Chapter 1 : A brief summary on the experimental activity carried out on helier – Structured Packing system

Thanks to its world-wide experience achieved in the engineering and construction of waste water treatment plants using its own air diffusers **Jet-Helix®** , Process Engineering S.r.l patented **structured packing** and **random packing** of its own.

The initial target was to develop an alternative equipment for the pharmaceutical bio-fermentation , but , as soon as the experimental research was completed , we found out we made **a new structured packing system** whose main properties are :

- Very **low pressure** drops
- **High Efficiency** in Mass Transfer Operation
- **No engulfing** velocity

These packings were called **helier** .

The experimental research , subject of a degree thesis , is summarized here and was conducted in collaboration with the

Faculty of Industrial Chemical Engineering of Pisa University

under the control of Doct. Alessandro Paglianti , who , as a member of Prof. Nardini's equipe , made numerous experimental studies on packing – both random and structured – and wrote many articles on Mass Transfer Equipments.

The experimental analysis was conducted in two different steps :

Phase 1 : **Experimental characterization of geometrical and fluidodynamic properties of HelieR™ packings :** June 1997 ~ September 1998

Phase 2 : **Experimental data analysis and identification of a computation model for gas phase and liquid phase resistance :** September 1998 ~ February 1999

The results achieved , and the identification of a **mathematical estimation model** for mass transfer resistance both in gas phase and in liquid phase , were a target not planned when we started the research.

The identification of a mathematical estimation model made it possible the development of a **software system** for the design and the simulation of columns with **helier – Structured Packing** in the Absorption , Desorption and Stripping operations .

Today we have and use the following **simulation software system** when we have to design the applications for **helier – Structured Packing** :

- **helier – Assorbimento 3.0**
- **helier – Desorbimento 2.5**

Phone : +39–031–895.374
Fax : +39–031–3524.907
Partita IVA/C.F. Reg. Imp.MI 13395210159
C.C.I.A.A. n. 1647291 Trib. Milano n. 213317 - Cap. soc. i.v. € 99.000,00.
URL : www.pe-process.it
E-mail : process@pe-process.it

Phase 1 : **Experimental characterization of geometrical and fluido-dynamic properties of helier – Structured Packing** : June 1997 ~ September 1998

1. Characterization of the specific area and of the fluido-dynamic properties

The first phase of the experimental analysis conducted on **helier** packing with or without window was to determine the following physical properties , consistent with packing diameter :

a. Specific Area

b. Void Space

c. Maximum Quantity (N° pieces / m^3)

d. Weight

Nominal Diameter (inch)	Weigth of one Element (gr)	Specific Area (m^2/m^3)	Void Space ε	Maximum Quantity (pieces/m^3)
1"	2.43	260	0.904	56,133
1.5"	5.38	160	0.936	17,511
2"	11.15	110	0.952	8,025
4"	44.59	50	0.976	1,075

Tab. 1 : technical characteristics of polypropylene **helier** with window **(open elements)**

Nominal Diameter (inch)	Weigth of one Element (gr)	Specific Area (m^2/m^3)	Void Space ε	Maximum Quantity (pieces/m^3)
1"	3.18	320	0.904	56,133
1.5"	7.34	210	0.936	17,511
2"	12.73	160	0.952	8,025
4"	50.89	80	0.976	1,075

Tab. 2 : technical characteristics of polypropylene **helier** without window **(closed elements)**

After the measurement of a high specific area for this family of packings , two experimental laboratory equipment were built : one with a 1.5” helier mono-tube and the other with a 4” helier mono-tube .
Using this equipment in a counter-current flow analysis , the following tests on the packing were made:

- Pressure Drops , with flows in the range : 1,000 – 10,000 Kg / m^2 * h
- Hold – up
- CO_2 stripping from a saturated solution , measurement of H_{OL} e K_L*a
- SO_2 absorption with sodium hydroxide , measurement of H_{OG} e K_G*a

Phone : +39–031–895.374 Partita IVA/C.F. Reg. Imp.MI 13395210159 URL : www.pe-process.it
Fax : +39–031–3524.907 C.C.I.A.A. n. 1647291 Trib. Milano n. 213317 - Cap. soc. i.v. € 99.000,00. E-mail : process@pe-process.it

The Pressure Drops diagrams for helier packing for industrial applications is shown in hereunder in **FIG. 1** , and it is based on data obtained by the experimental research.

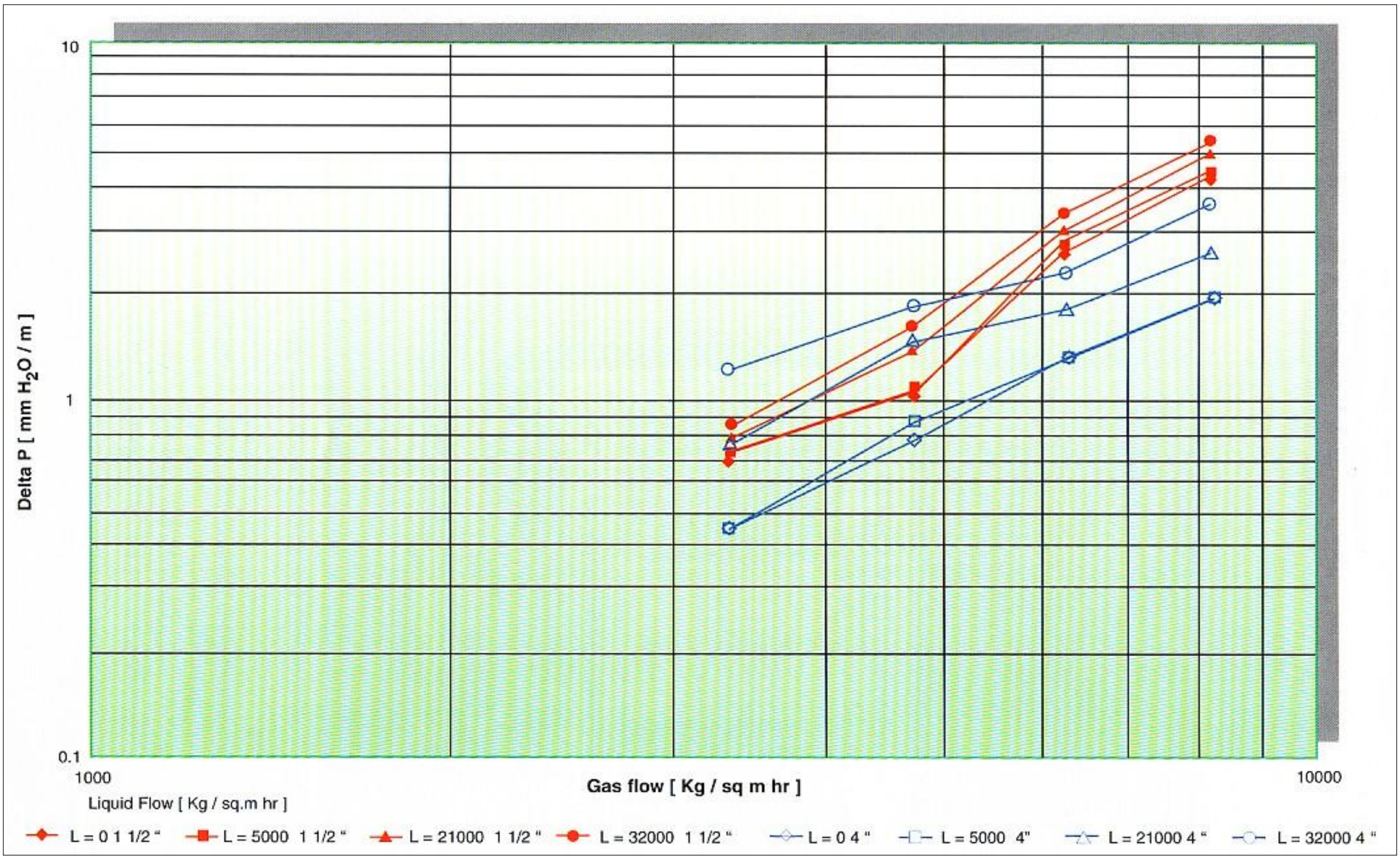

FIG 1 : **Pressure Drops Diagrams for helier – Structured Packing : INDUSTRIAL APPLICATIONS**

Liquid Flow Rate = 1,000 Kg/m2*h ÷ 10,000 Kg/m2*h

Pressure Drops (i.e. **Delta P**) are measured in mm H_2O/m

2. Identification of the geometry that magnifies mass transfer operation

K_L*a and **K_G*a** values obtained from the experimental tests conducted on the in-line mono-tubes were compared with those obtained from mono-tubes characterized by the following configurations :

- configuration 1 X 1 , having a 90° mismatch of the helix every each element ;
- configuration 3 X 3 , having a 90° mismatch of the helix every 3 elements ;
- configuration 6 X 6 , having a 90° mismatch of the helix every 6 elements ;

Comparing the results of the different configurations , best performances for the **type 3 X 3** : this result is covered by a **new Industrial Patent .**

Phone : +39–031–895.374 *Partita IVA/C.F. Reg. Imp.MI 13395210159* *URL : www.pe-process.it*
Fax : +39–031–3524.907 *C.C.I.A.A. n. 1647291 Trib. Milano n. 213317 - Cap. soc. i.v. € 99.000,00.* *E-mail : process@pe-process.it*

3. Packed bed construction and experimental analysis conducted in industrial column

Before the measurements in an industrial column , we had to design it .

Thanks to the column's dimensions (diameter = 400 mm ; net packed bed high = 2000 mm) , we had to solve the following problems :

a) hydraulic holding of the packings ;

b) absence of lateral fluid spilling ;

c) mechanic holding of the packings.

1.5" helier packing were used as **structured packings** ; a packed bed made by **1.5" helier columns** pre-assembled was built . In the packed bed there are two plates made in steel AISI316 with the holes to fit 1,5" helier columns ; the two plates are clasped by 6 symmetrical tie-rods .

This packed bed was inserted directly in the column and was flanged at its base with the column ; the holding was obtained using two O-ring and using a mechanical equipment that pushes the upper plate of the packing plate .

Using in counter-current flow this 400 mm column , characterized by a packed bed with 2000 mm height net , we made the following tests :

- **Pressure Drops** , with flows in the range : 1,000 – 10,000 $Kg / m^2 * h$
- SO_2 absorption with sodium hydroxide , **measurement of H_{OG}** and **measurement of K_G*a**

The comparison of the results obtained by the column with those obtained by the mono-tubes pointed out the following properties for **helier – Structured Packing** :

- **high performances** of this packed bed system , especially in presence of a mass transfer resistance in the gas phase ;
- **value of H_{OG}** obtained in the column higher than those obtained in the mono -tubes ;
- very **interesting** value for : $\eta = H_{OG} * \Delta P$, the **efficiency** of mass transfer

Phone : +39–031–895.374 Partita IVA/C.F. Reg. Imp.MI 13395210159 URL : www.pe-process.it
Fax : +39–031–3524.907 C.C.I.A.A. n. 1647291 Trib. Milano n. 213317 - Cap. soc. i.v. € 99.000,00. E-mail : process@pe-process.it

3.1 Resistance in Gas phase : tests with SO_2

Experimental tests data are shown in **FIG. 2** and **FIG. 3** here under.

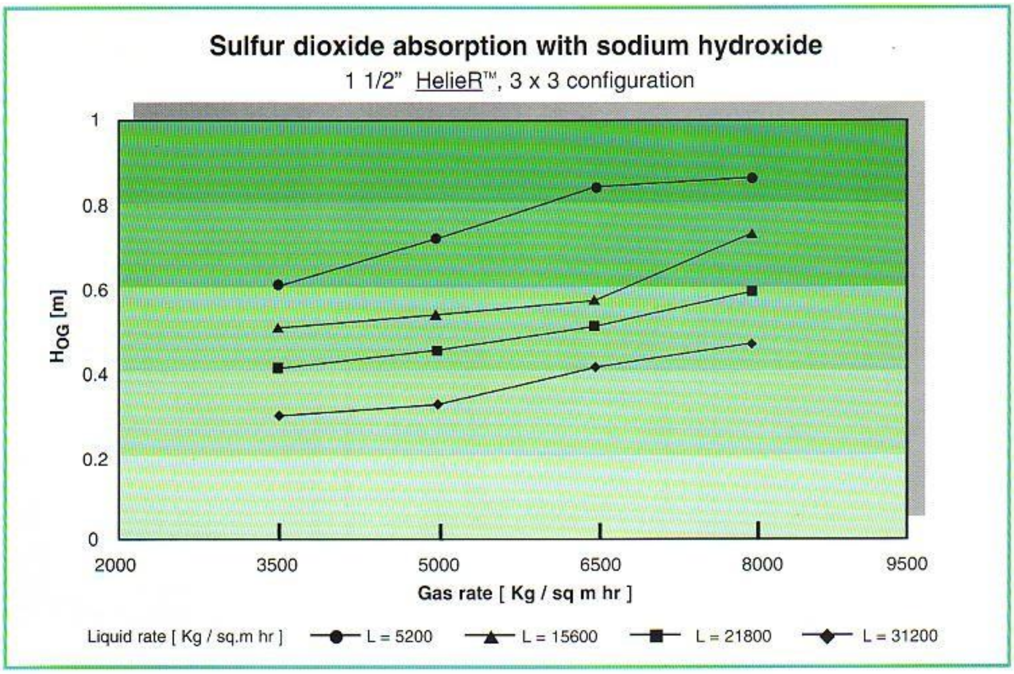

FIG 2 : **Experimental Tests with SO_2 – Value of H_{OG} : height of a transfer unit**

Heigth of transfer unit (i.e. **HOG**) for **helier – Structured Packing** with SO_2 are measured in m

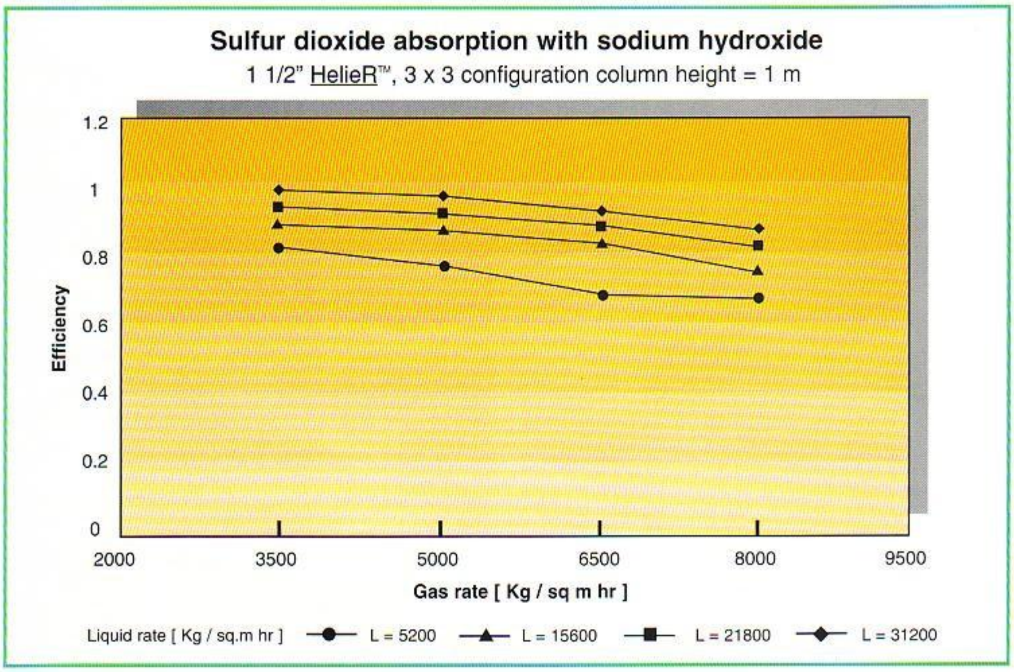

FIG 3 : **Experimental Tests with SO_2 – Efficiency Value : η**

Efficiency of mass transfer (i.e. **$\eta = H_{OG} * \Delta P$**) for **helier – Structured Packing** with SO_2

Phone : +39–031–895.374 Partita IVA/C.F. Reg. Imp.MI 13395210159 URL : www.pe-process.it
Fax : +39–031–3524.907 C.C.I.A.A. n. 1647291 Trib. Milano n. 213317 - Cap. soc. i.v. € 99.000,00. E-mail : process@pe-process.it

3.2 Comparison between 4" and 1.5" Elements

FIG. 4 compares the 1.5 " and 4 " packings , with to tests made with SO_2 , applyable in all processes where the mass transfer resistance is in the gas phase .

Comparing the test results obtained on 1.5" and 4" packings , a **better performance** was given by **1.5" packing** .

It is to be said that 4" packings shown no engulfing till flow value of 75,000 Kg. / m^2 * h .

This result proves the validity of helier geometry and opens new possibilities of applications .

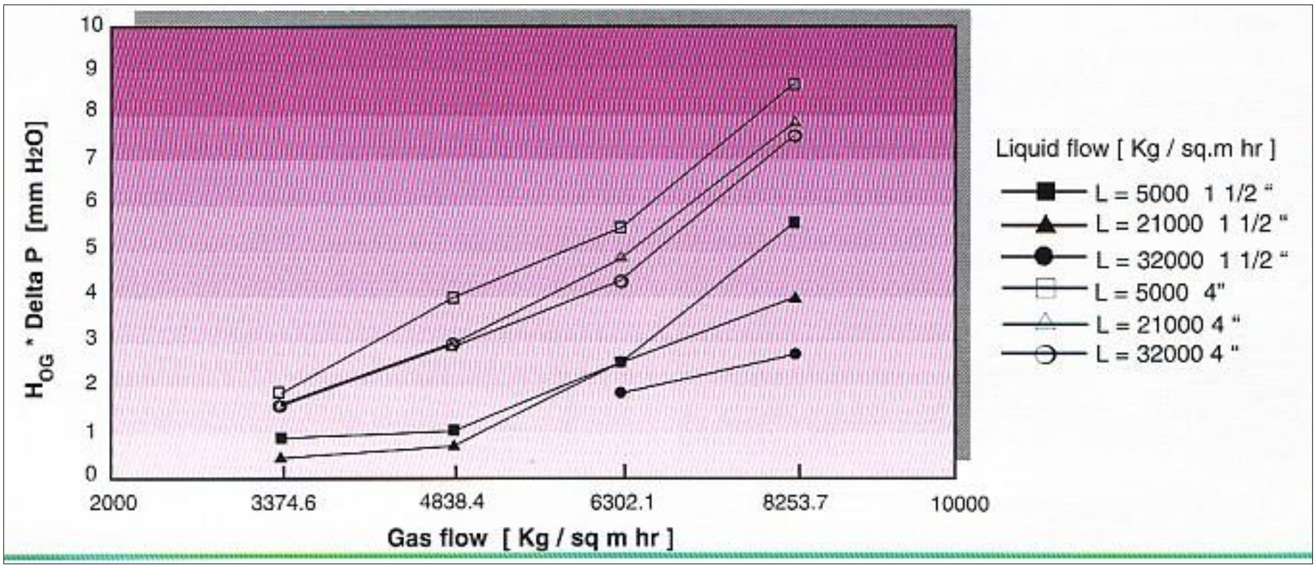

FIG 4 : **Efficiency Comparison : Comparison between 1.5" and 4" Efficiency**

Efficiency of mass transfer (i.e. η = H_{OG} * Δ P) comparison for **helier – Structured Packing** between 1.5" and 4" elements.

Data are Valid for Mass Transfer Resistance in Gas Phase

Phone : +39–031–895.374 Partita IVA/C.F. Reg. Imp.MI 13395210159 URL : www.pe-process.it
Fax : +39–031–3524.907 C.C.I.A.A. n. 1647291 Trib. Milano n. 213317 - Cap. soc. i.v. € 99.000,00. E-mail : process@pe-process.it

3.3 Resistance in Liquid phase : tests with CO_2

Experimental test data are shown in **FIG. 5** e **FIG. 6**.

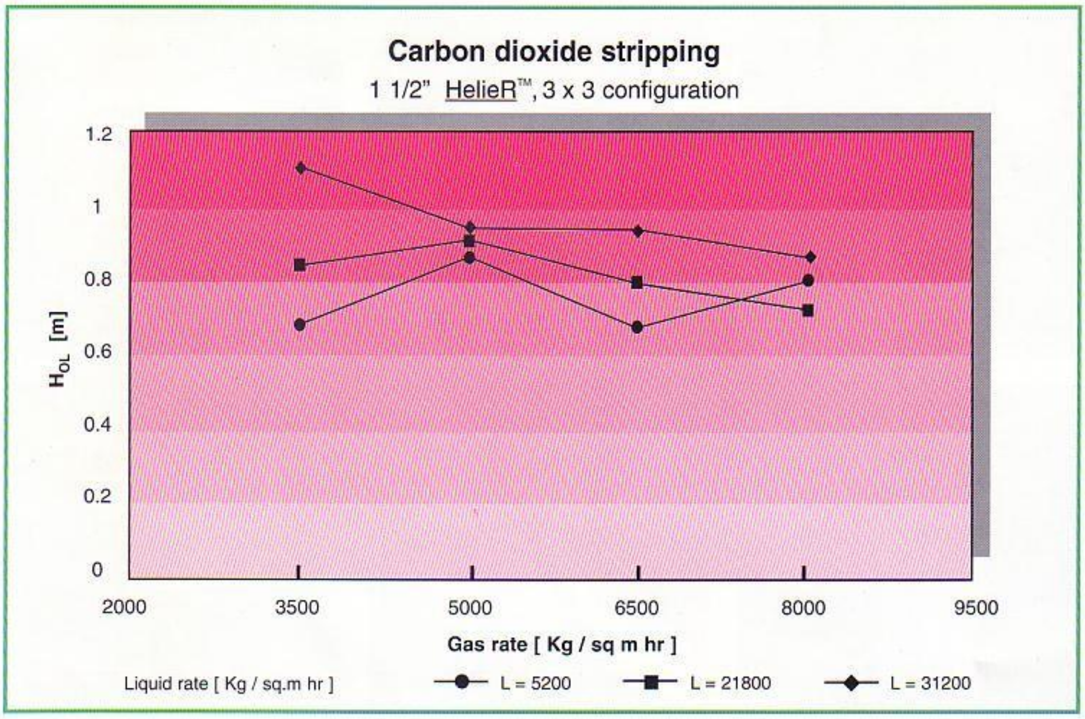

FIG 5 : Experimental Tests with CO_2 – Value of H_{OG} : height of a transfer unit

Heigth of transfer unit (i.e. $\mathbf{H_{OG}}$) for **helier – Structured Packing** with SO_2 are measured in m

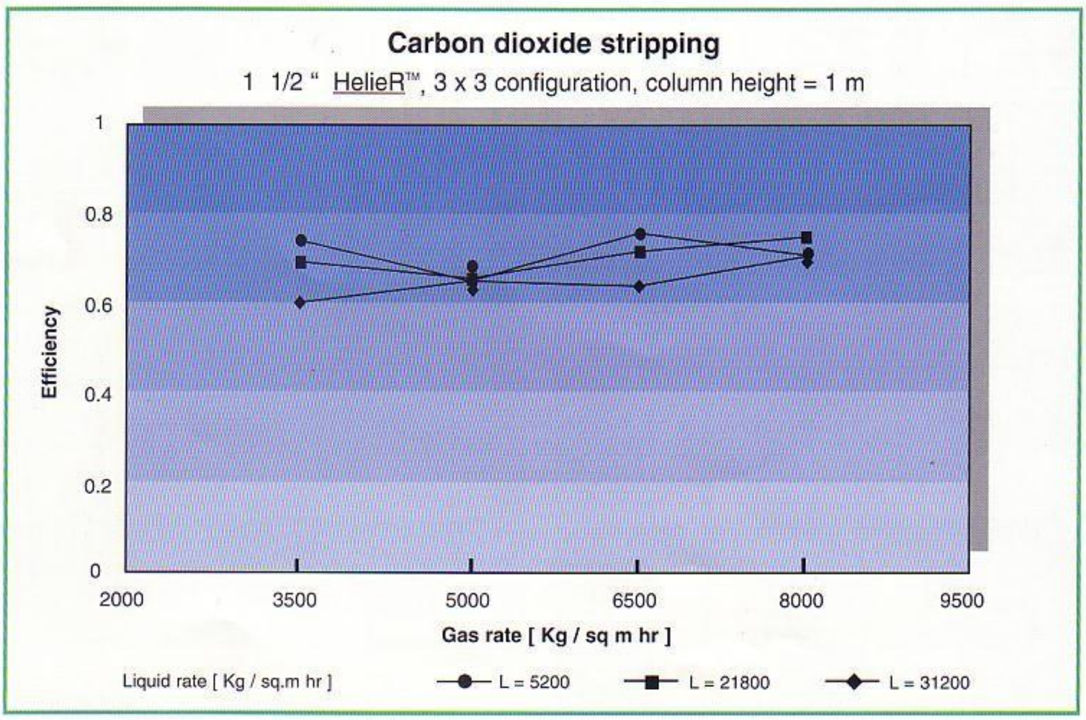

FIG 6 : Experimental Tests with CO_2 – Efficiency Value : η

Efficiency of mass transfer (i.e. $\boldsymbol{\eta = H_{OG} * \Delta P}$) for **helier – Structured Packing** with CO_2

Also in this case **helier – Structured Packing** system efficiency is proven , although there are better results if resistance to mass transfer is located in the gas phase .

Phone : +39–031–895.374 Partita IVA/C.F. Reg. Imp.MI 13395210159 URL : www.pe-process.it
Fax : +39–031–3524.907 C.C.I.A.A. n. 1647291 Trib. Milano n. 213317 - Cap. soc. i.v. € 99.000,00. E-mail : process@pe-process.it

4. Comparison with other packings

The same authors of this research wrote an article : " **Performances of Absorption Columns equipped with low Pressure Drops Structured Packings "** [2] , in which they compare **helier – Structured Packing** with others , using the following parameters :

1. High of a Transfer Unit , $\mathbf{H_{OG}}$
2. Pressure Drops , **Δ P**
3. Pressure Drops per High of a Transfer Unit , $\eta = H_{OG} * \Delta P$, **η** (the efficiency of mass transfer)

The **helier – Structured Packing** , used as structured packing , is the filling body that has :

- **the lowest** pressure drops ;
- **the best efficiency** in mass transfer : $\eta = H_{OG} * \Delta P$.

Phone : +39–031–895.374 Partita IVA/C.F. Reg. Imp.MI 13395210159 URL : www.pe-process.it
Fax : +39–031–3524.907 C.C.I.A.A. n. 1647291 Trib. Milano n. 213317 - Cap. soc. i.v. € 99.000,00. E-mail : process@pe-process.it

Phase 2 : **Experimental data analysis and identification of a computation model for gas phase and liquid phase resistance :**
September 1998 ~ February 1999

In this phase we proceeded to analyze the experimental data and to point out the formulation of the mathematical model to fit experimental data .

In particular , we have formulated two models :

- one is valid when the Resistance to mass transfer is in the Gas Phase ;
- the other is valid when the Resistance to mass transfer is in the Liquid Phase .

The mathematical models correspond to experimental data , especially when the Resistance to mass transfer occurs in the Gas phase .

Phone : +39–031–895.374 Partita IVA/C.F. Reg. Imp.MI 13395210159 URL : www.pe-process.it
Fax : +39–031–3524.907 C.C.I.A.A. n. 1647291 Trib. Milano n. 213317 - Cap. soc. i.v. € 99.000,00. E-mail : process@pe-process.it

BIBLIOGRAPHY

1 : **"Studio-Teorico Sperimentale sui Riempimenti Strutturati di Tipo Jet Helix " – FINAL REPORT**

2 : **" Performances of Absorption Columns equipped with low Pressure Drops Structured Packings " ,**
Pier Massimigliano Launaro and Alessandro Paglianti
Magazine : Industrial Engineering Chemical Research , published by American Chemical Society 9 September 1999 , Vol. N° 38 , pag. 3481 - 3488

RESOURCES

For **helier – Structured Packing** are available :

- **simulation software system** applying the mathematical model and the experimental data of the experimental activity conducted on helier – Structured Packing
- **industrial pilot column for special researches**

REFERENCES – Applications

Today , **helier** packing system has the following references :

1) **Experimental research** conducted on laboratory equipment and on a n industrial pilot column (column diameter = 400 mm ; net packed bed high = 2000 mm) ;

2) determination of its properties and performances for Absorption, Deabsorption and Stripping operations (**mass transfer Properties**)

3) **Operation Check up** run in an industrial pilot column (column diameter = 400 mm ; net packed bed high = 2000 mm) ;

4) Possibility to study and predict the operation conditions for any columns with helier – Structured packing , using the **simulation software system** developed for the purpose ;

5) Possibility to test working conditions other than those with CO_2 and SO_2

6) **Industrial Applications :**

A . in the " **RT Plant by** *P. E.* " engineered, manufactured and started-up by *P.E.* - *Process Engineering* in the production of High Quality Rubber Thread and of H.R.L.R.T. – Heat Resistant Latex Rubber Thread – to :

- properly mix Acetic Acid with Glacial Acid ;
- recover Acetic Acid through a structured packing film evaporator , i.e. the **AA Purification Plant** ;

B . in the **G.P.L. gas bottling plants** , to :

- separate solid particles from gas flow ;

C . in **waste water treatment plants** to :

- separate sludge from liquid flow

Phone : +39–031–895.374 *Partita IVA/C.F. Reg. Imp.MI 13395210159* *URL : www.pe-process.it*
Fax : +39–031–3524.907 *C.C.I.A.A. n. 1647291 Trib. Milano n. 213317 - Cap. soc. i.v. € 99.000,00.* *E-mail : process@pe-process.it*