

RESTRICTION ORIFICE**JGS 210-120-1-73E**

Rev.0 DATE NOV-30-'95

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1. SCOPE

Of many kinds of flow restriction devices, restriction orifices (abbreviated as RO hereafter in this standard practice) are frequently used, because they are simple and economical devices.

This standard practice provides the guidelines for sizing of RO.

Also, it should be noted that this standard practice is concerned with only single-phase fluids.

2. WORK PROCEDURE**2.1 Input to the Design**

The following summarized data shall be prepared by basic design engineers.

2.1.1 Process Conditions

Basic design data for RO shall be clarified into the following items:

(1) Source of data

The necessary design data will be obtained from, but not limited to, the following documents:

- Process Flow Diagram (PFD)
- Piping & Instrument Diagram (P&ID)
- Hydraulic Calculation Sheet (or Pump and Line Calculation Sheet)
- Piping Material Specification

(2) Operating Conditions

- Flow rate (Liquid or Gas)
- Upstream & downstream pressures
- Temperature
- Line Size

(3) Physical properties

For liquid service

- Density, viscosity, vapor pressure

For vapor service

- Molecular weight, C_p/C_v

2.2 Outputs from the Design**(1) Single orifice**

- Orifice diameter

(2) Multi stage orifice

- required quantity of orifices
- orifice diameter of each orifice
- distance between adjacent orifice plates
- pressure drop per each orifice

2.3 Work Steps

Design of RO will be carried out according to the work steps similar to the following guidelines.

(1) Determination of Application**(2) Data preparation for RO.****(3) Sizing by related basic design engineers or vendors.****(4) Checking of the critical items such as cavitation index, pressure drops, minimum orifice diameter and allowable space for piping layout.****(5) Filling out of the necessary information with regard to the restriction orifices in P&ID and other related documents.****2.4 Computer Programs**

The computer programs (BEST^{*1}) are available for rigorous solution.

3. DESIGN

3.1 Determination of Application

A variety of applications of RO are grouped into the following functions, and are exemplified in Fig. 1.

- (1) Restriction of flow rate to the specified pressures.
 - (a) Pump Minimum Flow. (Refer to RO-1)
 - (b) Injection, cooling and flushing of fluid. (Refer to RO-2 , 3 , 4 , 5 , 6 , 7)
 - (c) Sampling. (Refer to RO-8)
 - (d) Minimum bypassing. (Refer to RO-9)
- (2) Pressure reduction with the specified flow rate.
 - (a) Pressure reduction in gas discharge lines to atmosphere. (Refer to RO-10)
 - (b) Steam let down. (Refer to RO-11)
 - (c) N2 purge or constant seal gas (Refer to RO-12)
- (3) Uniform flow distribution
 - (a) Distribution from a feed header. (Refer to RO-13 , 14)
 - (b) Flow distribution by balancing pressure drops through ROs. (Refer to RO-15 , 16)
- (4) Controllability improvement or noise reduction in series with preceding flow controlling devices. (Refer to RO-17)
- (5) Use as a simple static mixer. (Refer to RO-18 , 19)
- (6) Buffer effect as regulating excess pressure fluctuations. (Refer to RO-20)

3.2 Determination of Process Condition

(a) Type-1

In the above cases (1), (2), (3), up and downstream pressures are generally determined along with process conditions.

Therefore, flow rate should be specified as follows.

- (1)-(a), (b) : specified by vendor
- (1)-(c) : enough rate for replacement of circulated sampling fluid (as rough guideline 0.2 ~ 0.4 m³/h) or enough rate for sampling (as rough guideline 0.1 ~ 0.2 m³/h)
- (1)-(d) : enough rate for warming up (as rough guideline 3 ~ 5 % of steam or pump rated flow rate)
- (2)-(a), (b), (c) : specified along with process requirements
- (3)-(a), (b) : uniformly divided flow rate

(b) Type-2

In the above cases (4), (5), flow rate and up or down stream pressure are fixed. Therefore, ΔP should be specified in consideration of pressure balance.

(c) Type-3

In the above case (6), $\beta = d/D$ should be specified, Unless otherwise specified, $\beta = d/D = 0.5$ under can be used.

3.3 Design Consideration

(1) Minimum orifice diameter $d_{\min}$ (mm)

$$\begin{aligned} d_{\min} &= 2.0 \text{ (clean liquid service)} \\ &= 1.0 \text{ (clean gas service)} \end{aligned}$$

For RO with d smaller than above $d_{\min}$ or fouling service, Replaceable strainer should be provided.

(2) Critical cavitation index

The following critical cavitation index (see "definition") should be used for both design and check.

$$K_c = 0.93$$

(3) Straight length (L/D) of RO downstream

$$\begin{aligned} L/D &= 3 : \text{(for liquid case, including Multi Orifice)} \\ &= 10 : \text{(for gas case, after critical flow type RO)} \end{aligned}$$

(4) Standard assembly

Details are shown on Technical Report No.1.

3.4 Design Calculation

For type-1, 2 (in para. 3.2), hole diameter can be determined according to the following practices.

Here, "design type" means determination of orifice hole diameter as new construction.

"performance check" means estimation of flow rate and cavitation check for existing RO.

(Derivations are shown on Technical Report No.2)

3.4.1 Sizing of RO for Liquid Services**CASE 1. Single RO design type**

Step 1 : Calculation of orifice dia.

$$d = 0.011 [Q^2 / (H_u - H_d)]^{0.25}$$

where,

d : orifice diameter (m)

Q : flow rate (m³/h)

H_u : upstream pressure head (m)

H_d : downstream pressure head (m)

$$H_u = 10^4 P_u / \rho, H_d = 10^4 P_d / \rho$$

P_u, P_d : upstream & down stream pressure (kg/cm²)

ρ : density (kg/m³)

Step 2 : Cavitation check

$$K_I = 7.3 [H_u - (H_u - H_d) / (1 - \beta^2) - H_v] / v^2, \beta = d/D$$

K_I : cavitation index (should be greater than 0.93)

H_v : vapor pressure head (m)

v : velocity (m/s)

D : pipe diameter (m)

$$v = Q / (3600 \cdot \frac{\pi}{4} \cdot d^2)$$

IF K_I > 0.93 calculation finished, (no cavitation)

IF K_I ≤ 0.93 cavitation occurs, so proceed to multi RO design

CASE 2. Multi RO design type

Step 1 : determination of design cavitation index K_I

$$K_I = 0.93 \cdot DM$$

DM : design margin (usually 1.05 ~ 1.1)

Step 2 : calculate α

$$\alpha = (1 / 2gC^2) [4Q / (3600 \cdot \pi D^2)]^2 = 0.1713 \cdot 10^{-7} \cdot Q^2 / D^4$$

C : discharge coefficient (assumed to be 0.61)

g : gravitational acceleration (= 9.81 m/s²)

D : pipe diameter (m)

Step 3 : calculate β_i (= d_i / D)

$$\beta_i = \{\alpha \cdot K_I / (H_d^i - H_v)\}^{0.25}$$

H_dⁱ : downstream pressure head of ith stage orifice (m)

H_v : vapor pressure head (m)

At initial H_dⁱ = H_d

Note : i counts from downstream to upstream

Step 4 : calculate orifice diameter d_i (m)

$$d_i = \beta_i \cdot D$$