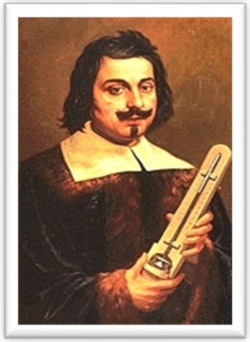
Chapter Seven

Orifice Discharge

Torricelli

1608-1647

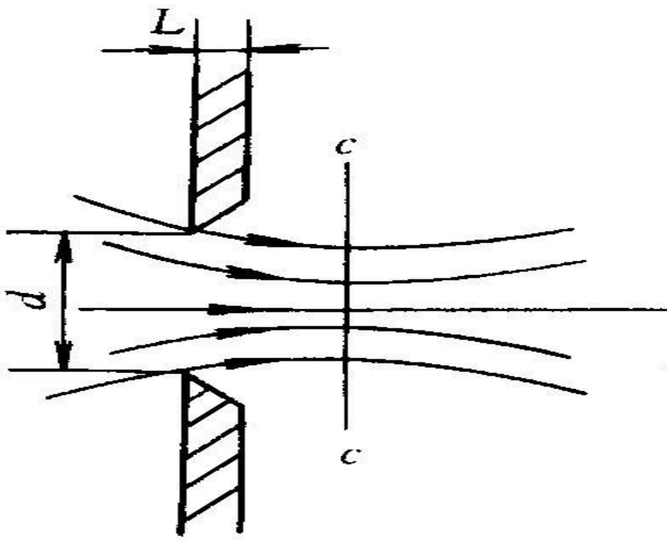


Classification

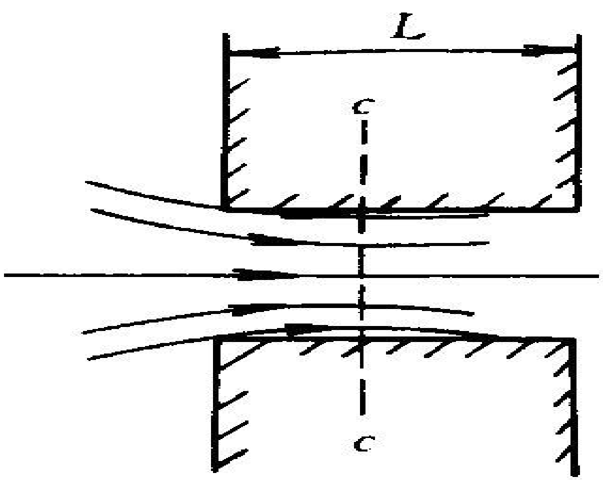
- Free Discharge
  - discharge to atmosphere
- Submerged Discharge
  - discharge to the liquid

Classification

- Sharp-edged orifice
  - L/D<=2
- Thick-edged orifice
  - 2=<L/D<4



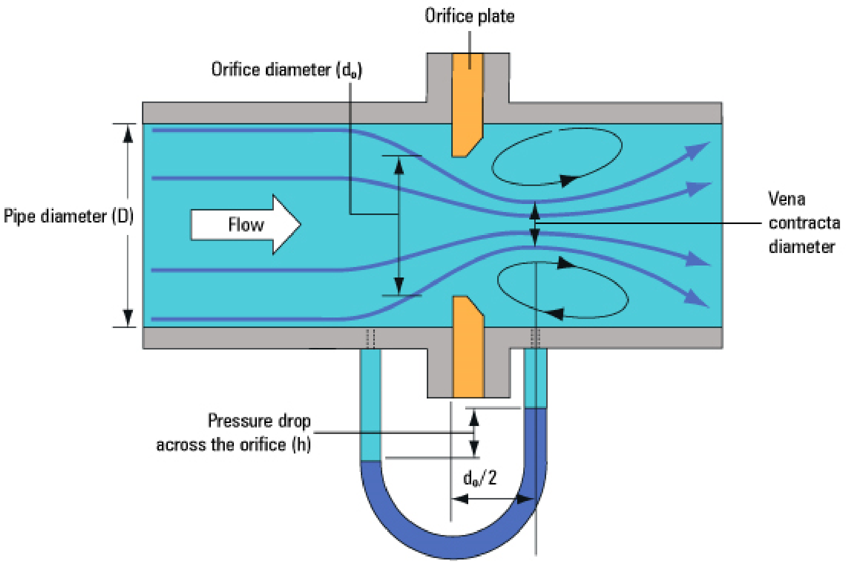
Sharp edged orifice

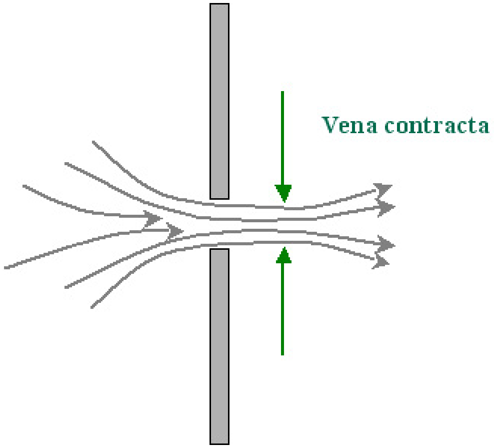


Thick edged orifice

Vena contracta

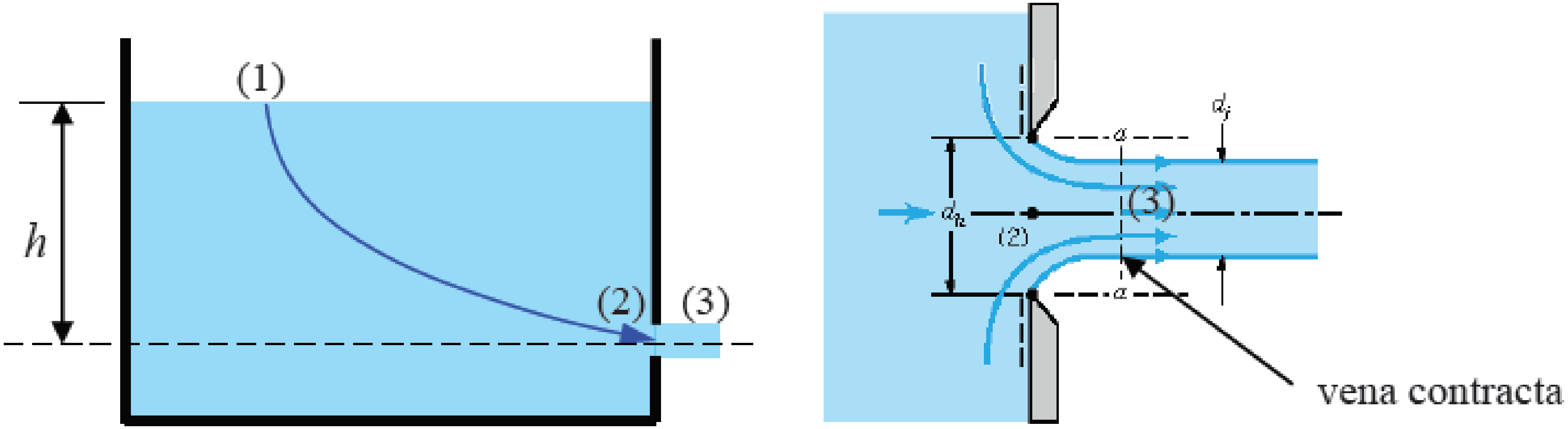
- When water flows through an orifice the water contracts with a smaller area than the original orifice opening (vena contracta)
- Contraction coefficient $C_c = A_c / A_0$





Sharp edged orifice discharge

- We are to consider the flow from a tank through a hole in the side close to the base



Tank and streamlines of flow out of a sharp-edged orifice

- The jet contract after the orifice to a minimum cross section where they all become parallel, at this point, the velocity and pressure are uniform across the jet. It is necessary to know the amount of contraction to allow us to calculate the flow.

Sharp edged orifice discharge

$$V_{\text{actual}} = C_v V_{\text{ideal}}$$

Each orifice has its own coefficient of velocity C_v, which usually lies in the range (0.97 - 0.99).

$$A_{\text{actual}} = C_c A_{\text{orifice}}$$

So the discharge through the orifice is given by

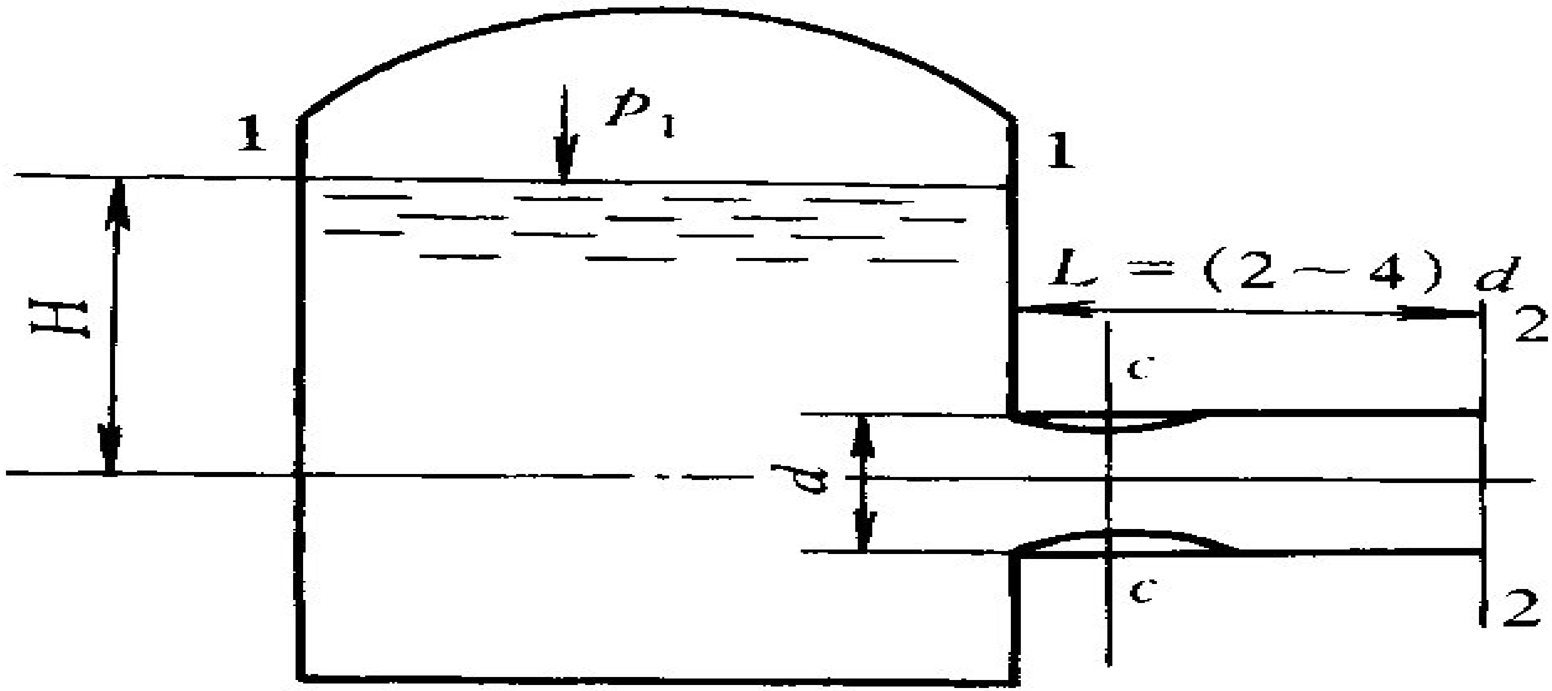
$$Q = AV$$

$$\Rightarrow \quad Q_{\text{actual}} = A_{\text{actual}} V_{\text{actual}} = C_c C_v A_{\text{orifice}} V_{\text{ideal}} = C_d A_{\text{orifice}} \sqrt{2gh}$$

where C_d is the coefficient of discharge, and $C_d = C_c\, C_v$.

Thick edged orifice discharge

- We are to consider the flow from a tank through a thick edged orifice to the base



- The jet contract after the orifice to a minimum cross section, and expand to fit the pipe

Thick edged orifice discharge

The minor losses :

$$\sum \zeta = \zeta_c{}' + \zeta_1 + \lambda \frac{L}{d}$$

$$\zeta_c = 0.06 \quad C_c = 0.64 \quad \Rightarrow \quad \zeta_c{}' = 0.06 \times \left(\frac{1}{0.64}\right)^2 = 0.146$$

Sudden expansion:

$$\zeta_1 = \left(\frac{A}{A_c} - 1\right)^2 = \left(\frac{1}{C_c} - 1\right)^2 \approx 0.316$$

Friction loss: $\lambda = 0.02$, $L/d = 2$

$$\lambda \frac{L}{d} = 0.04$$

$$\sum \zeta = 0.146 + 0.316 + 0.04 = 0.5$$

Coefficient of velocity:

$$C_v = \frac{1}{\sqrt{1 + \sum \zeta}} \approx 0.82$$

Flow coefficient

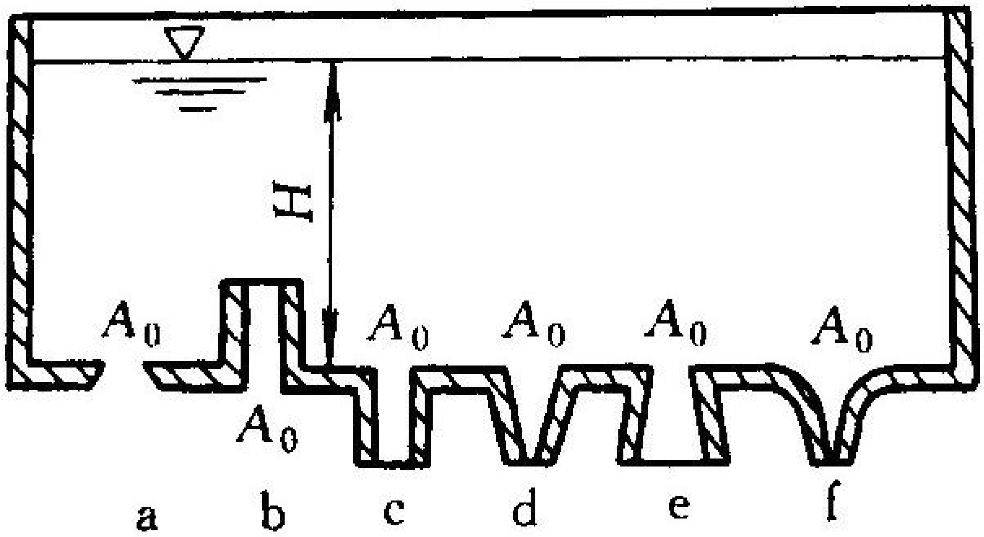
Cautions:

- C_d=0.82 for thick edged orifice , but C_d=0.61 for sharp edged orifice. Under the same situation, the C_d of former is larger than the latter one.

Reasons:

- The flow velocity to atmosphere V_2 ， at the contraction section the velocity $V_c > V_2$, the pressure $P_c < P_2$, the vacuum created at the contraction section helps sucking the fluid which increases the flow rate of the orifice.

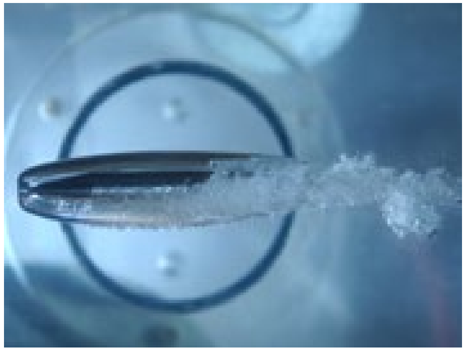
Flow coefficient of different orifice



		ζ	C_c	C_v	C_d
	a	0.06	0.64	0.97	0.62
	b	1	1	0.71	0.71
	c	0.5	1	0.82	0.82
	d	0.09	0.98	0.96	0.96
	e	4	1	0.45	0.45
	f	0.04	1	0.98	0.98

Cavitation

- Cavitation phenomenon
  - When the local pressure becomes equal to the vapor pressure of the liquid, small vapor bubbles are generated and these bubbls collapse when they enter a high-pressure region.
- Cavitation damage
  - In devices such as propellers, pumps and valve, cavitation causes a great deal of noise, damage to components, vibrations, and a loss of efficiency.

Cavitation at orifice

coefficient of Cavitation σ

$$\sigma = \frac{P_2 - P_v}{P_1 - P_2} \qquad (if \quad p_2 > p_v)$$

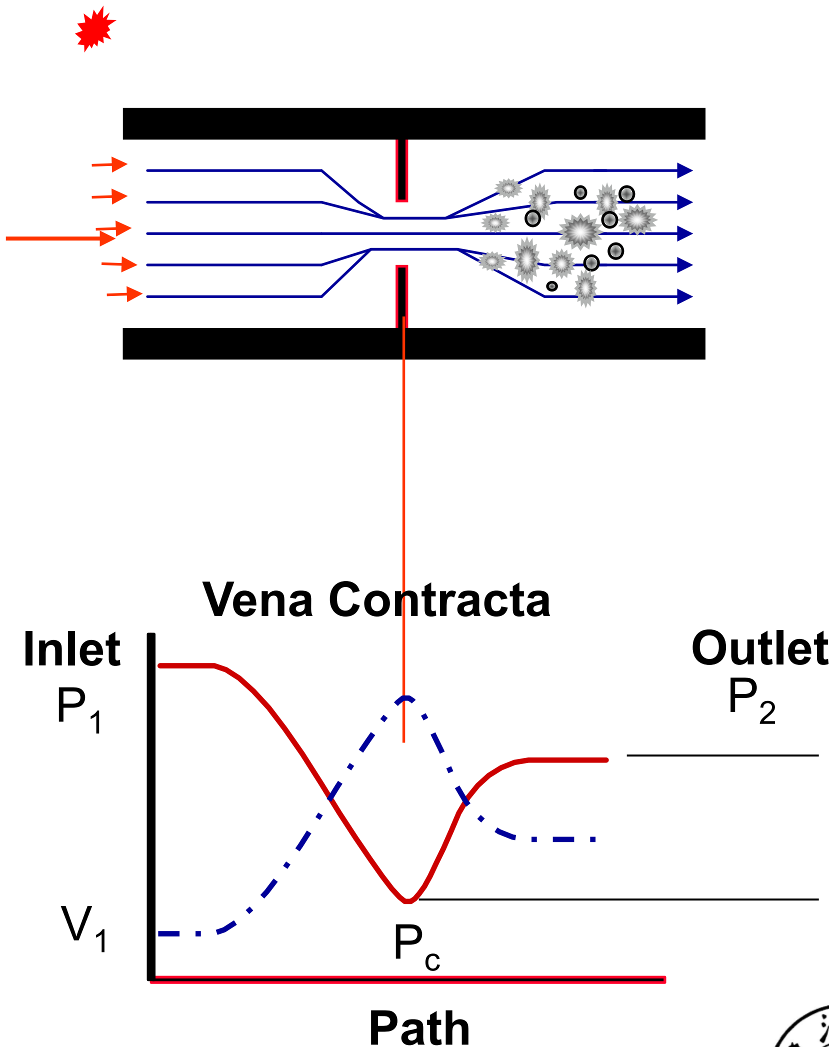
assume $P_v \approx 0$ (P_v一般很小)

then $\sigma = \dfrac{P_2}{P_1 - P_2}$

$\dfrac{P_1}{P_2} = 1 + \dfrac{1}{\sigma}$ from experiment $\sigma = 0.4$

$$\frac{P_1}{P_2} \cong 3.5$$

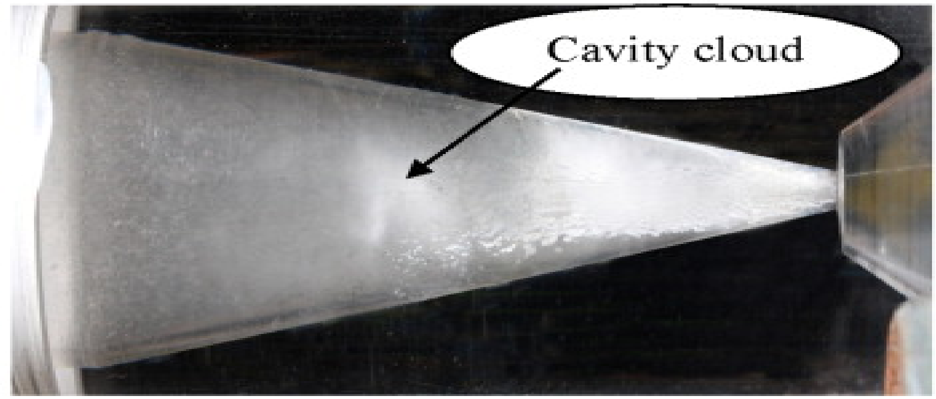
if $\dfrac{P_1}{P_2} > 3.5 \Rightarrow$ Cavitation



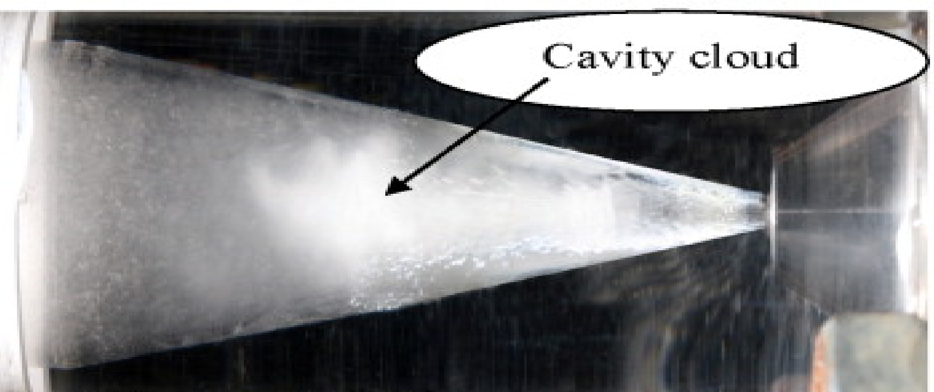
(a) P = 1 bar, $C_v = 0.45$, $v_o = 20.78$ m/sec

(b) P = 3 bar, $C_v = 0.21$, $v_o = 30.06$ m/sec

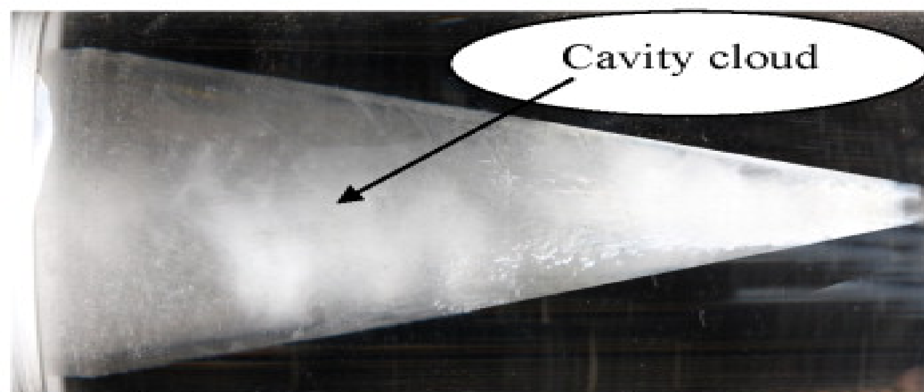
(c) P = 5 bar, $C_v = 0.15$, $v_o = 36.2$ m/sec



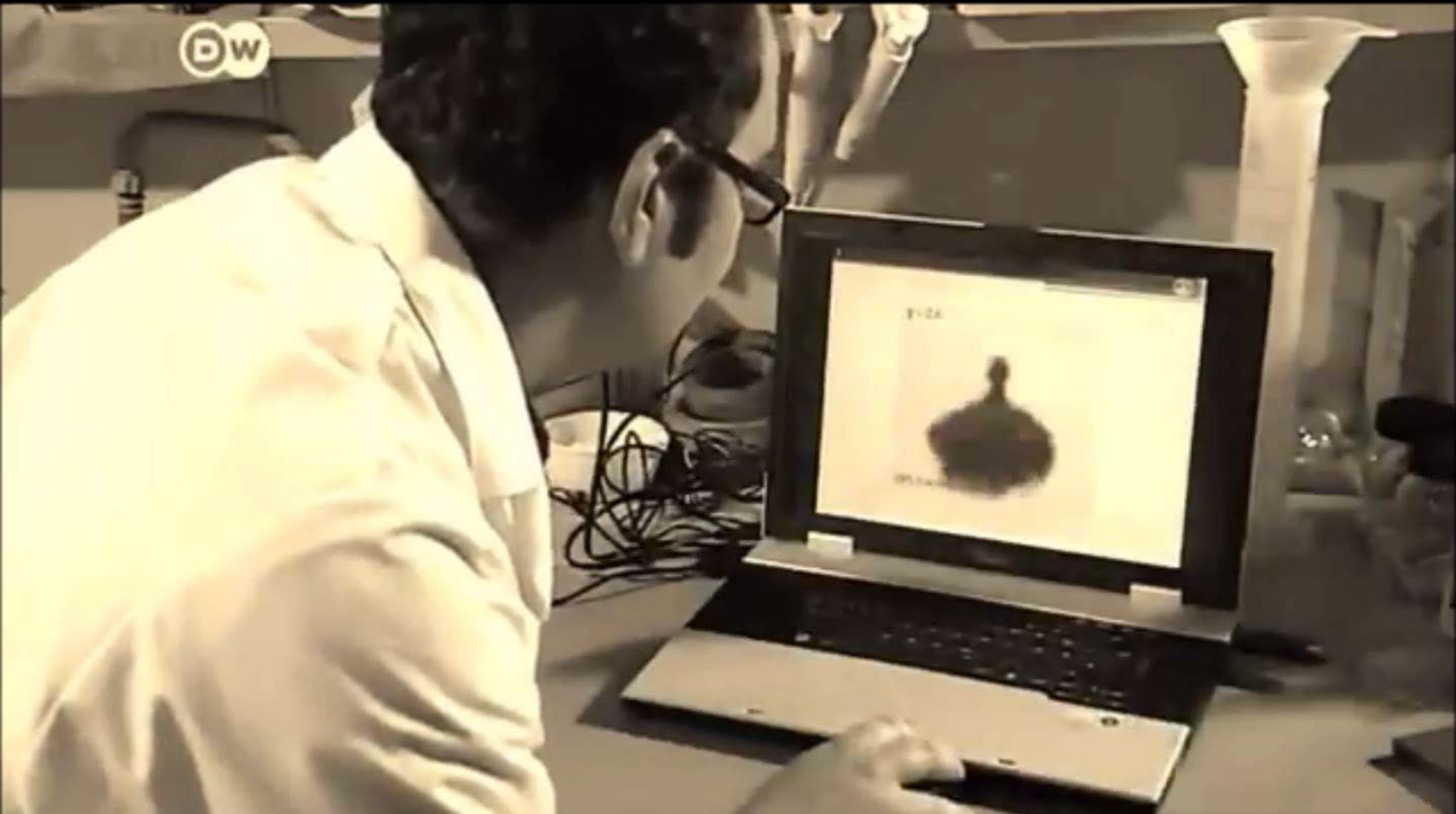
(d) P = 6 bar, $C_v = 0.13$, $v_o = 39.35$ m/sec



(e) P = 8 bar, $C_v = 0.1$, $v_o = 43.33$ m/sec



(f) P = 10 bar, $C_v = 0.09$, $v_o = 46.42$ m/sec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ENTRY #V0090

INERTIAL COLLAPSE OF A SINGLE BUBBLE NEAR A SOLID SURFACE

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