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GOING FOR ZERO

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In this work, we are looking for possibilities to put a Zero Emission program into action in Austria; we present four case studies carried out at Austrian companies. A short discussion of the case studies follows:

- Steel Production: This enterprise produces steel out of scrap metal. We propose a solution to reuse the waste heat of the smelter exhaust gases for the production of electricity.
- Coating of Vehicle Bodies: Here we are looking for possibilities to close the water cycles of different coating baths and rinses, because the company wants to reduce the chemical oxygen demand (COD) of its waste water.
- Production of Medical Infusion Solutions: The main emission is waste water in drinking water quality at a temperature of about 40°C. We were able to show that this waste water can be reused as cooling water in a closed loop.
- Mobile Dish Washer: In the city of Graz it is obliged to rent a mobile dish washer at large open air events requiring an official approval. We found a solution to close the water cycle of the "dish – mobile". Therefore, it can operate a few days without any fresh water supply.

Keywords: zero emission; cleaner production

Zero Emission Research

This project is inspired by ZERI, the Zero Emission Research Initiative at the United Nations University UNU founded by GUNTHER PAULI [1]. The aim of this Initiative is the reduction of all industrial emissions to zero. We would like to initiate a Zero Emission program in Austria.

In general, waste is nothing more than previously bought raw materials intended for products causing enormous costs. In extension of Cleaner Production measures we are searching for the reasons of this ineffective usage of raw materials and we try to reduce these emissions to zero.

Definition of Zero in Zero Emissions

During our work, we discovered that zero must not be interpreted as zero in a chemical analytical sense. If the concentration and the total mass flow of a substance in an emission are smaller than natural fluctuations in geogenic flows, we will assume that there is not any impact on the environment. We call these emissions "Zero – Emissions".

The input of any process has to be considered as well. The usage of renewable resources must not exceed the natural rate of replenishment. If non-renewable resources are used, the yearly exploitation must not exceed a quantity, which guarantees future generations further chances of development.

For further considerations a way to measure Zero has to be found. A possibility to measure the potential impact of an emission on the environment is the calculation of the Sustainable Process Index (SPI) [2]. The SPI concept considers everything leaving a process as an emission, in this sense a product is just an emission later. Using the SPI, you become aware of typical problems connected with indicators. The problem with the SPI, as with all other environmental indicators, is that the available data on dissipation and degradation of substances in nature are still very few and little is known about accumulation factors.

Now we are mainly interested to establish a zero emission program in Austria. In the following case studies we tried to make companies interested in the Zero Emission concept, we looked for the reasons why there are still emissions and we looked for an approach to Zero Emissions within the existing industrial structure in Austria.

Methods

Our work is based on mass and energy flow analyses [3]. We are comparing all input and output streams of every single process step and the energy and mass streams through the production are followed. The quality of our research depends directly on the completeness and accuracy of the data, so a lot of time has been spent acquiring and crosschecking all available information. A lot of the data we need for carrying out thorough mass and energy flow analyses is not readily available in the companies, especially if they have little to do with product quality, purchasing, sold products or waste disposal. Acquiring the data will be even more difficult if third party companies are involved.

With the information gathered we carry out mass and energy flow analyses. Based on these information we are able to determine where, when and why certain substances become an unwanted emission. With the help of the companies we analyse this information and try to determine where the introduction of cleaner production measures will reduce the usage of raw materials and/or energy.

Case Studies

The enterprises in our case studies are all long-standing partners in pollution prevention programs [4]. They already have introduced all easily realisable methods of pollution prevention in their processes. Besides technical problems in the realisation of zero emissions, we were confronted with financial, political and legal questions. We were able to propose technical and organisational changes that reduce water and energy consumption. A discussion of the case studies follows.

Steel and Rolling Mill Marienhütte GesmbH

This enterprise produces steel out of 100% scrap iron. The scrap is molten in an electric arc furnace and alloying ingredients are added. Then the molten steel is continuously cast into steel bars. Two thirds of the production is manufactured into high grade reinforcing steel using the TEMPCORE heat-treating process in an adjoining rolling mill, the rest is sold as raw material for other steel manufacturers in Styria.

Why is this case study interesting for ZERIA?

There are several reasons why this plant is of special interest to a Zero Emission program.

The most successful Zero Emissions projects to date are implemented at food and agriculture enterprises [1]. This is a heavy industry plant. We are searching for possibilities to introduce the zero emission concepts into this industrial sector.

One of the concepts to archive Zero Emission is the clustering of industries, where the waste of one factory is sold as raw material to another factory. In this plant, steel is produced out of 100% scrap metal. Such a refining process is a necessary step in any clustering of industries.

The smelting and refining of steel uses a lot of energy and water. Only a very small part of the energy (recrystallization energy) and water can not be found in the final product, but over 85% of all other input materials go into the steel bars and rods. This is an example that energy and input materials must be considered as well for a sustainable industry (see *Table 1*).

Table 1 Simplified input/output table of a steel mill

Output:	Steel		waste water		used air		solid waste *partially sold, reused and recycled*	
Input:	% out	of %	% out	of %	% out	of %	% out	of %
Scrap iron	85	100	0	100	0	100	15	100
Water	0	100	9	100	90	100	1	100
Alloying Ingredients	100	100	0	100	0	100	0	100
Natural gas	0	100	0	100	100	100	0	100
Packaging	0	100	0	100	0	100	100	100

A very small part of the energy is used as thermal energy for the heating of offices and flats. Most of the water is evaporated or decomposed by heat, the rest is reconditioned and reused in the rolling mill. The reconditioning process itself produces a relative small amount of wastewater, which is discharged into the sewerage.

Results of this Case Study

This is a working plant and changes in the production process itself are out of the question. The main work was acquiring and evaluating the information necessary for conducting a thorough material and energy flow analysis. On our way to Zero Emissions, we concentrated our efforts on the reduction of the wastewater and we looked for methods to reuse more of the wasted thermal energy.

We were not able to improve the wastewater treatment process with more effective technologies without excessive costs, but we propose a solution to reuse the waste heat of the smelter exhaust gases for the production of electricity.

A heat exchanger is installed directly after the cyclone and produces superheated steam at 550°C. This steam drives a turbine to produce electricity. The smelter works as a batch process, this means that the temperature of the exhaust gases changes cyclically. If the smelter is in stand by mode, a gas burner will be used for keeping the exhaust gases at a temperature of typically 650°C. See *Table 2* and *Fig.1* for more detail. All calculations are based on formula of the VDI Wärmeatlas [5], sheet Gf1 ff.

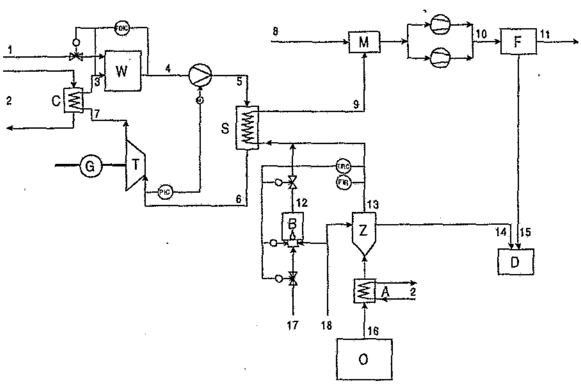

Fig.1 Apparatus for the reuse of thermal energy (Flows: 1 Fresh water supply; 2 Cooling water; 3 Outlet from condenser; 4 To pump (25°C, 0,032 bar); 5 From pump (25°C, 50 bar); 6 From boiler (550°C, 50 bar); 7 From turbine to condenser; 8 Air from building; 9 Exhaust from heat exchanger (120°C); 10 Exhaust to filter (60°- 120°C); 11 Exhaust to chimney (60°–120°C); 12 Exhaust burner; 13 Exhaust from electric arc furnace after cyclone; 14 Dust from cyclone; 15 Dust from filter; 16 Exhaust electric arc furnace (200°- 1200°C); 17 Natural gas supply; 18 Air supply
Processes: C Condenser; G Generator; W Water supply and purification; T Turbine; S Boiler; B Gas burner; M Mixing chamber; Z Cyclone; A Water cooling; O Electric arc furnace; F Filter; D Deposit for dust)

Vehicle Body Coating at Chrysler Eurostar Graz

Eurostar is a joint venture between "Chrysler Austria" and "Steyer – Daimler – Puch Fahrzeugtechnik AG & Co. KG". Eurostar is an automobile manufacturer and many problems implied here are typical for the modern industry. Analysis of the whole emission situation would have been too much, so in agreement with the company the water emissions were investigated. That includes particularly the areas of Phosphate coating, cathodic electrodeposition (CED) and the water treatment plant.

Why is this Case Study Interesting for Zeria?

Our targets are to find out further possibilities to close the various water cycles within the production areas mentioned above in order to avoid emission. The company was mainly interested in finding out the source of rather high chemical oxygen demand (COD) – values and to find a solution to lower them.

We were confronted with a lot of very typical problems. Data are mainly collected in the view of running the process and production quality. Because of this, much information is not available that would be necessary to close the cycles. A large part of the knowledge about the processes is held by the chemical suppliers, this kind of Know How in general is sensitive and they hardly provide it. Many substances appearing within the process have their origin in the production of raw materials which were bought. In our case, those are different types of oils and drawing greases.

Table 2 Calculated data for heat exchanger at a steel mill

	exhaust of electric arc furnace	steam process
Medium	air	water
Input Temperature (°C)	650*	25
Output Temperature (°C)	120	550
Volumetric flow rate ($m^3 h^{-1}$)	139.300 (20°C, 1 bar)	25,2
Theoretical possible heat exchange (kW)	-24400	+24400
Turbine Power (kW)		7800
Cooling load (kW)		15800
Mechanical load (kW)		800

* To stabilise this temperature the gas burner is necessary, without gas burner the temperature changes cyclically between 200°and 950°C

The automotive industry is a very competitive branch, e.g. the payback period prescribed by the major concern of our partner company is half a year, so projects where higher investments are necessary cannot be realised.

Results of this Case Study

A very detailed mass-flow analysis was carried out. As a result we found that COD-source is the acetic acid separated in CED and an organic solvent used there. The binder in the coating process is a caustic polymer dissolved in acetic acid. The body is immersed in a CED bath, where the paint particles are deposited on the steel surface by means of an electric current. This process releases the acetic acid which must be brought out of the process. This small organic mass flow causes the main part of the COD.

Most "state of the art" technologies to reduce the organic substances causing COD are realised, like ultra filtration of the CED bath, rinses with filtrate etc. [6]. Therefore, any further closing of cycles to reduce the wastewater would increase the COD – concentration even if the total amount of wastewater was decreasing, because the amount of acetic acid is a fixed percentage of the used binder. Thus, only a complete reengineering of the CED - paint and process could reduce the COD within the process.

The second possibility to reduce the COD – rate in the wastewater would be an end of pipe treatment. Usually bio – chemical processes are used to achieve that. However, our partner company releases their wastewater after the chemical water treatment to the sewerage system of the City of Graz, where a public wastewater treatment plant is installed.

Braun Medical, Infusion Solutions

This factory produces medical infusion solutions. The main ingredient of these infusions is desalinated and distilled water, but the largest amount of water is used for cooling purposes.

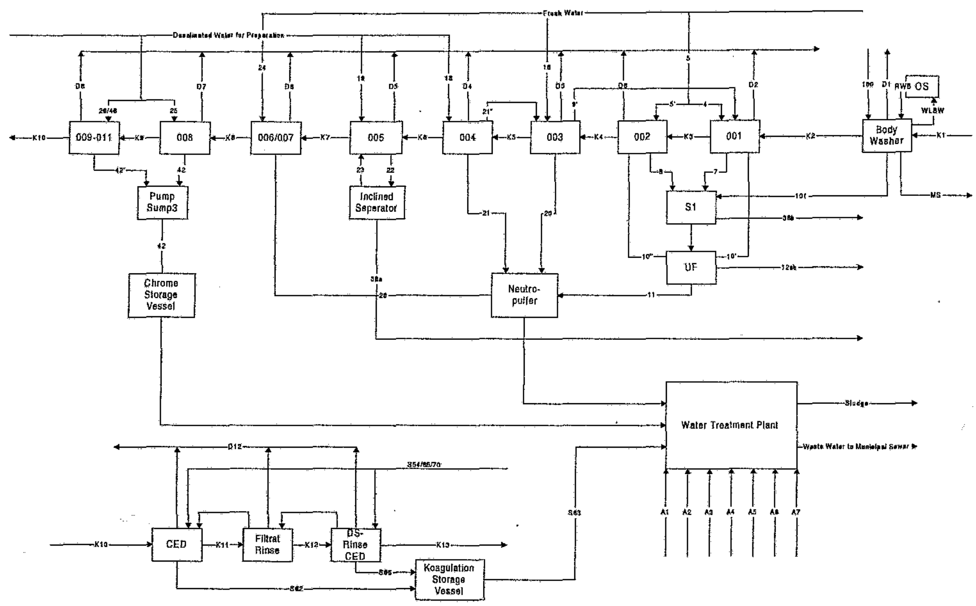

Fig.2 Vehicle Body Preparation (Flows: K1-K13 Water goes off with the bodies; D1-D12 Evaporation; 100,5,16,24 Input Water; 18,19,25,26/46,54/65/70 Input desalinated Water; MS,38b,12ab,38a Sludges; All other Waste Water; A1-A7 Rinses from other processes. Processes: 001,002 Cleaning; 003 Rinse after cleaning unit; 004 Activating process; 005 Phosphate coating; 006/007 Rinse with desalinated water; 008 Chromate passivation; 009-011 Rinse; OS Oil separator; CED Cathodic electrodeposition; SV1 Storage vessel)

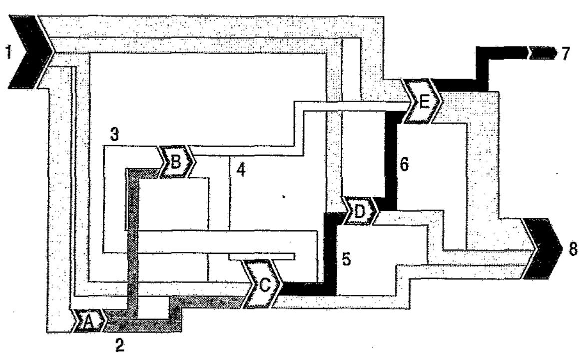

Fig.3 Simplified water flows (SANKEY) without cooling pond (For a description of flows and vessels see *Fig.4*)

Why is this Case Study Interesting for ZERIA?

The main emission of this enterprise is wastewater with the quality of drinking water at temperatures of about 40°C. Without further measures this temperature is too hot to be discharged into the environment, it is too hot to be used in a closed water cycle and the usable thermal energy is too low to be used in industrial processes. This situation can be found quite often in industries. Therefore, we were looking for a way either to reuse the water or the thermal energy in this plant or to use the warm water in other enterprises.

Results of this Case Study

If we are able to cool the waste water of the autoclave to about 35°C it will be capable of being reused as cooling water in a closed loop without exceeding the time limit for cooling set by the other processes in this company. The fire brigade of the community Maria Enzersdorf where this enterprise is located would like to have a water pond as a water source in the case of fire. We propose to meet both needs with a cooling pond near the company. *Fig.3* shows the simplified water flows for the process, *Fig.4* shows the flow sheet after the changes proposed. In *Fig.5* the calculated results for the cooling time are given. All calculations were carried out with formulas of the VDI Wärmeatlas [5], sheet Ec9 ff. and Gh1 and Perry's Chemical Engineers' Handbook [7].

Mobile Dish Washer

In the City of Graz, it is obligatory to rent a mobile dishwasher at large open-air events requiring an official approval. This "dish-mobile" is a trailer with two industrial dishwashers, one for glasses and tableware and one for kettles, pans etc. The use of glasses and tableware eliminates the need for throw away plates, cutlery and plastic or paper cups.

Why is this Case Study Interesting for ZERIA?

The idea of washing and reusing used tableware and cutlery for drinking and eating at open-air festivals is a great step towards the reduction of waste. A zero emissions "dish-mobile" would be a great opportunity to bring the idea of zero emissions to the public. Our aim is the construction of a "dish – mobile" independent of water and mains supply. The practical problems are typical for closing the water cycle: if water is cycled in a closed loop, the concentration of foreign substances rises.

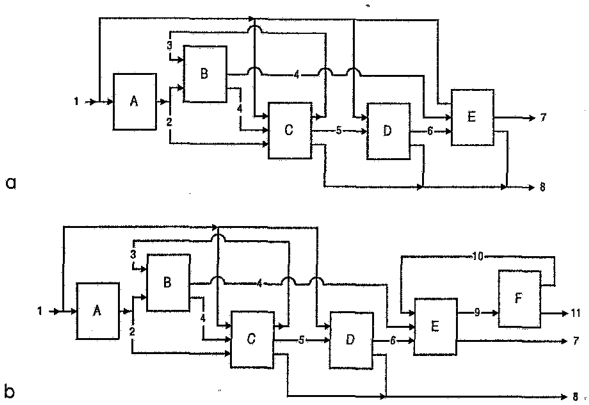

Fig.4 Flow sheet w/o cooling pond (a/b resp.) Flows: 1 Fresh Water; 2 Demineralised Water; 3 Recirculated Steam; 4 Steam; 5 Distilled Water; 6 Product; 7 Finished Product; 8 Waste Water; 9 To cooling pond (40°C); 10 From cooling pond (30°C); 11 Overflow. Processes: A Demineralisation; B Steam Boiler; C Distiller; D Mixing Process; E Autoclave; F Cooling pond

In this case, we were also confronted with questions relating to hygiene and health and with legal problems in case the wash is reused several times after purification.

Results of this Case Study

In this feasibility study, we found a solution to close the water cycle of the "dish – mobile". This solution uses industrial standard units. This "Dish - Mobile" could operate 18 hours continuously at a throughput of 800 plates per hour without any fresh water supply. In addition, a diesel power generator could be used to ensure the independence of a mains supply, the heat of exhaust gases would be used for preheating the wash - water. However, this solution was rejected because at nearly every event you will have music and therefore electricity. More details can be seen in *Fig.6*

Conclusions and Further Steps to Zero Emission

Improvements in environmental protection will only be possible if the ongoing processes and all mass and energy flows are known. Most companies collect a great amount of data for process and quality control, but only a small part of these are usable for carrying out energy and mass flow analyses. A lot of the data necessary for mass and energy flow analyses is not available, either because nobody has asked for it before or because it is sensible information held by third party companies. The main part and the indispensable first step in any energy and mass flow analysis is the collection and evaluation of data.

Based on this data it is possible to find the weak points. We try to eliminate them with ecological sound solutions as a first step towards Zero Emission. In some cases, we are not able to improve process steps with more efficient technologies without excessive costs, in other cases other technologies or methods do not exist.

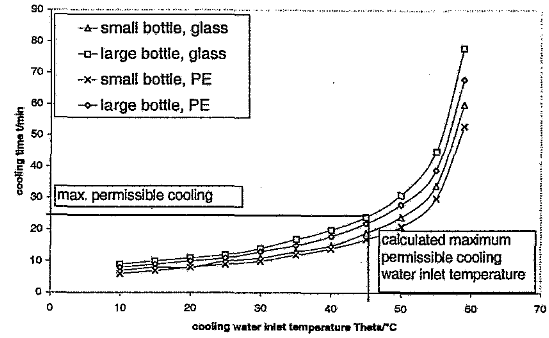

Fig.5 Result of calculation of cooling time

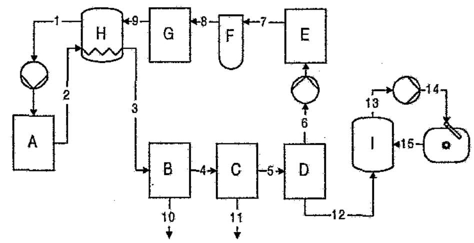

Fig.6 Dish – mobile (Flows: 1 Fresh water from tank; 2 Waste water from dish – washer; 3,4,5,6,7,8 Circulated water; 9 Reconditioned water in drinking water quality; 10 Oil and fat sludge; 11 Suspended matter; 12 Concentrate; 13, 14, 15 Concentrate is used for preliminary washing of dishes. Processes: A Dish – washer; B Plate precipitator; C Flotation; D Reverse osmosis; E Ion exchanger; F Activated charcoal absorber; G UV sterilisation; H Fresh water tank; I Waste water tank)

By this way, we are able to determine which areas need further research and development. The most important areas are closing of water cycles, usage of low temperature waste heat, substitution of toxic or indecomposeable substances with renewable and degradable materials.

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