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COMMUNICATION

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THE METHOD FOR IMPROVEMENT OF SULPHUR DIOXIDE ABSORPTION EFFICIENCY IN THE CROSS-FLOW SCRUBBER

NOTATIONS

F_{kr} — surface area of sprayed droplets (m^2),
G — spraying flux (m^3/m^2h),
M — number of SO_2 moles absorbed (M_{SO_2}/h),
NTU — number of mass transfer units,
V_c — volumetric flow rate of liquid (m^3/h),
V_g — volumetric flow rate of gas (m^3/h),
a — width of the scrubber (m),
b — depth of the scrubber (m),
c — heigth of the scrubber (m),
c_k — outlet SO_2 concentration (g/m^3),
c_p — inlet SO_2 concentration (g/m^3),
d_m — mean diameter of the droplet (μm),
s — width of the gap (m),
w_g — gas velocity in the scrubber's segment (m/s),
w_s — gas velocity in the scrubber's gap (m/s),
Δ_p — pressure drop (Pa),
η — scrubbing efficiency (%),
η_m — mean scrubbing efficiency (%).

1. INTRODUCTION

The cross-flow scrubber is within the group of spray scrubbers an original apparatus. It has been designed in Environment Protection Engineering Institute of Technical University of Wrocław, patented [1] and successfully applied for industrial purposes ("Bobrek" steel plant in Bytom and in "Wałbrzych" glass works in Wałbrzych).

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2. DESCRIPTION OF THE SCRUBBER

The flow-sheet is shown in fig. 1 where: $a \times b = 0.57$ m$\times$0.18 m, the length of a tray – 0.50 m, $b \times c = 0.18$ m$\times$0.12 m, and width of gap $s = 0.007$ m. Sulphurized gas, introduced into the scrubber by inlet pipe (*1*) placed in the lower part of the apparatus, passed through the sprayed scrubber segments (*2*). On its way to the outlet (*3*) the flow direction as well as compression and decompression of gas were alternately changed. The above changes have contributed to the effective sorption.

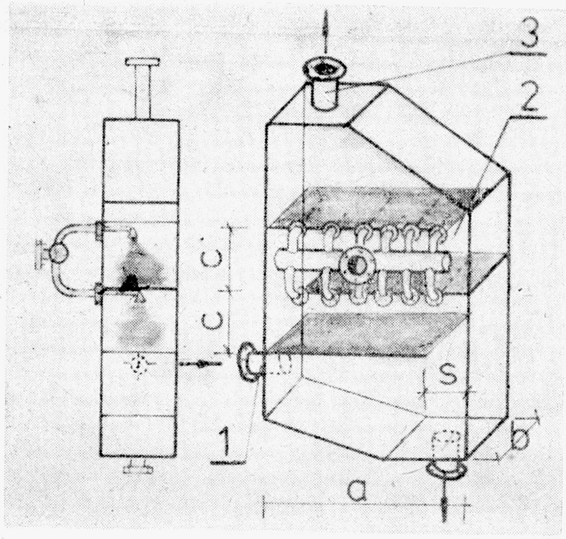

Fig. 1. Flow-sheet of the scrubber
1 – inlet connection pipe, *2* – scrubber segments, *3* – outlet

Rys. 1. Schemat skrubera o krzyżowym przepływie faz
1 – wlotowy łącznik rurowy, *2* – segmenty skrubera, *3* – wylot

3. THE EXPERIMENTAL STAND

The flow-sheet of the experimental stand is given in fig. 2. The mixture of air and SO_2 was pressed into the scrubber (*1*) by the fan (*2*). Purified air was let to the atmosphere through the demister (*3*). Scrubbing liquor from the feed tank (*4*) was pressed by a centrifugal pump (*5*) and sprayed in the scrubber by 12 hollow cone ramp bottom nozzles of diameter of 3 mm. The pressure of liquor $\Delta p = 50$ kPa guaranteed

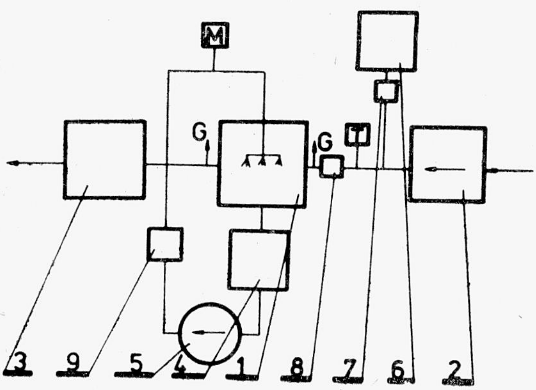

Fig. 2. Flow-sheet of the experimental stand
1 – scrubber, *2* – fan, *3* – demister, *4* – feed tank, *5* – centrifugal pump, *6* – SO_2 cylinder, *7* – regulators, *8* – orifice plate, *9* – rotameter

Rys. 2. Schemat instalacji doświadczalnej
1 – skruber, *2* – wentylator, *3* – urządzenie zapobiegające zamgleniu szyb, *4* – zbiornik zasilający, *5* – pompa odśrodkowa, *6* – cylinder SO_2, *7* – regulatory, *8* – płaszczyzna krzyżowa, *9* – rotametr

mean droplet diameter $d_m = 335$ μm. The flow rate of SO_2 from a cylinder (*6*) was adjusted by the regulators (*7*). Volumetric flow rate of air–SO_2 mixture was measured by measuring orifice plate (*8*). The volumetric flow rate of the liquid was measured with a rotameter (*9*). Gas for analysis was taken in the points denoted by *G* before it entered and after it left the scrubber pipes (fig. 2).

4. EXPERIMENTAL

Sprayed liquid flowing down the inclined trays formed cascades at their egdes. The gas bubbling through the cascade caused its rise and vortex, as well as secondary spraying. The vortex in cascade is shown in fig. 3. The intensity of vortex grew with the increasing gas velocity in the gap. Absorption efficiency of SO_2 was investigated for two gas velocities: $w_g = 1.98$ m/s and 3.86 m/s at gas velocity in the gap w_s ranging from

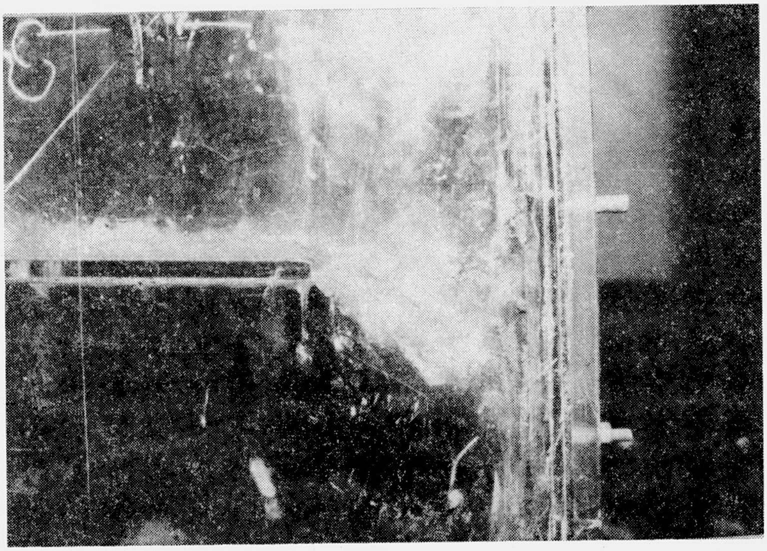

Fig. 3. The vortex in cascade ($w_g = 1.98$ m/s, $w_s = 3.97$ m/s)
Rys. 3. Zawirowania w strefie kaskady ($w_g = 1{,}98$ m/s, $w_s = 3{,}97$ m/s)

3.97 m/s to 14.00 m/s. The volumetric flow rate of liquid $V_c = 1.5$ m³/h assured the gas to liquid ratio $V_g/V_c = 100$ and 200 for gas velocities in the scrubber $w_g = 1.98$ m/s and $w_g = 3.86$ m/s, respectively. The results are shown in tab. 1. *NTU* versus gas velocity in the gap is shown in fig. 4. *NTU* increased with w_s, this increase being more significant for lower gas velocities in the scrubber. The pressure drops in the scrubber are marked with the broken line in fig. 4. The increment of sorption efficiency versus pressure drop has been plotted for two different gas velocities in the scrubber $w_g = 1.98$ m/s and $w_g = 3.86$ m/s. The values of pressure drops Δp corresponded to gas velocities in the gap w_s for the given w_g. They were read from fig. 4 (for example for $w_g = 3.86$ m/s, $\Delta p = 200$ Pa corresponded to gas velocity in the gap $w_s = 7.30$ m/s) (fig. 5). From the analysis of figs. 4 and 5 it follows that at the gas velocity $w_g = 1.98$ m/s *NTU* is twice as much as for $w = 3.86$ m/s. Considering high pressure drop the gas velocity in the gap w_s should not exceed 8 m/s. As it follows from fig. 5 for $w_g = 1.98$ m/s the pressure drop increased from 100 Pa to 150 Pa ($w_s = 9$ m/s) increased the scrubbing efficiency by 12% (from 63.22% up to 75.35%), whereas the pressure drop increased from 150 Pa ($w_s = 9$ m/s) to 200 Pa (11.5 m/s) increased this efficiency by 4.86% only (75.35% up to 80.21%) if compared with 12.13% for the same gas velocity.

Table 1

Scrubbing efficiency versus gas velocity in the gap
(the whole liquid $V_c = 1$ m³/h was sprayed)
Przyrost skuteczności sorpcji w zależności od prędkości gazu w szczelinie
(rozpylona cała ciecz, $V_c = 1$ m³/h)

w_g	w_s	c_p	c_k	η	η_n	M	Δp
m/s	m/s	g/m³	g/m³	%	%	M_{SO_2}/h	Pa
		1.025	0.625	39.02			
		1.025	0.625	39.02			
		1.038	0.625	39.76			
		1.038	0.638	38.55			
3.86	3.97	1.013	0.613	39.51	39.17	1.84	150
		1.025	0.610	40.49			
		1.025	0.610	40.49			
		1.038	0.588	43.37			
		1.038	0.610	41.23			
3.86	8.00	1.038	0.610	41.23	41.36	1.94	215
		1.038	0.563	45.78			
		1.025	0.550	46.34			
		1.013	0.563	44.44			
		1.025	0.538	47.56			
3.86	12.00	1.025	0.550	46.34	46.09	2.16	370
		1.025	0.475	53.66			
		1.025	0.488	52.44			
		1.038	0.513	50.60			
		1.038	0.513	50.60			
3.86	14.00	1.038	0.500	51.81	51.82	2.43	550
		1.025	0.388	62.20			
		1.038	0.388	62.65			
		1.038	0.400	62.65			
		1.025	0.388	62.20			
1.98	3.97	1.013	0.375	62.96	62.56	1.47	90
		1.025	0.250	75.61			
		1.025	0.250	75.61			
		1.038	0.263	74.70			
		1.038	0.263	74.70			
1.98	8.00	1.025	0.263	74.39	75.00	1.76	155
		1.025	0.200	80.49			
		1.025	0.200	80.49			
		1.038	0.213	79.52			
		1.038	0.200	80.73			
1.98	12.00	1.038	0.213	79.52	80.15	1.88	205
		1.025	0.161	84.29			
		1.025	0.161	84.29			
		1.025	0.174	83.02			
		1.038	0.187	81.98			
1.98	14.00	1.038	0.174	83.24	83.36	1.95	320

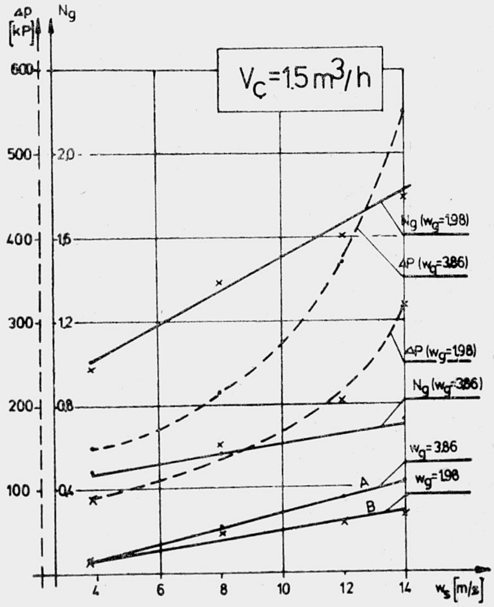

Fig. 4. *NTU* (Ng) versus gas velocity in the gap
Rys. 4. *NTU* (Ng) i wielkość oporów przy różnych prędkościach gazu w szczelinie

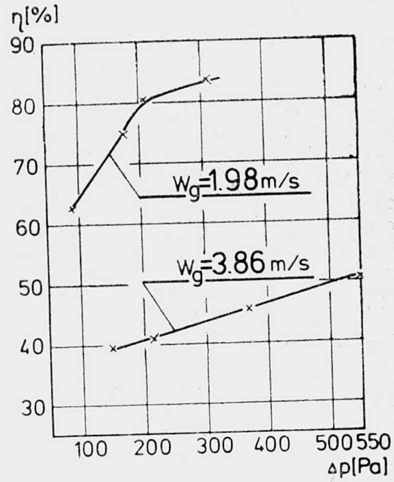

Fig. 5. Scrubbing efficiency of SO_2 versus pressure drop ($w_g = 1.98$ m/s, $w_g = 3.86$ m/s)
Rys. 5. Przyrost skuteczności sorpcji SO_2 w zależności od oporu przepływu ($w_g = 1{,}98$ m/s, $w_g = 3{,}86$ m/s)

In order to measure the sorption efficiency in the cascades alone at different gas velocities in the gap, the whole scrubbing liquor ($V_c = 1.5$ m³/h) was delivered directly onto the trays of scrubber. The results are shown in tab. 2. The obtained *NTU* are denoted by the straight lines *A* and *B* for $w_g = 3.86$ m/s and $w_g = 1.98$ m/s, respectively. *NTU* increased with w_s. Within the whole range of measurements pressure drop were below 300 Pa. The values of *NTU* plotted in fig. 4 were calculated from the formula [2]:

$$NTU = \ln \frac{c_p}{c_k}.$$

Table 2

Scrubbing efficiency versus gas velocity in the gap
(the whole liquid $V_c = 1$ m³/h was delivered directly onto the trays)
Przyrost skuteczności sorpcji w zależności od prędkości gazu w szczelinie
(cała ciecz bezpośrednio dostarczona na półki, $V_c = 1$ m³/h)

w_g	s	w_s	c_p	c_k	η	η_m	M
m/s	m	m/s	g/m³	g/m³	%	%	M_{SO_2}/h
3.86	0.058	8.00	1.038	0.825	20.52		
			1.013	0.813	19.74		
			1.025	0.838	18.24		
			1.025	0.838	18.24		
			1.038	0.825	20.52	19.45	0.91
	0.038	12.00	1.025	0.713	30.49		
			1.025	0.725	29.27		
			1.025	0.700	31.71		
			1.038	0.738	28.90		
			1.025	0.713	30.49	30.17	1.41
	0.033	14.00	1.038	0.688	33.72		
			1.038	0.688	33.72		
			1.025	0.650	36.59		
			1.038	0.675	34.97		
			1.025	0.650	36.59	35.12	1.65
1.98	0.029	8.00	1.013	0.825	18.59		
			1.013	0.825	18.59		
			1.025	0.850	17.07		
			1.025	0.838	18.24		
			1.025	0.838	18.24	18.15	0.43
	0.019	12.00	1.038	0.825	20.52		
			1.038	0.813	21.68		
			1.038	0.825	20.52		
			1.038	0.825	20.52		
			1.025	0.825	19.15	20.48	0.48
	0.016	14.00	1.025	0.775	24.39		
			1.025	0.775	24.39		
			1.038	0.788	24.08		
			1.038	0.788	24.08		
			1.025	0.763	25.56	24.50	0.57

5. CONCLUSIONS

1. The highest SO_2 scrubbing efficiency has been obtained for the following gas flow parameters: gas velocity in the segment $w_g = 2$ m/s, gas velocity in the gap $w_s = 8$ m/s.

2. The efficiency can be improved by increasing the vortex intensivity in the cascade zone.

3. A certain degree of scrubbing efficiency that can be achieved if the whole liquid is delivered directly onto the trays suggests the operational possibilities for wet scrubber based at the construction of cross flow scrubber.

LITERATURE

[1] Polish Patent No. 101910, 1979.
[2] PREYBAL R. E., *Mass Transfer Operations*, McGraw-Hill, New York 1975.