INVESTIGATION OF THE HYDRAULIC PARAMETERS OF OPERATION IN A WEIR WITH SELF-CLEANING EFFECT IN LABORATORY CONDITIONS

Stanislav Darachev[1*] and Boris Tzankov[2]

[1] *National Institute of Meteorology and Hydrology, 66, Tsarigradsko Shose Blvd, 1784 Sofia, Bulgaria, e-mail: sdarachev@meteo.bg*

[2] *University of Architecture, Civil Engineering and Geodesy, 1, H. Smirnenski Blvd, 1146 Sofia, Bulgaria, e-mail: b_tzankov@abv.bg*

Abstract. Sewerage, as a system designed for the collection and disposal of wastewater, also accepts many other accidental objects, defined as sediments. Their removal from the network usually takes place in the Waste Water Treatment Plant (WWTP), where they are removed by known methods. However, this does not provide a solution to the solid sediments clogged before the WWTP, which reduces network capacity. Such a solution could be the modification of well known sewage weir in a new type of construction, known as a self-cleaning weir. To this end, the performance of this type of structure should be well studied, both in terms of flow distribution and sediment distribution, whether or not there is an overflow. This article presents the results of a study of the facility in laboratory conditions on a scale model for flow bifurcation only.

Keywords: sewerage, sediments, overflow, weir.

1. INTRODUCTION

Sewerage, as a system designed for the collection and disposal of wastewater, accepts many other objects and materials of all kinds that have fallen into the species. The origin of these materials is heterogeneous, ranging from materials used in winter maintenance of the street network, waste from infrastructure construction, abrasion from the earth's surface, to waste from households, directly dependent on the cultural habits of the population. All these randomly added materials are defined as sediments. Their removal mostly depends on the transport capacity of the sewage flow to the Waste Water

[*] Corresponding author.

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Treatment Plant (WWTP), where they can be removed from the system by set of known methods. However, transportation time is a variable that depends on many factors, and, in fact, the condition of a number of sewerage networks shows that clogging is a problem that needs to be taken seriously. A possible solution could be the modification of existing sewage weir into a new type of construction, known as a self-cleaning weir [1]. To this end, both the hydraulic action of the facility in relation to the distribution of the sewage flow and the behaviour of the sediments dragged into it should be well studied. These processes should be studied in detail, both during storm water and only domestic runoff.

Sediments can be classified as dissolved, suspended or solid depending on the condition in which they are transported. While dissolved and partially suspended sediments are usually transported and disposed of in wastewater treatment plants, depending on the time allotted for drainage into the network, solid sediments and partially suspended sediments move under specific conditions.

Deposition of these sediments along the sewerage network leads to a reduction of the effective cross-section of the given sewerage section, increase of the conditional roughness and reduction of its capacity, which violates the design parameters set for normal operation of the facility.

The set minimum speeds control the clogging, but the presence of solid sediments in the current is not taken into account. It should be noted here that in the design process, the check for minimum speeds in a combined sewerage system is done for the maximum discharge with the probability of exceedance, which is usually at least once a year to once every ten years [2–3]. This time is sufficient to homogenize the accumulated sediments and make it difficult to wash them away in the event of a sizing event. Their removal is embedded in the technologies provided for the WWTP, which recognizes the presence of bottom sediments, but the time of movement and the impact on the expected operation of the network to dimensional cases is not considered. This problem is taken into account in the standards and the described methods for maintenance of a sewerage system, which include activities for its mechanical cleaning.

In operational terms, this would increase the frequency of events set in the design conditions. From overflow through sewage weir, to work under pressure in the pipeline branches and overflow in the terrain, which leads to damages of ecological, material and other nature.

The constructions of sewage weir known in practice are numerous and new solutions are common. The tendency is to improve the ecological effect and in the various modifications we are working on the separation of main light floating waste materials, mainly of polymeric origin.

2. THE CONCEPT OF A SEWAGE WEIR WITH A SELF-CLEANING EFFECT

A solution to the problem described above is presented in the concept of a weir with a self-cleaning effect, which aims to transform the problem of the available kinetic energy of the upstream flow into a solution to the problem of removing solid sediments.

A solution was sought with a simple streamlined construction, without sharp narrowings.

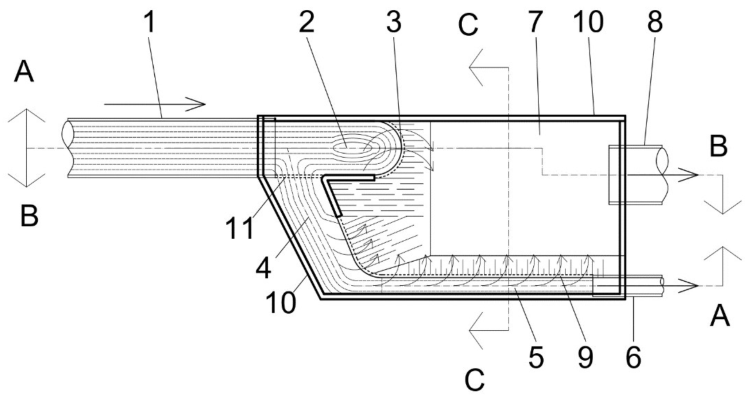


Fig. 1. Spillway sketch in weir with self-cleaning effect, [1]

As seen in Fig. 1, in the chamber of the device 10 along the axis of the supply conduit 1 a front weir 3 is located, designed as a flip bucket. A well 2 is located in front of the spillway ramp, with a bottom below the bottom of the feeding pipe. A side opening 4 is formed between the feeding pipe and the pit on one side, which is the beginning of a classic side-weir 5. At the end of the side-weir, a connection to the WWTP conduit 6 is provided. The height of the side-weir edge 9 is less than of the front weir 3. A reservoir 7 is provided between the front and side-weir. A connection to the discharge 8 is provided on the reservoir.

In order to direct the bottom speeds in the direction of the front flip bucket in the direction of the axis of the feeding pipe at the opening to the side overflow, a bottom threshold 11 can be built, Fig. 2.

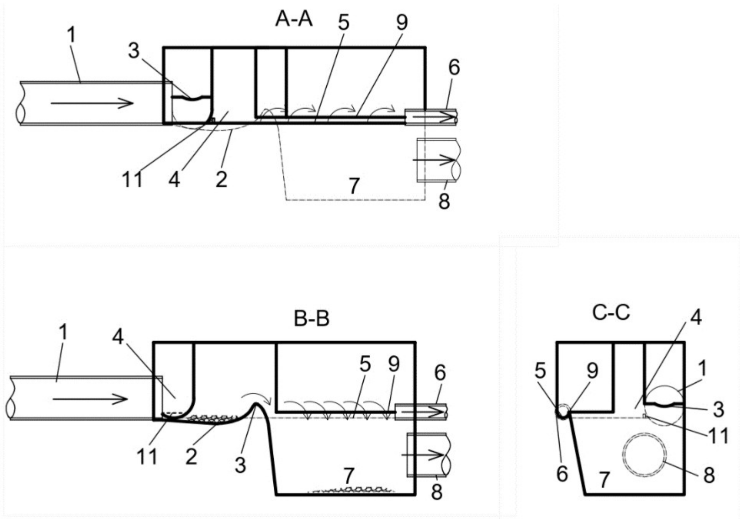


Fig. 2. Weir cross-sections, [1]

Operating principle

The “sanitary flow” from the supply conduit to the chamber 10 passes through the side opening 4 and through the side-weir to the WWTP conduit 6. The pit 2 retains the vortex deposits entrained by the tangential velocities generated at the opening 4. In cases of set bottom threshold, the bottom sediments are submerged and deposited in the feeding pipe and the overflow body before the threshold.

During rain, when the incoming waters increase, overflow over the lateral weir edge begins, and during additional increase of the incoming water, overflow through the front weir begins. Along with the water that has overflowed above 3, the solid sediments trapped and dragged along the bottom and the pit are also entrained, thus they are removed from the sewer system and separated in the reservoir 7.

Depending on additional requirements, the bottom of the reservoir 7 can be at an elevation lower than the bottom of the discharge conduit 8. The outlet section should be shaped in such a way so as to retain the exported materials or to provide a grid at the inlet of 8, after which the solid materials discharged from the system are mechanically removed before being exported to the discharge.

The non-overflowing water is directed outside the direction of the supply pipeline 1, whereby the diverted flow is based mainly on the potential energy and minimizes the influence of the kinetic energy in the pipeline 1. Thus, the flow before the weir edge 9 is without significant changes, which allows the facility to be accurately dimensioned, to form a shorter section and not to allow the overflow of water to exceed the expected, even in extreme rainfall.

The advantages of the sewage weir according to the proposed design are that the sediments carried along the bottom of the collector accumulate due to the presence of the pit and/or threshold or are exported through the front weir. In this way the pipes after the sewer weir are protected from clogging and the system is self-cleaning.

3. CONDUCTING THE EXPERIMENT

Construction of a test bench

Physical experimental modelling has been adopted as the research method [4–6]. The sketch of the test set-up is shown in Fig. 3.

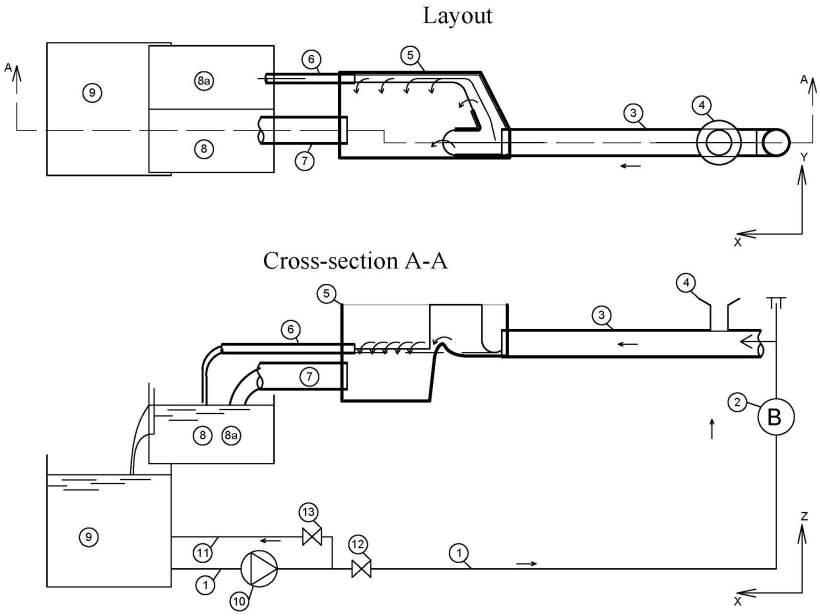
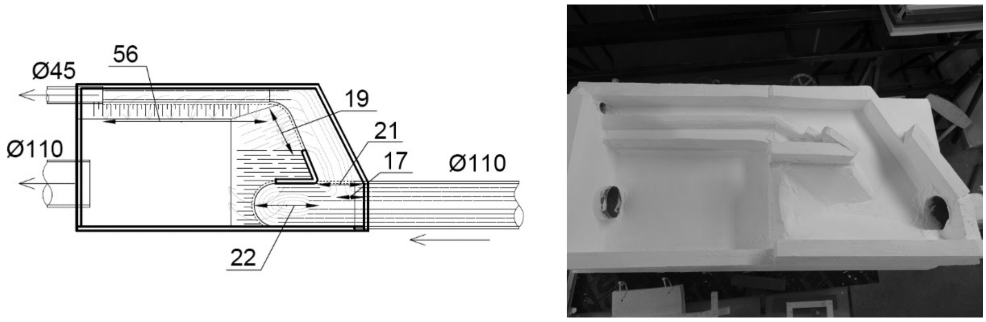


Fig. 3. Sketch of the stand for conducting the experiment: piping (1, 11); flow meter (2); inlet pipe (3); hole for adding solid deposits (4); weir body (5); pipe for non-overflow water (6); pipe for overflow water (7); triangular spillway for measuring split streams (8, 8a); pumping tank (9); pump (10); valves (12, 13)

The experimental data in the present study are recorded with index (u) for the incoming waters, index (d) for the overflow waters and index (b) for the non-overflow waters.

The following quantities were measured: Quantities (incoming quantity (u); overflows (d) and non-overflows (b)), velocities, depths and lengths. The initially selected installation is illustrated in Fig. 4.

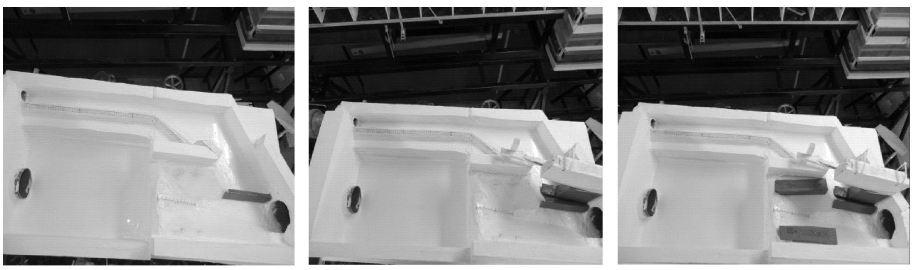


(a) (b)

Fig. 4. (a) Sketch of the tested body, [1]; (b) photo of the model body

The water supply into a pipe with a diameter of 103 mm, and the non-overflow water quantity is discharged from a pipe with a diameter of 45 mm. The side opening is 17/21 cm. The front overflow is 7 cm high, and the width before it varies from 10 cm at the bottom to 20 cm at the weir edge. The ramp before front weir is 18 cm long, the slope is 42% and the pit in front of it is 2 cm deep. The distance from the edge of the front weir to the branch is 22 cm. The side-weir is 75 cm long and 2.5 cm high.

During the experiment, the initially proposed construction was studied, and in the process of observation, three or more types with additional attachments were proposed, Fig. 5.



(a) (b) (c)

Fig. 5. Types of attachments: (a) type “A”; (b) type “B”; (c) type “C”

- Type “O” – without any attachments;
- Type “A” – with bottom threshold;
- Type “B” – with placement of the bottom threshold and narrowing of the cross-section in the flow distribution;
- Type “C” – includes attachments of type “B” and attachment for narrowing the cross-section after flow distribution.

It works with four types of incoming discharges: 2.38; 3.66; 4.57 and 4.88 l/s.

4. ANALYSIS AND PRESENTATION OF THE RESULTS OBTAINED FROM THE STUDY OF HYDRAULIC PARAMETERS IN LABORATORY CONDITIONS

The results of the conducted experimental work are given in Table 1. It should be noted that Q_b is the amount of water that is discharged into the pipe in a non-overflowing amount of water, and Q_d is the sum of the water overflow through the front and side overflow – $Q_d = Q_u - Q_b$.

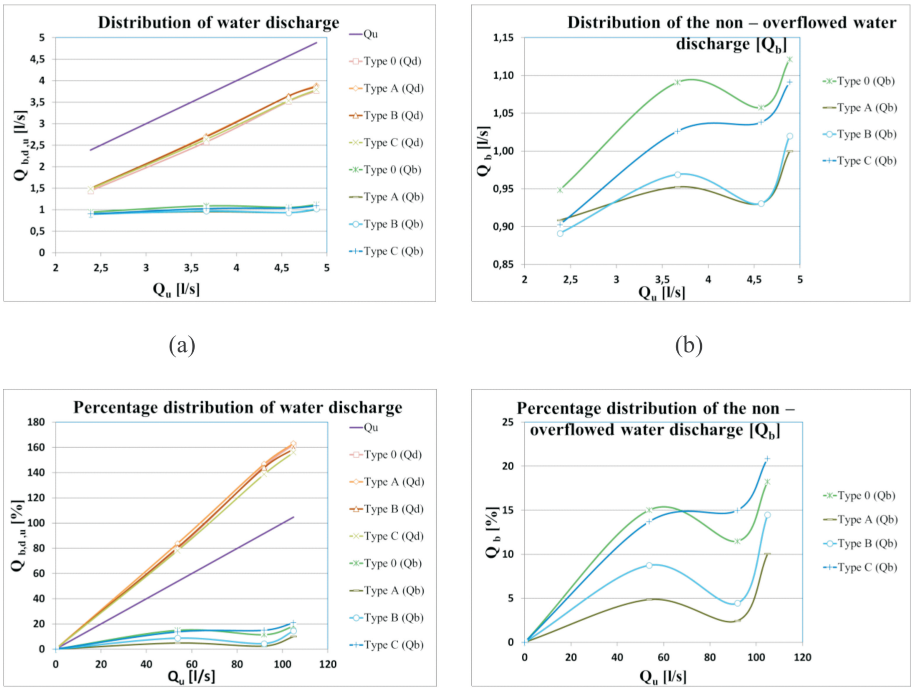
From the measurements made, what clearly stand out is the mode of operation of the facility where, as the inflow increases, the overflow water discharge increases proportionally, while the non-overflow increases within narrow limits, Fig. 6(a, b).

In percentage terms, when increasing the inlet water discharge by up to 100%, we have an increase in the overflow water amount by up to 160% , and an increase in the non-overflow water amount by only up to 20%, Fig. 6(c). In the case of non-overflowing water, we have a maximum runoff in a situation without an attachment type “0” followed by type “C” which can be explained by the dammed flow caused by the attachment narrowing the cross-section before the front weir, Fig. 6(d). In the case of attachments type “A” and “B”, in terms of non-overflow water, we have the lowest values of outflow with very close values, which indicates the weak influence of the width of the opening in the lateral outflow for the studied case for the whole structure.

In the case of a relative increase in the non-overflowing water, a double difference in the overflowing water is established for the attachments “A” and “B”. The largest relative increase in the non-overflowing water is in the version without attachment – type “0”. Type “C” displays results that are close to this. With the “B” attachment we have a 50% less relative increase, and with the “A” attachment the smallest change is up to 10%.

Table 1. Results of the conducted experiments

Type	Q_u [l/s]	Q_d [l/s]	Q_b [l/s]	Q_d [%]	Q_b [%]	V $[m/s]$			Flow type (upstream)	Hydraulic jump (upstream)
						upstream (bottom)	upstream (max)	Flip bucket		
0	4.885	3.76	1.12	77	23	1.05	1.07	0.69	supercritical	in the chamber
A	4.885	3.89	1.00	80	20	0.95	1.04	0.72	supercritical	in the chamber
B	4.885	3.86	1.02	79	21	0.98	1.06	0.74	supercritical	in the chamber
C	4.885	3.79	1.09	78	22	0.93	1.07	0.75	supercritical	in the chamber
0	4.575	3.52	1.06	77	23	1.04	1.07	0.69	supercritical	in the chamber
A	4.575	3.64	0.93	80	20	0.85	0.91	0.67	supercritical	in the chamber
B	4.575	3.64	0.93	80	20	0.87	0.99	0.71	supercritical	in the chamber
C	4.575	3.54	1.04	77	23	0.86	1.00	0.77	supercritical	in the chamber
0	3.665	2.57	1.00	70	30	0.86	1.03	0.64	supercritical	chamber–pipe
A	3.665	2.71	0.95	74	26	0.85	0.97	0.69	supercritical	in the pipe
B	3.665	2,70	0.97	74	26	0.75	0.89	0.70	supercritical	in the pipe
C	3.665	2.64	1.03	72	28	0.65	0.92	0.70	supercritical	in the pipe
0	2.385	1.44	0.95	60	40	0.72	0.75	–	supercritical	in the pipe
A	2.385	1.48	0.91	62	38	0.54	0.70	0.20	subcritical	in the pipe
B	2.385	1.49	0.98	63	37	0.41	0.50	0.41	subcritical	in the pipe
C	2.385	1.48	0.90	62	38	0.35	0.45	0.39	subcritical	in the pipe



(a) (b)

(c) (d)

Fig. 6. Distribution of water discharge in laboratory tests

5. RELATIVE BIFURCATION

Analysis

Relative bifurcation with increasing inlet discharge is shown in Figs 7, 8, 9. The graphical representation of the obtained results confirms the expected dependence of the increase of the overflow water with the increase of the feeding pipe discharge and, respectively, the decrease of the non-overflow discharge.

No significant deviation was found in the final flow distribution as a function of the respective attachment. Here it is not possible to estimate the influence of the attachments (shape design) in the distribution of water to the overflow due to structural inconveniences of the model (measurement is common for the amount of water spilled through the front and side spillway).

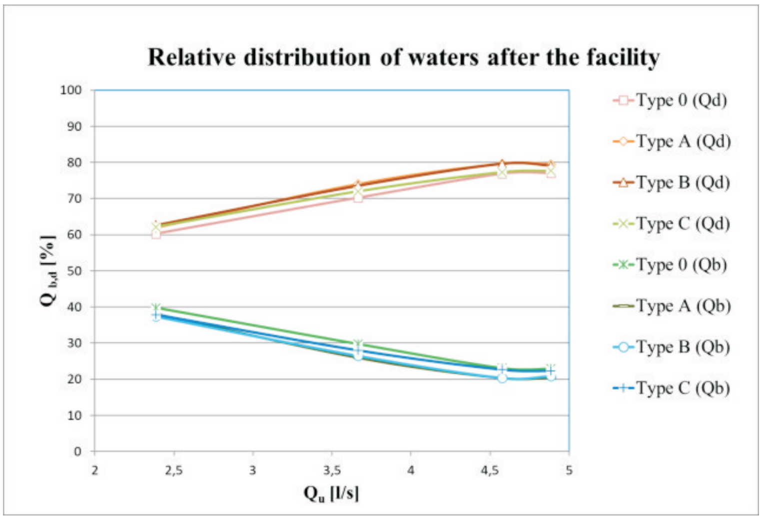


Fig. 7. Relative distribution of the discharge passed through the facility

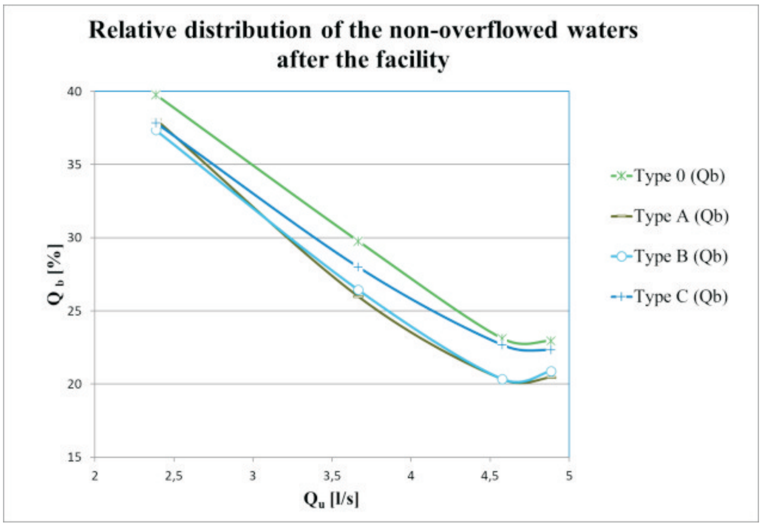


Fig. 8. Relative distribution of non-overflow water depending on the current case

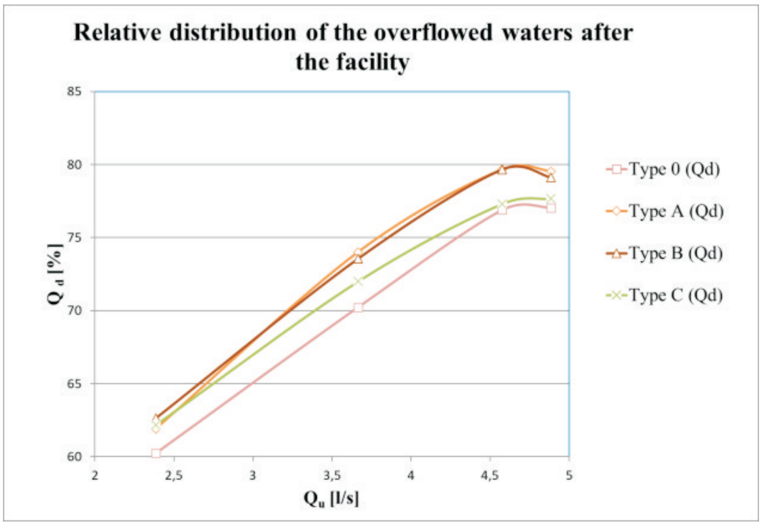


Fig. 9. Relative distribution of non-overflow water depending on the current case

6. CONCLUSIONS FROM THE CONDUCTED RESEARCH IN LABORATORY CONDITIONS

The following conclusions can be summarized from the measurements made in the above way:

– The operation of the facility in its current form is confirmed.
– Due to the small scale and the impossibility of interpreting the results in kind, the size of the attachments is not taken into account.
– Having thus the performed experiment, the good trends of the expected operation of the facility should be taken into account.
– The reported results can be considered as a reason to proceed to a more in-depth study of the operation of the facility thus constructed on near to real sizing.

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