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A STUDY OF THE RELATIONSHIP BETWEEN PRIMING HEADS OF MODELS AND PROTOTYPES OF AUTOMATIC SIPHONS

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TRANSLATED FROM THE ITALIAN

By

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Denver, Colorado

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"A STUDY OF THE RELATIONSHIP
BETWEEN THE PRIMING HEADS OF MODELS
AND OF THE PROTOTYPE OF A SELF-PRIMING SIPHON"

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A Translation of

Ricerche sulla relazione che
intercede tra l'altezza di adescamento
dei sifoni autolivellatori sperimentati
in modelle e quella dell'originale

By

Alezzandro Veronese

in

L'Energia Elettrica

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"A STUDY OF THE RELATIONSHIP BETWEEN THE PRIMING HEADS OF MODELS AND OF THE PROTOTYPE OF A SELF-PRIMING SIPHON"

By

Doctor Engineer Alessandro Veronese

The priming head (h) of a self-priming siphon is defined as the difference of elevation between the overflow sill and the water level in the forebay at which the siphon is completely primed or the head that is created by complete vacuum in the siphon throat.

The evaluation of this quantity is very important in the study of the self-priming siphon, first, because it is an index of the sensitiveness of the structure, and second, because in each case it is needed to understand and to establish the basic theory free of any works contiguous to siphon.

The present experimental research was carried out to set up the relationship that exists between the priming head (h) of a ($1/\lambda$) model siphon and the priming head (h_o) of ($\lambda = 1$) the prototype siphon.

The experiments were performed on three siphons of different types. Their internal outlines on which are recorded the prototype priming heads, (h_o), are given by the figures 1, 2, and 3. These heads were measured on the installed siphons.

For each type of siphon that was tested, three different scale (1/) models were used.

Model I (Canale Camuzzoni)

λ = 20, 10, and 5

Model II (Carron)

λ = 20, 12, and 8

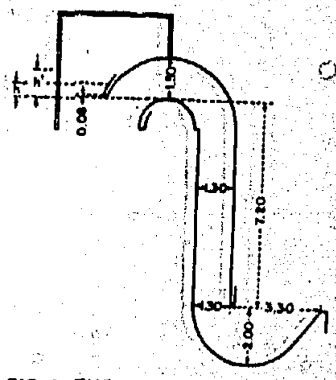

FIG. 1 THE CAMUZZONI SIPHON
(WIDTH OF THROAT, 2 m.)

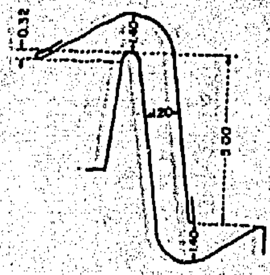

FIG. 2 THE CARRON SIPHON
(WIDTH OF THROAT, 1.5 m.)

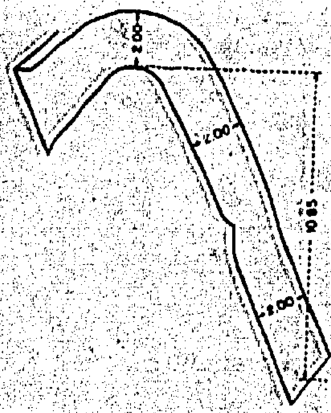

FIG. 3 THE S. CATERINA SIPHON
(WIDTH OF THROAT, 3 m.)

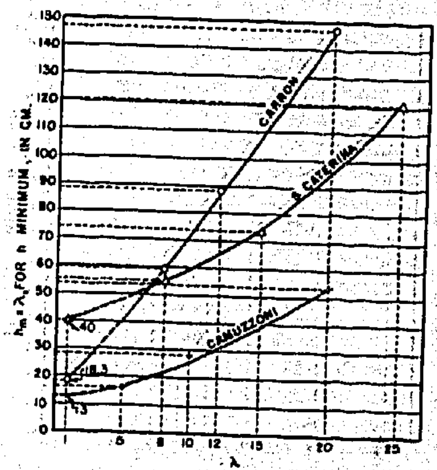

DIAGRAM A
Experimental and extrapolated values of the product $h_m \times \lambda$ as a function of λ.

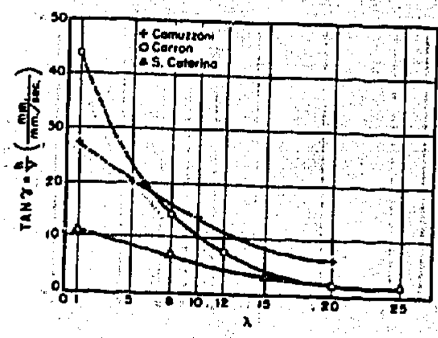

DIAGRAM D_1
Experimental and extrapolated values of tan γ as a function of λ

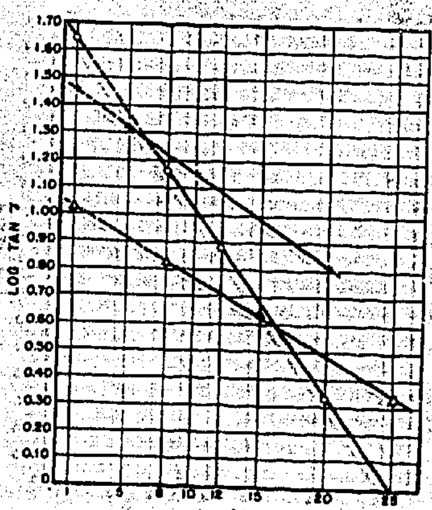

DIAGRAM D_2
Experimental and extrapolated values of log tan γ as a function of λ

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X-D-1850

Model III (S. Caterina)

λ = 25, 15, and 8

The models were constructed of cement with glass side walls through which one could observe the priming phenomena during the period of priming, figure 4, 5, and 6.

The models of the siphons were installed at the end of a canal that was supplied through a calibrated orifice. Two piezometers, inclined to amplify the movement of the liquid, indicated, respectively, the elevation of the water level in the forebay (h) and the elevation of the pressure or of the vacuum in the upper throat of the siphon (h'). These elevations are referred to the overflow sill of the siphon.

The elevation (h') is measured, first, to obtain the changes in the internal pressure of the siphon during the period of priming, and second, to determine the exact point of complete priming which is indicated by an instantaneous increase of (h').

The head readings (h') at different points during the priming period have shown the different priming characteristics of the three types of experimental siphons. From the start to the end of such a period, the characteristics shown are:

(1) for the type of siphon, "Canale Camuzzoni"

(h') was less than (h). This fact indicated that the upper throat pressure was greater than atmospheric pressure.

(2) for the type of siphon "S. Caterina"

(h') was greater than (h) which is an index of a pressure less than atmospheric pressure.

Fig. 4 - Model (1/5) of the Type of Siphon Used on "Canale [illegible]"

[illegible] (1/10) [illegible]

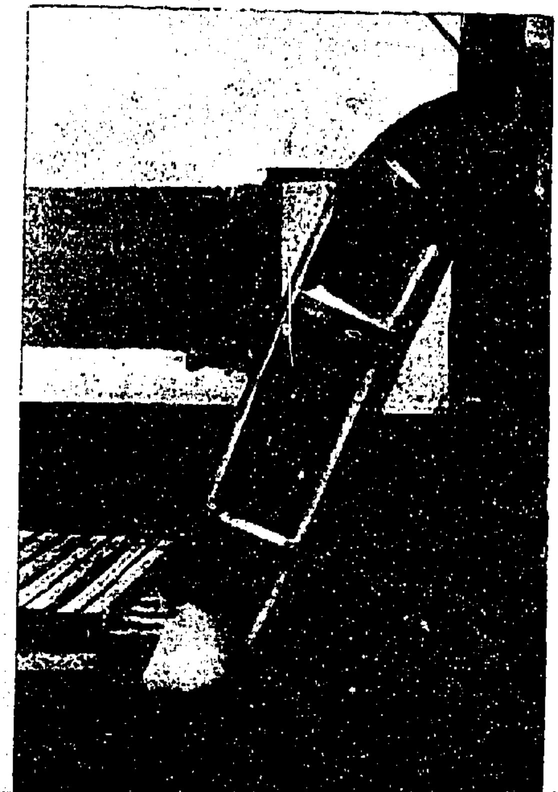

Fig. 6 - Model (1/8) of the Type of Siphon Used on "Santa Caterina

(3) for the siphon type, "Carron"

(h') was approximately equal to (h) which indicated that the pressure was about equal to atmospheric pressure.

It follows that the siphons which were tested by models had different priming characteristics. In each model, one of the three possible conditions of pressure in the throat for the priming period is noted.

MINIMUM PRIMING HEAD

To establish a steady flow condition which could be sustained for some time without priming the siphon, small discharges were used to start the experiments. After the forebay level was allowed to fall below the elevation of the overflow sill, the experiment was continued by increasing the discharge very slowly until the level (h_m) which caused priming of the siphon was reached. This elevation was considered as the minimum elevation for priming.

Subsequently, experiments with larger discharges were performed to determine the priming time for increased mean velocities of rise in the forebay. The observations showed that the priming head was always larger than the minimum. This increase in the priming head when compared to the minimum gives factors which can be used either to increase or to decrease the dimensions of the model or the value of (λ). (Diagram B, appendix).

The readings from the two piezometers which are taken at short intervals during the period of priming show the progress of the experiment. These values are reproduced in the tables and diagram B of the appendix.

The results of the experiments performed on the models as compared to the observations made on the originals ($\lambda = 1$) are tabulated in table I.

In the problem under investigation, the relationship between the priming heads of the model and of the prototype should be according to the laws of geometric similitude.

$$h_o = \lambda h_m$$

However, this is not verified by the results of table II which gives the values shown in table I multiplied by λ (also see diagram A).

Table I

	h_m - Minimum priming head							
For λ	25	20	15	12	10	8	5	1
Camuzzoni siphon	--	2.65	--	--	2.81	--	3.37	13.0
Carron siphon	--	7.37	--	7.33	--	7.45	--	18.3
S. Caterina siphon	4.62	--	4.95	--	--	6.90	--	40.0

Table II

	Values $h' = \lambda h_m$							
For λ	25	20	15	12	10	8	5	1
Camuzzoni siphon	--	53.0	--	--	28.10	--	16.85	13.0
Carron siphon	--	147.4	--	87.96	--	59.60	--	18.3
S. Caterina siphon	120.50	--	74.25	--	--	55.20	--	40.0

An examination of the experimental results above shows that the equation, $h_o = f \times h_m$, is not linear.

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Table II

	Values h' x λh_m							
For λ	25	20	15	12	10	8	5	1
Camuzzoni siphon	--	53.0	--	--	28.10	--	16.85	13.0
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An examination of the experimental results above shows that the equation, $h_o = f \times h_m$, is not linear.

The priming head depends primarily on the form of the siphon and on the priming time. The value of the product "λh_m" instead of being constant and equal to "h_o" has values differing by a function of "λ." This function of λ varies for each type and form of siphon. This function can be represented graphically when the values of "h_m" are obtained for at least three different scale models of the same type of siphons.

The value of h_o (of the prototype) can be determined by extrapolation of the line which was indicated by at least three points that were obtained from model experiments. This value "h_o" from the field is desirable because it confirms the curve of diagram A. Therefore, as previously stated, the priming head was obtained for the siphons whose models are under investigation.

A study of the tables and of the graphs of these results, diagram A, shows that the equation $\lambda h_m = f(\lambda)$ has a different form for each type of siphon tested. Therefore, a general law that gives "h_o" as a function of "λ" and of "h_m" does not exist. As previously stated, the only way to determine the value of "h_o" for practical use is to build and to experiment on at least three models of different scales of the same type of siphon.

On the other hand, cases arise where one desires only an approximate indication of the value of h_o. This point is illustrated for example by some projects that have the design fixed. So given a certain proposed internal outline, one can determine from the experimental investigation of a single model a value of h_o that should at least indicate the advisability of continuing the studies or of changing without further experiments, the designed form of the siphon.

This approximation of the value of h_o can be determined from the value of "h_m" found from a single model when h_o is made to depend on "h_m", on "λ" and on the priming time "T_m" in the model for the minimum priming head, "h_m."

PRIMING TIME

The priming time, "T", in the present investigation is defined as the interval of time that elapses between the start of the overflow and the point at which the siphon is completely primed. Such a period is divided into two parts:

I° = the time that elapses between the start of the overflow and the moment at which the water elevation reaches the priming head.

II° = the time that elapses between the moment at which the water reaches the priming head and the instant at which the siphon becomes completely primed.

Some authors define the priming time equal to only the second phase, II°, which is very short, a duration of the order of a few seconds, and which is approximately constant whatever be the velocity of rise of the water in the forebay.

The first phase is preparatory and its duration influences the priming head.

The experimental procedure which was previously noted is first, to make the inflow to the forebay of the model of the siphon a constant quantity which can be cleared through the siphon without priming it; second, to continue the experiment by slowly increasing the discharge until the minimum priming head is reached. Under these last conditions the priming time "T_m" of the model is a quantity

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The minimum priming head divided by the time "T_m" gives the value of the maximum mean velocity of rise in the forebay that permits the priming of the siphon at the minimum elevation. Thus the water should be introduced into the forebay with the energy evenly distributed so as to obtain a velocity of rise smaller than that obtained by the indicated computation. However, the minimum priming elevation should always remain the same since the siphon can not be primed at a lower head. The time "T_m" which is determined from an experiment that is conducted as indicated above, is, therefore, the minimum priming time because the siphon primes itself at the minimum elevation.

On the other hand, an increase in the mean velocity of rise in the forebay and a reduction in the priming time increase in effect, as has already been observed, the priming head, diagram B, appendix.

Multiplying the priming time, "T_m" obtained from the experiments for each series of models with the values of   gives approximately:

$$T_m / \sqrt{\lambda} = \text{constant } (T_m \text{ in seconds})$$

The tabulated results are:

I. "Camuzzoni" type of siphon

λ	T_m sec.	$T_m / \sqrt{\lambda}$
20	170	$170/\sqrt{20} = 38.03$
10	120	$120/\sqrt{10} = 37.97$
5	80	$80/\sqrt{5} = 35.71$

Average in round numbers = 37.00

II. "Carron" type of siphon

20	270	$270/\sqrt{20}$	= 60.40
12	210	$210/\sqrt{12}$	= 60.69
8	170	$170/\sqrt{8}$	= 60.07
Average in round numbers			= 60.00

III. "S. Caterina" type of siphon

25	165	$165/\sqrt{25}$	= 33.00
15	120	$120/\sqrt{15}$	= 31.00
8	90	$90/\sqrt{8}$	= 31.80
Average in round numbers			= 32.00

Therefore, for $\lambda = 1$, the priming time for the minimum priming head for the originals, "T_o" should be respectively equal to approximately 37, 60, and 32 seconds. As a check on the preceding hypothesis, it was possible to perform an experiment only on the original siphon "carron" for which the "T_o" was accurately found to be equal to an average of 60 seconds.

Since in practice the values of $T_m/\sqrt{\lambda}$ are considered constant for a single type of a siphon, the law that expresses the constancy of the expression $T_m/\sqrt{\lambda}$ was accurately deduced.

From the recorded time, "T_m", that is obtained from the experiments repeated on a single model, an approximate formula that gives h_o in terms of h_m, λ, T_m of the single model was determined.

Placing the equation:

$$h_o = f(\lambda, h_m)$$

in the form:

$$h_o = \lambda^n h_m$$

in which the values of "n" for each model investigated are

Siphon type	λ	h_m (cm.)	$n = \frac{\log h_o - \log h_m}{\log \lambda}$
Camuzzoni	20	2.65	0.53
h_o = 13 cm.	10	2.81	0.67
	5	3.37	0.83
	Average n_m		0.68
Carron	20	7.37	0.30
h_o = 18.3 cm.	12	7.33	0.36
	8	7.45	0.43
	Average n_m		0.36
S. Caterina	25	4.82	0.66
h_o = 40 cm.	15	4.95	0.77
	8	6.90	0.84
	Average n_m		0.76

An inspection of the values of "n" shows that this exponent not only varies from siphon to siphon but also varies from model to model of the same siphon.

Now, knowing that the determination of h_o can be only approximate, considering the average value of "n", and introducing in the preceding equation the value of T_m, the value of average "n" can be expressed as a function of T_m.

From the observed experimental data, one deduces

$$(T_m / \sqrt{\lambda})\, n_m = \text{constant}$$

Giving for:

Camuzzoni siphon = 37 x 0.68 = 25

Carron siphon = 60 x 0.36 = 22

S. Caterina siphon = 32 x 0.76 = 25

Average in round numbers = 24

From the formula

$$h_o = \lambda^n h_m$$

It follows that:

$$n = \frac{24\sqrt{\lambda}}{T_m}$$

To illustrate the approximations obtained from this method, the preceding formula is applied for each value of h_m, T_m, and λ to determine the values of h_o (table III) for each model of the different siphons under investigation.

Table III

Siphons	λ	h_m (cm.)	$\frac{T_m}{\sqrt{\lambda}}$	$n = \frac{24\sqrt{\lambda}}{T_m}$	$h_o = \lambda^n h_m$ (cm.)	Average h_o
Camuzzoni	20	2.65	38.03	0.63	17.7	13.0
	10	2.61	37.97	0.63	12.0	
	5	3.37	35.71	0.67	9.9	
Carron	20	7.37	60.40	0.40	24.4	18.3
	12	7.33	60.69	0.40	20.4	
	8	7.45	60.07	0.40	17.1	
S. Caterina	25	4.62	33.00	0.73	50.5	40.0
	15	4.95	31.00	0.77	39.9	
	8	6.90	31.80	0.75	32.8	

The application of the formula shown above gives only an approximate value for the types having the form and the dimensions analogous to those used in the model. The preceding table shows that much closer values of "n" are obtained for models in which " " will have values between 10 to 15, inclusive.

THE VELOCITY OF RISE OF THE WATER

IN THE FOREBAY

An inspection of diagram B shows, as previously observed, that the priming head increases with a reduction in the priming time or, that which is the same, increases with an increase of the mean velocity of rise (V) of the water in the forebay. Furthermore, diagram C shows that the equation $h = f(V)$ is linear. (Also see Hebert H. Wheaton, Siphon - Spillway Models - Eng. News Record - August 18, 1932.)

It was previously stated that the value of T_o (minimum) for the prototype should be equal to 36, 60, and 32 seconds, respectively. Therefore, the minimum priming heads are respectively equal to 13, 16.3, and 40 cm. The maximum velocities of rise in the forebay at which the prototypes prime at the minimum elevation are respectively equal to 3.5, 3.05, 12.5 mm./sec. These quantities are relatively rare and seldom occur in nature. Generally, the siphons in nature start at the minimum elevations. Only for rare conditions does the mean velocity of rise in the forebay exceed the minimum limit which would create a marked increase in the priming head.

The equation $h_m = f(V)$ is graphically shown in diagrams C. From these curves, the important values of the tangents h_m/V = tangent γ_m.

When the value of tan γ_o in the prototype must be determined, such values can be deduced through extrapolation from diagrams D_1 that give the tangent γ_m as a function of λ, or better from the diagrams D_2 that express the log tangent γ_m as a function of λ.

Having determined the minimum priming elevation, the priming time corresponding to that of the prototype, and the value of the tangent γ_o, it is possible to trace a diagram of the type C even for the prototype.

Furthermore, intensive studies were made to determine the value of tangent γ_o from a single value of tangent γ_m, but these experiments have shown that a practical formula cannot be found that will give data even of the accuracy of the value of h_o as determined from a single value of h_m. Therefore, the value of tangent γ_o ought to be determined from the results of experiments which were performed on at least three different-scale models of the same siphon.

CONCLUSIONS

The results of the present investigation confirm the known geometric, kinematic, and dynamic relations of similitude between elements of the model and of the prototype when quantities of the original which are to be determined from analogous quantities of the experimental model are only a function of the elements that enter into the expression of the same relations.

When this does not occur, the relations are not applicable, as in the case under investigation.

For this condition, without doubt, there exists a special law of similitude, as for example that found by these studies:

$$h_o = h_m \cdot \lambda^{24\sqrt{\lambda}/T_m}$$

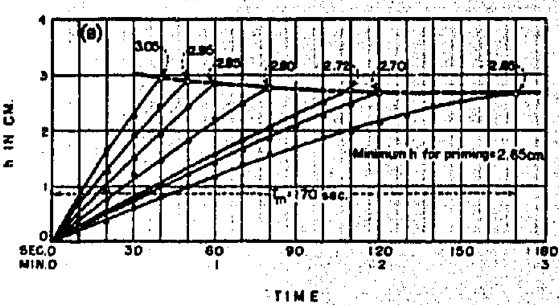
This formula in the majority of cases should not be used because it gives questionable practical results of the elements concerned.

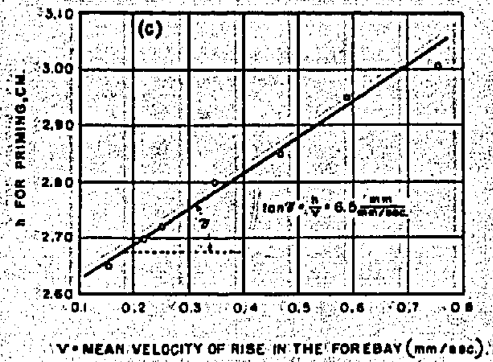
Therefore, the purer and simpler system of determining results from experiments on as many different-scale models (in this case, three were sufficient) as may be necessary to arrive at satisfactory and pursuasive practical results is recommended.

APPENDIX

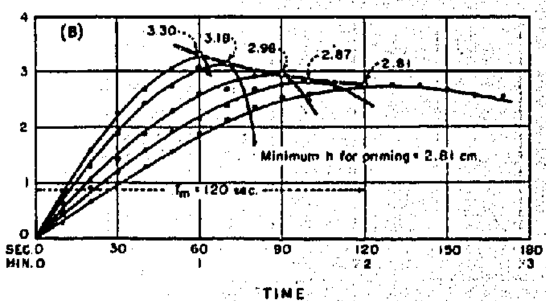
Diagrams B: Values of h as a function of T (total priming time).

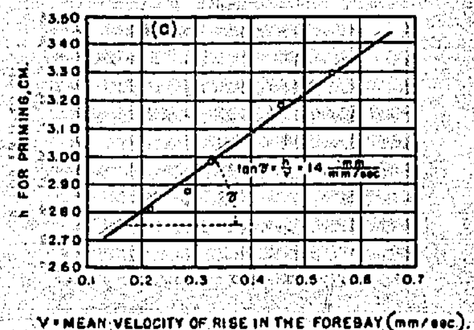
Diagrams C: Values of h as a function of v (mean velocity of rise in the forebay).





SCALE RATIO 1:20





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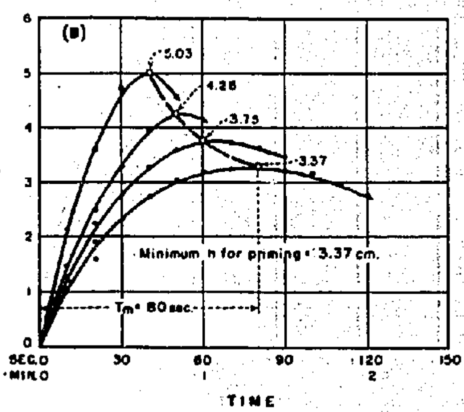
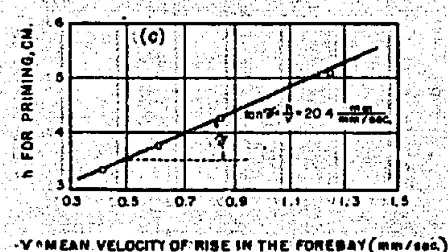
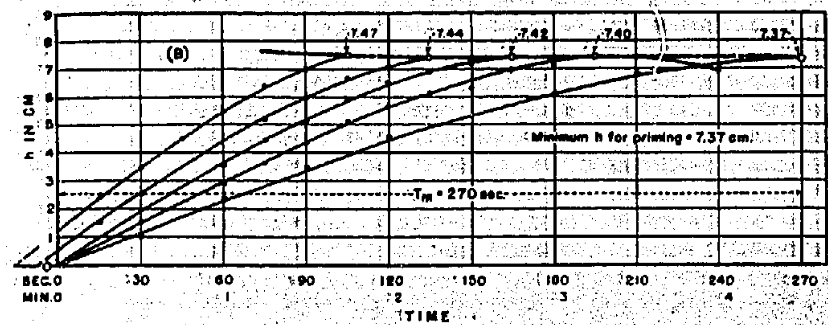
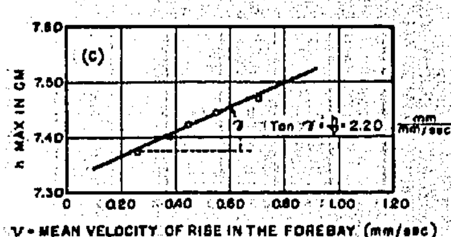




SCALE RATIO 1:5

MODELS OF THE CANALE CAMUZZONI





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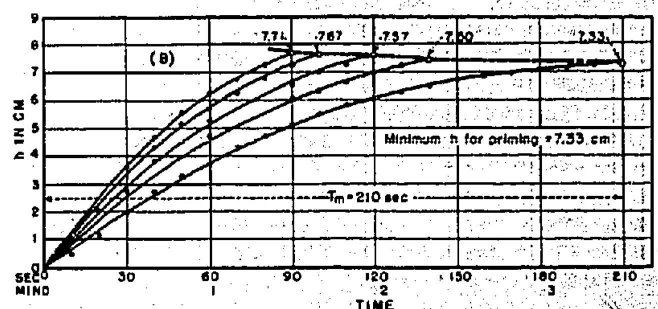

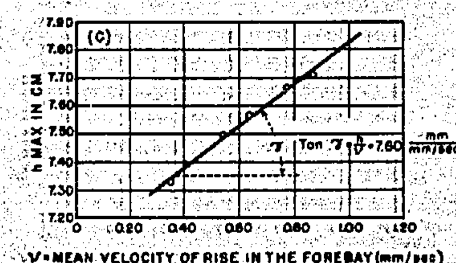

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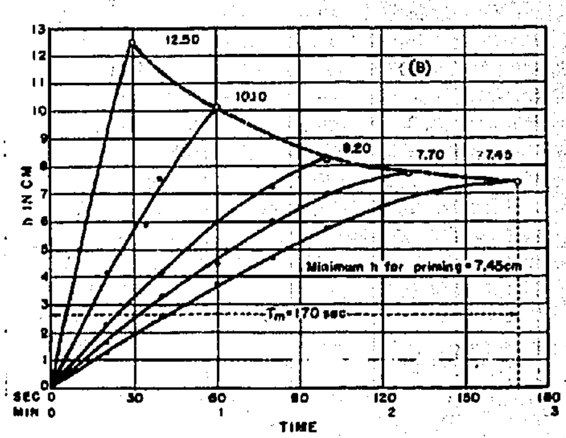

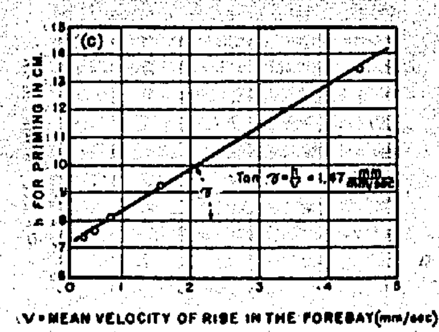

SCALE RATIO 1:8

MODELS OF THE CARRON

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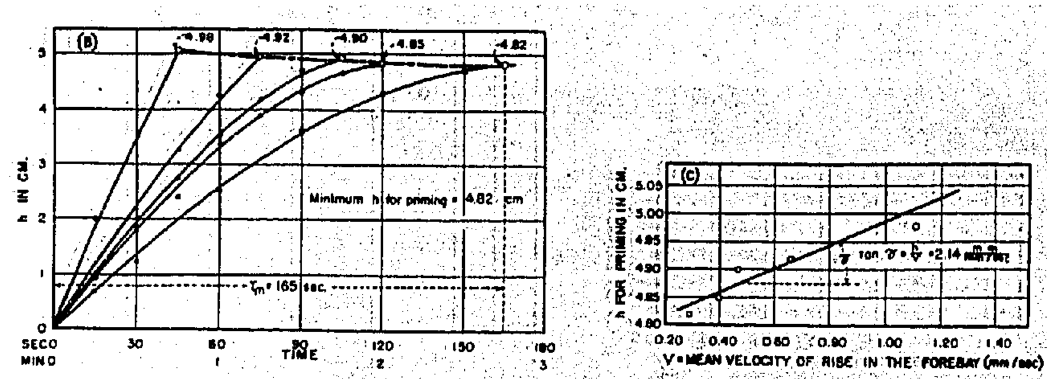
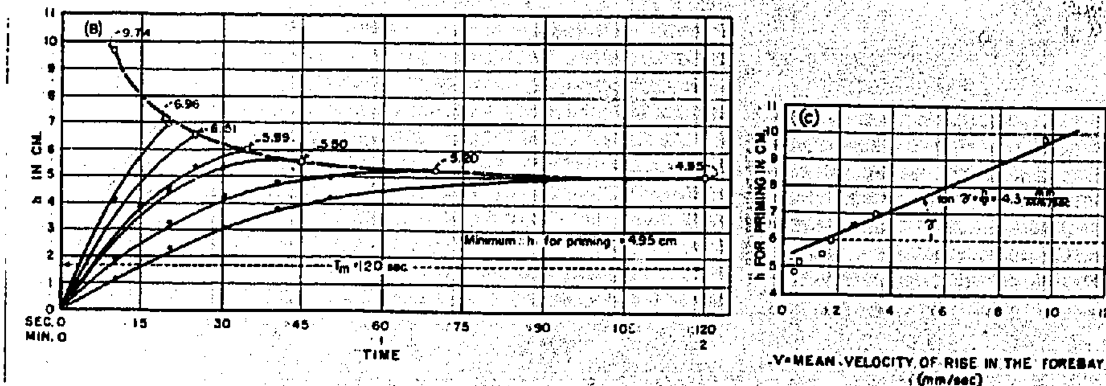
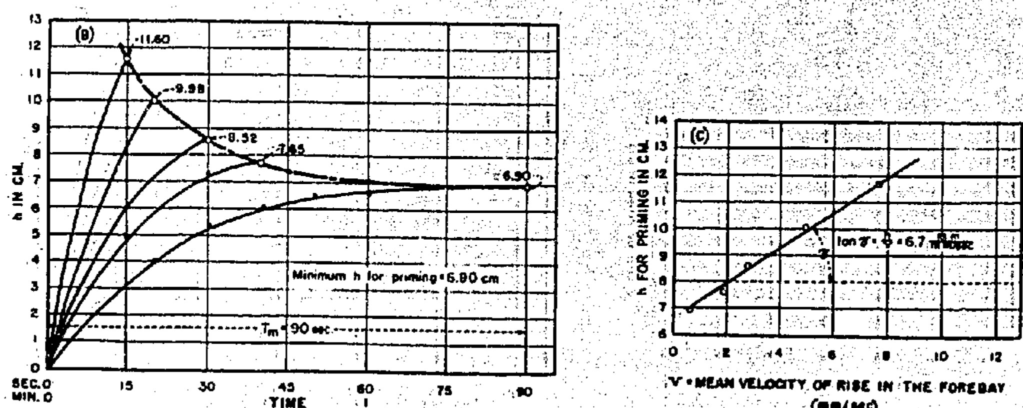


SCALE RATIO 1:25



SCALE RATIO 1:15



SCALE RATIO 1:8

MODELS OF THE SANTA CATERINA

Appendix IA.

Experiments on Siphons of the Type Used on the "Camuzzoni Canal"

Scale 1:20

Priming heads

h^1 and h = heads in cm.

t = priming time

t	h'	h	h'	h	h'	h	h'	h	h'	h	h'	h	h'	h
0,00	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0,10	0,18	0,14	0,24	0,82	0,20	0,20	0,31	0,30	0,30	0,40	0,40	0,70	0,50	0,8
0,20	0,25	0,38	0,30	0,54	0,28	0,46	0,45	0,75	0,50	0,90	0,75	1,25	1,00	1,65
0,30	0,29	0,59	0,36	0,80	0,34	0,79	0,56	1,20	0,75	1,50	1,10	1,90	1,50	2,25
0,40	0,33	0,80	0,44	1,02	0,44	1,09	0,80	1,45	1,10	1,90	1,80	2,40	16,5	3,05
0,50	0,39	1,00	0,60	1,23	0,59	1,36	1,14	1,80	1,30	2,40	16,0	2,95		0
1,00	0,45	1,20	0,70	1,43	0,77	1,60	1,75	2,20	8,00	2,85		0		
1,10	0,59	1,40	0,88	1,64	0,93	1,82	7.00	2,45	16,00	2,70				
1,20	0,69	1,58	1,00	1,85	1,09	2,07	16,00	2,80	13,00	1,20				
1,30	0,81	1,71	1,13	2,06	1,27	2,28	4.50	1,00	2,00	0,30				
1,40	0,92	1,86	1,26	2,27	1,44	2,50	2,00	0,40	0	0				
1,50	1,01	1,98	1,42	2,45	2,10	2,72	0,00	0,00						
2,00	1,12	2,12	1,50	2,70	16,00	2,45								
2,10	1,20	2,26	1,60	2,65	14,30	1,00								
2,20	1,30	2,39	4,00	0,77	1,30	0,20								
2,30	1,36	2,51	15,00	0,40	0,00	0,00								
2,40	1,46	2,66	10,00	0,10										
2,50	1,59	2,65	5,00	0,00										
3,00	6,50	2,60	0,00											
3,10	6,50	1,05												
3,20	15,00	0,30												
3,30	1,00	0,—												
mean velocity of rise in forebay (mm / sec)														
		0,16		0,22		0,25		0,35		0,47		0,59		0,76

Value of $h_m \cdot \lambda = 2,65 \times 20 = 53,00$ cm

Appendix IB.

Experiments on Siphons of the Type Used on the "Camuzzoni Canal"

Scale 1:10

Priming heads

h^1 and h = heads in cm.

t = priming time

t	h'	h	h'	h	h'	h	h'	h	h'	h
0,00	—	—	—	—	—	—	—	—	—	—
0,10	0,10	0,33	0,11	0,40	0,12	0,50	0,20	0,66	0,20	0,80
0,20	0,20	0,67	0,35	0,90	0,40	1,04	0,46	1,30	0,50	1,60
0,30	0,37	0,99	0,50	1,20	0,60	1,45	0,80	1,90	0,90	2,30
0,40	0,58	1,20	0,70	1,63	0,86	1,91	1,12	2,47	1,30	2,70
0,50	0,74	1,60	0,90	1,95	1,11	2,33	1,51	2,75	1,80	3,10
1,00	0,80	1,90	1,10	2,22	1,29	2,64	2,23	3,07	3,00	3,30
1,10	1,04	2,16	1,60	2,40	1,60	2,74	4,60	3,18	10,00	1,00
1,20	1,12	2,40	2,00	2,69	2,05	2,93	10,52	1,73	1,40	
1,30	1,24	2,55	2,40	2,80	3,08	2,98	1,33	1,00		
1,40	1,34	2,64	2,80	2,87	3,17	2,00		0,5		
1,50	1,48	2,70	3,00	2,30	3,32	0,80				
2,00	1,76	2,81	3,50	1,70	9,70					
2,10	2,10	2,80	9,50	0,90	2,00					
2,20	3,14	2,75	8,00							
2,30	3,20	2,70								
2,40	3,30	2,64								
2,50	9,00	2,58								
Mean velocity of rise in forebay (mm / sec)										
		0,22		0,29		0,33		0,46		0,55

Value of $\lambda = 2,81 \times 10 = 28,10$ cm

Appendix I[illegible]

Experiments on Siphons of the Type Used on the "Camuzzoni Canal"

Scale 1:5

Priming heads

t = priming time

h^1 and h = heads in cm.

t	h'	h	h'	h	h'	h	h'	h
0,00	—	—	—	—	—	—	—	—
0,10	1,12	1,20	1,30	1,27	1,50	1,40	1,78	2,16
0,20	1,62	1,90	1,90	2,22	2,38	2,52	2,35	3,60
0,30	1,70	2,32	2,05	2,75	2,55	3,27	3,00	4,70
0,40	1,83	2,72	2,20	3,22	2,70	3,01	3,55	5,03
0,50	2,00	3,02	2,35	3,60	3,42	4,26	4,35	4,55
1,00	2,16	3,17	2,47	3,75	4,00	4,10		
1,10	2,25	3,22	2,65	3,70				
1,20	2,35	3,37	2,70	3,60				
1,30	2,36	3,30	2,70	3,48				
1,40	2,37	3,15						
1,50	2,42	2,97						
2,00	2,43	2,80						
2,10	2,43	2,69						
2,20	2,42	2,47						
2,30	2,40	2,35						
2,40	2,40	2,25						
2,50	2,40	2,17						
Mean velocity of rise in forebay (mm / sec)								
		0,41		0,63		0,85		1,26
Value of $h_m \cdot \lambda = 3{,}37 \times 5 = 16{,}85$ cm								

Note: The priming time required to attain the maximum, fully primed discharge in the model requires but an instant. This explains why the measured values of h^1 are always less than those of h.

Appendix IIA.

Experiments on Siphons of the Type Used on the "Carron"

Scale 1:20

Priming heads

t = priming time

h^1 and h = heads in cm.

t	h'	h	h'	h	h'	h	h'	h	h'	h
0,00	—	—	—	—	—	—	0,50	0,50	1,33	1,33
0,15	—	—	—	—	—	—	1,00	1,53	2,25	2,33
0,30	0,94	1,00	1,40	1,50	1,85	1,95	2,30	2,50	2,85	3,50
0,45	—	—	—	—	—	—	3,00	3,42	4,50	4,50
1,00	2,23	2,33	2,54	2,83	3,00	3,50	4,35	4,35	5,50	5,50
1,15	—	—	3,18	3,67	4,42	4,42	5,19	5,19	7,33	6,33
1,30	3,00	3,47	4,33	4,33	5,12	5,12	6,01	6,01	7,12	7,00
1,45	—	—	5,07	5,07	5,85	5,85	6,60	6,60	12,20	7,47
2,00	4,53	4,33	5,63	5,63	6,51	6,51	7,40	7,15		
2,15	—	—	6,13	6,13	7,30	6,92	12,22	7,44		
2,30	5,36	5,36	6,63	6,63	7,90	7,20				
2,45	—	—	7,22	7,00	12,30	7,42				
3,00	6,10	6,10	7,70	7,20						
3,14	—	—	12,10	7,40						
3,30	6,80	6,80	12,20	7,20						
4,47	7,47	7,17	12,20	6,03						
4,30	12,35	7,37								
4,30	12,35	7,37								
5,00	12,35	7,00								
5,30	—	6,60								
6,90	—	6,00								
Mean velocity of rise in forebay (mm / sec)										
		0,27		0,38		0,45		0,55		0,71
Value of $h_m \cdot \lambda = 7{,}37 \times 20 = 147{,}40$ cm										

Appendix IIB.

Experiments on Siphons of the Type Used on the "Carron"

Scale 1:12

Priming heads

t = priming time

h^1 and h = heads in cm.

t	h'	h	h'	h	h'	h	h'	h	h'	h
0,00	—	—	—	—	—	—	—	—	—	—
0,10	—	0,40	—	—	—	0,60	0,50	0,75	0,66	0,75
0,20	—	1,18	—	—	—	1,78	1,00	1,00	1,00	2,11
0,30	0,88	1,99	1,61	2,72	1,94	2,83	2,83	3,28	3,20	3,58
0,40	—	2,72	—	—	3,24	3,87	3,50	4,37	4,41	4,72
0,50	—	3,24	—	—	4,00	4,64	4,87	5,18	5,32	5,58
1,00	4,66	3,71	4,40	4,74	5,27	5,27	5,58	5,70	6,13	6,24
1,10	—	4,29	—	—	5,57	5,79	5,92	6,27	6,71	6,76
1,20	—	4,76	—	—	5,87	6,22	6,35	6,75	7,39	7,28
1,30	5,08	5,12	5,91	6,04	6,44	6,63	7,42	7,22	8,31	7,71
1,40	5,28	5,50	6,31	6,34	9,00	7,03	20,00	7,67	20,30	6,56
1,50	5,50	5,84	6,68	6,60	10,00	7,37	—	7,41	—	5,78
2,00	5,67	6,08	7,08	6,98	20,50	7,57	—	6,67	—	4,78
2,10	6,50	6,27	7,50	7,30	—	7,50	—	5,87	—	
2,20	6,72	6,40	8,00	7,50	—	6,00				
2,30	6,93	6,77	20,50	6,25	—	4,67				
2,40	7,17	6,82	—	5,33						
2,50	7,33	6,93								
3,00	7,50	7,04								
3,10	7,67	7,14								
3,20	7,90	7,23								
3,30	20,17	7,33								
Mean velocity of rise in forebay (mm / sec)										
		0,35		0,54	0,63		0,77		0,84	

Value of $h_m . \lambda = 7,33 \times 12 = 87,06$ mc.

Appendix IIC.

Experiments on Siphons of the Type Used on the "Carron"

Scale 1:8

Priming heads

t = priming time

h^1 and h = heads in cm.

t	h'	h	h'	h	h'	h	h'	h	h'	h
0,00	—	—	—	—	—	—	—	—	—	—
0,10	—	—	—	—	—	—	—	2,00	—	5,00
0,20	—	1,25	—	1,60	—	2,30	—	4,20	—	8,80
0,30	—	—	—	—	—	—	—	5,80	22,00	12,50
0,40	—	2,60	—	3,35	—	3,40	—	7,60		
0,50	—	—	—	—	—	—	—	0,00		
1,00	—	3,70	—	4,50	—	6,05	23,00	10,10		
1,10	—	—	—	—	—	—				
1,20	—	4,65	—	6,00	—	7,30				
1,30	—	—	—	—	—	—				
1,40	—	5,80	—	7,00	22,50	8,20				
1,50	—	—	—	—						
2,00	—	6,40	—	—						
2,10	—	—	22,—	7,70						
2,20	—	7,00								
2,30	—	—								
2,40	—	7,40								
2,50	23,00	7,45								
3,00	—	—								
3,10	—	—								
3,20	—	—								
Mean velocity of rise in forebay (mm / sec)										
		0,44		0,50		0,82		1,55		4,50

Value of $h_m . \lambda = 7,45 \times 8 = 59,60$ cm

Appendix IIB.

Experiments on Siphons of the Type Used on the "Carron"

Scale 1:12 — Priming heads

t = priming time — h^1 and h = heads in cm.

t	h'	h	h'	h	h'	h	h'	h	h'	h
0,00	—	—	—	—	—	—	—	—	—	—
0,10	—	0,49	—	—	—	0,69	0,50	0,75	0,66	0,75
0,20	—	1,18	—	—	—	1,78	1,00	1,09	1,09	2,11
0,30	0,88	1,99	1,61	2,72	1,94	2,83	2,83	3,28	3,20	3,58
0,40	—	2,72	—	—	3,24	3,87	3,50	4,37	4,41	4,72
0,50	—	3,24	—	—	4,09	4,64	4,87	5,18	5,32	5,58
1,00	4,66	3,71	4,40	4,74	5,27	5,27	5,58	5,70	6,13	6,24
1,10	—	4,29	—	—	5,57	5,79	5,92	6,27	6,71	6,76
1,20	—	4,76	—	—	5,87	6,22	6,35	6,75	7,39	7,28
1,30	5,08	5,12	5,91	6,04	6,44	6,63	7,42	7,22	8,33	7,71
1,40	5,28	5,50	6,31	6,34	9,00	7,03	20,00	7,67	20,30	6,56
1,50	5,50	5,84	6,68	6,69	10,00	7,37	—	7,41	—	5,78
2,00	5,67	6,08	7,08	6,98	20,50	7,57	—	6,67	—	4,78
2,10	6,50	6,27	7,50	7,30	—	7,50	—	5,87	—	
2,20	6,72	6,49	8,00	7,50	—	6,00				
2,30	6,93	6,77	20,50	6,25	—	4,67				
2,40	7,17	6,82	—	5,33						
2,50	7,33	6,93								
3,00	7,50	7,04								
3,10	7,67	7,14								
3,20	7,90	7,23								
3,30	20,17	7,33								
Mean velocity of rise in forebay (mm / sec)										
		0,35		0,54	0,63		0,77		0,84	

Value of $h_m \cdot \lambda = 7{,}33 \times 12 = 87{,}96$ mc

Appendix IIC.

Experiments on Siphons of the Type Used on the "Carron"

Scale 1:8 — Priming heads

t = priming time — h^1 and h = heads in cm.

t	h'	h	h'	h	h'	h	h'	h	h'	h
0,00	—	—	—	—	—	—	—	—	—	—
0,10	—	—	—	—	—	—	—	2,00	—	5,00
0,20	—	1,25	—	1,60	—	2,30	—	4,20	—	8,80
0,30	—	—	—	—	—	—	—	5,80	22,00	12,50
0,40	—	2,60	—	3,35	—	3,40	—	7,60		
0,50	—	—	—	—	—	—	—	9,00		
1,00	—	3,70	—	4,50	—	6,05	23,00	10,10		
1,10	—	—	—	—	—	—				
1,20	—	4,05	—	6,00	—	7,30				
1,30	—	—	—	—	—	—				
1,40	—	5,80	—	7,00	22,50	8,20				
1,50	—	—	—	—						
2,00	—	6,40	—	—						
2,10	—	—	22,—	7,70						
2,20	—	7,00								
2,30	—	—								
2,40	—	7,40								
2,50	23,00	7,45								
3,00	—	—								
3,10	—	—								
3,20	—	—								
Mean velocity of rise in forebay (mm / sec)										
		0,44		0,50		0,82		1,55		4,50

Value of $h_m \cdot \lambda = 7{,}45 \times 8 = 59{,}60$ cm

Appendix IIIA.

Experiments on Siphons of the Type Used on the "S. Caterina"

Scale 1:25

Priming heads

t = priming time

h^1 and h = heads in cm.

t	h'	h	h'	h	h'	h	h'	h	h'	h
0,—	—	—	—	—	—	—	—	—	—	—
0,15	—	0,70	1,02	0,80	1,25	0,83	1,66	0,92	3,50	2,00
0,30	1,50	1,25	2,00	1,83	2,42	1,85	3,00	2,08	6,80	3,50
0,45	—	—	3,17	2,37	3,50	2,75	4,33	3,25	21,50	4,98
1,00	3,10	2,50	4,33	3,33	5,00	3,48	6,67	4,25		
1,15	—	—	5,17	3,90	5,02	4,15	21,00	4,92		
1,30	4,50	3,63	6,12	4,30	6,67	4,67				
1,45	—	—	6,50	4,67	21,00	4,90				
2,00	5,55	4,30	20,00	4,85						
2,15	—	—								
2,30	6,70	4,67								
2,45	20,50	4,82								
3.00	—	—								
3.15	—	—								
Mean velocity of rise in forebay (mm / sec)										
		0,20		0,40		0,47		0,66		1,11

Value of $h_m \cdot \lambda = 4{,}82 \times 25 = 120{,}5$ cm

Appendix IIIB.

Experiments on Siphons of the Type Used on the "S. Caterina"

Scale 1:15

Priming heads

t = priming time

h^1 and h = heads in cm.

t	h'	h	h'	h	h'	h	h'	h	h'	h	h'	h	h'	h
0,00	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0,10	2,50	1,10	3,50	1,80	4,60	2,55	—	—	—	—	6,50	4,11	3,00	2,74
0,15	—	—	—	—	—	—	5.—	3.85	7.—	55.—	—	—		
0,20	4,00	2,30	5,00	3,20	6,50	4,40	—	—	—	—	24.—	6,06		
0,25	—	—	—	—	—	—	8,—	5.40	25.—	6,51				
0,30	4.75	3,00	5,50	4,20	7,00	5,35	—	—	—					
0,35	—	—	—	—	—	—	17.—	5.09						
0,40	5,10	4,80	6,00	4,70	16,—	5,50								
0,45	—	—	—	—										
0,50	5,50	4,20	6,50	5,00										
0,55	—	—	—	—										
1,00	6,00	4,50	7,00	5,10										
1,10	—	—	15,00	5,20										
1,20	—	—												
1,30	7,30	4,80												
1,40	—	—												
1,50	—	—												
2,00	15.—	4,95												
Mean velocity of rise in forebay (mm / sec)														
		0,41		0,74		1,45		1,71		2,60		3,48		9,71

Value of $h_m \cdot \lambda = 4{,}95 \times 15 = 74{,}25$ cm

Appendix IIIC.

Experiments on Siphons of the Type Used on the "S. Caterina"

Scale 1:8 — Priming heads

t = priming time — h^1 and h = heads in cm.

t	h'	h	h'	h	h'	h	h'	h	h'	h
0,00	—	—	—	—	—	—	—	—	—	—
0,10	—	2,20	—	—	—	—	—	—	—	—
0,15	—	—	—	4,85	—	6,05	—	—	30,00	11,60
0,20	—	4,00	—	—	—	—	31,00	9,98		
0,25	—	—	—	—	—	—				
0,30	—	5,38	—	7,30	20,—	8,52				
0,35	—	—	—	—						
0,40	—	6,10	28,—	7,65						
0,45	—	—	—							
0,50	—	6,48								
0,55	—	—								
1,00	—	6,60								
1,30	26,00	6,90								
Mean velocity of rise in forebay (mm / sec)										
		0,77		1,91		2,84		4,99		7,73
Value of $h_m \lambda = 6{,}90 \times 8 = 55{,}20$ cm										

Padova May 1934 XII

DR. ING. ALESSANDRO VERONESE