

INLINE MIXING**JGS 210-120-1-72E**

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1. SCOPE

Inline-mixing devices are used in refineries, petrochemical plants, gas plants and other similar plants. There are many types of in-line mixing devices. In-line mixing devices fall into the following three groups:

- (1) Static mixers
- (2) Nozzle mixing such as axisymmetrical jet mixing or wall-injection mixing
- (3) Common usage of other equipment as a mixing device (pump etc.)

This standard practice provides design guidelines for static mixers and nozzle jet mixing devices used mainly in refineries and petrochemical plants. Namely, this practice deals with the above items (1) and (2). Descriptions concerning the above item (3) and a steam mixer are not given here.

2. WORK PROCEDURE

2.1 Input to the Design

Data to be prepared for calculation are summarized below.

2.1.1 Preparation of Data Source

Data to be used will be obtained from the following documents:

- Process Flow Diagram (PFD)
- Piping & Instruments Diagram (P&ID)
- Basic Engineering Design Data (BEDD) when necessary
- Equipment Data Sheets
- Piping Material Specification

2.1.2 Operating Conditions

- (1) Fluid name
- (2) Flow rate; normal or maximum
- (3) Inlet pressure at normal or maximum flow rate
- (4) Pressure drop across the Inline-Mixing Device at normal or maximum flow rate
- (5) Operating temperature
- (6) Physical properties at inlet conditions,
 - Density (kg/m^3)
 - Viscosity (c.p)

2.2 Output from the Design

The following items are determined.

- (1) Selection of mixing device
- (2) Mixing length
- (3) Pressure drop

2.3 Work Steps

Basic design work for Inline-Mixing will be conducted following the work steps described below.

- (1) Select a mixer type in accordance with the section 3. DESIGN.
- (2) Preparation of data sheet.
- (3) Sizing of the mixer (by basic engineer or vendor).
- (4) Check the vendor's designs by taking account of such information as described in this BDM and elsewhere.

3. DESIGN

3.1 Selection of Mixing Devices

There are three major mixing devices or methods as listed below.

(1) Static mixer (see Figs. 3.1a, 3.1b)

(1-1) Axial Mixing Type (JGC)

(1-2) Radial Mixing Type (Vendor)

Fig. 3.1a shows typical static mixer vendors and their popular commercial static mixers for liquid-liquid mixing. So-called KENICS static mixer shown in Fig. 3.1b is supplied by NORITAKE CO. in Japan.

(2) Axisymmetrical injection.

(3) Wall injection

Values of mixing length and pressure drop depend on each mixing device. The appropriate mixer type should be selected considering such allowable values as pressure drop, length/diameter ratio, cost, etc.

3.2 Guidelines to Select a Suitable Mixing Device

Fig. 3.2a or Fig. 3.2b is helpful to select an appropriate mixing device. Fig. 3.2a and Fig. 3.2b are for gas-gas mixing and liquid-liquid mixing, respectively. In case pipe length for mixing is long enough, static mixers are unnecessary.

3.3 Static Mixer

3.3.1 Gas-Gas Mixing (Axial Type Mixer)

For gas/gas mixing, Axial Type Mixers are primarily to be employed because of the following advantages.

- High mixing performance in spite of low pressure drop
- Cheap and easy maintenance because of the simple structure
- Many successful experiences are redundant.

This mixer comprises of two-stage Cross-Type lattices which are made of at least two small pipes. As is shown in Fig. 3.1b, two and four pipes are used for the first and the second lattices, respectively.

The following important items, at least, are to be strictly observed in actual designs of Axial Type Mixers.

Detail design procedure is shown on APPENDIX-1.

- Axial Type mixers are recommended for mixing gases introduced through injection nozzles.
- Injection nozzle ends must be located near the first mixer element and the injected gas jet must collide with the center of the first mixer element.
- This mixer is generally applied to mixing of gases from totally two pipes. However, in case that gases are injected from two nozzles (that is three gases are involved), first of all, the two gases must be well mixed prior to final mixing of all the three gases.
- Choose the gas whose flow rate is smaller than that of the other gas as the gas to be injected into the main pipe through a branch pipe.
- Standard mixing lengths are listed as follows:
 - (a) For gas injection zone, L_1 ; L/D is 1.0.
 - (b) For mixer element zone, L_2 ; L/D is 0.5.
 - (c) For gas mixing zone, L_3 ; L/D is 3.0.

Pressure drop and mixing length can be obtained according to the Technical Report[1]. An appropriate value of the total mixing length for this mixer is approximately 4.5 in terms of L/D (= mixer length/pipe inner diameter).

3.3.2 Liquid-Liquid Mixing(Radial Type Mixer)

Pressure drop and mixing length of a static mixer strongly depend on velocity and viscosity of the fluid. Carefully check the vendor's data using the following method. And pressure drop must be within the allowance.

(1) Number of element

Guideline to decide number of element is as follows: (see Technical Report [2])

$N_E = 4$	$Re \leq 10$
$= 3$	$10 < Re < 1,000$
$= 2$	$1,000 < Re < 2,000$
$= 1$	$2,000 \leq Re$

where N_E : number of element

Re : Reynolds number (-)

$$= \frac{D \cdot V \cdot \rho}{\mu}$$

D : inner diameter of pipe (m)

V : fluid velocity (m/sec)

ρ : fluid density (kg/m³)

μ : fluid viscosity (kg/m/sec) = $\times 0.001$ (C.P)

(2) Mixing length (L/D)

Mixing length is determined by a vendor, and a designer can roughly estimate the mixing length using , for instance, Figs. 3.2a, 3.2b.

(3) Pressure drop

Pressure drop is also calculated by a vendor based on its specific correlations.

However, the basic designer can check the submitted pressure drop values using Technical Report[2].

3.4 Injection

General relationship between Degree of Mixing and L/D for both (1)axisymmetrical injection and (2) Wall injection, are presented in Fig. 3.4. The guideline for the degree of mixing M of the vertical axis in Fig. 3.4 is as follows:

- $M = 0.85$ for static mixers upstream from temperature measurement sensors.
- $= 0.99$ for static mixers upstream from reactors.

3.4.1 Axisymmetric Injection

For axisymmetrical jet mixing, two modes of injection nozzle orientation exist as is shown in Figs. 3.4.1a and 3.4.1b. The definite criteria to select one of these two modes are not established so far. Since most literature deals with the mode shown in Fig. 3.4.1a, the design procedure described later is concerned with this mode. However, it should be noted that some JGC engineers have job experiences to adopt the method shown in Fig. 3.4.1b.

(1) Mixing Length

The basic engineer should take an appropriate value of L/D, taking account of a special value of D_j/D . Here D_j and D are inner diameters of an injection nozzle and a pipe, respectively. (See Figs. 3(a) to (b)).

The required mixing lengths were roughly 10 to 15 in terms of L/D according to the JGC experiments for $D_j/D = 0.24, 0.125$.