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**CHIMIE**  
*Chimie ingénierique*

**COMPARISON OF WETTABILITY OF PACKING'S MATERIALS  
USED IN COLUMN APPARATUSES \***

**E. Razkazova-Velkova, N. Kolev**

*(Submitted by Corresponding Member L. Boyadjiev on July 28, 1998)*

Experiments are carried out permitting to compare various materials and to estimate their fitness for production of packings for column apparatuses: operating at extremely low superficial velocities. It is found that tile material KR synthesized by the authors, as well as porous PVC, excel significantly the metal materials (stainless steel and zinc-plated iron sheets). For porous materials, it is also found that the liquid flows only in the pores when the liquid flowrate is below some limit.

**LIQUID PHASE LEAKAGE IN THE FREE VOLUME OF  
COLUMNS FILLED 'WITH VERTICAL-WALL PACKING'**

**N. Kolev, E. Razkazova-Velkova**

*(Submitted by Academician H. Hristov on March 28, 1998)*

It is known that from all kinds of packing for column apparatuses those with vertical walls and especially the 'honey comb' have the lowest pressure drop per transfer unit. One of the reasons they have not taken their reasonable place in the technology is: the risk of deviation of a part of the liquid phase from the wall, where it flows in the form of a film, and its leakage into the free section of the packing in form of drops and streams. This phenomenon, if it exist, would lead to two effects: a negative one connected with an increase of the axial mixing, due to the different velocities of the liquid-film and the leaking liquid, and a positive one, which results in higher interfacial surface, when the surface of the film and this of the drops and the streams have been summed.

When the liquid flows from one packing's element to another, at its down edge a liquid volume supported by capillary forces is formed. If the distance among the walls of the downlying element is small enough, the liquid flows from one element to another without leakage in its free section. The stability of this "hanging" canal, deviating the liquid horizontally, depends not only on the capillary forces determined by the surface tension and the wetting of the material, but also on the flow rate, closely connected with the superficial velocities and the hydraulic diameter of the packing's element.

Studies were carried out in a system water-air. The following materials suitable for packings were used: ceramics, stainless steel, zincified steel, sand blasted polystyrene with increased wetting capacity, sintered PVC, KR -a new8 specially produced by us material, characterized by high wetting capacity.

The examined material was given the form of a vertical plate, the surface of which was wetted by a capillar. Two deviating plates symmetrical in relation to the flow were placed perpendicularly to the plate down edge. The maximum distance between the two plates that does not permit leakage of the liquid was determined as a function of the flow rate. On the base of the received experimental results, with enough accuracy for practical purposes the superficial velocity, from which the liquid phase starts leaking in the free section of the packing, could be determined.

## STUDY ON THE ABSORPTION OF SULPHUR DIOXIDE INTO SOLUTIONS OF SODIUM SULPHITE-HYDROSULPHITE AT EXTREMELY LOW LIQUID SUPERFICIAL VELOCITY

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*Dedicated to Professor Dimiter G. Elenkov on the occasion of the 80th anniversary of his birth*

Received July 7th, 1999

It has been noticed that the widely used Wellman-Lord method for absorption of sulphur dioxide from flue gases without waste products is characterized by great capital investments and operational expenses. The reason for that is the impossibility of carrying out the process under conditions of a complete countercurrent flow, which results in a considerable decrease in the driving force. The development of a packing, efficient at extremely low liquid superficial velocity, gives the possibility to eliminate this disadvantage. In the present work the absorption of sulphur dioxide into an aqueous solution of sodium sulphite-hydrosulphite at extremely low liquid superficial velocity is studied and on the basis of the results obtained an equation for determining the volumetric mass transfer coefficient is derived. The calculations made by means of the developed mathematical model show that the total packing height, which can accomplish 98% degree of absorption of sulphur dioxide with an initial concentration of 0,3%, is only 2,6 m at 2,16 m/s gas velocity. The use of a complete countercurrent flow and additional saturation of the absorbing solution of sodium sulphite after its partial saturation in the column, provides the possibility to reduce the steam consumption for solution regeneration from 12 to 6,12 kg steam per 1 kg regenerated sulphur dioxide.

**Key words:** absorption, SO<sub>2</sub>, packed columns, flue gases, low liquid superficial velocities, Wellman-Lord method

# A new column packing for operation at extremely low liquid loads

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## Abstract

It has been demonstrated that the ‘honeycomb packing’ made of sintered PVC sheets is well wetted even at extremely low liquid velocities. For example, at a liquid superficial velocity of  $0.00008 \text{ m}^3/(\text{m}^2 \text{ s})$  the effective surface is between  $114$  and  $178 \text{ m}^2/\text{m}^3$  depending on the particular packing design. Having high effective surface at extremely low superficial velocities, the packing operates at full counter-current flow, while other packings demand a re-circulation of the absorbent. It is shown that compared to some of the highly efficient packings, the use of the new packing leads to considerable pressure drop reduction and to an increase of the volumetric mass-transfer coefficient. © 2001 Elsevier Science B.V. All rights reserved.

*Keywords:* Packed columns; Packing; Absorption; Extremely low liquid superficial velocity; Emission reduction

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## NEW PACKING FOR EXTREMELY LOW LIQUID SUPERFICIAL VELOCITY<sup>a</sup>

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Received June 6th 2001

It has been demonstrated that the “honeycomb packing “ made of sintered PVC sheets is well wetted even at extremely low liquid velocities. For example, at a liquid superficial velocity of  $0.00008 \text{ m}^3/(\text{m}^2\text{s})$  the effective surface is between  $114$  and  $178 \text{ m}^2/\text{m}^3$  depending on the particular packing design. Having a high effective surface at extremely low superficial velocities, the packing operates at a full counter-current flow, while other packings demand a re-circulation of the absorbate. It is shown that compared to some highly efficient packings, the use of the new packing leads to a considerable pressure drop reduction and to an increase in the volumetric mass-transfer coefficient. The investigation on the efficiency of the new packing for absorption of  $\text{SO}_2$  by the Weiman-Lord method shows the possibility for large reduction of the packing height and of the steam consumed for regeneration of the absorption solution.

**Key words:** packed columns, packing, absorption, extremely low liquid superficial velocity, sulfur dioxide removal, energy efficiency

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# Research News

## **New Packings for Operation at Extremely Low Liquid Superficial Velocity**

By *Nikolai Kolev\** and *Elena Razkazova-Velkova*

It is well known that the column apparatuses operating at full countercurrent flow ensure maximum driving force for mass transfer when equilibrium processes are used. It is also known, from the mass balance, that the ratio between gas and liquid superficial velocity, in case of countercurrent flow, is determined from the initial and end concentrations of the absorbed component in both phases. In many cases, especially in purification of waste gases, when the initial gas concentration is very low and its solubility is high, the necessary calculated liquid superficial velocity is extremely low. The lack of packings able to operate effectively at these conditions requires a division of the packing bed into layers with recirculation of the liquid phase in each of them, i.e., a refusal of the principle of complete countercurrent flow takes place. The paper shows the possibility to use this principle even at extremely low liquid superficial velocity.



# A new principle for creation of packings operating at extremely low liquid superficial velocity

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## Abstract

The lack of packings able to operate at extremely low liquid superficial velocities does not allow to carry out mass transfer processes at full countercurrent flow at too low concentrations of the component to be absorbed. For this reason, the full countercurrent flow in many important processes is replaced by division of the packing into layers and re-circulation of the absorbent in each of them. The latter increases the expenses for the construction of the apparatus with parallel decreasing the process driving force. A method for creation of packings with effective surface equal to their total surface even at liquid superficial velocities that tend towards zero is described. The construction of such effective packing is given. The volumetric mass transfer coefficient when the mass transfer is controlled by the gas-side boundary layer has been received from the results of the absorption of sulfur dioxide into a solution of sodium hydroxide. Data for the pressure drop and liquid hold-up of the packing are also presented. The comparison of the new packing with other types of highly efficient packings shows its great advantages.

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*Keywords:* Packed columns; Packing; Absorption; Extremely low liquid superficial velocity; Emission reduction

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Research Article

# Packing with Stamped Horizontal Lamellae Operating at Extremely Low Liquid Loads – II. Effective Surface Area

In the first part of this investigation a new packing material, specially designed for operation at extremely low liquid superficial velocity, was presented [1]. It consists of narrow, horizontal lamellae stamped in vertical plates with small distances between them. The liquid flows horizontally, wetting practically the whole surface of the lamellae, i.e., strips. One of the most important performance characteristics of packings is their effective surface area. This surface can be either smaller or greater than the specific surface [2]. The results of the investigation into the effective surface of the new packing are presented here. They show that it slowly increased with liquid superficial velocity,  $L$ . At the lowest liquid superficial velocity,  $L$ , equal to only  $2.6 \cdot 10^{-5} \text{ m}^3/(\text{m}^2\text{s})$  for a packing with a specific area of  $132.7 \text{ m}^2/\text{m}^3$ , and the effective surface area is more than 50 % higher than the specific one. At  $L = 10 \cdot 10^{-5} \text{ m}^3/(\text{m}^2\text{s})$ , for the same packing, the effective surface is about twice as high as the specific one.

**Keywords:** Liquid flows, Packed bed columns, Surfaces

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Research Article

## Packing with Stamped Horizontal Lamellae Operating at Extremely Low Liquid Loads – III. Packing Pressure Drop

It has been discussed in previous papers [1–7] that the design of packings capable of operating at extremely low liquid superficial velocity allows the development of effective countercurrent flow packed bed columns even if the concentration of the absorbed component is very low, the absorption is an equilibrium process, and the gas is well soluble in the liquid phase. The construction of the new packing is described in [7]. The present paper reports the results of an investigation of the pressure drop for dry and irrigated packings up to a gas velocity equal to 3 m/s ( $F_G$  factor equal to  $3.3 \text{ kg}^{1/2} \text{ m}^{-1/2} \text{ s}^{-1}$ ) as well as the equations for its calculation.

**Keywords:** Packed bed columns, Packings, Pressure drop

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CHIMIE  
Chimie industrielle

LIQUID-SIDE CONTROLLED MASS TRANSFER  
IN A PACKING WITH STAMPED HORIZONTAL  
LAMELLAS OPERATING AT EXTREMELY LOW LIQUID  
SUPERFICIAL VELOCITY

Nikolai Kolev, Borislav Kralev, Elena Razkazova-Velkova

*(Submitted by Corresponding Member D. Klisurski on November 8, 2007)*

**Abstract**

The liquid-side controlled mass transfer coefficient of a packing able to operate at extremely low liquid superficial velocity is investigated and an equation for calculation of this value is presented. It is mentioned that the design of the new packing gives the possibility for development of packed bed columns operating effectively in counter-current at practically fully wetted surface area at very low liquid to gas ratio. This is necessary in cases of equilibrium absorption of well soluble gases with low initial concentration. The investigated value is indispensable for determination of the overall mass transfer coefficient of the packing.

**Key words:** packed-bed column, new packing, low liquid superficial velocity, liquid-side controlled mass transfer coefficient, experiment, equation

# Utilization of Sulfide From Black Sea Water by Electrolysis

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## ABSTRACT

*The present paper presents experimental results on the anodic oxidation of sulfide ions in salt solutions. Model solutions of sodium chloride and natural marine water from the Black Sea with added sulfide were tested. Passivation of the anode took place by the released elemental colloidal sulfur, particularly at high initial sulfide concentrations and under batch conditions. Therefore anode potential was chosen in a way to oxidize sulfide straightforward to sulfate and the process was carried out under continuous conditions to avoid anode passivation.*

*The quantitative comparison between the calculated electric currents and efficiencies based on the chemical analyses and the measured ones confirmed the hypothesis of the straightforward anodic oxidation of sulfide to sulfate. The obtained results demonstrate the possibility to utilize hydrogen sulfide as energy in the form of hydrogen released on the cathode and simultaneously to return the sulfur in a sulfate form to the sea water.*

**Keywords:** Hydrogen Solphide, Electolysis, Sulfate, Water, Purification.

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**INFLUENCE OF THE VISCOSITY AND SURFACE TENSION OF THE LIQUID PHASE  
ON THE WETTABILITY OF DIFFERENT PACKING MATERIALS  
FOR COLUMN APPARATUSES**

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**Abstract**

*The study aims preliminary determination of the wettability of materials appropriate for design of packings for column apparatuses. Some classical and two new packing materials are investigated at dynamic conditions by measuring the width of a film flowing over a plate of every of them. The influence of the viscosity and surface tension of the liquid phase is presented. Dimensionless equations for calculation of the film width at different physicochemical properties of the liquid phase are given in the paper.*

**Key words:** *Packed-bed columns, packings, wettability, dimensionless equation*

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## **CURRENT PROBLEMS AND DEVELOPMENT IN FLUE GAS DESULFURIZATION**

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### **Abstract**

*One of the most widely used processes of SO<sub>2</sub> removal from flue gases is absorption by slurry containing CaCO<sub>3</sub>. The existing installations are designed for big capacity boilers and provide low degree of absorption. The stringent environmental protection regulations for SO<sub>2</sub> emissions in EU call for better solutions. The aim of the present discussion on the current problems and achievements in gas desulfurization is to help the finding of the proper direction of the efforts for developing of a new technology and the choice of apparatuses and equipment.*

**Key words:** *wet flue gas desulfurization, SO<sub>2</sub> removal efficiency, bisulfite oxidation, lime, limestone, slurry, gypsum, scrubber.*

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**LIQUID PHASE LEAKAGE IN THE FREE VOLUME SECTION OF COLUMN  
APPARATUSES FILLED WITH “HONEYCOMB” PACKINGS**

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**Abstract**

*Among all types of packings for packed-bed columns, the vertical-wall “honeycomb” packings show the lowest pressure drop per transfer unit, i.e. the lowest energy consumption for carrying out absorption processes. A limitation for its practical application is the possibility for tearing the liquid film flowing over the packing’s wall and its leakage in the free volume of the packing in the form of drops and trickles. This leads to two effects. The first one is positive, related to the increasing of the total interphase surface area due to the additional surface of the drops and trickles. The second effect is negative, because of the increasing rate of longitudinal mixing in the liquid phase due to the different velocity of the liquid film and leaky liquid. The influence of the viscosity and surface tension of the liquid phase over the leakage from packings manufactured from different materials is studied. The flowrates under which there is no leakage in the two different ways for arrangement of the “honeycomb” packings are obtained*

**Key words:** *packed-bed columns, Honeycomb packings, leakage of the liquid phase*

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**EQUILIBRIUM PARTIAL PRESSURE OF SO<sub>2</sub> OVER THE ABSORPTION SLURRY IN  
CASE OF PURIFICATION OF THE FLUE GAS FROM SULFUR DIOXIDE USING  
GYPSUM TECHNOLOGY**

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**Abstract**

*The most widely used process for purification of flue gases from SO<sub>2</sub> is its absorption with slurry containing CaCO<sub>3</sub>. Up to now there are installations for carrying out of the SO<sub>2</sub> absorption according to this process only for big capacity boilers because of the great height of the existing absorbers for this technology, about 20-30 m. To create new absorbers for small and middle capacity boilers, equilibrium data for the absorption of SO<sub>2</sub> are necessary. Up to now such data are available in the literature only for a temperature of 25°C. That is why experiments for obtaining of equilibrium data for the partial pressure of SO<sub>2</sub> over slurry containing CaCO<sub>3</sub>, CaSO<sub>3</sub> and CaSO<sub>4</sub> at different temperatures are carried out. The results show that the increasing of the temperature from 25 to 45°C leads to about 3 times increasing of the partial pressure of SO<sub>2</sub> in the area of the lowest partial pressures. The respective increasing for the range of 25° to 60°C is about 10 times.*

**Key words:** *SO<sub>2</sub>, purification of flue gas, equilibrium partial pressure, absorption slurry, gypsum, absorption degree, experiment.*

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**EQUILIBRIUM PARTIAL PRESSURE OF SO<sub>2</sub> OVER THE ABSORPTION SLURRY IN  
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**Key words:** *SO<sub>2</sub>, purification of flue gas, equilibrium partial pressure, absorption slurry, gypsum, absorption degree, experiment.*



**OXIDATION OF  $\text{CaSO}_3$  BY AIR IN THE TECHNOLOGY FOR PURIFICATION  
OF FLUE GASES FROM  $\text{SO}_2$**

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**Abstract**

*The presented investigations are connected with creation of a new suitable for small and middle capacity boilers technology for removal of  $\text{SO}_2$  from flue gases by absorption with  $\text{CaCO}_3$  slurry, producing gypsum for building material. To reduce the capital investments it was decided to eliminate the hydrocyclone block and the centrifuge of the existing technologies and to dry the slurry of  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$  directly in a spray dryer by flue gases, utilizing the heat of evaporation in a contact economizer system. This decision required practically full oxidation of the  $\text{CaSO}_3$  to  $\text{CaSO}_4$  in the oxidizer. A construction of a new oxidizer, divided by vertical partitions into 4 chambers with regular distribution of the air in the slurry by means of perforated horizontal tubes, is described. Some possibilities for cleaning of the orifices of the tubes are specially investigated and a solution is found. It is shown that at presence of catalysts, Fe and Mn ions, more than 99% of the slurry can be oxidized in 9 hours. The obtained after the drying of the slurry gypsum is white. The test of its compressive strength shows a value of 3.5 MPa, i.e. 40% higher than the requirements of the Bulgarian national standard for building gypsum. The obtained data are used for designing the oxidizer of an industrial installation for purification of flue gases from  $\text{SO}_2$ .*

**Key wards:** *purification of flue gases,  $\text{SO}_2$  removal, absorption degree, new technology, catalyst,  $\text{CaSO}_3$  oxidation, slurry, gypsum compressive strength.*

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## NEW TECHNOLOGY FOR PURIFICATION OF THE FLUE GAS FROM SULFUR DIOXIDE

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### Abstract

*A new type of installation for SO<sub>2</sub> removal from flue gas, producing high quality gypsum, is described. It ensures conditions at which the absorption process is practically gas side controlled with elimination of the resistance in the liquid phase boundary layer between gas and liquid and between the liquid and solid CaCO<sub>3</sub> used as absorbent. This gives the possibility to calculate the absorption using data from literature, which eliminates the necessity of performing experiments for the given system and absorber construction. The new installation ensures high absorption degree, more than 99%, and provides optimal conditions for oxidation of the CaSO<sub>3</sub> to gypsum, small height of the packing of the absorbers and low pressure drop. The installation is intended for removal of SO<sub>2</sub> from the flue gases from small and middle capacity boilers, but with small changes can be used for big boilers too.*

**Key words:** *SO<sub>2</sub> removal, flue gas, new type of installation, slurry, gypsum, absorption degree, gas side controlled absorption, packed bed column, Holpack packing, small and middle capacity boilers.*

## ВЛИЯНИЕ НА ФИЗИКОХИМИЧНИТЕ СВОЙСТВА НА ТЕЧНАТА ФАЗА ВЪРХУ ПРОКАПВАНЕТО Й В СВОБОДНОТО СЕЧЕНИЕ НА КОЛОННИ АПАРАТИ, ЗАПЪЛНЕНИ С ПЪЛНЕЖИ С ВЕРТИКАЛНИ СТЕНИ

Елена Разказова-Велкова, Даниела Джонова-Атанасова

## INFLUENCE OF THE PHISICOCHEMICAL PROPERTIES OF THE LIQUID PHASE ON ITS LEAKAGE IN THE FREE VOLUME SECTION OF COLUMN APPARATUSES FILLED WITH VERTICALLY WALLED PACKINGS

Elena Razkazova-Velkova, Daniela Dzhonova-Atanasova

**ABSTRACT:** *Among all types of packings for packed-bed columns, the vertical-wall honeycomb packings show the lowest pressure drop per transfer unit, i.e. the lowest energy consumption for carrying out absorption processes. A limitation for its practical application is the possibility for tearing of the liquid film flowing over the packing's wall and its leakage in the free volume of the packing in the form of drops and trickles. This leads to two effects. The first one is positive, related to the increasing of the total interphase surface area due to the additional surface of the drops and trickles. The second effect is negative, because of the increasing rate of longitudinal mixing in the liquid phase due to the different velocity of the liquid film and leaking liquid. The influence of the viscosity and surface tension of the liquid phase over the leakage from packings manufactured from different materials is studied. The maximum dimension of the various packings that does not allow leakage is shown and equations for its calculation are derived.*

**Key words:** *Packed-bed columns, Vertical-wall packings, Leakage of the liquid phase*