JAPAN STAINLESS STEEL ASSOCIATION

Nickel INSTITUTE

Piping Manual for Stainless Steel Pipes for Buildings

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Foreword

In the building equipment sector, stainless steel pipe, which offers high corrosion resistance and solid strength, is used for air-conditioning piping systems for fluids including steam, chilled and hot water and cooling water, as well as for sanitary piping systems, such as water supply and hot-water supply. Since 2006, stainless steel pipe has also been used in piping systems for fire fighting equipment.

The Japan Stainless Steel Association (JSSA) published the first edition of *Piping Manual for Stainless Steel Pipes for Buildings* in 1983 and revised editions in 1987 and 1997 to better cover the proper design and construction of stainless steel piping systems. During the next dozen years or so, construction techniques for stainless steel piping, including those for coupling stainless steel pipes, progressed remarkably, and substantial new information including information from construction experience is now available. The construction industry is also working to reduce the environmental load, including new trends focusing on long service life, ease of maintenance management and renewal, and promotion of recycling. Stainless steel pipe is being used more and more due to all the advantages presented.

Research has provided more and more data and possibilities including research on flow characteristics in stainless steel piping conducted by the Fire Equipment and Safety Center of Japan (FESC); standardization for manufacturing prefabricated units conducted by the Technical Committee of Construction and Maintenance of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan (SHASE); and a Housing and Building Advanced Technology Development Subsidy Project (fiscal 2007 to 2009) initiated by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), which is a titled "*Technical Development of Super Durable All-Stainless Steel Piping System*."

In light of these developments, the JSSA is publishing this third revised edition of the *Piping Manual for Stainless Steel Pipes for Buildings*. In preparing this revised edition, the JSSA focused on working closely with users and manufacturers to meet their needs, setting up the editorial supervision committee and organizing the writing team to substantially revise the manual. The writing team has incorporated many of the fruits of research from FESC, SHASE and MLIT. In particular, this revised edition features significant achievements from the abovementioned project subsidized by MLIT.

We hope this technical manual will be instrumental for designing and constructing stainless steel piping systems.

March 2011

Kyosuke Sakaue, Chairman
Editorial Supervision Committee on Piping Manual for Stainless Steel Pipes for Buildings
Japan Stainless Steel Association

This publication is an English translation based on the completely updated contents of the 2011 Japanese edition of the *Piping Manual for Stainless Steel Pipes for Buildings*. The original edition was prepared and published by the Japan Stainless Steel Association in March 2011.

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Note: The Reference Material Chapter is not included in this English translation. If necessary, referring to the original Japanese edition is recommended.

Contents

NOTE

JIS G3448 covers the main products discussed in this manual, which are called ***light gauge stainless steel tubes for ordinary piping***. However, they are frequently compared in the book with other similar products made of carbon steel, copper and other materials, most of which are called pipes. To make this manual easier to read, all the tubular products in this manual will be called pipe(s) except in the citations, and when used to mean part(s) of finished equipment.

THE BASICS 1

1 THE BASICS

1.1 Definition and Classification of Stainless Steel

1.1.1 Definition of stainless steel

When iron is alloyed with chromium (Cr), its corrosion mass in ordinary air decreases; when Cr content is increased to 11 to 12% or greater, corrosion resistance will markedly increase. In clean air, rusting is greatly reduced, which is why the alloy is called stainless steel. In the past, the alloy was called rust-free steel and rustless steel, but today the name stainless steel is almost always used. As the name indicates, this metal has outstanding corrosion resistance, compared with other ordinary steels. However, stainless steel requires proper use; otherwise it may rust under environment or use conditions. Stainless steel has no clear definition. In general, iron alloy containing 10.5% or more Cr may be called stainless steel. JIS defines that "stainless steel is alloy steel containing 10.5% or more Cr content and 1.2% or less carbon content, to improve corrosion resistance."

By its composition, stainless steel is classified into Cr and Cr-Ni types. The first stainless steel put into practical application was 12-13% Cr steel (in 1912, for edged tools), and about ten years later steel containing 18% Cr and 8% Ni appeared on the market. This 18 Cr-8 Ni steel has an austenitic structure and excellent corrosion resistance, workability and weldability.

The superior corrosion resistance of stainless steel is explained by its passivity. Metal elements such as iron, nickel and chromium exhibit passive characteristics. For example, one well-known phenomenon is that iron stops dissolving in concentrated nitric acid. Although the true nature of passivity is still unclear in many respects, a general description will be given in Subsection 1.2.3 under “Corrosion properties of stainless steel.”

Since appearing, the performance of stainless steel has been continuously improved including corrosion resistance, high temperature oxidation resistance, strength, formability, machinability and weldability. In line with this progress, JIS-defined stainless steel has increased in variety—the number of different types of stainless steels has now reached about 60. Austenitic stainless steels, which are superior in terms of corrosion resistance, are the greatest in number. In particular, SUS 304 and SUS 316 are today most widely used in product shapes including sheets, strips, pipes, and wire.

1.1.2 Classification of stainless steel

Stainless steels are classified broadly into Cr and Cr-Ni types, depending on the main alloy elements added. In terms of metallographic structure, stainless steels are classified as ferritic, martensitic or austenitic as indicated in Fig. 1.1-1. Some special stainless steels are classified as austenitic-ferritic (duplex) or precipitation hardening. Ferritic stainless steel is a class of Cr types often used for oxidation resistance at high temperatures. Martensitic stainless steel is also a Cr type. Its hardness and strength are improved into a martensitic structure through heat treatment. Austenitic-ferric stainless steel is biphasic with mixed austenitic and ferritic structure at room temperature. This stainless steel has high corrosion resistance in seawater and other environments. Precipitation hardening stainless steel is made when a small quantity of aluminum, copper or other elements are added and such element(s) precipitates into metallic compounds through heat treatment for hardening and higher strength. Table 1.1-1 lists, by metallographic structure, the main chemical compositions (except iron), characteristics and major applications of these typical stainless steels. Table 1.1-2 lists the JIS-based chemical composition of stainless steels.

There are four main types of stainless steel, SUS 304, SUS 316, SUS 315J1 and SUS 315J2, which are stipulated in JIS G 3448 : ***Light gauge stainless steel tubes for ordinary piping*** used for piping for construction equipment. Among these, SUS 304 is most commonly used. Since SUS 316, SUS 315J1 and SUS 315J2 have higher corrosion-resistance than SUS 304, they are used for piping in more corrosive environments where using SUS 304 raises concern about possible corrosion, as indicated in Table 1.1-3.

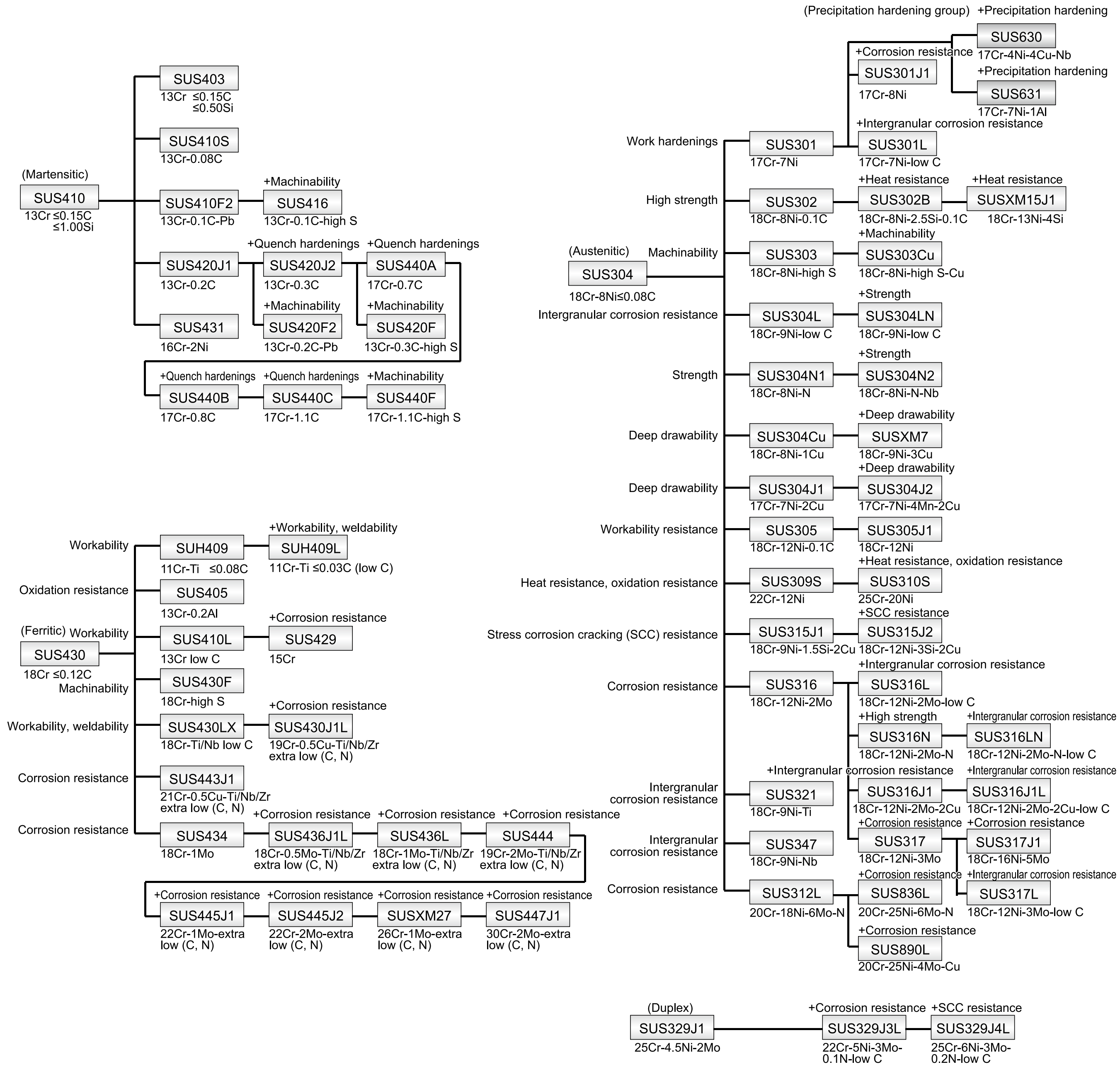


Fig. 1.1-1 Schematic Diagram of Stainless Steels[1]

Source: Japan Stainless Steel Association website

Table 1.1-1 Classification of stainless steel according to the metallographic structure[2]

Metallographic structure	Typical stainless steel	Main composition	Characteristic	Major application
Ferritic	SUS 430	18% Cr	Ferritic stainless steel of superior corrosion resistance for general purposes	Construction interiors, home appliances, etc.
	SUS 444	19% Cr - 2% Mo - Ti/Nb/Zr - low (C, N)	Stainless steel where C and N are substantially reduced and more Mo added than SUS 436L, to improve corrosion resistance. This stainless steel is used for components that require stress corrosion cracking resistance.	Water storage tanks, hot-water storage tanks, water heaters, food processing equipment, etc.
Martensitic	SUS 410	13% Cr	Martensitic stainless steel of excellent corrosion resistance and machinability for general purposes, in addition to hardenability	Knives, turbine blades, nozzles, brake nozzles, etc.
Austenitic	SUS 304	18% Cr - 8% Ni	Most typical austenitic stainless steel for general purposes that is also widely used as heat resistant steel.	Piping for building equipment. For food processing industry, petrochemical industry, vehicle components, building materials, nuclear power industry, etc.
	SUS 316	18% Cr - 12% Ni – 2.5% Mo	Steel where Mo is added to improve pitting corrosion resistance	
	SUS 315J1	18% Cr - 10% Ni -1 % Si - 2% Cu	Stainless steel where Si and Cu are added, while reducing Mo for SUS 316, to improve local corrosion resistance and stress corrosion cracking resistance	Piping for building equipment and for water supply, hot-water supply, drainage and cooling water, and other diverse types of water heaters
	SUS 315J2	18% Cr - 12% Ni - 3% Si - 2% Cu		
Austenitic- ferritic	SUS 329J4L	25% Cr - 6% Ni - 3% Mo - N	Austenitic and ferritic stainless steel of biphasic structure where Mo and N are added to low C and high Cr contents to distinguish pitting corrosion resistance and stress resistance	Salt production equipment, seawater desalination plants, exhaust gas desulfurization equipment, water storage tanks, hot-water storage tanks
Precipitation hardening	SUS 630	17% Cr - 4% Ni - 4% Cu - Nb	Martensitic stainless steel where Cu and Nb are added for precipitation hardening	Steel belts, springs, shafts, turbine components, etc.

Source: Stainless Steel Databook (Home Electric Appliances).

Table 1.1-3 Stainless Steels Used for Piping for Building Equipment[3]

Type code	Application (Reference)
SUS 304TPD	Piping for general water supply, hot-water supply, drainage, chilled and hot water, etc.
SUS 315J1TPD SUS 315J2TPD	Applications that require corrosion resistance stronger than that of SUS 304 in terms of water quality and the environment, and hot-water applications that require stress corrosion cracking resistance stronger than that of SUS 316
SUS 316TPD	Applications that require corrosion resistance stronger than that of SUS 304 in terms of water quality and the environment

Reference: JIS G 3448 (2004)

As to piping applications other than for building equipment, SUS 304L and SUS 316L are used in industrial plants. These stainless steels contain low carbon content to improve intergranular corrosion resistance during welding.

Table 1.1-2 Chemical composition of JIS stainless steels[4]

a. Chemical composition of austenitic stainless steels

JIS Grade	Chemical composition (%)									
	C	Si	Mn	P	S	Ni	Cr	Mo	Cu	N	Other
SUS 201	≤0.15	≤1.00	5.50 - 7.50	≤0.060	≤0.030	3.50 - 5.50	16.00 - 18.00	-	-	≤0.25	-
SUS 202	≤0.15	≤1.00	7.50 - 10.00	≤0.060	≤0.030	4.00 - 6.00	17.00 - 19.00	-	-	≤0.25	-
SUS 301	≤0.15	≤1.00	≤2.00	≤0.045	≤0.030	6.00 - 8.00	16.00 - 18.00	-	-	-	-
SUS 301L	≤0.030	≤1.00	≤2.00	≤0.045	≤0.030	6.00 - 8.00	16.00 - 18.00	-	-	≤0.20	-
SUS 302	≤0.15	≤1.00	≤2.00	≤0.045	≤0.030	8.00 - 10.00	17.00 - 19.00	-	-	-	-
SUS 302B	≤0.15	≤2.00	≤2.00	≤0.045	≤0.030	8.00 - 10.00	17.00 - 19.00	-	-	-	-
SUS 303	≤0.15	≤1.00	≤2.00	≤0.20	≥0.15	8.00 - 10.00	17.00 - 19.00	(1)	-	-	-
SUS 303Se	≤0.15	≤1.00	≤2.00	≤0.20	≤0.060	8.00 - 10.00	17.00 - 19.00	-	-	-	Se ≥ 0.15
SUS 304	≤0.08	≤1.00	≤2.00	≤0.045	≤0.030	8.00 - 10.50	18.00 - 20.00	-	-	-	-
SUS 304L	≤0.030	≤1.00	≤2.00	≤0.045	≤0.030	9.00 - 13.00	18.00 - 20.00	-	-	-	-
SUS 304N1	≤0.08	≤1.00	≤2.50	≤0.045	≤0.030	7.00 - 10.50	18.00 - 20.00	-	-	0.10 - 0.25	-
SUS 304N2	≤0.08	≤1.00	≤2.50	≤0.045	≤0.030	7.50 - 10.50	18.00 - 20.00	-	-	0.15 - 0.30	Nb ≤ 0.15
SUS 304LN	≤0.030	≤1.00	≤2.00	≤0.045	≤0.030	8.50 - 11.50	17.00 - 19.00	-	-	0.12 - 0.22	-
SUS 304J1	≤0.08	≤1.70	≤3.00	≤0.045	≤0.030	6.00 - 9.00	15.00 - 18.00	-	1.00 - 3.00	-	-
SUS 304J2	≤0.08	≤1.70	3.00 - 5.00	≤0.045	≤0.030	6.00 - 9.00	15.00 - 18.00	-	1.00 - 3.00	-	-
SUS 304J3	≤0.08	≤1.00	≤2.00	≤0.045	≤0.030	8.00 - 10.50	17.00 - 19.00	-	1.00 - 3.00	-	-
SUS 305	≤0.12	≤1.00	≤2.00	≤0.045	≤0.030	10.50- 13.00	17.00 - 19.00	-	-	-	-
SUS 309S	≤0.08	≤1.00	≤2.00	≤0.045	≤0.030	12.00 - 15.00	22.00 - 24.00	-	-	-	-
SUS 310S	≤0.08	≤1.50	≤2.00	≤0.045	≤0.030	19.00 - 22.00	24.00 - 26.00	-	-	-	-
SUS 315J1	≤0.08	0.50 - 2.50	≤2.00	≤0.045	≤0.030	8.50 - 11.50	17.00 - 20.50	0.50 - 1.50	0.50 - 3.50		
SUS 315J2	≤0.08	2.50 - 4.00	≤2.00	≤0.045	≤0.030	11.00 - 14.00	17.00 - 20.50	0.50 - 1.50	0.50 - 3.50		
SUS 316	≤0.08	≤1.00	≤2.00	≤0.045	≤0.030	10.00 - 14.00	16.00 - 18.00	2.00 - 3.00	-	-	-
SUS 316L	≤0.030	≤1.00	≤2.00	≤0.045	≤0.030	12.00 - 15.00	16.00 - 18.00	2.00 - 3.00	-	-	-
SUS 316N	≤0.08	≤1.00	≤2.00	≤0.045	≤0.030	10.00 - 14.00	16.00 - 18.00	2.00 - 3.00	-	0.10 - 0.22	-
SUS 316LN	≤0.030	≤1.00	≤2.00	≤0.045	≤0.030	10.50 - 14.50	16.50 - 18.50	2.00 - 3.00	-	0.12 - 0.22	-

(Continued)

SUS 316Ti	≤0.08	≤1.00	≤2.00	≤0.045	≤0.030	10.00 - 14.00	16.00 - 18.00	2.00 - 3.00	-	-	Ti ≥ 5 × C%
SUS 316J1	≤0.08	≤1.00	≤2.00	≤0.045	≤0.030	10.00 - 14.00	17.00 - 19.00	1.20 - 2.75	1.00 - 2.50	-	-
SUS 316J1L	≤0.030	≤1.00	≤2.00	≤0.045	≤0.030	12.00 - 16.00	17.00 - 19.00	1.20 - 2.75	1.00 - 2.50	-	-
SUS 317	≤0.08	≤1.00	≤2.00	≤0.045	≤0.030	11.00 - 15.00	18.00 - 20.00	3.00 - 4.00	-	-	-
SUS 317L	≤0.030	≤1.00	≤2.00	≤0.045	≤0.030	11.00 - 15.00	18.00 - 20.00	3.00 - 4.00	-	-	-
SUS 317LN	≤0.030	≤1.00	≤2.00	≤0.045	≤0.030	11.00 - 15.00	18.00 - 20.00	3.00 - 4.00	-	0.10 - 0.22	-
SUS 317J2	≤0.06	≤1.50	≤2.00	≤0.045	≤0.030	12.00 - 16.00	23.00 - 26.00	0.50 - 1.20	-	0.25 - 0.40	-
SUS 836L	≤0.030	≤1.00	≤2.00	≤0.045	≤0.030	24.00 - 26.00	19.00 - 24.00	5.00 - 7.00	-	≤0.25	-
SUS 890L	≤0.020	≤1.00	≤2.00	≤0.045	≤0.030	23.00 - 28.00	19.00 - 23.00	4.00 - 5.00	1.00 - 2.00	-	-
SUS 321	≤0.08	≤1.00	≤2.00	≤0.045	≤0.030	9.00 - 13.00	17.00 - 19.00	-	-	-	Ti ≥ 5×C%
SUS 347	≤0.08	≤1.00	≤2.00	≤0.045	≤0.030	9.00 - 13.00	17.00 - 19.00	-	-	-	Nb≥ 10×C%
SUS XM7	≤0.08	≤1.00	≤2.00	≤0.045	≤0.030	8.50 - 10.50	17.00 - 19.00	-	3.00 - 4.00	-	-
SUS XM15J1	≤0.08	3.00 - 5.00	≤2.00	≤0.045	≤0.030	11.50 - 15.00	15.00 - 20.00	-	-	-	-

(1) Up to 0.60% Mo may be contained.

Reference: JIS G 4303 (2005), G 4308 (1998), G 4304 (2010) and G 4305 (2010)

b. Chemical composition of austenitic-ferritic stainless steels

JIS Grade	Chemical composition (%)								
	C	Si	Mn	P	S	Ni	Cr	Mo	N
SUS 329J1	≤0.08	≤1.00	≤1.50	≤0.040	≤0.030	3.00 - 6.00	23.00 - 28.00	1.00 - 3.00	-
SUS 329J3L	≤0.030	≤1.00	≤2.00	≤0.040	≤0.030	4.50 - 6.50	21.00 - 24.00	2.50 - 3.50	0.08 - 0.20
SUS 329J4L	≤0.030	≤1.00	≤1.50	≤0.040	≤0.030	5.50 - 7.50	24.00 - 26.00	2.50 - 3.50	0.08 - 0.30

In addition to elements in the JIS grades mentioned above, one or more elements of Cu, W and N may be contained, as needed.

c. Chemical composition of ferritic stainless steels

JIS Grade	Chemical composition (%)								
	C	Si	Mn	P	S	Cr	Mo	N	Other
SUS 405	≤0.08	≤1.00	≤1.00	≤0.040	≤0.030	11.50 - 14.50	-	-	Al 0.10 - 0.30
SUS 410L	≤0.030	≤1.00	≤1.00	≤0.040	≤0.030	11.00 - 13.50	-	-	-
SUS 429	≤0.12	≤1.00	≤1.00	≤0.040	≤0.030	14.00 - 16.00	-	-	-
SUS 430	≤0.12	≤0.75	≤1.00	≤0.040	≤0.030	16.00 - 18.00	-	-	-
SUS 430F	≤0.12	≤1.00	≤1.25	≤0.060	≥0.15	16.00 - 18.00	(2)	-	-
SUS 430LX	≤0.030	≤0.75	≤1.00	≤0.040	≤0.030	16.00 - 19.00	-	-	Ti or Nb 0.10 - 1.00
SUS 430J1L	≤0.025	≤1.00	≤1.00	≤0.040	≤0.030	16.00 - 20.00	-	≤0.025	Ti, Nb, Zr or combination thereof, 8×(C%+Ni%)-0.80 Cu 0.30-0.80
SUS 434	≤0.12	≤1.00	≤1.00	≤0.040	≤0.030	16.00 - 18.00	0.75 - 1.25	-	-
SUS 436L	≤0.025	≤1.00	≤1.00	≤0.040	≤0.030	16.00 - 19.00	0.75 - 1.50	≤0.025	Ti, Nb, Zr or combination thereof, 8×(C%+Ni%)-0.80
SUS 436J1L	≤0.025	≤1.00	≤1.00	≤0.040	≤0.030	17.00 - 20.00	0.40 - 0.80	≤0.025	Ti, Nb, Zr or combination thereof, 8×(C%+Ni%)-0.80
SUS 444	≤0.025	≤1.00	≤1.00	≤0.040	≤0.030	17.00 - 20.00	1.75 - 2.50	≤0.025	Ti, Nb, Zr or combination thereof, 8×(C%+Ni%)-0.80
SUS 447J1	≤0.010	≤0.040	≤0.40	≤0.030	≤0.020	28.50 - 32.00	1.50 - 2.50	≤0.015	-
SUS XM27	≤0.010	≤0.040	≤0.40	≤0.030	≤0.020	25.00 - 27.50	0.75 - 1.50	≤0.015	-

(2)Up to 0.60% Mo may be contained.

1. Types other than SUS 447J1 and SUS XM27 may contain up to 0.60% Ni.
2. SUS 447J1 and SUS XM27 may contain up to 0.50% Ni, up to 0.20% Cu and up to 0.50% (Ni+Cu)
   In addition to elements in the JIS grades mentioned above, one or more elements of V, Ti or Nb may be contained.
3. SUS 430J1L may contain V other than listed above as needed.

d. Chemical composition of martensitic stainless steels

JIS Grade	Chemical composition (%)								
	C	Si	Mn	P	S	Ni	Cr	Mo	Pb
SUS 403	≤0.15	≤0.50	≤1.00	≤0.040	≤0.030	(3)	11.50 - 13.00	-	
SUS 410	≤0.15	≤1.00	≤1.00	≤0.040	≤0.030	(3)	11.50 - 13.50	-	
SUS 410S	≤0.08	≤1.00	≤1.00	≤0.040	≤0.030	(3)	11.50 - 13.50	-	
SUS 410J1	0.08 - 0.18	≤0.60	≤1.00	≤0.040	≤0.030	(3)	11.50 - 14.00	0.30 - 0.60	
SUS 410F2	≤0.15	≤1.00	≤1.00	≤0.040	≤0.030	(3)	11.50 - 13.50	(4)	0.05 - 0.30
SUS 416	≤0.15	≤1.00	≤1.25	≤0.060	≥0.15	(3)	12.00 - 14.00	(4)	
SUS 420J1	0.16 - 0.25	≤1.00	≤1.00	≤0.040	≤0.030	(3)	12.00 - 14.00	-	
SUS 420J2	0.26 - 0.40	≤1.00	≤1.00	≤0.040	≤0.030	(3)	12.00 - 14.00	-	
SUS 420F	0.26 - 0.40	≤1.00	≤1.25	≤0.060	≥0.15	(3)	12.00 - 14.00	(4)	
SUS 420F2	0.26 - 0.40	≤1.00	≤1.00	≤0.040	≤0.030	(3)	12.00 - 14.00	-	0.05 - 0.30
SUS 431	≤0.20	≤1.00	≤1.00	≤0.040	≤0.030	1.25 - 2.50	15.00 - 17.00	-	
SUS 440A	0.60 - 0.75	≤1.00	≤1.00	≤0.040	≤0.030	(3)	16.00 - 18.00	(5)	
SUS 440B	0.75 - 0.95	≤1.00	≤1.00	≤0.040	≤0.030	(3)	16.00 - 18.00	(5)	
SUS 440C	0.95 - 1.20	≤1.00	≤1.00	≤0.040	≤0.030	(3)	16.00 - 18.00	(5)	
SUS 440F	0.95 - 1.20	≤1.00	≤1.25	≤0.060	≥0.15	(3)	16.00 - 18.00	(5)	

(3) Up to 0.60% Ni may be contained.

(4) Up to 0.60% Mo may be contained.

(5) Up to 0.75% Mo may be contained.

e. Chemical composition of precipitation hardening stainless steels

JIS Grade	Chemical composition (%)								
	C	Si	Mn	P	S	Ni	Cr	Cu	Other
SUS 630	≤0.07	≤1.00	≤1.00	≤0.040	≤0.030	3.00 - 5.00	15.00 - 17.50	3.00 - 5.00	Nb 0.15 - 0.45
SUS 631	≤0.09	≤1.00	≤1.00	≤0.040	≤0.030	6.50 - 7.75	16.00 - 18.00	-	Al 0.75 - 1.50

1.2 Properties of Stainless Steel

1.2.1 Physical properties of stainless steel

Table 1.2-1 compares the physical properties between typical stainless steels and other materials. Comparing with the physical properties of carbon steels, austenitic stainless steels used for piping in buildings have higher thermal expansion coefficients, lower thermal conductivity, higher electrical resistivity and are usually nonmagnetic. These properties are very important in work involving heat and electricity, such as welding. Because they have lower longitudinal modulus of elasticity (Young's Modulus) than carbon steels, they tend to have greater deflection than carbon steels under the same load.

1.2.2 Mechanical properties of stainless steel

Table 1.2-2 compares the mechanical properties between typical stainless steels and other materials including tensile strength, proof stress (0.2%), elongation and hardness.

Austenitic stainless steels used to make stainless steel pipe for ordinary piping have high strength over a wide range of low to high temperatures and excellent ductility. Because the crystalline structure is a face-centered cubic lattice, even if the material is under a tensile load, none of the clear breakdown phenomenon occurs that is seen in the stress-strain curve of carbon steels (see Figures 1.2-1 and 1.2-2). Therefore, for stainless steels the stress value that corresponds to the yield point is usually defined as the stress at which 0.2% of permanent strain remains when the load is removed. This value is the proof stress. The proof stresses of austenitic stainless steels are lower than those of ferritic stainless steels; the proof stress/tensile strength ratios are low as well at 40-50%. These, along with their high elongation values, demonstrate that austenite stainless steels are easy to work with.

SUS 304, SUS 316 and other austenitic stainless steels have a fully austenitic structure in the solution treated state, but as their structure is on the borders of the austenite range, they are unstable. For example, when they are cold-worked, a structure called work-induced martensite occurs and hardens the material. This property, called work hardening, is effective for hardening austenitic stainless steels that cannot be hardened by heat treatment and is utilized to produce materials such as for springs.

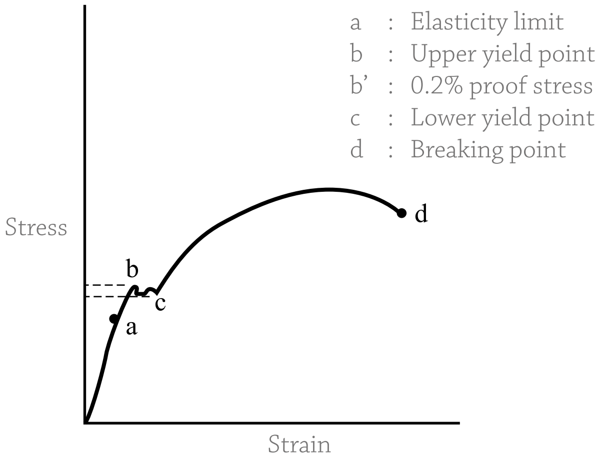


Fig.1.2-1 Stress-strain curve of carbon steel[5]

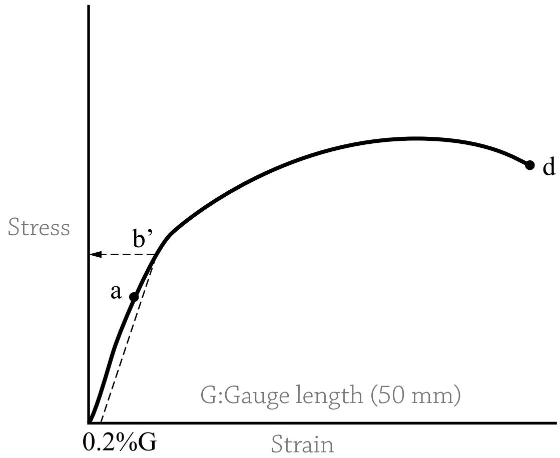


Fig.1.2-2 Stress-strain curve of stainless steel[5]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

Table 1.2-1 Physical properties of stainless steels and other materials[6]

Material \ Property	Basic mass g/cm³	Coefficient of thermal expansion 0 - 100°C × 10^{-6}/K	Thermal conductivity 20 - 100°C W/m·K	Specific heat 0 - 100°C J/g·K	Electrical resistivity R.T μΩ·cm	Modulus of longitudinal elasticity N/mm²	Magnetism
SUS 410	7.75	9.9	24.9	0.47	57	205,000	Yes
SUS 430	7.75	10.4	26.4	0.46	60	200,000	Yes
SUS 444	7.75	10.4	25.9	0.46	60	200,600	Yes
SUS 304	7.93	17.3	16.3	0.50	72	193,000	No
SUS 316	7.98	16.0	16.3	0.50	74	193,000	No
SUS 315J1 *1 SUS 315J2 *1	7.98	16.0	17.0	0.50	74	193,000	No No
SUS 630	7.78	10.8	16.3	0.46	98	192,000	Yes
SUS 329J4L	7.80	12.8 *2	21.0	0.50	75	190,000	Yes
Carbon steel	7.87	12.6	74.6	0.48	13	200,600	Yes
Copper	8.90	16.8	389.1	0.38	1.7	129,000	No
Aluminum	2.71	23.6	221.8	0.98	3.0	70,000	No
Titanium	4.51	8.9	17.1	0.52	55	106,000	No
PVC	1.43	60 - 70	0.20 - 0.21	0.85 - 1.17	3 - 5 × 10^9	3,334	No

*1: Indicates an example of physical properties.

*2: 0 – 650 °C

Source: Stainless Steel Databook (Home Electric Appliances) and Technical Document on Unplasticized Vinyl Chloride Pipes for Waterworks (Standard and Design Volume)

Table 1.2-2 Mechanical properties of stainless steels and other materials[6]

Properties / Material	State	Tensile strength N/mm²	Proof stress (0.2%) N/mm²	Elongation %	Hardness HRB	
SUS 410	Annealed	≥440	≥205	≥20	≤93	
SUS 430	Annealed	≥450	≥205	≥22	≤88	
SUS 444	Annealed	≥410	≥245	≥20	≤96	
SUS 304	Solid solution	≥520	≥205	≥40	≤90	
SUS 316	Solid solution	≥520	≥205	≥40	≤90	
SUS 315J1	Solid solution	≥520	≥205	≥40	≤90	
SUS 315J2	Solid solution	≥520	≥205	≥40	≤90	
SUS 630	H1075	≥1,000	≥860	≥5 *1	≤31 *2	
SUS 329J4L	Solid solution	≥620	≥450	≥18	≤32 *2	
Carbon steel	Annealed	433	231	41	132 *3	Measured value
Copper	Soft	225	70	45	50	Measured value
Aluminum	Industrial purity	90	40	35	23	Measured value
Titanium	Industrial purity	392	274	42	130	Measured value
PVC	Soft	52	-	-	70 - 90	

*1. Less than 5 mm thickness

*2. HRC

*3. HV equivalent

Source: Stainless Steel Databook (Home Electric Appliance Volume) and Technical Document on Unplasticized Vinyl Chloride Pipes for Waterworks (Standard and Design Volume)

1.2.3 Corrosion properties of stainless steel

The corrosion resistance of stainless steel is attributed to its passivity. Strictly defining passivity is quite complicated. Here it is defined very generally as the phenomenon noted as a thin, stable oxide film is formed on the surface of a metal or alloy that is highly active and easily forms oxides from reacting with oxygen, making the metal unreactive with the environment and improving its corrosion resistance.

As shown in Fig. 1.2-3, the surface of stainless steel is coated with a thin, fine-grained oxide film (passive film) that immediately reacts with oxygen in the environment and repairs itself when scratched or otherwise damaged. This film existing has been confirmed in experiments, along with measurements of its thickness, and the composition of its oxides has been confirmed through precise analyses.

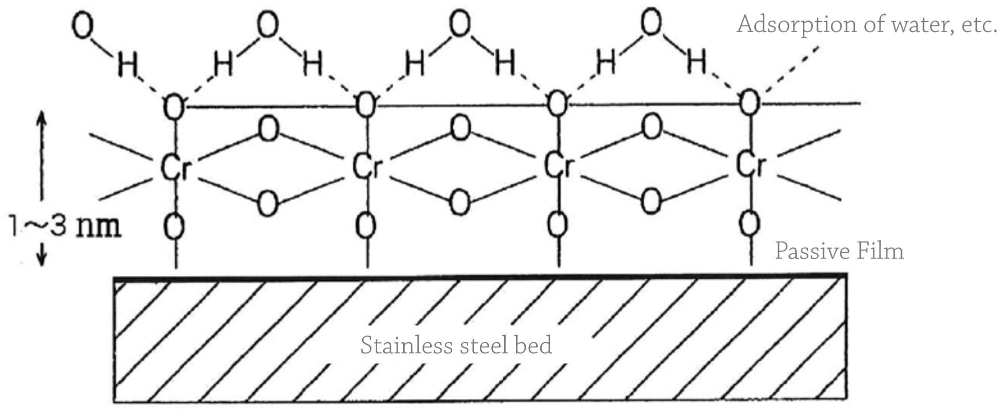


Fig. 1.2-3 Stainless steel passive film model[7]

Source: Stainless Steel Databook (Home Electric Appliances)

1.3 Corrosion of Stainless Steel

The superior corrosion resistance of stainless steel is attributed to its passivity. Still, the passive film on stainless steel can be locally damaged by chloride and bromide ions in aqueous solutions, especially chloride ions present in great quantities in the earth, which leads to local corrosion such as pitting corrosion, crevice corrosion and stress corrosion cracking.

1.3.1 Pitting corrosion

When the surface of stainless steel is in contact with an aqueous solution that includes chloride ions and oxidizing agents such as oxygen, pitting corrosion as shown in Fig. 1.3-1 may occur, depending on the concentration, temperature and flow velocity. Fine pits often occur on the surface of stainless steel exposed to the atmosphere in coastal regions due to the deposition of airborne salt particles and the presence of water. According to the local cell theory of corrosion, pits form anodes; the following anode dissolution reactions occur:

$$Fe \rightarrow Fe^{2+} + 2e$$
$$Cr \rightarrow Cr^{3+} + 3e$$
$$Ni \rightarrow Ni^{2+} + 2e$$

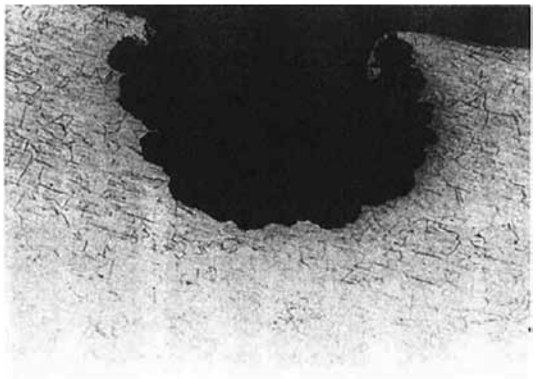


Fig. 1.3-1 Pitting corrosion in SUS 304

Courtesy of: Nippon Metal Industry Co., Ltd.

The area around an anode is a cathode, and a cathode reduction reaction of the oxygen in solution can occur.

$$1/2O_2 + H_2O + 2e \rightarrow 2OH^-$$

The explanation for the effect of the chloride ions is that they replace the oxygen in the film (oxides) at the defect areas of the passive film, thereby promoting the destruction of the film.

The progress of the above anode dissolution reactions requires cathode reactions associated with consuming the same number of electrons (e), and thus oxidizing agents such as oxygen are needed for pitting to proceed. Corrosion develops as anode and cathode reactions advance simultaneously. (See Fig. 1.3-2). For example, in the ferric chloride solution used as a pitting testing solution, the ferric ions constitute the oxidizing agent and are cathodically reduced.

$$Fe^{3+} + e \rightarrow Fe^{2+}$$

Electrochemically, the pitting potential Vc of stainless steel is important. This value varies depending on the stainless steel type and the environment, and is useful for comparing the pitting resistance of stainless steels. Vc is higher with higher chromium and molybdenum content of the stainless steel, lower chloride ion concentration in the solution and lower temperature.

How fast the liquid flows is an important environmental factor. In general, the faster the flow, the less pitting. Pitting is prone to occur where the flow stagnates, which is explained as related with how easily oxygen is supplied to the passive film.

One obvious way to prevent pitting is to select a stainless steel type with high chromium and molybdenum content (e.g. *SUS316*, *SUS317*, and *SUS329J4L*). Other very effective methods are lowering the buildup of chloride ions in the environment, watching the flow and eliminating areas where the liquid stagnates, and applying cathodic protection so that the potential of the stainless steel falls below Vc. (For example, measures for preventing stainless steel-made hot-water tanks from corrosion include cathodic protection of the external power supply system or galvanic anode system.)

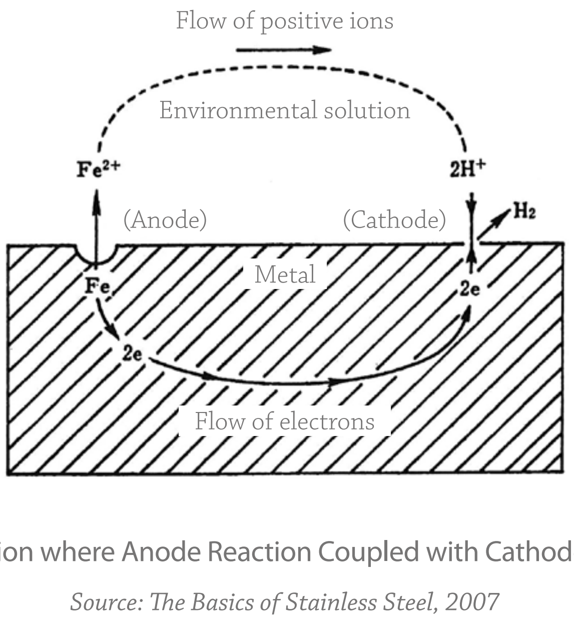


Fig. 1.3-2 Rust Reaction where Anode Reaction Coupled with Cathode Reaction Develops

Source: The Basics of Stainless Steel, 2007

1.3.2 Stress corrosion cracking

Stress corrosion cracking is a phenomenon caused jointly by tensile stress and a corrosive medium. This phenomenon is specific to austenitic stainless steel and only occurs with both tensile stress and a corrosive environment. Since the specific environment for stainless steel is chloride ion, JIS stipulates the methods for testing stress corrosion cracking resistance of stainless steel in two types of solution: 42% magnesium chloride and 30% calcium chloride.

In practice, stress corrosion cracking often occurs under concentration from heating, such as at the gas-liquid interface, even when the chloride ion concentration is at the very low level of pure water. Stress corrosion cracking in stainless steel tubes causes many of the often reported cases of cooling water leakage in nuclear power plants.

Two kinds of stress corrosion cracking of stainless steel exist. One is transgranular cracking not related to sensitization of the grain boundaries (Fig. 1.3-3) and the other is intergranular cracking related to such sensitization. Since the latter can be solved by avoiding sensitization, in general transgranular cracking is harder to handle.

Stress relief annealing (SR treatment) reduces the level of stress on stainless steel. This method for reducing the risk of stress corrosion cracking is important as a practical preventive measure, and many experimental results have been reported. Air-cooling treatment at 870°C for 1/2 hour is often cited. Reducing tensile stress of an industrial product to a negligible level is very difficult.

Stress corrosion cracking requires tensile stress and does not occur with compressive stress. One method for preventing this kind of cracking is to make stainless steel products so that some compression stress remains in their surface, such as by shot-peening. The effectiveness of this technique has been reported.

Many experimental reports exist on preventive measures with cathodic protection. However, the limit potential below which cracking does not occur is a variable value because it is affected by the stress level and other environmental conditions of the test.

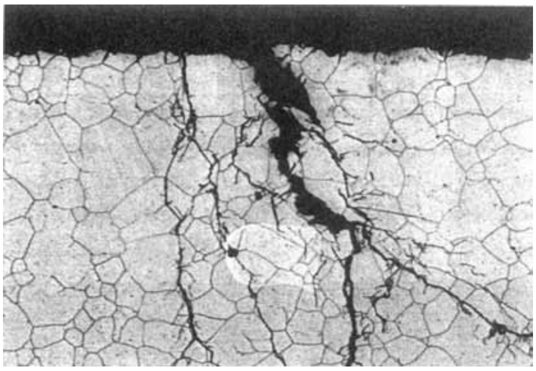


Fig. 1.3-3 Stress corrosion cracking in SUS 304

Courtesy of : Nippon Metal Industry Co., Ltd.

1.3.3 Crevice corrosion

The crevice corrosion pictured in Fig. 1.3-4 occurs on the surface of stainless steel located inside crevices when a metal or nonmetal piece is attached tightly to the surface of the stainless steel, leaving a gap, and the object is immersed in an aqueous solution containing chloride ions such as seawater.

The corrosion cause in this case is similar to that which causes pitting: defect areas in the passive film on the surface of the stainless steel located within the crevice act as an anode and the part outside the crevice acts as a cathode. Crevice corrosion proceeds. The factors associated with the occurrence and growth of this corrosion are also similar to those for pitting. Chloride ion concentration, oxidizing agent concentration and the temperature are important environmental factors, while chromium and molybdenum are important as alloy components.

Crevice corrosion in general occurs and grows more easily than pitting corrosion because oxygen from outside is unable to reach and diffuse the anodic site in the crevice, hindering the repair of the passive film. Simultaneously, diffusing corrosive products to the outside is prevented; the hydrogen ions produced by hydrolysis of the metallic ion build up significantly. This lowers the pH inside the crevices, making it difficult for the anode to become passivated again.

The repassivation potential E_R is electrochemically defined as the reproducible characteristic potential. Crevice corrosion that has occurred and begun to grow is rendered passive again; crevice corrosion can be prevented by maintaining a potential less than E_R. This process is cathodic protection against crevice corrosion. Many precedents demonstrate the successful application of cathodic protection against crevice corrosion using sacrificial anodes.

A typical case in which crevice corrosion occurs is the combination of a stainless steel flange and an asbestos gasket. The problem is the salt content in the asbestos gasket. Thus, non-asbestos sheets are used now, replacing asbestos gaskets, to prevent corrosion. Gaskets covered with polytetrafluoroethylene (PTFE) sheet are now used

Fig. 1.3-4 Crevice corrosion in SUS 316L

Courtesy of: Nippon Metal Industry Co., Ltd.

1.3.4 Intergranular corrosion

Selective corrosion near the boundary of grains in metal is called intergranular corrosion. Austenitic stainless steel is a typical metal susceptible to such corrosion. When heated to 550° - 800°C, chromium carbide ($Cr_{23}C_6$) may precipitate on the grain boundaries, creating thereby a low-chromium region that is selectively corroded. This heat treatment is called sensitization. During the welding or brazing process, a sensitized zone is created in a narrow band adjacent to the joint.

Figure 1.3-5 shows chromium carbide precipitated into SUS 304 intercrystalline. If the chromium carbide remains exposed to a corrosive environment, the intercrystalline will decay as indicated in Fig. 1.3-6, resulting in weaker material.

Intergranular corrosion in stainless steel is linked with the amount of carbon available for the precipitation of chromium carbide on the grain boundary. This has prompted the development and wide use of stainless steel grades having an L at the end of their designations, such as SUS 304L and 316L, in which the carbon content is limited to no more than 0.030%, or SUS 321 (18%Cr-9%Ni-Ti) and 347 (18% Cr-9% Ni-Nb), in which a small amount of niobium or titanium is added so that carbon will combine to form niobium carbide or titanium carbide rather than chromium carbide.

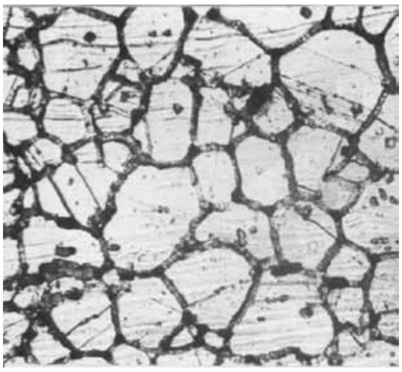


Fig. 1.3-5 Chromium carbide precipitated into SUS 304 intercrystalline

Courtesy of: Nisshin Steel Co., Ltd.

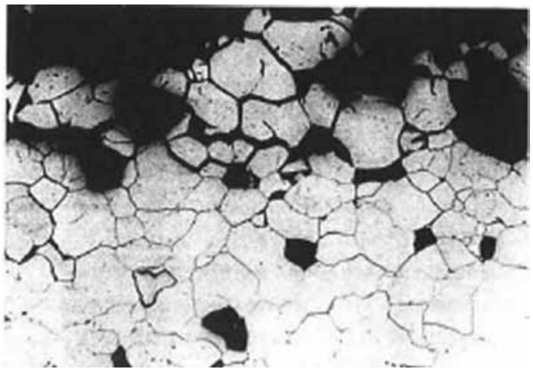


Fig. 1.3-6 Intergranular corrosion in SUS 304

Courtesy of: Nippon Metal Industry Co., Ltd.

1.3.5 Bimetallic corrosion (Galvanic corrosion)

When a metal is steeped in an electrolyte solution such as water, the metal indicates its specific natural potential. When different metals are steeped in the same electrolyte solution, these metals indicate different self-potentials. When two metals are connected with each other in an electrolyte solution, electric current passes through the contact surface from the metal of a higher natural potential (noble) to the metal of a lower natural potential (base). The electric current in the solution passes from the metal of the lower natural potential to the metal of the higher natural potential, thus forming an electric circuit (cell). The base metal of the lower natural potential turns into metallic ions and begins to be dissolved and corroded in the solution. This phenomenon is called bimetallic corrosion, which is galvanic corrosion.

Table 1.3-1 lists galvanic series of different metals with different natural potentials in seawater. Stainless steel and copper are classified into a group of noble metals with a relatively high electric potential, while steel (iron) and zinc are classified into a group of base metals. When stainless steel contacts with a base metal, such as carbon steel in electrolyte solution, galvanic current occurs because of the large difference between their electric potentials. The carbon steel begins to corrode.

When stainless steel is connected with a dissimilar metal with an electric potential that has a small difference from that of stainless steel, these metals may be connected directly. However, when two metals have a large difference in their electric potentials, they must be electrically insulated from each other to prevent galvanic corrosion. As to the acceptability of direct connections between stainless steel pipe and dissimilar metal pipe, refer to 3.6, "Joints with Other Kinds of Pipe" in this manual.

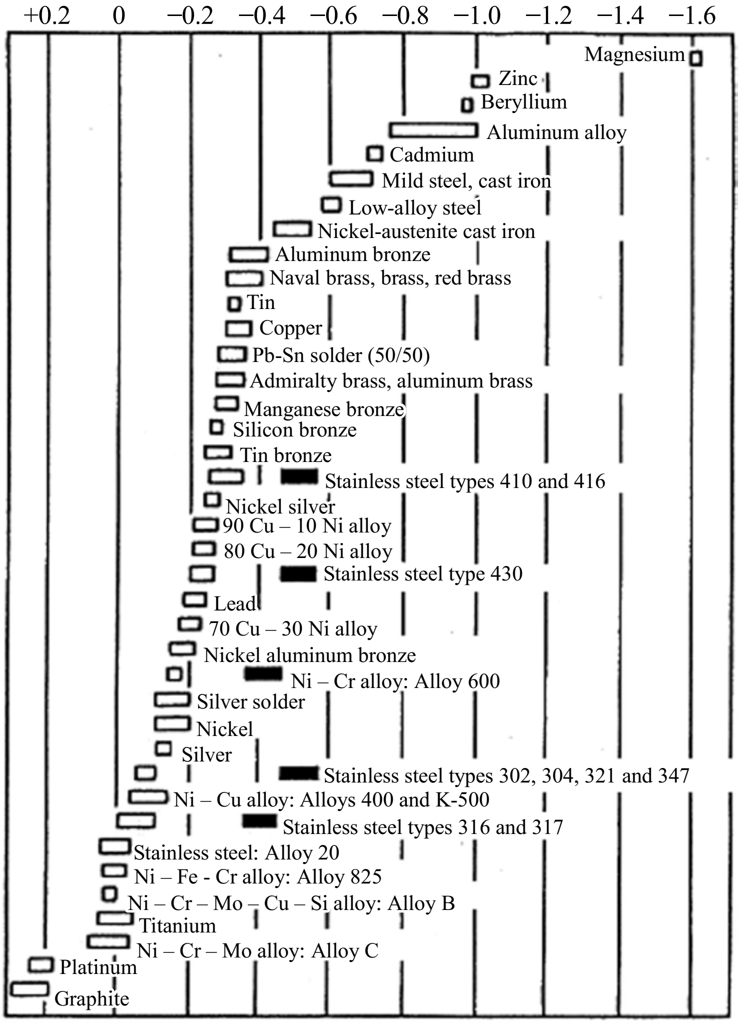
1.3.6 Erosion-corrosion

Erosion is a process where part of a material surface collides with a fluid, is mechanically damaged and wears away. Such damage is observed in multi-phase flows that contain solid particles. The phenomenon of erosion to which corrosion is added is referred to as erosion-corrosion.

Stainless steel, unlike soft metals such as copper alloys, is highly tolerant of erosion and is therefore considered relatively resistant to erosion-corrosion. This phenomenon does not occur in the general construction sector. However, parts such as pumps or mixing vessel impellers and valve seats that contact with fluids flowing at high speeds and are exposed to chlorine ions, sulfides, sand-like particles or a low pH environment suffer considerable damage. Typical corrosive environments include pipe fluid from a geothermal power plant well and slurry in a coal liquefaction plant.

Table 1.3-1 Galvanic series in seawater[9]

Electric potential (V vs. SCE)



1. Measurement condition: Flow rate: 24 to 40m/s Temperature: 10° to 27°C

2. ▬ : Electric potential when the metal has local corrosion (electric potential in active state)

Source: Stainless Steel Handbook, Third Edition

1.4 Fatigue Failure

Metallic materials may normally fail when subject to repeated stress far lower than their static strength. This phenomenon is called fatigue failure, or fatigue, of the material.

Ductile fracture occurs when a material receives stress greater than its strength, accompanying plastic deformation. Fatigue failure may occur even when a material receives stress far lower than its strength, without plastic deformation. Fatigue failure is subdivided into cracking occurring and development processes. When a material receives repeated stress, slipping occurs; slipping points spread the cracking and result in unstable fractures. While ductile fractures form numerous hollows called dimples in the fractured surface, fatigue failure is characterized by the formation of a striped pattern called striation. (Refer to Figs. 1.4-1 and 1.4-2.)

One type of fatigue failure that causes a problem in stainless steel piping on rare occasions is thermal fatigue. Compared with carbon steel, austenitic stainless steel grades, such as SUS 304 used for building equipment piping, have a large linear expansion coefficient. When stainless steel pipes are used to construct hot-water supply piping, the piping system will receive heat stress. Repeated changes in heating and cooling induced by hot-water supply over a long period of time lead to expansions and contractions due to the difference between thermal expansions, which could cause failure in the piping coupling areas. Therefore, measures against thermal fatigue due to heat stress load are important for stainless steel pipes for ordinary piping that have a large value of thermal expansion and contraction. For measures to control piping expansion and contraction, refer to 2.7, Measures for Controlling Expansion and Contraction, of the Design section.

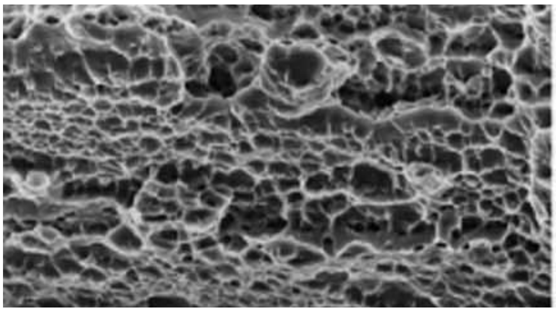


Fig. 1.4-1 Dimples formed by ductile fracture

Courtesy of: Nisshin Steel Co., Ltd.

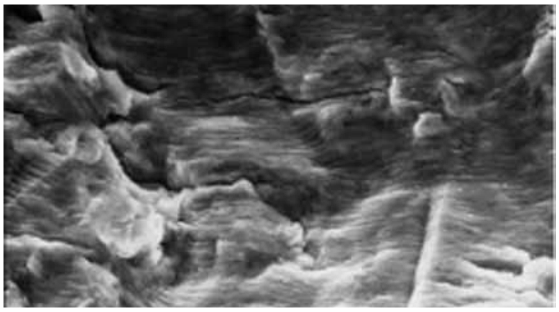


Fig. 1.4-2 Striation formed by fatigue failure

Courtesy of: Nisshin Steel Co., Ltd.

1.5 Comparison with Other Pipe Materials

Stainless steel pipe has outstanding corrosion resistance and mechanical properties, compared with carbon steel pipe and copper pipe. Stainless steel pipe is unlikely to clog due to rust deposits inside. Due to its strength, stainless steel pipe can be thinner and consequently lighter.

1.5.1 Dimensions and weight

Table 1.5-1 lists the dimensions and weights of stainless steel pipes for ordinary piping and of other pipe materials. The outside diameters of stainless steel pipes are the same as for copper pipes up to a nominal diameter of 25 Su (28.58 mm). Stainless steel pipes in the beginning were developed for copper pipe couplings used for hot-water supply. The outside diameters of stainless steel pipes have been made identical with those of copper pipes for 25 Su or less in accordance with ASTM B88 (*copper pipes for waterworks*), assuming that copper pipe couplings can be used for stainless steel pipes as well by brazing and soldering. Pipe diameters of 30 Su (34.0 mm) or greater are difficult to join by such processes. Copper pipe couplings are also expensive. Thus, the outside diameters of the pipes have been made the same as those of carbon steel pipes for ordinary piping, to which other joining and coupling methods may be applied. Stainless steel pipes weigh almost the same as copper pipes and are lighter than carbon steel pipes for ordinary piping, small-diameter pipes having about a third of the weight and large-diameter pipes about half the weight. Since stainless steel pipes for ordinary piping are thinner-walled, their inside diameters are greater than those of other types of pipes having the same nominal diameters, and their smooth surface allows a greater flow of water for a given friction loss.

1.5.2 Physical properties of pipe materials

Physical properties of pipe materials are as listed in Table 1.5-2. Stainless steel pipe has a thermal expansion coefficient equivalent to that of copper pipe, very low thermal conductivity compared with that of copper pipe, very high electrical resistivity, and specific heat similar to that of carbon steel pipe.

Table 1.5-1 Dimension and weight compared with other pipe materials

Nominal diameter			Stainless steel pipe for ordinary piping (SUS304)						Copper pipe for construction piping (M type)						Unplasticized polyvinyl chloride lined steel pipe						Carbon steel pipe for ordinary piping					
Su	A	B	Outside diameter (mm)	Thick-ness (mm)	Actual inside diameter (mm)	Inner area (cm2)	Weight (kg/m)	Weight ratio	Outside diameter (mm)	Thick-ness (mm)	Actual inside diameter (mm)	Inner area (cm2)	Weight (kg/m)	Weight ratio	Outside diameter (mm)	Thick-ness* (mm)	Actual inside diameter (mm)	Inner area (cm2)	Weight (kg/m)	Weight ratio	Outside diameter (mm)	Thick-ness (mm)	Actual inside diameter (mm)	Inner area (cm2)	Weight (kg/m)	Weight ratio
8	8	1/4	9.52	0.7	8.12	0.52	0.15	0.23	-	-	-	-	-	-	-	-	-	-	-	-	13.8	2.3	9.20	0.66	0.65	1
10	10	3/8	12.7	0.8	11.10	0.97	0.24	0.28	12.7	0.64	11.42	1.02	0.22	0.26	-	-	-	-	-	-	17.3	2.3	12.70	1.27	0.85	1
13	15	1/2	15.88	0.8	14.28	1.60	0.30	0.23	15.88	0.71	14.46	1.64	0.30	0.23	21.7	1.5	13.1	1.35	1.40	1.07	21.7	2.8	16.10	2.04	1.31	1
20	20	3/4	22.22	1.0	20.22	3.21	0.53	0.32	22.22	0.81	20.60	3.33	0.49	0.29	27.2	1.5	18.6	2.72	1.82	1.08	27.2	2.8	21.60	3.66	1.68	1
25	25	1	28.58	1.0	26.58	5.55	0.69	0.28	28.58	0.89	26.80	5.64	0.69	0.28	34.0	1.5	24.6	4.75	2.61	1.07	34.0	3.2	27.60	5.98	2.43	1
30	-	-	34.0	1.2	31.60	7.84	0.98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	32	1 1/4	42.7	1.2	40.30	12.76	1.24	0.37	34.92	1.07	32.78	8.44	1.02	0.30	42.7	1.5	32.7	8.40	3.61	1.07	42.7	3.5	35.70	10.01	3.38	1
50	40	1 1/2	48.6	1.2	46.20	16.76	1.42	0.37	41.28	1.24	38.80	11.82	1.39	0.36	48.6	1.5	38.6	11.70	4.16	1.07	48.6	3.5	41.60	13.59	3.89	1
60	50	2	60.5	1.5	57.50	25.97	2.20	0.41	53.98	1.47	51.04	20.46	2.17	0.41	60.5	1.5	49.9	19.56	5.66	1.07	60.5	3.8	52.90	21.98	5.31	1
75	65	2 1/2	76.3	1.5	73.30	42.20	2.79	0.37	66.68	1.65	63.38	31.55	3.01	0.40	76.3	1.5	64.9	33.08	7.92	1.06	76.3	4.2	67.90	36.21	7.47	1
80	80	3	89.1	2.0	85.10	56.88	4.34	0.49	79.38	1.83	75.72	45.03	3.99	0.45	89.1	2.0	76.7	46.20	9.50	1.08	89.1	4.2	80.70	51.15	8.79	1
100	100	4	114.3	2.0	110.3	95.55	5.59	0.46	104.78	2.41	99.96	78.48	6.93	0.57	114.3	2.0	101.3	80.60	13.10	1.08	114.3	4.5	105.3	87.09	12.18	1
125	125	5	139.8	2.0	135.8	144.8	6.87	0.46	130.18	2.77	124.6	122.0	9.91	0.66	139.8	2.0	126.8	126.3	16.21	1.08	139.8	4.5	130.8	134.4	15.01	1
150	150	6	165.2	3.0	159.2	199.1	12.1	0.61	155.58	3.10	149.4	175.3	13.3	0.67	165.2	2.5	150.2	177.2	21.50	1.09	165.2	5.0	155.2	189.2	19.75	1
200	200	8	216.3	3.0	210.3	347.4	15.9	0.53	-	-	-	-	-	-	216.3	2.5	199.7	313	32.37	1.08	216.3	5.8	204.7	329.1	30.11	1
250	250	10	267.4	3.0	261.4	536.7	19.8	0.47	-	-	-	-	-	-	267.4	3.0	248.2	483	45.83	1.08	267.4	6.6	254.2	507.5	42.45	1
300	300	12	318.5	3.0	312.5	767.0	23.6	0.45	-	-	-	-	-	-	318.5	3.0	298.7	700	57.08	1.08	318.5	6.9	304.7	729.2	53.02	1

* Lining thickness

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition. The table has been modified.

Table 1.5-2 Physical properties of pipe materials (reference values)

Type of pipe (JIS Standard)	Specific gravity	Average coefficient of thermal expansion (10^{-6}/K)	Thermal conductivity (W/m-K)	Specific heat (J/g·K)	Electrical resistivity (μΩ·cm)	Young's modulus (GPa)	Magnetism
		(0-100 °C)	(100 °C)	(0-100 °C)	Room temperature		
Light gauge stainless steel tubes for ordinary piping (JIS G3448)	7.93	17.3	16.3	0.50	72	193	No
Carbon steel pipes for ordinary piping (JIS G3452)	7.86	11.6	59.5	0.48	14.2	206	Yes
Copper and copper alloy seamless pipes and tubes(Phosphorous deoxidized copper) (JIS H3300 (M) type)	8.96	17.6	391.5	0.39	1.71	108	No
Unplasticized poly (Vvinyl chloride) (PVC-U) pipes for water supply (JIS K6742)	1.43	60 - 70	0.20 - 0.21	0.85 - 1.17	3 - 5 × 10^{15}	3.3	No

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition and Technical Document on Unplasticized Vinyl Chloride Pipes for Waterworks

1.5.3 Mechanical properties of pipe materials

Table 1.5-3 lists the mechanical properties of pipe materials. Stainless steel pipes obviously have much higher tensile strength than pipes made from other materials. The properties of stainless steel bars and plates should be referred to for understanding the metal's hardness and other mechanical properties as a pipe material.

Table 1.5-3 Mechanical properties of pipe materials (reference values) [10]

	Tensile strength (N/mm²)	Elongation (%)
Stainless steel tubes for ordinary piping	722 (≥520)	47.5 (≥35)
Carbon steel pipes for ordinary piping	348 (≥290)	46.4 (≥30)
Copper and copper alloy seamless pipes and tubes (Phosphorous deoxidized copper) (Class O)	242 (≥205)	53 (≥40)
Unplasticized poly(vinyl chloride) pipes for water supply	52 (VP: ≥45)	100 (No standard)

*Figures within parentheses ( ) denote JIS values.

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition and Technical Document on Unplasticized Vinyl Chloride Pipes for Waterworks. The table has been modified.

1.5.4 Corrosion resistance of pipe materials

Below is a summary of the corrosion resistance of different pipes, including stainless steel pipes for tap water (city water). The corrosion resistance of carbon steel pipes, galvanized steel pipes, unplasticized vinyl chloride lined steel pipes, and copper pipes to city water is discussed in the excellent review by Toshiaki Kodama. Interested readers are encouraged to refer to this paper.

(1) Stainless Steel pipe

JSSA's examination of corrosion resistance of stainless steel pipes used for water supply and hot water supply systems confirmed that they are still in good condition with almost no corrosion, even after 31 years. Stainless steel pipes have sufficient corrosion resistance to tap water. However, since the corrosion resistance of stainless steel pipe still largely depends on the use, special attention should be paid to the chloride ion concentration and residual chlorine concentration of tap water.

The tap water quality standards to verify the relevant applicability of stainless steel pipe are described in the water quality guidelines in the Maintenance section of this Piping Manual.

(2) Carbon Steel pipe

Non-treated carbon steel pipes are never used as feed pipes for city water. When galvanized steel pipes are used, the corrosion occurring after the zinc wears off should be regarded as corrosion of carbon steel pipes. Although the corrosion rate of carbon steel is normally about 0.1-0.2 mm/year over the long range, pitting corrosion under rust deposits advances at a rate two to three times faster. Red water is a phenomenon of water coloring from rust and ferric hydroxide that is suspended in water. With the increased pH of water, the rust tends to coagulate, eliminating its suspension in water. The essential measure against red water is to replace the existing piping. As a tentative treatment, an inhibitor may be used. Only two usable substances, sodium polyphosphate and sodium silicate, are used as inhibitors for city water. As can be seen from Fig. 1.5-1, which shows the relationship between the concentration of phosphate and corrosion rate of steel, a phosphate concentration of at least 10 ppm is needed for corrosion protection. Phosphate at a concentration of 2-5 ppm, which is normally added to city water, produces no anti-corrosion effect, only turning red water colorless because it reacts with ferrous and ferric ions to form a complex compound.

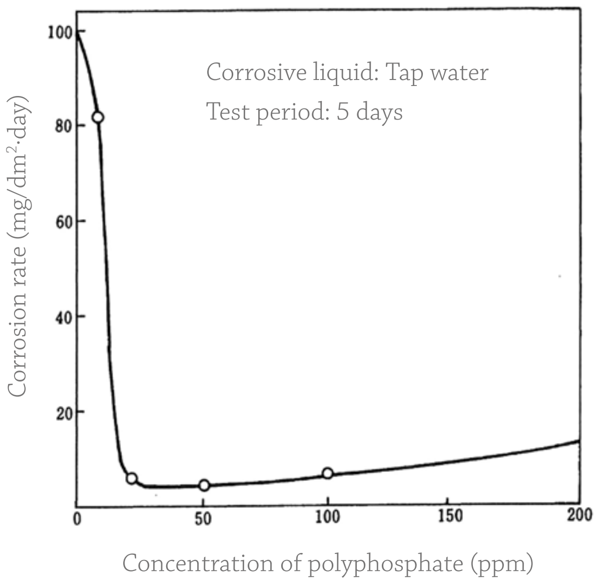
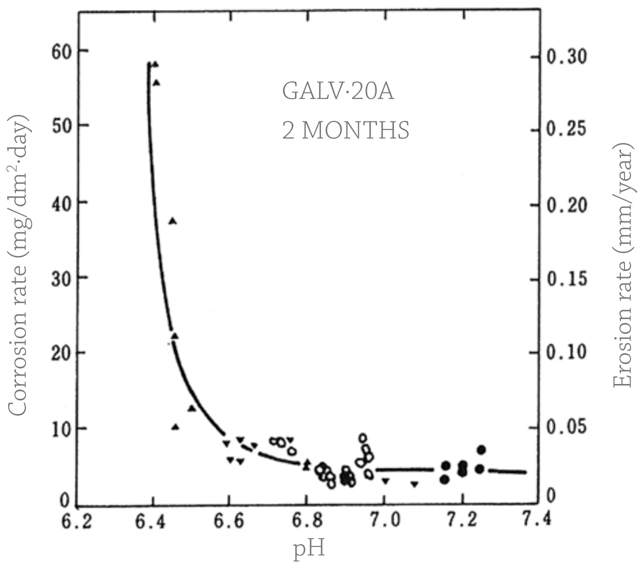


Fig. 1.5-1 Effect of concentration of polyphosphate on corrosion rate of mild steel[5]
Polyphosphate is used as an inhibitor for city water.

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(3) Galvanized steel pipes

The corrosion resistance of galvanized steel pipes varies significantly with water quality. The galvanized layer is covered with a white protective film that exhibits high corrosion resistance. Under this condition, the corrosion rate of zinc is about 1/10 of that of carbon steel. As is clear from Fig. 1.5-2, which shows the results of an experiment on the effect of pH on corrosion rate, the corrosion of zinc increases rapidly at pH 6.6 or lower. Since the corrosion potentials of zinc and steel are reversed in hot water, this material is not for the supply of hot water. Today, using this material for waterworks and water supply is prohibited.



Effect of pH on corrosion rate
●: Sakai, ▲: Kinutashimo, ○: Asaka, Δ: Kanamachi (Tokyo)
∇: Nabeyaueno (Nagoya), □: Kunijima, ▼: Toyono (Osaka)

Fig. 1.5-2 Result of Corrosion Test with Galvanized Steel Pipe at Purification Plant [5]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(4) Resin lined steel pipes

Unplasticized vinyl chloride lined steel pipes have already served for a long time as feed water pipes and have now come into wide use. The difficulty in using these pipes lies in cutting them and treating their screwed parts and ends. In cutting them, they need to be sufficiently cooled to prevent burning or separation of vinyl chloride and/or adhesive agents due to heat. Applying liquid sealing agents with a small amount of anticorrosive to the sections of the screwed parts that will contact with water and to the pipe ends is also necessary.

(5) Copper pipes

Copper pipes for construction piping are commonly used for supplying hot water. As a hot-water supply material, they have been very popular because of the ease of brazing, but corrosion has increased accordingly. The corrosion resistance of copper comes from the protective film (oxide) generated on its surface. Since the generation of this film is closely related to water quality, corrosion resistance greatly dependents on the water as described later. The problems due to copper corrosion are blue water, erosion-corrosion, and pitting corrosion.

Copper ions may be adsorbed by, or react with, soap ingredients on bathroom walls or their joints and form a blue-colored stain, which is referred to as blue water. The dissolution rate of copper is high when the water contains free carbon dioxide in large quantities and has a low pH value. This is presumed to be due to cuprous oxide, which forms a protective film, not being easily generated at low pH values.

Because of its softness, copper tends to erode easily at high flow velocity. When erosion-corrosion occurs, the film is also destroyed. Since the major causal factor in film formation is the pH value of water, the critical water flow velocity also depends on the pH, which is, for example, 1 m/sec for water of pH 6.5 at 65°C. As a general trend, the flow velocity in hot-water supply systems is maintained at about 1 m/sec. As another measure to prevent erosion-corrosion, increasing the bend radius of the pipes or adopting a design that allows easy release of dissolved gases is advisable.

Of types of damage to copper pipes for hot-water supply, pitting corrosion is the most difficult one to take countermeasures against. The number of instances of this corrosion is large in the Kanto area and Hokkaido, and small in the Kansai area. This suggests that water quality exists that tends to easily cause pitting corrosion. Pitting corrosion tends to occur in the presence of water with $(HCO_3^-)/(SO_4^{2-}) < 1$ such as that in the Tone River and in Sapporo City water. Water that tends to cause pitting corrosion easily can be defined as water which forms an imperfect protective film, contains high concentrations of eroding ions such as SO_4^{2-} and Cl^-, and contains an oxidizing agent (dissolved oxygen or residual chlorine) that shifts to noble potential. As a measure to prevent pitting corrosion, making the protective film perfect, lowering the concentration of SO_4^{2-} and Cl^-, or turning the atmosphere into a non-oxidizing one to reduce the corrosion potential is advisable.

Described above are the corrosion properties of pipes with respect to tap water. In addition, a published report also discusses the effect of slime on the corrosion of pipe materials for use in open circulatory cooling water systems.

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DESIGN 2

2 DESIGN

2.1 Design Concept of Stainless Steel Piping

When designing a piping system for building equipment, the purpose of the building, application range, required piping performance and cost must be considered.

Examples of considering the purpose of the building and application range include installing corrosion-resistant sanitary piping for drinking water for hospitals and residences and piping with corrosion-resistant long service life at data centers that require performance without any down time. In most cases, these buildings adopt stainless steel piping.

Examples of required piping performance include sanitary piping, non-corrosive piping and piping focusing on environmental performances such as long service life and renewability. These performances are determined in relation to the design concept. Seeking to build long-life quality housing based on the Fukuda Vision (200 year housing) is one example appropriate for using stainless steel piping. If water leakage is to be prevented as much as possible, stainless steel piping can be an option.

For cost consideration, initial and life cycle costs are the main factors. If much importance is attached to life cycle cost, laying stainless steel piping is the prevailing choice. Since stainless steel piping has small pipe resistance, the inner flow rate can also be accelerated. This enables using a pipe whose diameter is smaller than other pipe materials, which reduces costs.

A piping system is designed after the above-mentioned points are considered. For an air-conditioning system, the applicability of stainless steel pipes will vary depending on whether the piping system is closed or open. For an open piping system, stainless steel will be primarily used where much dissolved oxygen flows in the pipe. With steam, stainless steel pipes will be the primary choice to prevent carbon dioxide corrosion in areas of the condensate return pipe. When building a water supply or drainage system that requires sanitary quality and sustainability, and when building a system with a water receiving tank or high-level tank that increases the quantity of dissolved oxygen in the pipe, stainless steel pipes will be the primary choice. Copper pipes are widely used for hot-water supply piping systems, but stainless steel pipes are now used for a limited number of systems that need to prevent corrosion (erosion) and dissimilar metal contact corrosion. Although stainless steel pipes for building equipment are limited, stainless steel pipes are used for piping for clean rooms and for systems running pure water.

Based on the abovementioned points, factors must be compared looking at all the information before the materials for the piping system are determined. The factors include costs and the many properties of pipes: service life, pressure resistance, temperature resistance, water quality resistance, constructional workability and specification. Figure 2.1-1 illustrates a piping design workflow, which is the process of selecting piping materials.

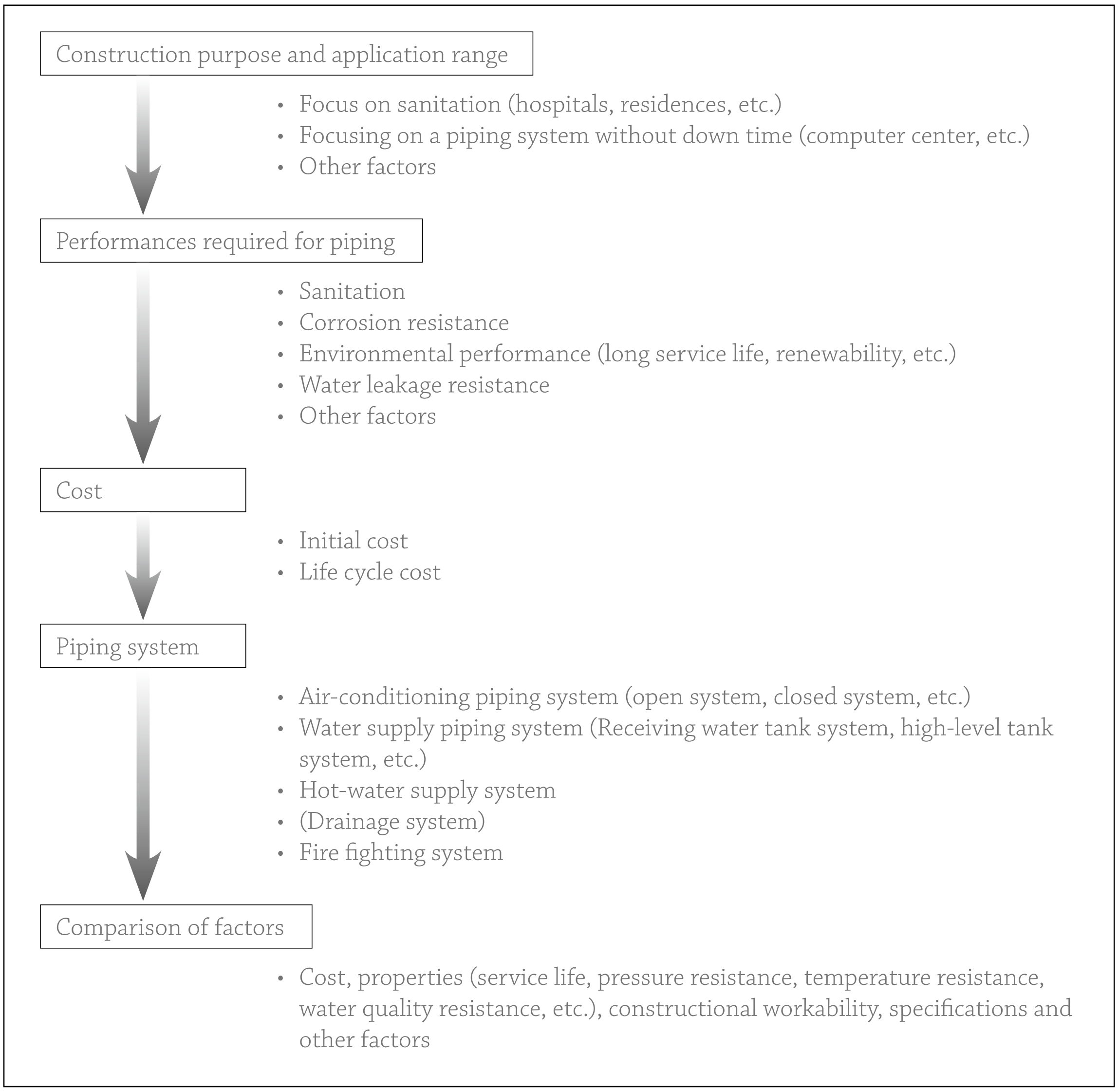

Fig. 2.1-1 Piping design workflow (process of selecting piping materials)

Prepared by: Hiroshi Iizuka

2.2 Range of Use of Stainless Steel Piping

2.2.1 Range of use of stainless steel pipes for ordinary piping, classified by application

Many different pipes are used in construction, including pipes made of carbon steel, cast iron, copper, plastic, lead and cement. The right kind of pipe has been chosen to fit the particular application and construction site.

The Japan Stainless Steel Association's Committee on Examining Stainless Steel Pipes for Building Equipment has studied and examined the use of stainless steel pipes for some 30 years. As a result, the Committee has set the range of applications of ***light gauge stainless steel tubes for ordinary piping*** (JIS G 3448) discussed in this manual to piping for water supply, hot-water supply, cooling water, chilled and hot water, steam, steam return water, domestic wastewater drainage and fire fighting water. In terms of drainage, use is limited to domestic sewage and gray water. Couplings for drainage not being prepared for these piping systems should also be considered. The possibility of uses for other applications has been discussed at length and reviewed since October 1990 in the Committee. At this time, recycled city water, rainwater, well water and river water remain as items to be discussed in the future because their qualities vary greatly and are difficult to predict.

The description in this manual is limited to the indoor use of stainless steel pipe for ordinary piping. However, stainless steel pipe (JIS G 3459) can also be used for drainpipes at factories and plants. The application range of stainless steel pipe has been steadily expanding.

Table 2.2-1 lists the use categories of pipe materials mentioned above. This table is prepared after the applications that the Committee has authorized as acceptable are added to the table on "Category of use of stainless steel pipe for ordinary piping and other types of pipes" that is from *the Heating, Air-Conditioning and Sanitary Equipment Engineering Works Standard Specifications* (SHASE-S 010). The * mark indicates such additions.

For water quality to which stainless steel pipe is applicable, refer to 2.9.1, Water quality standards for piping systems.

When used for water supply pipes, the dissolution of chromium and other metals into waterworks water could be a problem, but the results of experiments conducted by the Tokyo Municipal Sanitation Laboratory and independently by JSSA did not detect any hexavalent chromium. Even the total chromium is sufficiently below the water quality standard values for waterworks water (***No. 101 Ordinance of Ministry of Health, Labor and Welfare in 2003*** [revised as of April 1, 2010], see Table 2.2-2), indicating that no problems appear to be presented.

Table 2.2-3 lists water quality standard values for cooling water, cold water, hot water and make-up water from *the Guidelines of Water Quality for Refrigeration and Air-Conditioning Equipment* (JRA-GL-02-1994) issued by the Japan Refrigeration and Air Conditioning Industry Association (JRAIA) in 1994. The guidelines were formulated to maintain the performance, efficiency and service life of refrigeration and air-conditioning equipment that constitutes refrigeration and air-conditioning facilities and prevent degradation. Although piping is not covered in the guidelines, concentrations of chloride ions, sulfate ions, residual chlorine and more set for various types of systems may be referred to.

Table 2.2-1 Categories of use of stainless steel pipes for ordinary piping and of other types of pipes1

Segment	Type of pipe	Designation	Standard	Category of use: Steam	High-temperature water	Chilled/hot water	Cooling water	Heat source water	Oil	Refrigerant	Water supply	Hot-water supply	Drainage	Ventilation	Fire fighting	Remarks
Metal pipe	Cast iron pipe	Ductile iron pipes for water supply	JWWA G 113								○				○	
		Cast-iron drainage pipes and fittings	JIS G 5525													
		Mechanical type (class 1)											○	○		
		Set-in type (RJ pipe)											○	○		Dedicated to vertical pipe
	Steel pipe	Galvanized steel pipes for ordinary piping	JIS G 3442	○		○	○	○	○	○			○	○	○	The color of pipes for steam, high-tem-
		Carbon steel pipes for ordinary piping *1	JIS G 3452	○		○	○	○	○	○			○	○	○	perature water, oil, and refrigerant stated
		Carbon steel pipes for pressure service *2	JIS G 3454	○		○	○	○	○	○					○	in *1 to *3 shall be black, while the others
		Carbon steel pipes for high-pressure service *3	JIS G 3455	○		○		○							○	shall be white.
		Ark-welded carbon steel pipes	JIS G 3457	○		○	○	○	○	○			○	○	○	◎ indicates schedule (40) pipe.
	Stainless steel pipe	Light gauge stainless steel tubes for ordinary piping	JIS G3448	○	*	○	○	○	*		○	○	*	*	○	SUS 304/SUS 316
		Stainless steel pipes	JIS G3459	○	*	○	○	○	*		○	○	*	*	○	Schedule 5S – 160
		Large-diameter welded stainless steel pipes **	JIS G 3468			*	*	*			*			*		Schedule 5S – 160
		Stainless steel tubes for water supply	JWWA G 115			○	○	○			○					A: SUS 304, B: SUS 316
		Corrugated stainless steel tubes for water supply	JWWA G 119			○					○	○				
	Lined steel pipe	Chlorinated polyvinyl chloride lining steel pipes for water works	JWWA K 140			○		○				○				SGP-HVA
		Heat-resistant resin lined steel pipe with flange	WSP 054			○		○				○				H-FVA/H-FCA
		Nylon-coated steel pipe	WSP 067			○	○	○			○					
		Unplasticized polyvinyl chloride lining steel pipes for water works	JWWA K116				○				○					SGP-VA/VB/VD
		Unplasticized vinyl chloride lined steel pipe with flange	WSP 011				○				○					F-VA/VB/VD
		Polyethylene powder lining steel pipes for water works	JWWA K 132				○				○					SGP-PA/PB/PD
		Polyethylene powder lined steel pipe with flange	WSP 039				○				○					F-PA/PB/PC
		Non-tar epoxy coated steel pipe for drainage	WSP 032										○			SGP-TA
		Unplasticized vinyl chloride lined steel pipe for drainage	WSP 042										○			D-VA
		Unplasticized vinyl chloride laminated steel pipe for fire fighting	WSP 041												○	VS: For underground piping
		Polyethylene coated steel pipes	JIS G 3469			○	○	○	○							
	Lead pipe	Lead pipe for drainage or ventilation	SHASE-S 203										○	○		
	Copper pipe	Copper and copper alloy seamless pipes and tubes	JIS H 3300			○	○	○		○	○	○	●	●	◎	●: not including usage for urinal systems.
		Copper pipes for water supply	JWWA H 101								○	○				◎ indicates steel pipes for sprinkler
		Plastic covered copper tube for water supply	JBMA-T 202								○	○				systems. Nominal diameters 65 or lower
		Plastic covered copper tubes	JIS H 3330			○		○			○	○				shall be limited to K, L, and M of C1020 or C1220. (However, C1220 shall be used for cooling water.)

Segment	Type of pipe	Designation	Standard	Category of use												Remarks
				Steam	High-temperature water	Chilled/hot water	Cooling water	Heat source water	Oil	Refrigerant	Water supply	Hot-water supply	Drainage	Ventilation	Fire fighting	
Non-metal pipe	Plastic pipe	Unplasticized polyvinyl chloride pipes	JIS K 6741													VP (However, VU may be used for drain-
		Unplasticized polyvinyl chloride pipes					○				△		○	○		age underground piping.)
		Shock-resistant unplasticized polyvinyl chloride pipes					○				△		○	○		HIVP
		Unplasticized polyvinyl chloride pipes for water supply	JIS K 6742				○				○					VP/HIVP
		Polyethylene pipes for general purposes	JIS K 6761				○				△					The symbol △ indicates a water supply
		Double wall polyethylene pipes for water supply	JIS K 6762				○				○					pipe other than for drinking water.
		Crosslinked polyethylene(PE-X) pipes	JIS K 6769			○		○			△	○			◎	The symbol ◎ indicates an alarm valve for
		Polybutene pipes	JIS K 6778			○		○			△	○				sprinkler systems that is used for 50 or lower nominal diameters.
		Chrolinated poly(vinyl chloride)(PVC-C) pipes for hot and cold water supply	JIS K 6776			○		○				○			◎	HT: Application temperature 90 °C or lower
		Crosslinked polyethylene(PE-X) pipes for water supply	JIS K 6787								○					
		Polybutene pipes for water supply	JIS K 6792								○					
		Rubber ring unplasticized vinyl chloride pipe for waterworks	JWWA K 127								○					Type I, type II
		Shock-resistant rubber ring unplasticized vinyl chloride pipe for waterworks	JWWA K 129								○					Type I, type II
		Fire resistive dual pipes for drainage	FDPS-1										○	○		
		Unplasticized polyvinyl chloride oval pipe for sewerage	JSW AS K-3										○			External pressure pipe VU
		Unplasticized polyvinyl chloride three-layer pipes with recycled solid core	JIS K 9797										○			For underground burial
		Unplasticized polyvinyl chloride three-layer pipes with recycled foamed core	JIS K 9798										○	○		For drainage in building
		Recycled foamed unplasticized polyvinyl chloride three layer pipe for sewerage	AS 62										○			
		Fire-resistant unplasticized polyvinyl chloride pipe for buildings	-										○	○		
	Concrete pipe	Precast reinforced concrete products	JIS A 5372										○			Centrifugal reinforced concrete pipe for type I waterways Types A, B, NB, C, NC

JIS: Japanese Industrial Standards JWWA: Japan Water Works Association JAWAS: Japan Sewage Water Association Standards SHASE: The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan

WSP: Water Steel Pipe Association JBMA: The technical standards of Japan Brass Copper Association FDPS: Fire resistive Dual Pipes Association standards

The symbol △ indicates the application of water supply pipe to other than drinking water.

The symbol * indicates the pipe selected by this Revision Committee on Piping Manual for Stainless Steel Pipes for Buildings. Other pipes are based on SHASE-S-206-2007. Drainage shall be limited to sewerage and gray water of household wastewater.

** ***Large-diameter welded stainless steel pipes*** (JIS G 3468) can be used for the same application as ***Stainless steel pipes*** (JIS G 3459). However, since the use of the large-diameter pipe is limited, the steel pipe is set to this category of use. Firefighting is in accordance with the *Fire Service Act Enforcement Ordinance*.

Reference: SHASE-S 010-2007: Heating, Air-Conditioning and Sanitary Equipment Engineering Works Standard Specification

Table 2.2-2 Water quality standards for waterworks water[2]

	Item	Water quality standard for waterworks water
1	General bacteria	Number of colonies formed in 1 mL of test water must not exceed 100.
2	Coliform	must not be detected
3	Cadmium and its compounds	The quantity of cadmium must not exceed 0.003 mg/L.
4	Mercury and its compounds	The quantity of mercury must not exceed 0.0005 mg/L.
5	Selenium and its compounds	The quantity of selenium must not exceed 0.01 mg/L.
6	Lead and its compounds	The quantity of lead must not exceed 0.01 mg/L.
7	Arsenic and its compounds	The quantity of arsenic must not exceed 0.01 mg/L.
8	Hexavalent chromium (CrVI) compounds	The quantity of CrVI must not exceed 0.05 mg/L.
9	Cyanide ion and cyanogen chloride	The quantity of cyanogen must not exceed 0.01 mg/L.
10	Nitrate nitrogen and nitrite nitrogen	must not exceed 10 mg/L
11	Fluorine and its compounds	The quantity of fluorine must not exceed 0.8 mg/L.
12	Boron and its compounds	The quantity of boron must not exceed 1.0 mg/L.
13	Carbon tetrachloride	must not exceed 0.002 mg/L
14	1,4-dioxane	must not exceed 0.05 mg/L
15	Cis-1,2-dichloroethylene and trans-1,2-dichloroethylene	must not exceed 0.04 mg/L
16	Dichloromethane	must not exceed 0.02 mg/L
17	Tetrachloroethylene	must not exceed 0.01 mg/L
18	Trichloroethylene	must not exceed 0.03 mg/L
19	Benzene	must not exceed 0.01 mg/L
20	Chloric acid	must not exceed 0.6 mg/L
21	Chloroacetic acid	must not exceed 0.02 mg/L
22	Chloroform	must not exceed 0.06 mg/L
23	Dichloroacetic acid	must not exceed 0.04 mg/L
24	Dibromochloromethane	must not exceed 0.1 mg/L
25	Bromic acid	must not exceed 0.01 mg/L
26	Trihalomethane (Sum of the concentrations of chloroform, dibromochloromethane, bromodichloromethane and bromoform)	must not exceed 0.1 mg/L
27	Trichloroacetic acid	must not exceed 0.2 mg/L
28	Bromodichloromethane	must not exceed 0.03 mg/L
29	Bromoform	must not exceed 0.09 mg/L
30	Formaldehyde	must not exceed 0.08 mg/L
31	Zinc and its compounds	The quantity of zinc must not exceed 1.0 mg/L.
32	Aluminum and its compounds	The quantity of aluminum must not exceed 0.2 mg/L.
33	Iron and its compounds	The quantity of iron must not exceed 0.3 mg/L.
34	Copper and its compounds	The quantity of copper must not exceed 1.0 mg/L.
35	Sodium and its compounds	The quantity of sodium must not exceed 200 mg/L.
36	Manganese and its compounds	The quantity of manganese must not exceed 0.05 mg/L.
37	Chloride ions	must not exceed 200 mg/L
38	Calcium, magnesium, etc. (hardness)	must not exceed 300 mg/L
39	Evaporation residues	must not exceed 500 mg/L
40	Anionic surfactant	must not exceed 0.2 mg/L
41	(4S,4aS,8aR)-octahydro-4,8a-dimethyl naphthalene-4a(2H)-ol (a.k.a. Geosmin)	must not exceed 0.00001 mg/L
42	1,2,7,7-tetramethylbicyclo[2,2,1]heptane-2-ol (a.k.a. 2-methylisoborneol)	must not exceed 0.00001 mg/L
43	Non-ionic surfactant	must not exceed 0.02 mg/L
44	Phenols	The quantity converted into phenol must not exceed 0.005 mg/L.
45	Organic matters (quantity of total organic carbon [TOC])	must not exceed 3 mg/L
46	pH value	Not lower than 5.8 and not higher than 8.6
47	Taste	must not be abnormal
48	Odor	must not be abnormal
49	Chromaticity	must not exceed 5
50	Turbidity	must not exceed 2

Source: No. 101 Ordinance of Ministry of Health, Labour and Welfare in 2003, revised edition as of April 1, 2010

Table 2.2-3 Water quality standards for cooling water, cool water, hot water and make-up water(5) 3

	Item(1)(6)	Cooling water system(4)			Cool water system		Hot water system(3)				Tendency(2)	
		Circulation type		Single pass type			Low-level medium/high-temperature water system		High-level medium/high-temperature water system			
		Circulating water	Make-up water	Single pass water	Circulating water [Lower than, or equal to, 20°C]	Make-up water	Circulating water [Higher than 20°C and lower than, or equal to, 60°C]	Make-up water	Circulating water [Higher than 60°C and lower than, or equal to, 90°C]	Make-up water	Corrosion	Scale generation
Basic items	pH (at 25°C)	6.5-8.2	6.0-8.0	6.8-8.0	6.8-8.0	6.8-8.0	7.0-8.0	7.0-8.0	7.0-8.0	7.0-8.0	○	○
	Electrical conductivity (mS/m) (at 25°C) {μS/cm} (at 25°C)(1)	80 or less {800 or less}	30 or less {300 or less}	40 or less {400 or less}	40 or less {400 or less}	30 or less {300 or less}	30 or less {300 or less}	30 or less {300 or less}	30 or less {300 or less}	30 or less {300 or less}	○	○
	Chloride ion ($mgCl^-/L$)	200 or less	50 or less	50 or less	50 or less	50 or less	50 or less	50 or less	30 or less	30 or less	○	
	Sulfate ion ($mgSO_4^{2-}/L$)	200 or less	50 or less	50 or less	50 or less	50 or less	50 or less	50 or less	30 or less	30 or less	○	
	Acid consumption (pH4.8) ($mgCaCO_3/L$)	100 or less	50 or less	50 or less	50 or less	50 or less	50 or less	50 or less	50 or less	50 or less		○
	Total hardness ($mgCaCO_3/L$)	200 or less	70 or less	70 or less	70 or less	70 or less	70 or less	70 or less	70 or less	70 or less		○
	Calcium hardness ($mgCaCO_3/L$)	150 or less	50 or less	50 or less	50 or less	50 or less	50 or less	50 or less	50 or less	50 or less		○
	Ionic silica ($mgSiO_2/L$)	50 or less	30 or less	30 or less	30 or less	30 or less	30 or less	30 or less	30 or less	30 or less		○
Reference items	Iron (mgFe/L)	1.0 or less	0.3 or less	1.0 or less	1.0 or less	0.3 or less	1.0 or less	0.3 or less	1.0 or less	0.3 or less	○	○
	Copper (mgCu/L)	0.3 or less	0.1 or less	1.0 or less	1.0 or less	0.1 or less	1.0 or less	0.1 or less	1.0 or less	0.1 or less	○	
	Sulfide ion (mgS^{2-}/L)	No detection	No detection	No detection	No detection	No detection	No detection	No detection	No detection	No detection	○	
	Ammonium ion ($mgNH_4^+/L$)	1.0 or less	0.1 or less	1.0 or less	1.0 or less	0.1 or less	0.3 or less	0.1 or less	0.1 or less	0.1 or less	○	
	Residual chlorine (mgCl/L)	0.3 or less	0.3 or less	0.3 or less	0.3 or less	0.3 or less	0.25 or less	0.3 or less	0.1 or less	0.3 or less	○	
	Free carbon dioxide ($mgCO_2/L$)	4.0 or less	4.0 or less	4.0 or less	4.0 or less	4.0 or less	0.4 or less	4.0 or less	4.0 or less	4.0 or less	○	
	Stability index	6.0-7.0	-	-	-	-	-	-	-	-	○	○

(1) The names of the items and their terminology are as defined in JIS K 0101. The parenthesized numerical values are those expressed in the previously-used unit. They are written along with the official data for reference purposes.
(2) The circles in the tendency column indicate that the corresponding items are factors associated with corrosion or scale generation.
(3) In general, corrosiveness is remarkably high under high temperature conditions (40°C or higher). In particular, when a steel material is not provided with any protective coat and is to come into direct contact with water, taking effective anticorrosive measures such as the addition of anticorrosive and deairing is desirable.
(4) In cooling water systems using a sealed cooling tower, the closed circuit circulating water and its make-up feed shall conform to the water quality standard for the hot water system, and the spray water and its make-up feed to the water quality standard for the circulation type cooling water system.
(5) The raw water supplied or replenished shall be tap water (clean water), industrial water or ground water. No use shall be made of demineralized water, intermediate water or softened water.
(6) The above 15 items are typical factors responsible for corrosion or scale generation.

Source: Japan Refrigeration and Air Conditioning Industry Association, JRA-GL-02-1994

2.2.2 Temperature and pressure ranges for stainless steel pipe for ordinary piping

The choice of piping material is based on the type of fluid and its temperature, pressure and flow speed. The temperature and pressure are directly related to the mechanical properties of the material, such as its allowable tensile stress value. The flow speed affects the system design and is also related to the mechanical properties of the pipe material, considering the hydraulic pressure increase during water hammer. Figure 2.2-1 shows the recommended application range for ***light gauge stainless steel tubes for ordinary piping*** SUS-TPD (JIS G 3448) with respect to temperature and pressure, along with that for ***carbon steel pipes for ordinary piping*** SGP (JIS G 3452) and ***stainless steel pipes*** SUS-TP (JIS G 3459). In general, if the temperature is low, the pressure can be high and the diagram represents downward-sloping, but like the SGP it has been made rectangular. The basis for selecting the range of application is the official gazette (***extra edition No. 63, dated October 15, 1979***). First, the SGP is set to 1 MPa, 350°C and then SUS-TP, which can be used in a range from low temperatures to high temperatures. Then, at high pressure, it is partitioned at 350°C, the same as SGP, and at a pressure of 3.0 MPa, which is used with steam, but very rarely. Concerning stainless steel pipe for ordinary piping discussed in this manual, the provision that limits maximum operation pressure to 1.0 MPa or under was deleted in February 2004 during the JIS revision. Accordingly, the Japan Stainless Steel Association has set a guidepost of recommended maximum operation pressure to 2.0 MPa or lower for the piping systems including couplings. Likewise, the upper temperature limit has been set to 150° C because present high-temperature applications of piping include steam, hot-water supply, chilled and hot water, etc.

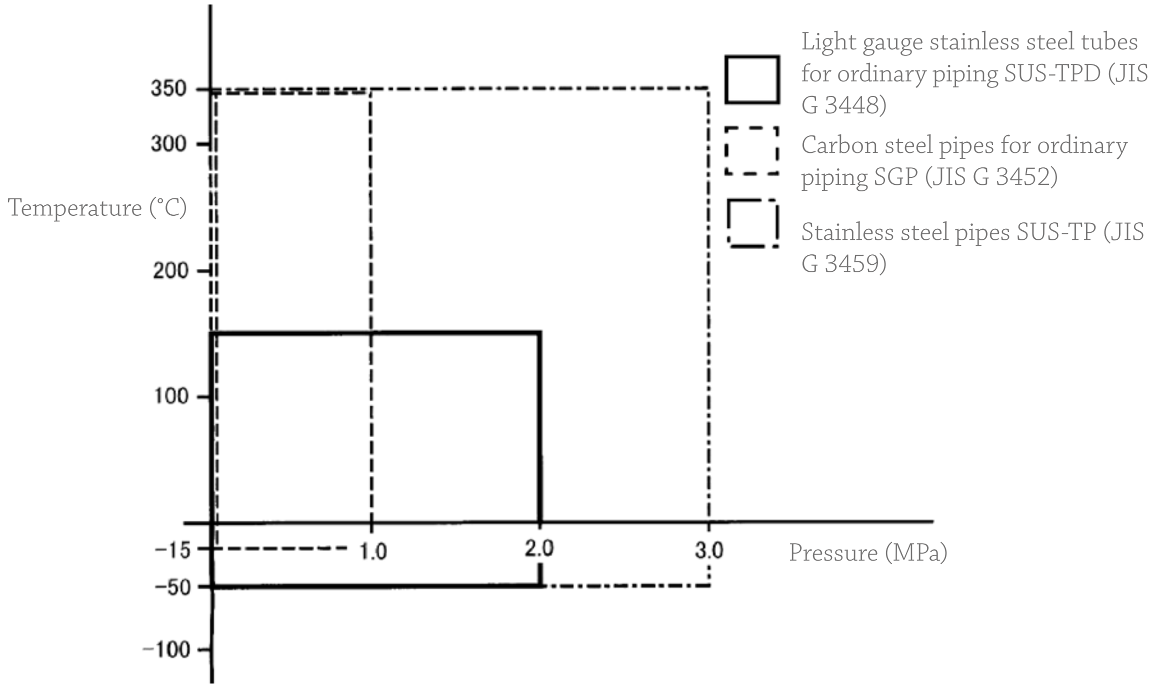

Fig. 2.2-1 Recommended temperature and pressure applicability ranges for stainless steel pipe for ordinary piping in building services

Prepared by: the Japan Stainless Steel Association

2.2.3 Designed allowable stress and maximum allowable pressure of stainless steel pipe for ordinary piping

The designed allowable stress of stainless steel pipe for ordinary piping is set to 130 MPa. This is one-fourth of the 520 MPa tensile strength of SUS 304 as set forth in JIS and was decided partly because it is less than the 0.2% proof stress [4] of 205 MPa defined in the JIS.

Based on the exposition of JIS G 3448 (*light gauge stainless steel tubes for ordinary piping*), using this allowable stress of 130 MPa, the maximum allowable pressure, which is the maximum allowable pressure for each pipe diameter corresponding to the allowable stress, is given by formula (2.2-1).

$P = 2 \times S \times \eta \times t/D$..Formula (2.2-1)

Where	P:	maximum allowable pressure	(MPa)
	S:	designed allowable stress	(130 MPa)
	η:	weld efficiency	(0.85)
	t:	wall thickness of pipe	(mm)
	D:	outside diameter of pipe	(mm)

Table 2.2-4 lists additions of maximum allowable pressures that were calculated based on outside diameters and thickness of stainless steel pipes in a table from JIS G 3448 (2004): ***light gauge stainless steel tubes for ordinary piping***. The recommended maximum operation pressure of 2.0 MPa or under for stainless pipes stated in the foregoing Chapter 2.2.2 is only a guidepost for maximum operation pressure. Thus, the value should be treated differently from the calculation values in Table 2.2-4.

Table 2.2-4 Maximum allowable pressure for stainless steel pipe for ordinary piping[4]

Segment	Nominal diameter Su	Outside diameter (mm)	Allowable difference in outside diameter		Thickness (mm)	Allowable difference in thickness	Unit mass (kg/m)		Maximum allowable pressure (MPa)
			Outside diameter	Cercum-ferential length			SUS 304TPD	SUS 315J1TPD SUS 315J2TPD SUS 316 TPD	
Straight pipes and coiled pipes	8	9.52	0	–	0.7	±0.12	0.154	0.155	16.3
	10	12.70	-0.37		0.8		0.237	0.239	13.9
	13	15.88			0.8		0.301	0.303	11.1
	20	22.22			1.0		0.529	0.532	9.9
Straight pipes	25	28.58			1.0		0.687	0.691	7.7
	30	34.0	±0.34	±0.20	1.2		0.980	0.986	7.8
	40	42.7	±0.43		1.2		1.24	1.25	6.2
	50	48.6	±0.49	±0.25	1.2		1.42	1.43	5.5
	60	60.5	±0.60		1.5	±0.15	2.20	2.21	5.5
	75	76.3	±1%	±0.5%	1.5		2.79	2.81	4.3
	80	89.1			2.0	±0.30	4.34	4.37	5.0
	100	114.3			2.0		5.59	5.63	3.9
	125	139.8			2.0		6.87	6.91	3.2
	150	165.2			3.0	±0.40	12.1	12.2	4.0
	200	216.3			3.0		15.9	16.0	3.1
	250	267.4			3.0		19.8	19.9	2.5
	300	318.5			3.0		23.6	23.8	2.1

JIS G 3448 (2004) with the addition of maximum allowable pressures prepared by the Japan Stainless Steel Association

2.2.4 Dimensional designations for stainless steel pipe for ordinary piping

In the standards for stainless steel pipe for ordinary piping, the designations (Su designations) unique to these pipes require special attention when designing. Table 1.5-1 (in 1.5 of 1, The Basics) compares their dimensions and weights with other pipe materials, and the designations do not always indicate exactly the same outside diameters of corresponding carbon steel pipes or copper pipes.

The designation of piping has been treated as an indicator. For example, it is convenient to remember them by integers such as 25 A, 50 A, and 100 A. This makes them easy to handle, and thus these designations are still in use today. But none of these nominal diameters agree with the actual inside or outside diameters. In actual design or construction, the inside diameter is taken as the standard for calculating the flow volume that determines the piping diameter, and the outside diameter is taken as the standard for installation.

The nominal diameters of stainless steel pipe for ordinary piping are derived to a great extent from their history as product. They are an outside diameter standard product that agrees in all its dimensions with the outside diameters of copper or carbon steel pipes. Because copper pipe couplings were used for convenience when couplings were not as well organized as they are today, pipes of 25 Su or less are aligned with the outside diameters of copper pipes, and pipes of 30 Su (corresponding to 25 A for carbon steel pipe) or greater are aligned with the outside diameters of carbon steel pipes.

Thus the designations of stainless steel pipe for ordinary piping do not agree with the conventional nominal diameter A of carbon steel pipe, and from 30 Su to 75 Su they are completely different from such A designations. If an user specifies 40 Su for stainless steel pipe for ordinary piping with the intention of purchasing pipe equivalent to 40 A of carbon steel pipe, the outside diameter of stainless steel pipe ordered will be equivalent to 32 A of carbon steel pipe. These points require close attention because they also affect choosing valves, pipe joints and heat insulating materials.

2.2.5 Points in selecting stainless steel pipe

Determining the basis for adopting stainless steel pipe for ordinary piping is quite difficult. As discussed in Chapter 2.1, an evaluation is made and a decision arrived at after studying the criteria and points for piping design. This section covers several characteristics of stainless steel pipe that will be the points for comprehensively evaluating as compared with other pipe materials in terms of economy and product features.

(1) Stainless steel pipe is outstanding in durability.

(2) It is clean and sanitary.

(3) Since the surface roughness is small, the friction loss is also small. This may allow the user to downsize the system.

(4) The surface roughness will remain unchanged despite aging, enabling the user to keep up the same flow rate as at the time of piping installation.

(5) It is light-weight and outstanding in constructional workability.

(6) It is outstanding in life cycle cost (LCC).

(7) It is a material friendly to the global environment.

- Almost 100% reusable.
- Life cycle CO_2 ($LCCO_2$) is low.
- Matches green procurement.

2.2.6 Service life of stainless steel piping system

(1) Definition of service life

The service life of an industrial product means the period until the product is no longer reliable, safe to use or operational due to electrical or mechanical performance degradation. Such degradation usually derives from stress during operation and aging. For example, service life can refer to a period until a product suffers metallic destruction. The service life is subdivided primarily into expected service life, average service life, mean time to failure, fatigue life and material life. Their definitions are as follows:

(a) Expected service life: Period of use during which a product is estimated by the manufacturer to be usable under the conditions of use specified by the manufacturer.

(b) Mean life: Average period of service of a product under the conditions of use specified by the manufacturer.

(c) Mean time to failure (MTTF): Average period until a non-repairable item fails (JIS Z 8115: *Glossary of terms used in dependability*). MTTF is one of the barometers that indicate the service life property of a system.

(d) Fatigue life: Period of use until a product suffers the fracture limit under repeated stress - typically metallic fatigue.

(e) Material life: Period of use for the main material under such environments of use as pressure and temperature - typically creep property of resin pipe.

(2) Expected service life of straight pipe

The service life of straight pipe is set to end when water leaks from the host material. The service life of stainless steel piping is determined by corrosion resistance. The coverage of this discussion is limited to the piping of water supply, hot-water supply, cooling water, chilled and hot water, steam, steam return water and fire fighting. The water quality shall conform to the relevant standards indicated in Chapter 2.9.1 (residual chlorine concentration, hydrogen carbonate concentration, chloride ion concentration) of this manual.

In general, the highest risk of water leakage in straight pipes is found in areas joined with screws, which is due to decreasing thickness from screw cutting, and in welded areas, which is due to the effect of heat on the metallic structure. Light-gauge stainless steel pipe used for building equipment has most of such leakage risk in welded areas. Proper work control can prevent defects before they occur. For stainless steel piping, dissimilar metal contact corrosion is the major concern about degradation from corrosion. Thus, proper insulation treatment on coupling areas of pipes is essential to improve corrosion resistance.

Considering the abovementioned points, the expected service life of stainless steel straight pipe is estimated as listed in Table 2.2-5.

Table 2.2-5 Service life of straight pipe[6]

Application	Expected service life	Remarks
For actual water quality	200 years or more	Required to select an appropriate grade, depending on the environment

1. Piping coverage is limited to water supply, hot water supply, cooling water, chilled and hot water, steam, steam return water and firefighting.
2. The water quality shall conform to the water quality standards specified in Chapter 2.9.1 of this manual.
3. Welding shall be done under proper conditions.

Source: Guidelines for Super-Durable All-Stainless Steel Piping System

(3) Expected service life of couplings

The expected service life of couplings is the period until the sealing performance or pressure resistance performance required for water shut-off or flexibility is lost. The service lives of a mechanical pipe coupling and a housing pipe coupling depends on the extent of degradation of the synthetic rubber used to shut the water off.

The service life of synthetic rubber is estimated with the Arrhenius plot method where one property value serves as a representative. The service life can be roughly assessed with the Arrhenius plot method if the assessment only examines heat degradation effects. However, synthetic rubber used in water flowing areas of building equipment to shut off water is constantly exposed to effects from oxidizers such as residual chlorine and hydroxide ion, as well as effects from shearing force accompanied by flowing water. Accordingly, the period of use and other conditions of synthetic rubber must be examined considering composite degrading factors (refer to Table 2.2-6).

This section projects the expected service life of synthetic rubber used in water shut-off area based on the results of the analysis of used specimens collected from the market, a heat aging test by dumbbell specimens, a promoted durability test against residual chlorine and the residual rate of anti-aging agent. Thus, the time of wager leakage from couplings, i.e. the expected service life of couplings, is estimated and shown in Table 2.2-7

For water supply systems, the residual rate of anti-aging agent will fall to approximately 10% after 40 years in service according to the abovementioned tests. Thus, the expected service life is estimated at approximately 50 years. However, synthetic rubber degradation largely depends on the contact surface with flowing water. A type of coupling whose structure enables synthetic rubber to avoid contact with flowing water, which is a coupling where synthetic rubber is enclosed, as shown in Figs. 2.2-2 and 2.2-3, has limited surface contact with flowing water. Assuming that the compression set has no major change from the effects of years in service, the expected service life is estimated at about 50 years, as mentioned earlier. For a coupling whose structure has synthetic rubber in constant contact with flowing water, which is a coupling shown in Fig. 2.2-4, elution of the anti-aging agent from the contact surface will be accelerated. The expected service life is estimated at approximately 20 years.

Concerning effects from residual chlorine, observation shows that, as the concentration increases, the property degradation tends to be facilitated. When residual chlorine in a system where a conditioner was injected exceeds 1 ppm, the expected service life of the system is estimated at approximately 2/3 (approximately 30 years) pursuant to that of the water supply system (approximately 50 years).

For hot-water supply systems, the expected service life will be approximately 15 to 20 years because the physical property change will be two to four times greater when the temperature doubles and because of the test result where the residual rate of the anti- aging agent fell to about 10% after 17 years in service.

Table 2.2-6 Parameters affecting service life of synthetic rubber[6]

Application	Service life	Remarks
Residual chlorine*	Will become about 2/3	Under actual conditions
Water temperature**	Will become about 1/4 to 1/2	Under actual conditions
Acting force***	Little change	Under actual conditions

* Effects must be assumed if the residual chlorine concentration exceeds 1 ppm.
** Effects must be assumed if the water temperature of the hot-water supply system is high.
*** Effects on compression set by acting force are assumed to be small.

Source: Guidelines for Super-Durable All-Stainless Steel Piping System

Table 2.2-7 Expected Service Life of Couplings[6]

Application	Coverage	Surface contacting with flowing water		Remarks
		Small	Large	
Main material	Piping of water supply, hot-water supply, cooling water, hot and cool water, steam, steam return water and fire fighting	200 years or longer		Including material equivalent to SUS 304
Synthetic rubber	Piping of water supply, cooling water, and fire fighting	About 50 years	About 20 years	Affected by the extent of contact with and temperature of flowing water, and by residual chlorine
	Piping of hot-water supply, and chilled and hot water	About 15 to 20 years		

1. The water quality shall conform to the relevant standards in Chapter 2.9.1.
2. Welding shall be done under proper conditions.

Source: Guidelines for Super-Durable All-Stainless Steel Piping System

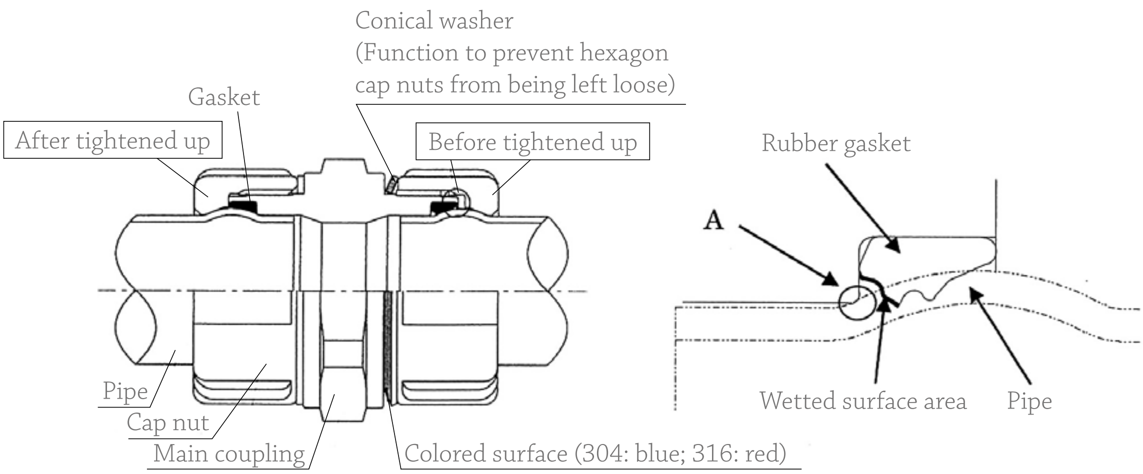

Fig. 2.2-2 Coupling structure whose synthetic rubber does not contact with flowing water I[5]

Source: Technical Development of Super-Durable All-Stainless Steel Piping Systems, Fiscal 2009 Technical Development Report

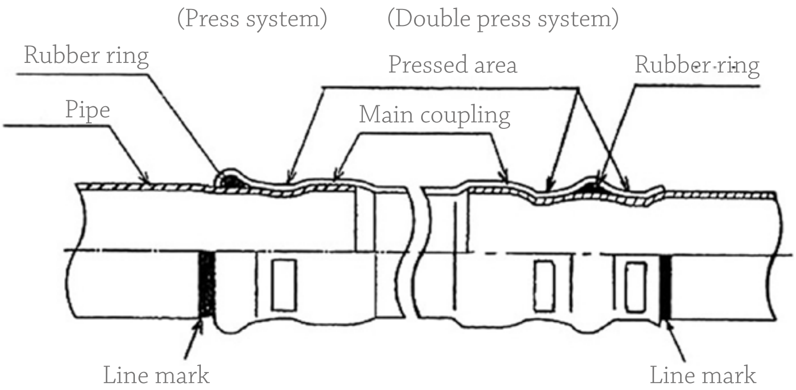

Fig. 2.2-3 Coupling structure whose synthetic rubber does not contact with flowing water II[5]

Source: Technical Development of Super-Durable All-Stainless Steel Piping Systems, Fiscal 2009 Technical Development Report

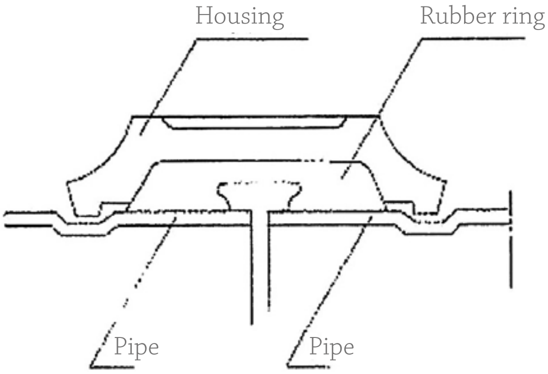

Fig. 2.2-4 Example of coupling structure whose synthetic rubber contacts with flowing water[5]

Source: Technical Development of Super-Durable All-Stainless Steel Piping Systems, Fiscal 2009 Technical Development Report

(4) Valves

The service life of a valve ends when any one of the following fails. The service life depends on the material of the valve selected to match stainless steel piping, proper method of use and maintenance and preservation.

- Pressure resistance: Pressure resistance of components, such as packing and gaskets, other than consumable parts
- Shut-off: Stopping liquid
- Operation: Operating (manipulating) the valve

The legal service life of valves is set to 15 years. Valves, however, have been used for as long as 30 years. Thus, the expected service life of valves should be estimated after pressure resistance, shut-off and operation are considered based on the durability of materials (dissimilar metal contact corrosion between stainless steel and copper alloy, and comparison of corrosion resistance between stainless steel vs. copper alloy and other materials). With this in mind, the corrosion resistance of the materials for valve components stated below was examined in relation to the pressure resistance of the main valve units (body, bonnet), shut-off of the seat (disc, body seat ring), and operation of the stem.

- Body and bonnet related to pressure resistance: Stainless steel, bronze
- Seat related to shut-off:
  Disc—stainless steel, bronze, dezincing resistant brass
  Body seat ring—Stainless steel, bronze, PTFE, synthetic rubber
- Stem related to operation: Stainless steel, dezincing resistant brass

Tables 2.2-8 and 2.2-9 list the results of assessing the expected service life of valves by material after corrosion of copper-alloy valves used in stainless steel piping was examined based on the following data.

- Reference literature on dissimilar metal contact corrosion
- Simulated cyclic corrosion testing
- Examining valve items collected after actual use

In general, valves used for the piping of common units include gate, ball and butterfly valves. If the nominal diameter is 50 A or larger, butterfly valves are usually used because of their light mass weight, outstanding operability and smaller piping space. Thus, valves in these tables are listed by nominal diameter.

Table 2.2-8 Assessment of durability of nominal diameter 50 A or smaller valves (gate valve or ball valve)[6]

Type of valve	Main unit	Seat		Stem	Assessment
		Disc	Body seat ring		
Gate valve	Stainless steel	Stainless steel	Stainless steel	Stainless steel	◎
	Bronze	Bronze or dezincing resistant brass	Bronze	Dezincing resistant brass	○
Ball valve	Stainless steel	Stainless steel	PTFE	Stainless steel	◎
	Bronze	Stainless steel or dezincing resistant brass	PTFE	Dezincing resistant brass	○

◎ : Indicates that the valve has corrosion resistance equivalent to 40 years of expected service life.
○ : Indicates that minor corrosion may occur, depending on the water quality.

Source: Guidelines for Super-Durable All-Stainless Steel Piping Systems

Table 2.2-9 Assessment of durability of nominal diameter 50 A or larger valves (butterfly valve)[6]

Type of valve	Body	Seat		Stem	Assessment
		Disc	Body seat ring		
Centric	Aluminum alloy, etc. (surface not wetted)	Stainless steel	Synthetic rubber	Stainless steel	△
Eccentric	Stainless steel	Stainless steel	PTFE	Stainless steel	◎

◎ : Indicates that the valve has corrosion resistance equivalent to 40 years of expected service life.

△ : Indicates that the durability of the rubber used for the butterfly valve is 10 to 15 years.

Source: Guidelines for Super-Durable All-Stainless Steel Piping Systems

2.3 Economical and Environmental Assessment of Stainless Steel Piping

2.3.1 Economical assessment of stainless steel pipe for ordinary piping

Cost planning is essential for implementing a project. Calculating life cycle cost (LCC), including planning, designing, construction, maintenance and disposal, besides estimating initial construction cost (installation cost) is also important.

(1) Installation cost

Estimating installation costs is one of the processes for calculating the total construction costs in order to realize a project. In an earlier phase such as master planning, both installation costs for stainless steel piping and those for other types of piping are sometimes estimated for comparison to develop decision-making criteria to select pipes.

In this section, the explanation is limited to piping works, one part of the above-mentioned initial estimation. The estimation is intended to prepare a detailed quantity survey based on the design drawing by measuring and calculating lengths and quantities of pipe and valves in the specifications and multiplying unit prices by quantities and obtaining results. In many cases, unit prices are composite unit prices covering labor costs including delivery and pipe-laying, in addition to material costs. Testing costs, temporary overhead expenses, regular overhead expenses, etc. must also be covered and totaled in the prior calculation mentioned earlier in preparing a detailed quantity survey.

The standards for composite unit prices used for public works are called the "Integration Standard and Standard Unit Price for Public Construction Works." In many cases, the standards are correspondingly applied to construction works in the private sector. For piping, diameter-based tables are prepared by pipe material, type of couplings for piping and by construction area of piping.

Tables 2.3-1 to 2.3-3 list yardsticks for preparing composite unit prices of stainless steel piping. Pipe unit prices and labor costs include published market prices, while other costs are assumed to account for 10 to 20% of labor costs.

Table 2.3-1 Stainless steel pipe for ordinary piping (water supply and hot-water supply; compression and press type)[7]

Item	Unit	Name	Unit	Nominal diameter													
				13^{SU}	20	25	30	40	50	60	-	-	-	-	-	-	-
Indoor general piping	m	Pipe	m	1.10													
		Coupling		Complete set (pipe unit price × 1.45)													
		Sealant, etc.		-													
		Metallic support		Complete set (pipe unit price × 0.10)													
		Plumber	Worker	0.052	0.071	0.090	0.106	0.132	0.149	0.185	-	-	-	-	-	-	-
		Chipping and patching		Complete set (labor cost × 0.08)													
		Other		Complete set													
Piping for machine rooms and restrooms	m	Pipe	m	1.10													
		Coupling		Complete set (pipe unit price × 2.30)													
		Sealant, etc.		-													
		Metallic support		Complete set (pipe unit price × 0.10)													
		Plumber	Worker	0.062	0.085	0.108	0.127	0.158	0.179	0.222	-	-	-	-	-	-	-
		Chipping and patching		Complete set (labor cost × 0.08)													
		Other		Complete set													
Outdoor piping (aerial, in culverts, in multi-purpose underground conduits)	m	Pipe	m	1.05													
		Coupling		Complete set (pipe unit price × 1.25)													
		Sealant, etc.		-													
		Metallic support		Complete set (pipe unit price × 0.10)													
		Plumber	Worker	0.047	0.064	0.081	0.095	0.119	0.134	0.167	-	-	-	-	-	-	-
		Chipping and patching		-													
		Other		Complete set													
Underground piping	m	Pipe	m	1.05													
		Coupling		Complete set (pipe unit price × 0.90)													
		Sealant, etc.		-													
		Metallic support		-													
		Plumber	Worker	0.036	0.050	0.063	0.074	0.092	0.104	0.130	-	-	-	-	-	-	-
		Chipping and patching		-													
		Other		Complete set													

Source: Public Construction Works Standard Unit Price Estimation Standards

Table 2.3-2 Stainless steel pipe for ordinary piping (water supply and hot-water supply; cexpanding type)[7]

Item	Unit	Name	Unit	Nominal diameter													
				13^{SU}	20	25	30	40	50	60	-	-	-	-	-	-	-
Indoor general piping	m	Pipe	m	1.10													
		Coupling		Complete set (pipe unit price × 1.45)													
		Sealant, etc.		-													
		Metallic support		Complete set (pipe unit price × 0.10)													
		Plumber	Worker	0.052	0.071	0.090	0.106	0.132	0.149	0.185	-	-	-	-	-	-	-
		Chipping and patching		Complete set (labor cost × 0.08)													
		Other		Complete set													
Piping for machine rooms and restrooms	m	Pipe	m	1.10													
		Coupling		Complete set (pipe unit price × 2.30)													
		Sealant, etc.		-													
		Metallic support		Complete set (pipe unit price × 0.10)													
		Plumber	Worker	0.062	0.085	0.108	0.127	0.158	0.179	0.222	-	-	-	-	-	-	-
		Chipping and patching		Complete set (labor cost × 0.08)													
		Other		Complete set													
Outdoor piping (aerial, in culverts, in multi-purpose underground conduits)	m	Pipe	m	1.05													
		Coupling		Complete set (pipe unit price × 1.25)													
		Sealant, etc.		-													
		Metallic support		Complete set (pipe unit price × 0.10)													
		Plumber	Worker	0.047	0.064	0.081	0.095	0.119	0.134	0.167	-	-	-	-	-	-	-
		Chipping and patching		-													
		Other		Complete set													
Underground piping	m	Pipe	m	1.05													
		Coupling		Complete set (pipe unit price × 0.90)													
		Sealant, etc.		-													
		Metallic support		-													
		Plumber	Worker	0.036	0.050	0.063	0.074	0.092	0.104	0.130	-	-	-	-	-	-	-
		Chipping and patching		-													
		Other		Complete set													

Source: Public Construction Works Standard Unit Price Estimation Standards

Table 2.3-3 Stainless steel pipe for ordinary piping (chilled and hot water supply, water supply, hot-water supply and firefighting; housing pipe couplings)[7]

Item	Unit	Name	Unit	Nominal diameter														
				-	-	-	-	-	-	60SU	75	80	100	125	150	200	250	300
Indoor general piping	m	Pipe	m	1.10									1.05					
		Coupling		Complete set (pipe unit price × 1.47)									Complete set (pipe unit price × 1.10)			Complete set (pipe unit price × 0.74)		
		Sealant, etc.		-														
		Metallic support		Complete set (pipe unit price × 0.10)														
		Plumber	Worker	-	-	-	-	-	-	0.106	0.133	0.173	0.256	0.302	0.368	0.485	0.653	0.787
		Chipping and patching		Complete set (labor cost × 0.08)														
		Other		Complete set														
Piping for machine rooms and restrooms	m	Pipe	m	1.10									1.05					
		Coupling		Complete set (pipe unit price × 2.32)									Complete set (pipe unit price × 1.69)			Complete set (pipe unit price × 1.13)		
		Sealant, etc.		-														
		Metallic support		Complete set (pipe unit price × 0.10)														
		Plumber	Worker	-	-	-	-	-	-	0.127	0.159	0.207	0.307	0.363	0.441	0.582	0.784	0.944
		Chipping and patching		Complete set (labor cost × 0.08)														
		Other		Complete set														
Outdoor piping (aerial, in culverts, in multi-purpose underground conduits)	m	Pipe	m	1.10									1.05					
		Coupling		Complete set (pipe unit price × 1.24)									Complete set (pipe unit price × 0.94)			Complete set (pipe unit price × 0.68)		
		Sealant, etc.		-														
		Metallic support		Complete set (pipe unit price × 0.10)														
		Plumber	Worker	-	-	-	-	-	-	0.095	0.119	0.155	0.230	0.272	0.331	0.437	0.588	0.708
		Chipping and patching		-														
		Other		Complete set														

Source: Public Construction Works Standard Unit Price Estimation Standards

Table 2.3-4 lists yardsticks for preparing composite unit prices for valves and other piping accessories.

Table 2.3-4 Yardsticks for preparing composite unit prices of valves and other piping accessories[7]

Item	Unit	Name	Unit	Nominal diameter													
				15A	20	25	32	40	50	65	80	100	125	150	200	250	300
Gate valve, globe valve, check valve	Pieces	Gate valve, globe valve	Pieces	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
		Plumber	Worker	0.07	0.08	0.09	0.11	0.13	0.16	0.28	0.34	0.40	0.48	0.65	0.72	0.90	1.10
		Other	Sets	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Source: Public Construction Works Standard Unit Price Estimation Standards

Figures 2.3-1 and 2.3-2 list comparisons of composite unit prices by pipe material for indoor general specifications. The figures indicate composite unit prices per inside diameter and unit flow rate (500 Pa of unit friction loss). Stainless steel pipe is a cost-efficient material when compared with vinyl chloride lined steel pipe commonly used for water supply and with heat-resistant vinyl chloride lined steel pipe commonly used for hot-water supply.

For chilled and hot water piping, stainless steel pipe is also a cost-efficient material when compared with carbon steel pipe for ordinary piping.

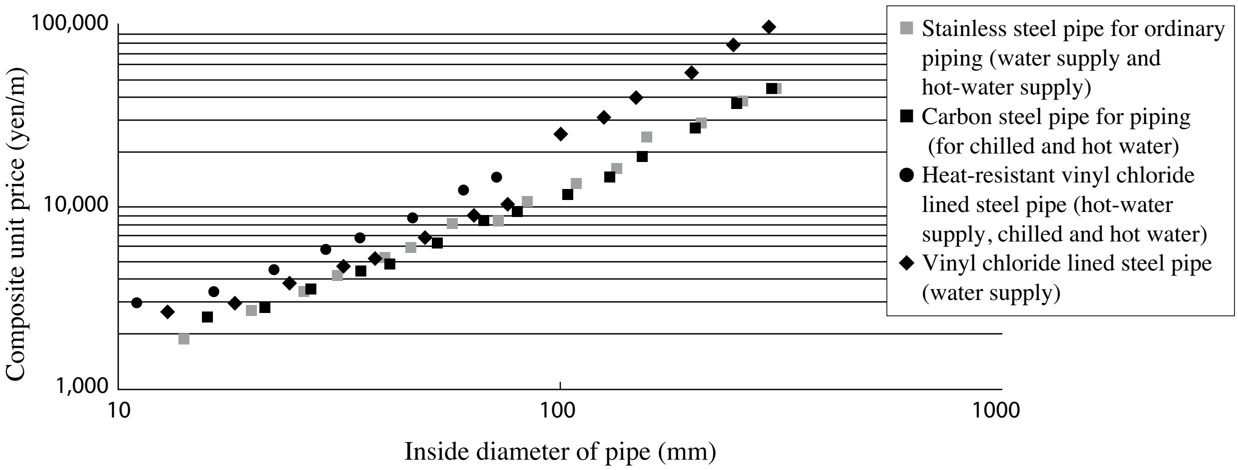

Fig. 2.3-1 Composite unit price per inside pipe diameter[8]

1. For stainless steel pipe couplings for ordinary piping, pipes of diameter 60Su or under shall adopt a compression coupling, while those of diameter 75Su or above shall adopt a housing coupling. For other pipes, those of diameter 80Su or under shall adopt a screw, while those of diameter 100Su or above shall adopt a flange.

Prepared by: Naoto Obara based on Building Equipment Works Estimation Practical Manual 2010, Zennichi Publishing Co.

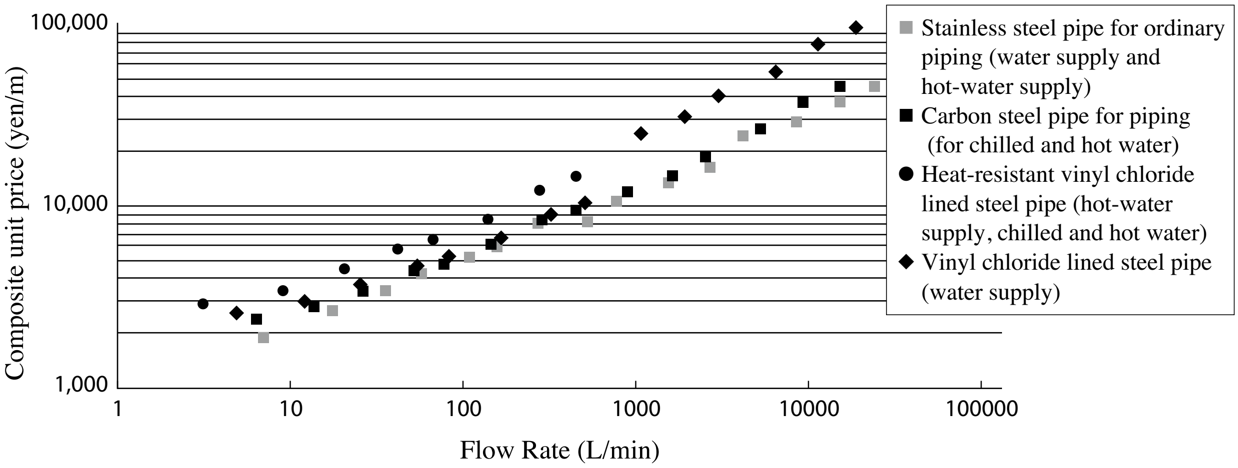

Fig. 2.3-2 Composite unit price per unit flow rate (500 Pa of unit friction loss)[8]

1. For stainless steel pipe couplings for ordinary piping, pipes of diameter 60Su or under shall adopt a compression coupling, while those of diameter 75Su or above shall adopt a housing coupling. For other pipes, those of diameter 80Su or under shall adopt a screw, while those of diameter 100Su or above shall adopt a flange.

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(2) Life cycle cost

Life cycle cost (LCC) is a method for complete economic assessment by aggregating total costs that accrue in a process of planning, design, construction, maintenance and demolition of a building and reusing the building materials.

The LCC method was developed in the 1960s in the United States and has since been introduced elsewhere. A number of studies have been made on LCC in Japan as well. ***Life Cycle Cost for Buildings***, a book published in Japan (Building Maintenance and Management Center, 1993) describes the calculation methods. Rough and detailed calculation methods are shown here. For stainless steel piping, the database in the book refers to installation cost and removal and renewal coefficients of 30 A.

Since equipment maintenance costs are expensive and will reach approximately three times greater than the construction cost, LCC is useful for systematic comparison. Among many estimation methods, the Equivalent Annual Cost (EAC) method and the Net Present Value (NPV) method have been widely adopted. Because these methods are for comparing costs, the assumption is that no difference in performance exists among the proposed projects.

The EAC method considers a proposed project with a lesser cost as economically advantageous among those compared. Specifically, it compares annual costs of proposed projects, which are "the amount for a certain year that aggregates the cost allocated to the year to recover a portion of the invested amount (capital recovery ratio), water, gas and electricity charges and maintenance costs, etc. that are required to maintain the subject equipment for that year." If the proposed project has no additional investments and investment is made only once in the initial year or if the replacement of equipment is under study, this method is sufficient to compare costs. Annual cost for some equipment is available with the following formula:

$$A = f\,[C + E/f - S/(1+i)^n] = f\,[C - S/(1+i)^n] + E$$

If the price fluctuation rate is considered,

$$A = f\,[C + [(1+k)\{(1+i)^n - (1+k)^n\} / \{(i - k)(1+i)^n\}]\,E - S(1+k)^n/(1+i)^n]$$

However, if $i = k$,

$$A = f\,(C + nE - S)$$

Where,

- A : Annual cost
- C : Construction cost (total of equipment installation, site preparation and their indirect expenses)
- S : Net residual value (proceedings obtained when the equipment is disposed of after n years)
- f : Capital recovery factor
  $f = i\,(1+i)^n / (1+i)^n - 1$
- i : Interest rate
- k : Price fluctuation rate
- n : Period of operating the equipment (average working service life)
- E : Annual expenses

As to piping work, costs for construction, repair and removal as well as costs for maintenance and operation are aggregated. Stainless steel is characterized as having a material property that offers long service life and is highly recyclable. Stainless steel can be cost-competitive on a life cycle basis, leading to effective LCC.

The number of planned renewal years for the main unit of stainless steel piping could reach 200 years if proper welding and control of water quality, etc. are provided. For minimizing LCC, at the same time, planning renewals of shorter service life items, such as synthetic rubber used for couplings and valves, and preparing proper plans on related additional jobs is also necessary.

It is prudent to study options by preparing a schedule to replace couplings and valves that would make the most of stainless steel pipes with long service life, and by conducting an LCC assessment of the economic stainless steel piping.

Figures 2.3-3 and 2.3-4 show LCC unit prices (yen/year/m). These figures are prepared assuming that the piping is made to indoor general specifications, the service life of the building is 100 years and the piping service life set by BELCA (Building and Equipment Long-Life Cycle Association) in Japan. However, the stainless steel piping with compression type coupling (a type of mechanical coupling) is supposed to have a service life of 50 years. Figure 2.3-3 lists composite unit prices based on inside diameter, while Fig. 2.3-4 lists composite unit prices based on flow rate.

Compared with vinyl chloride lined steel pipe used for most water supply and heat-resistant vinyl chloride lined steel pipe used for hot-water supply, stainless steel pipe is an outstanding material. Furthermore, compared with carbon steel pipe used for most chilled and hot water piping, stainless steel pipe is still outstanding.

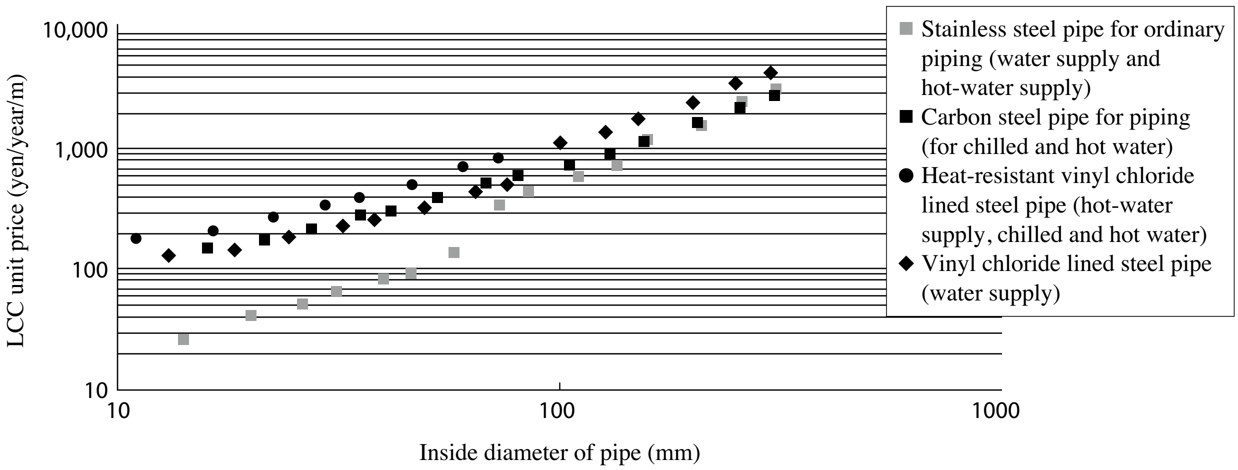

Fig. 2.3-3 LCC per inside diameter of pipe[8, 9]

1. For stainless steel pipes couplings for ordinary piping, pipes of diameter 60Su or under shall adopt a compression coupling, while those of diameter 75Su or above shall adopt a housing coupling. For other pipes, those of diameter 80Su or under shall adopt a screw, while those of diameter 100Su or above shall adopt a flange.

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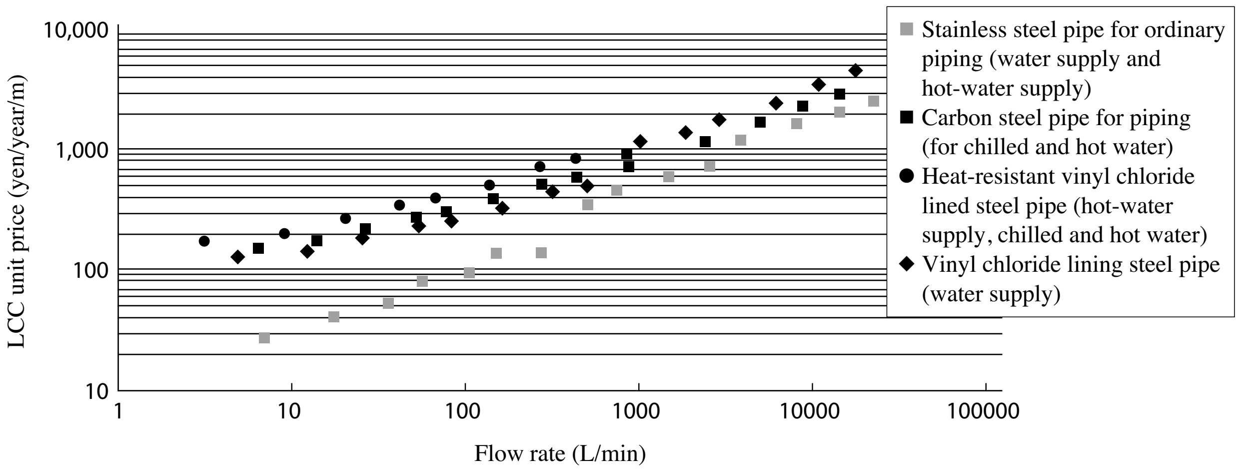

Fig. 2.3-4 LCC per unit flow rate (500 Pa of unit friction loss) [8, 9]

1. For stainless steel pipes couplings for ordinary piping, pipes of diameter 60Su or under shall adopt a compression coupling, while those of diameter 75Su or above shall adopt a housing coupling. For other pipes, those of diameter 80Su or under shall adopt a screw, while those of diameter 100Su or above shall adopt a flange.

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2.3.2 Environmental assessment of stainless steel pipe for ordinary piping

Environmental impact from human beings has spread from local settings in the past to a global scale these days, bringing about emerging global environmental problems. Construction and operation are also required to take proper and imperative measures.

Japan has introduced the *Law Concerning Rational Use of Energy* (commonly known as the *Energy Conservation Law*) in the building sector. The law defines coefficients, such as PAL (Perimeter Annual Load) and CEC (Coefficient of Energy Consumption for air-conditioning, hot-water supply, power, etc.). In recent years, the law has expanded the scope of coverage and areas, developing better assessment methods for promoting energy conservation.

Assessing reduction in energy consumption alone is insufficient for reducing the load on the global environment. Making environmental assessments of reductions in global warming gases, such as CO_2, NOx and SOx, and in waste volume is useful too. Assessing CO_2 emissions has prevailed as an index because CO_2 is viewed as a global warming gas and having the highest impact on global warming.

In assessing the environmental load of materials and equipment, simply assessing global warming gas emissions upon the completion of a building is insufficient. Broader assessment that covers operation, disposal and recycling of materials and equipment is necessary. Such methods include life cycle assessment (LCA) and life cycle CO_2 ($LCCO_2$).

Stainless steel, having long service life, is a semi-permanently reusable metal. Stainless steel pipes, when adopted, will contribute to reducing the environmental load, such as industrial waste and CO_2 emissions.

Environmental advantages of stainless steel can be assessed with $LCCO_2$. The concept and method of this environmental assessment are detailed in ***the Manual for Measures to Reduce Environmental Load from Heating, Air-Conditioning and Sanitary Equipment*** compiled by the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan.

(1) Basic unit of production of global warming gasses

Today, there are two types of basic units of global warming gasses such as CO_2, NOx and SOx. One type is based on an Input-Output table prepared by the Ministry of Internal Affairs and Communications. The second type, which is based on the summation method, is prepared by material producers and member organizations in the industry.

Since the Input-Output table is based on macro analysis, the table has some limits in calculating details. Therefore, the summation method is considered recommendable where available.

Table 2.3-5 lists basic units of production of global warming gasses from major piping components and stainless steel pipe. As far as stainless steel pipe goes, no difference exists in basic units of production between the method by Input-Output table and the summation method.

Table 2.3-5 Basic units of global warming gasses from pipes and valves[9]

Piping material	Summation method				Method by Input-Output table			
	Energy (MJ/kg)	CO_2 (kg·CO_2/kg)	SO_2 (kg·SO_2/kg)	NO_2 (kg·NO_2/kg)	Energy (MJ/kg)	CO_2 (kg·CO_2/kg)	SO_2 (kg·SO_2/kg)	NO_2 (kg·NO_2/kg)
Unplasticized vinyl chloride lined pipe	23.520	1.533	0.002608	0.004947	22.631	1.497	0.00265	0.005195
Stainless steel pipe		2.67	0.004742	0.009443	40.457	2.683	0.004746	0.009451
Unplasticized polyvinyl chloride pipe	27.518	1.561	0.00206	0.002267	50.517	3.148	0.004408	0.00702
Crosslinked polyethylene pipe	40.092	2.167	0.003162	0.002903	-	-	-	-
Polybutene pipe	25.820	3.863	0.00469	0.00583	-	-	-	-
Copper pipe	-	-	-	-	48.947	3.119	0.005589	0.006205
Carbon steel pipe for piping	-	-	-	-	22.289	1.488	0.002612	0.00511
Lead pipe	-	-	-	-	31.487	2.78	0.003433	0.004007
Cast iron pipe	-	-	-	-	30.472	2.368	0.003224	0.005238
Bronze valve	63.242	3.3258	0.0023	0.0023	-	-	-	-
Brass valve	42.686	2.3554	0.0014	0.0011	-	-	-	-
Cast iron valve	29.563		0.012	0.0013	-	-	-	-
Ductile valve	29.584	1.458	0.025	0.026	-	-	-	-
Stainless steel valve	66.213	3.5625	0.0026	0.0029	-	-	-	-
Aluminum butterfly valve	15.062	8.8469	0.052	0.3443	-	-	-	-

Source: Environmental Preservation Design Manual for Building Equipment

(2) Life Cycle CO_2 ($LCCO_2$)

The International Organization for Standardization (ISO) defines in ISO 14042 (*Environmental management—Life cycle assessment—Life cycle impact assessment*) and ISO 14043 (*Environmental management—Life cycle assessment—Life cycle interpretation*) that $LCCO_2$ is a technique of life cycle assessment (LCA) where a quantitative study on the environmental impact is conducted through the life cycle of a product ranging from collection of the raw and processed materials to production, use and disposal. Japan has introduced JIS Q 14042 and JIS Q 14043 standards corresponding to the ISO standards mentioned above.

It has become common to evaluate CO_2 emissions from building equipment by applying $LCCO_2$, an LCA technique, which conducts total assessment of CO_2 emitted from raw and processed materials, during planning, design, construction and operation, and from repair and disposal of a building.

Figures 2.3-5 and 2.3-6 list $LCCO_2$ (CO_2 kg/m) per inside diameter and per unit flow rate (500 Pa of unit friction loss) of stainless steel pipe. These figures assume that the piping is made to indoor general specifications, the service life of the building is 100 years and the service life of the piping is set by BELCA. The service life of stainless steel pipe on which mechanical couplings are mounted is assumed as 50 years.

Compared with vinyl chloride lined steel pipe used for most water supply and heat-resistant vinyl chloride lined steel pipe used for most hot-water supply, stainless steel pipes are an outstanding material in terms of $LCCO_2$. Compared with carbon steel pipes used for most piping, stainless steel pipe is outstanding in chilled and hot water supply.

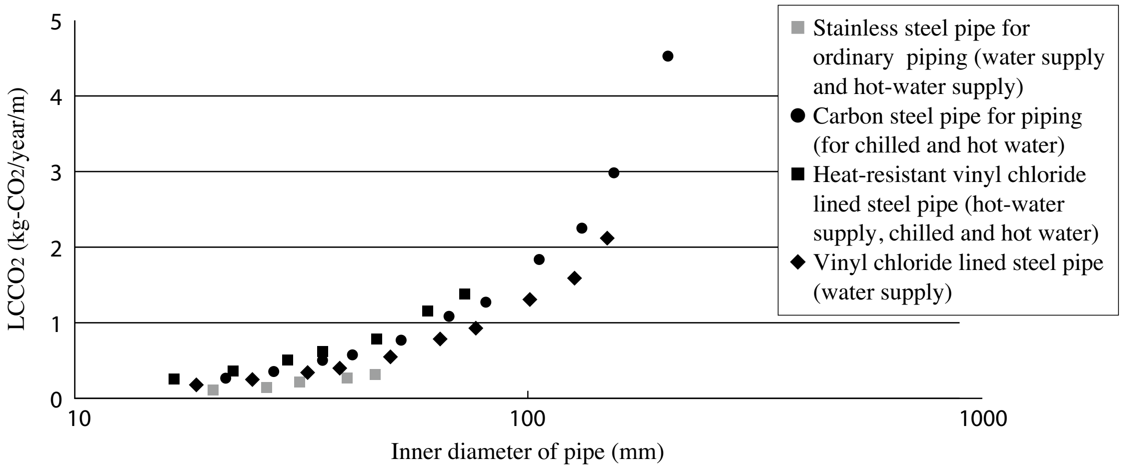


Fig. 2.3-5 LCCO$_2$ per inner diameter of pipe[9]

1. For stainless steel pipes couplings for ordinary piping, pipes of diameter 60Su or under shall adopt a compression coupling, while those of diameter 75Su or above shall adopt a housing coupling. For other pipes, those of diameter 80Su or under shall adopt a screw, while those of diameter 100Su or above shall adopt a flange.

Prepared by: Naoto Obara according to the Manual for Environmental Preservation Design of Building Equipment, p. 241. However, LCCO$_2$ is recalculated based on the assumption that compression type stainless steel pipe for ordinary piping has a service life of 50 years.

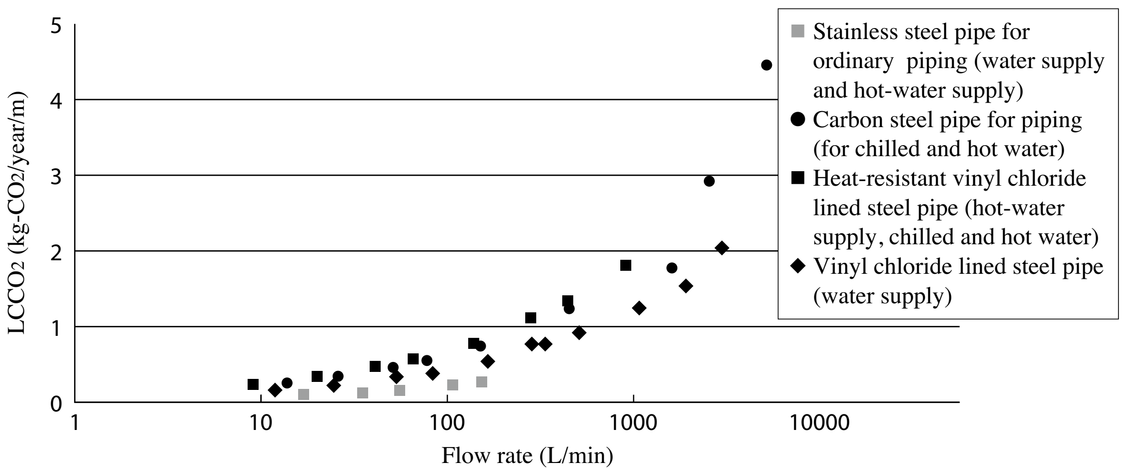


Fig. 2.3-6 LCCO$_2$ per unit flow rate (500 Pa of unit friction loss) [9]

1. For stainless steel pipes couplings for ordinary piping, pipes of diameter 60Su or under shall adopt a compression coupling, while those of diameter 75Su or above shall adopt a housing coupling. For other pipes, those of diameter 80Su or under shall adopt a screw, while those of diameter 100Su or above shall adopt a flange.

Prepared by: Naoto Obara according to the Manual for Environmental Preservation Design of Building Equipment, p. 241. However, LCCO$_2$ is recalculated based on the assumption that compression type stainless steel pipe for ordinary piping has a service life of 50 years.

2.3.3 Recycling stainless steel pipe for ordinary piping

(1) The world is changing rapidly from a mass-consumption society to a recycling society.

Stainless steel, all of which can be recycled, is a precious resource in the coming recycling society. Recycling stainless steel piping should be promoted to save the expensive metal.

Since stainless steel is rust-resistant, almost all of it can be recycled. Stainless steel products can be melted and made into new stainless steel over and over again. Some 50% of stainless steel products, including stainless steel piping, are made of scrapped stainless steel.

Stainless steel contains many precious expensive metals, including chromium and nickel for improved corrosion resistance. Compared with remnants and scraps of other pipe materials, those of stainless steel can be sold at a high price to recycling dealers. In some cases, however, grades of stainless steel must be identified.

Stainless steel is a valuable resource, offers long service life, and is semi-permanently recyclable. Adopting stainless steel piping means leaving a precious asset for the future and reducing the environmental load, such as industrial waste and CO_2 emissions.

(2) Recycling stainless steel piping will begin, in reality, from now.

Most food processing companies and chemical industry related companies, which have used stainless steel for production equipment, and processing companies that have used stainless steel as raw material for products, have naturally recycled stainless steel. Over 80% of stainless plates/sheets and strips have been collected.

Over 30 years have passed since stainless steel pipes and couplings were first used for piping in buildings. Most such durable stainless steel pipes are still in use and yet to be scrapped. Thus, the recycling of stainless steel piping is about to begin from now.

(3) Many stainless steel products are already in the recycling system. The system is readily available for use. Specifically, stainless steel has been collected by member companies of the Japan Iron And Steel Recycling Institute and delivered to electric furnace manufacturers. Stainless steel has already established a fine recycling system.

2.4 Piping Planning

2.4.1 Characteristics of and points for piping planning

Piping planning involves the style and structure of the building as well as the equipment, which are all considered as the work proceeds from basic planning to actual design. Here, characteristics of stainless steel pipe for ordinary piping are discussed from the design perspective.

Table 2.4-1 is a checklist of what needs to be decided in piping planning. Among the items in this table, those with particular relevance to stainless steel pipe for ordinary piping are the qualities, diameters, wall thicknesses of the pipes, shapes of the couplings and where they are used, how the thermal expansion and contraction of the pipes is absorbed and the pipes are supported, and the thermal insulation and gasket specifications.

Regarding the pipe material, a hasty decision to accept stainless steel pipe without proper understanding of the features could result in the inaccurate interpretation that it is a completely problem-free pipe material. This has been referred to in the Chapter on the basics, but the main characteristics of stainless steel pipe for piping are that, because it is austenitic stainless steel, it has work hardening rather than quench hardening and is susceptible to intergranular corrosion in the temperature range from 400° to 850°C. While weldability is excellent, due care should be exercised to perform welding in a sufficiently inactive atmosphere. Also, an allowable bent radius, which must not be less than 4D, should be observed. Properly speaking, after welding areas reach the temperature of 1000° - 1100°C, they should be given a subsequent solution anneal with quick cooling. As long as the above-described precaution is taken though, this step may be dispensed with for the kind of piping covered by this manual. A characteristic physical property of stainless steel pipe is that it has about the same coefficient of thermal expansion as copper pipe and expands a great deal. This is relevant for deciding on piping routes and support methods. A characteristic mechanical property of stainless steel is that it is very hard. Its Brinell hardness is about twice that of carbon steel, and it has superior anti-cavitation properties.

Concerning pipe diameters and thicknesses, the aforementioned size designations correspond to the outside diameters of copper pipes and carbon steel pipes. The designations do not mean exactly what they mean for conventional carbon steel pipes, and stainless steel pipes are light-gauge. Their thin walls mean that they are lighter and easier to transport. For deciding on the piping sizes, their larger inside diameters than carbon steel pipes of the same outside diameters, along with their smoother inside surface, are important. In terms of design, due to these factors, stainless steel pipe provides a greater flow volume than carbon steel pipe with the same outside diameters and pressure loss.

Couplings are presently subdivided, as a JSSA standard, into mechanical and housing couplings, while butt-welded pipe fittings are specified in the JIS standard. Mechanical pipe couplings are classified into six sub-types, having specific characteristics. (For such characteristics, refer to Chapter 3. Construction of this manual.) Commonly used flange joints are of the loose flange type that uses a lap joint (stub end joint). Loose flange joining with flanged pipe ends has recently come into use. This type of joining is carried out by flanging the pipe end at low or high temperatures (150° - 300°C) and a loose flange is used to process the pipe ends for joining, in the same manner as for the lap joint. Although no such specifications or standards as JIS, SHASE or SAS are available, some flare coupling producers are authorized by *the Regulations for Review, Certification and Operation Authorization of Construction Technology Developed by Private Sector* (*Notification No. 1451 of the Ministry of Construction on July 28, 1987*) defined by the Ministry of Construction, which is currently the Ministry of Land, Infrastructure, Transport and Tourism.

Which type of coupling to select depends on what characteristics are desired, which will involve considering the following points. First, for corrosion-related characteristics, couplings should not have crevices, they should not have parts having excessive residual stress, and during construction they should not be exposed for long time to a temperature range that would induce intergranular corrosion susceptibility.

Because of the high coefficient of thermal expansion of stainless steel pipe, a larger amount is required for displacement absorption than with carbon steel pipe. As a result, the position of the expansion joints as well as the position of anchors (fixed supports) and restraints (supports that bind at right angles to the axis) should be carefully considered.

Regarding heat insulation and gaskets, there should be no dissolution of halogen ions (especially chloride ions) from the material at parts where there is moisture condensation or contact with the liquid. With actual heat insulation materials, this need not be thought of as a fatal problem. During the design process it suffices to bring up this point when consulting with the manufacturers of the heat insulation and gasket materials. In terms of the gasket material, as stated above, a structure without crevices should be selected.

Table 2.4-1 Decision criteria and points for piping design of stainless steel pipe for ordinary piping[10]

Decision criteria	Characteristic as stainless steel pipe	Points
(1) Pipe material	Has superior corrosion resistance. If used incorrectly, halogen ions may cause local corrosion such as pitting, crevice corrosion and stress corrosion. Nonmagnetic.	Cannot be bent with a radius smaller than 4 times the diameter. Hand welding requires care. Adversely affected by halogen ions; care is required for use in sea or well water. (Corrosion could be caused by water components.)
(2) Pipe diameter	Su designation. Large inside diameter. Smooth inside surface. Occasionally the pipe diameter is decreased by one or two sizes.	Care is required when matching copper and steel pipe. Maximum flow speed is 3.5 m/s, but beware of water hammer.
(3) Pipe thickness	Thin. Light.	When handling, be careful not to cause any deformation.
(4) Piping route	As with conventional pipe.	
(5) Arrangement of pipe	As with conventional pipe.	
(6) Method of branching and confluence	As with conventional pipe.	
(7) Shape of couplings and where they are used	Classified into mechanical couplings, housing couplings and butt welding pipe fittings.	Dissimilar metals: insulate well to avoid galvanic effects. Welding: form adequate inner surface gas shield and control heat input.
(8) Support method	Could be galvanic corrosion.	Insulation support.
(9) Shape of valves and where they are used	As with conventional pipe.	Attention required for the valve material and the installation method. Consider using valves made of stainless steel.
(10) Absorption of pipe's thermal expansion and contraction	Expands (displacement is large). Expands and contracts at the same level to copper pipe.	Measures are taken to correctly ascertain the degree of expansion and contraction and absorb it. Observe the materials of expansion joints (made of SUS) and understand quantities of expansion and contraction, etc.
(11) Insulation specifications	Stainless steel adversely affected by halogen ions.	There must be no solution of chlorine ions (Especially, watch the pipes for condensation, leakage and water infiltrating from outside.)
(12) Method of drain removal and air removal	As with conventional pipe.	
(13) Gasket specifications	Crevice corrosion can occur with gaskets that have high halogen ion content.	Use those intended exclusively for use with stainless steel.

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

2.5 Pipe Diameter

2.5.1 Flow velocity standards

In deciding the pipe diameter, the equal friction loss method is often used. The pipe diameter for a flow volume is selected by setting the unit pressure loss due to friction to a constant value. As the flow volume increases, the flow velocity increases too. Here methods are also used to limit the flow velocity and minimize its effects on erosion and water hammer.

Figure 2.5-1 shows flow velocity standards for different types of pipe. Flow velocities within the areas indicated with the solid lines in the figure are generally applied. Since stainless steel pipes for ordinary piping are outstanding in cavitation and corrosion resistance, they can adopt a flow velocity faster than that of other steel pipes. The upper limit of flow velocity for stainless steel pipe is set at 3.5 m/sec.

However, determining the standards for setting flow velocity is very difficult. Flow velocity standards can be determined based on the pipe diameter or area where the piping is located, or based on the corresponding number of annual operation hours although it is not indicated in the figure. In reality, flow velocity standards are determined in reference to all such parameters. However, as evident from Fig. 2.5-1, the smaller the pipe diameter is, the lower the flow velocity must be so that the unit pressure loss due to friction does not increase. Combining the abovementioned equal friction loss method with an upper value for the flow velocity is a practical method. Naturally the smaller the pipe diameter, the lower the flow velocity that can be selected.

Type			Flow velocity within pipe (m/s)
Air conditioning piping	Stainless steel pipe for ordinary piping		0.6 – 2.0 – 3.5
	Steel pipe	≥ 125A	2.1 – 2.8
		50 – 100A	1.2 – 2.1
		≤ 40A	0.6 – 1.2
		Pump suction pipe	1.4 – 2.1
	Copper pipe		0.6 – 1.5 – 1.8
Water and hot water supply piping	Stainless steel pipe for ordinary piping		0.6 – 2.0 – 3.5
	Steel pipe	Ordinary steel pipe	0.5 – 1.2
		Pump suction pipe	0.5 – 1.0
		Pump discharge pipe	1.5 – 2.0
	Copper pipe		0.5 – 1.5

Fig. 2.5-1 Flow velocity standard for pipe materials[10]

1. To use stainless steel pipe for ordinary piping at a flow rate of 2.0 m/sec or faster, noise, vibration, water hammer, pressure power and other conditions must be considered.

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition. The figure has been modified.

Table 2.5-1 Comparison of flow rate (L/min) between stainless steel pipe for ordinary piping and other types of pipe, using the Hazen-Williams formula[10]

Type of pipe	Basis for setting flow volume	Nominal diameter (upper row: stainless steel pipe for ordinary piping, middle row: carbon steel pipe for ordinary piping, polyvinyl chloride lined steel pipe, lower row: copper pipe)														
		13su	20	25	30	40	50	60	75	80	100	125	150	200	250	300
		15A	20	-	25	32	40	50	65	80	100	125	150	200	250	300
		13A	20	25	-	32	40	50	65	80	100	125	150	–	–	–
Stainless steel pipe for ordinary piping (C=150*1)	by v=2.0	-	-	-	-	-	-	-	-	683	1,147	1,738	2,389	4,168	6,455	9,204
	by R=440	7	16	34	53	101	144	257	486	-	-	-	-	-	-	-
	by v=3.5	-	-	-	-	-	-	-	-	-	-	-	-	7,294	11,296	16,107
	by R=440	7	16	34	53	101	144	257	486	720	1,424	2,461	4,180	-	-	-
Carbon steel pipe for ordinary piping (C=100*2)	by v=2.0	-	-	-	-	-	-	-	-	-	-	-	2,270	3,949	6,090	8,750
	by R=440	6	13	-	25	49	73	138	265	417	841	1,488	-	-	-	-
Polyvinyl chloride lined steel pipe (C=130*3)	by v=2.0	-	-	-	-	-	-	-	-	-	967	1,515	2,126	3,759	5,806	8,409
	by R=440	5	11	-	24	50	78	153	306	475	-	-	-	-	-	-
Copper pipe (C=130*3)	by v=1.4	-	-	-	-	-	-	-	265	380	660	1,025	1,470	2,580	4,006	5,745
	by R=440	6	15	30	-	51	79	160	-	-	-	-	-	-	-	-

v: flow velocity (m/s), R: unit pressure loss due to friction (Pa/m), C: flow coefficient

1. Japan Stainless Steel Association
2. Heating and Air-Conditioning Equipment in *Handbook for Heating, Air-Conditioning and Sanitary Engineering (14th edition)*
3. SHASE-S 206-2009: *Water Supply and Drainage Sanitary Equipment Standards and its description*

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

Figure 2.5-2 illustrates friction loss pressure values shown in the flow rate chart and the application scope based on the set flow rate standard. Since stainless steel pipe for ordinary piping offers outstanding cavitation resistance, greater flow velocity can be set to contribute to economizing. However, when using such stainless steel pipe at a flow velocity of 2.0 m/sec or faster, noise, vibration, water hammer, pressure power and other conditions must be considered.

Compared with carbon steel pipe for ordinary piping, a smaller diameter stainless steel pipe for the same flow rate may be selected. Stainless steel pipe has an inside diameter larger than that of a carbon steel pipe if their nominal diameters are the same and the application scope in the flow rate chart has been expanded. Table 2.5-1 shows the flow volume for pipe materials as calculated with the Hazen-Williams formula. A flow velocity standard of 2.0 m/s (1.4 m/s for copper pipe) and a unit loss of pressure due to friction of 440 Pa/m were used, in conformity with the normal application range in Figure 2.5-2. For stainless steel pipe for ordinary piping, 3.5 m/s was also added. As is clear from Table 2.5-1, the pipe size falls off more in the range where the flow rate is determined by the flow velocity standard. What corresponds to 200 A for v=3.5 m/sec., Q=7000 L/min for stainless steel pipe for ordinary piping is 300 A for carbon steel pipe for ordinary piping, a difference of two sizes. However, if, as in water supply piping, the pipe diameter is set according to the hydraulic gradient determined from the potential pressure between an elevated tank and the equipment and the pressure needed for the equipment, then the flow velocity standard cannot always be followed. In such cases, the above examples cannot be applied.

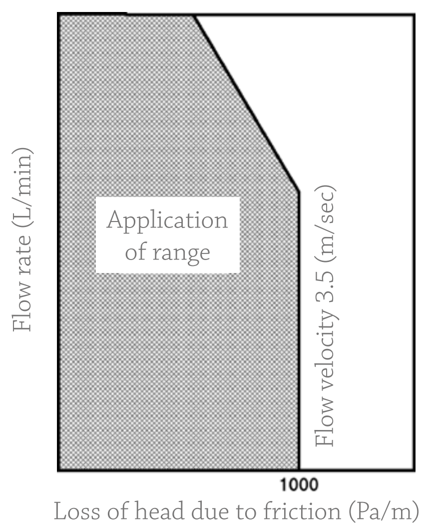


Fig. 2.5-2 Standard (upper limit) for flow velocity and loss of pressure due to friction for stainless steel pipe for ordinary piping

Prepared by: Japan Stainless Steel Association

2.5.2 Flow rate chart and local loss equivalent length

Flow rate charts for stainless steel pipes are shown in Figs. 2.5-3, 2.5-4 and 2.5-5. Figures 2.5-3 and 2.5-4 were prepared using the Darcy-Weisbach formula. Verification tests were also conducted and good results obtained. Figure 2.5-3 applies to ambient-temperature fluids in water supply pipes, cold water pipes and cooling water pipes, while Figure 2.5-4 applies to hot-water-supply pipes and hot-water pipes. Figure 2.5-5 illustrates the results of calculations with the Hazen-Williams formula at flow coefficient C=150. The results of these two calculations indicate almost the same values. The Japan Stainless Steel Association (JSSA), therefore, considers it appropriate that the flow coefficient of stainless steel is set to C=150.

The *Water Supply and Drainage Sanitary Equipment Standards and its description* (SHASE-S 206-2009) set flow coefficient C to 140. The *Guidelines for Mechanical Equipment Engineering Works Administration* (*2007 edition*) of the Ministry of Land, Infrastructure, Transport and Tourism have also set flow coefficient C to 130.

The JSSA has been encouraging the editors of these documents to adopt the flow coefficient of C=150. The *2000 edition of the Heating, Air-Conditioning and Sanitary Equipment Engineering Works Standard Specifications* (SHASE-S 010-2000) had a flow coefficient of C=130. However, upon JSSA's request, the *2007 edition* (SHASE-S 010-2007) revised the flow coefficient to C=140. Flow coefficient C=130 in the *Guidelines for Mechanical Equipment Engineering Works Administration* (*2007 edition*) compiled by the Ministry of Land, Infrastructure, Transport and Tourism was from the *former edition of Heating, Air-Conditioning and Sanitary Equipment Engineering Works Standard Specifications* (SHASE-S 010-2000).

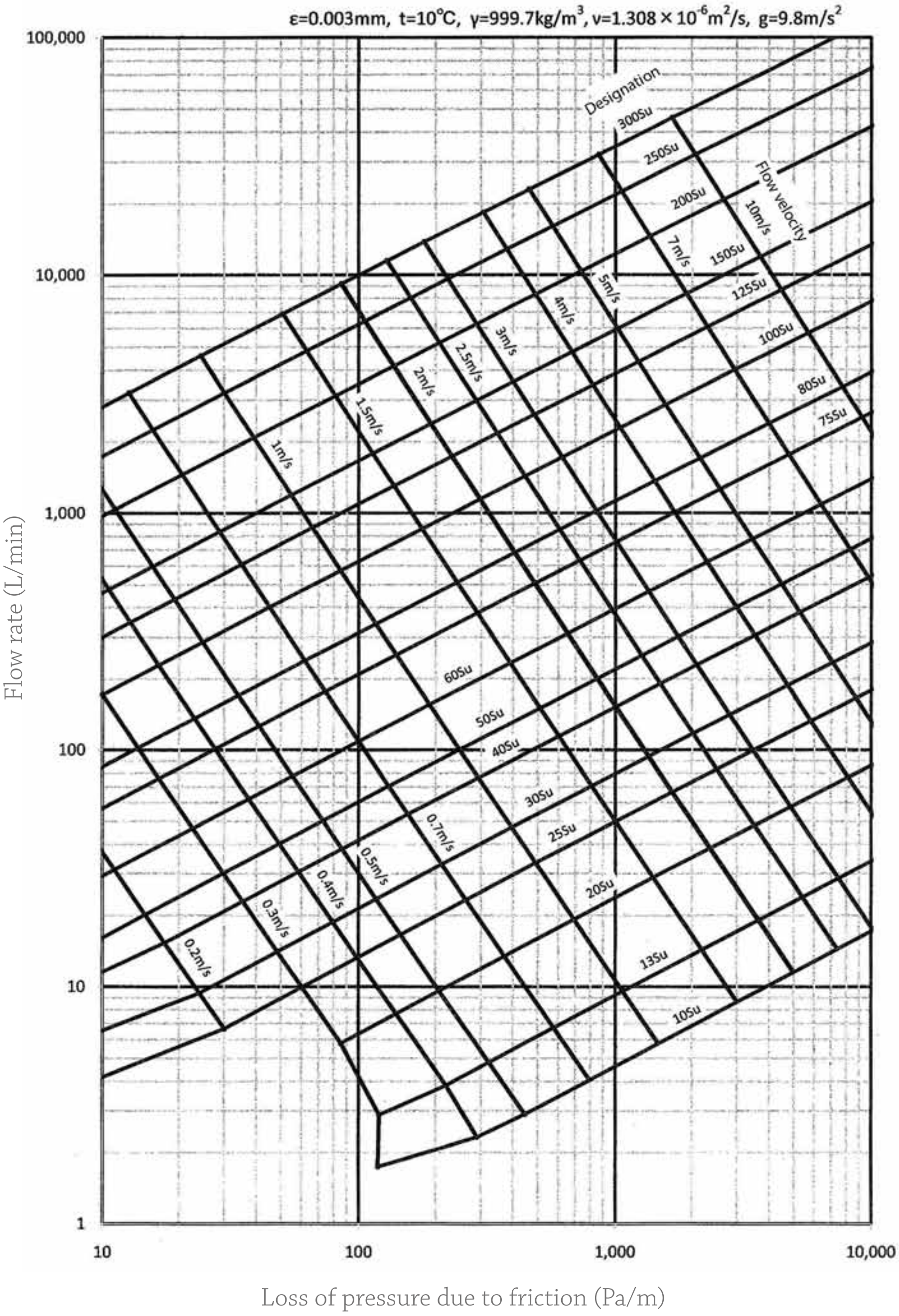


Fig. 2.5-3 Flow rate chart for stainless steel pipe for ordinary piping(10°C, Darcy-Weisbach formula)

Prepared by: Japan Stainless Steel Association

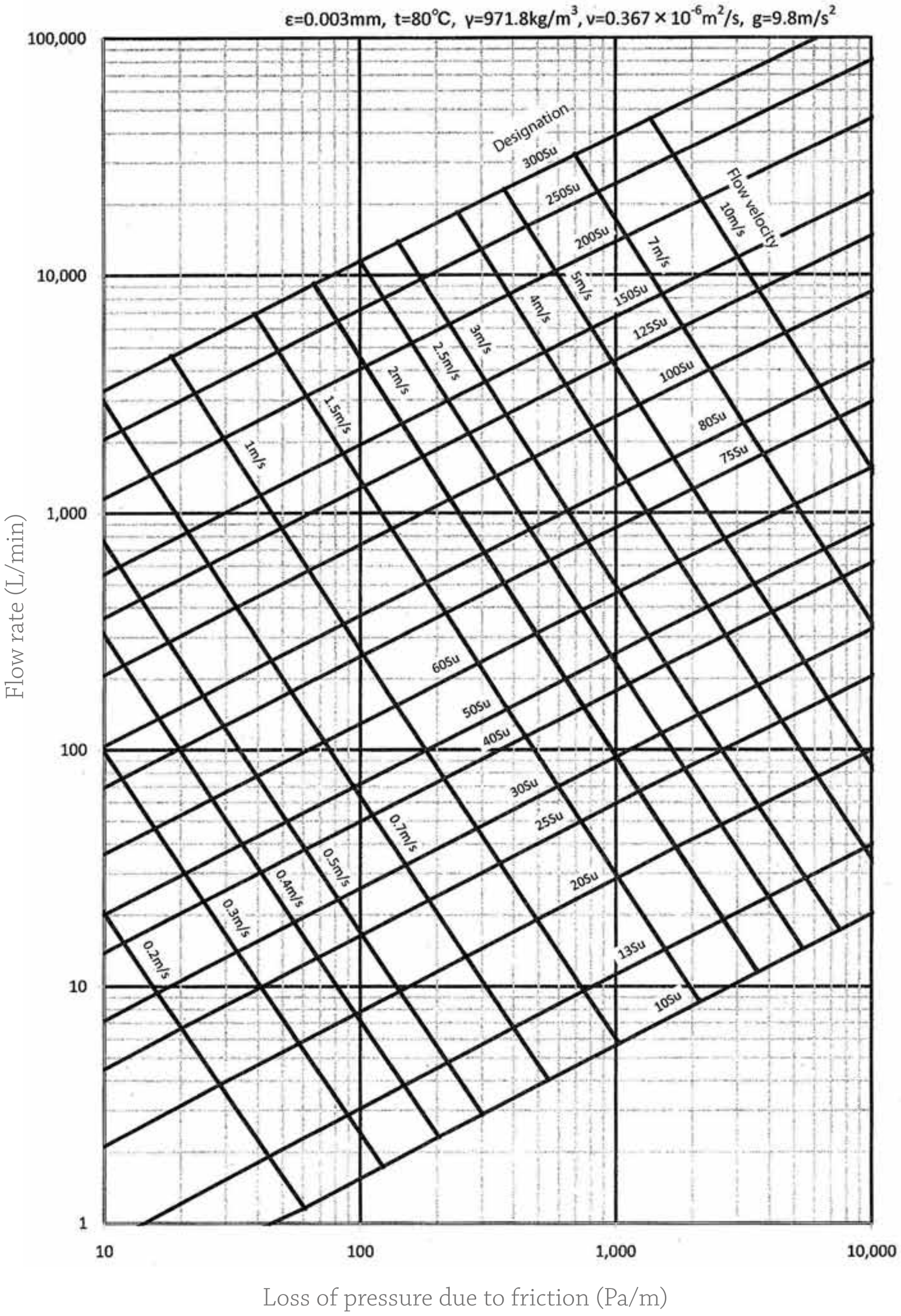


Fig. 2.5-4 Flow rate chart for stainless steel pipe for ordinary piping (80 °C, Darcy-Weisbach formula)

Prepared by: Japan Stainless Steel Association

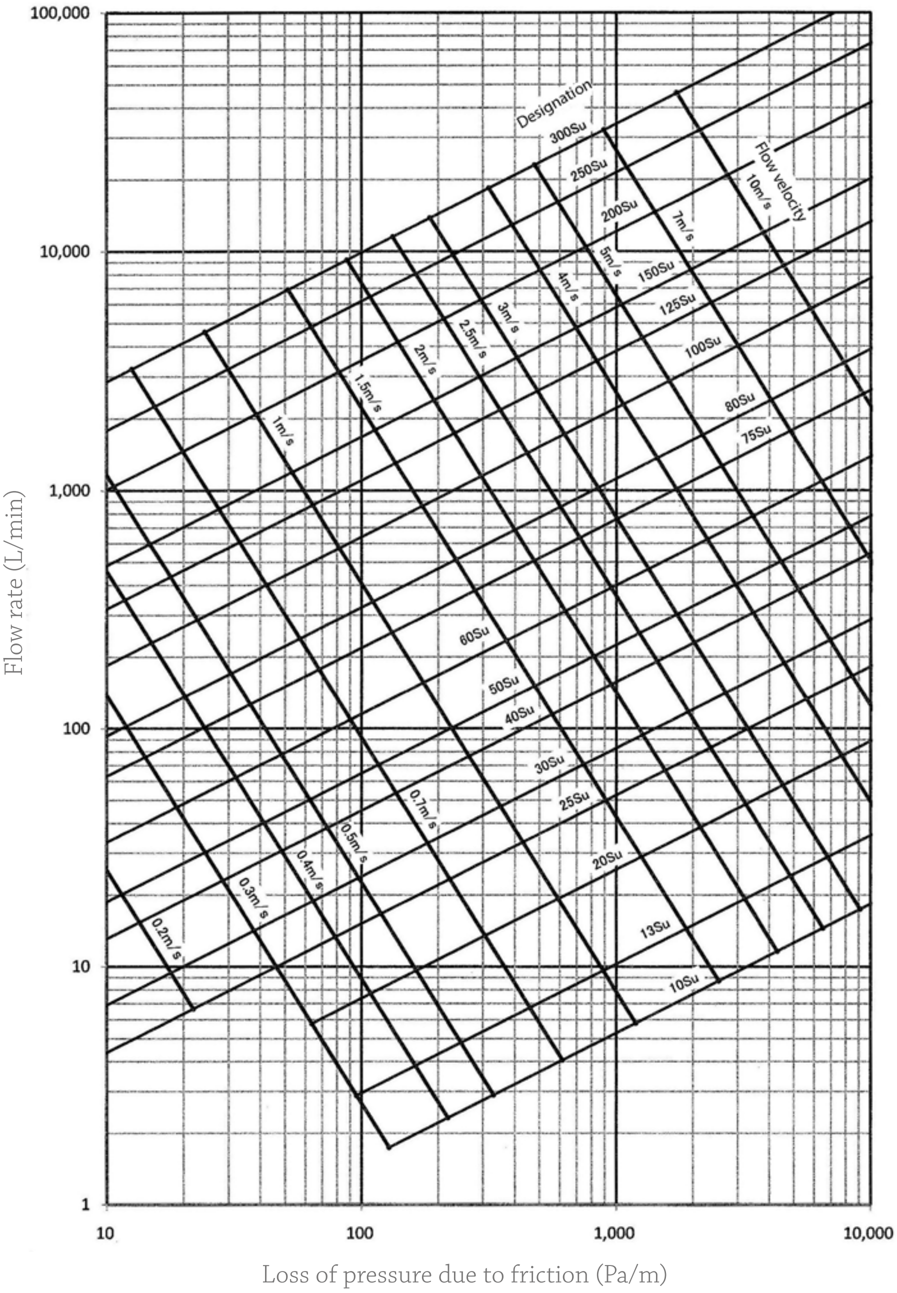


Fig. 2.5-5 Flow rate chart for stainless steel pipe for ordinary piping (Hazen-Williams formula at flow coefficient C = 150)

Prepared by: Japan Stainless Steel Association

Table 2.5-2 lists the pipe lengths corresponding to local resistance of stainless steel couplings. Based on C=150 set by JSSA, the values of elbows and 90° T described in the table were obtained with the same formula adopted in *Notification No. 38 of the Fire and Disaster Management Agency* described later. Data on valves are from *Notification No. 38 of the Fire and Disaster Management Agency* issued on December 27, 2006. In this connection, when using tee and cross for straight flow and sockets, their values may be calculated by converting into equivalent values for the straight stainless steel pipe.

Table 2.5-2 Pipe lengths equivalent to local resistance of stainless steel couplings[11]

Nominal diameter		Equivalent pipe length (m)						
Su	A	90° elbow	45° elbow	90° T (side branch)	Gate valve	Globe valve	Angle valve	Swing check valve
13	15	0.78	0.18	0.79				
20	20	1.07	0.24	1.40				
25	25	1.32	0.31	1.73	0.2	12.1	6.0	3.0
40	32	2.18	0.48	2.67	0.3	15.4	7.7	3.9
50	40	2.52	0.56	3.10	0.3	17.7	8.8	4.4
60	50	3.08	0.72	3.78	0.4	22.0	11.0	5.5
75	65	2.66	0.97	3.75	0.5	28.0	14.0	7.0
80	80	2.78	1.14	3.87	0.6	32.5	16.3	8.1
100	100	3.77	1.51	5.26	0.8	42.2	21.1	10.5
125	125				1.0	51.9	26.0	13.0
150	150				1.2	60.9	30.4	15.2
200	200				1.5	80.4	40.2	20.1
250	250				1.9	99.9	50.0	25.0

1. Data on valves are from *Notification No. 38 of the Fire and Disaster Management Agency* issued on December 27, 2006.
2. Values of elbows and T described were obtained through independent calculation by the Japan Stainless Steel Association.

2.6 Supports and Anchors

The issue of supports and anchors is not specific to stainless steel pipe for ordinary piping, but is discussed here, along with general matters, considering that stainless steel pipe is thinner and lighter than pipe made of other materials.

2.6.1 General considerations

(1) Load on piping and support and anchor points

The load on piping is broadly classified as follows.

(a) Stress in the axial direction

① Stress due to internal pressure

② Stress due to own weight, water, thermal insulation material and valves (including stress due to bending moment)

③ Thermal stress (including thermal stress due to bending moment)

④ Earthquake force (including earthquake force due to bending moment)

(b) Stress in the circumferential direction

① Hoop stress (stress in the circumferential direction due to internal pressure)

In general, the pipe wall is subject to a number of the above stresses in combination, but the supports and anchors must be such that the combined stress is no greater than the allowable stress value. The following are items to consider regarding supports and anchors in summary form.

- Weight of the piping
- Vibration and shock from outside
- Allowance for thermal stress of tubes
- Mutual vibration of pipe and structure
- Support spacing with respect to deflection of the pipe

(2) Support and anchoring methods

Support and anchoring methods are classified as follows from various standpoints.

(a) Classified by direction of the piping

① Vertical anchoring

② Horizontal anchoring

③ Anchoring in the axial direction

(b) Classification by flexibility

① Rigid anchoring (no displacement at all)

② Flexible anchoring

- Considering displacement in the direction of the pipe's axis

- Considering displacement in the direction perpendicular to the pipe's axis
- Vibration isolation support such as springs, rubber, etc.

(c) Classified by pressure

① Under constant load

② Multiple pipes supported collectively

Examples of these are illustrated in Figs. 2.6-1 through 2.6-10.

The following methods are available for supporting both electrical insulation and earthquake resistance.

(d) Vibration isolation support

Used for column pipe, water supply pipe, chilled and hot water pipe, cooling water pipe, fire-hydrant piping, fire department connection, etc.

(e) Vibration-proof fixed support

In principle, for the same purpose of application mentioned above, fixed on the lowest story on a straight line or before and after flexible couplings

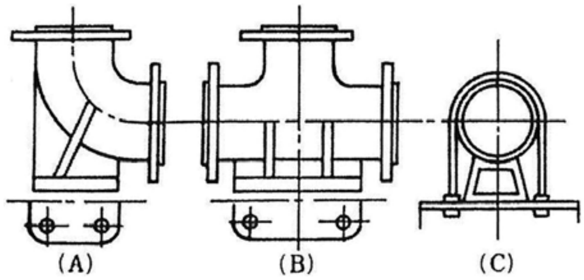


Fig. 2.6-1 Fixed anchor (fixed support platform)[10]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

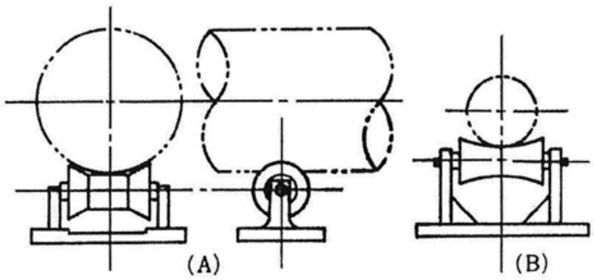


Fig. 2.6-2 Guide anchor (sliding support platform) [10]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

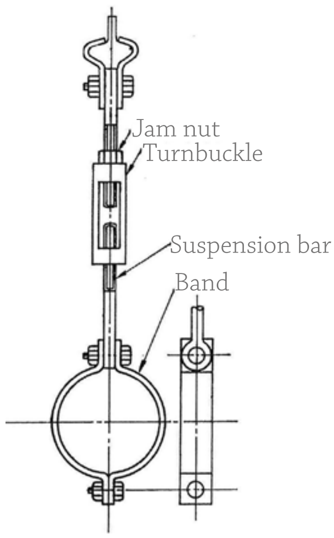


Fig. 2.6-3 Bar hanger (pipe suspension)[10]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

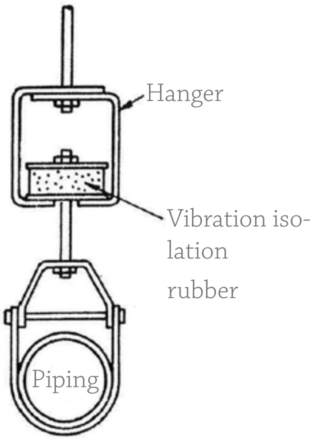


Fig. 2.6-4 Vibration isolation support for horizontal pipe[10]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

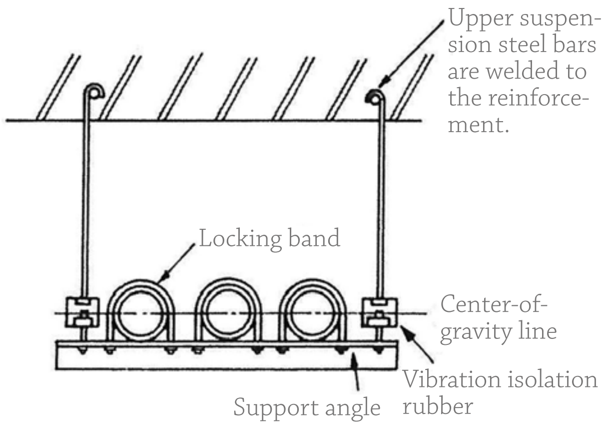


Fig. 2.6-5 Vibration isolation support for multiple horizontal pipes[10]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

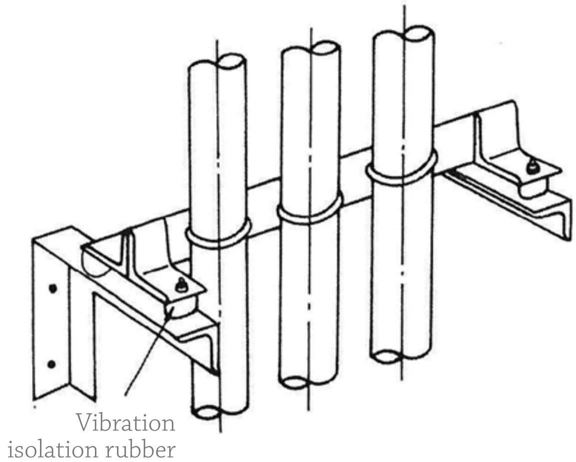


Fig. 2.6-6 Vibration isolation support for multiple vertical pipes[10]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

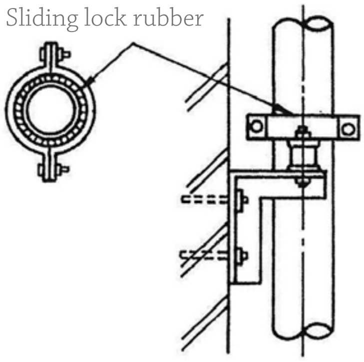


Fig. 2.6-7 Vibration isolation support for vertical pipe[10]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

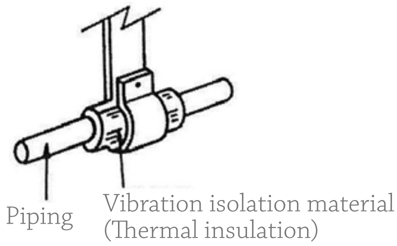


Fig. 2.6-8 Simple vibration isolation[10]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

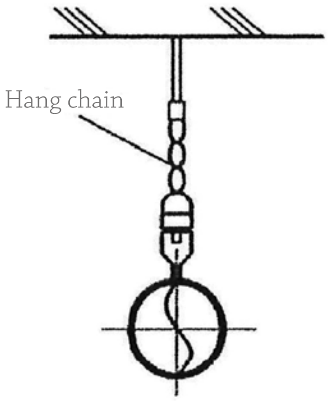


Fig. 2.6-9 Chain hanger

Prepared by: Japan Stainless Steel Association

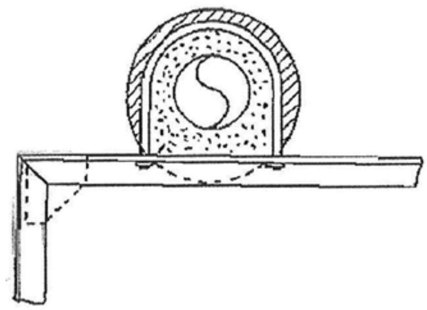


Fig. 2.6-10 Support stool made of rigid urethane foam

Prepared by: Japan Stainless Steel Association

(3) Measures for earthquake resistance

Measures for earthquake resistance can be designed for and applied to stainless steel piping, like carbon steel pipe (SGP, etc.). ***The Public Construction Works Standard Specifications (Mechanical Equipment Works Volume)*** of the Ministry of Land, Infrastructure, Transport and Tourism considers that stainless steel pipes are the same as carbon steel pipes (SGP, etc.) in terms of standards for support intervals and vibration isolation, etc. Thus, the standard for earthquake resistance support may be considered the same as for carbon steel pipe (SGP, etc.)

The earthquake resistance classes for building equipment are defined in ***the 2005 Edition of Guidelines for Building Equipment Earthquake Resistance Design***, which was issued by the Building Center of Japan. According to the guidelines, the classification of a building may be decided arbitrarily, depending on the use of the building (whether it is a disaster control base building), the use of the equipment (water tanks with high importance) or on the amplification ratio of the equipment (whether it is a type of equipment with a vibration isolation system).

(a) Types and applications of antiseismic supports

① Antiseismic supports are classified into three types: S_A, A and B.

Types S_A and A antiseismic supports are defined as made of components to cope with the tension force, compression force and bending moment that affect the support during earthquakes.

Type B antiseismic support is defined as consisting only of tension force of hanging rods and vibration isolation diagonal bracing (reinforcing steel, flat bar, etc.) so that the tension force of the self-weight is balanced with the seismic force's compression force affecting the support (Table 2.6-2 lists examples of antiseismic supports for piping).

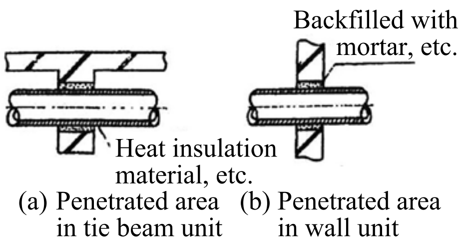
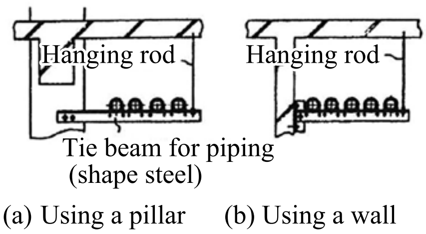
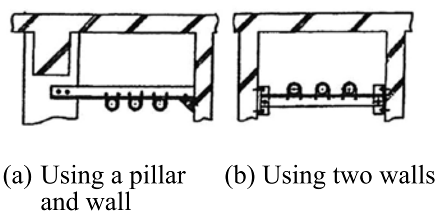
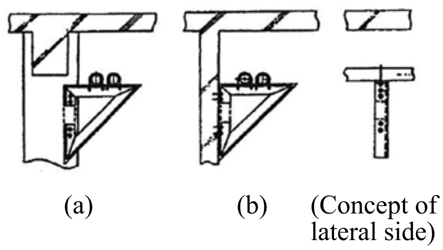
② Applying an antiseismic support shall conform to Table 2.6-1.

Table 2.6-1 Application of antiseismic support for horizontal piping[12]

Place of installation	Piping	
	Spacing	Type
Supporting antiseismic classes A and B		
Higher floors, roof, towers	Within three times the standard support spacing for the piping	All are type A.
Middle floors		Within 50 m, one shall be type A and the rest may be type B.
Basement, first floor		All may be type B.
Supporting antiseismic class S		
Higher floors, roof, towers	Within three times the standard support spacing for the piping	All are type S_A.
Middle floors		Within 50 m, one shall be type S_A and the rest may be type A.
Basement, first floor		All may be type B.
However, the above does not apply in any of the following cases.		
	(i) Piping of 60 Su or less. (ii) Piping in which the hanging rod length is no greater than 30 cm on average.	

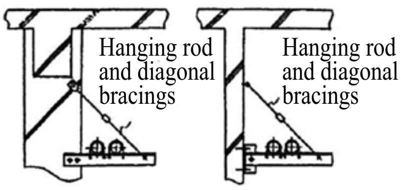
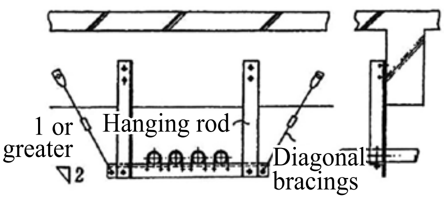
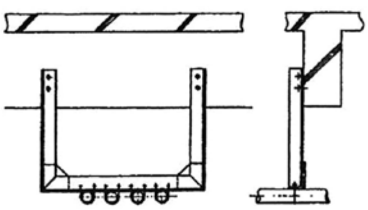
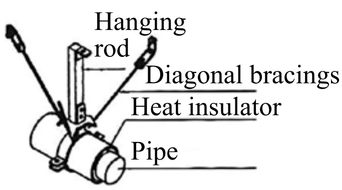
Source: Guidelines for Building Equipment Earthquake Resistance Design, 2005 Edition

Table 2.6-2 (1) Types of antiseismic support for horizontal piping[12]

Category		Concept of antiseismic support	Selecting components	Remarks
Examples of types S_A and A antiseismic support	Penetrated area in tie beam and wall units, etc.			When the surrounding area of a penetrated area (in tie beam, wall, floor units, etc.) of construction framework is backfilled with mortar, vibration in the direction rectangular to the axis of the pipes can be isolated. The following are examples of methods for treating areas penetrated by pipe. (i) Pipe whose heat is insulated Backfill the gap between the thermal insulation material surface and the penetrated areas with mortar, etc. (ii) Bare pipe Backfill the pipe in the same way.
	How to use a pillar, wall, etc.		Conform to the tables[12] of selecting components as listed in Tables 5.7-1 and 5.7-9 as well as Figure 5.7-1 in Appendix 5.7, Chapter 5.	When a pillar (or wall) is used, vibration in the direction rectangular to the axis of the pipe can be isolated relatively easily. The example is illustrated on the left.
	How to use the space between a pillar and wall, etc.		Conform to the tables[12] of selecting components as listed in Tables 5.7-2 and 5.7-10 as well as Figure 5.7-2 in Appendix 5.7, Chapter 5.	In case of building piping in the space between a pillar (or wall) and wall, vibration in the direction rectangular to the axis of the piping can be isolated relatively easily. The example is illustrated on the left.
	How to support by bracket (1)		Conform to the tables[12] of selecting components as listed in Tables 5.7-3 and 5.7-11 as well as Figure 5.7-3 in Appendix 5.7, Chapter 5.	The pipe supported by a bracket on a pillar or wall, etc. can isolate vibration in the direction rectangular to the axis of the pipe. The example is illustrated on the left.

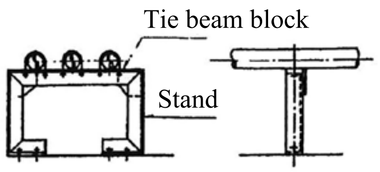
Source: Guidelines for Building Equipment Earthquake Resistance Design, 2005 Edition

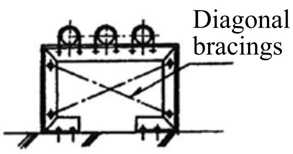
Table 2.6-2 (2) Types of antiseismic support for horizontal piping[12]

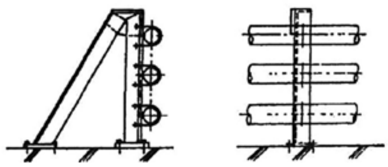
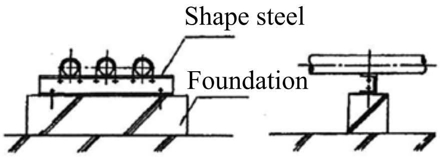
Category		Concept of method for antiseismic support	Selecting components	Remarks
Examples of types S_A and A antiseismic support	How to support by bracket (2)	 (a) Supporting a bracket from the lateral side of pillar (or wall) (b) Supporting a bracket from the wall (or pillar)	Conform to the tables[12] of selecting components as listed in Tables 5.7-4 and 5.7-12 as well as Figure 5.7-4 in Appendix 5.7, Chapter 5.	The pipe supported by a bracket on a pillar or wall, etc. can isolate vibration in the direction rectangular to the axis of the pipe. The example is illustrated on the left.
	How to hang pipe on the tie beam or ceiling slab (1)	 (a) Hanging piping on the tie beam (or slab) (truss frame)	Conform to the tables[12] of selecting components as listed in Tables 5.7-5 and 5.7-13 as well as Figure 5.7-5 in Appendix 5.7, Chapter 5.	The hanging rods for antiseismic support must be made of material that does not buckle under compression force. The illustration at left shows vibration isolation supports in a truss frame.
	How to hang pipe on the tie beam or ceiling slab (2)	 Hanging piping on the tie beam (or slab) (rigid frame)	Conform to the tables[12] of selecting components as listed in Tables 5.7-6 and 5.7-14 as well as Figure 5.7-6 in Appendix 5.7, Chapter 5.	The illustration at left is a rigid frame under the same concept mentioned above. However, the joints between the hanging rods and the tie beam must be connected rigidly to pass bending.
	How to hang pipe on the tie beam or ceiling slab (3)	 Hanging piping on the tie beam (or slab)	Both the hanging rod and the diagonal bracings must be fixed so that the intensity of stress caused by the weight of the piping (including fluid in the piping) and seismic force are within allowable unit stress for temporary loading. In addition, the hanging rod must be made of material that does not buckle under compression force.	The illustration at left is a truss frame where a special hanging metal rod is used to hang the pipe.

Source: Guidelines for Building Equipment Earthquake Resistance Design, 2005 Edition

Table 2.6-2 (3) Types of antiseismic support for horizontal piping[12]

<table>
<tr><th colspan="2">Category</th><th>Concept of method for antiseismic support</th><th>Selecting components</th><th>Remarks</th></tr>
<tr><td rowspan="4">Examples of types S_A and A antiseismic support</td><td>How to support piping on the floor slab (1)</td><td>

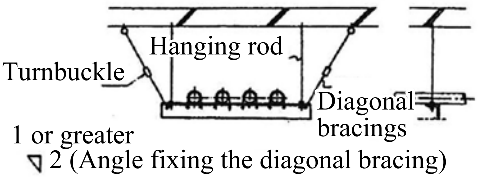
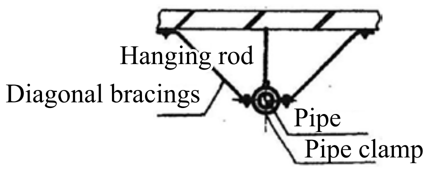
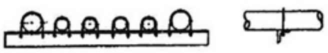
Rigid frame</td><td>Conform to the tables[12] of selecting components as listed in Tables 5.7-7 and 5.7-15 as well as Figure 5.7-7 in Appendix 5.7, Chapter 5.</td><td>This method deters vibration in the direction rectangular to the axis of the piping on the trestle above the floor.
The illustration at left shows a rigid frame. However, the joints between the stands and the tie beam blocks must be connected rigidly to transfer the bending.</td></tr>
<tr><td>How to support piping on the floor slab (2)</td><td>

Truss frame</td><td>Conform to the tables[12] of selecting components as listed in Tables 5.7-8 and 5.7-16 as well as Figure 5.7-8 in Appendix 5.7, Chapter 5.</td><td>The same method is also adopted. The illustration at left shows an example of a truss frame.</td></tr>
<tr><td>How to support piping on the floor slab (3)</td><td>
Method for lining pipes in on a vertical plane (truss frame)</td><td>The components must be built so that the intensity of stress caused by the weight of the piping (including the fluid in the pipe) and seismic force are within the allowable unit stress for temporary loading.
In addition, the components must not buckle under compression force.</td><td>This is the same method mentioned above. The illustration at left shows an example of a truss frame where pipes are lined on a vertical plane.</td></tr>
<tr><td>How to support piping on the floor slab (4)</td><td>

Non-fixed piping, etc.</td><td>Select necessary shape steel for the thickness of U bolts and frame fixing anchors to use.</td><td>The illustration at left is an example of non-fixed piping connecting to the foundation via the shape steel. Vibration in the direction rectangular to the axis of the piping can be isolated easily.</td></tr>
</table>

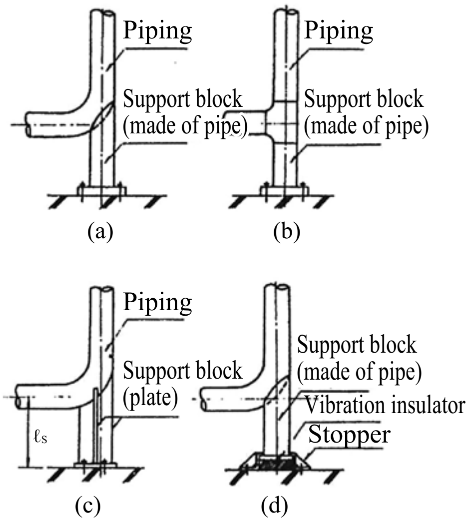
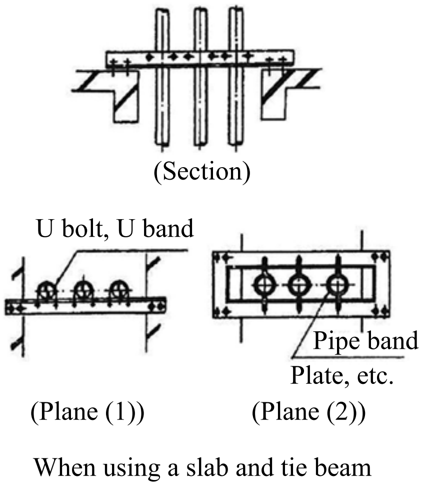
Source: Guidelines for Building Equipment Earthquake Resistance Design, 2005 Edition

Table 2.6-2 (4) Types of antiseismic support for horizontal piping[12]

Category		Concept of method for antiseismic support	Selecting components	Remarks
Examples of type B antiseismic support	How to hang pipe on the tie beam or ceiling slab		Select both hanging rods and tie beam that have sufficient allowance of strength against stress. These materials must satisfy that the intensity of the stress caused by the weight of the piping (including the fluid in the pipe) is within the allowable unit stress for long sustained loading. The components for the diagonal bracings must also have the same strength or greater against stress than that of the hanging rods.	Use a diagonal bracing whose stress resistance is the same or greater than that of the hanging rods for supporting the self-weight, to isolate vibration in the direction rectangular to the axis of the pipe. Tighten the diagonal bracing so that no rattling occurs. Prevent the diagonal bracing from bearing the extra weight of the pipe that will occur when tightened too rigidly. The illustration at left shows an example that supports multiple pipes.
	How to hang pipe on the tie beam or ceiling slab		Same as above.	The illustration at left shows an example of piping of one tube. The concept is the same as mentioned above.
How to connect different-diameter pipes lined in parallel		 Connecting pipes in parallel with shape steels	Select necessary shape steel for the thickness of the U bolt.	If different-diameter pipes having different intervals of earthquake-resistant supports are lined in parallel, connect such pipes in every short interval of the earthquake-resistant supports, as shown in the illustration at left, instead of connecting in every long interval of earthquake-resistant supports. In such case, when an increase in the load on pipes having long intervals of earthquake-resistant supports is within 100%, select the support materials corresponding to the load. In this case, reduce the value of maximum intervals of earthquake-resistant supports by 10%.

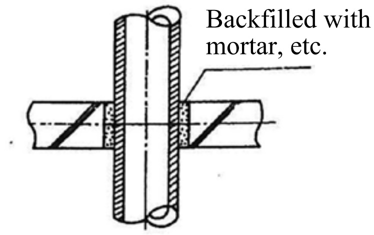
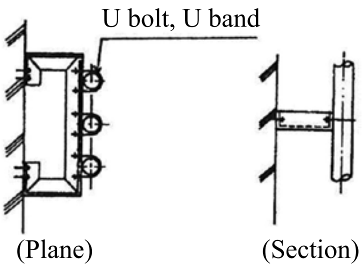
Source: Guidelines for Building Equipment Earthquake Resistance Design, 2005 edition

Table 2.6-2 (5) Types of antiseismic support for vertical piping (supporting self-weight)[12]

Category		Concept of method for antiseismic support	Selecting components	Remarks
Examples of antiseismic support for Vertical Piping	How to support lower part of piping (for steel pipe case)		The support block must have the same strength as the main pipe unit.	If the pipe supports its weight on the lower part, this part can hold down vibration in the direction rectangular to the axis of the pipe. The illustration at left is an example of such support. In line with this, it would be better to avoid (c) type if it has a long ℓ_s.
	How to support the pipe in the middle		(i) When using the self-weight support as an earthquake resistant support (vibration stopper), follow the tables and figure to select components, as shown in Tables[12] 5.7-19 and 5.7-21 and Figure 5.7-11, Appendix 5.7, Chapter 5. (ii) When using only earthquake-resistant support (vibration stopper), follow Tables[12] 5.7-18 and 5.7-20, Appendix 5.7, Chapter 5.	The illustration at left indicates that the surrounding frameworks (slab, tie beam, etc.) for the pipe space, etc. are used for holding the pipe in the direction rectangular to the axis of the pipe and for supporting its own weight.

Source: Guidelines for Building Equipment Earthquake Resistance Design, 2005 edition

Table 2.6-2 (6) Types of antiseismic support for vertical piping (vibration stopper)[12]

Category		Concept of method for antiseismic support	Selecting components	Remarks
Examples of antiseismic support for vertical piping	Penetrated area in the slab unit	 Penetrated area in floor slab unit		When the surroundings of the area penetrated in the slab unit are backfilled with mortar, etc., vibration in the direction rectangular to the axis of the pipe can be isolated. Examples of treating penetrated areas (i) Pipe whose heat is insulated Backfill the gap between the thermal insulation material surface and the penetrated areas with mortar, etc. (ii) Bare pipe Backfill the pipe in the same way.
	How to support the pipe in the middle	 Case of using wall	Select components so that the intensity of the stress caused by seismic force that acts against the pipe (including fluid in the pipe) is within the allowable unit stress for temporary loading.	The illustration at left shows a method where wall, etc. is used to hold down displacement in the direction rectangular to the axis of the vertical pipe. In this case, no self-weight support can be used concurrently.

Source: Guidelines for Building Equipment Earthquake Resistance Design, 2005 edition

(b) Points for when providing antiseismic support

① Considering intense load on the pipe

If a very heavy valve or the like is mounted on the pipe, take the necessary measures corresponding to the weight of the component to prevent damaging the pipe during an earthquake. Figure 2.6-11 shows an example.

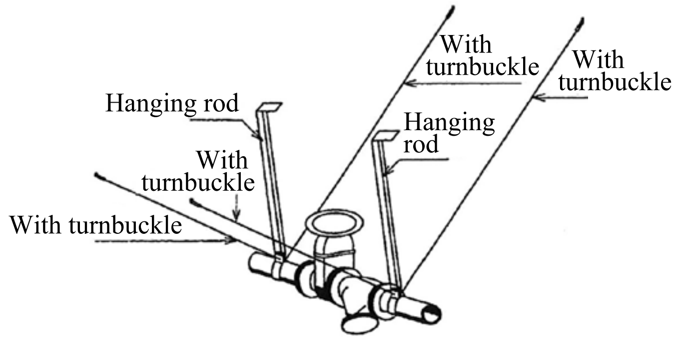


Fig. 2.6-11 Supporting intense load midway on the piping[12]

Source: Guidelines for Building Equipment Earthquake Resistance Design, 2005 edition

② Piping and support at branch

If a small-diameter pipe is branched out of a large-diameter pipe, consider the pipe form and supporting method so that the stress on the large-diameter pipe does not pass directly to the small-diameter pipe. Figure 2.6-12 illustrates such a case.

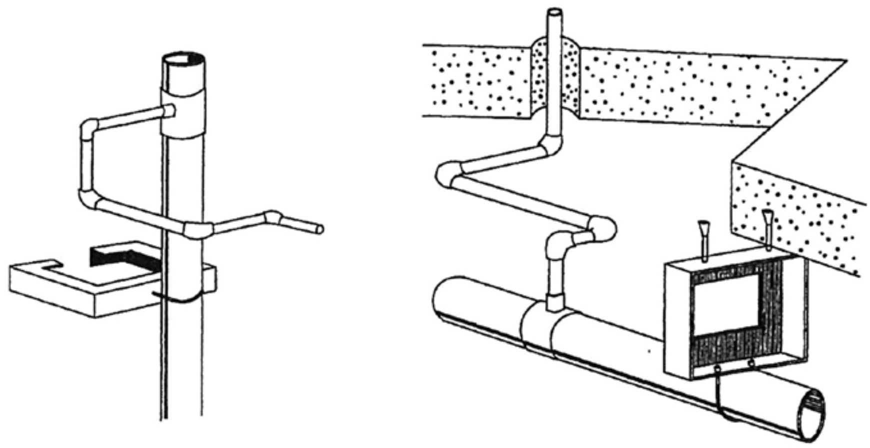


Fig. 2.6-12 Pipe and support location at branch[12]

Source: Guidelines for Building Equipment Earthquake Resistance Design, 2005 edition

(4) Allowable stress in stainless steel piping

The designed allowable stress of stainless steel pipe for ordinary piping is assumed as 130 MPa. The value is determined because it is one-fourth of the 520 MPa tension strength of JIS-based SUS 304 steel, which is lower than the 205 MPa or a JIS-based 0.2% proof stress.

2.6.2 Horizontal piping

Calculation formulas for a beam anchored at both ends and bearing an uniformly distributed load are used for determining the spacing between supports for horizontal piping. There are calculation formulas for simple beams and for continuous beams. When the calculation is made for the same spacing between supports, the deflection (δ) of the former is about five times that of the latter, as is clear from the formulas in Table 2.6-3. If safety is the top priority, there will be no problems if the allowable stress from using the simple-beam formula is considered and the minimum slope of the piping is set to eliminate standing water caused by deflection. However, the shape of most piping can be construed as a continuous beam. During use the water is not drained from pipes for water supply, hot-water supply, or cooling water. As a practical matter there will be no major problems even if the calculation is made with the continuous beam formula. Also, the support spacing for stainless steel pipes and copper pipes is determined in conformity with a continuous beam, and has been treated as such.

Based on the foregoing, the following two principles for determining horizontal support spacing have been set:

(a) The stress on the piping must be no greater than the allowable stress.

(b) There must be no standing water caused by the deflection (δ) of the piping as in Fig. 2.6-13 (the piping must slope).

Table 2.6-4 lists the support spacing calculated on the basis of a continuous beam, which may be used for design purposes (for the calculation formula, see Table 2.6-3). According to the calculation, the stress that arises in piping having this support spacing is about one-tenth of the allowable stress, resulting in no problem at all. Table 2.6-8 gives the maximum spacing between anchors to avoid buckling when subjected to acceleration of 500 and 1000 gal in the horizontal direction.

Table 2.6-3 Maximum bending stress and deflection in horizontal piping made of stainless steel pipe for ordinary piping[13]

Type of support	Maximum stress σ (N/cm^2)	Location of σ	Maximum deflection δ (cm)	Location of δ
Simple beam	$\frac{(6.34wL^2 + 12.6WL)D}{I}$	In the middle of the span	$\frac{12{,}850wL^4 + 20{,}600WL^3}{EI}$	In the middle of the span
Continuous beam	$\frac{(4.23wL^2 + 6.30WL)D}{I}$	Support point	$\frac{2{,}570wL^4 + 5{,}160WL^3}{EI}$	In the middle of the span

w : uniformly distributed load (N/m) (weight of the pipe itself + water + covering)
W : concentrated load affecting the middle of beam (N)
E : Young's modulus (N/cm^2)
I : geometrical moment of inertia (cm4)
L : length of the piping (m)
D : outside diameter of the piping (cm)

Source: Piping Manual, 1964

(1) Vibration

The natural frequency (f) of horizontal piping supported or anchored at a given spacing can be calculated from the formula in Table 2.6-6 using the coefficients in Table 2.6-5, which are determined by the form of the support or anchoring. The value of the natural frequency is often an issue when $f/f_0 \geq 2$ (where f_0 is the frequency of a building during an earthquake) and the resonance point is to be avoided, or when, for example, f is more rigid than 20 Hz and the resistance to vibration is to be improved. Table 2.6-6 shows the results of calculations for simple support and band anchoring.

Although in principle f_0 is calculated by the structure designer, in general it is given by formulas (2.6-1) and (2.6-2).

Steel structures: $f_0 = 1/0.03H$ ....(Formula 2.6-1)

RC structures and structures in which different types are mixed: $f_0 = 1/0.02H$

....(Formula 2.6-2)

Where

f_0 : frequency of the building (Hz)

H : above-ground height of the building (m)

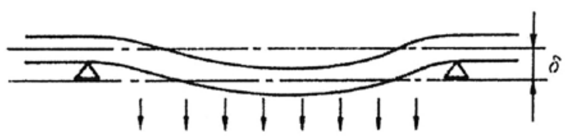


Fig. 2.6-13 Deflection in horizontal piping[10]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

Table 2.6-4 Spacing between supports in horizontal piping made of stainless steel pipe for ordinary piping[14]

Nominal diameter (Su)	Uniformly distributed load (N/m)	Spacing between supports*1 (m)	Load on support points (N)	Spacing between supports for other types of pipe (m)*2			
				Steel pipe		Copper pipe	
				Nominal diameter	Spacing between supports	Nominal diameter	Spacing between supports
10	5.6	1.5	4.1	10	2.0	10	1.0
13	8.0		6.1	15		15	
20	13.0	2.0	13.0	20		20	
25	16.9		16.9	25		25	1.5
30	22.7	2.5	28.4	32		32	
40	35.0		43.7	40		40	
50	42.3	3.0	63.5	50	3.0	50	2.0
60	60.6		90.8	65		65	2.5
75	87.4		131.1				
80	118.8	4.0	237.5	80		80	
100	172.2		344.3	100		100	
125	237.3	5.0	593.2	125		125	3.0
150	345.3		863.4	150		150	
200	536.3	6.0	1608.8	200			
250	766.7		2300.0	250			
300	1037.0		3111.1	300			

*1 Calculation formula and conditions are as below.

$$L = 4\ \sqrt{EI\delta/2.570w}$$

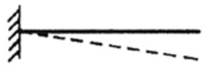
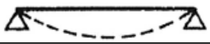
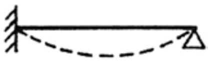
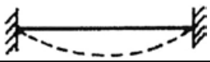
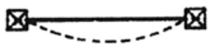
E : Young's modulus (kg/cm^2)
I : Geometrical moment of inertia (cm^4)
L : Spacing between supports (m)
w : Uniformly distributed load (N/m)
δ : Deflection 0.1 (cm)

Conditions;

(1) Own weight when full of water and thermal insulated

Source: SHASE-S 010-2007 *Heating, Air-Conditioning and Sanitary Equipment Engineering Works Standard Specifications*

Table 2.6-5 Value of the coefficient a of the natural frequency of piping[15]

Form		a
1. Cantilever		17.6
2. Simple support		49.2
3. Anchored at one end		76.9
4. Anchored at both ends		112
5. Band anchored (experimental value)		84

Source: Piping Manual Lecture, 1966

Table 2.6-6 Natural frequency of supported or anchored horizontal piping (stainless steel pipe for ordinary piping)[10]

Nominal diameter (Su)	Natural frequency (Hz)		Calculation formula, conditions
	Simple support	Band anchor	
10	9.3	15.9	
13	11.1	18.9	
20	9.1	15.6	
25	11.9	20.3	$f = a\sqrt{EI/W\ell^3}$
30	9.3	15.9	
40	10.7	18.3	f : Natural frequency
50	8.2	14.1	a : Coefficient depending on form of support (Table 2.6-5)
60	10.7	18.3	
75	12.7	21.7	E : Young's modulus 1.93×10^7 (N/cm^2)
80	8.9	15.2	I : Geometrical moment of inertia (cm^4)
100	10.8	18.5	W : Weight of piping between support points (N) W=wL
125	8.0	13.7	L,ℓ : Spacing between support points (m), (cm)
150	10.4	17.7	(Table 2.6-4 is used for w, ℓ.)
200	8.7	14.9	
250	10.1	17.2	
300	11.3	19.3	

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(2) Spacing between anchor points with respect to acceleration in the horizontal direction

When horizontal piping is long and supported by suspension bolts, then even if the spacing conforms to Table 2.6-4, the piping is relatively free with respect to forces in the horizontal direction. In this case, long spans between two points spaced farther apart than the hanger spacing act as beams anchored at both ends and are subject to a large bending moment. Formulae for the bending moment for beams supported at both ends and for cantilevers are given in Table 2.6-7. The bending stress that then arises is given by formula (2.6-3). This bending stress should be no greater than the allowable stress.

$\sigma^b = M/Z$ ....(Formula 2.6-3)

Where σ^b : Bending stress (N/cm^2)
M : Bending moment ($N \cdot cm^2$)
Z : Section modulus (cm^3)

Table 2.6-7 Bending moment due to acceleration in the horizontal direction in anchored horizontal piping [10]

Type of support	Maximum bending moment	Point where maximum bending moment occurs
Beam anchored at both ends	$\alpha wL^2/8$	Support point
Cantilever	$\alpha wL^2/2$	Support point

Where α : Acceleration (m/sec^2)
w : Uniformly distributed load (N/m)
L : Spacing between anchors (m)

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

Table 2.6-8 gives the maximum spacing between anchors when the acceleration in the horizontal direction is assumed at 500 and 1000 gal. Thus buckling will occur unless the spacing between anchors is less than the values in this table.

Table 2.6-8 Maximum spacing between anchors (m) for which there is no buckling in horizontal piping subject to a horizontal load (stainless steel pipe for ordinary piping)

Nominal diameter (Su)	Maximum spacing between anchors 500 gal	1000 gal
10	5.8	4.1
13	6.5	4.6
20	8.0	5.7
25	8.9	6.3
30	9.9	7.0
40	10.3	7.3
50	10.7	7.6
60	12.2	8.6
75	12.9	9.1
80	14.7	10.4
100	15.6	11.0
125	16.3	11.5
150	19.3	13.6
200	20.3	14.0
250	21.0	14.8
300	21.6	15.3

Where, the values are taken to be acceleration α= 500 gal, 1000 gal, allowable stress σb=130 MPa

Prepared by: Japan Stainless Steel Association

2.6.3 Vertical piping

The spacing between supports or anchors of vertical piping is often determined by if it will withstand the bending moment caused by the displacement between strata (Figure 2.6-14) and if it is free from buckling due to its own weight. Thus, long spacing between supports is adopted in flexible-structure buildings that have large displacement between strata. In that case buckling may generally be disregarded, although there is a greater risk of twist buckling. If the spacing between supports is long, as with vertical piping discussed above, the length must be within the maximum spacing between supports that withstands the bending moment caused by loads in the horizontal direction (Figure 2.6-15), such as the acceleration that occurs during earthquakes.

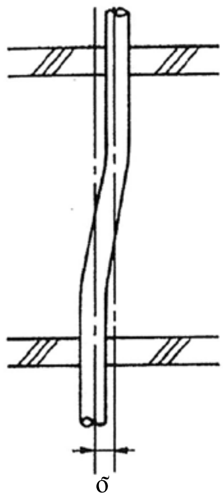


Fig. 2.6-14 Support of vertical piping[10]

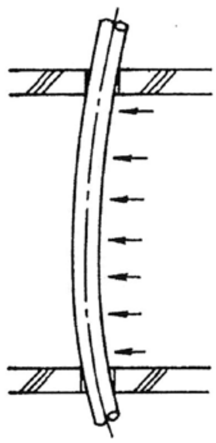


Fig. 2.6-15 If vertical piping is subjected to acceleration[10]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

The calculation formulas in Table 2.6-9 provide the minimum spacing between supports to withstand displacement between strata in flexible- and rigid-structure buildings, and the maximum spacing between supports to withstand the bending moment caused by loads in the horizontal direction. Actually, spacing between two supports is permitted, but as a practical matter one support on each floor suffices.

Table 2.6-9 Spacing between supports in vertical piping (stainless steel pipe for ordinary piping)[10]

[Unit: m]

Nominal diameter (Su)	Minimum spacing between supports to withstand displacement between strata		Maximum spacing between supports for which there is no buckling when subjected to a horizontal load
	Flexible structure	Rigid structure	
10	0.8	0.6	5.8
13	0.9	0.6	6.5
20	1	0.7	8
25	1.2	0.8	8.9
30	1.3	0.9	9.9
40	1.4	1	10.3
50	1.5	1.1	10.7
60	1.7	1.2	12.2
75	1.9	1.4	12.9
80	2.1	1.5	14.7
100	2.3	1.7	15.6
125	2.6	1.8	16.3
150	2.8	2	19.3
200	3.2	2.3	20.3
250	3.5	2.5	21
300	3.8	2.7	21.6
Calculation formula	$\ell \geq \sqrt{3EI\delta/(\sigma Z)}$ $= 0.9535\sqrt{I/Z}$	$\ell \geq \sqrt{3EI\delta/(\sigma Z)}$ $= 0.6742\sqrt{I/Z}$	$\ell \leq \sqrt{8Z\delta/(0.5w)}$ $= 14.4\sqrt{Z/W}$
	where ℓ: Spacing between supports (m), Z: Section modulus (cm3), Acceleration = 500 gal, σ: allowable stress 130 MPa, E: Young's modulus 1.93×10^3 MPa, w: uniformly distributed load (kg/m), δ:displacement between strata, flexible = 2 cm, rigid = 1 cm		

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

2.7 Handling the Expansion and Contraction of Piping

2.7.1 Expansion and contraction of piping

(1) Linear expansion coefficient and the amount of expansion or contraction

The expansion or contraction of piping caused by heat occurs as thermal stress and can cause the rupture of the support points, buckling of the pipes themselves or breakage of the equipment connected to the piping. This is important concerning stainless steel pipe for ordinary piping, which expand and contract more than other materials. Table 2.7-1 lists the average coefficient of linear expansion for various materials. The value for 18-8 stainless steel, which is used to make stainless steel pipe for ordinary piping, is approximately 17×10^{-6}, about 50% greater than that for carbon steel. Table 2.7-2 calculates the expansion per 10 m of pipe length at various temperatures, taking 0°C as the base.

Table 2.7-1 Average coefficient of expansion for various materials[13]

[Unit: /°C × 10^{-6}]

Materials \ Temperature (°C)	-100-0	0-100	0-200	0-300	0-400	0-500	0-600	0-700
18 Cr-8 Ni stainless steel	16.2	16.7	17.2	17.6	18.1	18.5	18.8	19.1
12 Cr stainless steel	9.7	11.0	11.5	12.1	12.3	12.9	13.2	13.3
Carbon steel (0.3-0.4 C)	10.5	11.5	11.9	12.6	13.3	14.0	14.2	14.5
Cast iron	8.3	10.4	11.0	11.7	12.4	-	-	-
Brass	16.6	17.5	18.0	18.5	18.9	19.3	20.0	20.6
Copper	15.7	16.6	16.9	17.3	17.8	18.2	18.5	18.9
Aluminum	21.0	24.0	24.7	25.5	26.1	26.6	27.9	28.3

Source: Piping Manual, 1964

Table 2.7-2 Expansion per 10 m length of pipe (set to 0 at 0°C)[10]

[Unit: mm/10 m]

Temperature °C	-10	0	10	20	30	40	50	60	70	80	90	100
Stainless steel pipe for ordinary piping (SUS 304)	-1.6	0	1.7	3.3	5.0	6.7	8.4	10.0	11.7	13.4	15.0	16.7
Carbon steel pipe for ordinary piping	-1.1	0	1.2	2.3	3.5	4.6	5.8	6.9	8.1	9.2	10.4	11.5
Copper pipe	-1.6	0	1.7	3.3	5.0	6.6	8.3	10.0	11.6	13.3	14.9	16.6
Calculation formula	$\Delta l=\alpha l\Delta t$				Δl: expansion of the pipe (mm) α: coefficient of linear expansion (/°C × 10^{-6}) l: total length of pipe (mm) Δt: temperature difference (°C)							

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(2) Thermal stress and reactive force

Thermal stress occurs when a piping system is heated, resulting in a reaction on support and anchor points and on the equipment. In a straight pipe that is anchored at both ends and has no displacement, the compression stress given by formula 2.7-1 arises, and its support points are subjected to the reactive force given by formula 2.7-2.

$\sigma = E\cdot\alpha\cdot\Delta t$ ....(Formula 2.7-1)

Where σ : Compression stress (MPa)
E : Young's modulus 193 × 10^3 (MPa)
α : Coefficient of linear expansion (/°C × 10^{-6})
Δt : Temperature difference (°C)

$F = \sigma A$ ....(Formula 2.7-2)

Where F : Reaction (N)
σ : Compression stress (N/mm^2 = MPa)
A : Cross-sectional area of the piping (mm^2)

Detailed figures and tables for calculating the reactive force in bent pipes such as shown in Figs. 2.7-1 and 2.7-2 are omitted here but there are dedicated documents that can be used for the calculations. Also, the reactive force on the connected equipment must be no greater than the allowed value for the equipment, but the relevant data need to be obtained from the manufacturers.

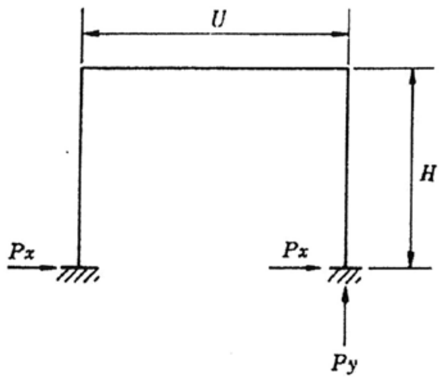


Fig. 2.7-1 Bent pipe in a plane[10]

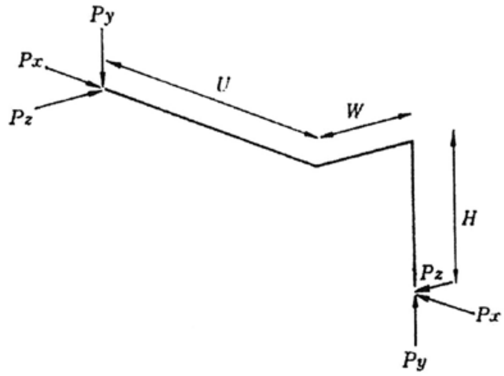


Fig. 2.7-2 Bent pipe in three dimensions[10]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

2.7.2 Measures for absorbing expansion and contraction

There are two basic ways to absorb the change in dimensions caused by the thermal expansion of piping. One is to absorb it with the flexibility of the pipes; the other is to insert expansion joints. The flexibility method that absorbs changes in pipe dimensions without using any special expansion joints is advantageous because of low cost and freedom from any risk associated with defective couplings. However, the method has weaknesses; the piping can absorb only a limited quantity of expansion and contraction while requiring large three-dimensional space. Thus, expansion joints are used in most cases because they can absorb a large quantity of expansion and contraction without requiring much space to insert.

(1) Measures for absorbing expansion and contraction of pipe with flexibility

To use the pipe flexibility, the reactive force, bending moment and angular moment on the piping, its support and anchor points, and the equipment connected with the contemplated piping are calculated and compared with their permissible values. However, this involves an enormous amount of calculations and requires a computer. Discussions on this matter here are limited to some remarks about a simple discrimination method.

This simple discrimination method, described in ANSI/ASME B31, is an empirical formula that says that the flexibility of piping can absorb its expansion if it is less than the value given in formula (2.7-3), which may be used under constraints (a) through (c).

$$\frac{DY}{(L-U)^2} \leq 205 \quad \text{(Formula 2.7-3)}$$

Where D : nominal diameter of the pipe (mm)

Y : total expansion to be absorbed (mm)

L : piping extension (m)

U : Spacing between anchor points (m)

$$Y=\sqrt{(\Delta x + \Delta x')^2 + (\Delta y + \Delta y')^2 + (\Delta z + \Delta z')^2} \quad \text{(Formula 2.7-4)}$$

Δx, Δy, Δz: amount of thermal expansion in x, y, and z directions (mm)

$\Delta x'$, $\Delta y'$, $\Delta z'$: displacement of the anchor point in x, y, and z directions (mm)

(The direction opposite to the expansion of the pipe is taken to be positive, and in the same direction negative.)

Constraints:

- The piping system has no branches.
- Throughout the entire piping length, pipe diameter, thickness, material quality, temperature, etc. remain the same.
- The anchor points are two – one at each end.

Shown below is a calculation example with the simple discrimination method. If piping has a pipe diameter of 150 Su (150 A) and 2 mm/m thermal expansion, as shown in Figure 2.7-3, the user can judge whether the pipe flexibility can absorb such thermal expansion, using the following formulas:

Obtain values to substitute for formula (2.7-4) from the figure.

$\Delta x = 3 \times 2 = 6$ mm $\quad \Delta x' = 0$

$\Delta y = 2 \times 2 = 4$ mm $\quad \Delta y' = 0$

$\Delta z = 10 \times 2 = 20$ mm $\quad \Delta z' = 0$

$Y = \sqrt{6^2 + 4^2 + 20^2} \approx 21.3$ mm

Substitute values for formula (2.7-3) as follows:

$U = \sqrt{3^2 + 2^2 + 10^2} \approx 10.63$ m

$L = 3 + 2 + 10 = 15$ m

Therefore,

$$\frac{DY}{(L-U)^2} = \frac{150 \times 21.3}{(15-10.63)^2} = 167.3 < 205$$

As a result, this piping can absorb the thermal expansion mentioned above, with its own pipe flexibility.

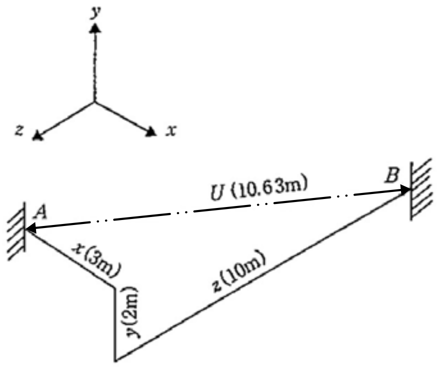


Fig. 2.7-3 Calculation example in deciding the measure for expansion and contraction based on pipe flexibility[24]

Source: Steam and High-Temperature Water Systems

(2) Absorbing expansion and contraction with expansion joints

An expansion joint absorbs pipe displacement caused by thermal expansion or contraction of the pipe, using the joint's expansion or contraction. For an expansion joint standard, JIS B 2352: *Bellows type expansion joints* is available.

Below is an example of calculating the expansion or contraction of a vertical pipe to select an expansion joint for the pipe. In this calculation, the vertical pipe in the structure shown in Figure 2.7-4 is assumed. Formula 2.7-5 below is used to calculate the expansion or contraction of the vertical pipe.

$L = a \cdot (T - t) \cdot L$ ....(Formula 2.7-5)

L : Expansion or contraction (mm)

a : Thermal expansion coefficient ($/°C \times 10^{-6}$)

a of SUS 304 = 17.3 ($/°C \times 10^{-6}$)

T : Highest temperature applicable (°C)

t : Temperature during construction (°C)

L : Pipe length

[Setting conditions for calculation]

Chilled and hot water pipe: Normal pressure 1.0 MPa or lower

Total pipe length: L = 46 (m)

(Summer season)

Chilled water temperature: $T_1 = 7$ (°C)

Outside air temperature: $T_2 = 32$ (°C)

(Winter season)

Hot-water temperature: $T_1 = 65$ (°C)

Outside air temperature: $T_2 = 0$ (°C)

t = 20°C is set to the temperature during construction in summer and winter.

The above conditions are used in calculation.

Expansion and contraction in summer

$\Delta L_1 = 17.3 \times 10^{-6} \times (7 - 20) \times 46 = -10.35$ (mm, on the contraction side)

$\Delta L_2 = 17.3 \times 10^{-6} \times (32 - 20) \times 46 = 9.55$ (mm, on the expansion side)

Expansion and contraction in winter

$\Delta L_1 = 17.3 \times 10^{-6} \times (65 - 20) \times 46 = 35.81$ (mm, on the expansion side)

$\Delta L_2 = 17.3 \times 10^{-6} \times (0 - 20) \times 46 = -15.92$ (mm, on the contraction side)

As stated above, the user must insert an expansion joint that satisfies 35.8 mm on the expansion side and -15.9 mm on the contraction side.

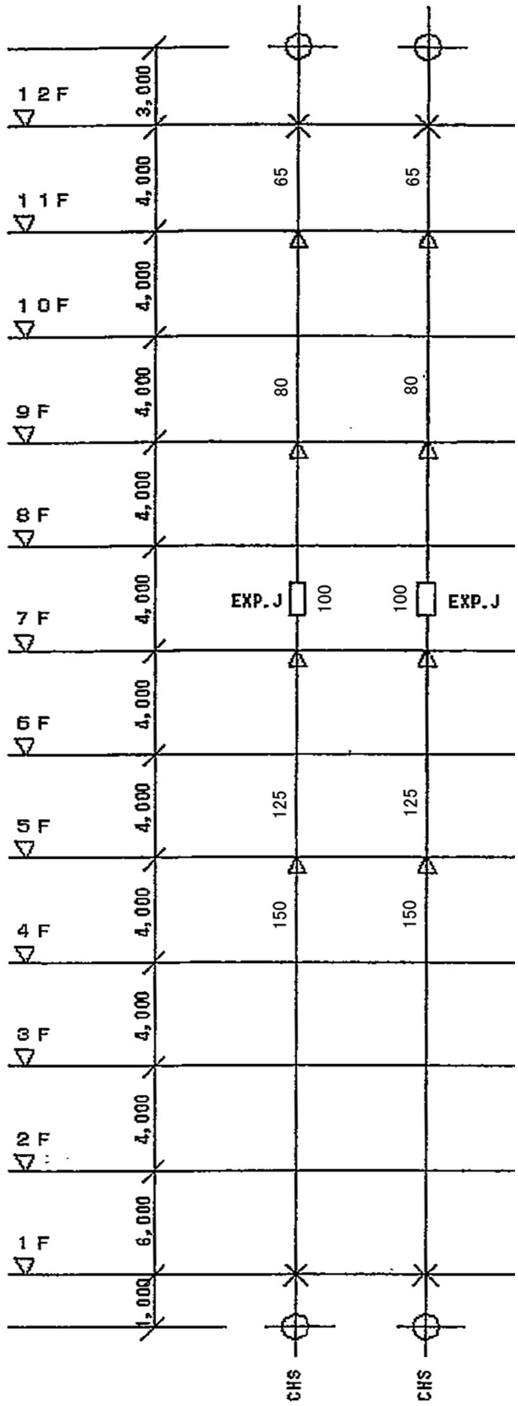


Fig. 2.7-4 Calculation in selecting an expansion joint for vertical pipe

Prepared by: Japan Stainless Steel Association

2.8 Preventing Water Hammer in Piping

Water hammer means a phenomenon where the pipe walls and connected equipment are subjected to water impact when the pump that is a part of the piping system stops, or when the valves are suddenly shut. The pressure in the piping suddenly increases; a pressure wave travels back and forth in the closed-off portion of the piping. Determining if the proof stress of stainless steel pipes for ordinary piping is better than that of carbon steel pipes when water hammer occurs is difficult. Because the 520 MPa tensile strength of stainless steel is about twice that of carbon steel, stainless steel pipes have thinner walls. Therefore, they cannot be deemed superior to carbon steel pipes with respect to the increase in internal pressure in the pipes during water hammer when considering the entire piping system, including the couplings, and that stainless steel piping designs allow greater velocity within the pipes. Stainless steel pipes must be treated the same as carbon steel pipes for understanding the water hammer phenomenon, calculating the increase in pressure that it causes, and preventing it.

2.8.1 Preventing water hammer

The following are examples of measures for preventing water hammer and water column separation.

(a) Check valves on the discharge side of the pump are of water hammer prevention type using springs or heavy weights, not the general swing type.

(b) Couple a dash pot to the check valve to give the valve resistance and lengthen its closing time if water flows in the reverse direction in the pipes.

(c) Install an air chamber to absorb the impact pressure.

(d) Install an automatic pressure control valve or surge tank to prevent an increase in pressure in the pipeline.

(e) Keep the water speed in the pipes to a minimum.

(f) If the horizontal portion of a lift riser is long, avoid water column separation by placing the horizontal portion at as low an elevation as possible.

(g) In an underwater pump or a pump in a closed-circuit pipeline network, making all the water flow backwards by omitting check valves may be effective.

(h) Use the water hammer arrestor.

2.9 Preventing Piping Corrosion

Piping corrosion is divided into inner-surface corrosion primarily caused by the quality of the water or other fluid in the pipes, and outer-surface corrosion primarily caused by the quality of the soil in which the pipes are buried or the gases in the atmosphere. Anticorrosion measures are taken for each of these types of corrosion. With carbon steel or copper pipe, inner surface corrosion is prevented by either lining the pipes with polyvinyl chloride or another substance, or by injecting a chemical to form an anticorrosive coating on the inner surface. Inner-surface corrosion prevention is ordinarily not needed for stainless steel pipes for ordinary piping, because stainless steel has a passive chromium oxide coating (See Table 2.9-1).

As for outer-surface corrosion, although stainless steel pipe for ordinary piping is not completely damage-free, burial experiments performed at several places in Japan by the Japan Stainless Steel Association have yielded quite good results. Stainless steel pipe presents no major problems as long as the pipe is used within the general application range of construction equipment. Still, examining the soil and taking appropriate measures in regions near the seashore, on reclaimed land and in areas where there is much upwelling ground water in the soil is advisable. Anticorrosion measures in the design phase related to the particular nature of stainless steel are listed as follows:

(a) Use heat/thermal insulation materials that do not include halogen ions, especially chloride ions (consult with the manufacturer).

(b) When using water treatment agents, exercise care, including water quality control, because some of them contain chlorides.

(c) Use gaskets intended especially for stainless steel piping, which do not elute chloride ions.

(d) Take care to ascertain if insulation treatment is needed for joining different metals, especially for connection with carbon steel pipes.

(e) If a bender is used, the bend radius of the pipes should be at least 4D, where D is the outside diameter of the pipes.

(f) In using a chlorine sterilizer or the like, be careful of the concentration or detention of residual chlorine or Cl^-.

(g) Make sure that extreme concentrations of stress do not occur in particular parts of the piping.

(h) Avoid right-angled arch/nverted right-angled arch piping that leads to detention of fluid in the pipes. If unavoidable, install a drain valve and periodically clean and flush.

Table 2.9-1 Types of Corrosion, Occurrence Mechanism, and Prevention Measures

	Type of corrosion	Occurrence mechanism and patterns	Major cause of corrosion occurrence	Prevention measure for water supply and hot-water supply piping	
				Material	Environment
1	Pitting corrosion	Active and passive state co-existing on the identical surface will cause local corrosion when a passive-active cell (occluded cell corrosion) is formed. Such local corrosion is subdivided into pitting corrosion and crevice corrosion, depending on the cause and development. Pitting corrosion occurs when a local cell is formed as passive film is destroyed in the environment. Crevice corrosion will occur when a local cell is formed due to shortage in the supply of oxygen in the occluded area and adhesive deposit of corrosive products, etc.	Local corrosion will occur when passive film is destroyed, depending on the halide ions and oxidizer at a certain or greater concentration, and on the temperature.	- Selecting materials to improve corrosion resistance, such as addition of high Cr, Mo and Ni contents. - Adopting SUS 315J1, SUS 315J2 and SUS 316	- Reducing the halide ion concentration and lowering the oxidizer concentration
2	Crevice corrosion				- Preventing oxidation during welding - Avoiding piping design that leads to an occluded state - Avoiding dust and foreign substances entering the gap
3	Intergranular corrosion	Compared with inside crystal grains, diffusion, segregation, deposition, etc. tends to develop in grain boundary, into which carbide or metallic compounds, etc. precipitate, or eluted tramp elements, etc. tend to segregate. This phenomenon will cause greater degradation in the corrosion resistance of the grain boundary than the corrosion resistance inside crystal grains.	When 400° to 850°C heat is added to pipe, CrCx precipitates into grain boundary. This will form a Cr absentee layer that will have corrosion greater than others.	- Adopting low C material - Adopting SUS 304L and SUS 316L	- Reducing the halide ion concentration and lowering the oxidizer concentration - Preventing high temperature during welding
4	Stress corrosion cracking	Will occur in the state of multiple corrosive factors, such as tension stress, material and water quality, which is accompanied with cracking.	Will occur when combinations of tension stress, halide ions, oxidizer, and temperature conditions are coupled with absence of Cr layer in the intercrystalline.	- Reducing tension stress - Adopting low C material - Adopting improved materials: SUS 315J1 and SUS 315J2	- Reducing the halide ion concentration and lowering the oxidizer concentration
5	Galvanic corrosion (Dissimilar metal contact corrosion)	Will occur when two types of metals with differing electric potential contact, forming a cell where the base metal becomes anodic.	For carbon steel pipe, galvanic corrosion will occur due to incomplete insulation between dissimilar material contact.	- Adopting insulation couplings and insulation packing	- For carbon steel pipe, avoid dissimilar material contact - Be careful of dissimilar metallic contact
6	Erosion-corrosion (Flow induced local corrosion)	Will occur when the oxidized film of the metal surface is destroyed with a high flow rate and turbulence, causing the underlying metal to directly contact in the solution. The passive film of stainless steel is so strong that erosion corrosion rarely occurs.	Corrosion will occur with high temperature liquid containing chloride ions, sulfate ions, or sandy particles, etc. or having a low pH, etc.		

Prepared by: Japan Stainless Steel Association

2.9.1 Water quality standards for piping

The concentrations of chloride ions and residual chlorine that are contained in clean water, supplied by water utility operators, greatly impact the corrosion resistance of stainless steel piping. According to *the Enactment of Ministerial Ordinance on Water Quality and Partial Revision of Water Supply Act Enforcement Regulations (Notification No. 1010004)* issued on October 10, 2003 by the Health Service Bureau of the Ministry of Health, Labour and Welfare, management targets were made public concerning the concentration of chemical substances that are contained in tap water. The issuance has aimed to doubly assure the safety of tap water. One management target is to control the residual chlorine concentration within 1.0 ppm or lower.

Since water utilities in Japan have been working on supplying safe and delicious water, the concentrations of chloride ions and residual chlorine contained in clean water have been decreasing. The Delicious Water Committee under the Ministry of Health, Labour and Welfare set residual chlorine to 0.4 ppm or lower as one requirement for delicious water in 1985. In addition, according to the reference flow sheet for delicious water production treatment listed in Table 5.3 on page 81 in the *Water Supply and Drainage Sanitary Equipment Design, Handbook for Heating, Air-Conditioning and Sanitary Engineering (13th edition)*, the controlling object for residual chlorine concentration has been set to 0.4 ppm or lower.

Tables 2.9-2 and 2.9-3 summarize water quality data of water purification plants in Japan for fiscal 2004 and 2007. When the data are compared, their chloride ions barely differ. However, the highest value of residual chlorine has decreased from 8.4 ppm to 2.7 ppm. A less-corrosive environment for stainless steel piping systems is being formed.

Table 2.9-2 Summary of water quality held by water purification plants in Japan (fiscal 2004)[5]

Category	Chloride ions			Residual chlorine		
	Highest value	Average value	Lowest value	Highest value	Average value	Lowest value
Maximum value	200	200	200	8.4	6.2	5.0
Average value	16.1	12.4	9.7	0.5	0.4	0.2
Minimum value	0.4	0.1	0.0	0.1	0.1	0.0

Source: Technical Development of Super-Durable All-Stainless Steel Piping System, Fiscal 2009 Technical Development Report

Table 2.9-3 Summary of water quality held by water purification plants in Japan (fiscal 2007)[5]

Category	Chloride ions			Residual chlorine		
	Highest value	Average value	Lowest value	Highest value	Average value	Lowest value
Maximum value	240	155.6	130.0	2.7	2.0	1.0
Average value	15.8	12.4	9.9	0.5	0.4	0.2
Minimum value	0.3	0.2	0.0	0.1	0.1	0.0

Source: Technical Development of Super-Durable All-Stainless Steel Piping System, Fiscal 2009 Technical Development Report

Parts of the piping that are most likely to corrode are coupling units. Couplings are subdivided into welded and mechanical couplings in terms of corrosion resistance. This section explains water quality standards to prevent couplings from corroding. The water quality standards conform to ***the*** *Guidelines for Water Quality of Stainless Steel Pipes for Building Equipment—Revised Edition 1* prepared by the Japan Stainless Steel Association.

(1) Water quality standards for welded joints

Figure 2.9-1 illustrates a simplified diagram of water quality limits with corrosion estimated and formulated through experiments in relation to welded joints.

The preconditions for the water quality include welding quality A (see Chapter 3: Construction), 1.0 ppm or lower of residual chlorine concentration of make-up water, and a water supply, central circular hot-water supply and air-conditioning system that have, at longest, approximately three to four hours of high levels of water supply and hot-water supply per day.

Figure 2.9-1 shows a corrosion resistance region and a corrosion region by chloride ion concentration and M alkalinity with acid consumption at pH 4.8.

SUS 304 welded joints for water supply mostly remain within the corrosion resistance region under residual chlorine at 1 ppm or lower, chloride ions at 90 ppm or lower, and M alkalinity at 100 ppm or lower.

SUS 304 welded joints for hot-water supply mostly remain within the corrosion resistance region with residual chlorine at 1 ppm or lower, chloride ions at 50 ppm or lower, and M alkalinity at 100 ppm or lower.

Table 2.9-4 lists the examination results in percentages of how well SUS 304 welded joints can cover the quality of water that is supplied by water utility operators in Japan, within the scope of water quality mentioned above. Specifically, SUS 304 piping for water supply can cover 97% or more of such water, while SUS 304 piping for hot-water supply can cover 96% of such water supplied by water utilities in Japan.

In reality, however, the concentrations of residual chlorine, chloride ions, and M alkalinity are unlikely to concurrently indicate values outside the scope mentioned above. Thus, SUS 304 welded joints can be used in most localities throughout Japan.

Table 2.9-4 Applicability of SUS 304 to quality of water supplied by water utilities in Japan

Category	Residual chlorine (ppm)	Chloride ions (ppm)	M alkalinity (ppm)	Probability that SUS 304 satisfies standards for the three substances concurrently
Water supply	1.0 or less	90.0 or less	Approximately 100 or less	97.38%
	99.86%	99.70%	97.81%	
Hot-water supply	1.0 or less	50.0 or less	Approximately 100 or less	96.40%
	99.86%	98.70%	97.81%	

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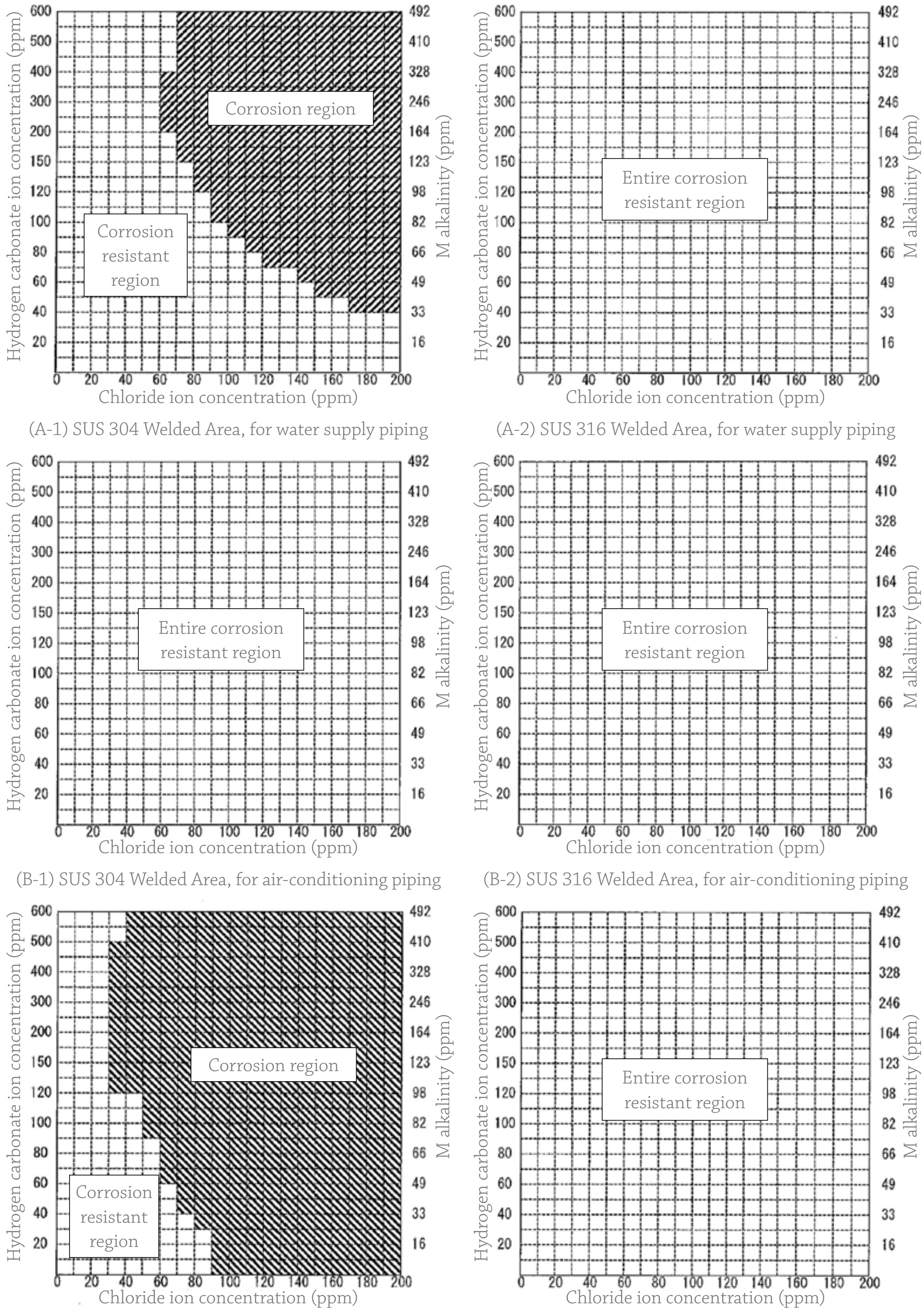


(A-1) SUS 304 Welded Area, for water supply piping

(A-2) SUS 316 Welded Area, for water supply piping

(B-1) SUS 304 Welded Area, for air-conditioning piping

(B-2) SUS 316 Welded Area, for air-conditioning piping

(C-1) SUS 304 Welded Area, for hot-water supply piping

(C-2) SUS 316, for hot-water supply piping

Fig. 2.9-1 Water quality for welded joint areas

Prepared by: Japan Stainless Steel Association

(2) Water quality standards for mechanical couplings

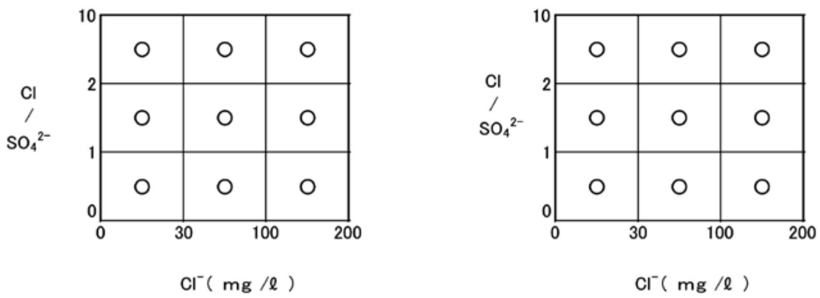
Figures 2.9-2 and 2.9-3 illustrate the water quality standards for mechanical couplings. The simplified diagram of water quality limits concerning crevice corrosion in mechanical couplings in *the Guidelines for Water Quality for Stainless Steel Pipes for Building Equipment (former edition)* is well illustrated. In addition, water supply pipes for clean water had no leaks due to corrosion. Thus, part of the diagram is modified to use as water quality standards for mechanical couplings.

However, the electric potential of crevice corrosion depends on the structure of the coupling.

Thus, depending on the type of coupling, the water quality could be applied up to the △ region. It is therefore recommended to decide water quality for mechanical couplings, pursuant to the past records of coupling manufacturers.

SUS304 SUS316

(1) M alkalinity 75 mg/L



(2) M alkalinity 75 – 500 mg/L

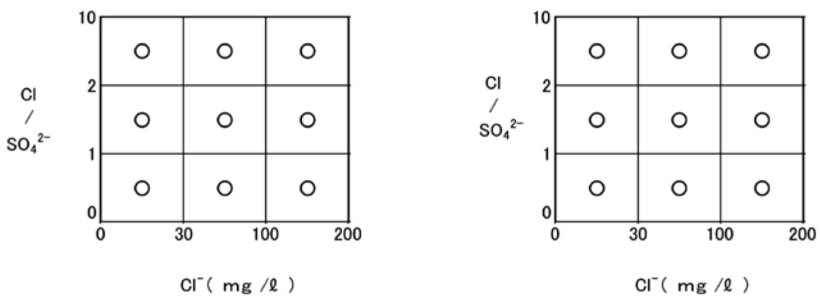


Fig. 2.9-2 Water quality for mechanical coupling areas (for water supply)

○: Corrosion is less likely to occur; ×: Corrosion is likely to occur;
△: Unclear if corrosion is more or less likely to occur

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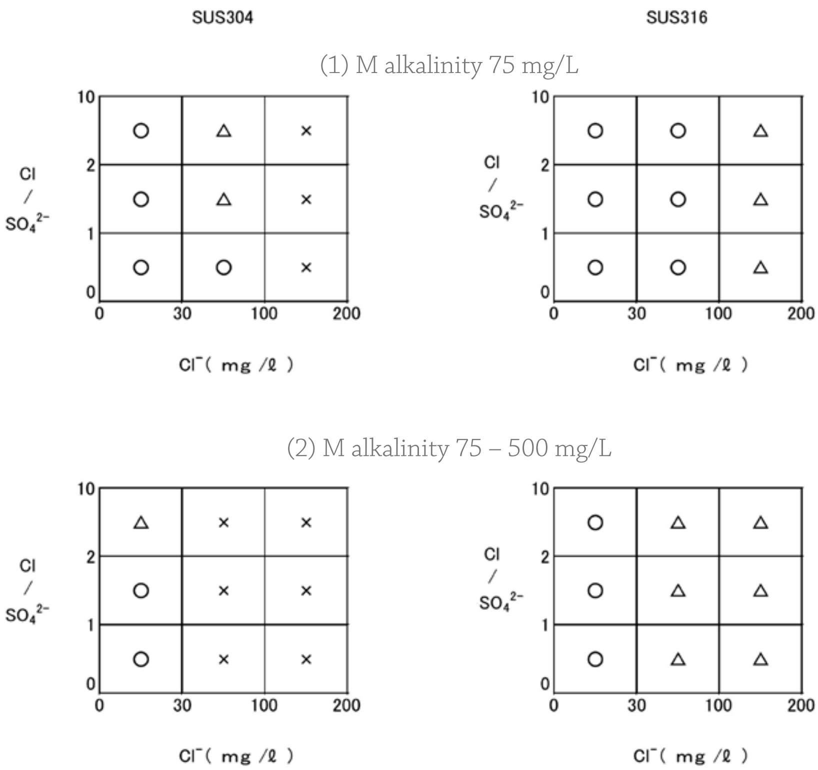


Fig. 2.9-3 Water quality for mechanical coupling areas (for hot-water supply and air-conditioning)

○: Corrosion is less likely to occur; ×: Corrosion is likely to occur;
△: Unclear if corrosion is more or less likely to occur

Prepared by: Japan Stainless Steel Association

2.10 Heat-insulation and Dew Condensation Prevention for Piping

2.10.1 Heat loss from stainless steel piping

Calculations show that the heat loss from stainless steel pipes is slightly less than that from carbon steel pipes due to differences in thermal conductivity. Practically, they may be considered as equal. Perform new calculations is unnecessary; the existing data for carbon steel pipes can be used.

2.10.2 Selecting the insulation material

Table 2.10-1 lists types of heat/thermal insulation materials and their major properties. Table 2.10-1 covers heat/thermal insulating molds and coupling covers included in an appendix to JIS A 9501: *Standard practice for thermal insulation works*. Selecting materials that do not contain soluble halides is recommended, as mentioned earlier. However, some insulation materials contain soluble halides, especially chloride ion Cl^-. Such materials may cause stress corrosion cracking (SCC) on stainless steel pipes if they form condensation or contain moisture.

As shown in Fig. 2.10-1, since sodium + silicate ions of a heat insulation material deter halide ion corrosion, the material may be used within the allowable application range.

Accordingly, when the contents of chloride ions and sodium + silicate ions are known, a decision on if to use such heat insulation material can be made (See Fig. 2.10-2).

In principle, the use of the heat insulation materials listed in Table 2.10-1 may be considered problem-free, but glass wool insulation material sometimes causes problems in hot-water storage tanks. The matter must be considered on a case-by-case basis.

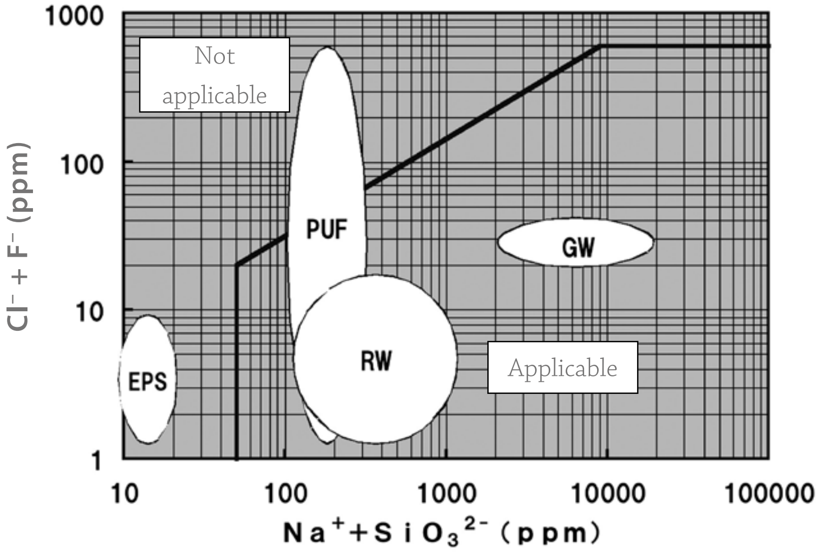
Table 2.10-1 Types of heat/thermal insulation materials and their major properties[16]

Standard code	Type			Density kg/m³	Shrinkage temperature °C (or higher)	Operating temperature °C (or lower)	Thermal conductivity W/(m·K) or lower		Class of formal-dehyde emission
							Mean tem-perature		
JIS A 9504	Rock wool	Heat insulating mold		40-200	600	–[1]	70	0.044	F☆☆ class through F☆☆☆☆ class
	Glass wool	Heat insulating mold		37 - 52	350		70	0.052	
JIS A 9510	Calcium silicate	Heat insulating mold	No. 1-13	≤135[2]	–	1000	100	0.054	–
							200	0.066	
							300	0.079	
							400	0.095	
							500	0.114	
			No. 1-22	≤220	–	600	100	0.065	
							200	0.077	
							300	0.088	
							400	0.106	
							500	0.127	
			No. 2-17	≤170	–	650	100	0.058	
							200	0.010	
							300	0.088	
							400	0.113	
							500	0.146	
			No. 2-22	≤220	–	650	100	0.065	
							200	0.077	
							300	0.088	
							400	0.106	
							500	0.127	
	Water- repellent pearlite	Heat insulating mold	No. 3-25	≤250	–	900	70	0.072	
			No. 4-18	≤185	–	650	70	0.056	
JIS A 9511	Extruded polysty-rene foam	Heat insulating mold	Class 1		–	70	23	0.040	F☆☆☆☆ class
			Class 2		–	70	23	0.034	
			Class 3		–	70	23	0.028	
	Rigid urethane foam	Heat insulating mold	Class 1 No. 1	≥35	–	100	23	0.024	
			Class 1 No. 2	≥25	–	100	23	0.025	
			Class 1 No. 3	≥35	–	100	23	0.029	
			Class 2 No. 1	≥35	–	100	23	0.024	
			Class 2 No. 2	≥35	–	100	23	0.026	
	Polystyrene foam	Heat insulating mold	Class 1	≥10	–	70	23	0.043	
			Class 2	≥20	–	120	23	0.043	
	Phenol foam	Heat insulating mold	Class 1 No. 1	≥45	–	130	23	0.022	F☆☆☆☆ class
			Class 1 No. 2	≥25	–	130	23	0.022	F☆☆☆ class
			Class 2 No. 1	≥45	–	130	23	0.036	–
			Class 2 No. 2	≥35	–	130	23	0.034	
			Class 2 No. 3	≥25	–	130	23	0.028	

(1) Refer to JIS A9501 for points concerning the highest operating temperature after the actual usage conditions are considered.

(2) Insulation materials of a 30-mm thickness or lower may have 155 kg/m³ density or lower.

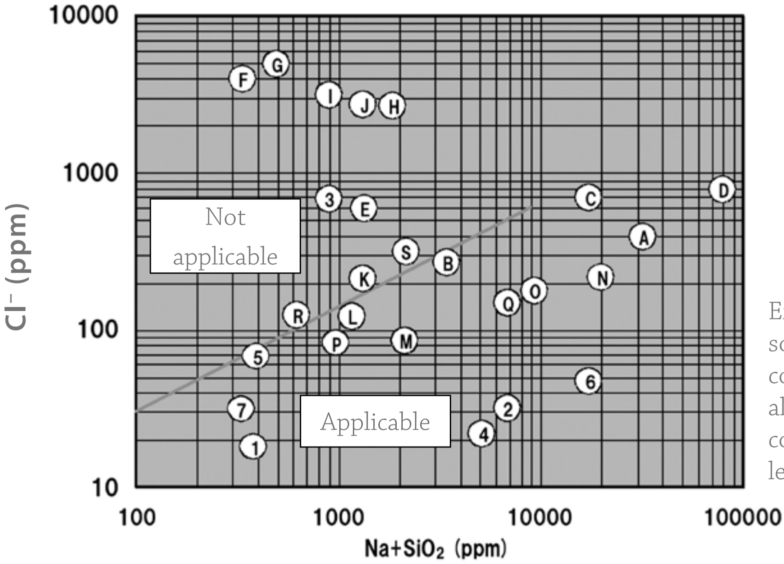
JIS A 9501(2006): Standard practice for thermal insulation works



RW : Rock wool heat insulation mold (JIS A 9504)
GW : Glass wool heat insulation mold (JIS A 9504)
PUF : Polyurethane foam heat insulation mold No. 3 (JIS A 9511)
EPS : Expanded polystyrene foam heat insulation mold No. 3 (JIS A 9511)

Fig. 2.10-1 Results of heat insulation mold elution test and region applicable to stainless steel[17]

Source: Research on Stainless Steel Heat Insulation Materials (Figure 2), Japan Stainless Steel Association Piping System Promotion Committee website



Example of relation between soluble halogen and silica+sodium contents of heat insulation materials (ASTM C-795) that affect stress corrosion cracking (SCC) of stainless steel.

Manufacturer		Name of product	pH	Cl$^-$ (ppm)	Na*+SiO_2 (ppm)
	A	Glass wool	9.62	390	31,900
	B	Rock wool cover	7.37	290	3,490
	C	Silica cover	9.70	680	16,780
	D	Perlite cover	10.16	780	77,180
	E	Polystyrene cover	7.18	580	1,340
	F	Rockcell Board	3.06	3,970	330
	G	Rockcell Board	3.06	4,850	470
	H	Rigid urethane	3.39	2,710	1,920
	I	Rigid urethane	3.34	3,000	910
	J	Flexible urethane	3.54	2,710	1,450
	K	Polyethylene	7.57	190	1,340
	L	Polyethylene	6.98	140	1,140
	M	Calcium silicate	–	85	2,100
	N	Asbestos ‘A’	–	205	20,920
	O	Rock wool	–	175	9,300
	P	Glass wool	–	87	980
	Q	Asbestos ‘B’	–	153	6,930
	R	Gypsum kneaded with water	–	123	645
	S	Finished cement kneaded with water	–	295	2,236
Nichias	①	Rock wool cover	9.2	18	365
Nippon Micro G-Wool	②	Glass wool cover	9.4	28	6,588
Marusho Natsuyama felt	③	Cattle hair felt cover	6.8	650	908
Nichias	④	Calcium silicate	9.4	23	5,300
Adia	⑤	Polystyrene foam	7.2	66	402
Mitsui Mining & Smelting	⑥	Water-repellent pearlite	9.6	46	17,130
Nichias	⑦	Rigid urethane foam	6.5	30	335

①, ②, ③, ④, ⑤, ⑥ and ⑦ in the table above are reference results (March 5, 1993)

Fig. 2.10-2 Range applicable to heat insulation materials for stainless steel pipe[18]

Source: ASTM C795 (2008)

2.10.3 Determining the thickness of heat insulation material

Determining the thickness of the heat insulation material by the calculation formulas given in JIS A 9501, considering cost, is desirable. *The Public Construction Works Standard Specifications* (*Mechanical Equipment Works, 2010 Edition*), *the Heating, Air-Conditioning and Sanitary Equipment Engineering Works Standard Specifications* (SHASE-S 010-2007) and *the Building Equipment Works Common Specifications 2010* of the Japan Institute of Architects (JIA) have tables indicating necessary thicknesses of heat insulation materials that are calculated under specific conditions. The user may consult one of these tables for such thicknesses. This manual shows Table 2.10-2 from *the Public Construction Works Standard Specifications* (*Mechanical Equipment Works, 2010 Edition*), which has been widely used for public works.

Table 2.10-2 Thicknesses of heat insulation materials1[9]

[Unit: mm]

<table>
<tr><th colspan="2">Heat insulation type \ Nominal diameter</th><th>15</th><th>20</th><th>25</th><th>32</th><th>40</th><th>50</th><th>65</th><th>80</th><th>100</th><th>125</th><th>150</th><th>200</th><th>250</th><th>300</th><th colspan="2">Referential application segment</th></tr>
<tr><td rowspan="2">I</td><td>A</td><td colspan="8">20</td><td colspan="3">25</td><td colspan="3">40</td><td>Rock wool</td><td>Hot water pipe</td></tr>
<tr><td>B</td><td colspan="8">20</td><td colspan="3">25</td><td colspan="3">40</td><td>Glass wool</td><td>Hot-water supply pipe</td></tr>
<tr><td rowspan="2">II</td><td>A</td><td colspan="2">20</td><td colspan="3">30</td><td colspan="9">40</td><td>Rock wool</td><td rowspan="2">Steam pipe (low pressure 0.1 MPa or lower)</td></tr>
<tr><td>B</td><td colspan="2">20</td><td colspan="3">30</td><td colspan="9">40</td><td>Glass wool</td></tr>
<tr><td rowspan="3">III</td><td>A</td><td colspan="3">30</td><td colspan="9">40</td><td colspan="2">50</td><td>Rock wool</td><td>Cool water pipe</td></tr>
<tr><td>B</td><td colspan="3">30</td><td colspan="9">40</td><td colspan="2">50</td><td>Glass wool</td><td rowspan="2">Chilled and hot water pipe</td></tr>
<tr><td>C</td><td colspan="3">30</td><td colspan="9">40</td><td colspan="2">50</td><td>Polystyrene foam</td></tr>
<tr><td>IV</td><td>C</td><td>30</td><td colspan="7">40</td><td colspan="6">50</td><td>Polystyrene foam</td><td>Cool water pipe (cool water temperature 2° to 4°C)</td></tr>
<tr><td>V</td><td>C</td><td colspan="3">40</td><td colspan="4">50</td><td colspan="7">65</td><td>Polystyrene foam</td><td>Brine pipe</td></tr>
<tr><td rowspan="2">VI</td><td>A</td><td colspan="3">30</td><td colspan="9">40</td><td colspan="2">50</td><td>Rock wool</td><td rowspan="2">Refrigerant pipe</td></tr>
<tr><td>B</td><td colspan="3">30</td><td colspan="9">40</td><td colspan="2">50</td><td>Glass wool</td></tr>
<tr><td rowspan="3">VII</td><td>A</td><td colspan="8">20</td><td colspan="3">25</td><td colspan="3">40</td><td>Rock wool</td><td rowspan="3">Water supply pipe
Drainage pipe</td></tr>
<tr><td>B</td><td colspan="8">20</td><td colspan="3">25</td><td colspan="3">40</td><td>Glass wool</td></tr>
<tr><td>C</td><td colspan="8">20</td><td colspan="6">25</td><td>Polystyrene foam</td></tr>
<tr><td colspan="2">VIII</td><td colspan="14">25</td><td colspan="2" rowspan="3">Machine, exhaust pipe, air flue, pasting inside</td></tr>
<tr><td colspan="2">IX</td><td colspan="14">50</td></tr>
<tr><td colspan="2">X</td><td colspan="14">75</td></tr>
<tr><td colspan="2">XI</td><td colspan="14">25 for indoor exposure (machine rooms, libraries and warehouses) and covered areas; 50 for indoor exposure (living rooms in general and corridors), outdoor exposure and high-humidity areas</td><td colspan="2"></td></tr>
</table>

Source: Public Construction Works Standard Specifications, Mechanical Equipment Works, 2010 Edition

2.11 Precautions for Devices Connected to Stainless Steel Piping

Using devices made of stainless steel to be connected to stainless steel piping and couplings such as valves, pumps, water tanks, hot-water tanks and grease traps is desirable. Devices made of other materials may be used because stainless steel is expensive or such stainless steel devices are not available. This section explains points to note for various devices, but air-conditioning systems are not covered here because the systems and devices are so diverse.

2.11.1 Valves

In selecting and determining valves for stainless steel pipe for building equipment, dissimilar metal contact corrosion, corrosion resistance, LCC and other factors need to be considered. For example, although a bronze valve has a natural potential (corrosion potential) almost as high as that of a stainless steel pipe, its long-term corrosion resistance is inferior to that of a stainless steel pipe. Also, even if an insulated cast iron valve is connected to a stainless steel pipe, red rust can still develop.

Standards of valves for stainless steel piping for building equipment include *Stainless Steel Valves for General Piping* (SAS 358, 1992), prepared by the Japan Stainless Steel Association, and *Stainless Steel Valves for General Piping* (JV 8-1, 2007), prepared by the Japan Valve Manufacturers' Association (JVMA). SAS 358 defines gate valves, check valves, ball valves and butterfly valves, all with the nominal pressure of 10K. JV 8-1 defines gate valves, globe valves, check valves, butterfly valves and ball valves, with the nominal pressures of 10K, 16K and 20K.

These standards stipulate types of valves, relations between temperatures and the highest allowable pressures of fluids, quality, materials, tests, inspections and other items.

Table 2.11-1 lists the types of valves stipulated in JSSA standard SAS 358. Table 2.11-2 lists the types of valves stipulated in JVMA JV 8-1. For nominal diameter 50 A or lower, ball valves are mostly used, while for nominal diameters of 65 or greater, butterfly valves are mostly used.

Table 2.11-1 Types of valves[20]

Nominal pressure	Type of valve	Nominal diameter													
		A	15	20	25	32	40	50	65	80	100	125	150	200	250	300
		B	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4	5	6	8	10	12
10K	Threaded end inner-screw gate valve		○	○	○	○	○	○	–	–	–	–	–	–	–	–
10K	Flanged end outer-screw gate valve		–	–	–	–	–	–	○	○	○	○	○	○	○	○
10K	Threaded end check valve		○	○	○	○	○	○	–	–	–	–	–	–	–	–
10K	Flanged end check valve		–	–	–	–	–	–	○	○	○	○	○	○	○	○
10K	Wafer type check valve		–	–	–	–	–	–	○	○	○	○	○	○	○	○
10K	Threaded end ball valve		○	○	○	○	○	○	–	–	–	–	–	–	–	–
10K	Flanged end ball valve		–	–	–	–	–	–	○	○	○	○	○	○	○	○
10K	Wafer type butterfly valve		–	–	–	–	–	–	○	○	○	○	○	○	○	○

Source: SAS 358 (1992): Stainless Steel Valves for General Piping, Japan Stainless Steel Association

Table 2.11-2 Types of valves[21]

Nominal pressure	Types of valves	Seat		Nominal diameter													
			A	15	20	25	32	40	50	65	80	100	125	150	200	250	300
			B	1/2	3/4	1	1 1/4	1 1/2	2	–	–	–	–	–	–	–	–
			Su	13	20	25	30	40	50	60	–	–	–	–	–	–	–
10K	Threaded end inner-screw gate valve	Metal		○	○	○	○	○	○	–	–	–	–	–	–	–	–
	Flanged end inner screw gate valve	Metal		○	○	○	○	○	○	–	–	–	–	–	–	–	–
	Flanged end outer screw gate valve	Metal		○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Mechanical inner screw gate valve	Metal		○	○	○	○	○	○	○	–	–	–	–	–	–	–
	Threaded end inner screw globe valve	Metal / Soft		○	○	○	○	○	○	–	–	–	–	–	–	–	–
	Flanged end inner screw globe valve	Metal / Soft		○	○	○	○	○	○	–	–	–	–	–	–	–	–
	Flanged end outer screw globe valve	Metal / Soft		○	○	○	○	○	○	○	○	○	○	○	○	–	–
	Mechanical inner screw globe valve	Metal / Soft		○	○	○	○	○	○	○	–	–	–	–	–	–	–
	Threaded end swing check valve	Metal		○	○	○	○	○	○	–	–	–	–	–	–	–	–
	Flanged end swing check valve	Metal		○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Mechanical swing check valve	Metal		○	○	○	○	○	○	○	–	–	–	–	–	–	–
	Threaded end lift check valve	Metal		○	○	○	○	○	○	–	–	–	–	–	–	–	–
	Flanged end lift check valve	Metal		○	○	○	○	○	○	–	–	–	–	–	–	–	–
	Mechanical lift check valve	Metal		○	○	○	○	○	○	–	–	–	–	–	–	–	–
	Wafer check valve	Metal / Soft		–	–	–	–	–	○	○	○	○	○	○	○	○	○
	Wafer butterfly valve	Soft		–	–	–	–	–	○	○	○	○	○	○	○	○	○
	Threaded end ball valve	Soft		○	○	○	○	○	○	–	–	–	–	–	–	–	–
	Flanged end ball valve	Soft		○	○	○	○	○	○	○	○	○	○	○	○	–	–
	Mechanical ball valve	Soft		○	○	○	○	○	○	○	–	–	–	–	–	–	–
16K	Wafer butterfly valve	Soft		–	–	–	–	–	○	○	○	○	○	○	○	○	○
20K	Flanged end outer screw gate valve	Metal		○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Flanged end outer screw globe valve	Metal		○	○	○	○	○	○	○	○	○	○	○	○	–	–
	Flanged end swing check valve	Metal		–	–	–	–	–	○	○	○	○	○	○	○	○	○
	Flanged end lift check valve	Metal		○	○	○	○	○	–	–	–	–	–	–	–	–	–
	Wafer check valve	Metal / Soft		–	–	–	–	–	○	○	○	○	○	○	○	○	○
	Flanged end ball valve	Soft		○	○	○	○	○	○	○	○	○	○	○	○	–	–
	Mechanical inner screw gate valve	Metal		○	○	○	○	○	○	○	○	–	–	–	–	–	–
	Mechanical ball valve	Soft		○	○	○	○	○	○	○	○	–	–	–	–	–	–

Note: The nominal diameter for flanged end and wafer valves is called A; for threaded end, B; and for mechanical, Su.

Source: JVMA Standard JV 8-1(2007): Stainless Steel Valves for Ordinary Piping

(1) Selecting valves

(a) Types of valves

In selecting a valve for stainless steel piping where long service life is important, the user needs to consider the following points: it must fit for blocking, have small pressure loss, and be built for easy maintenance. Considering these points, the following valves are recommended.

- Nominal diameter 50 A or lower: gate valve or ball valve
- Nominal diameter 65 A or above: eccentric butterfly valve

Table 2.11-4 lists the basic types, structures and characteristics of valves. In terms of the piping of the common units, gate or ball valves are suitable for the nominal diameter of 50 A or lower, and butterfly valves are suitable for the nominal diameter of 65 A or above. This is mainly because these valves are suitable for blocking and have limited pressure loss. Since globe valves have large pressure losses, they are inappropriate for piping of common units that are left always open.

Table 2.11-5 lists the structures and characteristics of the centric rubber seat butterfly valve and eccentric PTFE seat butterfly valve. Though centric rubber seats cannot be easily replaced at the job site, eccentric PTFE seats can. In addition, the PTFE seat is superior to rubber seat for corrosion resistance.

(b) Valve Materials

Table 2.11-3 lists materials for the main unit, seats, and stems of 40-year service life valves.

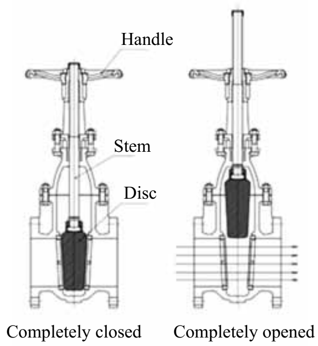
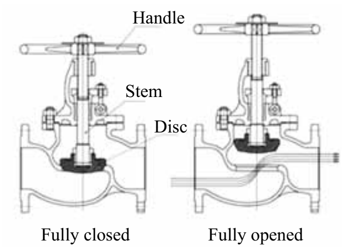
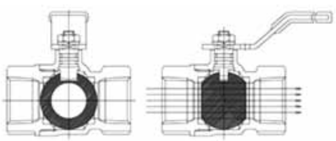
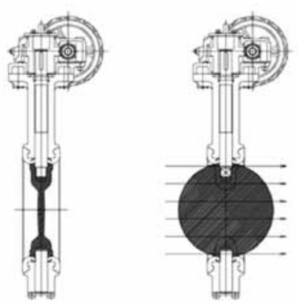
Table 2.11-3 Materials for 40-year service life valves[6]

Type of valve	Main unit	Seat		Stem
		Disc	Body seat ring	
Gate valve	Stainless steel	Stainless steel	Stainless steel	Stainless steel
Ball valve			PTFE	
Eccentric butterfly valve				

Source: Guidelines for Super Durable All Stainless Steel Piping System for Common Units

Table 2.11-6 lists categories of materials used for building equipment. In general, in addition to stainless steel valves, bronze and leadless bronze valves, which have natural potential (corrosion potential) similar to stainless steel, are used with stainless steel pipes. The Public Construction Works Standard Specifications do not permit using brass because brass is likely to develop dezincification corrosion and stress corrosion cracking.

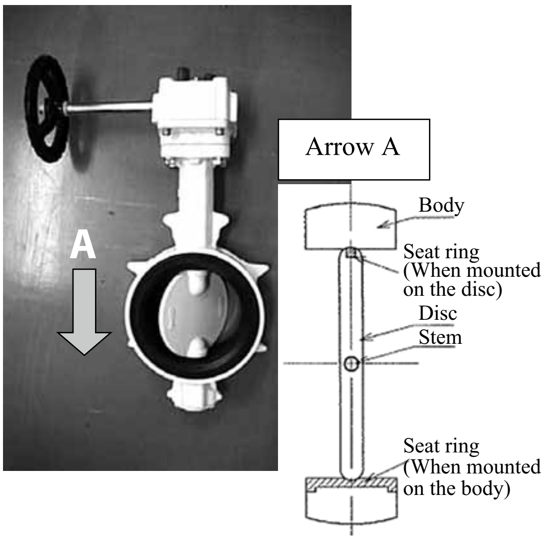
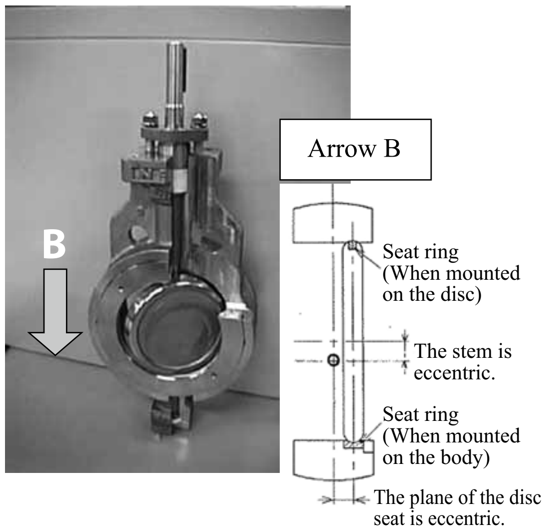
Table 2.11-4 Basic structure and characteristics of valves[6]

Type and structure	Characteristic	Suitable for blocking	Suitable for controlling	Small pressure loss	Suitable for high pressure	Suitable for high temperature	Usable for large diameter
	Gate valve 1) Used mainly for shutoff valves (basically not used for control valves) 2) Having straight flow passage and small flow resistance	◎	△	◎	◎	◎	◎
	Globe valve 1) Mainly used for controlling flow rate 2) Power larger than for gate valves is required to operate	◎	◎	△	◎	◎	△
	Ball valve 1) More rapid shutoff than other kinds of valves 2) Having straight flow passage and quite small flow resistance 3) Used mainly for shutoff valves (not used for control valves)	◎	△	◎	○	△	○
	Butterfly valve 1) Used for blocking pipeline or controlling flow rate (some valves can be used under more stringent conditions) 2) Having straight flow passage and small flow resistance	◎	○	○	△	△	◎

◎: Good; ○: Applicable; △: Applicable, depending on the condition

Source: Guidelines for Super Durable All Stainless Steel Piping System for Common Units

Table 2.11-5 Structures and characteristics of centric and eccentric butterfly valves[6]

Type	Centric rubber seat butterfly valve	Eccentric PTFE seat butterfly valve
Structure	Structural form where the circumference of the disc is on the same plane as the center of the stem	Structural form where the rotation center (stem) of the disc is not on the center of the valve diameter and the plane of the disc seat is eccentric to the center of the stem.
Material	Body: Since the inner surface is covered with rubber, the valve does not depend on the material of the pipe. Aluminum alloy valves are used for many types of building equipment.	Body: Since the inner surface contacts solution, the material of the valve must be the same as that of the pipe.
	Body seat ring (seat): Rubber	Body seat ring (seat): PTFE
	Disc and stem: Stainless steel	Disc and stem: Stainless steel
Service life	Rubber seat: 10 to 15 years	PTFE: 40 years of service life is available, because no stress release occurs when the disc is fully opened due to no contact between the disc and seat. In addition, the valve is outstanding in chemical resistance.
Replacing the seat	Difficult	Easy
Price	Inexpensive	Expensive (about five times more expensive than rubber seat)
Structural diagram		

Source: Guidelines for Super-Durable All-Stainless Steel Piping System

Table 2.11-6 Materials of Valves Used for Building Equipment[6]

Category			Type	JIS material code	Stipulations of the Standard Specifications of the MLIT	
					Standard number	Standard name
Nonmetal	Plastic		Unplasticized vinyl chloride	PVC	–	–
Metal	Nonferrous	Copper alloy	Bronze (casting)	CAC406	JIS B 2011	Bronze valve
			Leadless bronze (casting)	CAC911		
			Brass (forging)	C3771BD	–	–
		Aluminum alloy	Aluminum alloy (casting)	ADC12	JIS B 2032	Wafer rubber seat butterfly valves
	Steel	Cast iron (casting)	Gray iron casting	FC200	JIS B 2031	Gray cast iron valve
			Spheroidal graphite iron casting	FCD400, 450	JV 4-2	Iron casting valve: small valve made of malleable cast iron and ductile cast iron
			Black heart malleable iron casting	FCMB360	JV 4-3	Iron casting valve: malleable cast iron valve and ductile cast iron casting valve
			Ductile iron casting	FCD-S	JV 4-4	Iron casting valve: small valves made of malleable iron and ductile cast iron
			Malleable iron casting	FCMB-S35	JV 4-5	Iron casting valve: valves made of malleable iron and ductile cast iron
		Cast steel (casting)	Carbon steel casting	SCPH2	JIS B 2071	Steel valve
			Stainless steel casting	SCS13	JV 8-1	Stainless steel valve for ordinary piping
				SCS13A		
				SCS14		
				SCS14A		
		Forged steel (Forging)	Carbon steel forging	SFVC2A	–	–
			Stainless steel forging	SUSF3004	–	–
				SUSF316	–	–

Source: Guidelines for Super-Durable All-Stainless Steel Piping System

(c) Valve materials optimum for stainless steel pipes

① Nominal diameter 50 A or lower (gate valve, ball valve)

Table 2.11-7 lists the assessment of corrosion resistance of gate and ball valves made of stainless steel and of bronze, assuming a 40-year service life. Bronze valves may develop minor corrosion from water quality.

② Nominal diameter 65 A or above (butterfly valve)

Table 2.11-8 assesses the corrosion resistance of the rubber seat butterfly valve and

PTFE seat butterfly valve. The main unit of the centric butterfly valve has no contact with the solution because the inner surface of the body is covered with rubber. However, the rubber may deteriorate in 10 to 15 years, depending on the water quality.

Table 2.11-7 Assessment of corrosion resistance of stainless steel valves and bronze valves[6]

Type of valve	Main unit	Seat		Stem	Assessment
		Disc	Body seat ring		
Gate valve	Stainless steel	Stainless steel	Stainless steel	Stainless steel	◎
	Bronze	Bronze or dezincing-resistant brass	Bronze	Dezincing-resistant brass	○
Ball valve	Stainless steel	Stainless steel	PTFE	Stainless steel	◎
	Bronze	Stainless steel or dezincing-resistant brass		Dezincing-resistant brass	○

Source: Guidelines for Super-Durable All-Stainless Steel Piping System

Table 2.11-8 Assessment of corrosion resistance of rubber seat and PTFE seat butterfly valves[6]

Type of valve	Main unit	Seat		Stem	Assessment
		Disc	Body seat ring		
Centric	Aluminum alloy, etc. (surface not wetted)	Stainless steel	Rubber	Stainless steel	△
Eccentric	Stainless steel		PTFE		◎

* ◎: 40-year service life; △: The rubber may deteriorate in 10 to 15 years, depending on the water quality.
Source: Guidelines for Super-Durable All-Stainless Steel Piping System

(d) Legal restrictions

Valves to be selected for water supply equipment and fire fighting equipment shall satisfy the following provisions of the laws.

① Valves for water supply equipment (*Water Supply Act*)

(i) The materials for valves shall satisfy the leaching performance for water quality standards including lead, specified under an ordinance of the Ministry of Health, Labour and Welfare.

(ii) Valves used for directly-connected water supply other than JIS B 2011: *Bronze, gate, globe, angle, and check valves* shall obtain approval of a third party inspection body registered with the Ministry of Health, Labour and Welfare.

② Valves for fire fighting equipment (*Fire Service Act*)

Valves for fire fighting equipment exclude deluge valves, alarm and other automatic fire valves, and on-off valves such as for fire hydrants.

(i) The valves shall conform to the standards for metallic couplings and valves specified in the provisions of *the Fire Service Act Enforcement Regulations*.

(ii) Valves other than JIS B 2011: ***Bronze, gate, globe, angle, and check valves,*** JIS B 2031: ***Gray cast iron valves*** and JIS B 2051: ***Malleable iron 10 K screwed valves*** shall obtain approval of a third party inspection body registered with the Fire and Disaster Management Agency of the Ministry of Internal Affairs and Communications.

2.11.2 Pumps

Since the quality of water raised or moved by pumps for buildings is comparatively mild, the material of the pump including its wetted section was rarely stainless steel. Recently, however, stainless steel has been increasingly used as the main material for water supply pumps and water supply pump units in skyscraper office buildings, considering red water control measures and service life extension.

In a piping system employing stainless steel pipes, if the material of the wetted section of the pump - the main component of the system- is carbon steel or cast iron, the pump becomes electrochemically basic against the stainless steel pipes and suffers corrosion damage, resulting in red water. The stainless steel piping is a perpetrator.

Table 2.11-9 lists materials for pumps specified in the pump section of the *Heating, Air-Conditioning and Sanitary Equipment Engineering Works Standard Specifications* of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan (SHASE-S 010-2007). The standard specifications stipulate that a pump shall conform to JIS B 8313: *End suction centrifugal pump*s, JIS B 8319: *Small size multi-stage centrifugal pumps*, or JIS B 8322: *Double suction volute pumps Double*, or the standard specifications of the manufacturer if any of these JIS standard pumps is not available. In addition, the standard specifications designate, as material, stainless steel (JIS G 4305: *Cold-rolled stainless steel plate, sheet and strip, or JIS G 5121: Corrosion-resistant cast steels for general applications*), in parallel with descriptions of *gray iron castings* (JIS G 5501) and *Copper and copper alloy castings* (JIS H 5120).

A wide variety of stainless steel pumps is supplied by different pump producers. They include city water pumps, such as feed water pump units, small-size centrifugal pumps, and line pumps, and special solution pumps (which can handle tap water as well) for use in the chemical, food and water treatment industries. The latter are available in various types—they include centrifugal, multi-stage centrifugal, submerged, and submerged sewage pumps. Table 2.11-10, a rearranged version of pump makers' informational materials, provides an overview of stainless steel pump products although the data provided slightly differs from the numerical values used for actual pump selection because of the overlapping of data from a plurality of makers.

Table 2.11-9 Materials Specified in SHASE-S 010-2007[22]

Standard	Region	Material
End suction centrifugal pumps (JIS B 8313) Small size multi-stage centrifugal pumps (JIS B 8319) Double suction volute pumps (JIS B 8322)	Main pump unit	JIS G 5501 (Gray iron castings) JIS G 4305 (Cold-rolled stainless steel plate, sheet and strip) JIS G 5121 (Corrosion-resistant cast steels for general applications)
	Impeller	JIS H 5120 (Copper and copper alloy castings) JIS G 4305 (Cold-rolled stainless steel plate, sheet and strip) JIS G 5121 (Corrosion-resistant cast steels for general applications)
	Main shaft	JIS G 4305 (Cold-rolled stainless steel plate, sheet and strip)

Source: SHASE-S 010(2007): Heating, Air-Conditioning and Sanitary Equipment Engineering Works Standard Specifications

Table 2.11-10 Overviews of Stainless Steel Pumps

	Centrifugal pump	Centrifugal pump	Centrifugal pump	Multistage centrifugal pump	Line pump	Submerged pump	Submerged sewage pump	Feed water pump unit	Submerged pump unit
Material Note									
Impeller	SUS 304	SCS 13	SCS 13	BC 6	SCS 13	SUS 304	SCS 13	BC 6	SUS 304
Main shaft	SUS 420J2	SUS 304	SUS 304	S 35C	SUS 304	SUS 420J1	SUS 304	SUS 304	SUS 420J1
Casing	SUS 304	SCS 13	SCS 13	SCS 13	SCS 13	SUS 304	SCS 13	SCS 13	SCS 13
Discharge aperture (mm)	32-65	25-100	25-200	25-65	32-100	32-65	40-65	32-65	32-50
Discharge rate (m^3/min)	0.04-0.65	0.03-1.20	0.03-6.0	0.12-1.6	0.02-1.2	0.05-0.8	0.01-0.80	0.1-0.75	0.1-0.35
Total pump head (m)	26-65	17-100	7-50	23-255	6-52	16-130	8-21	30-55	18-62
Liquid quality	Clean water	Clean water/ special liquid	Clean water/ special liquid	Clean water	Clean water/ special liquid	Clean water	Sewage	Clean water	Clean water
Liquid temperature	0°-100°C	-20°-180°C	-20°-180°C	0°-40°C	0°-100°C	0°-40°C	0°-50°C	0°-40°C	0°-32°C
Applications									
For water supply	○			○	○	○		○	○
For hot water supply	○				○				
For chilled/hot water circulation	○				○				
For general industrial use	○			○	○	○		○	○
For special liquid		○	○						
For sewage							○		

* SUS 304: SUS 304 in JIS G 4305: ***Cold- rolled stainless steel plate, sheet and strip***; SUS 402J2: SUS 402J2 in JIS G 4305:***Cold-rolled stainless steel plate, sheet and strip***;

SCS 13: SCS 13 in JIS G 5121: ***Corrosion-resistant cast steels for general applications***; BC 6: BC 6 in JIS H 5111: ***Bronze castings***; S 35C: S 35C in JIS G 4501: ***Carbon steel tubes for machine structural purposes***

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

2.11.3 Water storage tanks

Water receiver tanks or elevated water tanks are made of materials such as carbon steel plates, FRP, stainless steel plates and wood. Structurally, they are classified into integrated and panel built-up types. Panel-built-up water storage tanks of stainless steel plates have been widely adopted because of their advantages in corrosion resistance, hygiene, weathering resistance, earthquake resistance, shielding and resistance to aging deterioration as well as aesthetic appearance.

Table 2.11-11, from *the Air-conditioning and Sanitary Engineering Handbook* (*14th Edition, 2010*) shows the corrosion resistance, workability, cost effectiveness and other characteristics of various materials.

(1) Corrosion in water storage tanks

Water storage tanks greatly differ in several points from hot water storage tanks in terms of the usage environment. The major differences are the use at room temperature, a gas phase above the water in the tank and inclusion of a relatively large amount of residual chlorine in tap water for sterilization. Use at room temperature is not necessarily a drawback, but the other two are problems. The form of corrosion in water storage tanks is usually pitting corrosion in the gaseous phase section. Chlorine gas diffused or concentrated in the gaseous phase section due to aeration at the water storage tank inlet is re-dissolved in water droplets on the inner surface of the gaseous phase section. This forms a local cell through destruction of the passive film, resulting in generating pitting corrosion. Although this phenomenon in the gaseous phase is very characteristic of water storage tanks, the same consideration as for hot water storage tanks should be given to the possibility of crevice corrosion or stress corrosion cracking resulting from the type of stainless steel, the structure, or the fabricating process adopted.

(2) Materials used for water storage tanks

As with hot water storage tanks, plates of austenitic stainless steel, ferritic stainless steel and austenitic stainless-clad steel have been used as materials for water storage tanks. Given apprehension that SUS 304(*Austenitic stainless steel*) may not maintain sufficient corrosion resistance in the environment in the gaseous phase, duplex stainless steel has recently been used.

Table 2.11-11 Comparison in Characteristics of Materials[23]

Material	Item	Moisture condensation	Corrosion resistance	Weather resistance	Cold resistance	Raising weight	Carrying-in	Workability		Cost effectiveness	Remarks
								Factory	On-site		
Carbon Steel plate	Integrated type	△	△	○	○	△	△	◎	○	○	Heavy. Dependent on the rust-proofing quality.
	Panel built-up type	△	△	○	○	◎	◎	◎	○	○	Large-capacity tanks can be constructed. Suitable for on-site assembly.
Stainless steel	Integrated type	△	○	◎	○	△	△	△	△	△	Inferior for cost-effectiveness.
	Single-plate panel built-up type	△	○	◎	○	◎	◎	○	△	△	Same as above. Suitable for on-site assembly.
	Composite panel built-up type	◎	○	◎	◎	◎	◎	◎	△	△	Same as above.
Plastic	Single-plate integrated type	△	◎	○	△	△	△	○	○	◎	Light. Care should be taken to prevent damage.
	Single-plate panel built-up type	△	◎	○	△	◎	◎	◎	◎	◎	Same as above. Suitable for on-site assembly.
	Sandwich integrated type	◎	◎	○	◎	△	△	○	○	○	Light. Care should be taken to prevent damage.
	Sandwich panel built-up type	◎	◎	○	◎	◎	◎	◎	◎	○	Same as above. Suitable for on-site assembly.
Wood plate		◎	◎	○	○	○	◎	◎	◎	△	Slightly heavy. Designed especially for on-site assembly. Slightly inferior for cost-effectiveness.

◎ : Excellent; ○ : Ordinary; △ : Slightly unsatisfactory

Source: Water Supply and Drainage Sanitary Equipment Design, Air-conditioning and Sanitary Engineering Handbook, 14th edition, Volume 4, 2010

2.11.4 Hot water storage tanks

The heat exchangers used for buildings are roughly classified into two types: shell-and-tube heat exchangers and hot water storage tanks. The materials for the tubes of heat exchangers with stainless steel or stainless clad steel-made shells are characterized as follows: SUS 304 or SUS 304L is frequently used for the heat exchangers, and CuT for hot water storage tanks. Since the former are often used in severer environments in terms of factors such as the types of fluids and requirements on temperature and pressure, only the latter are discussed below.

Stainless steel hot water storage tanks have been brought into wide use since about 1963, due to improving corrosion resistance and cleanliness. The material most frequently used for hot water storage tanks has been carbon steel plate of SS 400 (JIS G 3101: ***Rolled steels for general structure***) provided with a lining on its inner surface (zinc metallikon thermal spraying, immersion galvanization, zinc paint coating, epoxy resin coating or glass lining). However, the lining process may require meticulous attention, or involve difficulty, in fabrication or maintenance. This is one reason why stainless steel or stainless-clad steel hot water storage tanks have come into wide use.

(1) Corrosion in hot water storage tanks

In a hot water storage tank, bends, crevices, and welds exist in various places because of the structures of its sections or their fabricating processes. For this reason, all forms of corrosion exist: pitting corrosion, crevice corrosion, intergranular corrosion and stress corrosion cracking. Table 2.11-12 summarizes the relationships between typical sections of a hot water storage tank and the forms of corrosion.

Stress corrosion cracking occurs most frequently in hot water storage tanks in the service temperature range of 50° to 100°C. Thus, when using hot water storage tanks in this temperature range, special care should be taken to eliminate crevices and an excessive bending radius, or to provide sufficient thermal control during welding.

Table 2.11-12 Typical sections of hot water storage tank and forms of corrosion[10]

	Inside tank	Welds or their adjacent areas	Sludge buildup section	Manhole/nozzle mount	Bend in panel board	Heat exchange pipe support weld
Pitting corrosion	○	○	○			
Crevice corrosion		○ (Gap in weld)		○		○
Intergranular corrosion		○				
Stress corrosion cracking		○			○	

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(2) Materials used for hot water storage tanks

The most typical material used for hot water storage tanks is SUS 444(*Ferritic stainless steel plates*).

This is a grade in which impurities—carbon and nitrogen—are reduced to a very low concentration and improvement in corrosion resistance is achieved by adding molybdenum, titanium and niobium. Since ferritic stainless steel plates require meticulous dimensional control in bending and welding processes because of their limited toughness, have high notch sensitivity and tend to become coarse in micro-structure when affected by heat, they need severer fabricating and thermal controls than austenitic stainless steel plates.

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CONSTRUCTION 3

3 CONSTRUCTION

3.1 Construction Planning for Piping

3.1.1 Construction planning flow

(1) Understanding and planning the construction work

Pipe laying, like all construction work, must be carried out according to an orderly plan. Generally, when laying piping, because contractors handle materials in common use, they are apt to proceed with the actual job without careful advance preparation. Sometimes, the expected performance, including durability, is not obtained. Today, when various kinds of pipe materials and joints are being used for maximum durability and ease of construction work, instilling the habit of doing the right kind of construction planning and faithfully executing it is necessary.

Table 3.1-1 summarizes the procedures that should be considered and the items that should be studied at various stages when planning piping construction. A thorough familiarity with the characteristics of both the fluid to be transported through the piping system and the system's parts is required. The fluid could be a factor in causing the constant deterioration of the materials that make up the system.

(2) Need for working drawings

Design drawings for the systems handled by our industry generally set forth the rough route of the pipe, the pipe diameter and the specifications of the materials to be used. This is insufficient for laying the pipes; their detailed position and shape and the required auxiliary equipment must be determined according to working drawings. The most important job in ensuring piping quality is to determine the optimum measures to take for maintenance so as to obtain all the desired characteristics of the piping system, subject to constraints such as complex interrelationships and the ceiling height.

One point to consider in preparing working drawings is the shapes of bends and branches. Their shapes need to be chosen with regard to the properties of the fluid that will move through the piping and the pipe material to be used so that resistance is minimized and the pipes themselves are not damaged.

Most fluids that move through pipes contain dissolved gases that separate when the temperature and pressure change. These separated gases increase the resistance against the fluid movement through the piping and can cause vibration and noise. They can destroy the oxide film that protects the pipes from corrosion. All these factors shorten the useful life of the pipes; attention should be given to smoothly discharging gases.

Deposits and dirt will accumulate and damage piping materials in piping systems connecting, for example, the main water pipes of cities, cooling water systems directly open to the air and open circuits with heat storage tanks.

In such piping systems, strainers and dirt pockets must be installed as necessary at the right locations to keep the inside clean.

The temperature of the fluid as well as changes in ambient temperature during the year cause thermal stress on piping systems. The proper pipe shape and expansion joints can absorb thermal stress, but ensuring their effectiveness requires that care be taken that they are installed in the right place and anchored correctly.

The main purpose for preparing working drawings, besides making clear exactly where the pipes should be laid, is to confirm the positions of the equipment needed to ensure, maintain and preserve the piping, including (1) the shape of the pipes, (2) where dissolved gases will be exhausted, (3) where mixed-in substances will be discharged, (4) where the thermal stress will be absorbed, (5) where the inspection peepholes needed for maintenance will be positioned, and (6) where the monitoring pieces will be inserted.

(3) Deciding on the parts and members of the system

Besides auxiliary equipment such as valves, measuring instruments and traps, shown in the design drawings, the working drawings list additional auxiliary equipment needed and prescribe specifications including the capacity of each piece of equipment.

Pieces of auxiliary equipment are often made of different kinds of metals. If they are used unthinkingly, the piping could be hampered by local damage caused by bimetallic corrosion, dezincification or scale buildup. The following measures must be taken to avoid this problem.

- Install insulation if different types of metals are connected. (See Chapter 3.6. Joints with Other Kinds of Pipes.)
- Select components where dezincification corrosion retardant is applied. (Dezincification corrosion will occur when brass contains 15% or more zinc. Dezincification can be prevented by adding elements such as As, S, Ni, Al, Sb, P, W and Pb.)
- Implement proper water quality control to prevent scales from settling. (See Chapter 4.3.3. Water Quality Control.)

Support and anchor fixtures and specially fabricated parts should also be checked as needed for their strength against outside forces such as thermal stress, water hammer stress and earthquakes. Particularly for common support fixtures used in multiple systems, their strength and the strength of their members, including floor anchors, need to be considered, as well as antivibration measures for systems in which vibration and noise is a factor.

Table 3.1-1 Construction planning flow[1]

Step	Items
Verification and study of the construction content	1. Verify the applications of the piping system 2. Verify the design policy (flow volume, flow speed) 3. Consider the characteristics of the piping materials and auxiliary equipment 4. Verify the characteristics of the fluid to be transported
↓	
Detailed decisions concerning the piping system (preparation of working drawings)	1. Decide upon the position and shape of the piping 2. Decide where the necessary auxiliary equipment is to be installed 3. Consider the piping's strength performance 4. Consider how it will be maintained 5. Decide how it will be heat-insulated 6. Decide upon anticorrosion methods for buried pipe
↓	
Deciding upon the constituent parts (calculate capacity and strength)	1. Vibration-resistant joints, expansion joints 2. Support and anchoring fixtures and anchors 3. Specially fabricated parts (air chambers, etc.) 4. Air bends, safety valves, gauges 5. Strainers, drain valves 6. Water hammer prevention, shock absorbers 7. Cleaning, inspection holes, monitor pieces
↓	
Deciding upon construction methods	1. Decide upon the kinds of joints 2. Select the construction methods and processing machinery 3. Decide upon work procedures 4. Decide upon precision checking methods and judgment criteria
↓	
Preparation of construction control plan	1. Prepare documents for promulgating policies 2. Set inspection items and inspection points 3. Make clear the division of responsibilities 4. Decide what to do if standards are not met

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(4) Deciding on the construction method

Construction refers here to the series of jobs determined up to the preceding section: the processing, assembly, installation and testing of pipe materials, parts and members. The construction goals are to obtain full advantage of the properties of the materials that make up the system, to improve operating efficiency and to ensure uniform precision.

Joints are important in piping construction. They must ensure long-term strength and resist the damaging effects caused by the nature and temperature of the fluid in the pipes. The expected lives of pipe materials or joints may vary depending on their location within the building where the piping is installed. This is determined based on their exchange performance. The standards are based on life cycle costs, considering a longer life for buried piping and a shorter life for exposed piping.

The method of joining is decided based on the above conditions. The construction method determines what processing machinery and construction procedures to use. At the same time, a method for measuring the precision of the finished work must be prepared.

(5) Deciding on the construction control method

To ensure quality in piping equipment, deciding on a control method for monitoring the above procedures and checking how well the work is carried out is necessary. At all the stages of work flow from design and construction planning to construction, the people in charge must carry out their own duties. They must exercise control by preparing documents that clearly set out the work results required by those responsible in the next step as well as the method for verifying that the intended results have been achieved. Then they must show them to their direct supervisors and those they supervise, obtaining their confirmation.

These procedures are set forth in Table 3.1-2. The column at the left of the table lists, in the work sequence to be followed, the control documents for the job, while the row across the top lists the matters to be decided. The contents of each document are listed as work to be done in the box where its row intersects with each relevant column.

Similarly, each working drawing should clearly state the purpose of the work, the sequence in which it is to be done, what it will be like when it is done, how it will be inspected and the criteria by which it will be judged, and what the person in charge should do if the set standards are not met.

At the worker level, documents on work procedures and work standards are prepared. The former cover matters requiring particular attention in construction and must be prepared anew every time. The latter work with normal equipment and technology data that all workers should be familiar with.

Since these control documents serve to communicate from supervisors to supervisees in the workflow, the most important item for construction control in going ahead with the work is to consult with the responsible person listed in the right-hand column in the table.

Table 3.1-2 Determining the content of piping construction work[1]

Decision items / Drawing required		Deciding on the members that will make up the piping system			Deciding on the construction conditions		Person in charge of the work
		Configuration of the system	Measures for strength	Auxiliary equipment for better performance	Joining method	Installation location	
Design drawings and documentation	Design drawings	Deciding on the capacity and pipe diameter	——	Instructions concerning capacity selection standards	——	Deciding on the route	Construction supervisor
	Specification sheets	Deciding on the quality of the material	Installation standards	Specification of type of material and equipment models	Specification of the construction method	——	
Working drawings and documentation	Working drawings	——	Strength calculations	Deciding on the position and pipe diameter	Specifications of the shape	Deciding on the position	Construction overseer
	Fabrication drawings	——	Deciding on the shape and dimensions, strength calculations	——	Shape of the joint groove	——	
Control drawings and documentation	Construction plans	Method for receiving and inspecting the materials	Receipt and inspection method	Receipt and inspection method	Deciding on the joints and construction method, judgment standards	Method of checking the position	Actual worker
	Operating procedures Operating standards	——	——	——	Establishment of the work procedures, check items and method, and inspection and record-keeping methods	——	
Remarks		Fluid and quality of the materials	Expansion joint support and anchoring	Air bends, sludge valves, traps, safety valves and gauges	Types of couplings, welding and soldering	Maintenance measures, and cleaning and inspection	Quality assurance

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

3.1.2 Matters for when using stainless steel pipe

Stainless steel tubes for ordinary piping (JIS G 3448) is manufactured to apply the corrosion-resistant properties of stainless steel to general municipal water works and building facilities. Light gauges are adopted both to satisfy cost requirements and to improve work efficiency by reducing the pipe weight. The pipes are specified by their outside diameters; 25 Su and less match copper pipes, while 30 Su and above match carbon steel pipes. Conformity is also sought with valves and other auxiliary equipment for piping.

As mentioned in the previous section with reference to planning, in using stainless steel pipes, everyone including the workers on the site should be aware of the properties of the material and of the characteristics of the shapes of the products. These are explained in detail in other chapters of this manual, including the physical and mechanical properties of stainless steel (see Chapter 1. The Basics), and its applicable range, flow speed standards and the expansion and contraction of piping (see Chapter 2. Design). The matters to remember in construction are as follows:

(1) Heating process: heating temperature, atmosphere and quality of the material used for welding
(2) Cold working: elimination of residual stress and bend radius
(3) Parts: prevention of galvanic corrosion and insulation of joints
(4) Assembly: prevention of crevice corrosion and deposit attack, and insulation of support fixtures (cold-water systems)
(5) Storage: deformation (ensuring roundness) and scratches
(6) Halogen ions: heat insulation material and gaskets for joints
(7) Pipe cutting: maintaining roundness, eliminating burr (preventing damage to gaskets, etc.) and avoiding overheating
(8) Buried pipe: ground wet with seawater and areas of hot-water springs in volcanic regions

Specific measures to take are discussed in the next chapter.

Table 3.1-3 lists the items to check when using stainless steel pipes.

Table 3.1-3 Checklist for using stainless steel pipe

Item	Check	Confirma-tion
Transporting and handling pipes	1) That no scratches and deformation are made on the pipes during transport.	
	2) That no scratches on the pipe from clasps, hooks, etc. are made when the pipe is lifted up or down.	
	3) Protect and take care of pipe ends to prevent deformation and burr.	
Safekeeping	1) That no contact with a different type of metal, such as with steel pipe, is made and that the pipe is taken care of to prevent foreign matter, including refuse, oil and sewerage, from entering the pipe.	
Type and material of pipe	1) That no mistake is found after the pipe is checked for the notation, JIS mark, manufacturer's name, manufacturing method, outer diameter and thickness.	
	2) That the pipe conforms to JIS G 3448, 3459, 3468 or JWWA G 115, etc.	
	3) That the material of pipe is certainly SUS 304, 316, 315J1, 315J2, etc.	
Checking jointing method and type of coupling	1) That the pipe is a product certified in accordance with mechanical type pipe coupling (SAS 322: Pipe coupling performance standards for stainless steel pipes for general piping). Steel type: SUS 304, SUS 316	
	2) That the coupling belongs to a groove type or ring type of housing type pipe couplings (SAS 361: housing type pipe couplings).	
	3) That the joint is a weld joint (JIS B 2309: Butt-welding pipe fittings for light gauge stainless steel tubes for ordinary use, JIS B 2313: Steel plate butt-welding pipe fittings)	
	4) That the flange joint is a welded flange joint (JIS B 2220: Steel pipe flanges), or a loose flange joint either with stub end (JIS B 2309: Butt-welding pipe fittings for light gauge stainless steel tubes for ordinary use, or JPF SP 001: Lap joint stub end for piping) or with flared rim forming (SAS363: Stainless steel fittings of flared rim flange forming).	
Points for jointing, for flanges	1) Gasket: Use a gasket with non-asbestos sheet lapped with PTFE.	
	2) Tighten the flange bolts on diagonal lines one by one so that the bolts are tightened evenly.	
	3) Tighten the bolts according to the specified torque.	
Points for jointing, for housing type pipe couplings	1) That the pipe connecting with a gasket has no dents.	
	2) Use gaskets in the specifications.	
	3) Make no marks on the gaskets when fixing them	
	4) Tighten the gaskets evenly.	
Screw joint	Check the points to note in jointing screws.	
Points for jointing, for mechanical type pipe couplings	For different types of joint methods, check the points to note in jointing on the manufacturer's fixing manual.	
Processing components	1) Cutting: A blade dedicated to stainless steel cutting is used. That the cut surface is checked to be free of deformations and burrs, as well as lubrication oil, refuse adhered, etc.	
	2) Bending work: That bent components less than 4DR Should have passed a corrosion resistance test.	
	3) That the rim surface of stainless steel of flared rim flange forming is free of marks, notches, refuse adhered, etc.	
	4) That the processed pipe area of the housing type coupling is free of marks, notches, refuse adhered, etc.	
Points for jointing, for butt welding	Welding: Adopt the TIG welding method. Use argon or nitrogen gas for the back shield gas for welding. Check the inner welding areas to be free of oxidized scales adhered and, if any, remove them with acid or electro-polishing.	

Jointing with pipes, whether or not insulation is required	1) Decide if joints with different types of material require insulation. Insulate malleable cast iron, carbon steel, alloy steel and cast iron (including plating and lining).	
	2) In the past dezincification brass was thought to need insulating because of the large electric potential. However, according to the results of a recent study initiated by the Japan Copper and Brass Association, dezincification brass may be treated like bronze.	
	3) Insulation is desirable for jointing embedding stainless steel pipe with a bronze corporation cock with saddle or stop valve, etc.	
Jointing with accessories (valve, faucet, pump and flexible type joint)	1) Install the above-mentioned insulation when the joint between the stainless steel pipe and the accessory item is a different type of material.	
Points for insulation treatment	1) If an external short circuit is likely to form, connect a pipe 500 mm or longer with the insulation face before insulating both ends.	
Embedment Underground embedment	1) Direct embedment (bare embedment) or covered embedment	
	2) If the material is SUS 304 or 316	
	3) If to adopt a corrosion protection method by fixing polyethylene sleeves	
	4) If to adopt a petrolatum anticorrosion measure	
Points for polyethylene sleeve embedment	1) Bend a sleeve so that the bending meets the crown of the pipe (three-folded area) to prevent the pipe from shock when backfilling with sand and soil.	
	2) Give adequate looseness so that the sleeve will conform to the concavo-convex of the pipe coupling area.	
	3) Make sure that the joint area of the sleeve is overlapped in the pipe axis direction.	
	4) Avoid sleeved pipes from getting damaged when they are moved.	
	5) If a pipe line is inclined, take a measure to prevent underground water from inflowing through the joint of the sleeve.	
Points for petrolatum covering	1) Clean the pipe by removing dust and adhesives from the pipe.	
	2) Apply petrolatum paste on the pipe and overlap a 1/2 width of the tape and wind once.	
	3) Use petrolatum anticorrosion sheets to wrap the coupling, etc. and wrap the coupling with anticorrosion vinyl adhesive tape.	
	4) Use flexible couplings or high flexibility type couplings between the pipe and building to protect the piping against ground subsidence, etc.	
	5) For anticorrosion, use insulated couplings to insulate between indoor piping and underground embedded piping.	
Embedment in concrete	1) Take insulation measures to prevent piping from having contact with the reinforcing steel of the building.	
	2) Do not fix the piping on the concrete but make heat insulation coverage so that the piping can expand and contract from changes in temperature.	
	3) Reduce the embedded straight pipe length if the pipe is long, but increase the embedded bent length.	
Pipe support and anchor supporting hanger	1) Use plastic or rubber lined support hangers instead of using metallic ones to connect with the pipe, to prevent dissimilar metal contact corrosion.	
Method for support and anchor	1) Do not double-hang.	
	2) Adopt single hanging on the ceiling or tie beam to support the piping. If long hang bolts are needed, use shape steel to hold the piping.	
Supporting pipe in terms of earthquake resistance	1) For earthquake resistance support for horizontal piping, conform to Chapter 2.6. Supporting and Fixing in Design of this Piping Manual.	
	2) For vertical piping, fix, in principle, one vibration stopper (earthquake resistance support) or more on every story of the building. Hold these down on the lowest story floor and, if necessary, on the other story floors so that they receive the piping load and play a role as earthquake resistance supports.	

Measure for managing expansion and contraction of pipe	1) Whether expansion and contraction are managed through expansion bending, slip expansion joints or bellows type expansion joints.	
	2) That bellows type expansion joints of single bellows elements are fixed at approximately 20 meter intervals and that such expansion joints of dual bellows elements are fixed at approximately 40 meter intervals.	
	3) Pipe support fittings must be fixed on expansion joints or in their vicinity.	
	4) For areas of the pipe to fix other than expansion joints, horizontal pipe must have support fittings with rollers, or after a sleeve is fixed on a support fitting, the horizontal pipe must be let through the sleeve.	
	5) That anticorrosion is treated on areas where the pipe contacts support fittings with iron rollers or with iron sleeves.	
	6) If fixing an expansion bend with straight pipe, a pipe support fitting must be set in the middle of the expansion bend.	
Pipe corrosion prevention Preventing pitting corrosion and crevice corrosion	1) A different type of metal must not be retained in the pipe. No refuse, etc. must be left inside the pipe when it is jointed.	
	2) If an inverted right-angled arch piping is necessary, a drainage pipe to remove scales and depositions must also be furnished.	
	3) The inside of the pipe must be cleaned well after piping.	
	4) The pipe after piping must be taken care of so that no refuse, etc. enters the pipe.	
	5) For flange gaskets, those dedicated to stainless steel and wrapped with PTFE containing no soluble salts must be used.	
	6) Use gaskets that meet with the inner diameter of pipes.	
Preventing stress corrosion cracking (SCC)	1) That the pipe is prevented from being deformed. The bent pipe whose radius is under 4D should have passed a corrosion test.	
	2) That heat insulation materials dedicated to stainless steel are used.	
	3) That heat insulating materials are fixed to prevent moisture, including rainwater, from entering the heat insulation materials.	
	4) That heat expansion relief is considered when furnishing piping. (See Pipe Expansion Treatment of this Piping Manual.)	
Preventing intergranular corrosion	1) Weld work must be completed swiftly. Do not over-raise heating temperature nor spend more time than needed.	
	2) Silver brazing should not be done.	
Preventing bimetallic corrosion	1) That measures are taken to prevent dissimilar metal contact or joint corrosion. See sections of joint with different types of metals, embedment, pipe support and fixing, etc.	
Preventing piping from dewing and measures for heat insulation Making anti-sweat covering and heat insulation measures	1) Note that the nominal diameters of stainless steel pipes are different from those of carbon steel pipes. (Example: Stainless steel pipe 30 Su is equivalent to carbon steel pipe 25 A.)	
	2) That the joints of heat insulating materials have no gap.	
	3) Cover the heat insulating materials of outdoor piping with galvanized sheet iron, etc. and prevent rainwater from entering.	
Painting and identification of pipes Painting	1) If painting is needed must be studied.	
	2) The pipe in areas especially in an adverse environment must be painted. For example, stainless steel pipe furnished above the surface of a water receiving tank may corrode due to Cl^- generating in the water. Such piping needs synthetic resin coating.	
	3) In painting, a coating material conforming to stainless steel must be used.	

Markers and different colors	1) Characters and labels must be indicated on the pipe, or a different color line must be marked on the pipe, by place and type of usage.	
	2) A label must be made to prevent mistakes when a pre-processed component is transported to a specified area.	
	3) When piping is completed, a label must be made on the pipe and a different color line must be marked by usage and system. Also, an arrow mark must be painted on the pipe in the flow direction.	
Testing and inspecting pipe Water pressure test	1) It is impossible, in terms of process flow, to conduct a water pressure test of all the piping at once. Thus, such tests must be conducted after the piping is subdivided into sections by process flow on the site.	
	2) In a water pressure test, the air in the piping must be suctioned out completely before the test pressure is raised.	
	3) Test pressures must be applied in accordance with the specified values (example: SHASE-S 010, etc.).	
Flow test	1) It is difficult, in terms of the process flow, to conduct a flow test on a specific piping section. Thus, the test must be conducted on each piping system as a whole in coordination with the process flow.	
	2) In particular, a flow test of piping sections that will be covered with the ceiling or hidden inside the shaft must be conducted before the sections are covered or hidden.	
	3) A flow test of the whole piping system must be conducted after piping is completed. However, check the flow states pursuant to the water volume corresponding to the conditions of use of apparatuses.	
Measuring and checking residual chlorine	1) After piping is completed, a water fill test for the entire pipes must be conducted before trial operations of all the devices and systems are conducted. After completing the functional tests of all the piping systems, residual chlorine in the drinking water supply and hot-water supply systems, etc. must be measured.	
	2) Some water must be sampled out of the drinking water system tanks and faucets of pipe ends to check for pollution. Whether the water is sterilized with chlorine must be inspected. In this case, residual chlorine shall be 0.2 ppm or higher. (However, the reference concentration on ordinary occasions shall be 0.1 ppm or higher.) The upper limit of residual chlorine shall be 1.0 ppm or under. In terms of corrosion resistance, however, it is desirable to control the residual chlorine concentration at 0.4 ppm or under. (See Chapter 2.9.1. Design of this Piping Manual.) As residual chlorine easily decomposes in water, it must be measured right after it is sampled.	
Handling after the test	1) After the test, the water must be drained out of the piping system without delay. The piping must be checked to be free of refuse and other impurities left inside before water is filled in the piping system.	
Inspection	1) When using stainless steel pipe that connects directly with municipal waterworks, they must be inspected as prescribed by the relevant water utility.	
	2) When using stainless steel pipe that connects with a piping system other than municipal waterworks, a water pressure test must be conducted pursuant to the specifications or SHASE-S 010 standard values to inspect the piping system for the completeness of the joint areas.	
	3) After piping is completed, appearance inspection of the piping must be conducted to check for both damage and contact with different types of metal.	

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3.2 Transport, Handling, Storage and Inspection of Pipes

3.2.1 Transport, handling and storage of pipes

(1) Transport and handling

Stainless steel pipes are lightweight, but because they are thin-walled they must be transported and handled with care.

(a) When transporting them, take care that they are not damaged or crushed by contact with other objects. When necessary, protect them with covering so that no grease or other foreign substances adhere to them and cause problems when the pipes are fitted together.

(b) Use rubber, wood, plastic or the like to protect those parts that come into contact with fixtures or wires when the pipes are lifted or set down, protecting them from being scratched by crane hooks or wires.

(c) When transporting or handling the pipes, including shocks caused by load collapse, etc., protect the pipe ends so that they do not get crushed or burred.

(2) Storage

The pipes must be handled so they do not come into contact with other metals. Caution must be exercised that no dirt, grease, sewage, soot or other foreign matter gets into them. If necessary, the pipe ends should be sealed. The place chosen for storage must have low humidity and be free from the danger of objects falling from above. If they are stored in a warehouse, it should be fully enclosed and have a concrete floor.

3.2.2 Incoming inspection of the pipe

Pipe inspection includes appearance inspection, in which the inside and outside of the pipe and its ends are visually checked for defects, and standard inspection, in which the labeling, outside diameter, thickness and length of delivered pipe are verified.

(1) Appearance inspection

The pipe is visually checked for bending, uniform outside diameter and defects or scratches on the finish of its inner and outer surfaces. The pipe is rejected if any scratches, cracks, scales or defects are found. For scratches caused during transport or delivery, shallow scratches may be accepted as long as the outside diameter and thickness are within allowed dimensional tolerances after they are eliminated by polishing, but for deep scratches, the affected parts should be cut off. Any scratches or burrs on the pipe ends should be cut off before use.

(2) Standard inspection

Labeling on the outer surface of the pipe as well as the pipe diameter, thickness and length are checked as follows:

(a) Labeling

On each pipe, its type symbol, indicating its method of manufacture, its designation and dimensions and the name or abbreviation of the manufacturer must be clearly displayed. For stainless steel pipe for ordinary piping, there are four grades: SUS 304 TPD*, SUS 316 TPD, SUS 315J1 TPD and SUS 315J2 TPD.

* TPD stands for Tube Piping for Domestic water.

(b) Outside diameter and thickness

Outside diameter, thickness and tolerance for the designation must conform to requirements in 2.5 in 2. Design.

(c) Length

The standard length of pipe is 4 meters. Inspection is required upon delivery if other lengths are specified due to constraints attributable to the on-site crane, service entrance, containers, etc. when the pipes are worked into members at the factory.

3.3 Cutting Pipe

When pipe is cut, a cut surface that is usable for a pipe joint is required. As necessary conditions, the cut surface must be perpendicular to the axis of the pipe, there must be no shear drop or burr, and it must not be elliptical.

(1) Cutting tools for stainless steel pipe

The types of cutting tools generally used and their ranges of applicability are presented in summary form in Table 3.3-1. The cutting tools must all use blades dedicated for stainless steel.

Table 3.3-1 Types of cutting tools for stainless steel pipe and application range

Type of cutting tool		Range of application	Workability	Development of burrs	Processing the pipe ends after cutting	Points and characteristics
Rotary cutter	Pipe-fixed type (manual)	for small pipe diameter of 60 Su or less	○	Developed inside the pipe	After cutting the pipe, use a reamer or file, etc. to remove the burrs on the inner surface of the pipe.	Manual types are used mainly for small-sized piping works. Manual cutters are relatively inexpensive. Since these types tend to make no burrs on the outer surface of the pipe, the user may omit the processing of the pipe ends, depending on the type of coupling to joint. Some electric-motor driven cutters may process burrs on the inner surface of the pipe with the reamer attached to the cutter. This type is not suitable for pipe-expanding type joints.
	Pipe-fixed type (electrical)	for small pipe diameter of 60 Su or less	◎	Developed inside the pipe		
	Pipe-rotating type (electrical)	for small pipe diameter of 60 Su or less	◎	Developed inside the pipe		
Circular saw cutter	Pipe-fixed type	for small and medium pipe diameters	○	Developed inside the pipe	Deburring is required on the inner and outer surfaces of the pipe.	Do not press the circular saw cutter strongly.
	Pipe-rotating type	for medium and large pipe diameters	○	Developed inside/outside the pipe		
Metal-cutting saw	Manual	for small pipe diameters	△	Developed inside/outside the pipe	Deburring is required on the inner and outer surfaces of the pipe.	May be used for small-sized piping works. Cutting tools are relatively inexpensive.
Band saw (machine)	Electric	for small and medium pipe diameters	◎	Developed inside/outside the pipe	Deburring is required on the inner and outer surfaces of the pipe.	Can cut more than one pipe at a time. (In such case, fasten the pipes firmly before cutting.)
Saber saw (reciprocating saw)	Electric	for small and medium pipe diameters	◎	Developed inside/outside the pipe	Deburring is required on the inner and outer surfaces of the pipe.	Used mostly for cutting existing pipes to remove. When the right angle is necessary, fasten the pipe correctly before cutting.

1. Use blades of cutting tools that are suitable for cutting stainless steel pipes.
2. Select an appropriate cutting tool for joints. Follow the manual of the cutting tool to cut the pipe properly.
3. ◎: Good; ○: Applicable; △: Less applicable

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(2) Cutting methods

(a) Fixed-pipe rotary cutter (hand tube cutter)

As shown in Figure 3.3-1, the pipe is placed in a receiving roller, a handle (knob) is turned and the cutter is aligned on the cutting line. Then the rotary cutter is made to revolve once and, after verifying that the cutter has not strayed from the cutting line, the rotary cutter is turned and the pipe cut. Fixing the pipe in a pipe vise or the like rather than trying to hold it by hand is easier.

(b) Pipe-turning rotary cutter

As shown in Figure 3.3-2, the pipe is set onto a receiving roller and made to revolve by turning the receiving roller, thereby holding the rotating cutter against the pipe and cutting it. Stainless steel pipes are sometimes cut at the construction site with a threader for carbon steel pipes.

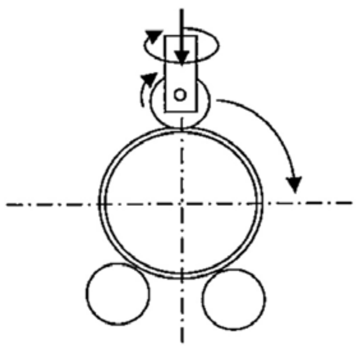


Fig. 3.3-1 Fixed-pipe rotary cutter[1]

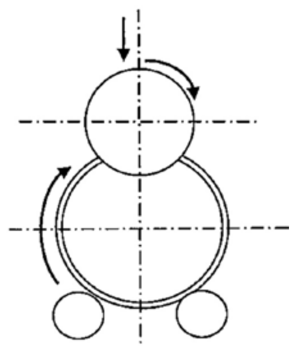


Fig. 3.3-2 Pipe-rotating type rotary cutter[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(c) Circular-saw cutter

The pipe is cut by turning a circular saw. Care must be taken that the circular saw is held tightly against the pipe and that the pipe is not turned too fast. For butt welding the cut surface of the pipe must be at right angles and in the same plane; a circular-saw cutter is ideal for this.

(d) Metal saw

The pipe is held in a pipe vise or the like and is cut either manually or electrically.

(3) Points concerning the cutting methods

When cutting the pipe, care must be taken concerning the following basic matters:

(a) Blades suitable for cutting stainless steel should be used. Since stainless steel has poor heat conductivity, the blade tip gets very hot and the cutting tip gets dull and can easily seize. Consequently, using a high-speed tool steel is advisable. Also, the cutting speed must be slow enough so that the blade tip temperature is controlled.

(b) The pipe must be held rigidly to ensure a proper cut surface. Care must be taken to avoid deformation.

(c) Avoid coating the pipe with lubricating oil, otherwise the pipe must be degreased and rinsed after cutting; joints will not be perfect. Also, lubricating oil can contaminate water running in the pipe and cause leakage.

(d) Die wear and contamination on the cut surface should be meticulously removed. If a pipe is inserted into a coupling with die wear, burrs, cut dust, dirt and the like left on the cutting surface, the gasket and rubber ring of the coupling may be damaged, which can lead to imperfect joints and leakage.

(e) The spot at which the pipe is to be cut must be inspected beforehand. Since many methods require a tight fit between the outer surface of the pipe and the inner surface of the joint, the worker must check carefully for any deformation, depression or scratches at the spot where the cut is to be made.

(f) Do not use the same blades for cutting stainless steel pipes and carbon steel pipes. Iron cut dust will adhere to the end faces of the stainless steel pipes, which will rust.

3.4 Pipe Bending

In bending the pipe, changes in thickness, wrinkling and out-of-roundness must be avoided. Wrinkling is a particularly serious problem. Wrinkling occurs on the inner side of the bent portion when the bend radius is less than a certain value with respect to the outside diameter of the pipe. Four times the outside diameter of the pipe is taken as the standard value for the minimum bend radius with respect to stainless steel. Stress corrosion cracking is more likely with a bend radius that is smaller than this standard value.

(1) Bending tools

The bending tools are classified by size as follows.

- Stationary type
  - Hydraulic electric type
  - Electric type
- Portable type
  - Hydraulic electric type
  - Hydraulic manual type
  - Manual type

(a) Stationary type

These pipe bending tools are large and used mainly for bending pipes of medium and large diameters of 25 Su or greater. Since the main bodies of the bending machines themselves are heavy and difficult to transport to the site for installation, they are generally kept at the processing plant and used to manufacture piping members.

(b) Portable type

These pipe bending tools are lightweight and used for bending small-diameter pipes (13-25 Su). Their power source can be hydraulic electric, hydraulic manual or manual. Generally the manual type is used in combination with a worm gear. For the operation, either a bending die or side plate, which are replaceable, is selected, depending on the pipe diameter. An example of a manual type is shown in Fig. 3.4-1 (external appearance) and Table 3.4-1 (manual bending tool specifications and accessory tools).

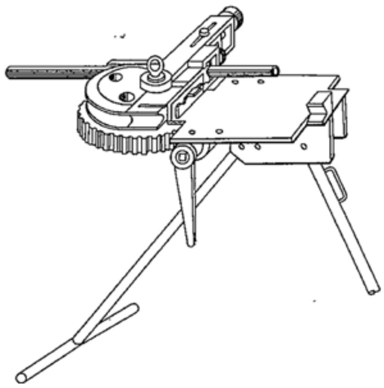


Fig. 3.4-1 Pipe Bender[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

Table 3.4-1 Manual bending tool specifications and accessory tools[1]

	Item		Type	
			For 13-25 Su	For 13-20 Su
Specifications	Area required for installation		970 × 460 mm	970 × 460 mm
	Weight		45 kg	38 kg
	Bending radius	13 Su	70 mm	70 mm
		20 Su	100 mm	100 mm
		25 Su	130 mm	-
	Maximum bending angle		0-180 °	0-180 °
Accessory tools	Toolbox		1 box	1 box
	Bendingdie, side plate	13 Su	1 set	1 set
		20 Su	1 set	1 set
		25 Su	1 set	
	Ratchet handle		1 pc	1 pc
	Pipe vise		1 set	1 set
	Allen wrench (10 mm)		1 pc	1 pc

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(2) Bending methods

In general when the pipe is bent naturally, the inside radius with respect to the pipe axis is compressed while the outside radius is stretched. In the draw bending technique, bending is performed while strongly stretching the compressed portion. Manual pipe benders having a mechanism for this bending with inner-radius stretching have been developed and are commercially available, but their range of application is limited to 13-25 Su.

(a) Bending methods using manual pipe benders

As shown in Figure 3.4-2, the work procedure for bending a pipe with a manual pipe bender is to hold the pipe securely with a clamp and put the side plate between the pipe and the clamp roller. Then, with the clamp roller anchor the side plate to the bending die. When the ratchet handle is turned, the pipe is bent by the rotational motion of the rotating arm. For a 90° bend the rotating arm is moved to the R or L line marked on the surface of the bending die.

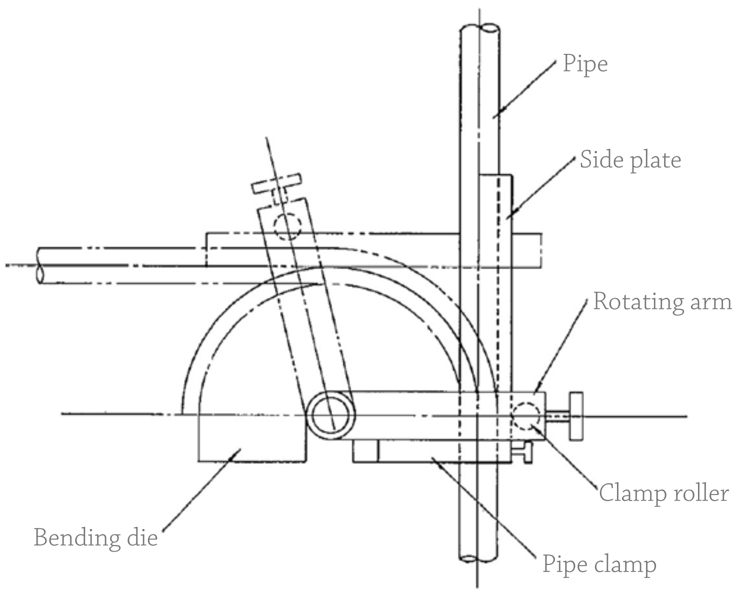


Fig. 3.4-2 The bending process using a pipe bender[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(3) Points when bending the pipe

In manual operation, ensure that attachment bolts are tight and that the pipe is held securely to attain the prescribed direction and angle of bend, and to avoid wrinkling.

3.5 Pipe Joints

Available methods for joining stainless steel pipes for ordinary piping are mechanical coupling pipe joints, coupling housing joints, welding joints and flange joints. When joining the pipes, see Table 3.5-1 for pipe dimensions, purposes of use, piping conditions, etc.

Table 3.5-1 Coupling types and joint characteristics[1]

Coupling type and joint method			Product name	Removability of the joint spot	Level of skill required	Tool	Ease of on-site fitting	Applicable size: Su
Mechanical couplings	Press type	Press coupling	Morco joint	No	Average	Dedicated tool	Easy	13 – 60
			SUS press	No	Average	Dedicated tool	Easy	13 – 60
			JF joint	No	Average	Dedicated tool	Easy	13 – 25
		Double press coupling	Double press	No	Average	Dedicated tool	Easy	13 – 60
		Grip coupling	Mie grip	Yes	Average	Dedicated tool	Easy	13 – 60
	Pipe-expanding type	Pipe- expanding coupling	Nice joint	Yes	Average	Dedicated tool	Easy	13 – 60
			Nice joint	Yes	Average	Dedicated tool	Easy	75 – 100
			Zlok	Yes	Average	Dedicated tool	Easy	13 – 60
			Susfit	Yes	Average	Dedicated tool	Easy	13 – 60
			Yodoshi SUS fit	Yes	Average	Dedicated tool	Easy	13 – 60
			BK joint	Yes	Average	Dedicated tool	Easy	13 – 60
	Nut type	Compression coupling	MR joint II	No	Average	-	Easy	13 – 25
		Dresser snap ring coupling	MR-LA coupling	Yes	Average	Dedicated tool	Easy	30 – 80
	Rolled screw bolt type	Rolled screw bolt coupling	Abacus	Yes	Average	Dedicated tool	Easy	13 – 60
	Insert type	Insert coupling	Koma push-joint A-1 type	No	Average	Dedicated tool	Easy	13 – 25
			New SUS lock	No	Average	Dedicated tool	Easy	13 – 60
		Quick coupling	EG joint	Yes	Average	-	Easy	13 – 50
	Coupling type	Coupling type coupling	Straub coupling grip type	Yes	Average	Dedicated tool	Easy	40 – 80

Housing type pipe coupling	-	Yes	Average	Dedicated tool	Easy	40 – 300
Flange joint	Welding flange	Yes	Required	-	Easy	15 – 650 A
	Stub end (loose flange)	Yes	Required	-	Easy	30 – 300
	Stainless steel pipe fitting for flared rim flange forming (loose flange)	Yes	Required	-	Easy	30 – 300 20 – 500 A
Weld joint(1)	Butt welding pipe fittings for stainless steel pipe for ordinary piping	No	Required	TIG welding machine(2) (automatic or manual)	Difficult	13 – 300
	Steel plate butt welding pipe fittings for piping	No	Required	TIG welding machine(2) (automatic or manual)	Difficult	15 – 650 A
Screw joint	Screwed pipe coupling	Yes	Average	-	Easy	6 – 100 A
High flexibility coupling	-	Yes	Average	Dedicated tool	Easy	20 – 50

(1) Welding must be performed at the factory.
(2) Tungsten inert gas ark welding machine
Prepared by: Japan Stainless Steel Association

3.5.1 Welding joints

(1) Area to conduct welding and processing

Welding and processing stainless steel pipes in a section of the factory that is isolated from other areas where carbon steel pipes are processed is important.

Only dedicated jigs, including cutting tools and grinding tools, can be used for stainless steel pipes. They cannot be used for carbon steel pipes.

(2) Worker qualifications for welding

- A worker who engages in automatic welding shall have adequate skill and experience in operating the automatic welder and shall be approved by the supervisor.
- Except for automatic welding, a welder shall have skill equivalent to JIS Z 3821: *Standard qualification procedure for welding technique of stainless steel*, or shall be approved by the supervisor as having skill equivalent or superior to the preceding skill.

(3) Type of weld joint

TIG (Tungsten Inert Gas ark) welding, semi-automatic arc welding, automatic welding or a combination of these shall be adopted.

(4) Weld joints

Table 3.5-2 presents a welding process where the strength of the weld joint area is close to that of the base material. Manual and automatic welding methods are available, but the manual welding requires a high level of skill and proficiency.

The welding most often used for stainless steel pipe is TIG welding because the pipe has relatively thin walls. As shown in Fig. 3.5-1, in TIG welding, tungsten is used for the electrode and the welding is performed while blocking out the air with argon gas. Welding can be performed either with or without a welding rod, but a welding rod is generally used if the pipe wall is thick. Filler metals are commonly Y 308, Y 309 and Y 316 as set forth in JIS Z 3321 (*Stainless steel rods, wires and strip electrodes for welding*).

Although JIS B 2309 fittings: ***Butt-welding pipe fittings for light gauge stainless steel tubes for ordinary use*** are used for the joint, the products stipulated in JIS B 2313: ***Steel plate butt-welding pipe fittings*** or JPF SP 001: ***Stainless steel stub end for piping*** are used for the stainless steel pipes stipulated in JIS G 3459: ***Stainless steel pipes***.

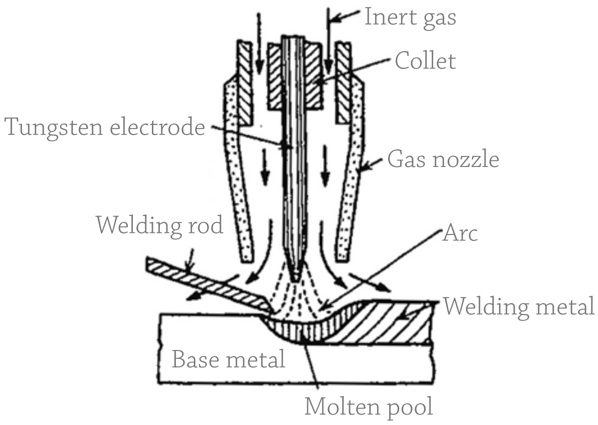


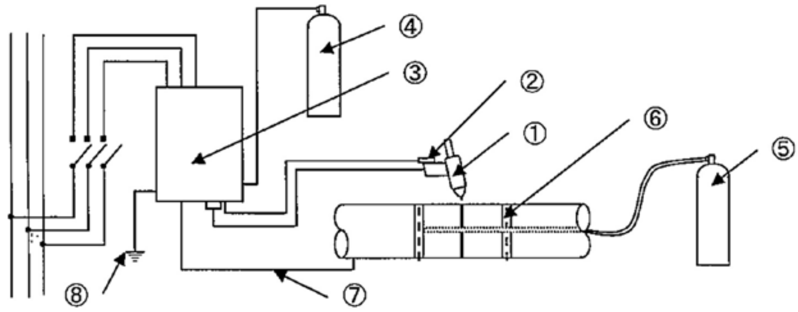
Fig. 3.5-1 TIG welding[2]

Source: Welding and Joint Technology Databook

(5) Welding machines and jigs and tools

Welding machines include those used for manual and automatic welding.

(a) Besides the main welding machine unit, a gas container for torching (argon gas), a gas container for back shielding (argon gas or nitrogen gas), a weld torch, jigs for inner shielding, a back shield oxygen concentration gauge and other tools need to be prepared. Figure 3.5-2 illustrates the configuration of a welding machine.



① Weld torch, ② Weld switch, ③ TIG welding machine, ④ Weld torch gas (argon gas),
⑤ Back shield gas (argon gas or nitrogen gas), ⑥ Jig for inner shielding,
⑦ Base material cable, ⑧ Earth wire

Fig. 3.5-2 Configuration of TIG welding

Prepared by: Japan Stainless Steel Association

(b) Welding machine characteristics

In welding stainless steel pipe, since the pipe wall is relatively thin and a uniform penetration bead is required, welding requires the following:

① Positive and stable arc start

Since weld defects are prone to occur when welding begins unless the arc start is stable, the arc must be initiated smoothly.

② Constant electric current

(6) Welding management and method

(a) When welding piping, prevent the inside welded areas of the pipe from oxidizing.

In order for the inside welded area to meet the weld surface standard, observe the following:

① Measure the oxygen concentration level of the gas container or liquid tank to use.
② Seal up all the areas to tack-weld (a temporary measure) with aluminum tape, etc.
③ Use an oxygen meter that has passed periodical inspections.
④ Use an oxygen meter. (Figure 3.5-3 shows an example of an oxygen meter that can measure oxygen up to a ppm level.) Feed a back shield gas and start welding when the oxygen concentration reaches the prescribed level.

(b) To prevent defective welds, have the weld metal penetrate until an adequate back bead is formed.

(c) In principle, do not perform on-site welding. If such welding is unavoidable, consult with the customer in advance on how to check the quality of the welded areas, etc. Observe cautionary instructions during welding.

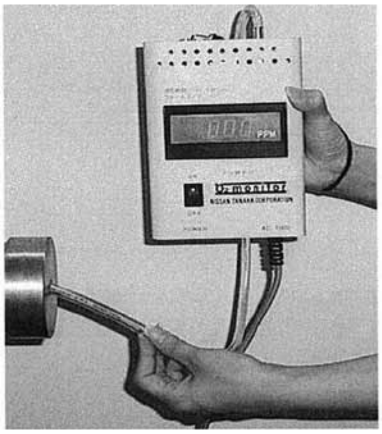


Fig. 3.5-3 Oxygen meter[3]

Source: Guidelines for Super Durable All-Stainless Steel Piping System

(7) Welding Specifications

(a) Necessity of back shielding for anti-oxidation of welded area on the inner surface in butt welding

When back shielding is inadequate, penetration will become unstable, resulting in an uneven bead, which will lead to oxidization of the bead surface. This, in turn, will lead to deterioration in the penetration bead form, causing greater roughness, which will adversely affect the strength and corrosion resistance of the welded area.

(b) Types of back shield gas

In welding pipes, a large quantity of gas is used for back shielding. In most cases, argon gas is used. Compared with argon gas, nitrogen gas is generally inexpensive. This is why nitrogen gas shielding is used in welding pipes, etc.

(c) Oxygen concentration in back shield gas and color of oxidation scale

Figure 3.5-4 shows a sample of internal oxidized scale, a result of an inner surface back shield gas weld test. The numerical values in the figure indicate the oxygen concentration of back shield gas (nitrogen gas). As the oxygen concentration of the inner surface shield gas increases, the colors of the inner surface oxidation scales obviously change as well.

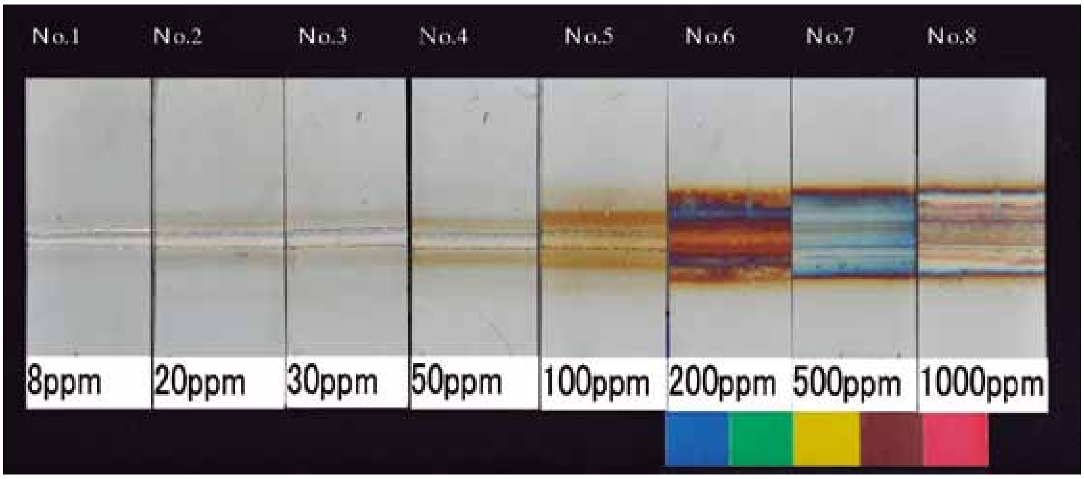


Fig. 3.5-4 Sample of an internal oxidized scale in a 100 Su inner surface nitrogen gas back shield weld test[3]

Source: Guidelines for Super Durable All-Stainless Steel Piping System

(d) Oxygen concentration of back shield gas when starting welding

To prevent inadequate penetration and oxidation in the welded area, use argon gas or nitrogen gas and ensure back shielding in the welded pipe. Feed such back shield gas during welding. Adjust after considering the bore and length of the pipe so that the resulting surface meets the sample of the inner surface standard of the pipe, as shown in Figure 3.5-5. The oxygen concentration must be 50 ppm or under, as shown in Figure 3.5-4. In a corrosive environment, however, adjusting the oxygen concentration down to 30 ppm or under (when using nitrogen gas) is preferable.

Fig. 3.5-5 Sample of the inner surface standard of the pipe[4]

Source: Welding and Processing Manual at Factories for Stainless Steel Piping for Building Equipment

(e) Release temperature of back shield gas after welding

If high-temperature bead and heat-affected area are exposed to the air right after welding, oxidation or burn will develop. According to experiment results, the range of oxidation scales, color and density remained almost the same even when the release temperature of back shield gas was set to 100° or 200°C. No difference was noted (Fig. 3.5-6). The experiments also confirmed that release temperature of 200°C or under of back shield gas was workable to minimize oxidation. (With uneven control considered, it is recommended to reduce the release temperature down to 100°C or lower after the back shield gas is adequately cooled, in order to prevent temper color from developing after welding.)

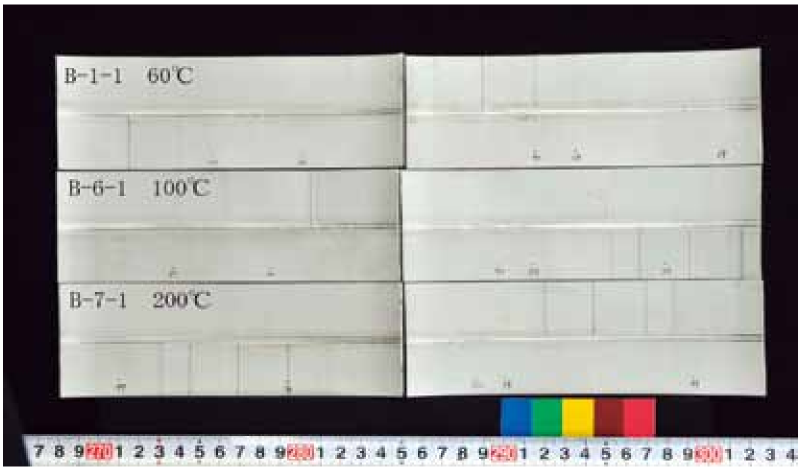
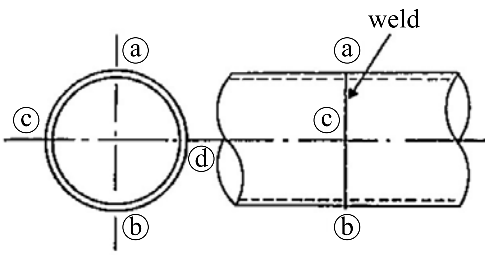
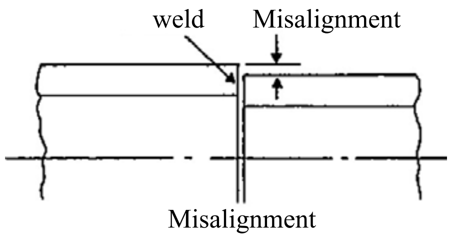


Fig. 3.5-6 100 Su Back Shield Gas Release Temperature and Oxidation Scales in 8-ppm Oxygen Concentration during Welding[3]

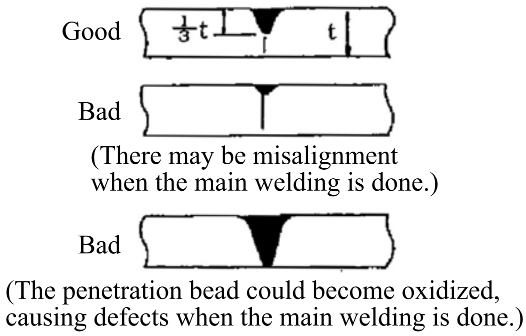
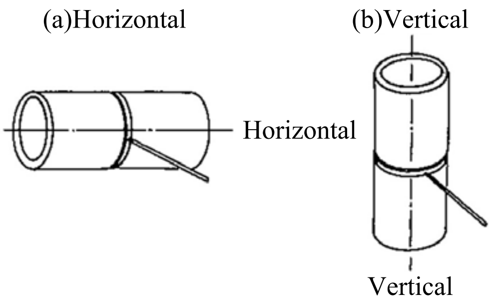
Source: Guidelines for Super Durable All-Stainless Steel Piping System)

Table 3.5-2 (1) Factory welding work procedure 1[1,4]

<table>
<tr><th>Type of work</th><th>Work method</th><th>Remarks</th></tr>
<tr><td>1. Pipe cutting</td><td>As a general rule, a pipe is cut perpendicular to its axis with a round saw machine or a band saw machine. Any die wear or burr should be removed.
</td><td>The degree of perpendicularity is checked with a right-angle scale.</td></tr>
<tr><td>2. Weld pretreatment</td><td>To clean the butt surface and around it, any rust, oil, paint, steel or other adhering substances harmful to the weld should be removed with an organic solvent such as thinner or TCE, a stainless steel wire brush (SUS 304), sandpaper, etc.</td><td>If the thickness is 3 mm or heavier, there should be a single V groove in order to achieve the right penetration bead shape.</td></tr>
<tr><td>3. Tack welding</td><td>Tack welding is performed by a qualified worker with the TIG welding method, as in the case of the main welding, by the following procedure.
(1) The piping member is precisely centered.
(2) Tack welding is done in the sequence (a)→(b)→(c)→(d) pictured below while minimizing the displacement by using a pipe end correction jig, etc.
Tacking should be done in at least four spots, with more depending on the pipe diameter and the extent of the displacement.

</td><td>

Misalignment quantities are as set in the table below.
(mm)
<table>
<tr><td>Thickness</td><td>0.7</td><td>0.8</td><td>1.0</td><td>1.2</td><td>1.5</td><td>2.0</td><td>2.5</td><td>3.0</td></tr>
<tr><td>Misalignment</td><td>0.14</td><td>0.2</td><td>0.2</td><td>0.24</td><td>0.3</td><td>0.4</td><td>0.5</td><td>0.6</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Thickness</td><td>3.5</td><td>4.0</td><td>4.5</td><td>5.0</td><td>6.5</td><td>8.0</td><td>9.5</td><td>12.7</td></tr>
<tr><td>Misalignment</td><td>0.7</td><td>0.8</td><td>0.9</td><td>1.0</td><td>1.3</td><td>1.6</td><td>1.9</td><td>2.5</td></tr>
</table>
* *Source: Welding and Processing Manual at Factories for Stainless Steel Piping for Building Equipment, Japan Stainless Steel Association, January 2006*</td></tr>
</table>

Table 3.5-2 (2) Factory welding work procedure 2[1, 4]

<table>
<tr><th>Type of work</th><th>Work method</th><th colspan="3">Remarks</th></tr>
<tr><td>3. Tack welding</td><td>(3) The appropriate penetration depth for tack welding is about one third of the thickness.</td><td colspan="3">Whether the tack welding was done well or badly

</td></tr>
<tr><td rowspan="12">4. Main welding</td><td rowspan="12">(1) Orientation
The main welding is performed by TIG welding using horizontal anchoring or vertical anchoring, depending on the position.


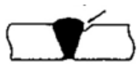
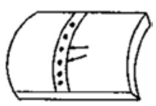
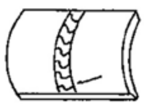
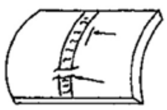
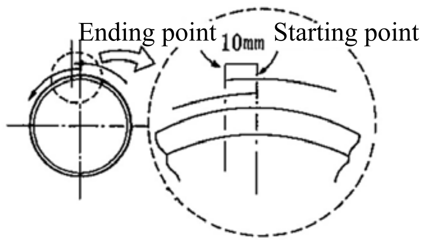
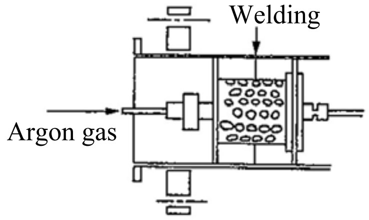
(2) Main welding
The welding is performed with reference to the welding conditions. In order to achieve the good bead shape shown in the remarks column, care is taken with the work environment including footing, vibration and wind. If multi-layer welding is performed, the welds in each layer should be cleaned.
Note: The weld overlay height of the penetration bead is set to up to one-half the wall thickness of the pipe.</td><td>Shape of the welding bead</td><td>Judgment</td><td>Reason</td></tr>
<tr><td></td><td>Good</td><td>Optimum penetration</td></tr>
<tr><td></td><td>Good</td><td>There is a depression, but strength is not seriously affected</td></tr>
<tr><td></td><td>Bad</td><td>Insufficient penetration</td></tr>
<tr><td></td><td>Bad</td><td>Weld center misalignment</td></tr>
<tr><td></td><td>Bad</td><td>Undercut</td></tr>
<tr><td></td><td>Bad</td><td>Overlap</td></tr>
<tr><td></td><td>Bad</td><td>Lack of fusion</td></tr>
<tr><td></td><td>Bad</td><td>Too much weld overlay</td></tr>
<tr><td></td><td>Bad</td><td>Blow holes</td></tr>
<tr><td></td><td>Bad</td><td>Crater</td></tr>
<tr><td></td><td>Bad</td><td>Vertical crack Horizontal crack</td></tr>
</table>

Table 3.5-2 (3) Factory welding work procedure 3[1, 4]

Type of work	Work method	Remarks
4. Main welding	(3) Crater treatment Crater treatment should always be applied upon completion of the main welding. The treatment is applied with an overlap of about 10 mm from the point where the welding begins. If multi-layer welding is performed, care should be taken that craters do not lie on top of one another. 	Pinholes and cracking could result unless appropriate crater treatment is applied.
	(4) Back shielding Back shielding should be provided with argon gas or nitrogen gas. To obtain a good, uniform penetration bead, the gas flow volume is determined in advance in accordance with the jig, pipe diameter and other conditions. <Reference example> For back shielding, both ends near the welded spots are sealed with urethane or thick paper, etc. Back shielding example 1 	Before starting welding, feed the back shield gas until the gas comes to have adequately low oxygen concentration. Adjust the gas flow after considering the bore and length of the pipe so that the resulting surface will meet the sample surface of the inner surface standard of the pipe, as shown in Fig. 3.5-5. If the back shielding is not adequate, there could be insufficient penetration of the penetration bead, oxidation or push-up.

(Continued)

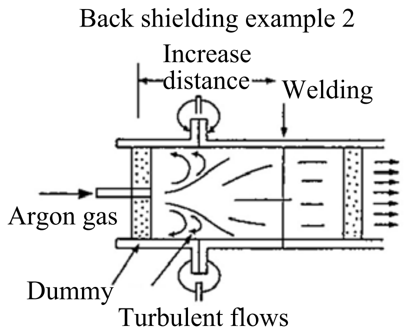
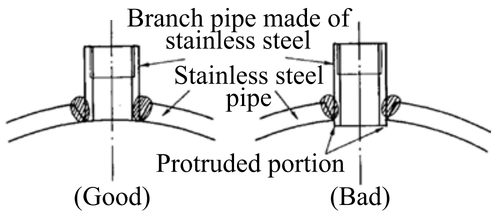
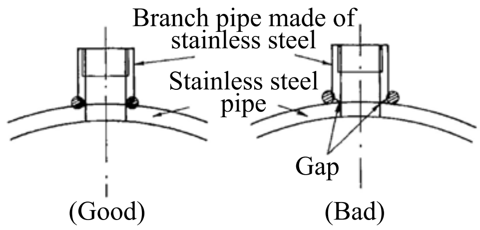
Type of work	Work method	Remarks
4. Main welding		

Table 3.5-2 (4) Factory welding work procedure 4[1, 4]

Type of work	Work method	Remarks
5. Branch pipe welding	When boring a hole in the main pipe and welding the hole with a branch pipe, the weld is basically similar to fillet welding. Keep weld conditions within the standards specified by the company (factory). (1) Boring a hole in the main pipe When boring a hole in the main pipe, take care to prevent the generation and adhesion of cutting chips, spatter, oil, etc. If any of these is generated, remove the burrs and degrease the pipe surface. (2) Processing when inserting a branch pipe in the main pipe Before the final weld, groove the hole in the main pipe and tack-weld the branch pipe for no protrusion in the main pipe. In the final weld, apply back shielding and make an adequate penetration bead. (3) Processing when placing a branch pipe in the main pipe When placing a branch pipe in the main pipe, groove and tack-weld the branch pipe before the final weld. In the final weld, apply back shielding and make an adequate penetration bead.	 When a branch pipe is inserted into a main pipe  When a branch pipe is placed in the main pipe

Includes data from Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition.

Source: Welding and Processing Manual at Factories for Stainless Steel Piping for Building Equipment.

3.5.2 Flange joints

Flange joints are commonly used with stainless steel pipes. The loose flange type shown in Fig. 3.5-7, in which a stub end (lap joint) made of stainless steel is welded to the pipe and a flange is made of carbon steel, is often used. In addition, a joint using a loose flange is also made with a flared rim flange forming process of the pipe end as shown in Fig. 3.5-8. These joints can be applied to improve work efficiency at the site if the members are processed at the factory.

(1) Joints

For JIS G 3448 pipes: ***Light gauge stainless steel tubes for ordinary piping***, use fittings stipulated in JIS B 2309: ***Butt-welding pipe fittings for light gauge stainless steel tubes for ordinary use***. For JIS G 3459 pipes: ***Stainless steel pipes***, however, use JIS B 2313 fittings: ***Steel plate butt-welding pipe fittings*** or JPF SP 001 stub ends: ***Stainless steel stub ends for piping***.

SAS 363 fittings: ***Stainless steel fittings of flared rim flange forming*** are available for both JIS G 3448: ***Light gauge stainless steel tubes for ordinary piping*** and JIS G 3459: ***Stainless steel pipes***

For flanges, use loose flanges stipulated in JIS B 2220: ***Steel Pipe Flanges***, which are electro- or hot-dip galvanized steel products.

(2) Joining method

Welding of stainless steel pipes and stub ends (lap joints) is performed with the methods described in Chapter 3.5.1.

(3) Points concerning the joining operation

The points for welding joints that are listed in Chapter 3.5.1 must be fully observed.

All the flange joints use gaskets that maintain sealing performance (waterproof performance). For jointing pipes, use PTFE cushion gaskets and expanded PTFE (Fig. 3.5-9).

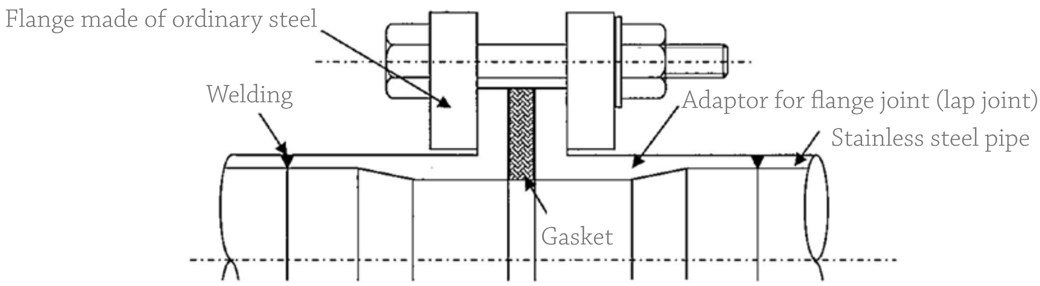


Fig. 3.5-7 Flange joint[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

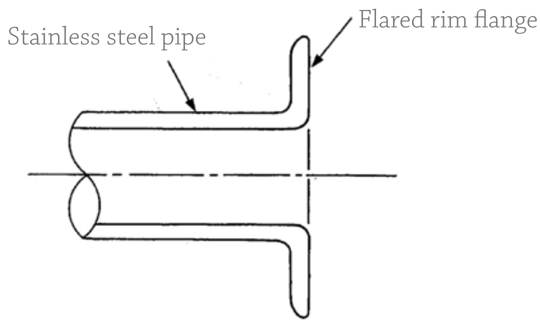


Fig. 3.5-8 Flared rim flange forming process[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

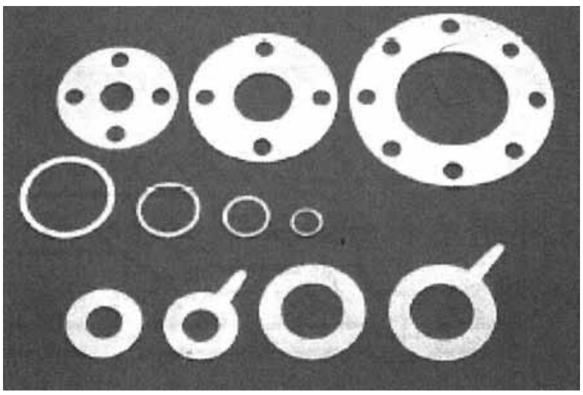


Fig. 3.5-9 Expanded PTFE gaskets[3]

Source: Guidelines for Super Durable All-Stainless Steel Piping System

(4) Points when adopting expanded PTFE gaskets

These gaskets are used for pipe joints for water supply, hot-water supply and firefighting water piping made of ultra-high durable stainless steel pipes under maximum working pressure of 2.0 MPa or lower. Expanded PTFE gaskets have the following characteristics: (See Figs. 3.5-10 and 3.5-11.)

(a) Have conformability and can seal even an irregular surface

(b) Have little deformation in the right angle direction against compression pressure, and have little plastic deformation compared with ordinary PTFE

(c) Have no erosion against most fluids and are usable for other than high-temperature and high-pressure fluorine gas and dissolved alkaline metals

(d) Have no elution of impurities

(e) Have little aging deterioration of the material

(f) Become a ring shape because no arbitrary formation is available. Since the maximum thickness available is 3 mm at present, shapes of pipe joints available are likely to have some limitations. Compared with rubber, they are more susceptible to plastic deformation. Thus, some structural device is necessary to provide the gaskets with repulsive force against plastic deformation.

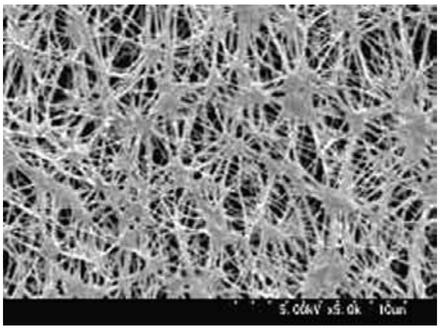


Fig. 3.5-10 Electron microscopic picture of sectioned face of a drawing PTFE gasket[3]

Source: Guidelines for Super Durable All-Stainless Steel Piping System

Fig. 3.5-11 Example of a drawing PTFE gasket pipe fitting[3]

Source: Guidelines for Super Durable All-Stainless Steel Piping System

3.5.3 Mechanical joints

3.5.3.1 Insert joints

A notable feature of insert joints is that the joining operation can be easily and quickly completed, even in a narrow space, because grooving the pipe end and inserting the pipe into the coupling results in joining.

(1) Coupling

With the insert pipe coupling, joining results from grooving the pipe end and inserting the pipe into the coupling so that the bite ring attached to the coupling is engaged in the groove. The range of use is the designations of 13-25 Su. A schematic view of the construction of the coupling is given in Fig. 3.5-12.

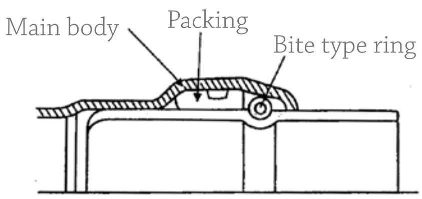


Fig. 3.5-12 Schematic view of construction of insert joint[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(2) Joining method

The pipe is normally cut with a rotary cutter. If another cutter is used, the pipe should be deburred and chamfered after cutting. After lines for the grooving position and insertion check position are drawn on it, the pipe should be grooved with a dedicated roll and inserted into the coupling until it comes into contact with the coupling stopper.

(3) Points in the joining operation

(a) Be sure to cut the pipe with a rotary tube cutter. If another cutter is used, the pipe should be deburred and chamfered after cutting.

(b) Insufficient groove depth or misalignment may cause leakage or pipe pullout.

(c) When inserting the pipe into the coupling seems difficult, apply dedicated lubricating oil to the pipe and coupling in advance.

3.5.3.2 Press joints

Press joints use a press tool, which is a special tightening tool, allowing quick joints without a great degree of skill. Some space is needed to operate the tool, but since no heating apparatus is used, the tool presents the advantage of being usable even where there is combustible material.

The joint is made by inserting the stainless steel pipe into the press-type pipe coupling and pressing the coupling with the press tool.

(1) Coupling

With the press-type pipe coupling, the end of the joint part of the coupling is filled with a rubber ring, the pipe inserted into the coupling and then pressed with a press tool. The area from the middle of the inserted portion to its end is compressed in diameter, and the pipe and coupling are joined. Thus the use range is limited to the designations of 13 - 60 Su (see Fig. 3.5-13.).

(2) Joining method

After the pipe is cut to the prescribed length, the part to be joined is cleaned and any die wear or burr removed. Use a line marker to mark a line to insert a coupling. Insert the pipe into the coupling until the pipe reaches the line mark. Press the joint with a press tool. The joining operation must be carried out in accordance with the instruction manual of the tool manufacturer.

(3) Points for the joining operation

(a) An exclusive press tool must be used.

(b) Before it is inserted into the joint, the surface of the part to be joined should be checked, and any grease, dirt or other adhering matter should be removed, along with any die wear or burr. In particular, care must be taken that the rubber ring does not get scratched or damaged.

(c) When using a coupling with an adaptor, first twist in the adaptor before using a dedicated press tool to join the pipe.

(d) The amount of insertion should be verified. Mark a line to insert the pipe into the coupling until the pipe reaches the line mark.

(e) The press tool must be inspected once a year, because frequent use can result in incomplete joints.

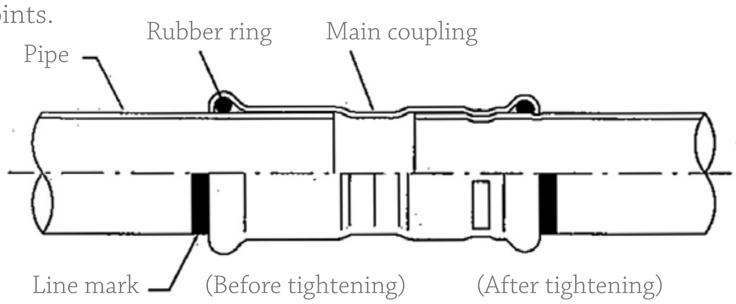


Fig. 3.5-13 Joint by press-type coupling[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

3.5.3.3 Double press joint

In the double press joint, which has similarities to the press joint, the pipe is tightened at two locations at the same time after it is inserted into the coupling. Some strength is assured even if the pipe is inadvertently inserted improperly. Because of the use of convex and concave rings, leakage is always detected in a pressure check if the pipe is not tightened.

(1) Coupling
As shown in Fig. 3.5-14, insert the pipe in a double press joint. Use an exclusive press tool to fasten two locations at the same time before and after the rubber ring (Fig. 3.5-15) to join the pipe. This type of joint is applicable to the designations of 13 - 60 Su.

(2) Joining method
Same as the press joint

(3) Points for the joining operation
Same as the press joint

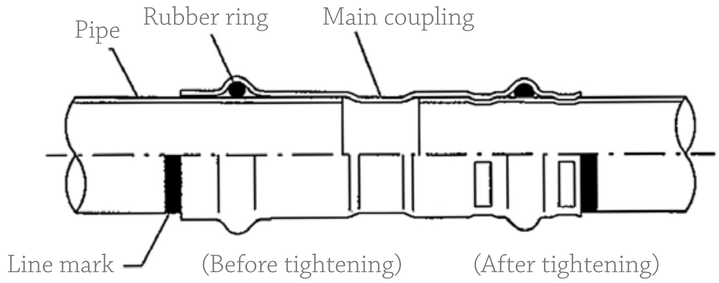


Fig. 3.5-14 Joint by double press-type coupling[1]
Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

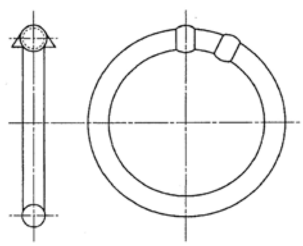


Fig. 3.5-15 Rubber ring of double press type joint (13-60 Su)[1]
Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

3.5.3.4 Grip joint

Because a grip tool, which is a special tightening tool, is used for this type of joint, a high degree of skill is not required. Moreover, the joining can be accomplished in a short time. Some space is needed in order to operate the special tightening tool, but since no heating apparatus is used, the tool presents the advantage of use even when combustible articles are present.

(1) Coupling

In the grip type pipe coupling, the pipe is inserted into the socket of the coupling, which is packed with a rubber ring and a bite ring, and the joint is tightened with a special grip tool (see Table 3.5-3). This causes the ring to bite into the pipe and prevents it from slipping out, while water-tightness is maintained by compression of the rubber ring. This method of joining the coupling and the pipe is diagramed in Fig. 3.5-16. The range of use includes the designations of 13-60 Su.

Table 3.5-3 Grip tool specifications[1]

Portable electric hydraulic pump		Grip tool (weight)		
Power source used	AC (100V 50-60 Hz)		13-25 Su	30-60 Su
Output	235 W	Hydraulic cylinder and tool	About 5 kg (re-chargeable type)	About 9 kg
Weight	About 13 kg	Processing die (three types)	0.6 kg each	1.0 kg each
Hydraulic hose	5 m			

Used with interchangeable processing dies chosen to fit the size of each coupling.

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

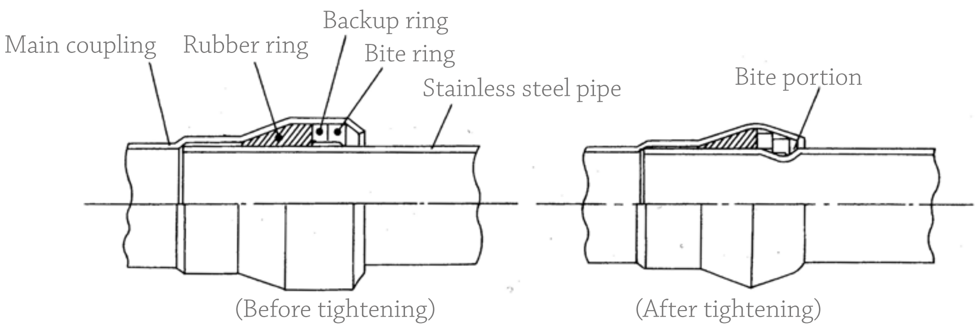


Fig. 3.5-16 Joint by grip coupling[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(2) Joining method

(a) As with the press type, cut the pipe to the prescribed length, then clean the part to be joined and remove any die wear or flash.

(b) Use a line gauge to mark a line on the pipe indicating the position of the coupling when the pipe is inserted. Then insert the pipe straight into the coupling until it hits the other end of the coupling. Check to make sure that the marked line aligns with the end of the coupling.

(c) The grip connection is made using the special grip tool. The joining operation should be performed in accordance with the tool manufacturer's instruction manual.

(3) Points for the joining operation

(a) The special tightening tool must be used.

(b) As with the press type, before inserting the pipe into the coupling, any soiling on the surface of the part to be joined must be removed, and care must be taken to ensure the rubber ring is not scratched.

(c) The extent of the insertion should be checked. When the pipe is fully inserted into the coupling, the line marked on the pipe should be just slightly visible from the end of the coupling. The line marked on the end of the coupling will enable checking if the pipe has slipped out when gripped.

(d) Piping support fixtures must be attached prior to gripping. Attaching afterwards could result in the caulking force of the caulking tool bending the piping.

3.5.3.5 Pipe-expanding joint

After the pipe end is expanded, hanging a box nut or a flange on the pipe tightens it. This joining method has the advantage of no fear of pipe removal.

(1) Coupling

The pipe expansion joint is used for joining the pipe by expanding the pipe end in advance with a device, hooking a box nut or a flange on the pipe end, inserting the pipe in the coupling itself where rubber packing was inserted, and tightening the cap nut or tightening the flange with a hexagon bolt and nut. This type of joint is applicable to the designations of 13-16 Su and 75-100 Su.

There are three types of such joints, types A, B and C, as shown in Fig. 3.5-17. Types A and C expand the pipe with compressed rubber at a fixed distance from the pipe end. Type B expands the pipe end with a rotary conical tool to prevent the coupling from falling off.

(2) Joining method

(Type A)

Cut the pipe to the specified length and deburr the inner and outer sides of the cut surface with a reamer or file. Next, install a box nut on the yoke of the pipe-expanding device (see Fig. 3.5-18) and insert the pipe into the guide rod as far as it goes. The hydraulic pump should then actuate the piston rod to compress the expanding rubber, expanding the pipe. The pipe expansion is complete when the sound from the pump changes due to the load applied to the hydraulic pump. At the same time the buzzer will sound and the lamp will light up.

Detach the pipe from the expanding device to check the expanded area. Insert the expanded pipe into the coupling itself and use a pipe wrench, etc. to tighten the box nut with the method specified.

The specifications for the pipe-expanding device are shown in Table 3.5-4.

(Type B)

Cut the pipe to the specified length. Use a reamer or file to deburr the inner and outer cutting surfaces of the pipe. Fix a clamp liner and a cone meeting the pipe bore on an expanding device (see Fig. 3.5-18). Insert the pipe fully until it contacts the pipe-positioning pin. Close the clamp and tighten the clamp lever before starting expanding the pipe (A red lamp lights up during expansion.)

After completing the pipe expansion, check the expanded area. Assemble the pipe in the coupling itself. Use two pipe wrenches, etc. to tighten the nut with the prescribed tightening torque until the nut is firmly tightened. When indicator B (white) overlaps with indicator A (red), the work is completed. If the final tightening with a tool is not yet completed, a gap will remain between the packing and the nut. In this case, water will leak out during a water pressure test and defective areas can be identified.

(Type C)

Cut the pipe to the specified length. Deburr the inner and outer surfaces of the pipe with a reamer or file. Next, fix a flange on the yoke of the pipe-expanding device (see Fig. 3.5-18). Insert the pipe into the guide rod as far as it goes. The hydraulic pump should then actuate the piston rod to compress the expanding rubber, expanding the pipe. Press the FOR switch button at hand to complete the pipe expansion. After the switch is held for five seconds, the motor will discontinue operation. Press the REVswitch button to return the guide rod and discontinue operation. The pipe expansion will be then completed.

Detach the pipe from the expanding device to check the expanded area. Insert the expanded pipe into the coupling itself. Use a box wrench to tighten the flange with a hexagon bolt and nut. Table 3.5-4 lists the specifications of the expanding device.

(3) Points for the joining operation

(Type A)

(a) Cutting and chamfering should be performed with care.

(b) The spacer should be tightened with a dedicated tool. If tightened with excessive force, the pin for preventing the rotation of the piston may be broken.

(c) The backup ring, pipe expanding rubber, guide rod and other parts should be installed in the correct order.

(d) The pipe should be securely inserted at the time of pipe expansion.

(e) Be sure to install the rubber packing when tightening the coupling.

(f) The nut should be tightened according to the tightening and checking method specified.

(Type B)

(a) Take care to cut and chamfer the pipe properly.

(b) Check the joint area of the pipe and the surface of the coupling to ensure that no foreign matter such as refuse, oil or sewage is left.

(c) Use a dedicated device in expanding the pipe. Check that the pipe expanded is within the range of the expansion gauge.

(d) Push the expanded area of the pipe straight to the coupling itself and tighten the nut by hand.

(e) Fully tighten the nut until the expanded area of the pipe is inserted between the coupling itself and the nut taper to have metal contact, and a sharp increase in torque is noted.

(Type C)

(a) Cut and chamfer the pipe with care.

(b) Use a dedicated tool to tighten the guide rod. If tightened with excessive force, the piston pin for preventing rotation may snap.

(c) Fix the backup ring, expansion rubber, guide rod, etc. in correct order.

(d) Make sure that the pipe is fully inserted when expanding the pipe.

(e) Remember the rubber packing when tightening.

(f) Make sure that the hexagon bolts and nuts are tightened one by one in the diagonal direction until the flange surface has close contact.

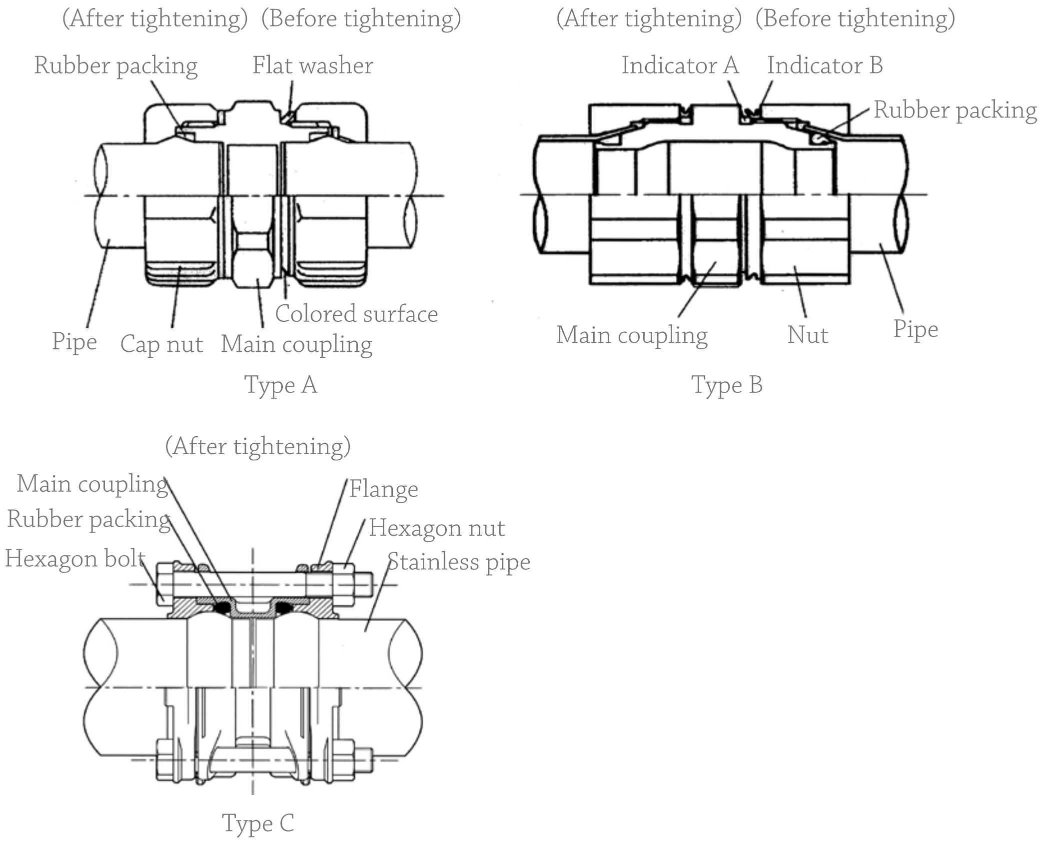
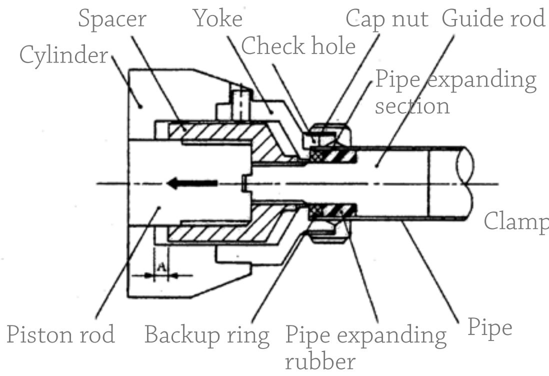
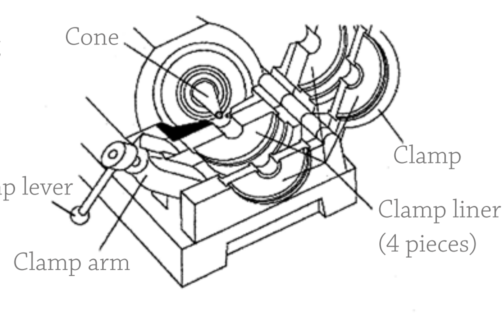


Fig. 3.5-17 Structure of pipe expansion type coupling[1]

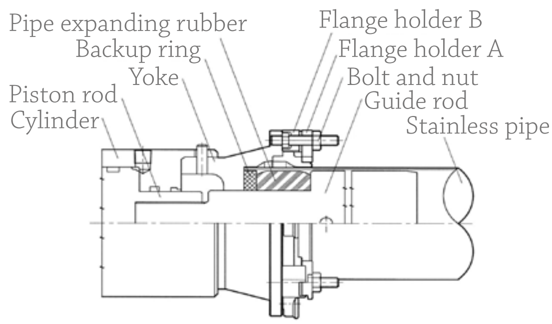
(Type A from *Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition,* and Type B and C added to this Manual)



Type A



Type B



Type C (75 – 100 Su)

Fig. 3.5-18 Specifications of pipe expansion tool[1]

(*Typ*e A from *Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition* and Type B and C added to this Manual)

Table 3.5-4 Pipe expansion tool specifications (13-100 Su)

Type A	
Motor-driven hydraulic pump	
Power source used	AC 100V 50-60 Hz
Capacity	320 W (7 A)
Discharge pressure	70 MPa (Max.)
Weight of parts	
Main unit pump base	23 kg
Set of attachments	11.3 kg

Type B	
Motor	Single phase series commutator motor
Power source used	AC 100V 50/60 Hz
Output	330 W
Current rating	6:00 AM
Number of revolutions (without any load)	80 rpm
Dimensions	370×220×250
Weight of the main unit	20 kg

Type C	
Motor-driven hydraulic pump	
Power source used	AC 100V 50-60 Hz
Capacity	400 W (3.8 A)
Discharge pressure	70 MPa (Max.)
Weight of parts	
Main unit pump base	74 kg
Set of attachments	51 kg

(Type A *from Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition,* and Type B and C added to this Manual)

3.5.3.6 Compression pipe joint

The coupling has the advantage that it can be joined with two off-the-shelf wrenches. Like press joints, this type of joint is usable even in places where fire cannot be used. This type of joint can be applied to copper pipes, in addition to stainless steel pipes (some of them require dedicated pipe end cores).

(1) Coupling

With the compression pipe joint, a sleeve-bearing pipe is inserted into the joint portion of the coupling itself and a cap nut tightened, pressing the sleeve to the pipe. The range of use for this type of pipe coupling is the designations of 13 – 25 Su (see Fig. 3.5-19).

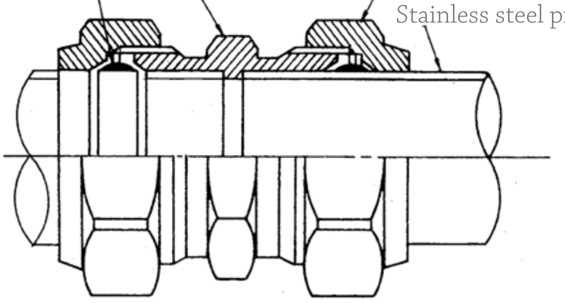


Fig. 3.5-19 Example of the structure of a compression pipe coupling[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(2) Joining method

Cut the pipe to the prescribed length, then clean the portion to be joined and remove any die wear or flash. Insert the pipe fully until it will go in no further, and tighten the cap nut by hand until it will turn no more. With a magic marker, draw alignment marks on the cap nut and on the coupling itself, and mark the position of the end of the coupling on the pipe. Then the joint should be made by putting a spanner or the like on the coupling and cap nut and tightening by turning a one and one-sixth turn from the alignment mark position for 13-25 Su pipes. The mark on the pipe serves to check if the pipe has come loose when the joint is tightened. The size of the spanner or monkey wrench used to tighten the coupling and nut differs depending on the nominal diameters of the pipes (see Table 3.5-5).

Table 3.5-5 Sizes for spanners used for compression couplings[1]

Nominal diameter	For the coupling itself	For the cap nut
13	22	24
20	30	32
25	36	41

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(3) Points for the joining operation

(a) Before inserting the pipe into the coupling, the surface of the portion to be joined should be inspected, any oil, dust or adhering matter removed, and checked for any dents or scratches.

(b) The coupling must be tightened slowly and carefully. Any pipe pull-out or turning of the pipe and coupling together could lead to an incomplete joint and cause leakage. A pipe wrench or similar tool must not be used for tightening the coupling, as this could cause deformation or scratches.

(c) When the piping is extended in a straight line, the pipe and coupling sometimes revolve in tandem, and the joined and tightened parts loosen. When this happens the coupling and cap nut should be slowly tightened with a spanner or similar tool.

3.5.3.7 Dresser and snap ring pipe joint

The pipe must be grooved, but the joint can be formed simply using a pipe wrench. Even after it is tightened, it can be removed. It is flexible and superior for preventing pull-out.

(1) Couplings

With the dresser and snap ring pipe coupling, the snap ring fits into a groove previously cut in the pipe, preventing pipe pull-out. By tightening the cap nut, a pressurized fluid is hermetically sealed with the rubber packing of the receptacle portion and the pipe and coupling are joined. The range of use is the designations of 30 - 80 Su (see Fig. 3.5-20).

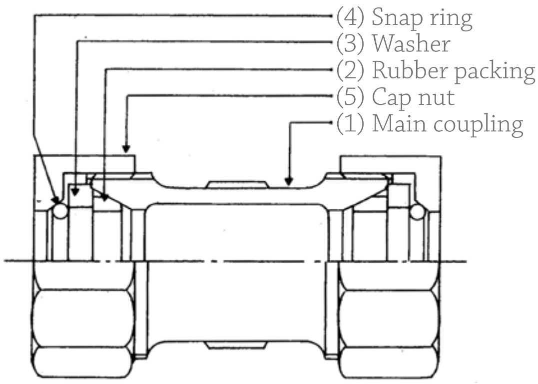


Figure 3.5-20 Example of the structure of dresser and snap ring pipe coupling[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(2) Joining method

Cut the pipe to the prescribed length; clean the part to be joined; remove any die wear or flash.

Next, hold the pipe in a pipe vise, mark the A dimension of the pipe's grooving position with a magic marker or the like and insert a plug for grooving into the pipe. The plug must be inserted until the collar of the plug hits the end of the pipe (see Fig. 3.5-21).

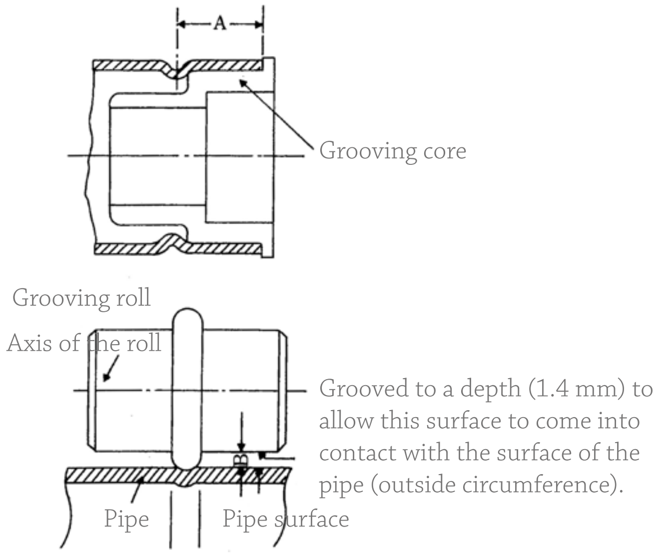


Figure 3.5-21 Grooving[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

The blade of the pipe cutter should be replaced with the grooving roll, with the tip of the roll placed against the A-dimension position of the pipe, and the same operation as in pipe cutting performed. That is, a groove should be cut around the entire circumference while moving the cutter in a pendulum motion (about 30° - 90°). This should be continued to the depth at which the shaft of the roll comes into contact with the pipe.

The cap nut, snap ring (inserted into the groove on the pipe), washer and rubber packing should be fitted onto the pipe in that order. Then the pipe should be inserted into the coupling itself and the nut tightened. The nut should be tightened with a pipe wrench until its torque increases and resistance is felt.

(3) Points for the joining operation

(a) Check that there are no vertical scratches on the pipe end.
(b) The pipe must be grooved to the prescribed depth.
(c) The parts must be put on in the correct sequence.
(d) The rubber packing must be fitted in the right direction, not upside-down.

3.5.3.8 Coupling pipe joint

The joint is accomplished simply by tightening two bolts after inserting the pipe into the coupling. In addition to flexibility, the grip type offers anti-removal function.

(1) Coupling

An example of a coupling joint is illustrated in Fig. 3.5-22.

The rubber lip is press-fit on the pipe surface by the spring and rubber protrusion incorporated in the coupling when the fastening bolts are tightened. In SAS 322, the range of use has been standardized to 40 - 80 Su.

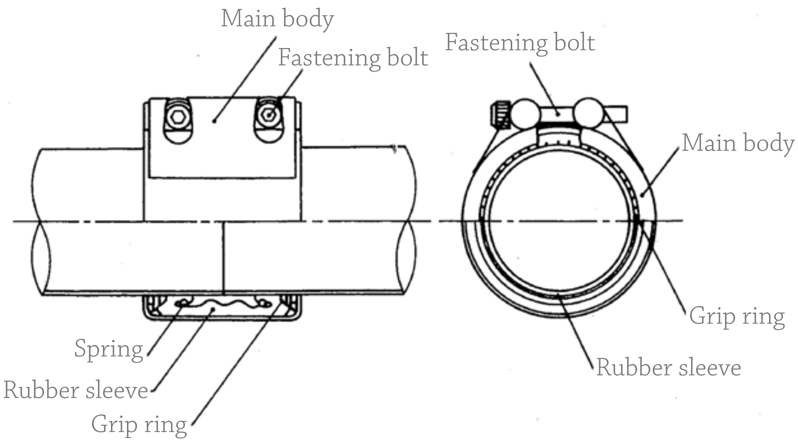


Fig. 3.5-22 Example of Construction of Coupling Type Joint[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(2) Joining method

After deburring the pipe end, mark the part of the pipe to be joined with the coupling at the position equivalent to 1/2 of the coupling width. Next, insert the coupling into the pipe, adjust the coupling to the marked position and tighten the bolts with the torque ratchet wrench to the specified torque.

(3) Points for the joining operation

(a) Do not use a pipe with a groove flaw in the axial direction.
(b) Any noticeable hollows in an old pipe should be corrected using putty.
(c) Any protuberances, rust or flaws should be removed with a file or disc sander.
(d) Uneven tightening may damage the bolts, resulting in leakage. Thus, tighten the bolts alternately.
(e) Do not tighten the bolts with excessive force.

3.5.3.9 Rolled screw bolt joint

This joint works as nuts of rolled screw bolts are tightened.

(1) Coupling

The coupling is fixed as the pipe is inserted and tightened with nuts as the rolled screw bolts on the outer side of the pipe are firmly bolted. The built-in O rings keep the pipe airtight.

This joint is applicable to the designations of 13 - 60 Su. Figure 3.5-23 shows the structure of a rolled screw bolt joint.

(2) Joining method

After cutting the pipe, use an off-the-shelf chamfering tool or file to deburr and chamfer the outer surface of the pipe. Use a marking gauge, etc. to mark a line on the pipe. Insert the pipe in the coupling until it reaches the line and tighten the retainer by hand. Fix the pipe and tighten the nut counterclockwise until the pink indicator on the retainer submerges.

(3) Points for the joining operation

(a) Be sure to chamfer the pipe after cutting. The O rings will be damaged if tightened without chamfering.

(b) Use normal retainers free of defects such as missing abacus-shaped beads.

(c) When re-jointing the pipe, cut off the rolled screw bolt area of the pipe. Replace the existing retainer with a new one.

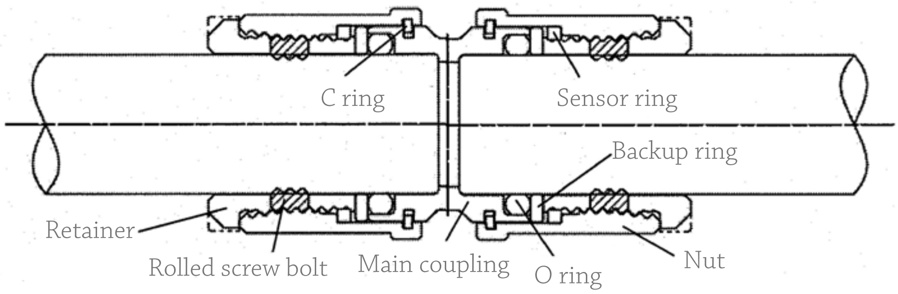


Figure 3.5-23 Structure of rolled screw bolt joint

Prepared by: Japan Stainless Steel Association

3.5.3.10 Quick pipe joint

This type of joint works as the pipe is just inserted into the coupling without using any dedicated or common tools such as wrenches.

(1) Coupling

Inserting the pipe into the coupling will provide sealing as well as joint strength with the edges contained inside the coupling. This type of coupling is applicable to the designations of 13 - 50 Su. (See Fig. 3.5-24.)

(2) Joining method

Make a line mark for the coupling on the chamfered pipe, apply silicon spray to the pipe and insert the pipe into the coupling to joint.

The pipe can be detached from the coupling with a remover, which is a dedicated tool, if it has not yet been pressurized.

(3) Points for the joining operation

(a) Remove foreign substances adhered to the coupling and pipe before they are joined.

(b) Be sure to chamfer the pipe, mark a line and apply silicon spray to the pipe.

(c) To prevent the rubber rings from being damaged, insert the pipe into the straight coupling while avoiding forced insertion.

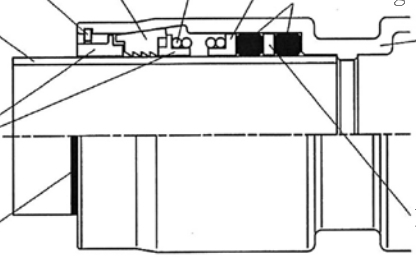


Figure 3.5-24 Structure of quick pipe coupling

Prepared by: Japan Stainless Steel Association

3.5.3.11 Selecting mechanical pipe couplings

Mechanical pipe couplings must be selected from those examined by and registered with the Japan Stainless Steel Association and conforming to the SAS 322 standard (*Performance standards for pipe fittings for stainless steel pipes for ordinary piping*).

(1) Fitting method and points for when fitting the pipe

The joining method and points for when joining the pipe vary from coupling to coupling. Carefully check the points before joining. Be sure to have proper training, etc. on joining and follow the manual of the coupling manufacturer when joining.

Table 3.5-6 describes a list of couplings certified pursuant to the SAS 322 standard.

Table 3.5-6 List of couplings certified by the Japan Stainless Steel Association pursuant to SAS 322

(Performance standards for pipe fittings for stainless steel pipe for ordinary piping as of March 31, 2011)[5]

Certification No.	Coupling name	Product Name	Manufacturer's name
32203	Press coupling	Morco joint	Benkan Japan KK.
32204	Double press coupling	Double press	Benkan Japan KK.
32205	Grip coupling	Mie grip	Mie Techno Co., Ltd.
32206	Pipe expanding coupling	Nice joint	O.N. Industries Ltd.
32207	Compression coupling	MR joint II	Riken Corporation
32209	Coupling pipe coupling	Strive coupling grip type	Sho-Bond Coupling Co., Ltd.
32211	Pipe expanding coupling	Zlok	Hitachi Metals, Ltd.
32212	Pipe expanding coupling	SUS fit	Riken Corporation
32213	Rolled screw bolt coupling	Abacus	Higashio Mech Co., Ltd.
32214	Pipe expanding coupling	Yodoshi SUS fit	Yodoshi Corporation
32215	Pipe expanding coupling	BK joint	Benkan Japan KK.
32219	Press coupling	SUS press	CK Metals Ltd.
32220	Press coupling	JF joint	O.N. Industries Ltd.
32221	Pipe expanding coupling	Nice joint	O.N. Industries Ltd.
32222	Quick coupling	EG joint	Benkan Japan KK.

For the conditions of use of these couplings, contact the manufacturer.

Source: Japan Stainless Steel Association website

3.5.4 Housing pipe joint

This joining method offers excellent flexibility and dilatation absorption. If pre-fabricated, on-site work efficiency is improved.

(1) Coupling

With self-sealing lip gaskets fitted on both ends of the pipe, the pipe is covered with the housing and tightened with bolts and nuts or with pins for sealing the fluid. This joint has a mechanism to prevent pipe slippage. Applicable pipe types and sizes are listed in Table 3.5-7.

As shown in Figs. 3.5-25 and 3.5-26, the two different types of joints are groove and ring.

For the former, a rolled groove is formed in the pipe by a rolling process. For the latter, an SUS 304 square or round ring is welded to the pipe to prevent slippage.

Table 3.5-7 Nominal pressure, maximum working pressure and applicable pipes[6]

Nominal pressure	Maximum working pressure	Applicable pipes	
10K	1.0 MPa	Groove type	Designations of JIS G 3448: 30 Su to 150 Su
			Nominal diameters of JIS G 3459: 25 A (1 B) to 150 A (6 B)
		Ring type	Designations of JIS G 3448: 30 Su to 300 Su
			Nominal diameters of JIS G 3459: 20 A (3/4 B) to 450 A (18 B)
			Nominal diameters of JIS G 3468: 150 A (6 B) to 450 A (18 B)
20K	2.0 MPa	Groove type	Designations of JIS G 3448: 30 Su to 125 Su
			Nominal diameters of JIS G 3459: 25 A (1 B) to 150 A (6 B)
		Ring type	Designations of JIS G 3448: 30 Su to 300 Su
			Nominal diameters of JIS G 3459: 20 A (3/4 B) to 450 A (18 B)
			Nominal diameters of JIS G 3468: 150 A (6 B) to 450 A (18 B)

SAS 361-2006 (***Housing Type Pipe Couplings***), a standard of the Japan Stainless Steel Association

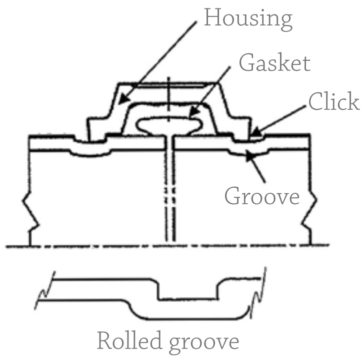


Fig. 3.5-25 Groove type construction example[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

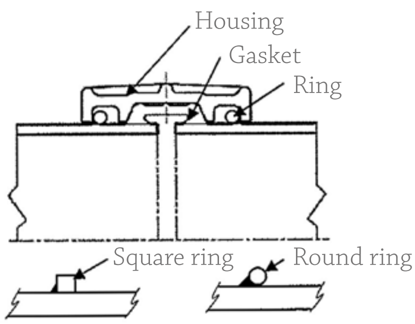


Fig. 3.5-26 Ring type construction example[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(2) Method for preventing the pipe from slipping off the coupling (rolled ring method)

Figure 3.5-27 shows the connecting section in the method for preventing the pipe from slipping off the coupling. This method is characterized with the following points:

(a) No pipe slippage is ensured, the same as with the ring type in Figure 3.5-26.

(b) Even if the manual tightening of bolts fastening the housing is defective, no pipe slippage will easily occur, the same as with the joining method in Figure 3.5-25 where the pipe is grooved.

(c) No ring to weld is needed.

(d) No welding is needed.

(e) For a thin-walled pipe like stainless steel pipe, no ring will be welded. This prevents the pipe from having holes and corrosion stemming from weld oxidation.

Rubber ring

Housing

Rolled convex ring

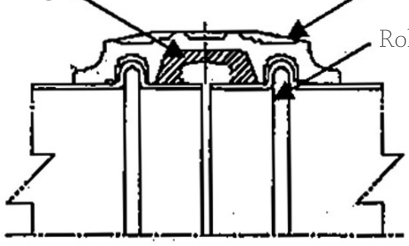


Fig. 3.5-27 Section of pipes connected with method for joining pipes by forming-rolled convex rings (rolled ring method)[3]

Source: Guidelines for Super Durable All-Stainless Steel Piping System

(3) Joining method

The procedure for joining is shown in Table 3.5-8.

(a) Do not use a pipe with groove flaws in the axial direction.

(b) Any noticeable hollows in old pipe should be corrected using putty.

(c) Any protuberances, rust or flaws should be removed with a file or disc sander.

(d) Uneven tightening may damage the bolts, resulting in leakage. Thus, tighten the bolts alternately.

(e) Do not tighten the bolts with excessive force.

Table 3.5-8 Housing type joint joining procedure[1]

No.	Process	Description	Precautions
1	Fitting gaskets	After applying silicon oil spray on the inner and outer surfaces of a gasket, expand the gasket with both hands to fix on the pipe end.	Be careful not to damage the gaskets.
2	Clearance adjustment	Insert the pipe to be connected and, while allowing the specified spacing, move the rubber ring to the center.	
3	Lubricant application	Apply silicon oil spray on the inner surface of the housing.	
4	Housing installation	Install the housing on the pipe and evenly tighten it with bolts and nuts.	

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

3.5.5 Other joining methods

3.5.5.1 High flexibility coupling joints

This joint was developed for buried pipes. The high flexibility is to withstand the shifting of the ground in which the pipes are laid.

(1) Coupling

By tightening the cap nut on the high-flexibility type coupling, the packing is squeezed into the tapering area of the end of the coupling itself, which maintains airtightness. A lock component is pressed against the pipe, preventing the pipe from slipping. There are two quick joint types: with and without a groove. The range of use is the designations of 20 - 50 Su (see Fig. 3.5-28).

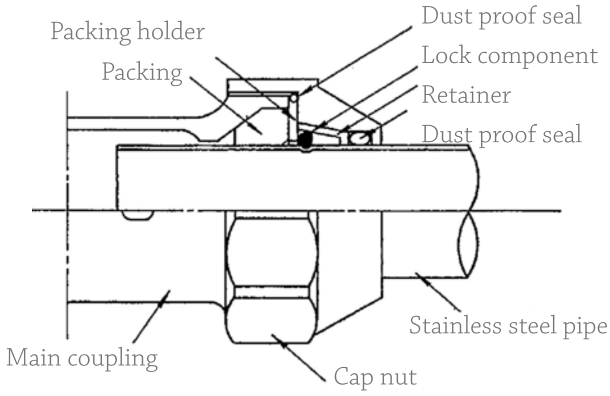


Figure 3.5-28 High flexibility coupling[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(2) Joining method

For cleaning, remove the die wear, flash, etc. from the end surface of the pipe. For the quick joint with a groove, use a dedicated roller to groove the pipe as shown in Table 3.5-9. Insert the pipe into the coupling with a moderately loosened cap nut. Check that the lock component has been fitted in the groove. After tightening the cap nut by hand, use a pipe wrench, etc. to tighten the nut firm.

For the quick joint with no groove, display the insertion size line at the location of an insertion size shown in Table 3.5-9. Insert the pipe into the moderately loosened coupling and align the insertion size line with the end face of the cap nut. After tightening the cap nut by hand, use a pipe wrench, etc. to tighten the cap nut firm.

Table 3.5-9 Point of Fitting a Pipe in a High-Flexibility Coupling and Insertion Size[7]

a. Grooving spot and groove depth — Unit: mm

<table>
<tr><td rowspan="2">Quick joint with groove</td><td>Designation</td><td>Distance from pipe end face</td><td>Grooving depth</td></tr>
<tr><td>20, 25, 30, 40, 50</td><td>49</td><td>0.75</td></tr>
</table>

b. Insertion size reference values — Unit: mm

<table>
<tr><td rowspan="4">Quick joint with no groove</td><td>Designation</td><td>Cap nut type</td><td>Push type</td></tr>
<tr><td>20, 25</td><td colspan="2">81</td></tr>
<tr><td>30</td><td rowspan="2">85</td><td>86</td></tr>
<tr><td>40, 50</td><td>93</td></tr>
</table>

JWWA G 116 (*Stainless steel tube fittings for water supply*)

(3) Points for the joining operation

Check thoroughly which joining method, the quick joint with groove or with no groove, is employed before joining the pipe pursuant to the corresponding procedure.

Slowly but firmly tighten the cap nuts on the coupling, while avoiding pipe slippage and simultaneous bolt-nut rotation.

3.5.5.2 Threaded joint

The threaded joint is a reliable and stable method as long as the pipes are properly connected.

Since connecting two stainless steel pipes with screws tends to have a galling phenomena, the threaded joint is generally for diameter of 50 A (60 Su) or under.

Since pipes of JIS G 3448: *Stainless steel tubes for ordinary piping* are thin-walled, a screw cannot be used. Thus, screwing is for a thick single pipe (under JIS G 3459: *Stainless steel pipes*), such as schedule 40, and the pipe ends are welded to joint them.

Described below are the key points in processing taper screws for the pipes and proper insertion of such screws.

(1) Processing screws

The standard is JIS B 0203(1999): *Taper pipe threads* for screws, and processing screws properly according to this standard is necessary. Thus, a screw processing machine with an automatic positioning device should be used. Screw processing is subdivided into cutting screw processing of the JIS standard and rolled screw processing described in a JIS appendix. For rolled screw processing, the same precautions for cutting screw processing apply as well.

(a) The main points for proper processing of screws are as follows:

① Cut the pipe at a right angle so that the section is smooth.

② Evenly chamfer the inner surface of the pipe end.

③ Chuck the pipe properly to be vibration free.

④ Make sure that an appropriate quantity of cutting oil (for rolled screw processing, apply the cutting oil used for processing a perfect circle prior to screw processing, hereafter applied in the same meaning) is fed continuously to the cutting area.

⑤ Do not leave cutting dust on the pipe ends during screw cutting.

⑥ Replace the chaser (for rolled screw processing, rolling roller) with a new one if ridges are nipped out or chipped.

⑦ Replace the cutting oil with a new lot if water, etc. has mixed in and discolored the cutting oil.

(b) The following defective screws are likely to cause leakage.

① Polygonal screw

② Screw whose diameter is smaller or greater, or twisted screw

③ Screw whose ridge is missing, nipped out, or worn

④ Screw whose thickness is uneven

⑤ Chattering screw

(2) Checking the screw for finished condition

When starting to work, changing work steps or as required by other circumstances, use a taper screw ring gauge to check the screw size. Then use your eye and hand to inspect the screw length (total screw length including the cutup part) and external appearance.

(a) Clean the processed screw and align it with the taper screw ring gauge before manually tightening it. If the pipe end is within the notch of the gauge, the processed screw is normal; if not, the screw is defective and should not be used (Fig. 3.5-29).

In particular, when starting to work or replacing the screw, run a trial processing to adjust the screw machining equipment so that the pipe end comes to the middle of the notch depth (d/2 location in Fig. 3.5-29). The screw size will necessarily vary even if adjusted screw machining equipment is used. Thus, adjusting the equipment helps minimize the production of defective screws.

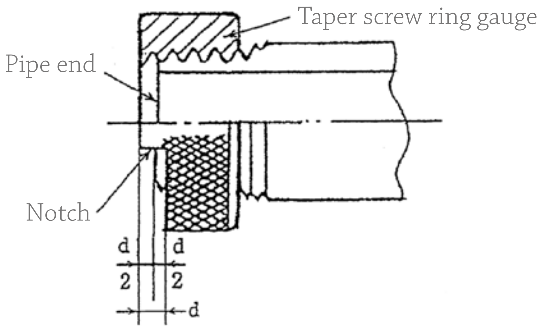
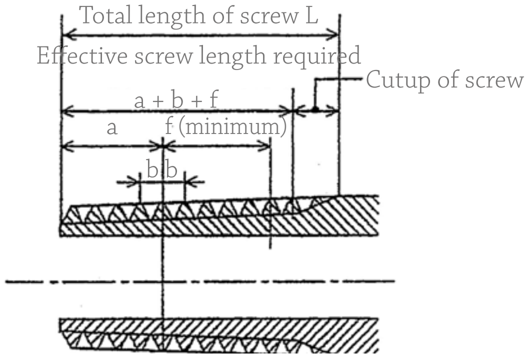


Figure 3.5-29 Checking the screw with a taper screw ring gauge

Pepared by Japan Stainless Steel Association

(b) Processing sizes of screws for standard pipes

Figure 3.5-30 shows the processing sizes of screws for standard pipes. Total length L of the screw includes the effective length used for aligning the male and female screws. Here, the necessary effective screw length is the sum of standard length (a), difference of the positive-side allowance of the male screw axially expending (b) and effective screw length toward the large diameter side from the gauge diameter (f).



Unit: mm

Nominal	Standard screw processing size				Reference value		
Nominal diameter of pipe	Nominal diameter of screw thread	Effective screw length required a + b + f	Cutup length of screw	Total length standard value of screw L	Point of value		Effective length of screw from the point of standard diameter toward the large diameter side (minimum) f*
					a*	Difference of allowance ±b*	
15	1/2	14.97	4.93	19.90 (11.0 ridge)	1.16	1.31 (1.0 ridge)	5.0
20	3/4	16.34	4.96	21.30 (11.2 ridge)	9.63	1.31 (1.0 ridge)	5.0
25	1	19.10	4.35	25.45 (10.2 ridge)	10.39	2.31 (1.0 ridge)	6.4
32	1. 1/4	21.41	4.40	25.81 (11.2 ridge)	12.70	2.31 (1.0 ridge)	6.4
40	1. 1/2	21.41	4.40	25.51 (11.2 ridge)	12.70	3.31 (1.0 ridge)	6.4
50	2	25.60	4.44	31.13 (13.1 ridge)	15.88	3.31 (1.0 ridge)	7.5
65	2. 1/2	30.13	4.51	34.13 (15.0 ridge)	17.45	3.46 (1.5 ridge)	9.2
80	3	33.30	4.63	37.15 (16.5 ridge)	20.64	3.46 (1.5 ridge)	9.2
100	4	39.25	4.63	43.88 (19.1 ridge)	25.40	3.46 (1.5 ridge)	10.4

* a, b, and f are values pursuant to JIS B 0203(1999)(*Taper pipe threads*).

Figure 3.5-30 Standard screw processing sizes[8]

Source: Study materials, Piping Manual WG, Japan Stainless Steel Association, 2004

(c) Threading and relevant points

Pay attention to the following points when threading.

① Use couplings that conform to JIS B 2308: *Stainless steel threaded fittings* and screws that conform to JIS B 0203: *Taper pipe threads*.

② Check the external appearances of the connecting parts for refuse and residual oil, etc. before connection. If any are found, use an organic solvent to remove such waste.

③ Apply a sealing agent that conforms to the purpose of use and is suitable for stainless steel pipes.

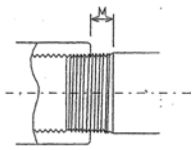
④ Use tools for threading (pipe wrench, etc.) with care.

⑤ Thread the pipe well by hand before using a pipe wrench to tighten the pipe by setting a target number of ridges (See Table 3.5-10).

Table 3.5-10 Normal remaining screw length M and normal threading length N[8]

Category	Unit	Nominal diameter of pipe								
		15	20	25	32	40	50	65	80	100
		Nominal diameter of screw								
		1/2	3/4	1	1. 1/4	1. 1/2	2	2. 1/2	3	4
Total screw length	Ridge	11.0	11.5	10.0	11.0	11.0	13.0	15.0	16.5	19.0
L*	mm	20.0	21.5	23.5	26.0	26.0	30.0	34.5	38.0	44.0
Normal remaining screw length	Ridge	5.0	5.0	4.0	4.0	4.0	4.0	5.0	5.0	5.5
M*	mm	9.0	9.0	9.5	9.5	9.5	9.5	11.5	11.5	12.5
Normal threading length	Ridge	6.0	7.0	6.0	7.0	7.0	9.0	10.0	11.5	14.0
N	mm	11.0	12.0	14.0	16.0	16.0	20.5	23.5	26.5	32.0

* The length of M varies depending on L, and represents a numeric value when L indicates the corresponding value in this table.



Source: Study materials, Piping Manual WG, Japan Stainless Steel Association, 2004

⑥ Compared with cast iron and bronze, stainless steel has high hardness and little conformability. Accordingly, joining two stainless steel pipes requires larger tightening torque.

Table 3.5-11 below shows standard tightening torques for the threading connection. Thus, tightening the pipes with a torque value larger than those defined in Table 3.5-11 is necessary.

⑦ When connecting different types of metals, insulation is required.

Table 3.5-11 Standard Tightening Torques[8]

Nominal diameter of pipe	Nominal diameter of screw	Standard torque (N·m)
15	1/2	40
20	3/4	60
25	1	100
32	1. 1/4	120
40	1. 1/2	150
50	2	200
65	2. 1/2	250
80	3	300
100	4	400

Source: Study materials, Piping Manual WG, Japan Stainless Steel Association, 2004

3.5.5.3 Socket joints

Cast iron pipe and vinyl chloride lined steel pipe are used mainly for drainage of collective housing. Many special couplings for drainage, made of special cast iron, are used for the piping of common units. Compared with couplings for water supply, special couplings for drainage have larger diameters but low water pressure performance. Thus, socket couplings are used in order to improve workability. Instead of socket joints (Fig. 3.5-31), however, coupling type couplings (Fig. 3.5-32) are recommended for easy updates and less extra construction work.

(1) Drawbacks of socket joints

The socket joint used for drainage pipes of common units has the following drawbacks:

(a) The service life of cast iron pipe and drainage vinyl chloride lined steel pipe, etc. is 40 to 60 years. Accordingly, compared with the service life of the building frame, pipes need to be replaced two to three times with new ones. Thus, the development of stainless steel socket couplings for large diameters is necessary.

(b) In recent years, local corrosion has occurred often due to deteriorated water quality of drainage. This has increased the frequency for replacing components. In such replacement, the chipping on the area penetrated in the slab and the pipes before and after the portion to be replaced need cutting, because of the socket type. Since such replacement work needs time, drainage use must be limited during the replacement.

Pipes and couplings made of durable austenitic stainless steel offer an advantage. Only deteriorated gaskets on the couplings need to be replaced without chipping on the area penetrating in the slab and cutting the pipes before and after the portion involved. Therefore, coupling type couplings are recommended.

(2) Characteristics of coupling type coupling

The coupling type coupling has the following characteristics:

(a) A gasket can be replaced by loosening the coupling.

(b) When the coupling is loosened and slid in the pipe axis direction, the pipe of the replacement portion can be removed horizontally.

(c) Extra installation work can be reduced.

(d) In such replacement work, the drainage suspension time can be reduced, which is very important for people relying on the drainage.

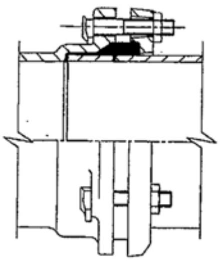


Fig. 3.5-31 Structure of socket coupling[3]

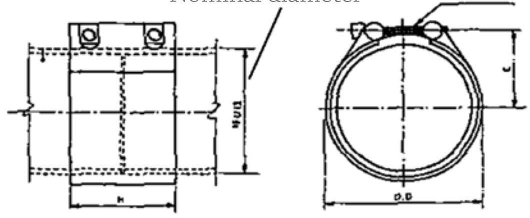


Fig. 3.5-32 Coupling type coupling[3]

Source: Guidelines for Super Durable All-Stainless Steel Piping System

3.6 Joints with Other Kinds of Pipes

When a stainless steel pipe has direct contact with another type of metal pipe, metal pipe with electric potential lower than that of the stainless steel pipe may develop dissimilar metal contact corrosion, which is galvanic corrosion.

① In water supply, hot-water supply and drainage systems, dissimilar metal contact corrosion develops due to oxygen dissolved in the fluids.

② Since closed chilled and hot water and cooling water supply systems have no oxygen supplied, these systems develop no dissimilar metal contact corrosion. Open supply systems will develop corrosion because oxygen is supplied.

If the solution pH is alkaline or the system supplies steam return water, there is no corrosion. Table 3.6-1 (a) lists applicability of direct contact between stainless steel pipe and different types of couplings, while Table 3.6-1 (b) lists applicability of direct contact between stainless steel couplings and other types of metal pipe. In this connection, press, compression, dresser snap ring and grip couplings all require dedicated couplings.

Table 3.6-1 (c) lists relations between stainless steel pipe, different components and piping conditions.

Table 3.6-1 (a) Applicability of direct connection between stainless steel pipe and different couplings[8]

With stainless steel pipe			Reason
Coupling material	Code	Applicability (1)	
Ductile cast iron, carbon steel, alloy steel, cast steel, etc. (including metal plating and lining)	FCMB27-05, etc.	×	Because the electric potential of stainless steel pipe greatly differs with that of cast iron, carbon steel, alloy steel, cast steel, etc., electric insulation is needed between them.
Copper	C1220, etc.	○	Since the electric potential of copper is close to that of stainless steel, no actual problems will occur.
Bronze (including surface treatment against lead)	CAC406, etc.	○	Since the electric potential is close to that of stainless steel, no actual problems will occur. (2)
Leadless alloy bronze	CAC911 etc.	○	
Dezincification-resistant brass	C3604, etc.	○	Electric insulation was referred to as needed because the metal has a large difference in electric potential. However, according to a study initiated by Japan Copper and Brass Association, this metal can be treated like bronze.
Plastic	PEX, PE, PB, PVC-U, etc.	○	Since plastics are electrically non-conductive, no problems are expected.

(1) ○: Applicable; ×: Needs insulation

(2) However, insulation is desirable when stainless steel pipe is jointed with a ferrule with a bronze saddle or a bronze stock cock, etc. in embedded piping.

Source: Study materials, Piping Manual WG, Japan Stainless Steel Association, 2004

Table 3.6-1 (b) Applicability of direct connection between stainless steel couplings and other types of pipe[8]

With stainless steel coupling			Reason
Pipe material	Code	Applicability (1)	
Carbon steel (including plated and lining metals)	SGP, SGPW, STPG307, etc.	×	Due to the large difference in electric potential with carbon steel, electric insulation is needed.
Ductile cast iron (including coatings and linings)	FCD, etc.	×	Due to the large difference in electric potential with carbon steel, electric insulation is needed.
Copper	C1220, etc.	○	Since the electric potential of copper is close to that of stainless steel, no problems will occur.
Dezincification-resistant brass	C2600, etc.	○	Electric insulation was referred to as needed because the metal has a large difference in electric potential. However, according to a study initiated by Japan Copper and Brass Association, this metal can be treated like bronze.
Plastic	PEX, PE, PB, PVC-U, etc.	○	Since plastics are electrically non-conductive, no problems are expected.

(1) ○: Applicable; ×: Needs insulation

Source: Study materials, Piping Manual WG, Japan Stainless Steel Association, 2004

Table 3.6-1 (c) Relation between components and piping conditions[9]

	Other Connecting Components and Environment							
	Piping	Faucet metal fittings	Couplings	Valves	Pumps	Tanks	Support fitting	Penetration area of wall
Insulation	According to Table 3.6-1 (a)	According to Table 3.6-1 (a)	According to Table 3.6-1 (a) (1)	According to Table 3.6-1 (a) (1)	× (2)	× (2)	× (2)	× (3)

(1) If a coupling and valve (valve shaft and valving element are made of stainless steel) have a structure where the area contacting with water is made of rubber and the main unit does not contact with water, no insulation is needed.

(2) This is for insulating with the building frame and other electrical appliances, etc. and forming no external short circuits. (If there is an external short circuit, an insulated short pipe of 500 mm or longer must be connected on one side of the contact with a different type of metal pipe, pump or tank, and on both sides of a coupling or valve.)

(3) This is for insulating the piping system from the building frame and preventing external galvanic corrosion due to condensation or other causes if the penetrating area of the wall contacts with reinforcing steel. In this connection, even if a different type of coupling is fixed, no insulation is needed if the coupling is for underground use and has a reinforced outer coat and inner surface corresponding to a coupling mentioned in (1) above.

Source: Insulation between Stainless Steel Pipe and Other Types of Metal Connection, Japan Stainless Steel Association

(Reference)

Using stainless steel pipe for underground embedment

There are areas where strong soil corrosion develops if bare stainless steel pipe is embedded. Thus, SUS 316 stainless steel pipe is recommended, in principle, for use underground. If SUS 304 is used for laying bare underground piping, some areas will develop soil corrosion. In this case, using anti-corrosion tape, polyethylene sleeves or the like to prevent contact with soil is recommended.

Even if stainless steel pipe is going to be connected with a different type of metal, no insulation is needed if the metal has a reinforced outer coat and inner surface corresponding to a coupling defined in (1) in Table 3.6-1 (a).

A number of insulation methods are available. Figures 3.6-1 (a) through 3.6-1 (d) show examples of insulated couplings to connect a stainless steel pipe with a carbon steel pipe or a lined steel pipe. Table 3.6-2 lists a comparison of cost and workability by the type of bolt to be used.

Table 3.6-2 Comparison of costs and workability[8]

Method for steel pipe insulation	Use of steel bolt	Use of insulated steel bolt
Cost	Low	High
Workability	Complicated	Easy

Source: Study materials, Piping Manual WG, Japan Stainless Steel Association, 2004

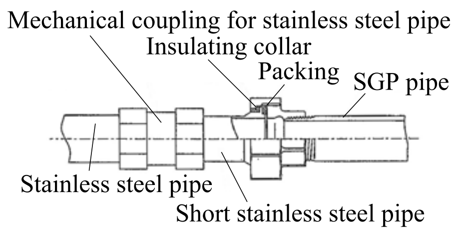
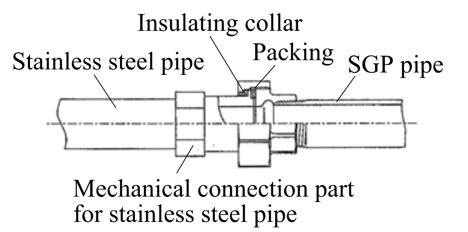
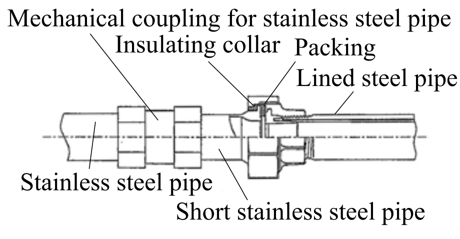
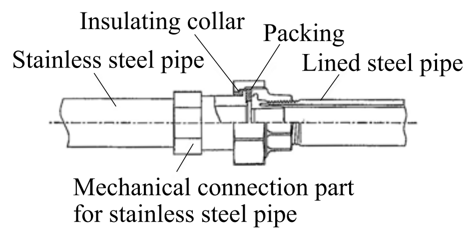
<table>
<tr><th></th><th>Insulation union with short stainless steel pipe + mechanical coupling</th><th>Insulation union with mechanical connection part for stainless steel pipe</th></tr>
<tr><td>Stainless steel pipe - SGP pipe connection</td><td>
</td><td>
</td></tr>
<tr><td>Stainless steel pipe - lined steel pipe connection</td><td>
</td><td>
</td></tr>
</table>

Fig. 3.6-1 (a) Example of connection where an insulation union is used (small diameter pipe)[8]

Source: Study materials, Piping Manual WG, Japan Stainless Steel Association, 2004

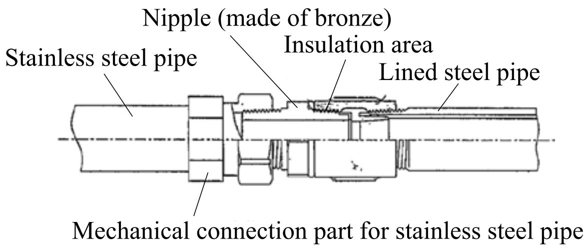
<table>
<tr><th></th><th>Pipe end anticorrosion insulation joint + mechanical coupling for stainless steel pipe</th></tr>
<tr><td>Stainless steel pipe – lined steel pipe connection</td><td>
</td></tr>
</table>

Fig. 3.6-1 (b) Example of connection where a pipe-end anticorrosion insulation joint is used (small diameter pipe)[8]

Source: Study materials, Piping Manual WG, Japan Stainless Steel Association, 2004

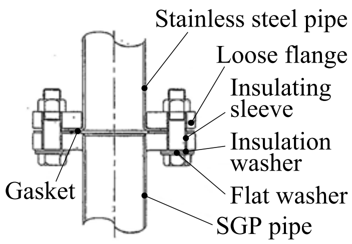
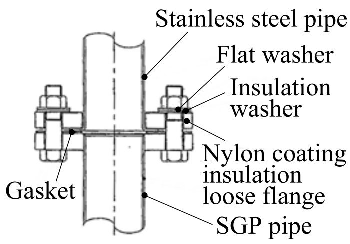
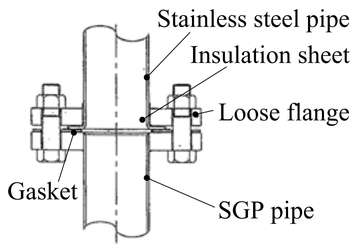
<table>
<tr><th>Flange connection with insulation sleeve and washer</th><th>Connection by insulation coat flange</th><th>Flange connection with insulation sheet</th></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
</table>

Fig. 3.6-1 (c) Examples of flange connection (medium and large diameter pipe)[9]

Source: Insulation between Stainless Steel Pipe and Other Types of Metal Connection, Japan Stainless Steel Association

Flange Type Insulation Coupling

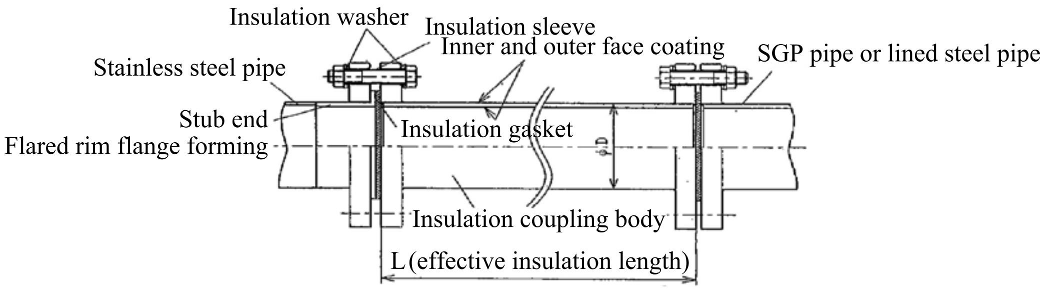


Figure 3.6-1 (d) Example of connection where a flange type insulation coupling is used (medium and large diameter pipe)[8]

Source: Study materials, Piping Manual WG, Japan Stainless Steel Association, 2004

3.6.1 Joint with carbon steel pipes

For joining a stainless steel pipe to a carbon steel pipe, a flange joint is generally used, as shown in Figs. 3.6-2 and 3.6-3, and an insulating bolt utilized. Figure 3.6-4 shows a joint by insulation union although it is limited to exposed pipes.

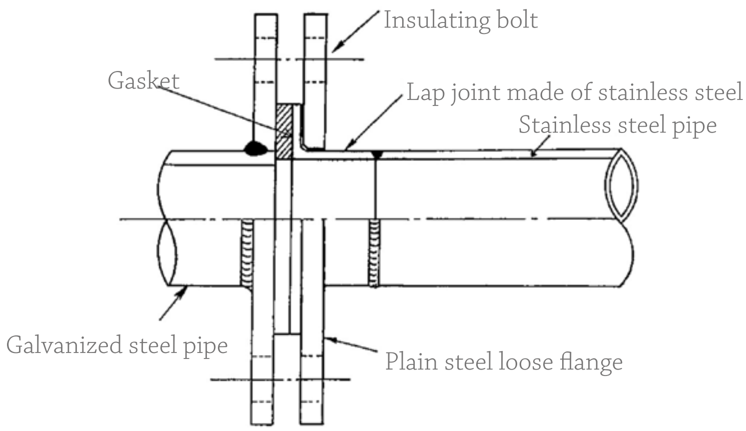


Figure 3.6-2 Joint with galvanized steel pipe[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

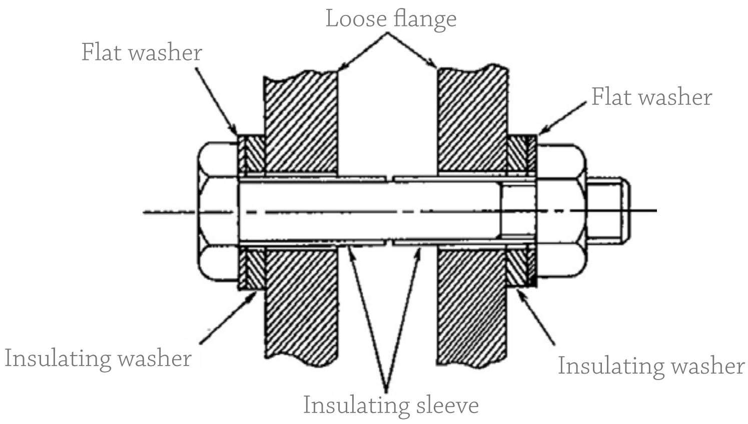


Figure 3.6-3 Insulating bolt[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

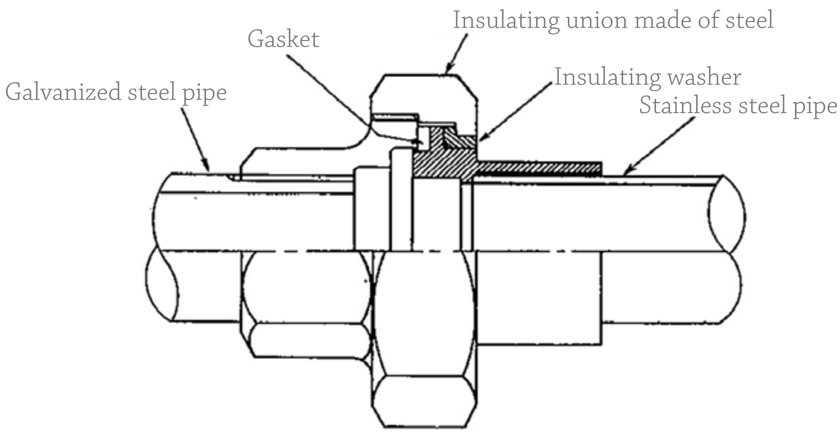


Figure 3.6-4 Steel insulating union[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

3.6.2 Joint with copper pipes

Small-diameter copper pipes (diameter of 28.58 mm or less) can be joined directly with such small-diameter stainless steel pipes with soldered couplings, since they are on the same diameter schedule. However, stainless steel is low in thermal conductivity, requiring skillful soldering. Medium- and large-diameter copper pipes are joined as shown in Figs. 3.6-5 and 3.6-6 because the pipe diameters differ.

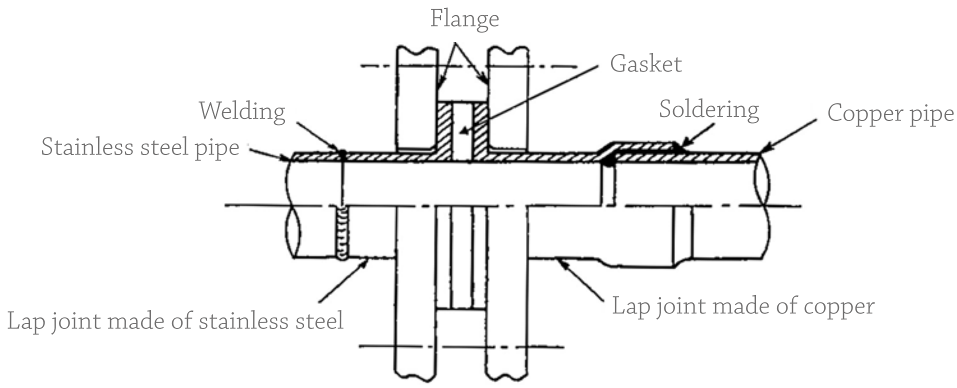


Figure 3.6-5 Flange joint with copper pipe[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

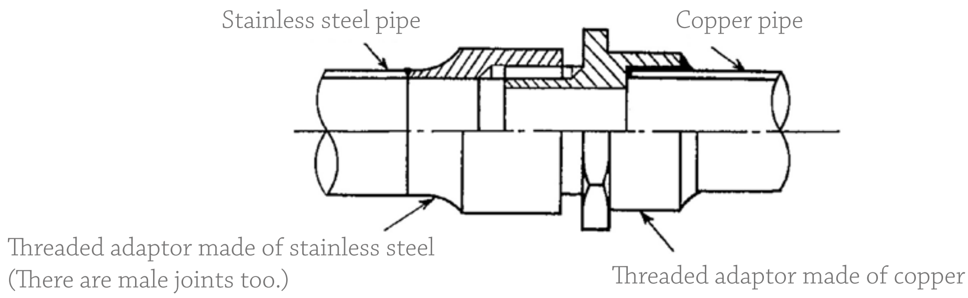


Figure 3.6-6 Union joint with copper pipe[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

3.6.3 Joint with unplasticized polyvinyl chloride pipe

For a joint with an unplasticized polyvinyl chloride pipe, solder joint is used with a stainless steel adaptor and valve socket (see Fig. 3.6-7).

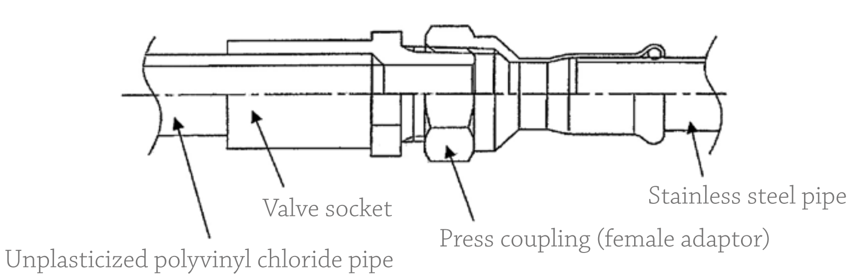


Figure 3.6-7 Connection using stainless steel adaptor and valve socket

Prepared by: Japan Stainless Steel Association

3.7 Connection with Accessories

Couplings for various types of joints, including mechanical pipe joints, weld joints, flange joints and screwed joints, are used for connecting accessories and stainless steel pipes. With accessories made of iron or similar material, insulating bolts such as shown in Figures 3.6-2 and 3.6-3 are used for flange connections, and steel insulating unions such as shown in Figure 3.6-4 are used for screwed joints. Also, the points for various joining operations described above must be fully observed if accessories are connected using screwed type adaptor couplings (see Figure 3.7-1).

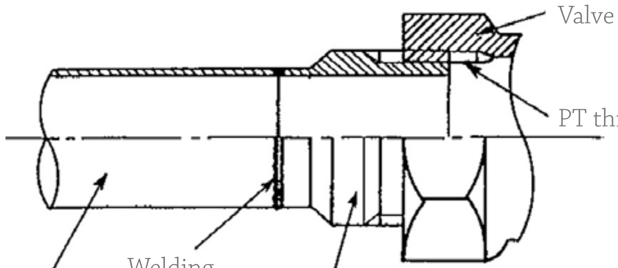


Fig. 3.7-1 Screwed type adaptor made of stainless steel[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

3.7.1 Connection with valves

Methods for connecting a valve with a pipe include the threaded end (Fig. 3.7-2), flanged end (Fig. 3.7-3), wafer (Fig. 3.7-4), housing (Fig. 3.7-5) and mechanical type (Fig. 3.7-6). Among these, the flanged end, wafer and housing types enable the user to detach and connect a valve for maintenance and replacement even if both pipe ends are fixed, without extra piping work. Accordingly, use the flanged end or housing type for connection with pipes of nominal diameter 50 A or under, and the wafer type with pipes of nominal diameter 65 A or above.

Fig. 3.7-2 Threaded end type connection (directly tightening a pipe screw on the pipe)[3]

Source: Guidelines for Super Durable All-Stainless Steel Piping System

Fig. 3.7-3 Flanged end type (valve where the facing flange couplings are connected by tightening the gasket with bolts and nuts)[3]

Source: Guidelines for Super Durable All-Stainless Steel Piping System

Fig. 3.7-4 Wafer type (valve inserted between flanges and tightened with bolts and nuts)[3]

Source: Guidelines for Super Durable All-Stainless Steel Piping System

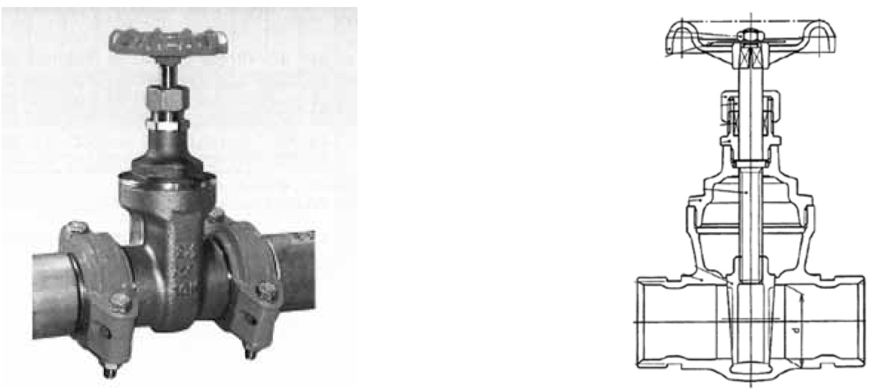


Fig. 3.7-5 Housing type (valve sealed with a rubber ring after grooved pipes are connected to prevent them from slipping off)[3]

Source: Guidelines for Super Durable All-Stainless Steel Piping System

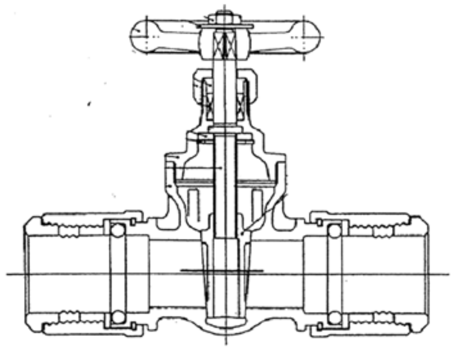


Fig. 3.7-6 Mechanical type (valve developed for thin stainless steel pipes where pipe screws cannot be used)[3]

Source: Guidelines for Super Durable All-Stainless Steel Piping System

3.7.2 Connections with faucets, etc.

For connections between stainless steel pipes and faucets or the like, various types of socket couplings for water supply faucets or elbow couplings for water supply faucets are used.

3.7.3 Connections with pumps or other equipment

Connections between stainless steel pipe and equipment such as pumps may be either the flange or screwed type. For the flange type, a flange connection adaptor is welded to the stainless steel pipe. For the screwed type, the connection is made using male and female adaptor couplings for various types of joints. Note the following points in such connections.

- For the flange type, major standards for pump flanges include JIS (Standard dimensions of JIS B 2220(2004): ***Steel Pipe Flanges*** and JIS B 2239(2004): ***Cast iron pipe flanges***), waterworks and ANSI (B16·1, B16·5). These standards categorize pump flanges by nominal pressure and dimensions. The user needs to pay attention to differences in flanges for stainless steel pipe.
- For the screwed type, small diameter (25 A or under) pumps are used in general.
- When the material of the pump to use is steel, cast iron or another type of metal, insulating the connecting part is required.

3.7.4 Connections with flexible joints

For connections between stainless steel pipes and flexible joints made of stainless steel, use the flange type (Fig. 3.7-7). If flanges of couplings for stainless steel pipes are connected directly, the connection would cause water leakage due to corrosion, etc. Thus, a gasket must be inserted between the flanges before connection. For the flexible type joint of stainless steel, the non-welding type must be used.

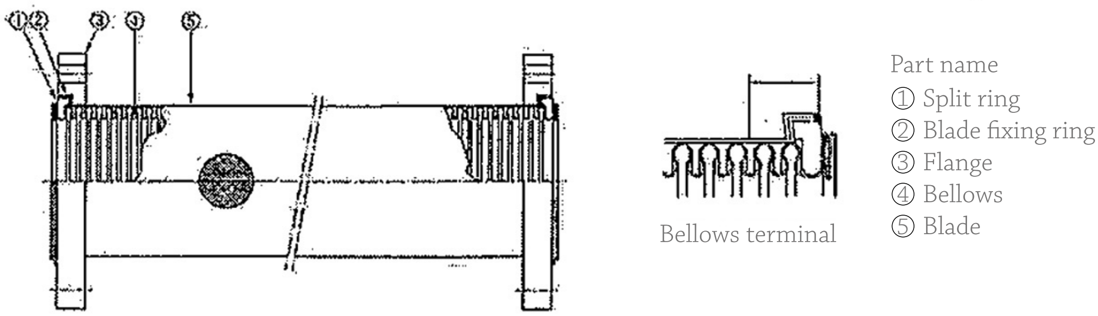


Fig. 3.7-7 Flanged end type: F4 bellows terminal non-weld structure (nominal diameter: 20 – 300)[10]

Source: SHASE-S-006(2008): Metal Made Flexible Pipe Joints

3.8 Member Processing (Prefabrication) for Piping

Press or compression couplings are used for joining stainless steel pipes. As these couplings are generally intended for small-diameter pipes, welded joints are normally used for medium- and large-diameter pipes of 60 Su or larger. Joints can be welded at the job site, but welding requires skill and presents considerable difficulties because the pipe is thin-walled and the work environment is not always very good. Due to this, welding is generally performed at the factory. A recommended method is illustrated in Fig. 3.8-1. Tees and elbows, flange-joint stub ends and housing type pipe joint rings, etc. are welded to the pipe, or member processed parts (prefabricated parts) are fabricated. Then they are brought to the site and connected by tightening bolts or another process, thereby completing the joining operation.

Fig. 3.8-1 Prefabricated parts

Courtesy of: Nowla Engineering Co., Ltd.

(1) Identifying pipe materials to be processed

Pipe materials to be processed must be colored so that their steel types can be identified after they are delivered and cut to the prescribed lengths. The coloring will prevent the user from processing the wrong steel pipe. Table 3.8-1 lists colors of stainless steel pipes for ordinary piping.

Table 3.8-1 Identifying Stainless Steel Pipes for Ordinary Piping

Steel type	SUS 304	SUS 316	SUS 315
Coloring	None 	Blue 	Brown 

Prepared by: Japan Stainless Steel Association

(2) Work procedure
First, isometric drawings are prepared. Then, based on them, the pipe is cut to the prescribed lengths. Next, couplings are welded on, following the notes for weld joints given in Chapter 3.5.1. After welding, the processed parts should be checked for appearance and leakage.

(3) Points for the operation
Follow the points to note for the joining operation that are given in Chapter 3.5.1.

(4) Inspection
The following inspections are required, in addition to those described in Chapter 3.5.1.

(a) Visual inspection of welded area
For adequate penetration, misalignment on the welding area and differences in pipe thicknesses must be avoided. Otherwise, inadequate penetration could result. In particular, if the coupling end for the scheduled pipe has been machined to adjust the pipe thickness, special attention must be paid. Complete visual inspection of the welded areas must be carried out.

(b) Leakage resistance test
In principle, all pipes must pass a leakage resistance test for water or air pressure. However, a sampling inspection or omitting such inspection may be permitted if the purchaser and manufacturer agree.

(5) Problems of on-site welding operations
The prime reason for using stainless steel pipe is anticorrosion. Based on this prerequisite, high durability is expected. On-site welding, however, has many unsolved problems. For example, when oxidation scales remain due to defective back shielding as a result of on-site welding, defective passive film will develop, which could lead to corrosion. Also, depending on the welding environment, on-site welding could invite impurities, which could deteriorate the corrosion resistance of the welded areas. Defects in welded areas are not easy to identify

by appearance. Thus, processing piping members at a factory where proper quality control is implemented is recommended.

Even if a design that reduces on-site welding to a minimum is implemented, on-site welding is inevitable in some situations. Figure 3.8-2 shows results of past stainless steel incidents studied. According to the study, many of these incidents are attributed to on-site welding.

(a) Control of on-site welding and points to note

In on-site welding, a fiberscope may be used for inner surface inspection of welded areas, but thorough inspection is not possible with the fiberscope. In principle, preventing the inside welded area from developing oxidation is essential to maintain the quality of such areas.

Since all position welding is necessary for different shapes of welded areas, the welding machine must be fully automated. Certain areas where a fully automated machine cannot operate must be welded manually. In such case, the welder must be skilled.

Concerning work safety, since welding must sometimes be performed in high places, sufficient safety control must be implemented.

(b) Back sealing at on-site welding

When the back seal inside the pipe is not adequate, oxidation scales could develop, leading to corrosion. Thus, the back seal must be checked for an acceptable level.

The following are cautionary points for welding to focus on preventing the inner surface of the welded areas from developing oxidation:

① The direction to inject a back shield gas must be considered, depending on the gas. For example, the specific gravity of argon gas is 1.38 against 1.00 of air, or heavier than air. In this case, argon gas must be injected from the lower stream side of the pipe to eject the air from the pipe. Nitrogen gas has a specific gravity of 0.97 against air and must be injected into the pipe from the upper stream side to eject the air from the pipe.

② To obtain the inner surface of a welded area that is equivalent to the sample of the inner surface standard indicated in Fig. 3.5-5, the inside of the pipe must be purged with back shield gas. Oxygen at the outlet end of the back shield gas must also be purged to lower the oxygen concentration before welding is started. Use an oxygen analyzer that can measure oxygen on a ppm level.

③ When there are many welded areas on the pipe, tack-welded areas must be taped to prevent back shield gas from leaking out of the pipe. Setting the effective piping length to 50 meters or under is desirable to purge inside the pipe with one-time gas shielding. When an open area of pipe is being sealed by welding, shield gas will blow up. In this case, a control measure must be taken such as leaking a slight quantity of shield gas from the pipe end, or by using the inner pressure control valve to regulate shield gas.

(c) Preventing defective joints in on-site welding

With on-site welding, repairing defective joints is difficult. Such faulty joints could induce secondary defects. Therefore, the welder must observe the following points for proper welding.

① A welding test must be conducted prior to on-site welding to determine whether factors such as current, voltage and welding speed for fully automated circular and manual welding methods meet in-house standards or acceptance inspections, such as the height and oxidation extent of the inner surface welded area. This also helps prevent inadequate penetration.

② A welder who operates an automated welding machine must be well trained and have qualifications for basic and professional skills.

③ Since manual welding requires advanced skill, the manual welder must be, without exception, well trained and have qualifications for basic and professional skills.

④ Ensuring adequate space for welding is important.

⑤ On-site welding must be limited to welding straight pipes. Welding a coupling with another coupling or welding a coupling with a straight pipe does not usually produce good results.

(d) Safety control in on-site welding

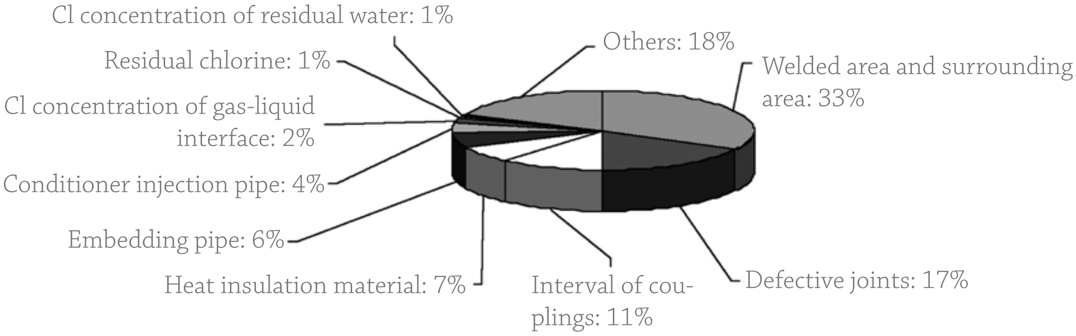
In terms of work safety, the difference of on-site welding from pre-fabricated weld processing lies in the necessity for preparing materials, equipment, protection tools, etc. in advance. On-site welding also requires good safety measures for the welder. When welding is required in high locations, a scaffold must be set up so that the welder can work with safety and avoid welding in unnatural positions.

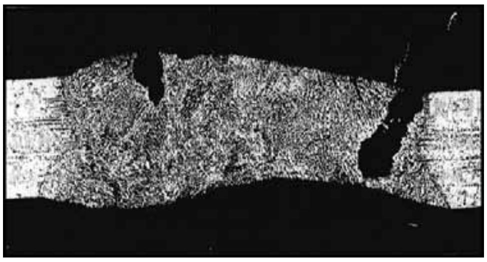
Compared with pre-fabricated processing, on-site welding is rather costly. Adopting a piping design that minimizes such necessity is desirable.

(e) Conclusion of on-site welding

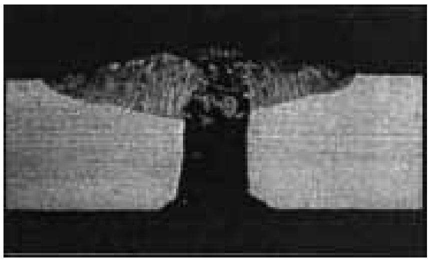
In principle, on-site welding must be avoided due to the potential problems demonstrated in Figure 3.8-2 because acid cleaning and electropolishing of oxidized areas on the inner welds as well as mechanical polishing of some welded areas cannot be conducted. Possible defective weld quality, such as inadequate penetration, and problematic methods for weld quality inspection and checking also remain unsolved. In principle, pipes that have been welded, machined and inspected at a prefabrication factory must be used for assembling at the building site.

If on-site welding is inevitable due to connection or fixing of pipes, the purchaser and the manufacturer must consult in advance to define the extent of on-site welding.





Welded area and surrounding corrosion



Insufficient penetration of welded area

Fig. 3.8-2 Results of Past Stainless Steel Pipe Incident Cases[3]

Source: Guidelines for Super Durable All-Stainless Steel Piping System

3.9 Curing Pipes

Care must be exercised in handling, processing and installing stainless steel pipes because they are lighter and thinner-walled than carbon steel pipes. In the factory where members are pre-processed, stainless steel pipes must be kept in order and clean. During storage finished members must be protected against damage from falling objects or other causes and from soiling by oil, mud, dust and other foreign substances. Iron/steel objects must not come in contact with the stored stainless steel pipes because this could cause corrosion. Since the pipe ends could get crushed or burred if they come in contact with other materials, they should be capped by curing covers when doing so is deemed advisable.

When pre-processed members are installed into their prescribed location on site, the pipes must also be protected. Anti-sweat and heat insulation should be put on horizontal ceiling pipes or vertical pipes as soon as possible. If piping is located in places that form traffic corridors, they must be protected by laying down boards or the like to keep other materials or machinery from touching or striking them. While the piping is being laid out, open pipe ends should be covered as necessary to prevent foreign material from adhering or getting into the pipes. Even after the piping is completed, care must be taken that it is not distorted with heavy objects placed on it or objects suspended from it.

3.10 Embedding Pipes

3.10.1 Embedding in the ground

In many places in Japan, the soil has a resistivity of 1000 Ω·cm or more and a Cl^- concentration of 100 mg/L or less. In such soil, stainless steel pipes exhibit excellent resistance to corrosion and can be buried as are, without any treatment on the outer surface. If underground piping is laid in areas such as wet coastal regions where seawater wells up or volcanic hot springs regions where gas comes out of the ground, stainless steel pipes must be protected from corrosion before embedding.

3.10.2 Polyethylene sleeve embedding

Polyethylene sleeve embedding is corrosion resistant as follows: ① It provides anticorrosion by preventing pipe from directly contacting corrosive soil; ② It prevents the pipe from macrocell corrosion by keeping the surroundings of the pipe in a uniform state; ③ It deters water relocation even if underground water penetrates and also deters the development of corrosion by consuming dissolved oxygen; and ④ It shields against electrochemical corrosion stemming from stray currents.

Since this embedding is performed at the pipe laying area, deterioration of anticorrosion film is slight. Pipes before embedding can also be repaired easily with adhesive tape, etc. Japan Water Works Association Code: JWWA K 158 covers this embedding. The embedding has a long history for ductile steel pipe and a history of 15 to 20 years for stainless steel pipe.

The polyethylene sleeve embedding, as a standard, has been much used. For example, the Bureau of Waterworks of the Tokyo Metropolitan Government and many water and sewage utility operators use this method.

Since this method protects pipes from corrosive soil and underground water, etc., it can also protect valves, faucets and other relevant tubular products as well. Prior to sleeve embedding work, adhesions on the surface of the pipe must be removed and the pipe must be covered to prevent direct contact with corrosive soil.

The entire pipe line to be embedded underground must be covered, including new steel pipes, gate valves and branch pipes. Polyethylene sleeves for protecting the pipes from corrosion (hereafter "Poly-Sleeves") must meet the corresponding pipe diameters.

(1) Fitting work

Poly-Sleeves to use must conform to JWWA K 158: *Polyethylene sleeves for ductile iron pipes* *for water supply*. Fitting work must conform to the JDPA W 08 stipulations: ***Guidelines for fitting polyethylene sleeves***.

(2) Fixing Poly-Sleeves

As shown in Figs. 3.10-1 and 3.10-2, Poly-Sleeves and pipes must be united firmly with rubber bands or adhesive tape, etc.

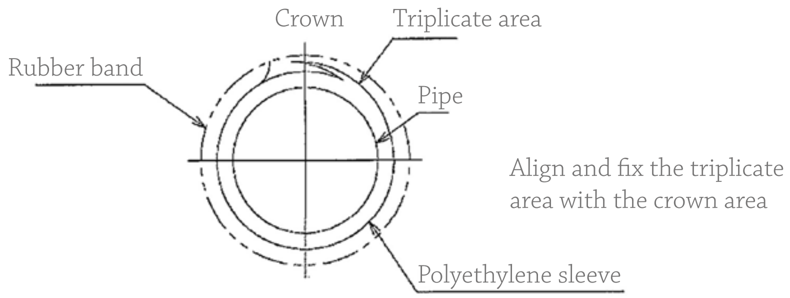


Fig. 3.10-1 How to fix poly-sleeves1[11]

Source: Piping Works Standard Specifications, Bureau of Waterworks, Tokyo Metropolitan Government

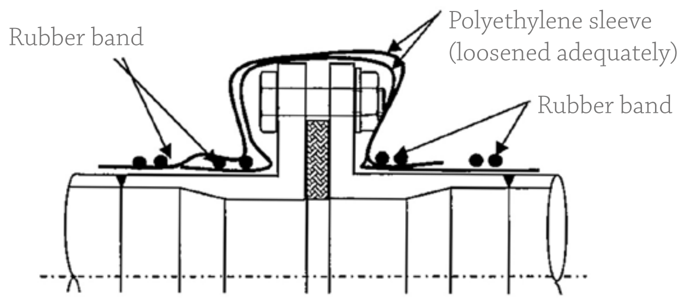
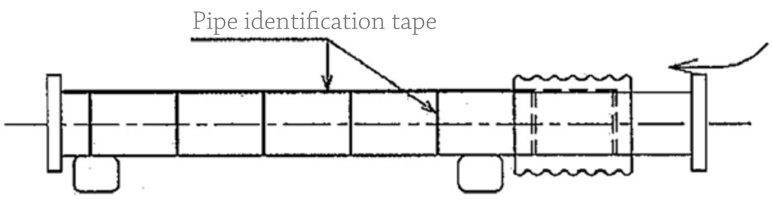


Fig. 3.10-2 How to fit the coupling part1[11]

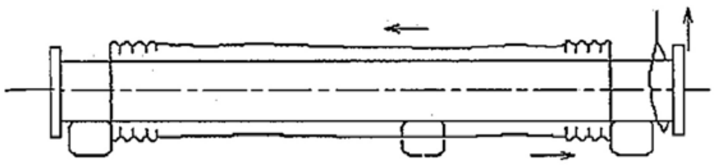
Source: Piping Works Standard Specifications, Bureau of Waterworks, Tokyo Metropolitan Government; modified flanged end type

Figure 3.10-3 shows an example of the procedure for rolling a poly-sleeve on a straight pipe.

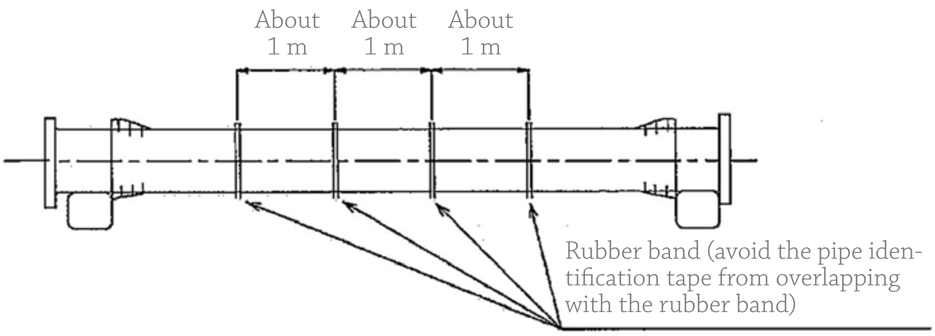
(a) Arrange pipe rests to support the socket and spigot. Put an identification tape on the pipe pursuant to the standard drawing. Cover the pipe from the spigot with a poly-sleeve.



(b) Hang the spigot, return the pipe rest in the center of the pipe to the spigot, and expand the poly-sleeve over the whole straight pipe.



(c) Use rubber band (at 1 meter intervals) to fasten the poly-sleeve so that the triplicated poly-sleeve meets on the crown area of the pipe.



(d) Use rubber band to fasten the socket area and insertion area of the poly-sleeve. Fold back both ends of the poly-sleeve toward the middle of the pipe.

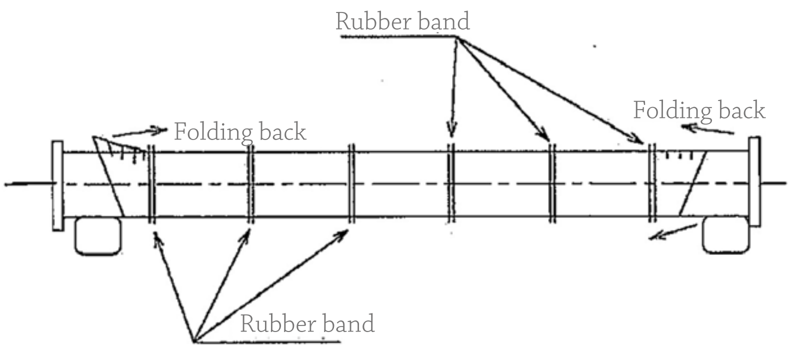


Fig. 3.10-3 Example of fitting a poly-sleeve wrapping a straight pipe[11]

Source: Piping Works Standard Specifications, Bureau of Waterworks, Tokyo Metropolitan Government (April 2010); modified for flanged end type

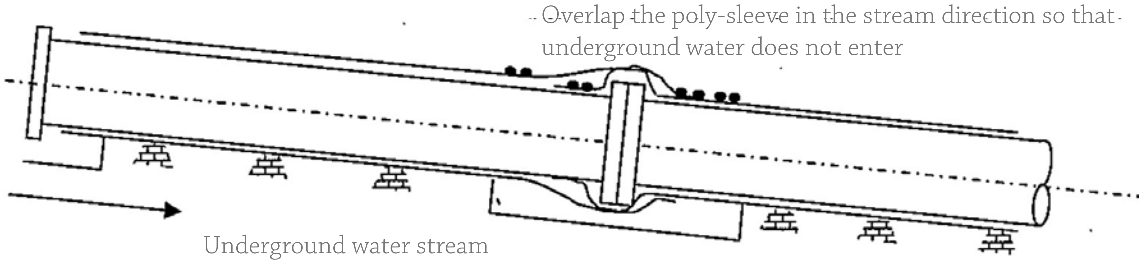


Fig. 3.10-4 How to fit a poly-sleeve on an inclined pipe[11]

Source: Piping Works Standard Specifications, Bureau of Waterworks, Tokyo Metropolitan Government; modified flanged end type

(3) Points to note when putting a poly-sleeve on the pipe

(a) Fold back the poly-sleeve so that the overlapped (triplicated) area meets on the crown of the pipe. This will prevent impact from soil and sand when they are backfilled.

(b) Loosen the poly-sleeve well to conform to the concavo-convex of the pipe coupling when installed. Take care of bolts, lugs, etc. so that the poly-sleeve put on the coupling will remain adhered along the shape of the coupling when it is returned and embedded underground.

(c) Overlap the joint areas of the poly-sleeve in the pipe axis direction without fail.

(d) When moving a pipe covered with a poly-sleeve, use wire-rope adequately protected with nylon rings and rubber so that the poly-sleeve will not be damaged.

(e) When installing a poly-sleeve on an inclined pipeline, prevent underground water from inflowing through the joint areas of the poly sleeves, as shown in Figure 3.10-4.

(f) Covering when an existing pipe is exposed
If an existing pipe is exposed in the same excavation (including inter-connection areas), also cover the existing pipe with a poly-sleeve.

(g) Note the product control number marked on the box where poly-sleeves, etc. are packed. Also check the marks on the poly-sleeves and record them.

3.10.3 Petrolatum anti-corrosive construction

For anti-corrosion treatment of stainless steel pipe, first remove any adhering dirt or other substances from the outer surface. Then, put Petrolatum paste on and wind Petrolatum corrosion protective tape around once with a one-half overlap. In addition, wind anticorrosion vinyl tape (JIS Z 1901, 0.4 mm thick) around once with a one-half overlap. Couplings and other such parts should also be wrapped with Petrolatum corrosion protective sheet and then wound with anticorrosion vinyl adhesive tape. Normally SUS 304 is used, but other types, such as the more corrosion-resistant SUS 316, should also be considered. As stainless steel pipes are thin-walled, backfilling must be performed carefully. Means such as the double-pipe method, waterproof coverings and packing in sand are used for backfilling. Embedding stainless steel pipe in soil should be avoided if temperature fluctuations would cause expansion and contraction. If pipe must be buried out of necessity, the distance should be kept as short as possible. To protect piping from ground subsidence, flexible joints or high flexibility couplings should be used between the piping and the building (see Fig. 3.10-5). For corrosion prevention, use insulating joints to insulate piping inside the building and underground pipe (see Fig. 3.10-6 (a)). Figure 3.10-6 (b) shows the insulating sleeve in Fig. 3.10-6 (a).

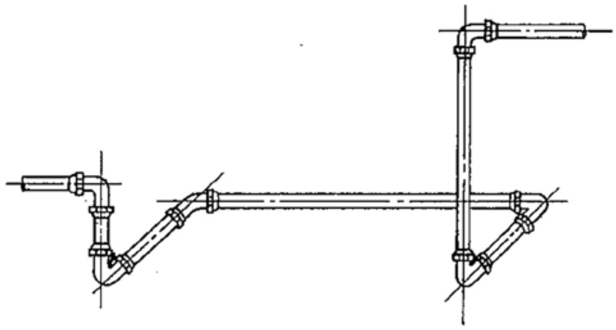


Fig. 3.10-5 How to use high flexibility-type couplings[1]
Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

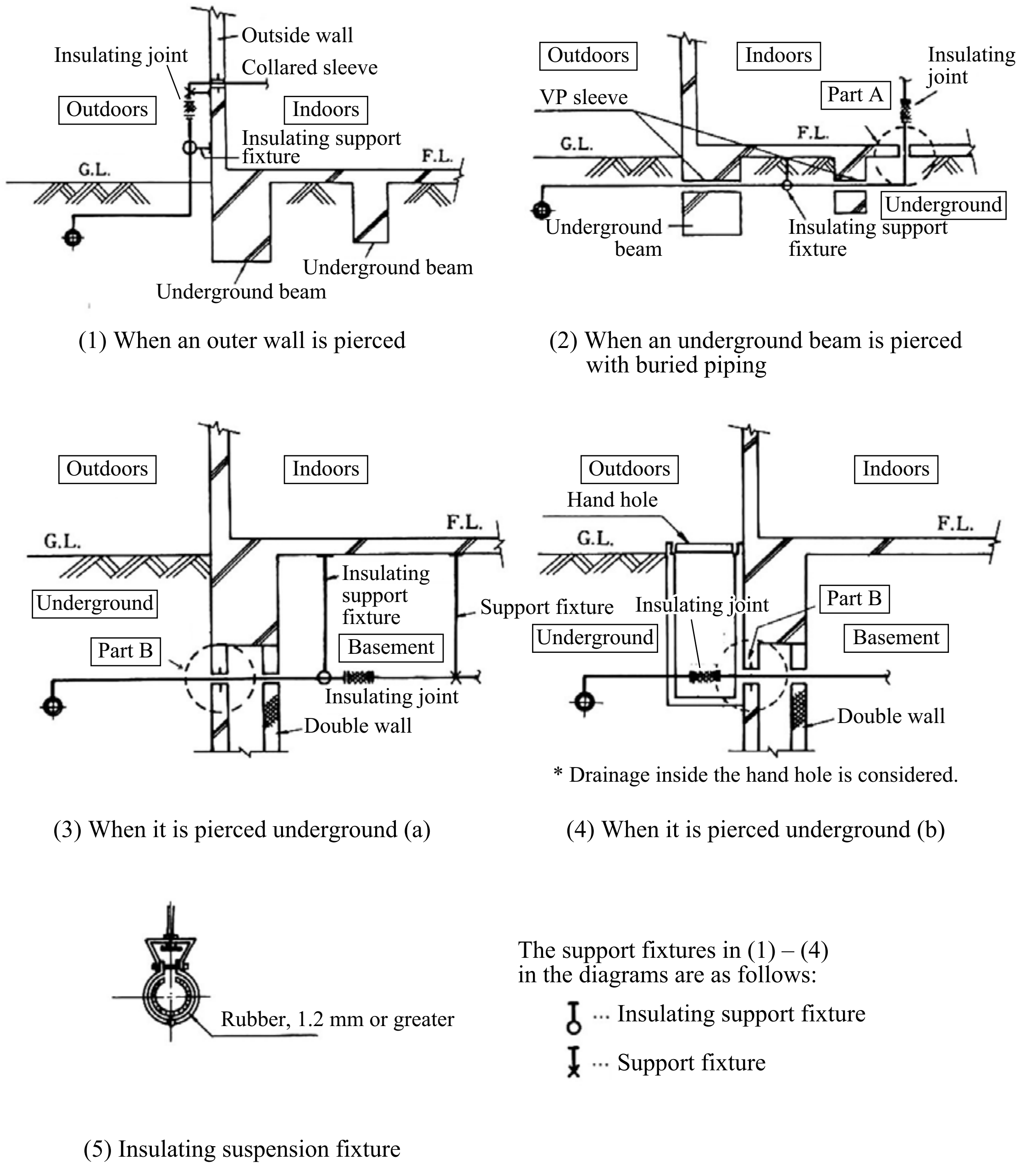


Fig. 3.10-6 (a) Installing insulated joints[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

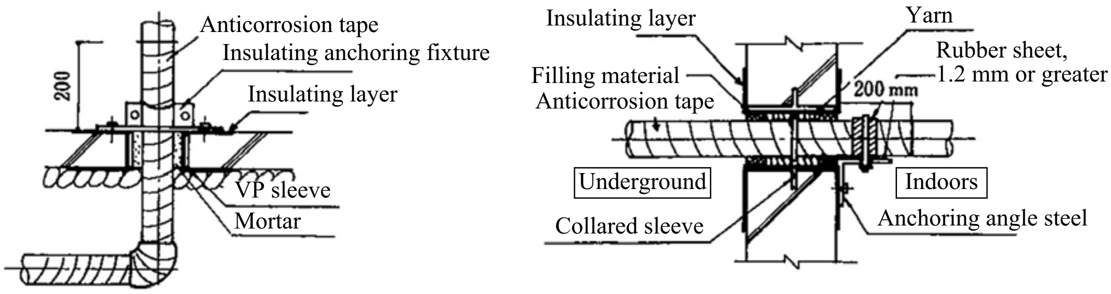


Fig. 3.10-6 (b) Insulated sleeve (parts A and B)[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

3.10.4 Embedding in concrete

Stainless steel pipes generally are corrosion resistant with respect to concrete and may be used in concrete-embedded piping. However, contact with the steel reinforcing bars in buildings must be avoided and insulation measures such as protecting with anticorrosive tape must be taken.

Temperature fluctuations cause about the same degree of expansion and contraction in stainless steel pipes as in copper pipes, which is why they are not anchored in concrete and are instead encased in thermal insulation so that they can expand and contract as much as needed. To the extent possible, embedding pipe in concrete must be avoided. If embedding many parts in concrete is unavoidable, piping methods that minimize the straight portions and maximize the bent portions must be used. This will help the amount of linear expansion and contraction to be as small as possible.

3.11 Supporting and Anchoring the Piping

Refer to 2.6 of Chapter 2. Design.

3.12 Compression and Expansion Treatment

Refer to 2.7 of Chapter 2. Design.

3.13 Preventing Water Hammer

Refer to 2.8 of Chapter 2. Design.

3.14 Preventing Corrosion

The corrosion resistance of stainless steel is due to the formation and maintenance of a passive surface film in atmospheric oxygen. This passive coating never completely dissolves in an environment such as that of tap water.

Sometimes local breakdown of the passive coating due to halogen ions causes pitting corrosion. Sometimes acquired local non-uniformity of the material or non-uniformity of the corrosion environment causes local corrosion such as stress corrosion cracking, intergranular corrosion or crevice corrosion. Sufficient knowledge on what causes these kinds of corrosion is required, based on which measures should be taken to prevent them.

(1) Preventing pitting corrosion and crevice corrosion

Among the factors that promote pitting corrosion and crevice corrosion are halogen ions, residual chlorine, an insufficient supply of oxygen in closed-off parts and the adhesion and buildup of corrosion-causing deposits. The following prevention measures are required:

(a) Care must be taken that no metal, dirt or other foreign matter enters the pipe when it is joined. The inside of the pipe must be brushed carefully prior to trial operation. The couplings must be closed with caps. Mouths such as pipe ends must be closed with sheets, etc.

(b) The piping must be arranged to minimize the buildup of scale and deposits inside the pipe. When inverted right-angled arch piping must be laid, a drainpipe should be installed to remove scale deposits.

(c) Since the material the gasket is made of affects crevice corrosion on the surface of a flange, hydroscopic gaskets should be avoided. Non-asbestos sheet that is covered with PTFE dedicated to stainless steel pipes must be used. The gasket size should also fit the inside diameter of the pipe because too large or too small a gasket could lead to crevice corrosion.

(d) The residual chlorine concentration of make-up water must be checked to keep the chlorine concentration at 0.4 ppm or under. If the concentration is excessive, a measure must be studied to reduce the ppm.

(2) Preventing stress corrosion cracking

Stress corrosion cracking is prone to occur where the surface of the stainless steel has tensile stress in a Cl^- or similar environment. The following prevention measures are required:

(a) Leave no more strain in the pipe than necessary. Avoid deforming the pipe. If the pipe is bent, bend it with a large radius (4D or larger).

In this connection, if the pipe is bent at a radius smaller than 4D, check the bent area in accordance with a corrosion test stipulated in the coupling performance standard for stainless steel pipes for ordinary piping (SAS 322). The bent pipes that pass such a test may be used.

(b) As with pitting corrosion, wash and remove scale and deposits using the following methods so that they do not cause crevice corrosion on the inner surface.

① The following methods of chemical cleaning are available:

- Applying acid cleaning agents
- Applying alkaline cleaning agents
- Applying neutral cleaning agents

Apply an organic acid detergent (sulfamic acid, organic mixed acid or DBA detergent) instead of a hydrochloric acid cleaning agent because the latter could develop corrosion on stainless steel pipes.

② Mechanical cleaning

If chemical cleaning is likely to largely impact the drainage treatment, or if accumulation is so much that chemical cleaning cannot treat it, or if the pipe is clogged with foreign matter, apply mechanical cleaning.

- Ultra-high water pressure washing: This washing method is used for cleaning drainage pipes, condenser tubes, cooling tubes, boilers, etc.
- Pig cleaning: The method of shooting synthetic resin bullets, called "pigs," into a pipe is available for cleaning if the diameter of the pipe does not vary on the halfway. This method produces outstanding results if employed together with chemical cleaning and ultra-high water pressure washing.
- Other methods: One is a wet sand blast method, which jets out wet sand mixed with water.

If the material clogging the pipe is not solid, shock waves of water may be able to dissolve the clogging.

(c) For outdoor piping, rainwater dissolves the Cl^- in heat insulation material and concentrates it on the surface of pipes. To avoid this, the piping should be constructed so that rainwater does not seep in, and heat insulation material without Cl^- should be used.

(d) Since stainless steel pipe has a large coefficient of linear expansion, allowance for heat-caused pipe expansion must be made, and the increase of tensile stress during expansion must be prevented. (Refer to 2.7 of Chapter 2. Design.)

3.15 Heat Insulation and Anti-sweating

(1) Heat insulation materials and anti-sweating

Refer to 2.10 of Chapter 2. Design.

(2) Anti-sweating and heat insulation construction

The anti-sweating and heat insulation for stainless steel pipes are similar to those used for pipes made of other materials, but care is called for in the use of anti-sweating and heat insulation materials because the pipe diameter designations for stainless steel pipes differ from those for carbon steel pipes. For example, the nominal diameter 25 A for carbon steel pipe corresponds to the outside diameter of 30 Su for stainless steel pipe. In general, attention must be paid to the following matters in piping construction:

(a) Shaped products are used for heat insulation material, but there should be no gaps in the joint portions. If there is any overlapping, the adhesion should be tight, and the joint sections should not be placed collinearly (see Fig. 3.15-1).

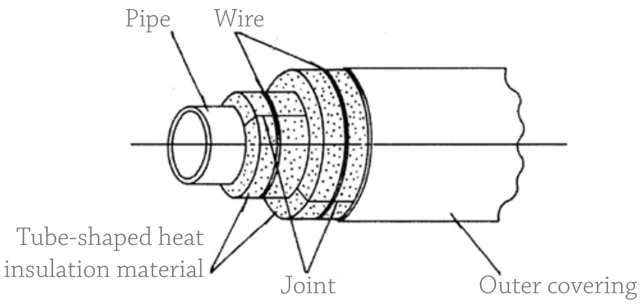


Fig. 3.15-1 How heat insulation material is put on[1]

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

(b) Steel wires used to attach heat insulation material should be placed in at least two locations, and any band-shaped material should be spiral-wound with a 50 mm pitch.

(c) Outdoor piping should be covered with galvanized steel sheet or the like after the heat insulation material is put on. This prevents rainwater from entering the piping.
(See paragraph (c), (2) Stress corrosion cracking, Chapter 3.14 Preventing Corrosion.)

(Supplementary information)

Points for when processing heat insulation materials

1. Points for when safekeeping, transporting and processing heat insulation materials
   - (a) Heat insulation materials must be kept free of where rainwater falls and pools are located nearby. Blocks, veneer-core plywood or duckboards must be laid on the floor to minimize effects from moisture on the heat insulation materials.
   - (b) Welding sparks entering heat insulation material could be difficult to easily extinguish and remain unnoticed by workers. Thus, proper means must be taken, such as covering heat insulation materials with anti-flaming sheets.

2. Fitting

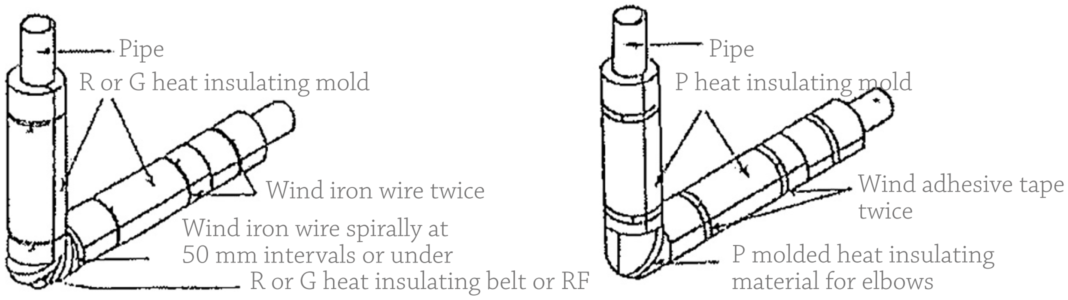
   Heat insulation materials are fitted for keeping a hot or cold temperature and preventing dewing. Such materials are usually fitted where rainwater could easily enter, and in pipe joints, support areas, fixing areas and elbow areas of couplings.

2.1 Fitting heat insulation materials
   - (a) Wrap the pipe closely to a heat insulating mold, the thickness of which is predefined pursuant to the corresponding pipe diameter, and install the mold tightly to another.
   - (b) Fit the horizontal pipe so that the joints of heat insulating molds do not stay on the top and bottom. Fit such joints slanting at approximately 45 degrees.
   - (c) Fit molded covers for bent areas and flanges, etc., if they are available.
   - (d) Do not excessively gouge heat insulating molds on coupling areas of the pipe and support fittings areas. However, note that inadequate gouging of heat insulating molds on such areas will leave joint seams partially open. Thus, appropriate processing is required.
   - (e) If duplicated heat insulating molds, corrugated heat insulating board and/or rock wool felts are necessarily used on bent areas and/or flange areas, fit them so that the seams of overlapped areas do not meet on the same line. For a heat insulating belt, wrap it on the pipe and fasten it spirally with iron wire at intervals of 50 mm or under. For rock wool felt or corrugated heat insulating board, wrap it on the pipe and fasten twice with iron wire at intervals of 500 mm or under at least at one point. However, do not fasten iron wire too tight, or it will bite into the heat insulating board. The negative tolerance on heat insulation thickness should be about 3 mm.
   - (f) When fitting a heat insulating mold of type A polystyrene foam, fix all the joint seams with adhesive tape. Wind the tape twice around the joints of both ends of the heat insulating mold. If the joint interval is 600 mm to 1,000 mm, wind adhesive tape twice around the middle of the heat insulating mold.

     Supplementary Figure 1 shows how to fix heat insulating materials on the pipe.

Codes in the Supplementary Figure refer the following:

R: rock wool; RF: rock wool felt; G: glass wool; P: Type A polystyrene foam



Supplementary Figure 1 Fixing heat insulating materials on the pipe[12]

Source: Guidelines for Mechanical Equipment Engineering Works Administration, 2010 edition

(g) Polyethylene film is used for moisture-proof and water-proof purposes. For the pipe, use flexible polyethylene film tape by lap-winding 1/2 or a larger area of the tape. It is better to use wide tape and minimize joints.

2.2 Winding tape for sheathing

(a) Wind the tape in the same direction. For a vertical pipe, wind the tape upward from the lower part of the pipe. Use a nail (18.2 mm length × 1.0 mm diameter) and adhesive tape, etc. to fix the starting and ending areas of the wound tape to avoid dislocation.

(b) Overlap a 15 mm or wider width of the winding tape, except for the outer area of a small diameter pipe elbow.

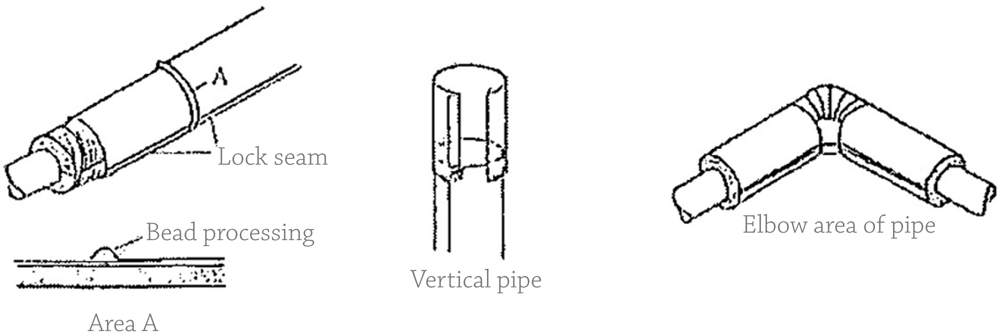
(c) For aluminum glass cloth tape, wind the tape by keeping the aluminum foil surface outside. Use nails (18 L), adhesive tape and/or bonding material, etc. to prevent dislocation.

(d) For colored aluminum glass cloth tape, wind the tape by keeping the colored aluminum foil surface outside. If the tape is likely to dislocate, use transparent adhesive tape or bonding material to prevent such dislocation.

2.3 Sheathing metal sheet

Apply lock seam jointing or button-hook jointing to the straight pipe in the long direction. For horizontal pipe, in principle, apply such jointing to an area lower than the center of the pipe. However, do not apply such jointing to the lowest area.

For the circumferential direction, overlap metal sheets by 25 to 50 mm in the long direction so that the bead processing area is kept outside. For rising pipe, make all of the overlapped parts in the downward direction so that no rainwater infiltrates. Bend elbow parts like a prawn, or use a molded cover (see Supplementary Figure 2).



Supplementary Figure 2 Sheathing metal plates on the pipe[12]

Source: Guidelines for Mechanical Equipment Engineering Works Administration, 2010 edition

2.3 Heat Insulation of Valves

For valves whose nominal diameters are 50 or under, arrange their heat insulation according to the corresponding pipes. Follow the instructions below for valves with nominal diameters of 65 or above.

(a) If a valve has a molded cover, use it.

(b) If a valve has no molded cover, fill the inside with a heat insulation belt or rock wool felt, etc., and process and fix a heat insulation board or corrugated heat insulation board. Or process and fix a heat insulating mold corresponding to the flange diameter and wind the mold with iron wire.

(c) For flanges used for connecting pipes, fix them pursuant to the heat insulation measure for the pipe, unless specified otherwise. In this case, metal detach cover is not needed.

2.4 Fitting Areas by Fitting Type

(a) Refer to Supplementary Table 1 for types of fitting pipe, coupling, and valve and fitting areas.

(b) Materials used for fitting areas and fitting order

- The diagram of fixing examples in Supplementary Table 2 is for cooling pipes and hot and cool water pipes.
- The codes of pipes in Supplementary Table 2 are as follows:
  HP: hot water pipe; SP: steam pipe; CHP: cool water and chilled and hot water pipes; LCP: low-temperature cool water pipe (cool water temperatures: 2° to 4°C); BP: brine pipe; RP: refrigerant pipe; WP: water supply pipe; DDP: discharge pipe and drain pipe; HSP: hot-water supply pipe
- The codes of heat insulation materials in Supplementary Table 2 are as follows:
  R: rock wool; G: glass wool; P: type A polystyrene foam

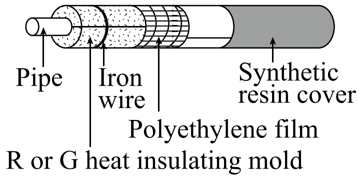
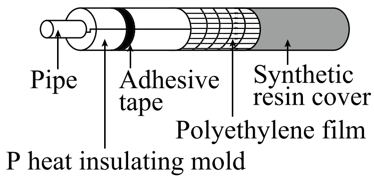
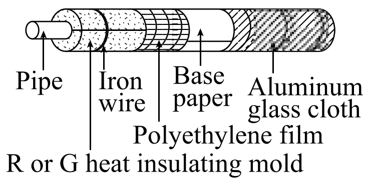
Supplementary Table 1 Types of fitting pipe, coupling, and valve and fitting areas[12]

Fitting type	Fitting area	HP (including expansion pipe)		SP (flow pipe)		CHP (including expansion pipe)		RP		WP		DDP*		HSP (including expansion pipe)		Reference
		Pipe	Valve and flange	Pipe	Valve and flange	Pipe	Valve and flange	Pipe	Valve and flange	Pipe	Valve and flange	Pipe	Valve and flange	Pipe	Valve and flange	
A a	Indoor exposure (ordinary room, corridor)	○	—	○	—	○	○	○	○	○	○	○	○	○	○	Restroom, hot-water service room, staircase, elevator, hall, lobby, etc.
B b	Machine room, warehouse, library	○	—	○	—	○	○	○	○	○	○	○	○	○	○	Water tank room, switch room, indoor parking area, etc.
C_1 C_2 c_2	In ceiling, in pipe and shaft, and in lacunar wall	○	—	○	—	○	○	○	○	○	○	○	○	○	○	Inside double slab of the ceiling of kitchen and lower floor
D_2 d_2	Under floor, under drain (including pit)	○	—	○	—	○	○	○	○	○	○	×	×	○	○	Inside the double-slab under the floor of lowest story, etc.
	In cool water, in hot and cool water	○	○	○	○	×	×	○	○	○	○	×	×	○	○	
	Laying underground	○	○	○	○	○	○	○	○	×	×	×	×	○	○	
E_3 e_3	Outdoor exposure (including balcony and open corridor)	○	○	○	○	○	○	○	○	○	○	×	×	○	○	Dry areas, etc.
	Humid areas such as bathroom and kitchen (not including inside the ceiling of the kitchen)	○	—	○	—	○	○	○	○	○	○	○	○	○	○	Bathroom, swimming pool, inside the ceiling, etc.
Special note	Common ditch	—	—	—	—	—	—	—	—	—	—	—	—	—	—	

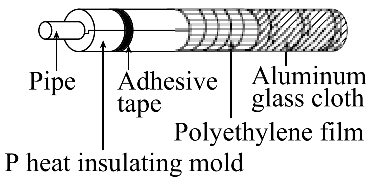
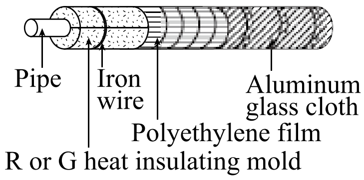
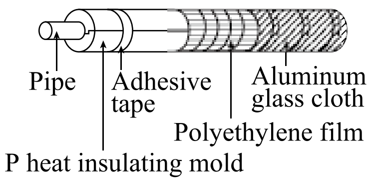
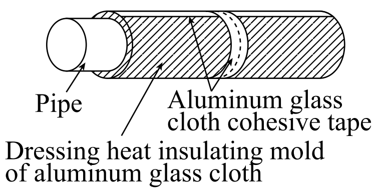
(1) ○: Fitting; ×: No need to fit; —: Special note.
(2) Types of fitting pipes in the common ditches are specified in a special note.
(3) For codes for fitting types, see Table 2.3.3, Types of Heat Insulation Works for Pipes and Apparatuses, and Table 2.3.6, Types of Heat Insulation Works for Pipes and Apparatuses, Part 2, Common Works, The Public Construction Works Standard Specifications (*Mechanical Equipment Works, 2010 edition*).
* Including vent pipe of 100 mm or closer from a branching spot

Source: Guidelines for Mechanical Equipment Engineering Works Administration, 2010 edition

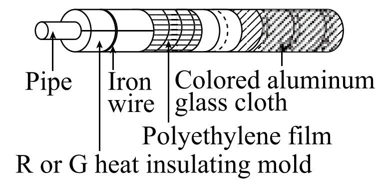
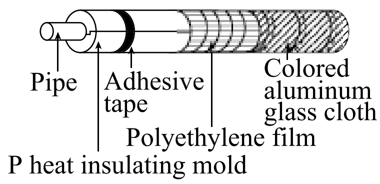
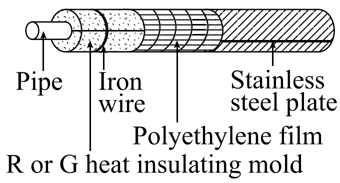
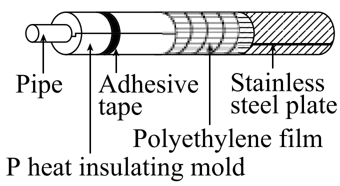
Supplementary Table 2 Materials used for fixing areas and fixing order[12]

Reference usage category by fitting type	Material and fixing order	Fixing example	Remarks
A and a Indoor exposure (ordinary room, corridor)	1. R or G heat insulating mold 2. Iron wire (Tightly winding iron wire twice on two areas or more of a heat insulating mold) 3. Polyethylene film (1/2 lap-winding) 4. Synthetic resin cover (overlapping width: 25 mm or more. Use resin cover pins to hold seam joints at intervals of 150 mm or under.) (Fixing a synthetic resin elbow on an elbow area of the pipe)		a. In case of HP, SP, WP, DDP and/or HSP, item 3 at left is omitted. b. When using a heat insulation dressing case on an RP, item 4 at left is not needed.
	1. P heat insulating mold 2. Adhesive tape (Use adhesive tape to hold all the seam joints. Wind the tape twice around the joints of both ends of the heat insulating mold. If the interval of joints is 600 mm or longer, wind adhesive tape twice around the middle of the heat insulating mold.) 3. Polyethylene film (1/2 lap-winding) 4. Synthetic resin cover (overlapping width: 25 mm or more. Use resin cover pins to hold seam joints at intervals of 150 mm or under.) (Fixing a synthetic resin elbow on an elbow area of the pipe)		a. When using an HP, SP, RP and/or HSP, P heat insulating mold cannot be used. b. When using a WP and/or DDP, item 3 at left is omitted. c. In case of BP
B and b Machine room, warehouse, library	1. R or G heat insulating mold 2. Iron wire (Tightly winding iron wire twice on two areas or more of a heat insulating mold) 3. Polyethylene film (1/2 lap-winding) 4. Base paper (overlapping width: 30 mm or wider) (In case of using an R or G heat insulating mold on an elbow area, fit an adjustment elbow.) 5. Aluminum glass cloth tape (overlapping width: 15 mm or wider)		a. For HP, SP, WP, DDP and/or HSP, item 3 at left is omitted. b. When using a heat insulation dressing case on a RP, items 4 and 5 at left are not needed.

(Continued)

Reference usage category by fitting type	Material and fixing order	Fixing example	Remarks
B and b Machine room, warehouse, library	1. P heat insulating mold 2. Adhesive tape (Use adhesive tape to hold all the seam joints. Wind the tape twice around the joints of both ends of the heat insulating mold. If the interval of joints is 600 mm or longer, wind adhesive tape twice around the middle of the heat insulating mold.) 3. Polyethylene film (1/2 lap-winding) 4. Aluminum glass cloth tape (overlapping width: 15 mm or wider)		a. When using an HP, SP, RP and/or HSP, P heat insulating mold cannot be used. b. When using a WP and/or DDP, item 3 at left is omitted. c. For LCP and/or BP
C_1 In ceiling, in pipe and shaft, and in lacunar wall	1. R or G heat insulating mold 2. Iron wire (Tightly winding iron wire twice on two areas or more of a heat insulating mold) 3. Polyethylene film (1/2 lap-winding) 4. Aluminum glass cloth tape (overlapping width: 15 mm or wider)		a. In case of CHP and/or RP
	1. P heat insulating mold 2. Adhesive tape (Use adhesive tape to hold all the seam joints. Wind the tape twice around the joints of both ends of the heat insulating mold. If the interval of joints is 600 mm or longer, wind adhesive tape twice around the middle of the heat insulating mold.) 3. Polyethylene film (1/2 lap-winding) 4. Aluminum glass cloth tape (overlapping width: 15 mm or wider)		a. For cool water pipe b. For BP
C_2 and c_2 In ceiling, in pipe and shaft, and in lacunar wall	1. Dressing heat insulating mold of aluminum glass cloth of R or G and P 2. Aluminum glass cloth cohesive tape (overlapping width: 15 mm or wider)		a. When using a WP, DDP, HP, and/or SP. However, when using an HP and/or SP, no P aluminum glass cloth dressing heat insulating mold can be used.

(Continued)

Reference usage category by fitting type	Material and fixing order	Fixing example	Remarks
D and d Under floor, under drain (including pit)	1. R or G heat insulating mold 2. Iron wire (Tightly winding iron wire twice on two areas or more of a heat insulating mold) 3. Polyethylene film (1/2 lap-winding) 4. Colored aluminum glass cloth (overlapping width: 15 mm or wider)		a. When using a WP, R and G heat insulating mold cannot be used. b. In case of using a DDP, item 3 at left is omitted.
	1. P heat insulating mold 2. Adhesive tape (Use adhesive tape to hold all the seam joints. Wind the tape twice around the joints of both ends of the heat insulating mold. If the interval of joints is 600 mm or longer, wind adhesive tape twice around the middle of the heat insulating mold.) 3. Polyethylene film (1/2 lap-winding) 4. Colored aluminum glass cloth (overlapping width: 15 mm or wider)		a. When using a WP, DDP, HP, and/or SP. However, for an HP and/or SP, no P aluminum glass cloth dressing heat insulating mold can be used. b. When using a DDP, no fixing is needed. c. Used mainly for a WP. d. For a BP.
E_2 and e_2 Outdoor exposure (including balcony and open corridor) and humid areas such as bathroom and kitchen (not including inside the ceiling of the kitchen)	1. R or G heat insulating mold 2. Iron wire (Tightly winding iron wire twice on two areas or more of a heat insulating mold) 3. Polyethylene film (1/2 lap-winding) 4. Stainless steel plate (SUS 304, thickness: 0.2 mm or above, No. 2B or No. 2D)		a. When using a WP and/or DDP, R and G heat insulating mold cannot be used. b. When using a heat insulation dressing case on a RP, items 4 and 5 at left are not needed.
	1. P heat insulating mold 2. Adhesive tape (Use adhesive tape to hold all the seam joints. Wind the tape twice around the joints of both ends of the heat insulating mold. If the interval of joints is 600 mm or longer, wind adhesive tape twice around the middle of the heat insulating mold.) 3. Polyethylene film (1/2 lap-winding) 4. Stainless steel plate (SUS 304, thickness: 0.2 mm or above, No. 2B or No. 2D)		a. In case of using an HP, SP, RP and/or HSP, P heat insulating mold cannot be used. b. For a DDP, no fitting is needed when DDP is exposed outdoors. c. Used mainly for a WP. d. For a BP.

Source: Guidelines for Mechanical Equipment Engineering Works Administration, 2010 edition

3.16 Coating and Identification

(1) Coating

Coating involves applying paint or another coating to the pipe surface. Coating protects the pipe by forming a layer of dried film and improves the appearance by giving it color. When the stainless steel piping is in a harsh environment, the pipes should be coated with a synthetic resin paint. For example, stainless steel pipes installed over the surface of the water in a break tank are sometimes corroded by Cl^- generated in the water unless they are coated. Factors to be considered in selecting a paint or coating are its relationship to the environment, performance as a paint, ease to work with, drying performance, adherence, the hardness of the coating left on the pipe, wear resistance, color, luster and finish. A painter who specializes in painting stainless steel pipes should be consulted.

(2) Identification and color coding

During construction work, identifying and color-coding the pipes with letters, tags or paint according to the places and purposes of their use will help to avoid confusion and errors. Proper identification helps in getting prefabricated members delivered to the right places. At the completion of the project, identification and color coding should be provided according to application and system, and the water flow direction marked with arrows.

3.17 Testing and Inspection

3.17.1 Testing

Tests for piping include running water pressure, water filling and water flow tests, which are conducted when part or all of the piping has been completed. Piping to be covered for preventing condensation or heat insulation, and piping to be concealed or buried, must be tested before such work is performed.

(1) Water pressure testing

Because water pressure testing cannot be conducted simultaneously for the entire piping system while it is being built, it is carried out in sections step by step on site. When a section of the piping is tested, it should be completely closed off by valves or test plugs, checked and then filled slowly with potable water with a test pump or the like. The testing pressure should be raised after all the air in the pipe has been purged. As standard values for the piping test, Tables 3.17-1 and 3.17-2 list the test conditions of the *Guidelines for Mechanical Equipment Engineering Works Administration*.

Table 3.17-1 Testing pressures and conditions for water supply and hot-water supply piping[12]

Target object, etc.		Testing method	Testing pressure (MPa)	Minimum holding time (minutes)	Remarks
(a) Water supply pipe	① Water feeding equipment	Water pressure test	1.75	60	If the water utility has regulations, comply with them.
	② Lifting pipe	Water pressure test	Total head of pump × 2 (minimum 0.75)	60	
	③ Below water tank on a high place	Water pressure test	Hydrostatic head × 2 (minimum 0.75)	60	
(b) Hot-water supply pipe		Pursuant to item (a)	Pursuant to item (a)	Pursuant to item (a)	

Source: Guidelines for Mechanical Equipment Engineering Works Administration, 2010 edition

Table 3.17-2 Testing methods and testing conditions for fire fighting pipe[12]

Target object, etc.		Testing method	Testing pressure (MPa)	Minimum holding time (minutes)	Remarks
(a) Water piping	① Piping connecting to pump	Water pressure test	Pump shutoff pressure × 1.5	60	
	② Piping connecting to siamese connection	Water pressure test	Larger of design water feed pressure × 1.5 and 1.75	60	
	③ Piping used concurrently for ① and ② above	Water pressure test	Larger of pressures in ① and ②	60	
(b) Inert gas fire fighting pipe and chemical powder fire fighting pipe	① Inert gas fire fighting pipe	Tightness leak test by air or nitrogen gas	(1)	10	
	② Chemical powder fire fighting pipe	Tightness leak test by air or nitrogen gas	(2)	10	

(1) (i) The piping from the storage container to the select valve shall be 10.8 MPa.

(ii) The piping from the select valve to the nozzle head shall have the value of the maximum operating pressure (value obtained when initial pressure drop is calculated, hereinafter applied with the same meaning.)

(iii) In case of fixing no select valve, the piping from the container to the nozzle head shall have the maximum operating pressure.

(2) Pressure in (1) shall be read as the setting pressure of pressure regulator. Maximum operating pressure in (ii) and (iii) shall be the same.

Source: Guidelines for Mechanical Equipment Engineering Works Administration, 2010 edition

(2) Water flow testing

Conducting water flow testing in a piecemeal fashion is difficult and should be carried out section by section, corresponding with the steps of the process of building a piping system. Sections to be hidden above ceilings and behind shafts must be tested as early as possible. Any leaks will seriously hamper all the related construction work. When the piping is completed, water should be run through the entire system, and the flow should be checked with the volume of water corresponding to the use condition of each piece of equipment.

(3) Measurement of residual chlorine

Upon completion of the piping project, the entire piping system is filled with water and tested and all the equipment test-run. After testing the entire system, the residual chlorine in the drinking water system, including the water supply and hot-water equipment, should be measured. Water samples should be taken from the stored water in the tank of the drinking water system and from end-of-pipe faucets and checked for the presence of sludge and inspected for sterilization by chlorine. At least 0.2 ppm of residual chlorine should be detected. (However, the standard residual chlorine concentration shall be 0.1 ppm or above in normal times.) Although the upper limit is set to 1.0 ppm or under, setting the limit to 0.4 ppm or under is desirable in terms of corrosion resistance. (Refer to Chapter 2.9.1 of Design.) The measurement should be taken immediately after collecting the water samples, because residual chlorine readily decomposes.

(4) Treatment after testing

Promptly after testing, the test water is drained. Care should be taken that no soiling or impurities remain inside the piping, which should be left full of water.

Leaving such impurities adhering inside the pipe could cause corrosion or local corrosion in a short period of time.

3.17.2 Inspection

If stainless steel pipes are used for a part that is directly connected to the municipal water works, they must be inspected as prescribed by the relevant water utility. If used for other parts, a water pressure test according to the written specifications or the standard values of SHASE-S 010 should be carried out and the completeness of the piping joint locations inspected. An inspection should be conducted as to whether the pipe materials, pipe diameters, and piping methods are as specified in the design drawings. During the stages of on-site work simultaneously inspecting the entire piping is difficult. If the piping is to be buried, concealed, heat-insulated, or covered, it must be partially inspected as each stage of the construction is finished. Upon completion of the piping, a completion inspection should be conducted, including water filling testing and function testing. For stainless steel pipes in particular, an adequate visual inspection must be made for damage to the pipes, contact with other metals, etc.

Standards for drinking water leaching from the supply equipment are subject to the *Ministerial Ordinance concerning the Structure of Water Supply Equipment and Standards for Materials* (Ministerial Ordinance No. 14 of Ministry of Health, Labour and Welfare, March 19, 1997, the last revision of which is Ministerial Ordinance No. 18 of Ministry of Health, Labour and Welfare made on February 17, 2010).

The basic concept in deciding specific items to analyze the leaching performance from the apparatuses, components and/or materials subject to the above ministerial ordinance is indicated in the Notification of Water Supply Division Director, Health Service Bureau, Ministry of Health, Labour and Welfare, titled *Ministerial Ordinance on Partial Revision of the Ministerial Ordinance concerning the Structure and Material for Water Supply Equipment and on Partial Revision of the Test of the Structure and Materials for Water Supply Equipment* (February 9, 2004, Notification No. 0209003; Partial Revision, February 17, 2010, Notification 0217000). The methods for testing such leaching performances are stipulated in JIS S 3200-7(2004): *Equipment for water supply service—Test methods of Leaching Performances*. Pursuant to these criteria, the user must decide the items and criteria on which the leaching performances of piping materials used for water supply equipment are analyzed. Table 3.17-3 lists examples of such leaching performances of stainless steel pipes that feed drinking water.

Table 3.17-3 Leaching performances of stainless steel pipe[13]
(For water supply equipment)

Analysis item	Decision standard
Taste	Must not be abnormal
Odor	Must not be abnormal
Color	Must not exceed 5
Turbidity	Must not exceed 2
Hexavalent chromium (CrVI) compounds	The quantity of CrVI must not exceed 0.05 mg/L.
Iron and its compounds	The quantity of iron must not exceed 0.3 mg/L.

* The nominal diameter of water supply equipment ranges from 13 to 50.

Source: Japan Water Works Association Code JWWA G 115 (Stainless steel tubes for water supply)

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7. Japan Water Works Association. JWWA G 116: *Stainless steel tube fittings for water supply*
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Public Buildings Association, Ltd. (2010). *The Public Construction Works Standard Specification (Mechanical Equipment Works), 2010 edition*. Editorial supervision by Ministry of Land, Infrastructure, Transport and Tourism.

Kyosuke Sakaue at Meiji University, Japan Stainless Steel Association, Japan Valve Manufacturers' Association and Nickel Institute (2009). *Fiscal 2009 Report on the "Technological Development of Super Durable All-Stainless Steel Piping System"*. House and Construction Advanced Technology Development Subsidy Project initiated by Ministry of Land, Infrastructure, Transport and Tourism.

MAINTENANCE MANAGEMENT 4

4 MAINTENANCE MANAGEMENT

4.1 Objectives

Since components, such as pipe couplings and valves, have service lives shorter than those of stainless steel pipes, they need to be replaced upon the expiration of their service lives. The piping system needs proper maintenance management over an ultra-long period. This requires establishing methods of maintenance management that will reduce extra work for the detachment and replacement of existing components as well as guidelines for maintenance management that will reduce the suspension of service time. If these methods and guidelines are established in advance, they can be utilized as precautions for system design, in addition to the operation of the piping system, contributing to proper comprehensive maintenance management of the piping system.

4.2 Maintenance Management Plan of Stainless Steel Piping System

For long-time use of a piping system, conducting proper maintenance management of the system components is essential.

The piping system, centering on pipes, couplings and valves, consists of a variety of components including support fittings, heat insulation materials and coating. When the piping system of a building is put into operation, these components are subject to deterioration, including corrosion, staining and clogging, that will lead to functional decline. The extent of the decline differs, depending on the component materials and installation environments. If such functional decline is not remedied without delay, significant problems will develop, including functional discontinuance and water loss from water leakage. To prevent such problems, the owner of the piping system is required to periodically inspect and clean, replace supplies and perform maintenance and preservation services that will maintain a proper functioning level. Figure 4.2-1 shows items of such maintenance and preservation services.

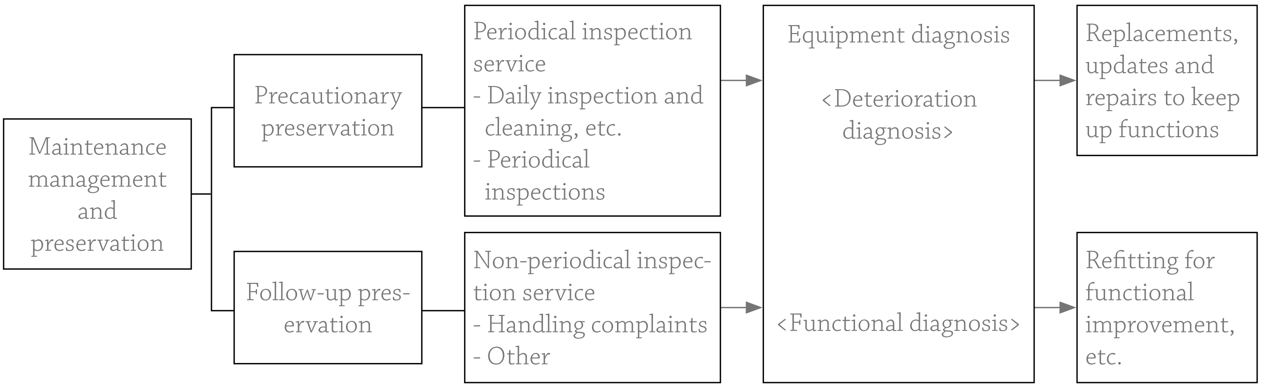

Figure 4.2-1 Items of Maintenance Preservation Service[1]

Source: Practical Knowledge of Maintenance and Control, Water Supply and Drainage by the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan

Even if such replacements and repairs are repeated, however, aging deterioration will continue. Eventually, the piping system will physically deteriorate to the extent that it can no longer satisfy the performance planned at the beginning.

The owner of the piping system will also face the limits of a social service life that an older system cannot satisfy due to changes in the social environment, consumer needs and obsolete equipment. The owner needs to consider such physical deterioration and the limits of the social service life. With an all stainless steel piping system, however, little physical deterioration is anticipated.

4.3 Inspection

4.3.1 Factors of physical deterioration

Factors of physical deterioration of all stainless steel piping systems include the following:

- Corrosion
- Wear and damage
- Adhesion of stains and scales, and clogging
- Physical deterioration of mechanical strength
- Exfoliation of painting

At inspection, the deterioration must be adequately understood.

4.3.2 Inspection and maintenance management

Piping equipment deteriorates and wears out, although the extent varies depending on how it is run and the environment it is used in. With stainless steel pipe, the owner can expect durability almost the same as that of the structural frame of the building if proper inspection and maintenance management as well as water treatment, etc. are applied to deter such deterioration and wear. The service life of a piping system will vary significantly though, depending on the maintenance management.

(1) Practical maintenance

There are diverse targets for maintenance management. For efficient maintenance management, a proper plan must be prepared and implemented.

Inspection includes daily inspections and periodical inspections that are conducted at more than one-month intervals. There are also inspections required by law.

(a) Prevention of pitting corrosion

① In cooling water piping systems, the strainers (40 – 80 mesh recommended) must be cleaned periodically to prevent dirt, iron shavings, slime and the like from adhering to the piping and causing pitting corrosion. For stainless steel piping, precipitation of calcium carbonate or silica does not easily occur in turbo refrigerating machines or cooling towers because of the smoothness of its surface.

② In sealed chilled and hot water piping, the leakage from the pump gland packing should be minimized and water replacement kept to a minimum. This will prevent any mixture of dissolved oxygen in supplying water into the piping system to the extent possible.

③ In chilled and hot water piping and hot water supply piping, air chambers should always be installed in parts where air might build up, and the air periodically let out.

④ Portions that were built with right-angled arch or inverted right-angled arch piping out of necessity should be periodically inspected to remove slime and depositions. If water stagnates in them, slime and deposits will cause pitting corrosion.

(b) Prevention of corrosion of the outside surface of piping covered by heat-insulator

① In the outdoor part of hot water piping systems, when heat insulation is insufficient, rainwater will soak into the heat insulator and dissolve corrosive components, such as chloride ions, from the heat insulation material. The lagging seal treatment must therefore be thorough to prevent such corrosions on the pipe surface.

② In cold water and chilled and hot water piping, vapor condensation occurs on the outside pipe surface when the heat insulation is insufficient. When this vapor condensation is extreme, the corrosive components in the heat insulation material will dissolve, creating a corrosive environment. The heat insulation material must therefore be checked for wetness. Attention must be paid in particular to sections where it is difficult to fix the heating insulator, such as automatic control valves, other valves and supports.

(c) Prevention of the corrosion of exposed piping

In outdoor exposed piping such as in cooling water piping near the seashore or in industrial regions, airborne salt particles from the ocean, chloride ions, sulfur dioxide and iron dust can cause rust on the pipe surface and decrease the gloss of stainless steel. This atmospheric corrosion, although it presents no problems for the function of the piping, often diminishes its aesthetic appearance. Periodic cleaning of the surface of the exposed piping is effective.

(d) Prevention of galvanic corrosion of other metals

The coefficient of linear expansion of stainless steel pipe is about 1.5 times that of carbon steel pipe. Thus rubber insulation on pipe supports or hanging fixtures shifts from thermal expansion/contraction due to changes in fluid temperature, so that support and suspension fixtures (made of steel) may directly contact the stainless steel pipe. When vapor condensation or other water is generated, galvanic corrosion of the steel due to contact with stainless steel may occur. The support and suspension fixtures must therefore be inspected periodically for metallic contact.

(2) Inspection/maintenance items

Inspection and maintenance both prevent mishaps and problems and extend the useful life of the piping equipment. Hence appearance inspection, visual inspection, inspection for vibration and noise and thorough maintenance such as periodic cleaning and air purging are required.

(a) Air conditioning piping systems

The inspection and maintenance items are determined to prevent corrosion of the piping sufficiently to ensure proper operation of the air conditioning system, prevent corrosion and scaling in the coils of refrigerators and similar equipment, and maintain suitable temperature and humidity. This involves daily checks of temperature and pressure and periodical air relief as well as strainer cleaning. The items are shown in Table 4.3-1 as reference examples.

(b) Water supply and hot-water supply piping systems

The inspection and maintenance items for water supply and hot-water supply piping systems are determined to prevent corrosion of the piping and devices and maintain a suitable water supply rate and water temperature in the same way as in air conditioning piping systems. The items are shown in Table 4.3-2 as reference examples.

Table 4.3-1 Items to inspect and maintain in air conditioning piping systems (reference example)[2]

Interval	Piping system / Inspection/maintenance item	Cooling water	Chilled/ hot water	Steam/re- turn water	Drain	Oil	Remarks
Daily or weekly	Air relief	○	○				
	Leakage from piping or valves	○	○	○	○	○	
	Abnormal noise or vibration	○	○	○		○	
	Related equipment temperature	○	○	○			
	Related equipment pressure	○	○	○			
	Leakage from pump gland packings	○	○				
	Valve operation			○			
	Expansion tank water level		○				
	Ball tap performance check	○	○				
	Strainer (oil) inspection/cleaning					○	
	Float switch (oil) performance check					○	
	Vapor pressure check			○			
	Vapor trap inspection			○			
	Reducing valve/safety valve inspection			○			
	Leakage from expansion joints		○	○			
	Drainage inspection				○		
	Steam hammer check			○			
Monthly or every two or three months	Strainer inspection/cleaning	○	○				
	Moisture condensation inspection		○		○		
	Blow inspection			○			
	Chemical injection inspection	○	○	○			
	Water quality inspection	○	○	○			
	Dirt pocket discharge			○			
	Water sealing trap inspection				○		
Quarterly or yearly	Hanging fixture and support fixture inspection	○	○	○	○	○	
	Heat insulator inspection		○	○			
	Heating/cooling switchover	○	○	○		○	
	Measures to prevent freezing	○	○	○	○	○	
	Touch-up with a rust-proof paint	○	○	○		○	
	Valve inspection	○	○	○		○	

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

Table 4.3-2 Items to inspect and maintain water supply and hot-water supply piping systems (reference example)[2]

Interval	Inspection/maintenance item \ Piping system	Water supply	Hot-water supply	Remarks
Daily or weekly	Leakage from piping or valves	○	○	
	Leakage from pump gland packings	○	○	
	Flow rate measurement	○	○	
	Pressure/temperature measurement		○	
	Air relief	○	○	
	Abnormal noise or vibration	○	○	
	Ball tap performance check	○		
	Relief valve/safety valve inspection		○	
	Leakage from expansion joints		○	
	Valve operation		○	
	Chemical injection inspection		○	
Monthly or every two or three months	Strainer inspection/cleaning	○	○	
	Moisture condensation inspection	○		
	Water quality inspection	○		
Quarterly or yearly	Hanging fixture and support fixture inspection	○	○	
	Heat insulator inspection	○	○	
	Cross connection check	○	○	
	Measures to prevent freezing	○		
	Heating/cooling switchover		○	
	Hot water tank inspection		○	
	Valve inspection	○	○	
	Touch-up with a rust-proof paint	○	○	

Source: Piping Manual for Stainless Steel Pipes for Buildings, 1997 edition

4.3.3 Water quality control

Water quality control needs to be performed to protect building users from health hazards, prevent equipment efficiency from deteriorating and prevent piping from corroding.

This section describes the key points in water quality control for preventing corrosion when stainless steel piping is used for building equipment.

When stainless steel pipes are used for water supply piping, problems such as red water associated with carbon steel piping and bluish water with copper piping do not appear. Basically, stainless steel piping for water supply needs no water treatment.

Stainless steel pipes have outstanding corrosion resistance. The management of stainless steel pipes is easier than that of carbon steel pipes. However, stainless steel pipes are vulnerable to stress corrosion cracking caused by chloride ions, crevice corrosion and pitting corrosion, all of which are characteristic to stainless steel. Stainless steel piping needs maintenance. In addition, when stainless steel pipes are used for the piping system of a building that contains some non-stainless steel materials, such a piping system requires more rigid water quality control than a single stainless steel piping system.

Corrosion resistance of stainless steel pipes is determined by ①temperature, ②pH, ③residual chlorine, ④chloride ions, ⑤M alkalinity and ⑥sulfate ions. For proper water quality control, these elements of water quality must be controlled by each piping system pursuant to the reference values.

(1) Quality control of drinking water

Tap water supplied by water utility operators is commonly used for drinking water in buildings. Tap water shall conform to the water quality standards of the *Water Works Law*. The details are stipulated in the ministerial ordinance regarding the water quality standard (Ordinance No. 101 of Ministry of Health, Labour and Welfare, May 30, 2003).

The water quality standard stipulated in the *Water Works Law* covers 50 items. Paragraph 3, Article 17 of *the Enforcement Regulations of the Water Works Law* stipulates the residual chlorine concentration of water supplied from faucets. The residual chlorine content shall be 0.1 ppm or higher (0.4 ppm or higher for combined residual chlorine). Thus, the owner of a drinking water piping system is required to check the residual chlorine concentration monthly and inject chlorine if the concentration is inadequate.

However, injection of more chlorine than needed must be avoided. Residual chlorine strongly impacts the corrosion of the stainless steel pipe and residual chlorine concentration of 0.4 mg/l or under is a water quality requirement for delicious water that has been promoted by water utilities in Japan.

The owner of a drinking water piping system is also required to inspect the water quality periodically in accordance with the *Act on Maintenance of Sanitation in Buildings* (hereinafter referred to as the *Building Sanitation Act*).

Deterioration in water quality is closely related with maintenance management of water tanks. Water receiving tanks and high-positioned water tanks, which are water storage tanks (drinking water tanks), shall be cleaned at least annually.

To disinfect the inside of a tank, strong chlorine water (50 to 100 ppm residual chlorine concentration) must be jetted inside the tank. After cleaning, such chlorine water must be washed away without fail.

(2) Quality control of water for miscellaneous use

Following a revision of the *Building Sanitation Act* in April 2002, water supplied for purposes other than living, which is called water for miscellaneous use, has become subject to the new standard.

Keeping residual chlorine in water is to disinfect bacteria, control slime and prevent algae from developing (control standard value: 0.1 ppm for residual chlorine content, and 0.4 ppm for combined residual chlorine.)

Locations to install disinfection equipment are usually just before the tank receiving miscellaneous-use water that has passed the final treatment. However, if water for miscellaneous use remains in the tank for a long time, residual chlorine may disappear. If quantities of water to be consumed vary greatly, disinfection equipment must be installed at some location after the lifting pump. This water quality standard and the frequency of inspections are listed in Table 4.3-3.

Table 4.3-3 Quality standards for water for miscellaneous use by purpose of use and frequency of inspections (when water to supply is reuse water from drainage, rainwater and well water)[3]

Water quality item	Standard value	Purpose of use		Frequency of inspections
		Watering, landscaping and cleaning water	Flushing water for restroom	
Free residual chlorine	0.1 ppm or above	Applicable	Applicable	At least weekly
pH value	5.8 – 8.6	Applicable	Applicable	At least weekly
Odor	Not abnormal	Applicable	Applicable	At least weekly
Appearance	Almost colorless and transparent	Applicable	Applicable	At least weekly
Coliform	Not detected	Applicable	Applicable	At least every two months
Turbidity	Not to exceed 2	Applicable	Not applicable	At least every two months

Source: Practical Knowledge of Maintenance and Control, Water Supply and Drainage, the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan

(3) Quality control of cooling tower

Because cooling water is generally circulated via an open cooling tower, the dissolved components in the water become concentrated due to aqueous evaporation in the tower. The condensation causes the water to generate an increased amount of scales in the tower.

As the temperature of cooling water rises in summer, the risk of Legionella bacteria development becomes higher. Hence, anti-Legionella agent, etc. must be added to cooling water to deter the propagation of such bacteria. Since checkups of stains alone cannot detect Legionella bacteria, periodical inspections must be carried out.

To prevent slime and scales that would lead to functional deterioration of the cooling tower, adding water treatment agent to circulating water and controlling the water quality by means such as blow-down is essential.

Table 4.3-4 lists quality standards for cooling water and make-up water defined in JRA-GL-02-1994: *Standards of the Japan Refrigeration and Air Conditioning Industry Association* (JRAIA).

(4) Quality control of water for the boiler

As the boiler attains higher performance and higher-intensity load conditions, techniques to control water quality for the boiler and water supply in daily maintenance have been upgraded, to improve the efficiency and safety of the boiler and to extend its service life. Such water quality control shall conform to the JIS B 8223 standard.

The owner of such boilers is required to check whether each water quality item indicates a value within the relevant standard. If any of the check items indicates a value outside the standard, an urgent countermeasure must be taken. Otherwise, the abnormal value may lead to problems. The owner is required to apply water softening treatment, which prevents scales from adhering to the heating surface, use a chemical feeding pump for periodical injections of boiler compound, and blow off of boiler water to prevent impurities from getting concentrated.

Table 4.3-4 Water quality standards for cooling water, cold water, hot water and make-up water(5), 4

	Items(1) (6)	Cooling water system(4)			Cold water system		Hot water system(3)				Tendencies(2)	
		Circulation type		Single pass type			Low-level medium/high-temperature water system		High-level medium/high-temperature water system			
		Circulating water	Make-up water	Single pass water	Circulating water [Lower than, or equal to, 20°C]	Make-up water	Circulating water [Higher than 20°C and lower than, or equal to, 60°C]	Make-up water	Circulating water [Higher than 60°C and lower than, or equal to, 90°C]	Make-up water	Corrosion	Scale generation
Basic items	pH (at 25°C)	6.5 - 8.2	6.0 - 8.0	6.8 - 8.0	6.8 - 8.0	6.8 - 8.0	7.0 - 8.0	7.0 - 8.0	7.0 - 8.0	7.0 - 8.0	○	○
	Electrical conductivity (mS/m) (at 25°C) {μS/cm} (at 25°C)(1)	80 or less {800 or less}	30 or less {300 or less}	40 or less {400 or less}	40 or less {400 or less}	30 or less {300 or less}	30 or less {300 or less}	30 or less {300 or less}	30 or less {300 or less}	30 or less {300 or less}	○	○
	Chloride ions (mgCl/L)	200 or less	50 or less	50 or less	50 or less	50 or less	50 or less	50 or less	30 or less	30 or less	○	
	Sulfate ions ($mgSO_4^{2-}/L$)	200 or less	50 or less	50 or less	50 or less	50 or less	50 or less	50 or less	30 or less	30 or less	○	
	Acid consumption (pH4.8) ($mgCaCO_3/L$)	100 or less	50 or less	50 or less	50 or less	50 or less	50 or less	50 or less	50 or less	50 or less		○
	Total hardness ($mgCaCO_3/L$)	200 or less	70 or less	70 or less	70 or less	70 or less	70 or less	70 or less	70 or less	70 or less		○
	Calcium hardness ($mgCaCO_3/L$)	150 or less	50 or less	50 or less	50 or less	50 or less	50 or less	50 or less	50 or less	50 or less		○
	Ionic silica ($mgSiO_2/L$)	50 or less	30 or less	30 or less	30 or less	30 or less	30 or less	30 or less	30 or less	30 or less		○
Reference items	Iron (mgFe/L)	1.0 or less	0.3 or less	1.0 or less	1.0 or less	0.3 or less	1.0 or less	0.3 or less	1.0 or less	0.3 or less	○	○
	Copper (mgCu/L)	0.3 or less	0.1 or less	1.0 or less	1.0 or less	0.1 or less	1.0 or less	0.1 or less	1.0 or less	0.1 or less	○	
	Sulfide ions (mgS^{2-}/L)	No detection	No detection	No detection	No detection	No detection	No detection	No detection	No detection	No detection	○	
	Ammonium ions ($mgNH_4^+/L$)	1.0 or less	0.1 or less	1.0 or less	1.0 or less	0.1 or less	0.3 or less	0.1 or less	0.1 or less	0.1 or less	○	
	Residual chlorine (mgCl/L)	0.3 or less	0.3 or less	0.3 or less	0.3 or less	0.3 or less	0.25 or less	0.3 or less	0.1 or less	0.3 or less	○	
	Free carbon dioxide ($mgCO_2/L$)	4.0 or less	4.0 or less	4.0 or less	4.0 or less	4.0 or less	0.4 or less	4.0 or less	4.0 or less	4.0 or less	○	
	Stability index	6.0-7.0	-	-	-	-	-	-	-	-	○	○

(1) The names of the items and their terminology are as defined in JIS K 0101. The parenthesized numerical values are those expressed in the previously-used unit. They are written along with the official data for reference purposes.
(2) The circles in the tendency column indicate that the corresponding items are factors associated with corrosion or scale generation.
(3) In general, corrosiveness is remarkably high under high temperature conditions (40°C or higher). In particular, when a steel material is not provided with any protective coat and is to come into direct contact with water, taking effective anticorrosive measures such as adding anticorrosive and deairing is desirable.
(4) In cooling water systems using a sealed cooling tower, the closed circuit circulating water and its make-up feed shall conform to the water quality standard for the hot water system, and the spray water and its make-up feed to the water quality standard for the circulation type cooling water system.
(5) The raw water supplied or replenished shall be tap water (clean water), industrial water or ground water. No use shall be made of demineralized water, intermediate water or softened water.
(6) The above 15 items are typical factors responsible for corrosion or scale generation.

Source: JRA-GL-02-1994, Japan Air Conditioning and Refrigeration Association Standards

4.3.4 Disinfection by chlorine

As mentioned earlier, since the revision of the *Building Sanitation Act* in April 2002, water quality control has been tightened. As a result, the water quality control stipulated in the *Water Works Law* has been applied to domestic water other than drinking water, and water for miscellaneous use, urging water suppliers to take measures to prevent health hazards.

The *Water Works Law of Japan* regulates that tap water be disinfected with chlorine or combined chlorine; that the residual chlorine content in water at the faucet be 0.1 ppm or higher (for combined chlorine, 0.4 ppm or higher); and that the residual chlorine content be 0.2 ppm or higher (for combined chlorine, 1.5 ppm or higher) if water is suspected to have disease-causing bacteria or during the spread of waterborne infectious disease. At specific occasions such as the completion of a piping system when a higher ppm is deemed necessary, keeping the residual chlorine content in water at 0.2 ppm or higher is recommended.

Chlorine as disinfectant is characterized as having outstanding performance. The effect of disinfection is strong and reliable; disinfection lasts for a long time (residual effect); chlorine can disinfect a large quantity of water; and residual chlorine content can be measured easily and therefore easily managed.

The rapid industrial development in Japan since around the 1960s caused increasing pollution in the natural environment, leading to increased contamination of surface water of rivers, lakes and marshes as well as underground water. Accordingly, injection quantities of chlorine have also increased, leading to the following problems.

- By-products, such as trihalomethanes, being produced.
- Certain materials react with chlorine. For example, phenol reacts with chlorine into chlorphenol, emitting a strong foul odor.
- Continuous supply is needed. Even when chlorine is used in the form of hypochlorous acid, long storage cannot be expected.
- Chlorine corrodes equipment, especially rusting pipe made of iron.

As mentioned above, although residual chlorine offers outstanding disinfection, it also promotes pipe corrosion, which cannot be ignored. In particular, the impact on stainless steel pipe must be considered.

Whether or not stainless steel pipes develop corrosion can be inferred based on the relation between repassivation potential for corrosion and self-potential in that environment, as indicated in Fig. 4.3-1.

When steel critical pitting /crevice corrosion potential is higher than the natural potential of the environment, no corrosion will develop. However, if critical pitting /crevice corrosion potential is lower than the natural potential, corrosion will develop.

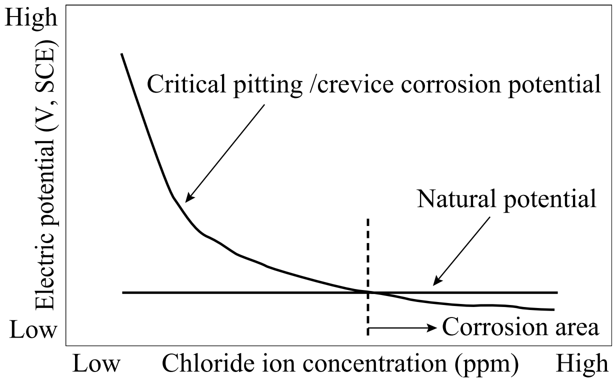

Fig. 4.3-1 Corrosion area based on the relation between critical pitting /crevice corrosion potential and natural potential
Prepared by: Toshiro Adachi

The natural potential of stainless steel pipes in a neutral environment will vary, depending on the physicochemical characteristics of the material surface, the residual chlorine, oxidizer such as dissolved oxygen and temperature in the environment. In particular, the impact of residual chlorine must be considered.

Critical pitting /crevice corrosion potential will vary, depending on the chemical composition and surface condition of the material, and on the presence of halogen ions, such as Cl^-, and liquid temperature, etc. in the environment. The higher the concentration of chloride ion (Cl^-) in the liquid, the more likely corrosion will occur. If the liquid has substantial residual chlorine (OCl^-) and oxidizer, such as dissolved oxygen, the natural potential will rise. Accordingly, even low chloride ion concentration will develop corrosion.

Disinfection by chlorine must be controlled so that the residual chlorine concentration will remain at 0.4 ppm or under.

4.3.5 Water quality inspection

(1) Water quality Inspection standard

Regarding the water quality standard defined in the Water Works Law, following the revision of Ordinance No. 101 of Ministry of Health, Labour and Welfare dated May 30, 2003, the quality inspection items for drinking water in accordance with Article 4 of the Enforcement Regulations of the Building Sanitation Act and the quality inspection items for water for miscellaneous use in accordance with Article 4-2 of the same regulations have also been revised.

As a result, the water supply piping system must be inspected for water quality pursuant to the following quality inspection items (Tables 4.3-5 and 4.3-6).

Table 4.3-5 Water quality standard (items regarding health)[5]

No.	Item	Standard value (mg/L)	No.	Item	Standard value (mg/L)
1	General bacteria	100 pieces/ml	16	Dichloromethane	0.02
2	Coliform	Not detected	17	Tetrachloroethylene	0.01
3	Cadmium and its compounds	0.003	18	Trichloroethylene	0.03
4	Hexavalent chromium compounds	0.05	19	Benzene	0.01
5	Mercury and its compounds	0.0005	20	Chloric acid	0.6
6	Selenium and its compounds	0.01	21	Bromic acid	0.01
7	Lead and its compounds	0.01	22	Chloroform	0.06
8	Arsenic and its compounds	0.01	23	Dibromochloromethane	0.1
9	Cyanide ions and cyanogen chloride	0.01	24	Bromodichloromethane	0.03
10	Nitrate nitrogen and nitrite nitrogen	10	25	Bromoform	0.09
11	Fluorine and its compounds	0.8	26	Total trihalomethane	0.1
12	Boron and its compounds	1.0	27	Chloroacetic acid	0.02
13	Carbon tetrachloride	0.002	28	Dichloroacetic acid	0.04
14	1,4-dioxane	0.05	29	Trichloroacetic acid	0.2
15	Cis-1,2-dichloroethylene and trans-1,2-dichloroethylene	0.04	30	Formaldehyde	0.08

Ordinance No. 101 of Ministry of Health, Labour and Welfare dated May 30, 2003, revised from April 2010

Table 4.3-6 Water quality standard (items regarding properties and condition)[5]

No.	Item	Standard value (mg/l)	No.	Item	Standard value (mg/l)
31	Zinc and its compounds	1.0	41	Non-ionic surfactant	0.02
32	Aluminum and its compounds	0.2	42	Phenols	0.005
33	Chloride ions	200	43	2-methylisoborneol	0.00001
34	Hardness (Ca, Mg)	300	44	Organic matters (TOC)	3
35	Iron and its compounds	0.3	45	Taste	Not abnormal
36	Copper and its compounds	1.0	46	Chromaticity	5
37	Sodium and its compounds	200	47	Odor	Not abnormal
38	Manganese and its compounds	0.05	48	Evaporation residues	500
39	Anionic surfactant	0.2	49	Turbidity	2
40	Geosmin	0.00001	50	pH	5.8 – 8.6

Ordinance No. 101 of the Ministry of Health, Labour and Welfare dated May 30, 2003, revised from April 2010

(2) Pollution of tap water

According to Article 4 of the *Water Works Law*, water supplied through water piping is defined as follows to ensure proper quality of drinking water.

(a) It shall contain neither living things nor matters that raise doubts that the water is polluted or likely to have been polluted with disease-causing organisms.

(b) It shall contain neither cyan nor mercury nor any other hazardous substance.

(c) It shall not contain copper, iron, phenol or other matter that exceeds the permissible concentration.

(d) It shall indicate neither abnormal acidity nor alkalinity.

(e) It shall have no abnormal smell except disinfection.

(f) It shall be almost colorless and transparent by appearance.

As mentioned above, tap water in Japan is defined in the *Water Works Law* and the Ministerial Ordinance concerning *Water Quality Standard* pursuant to the law. Accordingly, tap water shall neither cause health hazards to people when drinking nor other problems.

To this end, the owners of water supply facilities are required to take measures against corrosion and deterioration of distribution pipes, water supply piping, water storage tanks and other equipment, as well as contamination stemming from adhesion of water stains such as organic matter. In particular, according to the present legal system, since the owner of a water supply facility is responsible for managing the supply process up to the faucets, the following measures against red water, cross-connections, etc. must be considered and implemented as necessary.

(3) Measure to control red water

Red water is a phenomenon in which water turns amber or becomes cloudy with an auburn color. Such phenomena have been seen for some time. However, as chlorine came into use to disinfect tap water, carbon steel pipes have begun to have severe corrosion.

When stainless steel pipes are used for a tap water piping system, the piping does not cause its own red water. If existing carbon steel pipes are used for such a system, however, the owner of the piping system needs to consider the impact of red water.

If the cause of rust obviously stems from iron rust, the water pipe is very likely to have been decrepit. Temporary red water could also occur when water work is conducted or when a water storage tank, etc. is cleaned.

General measures to control red water include improving water quality by pH control, keeping up the conduit network, and using pipe whose inner surface is anti-corrosive and corrosion-resistant.

(4) Cross-connection

A cross-connection is a point where a tap water supply pipe and a pipe for other than tap water, such as for well water, are directly connected.

When the tap water supply piping is connected directly with a pipe for water from other sources such as well water, the latter may flow into the water main when a valve fails or is erroneously operated. Therefore, cross-connections are strictly prohibited in Article 129-2 of the *Enforcement Regulations of the Building Standard Act* and in Article 3-9, etc. of the *Water Works Law*, in accordance with public sanitation requirements for preventing tap water from pollution and for ensuring safety.

For example, when a building has a drinking water piping system and a drainage-recycled water piping system, connecting a tank for receiving drinking water with a tank for receiving drainage recycled water is regarded as a cross-connection.

To prevent cross-connections, the outer surface of the piping must have a marker indicating the purpose of use. In addition, when drainage pipe, well pipe, industrial water pipe or rainwater pipe, etc. are similar to water supply pipe by appearance, a marker on the outer surface of every pipe must be pasted, painted or taped to indicate the purpose of use.

4.3.6 Cleaning drainage pipe

In general, the inner surface of the drainage pipe clogs over time with the adhesion of refuse, oil and other stains. Failure to manage such adhesion will lead to discharge malfunctions, reverse flows, clogging, bad smells, etc. Such deteriorated and corroded pipe will lead to leakage and eventually impede drainage, making it difficult to keep sanitation control. Proper cleaning of the piping will prevent such incidents. Periodic inspections are essential for contributing to the comfortable daily lives of people in ordinary homes and people conducting business.

(1) Cleaning and related laws and regulations

For proper functional maintenance of drainage equipment, the *Act on Maintenance of Sanitation in Buildings* (hereinafter referred to as the *Building Sanitation Act*) stipulates that the drainage equipment shall be periodically cleaned at least every six months (Article 4-3 of the *Enforcement Regulations*). However, this provision applies only to buildings specified in the *Building Sanitation Act*. Other types of buildings and collective housing, etc. are not subject to the provision. Furthermore, since the cleaning frequency stipulated in the act is not an absolute standard, a building owner setting up his/her own standard that meets the actual requirements of the building is important. Table 4.3-7 lists indications of the frequencies for cleaning drainage pipe by type of building, including collective housing and ordinary buildings.

Table 4.3-7 Indication of frequency for cleaning drainage pipe in collective housing and ordinary buildings[6]

Type of building	Target for cleaning	Frequency of cleanings
Collective housing	Drainage from kitchen, bathroom, washing machine, etc.	From one to two years
	Disposal drainage	From four to six months
Office buildings	Drainage from kitchen used for business	From six months to one year
	Drainage from urinals	From one to two years
	Drainage from hot-water service room, hand-wash station, etc.	From one to two years
Detached stores and restaurants	Ramen places, Chinese and western restaurants, etc.	From three to six months

Source: Planning, Installation and Maintenance Management Section, Handbook for Heating, Air-Conditioning and Sanitary Engineering, 14th edition, Volume 5, 2010

As a drainage pipe has gradual adhesion of rotten food waste, oil, hair, textile waste and their stains on the inner surface, accumulated deposits will eventually clog the pipe, causing malfunctions and bad odors. Removing such stains and maintaining smooth flow inside the drainage pipe are essential to keep a comfortable living environment and sanitation and to prevent the drainage pipe from deteriorating.

One prevailing point that a building owner, building manager or home dweller should check when appointing a cleaning operator is if the cleaner has registered as a business operator of building drainage pipe cleaning with the prefectural government.

Drainage pipe cleaning operators must register themselves with their respective prefectural governors (city mayor or ward chief when the city or special ward has a health center) in accordance with the provision of Article 12-2-1 of the *Act on Maintenance of Sanitation in Buildings*.

Those who intend to register as mentioned above shall be equipped, as physical requirements, with the following items dedicated for drainage pipe cleaning: ① wired pipe cleaner, ② high-pressure washing machine, ③ high-pressure pipe cleaner, ④ drainage pump and ⑤ fiberscope and a dedicated cabinet.

(2) Cleaning

Based on the piping diagram, etc., the cleaner investigates the drainage equipment and system, checking their actual conditions with the records of on-site drainage, leaks, repairs, etc. by visual inspection and interviews. When such on-site checking indicates that cleaning the drainage pipe is likely to present difficulties, the cleaner should consult with the building manager for proper measures and request assistance from the manager for smooth cleaning.

Table 4.3-8 lists an example of the major cleaning process.

Table 4.3-8 Example of the major cleaning process[7]

	Work item	Description
1	Checking inside the piping	Use a fiberscope, etc. to check inside the pipe for adhesions.
2	Checking outfalls and cleanouts	Take measures to prevent drainage from gushing and flooding out of the pipe.
3	Curing measures	Curing cleaning apparatuses and high-pressure hoses, etc.
4	Safety measure	Check if work at a high place or underground pit is necessary.
5	Emergency measure	Check measures in case of facing drainage problems.
6	Choosing a cleaning method	Choose a method that meets the cleaning target.
7	Cleaning drainage pipe in the premises	Move from the final catch basin to upper catch basins to clean the drainage pipe.
8	Cleaning horizontal branch pipes and the horizontal water main	Clean the drainage pipe from a downstream unit to upper-stream units.
9	Cleaning vertical piping	Clean drainage pipes from a lower story to higher stories.
10	Checking drainage conditions	Visually inspect the drainage spot condition to clean.
11	Checking the surroundings of the piping equipment	Check the equipment for breakage and damage and repair it, if any.
12	Checking the piping after cleaning	Use a microscope to ensure better cleaning results.

Source: Planning, Installation and Maintenance Management Section, Handbook for Heating, Air-Conditioning and Sanitary Engineering, 14th edition, Volume 5, 2010

(3) How to clean the drainage pipe

There are two methods: mechanical cleaning and chemical cleaning. The mechanical method is also called the physical cleaning method.

The mechanical cleaning method physically removes adhesions, depositions and blockage from inside the drainage pipe after they are exfoliated and crushed by a machine. The method is common for drainage pipes. Table 4.3-9 lists types of major mechanical cleaning methods.

The chemical cleaning method dissolves blockage, etc. chemically. In many cases, this method is used as an emergency measure.

Table 4.3-9 Types of major mechanical cleaning methods[8]

Method	How to clean	Pipe diameter applicable (A)
Wired cleaning method	A flexible wire (coiled piano wire) has a brush or cutter on its head. After inserting a rotating flexible wire into the pipe, the operator repeats moving the wire back and forth to scrape off adhesions, depositions, etc. inside the drainage pipe. A manual type and electricity-drive type are available.	40 – 150
High-pressure washing method	Pressurized water from a washing machine with a high-pressure pump jets from the nozzle through high-pressure hose to wash off adhesions and depositions inside the pipe, together with a water jet. An engine type and electricity-drive type are available.	40 – 200
Air-pressure cleaning method	After pressing the manual pump to collect compressed air in the cylinder, the operator puts the nozzle of the air-gun on the outfall of the pipe to give shock waves and wash off adhesions inside the pipe. A manual type is available.	20 – 100

Source: Planning, Installation and Maintenance Management Section, Handbook for Heating, Air-Conditioning and Sanitary Engineering, 14th edition, Volume 5, 2010

4.4 Equipment Diagnosis

4.4.1 Diagnosis workflow

To use a piping system for a long time, good maintenance management of the components is essential. Beginning with pipe couplings and valves, a piping system consists of diverse components, such as support fittings, heat insulation materials and painting. When a building is put into use, these components begin to corrode, stain, clog and deteriorate, which leads to problems. The extent of such deterioration varies greatly, depending on the component materials and the installation environment. Ignoring this deterioration would eventually lead to significant problems, including problems with service and water loss due to leakage, etc. To prevent this, maintenance and preservation is essential through conducting periodical inspections and cleaning components, replacing consumables and keeping the system functional.

Table 4.4-1 indicates a basic workflow of equipment diagnosis. In general, deterioration diagnosis is subdivided into preliminary diagnosis, primary diagnosis and secondary diagnosis. Figure 4.4-1 shows an example of the deterioration diagnosis assessment standard.

(1) Preliminary diagnosis: Interviews held with the party who has requested a diagnosis to understand the present situation and identify problems, based on the completion drawing.

(2) Primary diagnosis: Primarily visual inspection of equipment conducted and judgment made on the extent of deterioration based on the diagnostician's technical knowledge and experience.

(3) Secondary diagnosis: Judgment on the extent of the internal deterioration of the equipment and components that cannot be identified by external appearance alone.

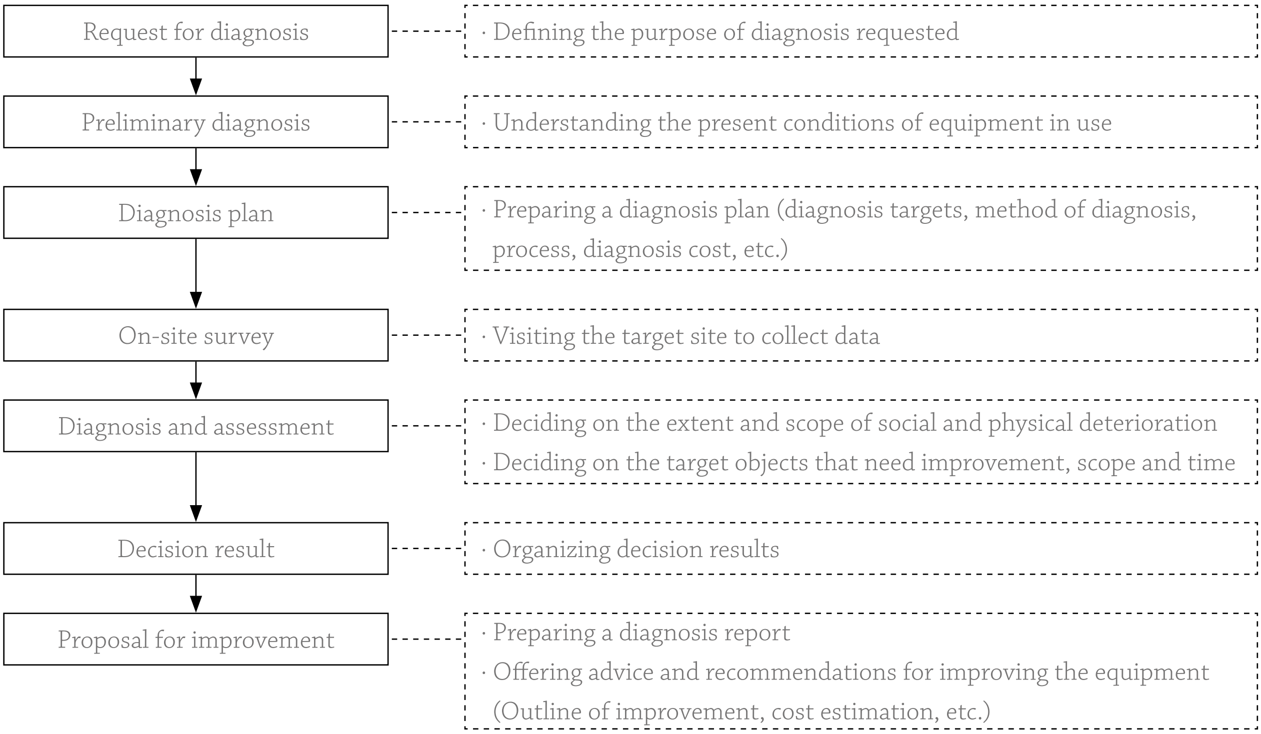

Figure 4.4-1 Basic workflow of diagnosis work[9]

Source: Building and Equipment Long-life Cycle Association's Textbook

Maintenance and preservation of equipment is subdivided into precautionary and follow-up preservation. Carrying out maintenance and preservation based on a prepared plan is important. Carrying out precautionary preservation after considering the service life of the piping system and understanding the deterioration of the pipes through diagnosis is also important.

Through daily inspections, periodical inspections, diagnoses and precautionary and follow-up preservation, maintenance and preservation of equipment must be carried out. For example, when the service life of equipment expires or the equipment is damaged due to a special factor, the equipment must be replaced with new equipment or updated.

In daily inspections, the equipment manager or users, etc. must check the functioning of equipment before and after operation, check the equipment for leakage, and check the meters for abnormal values. In periodical inspections, engineers of the equipment manufacturers, etc. must periodically inspect the equipment at intervals of one to several years.

Diagnosis must be conducted to investigate the extent of equipment deterioration in order to estimate the remaining service life and decide on the methods for maintenance and inspection, etc.

Precautionary preservation refers to service in general that aims to prevent the system and equipment from failing and causing problems, by executing a planned inspection, examination, test and readjustment, etc.

Follow-up preservation refers to a method for fixing problems after an abnormal event or failure occurs or is identified. Follow-up preservation aims to resume services by modifying and repairing equipment items without replacing them.

Table 4.4-1 lists an example of deterioration diagnosis assessment standard for stainless steel piping systems.

Table 4.4-1 Example of deterioration diagnosis assessment standard[10]

Equipment and material	Component and part	Detection item	Diagnosis method	Assessment standard	Countermeasure to take
Pipe	Stainless steel pipe	Red water	Visual inspection	No marked coloring identified	Secondary diagnosis or update
		Water leakage	Visual inspection	No water leakage identified	
		Outer surface corrosion of pipe	Visual inspection after uncovering	No outer corrosion identified	
Pipe joint	Housing pipe joint	Red water	Visual inspection	No marked coloring identified	Update
		Water leakage	Visual inspection	No water leakage identified	
		Outer surface corrosion	Visual inspection	No outer corrosion identified	
Valves	Gate valve Ball valve Butterfly valve	Outer surface corrosion	Visual inspection	No corrosion and deterioration identified	Repair or replacement
		Withstand pressure performance	Visual inspection	No water leakage identified	
		Sealing performance	Visual inspection	Water can be shut off	
		Operational performance	Operation test	Valves can be opened and closed easily	

Source: Building and Equipment Long-life Cycle Association's Textbook

4.4.2 Results of diagnosis and improvement

A decision on the diagnosis results must be stated as clearly as possible without being ambiguous. The following points must be considered when a decision is made. Prior to making a decision, the diagnostician:

(1) Must clarify the reasonableness and limits of the diagnosis.

(2) Must qualitatively or quantitatively analyze the examination data

(3) Must examine from diverse standpoints since items of the equipment system are closely inter-related.

(4) Must adequately consult with the owner of the building, users and equipment manager even though the diagnostician's objectivity is important.

If the diagnosis results are ambiguous, a proposal for improvement will also be difficult to prepare. The diagnostician must consider the needs of the party who has requested such diagnosis and accordingly precisely convey what to do now to the party. A report on the diagnosis results will thus ensure the preparation of a proposal for improvements.

4.4.3 Offering a proposal for improvement

Based on a diagnosis report, a refitting plan must be prepared by the designer of the equipment system. In principle, such an improvement plan must consist of the following descriptions:

(1) Period to implement the countermeasure: Indicate one of the following three stages: Immediate execution; execution in n years; and use under continuous monitoring.

(2) Scope of countermeasure: Indicate whether the countermeasure partially or totally involves the diagnosed unit.

(3) Proposing a refitting plan: An improvement plan must be prepared with the following classification.

- Updating to or replacing with a new component under the existing specification
- Modifying the system into a new system (same as a new system installation)
- Adding a new device to improve the service
- Continuing using existing devices and materials by correcting or reinforcing them
- Repairing components, such as functional recovery or adjustment
- Cleaning and washing inside the devices and pipe to recover their use

4.4.4 Roles of maintenance management

(1) Objectives of maintenance management

Under the present situation, a service life of 60 years or longer is expected for buildings, while individual equipment items in buildings have service lives of only 15 to 25 years. Due to this gap, proper repair of building and equipment items and, if necessary, refurbishing them to improve their performance are inevitable to ensure a comfortable living environment and maintain asset value. The objectives of such work can be subdivided into the following four categories: ① safety and reliability, ② comfort, health and environmental sanitation, ③ efficiency and convenience and ④ economy and durability.

(2) Life cycle plan

(a) Life cycle cost

Life cycle cost (LCC) consists of all the costs necessary for the whole life of a building, which include the costs for planning and design, construction, operation and management, demolition and recycle or scrapping. Of these costs, maintenance, repair and operation costs (light, fuel and water expenses, etc.) are generally greater than anticipated. Therefore, keeping the comfort of the indoor environment, restraining the load on the environment and ensuring the reliability of equipment must also be examined because they run counter to LCC minimization.

(b) Life cycle assessment

Life cycle assessment (LCA) is a method that covers, together with LCC elements, emission of carbon dioxide, which is the major global environmental problem, energy consumption, resource consumption, etc.

To minimize impact on the global environment, the following points must be considered:

- Energy-saving through the life cycle of a building and air-conditioning and sanitation equipment
- Deterring the emission of carbon dioxide
- Using eco-materials
- Deterring discharge of waste

(c) Maintenance management plan

Maintenance management covers many diverse equipment items. An efficient plan must be prepared prior to implementing maintenance management.

The *Construction Standard Act* also stipulates the preparation of a maintenance and preservation plan prior to implementing them. A notification and a notice of the ministry concerned respectively specify the corresponding guidelines and specific matters.

A long-term repair plan covers the whole life (life cycle) of a building. However, most of such plans cover just 10 to 15 years. These plans are often used as the basis for fund injection in, for example, equipment updates.

Concerning the period for implementing maintenance management, the durability of the target unit and component is the focus of the concern. What are available for reference are the service life of equipment items under the tax law and the description of maintenance management that the builder hands over to the owner upon the completion of the equipment system.

Table 4.4-2 lists examples of legal service lives of equipment items under the tax law (depreciation).

Table 4.4-2 Legal service lives of equipment items under the tax law[11]

Building equipment items		Legal service life
Water supply and drainage and sanitation equipment and gas equipment	15 years	
Cooling, heating and ventilation equipment or boiler equipment	Cooling and heating (refrigerator output: 22 kW or under)	13 years
	Other	15 years
Automatic switch systems of air-curtains or doors		12 years
Elevator equipment	Elevator	17 years
	Escalator	15 years
RC or SRC building frame	Office	50 years
	Store or shop or hospital	39 years
	Hotel	31 years

Source: Service Lives of Depreciating Assets

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