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# The Encapsulated Pickling System – New Challenges in Design and Calculation

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## 1. Introduction

The importance of surface pre-treatment, such as the chemical cleaning of iron and steel surfaces, has been known since the middle of the 19th century – especially for galvanizing. Thus the method of pre-treatment has remained more or less the same without any major innovations to the present day. For instance degreasing baths were not introduced until fairly recently.

The increasingly difficult market conditions and the demands made by customers for better quality combined with lower prices and a faster service, have obliged the operators to reflect on process optimization and cost-cutting in production. Another important aspect of pretreatment lines is the need to meet requirements of environmental regulations, which will become even stricter in the future.

This development has been used as the factor for working out new ideas for pickling lines, with the aim of optimizing processes and costs:

- Increasing productivity
- Improving quality
- Reducing personnel costs (through automation)
- Optimizing materials use
- Increasing the service life of baths
- Reducing waste-disposal costs
- Reducing maintenance costs

In order to implement these ideas, the old approaches had to be comprehensively rethought, with the results depending very much on the components used. All system elements needed to be adapted to each other and, as a total system contribute to achieving the objectives mentioned above.

What follows is a presentation of the Körner System of enclosed pre-treatment, a pioneering system for pickling techniques and technology. All the components are adapted to each other and everything comes from a single source – from planning, in-company production, delivery and assembly up to commissioning by Körner KVK.

## 2. The Körner System

The following presents the basic ideas of the encapsulated pickling plant according to the 'KVK System'.

### 2.1. Coating of the Installation Pit

The tanks used today are all free-standing and are installed in so-called installation pits (concrete troughs) which collect the chemicals in the event of a tank leak (caused by mechanical

damage from falling parts) and prevent them escaping into the ground water.

The chemicals used in the working tanks of pretreatment systems represent a risk to the environment if they enter the ground water. For this reason, environmental authorities demand that areas in which ground-water hazardous materials are used must be provided with additional safety measures.

The installation pits are coated with the KVK coating system, an unsaturated polyester resin – activator mixture that is hardened by means of peroxides. Optimum mechanical characteristics are achieved by the insertion of glass or plastic matting. This coating is then sealed with a special resin filler coat.

### 2.2. KVK Tanks

The working tanks are sturdy KVK tanks, specially designed for the tough operating conditions in pretreatment plants. The tanks are placed close to each other in order to minimize the required space for pickling tanks.

For encapsulated systems it is very important to use high quality tanks in terms of chemical and mechanical resistance. If the pretreatment is encapsulated it is very difficult to exchange a tank, because the enclosure of the pickling area has to be dismantled partly.

It should be considered a big advantage if the tanks can be repaired in the operating position (that means without moving the tank), in case of damages. The tanks can be equipped with additional parts, such as jig supports for exact positioning of jigs on the tanks, or tube bundle separators.

### 2.3. Enclosed Pre-Treatment

With open pre-treatment systems, it is inevitable that there is a higher content of aggressive chemicals in the air around the pickling baths than in other areas. This applies even if the baths are only minimally heated or not heated at all.

The greatest problem in connection with the production of emissions is the 'steaming off' of the acid when the material is taken out of the bath, a problem that is only minimally improved by the use of suction systems at the lateral side of tanks.

Pre-treatment is enclosed using KVK panels. These panels are mounted on a steel or wooden substructure and coated on the working side with glass-fibre reinforced plastic to create a diffusion-tight, chemical-resistant shell isolated from the other production areas.

The coating of the pit and the coating of the enclosure are sealed to each other and form a diffusion tight chemical resistant box.

Since the cranes are running outside the encapsulated area, the ropes or chains enter the encapsulated room through slots in the ceiling of the enclosure. These slots must be sealed extremely tightly in order to keep the fumes inside.

#### 2.4. KVK Floor Panels

Every effort is made to place the pre-treatment tanks as closely as possible to each other in order to ensure a small and compact pre-treatment area. In the Körner System, the tanks are placed side-wall to side-wall, making optimum use of the space available.

The side-walls are glued together in a special process absorbing the relative movements of the tanks (when filled to different levels) and the resulting stresses and at the same time sealing the gap between the tanks. This also ensures that spilt chemicals cannot drip between the tank walls into the installation pit.

The areas alongside the tanks are fitted with walkways made of acid-resistant, non-slip KVK floor panels. These panels are calculated and manufactured specially in accordance with the requirements and the width. The panels are mounted at the height of the upper edge of the tank, and slope inwards to the tank chamber. This ensures that any liquid drips will flow immediately back into the correct tank, thus saving a considerable amount of chemicals.

In order to prevent chemicals dripping into the installation pit, the KVK maintenance panels are bonded diffusion-tight with both the tank edges and the casing. The bonding is made in such a way that the relative movements between the casing/tanks and the floor panels do not give rise to any cracks.

This arrangement of maintenance access panels divides the pre-treatment unit into two completely independent areas. The upper part (emission area, wet area) contains the aggressive fumes resulting from the high solution temperatures.

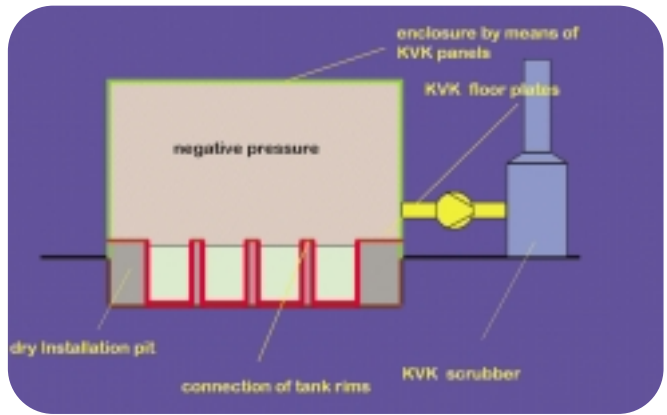
However, these fumes are prevented from escaping from the enclosed pre-treatment unit and from entering the floor area (cellar), since the KVK casing panels and the KVK maintenance access panels form a diffusion-tight shell.

Since no chemicals or aggressive fumes enter the cellar part, the latter can be referred to as dry installation pit.

This division of the pre-treatment unit into a wet emission area and a dry floor area can be exploited in order to locate any



▲ **Picture 1:** Dry cellar – no aggressive fumes attack the sensitive equipment



▲ **Table 1:** Principles of the encapsulated pickling according to the Körner System

sensitive parts requiring protection against corrosion at places where they do not come into contact with the aggressive atmosphere. The dry cellar contains all the automatic valves, pumps, electronic components such as transmitters, measuring sensors etc. (see picture 1)

#### 2.5. Fume Extraction System

The heating of the pickling liquid creates fumes in the emission area. However these fumes cannot escape thanks to the enclosed design of the pre-treatment unit. It is absolutely necessary to create a negative pressure atmosphere inside the enclosure to guarantee that no fumes will escape from the pickling area.

In the Körner System, these fumes are continuously extracted through an extraction channel and fed to a scrubber unit for purification. The purification process is based on the principle of counter-flow scrubbing of the air in water. A circulation pump continuously drives a precisely calculated quantity of scrubbing liquid in a circuit. The air passes through in counter-flow and the gaseous impurities are removed.

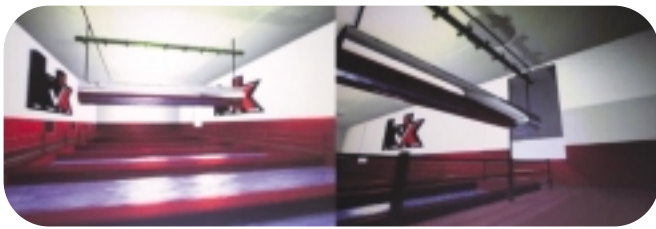
Depending on the specific acid used as pickling agent and the overall mass balance, the scrubbing liquid can either be returned to the process or partially lead to a neutralization plant.

The exhaust system is calculated specifically for each pre-treatment unit, since the complex interplay of casing volume, air-lock gate opening, arrangement of exhaust air lines, and the size and temperature of the bath surface make a simple design impossible.

Every Körner System unit is dimensioned in such a way that there is always a partial vacuum in the enclosed pre-treatment unit. This prevents any aggressive air escaping from the emission area even when the gates are opened for entry and removal of the materials.

This exhaust system also protects the crane equipment and the building, thus minimizing repair and maintenance costs for the operator. An equally important factor for the operator is also the permanent availability of the crane system, even after longer stoppages (e.g. weekends, factory holidays, etc.).

In order to optimize energy costs, the exhaust air system is equipped with a negative-pressure control that uses a frequency converter to regulate the speed and hence power take-up of the fan motor according to the partial vacuum in the pre-treatment unit. This ensures that no more air than necessary is extracted to ensure the proper operation of the system.



▲ **Picture 2:** Encapsulated pickling area – only chains or ropes are exposed to aggressive air, crane units are running outside

### 3. Criteria in Designing Encapsulated Pickling Systems

The new concept of encapsulated pickling systems is the optimum way to run a pickling line. The advantages are obvious:

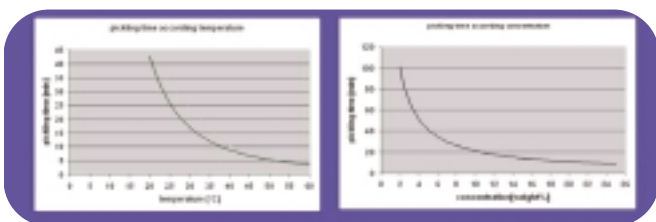
- Increasing productivity
- Improving quality
- Reducing personnel costs (through automation)
- Reducing waste-disposal costs
- Reducing maintenance costs

These advantages can be used only if the system is designed and calculated properly. To design an encapsulated system means more than only placing some tanks and installing an enclosure around them. It might be very dangerous to install an encapsulated pickling line without knowing the criteria in the design and calculation. The basic questions that have to be answered in the calculation of the pickling line are:

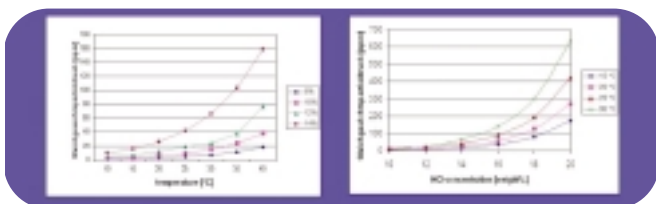
- What is the acid concentration inside the pickling area? (This is necessary to design the scrubber in the correct way).
- How can fog be avoided inside the enclosure?
- How can it be guaranteed that no fumes escape?
- How can the internal re-utilization of rinsing and scrubbing water be facilitated?

#### 3.1. Acid concentration in the air:

In order to design the scrubber correctly, it is absolutely necessary to know the complex relations between temperature, acid concentration, iron content and others, for the evaluation of the concentration of the air inside the enclosure.



▲ **Table 2:** The relation between pickling temperature/acid concentration (here: HCl as pickling agent) and pickling time is basically as shown above



▲ **Table 3:** It is a big advantage to reduce the pickling time, but it must be considered that the ‘acid push out’ is bigger with higher temperatures and higher concentration

Complicated calculation software was developed, where the theoretical basis was adopted and verified on the experience gained from plants that are in operation. Another major factor, which influences the emissions from the pickling tanks, is the iron concentration in the pickling acid. Of course, there is an enormous difference between highly volatile acids such as HCl or HF and barely volatile substances like H<sub>2</sub>SO<sub>4</sub>. In principle one can say that the acid concentration in the air is higher with higher temperature (exponential), with higher acid concentration (exponential) and higher iron content.

If all above mentioned calculations have been done, the scrubber can be designed, in order to fulfil all environmental regulations.

#### 3.2. Avoidance of Fog

Due to the heating of pickling baths and especially of the high-temperature process baths – degreasing, phosphatation, activation, preflux or soap – a certain amount of water will evaporate from the surface of the baths and from the surface of the material carried over from one bath to the other. Depending on the temperature and humidity of the inlet air, the flow rate and flow velocity of the evaporated amount of water can exceed the capacity of the air to take in the humidity, resulting in the formation of mist and fog.

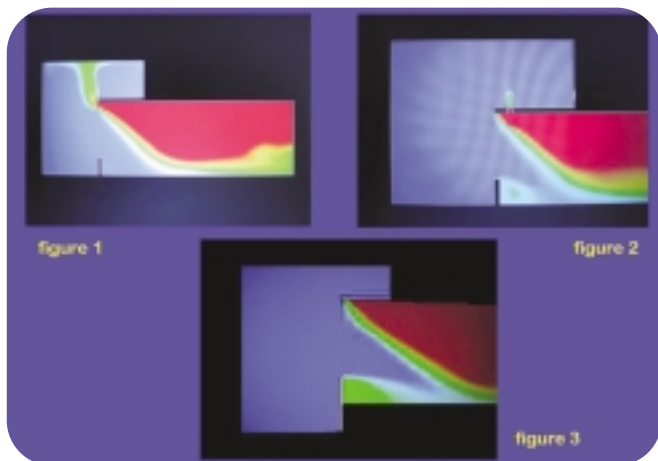
Fog in the encapsulation does not only decrease visibility but can even drastically increase emissions from volatile acids. Therefore it is decisive to avoid fog in the first place. The Körner design of



▲ **Picture 3:** Vapours from hot chemicals increase the relative humidity of the air



▲ **Picture 4:** Perfect conditions (without fog) inside the encapsulation



▲ **Illustration 1:** Flow simulation in encapsulated pre-treatment plants

plants is based on calculations of the evaporation taking into account all the above mentioned parameters. If necessary, Körner can apply a patented pre-heating-system for inlet-air, thus increasing the capacity of the air for humidity and avoiding the existence of fog inside encapsulation.

The pre-heating-system does not require any additional heating equipment, but uses the heat of the tanks.

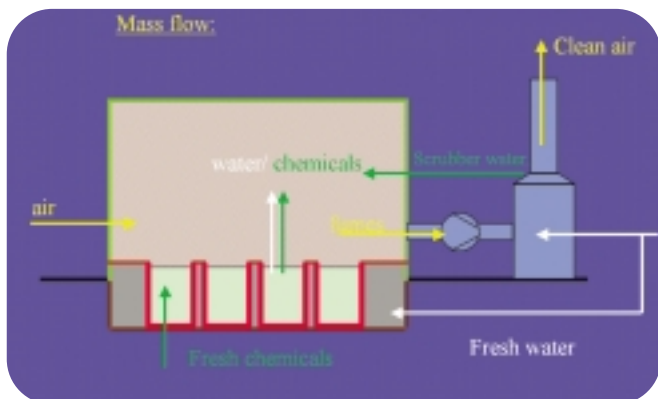
### 3.3. Flow Conditions Inside the Encapsulation

The third important point is the correct design of the flow conditions inside the encapsulation. The critical situation occurs when the material enters the pickling plant and the entrance door is open. The target is to create a flow of air from outside to inside at all times. Even if there is a calculated flow from outside to inside, it cannot be guaranteed that fumes will not escape (see illustration 1, figure 1).

There are too many factors, that influence the flow conditions (temperature, temperature gradient, location of fume extraction, location of fresh air supply etc.) that it can be calculated in a simple way.

Illustration 1 depicts flow simulations in encapsulated pretreatment plants, and the same plant that has optimum flow conditions (figure 3). In figure 2 it can be seen that fumes will escape if the slots for the crane ropes or chains are not perfectly sealed.

There is special know how, which enables Körner KVK to calculate encapsulated plants in the engineering stage of a project



▲ **Table 4:** Mass flow in pretreatment plants has to be calculated

to be sure that the system will work in the future. Körner has established several patents for this special knowledge.

### 3.4. Re-use of Process Liquids

If the above described points are solved successfully, then another issue that should be apparent in a modern, encapsulated system is to recirculate as much of the valuable components as possible.

This is in order to minimize the consumption of input chemicals and the discharge of waste liquid. Therefore it is necessary to know the exact mass flow in the pickling line for liquids and gaseous substances.

Modern, encapsulated pickling lines are focussing on the minimization of waste-water and thus meet all requirements of environment protection. In the case of HCl pickling lines the water circle can be closed since all the scrubbing liquid is used in the pre-treatment – these plants run waste water free.

## 4. Summary:

The ever-increasing pressure of competition must be met by new ideas for system techniques and technologies. In order to reduce production costs, every stage in the production process must be optimized and all system components optimally adjusted to each other.

In order to meet such requirements, the enclosed pre-treatment has been developed according the 'KVK-system', which permits operators to take full advantage of state-of-the-art techniques and technologies.

In conclusion, the core advantages of the Körner System are as follows:

- By fully isolating the pre-treatment from the other production areas, it is possible to operate the baths at high temperatures without corrosion in the rest of the production area.
- Space-saving (reduces building costs)
- Enclosing the pre-treatment unit and extraction of the emission area (permanent partial vacuum) provides the technical precondition for the use of modern automated transport systems, thus increasing the degree of automation
- A high degree of automation reduces labour costs and as far as possible eliminates the human factor as a source of errors
- Enclosure prevents the escape of aggressive fumes from the pre-treatment unit, thus preventing corrosion to the crane equipment and the building.
- Exhaust air cleaning and return of washing water for reuse ensures environment-friendly operation and a high degree of flushing purity.

The design of encapsulated systems requires a lot of technological know how and special knowledge in process engineering, in addition to thermodynamics and fluid dynamics. The encapsulated pickling plant according to the 'KVK-System' is running in more than 20 plants all over the world.

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