Experiment Instructions

HM 160.40 Radial Gate

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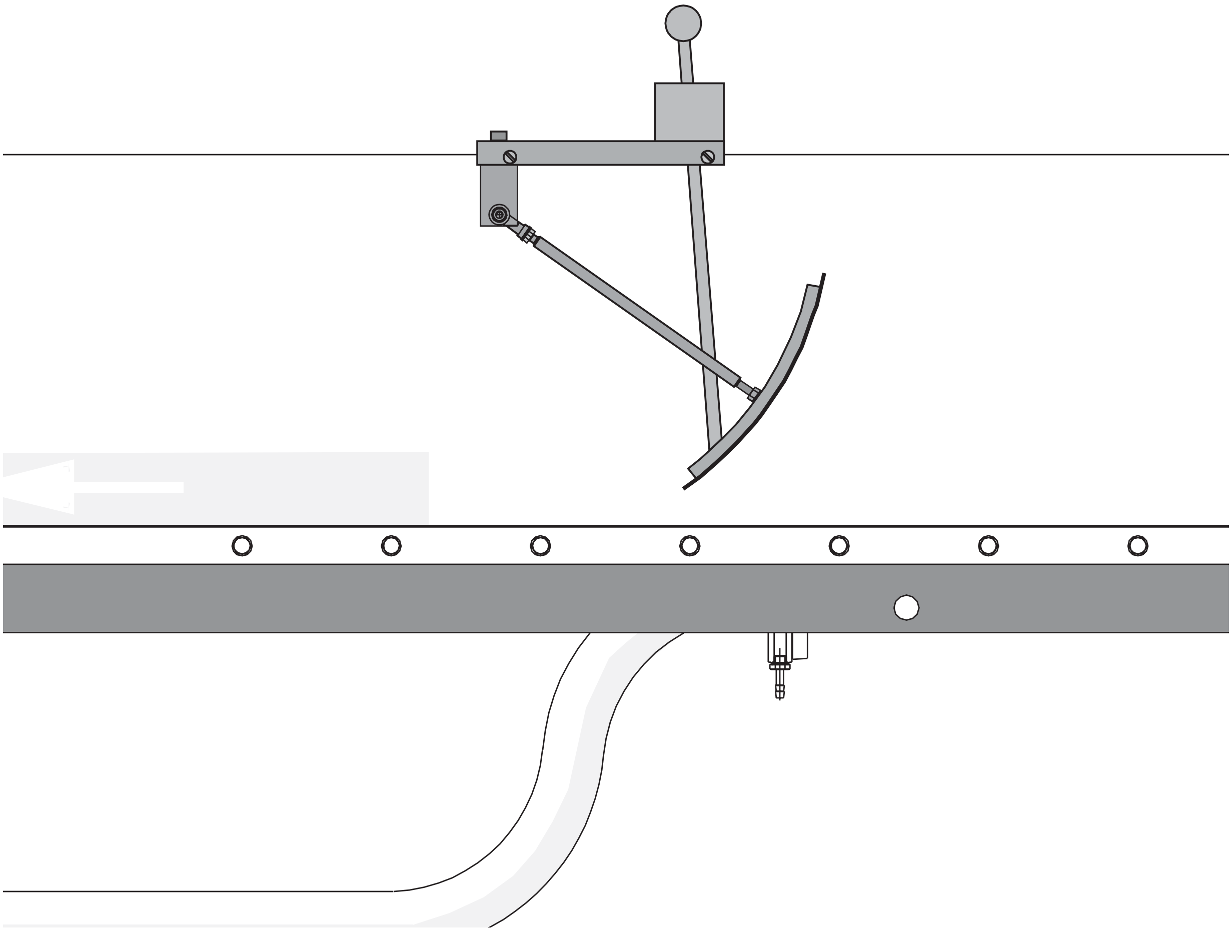

Experiment Instructions

Please read and follow the instructions before the first installation!

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Table of Contents

1 Introduction

The accessory unit **HM 160.40 Radial Gate** is the model of a segmented weir and is used to show the hydraulic processes involved in outflow under sluices and weirs. In addition to observing the subcritical and supercritical flow processes in the outflow area, measurements can also be carried out to determine the flow rate or overflow coefficient.

The unit **HM 160.40 Radial Gate** is designed for installation into the modular flow channel **HM 160** as far as shape and size are concerned. It has the following characteristics:

- The swivel angle can be freely adjusted between complete closure and full flow rate.
- The segmented weir can be freely positioned on the flow channel.
- Fitting requires no tools, making it very easy to use for instruction purposes.

The segmented weir covers the following **subject areas** (in some cases in conjunction with other G.U.N.T. accessories):

- Structure of moveable weirs
- Outflow under moveable weirs
- Flow processes of the water
- Jet contraction during outflow under weirs

2 Unit description

The **HM 160.40 Radial Gate** is the model of a genuine segmented weir. It is designed for installation in the modular flow channel HM 160 and its shape and size are adapted to this.

2.1 Components

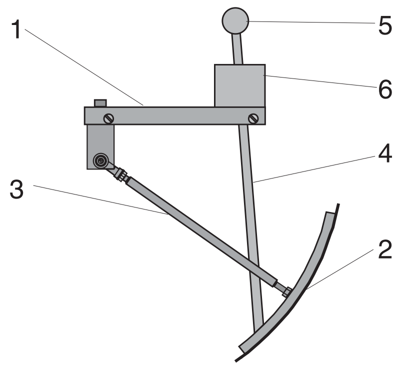

Fig.: 2.1

The HM 160.40 segmented weir consists of the components

- **Base plate** (1) with **fastening screws**
- **Weir body** as a circular section (2)
- **Pressure rod** (3)
- **Adjustment rod** (4) with **fixing screw** (hidden), **ball handle** (5) and **guide** (6)

2.2 Operation

The segmented weir is opened and closed by moving the adjustment rod (4) in the guide (6).

Caution: When undoing the fastening screw hold ball handle (5) securely so that the weir body (2) does not accidentally drop.

2.3 Assembly

Important: It is recommended to drain the water out of the channel for assembly and disassembly so that small parts cannot be rinsed on and enter the pump.

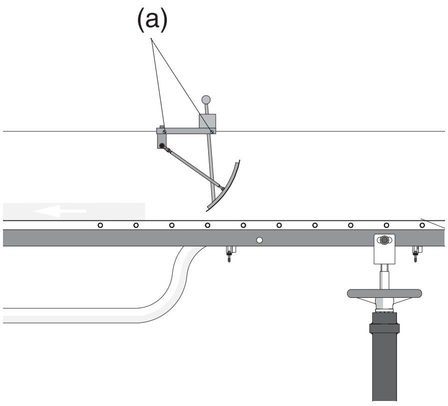

Fig.: 2.2

- In the first step, place the segmented weir from above onto the channel body. The segmented weir can be positioned as required along the flow channel.
- Next, fix the weir onto the channel sides using the 4 fixing screws (a).

3 Safety

In all circumstances, it is essential to prevent screws or other small parts from being rinsed into the outlet opening of the flow channel HM 160 by water.

This would destroy the centrifugal pump.

Therefore, always follow the safety instructions below:

- Carry out assembly and disassembly of the segmented weir only with the water drained off.
- After assembly, do not leave any tools in the flow channel.
- Always secure the segmented weir firmly so that it is not damaged.

4 Theory and experiments

4.1 Classification of the weirs

Weirs can be divided up into **fixed weirs** and **moveable weirs**. Moveable weirs are always used when as constant a water level of the upstream water as possible is required and also when a particular damming height must not be exceeded in the highest of high waters.

In the case of rivers with a high bed load-carrying capacity, a fixed weir is considered in addition to a moveable one, in order to prevent bed load colmation in front of the fixed weir and so that the bed load can be diverted into the downstream water.

The segmented weir is a moveable weir. As regards its function, the segmented weir is a **sluice**, i.e. the water flows under it rather than over it.

4.2 Characteristics of a segmented weir

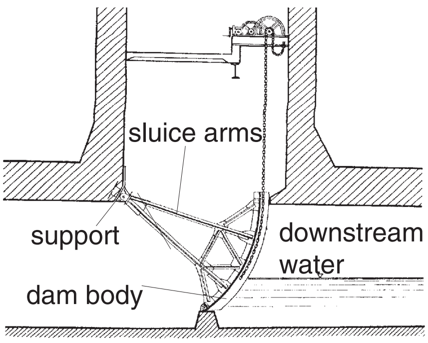

Fig.: 4.1

A segmented weir consists of the actual dam body in the form of a segment of a circle and the sluice arms. The center point of the circle segment drops together with the support of the sluice arms, so that all forces and surges from the dammed-up water act centrically. This prevents uneven stresses which can cause problems with other weir types.

The friction forces arising during movement are very low in the case of a segmented weir. Apart from the side seal, friction only occurs in the central bearing with a very small lever arm. For this reason, segmented weirs can be constructed with very large widths.

The disadvantage of segmented weirs is that they cannot be lowered and therefore the removal of bed load, ice etc., is only possible with major water losses.

4.3 Outflow under a segmented weir

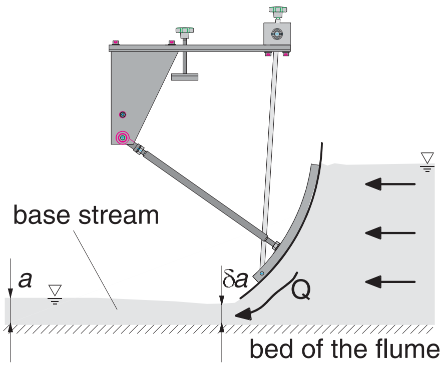

Fig.: 4.2

Because the segmented weir is important in hydraulic engineering, the hydraulic interrelationships of researchers have been subject to detailed mathematical investigations.

Firstly, it is intended to show qualitative characteristics in the case of outflow under a segmented weir. If the segmented weir is opened, the water is carried away through a gap and what is known as a **base stream** is produced. If there is no build-up and if the outflow capacity is therefore not influenced by the downstream water, a **full base stream** is said to exist in the same way as **full overflow** (Fig.4.2).

The most interesting thing is that a restriction (**stream contraction**) occurs with the level a shortly after the outflow opening is passed $\delta \cdot a$, which disappears again as the stream progresses. Of course, this constriction influences the outflow capacity of the segmented weir. The water normally leaves the segmented weir with **supercritical flow**.

The level of the outflow Q under a segmented weir as a function of the size of the gap opening can be calculated. The relationship for the outflow Q under sluices can be obtained as follows via a Bernoulli stream thread

$$Q = \mu \cdot ab \cdot \sqrt{2gh} \ . \qquad (4.1)$$

with

μ - Outflow coefficient

a - Height of the outflow opening

b - Width of the outflow opening (channel width)

h - Upstream water level

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

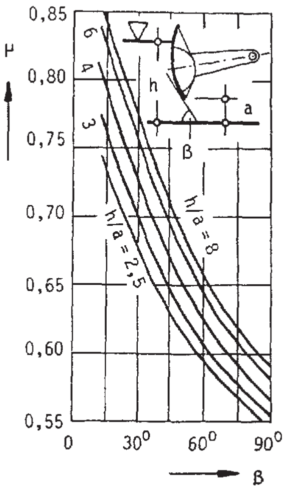

Fig.: 4.3

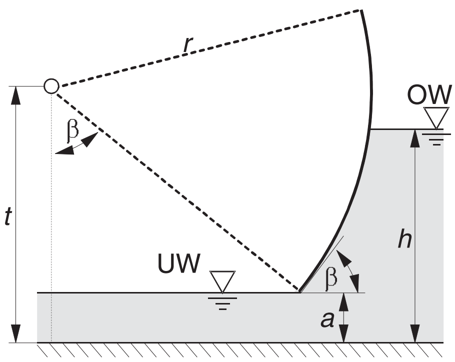

Fig.: 4.4

The outflow coefficient for the segmented weir can be seen in Fig. 4.3. It is also necessary to determinethe opening angle of the weir.

This angle β is obtained as shown in Fig. 4.4 by

$$\beta = arccos\frac{t-a}{r} . \qquad (4.2)$$

The structural framework conditions of the modular flow channel define t = 255mm and r = 298mm. For the **opening angle of the segmented weir** this gives

$$\beta = arccos\frac{255mm - a}{298mm} . \qquad (4.3)$$

Also! The opening angle β has an influence on the flow rate Q, as can be seen in Fig. 4.3. Furthermore, the stream contraction changes with angle β. Whether it becomes greater or smaller should be investigated by way of an appropriate experiment with the segmented weir HM 160.40 in the modular flow channel HM 160 (when doing so, keep the flow rate Q constant).

4.3.1 Determining the outflow with the segmented weir HM 160.40

Example: An experiment with a flow rate of $Q = 6$ m^3/h set at the pump's throttle valve produced the following values during reading-off:

Gap height at the segmented weir $a = 20$ mm

Water level in the upstream water: $h = 95$ mm

Supercritical outflow was observed.

The ratio of water level to gap height gives

$h/a = 95/20 = 4{,}8$

The opening angle of the weir is calculated in accordance with (4.3) at $\beta = 39°$. From the graphic in Fig. 4.3, this gives an overflow coefficient of approximately

$\mu = 0.67$

Application of the formula (4.1) with a channel width of b = 86 mm gives

$$Q = 0.67 \cdot 0.02 \cdot 0.086 \cdot \sqrt{2 \cdot 9.81 \cdot 0.95}\ \text{m}^3/\text{s}$$

$$Q = 5{,}7\ \text{m}^3/\text{h}$$

The observation showed a supercritical outflow. A complete base stream therefore exists.

4.4 Other experiments

It is **recommended** that in order to precisely measure water levels, the **level metering unit HM 160.52** be used.

If you want to delve more deeply into the theoretical relationships, it is recommended to determine the water velocity in the base stream. This is easy to determine experimentally if you use the Prandtl tube HM 160.50. The dynamic pressure measured here can easily be converted into the water velocity (see experiment instructions to HM 160.50).

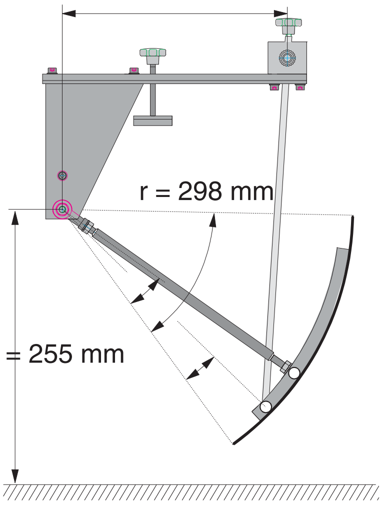

Fig.: 4.5

Use of the Bernoulli equation gives a theoretical velocity v in the base stream of

$$v = \sqrt{\frac{2gh}{1+\frac{\delta a}{h}}}. \tag{4.4}$$

The experimentally determined value can be compared with this result.

- Damming-up in the downstream water

Interesting observations can be made by damming-up in the downstream water (by closing the lower opening in the outlet element of the flow channel HM 160). You can then observe a complete base stream under the segmented weir.

- General instruction:

Determine the stress on the central bearing in the Technical Mechanics subject. Further details on the segmented weir's geometry are required for this purpose (Fig 4.5). (See section 4.5)

4.5 Water pressure calculation

The stress on the central bearing in size and direction should be determined in the following.

4.5.1 Determining the level of the resultant force

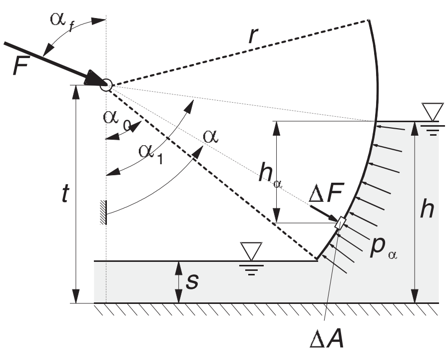

Fig.: 4.6

Defined or measured variables in accordance with Fig. 4.6:

t = 255 mm	Distance of bearing-channel bed
s = 20 mm	Gap height at the segmented weir
h = 200 mm	Water level in the upstream water
r = 298 mm	Radius of the segmented weir
b = 86 mm	Channel width

Let us first observe an infinitessimally small area ΔA of the circle section under the angle α:. The hydrostatic pressure p_α generates a force of ΔF:

$$\Delta F = p_\alpha \cdot \Delta A = \rho \cdot g \cdot h_\alpha \cdot b \cdot r \cdot \Delta\alpha \qquad (4.6)$$

h_α is obtained from the following relationship:

$$\cos\alpha = \frac{t - h + h_\alpha}{r} \text{, also} \qquad (4.6)$$

$$h_\alpha = (h - t) + r \cdot \cos\alpha \qquad (4.7)$$

(4.7) used in (4.5) produces:

$$\Delta F = \rho g b r \cdot [r \cos\alpha + (h - t)]\, \Delta\alpha \qquad (4.8)$$

Integrated within the limits α_0 and α_1 it follows that:

$$F = \rho g b r \cdot [r \int_{\alpha_0}^{\alpha_1} \cos\alpha \, d\alpha + (h - t) \int_{\alpha_0}^{\alpha_1} d\alpha \,] \qquad (4.9)$$

The following is obtained for the **resultant force F**: (4.6)

$$F = \rho gbr\,[r\,(\sin\alpha_1 - \sin\alpha_0) + (h - t)(\alpha_1 - \alpha_0)] \quad (4.10)$$

The variables α_1 and α_0 are obtained from

$$\cos\alpha_0 = \frac{t - s}{r} \quad (4.11)$$

$$\cos\alpha_1 = \frac{t - h}{r} \quad (4.12)$$

If we use the previously measured values, we obtain the resultant force F of

$F = 17{,}5$ N

4.5.2 Determining the direction of the resultant force

The formulation of the equilibrium of forces in a vertical direction produces:

$$F \cdot \cos\alpha_f = \Sigma\, \Delta F \cdot \cos\alpha \tag{4.13}$$

Equation (4.4) utilized and integrated, it follows that

$$\cos\alpha_f = \frac{(h-t)\cdot(\sin\alpha_1 - \sin\alpha_0) + r\left(\frac{1}{2}(\alpha_1-\alpha_0) + \frac{1}{4}(\sin 2\alpha_1 - \sin 2\alpha_0)\right)}{(h-t)(\alpha_1-\alpha_0) + r\,(\sin\alpha_1 - \sin\alpha_0)} \tag{4.14}$$

If we use the measured values (angle in radian measure), we obtain a direction of

$$\alpha_f = 52{,}8°$$

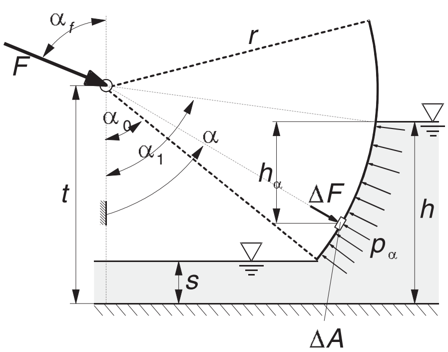

Fig.: 4.7

5 Appendix

5.1 Technical Data

Height of the rotation point above the channel bed	255 mm
Radius of the segmented weir	298 mm

Dimensions:

(LxWxH)	250 x 120 x 350 mm