NARSIMHA REDDY ENGINEERING COLLEGE

UGC AUTONOMOUS INSTITUTION

Accredited by NBA & NAAC with 'A' Grade | Permanently Affiliated to JNTUH

Maisammaguda (V), Kompally - 500100, Secunderabad, Telangana State, India

FLUID MECHANICS

Topic: UNIT III - Venturimeter Operations & Discharge Derivation

Fluid Measurement Instrumentation Overview

- Requires industrial devices capable of tracking flow rates without generating high energy loss.
- Venturimeters, Orificemeters, and Pitot tubes utilize Bernoulli-driven pressure differentials.
- Designs focus heavily on managing boundary layers to limit unrecoverable eddy turbulence.
- Selection balances structural spacing constraints, installation costs, and accuracy requirements.

Venturimeter Mechanical Geometry

- Converging Cone: Section featuring gradually narrowing area profiles to accelerate fluid velocity.
- Throat Section: Narrowest internal width zone where velocity peaks and static pressure drops.
- Diverging Cone: Gradually widening zone designed to systematically restore pressure head profiles.
- Diverging angle is restricted to 5° - 7° to prevent flow separation and eliminate major head loss.

Mathematical Derivation: Theoretical Flow

- Formulated by applying Continuity and Bernoulli equations between the inlet (1) and throat (2).
- Continuity Balance: $a_1V_1 = a_2V_2$, yielding direct link parameters between stream velocities.
- Energy Equation: $(p_1/\gamma) + (V_1^2/2g) = (p_2/\gamma) + (V_2^2/2g)$, assuming zero friction.
- Direct Head Substitution: Let $h = (p_1/\gamma) - (p_2/\gamma)$ represent the localized piezometric pressure drop.

The Venturimeter Discharge Equation

- Solving for theoretical velocity yields: $Q_{th} = (a_1 \cdot a_2 \cdot \sqrt{2gh}) / \sqrt{a_1^2 - a_2^2}$.
- Where a_1 represents the inlet channel area, and a_2 represents the tight internal throat area.
- Actual Discharge Form: $Q_{act} = C_d \cdot Q_{th}$, where C_d acts as the empirical calibration constant.
- Venturimeter Coefficient of Discharge (C_d) ranges from 0.95 to 0.99 due to streamlined profiling.

Orificemeter: Design and Comparison

- Comprises a thin flat plate with a sharp-edged circular aperture inserted coaxially into a pipe.
- Lower manufacturing cost compared to Venturimeters, but generates high permanent head loss.
- Vena Contracta: The minimal jet area zone formed downstream where fluid streamlines parallel out.
- Coefficient of Discharge (C_d) values cluster around 0.62 to 0.65 due to extensive eddy mixtures.

Pitot Tube & Local Velocity Tracking

- Right-angled glass conduit placed facing upstream to capture oncoming fluid streams directly.
- Stagnation Point: Location at the tube inlet mouth where localized velocity drops completely to zero.
- Kinetic energy converts into static pressure lift, raising column indicators above hydraulic grade lines.
- Target Governing Velocity Equation: $V = C_v \cdot \sqrt{(2gh)}$, tracking local velocity vectors accurately.

Momentum Principle & Pipe Bend Forces

- Evaluates net dynamic impact forces exerted by fluid streams turning across curved bends.
- Built upon the Impulse-Momentum framework: Net Force = Rate of Change of Fluid Momentum.
- Governing Cartesian Forms: $F_x = \rho Q(V_{2x} - V_{1x})$ and $F_y = \rho Q(V_{2y} - V_{1y})$.
- Structural anchor blocks are dimensioned using these equations to prevent pipeline joint failures.

Flow Over Notches and Weirs

- Notches: Sharp-edged structural openings built into channel walls to gauge flow rates.
- Weirs: Large-scale concrete or masonry barriers built across open streams to regulate water fields.
- End Contractions: Physical narrowing profiles generated as fluid curves inward past vertical edges.
- Velocity of Approach: Base velocity with which water streams advance toward weir structures.

Rectangular Notch Discharge Derivation

- Formulated by integrating theoretical flow across elemental fluid horizontal strips.
- Governing Equation: $Q = (2/3) \cdot C_d \cdot L \cdot \sqrt{2g} \cdot H^{3/2}$, where L represents crest length.
- H tracks the absolute upstream head height measured relative to the horizontal crest base line.
- Suppressed Weirs: Eliminate end contractions entirely, matching the full channel boundary layout width.

Triangular Notch (V-Notch) Advantages

- Features higher measurement accuracy under low-flow rates due to high head lift sensitivities.
- Governing Equation: $Q = (8/15) \cdot C_d \cdot \tan(\theta/2) \cdot \sqrt{2g} \cdot H^{5/2}$, where θ is the vertex angle.
- For a standard 90° V-Notch with $C_d \eqqcolon 0.6$, the discharge expression simplifies cleanly to $Q = 1.417 \cdot H^{5/2}$.
- Eliminates complex variations in discharge coefficients under fluctuating fluid depth flows.

Trapezoidal & Broad Crested Weirs

- Cippoletti Weir: Special trapezoidal opening featuring outward side slopes built at 1:4 ratios.
- Slope geometries add discharge capacity to offset losses from end contractions.
- Broad Crested Weir: Structure where crest width exceeds water head fields ($2b > H$).
- Maximum Discharge Equation: $Q_{max} = 1.705 \cdot C_d \cdot L \cdot H^{3/2}$, achieved under critical flow depths.

UNIT III Summary & High-Yield Viva-Voce Key

- Comprehensive tracking of Unit III core syllabus parameters and theoretical frameworks.
- High-yield focus on governing mathematical derivations and mechanical configurations.

 VIVA-VOCE ASSESSMENT CORE QUESTIONS:

1. Why is the divergence angle of a Venturimeter smaller than its convergence angle?
2. Define the terms 'vena contracta' and 'stagnation point' inside measurement devices.
3. State why a triangular notch provides superior measuring sensitivity under low discharge heads.

Thank You..