1 Differential pressure and pressure loss

When a throttle element is interposed in a closed passage of fluid in piping, a difference is produced between the pressure upstream and downstream the throttle element as illustrated in fig 1. This difference \((h=p_1-p_2)\) is called differential pressure. The fluid passing through the section 2 gradually regains its pressure as it flows downstream, but the downstream pressure cannot be recovered up to the upstream pressure, part of the pressure being lost. This loss is called pressure loss (permanent pressure loss= \(p_1-p_3\)). The extent of this pressure loss depends on the type of throttle elements and their open area ratio, as shown in fig 2. The relation between the flow rate and the differential pressure is given by:

\[
V = k \sqrt{\frac{\Delta p}{\rho}}
\]

\[
V_N = k \sqrt{\frac{\Delta p \rho_N}{\rho}}
\]

\[
M = k \sqrt{\frac{\Delta p \rho}{\rho}}
\]

with:

- \(V\) \([\text{m}^3/\text{h}]\): volume rate of flow at density under operating conditions
- \(V_N\) \([\text{Nm}^3/\text{h}]\): volume rate of flow at density under standard conditions
- \(M\) \([\text{kg/s}]\): mass flow
- \(\Delta p\) \([\text{kg/m}^2]\): differential pressure
- \(\rho\) \([\text{kg/m}^3]\): density under operating conditions
- \(\rho_N\) \([\text{kg/Nm}^3]\): density under standard conditions
- \(k\) \([\text{ }]\): coefficient (determined by type and size of throttle element).

From the above, the relation between the flow rate and the differential pressure where the density is constant but the flow rate is variable is as listed in Table 1. In other words, the flow rate is obtainable by measuring the differential pressure. When the density is variable (when pressure and temperature are variable), the true flow rate can be given by compensating the variation of the density by the above equations (that, however, is not applicable when the density varies to a great extent).
2 Orifice plate

2.1 Description

Orifice plates have a disadvantage of permitting a greater pressure loss than other throttle elements (flow nozzles, venturi tubes, etc.) but are most popularly used because of their simpler shape, easier manufacturability, lower cost and higher reliability. The types of orifice plates include concentric, eccentric, segmental, quarter-circle and square orifice plate, etc..

2.2 Specification

<table>
<thead>
<tr>
<th>orifice bore type:</th>
<th>concentric square edged orifices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>quadrant edged orifices</td>
</tr>
<tr>
<td></td>
<td>eccentric orifices</td>
</tr>
<tr>
<td></td>
<td>segmental orifices minimum</td>
</tr>
<tr>
<td></td>
<td>quadrant edged orifice diameter 4.5 mm</td>
</tr>
</tbody>
</table>

flow calculation standards:

- 1D-1/2D (radius) tap
- 2.5D-8D (pipe) tape are per “ASME Fluid Meters, Their Theory and Application, 5th Edition, 1959”
- eccentric orifices/ segmental orifices: bs1042

flange ratings:

- ASME, 300, 600, 900, 1500, 2500 lbs (RF, RTJ)
- (ASME B16.36 – ASME B16.47A and B)
- API 2000, 3000, 5000, 10000 15000 (API 6A)
**pressure taps:**

- flange tap
- corner tap
- 1D and 1/2D (Radius) tap –

**plate thickness:**

3, 6, 9, 12mm, etc.

**tab handle:**

welded to orifice plate

**materials: plate**

ASTM 304, 316SS, Duplex, exotic material

**drain and vent hole:**

per ISA-RP3.2 recommendations.
Not drilled for orifice bore smaller than 25.4 mm

**markings:**

Upstream side of tab handle stamped “+”

- bore type
- size,
- line size,
- TAG no.,
- quadrant edge radius
- flange rating,
- orifice material
- serial number.

**Special markings:**

- special marking may be furnished to meet specific requirements

**2.3 Types**

**concentric**

This has special features such as simple structure, high accuracy, easy mounting and dismounting. The orifice plates are correctly finished to the dimensions, surface roughness and flatness to the applicable standard. Differential pressure is measured through flange, vena contracta, radius or corner taps.

**Eccentric**

For liquids containing solid particles that are likely to sediment or for vapors likely to deposit water condensate, this orifice plate is used with its eccentric bore bottom flush with the bottom of the piping surface so that the sedimentation of such inclusions is avoided. Likewise, for gases or vapors, it may be installed with its eccentric bore top flush with with the bore top of the piping to avoid the stay of gas or vapor in its vicinity. Flange taps or vena contracta taps are used for the orifice plate.

**Segmental**
The bore of the orifice plate is a semicircle to perform the same function as the eccentric orifice plate. This is used for similar purposes. Flange taps or vena contracta taps are employed to take out fluid pressures.

**Quarterant**

The inlet edge of the bore of this orifice plate is rounded to a quarter circle. This orifice plate is principally used for measuring flow rates of low Reynolds numbers. Flange taps or corner taps are used.

![Quarterant Orifice Plate Diagrams]
3 Orifice plate with ring

3.1 Description

Orifice ring assemblies are used for flow measurement of smaller or medium sized pipes at lower pressures. Each assembly consists of one orifice plate and two orifice rings. Differential pressures are taken out in a corner tap system. Orifice blocks, which are of a unit-construction type and provide higher pressure ratings than the orifice ring assemblies, also are available. Differential pressures are taken out in a corner tap system.

3.2 Specification

orifice bore type:  
- concentric square edged orifices
- quadrant edged orifices
- minimum quadrant edged orifice diameter 4.5 mm
- minimum quadrant edge radius 0.5 mm

flow calculation standards:  
- concentric square edged orifices: ISO-5167-ASME 19.5
- 1D-1/2D (radius) tap
- 2.5D-8D (pipe) tape are per “ASME Fluid Meters, Their Theory and Application,

flange ratings:  
- ASME, 300, 600, 900, 1500, 2500 lbs (RF, RTJ)
- (ASME B16.36 – ASME B16.47A and B)
- API 2000, 3000, 5000, 10000 15000 (API 6A)

pressure taps:  
- corner tap

plate thickness:  
- 3, 6, 9, 12mm, etc.

tab handle:  
- welded to orifice plate

pressure tap handle:  
- 15 mm ( ½”) Sch80 length 150 mm tap connections ½”-NPT-male, socket weld, butt weld, flange (Flange rating to be the same as the of the process pipeline.)

materials:  
- ring and pressure tap nipple : carbon steel, ASTM 304SS, 316SS; DIN 1.4571, etc. plate : ASTM 304, 316SS, duplex, super duplex, exotic material
- tab handle : ASTM 304, 316SS,

drain and vent hole :
4 Orifice plate with holding ring (RTJ)

4.1 Description

The holding ring assembly is a combination of a holding ring and an orifice plate designed for ring-type-joint (RTJ) flanges of ANSI or JPI specifications. The holder ring has a function of holding the orifice plate and also a function as a gasket to prevent leakage of the process fluid. This metallic sealing system is applicable to a fluid of high temperature and high pressure. The pressure tapping system normally is of the flange tap type.

4.2 Specifications

orifice bore type: concentric square edged orifices
quadrant edged orifices


flange ratings: ASME, 300, 600, 900, 1500, 2500 lbs (RF, RTJ) (ASME B16.36 – ASME B16.47A and B API 2000, 3000, 5000, 10000 15000 (API 6A)

pressure taps: flange taps

plate thickness: 3, 6, 9, 12 mm etc.

tab handle: welded to ring
holding ring: riveted to plate, octagonal or oval

drain and vent hole: per ASME recommendations.
No drill for orifice bores smaller than 25.4 mm

materials: plate: ASTM 304SS, 316SS; duplex, super duplex, exotic material
holding ring: ARMCO, soft iron, Stainless Steel with hardness according to ASME B16.20

markings: Upstream side of tab handle stamped “+”
with bore type
line size,
TAG no.,
quadrant edge radius
flange rating,
orifice material
serial number.

Special markings: special marking may be furnished to meet specific requirements.

sheet gaskets 1.5 mm
spiral wound gasket 4.5mm –

piping connection method: ANSI: butt welding type (welded neck)