

Flow through a Hole

- As long as the Area of the hole is has an effective diameter that is less than 25% of the diameter of the pipe, then you can calculate leakage
- While the upstream pressure is greater than choked, then the flow is:

$$ID_{eff} = \sqrt{\left(\frac{4}{\pi}\right) A_{eff}}$$

$$P_{choked} = P_{down} \left(\frac{2}{k+1}\right)^{\frac{k}{1-k}}$$

$$\dot{m}_{sonic} = C_d A_{eff} P_{up} \sqrt{\left(\frac{SG}{R_{air} \cdot Z_{up} \cdot T_{up}}\right) \left(\frac{2 \cdot k}{k+1}\right)^{\frac{k+1}{k-1}}} \text{ for FPS units multiply SG times } g_c$$

- When the velocity drops below 0.6Mach, you can calculate flow rate by:

$$\dot{m}_{incompressible} = C_d A_{eff} P_{up} \sqrt{\left(\frac{SG}{R_{air} \cdot Z_{up} \cdot T_{up}}\right) \left(\frac{2 \cdot k}{k-1}\right) \left[\left(\frac{P_{down}}{P_{up}}\right)^{\frac{2}{k}} - \left(\frac{P_{down}}{P_{up}}\right)^{\frac{k+1}{k}}\right]}$$



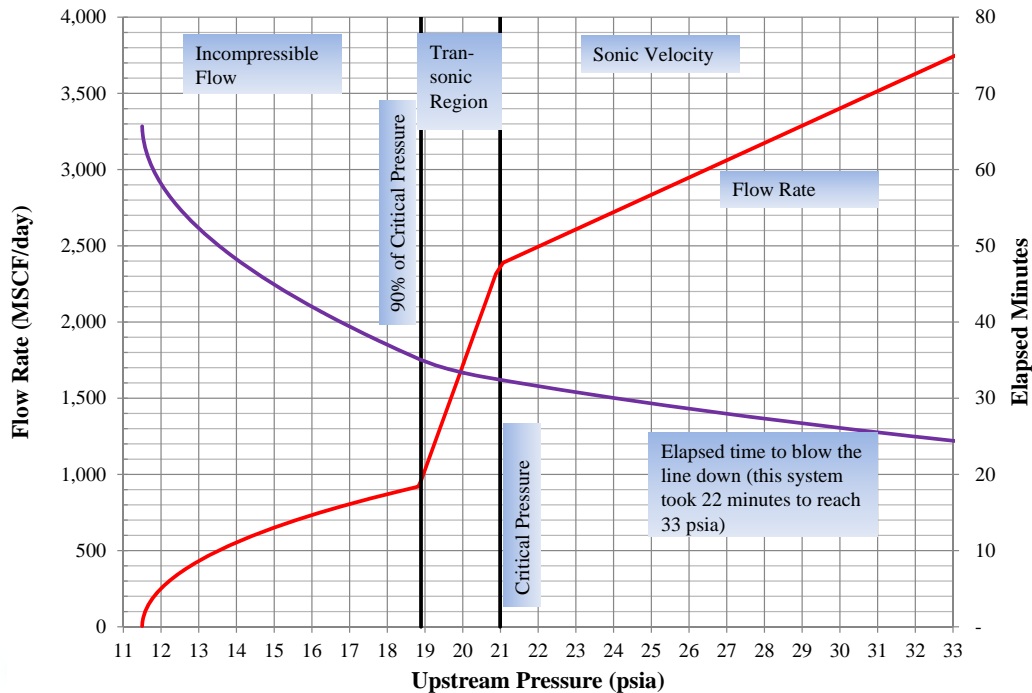
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Nomenclature

	Name	FPS Units	MKS Units
\dot{m}_{sonic}	Mass flow rate at sonic velocity	lb/sec	kg/sec
$\dot{m}_{incompressible}$	Mass flow rate after the velocity drops below 0.6 Mach	lb/sec	kg/sec
C_d	Discharge Coefficient (Square edged hole=0.8; Ragged hole=0.72; Ductile Failure=1.0		
ID_{eff}	The ID that a pipe would have if it had the same area as the hole	in	mm
A_{eff}	Flow area of the hole	in ²	m ²
P_{choked}	Minimum downstream pressure for choked flow	psia	kPaa



Flow through a Hole to atmosphere (Effective diameter 1.5 inch, irregular hole)



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Corrosion Prediction

- There are tools to predict corrosion
 - Corrosion Coupons
 - Deward-Milliams Nomograph for CO₂
 - Various NACE programs
- All of them work better in continuous phase liquid
 - Coupons are rarely placed where liquid accumulates (they are placed where they are convenient to pull)
 - Coupons show general metal loss, but the pipe damage is generally from localized pitting
 - The calculations and Nomographs assume a single attack, never CO₂, H₂S, and MIC concurrently.
- My approach has always been if you manage standing water (through pigging) then corrosion failures will become too rare to calculate

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