CLEANER PRODUCTION WORLDWIDE

United Nations Environment Programme
Industry and Environment Programme Activity Centre

INTRODUCTION

This booklet aims to show through examples that by applying cleaner production, industry and consumers anywhere in the world can gain environmental benefits while reducing costs.

Cleaner Production Programme

The concept of cleaner production is not new but it is receiving new recognition today. Industrialisation in all countries – developed and developing – has proven to be at some cost to public health and the environment. When no care is taken this is especially true. When end-of-pipe pollution controls are added to industrial systems, less immediate damage occurs. But these solutions come at increasing monetary costs to both society and industry and have not always proven to be optimal from an environmental aspect. End-of-pipe controls are also reactive and selective. Cleaner production, on the other hand, is a comprehensive, preventative approach to environmental protection. It requires people to be creative and to investigate all phases of manufacturing processes and product life cycles, including product usage in offices and homes. Cleaner production, thus, encompasses such actions as energy and raw materials conservation, eliminating toxic substances (as raw materials and as product constituents), and reducing the amount of wastes and pollutants created by processes and products, thereby lowering the amounts emitted to air, land and water.

The term cleaner production was coined by the UNEP IE/PAC when it launched the Cleaner Production Programme in 1989. Many other similar terms exist today. Among them are: clean technology, pollution prevention, waste reduction, waste prevention, eco-efficiency and waste minimisation. There is no universal consensus on what they mean. Sometimes they are synonymous with cleaner production; and sometimes they are not. This confusion of terminology requires people to look beyond the words and analyse the actions.

The purpose of this booklet is to illustrate the variety of approaches that are possible and to stimulate readers to find similar cost-effective solutions. The applications here range from low to high technology. They show examples from small and medium sized enterprises, large industrial companies, and from plants in rural locations to those in overcrowded and highly industrialised cities, in a variety of countries. They show how seriously the concept of cleaner production is being taken by some governments, industries and individuals. The fundamental point is this: It is better for society to prevent, than cure.

Striving for cleaner production is like striving for efficiency and quality in products and manufacturing processes. People must continue to reassess and fine tune, to apply the latest ideas and recalculate the economics. Thus the examples here are not necessarily optimal everywhere today but they are typical of recent projects and show the variety of creative solutions that people have found.

We hope that this is only the first volume of this booklet. We look to you to send us new ideas that you have implemented that we can share with others. What new product have you developed? What process reconfigured? How much have you managed to save in operating costs by changing a raw material? What energy savings have you made at work? Remember that cleaner production is the way to reconcile the environment and development. It reduces the risks to humans and the environment of industrial activities in the most cost-effective way possible.

The Editorial Board for this booklet was Mme Jacqueline Aloisi de Larderel, Director of the Industry and Environment Programme Acitivity Centre, United Nations Environment Programme, Paris and David L Pounder, Environmental Protection Technology Adviser, United Kingdom Department of the Environment (DoE), London.

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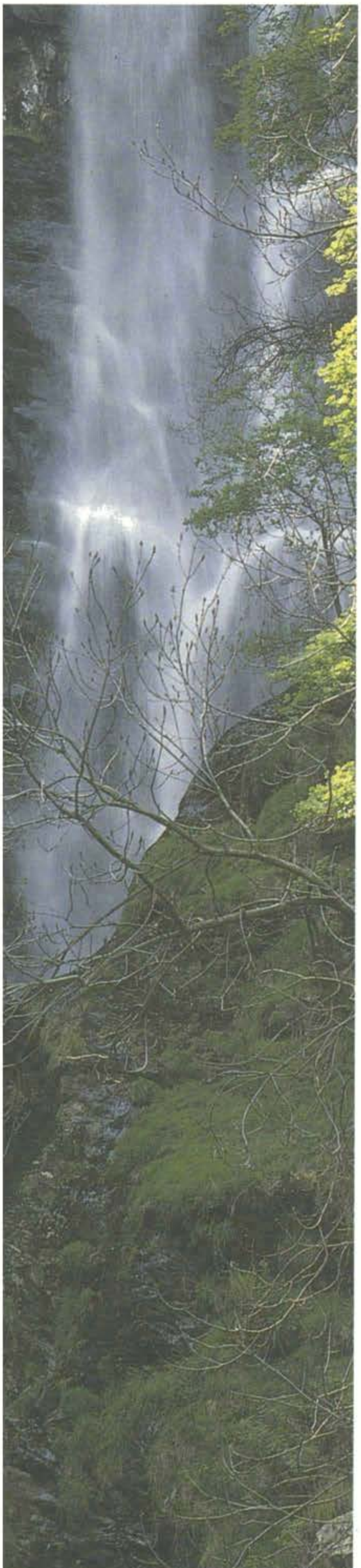
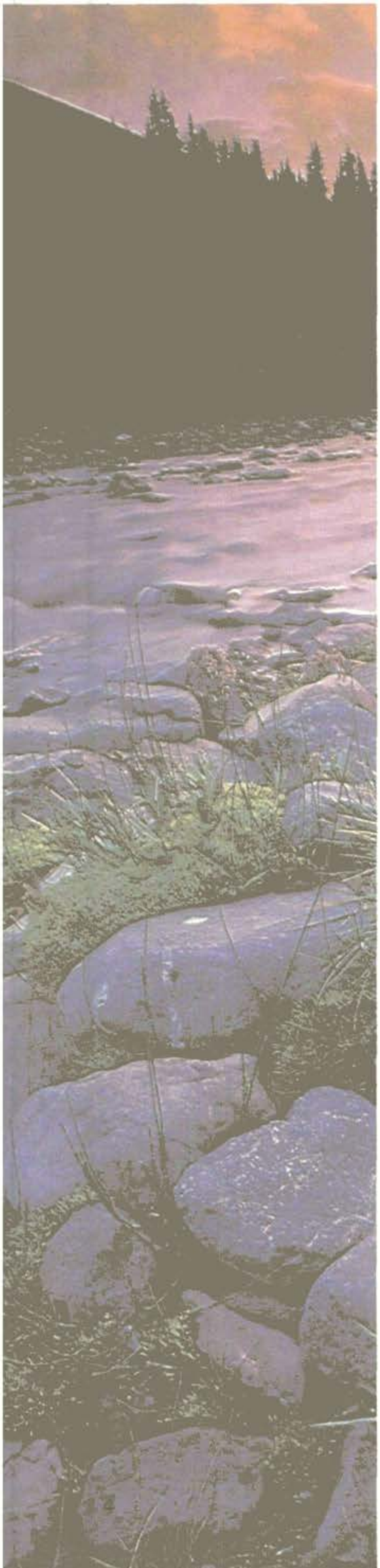


Gas Phase Heat Treatment of Metals



Background

The hardening, carburising and nitrocarburising of steel are heat treatment processes usually carried out in baths of molten salts, such as nitrites, nitrates, carbonates, cyanides, chlorides or caustics. The combination of chemicals and high temperature means that there are risks of explosion, burns and poisoning. Environmental problems arise from the resulting vapours and the removal, transport and disposal of the toxic salts. Disposal of cyanide salt costs US$3,300 per tonne. Neutralisation of quench water, oil, cleaning water and washing water has to be carried out before discharge to the sewer, but is not always carried out. Off-gases can be cleaned by passing the exhaust gases through a chemical scrubber, although this is also not always done.

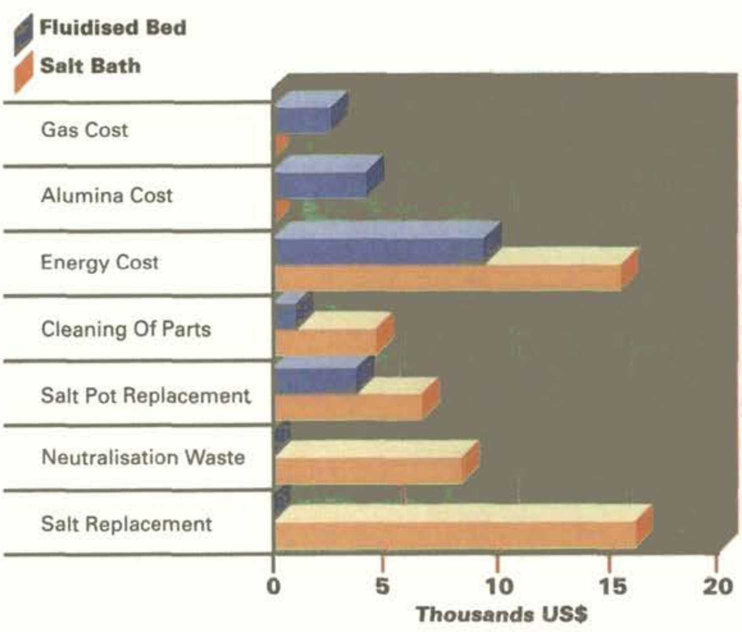
Cleaner Production

The new process avoids these problems by gas phase treatment using a fluidised bed of alumina particles. A mixture of air, ammonia, nitrogen, natural gas, lpg (liquified petroleum gas), and other gases are used as the fluidising gas to carry out the heat treatment. The bed is heated by electricity or gas and quenching is also carried out in a fluidised bed.

Enabling Technology

Fluidised beds have been used for some years in a variety of roles; heat exchange, gas absorption, chemical reaction and combustion. In this case the mixture of gases produce the fluidising atmosphere for heat treatment of the material immersed in the fluidised bed. Hydrocarbon gases are used for carburising, ammonia for nitriding and nitrogen for neutral hardening. The hot exhaust gases are used for heat exchange.

COMPARISON OF CONSUMABLE COSTS FOR CARBURISING IN SALT BATH AND A FLUIDISED BED



Advantages

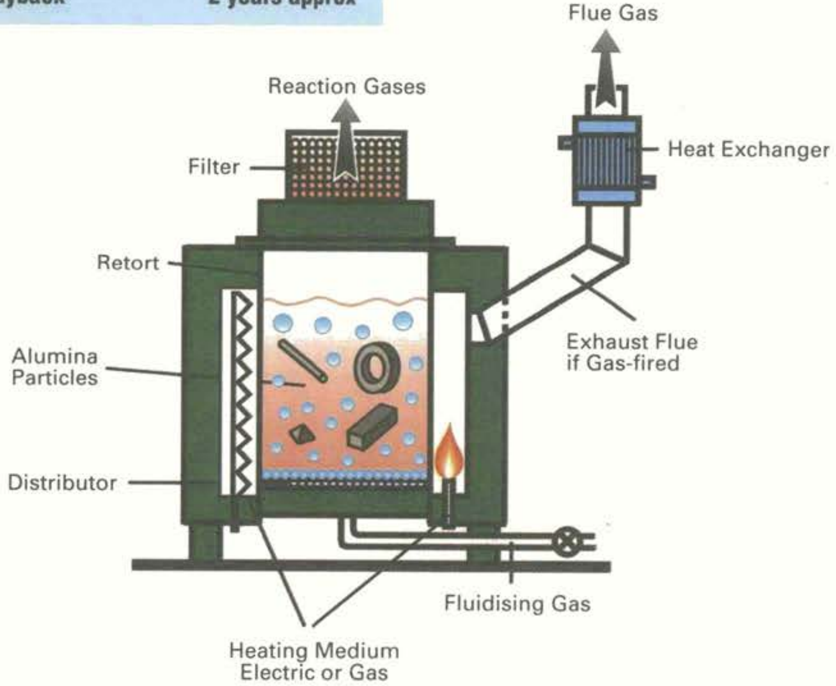
The most obvious advantages are the reduction in effluents and the improved working atmosphere. The safety aspects have also been improved to a very large extent and the quality of the product in many cases is superior to that produced by the older methods. All forms of heat treatment are amenable to fluidised bed techniques, but austempering is the most cost effective, in spite of the nitrate bath method being less troublesome than other traditional methods.

Economic Benefits

The figure shows typical savings achieved in the annual operation of a fluidised bed over salt bath methods of the same capacity.

The installation consists of four fluid beds used to replace their existing salt bath lines.

Cost saving	**US$/year**
Energy	36,000
Salt & maintenance	51,000
Total	**87,000**
Capital Investment	**US$180,000 approx**
Payback	**2 years approx**



Country
Singapore

Industry
Metal Processing

Companies
Chartered Metal Industries Toolroom produces a wide range of standard and customised products to support manufacturers in the metal industries. Their production includes high volume, batch-run precision parts, prototype components, sub-assemblies, tooling, fixtures and gauges.

Quality Heat Treatment Pty Ltd is an Australian company that designs and sells advanced technology heat treatment processing equipment for the metal processing industry. The company also carries out specialised heat treatment services for the industry.

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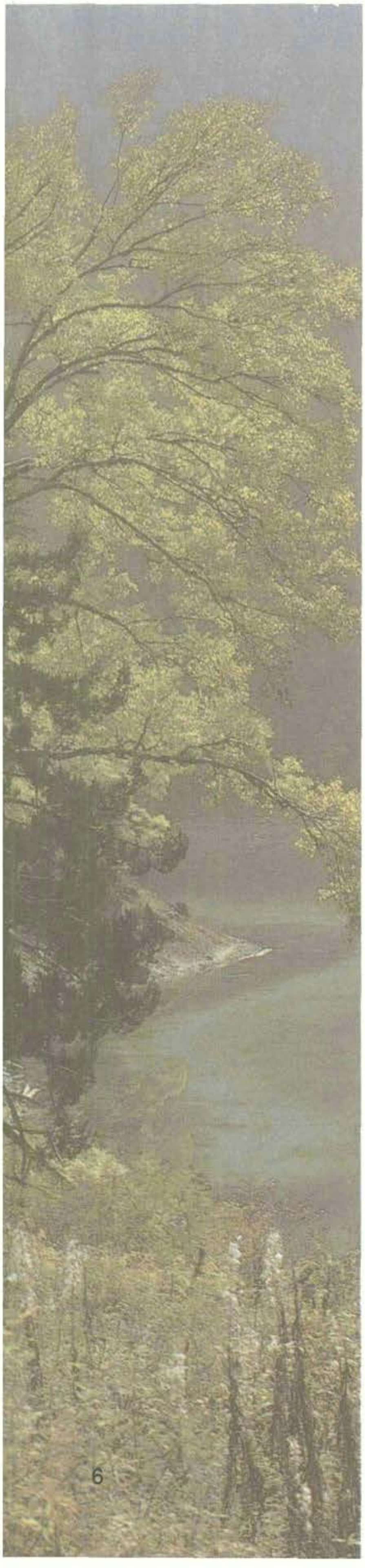
Chrome Recovery and Recycling in the Leather Industry



Background

The Greek and Dutch governments have a framework of bilateral collaboration in the field of environmental protection. One result of this has been that clean technology developed at TNO has been applied in a full scale co-operative R & D project between the two countries at the Germanakos tannery. The project was carried out from 1988 to 1990 with the support of the Commission of the European Communities.

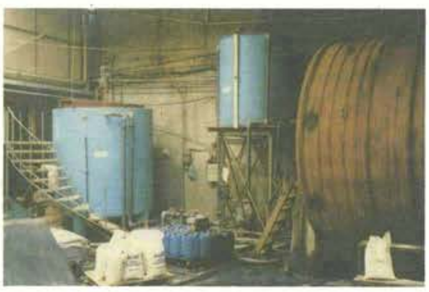
Tanning is a chemical process which converts putrescible hides and skins into a stable material. Vegetable, mineral and other tanning agents may be used – either separately or in combination – to produce leather with different qualities and properties. Trivalent chromium (Cr^{+++}) is the major tanning agent since it produces a modern, thin, light leather suitable for shoe uppers, clothing and upholstery. However recent limits for discharge to the environment have limited Cr^{+++} discharge to levels as low as 2mg/litre in waste waters.

Cleaner Production

The technology developed involves the recovery of Cr^{+++} from the spent tannery liquors and its reuse.

Tanning of hides is carried out with basic chromium sulphate, $Cr(OH)SO_4$, at a pH of 3.5–4.0. After tanning the solution is discharged by gravity to a collection pit. The liquor is sieved during this transfer to remove particles and fibres that have come from the hides. The liquor is then pumped to the treatment tank and a calculated quantity of magnesium oxide is added with stirring until the pH reaches at least 8. The stirrer is switched off and the chromium precipitates as a compact sludge of $Cr(OH)_3$. After settling the clear liquid is decanted off. The remaining sludge is dissolved by adding a calculated quantity of concentrated sulphuric acid (H_2SO_4) until a pH of 2.5 is reached. The liquor now contains $Cr(OH)SO_4$ and is pumped back to a storage tank for reuse.

In conventional chrome tanning processes 20–40% of the chrome used is discharged into waste waters. In the new process 95–98% of the waste Cr^{+++} can be recycled.



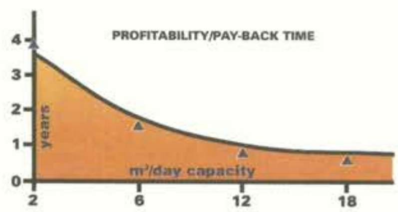
Advantages

Very little change to production process.

More consistent product quality.

Easier to monitor amounts of water and process chemicals used.

Much reduced chromium content of effluent waters.



Economic Benefits

For the Germanakos tannery, which has a chrome recycling capacity of 12 m^3/day, the approximate costs were as follows:

Cost saving	**US$/year**
Savings	73,750
Operating cost	30,200
Total net savings	**US$43,550**
Capital Investment	**US$40,000**
Payback	**11 months**

Savings can be made with any plant processing more than 1.7 m^3/day.

Country

Greece

Industry

Leather Industry

Companies

The Germanakos SA tannery near Athens in Greece was founded in 1978. Today it produces good quality upper leather from cattle hides, processing 2200 tons per year and with an annual turnover of US$8.4m and a staff of 65.

The Toegepast Natuurwetenschappelijk Onderzoek (TNO) is the Netherlands organisation for applied scientific research, and the project was carried out by their Institute of Environmental and Energy Technology.

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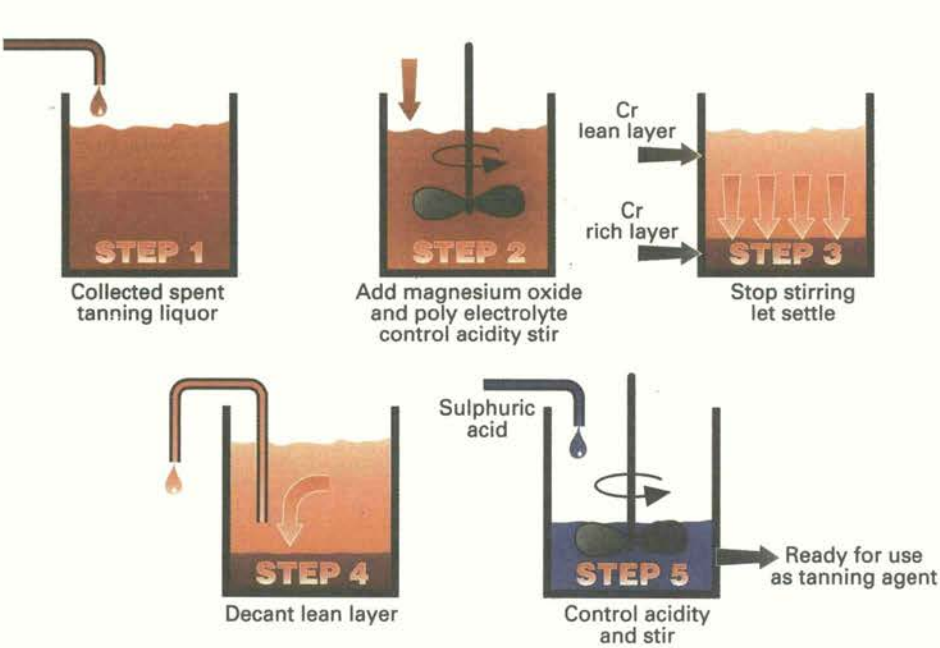
FIVE STEPS TO PROFIT IN CHROMIUM RECYCLING (Batch Process)



Minimised Environmental Effects in Cotton Production

Background

Cotton is a fibre obtained from the cotton plant and it is grown and processed widely throughout the world. Novotex's philosophy is to produce cotton with the smallest possible impact on the environment, by minimising emissions, energy conservation and waste minimisation. This can be seen to be cleaner production in the widest meaning of the term, involving all of the stages from growing to recycling of unwanted garments.

Novotex uses two approaches to all the stages of garment production. They have attempted to put a measure on the term environmentally friendly by means of an 'environmental value' for products between 0 and 100. An unattainable green product would be 100 and nuclear weapons could be thought of as 0. This principle has been applied to the stages of spinning, knitting, dyeing, finishing, garment production, packaging and transport. The company also carries out a Life Cycle Analysis of each stage of production. In this analysis the environmental aspects of every operation are examined in detail from beginning to end – 'from the cradle to the grave'. These two overlapping philosophies are frequently re-examined so that continuing improvements may be made.

Cleaner Production

The process starts with the cotton growing. The company is trying to insist that all the cotton they process is organically grown. This means growing without artificial fertilisers, chemical pesticides and defoliant sprays. Apart from the more obvious advantages, cotton pickers can suffer woefully from the effects of these chemicals. Machine harvested cotton additionally requires crop dusting with chemicals.

Company policy demands that all of the cotton used by Novatex is handpicked to avoid defoliants and does not contain pesticide residues. When the company started 1% of their cotton was organically grown, this is now 10% but the figure will increase with enlightenment of consumers around the world. In order that the term organic cotton is understood, the cotton is grown according to the ECO-labelling standards required for organic food production. The cotton is grown in various countries including Turkey, Peru, Morocco and Greece. New methods are allowing these principles to be applied. Vegetable compost and manure can supply the soil with sufficient nitrogen needs and organic materials.

Spinning and knitting is usually accompanied by large volumes of dust. The cotton is spun on advanced computer controlled machines that need greater control of an otherwise dusty atmosphere. Only water soluble dyes are used and chloride for bleaching is eliminated by using hydrogen peroxide. The dyeing process is carried out in fully enclosed high pressure jet machines with reduced water consumption and no air pollution. In the drying process mechanical finishing is carried out, eliminating the use of chemicals, eg formaldehyde, resulting in an improved material quality. The making up of cotton garments is also a dusty operation and is carried out with dust extraction at the cutting and sewing machines.

When a user disposes of a garment they should think of its potential for recycling either for continued reuse by others or for conventional recycling to another use.

All wastewater is purified in a neighbouring treatment plant.

Most of the dye and phosphorus is removed by chemical precipitation with lime and iron salts. Biological purification is carried out in 14m high towers using the activated sludge process. The water is then passed through sand filters and aerated before discharge.

Country
Denmark

Industry
Textiles

Company
Novotex A S is textile company that was founded in 1983 with nine employee shareholders. The company now has 100 people employed directly and another 100 in closely related companies. Its turnover is approximately US$18m.

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Economic Benefits

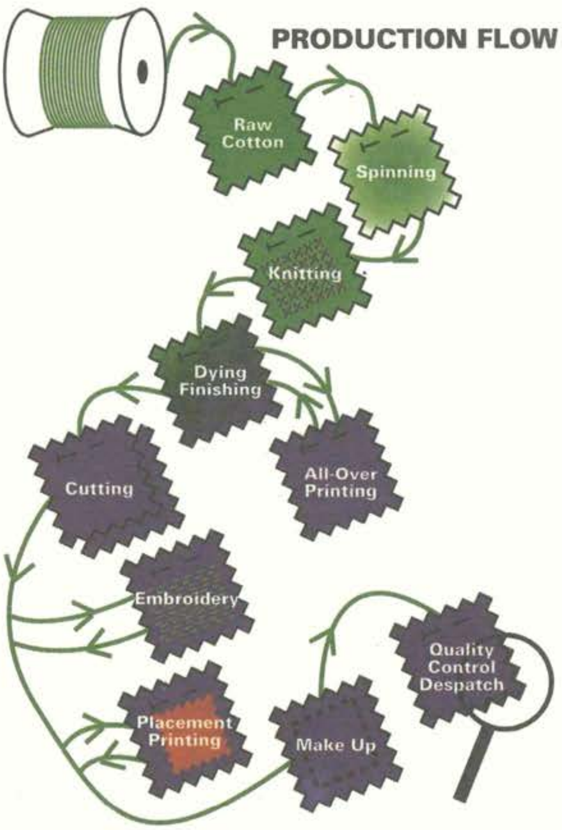
As might be imagined it is difficult to quantify all the benefits. The water consumption is reduced, with all of the cooling water being recycled. The dyeing processes now use only 50% of the original water consumption, the new cleaning processes use only one-third of the original heated cleaning water, the drying machines recycle 75% of the hot air used. The effluent water from the plant carries only a small fraction of the toxic material limits set by the water authority.

Advantages

Organic methods produce healthy plants, without polluting the soil and the surrounding environment.

Improved environment for workers at all stages.

The environmental impact of each stage of production has been minimised.



Pollution and Waste Reduction by Improved Process Control

Background

Cement is made by burning a fuel together with limestone and clay, shale or slate, (shale being used here), yielding a clinker which is then ground with gypsum to produce cement. The process, which is carried out in large rotating kilns, is a complex one, and it is easy to lose control and make substandard product. Conversion of the kilns from oil/gas to coal firing has the penalty of making control even more difficult. The limestone and shale are quarried locally, combined and ground to a fine powder, referred to as raw meal. Heat transfer between the kiln exhaust gases and the raw meal initiates the calcination process which continues in the kiln. When the calcination is complete, the material temperature rises rapidly causing sintering that produces clinker. The clinker is discharged, cooled and ground to give the finished product. The small amount of sulphur in the coal takes part in the chemical reactions and is transformed into part of the sulphur content of the cement. The use of coal increases slightly the dust content of the exhaust gases which is removed in the bank of electrostatic dust precipitators usually used with these plants.

Cleaner Production

The quality of the cement is determined largely by the firing temperature. However, both the NO_x and SO_x levels increase with higher temperatures. The process must, therefore, be operated within a certain band of temperature with the optimum at the lower end. If the process is operated too far below this optimum, off-specification product is produced. If the temperature is too high the fuel is wasted, cement quality is reduced and air pollution is increased. The LINKman system is designed to mimic best operating practice and maintain optimum process conditions. The objectives were to stabilise the running of the kiln, reduce fuel consumption and increase output, and produce a consistent quality of clinker with optimum free-lime levels. This final objective also reduces the energy required to grind the clinker. Note that the temperature is not uniform along the length of the kiln. The LINKman system monitors the NO_x, CO and O_2 levels, the temperature at the bottom of the four-stage preheater and the power required to turn the kiln. The process is optimised by controlling the feedrate to the kiln, its rotational speed, the fuel supply to the main and auxiliary burners and the speed of the kiln induced draft fan.

Economic Benefits

9% capacity increase

3% fuel saving

40% reduction in off-specification material produced.

The clinker requires less energy to grind.

Cost saving	**US$/year**
Power & fuel savings approx	**350,000**
Capital investment	**375,000**
Payback period	**less than one year**

Enabling Technology

The system has been made possible by improvements in:

The science of expert system control.

Measurement technology using a reliable and sensitive NO_x analyser.

Advantages

The wastage of coal at high temperature is avoided.

Higher quality clinker is produced.

The lining of the kiln has a longer life.

Some reductions in NO_x and SO_x emissions.

Country
Indonesia

Industry
Cement Production

Companies
PT Semen Cibinong is a cement company near Jakarta, who operate two 2000 tonne per day dry process kilns converted for economic reasons from a gas/oil fuel to a low sulphur coal.

ABB LINKman Systems of London was set up six years ago to develop expert systems and laser scanning devices. The company is now part of the Asea Brown Boveri Group.

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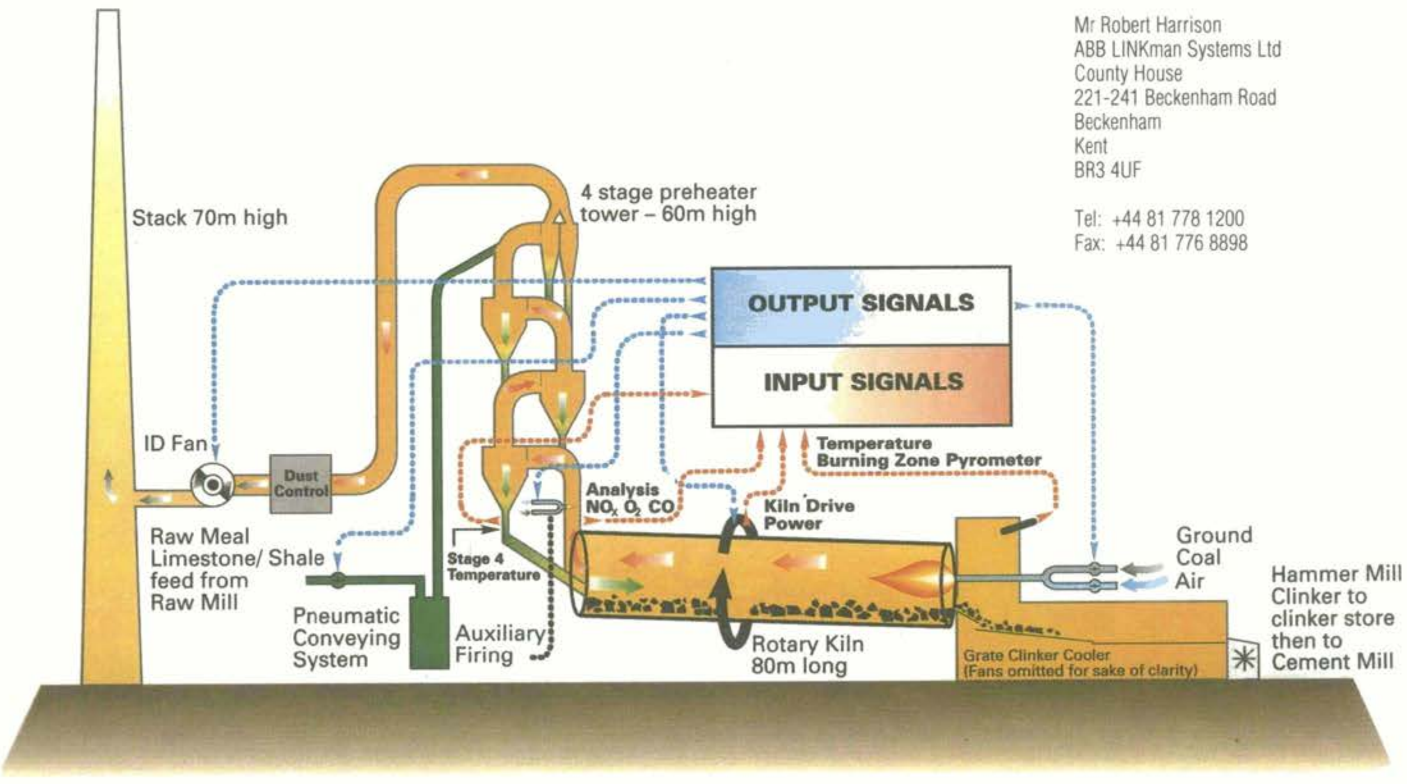

Recovery of Protein from Potato Starch Effluent

Background

The Avebe Foxhol site produces starch from potatoes. Potato starch production involves washing and grinding potatoes to produce a pulpy liquor of potatofruitwater, starch and fibres. The starch is extracted and refined by hydrocyclones, and the fibres are then separated from the liquor by centrifuge. The residual potatofruitwater contains protein, sugars and minerals at a concentration previously too dilute to recover.

The Foxhol site alone produces 2.2 million cubic metres per year of this potato water, which was originally disposed of without treatment into the North Sea and into Holland's canals. The effect was a major contamination of the waterways, the contaminants giving rise to strong odours and killing water life. This caused a public outcry.

Cleaner Production

In the late 1970's and early 1980's, Avebe made a major effort to clean up its production. After several years of test work, internal recycling has become possible by installing a reverse osmosis plant to concentrate the potatofruitwater to a level at which the protein could be recovered economically by coagulation.

The process installed at Avebe utilises open-channel tubular membranes which can handle high levels of suspended solids without clogging, and which are easy to clean. Since the concentration process is non-thermal and does not involve a change of phase, it is energy-efficient and does not change the nature of the proteins. The system which is designed for continuous operation, comprises six parallel process lines.

Following concentration of the potato water, protein is extracted from the concentrated stream by steam coagulation and dried. The product is a high grade protein concentrate used in animal feeds for small animals, such as piglets, poultry, furred animals including dogs, cats and minks. The residual potato water is evaporated and used for the enrichment of the potato fibres and incorporated in a cattle feed. The process thus produces two saleable products.

Due partly to the reverse osmosis process and partly to a counter-current extraction process installed at the same time, the volume of process water intake was reduced from 7 m^3/tonne of potatoes to 0.6 m^3/tonne, saving 17 million m^3 of water per annum. The process also recovers 1.1 million cubic metres per year of water (the filtrate from the reverse osmosis process) which is recycled within the factory to further reduce process water intake. Effluent emissions are thus greatly reduced.

Enabling Technology

Reverse osmosis is a process which separates water from dissolved and suspended solids using a membrane made of organic material.

A pressure of 40–50 Bar is applied to force water through the membrane while dissolved substances are retained. The process thus produces two streams: a concentrated liquor and clean water. The equipment is in the form of robust, open-channel membranes with the features of high retention and low-fouling.

Advantages

Major reduction in the volume of process water consumed through the recycling of wastewater.

The reduction in the quantity of water handled enables the heat coagulation and evaporation plant to be half the size, so giving capital and energy cost savings.

Production of two by-products from the effluent.

Economic Benefits

An effluent treatment problem is solved and wastewater disposal costs are avoided. Water consumption is also reduced, with further savings. Two by-products are produced, both of which generate revenue. The overall cost to Avebe of concentrating the liquor with reverse osmosis at the time of installation was approx. US\$0.54/m^3 of potato water treated. The economic benefits depend upon the market value for the by-products as well as water and wastewater charges.

Country

The Netherlands

Industry

Starch Manufacture

Companies

Avebe is the largest potato starch producer in the world. Founded in 1919, Avebe is now an international cooperative with four starch production plants in Holland, the largest being at Foxhol. The company also have plants in Germany, France, Sweden, Thailand and the USA.

PCI Membrane Systems Ltd is a specialist in membrane filtration equipment with 25 years experience in solving a wide range of effluent and processing problems. The company has a UK manufacturing base, and up to 90% of its business is exports.

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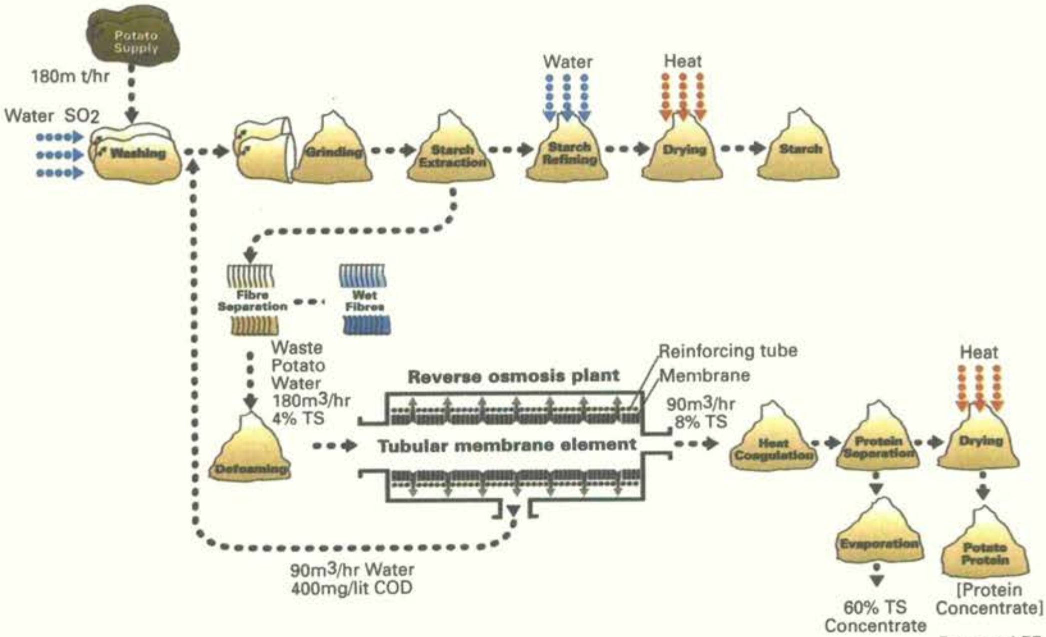


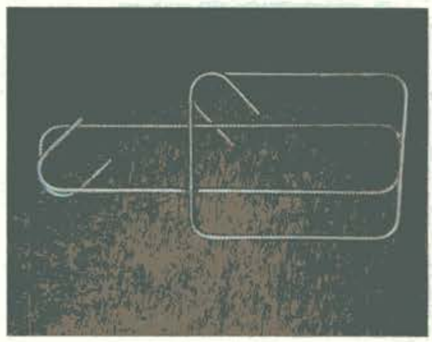
New Technology: Galvanising of Steel

Background

Galvanising is an anti-rust treatment for steel. The traditional technique consists of chemically pretreating the steel surface, then immersing it in 10–16 metre long baths of molten zinc at 450°C. The process involves large quantities of expensive materials, which increases the cost of the finished steel. In addition there are significant quantities of waste from the chemical and zinc baths. There is also the problem of fumes from these operations.

Cleaner Production

The company's objective was to galvanise steel products of constant cross-section, such as reinforcing and structural steel, tubes, wire, etc on a more compact production line, using up to two to three times less zinc, with reduced energy consumption and the suppression of all forms of pollution.



The raw steel is fed in automatically. The process can be operated continuously or in batches, depending on the material to be coated. The surface preparation is performed by controlled shot blasting. The steel is heated by induction and enters the coating chamber through a window profiled to match the cross-section of the steel. The zinc is melted in an inert atmosphere by an electric furnace and flows into the galvanising unit. The liquid zinc is held in suspension by an electromagnetic field. The speed of the production line is controlled by computer. Measuring the thickness of the coating using electromagnetic methods allows precise control of the process.

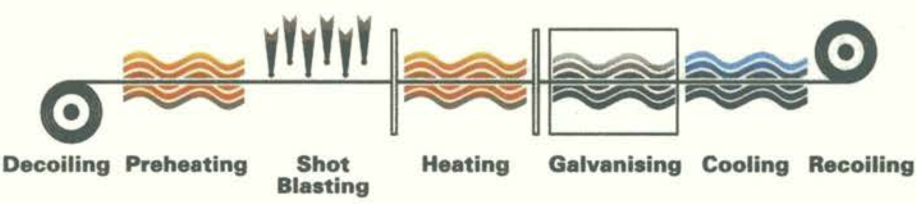
The first stage of the project has been to develop the technology for coilable material, ie wire and thin rod. The company are now developing the technology to handle rigid steel.

Enabling Technology

Induction heating to melt the zinc.

The use of an electromagnetic field to control the distribution of the molten zinc.

Modern computer control of process.



SKETCH OF THE PROTOTYPE LINE

Advantages

Total suppression of conventional plating waste.

Smaller inventory of zinc.

Better control of the quality and thickness of the zinc coating.

Reduced labour requirements. Reduced maintenance. Safer working conditions.

Economic Benefits

Capital cost reduced by two-thirds compared to traditional dip-coating process. Lower operating costs resulting in coating process being 18% of steel cost, compared to 60% with traditional methods.

Payback period three years when replacing existing plant.

Country
France

Industry
Metal Processing

Company
Delot Process S A is a company specialising in the development of new processes and services. It was founded in 1990 by Mr José Delot in partnership with Unimetal and Metaleurop, and has a staff of thirteen.

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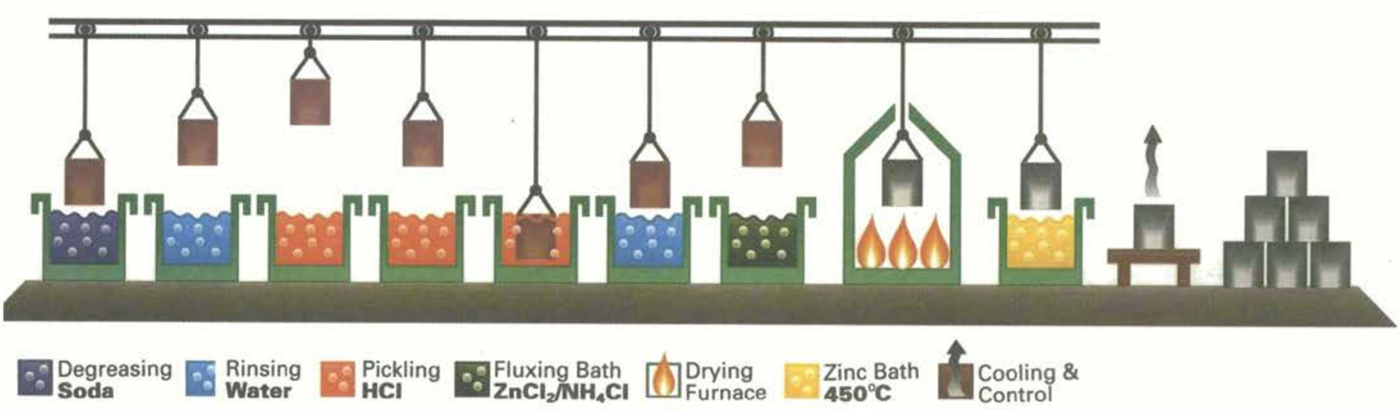


SKETCH OF A CLASSICAL HOT DIP

De-inking Process for Waste Paper

Background

This booklet is printed on Reprise paper containing almost 80% recycled fibres produced in a plant situated in a National Park in the south-west of England. Rather than just print a 'recycled paper' logo on the booklet we decided to describe the process by which waste paper is de-inked and processed into a feedstock suitable to make new paper.

The process includes a two stage de-inking treatment that allows a wider range of available waste papers to be converted to high quality printing paper.

Water is drawn from a stream passing through the plant. During the production process, the water is recycled and reused, and eventually passes to the effluent control plant. This plant treats the water by screening, settlement, and controlled microbic action. The discharges meet the strict requirements of the regulatory authority, the UK National Rivers Authority.

Pulping

The initial pulping is intended to breakdown and detach the ink from the fibres of the base paper. This process requires the use of some chemicals but the most significant factors are temperature, consistency and an efficient mechanical action. The conditions achieved disintegrate the waste paper and aid the detachment of the ink from the paper surface. This pulping stage is achieved at relatively low temperature with a low energy output. Considerable attention is given to the timing of the pulping cycle which contributes to the agglomeration of sticky contaminants and aids their removal at a later stage.

To ensure that the ink has been detached and dispersed, a sample sheet of paper is prepared and checked before the stock is diluted and discharged though a coarse dumping screen, to remove large foreign objects, to a holding tank at 5% concentration. Following further stages of progressively high density screening the stock is diluted to 1.5% concentration prior to de-inking.

First Stage De-inking

De-inking is carried out using a flotation cell which provides good de-inking efficiency and high fibre yield with minimal water and energy consumption. Flotation de-inking places a minimal load on the effluent system with both flow rate and chemical oxygen demand being kept relatively low. The process requires the generation of a foam by the injection of air in the presence of a chemical mix containing caustic soda for pH control, a proprietary 'soap' as a foaming agent, with sodium silicate and hydrogen peroxide to brighten and clean. Chemical usage is low and being progressively reduced as further technical developments allow. No chlorine bleaching is used.

Overall de-inking efficiency is aided by recirculating the liquids by pumping from the top of the cell to the bottom. The foam is removed at the top of the cell by suction heads and sent to a centrifuge where the ink-loaded sludge waste is concentrated to around 50% solids for landfill disposal. The landfill site is managed by the company and is subject to strict environmental control covering the emission of landfill gases and groundwater seepage. Special attention is given to any possible heavy metal contamination. Liquid waste is directed from the centrifuge to the effluent plant for treatment.

On leaving the cell, the de-inked stock is further diluted before passing through another fine screening process to remove small solids. The material is then pumped to a drum thickener prior to the dispersion stage.

Dispersion and Secondary De-inking

Dispersion is carried out at the lowest acceptable temperature (to minimise energy requirements) and is designed to complement the preliminary dispersion action in the pulper. Thickened stock is progressively dewatered to around 40% concentration in preparation for the kneader disperser stage which breaks down the ink/fibre bonding of more difficult printed materials.

Dewatering ahead of kneading is an essential requirement but throughout the entire process emphasis is placed on water recovery and re-use.

The intermediate dispersion stage contributes substantially to the reduction in dirt particles in the finished paper and allows the processing of a wider range of waste papers. The kneading action grinds down contaminants and produces an unavoidable 'greying' of the stock, however, the 'whiteness' is more than regained through the second stage of flotation de-inking which follows.

While operation of the second cell is similar to that of the first, no further chemicals are added, as the inevitable carry-over from the first stage is sufficient.

Following de-inking, the stock is pumped to a second drum thickener from which, at around 6% concentration, it is available to be blended with other constituents, if required, ahead of the papermaking process.

Advantages

The process allows the use of a wider range of printed waste paper.

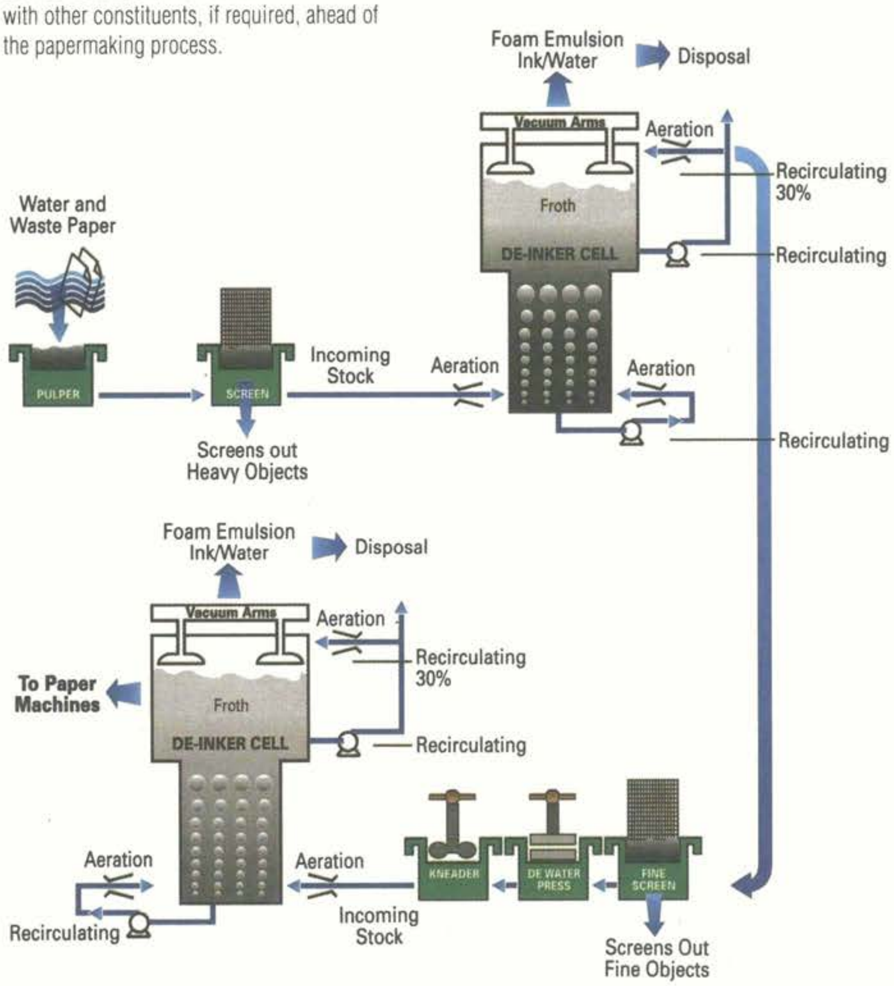
The amount of dirt in the finished paper is reduced thereby improving quality and reducing the amount of reject paper.

The brightness of the finished paper is improved without the use of chlorine bleaching.

The energy requirements are low.

The demands on effluent and waste disposal are minimal.

The plant is safe to operate giving minimum risk to personnel and the environment.



Country
United Kingdom

Industry
Paper making

Company
St Regis Paper Co Ltd is owned by David S Smith (Holdings) plc. St Regis Paper, in addition to eight paper mills, includes Severnside Waste Ltd which supplies large quantities of waste paper for recycling.

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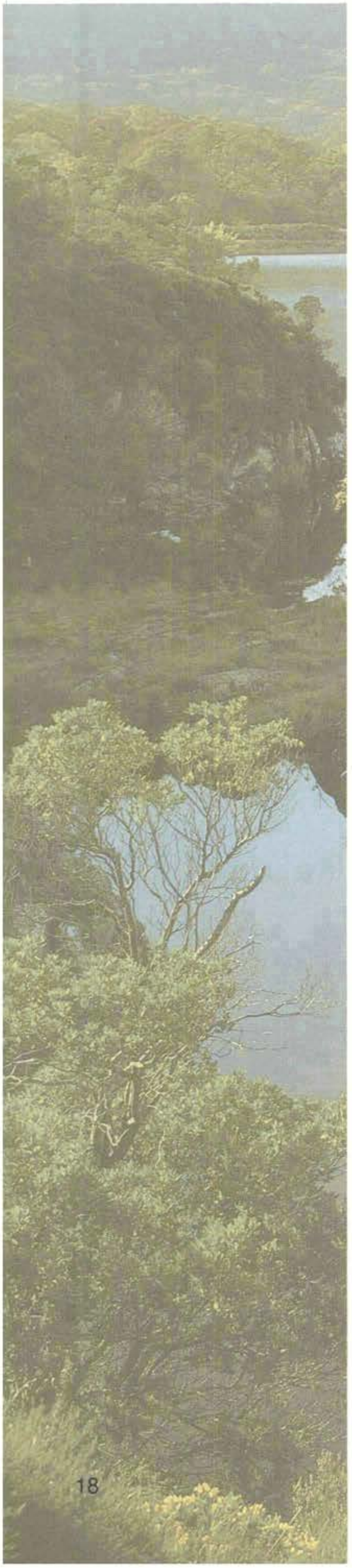
Reduction of Sulphide in Effluent from Sulphur Black Dyeing



Background

Sulphur dyes are an important range of dyes yielding a range of deep colours, but they cause a pollution problem due to the traditional reducing agent used with them. The black sulphur dye has excellent washing fastness, good light fastness and is relatively cheap.

Sulphur dyes are water insoluble compounds that have first to be converted into a water soluble form and then into a reduced form having an affinity for the fibre to be dyed.

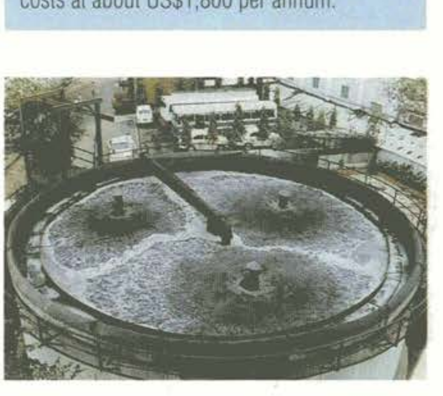
In the diagram representing the chemical equations involved, D represents the part of the molecular structure of the dye that produces the colour. The original dye ***(1)*** is dissolved in an alkaline solution of caustic soda or sodium carbonate. The dye ***(2)*** is then reduced to the affinity form ***(3)***. After dyeing the fabric the dye is converted back into the insoluble form ***(1)*** by an oxidation process. This last reaction prevents washing out of the dye from the fabric.

The traditional method of taking the original dye to the affinity form is treatment with an aqueous solution of highly polluting sodium sulphide. This causes an increase in the sulphide content of the mill's effluent. On account of its toxicity the State Pollution Control Board prescribes a limit of 2 ppm for sulphide in the treated effluent.

Economic Benefits

No capital expenditure was involved in this substitution and in fact the operating costs were found to be marginally lower. The saving in not having to install additional effluent treatment facilities was about US$20,000 in capital expenses and about US$3,000 in running expenses per annum. The substitution has not incurred any additional operating costs and there has been a considerable but unquantified saving in money and convenience due to the reduction in handling and storage.

The substitute chemical used was essentially a waste stream from the Maize Starch industry, which saved them an estimated US$12,000 in capital expenses with running costs at about US$1,800 per annum.



Cleaner Production

A study of the available methods of sulphur black colour dyeing and the treatment options was made. An investigation was also made into an alternative to sodium sulphide.

It was found that an alkaline solution of glucose could bring about satisfactory conversion of sulphur dyes. However, the high cost of glucose was the main constraint in practice.

A market survey was conducted for procuring an equivalent chemical at a competitive price. This lead to the identification of a by-product of the maize starch industry, hydrol, which contained about 50% of reducing sugars. Experiments revealed that 100 parts of sodium sulphide could be substituted by 65 parts of this alternative plus 25 parts of caustic soda. The dissolving and the affinity reactions are carried out in a single stage.

The substitution with hydrol was implemented with a redesigned mixing strategy. The dyeings obtained after this substitution were seen to be equivalent to conventional dyeings in depth of shades, fastness properties, etc, plus there were some other improvements in the quality of the dyed product. The process has been in use since April 1990 and has resulted in the reduction in the sulphide concentration of the effluent from 30 ppm to less than 2 ppm. The substitution resulted in a slight increase in the Biochemical Oxygen Demand (BOD) load on the plant but this increase was found not to be critical and was easily manageable with the existing biological treatment system.

Enabling Technology

Theoretical understanding of the chemistry involved and a search for suitable reagents.

Advantages

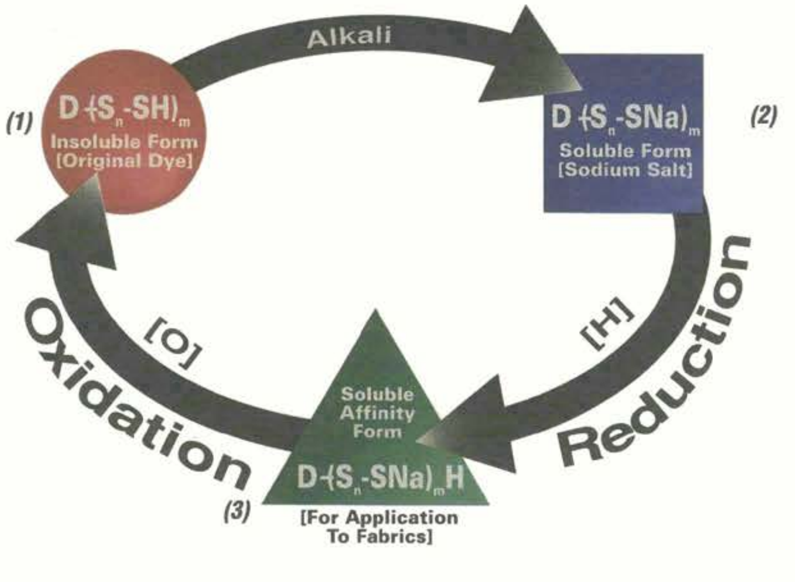
Reduction of sulphide in the effluent.

Improved settling characteristics in the secondary settling tank of the activated sludge unit.

Less corrosion in the treatment plant due to reduced sulphide levels in the effluent.

The foul smell of sulphide in the work place was eliminated.

THE DIFFERENT FORMS OF SULPHUR DYE



Country
India

Industry
Textiles

Company
Century Textiles and Industries Limited was established in Bombay, India in 1897. Its Textile Division employs 7,000 workers. The Company manufactures 100% cotton yarn and fabrics and is the world's largest exporter of 100% cotton fabrics. The turnover of the Textile Division for the year 1991–92 was US$99.75m, with 80% of its production being exported. The company has won many national and international awards for export performance and energy conservation.

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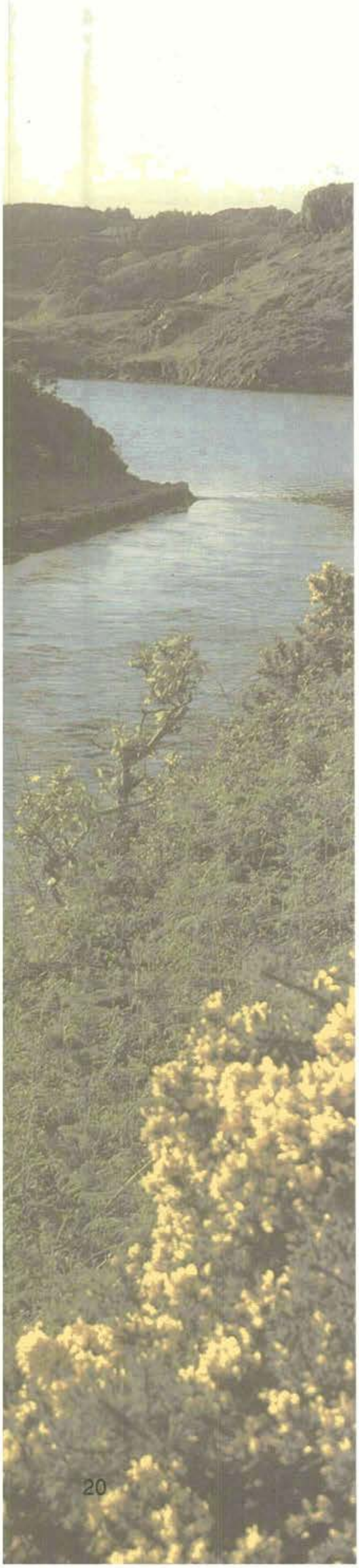
Waste Reduction in Electroplating



Background

FSM Sosnowiec manufactures automobile lamps, door locks and window winders. The lamp bodies are made of zinc-aluminium alloy and then copper-nickel-chromium plated. The door locks and window winders are made of steel and zinc plated. The waste streams contain cyanide and the following heavy metals: chromium-6, copper, zinc and nickel. The company carries out traditional treatment of detoxification, neutralisation and dewatering.

Cleaner Production

A pollution prevention audit was carried out to reduce environmental pollution, improve working conditions and improve efficiency. One of the results was that low concentration plating and pacifying is now being introduced. All of the rinsing systems have been modified so that some of the circulating (overflow) rinses have been changed to static rinses. The old and new system for chromium is shown. A similar system has been installed for nickel and cyanide. The final rinse tank in each rinsing sequence has been equipped with ion exchange columns which permit water recycling and raw materials recovery.

Advantages

A decrease in both water and raw materials consumption.

The reduction in both waste stream quantities are as follows:

chromic acid	80%
copper	95%
cyanide	80%
nickel	98%
zinc	96%
waste water	93%

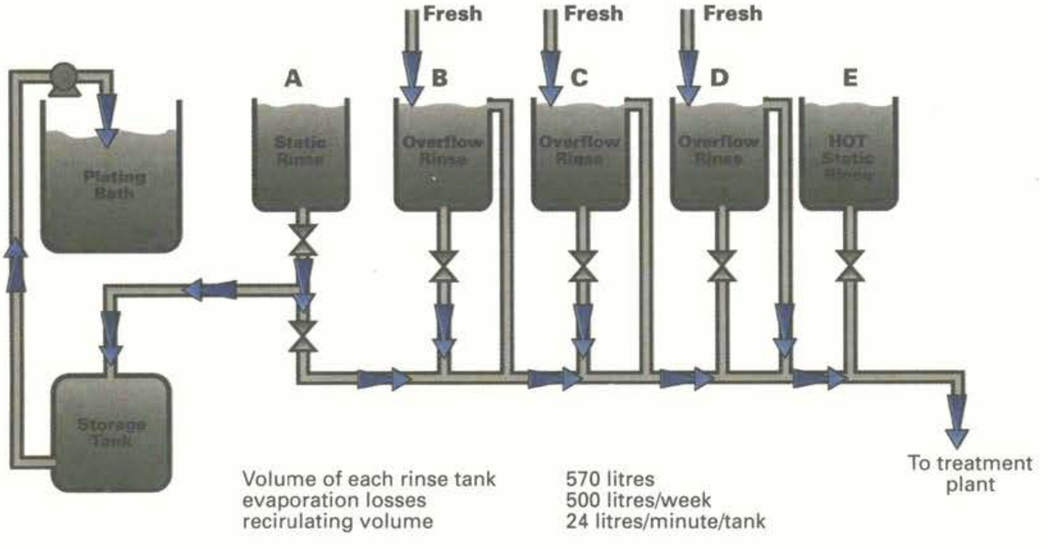
The waste water is purified to the following levels:

chromium	0.1 mg/litre
copper	0.1 mg/litre
nickel	1.0 mg/litre
cyanide	2.0 mg/litre
zinc	0.9 mg/litre

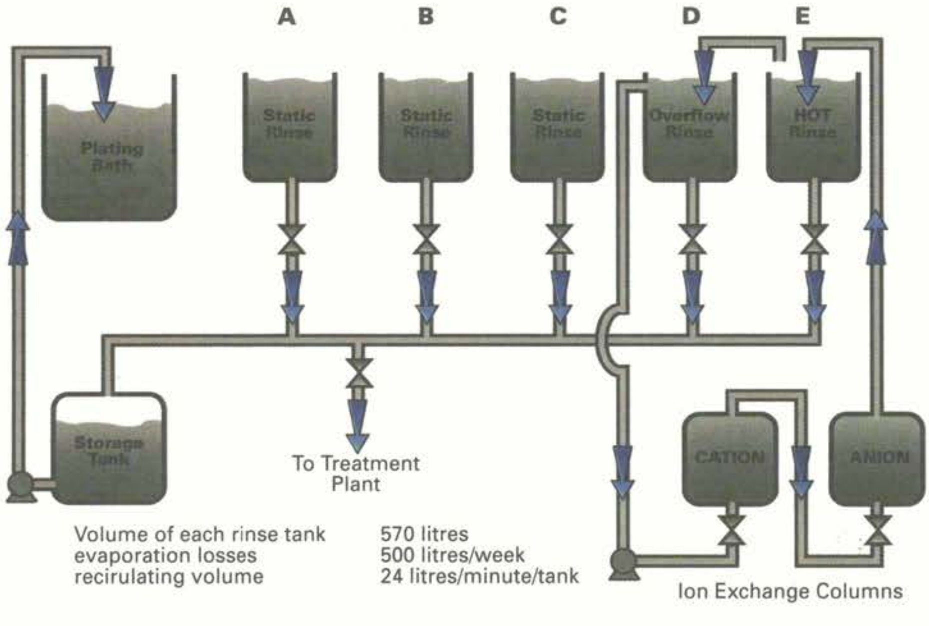
Economic Benefits

Cost saving	US$/year
Total savings	193,000 approx
Capital investment	36,000
Payback period	2 months

ORIGINAL RINSING SYSTEM



NEW RINSING SYSTEM



Country
Poland

Industry
Automobile Component Manufacture

Company
FSM Sosnowiec is a manufacturer of automobile components for the Polish manufactured FIAT cars.

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Waste Reduction in Steelwork Painting

Background

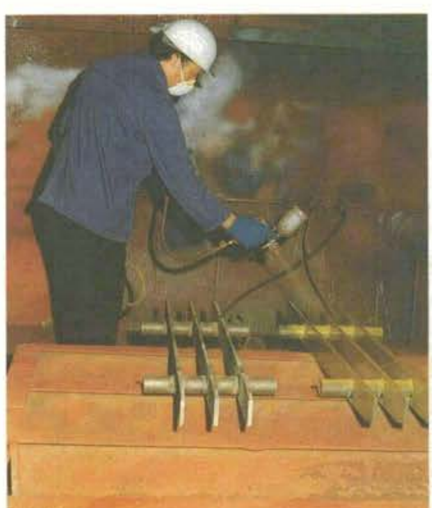
In the 'Ostrowiec' Steelworks the manufacture of steel products is carried out using production-line methods. The final operations required for almost all products are surface treatment and painting. In the Machinery Building Department these operations are carried out with shot-blasting machines and manually operated spray booths. The original painting method was air-atomised spraying which has the lowest transfer efficiency of the coating methods and yields large quantities of waste.

Cleaner Production

A pollution prevention audit was carried out to improve the environment and efficiency and working conditions in the painting areas. The objective of this programme was to reduce the quantity of wastes and costs of painting by a combination of improvements to the technology and good housekeeping. The overall aim was to improve the quality of coating, to reduce the amount of paint raw material and to reduce the quantities of wastes.

The existing painting method was compared with two more advanced painting technologies. The transfer efficiency for the different methods are as follows:

air-atomised spray (conventional)	30–50%
airless spray	65–70%
pressure atomised electrostatic spray	85–90%



In conventional spraying compressed air is used both to atomise the paint and carry it to the surface to be painted, Fig.1. With airless spraying the paint is pumped under high pressure to a small jet where the high velocity is sufficient to induce atomisation. The lack of any expanding compressed air stream eliminates unwanted spray mist, reduces the loss of paint by overspray and most of the paint adheres to the work surface, Fig.2. With pressure atomised electrostatic spray, paint is delivered at high pressure as before, but it is fed to a insulated nozzle. An electrostatic charge of about 100kV is applied to this nozzle. The charging of the paint particles assists the atomisation and causes them to repel each other. Additionally the charged paint moves along the field lines to the earthed work piece. As the electrostatic field lines envelop the object the paint particles cannot fly straight past, but 'wrap' themselves uniformly around the surface. It is this effect that gives the high paint efficiency and reduces waste, Fig.3. Note that electrostatic hand spray guns require a small mains transformer and a very reduced current to avoid accidental electrical shock. Tests carried out with the two improved painting methods showed the following results:

Comparison of raw material consumption and waste quantities of the different methods:

	Air-atomised spray	Airless spray	Pressure atomised electrostatic spray
Paints	8.0 m^3	6.8 m^3	5.6 m^3
Solvents	6.5 m^3	1.6 m^3	1.6 m^3
Wastes	2,400 kg	1,400 kg	500 kg

Advantages

Reduction of high disposal costs.

Reduced running costs.

Decreased financial liability by generating a smaller quantity of hazardous wastes.

Improved public perception and acceptance in the business community.

Also indicated were potential reductions in the effluent concentrations of about 45% for sludge and 75% for organic solvents.

Economic Benefits

(Estimates, based on Trials)

	Airless spray	Pressure atomised electrostatic spray
Cost saving	**US$/year**	
Total savings	**38,500**	**39,400**
Capital investment	**US$4,800**	**US$13,000**
Payback	**1.5 months**	**4 months**

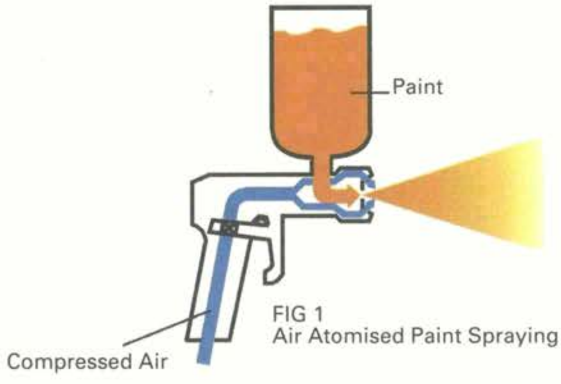


FIG 1
Air Atomised Paint Spraying

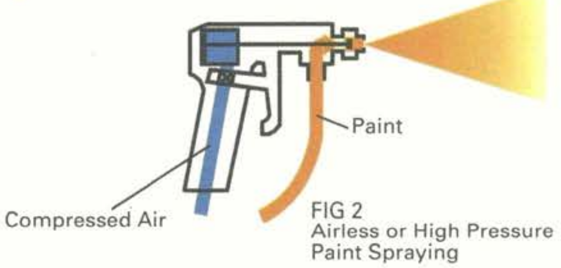


FIG 2
Airless or High Pressure Paint Spraying

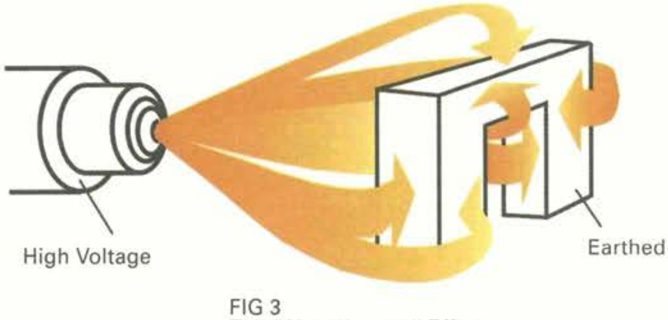


FIG 3
The 'Wrap-Around' Effect of Electrostatic Paint Spraying

Country
Poland

Industry
Iron and Steel Industry

Company
The 'Ostrowiec' Steelworks consists of eleven Departments, the main production departments are Steelworks, Processing, Steel Construction, Machinery Building and the Foundry.

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New Product: Water-Based Adhesives

Background

Blueminster have developed the technology of water-based adhesives by the production of a wide range of resin dispersions which enable solvent-free adhesive systems to improve upon and replace solvent-based adhesives. Water-based adhesives have a much higher solids content than solvent-based adhesives and less energy is required to remove water from the adhesive film. Various trials have been carried out and small-scale production has started.

Cleaner Production

When solvent-based adhesives are used the components of the adhesive, normally a polymer and a resin, (capable of becoming tacky), are dissolved in a suitable organic solvent. The adhesive film is obtained by laying down the solution and then removing the solvent by evaporation. In many adhesives, the solvent is a volatile organic compound (VOC) which evaporates to the atmosphere thus contributing to atmospheric pollution. In other cases, the solvent is removed by high energy drying and, in some cases, subsequently recovered. Hot-melt adhesives, which do not use solvents, are also high energy consumers.

These new adhesives are now finding application in flooring and mounting large sheets in exhibition and studio use, pressure sensitive tapes, food packaging and labelling, including use at low temperatures for frozen food.

Economic Benefits

The benefits are derived mainly from the lack of use of solvents and can amount to significant savings on equipment, raw materials, safety precautions and overheads.

Users have not been prepared to release any information on economic savings at this stage.

Enabling Technology

Blueminster have developed resin dispersion technology that can be applied to a very wide range of resins that have the necessary 'tackifying' properties. These resins are free from organic solvents, proteins and starches and are compatible with most polymer dispersions in all proportions. The dispersed resins remain liquid at all practical temperatures and, when intimately mixed with the polymer, allow uniform continuous adhesive films to be laid down having a very high degree of flexibility.

Advantages

Water-based adhesives are non-toxic, they do not pollute the atmosphere or water systems, they do not require special handling and are not a fire hazard.

Solvent-based adhesives require three to five times the drying energy of water-based adhesives, which need no special solvent recovery systems or explosion-proof equipment.

Water-based adhesives can generate higher levels of adhesion through penetration of absorbent substrates, such as cellulose, and will also allow more time for the precise positioning of adherents.

Particularly suitable for food packaging.

Country

United Kingdom

Industry

Adhesives

Company

Blueminster Ltd is a small research-based company which was founded as a chemical consultancy in 1981.

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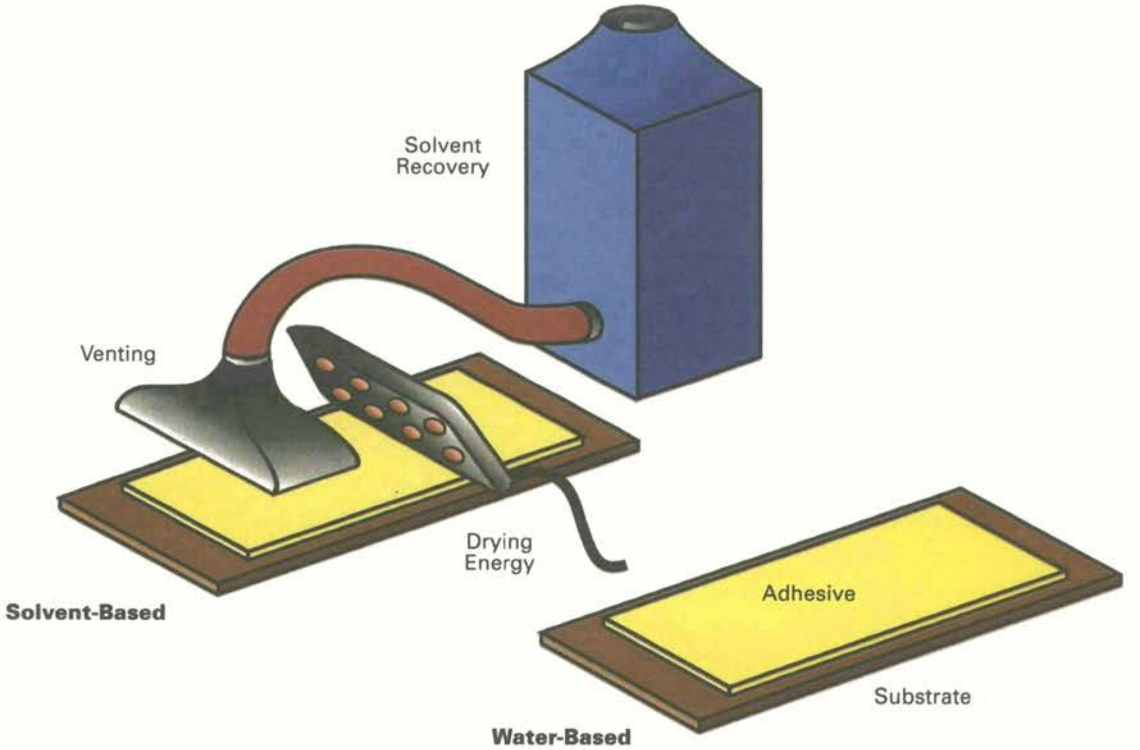
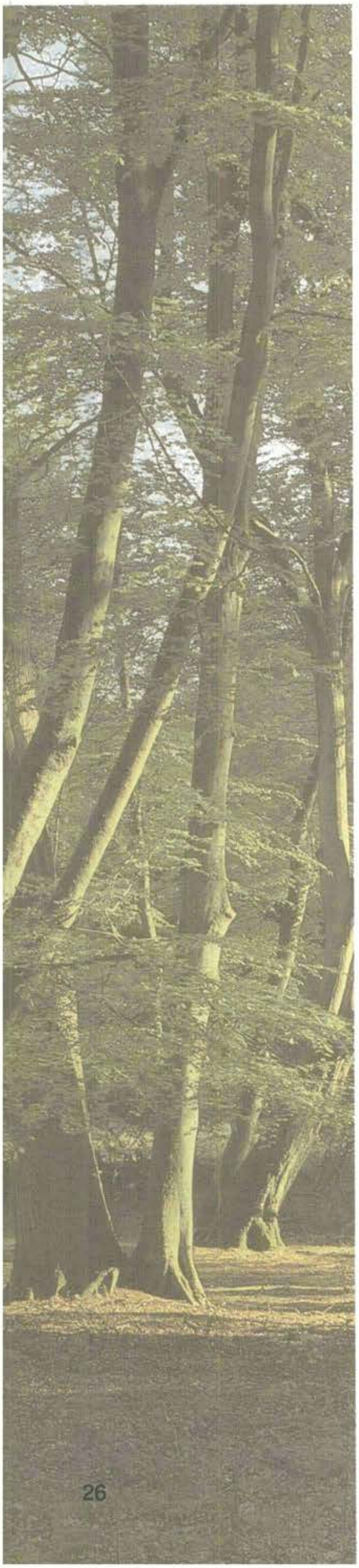


THE ADVANTAGES OF WATER-BASED ADHESIVE DRYING

Cleaner Production in a City-based Project



Background

The Environmental Protection Agency of the City of Graz in Austria and the Chemical Engineering Institute at Graz University of Technology combined together to put forward a clean technology initiative called **ECOPROFIT**, **ECO**logical **PRO**ject **F**or **I**ntegrated environmental **T**echnology in April 1991.

Eleven companies and their suppliers co-operated to carry out a total of 26 projects. We give here details of some of the projects carried out by just two of the companies in the first year. Company information is on p29. Three projects relate to a printing company and three projects relate to an automobile repair company. Substantial improvements in air emissions and wastes have been achieved. Emissions of halogenated hydrocarbons and some toxic wastes could be reduced by 100%. The emission of volatile organic compounds (VOC's) have been reduced in some instances by 70–90% and several substances are now recycled. There have also been substantial cost savings.

Cleaner Production

PRINTING SHOP EXAMPLES

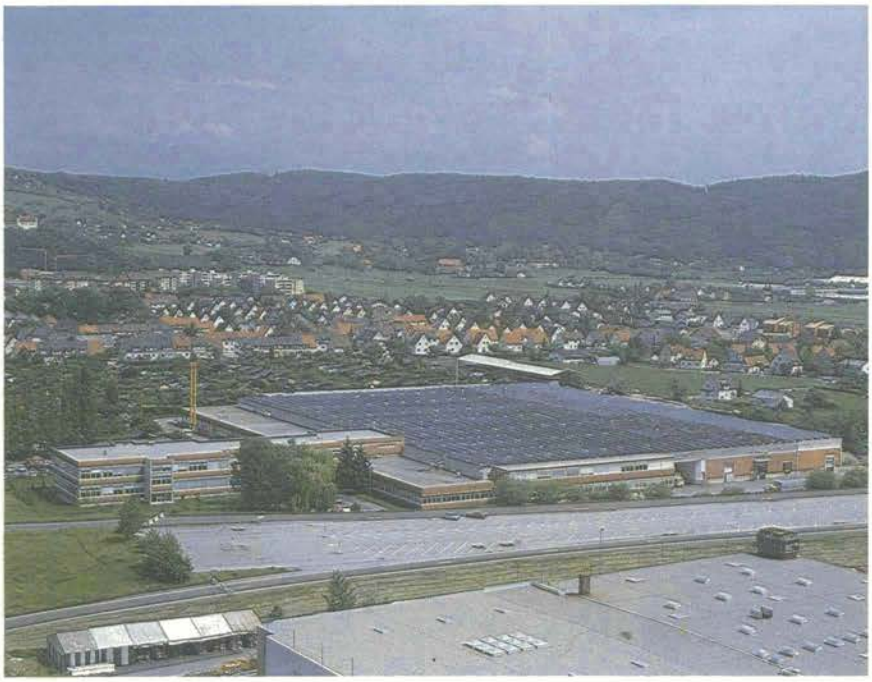
Alfred Wall's three projects involved (a) Ink in Bulk, (b) Mixing of Ink and (c) 'Good Housekeeping'.

(a) Ink in Bulk

Even large users of inks have the ink delivered in containers of 1 – 2.5 kg. This entails a large number of empties that have to be disposed of as hazardous waste, because of the contamination with ink. The drying process of inks also causes considerable emissions to the air. The development has been a system for delivering ink in 25 to 300 kg barrels, known as 'ink fountains', which are refilled by the manufacturer. The ink is transferred to the printing machine under pressure, so reducing solvent evaporation. The advantages of these bulk containers are: less work and time needed for handling, no problems of disposal, reduced pressure on the environment, reduction in cost from the previous empties disposal and no ink is wasted.

So far this method has only been introduced for black ink, but will be progressively introduced for the more popular colours.

The ink suppliers were: K & E Farbbrunnen, Vienna, Austria; Stehlin & Hostag AG, Lachen, Switzerland and Prismatec GmbH, Bad Camberg, Germany.



(b) Mixing Inks for Gravure Printing

Similarly in this operation, when printing jobs were finished there were a large number of partially filled containers with expensive materials including pigments, fixing agents and solvents left in them. The materials left in the containers also created an expensive hazardous waste problem as a cleaning process was required that in itself created further effluent for disposal.

The inks are now delivered in large containers (200 litres). Surplus ink is now returned to the containers as the containers are fitted with a stirring mechanism which prevents the settling of the suspended ink pigments even during long periods of storage. These more expensive containers are simply refilled by the manufacturer once they are empty. The evaporation of solvent that previously occurred in handling has been reduced substantially. A computer controlled mixing and dosing system has been developed which facilitates optimal dosing. This also contributes to the reduction of emissions, as mistakes during mixing are largely eliminated. Alfred Wall AG designed and built the equipment using their own resources.

(c) Good Housekeeping

The disposal of waste paper and cardboard resulting from printing processes is usually expensive due to the need to carry out de-inking before recycling of these valuable materials. Alfred Wall AG carried out an energy and mass balance on their processes which showed that between 20 and 30% of the waste paper need not be produced. Some other improvements in the production process were also shown up immediately.

CAR REPAIR WORKSHOP EXAMPLES

Salis and Braunstein's three projects involved (a) working with two-component paints, (b) repair of automobile air-conditioning units and (c) mixing systems for topcoat paints.

(a) Working with two-component paints
Single component paints do not have sufficient chemical and physical strength to be used on cars and therefore two-component systems are used. Two-component paints have a hardener which reacts chemically when mixed. This mixed paint has to be used within hours or it dries up and has to be disposed of as an expensive hazardous waste.

The solution was to mix the two components in a specially designed metering hopper. A more exact dosage of paint was possible guaranteeing a good surface and reducing the amount of sanding and the production of dust. In the spray gun itself the compressed air is heated up to 85°C, causing the paint to heat up to 65°C. This ensures that even paints with a solids content of up to 70% can be mixed without any problems. A pulsating air flow also aids the subsequent cleaning of the device, reducing the use of cleaning fluids by a factor of four.

(b) Repair of automobile air-conditioning units
Up to 5% of new cars in Austria have an air-conditioning system containing 1–1.5 kg of chlorofluorocarbons, CFC's, (usually CFC-12). Major repairs of the units entailing a refill of CFC generally occur three times during the ten year life of the vehicle. It is estimated that 27 tonnes of CFC per year are released from the repair of these units and 2.5 tonnes are released with the scrapping of vehicles.

This cleaner production exercise suggests that only repair agents who have facilities for extraction of the CFC should be allowed to carry out such repairs to air-conditioning units. Garages that carry out less than 50 air-conditioning repairs a year should use CFC extraction units. These suck out the refrigerant which can be recycled (or destroyed) by the manufacturer If more than 50 repairs per year are carried out, combined extraction and recycling units should be used. Currently only 12% of Austrian garages have facilities for extracting or recycling CFC.

Additionally it is suggested that CFC-12 (CCl_2F_2) is replaced by HFC-134a ($C_2H_2F_4$) which has an eleven times less affect on the ozone layer. Unfortunately units must be

designed for HFC-134a and existing units cannot simply be recharged with the new refrigerant.

The total cost of recycling equipment for CFC-12 is US$3,300 whilst for HFC-134a it is US$5,700. At the moment HFC-134a costs more than CFC-12, but this factor is likely to decrease with its increasing use and the effect of the Montreal Protocol ban on CFC-12 production.

This study was based on 1991 figures and work from the air-conditioning system supplier Ginner of Vienna, Austria and the refrigerant supplier Bruckner & Novak KG of Wr. Neudorf, Austria.

Editors note: Some British made Rolls-Royce, Jaguar and Rover cars are now fitted with Klea 134a based air-conditioning units.

(c) Mixing systems for Finalcoat Paints
A repair shop will require a very large number of colours for the vehicles likely to come in for repairs. The paints have to be prepared using fixed quantities of paint, taken from 0.5, 1, 2 and 3 litre cans. To spray a fender or mudguard takes only 0.3 litres of paint, but the minimum that can be prepared is 0.5 litre. Similarly to spray a hood or bonnet takes 0.7 litre of paint, but 1 litre has to be mixed. Not only is this wasteful of paint, but there is always the disposal problem.

It is suggested that computerised paint mixing systems could easily be developed that would dispense 40,000 shades of colour using only a hundred basic colours, in quantities of 0.1 to 6 litres. It is estimated that systems could be produced for US$4,750–US$9,520 and that the payback period could be as short as 1 year, depending on the throughput of the paint shop. These estimates are based on information supplied by Austro Lesonal GmbH and Elixhausen of Austria.

Results

The overall results from these studies showed that the following reductions could be achieved.

Printing shops

solvent emissions	90%
metal hydroxide sludge (preparation of cylinders)	40%
wash water (reproduction)	90%
use of chemicals (reproduction)	70%
waste of small containers (lithographic printing)	50%

Car repair workshops

halogenated materials	100%
oil-containing materials	100%
solvents	> 50%
waste	30%

Economic Benefits

Cost saving	**US$/year**
Based on 10 car respray jobs per day	50,000
Capital cost	**US$13,000**
Payback	**3 months**

Material and emission reduction

hardener	30%
sanding	15%
solvents	1,400 kg
dried-up paints/ hazardous waste	350 kg

The equipment supplier was MGV Moest, Landsberg, Germany.

Country
Austria

Industry
Printing
Automobile Repair

Companies
Alfred Wall AG is Austria's largest printer of wrapping materials. It was founded in 1868 and is one of the largest and most modern companies of its kind in Europe. In spite of this it has found further opportunities for cleaner production. The company has 500 employees and a turnover of US$100m.

Salis and Braunstein was formed in 1938 with two car mechanics and an apprentice. In those days there were only 33,000 cars in all Austria. Nowadays, there are three million cars, and Salis and Braunstein employ 235 people. The company has a turnover of US$80m.

Contact
This programme of cleaner production projects was instigated by

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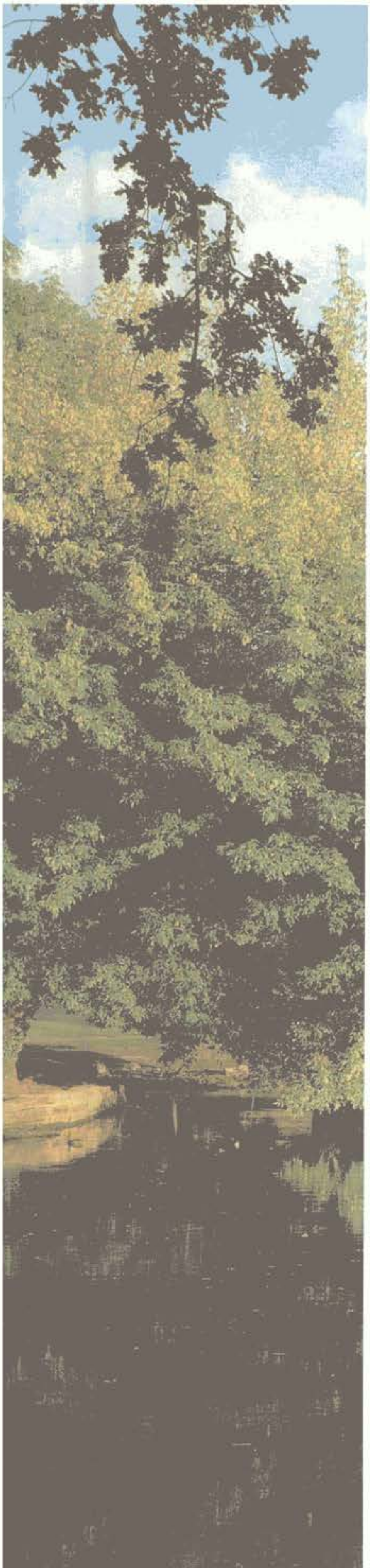
Minimisation of Organic Solvents in Degreasing and Painting



Background

Thorn make light fittings from aluminium or steel sheets. Metal working, degreasing and painting are the main phases in this production process. The degreasing of the metal sections has been carried out in the past by using the volatile organic compound, trichloroethylene, which is a pollutant and is now recognised as an environmental hazard.

The painting plant consisted of an automatic liquid lacquer line, with differing colours using different organic solvents. The air pollution and the accumulated remaining products were a considerable problem, both within the plant and externally.

When the company planned to expand production the local authorities ordered the company to reduce its current air emissions. As a result the company intended to install equipment to capture the trichloroethylene and incinerate the solvents from the painting plant. However, an independent research organisation, by carrying out a pollution prevention audit, suggested an alternative approach having environmental benefits.

Cleaner Production

The pollution prevention audit started with an analysis of the material flow in the degreasing process. It was shown that by better housekeeping, the need for trichloroethylene degreasing could be reduced by 50%, but this has now been cut to zero. The cutting of aluminium sheets required cutting fluids which were difficult to remove without the use of chlorinated solvents. A change to biodegradable cutting oils allowed an alkaline degreasing procedure in place of the previous trichloroethylene method.

The degreasing is carried out in a new piece of equipment in the form of a totally enclosed 'tunnel', 30 metres long. The metal products are suspended from an overhead conveyor and then pass through five zones where they are sprayed with various liquids. The stages carried out are degreasing, water rinse, iron phosphating to aid the adherence of the paint, water rinse, a de-ionised water rinse and drying. The liquid runs off the metal items into tanks below where it is recirculated back to the spray nozzles.

Electrostatic powder painting uses polymer based paints that do not have any solvent in their formulation. A long-term problem was that of changing to a different colour of paint. This is now accomplished by changing the whole module with containers of different colours. The company has now installed a new electrostatic powder painting line having twelve automatic powder guns. The paint is positively charged relative to the metal items. Now only 5% of the colours have organic solvents and are used only for the painting of short production runs in special colours or for retouching of the automatically sprayed items where necessary. Manual spraying is carried out in a ventilated booth fitted with two electrostatic guns.

Economic Benefits

The alkaline degrease turned out to be US$25,200 cheaper a year than the trichloroethylene degrease and did not require the installation of recovery equipment.

The powder painting techniques have led to considerably lower working costs. The following costs for solvent painting have disappeared with the use of powder painting.

Cost savings	US$/year
Paint	206,000
Cleaning	62,000
Disposal	47,000
Pumping	33,000
Labour	112,000
Total	**460,000**
Capital Investment	**US$430,000**
Payback	**11 months**

Advantages

Changed degreasing techniques

The environmental advantages that have been achieved are external and also within the workplace. The company more than adequately meets the demands from the authorities.

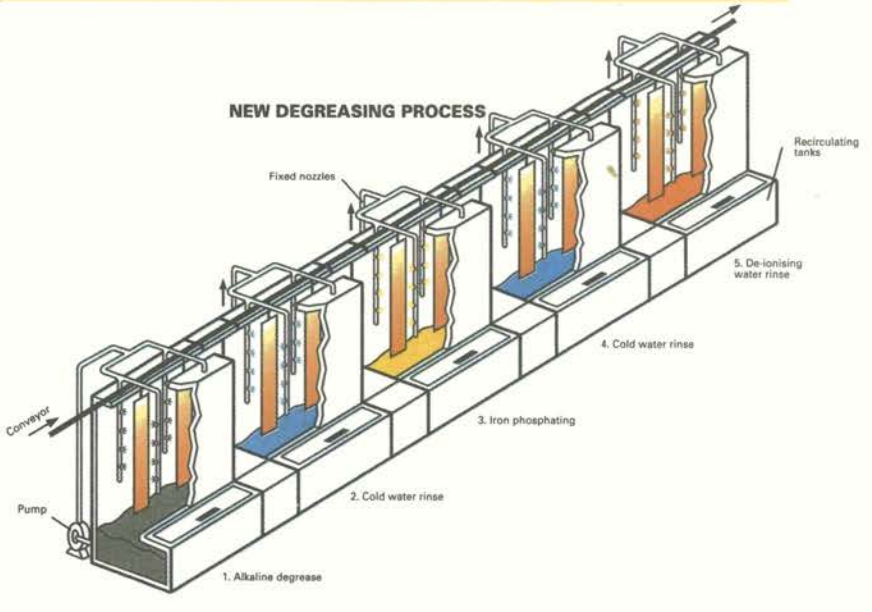
Environmental charge per annum	Previous trichloroethylene degrease	Present alkaline degrease
Air emission	11 ton trichloroethylene	0
Water emission	0	water purification plant
Hazardous waste	5 ton trichloroethylene sludge	< 2 ton sludge

The water purification plant, which is also used for other process baths, can be used for the alkaline degreasing too and results in little additional water pollution from the degrease stage.

Changed painting techniques

The environmental advantages are considerable with a large reduction of the discharge of organic solvents, reduction of hazardous waste, improved work environment and a situation which enabled production to expand without conflicting with environmental demands.

Environmental charge per annum	Previous liquid lacquering	Present powder painting (including 5% liquid lacquer)
Air emission (organic solvents)	65 ton	7 ton
Hazardous waste		
Solvents	10 m^3	2 m^3
Colour residues	47 ton	0.2 ton
Powder residues	< 0.5 ton	3 ton



Country
Sweden

Industry
Metal fabrication

Company
Thorn Järnkonst produces lighting fixtures for indoor and outdoor use. The production amounts to 750,000 units. They employ about 650 people and the turnover is US$93.45m per year. In 1988 the company merged with Thorn EMI, the main branch being in England.

Suppliers
5-zone degreasing plant – Br Michaelsen AB, Kungälv, Sweden

Automatic powder plant – Gema-Volstatic AG, St Gallen, Switzerland

Manual powder painting plant – Eisenmann AG, Böblingen, Germany

Contact
Egon Conradi/Lars Blomqvist
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P O Box 305
S-261 23 Landskrona
Sweden

Tel: +46 418 52000
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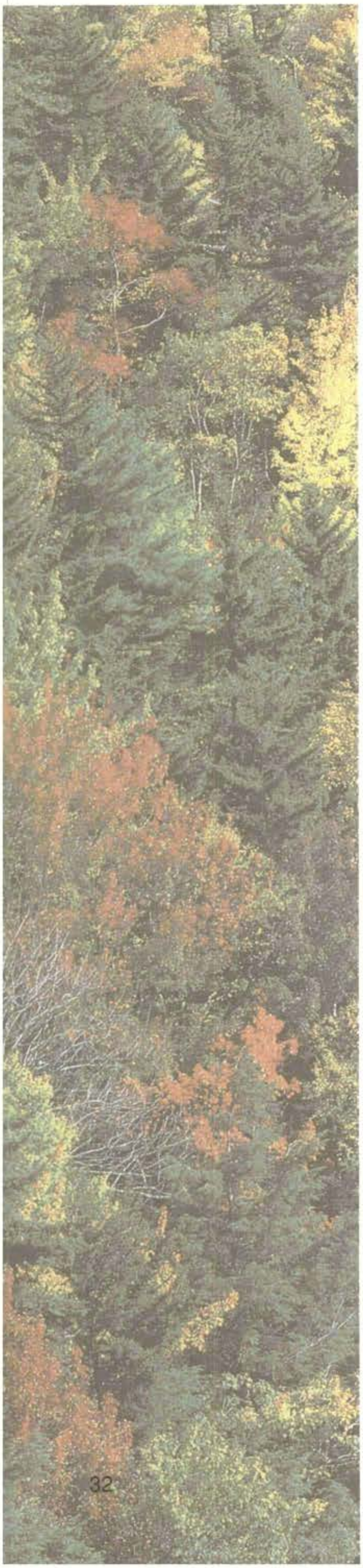
Recovery of Copper from Printed Circuit Board Etchant



Background

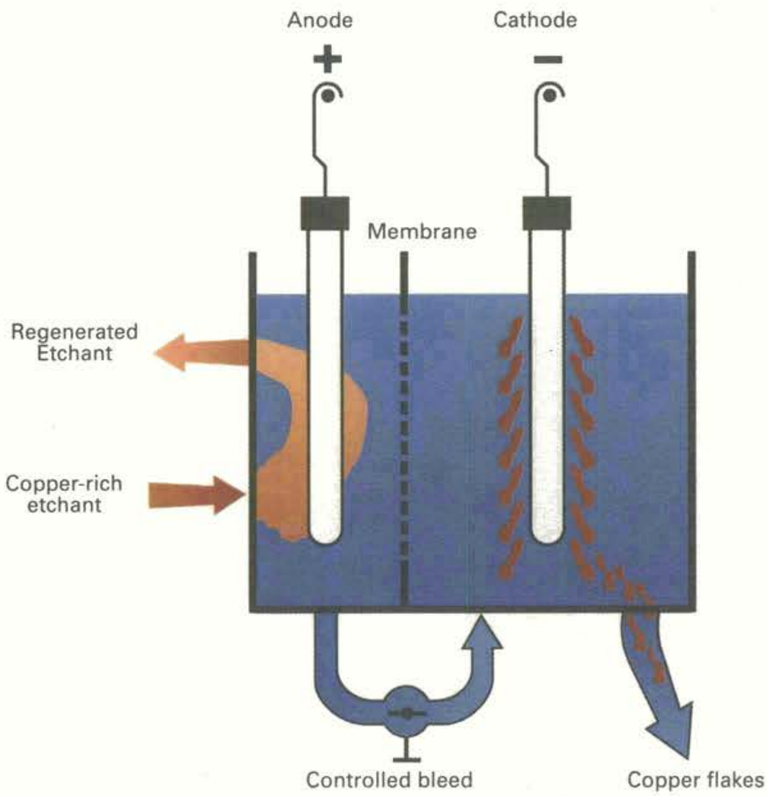
In the manufacture of printed circuit boards, the unwanted copper is etched away by acid solutions of cupric chloride, see Equation 1. As the copper dissolves, the effectiveness of the solution falls and it must be regenerated. The traditional way of doing this is to oxidise the cuprous ion produced with acidified hydrogen peroxide. During the process the volume of solution increases steadily and the copper in the surplus liquor is precipitated as copper oxide and usually landfilled.

Cleaner Production

The original proposal for recovering the copper in high quality form came from the UK Electricity Research Council. Using an electrolytic technique involving a divided cell, simultaneous regeneration of the etching solution and recovery of the unwanted copper is possible. A special membrane allows hydrogen and chloride ions through, but not the copper. The copper is transferred via a bleed valve and recovered at the cathode as pure flakes, see Equation 2.

IN THE ETCHING PROCESS

Equation 1 $$Cu + \underset{\text{cupric chloride}}{CuCl_2} \xrightarrow{\text{acid}} \underset{\text{cuprous chloride}}{2CuCl}$$



IN THE ELECTROLYTIC PROCESS

Equation 2 $$2CuCl \rightarrow \underset{\text{goes to anode}}{CuCl_2} + \underset{\text{goes to cathode}}{Cu}$$

Enabling Technology

The development of a suitable cell dividing material. The process development where the excess etchant is pumped to the recovery circuit and the copper is obtained in a recoverable form. Control of the process by means of the oxidation-reduction potential.

Advantages

The quality of the circuit boards is improved.

The disposal costs are virtually eliminated.

The etching solution is maintained at its optimum composition.

The copper is recovered in high value form.

There are no hazardous chemicals to be handled.

Economic Benefits

Based on 50 tonnes of copper recovered per year

Cost saving	**US$/year**
Copper	50,000
Materials	80,000
Disposal	25,000
Total	**155,000**
Capital Investment	**220,000**
Payback	**18 months**

Country

United States of America

Industry

Printed Circuit Board Manufacture

Companies

Praegitzer Industries Inc, founded in 1981, is a leading designer and manufacturer of advanced circuit boards. The company employs 500 people in three locations.

FSL was founded in 1967 to supply automated etching machines for the large scale production of printed circuit boards. They have a staff of 55 in the UK, have subsidiary companies in Germany and the USA and export through agencies to many countries throughout the world.

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Woburn Road Industrial Estate
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MK42 7BU

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The United Nations Environment Programme

UNEP is dedicated to bridging the gap between awareness and action. Since it was created in 1972 it has worked closely with other members of the UN network and forged new relationships among scientists and decision-makers, engineers and financiers, industrialists and environmental activists on behalf of the environment. It seeks the balance between national interests and the global good, aiming to unite nations to confront common environmental problems. Unique among UN bodies, it exists as a catalyst, spurring others to act and works through and with other organisations, including UN agencies, industrial bodies and governments.

The Industry and Environment Programme Activity Centre

The IE/PAC dates back to 1975. The office was created by UNEP to bring together industry and governments to work in cooperation towards environmentally sound development.

The UNEP-IE/PAC Cleaner Production Programme

This programme was launched in response to a decision from the UNEP Governing Council to reduce global pollution and waste.

The objectives of the programme are to:
- Increase worldwide awareness of the cleaner production concept;
- Help governments and industry develop cleaner production programmes;
- Foster the adoption of cleaner production throughout society;
- Facilitate the transfer of cleaner production technologies.

To meet these objectives, the programme focuses on training and the collection and dissemination of information on cleaner production that:
- Explains the concept;
- Illustrates technical applications;
- Helps people develop cleaner production programmes.

These efforts, initiated through a number of different activities, have cultivated an ever expanding informal network of cleaner production experts, both in industry and government agencies. Further details are available from the IE/PAC Office in Paris.

What to do next?

There is a variety of information and advice available from:

United Nations Environment Programme
Industry and Environment
Programme Activity Centre
Tour Mirabeau
39–43 quai André Citröen
75739 Paris Cedex 15

Tel: +331 40 58 88 50
Fax: +331 40 58 88 74
Telex: 204 997F
Cables: UNITERRA PARIS

TELEPHONE NUMBERS:

Note that all telephone numbers in this booklet have been shown in the internationally agreed format. The plus sign indicates the code for international dialling for the country you are in, these are generally different for each country. The next group of figures are the unique code for the country into which you are dialling. If you are telephoning from the same country, the international code is not required, but you may need a national code, often a zero.

UNEP

United Nations Environment Programme
Industry and Environment
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France

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