Equipment for Engineering Education

Experiment Instructions

HM 160.51 Venturi-Device
for Teaching Flume

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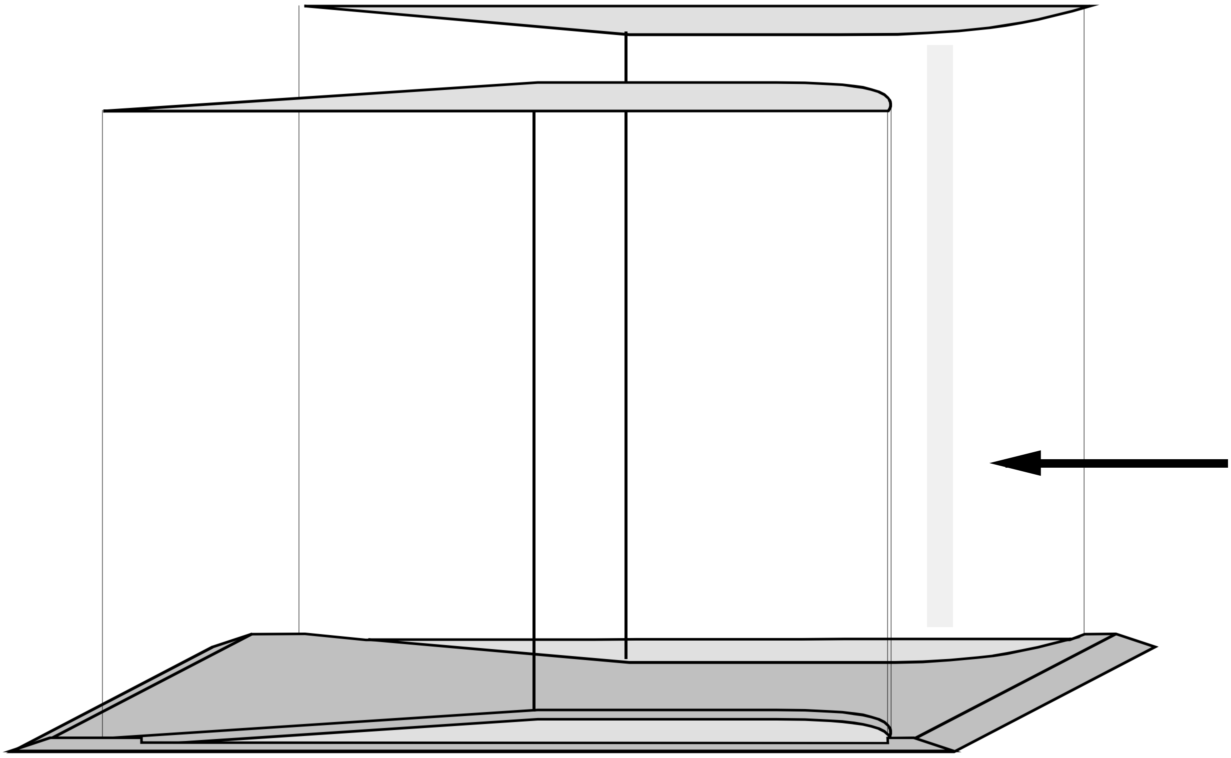
HM 160.51 Venturi-Device for Multi-Purpose Teaching Flume



Experiment Instructions

Please read and follow the safety comments before the first installation!

This apparatus is ment to be used only for Education, Teaching or Research.

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1 Introduction

The **HM 160.51 venturi device** is the fully functional model of a venturi channel flowmeter for metering of river flow. The device is designed for installation in the HM 160 multi-purpose teaching flume. The venturi effect is achieved by a horizontal contraction of the channel cross-section.

The flowmeter comprises two Plexiglas side panels, which can be simply slotted into a base plate. This provides a good view of the contraction cross-section. The subcritical and supercritical flow processes can be very clearly observed.

In addition to the actual flow metering, an energy comparison based on Bernoulli's equation can also be illustrated.

The venturi flowmeter covers the following topics:

- Metering of flows in open flumes with the venturi channel flowmeter
- Flow processes of water
- Application of Bernoulli's equation

2 Unit description

The **HM 160.51 venturi device accessory unit** comprises two Plexiglas panels, which are slotted into a base plate to provide horizontal contraction of the channel cross-section. The device is designed for installation in the HM 160 multi-purpose teaching flume.

2.1 Components

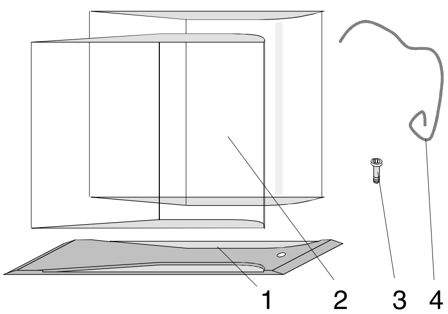

Fig. 2.1 Components

The HM 160.51 venturi device comprises the following components:

- **Base plate** (1)
- 2 venturi **side panels** made of Plexiglas (2)
- **Hexagon socket screw** M8 (3)
- **Plastic sealing tube** (4)

2.2 Assembly

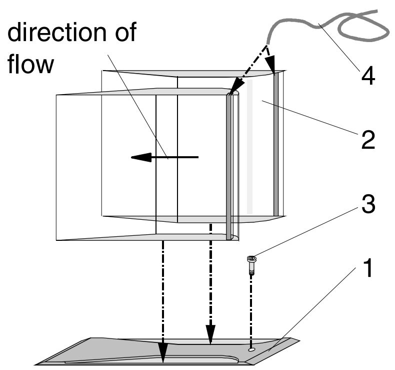

Fig. 2.2 Assembling the venturi - device

- First secure the base plate (1) on the channel bed of the HM 160 channel with the M8 hexagon socket screw (3)
- Slot in the two side panels (2), paying attention to the direction of flow!
- Insert appropriately shortened plastic tubes (4) into the grooves in the side panels

Important! Assemble and disassemble only when the channel is drained, to prevent parts from being swept away or flushed into the drain outlet.

3 Safety

ATTENTION

Screws or other small items must never be allowed to be carried by the water into the drain opening of the HM 160 flow channel. **The centrifugal pump would be destroyed!** You should therefore observe the following safety conditions:

- **Assemble and disassemble** the venturi flowmeter only **with the water drained out**.
- After assembly or disassembly **do not leave any tools lying** in the flow channel!

ATTENTION

- Always fix attachments fitted in the channel **securely**, to prevent damage to the attachments.

ATTENTION

- The side panels of the flowmeter are made of fragile, non-scratchproof Plexiglas. They should therefore **not be cleaned with abrasive cleaning agents**!

ATTENTION

- Please **do not drop** the side panels**!**

4 Theory and experiments

4.1 Subcritical and supercritical

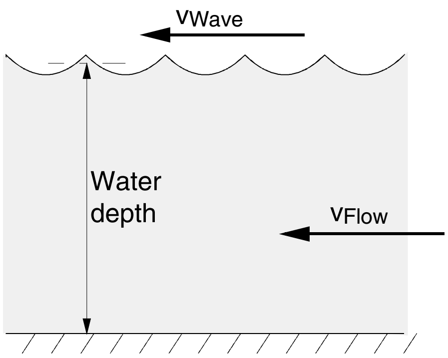

Fig.: 4.1 Wave speed in flat water

To understand the mode of functioning of the venturi flowmeter it is necessary to know the two basic flow states of a water course:

- Subcritical
- Supercritical

Subcritical outflow is characterised in that the wave speed, which as we know is dependent on the water depth, is higher than the flow speed.

In contrast, in the case of **supercritical outflow** the situation is reversed: the wave speed is lower than the flow speed of the water course. This means that a disturbance in the downstream water, as is triggered by a wave, cannot influence the upstream water in the case of supercritical outflow; or in other words: **waves cannot be propagated upstream in supercritical outflow!**

4.2 Mode of functioning of the venturi flowmeter

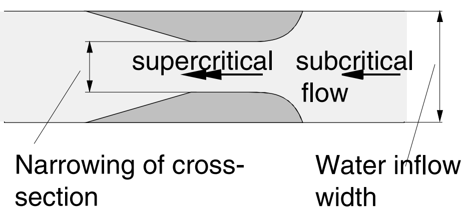

Fig.: 4.2 Venturi-channel flowmeter (view from the top)

Like the venturi pipe meter used for metering in pipe construction and in fluid mechanics, the venturi flowmeter serves to meter the flow in open water courses. It involves a narrowing of the outflow cross-section, as can be seen in Fig. 4.2. As a result of this profile the water changes to "supercritical" flow within the narrowing. Consequently, as detailed in Chapter 4.1, the downstream water level can exert no influence on the outflow process, as is the case in a underwater weir (e.g. HM 160.33) .

The venturi flowmeter is termed the venturi channel flowmeter in the following, to differentiate it clearly from the venturi pipe flowmeter.

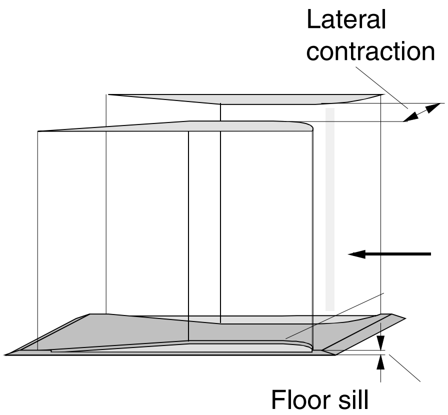

Fig.: 4.3 Contraction of the venturi-device

In relation to a measuring weir (HM 160.30), which can also be used to meter the flow rate, the venturi channel flowmeter has two advantages:

- Only low gradient loss
- No risk of sediment deposit

In a real case therefore, in contrast to a measuring weir, a venturi channel flowmeter can be used even in water courses carrying large amounts of bed load!

The narrowing of the cross-section can be effected by lateral contraction, by installing a floor sill, or even by means of both those measures, as detailed here

4.3 Calculating the flow rate

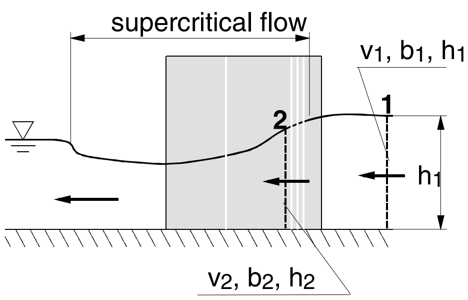

Fig.: 4.4 cross-section of venturi-device

Calculation of the flow rate Q by means of a venturi channel flowmeter is based on the law of continuity between cross-sections 1 and 2 of the channel:

$$Q_1 = Q_2, \text{ or} \quad (4.1)$$

$$v_1 \cdot b_1 \cdot h_1 = v_2 \cdot b_2 \cdot h_2 \text{ with} \quad (4.2)$$

v_i - Speed of water at cross-section i of the channel,

b_i- Channel width at cross-section i,

h_i - Water level at cross-section i .

If these findings are combined with Bernoulli's law between cross-sections 1 and 2, the ultimate result is the **outflow formula for the venturi channel flowmeter**:

$$Q = \mu \cdot b_2 \cdot \sqrt{g} \cdot C \cdot h_1^{3/2} . \quad (4.3)$$

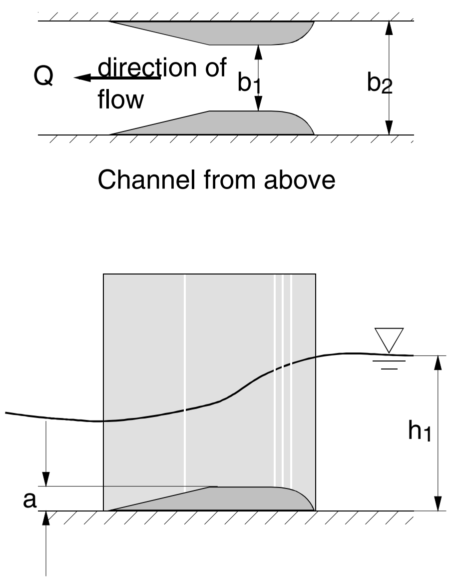

Fig. 4.5 horizontal and vertical contraction

Meanings:

Q - Calculated flow rate of the venturi channel flowmeter

μ - Outflow coefficient, in the venturi channel flowmeter is

μ=0.985

b_2 - Lateral contraction of the venturi channel flowmeter

g - Acceleration due to gravity (g=9.81 m/s^2)

C - Coefficient for contraction

h_1 - Channel height upstream of the venturi inlet

The **coefficient C** is dependent on the **contraction ratio in the horizontal**

$$m = \frac{b_2}{b_1} \text{, with} \qquad (4.4)$$

b_1 - Channel width upstream of the venturi inlet,

and the **contraction ratio in the vertical**

$$t = \frac{h_1 - a}{h_1} \qquad (4.5)$$

and can be read from Fig. (4.6).

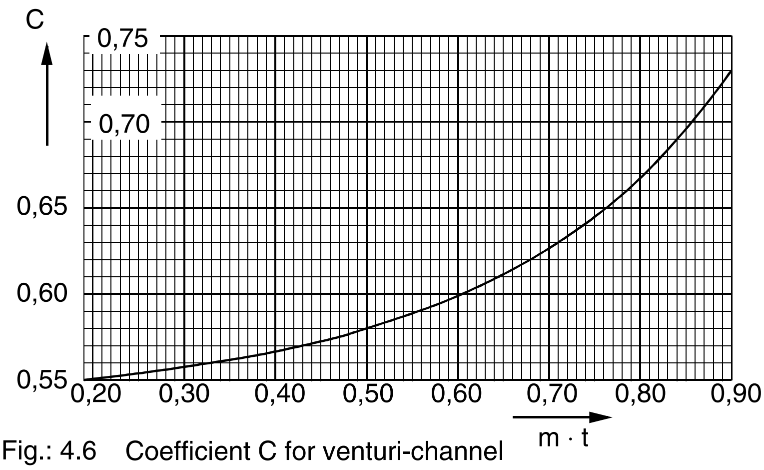

Fig.: 4.6 Coefficient C for venturi-channel flowmeter

4.4 Indications of various experiments

- Because of the small channel width in the HM 160 multi-purpose teaching flume, the friction losses are of great importance. Without appropriate calibration of the venturi channel flowmeter it is virtually impossible to obtain exact flow measurements.
- In the area of the narrowing of the venturi channel flowmeter the water flow is "supercritical". This can be clearly observed in an experiment.
- As described in Chapter 4.2, the upstream water level is not dependent on the downstream water level. This can be shown by creating an artificial damming effect in the downstream water.

If you have a Pitot tube for metering of the flow speeds, you can perform additional experiments:

- Check the continuity equation between cross-sections 1 and 2
- Reproduction of Bernoulli's law between any two cross-sections 1 and 2 of the flow channel upstream or downstream of the venturi channel flowmeter. The law states:

$$h_1 + \frac{v_1^2}{2g} = h_2 + \frac{v_2^2}{2g} \qquad (4.6)$$

5 Appendix

5.1 Technical data

Base plate:
Material: Anodised aluminium
Dimensions(L x W x H)
84 x 330 x 10 mm
Venturi side panels (x 2):
Material: Plexiglas
Dimensions(L x W x H)
22 x 250 x 280 mm

5.2 Venturi profile

See sketch of base section (Fig. 5.1)

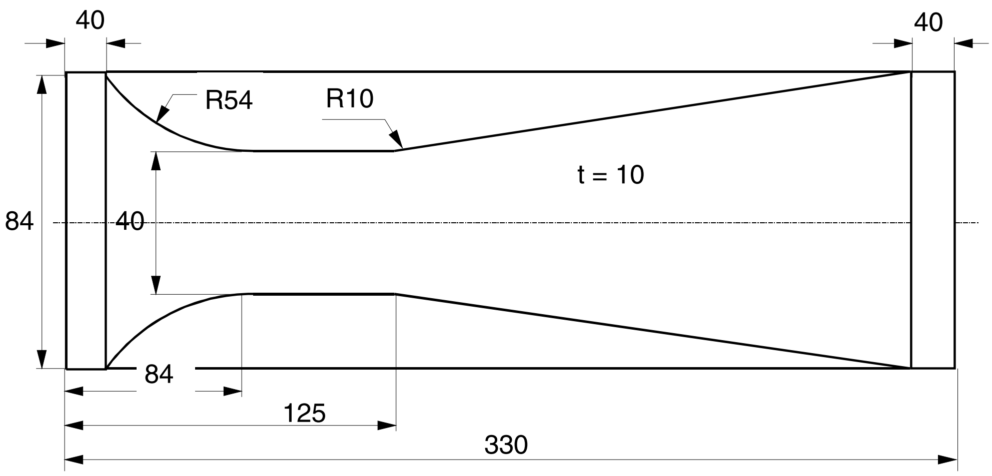

Fig.: 5.1 Venturi-profile (view from the top)

5.3 Bibliography

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Naudascher, E.: "Hydraulik der Gerinne und Gerinnebauwerke". Springer Verlag, Vienna, 1987.