

Comprehensive Guide to 90-Degree V-Notch Weir Flow Measurement: Technical Principles, Formulas, and Discharge Tables

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In the field of hydraulic engineering and environmental monitoring, the precise measurement of open channel flow is a fundamental requirement. Among the various primary devices used for this purpose, the **90-degree V-notch weir** (also known as a triangular weir) stands as one of the most reliable and sensitive instruments, particularly for monitoring low flow rates. This technical guide provides an exhaustive analysis of the 90-degree V-notch weir, covering its mathematical foundations, installation protocols, discharge calculations, and industrial applications.

The Fundamental Role of Weirs in Fluid Mechanics

A weir is essentially an obstruction placed across an open channel through which water flows. It is designed to cause a predictable relationship between the liquid level (head) and the flow rate (discharge). Unlike flumes, which constrict flow horizontally, weirs create a vertical rise in the upstream water level. The **90-degree V-notch** configuration is specifically favored in industrial waste surveys and environmental monitoring because its geometric shape maintains high sensitivity even when the flow volume decreases significantly. This makes it superior to rectangular weirs for applications where flow variability is high.

The Mechanics of the Nappe and Crest

To understand how a V-notch weir functions, one must understand the behavior of the **nappe**—the sheet of water flowing over the weir. For accurate measurement, the nappe must be **aerated**; that is, air must circulate freely under the falling water to prevent a vacuum from forming, which would cause the nappe to 'cling' to the downstream face of the weir. If the nappe clings, the discharge relationship is altered, leading to significant measurement errors. The **crest** of the V-notch is the lowest point of the 'V,' and it is from this point that the **head (H)** is measured.

Mathematical Framework: The Discharge Equation

The relationship between the head of water above the weir crest and the flow rate is non-linear. For a 90-degree V-notch weir, the general discharge equation is derived from Bernoulli's principle, assuming a theoretical velocity and then applying a **Coefficient of Discharge (Cd)** to account for real-world friction, turbulence, and contraction effects.

Standard Discharge Formulas

Depending on the standard used (ISO, ASTM, or British Standards), several variations of the discharge formula exist. The most common empirical formula for a 90-degree V-notch weir in English units (where Q is in cubic feet per second and H is in feet) is:

$$Q = 2.52 \times H^{2.47}$$

Alternatively, for metric calculations where Q is in cubic meters per second and H is in meters, a common representation is:

$$Q = 1.37 \times H^{2.5}$$

Technical data often cites the **Kindsvater-Shen equation**, which is widely regarded as the most accurate for fully contracted V-notch weirs because it accounts for both the viscosity of the fluid and the surface tension. The equation is typically expressed as:

$$Q = \frac{8}{15} \times \sqrt{(2g)} \times C_e \times \tan\left(\frac{\theta}{2}\right) \times h_e^{3/2} \times W$$

- g : Acceleration due to gravity (9.81 m/s² or 32.2 ft/s²).
- C_e : Effective coefficient of discharge.
- θ : The angle of the notch (90 degrees in this context).
- h_e : The effective head (Actual head H plus a small correction factor k_h).

Accuracy and Flow Ranges

The 90-degree V-notch weir typically offers an accuracy of **±2% to ±5%** under laboratory-controlled conditions. To maintain this accuracy, the head (H) must be at least 0.20 feet (0.061 m) to overcome surface tension effects. If the head is too low, the water will simply trickle down the face of the weir rather than springing clear in a well-defined nappe.

Comparison with Other Flow Measurement Devices

Selecting the correct measurement device requires a comparison of hydraulic characteristics. The following table highlights the differences between the 90-degree V-notch weir and other common devices like the rectangular weir and the Parshall flume.

Feature	90° V-Notch Weir	Rectangular Weir	Parshall Flume
Low Flow Sensitivity	Excellent	Poor	Moderate
Head Loss	High	High	Low
Debris Tolerance	Low (Traps sediment)	Low	High (Self-cleaning)
Ease of Installation	Moderate	Moderate	Complex / High Cost
Typical Accuracy	2% - 5%	3% - 7%	3% - 5%
Primary Usage	Clean water/Treated waste	Large canals	Inlet works/Raw sewage

Technical Specifications for Installation

The accuracy of a V-notch weir is heavily dependent on the physical installation. A "fully contracted" weir means that the side walls and the floor of the approach channel are far enough away from the notch that they do not interfere with the flow pattern.

1. The Weir Pool (Upstream Channel)

The approach channel, or weir pool, must be long enough to ensure that the water flow is **laminar**(smooth) and free from turbulence. Ideally, the weir pool should extend upstream for at least 10 times the maximum head ($10 \times H_{max}$). If the channel is too short or the water is too turbulent, the head measurement will fluctuate, leading to unreliable data.

2. Point of Measurement

The head (H) should not be measured directly at the notch because the water surface curves downward as it approaches the crest (a phenomenon called "drawdown"). The **point of measurement** must be located upstream at a distance of 3 to 5 times the maximum head ($3-5 H_{max}$) from the weir plate.

3. Weir Plate Requirements

- Material: Typically stainless steel or other non-corrosive materials.
- Thickness: The plate should be thick enough to prevent vibration but the edge of the notch itself must be sharp.
- The Sharp Edge: The upstream edge of the notch must be sharp-cornered. The thickness of the actual crest edge should be between 0.03 inches and 0.08 inches (0.8 mm to 2.0 mm). If the plate is thicker, the downstream edge must be beveled at a 45-degree angle.

4. Clearance Dimensions

To ensure a fully contracted flow:

- The distance from the crest to the channel floor should be at least $2 \times H_{max}$.
- The distance from the sides of the notch to the channel walls should be at least $2 \times H_{max}$.

Discharge Table for a 90-Degree V-Notch Weir

The following table provides standardized discharge values based on the head (H) height. These values are calculated using the standard formula for a fully contracted 90-degree V-notch weir. (Note: These are representative

values; for legal compliance, always refer to certified engineering tables).

Head (ft)	Head (m)	Flow (GPM)	Flow (CFS)	Flow (L/s)
0.20	0.061	18.1	0.040	1.14
0.30	0.091	49.6	0.111	3.13
0.40	0.122	101.8	0.227	6.42
0.50	0.152	178.6	0.398	11.27
0.60	0.183	282.8	0.630	17.84
0.70	0.213	417.4	0.930	26.33
0.80	0.244	584.5	1.302	36.87
0.90	0.274	786.5	1.752	49.61
1.00	0.305	1025.0	2.284	64.67
1.20	0.366	1633.0	3.638	103.03
1.50	0.457	2887.0	6.432	182.13

Industrial Applications and Flow Monitoring

The 90-degree V-notch weir is a staple in various industrial sectors. Organizations like the **Environment Agency** and various municipal wastewater authorities mandate specific flow monitoring protocols where these weirs are central components.

Industrial Waste Surveys

When conducting an industrial waste survey, it is critical to determine the volume of effluent being discharged into municipal sewers or natural water bodies. The V-notch weir is often integrated into **weir tanks**—portable or permanent tanks containing the weir plate and a stilling well. This setup allows for accurate measurement of discharge rates, which are then used to calculate billing or to ensure compliance with environmental permits.

Environmental Flow Monitoring

In environmental science, monitoring the base flow of small streams or the runoff from agricultural fields requires high sensitivity at low heads. The 90-degree V-notch is the preferred tool here because it can accurately measure flow that would be undetectable or within the error margin of a rectangular weir or a large flume.

Practical Implementation Field Guide

Implementing a flow measurement system using a V-notch weir requires a systematic approach to avoid common pitfalls. Follow these steps for a successful field installation:

Step 1: Site Selection

Choose a location in the channel where the flow is relatively straight and uniform. Avoid placing the weir immediately after a bend, a pipe discharge, or a steep slope. The water should enter the weir pool with minimal

velocity (less than 0.5 ft/s).

Step 2: Weir Plate Installation

Install the weir plate perfectly level across the channel. The "V" must be centered. Use a spirit level to ensure the crest is horizontal. Ensure the plate is securely anchored and sealed against the channel walls to prevent bypass leakage (flow going around or under the weir).

Step 3: Stilling Well Setup

For the highest accuracy, use a **stilling well** connected to the weir pool at the point of measurement (3-5 H_{max} upstream). The stilling well dampens surface waves and turbulence, allowing for a precise reading of the head using a float-based sensor or an ultrasonic level transmitter.

Step 4: Calibration and Zeroing

The most critical step in setup is "zeroing" the level sensor. The zero point of the sensor must correspond exactly to the lowest point of the V-notch crest. Even a small error in the zero setting (e.g., 5mm) can lead to a 10% or greater error in flow calculation at low heads.

Troubleshooting and Operational Challenges

Even with perfect installation, operational challenges can arise that affect the integrity of the data. Engineering teams must be vigilant in identifying these failure modes.

Sediment Accumulation

Because a weir acts as a dam, it naturally traps sediment and debris on the upstream side. If sediment builds up to the point where it reduces the depth of the weir pool below the required $2 \times H_{max}$, the velocity of approach will increase, leading to an **overestimation** of flow. Regular dredging of the weir pool is required.

Nappe Aeration Issues

If the nappe (the falling water) is not properly aerated, a partial vacuum forms behind it. This pulls the nappe toward the weir plate, increasing the discharge for a given head and causing an **underestimation** of flow. In some installations, aeration pipes are installed through the side walls to ensure atmospheric pressure is maintained under the nappe.

Submerged Flow Conditions

A weir must be **free-flowing**. This means the water level on the downstream side must be low enough that it does not interfere with the water falling over the crest. If the downstream level rises above the crest, the weir becomes "submerged," and the standard $Q=H$ relationship no longer applies. Measurements taken under submerged conditions are generally considered invalid unless complex correction factors are applied.

Broader Implications for Water Resource Management

The use of 90-degree V-notch weirs extends beyond simple flow measurement; it is a critical component of sustainable water management. By providing high-resolution data on effluent discharge and stream health, these devices allow engineers to model the impact of industrial activities on local ecosystems. As water scarcity increases and environmental regulations become more stringent, the role of precise, verifiable flow data becomes paramount. The V-notch weir, with its century-long history of proven hydraulic performance, remains a cornerstone of this effort.

Understanding the nuances of weir hydraulics—from the thickness of the crest edge to the importance of the approach velocity—ensures that the data collected is both scientifically sound and legally defensible. Whether used in a small-scale laboratory experiment or a large-scale industrial treatment plant, the 90-degree V-notch weir provides the clarity and accuracy required to manage the world's most precious liquid resource effectively.

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