent emissions from open vessels, etc.
- acid mists and fumes
- air borne particles

A wide range of organic and inorganic solvents are in use in engineering industriès as cleaners or reactant during product manufacture. Halogenated solvents are used in degreasing and cleaning operations. Non-halogenated solvents are used in limited cleaning operations. Processes that rely on solvents often result in wastes the contain excess solvents. Such wastes can be solid-phase sludges, waste waters, fugitive dusts or gasses, or a variety of other materials. The solvents contribute to many different broad environmental problems, such as water pollution, photochemical pollution in troposphere, ozone depletion, and global warming, all these in addition to direct influence to human health.

Since from all chemicals used, released and disposed in the workplace, solvents present some of the greates challenges to environmentalists, here in more details will be given the critical information on the use, and properties of solvents. Generally the solvent is defined as the component of a chemical system, that is not altered when all components are mixed together. This definition encompasses a great number of organic and inorganic chemical systems and situations. Due to this, in case of engineering industries, this definition will be limited to those solvents used in these industries, which are of greatest environmental concern. Such solvents include methylene chloride, trichloroethylene, perchloroethylene, etc. They are used in a wide variety of applications, with their most extensive use as a cleaning agent in engineering industries, especially in electronics, metal, precision apparatus industries.

<u>Methylene chloride</u>

Methylene chloride is the most versatile of the chlorinated solvents. From the total use of 100%, in electronics coatings/adhesives 10% is used, and 73% in metal cleaning.

<u>Trichloroethylene</u>

Trichloroethylene is the best solvent for metal degreasing, therefore from total use of 100%, in metals and electronics 90% is used. Trichloroethylene degreases more thoroughly and faster than alkaline cleaners. It has high solvency, is non-flammable and non-corrosive. The prevention of the solvent from breakdown caused by contaminants is achieved by an incorporated stabilizer package.

Perchloroethylene
Perchloroethylene is used in metals and electronics with 15% from total use of 100%. It is a colorless non-flammable liquid with excellent solvent properties, used internally for vapor decreasing.

CFC-113
High standards of cleaning are achieved by using CFC-113. This is especially important for electronics industries and precision engineering industries, where cleaning in critical assemblies such as printed circuit boards for computers, aircraft, etc. without affecting plastic components is very important. From the 100% of its world use 33% are used for flux removal, 30% for metal processing and 7% for plastic cleaning. CFC-113 is classified as halogenated solvent with properties of non-flammability and very low toxity, and effective cleaning power, but still it is a regulated product under the Montreal Protocol in 1987.

Although these solvents have excellent cleaning properties, the discovery in the mid 1970s that they are damaging the stratospheric ozone layer came as an extremely unpleasant surprise. Later by accumulating scientific evidence it was more clear that chlorofluorocarbons (CFC) are linked to the destruction of stratospheric ozone and that substantial ozone depletion had already occurred. Therefore the Montreal Protocol calls for the reduction of CFC use. In connection with environmental protection measures in section II.3. some CFC elimination measures are discussed.

Emission to Aqueous Environment

The principal waste streams to aqueous environment are:

- contaminated rinse water
- strong process solutions, when spent/diluted or contaminated
- spillage and leakage of process liquid materials
- aqueous phase discharge from air emission scrubbing systems
- solvents

The waste streams to aqueous environment contain the raw materials used in processing in original or modified form and the constituents dissolved or removed from the components processes. They can contain toxic metals up to a few hundred mg/l in concentration. Many of the components in emissions are immediately toxic to aqueous organisms and corrosive to plant and equipment.

Emission to land

Potential emissions to land include:

- spent process solutions
- spent solvents and solvent sludges
- chemical sludges from the water and wastewater treatment plants and from processes
- grinding materials from mechanical cleaning operation
- scrubs, etc.

II 3. PROTECTION MEASURES

II 3.1. General

On the earth people share the natural resources, the fauna, the flora and the water. Therefore, appropriate measures have to be applied to protect the earth from further increased pollution and resource depletion by introducing clean technologies, pollution control and recycling technologies, by formulation of environmental standards and norms, by applying energy efficiency and energy conservation methods and by using environmentally sound and renewable energy sources, as well as by creation of environmental information and data bases on sound technologies, standards and norms.

The developing countries have to recognize the important role of industry and its negative impact on the environment, but at the same time they should know how industrial problems could be solved by better planning and managing and by adjusted industrial policies on technologies to overcome the environmental problems.

The protection measures discussed in this paper are measures in relation to waste management techniques, which are of first priority in hierarchical order. The waste management includes the following measures in hierarchical order:

1. **Source reduction**
2. **Recycling and reuse**
3. **Waste separation and concentration**
4. **Waste exchange**
5. **Energy/material recovery**
6. **Waste incineration/treatment**
7. **Ultimate disposal**

Source reduction or waste minimization is a method of pollution prevention through reducing the generation and discharge of hazardous wastes by taking actions at its source. By source reduction the total volume or quantity of hazardous waste is reduced and the toxibility of hazardous waste is also reduced. Source reduction techniques include:

- **inventory management and good housekeeping**
- **equipment modifications**
- **production process modifications**

Reduction of waste by action at the source could have a significant impact on the less priority measures of waste management. For example the size of end-of-pipe treatment (waste incineration/treatment) bears direct relationship firstly to the volume of waste to be treated and then to the concentration of pollutants contained in the discharge. Of course an optimized end-of-pipe control for irreducible minimum of discharge is required.

Source reduction measures can be defined as the development of a full understanding of the nature of all waste streams and exact circumstances by which they are generated in order to eliminate or minimize pollution before it arises. Definitely should be recognized that it is cheaper to prevent than to clean up pollution. Reducing the quantity of waste at its source is an absolutely imperative factor, that must always be considered thoroughly.

Reduction of waste at its source by good housekeeping, equipment modification and production process modification as well as resource recovery is not only cheaper, but cost beneficial when compared to expensive treatment, immobilize and dumping charges.

So the demands of environmental protection are moving towards the concept of clean technologies including improvements in thermodynamic efficiency both of industrial processes and of recycling, and the substitution of hazardous materials, processes and products.

Recycling represents an important aspect of waste reduction at source. The recycling of wastes within a process often reduces the raw material input requirements. The same material can often be used twice by recycling before its properties become worse for further use.

By waste separation, segregation and concentration the hazardous and/or strong wastes are isolated from less polluting wastes. If the wastes are not separated, the volume of the waste requiring treatment is greater. Segregation of wastes can enhance opportunities for recycling and reuse with resultant saving in raw material costs. Concentrated simple wastes are more likely to be of value than diluted or complex wastes. If a highly concentrated waste is mixed with a large quantity of weak, relatively uncontaminated effluent the volume of waste for treatment is increased and costs are higher.

Waste exchange is a method for reducing waste for treatment or for disposal by exchanging the waste of one plant with useful waste from another one. If an information system exists containing all information about the generated wastes in a country, even region level, and if good transportation means exist, useful wastes from one factory can be used as input raw material in another factory.

Recovery of materials is applied when the wastes cannot be reduced by source reduction and recycling. Recovery means to separate the useful materials and energy from waste, either directly or through renovative technologies, and to reuse in the same or another process.

Waste reuse can often be implemented if materials of sufficient purity can be concentrated or purified. Technologies such as reverse osmosis, ultrafiltration, electrodialysis, distillation, electrolysis and ion exchange may enable materials to be reused and reduce or eliminate the need for waste treatment.

Waste incineration/treatment is used for combustible waste and wastewaters. The waste is treated by applying certain technological operations before final disposal. A variety of technologies can be considered for waste treatment, including physical, chemical and biological treatment processes. In same cases the treatment methods can also recover valuable materials for reuse.

II 3.2. Waste source reduction/waste minimization

As it was stated, source reduction can be achieved through inventory management, good operating and housekeeping practices, and equipment and production process modifications. These reduction measure require different levels of effort, time and final costs. More generally those measures include:

- Obvious waste reduction measures that can be implemented cheaply and quickly, such as improvements in management techniques and housekeeping procedures.

- Long term reduction measures that need more financial resources and time for their implementation. These measures include equipment and process modification, even process, material or product substitution.

II 3.2.1. Waste minimization through improvements in management techniques and housekeeping procedures

The wastes can be reduced considerably by applying improved operation and tightening up housekeeping procedures. Sometimes only more care in handling the materials, adjustment to processes and cleaning can simply and readily eliminate or reduce some waste emissions. At no cost or only small extra cost the following reduction measures can be implemented:

Material input

- The raw materials should be purchased in a form which is easy to handle and transport. Fewer toxic and more nontoxic materials should be purchased.

- Over-ordering of materials should be avoided, especially if raw materials or components can spoil or are difficult to store.

- The input materials and components must have a viable quality control certificate from the supplier. Furthermore, a visual inspection of all materials should be undertaken and the damaged materials and components should be refused and turned back to the supplier.

- The weight and volume of received materials should be checked and compared with ordered weight and volume.

Material storage and handling, and water transfer

- If the liquid materials are stored in tanks, following measures should be applied:

  - Installation of high-level control on bulk tanks to avoid overflows;
  - Tanks should be used that can be pitched and elevated, with rounded edges for ease of draining and rinsing;
  - Dedicated tanks, receiving only one type of material, should be applied, that there is no need for frequent cleaning;
  - Checking procedures for tanks should be implemented to avoid discharging a material into a wrong tank;
  - The tanks should be covered or closed in order to reduce evaporation losses.

- Drums should be stored in a stable arrangement to avoid damaging them while storage.

- The number of times materials are moved from one site to another should be minimized.

- The transfer lines should be checked for spills and leaks, and flexible pipes should not be too long.

- Drainages from transfer hoses should be caught.

- Excess water consumption should be avoided by applying flow restrictors and plugging leaks.

Process Control/Operating Practices

- Regular maintenance of all equipment should be undertaken, which will help to reduce process losses.

- A well designed monitoring programme should be implemented in order to check the emissions and wastes from each unit operation or a process

- The process operators should be informed about environment protection measures and what result is expected to be achieved from their implementation. The feedback on how waste reduction is improving the process, motivates the operators.

Cleaning Procedures

- The amount of water used to wash out and rinse should be minimized. Water should only be used when is applied to wash out and rinse. Self sealing valves should be fitted.

- If possible washing water should be contained and reused before discharge to drain.

- Reuse of solvents used to clean should be applied.

Management

- It is necessary to make senior management aware of environmental issues and to get their commitment

- Technical and operational staff should get better training in environmental protection measures

- The management structure should link production, pollution control and environmental management

- Disciplined monitoring of waste generation should be ensured.

- Financial aspects of better hauskeeping, but also to employ cleaner technologies, etc.

II.3.2.2. Long-term Waste Reduction Measures

Substantial long-term measures are required for waste problems that cannot be solved by obvious waste reduction measures described in clause II.3.2.1. These measures to increase production efficiency and reduce waste generation may include:

- equipment and installation modifications;
- production process modifications, sometimes to change batch process with continuous one;
- introduction of more automation in process control;
- changes in process conditions including temperature and pressure changes, retention times, agitation, catalysts;
- raw materials quantity and type reduction;
- raw material substitution through the use of less toxic materials or materials that produce less waste, or the use of wastes as raw materials;
- process substitution with cleaner technology;
- product improvements or changes with cleaner and more environmentally friendly products, both for existing products and in the development of new products.

II 3.3. Typical Measures of Environmental Protection

II 3.3.1. General

Environmental protection in general can be achieved with application of some typical measures specified in Figure II.3.-1.

II 3.3.2. Environmental protection measures - examples

Process, equipment and material substitution

Example N° 1

In order to eliminate the use of CFC-113 and trichloroethylene in solvent cleaning application, a number of alternative chemicals and processes can be applied, which for electronics industry include:

- **Aqueous cleaning:** This process replaces CFC-113 or 1,1,1 trichloroethylene with water. Water with or without saponifier has proven to be an excellent solvent for removal of contaminates and watersolubic fluxes,

- **Semi-aqueous cleaning:** This process replaces CFC-113 or 1,1,1 trichloroethylene with a hydrocarbon/surfactant blend. Special equipment is often required due to combustibility and odour of some ingredients,

- **Organic solvents:** The use of solvents such as alcohols and ketones can replace CFC-113 or 1,1,1 trichloroethylene in certain applications. Special care is required due to their flammability.

Example N° 2

To eliminate the necessity for use of cleaning solvents in electronics industry low-solids flux technology has been introduced in recent years. Low-solids flux or "no-clean" flux leaves very small amounts of residue on PCBs. In most cases, this residue will not hinder the product's performance or durability, and therefore need not to be removed.

Example N° 3

For metal cleaning CFC-113 and 1,1,1 trichloroethylene can be substituted by already mentioned aqueous and semi-aqueous cleaning and by other effective substitutes, such as:

- **Aliphatic hydrocarbons:** Mineral spirits or kerosene are used extensively in maintenance cleaning of metal parts. These solvents must be used with care because of their low worker exposure limits and their flammability,

- **Mechanical cleaning:** The products that require not a high level of cleanliness can be cleaned mechanically through brushing, wiping with a rag or sponge, or spraying with a pressurized gas,

- **Thermal vacuum de-oiling:** A heated vacuum chamber is used to remove oils from metal parts. The oil vapours are condensed and drained for recycle or disposal

- **No-clean lubricants and no-oil metal forming:** The lubricants are applied in such manner that little or no effort is required to remove them from metal parts. No-oil metal forming uses heat, sonic vibration gas or fluid cutting.

Example 4

Precision cleaning is required for some products and components, such as computer disk drives, gyroscopes and medical equipment. For this cleaning CFC-113 and 1,1,1 trichloroethylene are applied. In addition to aqueous cleaning, semi-aqueous cleaning and aliphatic hydrocarbons already described above, other alternatives for CFC-113 and 1,1,1 trichloroethylene cleaning are possible and proven, such as:

- **Organic solvents:** Alcohols and ketones are acceptable for some precison cleaning applications because of their material compatibility. Alcohols are often used with perfluorcarbons to reduce the flammability,

- **Pressurized gases:** Air, carbondioxide and nitrogen can be used in precision cleaning because of their low toxity, non-flammability and low costs. The gases remove contaminatants by force as they are fed out of a pressurized gas gun onto the surface to be cleaned,

- **Ultraviolet light or ozone cleaning:** For cleaning is used ultraviolet light in the presence of ozone. It is used for removal of thin organic films from a variety of surfaces.

Housekeeping practices and engineering controls

Example

The most immediate measures by which the consumption of CFC-113 can be reduced are better housekeeping procedure and engineering controls. These measures include:

- retrofitting degreasers with additional recondensation coils
- detecting and repairing leaks
- keeping batch degreasers covered when not in use and replacing hatch-type lids with sliding ones

- optimization of utilization of degreaser capacity
- redesigning baskets to minimize the "piston effect" which forces vapour out of the degreaser
- reducing drag out through better control cver temperature cycling and the insertion and withdrawal velocity of workpieces
- controlling blow-off air velocity

By these measures, solvent reduction can range from 20-40 percent resulting from adoption of such measures.

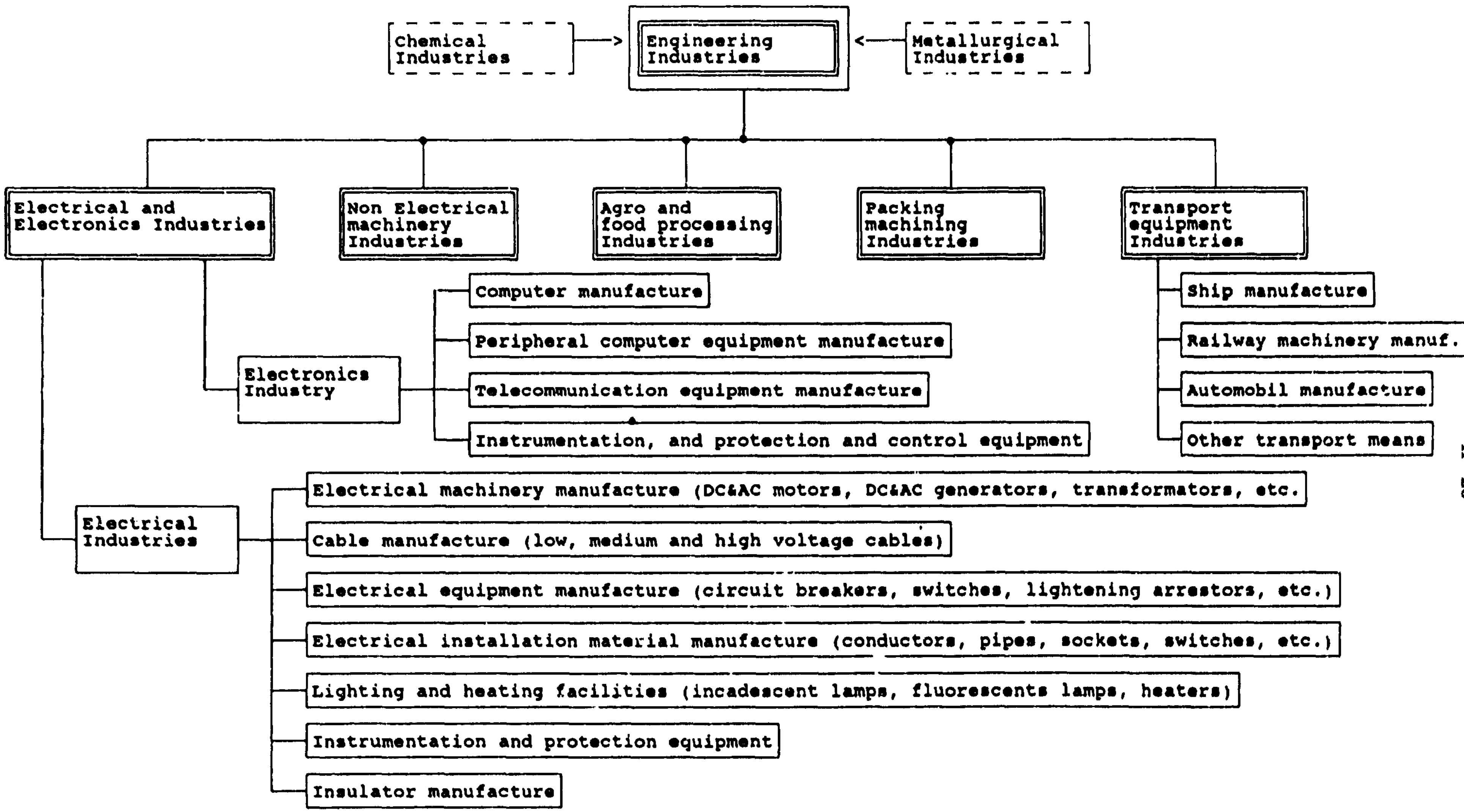

Figure II.1-1: Engineering industries

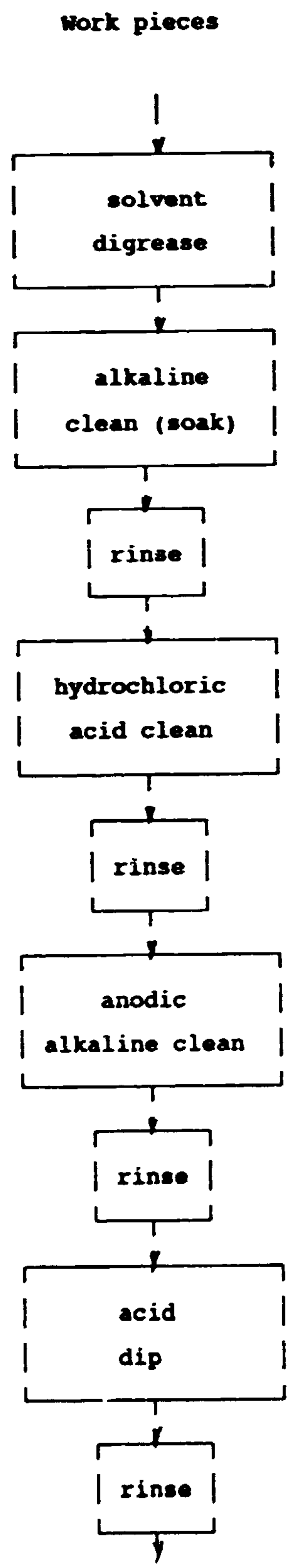

Figure II 1-2: Typical pretreatment sequence in electroplating process

ENVIRONMENT PROTECTION MEASURES

SOURCE REDUCTION

Withdrawal time	- Allow time for dewatering
Phase separation time	- Enhance efficiency
Dry cleaning	- Use wherever possible
Cooling water	- Select appropriate control chemicals
Process solution life	- Prolong usage factor
Mechanical seals	- Use mechanical seals rather then packed glands
Rotary vane compressors	- Use rotary vane units rather then liquid ring units
Clean compressed air	- Use clean compressed air to prevent corrosion
Alkali/enzyme based cleaners	- Use alkali or enzyme based cleaners, not solvents
Ion exchange	- Use counter current regeneration technique
Membranes	- Use membranes as an alternative to ion exchange

MATERIALS RECOVERY

Metal salts	- Recover electrolytically
Drug out	- Recover directly
Bathcleaning	- Recover first flush
Off-spec product	- Collect for reprocessing
Biogas	- Recover heat energy, generate biogas
Solvents	- Recover on site for reuse

WATER CONSERVATION REUSE/ RECYCLE

Counter flow rinsing	- Use 2 or 3 rinse stations
Cooling water recycle	- Recycle rather than once through
Conductivity control	- Input to meet quality requirement
Final rinse reuse	- Reuse final wash for first wash
Wash water	- Reuse for less critical dutes
Condensate recovery	- Recover, also eliminate steam leaks

Figure II.3-1: Typical measures for environment protection

III CONSIDERATIONS ON ENVIRONMENT PROTECTION IN ELECTRICAL AND ELECTRONICS INDUSTRIES

III 1. TECHNOLOGICAL PROCESSES AND OPERATIONS
(Opportunities for private small scale industries and employment of women)

III 2. POLLUTANTS IDENTIFICATION

III 3. MEASURES AND EQUIPMENT FOR ENVIRONMENT POLLUTION PREVENTION AND ENERGY MANAGEMENT
- **rehabilitation of equipment**
- **application of automation means**

III CONSIDERATIONS ON ENVIRONMENT PROTECTION IN ELECTRICAL AND ELECTRONICS INDUSTRIES

III 1. TECHNOLOGICAL PROCESSES AND OPERATIONS

A term process in electrical and electronics industries is taken to include all operations involved in production of electrical and electronic components and products. Therefore a process may begin with receipt of raw material's or components, storage, handling, through technological operations to product handling and waste treatment. An operation is a part of the process, such as cleaning, washing, heating, etc.

III 1.1. Electrical and electronics industries

III 1.1.1. General

Electrical and electronics industries cover a wide range of processes and operations involved in production of electric and electronic products for consumers and/or industrial/commercial use. Numerous metal preparation and finishing processes are involved too for certain electric and electronic product, such as cabinets, apparatous, an product housing, etc., although these processes are of metallurgical nature.

Generally speaking, electrical industries encompass manufacture of electrical machinery (AC/DC motors, AC/DC generators, transformers, rectifiers, invertors, etc.), electrical equipment (cables, conductors, switch boards, circuit breakers, insulation switches, lightening arrestors), lighting facilities, heaters, accumulators, etc. Electronics industry encompasses manufacture of semiconductors, printed circuit boards, radios, televisions, computers and peripherals, telecommunication equipment and installation material, etc.

III 1.1.2. Electrical and electronics industries and environment

Every manufacturing process encompasses a great number of operations, some of which employ toxic raw materials and generate wastes. Emissions of wastes to air, water and earth are generally shown in Figure III.1-1.

The most pollutive operations are involved in manufacturing processes in electronics industry. Manufacture of semiconductors and printed circuit boards employ operations with an input of high toxic raw material and in course of operation are generated toxic wastes which are of destructive nature to environment. Operations which are applied in the manufacturing processes of semiconductors and printed circuit boards are mostly of chemical nature and/or they can be categorized as metallurgical ones employed in metal preparation and finishing industry.

III 1.1.3. Private small scale firms and employment of women with emphasis on environment

Although electrical and electronics industries are pollutive, they are less pollutive then pure chemical and metallurgical industries. These industries are very convenient for small sized firms and employment of women, especially electronics industry. The work of woman can be made easier through further development and introduction of appropriate technologies. Many electrical and electromechanical components used in manufacturing processes of electrical and electronic products may also be produced in small firms. Most of the operations do not require high physical efforts, but they are labor intensive, therefore are very suitable for women employment.

Employment of women is very sensitive in developing countries, especially when it is considered with their role in society on one side, and on the other side women have their important role in environment protection. Women, as agents of change, have developed their own strategies to cope with environmental degradation. Women organize themselves and start networks to prevent degradation of their environment. Sensitive to pollution, as individuals, but even more as a group, women initiate specific activities, including waste management and resource conservation. Electrical and electronics small scale firms offer good opportunities for women to actively participate in development and environment protection. All the iniatives that could have a negative impact on the environment and on women have to be prevented.

Women have always contributed significantly to environmental care. Extensive knowledge, skills and perspective of the environment women could direct to productive activities in small sized electrical and electronics firms. Therefore, women have to prepare themself for environment management. Women's ability for decision-making, access to appropriate training and technologies, and development options are key factors which influence their role in environment protection. This is important for women because their exposure to toxic substances (for example to skinning solvents, radiation, polluted water, smoke) is more direct than that of men, and because women are more vulnerable to these due to their reproductive roles.

III 1.2. Description of technological processes and operations

A good understanding of all technological processes and each of processing operations and their interrelationships is crucial factor in recognizing the waste streams and developing of appropriate options for environment protection. A sound understanding of the technological process is possible by connecting the individual unit operations in the form of a block diagram, which is known as process flow diagram.

For complex processes a general flow diagram illustrating the main processes can help better understanding of manufacturing of a product. Flow diagrams for main processes further give details for each unit operation.

As an example for description of technological processes and operations in this paper is the next clause describing production line for manufacturing electronic products.

III 1.2.1. Production of electronic products

In production of electronic products are involved mainly five main processes (Figure III.1.-2.)

1. Semiconductor wafer manufacturing process
2. Semiconductor assembly
3. Printed Circuit Board (PCB) manufacturing process
4. PCB assembly
5. Final product assembly

In addition to these main processes other allied processes upon which electronic processes depend are in use. These processes include manufacture of electrical, metal and plastic parts. They can take place in a separate, or in the same factory where main production processes are executed.

III 1.2.2. Semiconductor wafer manufacturing process

Crystal growing

The semiconductor wafer manufacturing process begins with the crystal growing under doping and baking operations. Silicion, Germanium or gallium arsenide ingot are grown by use of dopants and gases. Dopants are metal compounds in solid, liquid, or gaseous state. They are injected as a gas or vapour into ovens which are heated. When heated the metal of the dopant is deposited.

Ingot grinding and sawing

The next step in semiconductor fabrication is ingot grinding and sawing, when the ingot is shaped and cut into thin wafers. These wafers are then treated with acids and solvents to obtain very clean and smooth surface of the wafers. A thick nonconductive layer of silicone dioxide is grown on the surface of the wafers by the next baking and doping operations.

Photomasking and etching

Photomasking and etching are the next steps, by which a desired pattern for electrical circuits is etched into the wafer. After cleaning, coating and baking the wafer is exposed to ultra violet light through a set of photomaps.

Doping

Developed, etched and rinsed, previously exposed patterns are doped in the next step at high temperatures, what makes the electrical circuits in each chip on the wafer. In order to enhance the electrical capabilities of the circuits, higher temperature doping with metals suspended in gas is carried out.

Deposition of metal contacts

Again, after cleaning, coating and baking each chip is exposed to another photomask in order to create a pattern where metal contacts are to be deposited. Through baking and doping operation, a metal is deposited at the exposed points to form contact surfaces for wire connection.

Final protection and testing

Finally, a thin transparent layer is applied to the surface of the wafer to protect the electrical circuits from the external influences and after testing of each chip on each wafer, the grooves are formed so that the chips can be easily separated by semiconductor assemblers.

III 1.2.3. Semiconductor Assembly

Bonding

After cleaning the chips are separated by sawing from the wafer. Each chip is mounted on the appropriate frame by application of a mix bonding agent between the chip and the frame. There are three methods to attach the chip to the frame.

- **Eutectic,** by which a small amount of gold or tungsten is deposited on the back of the chip or on the pre-heated frame,

- **Pre-form** by which a solid adhesive substance is placed in the pre-heated frame, it melts and when the chip is positioned on the frame, after cooling it forms a bond,

- **Epoxy,** by which a drop of epoxy resin is applied to the frame along with curing agent.

In the next step very fine gold or aluminium wires connect the metal contact on the chip with the electrical terminals on the frame on which it is mounted. Two automated ways to bond wires exist in the electronics:

- **Thermal compression,** when the frame and chip are heated and very thin gold wire pressed against the appropriate contact surfaces,

- **Ultrasonic,** when an electronic soundwave causes the molecules in the aluminium wire and the contact point to vibrate and shake together thus forming a bond.

Encapsulation

After bonding, the chip must be covered with an air tight cap in order to protect it from damage and corrosion. This operation is known as encapsulation and there are different techniques or methods to perform it. The techniques depend on the kind of the component to be encapsulated and the automation level. **Ceramic capping** is used in less automated production lines. A pre-formed ceramic cap is bonded to the frame over the chip with epoxy or a heated metal. The adhesive resins may be used to glue the ceramic cap in place and afterwards baking at high temperatures to harden the seal is carried out.

Other technique is based on use of **plastics or epoxy resins** for capping. Over the chip on the frame a semi-liquid plastics or epoxy mixture is applied with the addition of curing agent (hardener). The package is then baked to harden the seal.

Housing, marking and testing

Finally, semiconductor assembly is finished with housing, marking of the components, and testing for air tightness of seal and the components are also tested for their proper operation. Air tightness test is usually carried out with radioactive gas such as krypton. The gas is pumped into the cap to test the tiny leaks in the seal. Marking of components is done by painting and labelling. Each component is either painted in one or more colors or there is a lettering or numbering on the package or cap for the purpose of identification.

III 1.2.4. Printed Circuit Board (PCB) Fabrication

Laminating

Sheets of fiberglass, asbestos or other material are impregnated by resin, which is previously prepared in a reactor at the high temperature. After baking of impregnated sheets, so formed hardboard is in the next step bonded with clean copper sheets to one side or both sides of resin boards. The copper is fixed to the base board by use of adhesive and pressure/heat bonding. If the conductive layer is only on one side of the board, these PCBs are known as single-sided, boards with conductive layers on both sides are double sided and with alternating layers of conductive sheets and insulating boards are known as multilayer.

Usually, the laminating described above is carried out elsewhere, i.e., not in the electronics factories. Laminated boards (uncut) are usually supplied to PCB factories in large sheets. These sheets, first pass through a **shearing stage** where they are cut to desired size and then to **baking stage** to ensure that copper laminated boards are completely cured. The stacks of PCB cut to size are subsequently **bored** to form the holes for the components. Boring operation results in burrs being formed on one side or both sides of the boards. To remove the burrs, the boards pass through a **surface conditioning stage,** when the surface cleaned by a water spray. The smooth copper boards pass through a **conditioning** (sensitizing) **stage** and **electroless copper plating**. In this step the bored holes for electrical circuit connection are copper lined. The deposition of copper layer on the bored holes is achieved not using external electric power but involving the catalytic reduction of metallic ion in an aqueous solution containing reducing agent. This treatment prepares the holes for electroplating.

The next steps include treatment of boards such as **photomasking, etching,** electroplating and other operation. These operations are used to create desired electrical circuits on the board. By **photomasking** a photopolymer-resist material is applied to mask off area on the board where electroplated conducting material is not needed. Subsequently, the unexposed resistant areas are removed and the circuit pattern is formed by etching away unclad copper using an acid solution. **Electroplating** is the next operation. This operation uses electrolysis, whereby electrical current passes through electrolyte containing solution with metal and chemicals, causing the metal in the solution to be deposited on the areas where plating is needed. These areas receive several electro deposition layers. Tin/lead layer is one of the deposited layer, and it functions as another resistant layer which allows etching of copper foil in the non-circuit areas not damaging the circuit pattern. The circuit pattern, then, receives final electroplated layers as specified by the customer. There are two common methods of electroplating: barrel and rack. For electronic components the barrel method is more often used. In the rack method the boards are suspended on a rack, and then immersed in the bath.

The above described method is known as **substractive process.** There is also a method known as **additive,** which involves deposition of platting material onto the board only in areas which constitute the electric circuits. Plating resist is applied onto the unclad board in non-circuit areas. The desired thickness of the circuit is subsequently reached in electroless operation. In this way etching of copper is not necessary.

Finally, each PCB is marked for identification and tested for electrical functioning.

III 1.2.5. Printed Circuit Board (PCB) Assembly

Cleaning, soldering, marking and testing
Assembly of PCB starts with PCB and components preparation, what involves cleaning, trimming and sorting. After that, a variety of different components are mounted onto each PCB creating their specified function. Component terminals are soldered in place. There exist at least four methods of soldering in electronic assembly: hand, dip, wave and roll.

Hand Soldering - Metal contacts are cleaned and fluxed and then soldered by hand solder.

Dip Soldering - Metal contacts on the mounted PCB components are cleaned and degreased by dipping the PCB on the rack into a solvent bath. After that, the PCBs are dipped into a second bath of flux in case that the flux is not added to the molten solder bath. Finally, the PCBs are dipped into the molten solder.

Wave Soldering - After cleaning and fluxing, the PCBs with assembled components are placed just over the molten solder in bath. A special device creates waves which spread solder on the underside contacts of components on the PCBs.

Roll Soldering - Assembled PCBs are placed on a rack and cleaned as in the dip soldering. Molten solder and fluxing agents are fed into a roller. The roller is passed over the PCBs which are to be soldered, leaving a layer of solder on contacts. When the soldering is finished, excess solder is removed and wire ends are trimmed. Finally each assembled PCB is marked with identification marks (numbers and letters) and tested to electrical faults.

III 1.2.6. Final Product Assembly

Final product assembly starts with parts preparation involving cleaning of electronic and electrical parts and components. Metal parts are plated and plastic parts are moulded and trimmed.

So prepared parts and components are assembled by the use of screws, clips, solder etc. Assembled units are then tested and in case that the faults are discovered, repaired and reassembled. Finally, functional units are housed, marked and packed for the distribution to the market.

III 2. POLLUTANTS IDENTIFICATION

III 2.1. Chemical groups identification

Most of chemicals used or occurring in electrical and electronics industries are toxic and if appropriate protection measures are not taken them may appear in wastewater, in the air and in the soil. The chemicals are listed in groups which represent their similar characteristics or a common use, such as:

- Acids
- Alkalis
- Cryogenic gases
- Cyanides
- Dopants
- Fillers
- Oxidizers
- Metals
- Resins
- Semiconductors
- Solvents

A short description for every group along with their application and environmental impact will be given below.

III 2.1.1. Acids

Acids are liquid or powder corrosive substances, used throughout the electrical and electronics industry. They are used for operations, such as cleaning, plating, etching, stripping, etc. and sometimes as a component of final product, for example of accumulators.

Most of acids are hazardous especially when concentrated. Serious burns and damages to tissues beneath the skin may appear if the skin comes in contact with acids. Acid vaporous are also dangerous.

Acids can be organic and inorganic. Organic acids include acetic, adipic, citric, formic, lactic, oxalic acid. Inorganic acids include aqua regia, buffered oxide etch, and boric, chromic, hydrobromic, hydrochloric, hydrocyanic, hydrofluoboric, hydrofluoric, nitric, phosphoric, sulfonic and sulfuric acid.

III 2.1.2. Alkalis

Alkalis are alkaline or base substances used for operations like cleaning and scouring. In concentrated form they are acutely hazardous because of their strong caustic or corrosive action.

The most applied alkalis are: ammonia, ammonia persulfate, ammonium fluoride, ammonium hydroxide, calcium hydroxide, potassium hydroxide, sodium hydroxide, etc.

III 2.1.3. Cryogenic gases

Cryogenic gases are ultra-cold gases usually stored in liquid form under high pressure. They are used, for example, in semiconductor wafer fabrication to heat and cool ovens. They can be used also to carry dopants into the oven.

Most of these gases are extremely flammable and have a potential to explode. The death by asphyxiation can be caused by a leak of liquified gas.

Cryogenic gases include argon, carbon dioxide, carbon monoxide, deuterium, helium, hydrogen, nitrogen, oxygen, ozone, etc.

III 2.1.4. Cyanides

Cyanides are compounds containing often a metal or mineral molecule. Often cyanides are stored in solid or liquid form, but also in gas form. They are used for operations like cleaning, plating, metallizing, etc.

Cyanides are highly irritating and rapid acting poisons. They are especially dangerous in gas form due to their quick absorbtion through skin and lungs preventing the body tissues from taking up oxygen. This causes sudden death of exposed men by asphyxiation. The cyanides are dangerous even in case of low-level exposure of men, because repeated low-level exposure can cause severe dermatitis, thyroid disease, and muscle incoordination.

Cyanides incluo calcium cyanide, copper cyanide, hydrocyanic acid, nickel cyanide, potassium cyanide, potassium ferrocyanide, sodium cyanide, zinc cyanide.

III 2.1.5. Dopants

Dopants are metal compounds in solid, liquid, or gas form. They are used in semiconductor manufacture. By injecting dopants as a gas or vapour into ovens heated to high temperature, the metals of the dopants are deposited in the semiconductor wafer. Deposited dopants in the semiconductor wafer are penetrating its surface and gives it the ability to conduct electrical current.

Dopants are the most hazardous group of chemicals used in electronics industry due to their high toxity. If a leak or rupture occures with a substance like phosphine, arsine or the boranes, the whole plant and surrounding environment can be affected with many cases of serious harm and death.

The metals like aluminium, antimony and arsenic are more commonly used as dopants. Boron and phosphorus are also used. Many dopants are used, from which some in gas, liquid and solid form are listed.

Gas dopants include: arsenic pentafluoride, arsine, boron trichloride, boron trifluoride, dibrane, diethyl teluride, dimethyl telluride, hydrogen arsenide, hydrogen phosphide, pentaborone, phosphine, phosphorus pentafluoride, selenium hexafluoride, trichlorosilane

Liquid dopants include: antimony trichloride, antimony trioxide, arsenic tricxide, boron tribromide, boron trichloride, boron trioxide, phosphorus oxychloride, phosphorus pentoxide, phosphorus tribromide, phosphorus trichloride, silicon tetra bromide.

Solid dopants include: aluminium, antimony, antimony trioxide, arsenic, arsenic trioxide, beryllium, boron, boron nitride, boron trioxide, cadmium, chromium, gallium, germanium, phosphorus, phosphorus pentoxide, selenium, tellurium, tin, zinc arsenide.

III 2.1.6. Fillers

Fillers are powders or tiny fibres added to plastics, epoxies, glues, and paints to give bulk, strength and form. They are used to make printed circuit boards and other plastic products, because of their durability, heat and fire resistance, and isolation property.

Asbestos and chromates used as fillers can cause cancer. Fiberglass can cause serious lung problems if it is breathed in over a long time. By shaping, sawing or drilling resin-products fillers are easily realised as harmful dust.

Fillers include antimony trioxide, asbestos, chromate pigments, fiberglass, quartz, silica, titanium.

III 2.1.7. Metals and their compounds

Most of metals and their compounds are good electrical conductors and therefore they have a wide application in electrical and electronics industry. Metals are used or occur in many forms, such as solids, powder and liquid solutions and suspended in gas form.

Metals and their compounds can be very harmful if appear in drinking water or if breathed in in small unnoticeable amounts for a long time. When they are heated emission of fume appears, dust is emitted when drilling, sawing, filing operations take place.

Some of metals and their compounds applied in electrical and electronics industries include: aluminium, antimony, arsenic, barium, beryllium, boron, calcium, chromium, chromates, cobalt, copper, iron, gallium, germanium, gold, indium, lead, lithium, magnesium, mercury, molybdenum, nickel, phosphorus, platinum, rhodium, selenium, silver, tantalum, tellurium, tin, titanium, tungsten, vanadium, zinc.

III 2.1.8. Oxidizers

Oxidizers are highly reactive chemicals, some of which have strong corrosive action. They are used to clean or to render a metal surface free from corrosion. During oxidation, oxygen combines with a metal or semiconductor surface and forms a protective oxide layer.

Because of their strong corrosive action, some oxidizers are danger to the ayes, skin and lungs. Oxiderzs are also highly flammable.

The following chemicals are considered as oxidizers: ammonium persulfate, cerric ammonium sulfate, chlorine, chromic acid, hydrogen peroxide, iodine, nitrous oxide, nitrate, sodium persulfate.

III 2.1.9. Resins

With the exception of rosin (colophony), most resins used in electrical and electronics industry are man-made organic polymers, which are complex chemical substances. Polymers are formed from monomers. Resins are widely used in industry, particularly in wire and cable insulation processes, moulding plastics, making printed circuit boards, bonding, encapsulating, packaging, etc. There are many kinds of resins such as plastics, epoxies, synthetic fibres, synthetic rubber, waxes, and many others.

Resins can produce a wide range of highly toxic vapours and gases during heating operations. Uncured epoxy resins or monomers are very toxic and penetrate the skin and lungs rapidly. Therefore a curing operation is applied to them in order to cure and make them much less harmful. Epoxy resins are normally cured with phenol compound, and polyesters are cured with a peroxide compound.

Resins include: epoxy resins or epoxides, curing agents for epoxies, monomers (acrylonitrile, butene oxides, ethylene oxide, styrene oxide, vinyl chloride, vinyl cyclohexane dioxide), polymers (polyesters, polyethylene, polystyrene, polytetrafluorothylene, polyurethane, polyvinyl chloride, silicones) and resin ingredients/additives.

III 2.1.10. Semiconductors

Semiconductors are substances with special characteristics suitable for making semiconductor components (individual microcircuit devices, such as transistors or diods which perform simple electrical functions, and integrated circuits, such as a microprocessors or random access memories which perform complex electrical functions). Semiconductor substances, such as cadmium sulfide, gallium arsenide, germanium, indium, phosphide, silicon are made by chemical companies which are specialized in supplying chemicals to the electronics industry.

III 2.1.11. Solvents

The solvents were mentioned in previous subsections, especially that ones which endangers ozone layer. They are used in nearly every operation of electronics industry, as well as in cleaning, degreasing, thinning plastics, resins, glues, inks, paints and waxes in electrical industries, wherever these operations are applicable. In addition to their global environmental problems, many solvents, especially the aromatic compounds and the chlorinated hydrocarbons are perhaps the most dangerous since many of them are known to cause cancer and other serious diseases.

III 2.2. Identification of waste streams in PCBs manufacture

Identificatiion of waste streams in PCBs manufacture is given as example for identification the main pollutants streaming from different operations involved in manufacture of an electrical or electronics product. Most of operations involved in manufacturing processes of the electrical and electronics industries generate wastes, some of which are hazardous. It is not possible in this paper to identify all wastes generated in electrical and electronics industries, because every industry and every process involved in it has its characteristics, and the waste streams can differ. To every industry and process must be given a special attention through waste assessment or audit. Hence, for the purpose of this paper, the printed circuit board manufacture process has been selected for waste identification. This process generates a lot of wastes and can be considered that generates major part of total wastes in electronics production line.

The waste streams identified in common operation, such as cleaning and surface preparation, sensitizing and electroless plating, printing and masking, electroplating and etching are described in the subsections that follow this introduction note.

III 2.2.1. Cleaning and Surface Preparation

Typical waste streams generated from this unit operation are: airborne particles, acid fumes/organic vapours, spent acid/alkaline solution, spent halogenated solvents and waste rinse water. The composition of streams is as follows: board materials (copper, fiberglass etc.), sanding materials, metals, fluoride, acids, halogenated solvents, alkali.

III 2.2.2. Sensitizing and Electroless Plating

Typical waste streams generated during these operations are: spent electroless copper bath, spent catalyst solution, spent acid solution and waste rinse water. These waste streams are compound from acids stannic oxide, palladium, complex metals, chelating agents.

III 2.2.3. Printing and Masking

Spent developing solution, spent resist removal solution, spent acid solution and waste rinse water are typical waste streams for these operations. The stream composition is: vinyl polymers, chlorinated hydrocarbonates, organic solvents, alkali.

III 2.2.4. Electroplating

Electroplating generates typical waste streams from spent plating bath and waste rinse water. These waste streams contain copper, nickel, tin, tin/lead, gold, fluoride, cyanide, sulphate.

III 2.2.5. Etching

Spent etchant and waste rinse water are aste streams typically generated in etching operation. Such waste streams contain ammonia, chromium, copper, iron acids.

III 3. EQUIPMENT AND MEASURES FOR ENVIRONMENT PROTECTION

III 3.1. General consideration

Engineering equipment for preventing pollution and application of automation means for control and monitoring is described in this section with due attention paid to other measures such as rehabilitation of production equipment, introduction of new and cleaned technologies, change of raw material and product substitution.

Current state of and future trends in the production and application of engineering equipment for preventing environment pollution are surveyed. Due attention is paid to the use of automation means for increasing the efficiency of the relevant technological processes and so contributing to waste source reduction, energy saving and resources reduction. Engineering equipment is studied from such aspects as pollution detection and monitoring as well technological processes control in order to improve operating efficiency of equipment and economic and working conditions.

To give details of all the available equipment and means is not possible in this paper because the scope of the paper will be exceeded. Thus only the basic principles of the different devices and technologies are specified, with descriptions necessarily restricted to those technologies that are in comparatively widespread use.

Most factories in electrical and electronics industries produce different types of wastes in liquid, gaseous or solid state. The wastes can have various levels of hazardous substances which are used or which arise in the course of production. Contaminates must be removed completely or at least to the extent that they cannot harm those who use them subsequently. Measurement and monitoring of contaminate levels in the wastes is of major importance. If hazardous wastes or hazardous concentrations, for example in waste water, are detected in time, appropriate measures can be taken to avert danger. Application of automatic process control and measurements makes this feasible.

The equipment and systems. available today provide the necessary technology for solving almost all problems connected with environment protection. It is obvious that items of such equipment and systems can't be regarded as isolated products, almost all fields of human endeavour, such as chemical and metallurgical engineering through medicine to, in certain cases, aerospace technology have contributed to developments in this field. Electrical and electronics industry development has especially contributed in this field. By means of electric and electronic devices (motors, switches, instruments, transducers, microcomputers, computers, etc.). It is now possible to automate many process steps, reducing running costs and power consumption and optimizing the utilization of raw materials, what all together will contribute to reduction of environment pollution. The application of process computers for **Supervisory Control and Data Acquisition** (SCADA) permits continuous monitoring of the operation of the plant, control of operation by start-stop commands either automatically or manually initiated by operators, statistical analysis of the data, etc. All data by using appropriate telecommunication means, can be transferred in a remote control center from where all processes can be supervised and controlled.

Introduction of environment protection equipment and measures in industrial sector requires investment which is proportional to the investment in new plants, some 8 to 12 per cent of the cost of a plant being generally assigned for introduction of environmental protection measures. Engineering industries required less investment, in the Federal Republic of Germany in 1977. The per centage was 1,4 of total investment in engineering industries, out of 1,4 per cent of total investment in engineering industry for environmental protection 25 per cent was invested in the prevention of water pollution.

There is no one single way of determining the environmental protection measures for a process/operation since each process/operation has its own characteristics in terms of generation of wastes. Therefore on appropriate waste minimization assessment procedure or waste auditing has to be carried out, as described in section III 3.2.

III 3.2. Waste Minimization Assessment

Since Electrical and Electronics Industries cover a very wide range of manufacturing industries it is not possible to elaborate all environment protection measures without good understanding of technological processes where wastes are generated. With knowledge of waste generating processes only is possible to suggest equipment and measures that the waste may be reduced.

Waste minimization consists of source reduction and recycling. Source reduction is a technique that applies prevention of waste generation at its point of origin and is usually considered preferable to recycling from on environmental perspective.

Before starting to develop potential options for waste minimization the firms operations, manufacturing processes and waste generation and management practices have to be surveyed. Through a comprehensive waste minimization assessment is included a planning and organizational phase that includes getting management commitment, setting waste minimization goals and organizing an assessment programme task force, an assessment phase that includes gathering background data and information, selection of assessment targets, review data and site inspection, generation of options and screening and selection of options for feasibility study, a feasibility phase on specific waste minimization options and an implementation phase.

So the Assessment starts with a careful review of firm's operations and waste streams. The selection of specific process and specific areas inside of it to assess is the next step. In the following step for a particular industry for particular area inside of it and for certain waste stream a number of potential options to minimize/reduce wastes are developed. The potential options first are technically screened and for selected options their economic feasibility is then evaluated. The last step is implementation of the most promising options for waste minimization.

A brief description of steps in **assessment phase** is given below.

Step 1: Data collection

This step includes collection of data regarding the firm, processes and operations. Identification of waste streams and their characteristics are included. Quantity, types and rates of waste generating processes are identified in process flow diagrams. Material balances for various processes and operations can be useful in tracking unaccounted losses of materials and emissions.

Step 2: Selection of priority and assessment targets

Because of lack of time and resources always needs to prioritize and select assessment targets. With limited resources waste minimization efforts are concentrated in a specific area. Selection of the target stream depends on considerations such as quantity and hazardous properties of waste, waste disposal and cost of disposal, safety of employees, etc.

Step 3: Data review and site inspection

For the selected priority and target stream data are reviewed and inspected by following the target process from the point where raw materials enter the process area to the points where products and wastes leave. This inspection of target area may include the production process, maintenance operations, storage areas for raw materials and finished products.

Step 4: Generation of waste minimization options

Based on the information from the site inspection a set of waste minimization opportunities is formed. In creation of waste minimization opportunities should be used the ideas collected from different sources, such as technical and trade reports, consultants, plant engineers and operators, equipment vendors, trade associations and government agencies. Source reduction may be accomplished on the base of collected ideas about operating practices, technology changes, raw material and product substitution. Accomplishment of recycling can be done through opportunities in use and reuse of waste and reclamation.

Step 5: Screening and selection of options for a feasibility study

The most promising options are selected in this step. The options are screened through either an informal review or a quantitive decision-making process including criteria such as impacts on product quality, environmental impacts and employees safety. The options that appear marginal, impractical or inferior are eliminated from feasibility study.

III 3.3. Environmental protection measures

Every plant/firm needs to evaluate its own environmental problems, so as to be able to select the best environmental protection measures. The sources of pollutans may be many and they may have multiple origins, therefore a waste assessment described above has to be performed. After studying of selected options of protection measures, including improved house-keeping procedures, raw material and product substitution, process substation with cleaner technology, changes in production processes, changes of equipment, changes in process control by introducing more automation, etc. The options which are technically and economally proved will be considered for implementation.

Additional treatment technology using recycling, recovery, on-site and/or off-site end-of-pipe treatment and safe waste disposal has to be considered for remaining pollutans after implementation of above measures.

A number of environmental protection measures for minimization of effluents, air emission control and wastewater treatment in electrical and electronics industries are discussed below.

III 3.3.1. Minimization of effluents and general opportunities

General opportunities for air pollution control

If the pollutant cannot be eliminated from the process by its controlling at source through accomplishment of changes in raw materials, operating conditions, type of equipment, or even the drastic step of totally changing the process. Equipment which destroys, masks, counteracts, or traps the pollutant is required. Collection of the pollutants before they discharge to atmosphere is most commonly used method for reducing the air emissions. The particular type of air pollution control equipment depends upon the nature of the pollutants: their size, shape, density, stickiness and electrical properties.
The collection principles of air pollution control equipment are as follows:

- Collection of small particles from air stream by gravity settling.
  This method applies a air stream of high velocity carrying small particles. When the speed of that air stream is reduced many of particles, particularly the heavier ones, can settle to the bottom of the collector.

- Using the inertia principle
  When the direction of a moving air stream changes, the heavier particles have a tendency to continue in a straight line, colliding with a wall and then settle to the bottom of the collector.

- Filtration
  The air stream with particles passes through a porous material, where the particulate matter is retained on the surface. Clean air passes through filter.

- <u>Electrostatic attraction</u>

  The particles are electrostatically charged when the dirty gas is channelled between two electrodes, a high voltage discharge negative electrode and a grounded collecting electrode. The high negative voltage causes electrons to be emitted from the discharge electrode. These electrons then collide with the surrounding gas molecules, ionizing them. The negative gas molecules migrate to the relatively positive electrode which is grounded. Migration of negative gas molecules has a consequence of their collision with the entrained dust or mist particles, transfering their negative charge on these.

  The negative dust or mist particles then also migrate to the grounded electrode where they become neutralized and fall to the bottom of the collector.

  In electrical and electronics industry may be recognized some general types of control equipment used to handle the variety of emissions to atmosphere:

- Airborne particles generated from mechanical operations, such as cutting, sanding, routing, drilling, beveling, slotting, etc. may be normally collected and separated using bag house and cyclone separators. They are then disposed of.

- Acid fumes from acid cleaning may be collected via chemical fume hoods and sent to a scrubber where are removed with water. The scrubbed air then passes on to the atmosphere.

- Organic fumes from vapor degreasing are often collected and passed through a bed of activated carbon. The carbon bed is then regenerated with steam. The regenerative vapour is either condesed and the condensate containing water and solvents are drummed or combusted in a closed fumes burner.

General opportunities for other pollution control

Land and water can be polluted with spent acid and alkaline solutions from the cleaning steps, spant process bathes (electroless copper bath, spent plating bath, soldering bath, etc. and mostly with liquid waste streams from rinsing operations containing suspended solids, metals, flouride, phosphorous, cyanide, chelating agents, etc.

The liquid wastes may be controlled by using end-of-pipe treatment systems or a combination of in-line treatment and separate treatment of segregated waste streams.

Some of the opportunities, for example in PCBs manufacture, for minimization of effluents with improved house-keeping procedures, raw material, product and process substitution, changes in production processes and equipment rehabilitation, and recovery/reuse are shown in Table III 3-1. In more details are discussed some of these opportunities.

House keeping and better operating practices

A number of improved house keeping and better operating practices for engineering industries were already discused in subsection II 3.2.1. Some of measures for waste reduction discussed there, such as material input, storage and handling, process control and cleaning procedures, can be applied in electrical and electronics industries. In addition to these measures some economical measures can be recommended, such as

- To give incentives to employees for less generated wastes
- To introduce accounting measures through apportion waste management costs to departments where wastes are generated

Further more, specific better house keeping and operating practices that apply for example in PCBs manufacture are given below.

Prolongation of bath life through reduction of drag-in

As an example for this measure can be taken the proper design and maintenance of the racks used to carry the PCBs that have to be immersed into the bath solution. Corrosion and salt buildup deposits on the racks can fall into the solution contaminating it. Proper design of racks and regular cleaning will minimize the possiblity that contaminates can fall in bath. In this way the drag-in can be reduced.

Better precleaning and rinsing can be considered as an other example of reduction of drag-in. Efficient rinsing of the work pieces between.

different process baths reduces the drag-in from a solution in a previous bath into the next process bath.

Prolongation of bath life through reduction of drag-out

Through drag-out the bath solution is exhausted and the wastes of drag out may contain high concentrations of toxic compounds that require extensive treatment. Therefore the loss of solution from the bath has to be reduced. As examples for reduction of drag-out that are categorized as better operating practices can be considered minimization of bath chemical concentration, increase of bath temperature, proper positioning of work pieces on the rack, slow withdrawal and ample drainage of work pieces and drain boards.

Minimization of bath chemical concentration contributes to reduction of drag-out losses in two ways. Reduction of bath chemical concentration, reduces the quantity of applied chemicals and their chemical concentration perhaps toxity also in drag-out losses on one side, on the other side the viscosity of the solution decreases. Hence, the film that adheres to the workpiece as it is removed from the process bath is thiner and will drain back into the process bath quickly. Therefore the volume of drag-out loss is decreased with less concentration in the process bath. The lowest process bath concentration that will provide adequate product quality should be determined.

Increase of bath operating temperature decreases the viscosity and surface tension of the solution, thus reducing the drag-out. This method includes some disadvantages such as higher energy costs, higher chance for contamination due to increased make up requirement, and higher evaporation.

Proper positioning of work pieces on the plating rack faciliates maximum drainage of drag-out back into the bath. The proper position of workpiece on a rack understands that its surface is oriented as close to vertical as possible, its longer dimension is horizontal, and if possible the lower edge to be tilted from the horizontal so that the run off is from a corner rather than from an entire edge.

Slow withdrawal of workpieces from the process bath allows thiner film of the solution on the workpiece surface, thus reducing the drag-out volume. After the workpiece is withrawen from the solution, it has to be drained. The effect of slow withdrawal time on reduction of drag-out is higher than the drainage time.

Tabele III 3-1: Waste reduction opportunities for the Printed Circuit Board Manufacture

Waste reduction method	Short description of opportunity
1. House keeping and better operating practices	- Equipment maintenance - Specifying ordering, receiving, storage of material - Bath life extension through · proper rack design · better precleaning/rinsing - Bath life extension through reduction of drag-out by · minimization of bath chemical concentration · increase bath temperature · proper positioning on rack · slow withdrawal and ample drainage · draining boards - Bath life extension through maintaining bath solution quality by · temperature control · monitoring solution activity - agregate streams
2. Raw material, product and process substation	- Use abrasive instead of aqueous cleaning - Use non-chelated cleaners - Use non cynide stress relievers - Use purer anodes and anode bags - Use non-chelated etchants - Use deminaralized water as make up - Use deionized water - Use aqueous processable resist instead of solvent processable resist - Use screen-printing intead photolitography - Use Asher dry photoresist method instead use of organic resist stripping - Use mechanical board production methods instead operations involving chemicals - Use mechanical agitation instead air agitation - Use differential plating instead of the conventional electroless plating process - Use surface mount-technology for attaching packages to PCS - Use injection molded substrate and additive plating

Table III 3-1 (Continued)

Waste reduction method	Short description of opportunity
3. Process changes and improvements	- Use computerized/automated control systems - Use continuous filtering/carbon treatment - Regenerate solution through impurity removal - Use closed-circuit rinses - Use spray rinsing - Use fog nozzles - Increase degree of agitation - Use counter current rinsing stages
4. Recovery/Reuse	- Recycle/reuse cleaners and rinses - Recycle/reuse photoresist stripper - Recover metal values - Reuse/recycle etchants - Recover drag-out

Bath life extension through maintaining bath solution quality

If the temperature of bath solution is controlled and kept in certain range, and the activity of solution is monitored, bath life can be prolonged and period for its replacement is longer.

Bath temperature control is important for performance and bath life prolongation. If for cooling/heating immersed coils in tanks are used the salts from solution can form scales on the coils, preventing heat transfer and temperature control. Heat transfer efficiency can be maintained by periodic cleaning of the coils or by using jacketed tanks instead of coils.

Frequent **monitoring of solution activity** and regular replenishment of reagents or stabilizers can prolong bath life. The addition of stabilizers can sometimes decrease the deposition rate.

Segregation

Process chemical loss due to drag-out often enter the wastewater. Treatment of this wastewater is a major source of hazardous wastes in sludge. The volume of sludge is proportional to the level of contamination in the spent rinse water. The efficiency of a wastewater treatment system can be improved and volume of sludge decreased by waste stream segregation. An example of waste stream segregation is the **separation of chelating agent wastewaters from nonchelating agent streams.** Treatment of wastewater containing chelating agents separately from the wastewater without chelating agents will require less use of ferrous sulfate to break down the chelators, because the volume of chelating wastewater is less.

As an another example for segregation waste streams can be considered **separation of noncontact cooling water from industrial wastes.** Cooling water can bypass the treatment system and discharge directly to the sewer, in this way reducing wastewater volume for treatment. The amount of treatment chemicals is also decreased, and in turn the volume of suldge generated will be reduced.

Raw material, product and process substitution

All waste reduction methods for PCBs manufacture were enumerated in second row of Table III 3-1. It is not possible to consider all of them in this paper, but as examples will be discussed use of non-chelated cleaning chemicals for raw material substitution, use of surface mount technology in attaching packages to PCB for product substitution, and finally use mechanical agitation instead air agitation for process substitution.

Chelators are employed to enhance cleaning, etching and selective electroless plating. They allow metal ions to remain in solution beyond their normal solubility. The problem is now when the chelating compounds once entered the waste stream, they inhibit the precipitation of metals. Additional treatment chemicals must be used to precipitate metals from waste stream, and a consequence of this volume of hazardous waste sludge is enlarged.

Ferrous sulfate is a common additional treatment chemical breaking down the complex ion structures in waste waters that contain chelators. Usually is added to the wastewater to achieve an iron to metal ratio of 8:1, having a consequence in additional volume of sludge generated.

Use of mild chelators as ethylenediaminetetraacetic acid or non-chelated alkaline cleaners instead of strong chelators such as ferrocyanide, phosphates and ammonia can reduce the need for additional treatment of wastewaters. Using of non-chelated process bath has a disadventage due to requirement for continuous filtration to remove the solids that form in the bath.

Very good results in reduction of wastes are achieved by product substitution. **The use of surface mount technology** for attaching packages to PCBs instead of the conventional through-hole insertion of packages results in smaller size of PCBs for a given number of packages. Closer contact areas of component leads in surface mount technology enable that required surface for mounting the same number of components is only 35 percent to 60 percent as large as a PCB surface designed for the old style package. Since the metal area on which cleaning, plating and photoresist operations are performed is decreased, the wastes associated with these operations can be reduced.

If a process bath employs air agitation to increase and maintain the efficiency oil from the compressor or blower and carbon dioxide can enter into it. The oil will lead to organic loading. The carbon dioxide can lead to carbonate buildup in alkaline bath. Therefore **mechanical agitation** will be viable alternative instead of air agitation.

Process changes and improvements

From many possibilities to change process and to introduce improvement in efficiency, here **the use of computerized/automated control systems,** will be considered, because this opportunity has its base in electrical and electronics industries.

The automation and computers are used to increase the efficiency of relevant technological process, saving energy and resources, and reducing wastes. In addition to these goals, automation and computers (Personal Computers - PC) are increasingly used for carrying out potentially hazardous operations.

Simple automation processes can be introduced everywhere where a physical or chemical value has to be monitored and controlled. Such values in electrical and electronics industries are related to temperature, pressure, flow, volume, voltage, current, power, etc. Automation is possible if adequate measurements of process data are performed. Many instruments and methods are developed for this purpose, most of them applying electrical and electronic components. All the analog data in a production line can be measured and together with status data of some devices (equipment open, closed, any position in between) can be collected by using-terminal stations for data acquisition and via telecommunication lines transmitted in a control center. Control center can use computers and peripherals to acequire data, to make analysis and to store them for subsequent use. With feedback connections every process data through control of process can be adjusted to technological acceptable value.

For some simple automatic operations there are no needs for computers, such as control of water flow in rinsing operation. In order to keep water flowing only when the rinse operation is carried out, it is enough to implement a pressure activated valve. Control of fresh water flow in rinse system can be more automatized by use of a conducitivity or pH measurement illustrating the level of dissolved solids or hydrogen ions in the rinse solution. When this level reaches the preset minimum, the conductivity probe activates a valve that shuts off the flow of fresh water into rinse system. When the concentration of disolved solids or hydrogen is to high, the probe again activates the valve which then opens the flow of fresh water into rinse system.

Recovery/Reuse

Recovery and reuse of spent materials includes technologies that reuse waste as raw material for another process or that recover valuable materials from a waste stream. There are many opportunities of direct use of waste materials and the recovery of materials in electrical and electronics industries. The spent chemical process baths, rinse water, etc. can be reused in the same process or other processes.

By segregating the wastes, their reuse or recycling is promoted. Recovery of metals from various streams is also made easier if they are not mixed. Some of the technologies that are successfully used to recover metals and metal salts include evaporation, reverse osmosis, liquid membranes, electrolytic recovery, electrodialysis, high surface area electrowinning/electrorefining.

III 3.4. Energy management

Energy must be managed like any other item of consumption in a production line. Energy management in a firm should be considered as a normal aspect of general management. It gives the opportunities to reduce energy consumption and to involve first step towards automation. Since in most cases there is a direct relationship between energy consumption and the production of effluents which are harmful to environment, energy management is a useful tool for environment protection.

Energy management is possible only when the energy is measured, quantified, and monitored. Measuring and monitoring of energy consumption is possible installation of energy meters. Through energy metering better information are provided on energy consumption at user scale and for each end-use and so are at disoosal the means to detect rapidly and to remedy any abnormal consumption by users. Various levels of metering and monitoring are introduced:

- factory gate
- each production sector
- each large piece of energy using equipment

As electronic components have become progressively cheaper and more reliable, energy management systems based on computers have become more widely used and their contribution has become more significiant.

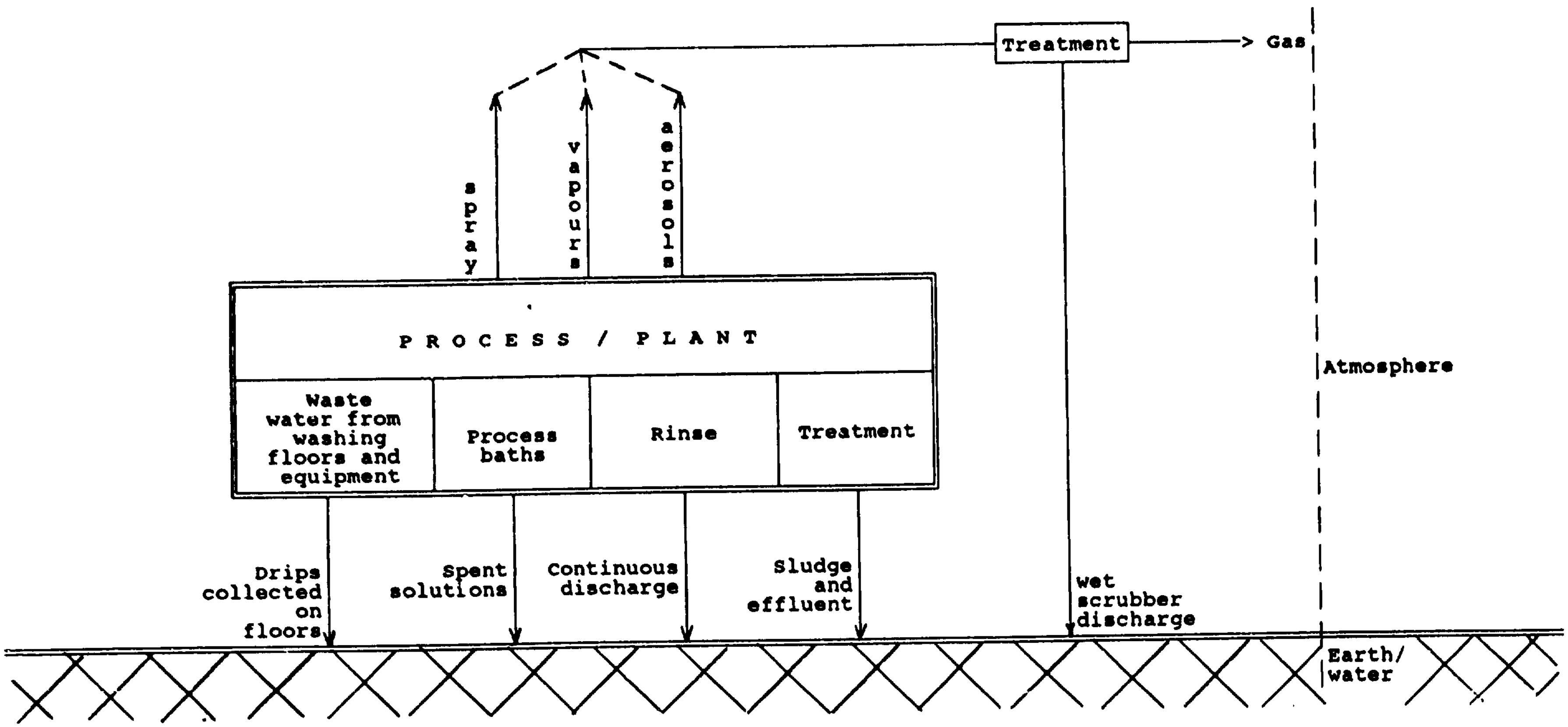

Figure III.1-1: Waste emissions to air, water and earth

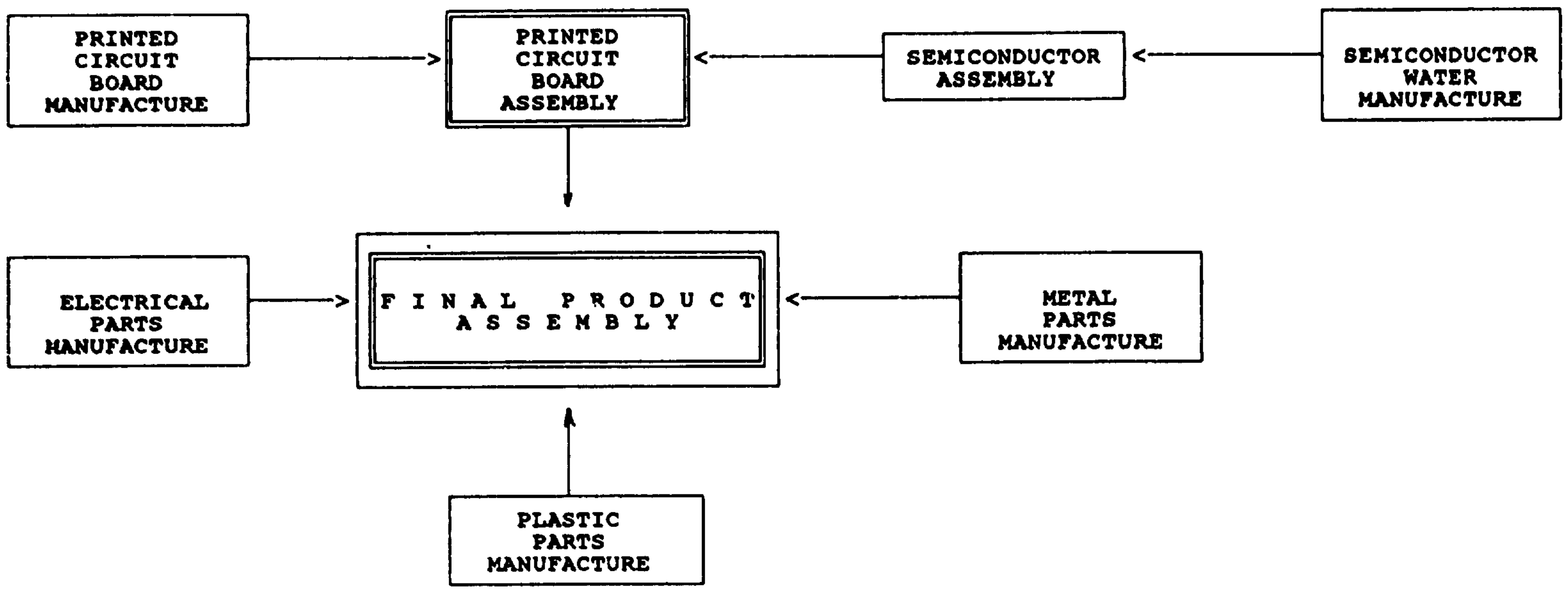

Figure III.1-2: Electronic product manufacturing processes

IV ENERGY SAVINGS AND EFFICIENCY IMPROVEMENT IN ELECTRICAL AND ELECTRONICS INDUSTRIES

IV 1. GENERAL CONSIDERATIONS

IV 2. OPPORTUNITIES

IV EMERGENCY SAVINGS AND EFFICIENCY IMPROVEMENT IN ELECTRICAL AND ELECTRONICS INDUSTRY

IV 1. GENERAL CONSIDERATIONS

A more through thinking about improved energy efficiency and conservation stated during the 1970s when the sharp rises in the price of fuel appeared. Today the thinking is more global and concentrated in addition to the costs to environmental problems, such as global warming, acid rains, smog, etc. Emission of greenhouse gases in the atmosphere, such as carbon dioxide (CO_2), nitrogen oxide (N_2O), especially by combustion during energy production, and methane (CH_4) and chlorofluorocarbons (CFCs) will lead to dangerous warming of the earth's surface. Should the trends in emissions continue then the earth's surface may continue to warm on average rising 2-4°C within the next 60 years. Confronted with this danger facing mankind, strategies and policies have been suggested for holding global warming down to acceptable levels. In addition to the phasing out of chlorofluorocarbons (the subject discussed in Section II) use, reduction of NOx and CO_2 emissions through energy efficiency, energy conservation and the use of environmentally sound and renewable energy sources are suggested.

Inefficient use of energy and poor pollution control tend to go hand in hand, causing environmental problems. There are a number of ways in which energy efficiency can be pursued. We will discuss in this paper some of energy efficiency ways connected to electrical and electronics industry, even this industry is not a energy-intesive one. Many examples/have shown that in-plant energy audits carried out have led to the implementation of practical energy saving measures, resulting in both environmental and economic benefits.

Saving energy and energy efficiency improvement contribute to waste minimization and cleaner environment. Therefore energy saving and efficiency can be considered as environmental protection measures. By reducing the energy consumption the energy costs will be lower, but most important is also that this will have positive influences on the environment. It is better, from both an environmental and an economic point of view, to invest in more energy-efficient technology than to rely on more energy consumption, especially if a industry is energy-intensive. The energy-intesive industry is polluting directly or indirectly the environment through inefficient production more than less energy-intesive industries. Electrical and electronics industries are considered as less energy-intesive. The technological processes apply equipment that mostly require smaller motor drives, small thermal processes, etc. except some metal finishing processes where many process baths are involved.

Effective use of energy in electrical and electronics industry is reducing the energy costs, as well as the negative impact on the environment. It is better, from both on environmental and an economic point of view, to spend money in more energy-efficient technology. Energy conservation is a very important instrument in achieving both energy policy and environmental policy goals. Therefore, those who use energy in the operation in factories must make efforts to rationalize energy use through energy saving and conservation measures opportunities for this are given in next subsection IV 2.

For the factories which consume a large amount of energy, annually more equivalent consumption than 3000 000 l of oil, or more than 12 GWh of electricity, a certain number of educated energy managers have to be appointed. Small energy consumers need energy audits and guidance, training of employees engaged in energy management and provision of information on techniques of improved energy efficiency.

Energy auditing is the essential tool for effective energy management, including energy saving and efficiency improvement and conservation. It helps to identify technical and economic measures by considering the following:

- energy metering plan
- quantity and costs of various energy inputs
- relation of energy inputs and production output
- determination of energy targets for processes, such as
    - reduction of heat losses (heating, hot water, compressed air)
    - insulation of pipes
    - renewal of equipment because of obsolence
    - introduction of low level of automation
    - integration of control
    - replacement of thermal equipment with clean and efficient technologies
- global process analysis to determine if new design work is needed
- economic and financial analysis of each proposed solution in different processes

In electrical and electronics industries for various unit operations energy audit studies have to be conducted. For this purpose institutions with expertise and technical services, equipped with sophisticated and modern technical facilities with efficient measuring system, are necessary.

IV 2. OPPORTUNITIES

There are many opportunities for efficiency improvement on the demand side, known as the classical energy conservation measures. Energy efficiency improvements produce "megawatts" which mean the not-needed capacity for energy sources. The consequence of "negawatts" production is a significiant reduction of pollution.

Opportunities for energy saving and efficiency improvement exist in all end-use industries through reduction of energy losses or good house-keeping, improvements in process efficiency and recovery of waste heat. They can be seen as management techniques and evaluation methods, energy auditing and measurement, technology transfer, motor-driven improvements, combined heat and power, process control systems, waste heat recovery, transmission losses, etc. Energy efficiency improvements are very difficult to achieve in small sized firms due to lack of energy management, essential metering and measuring equipment.

House-keeping improvements are easy for implementation by the plant engineer or maintenance supervisor. ·These improvements can be made on steam systems, including boiler operation, steam distribution system, steam utilization, and condensate return system; compressed air systems, including compressor station, distribution of air and utilization of air; lighting systems, including lamp types and buildings factors, and control of the lighting systems, and electrical motors operation, including motor size appropriate to load, high efficiency, speed control, motive drives and voltage and temperature control.

Improvements in process efficiency are not so simple as house-keeping improvements. For these improvements one needs to monitor the energy flows by instruments and meters and to assess process efficiency. Often for assessing process efficiency a consultant is needed to advise on these maters. It is necessary firstly to carry out processing analysis, afterwards measurements and energy balance and finally to investigate the effects of process variables.

The opportunities for efficiency improvements of processes are in the insulation of vessels, fitting lids where liquid surfaces are exposed, use of direct heat, improved process control by computer, minimize wasteful use of high grade energy, utilization of wastes as fuel, etc.

After it is ensured that the process operates at its maximum efficiency, waste heat recovery can be considered, that means the waste heat from one process to be used in another process. There are not so many opportunities in electrical and electronics industries for this, except where combined heat and power stations (diesel generators) are in use.

The energy efficiency improvements if a company depend on:

- the type of production activity
- processes used and activity
- the cost of different energy sources
- clearly identified energy saving potential
- technical and investment capabilities.

Since in this report electrical and electronics industries are concerned, it is important that these industries, contribute much to energy saving. Electrical motors, heaters, lighting, etc. are more efficient than other consumers which perform the same operation and consuming other type of energy. Fuel-burning replaced with electricity at point-of-use saves energy, even when the energy required to make electricity is taken into account. More efficient electrical equipment, compact fluorescent lighting and advanced high-efficiency electrical motors with adjustable spead-drives are at disposal today. Efficient end-use of electricity is becoming more and more interesting to electrical and electronics companies.

V FOLLOW-UP ACTIONS OF THE ENGINEERING INDUSTRIES BRANCH OF UNIDO RELATED TO THE RECOMMENDATIONS GIVEN AT THE JOINT UNIDO/APCTT WORKSHOP ON ENVIRONMENTAL CONSIDERATIONS AND WASTE RECYCLING IN THE CHEMICAL, METALLURGICAL AND ENGINEERING INDUSTRIES, HELD IN MANILA, THE PHILIPPINES, 9 to 13 DEC. 1991.

V FOLLOW-UP ACTIONS OF THE ENGINEERING INDUSTRIES BRANCH OF UNIDO RELATED TO THE RECOMMENDATIONS GIVEN AT THE JOINT UNIDO/APCTT WORKSHOP ON ENVIRONMENTAL CONSIDERATIONS AND WASTE RECYCLING IN THE CHEMICAL, METALLURGICAL AND ENGINEERING INDUSTRIES, HELD IN MANILA, THE PHILIPPINES, 9 to 13 DEC. 1991.

1. Immediate actions to support developing countries to recognize the important role of engineering industries and their possible negative impact on the environment is necessary. At the same, instructions should be given on the application of the known preventive and remedial antipollution techniques. Pollution control expert missions should be undertaken.

2. Programme for promotion of and the transfer of clean technologies, pollution prevention measures, recycling technologies, energy efficiency and energy conservation are important for engineering industries. To the promotion of environmentally friendly and cleaner engineering industries technologies support is given. For this purpose a support system of engineering technologies of low-waste and non-waste processes should be developed.

3. Immediate actions to be taken to find appropriate forms of organization to help small sized firms in developing countries, which often lack in technical knowledge, managerial abilities and financial facilities to cope with their environmental protection.

4. Increased environmental pressure and awareness is necessary in engineering industries to meat environmental standards on a global basis. Awareness should put that sustainability in engineering industries is above all, progress and profits. Promotion of "eco" thinking of zero-waste as a way of the future is necessary.

5. Expert assistance is necessary in developing countries to operate existing engineering plants efficiently and to advise on the application of

appropriate technologies and equipment. Many current practices of house-keeping, have to be reexamined, and identification and implementation of new practices and procedures are necessary. Environmental protection measures in engineering small firms have to become an integral part of production process, thereby automatically causing the reduction or reuse of waste, rather than end-of-pipe waste treatment. For irreducible waste, promotion of waste exchange systems for small companies, with multiple metals is necessary, because for them a closed load recycling system is very expensive.

6. Promotion of integrated measures, where environmental protection and energy efficiency are an integral part of new industrial equipment and processes and of energy management systems is necessary. Expert assistance in introduction of energy and environmental management systems based on application of computer systems (mostly Personal Computers-PC) and advanced application software will be necessary.

7. Top management of engineering firms should include the cost and the benefits of proper environmental protection measures into their total corporate planning strategies for the future.

8. Laboratories for environmental and energy measurements with right kind and amount of instrumentation and trained personnel should be provided. Expert assistance in choosing instrumentation and training of personnel is necessary for waste and energy audits.

9. Analysis concerning the need for information and education of personnel for operation and maintenance in engineering industries, and how information sharing and education in these industries can be carried out are necessary.

10. Analysis of current projects, if any, in country aiming at more cleaner production and efficient technologies should be carried out.

11. Projects concerning research, development and demonstration studies in developing countries on environment protection in engineering industries, as well as activities for spreading knowledge, should be carried out. Knowledge improving projects or preliminary studies in environmental

protection measures in a given engineering firm have to be carried out. Expert assistance is necessary.

12. Projects for implementing actual state-of-the-art techniques should be carried out.
    Expert assistance is necessary.

13. Urgently it is necessary to create Energy Conservation and Environmental Centers in developing countries where these centres do not already exist in order to assist public and private industries in efficient use of energy and environment management.

14. These recommendations can be positively implemented only in cooperation with governments and engineering industries in developing countries. Further elaboration of each separate activity has to be carried out, based on a proper scheduling of activities.

VI REFERENCES

VI REFERENCES

1. Audit and Reduction Manual for Industrial Emissions and Wastes, UNEP/UNIDO, Technical Report Series N°7, 1991.

2. Chemical Pollution from Industry - Management and Control, C. Appleyard, Environmental Resources Limited - Paper presented in Joint UNIDO/APCTT Workshop at Manila, the Philippines, December 1991.

3. Cost Saving through Energy Conservation, Booklet 2, An Energy Saving Project of the ESCAP Club for Industrial Cooperation, United Nations - Energy Management Centre Gas and Fuel Corporation of Victoria, Australia 1984.

4. Ecowatts: The Clean Switch. Using Electricity to Save Energy & Cut Greenhouse Gases - An Analysis by Science Concepts, Inc; April 1991.

5. Electronics, degreasing and dry cleaning solvents technical options report, UNEP, Nairobi, 1989.

6. Engineering Equipment and Automation Means for Waste-Water Management in ECE Countries - A report on prevailing practices and recent experience in production and use of engineering equipment and automation means for preventing water pollution, United Nations, New York, 1984.

7. Environmental Issues and UNIDO Activities in the Engineering Industries, C Guerkoek, UNIDO - Paper presented in Joint UNIDO/APCTT Workshop at Manila, the Philippines, December 1991.

8. Economics, Development and Hazardous Waste, Dr. Tim Jackson, Stockholm Environment Institute - Paper presented in Joint UNIDO/APCTT Workshop at Manila, the Philippines, December 1991.

9. Environmental Considerations in the Electrical and Electronics Industries in the Countries of Asia and Pacific Region, G. Blagojevic, Energoprojekt - Paper presented in Joint UNIDO/APCTT Workshop at Manila, the Philippines, December 1991.

10. Environmental Aspects of the Metal Finishing Industry - A Technical Guide, Technical Report Series N°1.

11. Guides to Pollution Prevention - The Printed Circuit Board Manufacturing Industry, EPA, June 1990.

12. Health Hazards in Electronics, A Handbook, Thomas Gassert, Asia Monitor Resource Center, Hong Kong

13. Industrial pollution control, Issues and Techniques, Nancy J. Sell, University of Wisconsin - Green Bay

14. Industry and Environment, UNEP - Energy Efficiency N°1, January-February-March 1990.

15. Industry and Environment, UNEP - Energy Efficiency N°2, April-May-June 1990.

16. Industry and Environment, UNEP - Computers: tools for environmental management in industry - Part I, April-May-June 1991.

17. Industry and Environment, UNEP - Computers: tools for environmental management in industry - Part II, July-August-September 1991.

18. Industry and Environment, UNEP - Solvents and the environment, October-November-December 1991.

19. Pollution from the metal preparation and finishing industry-Sources, emissions and effects, C. Appleyard, Environmental Resources Limited - paper presented in Joint UNIDO/APCTT Workshop at Manila, the Philippines, 1991.

20. UNDP's Handbook and Guidelines for Environmental Management and Sustainable Development, Environment and Natural Resources Group, New York, February 1992.