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AN EXPERIMENTAL INSTALLATION FOR THE STUDY OF THE FLOW IN AN ADIABATIC REGIME THROUGH CAPILLARY TUBES

BY

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Abstract. The flow in adiabatic regime through long pipes raises a series of problems. The pipes may be researched in a theoretical way by mathematical moulding but the validation of the results has to be done through experimental research. The paper presents a type of experimental installation for the study of the flow in adiabatic regime through long pipes and some values that were obtained and analyzed after the experimental research of some flowing procedures.

Key words: adiabatic flow, capillary tubes.

1. Introduction

Thanks to the complexity of the subject that was proposed to be studied was designed and developed an installation with an elastic structure and performance that will allow a variety of stabile regimes with reproducible measurable parameters. With its help may be preformed experimental verifications of the results that were obtained through mathematical modulation of some similar processes.

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2. Experimental Installation

The experimental installation for the study of the flow in an adiabatic regime conceived, developed and used, allows ample structural modifications and its usage in a variety of versions necessary for the edification as accurate as possible on the phenomenon and desired and studied dimensions.
The experimental installation (Vartolomei, 2001) is made up from the following elements, interconnected pieces, according to the layout presented in Fig. 1.

− air compressor K;

− buffer tank for the compressed air, with an adjustable pressure switch;

− separation/control valve R_1;

− thermal insulated tank Rez_1 for the quality control of the working agent studied at the entrance in the process, that has a manometer to measure the entry pressure p_1, a thermometer for determining the entry temperature t_1, blow-out valve R_2;

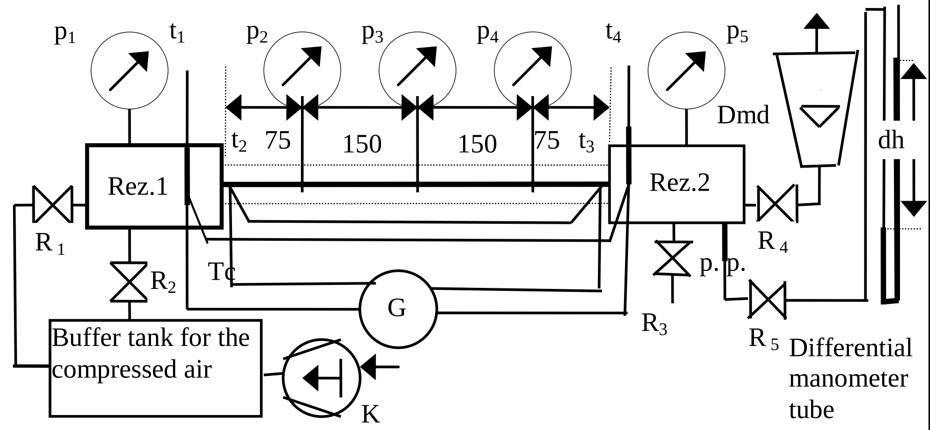

Fig. 1 − The experimental installation.

− Interchangeable pipe that is thermal insulated, having two pressure intake ports located at precise distances, connected to the manometers that allow the reading of the pressures p_2, p_3, p_4, on the length of the pipe as it is covered by the working agent;

− a tank that is thermal insulated Rez_2 for the quality control when the studied working agent exits the process, the tank has a manometer for the measurement of the counter-pressure at exiting the pipe p_5, a thermometer for determining the exit temperature t_4, blow-out valve R_3;

− separation/control valve R_4;

− rotameter Dmd;

− separation valve R_5;

− differential manometer tube for an accurate measurement of the counter-pressure at the end of the lamination (at exiting the flow pipe);
− thermocouples Tc;
− the galvanometer G.

3. Experimental Results

The experimental results measured on the installation were written in the data table Tables 1÷4 and for a quicker edification over the accuracy and over the variation mode they were graphically represented and also present in the paper.

Table 1

p_1 bar	t_1 ºC	p_2 bar	p_3 bar	p_4 bar	Δt_{23} div	Δt_{23} div	Δt_{14} div	t_4 ºC	Δh mmH_2O	$\dot{V}_e$ l/h
					Tc 10	Tc 6	Tc 2			
	27							27		
4.4		3.65	2.40	1.13	11.0	2.0	6.2		121	430
4.2		3.50	2.15	1.06	10.0	2.0	4.5		118	410
4.0		3.35	2.11	1.01	10.0	2.0	4.0		117	400
3.8		3.15	2.00	0.93	11.0	2.0	3.0		111	380
3.6		3.00	1.95	0.89	7.5	2.5	3.0		104	360
3.4		2.80	1.80	0.82	8.0	2.0	2.0		104	340
3.2		2.65	1.70	0.78	7.0	1.5	2.0		102	330
3.0		2.45	1.60	0.71	6.0	1.0	1.0		99	320
2.8		2.30	1.45	0.66	7.0	1.0	1.5		94	300
2.6		2.15	1.40	0.60	5.0	1.0	1.0		93	280
2.4		1.85	1.22	0.54	6.0	1.0	0.5		90	270
2.2		1.80	1.15	0.49	4.0	0.5	0.0		30	212
2.0		1.62	1.00	0.44	3.9	0.3	−0.2		28	200
1.8		1.50	0.92	0.40	3.0	0.0	−0.9		25	184
1.6		1.31	0.80	0.36	2.0	0.0	−1.0		23	168
1.4		1.15	0.70	0.30	1.0	−1.0	−1.0		20	148
1.2		1.00	0.60	0.26	1.1	−0.5	−1.0		19	130
1.0		0.85	0.50	0.22	0.0	−1.0	0.5		17	112
0.8		0.65	0.40	0.18	−0.5	−1.0	−0.2		15	98
0.6		0.51	0.30	0.14	−1.0	−0.7	−0.5		13	86
0.4		0.25	0.15	0.10	−2.2	−1.2	−1.4		13	84
0.2		0.11	0.10	0.06	−2.2	−1.0	−1.5		11	74

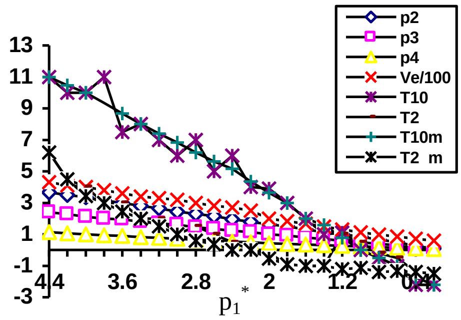

Fig. 2 − Plot of the measured parameters Table 1.

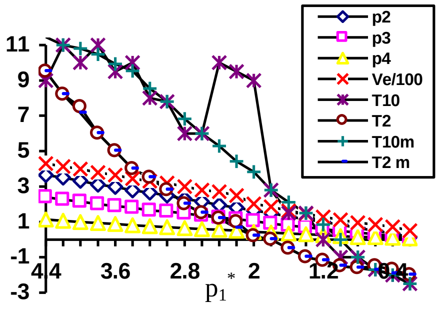

Fig. 3 − Plot of the measured parameters Table 2.

Table 2

p_1 bar	t_1 ºC	p_2 bar	p_3 bar	p_4 bar	Δt_{23} div	Δt_{23} div	Δt_{14} div	t_4 ºC	Δh mmH_2O	$\dot{V}_e$ l/h
					Tc 10	Tc 6	Tc 2			
	27							27		
4.4		3.65	2.40	1.13	9.0	2.0	9.5		121	430
4.2		3.50	2.25	1.06	11.0	2.0	8.2		117	414
4.0		3.32	2.15	1.00	10.0	2.0	7.5		115	400
3.8		3.10	2.00	0.93	11.0	2.0	6.0		111	380
3.6		2.98	1.90	0.89	9.5	2.5	5.0		107	365
3.4		2.79	1.80	0.82	10.5	2.0	4.0		103	345
3.2		2.65	1.65	0.76	8.0	1.5	3.5		100	330
3.0		2.44	1.59	0.71	7.8	1.0	2.8		97	320
2.8		2.30	1.48	0.65	6.0	1.0	2.0		95	300
2.6		2.15	1.35	0.60	6.0	1.0	1.5		93	280
2.4		1.95	1.25	0.55	10.0	1.0	1.2		91	270
2.2		1.80	1.15	0.50	9.5	0.5	1.0		87	255
2.0		1.65	1.05	0.44	9.0	0.3	0.2		81	202
1.8		1.50	0.91	0.40	2.8	0.0	0.0		25	186
1.6		1.30	0.80	0.35	1.5	0.0	−0.5		23	162
1.4		1.15	0.70	0.30	1.5	−1.0	−1.0		20	146
1.2		1.00	0.60	0.25	0.0	−0.5	−1.2		19	128
1.0		0.85	0.49	0.20	−1.0	−1.0	−1.5		17	112
0.8		0.65	0.39	0.15	−1.0	−1.0	−1.6		15	96
0.6		0.51	0.30	0.14	−1.7	−0.7	−1.5		13	85
0.4		0.35	0.20	0.11	−2.0	−1.2	−1.7		12	72
0.2		0.15	0.05	0.07	−2.5	−1.0	−2.0		11	50

Table 3

p_1 bar	t_1 °C	p_2 bar	p_3 bar	p_4 bar	Δt_{23} div	Δt_{23} div	Δt_{14} div	t_4 °C	Δh mmH_2O	$\dot{V}_e$ l/h
					Tc 10	Tc 6	Tc 2			
	26							26		
4.4		3.65	2.39	1.13	10.5	2.0	6.0		121	430
4.2		3.50	2.25	1.06	10.0	2.0	6.0		118	415
4.0		3.35	2.12	1.00	10.0	2.0	5.0		115	400
3.8		3.15	2.05	0.94	9.5	2.0	3.2		110	380
3.6		3.02	1.95	0.89	9.1	2.5	3.0		106	365
3.4		2.80	1.80	0.80	7.6	2.0	2.0		105	347
3.2		2.65	1.65	0.75	7.8	1.5	1.5		101	330
3.0		2.46	1.56	0.71	8.5	1.0	1.0		98	320
2.8		2.30	1.46	0.65	6.0	1.0	0.5		95	300
2.6		2.15	1.32	0.60	7.0	1.0	0.0		93	280
2.4		1.97	1.25	0.55	4.5	1.0	−0.2		90	270
2.2		1.80	1.14	0.50	6.0	0.5	−0.8		30	232
2.0		1.65	1.01	0.44	2.8	0.3	−1.0		27	198
1.8		1.52	0.90	0.40	2.8	0.0	−1.3		25	184
1.6		1.31	0.80	0.35	1.5	0.0	−1.8		23	162
1.4		1.15	0.70	0.30	−0.5	−1.0	−2.0		21	142
1.2		1.00	0.60	0.26	0.0	−0.5	−2.6		19	128
1.0		0.85	0.50	0.21	−1.2	−1.0	−2.8		16	112
0.8		0.65	0.40	0.17	−1.5	−1.0	−3.0		15	97
0.6		0.51	0.32	0.14	−2.5	−0.7	−3.0		13	84
0.4		0.32	0.20	0.11	−2.0	−1.2	−3.2		13	66
0.2		0.15	0.10	0.07	−2.3	−1.0	−3.0		11	54

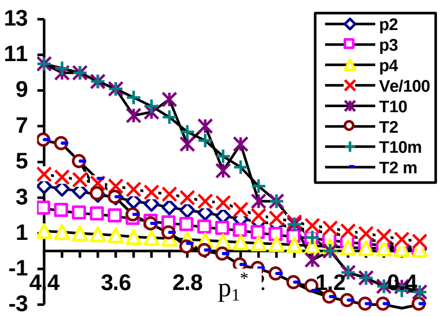

Fig. 4 − Plot of the measured parameters Table 3.

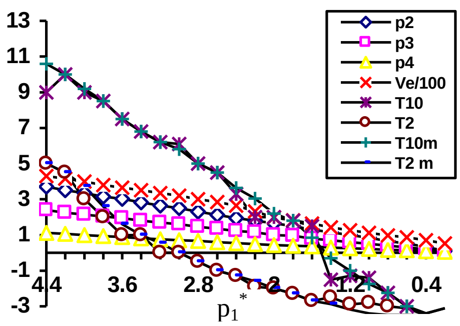

Fig. 5 − Plot of the measured parameters Table 4.

Table 4

p_1 bar	t_1 ºC	p_2 bar	p_3 bar	p_4 bar	Δt_{23} div	Δt_{23} div	Δt_{14} div	t_4 ºC	Δh mmH_2O	$\dot{v}_e$ l/h
					Tc 10	Tc 6	Tc 2			
	26							26		
4.4		3.70	2.39	1.13	9.0	2.0	5.0		123	430
4.2		3.50	2.25	1.06	10.0	2.0	4.5		118	415
4.0		3.35	2.15	1.00	9.0	2.0	3.0		115	400
3.8		3.15	2.03	0.94	8.5	2.0	2.0		111	380
3.6		3.02	1.95	0.89	7.5	2.5	1.5		107	365
3.4		2.82	1.80	0.82	6.8	2.0	1.0		105	350
3.2		2.65	1.70	0.76	6.2	1.5	0.0		101	335
3.0		2.50	1.60	0.71	6.1	1.0	0.0		98	320
2.8		2.30	1.45	0.66	5.0	1.0	−0.5		95	300
2.6		2.12	1.39	0.60	4.5	1.0	−1.0		93	285
2.4		1.95	1.23	0.53	3.3	1.0	−1.3		91	265
2.2		1.80	1.15	0.49	2.0	0.5	−1.9		41	232
2.0		1.65	1.00	0.44	2.0	0.3	−2.0		27	198
1.8		1.50	0.95	0.40	1.8	0.0	−2.3		25	182
1.6		1.32	0.80	0.36	1.5	0.0	−2.7		23	164
1.4		1.15	0.70	0.29	−1.5	−1.0	−2.5		21	142
1.2		1.00	0.60	0.26	−1.3	−0.5	−2.9		19	126
1.0		0.85	0.50	0.22	−1.4	−1.0	−2.8		17	112
0.8		0.65	0.39	0.17	−2.5	−1.0	−3.0		15	98
0.6		0.52	0.30	0.14	−3.0	−0.7	−3.1		15	86
0.4		0.33	0.20	0.10	−3.4	−1.2	−3.5		13	70
0.2		0.11	0.10	0.06	−3.1	−1.0	−3.5		11	52

Because the measurement of the difference of temperature was done with the help of the sensible thermocouples, known for their special sensibility of measurable dimensions at different disturbing factors, present in the installation or in the working environment, the values that were read on the measurement devices are not on a stabile variation curve. The graphic representation of these values placed them in an adjacent stabile variation area that is marked in graphics by dots that resulted from the measurements.

3. The Operation and the Interpretation of the Results

Through the operation of the experimental data with the help of the calculus program, for each table that was previously presented, was obtained a set of data that was graphically represented according to the values of p_1* that were between 1,2 şi 5,4 bar. This lead to the development of two graphic representations that were cumulated for each table. Point 1 was considered to be at the entry in the capillary and point 2 at the exit. From the graphics, in order to save some space, were reproduced only the ones corresponding to Table1.

Also for saving space, references to calculus relations used for the establishing the values of the calculated measurements are not done because the calculus program used for the operation of the experimental data is derived through particularization from the calculus program presented in a paper that was previously published.

From the analysis of the variation graphic of calculated sizes that resulted from the data operation which is Fig. 6 shows a slight growth of w_1 once with the growth of p_1^* (maximum 7.18), in comparison with the accentuated growth of w_2 (maximum 37). There is also a variation difference in the case of ρ. While ρ_1 grows significantly with its size p_1^*, ρ_2 has a small corresponding growth, close in size, with p_2 cause by the counter pressure from Rez_2, generated by the rotameter. Also, significant growths have $\dot{m}$ and $\dot{V}_e$.

In Fig. 7, the value for $\zeta = \zeta_{experimental}$ (maximum 4.17) is with approximately two sizes bigger than ζ_C that was calculated with the relation Re function, ($\zeta_{C\ maxim}$ = 0.0559). The development of the experiments validates through effects (the growth of the volume debits) the size order of $\zeta_{experimental}$. The curves represent the entropy variation and first of all of Re have powerful ascending inclination. Decreasing in perfect relation with reality is the variation curve of σ, (σ_{min} = 0.191).

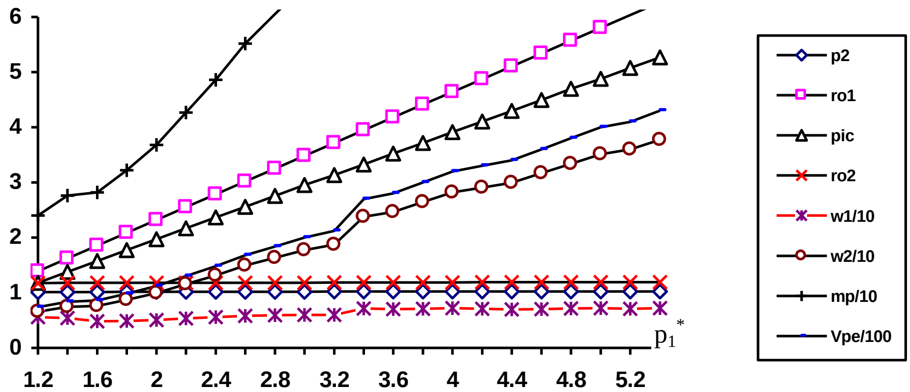

Fig. 6 − Plot of the calculated sizes resulted from the data operation from Table 1.

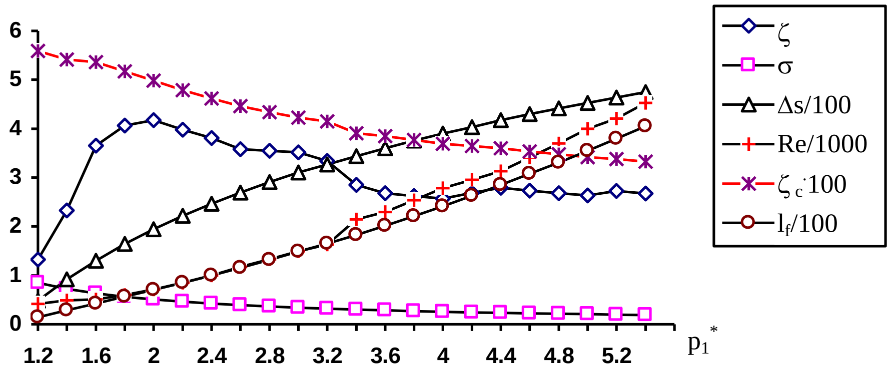

Fig. 7 − Plot of the calculated sizes resulted from the data operation from Table 1.

4. Conclusions

From the analysis of the data that was experimentally obtained and of the graphic representations it is obvious that the installation that was conceived and developed works properly in different working regimes and offers accurate data that may define the studied processes.

By operating the data experimentally obtained may be verified results obtained thorough mathematical moulding conceived for similar working conditions, therefore validating them. The installation proves its usability.

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O INSTALATIE EXPERIMENTALA PENTRU STUDIEREA CURGERII IN REGIM ADIABATIC PRIN TUBURI CAPILARE

(Rezumat)

Curgerea în regim adiabatic prin tuburi capilare şi conducte lungi ridică o serie de probleme. Ele pot fi cercetate teoretic prin modelare matematică dar validarea rezultatelor trebuie facută prin cercetarea experimentală.

Lucrarea prezintă o variantă de instalaţie experimentală pentru studierea curgerii în regim adiabatic prin tuburi capilare şi câteva valori ale parametrilor fluidului obţinute şi analizate în urma cercetării experimentale a unor procese de curgere.